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# ORNL WAG 6 RFI REPORT

DRAFT

## VOLUME I: MAIN REPORT

OAK RIDGE NATIONAL LABORATORY
REMEDIAL INVESTIGATION/FEASIBILITY STUDY

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## ACRONYMS

| | |
|---|---|
| ACD | Analytical Chemistry Division |
| AEA | Atomic Energy Act |
| ALARA | as low as reasonably achievable |
| ALS | analytical laboratory subcontractor |
| ARAR | applicable or relevant and appropriate requirement |
| ASEMP | Active Sites Environmental Monitoring Program |
| ATDD | Atmospheric Turbulence and Diffusion Division Lab |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| BCF | bioconcentration factors |
| BNAE | base neutral and acid extractable |
| BNI | Bechtel National, Inc. |
| BOD | biochemical oxygen demand |
| BTF | biotransfer factors |
| BTX | benzene, toulene, and xylene |
| BUN | blood urea nitrogen |
| CAG | carcinogen assessment group |
| CAS | corrective action study |
| CEC | cation exchange capacity |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CFR | Code of Federal Regulations |
| CLP | Contract Laboratory Program |
| CMI | corrective measures implementation |
| CMS | corrective measures study |
| COC | chain of custody |
| COD | chemical oxygen demand |
| CREAMS | chemicals, runoff, and erosion from agricultural management system |
| CRQL | contract required quantitation limit |
| CSL | close support laboratory |
| CT | custody transfer |
| CWA | Clean Water Act |
| DCF | dose conversion factor |
| DOE | U.S. Department of Energy |
| DQO | data quality objective |
| DUP | duplicate |
| EDT | Explosives Detonation Trench |
| EM | electromagnetic |
| EMSL-LV | USEPA Environmental Measurements Laboratory-Las Vegas |
| EPA | U.S. Environmental Protection Agency |
| ER | Environmental Restoration |
| ES&H | environmental safety and health |
| ESD | Environmental Science Division |

## ACRONYMS

| | |
|---|---|
| ET | evapotranspiration |
| ETF | Engineering Test Facility |
| EWB | Emergency Waste Basin |
| FB | field blank |
| FFA | Federal Facilities Agreement |
| FOF | Field Operations Facility |
| FSC | field sample coordinator |
| FSP | field sampling plan |
| FSS | field services and support |
| GC | gas chromatograph |
| GCD | greater confinement disposal |
| HDPE | high density polyethylene |
| HFIR | High Flux Isotope Reactor |
| HHMS | hydraulic head monitoring station |
| HI | hazard index |
| HQ | hazard quotient |
| HSWA | Hazardous and Solid Waste Amendments Act |
| ICM | Interim Corrective Measure |
| ICP | inductively coupled plasma |
| ICRP | International Commission on Radiological Protection |
| IRIS | Integrated Risk Information System |
| ISCLT | industrial source complex long term |
| ISV | in situ vitrification |
| IWMF | interim waste management facility |
| Kd | distribution coefficient |
| LDR | land disposal restrictions |
| LET | linear energy transfer |
| LLW | low-level waste |
| M&O | management and operating |
| MCL | maximum contaminant limit |
| MDA | minimum detectable activity |
| MS | mass spectrometry |
| MS/MSD | matrix spike duplicate pairs |
| MSL | mean sea level |
| NAAQS | National Ambient Air Quality Standard |
| NCP | National Contingency Plan |
| NCRP | National Council on Radiation Protection and Measurement |
| NEPA | National Environmental Policy Act |
| NESHAP | National Emission Standards for Hazardous Air Pollutants |
| NOAA | National Oceanic and Atmospheric Administration |
| NPDES | National Pollutant Discharge Elimination System |
| NPL | National Priority List |
| NRWTP | nonradiological wastewater treatment plant |
| ORNL | Oak Ridge National Laboratory |

## ACRONYMS

| | |
|---|---|
| ORR | Oak Ridge Reservation |
| OVA | organic vapor analyzer |
| PARCC | precision, accuracy, representativeness, completeness and comparability |
| PCB | polychlorinated biphenyls |
| PCE | tetrachloroethylene |
| PE | performance evaluation |
| PIC | pressurized ionization chamber |
| PMF | probable maximum flood |
| PNL | Pacific Northwest Laboratory |
| PQL | probable quantitation limits |
| PVC | polyvinyl chloride |
| PWTP | process wastewater treatment plant |
| QAPP | quality assurance project plan |
| QC | quality control |
| QSAR | quantitative structure activity relationships |
| RAGS | Risk Assessment Guidance for Superfund |
| RCRA | Resource Conservation and Recovery Act |
| REP | NON-QC Replicated |
| RFA | RCRA facilities assessment |
| RFI | RCRA facility investigation |
| RIC | reconstructed ion chromatogram |
| ROD | record of decision |
| RPD | relative percent differences |
| SARA | Superfund Amendments and Reauthorization Act |
| SCS | site characterization summary |
| SDWA | Safe Drinking Water Act |
| SEG | Scientific Ecology Group |
| SEIR | sample event initiation request |
| SIMS | Sample Information Management System |
| SLB | shallow land burial |
| SMOW | standard mean ocean water |
| SO | shipping officer |
| SOP | standard operating procedure |
| SPT | standard penetration test |
| SVOC | semivolatile organic compound |
| SWIMS | solid waste information management system |
| SWMU | solid waste management unit |
| SWSA | solid waste storage area |
| TAL | target analyte list |
| TARA | test area for remedial activities |
| TB | travel blank |
| TBC | to be considered |

## ACRONYMS

| | |
|---|---|
| TCA | Tennessee Code Annotated |
| TCE | trichloroethylene |
| TCL | target compound list |
| TD | total depth |
| TDC | Tennessee Department of Conservation |
| TDS | total dissolved solids |
| TEGD | technical enforcement guidance document |
| TIC | tentatively identified compound |
| TKN | total kjeldahl nitrogen |
| TM | technical memorandum |
| TOC | total organic carbon |
| TOX | total organic halides |
| TRU | transuranic |
| TSDF | treatment, storage, and disposal facilities |
| TSP | total suspended particulates |
| TVA | Tennessee Valley Authority |
| USGS | U. S. Geologic Survey |
| VOC | volatile organic compound |
| WAG | waste area grouping |
| WOC | White Oak Creek |
| WOL | White Oak Lake |
| WQC | water quality criteria |

# EXECUTIVE SUMMARY

This Executive Summary provides an overview of activities and a summary of results of the Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) of Waste Area Grouping 6 (WAG 6) at the U.S. Department of Energy's (DOE) Oak Ridge National Laboratory (ORNL).

## ES.1 OVERVIEW

As a shallow land burial facility for disposal of low level radioactive wastes and, until recently, chemical wastes, WAG 6 is subject to regulation under RCRA and the Comprehensive Environmental Response Compensation and Liability Act (CERCLA). To comply with these regulations, DOE in conjunction with the Environmental Protection Agency (EPA) and the Tennessee Department of Conservation (TDC) developed a strategy for closure and remediation of WAG 6 by 1997. A key component of this strategy was the completion of an RFI by September 1991. The primary objectives of the RFI were to evaluate potential human health and environmental impacts of the site, and to develop a preliminary list of alternatives to mitigate these impacts.

The RFI evaluated existing waste disposal records and sampling data, and supplemented this information with additional sampling and analyses. The foregoing data were synthesized to describe the nature and extent of contamination and to characterize key contaminant transport pathways. Potential risks to human health and the environment were assessed through development and evaluation of hypothetical receptor scenarios. Estimated excess lifetime cancer risks as a result of exposure to radionuclides and chemicals were quantified for each hypothetical human receptor. For environmental receptors, potential impacts were qualitatively assessed.

Taking into account regulatory requirements and baseline risk assessment results, preliminary site closure and remediation objectives were identified, and a preliminary list of alternatives for site closure and remediation developed. Site objectives and the list of alternatives will be finalized in a Corrective Measures Study (CMS) Report to be completed by February 1992.

## ES.2 BACKGROUND

ORNL is one of three principal facilities on DOE's Oak Ridge Reservation (ORR), which was established during the World War II "Manhattan" atomic weapons project. ORNL is currently managed and operated for DOE by Martin Marietta Energy Systems, Inc. (Energy Systems). The location of ORNL is shown in Fig. ES.1.

The subject of this report, WAG 6, comprises three solid waste management units (SWMUs). The largest and most important is the 68 acre Solid Waste Storage Area 6 (SWSA 6), which is the current disposal area for solid low-level radioactive waste (LLW)

at ORNL. Areas of SWSA 6 also received chemically hazardous wastes prior to May 1986, which makes these areas subject to regulation as units of a hazardous waste landfill under RCRA. The other two WAG 6 SWMUs are the Emergency Waste Basin (EWB) and the Explosives Detonation Trench (EDT). Constructed as an emergency holding basin for liquid wastes from the ORNL Main Plant Area, the 2 acre EWB has never been used for its intended purpose, but does contain water from groundwater discharge and surface water runoff from the up-gradient SWSA 6. A trench measuring about 15 ft by 5 ft, the EDT was used to detonate explosives and shock-sensitive chemicals. The EDT is no longer used and has been backfilled.

SWSA 6 contains RCRA-regulated waste disposal units as a result of the disposal of hazardous chemical wastes at the site. As required by law, ORNL prepared a RCRA Closure Plan for SWSA 6, which was approved by the State of Tennessee in September 1988 (BNI 1988a). The SWSA 6 Closure Plan specified a series of activities leading to final closure and remedial action. One of the initial activities specified for SWSA 6 was an RFI. Because of the prior grouping of SWMUs into WAGs, ORNL chose to increase the scope of the RFI to formally include consideration of the EWB and the EDT in addition to SWSA 6. Hence this is the WAG 6 RFI Report and the scope formally encompasses all three SWMUs.

EPA has recently listed the ORR (including ORNL) on the CERCLA National Priorities List (NPL); therefore, ORNL conducted the WAG 6 RFI in general conformity with both RCRA and CERCLA guidelines. Also, WAG 6 RFI activities were conducted in accordance with requirements of the National Environmental Policy Act (NEPA).

### ES.2.1 Site Description and History

SWSA 6 is the principal source of environmental contamination in WAG 6. The site covers 68 acres, approximately 19 acres of which are used for waste disposal. It was opened for limited disposal operations in 1969 and began full-scale operation in 1973. It has received LLW, chemical, biological, and mixed wastes. Wastes have been disposed in a variety of waste disposal units, including unlined trenches and auger holes, silos, and tumulus waste disposal pads. Fig. ES.2 illustrates the locations of these units.

Records have been kept for most shipments of waste disposed of at SWSA 6. These records generally include estimates of the radionuclides present and their respective activities for each waste shipment. Fig. ES.3 illustrates SWSA 6 disposal log inventories (in curies) by radionuclide and by unit type.

Inventory records indicate that approximately 80 percent of radioactivity at SWSA 6 is due to isotopes of europium. These isotopes are associated with reactor control plates which were buried in the high activity auger hole area. The europium is relatively well contained due to an aluminum cladding on the plates; europium isotopes were not detected in environmental samples.

### ES.2.2 Demography

Because SWSA 6 is an active facility, ORNL workers are on-site daily during the work week and frequently on weekends. WAG 6 is approximately 1 mile from the ORNL Main Plant Area, where the majority of ORNL's approximately 5000 employees work. Within a 1/2 mile of the boundary of WAG 6, all land is federally owned, and there are no residents. Within a 1 mile boundary extension of WAG 6, there are approximately 25 residents; all are located across the Clinch River southwest of WAG 6. Within a 5-mile radius of WAG 6, there are an estimated 580 residents.

## ES.3 PHYSICAL CHARACTERISTICS OF WAG 6

### ES.3.1 Site Geology

The overall geology of WAG 6 is complex; this is a result of the original depositional environment, severe and variable structural deformation, variable degrees of weathering, and on-site activities such as cut and fill grading, trenching, and waste disposal operations. The geologic complexity renders it unlikely that hydrogeologic processes can be characterized on a local scale with any certainty. Detailed characterization of flowpaths from a particular source to a well would be infeasible without intensive study of that particular area.

### ES.3.2 Groundwater Hydrology

The majority of groundwater flow in the saturated zone is local rather than regional; groundwater flows from recharge areas at higher elevations on-site to discharge areas along intervening surface water drainages on-site and at the site boundary.

United States Geological Survey (USGS) modeling results indicate 90 to 98% of groundwater flow at WAG 6 occurs in the upper 50 to 100 ft of the aquifer, with virtually no flow occurring below 250 ft. Evidence supporting these results includes geochemical, age-dating, contaminant sampling, and hydraulic conductivity data.

It can be assumed that on a large scale and to a depth of approximately 65 ft in the bedrock, flow is generally in the direction of hydraulic gradient as determined from potentiometric mapping. Aquifer testing indicates that bedrock aquifer well yields are generally too low to encourage use as a potable water supply (< 1 gpm).

The storm flow zone is highly variable and discontinuous due to removal or reworking of surficial soils and physical features such as waste disposal trenches, the 49-Trench area French Drain, and numerous wells and piezometers. Transient storm flow flowpaths are short, from point of infiltration to discharge along streams or seeps, generally all within WAG 6.

### ES.3.3 Surface Water Hydrology

The four principal streams originating on WAG 6 are generally dry during summer months except during storm events. Contributions to stream flow include surface runoff (overland flow, saturated overland flow, subsurface storm flow) and base flow (groundwater discharge). Storm hydrographs at the stream outlets at the site boundary exhibit storm peaks occurring within one hour of the onset of the storm rainfall. This indicates that overland flow and saturated overland flow dominate the storm hydrograph shape and the storm volume.

## ES.4 NATURE AND EXTENT OF CONTAMINATION

Data collected at WAG 6 clearly indicate the release of contaminants from source areas to the environment on-site, and the subsequent migration of some of these contaminants off-site. Table ES.1 lists radionuclides and chemicals detected at least once during WAG 6 RFI sampling. Although a large number of contaminants was detected in WAG 6 samples, many were detected only once or were detected at low concentrations.

### ES.4.1 On-Site Contamination

RFI data reveal very little contamination of surface soils at WAG 6, which is consistent with site waste disposal methods. In the vicinity of waste disposal areas, the primary zone of contamination lies between the soil cover and the top of bedrock. Sampling does not indicate the presence of zones of gross soil contamination around the perimeter of waste disposal areas. Subsurface contamination decreases dramatically with depth. This trend is well illustrated by tritium, by far the most ubiquitous and mobile contaminant at WAG 6, which was not detected below 100 ft.

No temporal trends or relationships of contaminant concentrations to seasonal variations in the hydrogeologic system were identified. Rather, contaminant concentrations show an apparently random fluctuation from sampling event to sampling event.

Contaminant data collected during the RFI indicate widespread contamination of shallow groundwater on-site, generally at low concentrations. Within this shallow groundwater system, there are discernible areas where particular contaminants predominate and there are areas of elevated contaminant concentrations. Precise delineation of plumes, however, appears to be infeasible due to the complex hydrogeology. Discrete contaminant transport along fractures means that detection of contamination in a given monitoring well may not correlate to adjacent wells.

### ES.4.2 Off-Site Migration Patterns

The primary media by which contaminants are transported off-WAG are groundwater and surface water. Figure ES.4 and associated Table ES.2 identify areas of the site perimeter where off-site migration of radionuclides is most likely. Figure ES.5 and Table ES.3 present the same information for chemicals.

## ES.5 FATE AND TRANSPORT

Contaminant fate and transport modeling was conducted to support the baseline human health evaluation and to aid in definition of remedial alternatives. The baseline human health evaluation considered hypothetical present day and future on-site and off-site receptors. For on-site receptors, predictions of contaminant concentrations in groundwater, surface water, sediment, soil, and air were required. For predictions regarding the off-site receptor, an estimate of contaminant flux via surface water to White Oak Lake was required; this flux was used to calculate a corresponding concentration downstream in the Clinch River, where the off-site receptor was assumed to be located.

Modeling to predict the variation of concentrations and fluxes in the future was performed for radionuclides only. Such modeling was not appropriate for hazardous chemicals detected at the site because no inventory information existed for chemicals; however, fluxes representative of current conditions were computed.

Water was identified as the major transport mechanism for off-site migration of contaminants, with most of the radionuclide flux out of WAG 6 expected via surface water.

In groundwater, tritium, cobalt-60, strontium-90, and cesium-137 were predicted to occur in most of the wells in WAG 6. Peak future groundwater concentrations for those radionuclides were predicted to be within two orders of magnitude of the present-day concentrations. The first occurrences of europium and uranium in groundwater were predicted to be in years 1998 and 2025, respectively.

Air modeling which was performed conservatively, indicated that air pathway contributed negligible amounts of exposure-point concentrations of contaminants on-site and off-site.

## ES.6 BASELINE HUMAN HEALTH EVALUATION

A baseline risk assessment was performed to assess the potential impacts of contaminants at WAG 6 on human health and the environment if no remedial actions are taken. The baseline risk assessment is comprised of two parts: a baseline human health evaluation, described in this section, and baseline environmental evaluation, described in Sect. ES.7.

The methodology for the human health evaluation involved selection of potential contaminants of concern; identifying receptor scenarios and associated exposure pathways; estimating representative contaminant concentrations at receptor locations; collecting toxicity information; and finally, estimating risks for each receptor. Hypothetical receptors and associated risks are summarized below.

### ES.6.1 Exposure Assessment

Two hypothetical scenarios were assumed for WAG 6 - a no action scenario and an institutional control scenario.

#### ES.6.1.1 No Action Scenario

The no-action scenario assumed that DOE's current access restrictions for the site become ineffective immediately. Site fencing, warning signs, patrols, and institutional controls are effectively assumed to disappear. This scenario is high unlikely - if not impossible; however, evaluation of a no action scenario is required under Section 300.68(f)(1)(v) of the National Contingency Plan (NCP). In accordance with CERCLA methodology, when risks associated with a no action scenario prove unacceptable, then the need for remedial action is established.

For the WAG 6 no action scenario, risks were evaluated for a hypot ical receptor who homesteads on the WAG over the course of the next 30 years. Risks r the homesteader were evaluated for contaminant concentrations corresponding to an aver e for the entire site and for contaminant concentrations corresponding to an average for t nigh activity auger hole area. The high activity auger hole area, which comprises appr mately 2 acres and contains greater than 80 percent of the WAG's radioactivity, represer an upper bound for exposure to radionuclides.

It is emphasized that the no-action scenario is not a realistic sc rio and was evaluated solely to define a baseline against which to compare alternati for site closure and remediation. The location of SWSA 6 on the U.S. government o ed ORR adjacent to an operating facility (ORNL), and the existence of site fencing anc ecurity patrols make it highly unlikely that a member of the public could occupy the site nd remain undetected.

#### ES.6.1.2 Institutional Control Scenario

The second hypothetical scenario (termed the institutional control scenario) assumed that DOE would continue to use WAG 6 as an LLW disposal site for the next 10 years and that this operational period would be followed by a 100-year institutional control period. This scenario corresponds to DOE's operational and institutional control plans for WAG 6 for the next 110 years with the exception that, for assessment purposes only, the scenario assumed that DOE would not perform site closure or remediation other than maintenance of the existing soil cover and vegetation over the disposal units.

For the institutional control scenario, risks were evaluated for hypothetical receptors corresponding to two different periods. For the period corresponding to the next 30 years (1990-2020), four receptors were evaluated, one representing an occupational risk (an ORNL employee) and the remaining 3 representing potential risks to the public (a hunter, a boundary receptor, and an off-WAG homesteader resident downstream along the Clinch River.)

For the period corresponding to the release of institutional controls and other access restrictions in 2100, an on-WAG homesteader was evaluated.

Associated with each hypothetical receptor were a variety of pathways by which that individual could potentially be exposed. Exposure pathways evaluated are identified in Fig. ES.6.

### ES.6.2 Risk Characterization Results

#### ES.6.2.1 Carcinogenic Risks

Excess lifetime cancer risk was quantified for radionuclides and chemicals of concern. Excess lifetime cancer risk is the probability that an individual will develop cancer as a result of exposure to the carcinogen(s) being evaluated. For convenience, this probability is typically presented in exponential notation. For example, a risk of 0.000002 (or 2 in 1,000,000) is represented as 2E-6. Fig. ES.7 summarizes results for each receptor evaluated. For radionuclides, radiation dose was also computed separately for each receptor, these results are summarized in Table ES.4.

As illustrated in Fig. ES.7, under the toxicological and exposure assumptions used in the evaluation, the lower limit of EPA's target range for risk to the public (1E-6 to 1E-4) was exceeded for the following receptors:

- No action scenario
  - On-WAG homesteader (1990-2020)

- Institutional control scenario
  - On-WAG ORNL worker (1990-2020)
  - Off-WAG (Clinch River) homesteader (1990-2020)
  - On-WAG homesteader (2100-2130)

Risks to these receptors are briefly discussed in the following paragraphs.

##### ES.6.2.1.1 Receptor for No Action Scenario

**On-WAG homesteader (1990-2020).** The estimated radionuclide and chemical risks for the hypothetical on-WAG adult homestead receptor evaluated for site average concentrations were 1E-0 and 4E-4 respectively. Because these risks exceed EPA's target risk range, the need for continued DOE control of the site has been demonstrated.

Ninety nine percent of the radiological risk was associated with external exposure, with the majority of the dose resulting from isotopes of europium associated with the reactor control plates disposed in the high activity auger hole area. Although the computed radionuclide risks and doses were high, they were almost exclusively the result of very conservative assumptions regarding the homesteader excavating deep into the wastes and

spreading the waste across the ground surface. If the homesteader did not exhume wastes, estimated radionuclide risk would be orders of magnitude less (9E-3).

Ninety-seven percent of the chemical risk was due to ingestion of groundwater and inhalation of water vapor while showering. Vinyl chloride and 1,1-dichloroethene were the predominant contributors to the groundwater risk.

### ES.6.2.1.2 Receptors for Institutional Control Scenario

**Worker (1990-2020).** The estimated radionuclide risk for the hypothetical maintenance worker receptor was 1E-3. This risk was almost exclusively attributable to hypothetical external radiation. The estimate is conservative due to the assumption that the worker spends 8 hours a day for 30 years working directly over SWSA 6 waste disposal areas.

**Off-WAG homesteader (1990-2020).** The estimated radionuclide risk for the off-WAG homesteader was 6E-5. This risk was primarily a result of external exposure from decay of cobalt-60 and cesium-137 that have accumulated in soils as a result of crop irrigation over a period of decades. The risk contribution from assumed ingestion of surface water was 3E-6. Because heavy irrigation is highly unlikely given the abundant rainfall in the region, and because a homesteader is most likely to use groundwater as a drinking water source rather than surface water, this scenario is very conservative.

**On-WAG homesteader (2100-2120).** The estimated radionuclide risk for the future on-WAG receptor evaluated for site average concentrations was 3E-1. As described for the no action scenario homesteader, the majority of the radionuclide risk was associated with external exposure resulting from conservative scenario assumptions. Estimated chemical risks were the same as for the no action scenario homesteader due to the assumption of steady state conditions for chemicals. Because risks exceed EPA's target risk range, the need for remedial actions effective beyond the year 2100 has been demonstrated.

### ES.6.2.2 Noncarcinogenic Risks

The potential for noncarcinogenic effects on health was evaluated by comparing an exposure level with a reference dose. This ratio of exposure to toxicity is called a hazard quotient. If the hazard quotient exceeds one, then the potential exists for noncarcinogenic effects. Noncarcinogenic risks are summarized in Fig. ES.8.

Of all the receptors evaluated, the critical effect specific hazard index exceeded one for only the on-WAG homesteader receptors. The target organ of greatest concern for these effects was the liver. These results support the demonstrated need for continued DOE control of the site.

## ES.7 BASELINE ENVIRONMENTAL EVALUATION

The baseline environmental evaluation was the second component of the baseline risk assessment. The purpose of the evaluation was to evaluate potential risks to the environment from contaminants at WAG 6.

Field surveys conducted to support this evaluation indicated the following: No rare plant species are present in SWSA 6. SWSA 6 stream drainages contain essentially no wetland community development. No threatened or endangered bird or mammal species listed by the U.S. Fish and Wildlife Services are present at WAG 6. SWSA 6 streams contain no invertebrate species listed as threatened or endangered by the State of Tennessee or the U.S. Fish and Wildlife Service.

### ES.7.1 Methodology

Large areas of WAG 6 have been cleared for waste disposal such that very little natural wildlife habitat remains. Wildlife that might be expected to occupy cleared land is discouraged by regular mowing and maintenance and by the frequent traffic associated with ongoing site operations. To assess potential environmental impacts under a no action scenario, hypothetical target species were selected. For each species, impacts were qualitatively addressed to the extent feasible given the available data.

The target species selected were the tulip poplar, representing terrestrial flora; the white-tailed deer, red-tailed hawk, and racoon, representing terrestrial fauna; bluegill and fathead minnow, representing aquatic vertebrates; and benthic macroinvertebrates representing aquatic invertebrates.

### ES.7.2 Potential Impacts

#### ES.7.2.1 Terrestrial Flora

The evaluation indicated that terrestrial flora (tulip poplar tree) would uptake contaminants, but because the literature contains no bioaccumulation or effects information, characterization of specific effects was not possible.

#### ES.7.2.2 Terrestrial Fauna

Terrestrial fauna would likely be impacted by WAG 6 under a no action scenario. Strontium-90, as an analog of calcium, is readily absorbed and deposited in bone tissue, where it can result in bone tumors and leukemia. Because of the large inventory of strontium-90 at WAG 6, species from the lower trophic levels such as rabbits and shrews are likely to suffer adverse effects, to bioconcentrate strontium-90 in their bone tissue, and subsequently to result in contamination of red-tailed hawks and raccoons that prey upon them. Cadmium levels exceeded the SDWA MCL and suggested standards from the U.S. Fish and Wildlife Service. This metal is known to bioconcentrate in liver and kidney tissue

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of shrews. Not only can cadmium adversely affect the soft tissues of shrews but also those of red-tailed hawks that feed upon them.

### ES.7.2.3 Aquatic Environment

Fish populations, although essentially non-existent at WAG 6 due to unsuitable habitat, could potentially be impacted by WAG 6 under a no action scenario. Cadmium and copper exceed the ambient water quality criteria for protection of aquatic organisms. Strontium-90 is a concern because surface water has been reported to contain strontium-90, concentrations of strontium-90 in White Oak Lake fish are elevated, and strontium-90 tends to concentrate in bone tissues where the biological half-life may be long. The uptake of strontium-90 in fish has been known to cause morphological abnormalities.

## ES.8 PRELIMINARY DEVELOPMENT AND SCREENING OF ALTERNATIVES

As specified in the SWSA 6 closure plan, DOE/ORNL is conducting a CMS to develop and evaluate alternatives for site closure and remediation. This section presents a brief summary of the preliminary development of alternatives; the alternatives listed here will be defined and evaluated in detail in the CMS. Alternatives were developed consistent with CERCLA, RCRA, and NEPA guidance and requirements.

### ES.8.1 Remedial Action Objectives

The general goal of WAG 6 closure and remedial action is to protect human health and the environment by closing the site to segregate wastes from the environment for as long as the waste remains a threat and by remediating unacceptable levels of environmental contamination. Based on (1) this general goal, (2) the nature and extent of contamination, and (3) the results of the baseline risk assessment, it is concluded that closure and remedial action at WAG 6 is required for source areas and groundwater, respectively. Specific remedial objectives for each of these waste media are as follows:

- Sources: protect public health and the environment by limiting direct contact/emissions, surface runoff, and leachate generation from on-site sources and associated contaminated leachate and soil.

- Groundwater: protect public health and the environment by controlling the migration of contaminants off-WAG and by protecting against future use of contaminated groundwater on-WAG.

### ES.8.2 Closure and Corrective Action Alternatives

Using the methodology recommended in EPA's Guidance for Conducting Feasibility Studies Under CERCLA (EPA 1988a), a range of seven alternatives was developed for addressing source areas and groundwater. The alternatives were developed to span a range of cost and permanence. The seven alternatives are summarized in Table ES.5.

## ES.9 SUMMARY AND CONCLUSIONS

As a key component of DOE's strategy for closure and remediation of WAG 6 under RCRA and CERCLA, an RFI was completed to evaluate potential human health and environmental impacts of the site, and to develop a preliminary list of alternatives to mitigate these impacts.

Physical characteristics and the nature and extent of contamination were evaluated to develop a conceptual model of the site. Using contaminant data and the site conceptual model as a basis, potential risks to human health and the environment were assessed through development and evaluation of hypothetical receptor scenarios.

Risks computed for a no action scenario on-WAG homesteader exceeded EPA's target risk range of 1E-6 to 1E-4, and therefore demonstrated the need for continued site controls and continued progress towards site closure and remedial action.

For the scenario that assumes DOE maintains and controls access to the site for 110 years, risks computed for receptors representing potential current public exposures did not exceed the upper limit of EPA's target risk range. The risk computed for the hypothetical off-site (Clinch River) receptor fell in the lower end of the range; however, due to conservative scenario assumptions, this estimate alone should not be used as the basis for actions beyond those already inherent in the scenario (e.g., access restrictions, site maintenance).

Computed risks for the hypothetical institutional control homesteader who moves on to the WAG following the release of site controls in 2100 exceeded EPA's target risk range. This demonstrated the need for site closure and remedial actions that are effective beyond the year 2100.

For both the no action and institutional control homesteader scenarios, computations showed that the majority of the risk was due to isotopes of europium associated with reactor control plates which were disposed in relatively small area of the site. If these control plates were removed, risks would be substantially reduced; however, risks associated with remaining radionuclides, which are more broadly distributed, were still predicted to exceed EPA's target risk range. Consequently, remedial action beyond removal of the control plates would still be required.

Based upon regulatory requirements, the nature and extent of contamination, and results of the baseline risk assessment, source areas and groundwater were identified as media that must be addressed in the CMS. Six alternatives (in addition to a no action alternative) were developed to address preliminary remedial action objectives established for these waste media.

# Executive Summary Tables

**Table ES.1. Summary of contaminants detected[a]**

| Analyte | CAS number | Groundwater | Surface water | Sediment | Soil |
|---|---|---|---|---|---|
| **Volatile Organic Compounds** | | | | | |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | S | S | -- | -- |
| 1,1,1-Trichloroethane | 71-55-6 | S | S | -- | -- |
| 1,1,2-Trichloroethane | 79-00-5 | S | -- | -- | -- |
| 1,1-Dichloroethane | 75-34-3 | S | S | -- | -- |
| 1,1-Dichloroethene | 75-35-4 | S | S | -- | R |
| 1,2-Dichloroethane | 107-06-2 | S | S | -- | -- |
| 1,2-Dichloroethene | 540-59-0 | S | S | S | S |
| 1,2-Dichloropropane | 78-87-5 | -- | -- | S | -- |
| 1,3-Dichloropropene | 10061-01-5 | -- | -- | S | -- |
| 1,4-Dioxane | 123-91-1 | S | -- | -- | -- |
| 2-Butanone | 78-93-3 | S | S | S | S/R |
| 2-Hexanone | 591-78-6 | -- | S | -- | S |
| 4-Methyl-2-Pentanone | 108-10-1 | R | S | -- | -- |
| Acetone | 67-64-1 | S/R | S | S | S |
| Benzene | 71-43-2 | S | S | -- | R |
| Carbon Disulfide | 75-15-0 | S/R | S | -- | S |
| Carbon Tetrachloride | 56-23-5 | S | -- | -- | -- |
| Chlorobenzene | 108-90-7 | -- | S | -- | S |
| Chloroethane | 75-00-3 | S | -- | -- | -- |
| Chloroform | 67-66-3 | S | S | S | S/R |
| Chloromethane | 74-87-3 | S | -- | -- | -- |
| Dichlorodifluoromethane | 75-71-8 | -- | S | -- | -- |
| Ethylbenzene | 100-41-4 | S/R | -- | -- | S |
| Isobutyl Alcohol | 78-83-1 | -- | -- | S | -- |
| Methylene Bromide | 74-95-3 | -- | -- | S | -- |
| Methylene Chloride | 75-09-2 | S/R | -- | S/R | S/R |
| Styrene | 100-42-5 | -- | -- | S | -- |
| Tetrachloroethene | 127-18-4 | S | S | S | S |
| Toluene | 108-88-3 | S | S | S | S/R |
| Trichloroethene | 71-55-6 | S | S | S | S/R |
| Trichlorofluoromethane | 75-69-4 | S | -- | S | R |
| Vinyl Acetate | 108-05-4 | -- | S | -- | -- |
| Vinyl Chloride | 75-01-4 | S | S | -- | -- |
| Xylene, total | 1330-20-7 | S | -- | S | S |

**Table ES.1. (continued)**

| Analyte | CAS number | Groundwater | Surface water | Sediment | Soil |
|---|---|---|---|---|---|
| **Semivolatile Organics** | | | | | |
| 2-Chlorophenol | 95-57-8 | -- | -- | -- | S |
| 2-Methyl-1,3 DIN Benzene | 606-20-2 | -- | -- | S | -- |
| 2-Methyl-Phenol | 95-48-7 | S | -- | -- | -- |
| Benzo(a)Anthracene | 56-55-3 | -- | -- | -- | S |
| Benzo(a)Pyrene | 50-32-8 | -- | -- | -- | S |
| Benzoic Acid | 65-85-0 | -- | -- | S | S/R |
| Bis(2-Ethylhexyl)Phthalate | 117-81-7 | S/R | S | S/R | S |
| Butyl Benzyl Phthalate | 85-68-7 | -- | -- | S | S |
| Chrysene | 218-01-9 | -- | -- | -- | S |
| Di-N-Butyl Phthalate | 84-74-2 | S/R | S | R | S |
| Di-N-Octyl Phthalate | 117-84-0 | S | -- | -- | S |
| Diethyl Phthalate | 84-66-2 | S/R | -- | -- | -- |
| N-Nitroso N-Phenyl Benzamine | 86-30-6 | -- | -- | S/R | S/R |
| N-Phenyl Benzamine | 122-39-4 | -- | -- | R | R |
| Naphthalene | 91-20-3 | S | S | -- | S |
| Pentachlorophenol | 87-86-5 | -- | -- | -- | S |
| Phenol | 108-95-2 | -- | -- | S | S |
| 2,4,5-T | 93-76-5 | S | -- | -- | -- |
| 2,4,5-TP (Silvex) | 93-72-1 | S/R | -- | -- | -- |
| 2,4-D | 120-83-2 | S/R | -- | -- | -- |
| Aroclor-1254 | 11097-69-1 | S | -- | -- | -- |
| **Inorganic constituents** | | | | | |
| Aluminium | 7429-90-5 | S/R | S/R | S/R | S/R |
| Antimony | 7440-36-0 | S | -- | -- | S/R |
| Arsenic | 7440-38-2 | S | S | S/R | S/R |
| Barium | 7440-39-3 | S | S/R | S/R | S/R |
| Beryllium | 7440-41-7 | S/R | S | S/R | S/R |
| Boron | 7440-42-8 | S | -- | -- | -- |
| Cadmium | 7440-43-9 | S/R | S | S/R | S/R |
| Calcium | 7440-70-2 | S/R | S/R | S/R | S/R |
| Chromium | 7440-47-3 | S | S | S/R | S/R |
| Cobalt | 7440-48-4 | S/R | S | S/R | S/R |
| Copper | 7440-50-8 | S/R | S/R | S/R | S/R |
| Iron | 7439-89-6 | S/R | S/R | S/R | S/R |
| Lead | 7439-92-1 | S/R | S/R | S/R | S/R |

Table ES.1. (continued)

| Analyte | CAS number | Groundwater | Surface water | Sediment | Soil |
|---|---|---|---|---|---|
| Magnesium | 7439-95-4 | S/R | S/R | S/R | S/R |
| Manganese | 7439-96-5 | S/R | S/R | S/R | S/R |
| Mercury | 7439-97-6 | S/R | S | S | S/R |
| Nickel | 7440-02-0 | S/R | S | S/R | S/R |
| Osmium | 7440-04-2 | -- | -- | S | R |
| Potassium | 7440-09-7 | S | S | S/R | S/R |
| Selenium | 7782-49-2 | -- | S | S | S/R |
| Silicon | 7440-21-3 | S/R | -- | -- | -- |
| Silver | 7440-22-4 | S | S | S/R | S/R |
| Sodium | 7440-23-5 | S/R | S/R | S/R | S/R |
| Strontium | 7440-26-6 | S | -- | -- | -- |
| Thallium | 7440-28-0 | -- | -- | -- | S/R |
| Titanium | 7440-32-6 | S/R | -- | -- | -- |
| Tin | 7440-31-5 | -- | -- | S/R | R |
| Vanadium | 7440-62-2 | S/R | S | S/R | S/R |
| Zinc | 7440-66-6 | S/R | S/R | S/R | S/R |
| **Gross Radioactivity** | | | | | |
| Gross Alpha | 12587-46-1 | S/R | S/R | S/R | S/R |
| Gross Beta | 12587-47-2 | S/R | S | S/R | S/R |
| **Manmade Radionuclides** | | | | | |
| Tritium | 10028-17-8 | S/R | S/R | S | -- |
| Cobalt-60 | 10198-40-0 | S | S | S | S |
| Strontium-89 | 14158-27-1 | -- | -- | R | S |
| Strontium-90 | 10098-97-2 | S | S | S/R | S/R |
| Cesium-137 | 10045-97-3 | S/R | S | S/R | S/R |
| Americium-241 | 14596-10-2 | S | -- | -- | -- |
| Lead-210 | 14255-04-0 | -- | -- | -- | S |
| Plutonium 238 | 13981-16-3 | S | S | -- | -- |
| Plutonium 239/240 | 0-013 | S | S | -- | -- |
| Actinium | 14952-40-0 | -- | -- | -- | S |
| Curium-244 | 13981-15-2 | S | S | -- | -- |
| Curium-242 | 15510-73-3 | -- | S | -- | -- |
| **Naturally Occurring Radionuclides** | | | | | |
| Potassium-40 | 13966-00-2 | S | S | S/R | S/R |
| **Uranium Series** | | | | | |
| Uranium-238 | 7440-61-1 | S | -- | S/R | S/R |
| Thorium-234 | 15065-10-8 | S | S/R | S/R | S/R |

**Table ES.1. (continued)**

| Analyte | CAS number | Groundwater | Surface water | Sediment | Soil |
|---|---|---|---|---|---|
| Uranium-234 | 13966-29-5 | S | -- | S/R | S/R |
| Thorium-230 | 14269-63-7 | S | S/R | S/R | S/R |
| Radium-226 | 13982-63-3 | S | -- | S/R | S/R |
| **Thorium Series** | | | | | |
| Thorium-232 | 7440-29-1 | S | S | S/R | S/R |
| Radium-228 | 15262-20-1 | S | S | S/R | S/R |
| Thorium-228 | 14274-82-9 | S | S | S/R | S/R |
| Radium-224 | 13233-32-4 | S | S/R | S/R | S/R |

[a] S = Detected at least once in site samples; R = detected at least once in reference (background) samples; "--" not detected.

[b] Based on unfiltered samples.

**Table ES.2. Migration of radionuclides off-site**

| Perimeter segment | Radionuclides | Discussion |
|---|---|---|
| | Areas likely for off-site migration of contaminants | |
| H-1 | Surface Water<br>Tritium<br>Strontium-90 | Storm flow sampling identified significant flux of contaminants off-site in surface water. |
| | Groundwater<br>Tritium<br>Strontium-90 | Wells upgradient are contaminated. |
| H-2 | Surface Water<br>Tritium | Storm flow sampling identified significant flux of tritium off site. |
| | Groundwater<br>Tritium | Concentrations exceeding MCL detected in several upgradient wells. |
| H-3 | Groundwater<br>Tritium<br>Cobalt-60<br>Strontium-90 | Compliance and RFI monitoring data indicate presence of radionuclides in groundwater. |
| | Areas not likely for off-site migration of contaminants | |
| L-1 | | Upgradient to waste disposal areas |

**Table ES.3. Migration of chemicals off-site**

| Perimeter segment | Chemicals | Discussion |
|---|---|---|
| | Areas likely for off-site migration of contaminants | |
| H-1 | Surface water<br>none | No significant VOC concentrations detected during storm flow sampling |
| | Groundwater<br>VOCs | Upgradient wells contaminated, monitor unconsolidated zone and bedrock zone. Groundwater wells in this vicinity monitor bedrock zone only. |
| H-2 | Surface water<br>VOCs | Low concentration detected during storm flow. |
| | Groundwater<br>None | Well positioned between creeks DA and DB have had relatively low concentrations of VOCs detected in it. |
| H-3 | Surface water<br>None | No surface water features in this area. |
| | Groundwater<br>VOCs | VOCs detected during compliance and RFI monitoring. |
| | Areas not likely for off-site migration of contaminants | |
| L-1 | Surface and Groundwater<br>None | Upgradient to any waste disposal area |
| L-2 | Surface water<br>None | No contamination detected. |
| | Groundwater<br>VOCs | VOCs have been detected; however, in relatively low concentrations. |

**Table ES.4. Summary of risk characterization results**

| Scenarios and Associated Receptors | Time Period[a] | Radionuclide Dose (rem) | Radionuclide Risk | Chemical Risk | Chemical Hazard Index[c] |
|---|---|---|---|---|---|
| **No Action Scenario** | | | | | |
| On-WAG homesteader -- adult (WAG-wide) | Current | 2E+5 | 1.0 | 4E-4 | 1 (T) |
| On-WAG homesteader -- child (WAG-wide) | Current | --[d] | --[d] | 2E-4 | 3 (T) |
| On-WAG homesteader -- adult (auger hole subarea) | Current | 1E+6 | 1.0 | 3E-4 | 2 (L) |
| On-WAG homesteader -- child (auger hole subarea) | Current | --[d] | --[d] | 2E-4 | 1.0 (K)<br>5.0 (L) |
| **Institutional Control Scenario** | | | | | |
| ORNL worker | Current | 2E+0 | 1E-3 | 4E-11 | 2E-8 (T) |
| Hunter | Current | 3E-5 | 8E-9 | 2E-12 | 2E-5 (T) |
| Boundary receptor | Current | 9E-6 | 1E-8 | 2E-10 | 4E-8 (T) |
| Off-WAG homesteader -- adult | Current | 1E-1 | 6E-5 | 1E-7 | 7E-3 |
| Off-WAG homesteader -- child | Current | --[d] | --[d] | 3E-8 | 2E-2 |
| On-WAG homesteader -- adult (WAG-wide) | Future | 4E+3 | 3E-1 | 4E-4[b] | 1 (T)[b] |
| On-WAG homesteader -- adult (auger hole subarea) | Future | 3E+4 | 9E-1 | 3E-4[b] | 2 (L)[b] |

[a]"Current" time period means receptor risk evaluated using estimated contaminant concentrations for 1990-2020 time period. "Future" time period means receptor risk evaluated using estimated contaminant concentrations for 2100-2130 time period.

[b]Steady state conditions assumed for chemical contaminants; therefore, estimates of future risk and hazard indices are identical to those for "current"-day on-site homesteader.

[c]T= total; L= lower; K= kidney; For T≥1.0, effect-specific hazard indixes all less than 1.0

[d]Current state of the art for radionuclide risk assessment does not provide specific tools for estimating dose/risk to children; dose/risks computed for adults are assumed representative for children.

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**Table ES.5. Preliminary closure alternatives for WAG 6**

| Alternative | Description |
|---|---|
| 1 | **No Action** (required by CERCLA) |
| 2 | **Source Areas:** Small caps covering individual groups of disposal units will be constructed. Wastes inundated by White Oak Lake will be excavated and relocated on-site to minimize leaching. Wastes in outlying areas will be relocated on-site to minimize the need for outlying caps.<br><br>**Groundwater:** Institutional controls will be implemented to prevent groundwater use and groundwater will continue to be monitored; a final decision on groundwater will be deferred until remediation of WAG 2. |
| 3 | **Source Areas:** Same as Alternative 1<br><br>**Groundwater:** In those areas where significant off-site migration of contaminants is occurring, trench drains will be constructed to collect the contaminated groundwater; if necessary, the groundwater will be treated in the ORNL liquid waste treatment system. Institutional controls will be implemented to prevent groundwater use and groundwater will continue to be monitored. |
| 4 | **Source Areas:** Large caps covering numerous adjacent groups of disposal units will be constructed. Prior to capping, structural stabilization of trench wastes (either by grouting or dynamic compaction) will be performed. Wastes inundated by White Oak Lake will be excavated and relocated on-site to minimize leaching. Wastes in outlying areas will be relocated on-site to minimize the need for outlying caps.<br><br>**Groundwater:** Institutional controls will be implemented to prevent groundwater use and groundwater will continue to be monitored. |
| 5 | **Source Areas:** Same as Alternative 4.<br><br>**Groundwater:** Institutional controls will be implemented to prevent groundwater use and groundwater will continue to be monitored; a final decision on groundwater will be deferred until remediation of WAG 2. |
| 6 | **Source Areas:** Same as Alternative 4.<br><br>**Groundwater:** In those areas where significant off-site migration of contaminants is occurring, trench drains will be constructed to collect the contaminated groundwater; if necessary, the groundwater will be treated in the ORNL liquid waste treatment system. Institutional controls will be implemented to prevent groundwater use and groundwater will continue to be monitored. |

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**Table ES-5.** (continued)

| Alternative | Description |
|---|---|
| 7 | **Source Areas:** Same as Alternative 4, except in-situ vitrification will be used in selected areas of the site for long term immobilization of radiological contaminants.<br><br>**Groundwater:** In those areas where significant off-site migration of contaminants is occurring, trench drains will be constructed to collect the contaminated groundwater; if necessary, the groundwater will be treated in the ORNL liquid waste treatment system. Institutional controls will be implemented to prevent groundwater use and groundwater will continue to be monitored. |

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# Executive Summary Figures

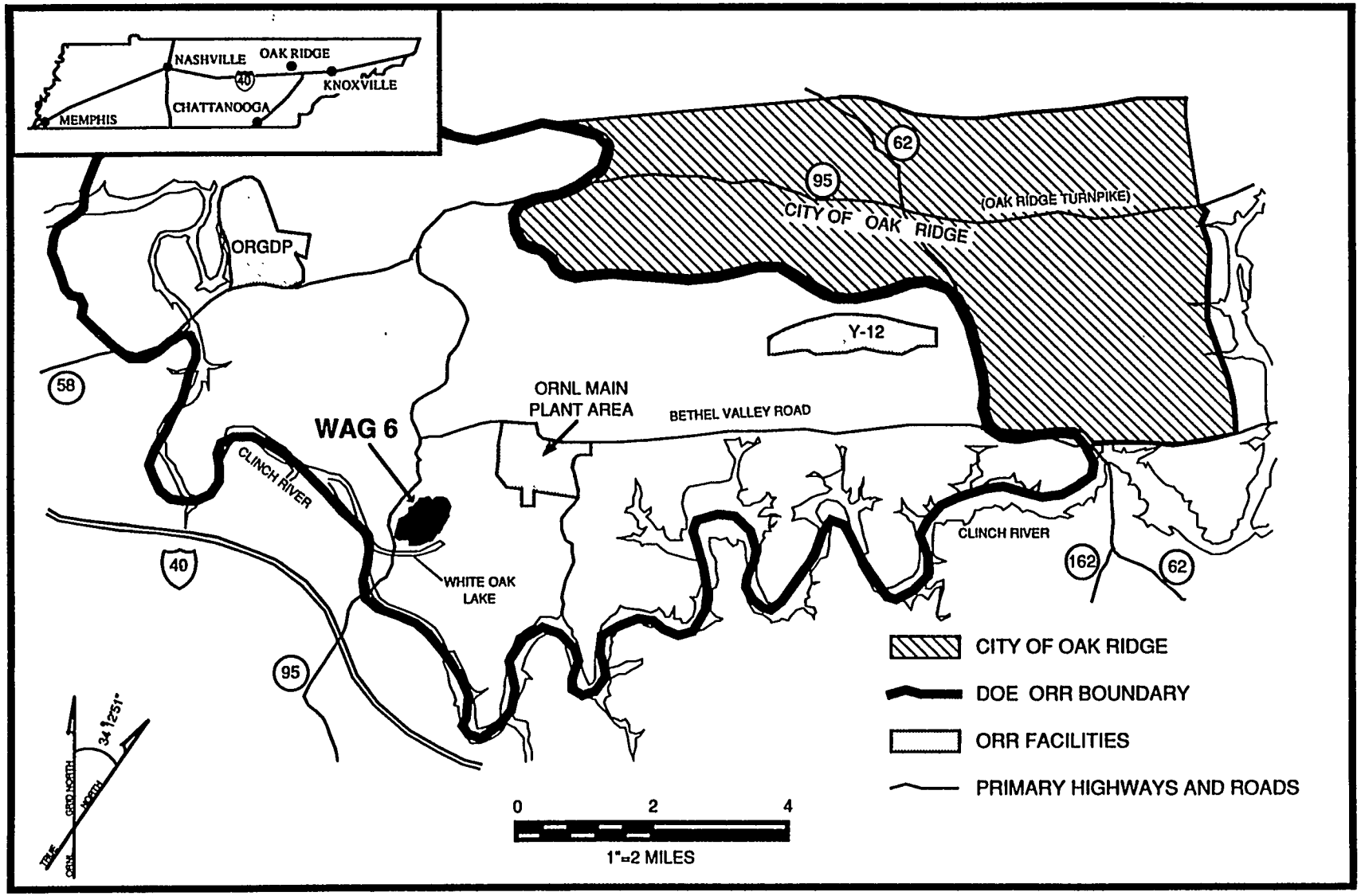
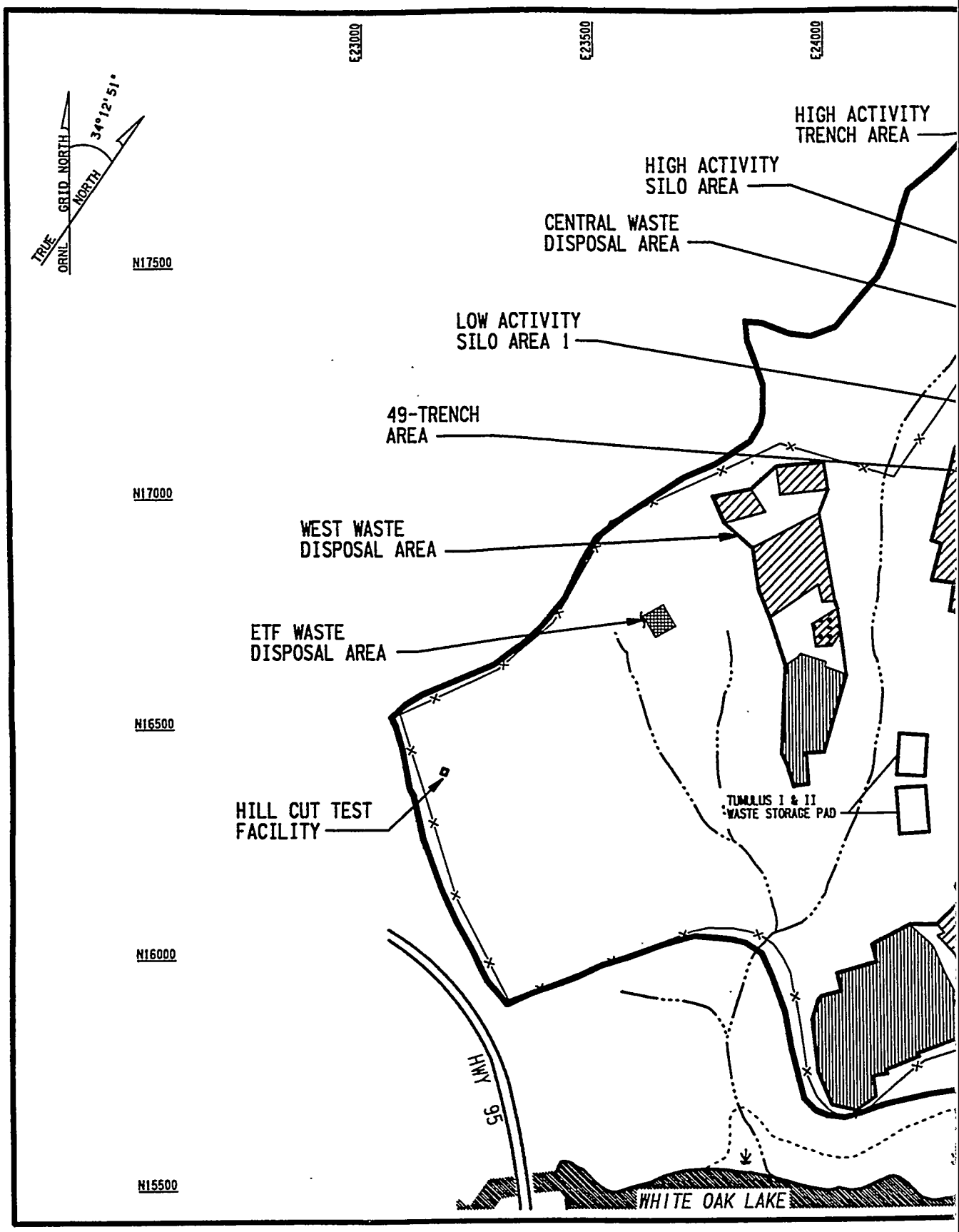



**Fig. ES.1. DOE Oak Ridge Reservation.**

5.18 4104.7




WAG 6 06F247.DGN

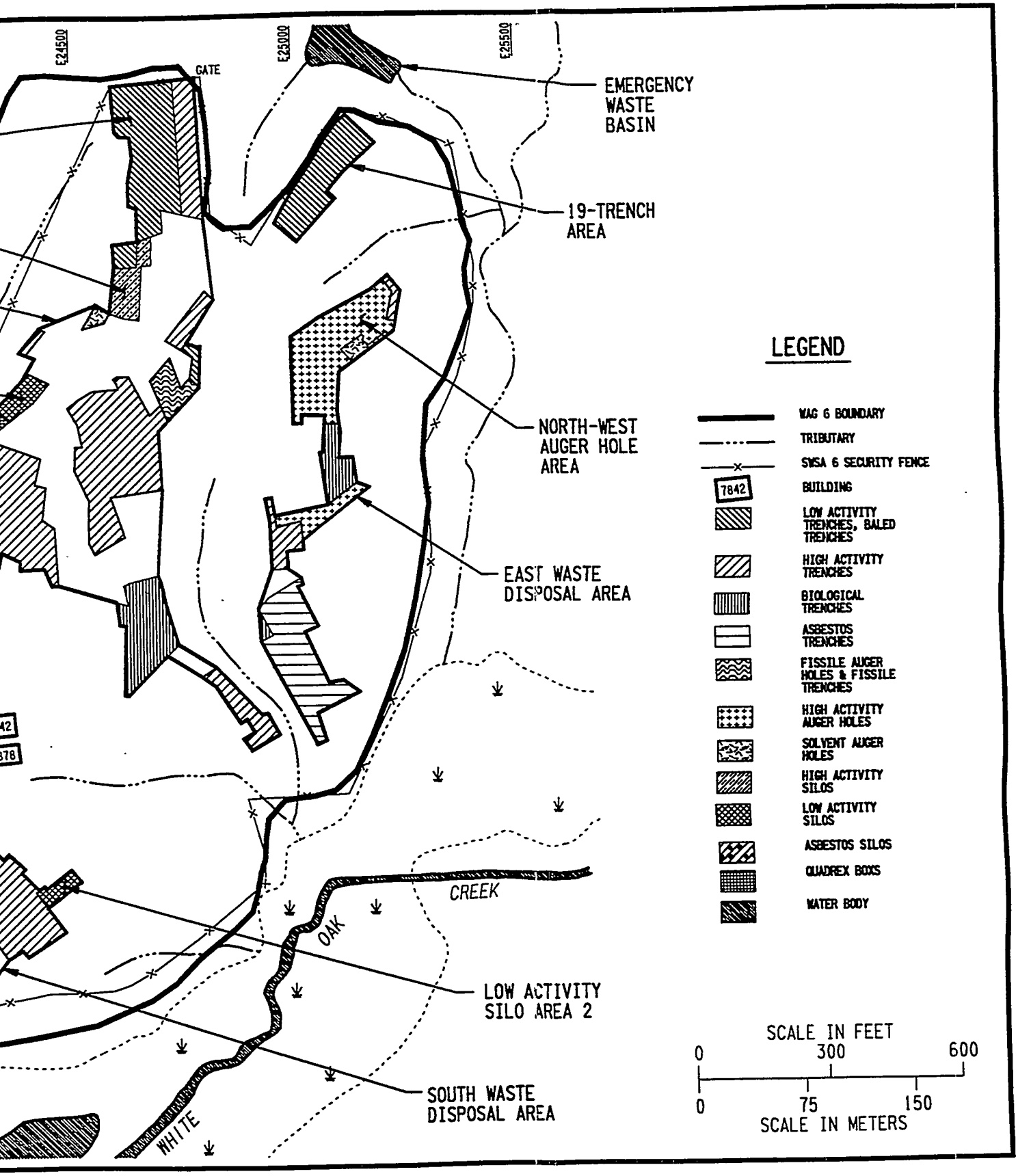



**Fig. ES.2. Waste disposal unit locations.**

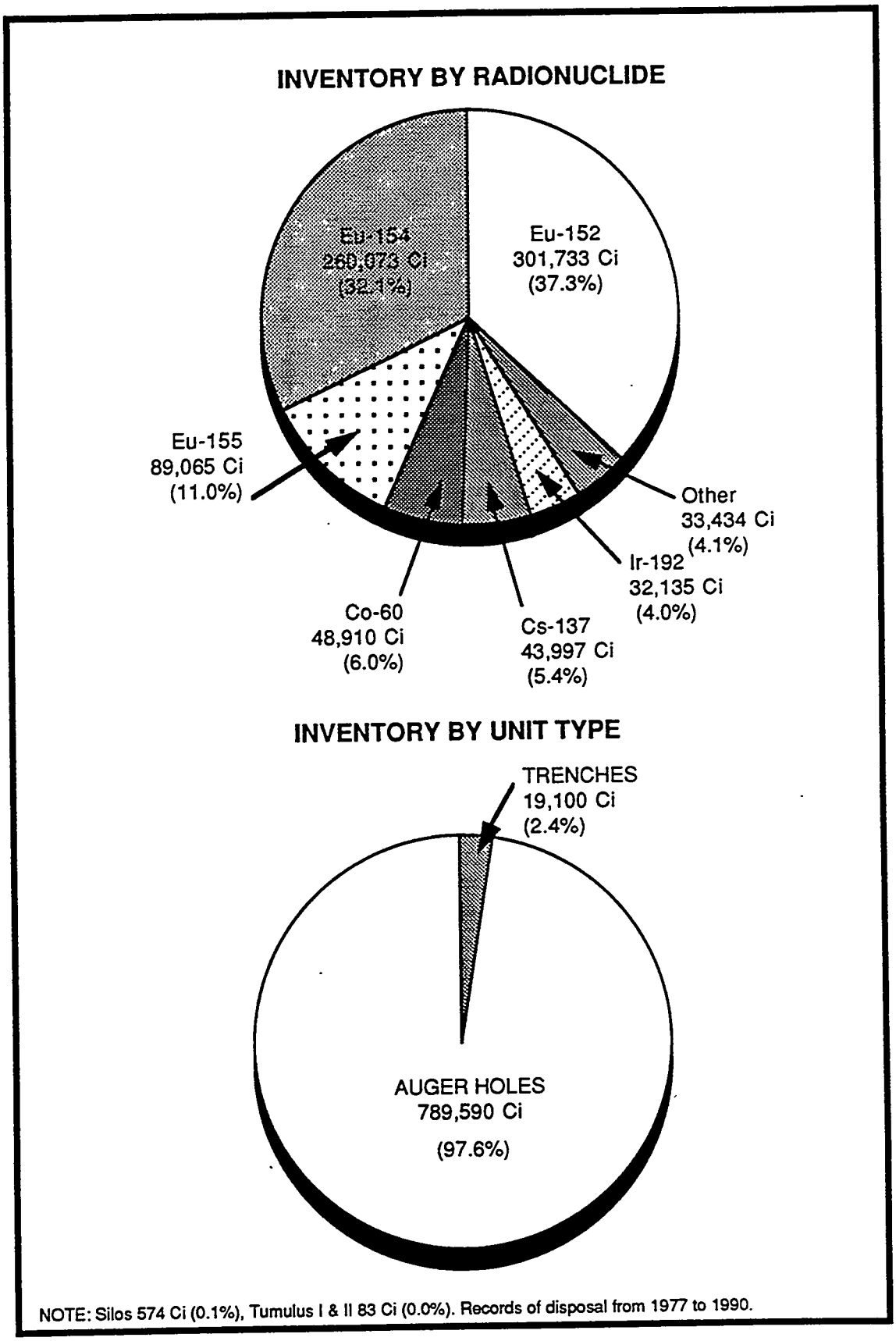
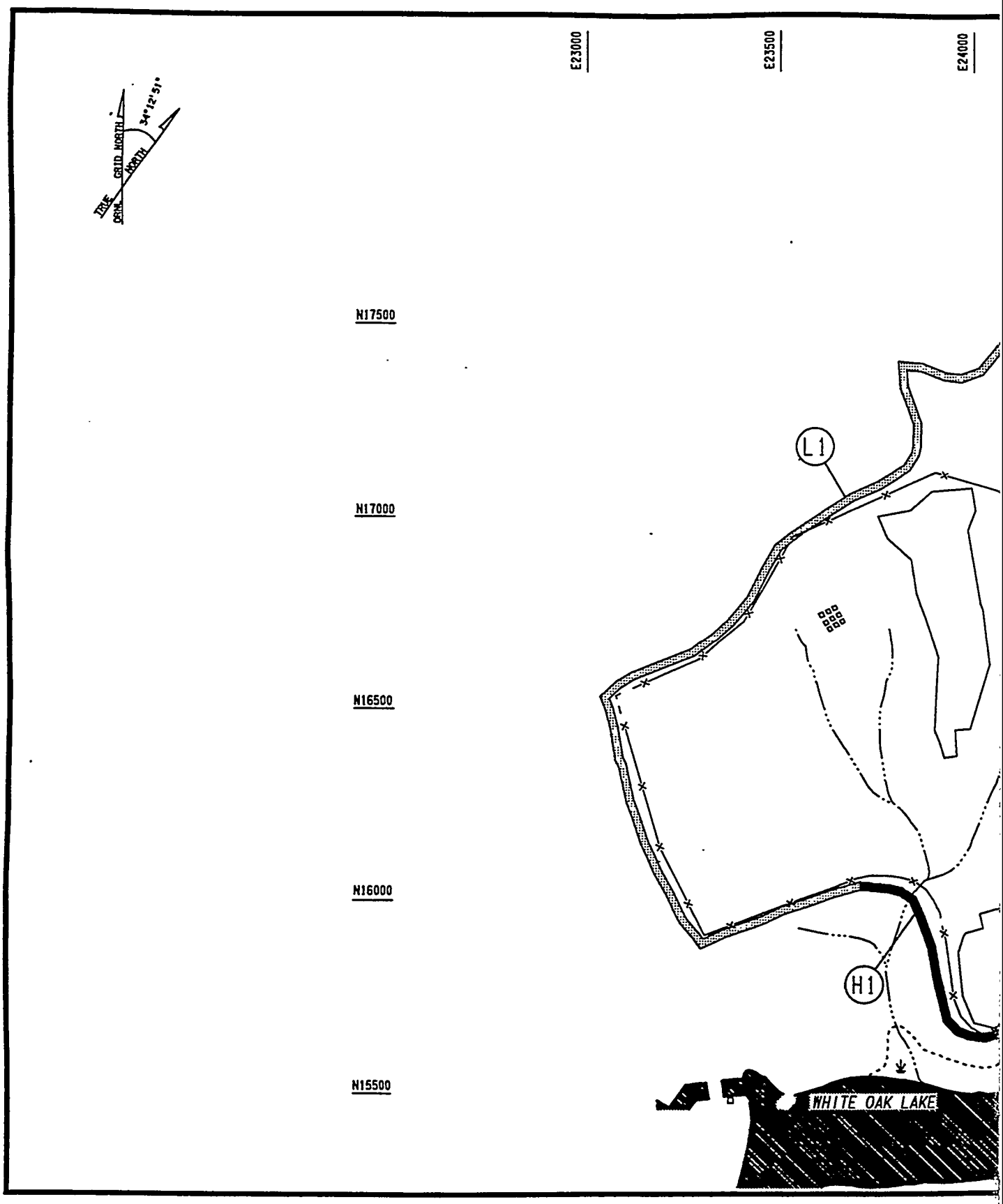



**Fig. ES.3. Summary of radioactive waste disposal log for SWSA 6.**




WAG6 06F335.DGN CHEM

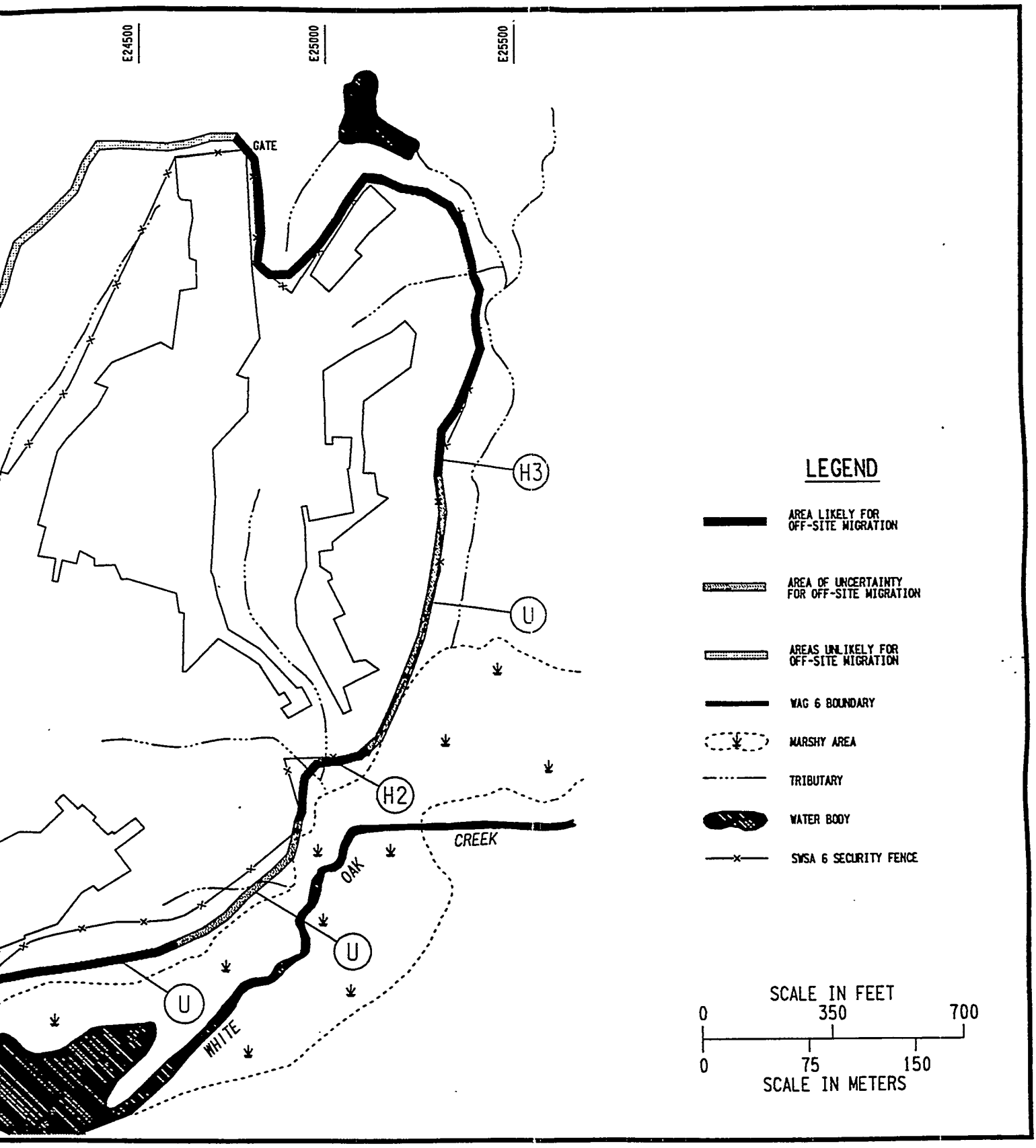
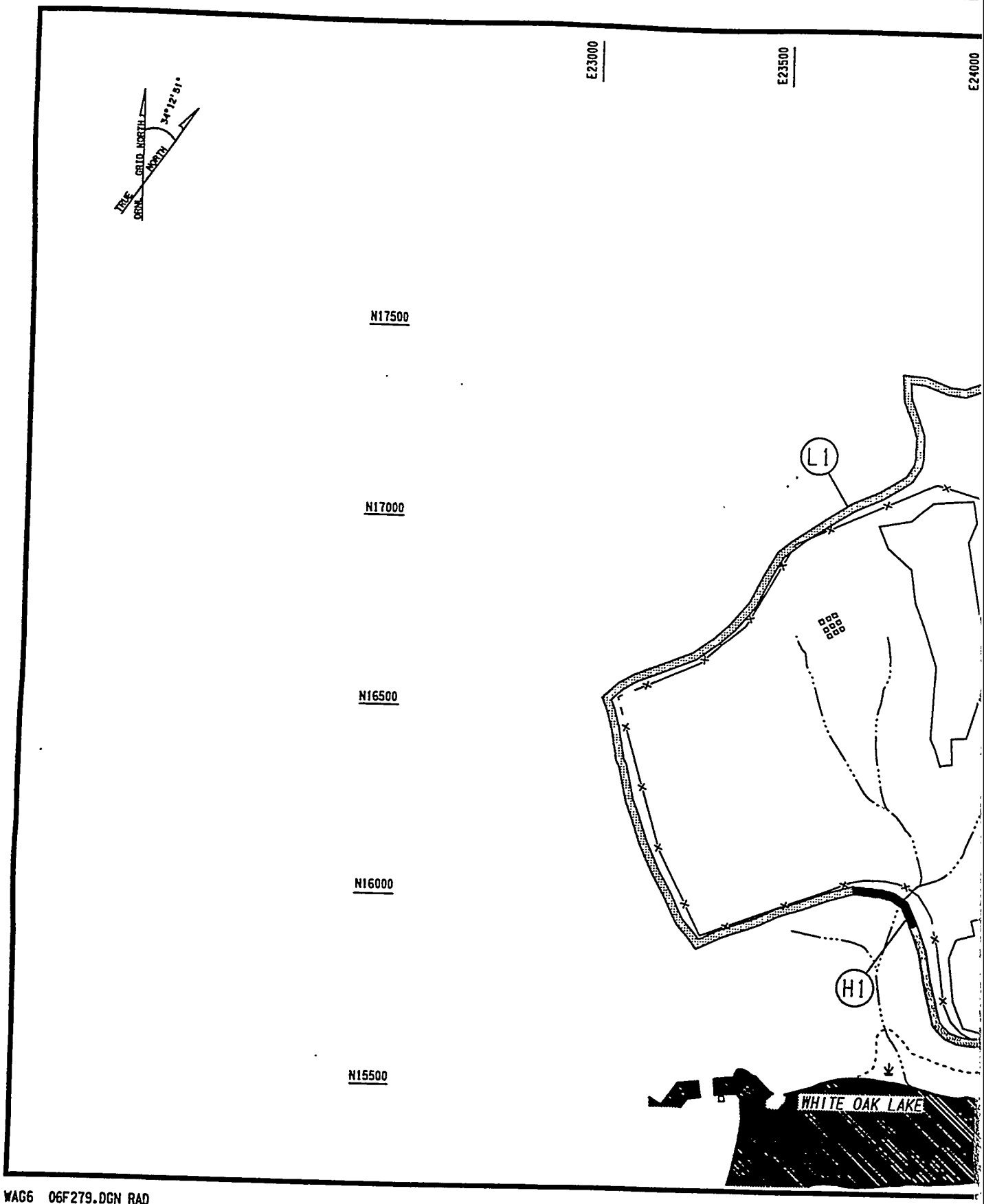



**Fig. ES-4. Possible off site migration routes for radionuclides**




WAG6 06F279.DGN RAD

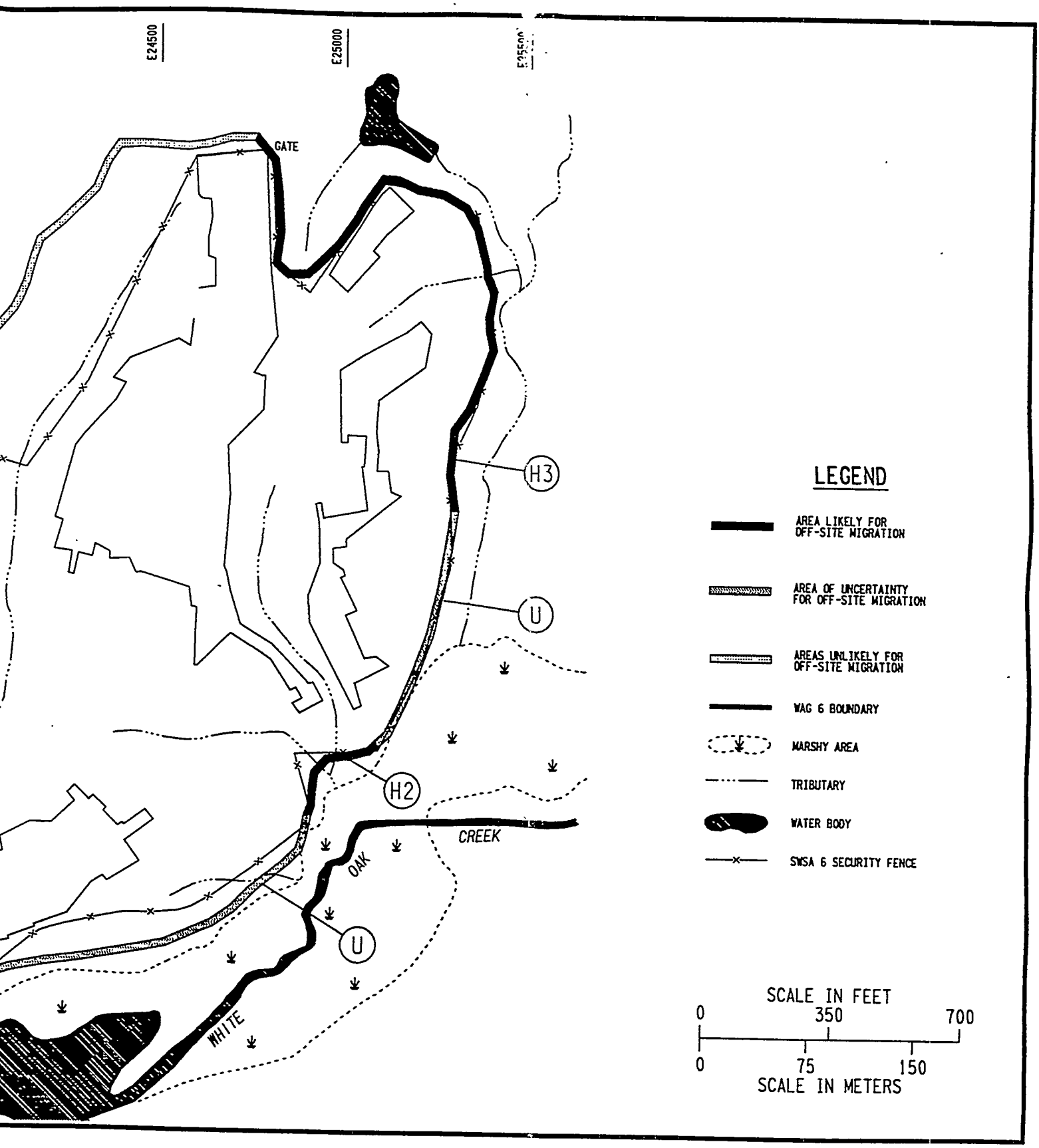



**Fig. ES-5. Off site migration patterns for chemicals.**

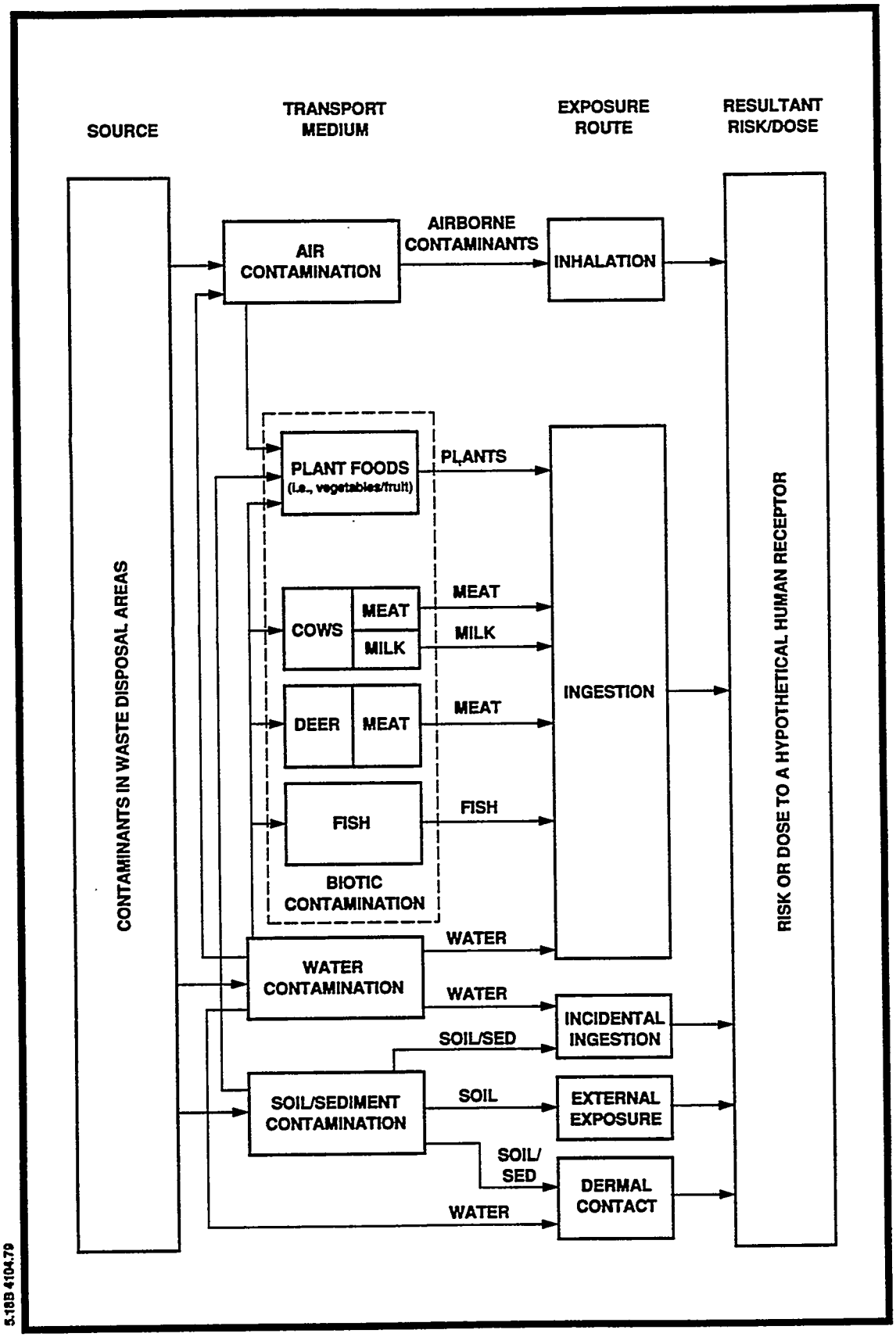



Fig. ES.6. Flow diagram of exposure pathways for WAG 6.

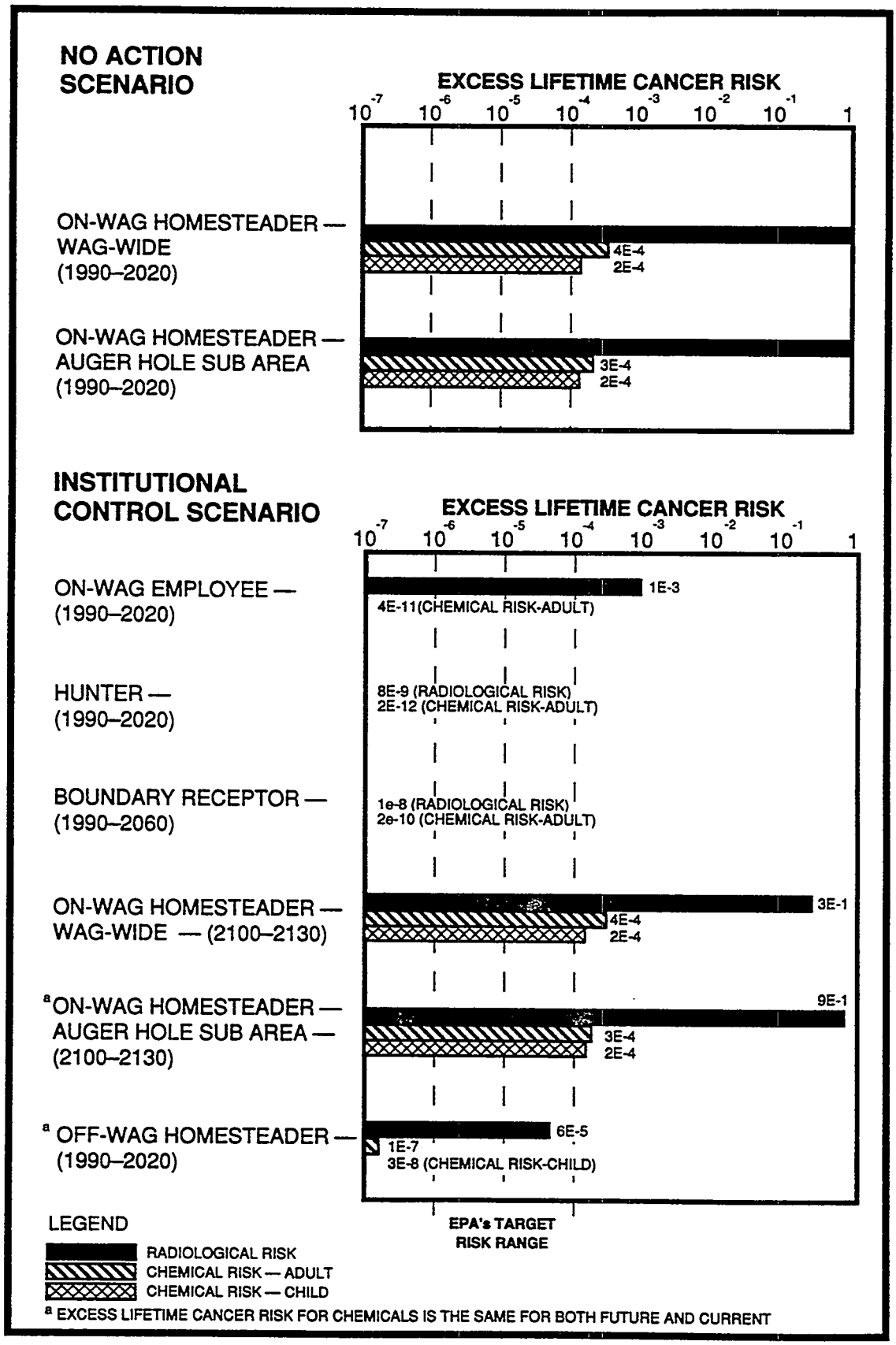



**Fig. ES.7. Summary of carcinogenic risk values.**

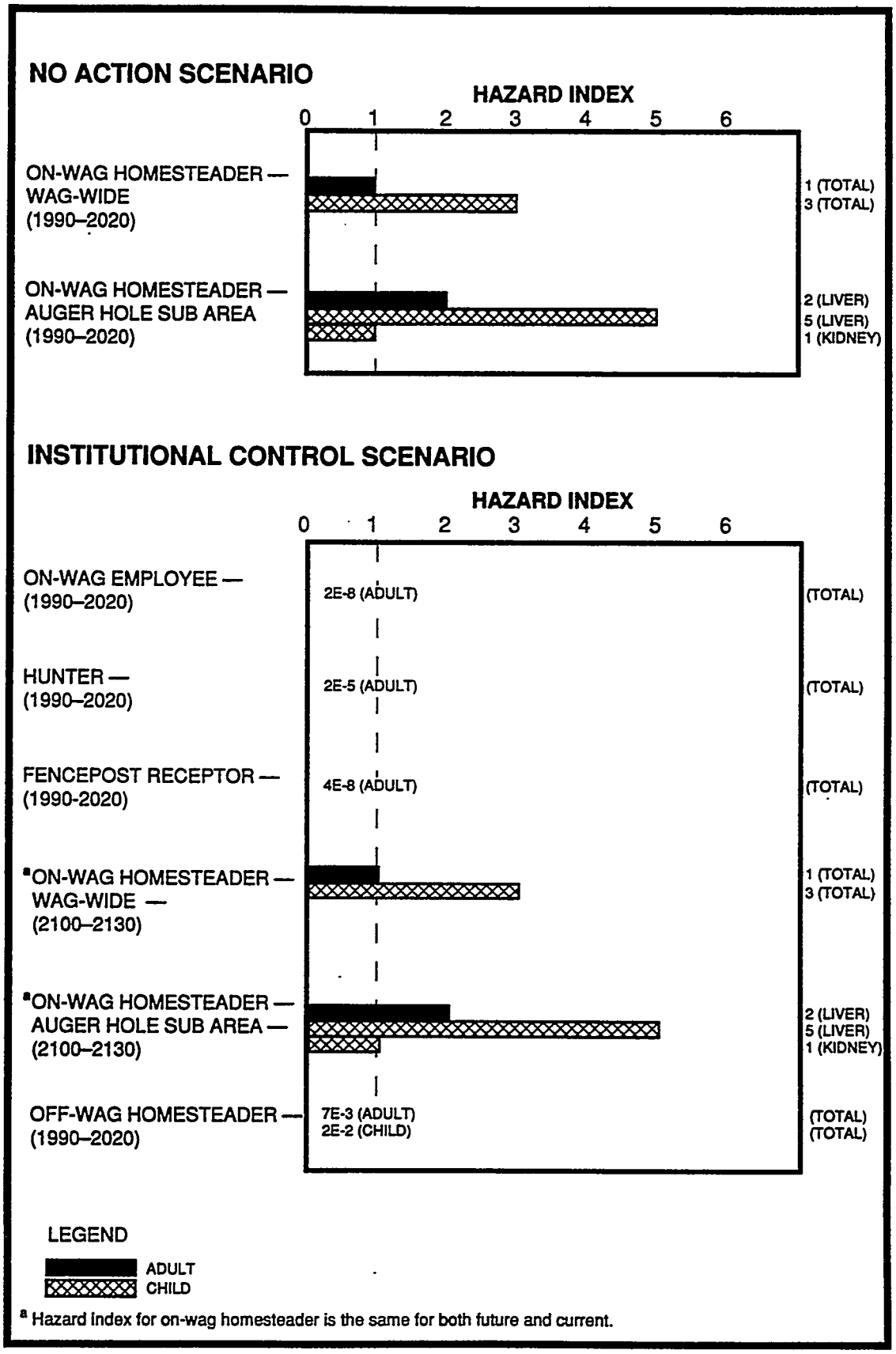



**Fig. ES.8. Summary of noncarcinogenic effects.**

5.18F 4104.168

# 1. INTRODUCTION

This report documents the results and describes the activities associated with the Resource Conservation and Recovery Act Facility Investigation (RFI) of Waste Area Grouping (WAG) 6 at the U. S. Department of Energy's (DOE) Oak Ridge National Laboratory (ORNL). This introductory section provides an overview (Sect. 1.1) that briefly summarizes organizational, programmatic, regulatory, and site information that is relevant to the development and performance of the WAG 6 RFI. Subsequent sections of the introduction provide more detail on regulatory initiatives (Sect. 1.2), site information and background (Sect. 1.3), purpose and scope of the WAG 6 RFI (Sect. 1.4), and, finally, a reader's guide to the organization of the remainder of the RFI report (Sect. 1.5).

## 1.1 OVERVIEW

ORNL is one of three principal facilities on DOE's Oak Ridge Reservation (ORR), which was established during the World War II "Manhattan" atomic weapons project in 1942 and 1943. ORNL is currently managed and operated for DOE by Martin Marietta Energy Systems, Inc. (Energy Systems). The ORR is shown in Fig. 1.1.

In contrast to the production-oriented operations of the other two ORR facilities, the Y-12 Plant and the Oak Ridge Gaseous Diffusion Plant, ORNL has maintained a research-oriented mission. As a result of the many and varying research projects conducted throughout its operational history, ORNL has generated diverse streams of radioactive, hazardous, and mixed (radioactive and hazardous) wastes. Some of these wastes have been disposed of on the ORR by various methods, including shallow land burial (SLB) in trenches and auger holes.

As part of DOE's national Environmental Restoration (ER) Program, ORNL's ER Program addresses the cleanup of areas or facilities potentially contaminated by past activities including waste disposal. Initially, guidance for accomplishing cleanup tasks was provided by DOE orders, one of which, DOE Order 5480.14, set a timetable for bringing DOE facilities into compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), even though the Environmental Protection Agency (EPA) had no direct CERCLA enforcement authority at ORNL. However, in April 1986, EPA issued a permit for the DOE/ORNL Hazardous Materials Storage Area, Building 7652. This permit gave EPA enforcement authority for ORNL remedial response activities through RCRA Section 3004(u).

As the first phase of the RCRA 3004(u) Corrective Action Program, in March 1987 ORNL submitted to EPA a RCRA Facilities Assessment (RFA) (ORNL 1987). The RFA identified approximately 250 solid waste management units (SWMUs). Included among the SWMUs were waste tanks, solid waste storage areas (SWSAs), waste treatment units, impoundments, and leak and spill sites. Because of the large number of sites and the interaction among many of them, ORNL proposed to EPA that the SWMUs be grouped into areas that were geographically contiguous or within defined hydrologic units. The Waste Area Grouping (WAG) concept produced 20 WAGs.

The subject of this report, WAG 6, comprises three SWMUs. The largest and most important is SWSA 6, which is the current operating disposal area for low-level radioactive waste (LLW) at ORNL. Also, from November 1980 to May 1986, chemically hazardous wastes were disposed within SWSA 6, which makes it subject to regulation under RCRA. The other two WAG 6 SWMUs are the Emergency Waste Basin (EWB) and the Explosives Detonation Trench (EDT). Greater detail about WAG 6 is provided in Sect. 1.3.

## 1.2 REGULATORY INITIATIVES AND BACKGROUND

The WAG 6 RFI and all subsequent actions leading to eventual closure and remedial action of SWSA 6 and other portions of WAG 6 are being conducted in accordance with RCRA, as amended by the Hazardous and Solid Waste Amendments Act of 1984 (HSWA). WAG 6 activities also are subject to CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, and the National Environmental Policy Act (NEPA) of 1969, as amended. The following paragraphs describe these regulatory initiatives and how they apply to the ORNL ER Program and WAG 6.

### 1.2.1 The ORNL ER Program

When ORNL established its ER Program (formerly called the Remedial Action Program), the ORNL program pursued its mission in accordance with DOE Orders 5820.2, "Radioactive Waste Management," and 5480.14, "Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Program." DOE orders are the mechanism by which DOE issues formal operational and safety instructions to management and operating (M&O) contractors operating DOE facilities. DOE Order 5820.2 (superseded by 5820.2A in August 1988) establishes policies, guidelines, and minimum requirements for DOE management of radioactive and mixed waste and contaminated facilities. DOE Order 5480.14 provides instructions for implementing a DOE CERCLA program to identify and investigate inactive waste disposal sites and to implement remedial actions where needed. ORNL ER projects mandated by these DOE orders were integrated into a comprehensive long-range environmental plan for the facility.

EPA's enforcement role in ORNL ER activities began in September 1986, when EPA issued its RCRA permit for the ORNL Hazardous Material Storage Area, Bldg. 7652, and invoked Section 3004(u) of RCRA. The primary objective of RCRA 3004(u) is to address releases of hazardous constituents from SWMUs at RCRA-permitted facilities. To achieve the objectives of Section 3004(u), EPA has established the RCRA Corrective Action Program, which requires the following four steps (EPA 1987a):

1. An RFA, which documents SWMUs with actual or potential contaminant releases requiring further investigation

2. An RFI, which characterizes the extent and impact of contaminant releases identified in the RFA

3. A Corrective Measures Study, (CMS), which identifies appropriate remedies for problems identified in the RFI

4. Corrective Measures Implementation (CMI), which includes design, implementation, and monitoring of performance for the corrective measures selected

An RFA submitted to EPA in March 1987 (ORNL 1987) identified 20 WAGs.

On November 21, 1989, EPA placed the DOE ORR on the CERCLA National Priority List (NPL), which made CERCLA enforceable on the ORR, including ORNL. Because of the number of regulatory programs and regulatory agencies involved, DOE, EPA, and the State of Tennessee are negotiating a three-party Federal Facilities Agreement (FFA) to guide environmental restoration on the ORR. The FFA will likely specify a methodology mirroring the CERCLA process for addressing contamination of facilities and the environment.

### 1.2.2 WAG 6 Regulatory Background

As noted, WAG 6 is unique among the ORNL WAGs in that remediation of the site is conducted primarily under the authority and terminology of RCRA. While waste disposal activities at SWSA 6 are described in detail in Sect. 1.3 and Appendix 1A of this report, a brief summary is needed for understanding the site's regulatory history and status and the impacts the regulatory requirements have had on activities at the site.

SWSA 6 was opened and began receiving limited waste shipments in 1969, and by 1973, was receiving most of ORNL's solid LLW. Although most of the waste disposed in the SWSA was radioactive waste, hazardous chemical wastes were also disposed at the site until April 1986, when chemical disposal ceased. LLW disposal has continued.

For RCRA-regulated facilities ceasing operations under RCRA interim status (as did SWSA 6), the law specifies that site closure must begin no later than November 1988. Consequently, ORNL prepared a RCRA Closure Plan for SWSA 6, which was approved by the State of Tennessee in September 1988 (BNI 1988a). Although RCRA required the closure of only those SWSA 6 disposal units that had received hazardous wastes, ORNL determined that it was technically inappropriate to close these units independently of the adjacent non-RCRA units. In addition, because the nature and extent of radiological and chemical contamination associated with the site was unknown, ORNL proposed that environmental investigations of all of WAG 6 precede final closure of SWSA 6 so that all sources and all environmental contamination could be addressed comprehensively.

Consequently, the SWSA 6 Closure Plan prepared by ORNL specified a series of activities leading to final closure and corrective action. The initial activity was an Interim Corrective Measure (ICM) to reduce releases of contaminants from the RCRA-regulated disposal trenches and auger holes at SWSA 6. The ICM (described in Sect. 1.3.1.1) consisted of a high-density polyethylene (HDPE) interim cap and drainage improvements. Subsequent activities leading to final closure will follow the RCRA Corrective Action Program described above.

At the time the closure plan was prepared, ORNL anticipated that the ORR would be listed on the NPL, so the closure plan also states that SWSA 6 closure activities and WAG 6 investigations will be conducted in general conformance with CERCLA guidance. As previously noted, EPA did place the DOE ORR on the CERCLA NPL, which made CERCLA enforceable at ORNL, including WAG 6. However, because SWSA 6 is being closed under a RCRA closure plan prepared more than 2 years before the NPL listing and before preparation of the draft FFA, EPA, the Tennessee Department of Conservation (TDC), and DOE decided that the closure should proceed as outlined in the closure plan.

The second activity specified in the closure plan was an RFI for WAG 6. An RFI Plan was prepared (BNI 1989) and submitted to TDC and EPA for review. Comments were received and responded to in writing by DOE/Energy Systems. RFI field activities were performed in two parts, referred to as Activity 1 and Activity 2. Activity 1 comprised field activities conducted from December 1988 through fall 1989. Activity 2 field activities were conducted from winter 1989 through summer 1990. Analytical results of Activity 1 were reported and summarized in a Site Characterization Summary Report (BNI 1990) prepared for submittal to the Agency for Toxic Substances and Disease Registry (ATSDR). Both Activity 1 and Activity 2 analyses and results are presented in this RFI Report. The purpose and scope of the RFI are described in Sect. 1.4.

## 1.3 SITE INFORMATION AND BACKGROUND

Site information and background on WAG 6 is presented in four sections. Section 1.3.1 provides a general site description and history of operations. Section 1.3.2 and 1.3.3 summarize remedial action technology demonstrations and previous investigations conducted at WAG 6, respectively. Relevant demographic information is presented in Section 1.3.4.

### 1.3.1 Site Description and History

As shown in Fig. 1.1, WAG 6 is located on the ORR, approximately 10 miles southwest of Oak Ridge, Tennessee. WAG 6 is part of ORNL and is located approximately 2 miles southwest of the ORNL Main Plant Area. The location of WAG 6 in relation to other ORNL WAGs is shown in Fig. 1.2.

WAG 6 lies within Melton Valley, between Haw Ridge on the north and Copper Ridge on the south. WAG 6 is bordered on the south by White Oak Lake (WOL), on the east by a tributary of White Oak Creek (WOC), and on the west by State Highway 95. The site's topography is gently to moderately sloping, draining to WOL on the south and to an unnamed tributary of WOC on the east (Fig. 1.3).

WAG 6 comprises three SWMUs:

- SWMU 6.1—SWSA 6
- SWMU 6.2—Emergency Waste Basin (EWB)
- SWMU 6.3—Explosives Detonation Trench (EDT)

SWSA 6 is the only SWMU in WAG 6 that includes disposed wastes. The EWB was constructed for emergency storage of ORNL process wastewater but was never used for this purpose. The EDT, which is no longer in use and has been backfilled, lies within the geographic boundary of SWSA 6 and is adjacent to SWSA 6 waste disposal trenches. Figure 1.4 shows the relative locations of the three SWMUs and summarizes land use within WAG 6.

Access to SWSA 6 is closely controlled. It is enclosed by a 8-ft-high chain link fence topped with barbed wire, and access is controlled by two electronically operated gates activated by access cards. Other key surface features include two permanent buildings (7842 and 7878); several temporary (shed-type) structures; overhead power and telephone lines; poles and stanchions; two tumulus pads with stacked concrete vaults; two weather stations; and numerous wells and piezometers. Concrete vaults and large-diameter corrugated pipe used in construction of waste disposal units are also on-site but are moved frequently. Culverts have been constructed where natural or man-made drainages cross site roads. Flumes and weirs installed before, or as part of, the WAG 6 RFI exist on most of the interior drainage channels. In 1990, work began on the construction of the Interim Waste Management Facility (IWMF) in the southwestern portion of WAG 6. To date, the construction has involved clearing and grading an approximately 6-acre area. Other areas of WAG 6 are grass-covered, and these are mowed regularly.

Each SWMU is described in the following paragraphs.

#### 1.3.1.1 SWSA 6 (SWMU 6.1)

SWSA 6 is the principal source of environmental contamination at WAG 6. It was opened for limited disposal operations in 1969 and began full-scale operations in 1973. It has received LLW, chemical, biological, and a variety of other wastes resulting from operations conducted at ORNL (e.g., solvents, scintillation liquids, laboratory glassware and equipment, and protective clothing). Waste packaging has varied from complete lack of containerization to plastic bags to stainless steel drums. Since April 1986, only LLW has been disposed of in SWSA 6. Figure 1.5 summarizes waste disposal operations at SWSA 6.

SWSA 6 covers approximately 68 acres, approximately 19 acres of which are used for waste disposal. The following paragraphs describe the SWSA 6 waste disposal units, waste inventory, planned site operations, and ICMs.

**Waste Disposal Units.** The variety of waste types and forms, coupled with the evolution of waste disposal regulations and disposal techniques, has resulted in several different types of waste disposal units at SWSA 6, including trenches, auger holes, silos, and aboveground container storage facilities. Table 1.1 summarizes the general types of waste disposal units; cites the approximate number of units, land area occupied, and inventory; and briefly describes how each unit has been used. Information on the type and form of the waste received in each type of disposal unit is provided in Appendix 1A.

Figure 1.6 illustrates the locations of the different types of waste disposal units within SWSA 6.

**Waste Inventory.** Since SWSA 6 was opened, records have been kept for each shipment of waste disposed there. These records are part of the ORNL Solid Waste Disposal Log, a computerized data base documenting ORNL waste shipments. Appendix 1A describes data base records for SWSA 6 and provides tables summarizing the records. Figure 1.7 illustrates the inventories (in curies) of various radionuclides disposed in SWSA and the total activity in curies disposed in the unit types.

**Planned Site Operations.** Site operations ongoing and planned for SWSA 6 fall into three categories: waste disposal operations, preliminary activities leading to closure, and technology demonstrations. Each of these is described below.

- **Waste Disposal Operations.** As illustrated in Fig. 1.5, waste disposal operations at SWSA 6 will continue until September 1996, but only the IWMF will receive wastes after June 1991. The operation of the IWMF will not impact closure activities for the remainder of SWSA 6. Those areas of the site where waste disposal operations are ongoing (active areas) are shown in Fig. 1.8. Waste disposal projections for active units excluding the IWMF are summarized in Appendix 1A.

- **Preliminary Closure Activities.** Four site preparation activities must precede final closure of SWSA 6. These are:

  - **Relocation of Tennessee Valley Authority (TVA) Power Lines.** The site is traversed by high-voltage power lines that would interfere with closure and long-term maintenance. The power lines are scheduled to be relocated by April 1994.

  - **Plugging and Abandonment of Wells.** There are approximately 600 observation wells and piezometers in SWSA 6. Because these may act as a route for contaminant migration to groundwater, they are scheduled to be plugged and abandoned by April 1994.

  - **Tumulus Demonstration Cover.** Operational plans for the Tumulus call for its capping. However, to ensure compatibility with other site caps, the Tumulus cap will not be constructed until the final site-wide closure design is complete. An interim soil cover will be placed over the Tumulus by the end of 1993.

  - **Support Facilities.** To expedite closure, ORNL plans to install construction support facilities before completion of closure design. Facilities will include a decontamination pad and trailers for field offices, environmental safety and health support, and lunchrooms. These facilities also will support plugging and abandonment of wells and construction of the Tumulus interim cover.

- **Technology Demonstrations.** Remedial action technology demonstrations are discussed in Sect. 1.3.2. Brief descriptions of past and ongoing technology demonstrations are presented in Table 1.2.

**Interim Corrective Actions.** Three interim corrective actions have been implemented at SWSA 6: a bentonite seal and a French drain in the 49 Trench area, and geomembrane caps over RCRA-regulated waste disposal units. Each of these is described in the following paragraphs.

- **Bentonite Seal.** To try to alleviate water infiltration in the 49 Trench area of SWSA 6, the area was sealed with a soil-bentonite mixture in 1976. The ground surface was then seeded to prevent erosion. However, water was still observed in the underlying trenches (ORNL 1986).

- **French Drain.** In 1983, a French drain designed to intercept flow of groundwater into trenches was installed in the 49 Trench area (Fig. 1.6). The drain surrounded the trenches on the north and east sides, and was installed at a maximum depth of about 9.2 m (30 ft) (Davis and Stansfield 1984). Trenches close to the drain have been dewatered, and there has been a general lowering of the groundwater table. Groundwater table contour maps show significant changes in localized groundwater flow directions. Maximum drawdown of approximately 12 ft occurs where the two drain legs intersect in the northeast corner of the site (ORNL 1986).

- **RCRA ICM.** The Closure Plan for SWSA 6 (BNI 1988a) specified that ICM caps would be installed over areas that had received RCRA-regulated wastes. The caps were installed from November 1988 to May 1989 and were designed to reduce surface water infiltration into the waste disposal areas. Each cap consisted of 80-mil HDPE, which is resistant to ultraviolet light. Cap design life is 5 years. The locations of the capped areas are shown in Fig. 1-9. Performance of the RCRA ICM is discussed in Sect. 3.

#### 1.3.1.2 Emergency Waste Basin (SWMU 6.2)

Constructed in 1961 to 1962 to serve as an emergency holding basin for LLW or process wastes from the ORNL Main Plant Area, the EWB was to be used if ORNL treatment plants were not operational or if treatment plant effluent could not be discharged to WOC. The basin encompasses approximately 2 acres and has a potential storage volume of 15 million gal. It reportedly has never been used for its intended purpose but does contain water from groundwater infiltration and surface water runoff.

The EWB technically is outside the ORNL boundary for WAG 6, which, along this northern edge of the WAG, is marked by the SWSA 6 fence. However, the EWB receives some runoff from the northern portion of WAG 6, and for that reason is considered a WAG 6 SWMU.

#### 1.3.1.3 The EDT (SWMU 6.3)

The EDT is no longer used and has been backfilled. It was located in the southeastern portion of SWSA 6. The trench measured approximately 15 ft long by 5 ft wide by 4 ft deep and was used to detonate explosives and shock-sensitive chemicals such as picric acid, phosphorus, and ammonium nitrate. The exact location of the trench is unknown; however, Fig. 1.4 indicates its approximate location based on interviews with personnel who were involved in trench operations.

During operations, wastes were placed in the bottom of the trench and detonated with small plastic charges. Debris from the explosions generally remained in the trench. Table 1.3 lists wastes known to have been detonated at the EDT (ORNL 1985). A closure plan for the EDT was filed in accordance with 40 CFR Section 270.14(b)(13-18), Sections 264.110-115, Section 264.178, and Tennessee Rule 1200-1-11-.07(5)(a)(13-16) (ORNL 1985).

### 1.3.2 Remedial Action Technology Demonstrations

During the past several years, ORNL has demonstrated technologies potentially applicable to remediation and closure of SWSA 6. The general purpose of the demonstrations is to develop reliable, site-specific information regarding technology performance, methods of implementation, and costs. The demonstrations have focused on technologies for decreasing groundwater interaction with trench wastes and on increasing the structural stability of trench wastes to support a multilayer cap without settling. Dynamic compaction of trench wastes and waste grouting with both chemical and particulate grouts have been demonstrated. In addition, an ISV demonstration is being conducted on mock trenches specially constructed to simulate liquid waste seepage trenches at WAG 7. Although the demonstration is designed primarily to support activities planned for WAG 7, considerable performance information will result that is pertinent to application of the technology to SWSA 6.

Implementation and performance data derived from technology demonstrations are being employed in the WAG 6 CMS. In addition, site characterization data generated in the course of the technology demonstrations are presented in the RFI report, as appropriate. Brief descriptions of past and ongoing SWSA 6 technology demonstrations are presented in Appendix 1A.

### 1.3.3 Previous Environmental Investigations and Ongoing Monitoring Programs

Numerous investigations of site physical characteristics and contamination have been conducted at SWSA 6 over the past 20 years. There also are several ongoing environmental monitoring programs for SWSA 6. Pertinent results from these previous investigations and site monitoring were employed in developing the scope of the WAG 6 RFI and have contributed to the conceptual site model. This section briefly describes the general scope of these investigations and monitoring programs. More detailed descriptions of individual

investigations and pertinent results are presented in Appendix 1B; complete results are available in the referenced reports.

#### 1.3.3.1 General programs of site investigation

Most previous investigations and studies performed at WAG 6 have concentrated on SWSA 6 and have been conducted under one of the following programs:

- Study of ORNL contaminant releases to WOC watershed
- SWSA 6 ETF site characterization
- SWSA 6 DOE Order 5820.2A site characterization activities
- SWSA 6 RI preliminary site characterization activities
- ER program technology demonstration

Some of these investigations focused on SWSA 6 or WAG 6 exclusively; others focused on larger areas of ORNL but included all or part of WAG 6 within their scope. The general scope of each program, specific studies conducted under these programs, and data pertinent to the WAG 6 RFI are presented in Appendix 1B.

#### 1.3.3.2 Ongoing monitoring programs

Ongoing monitoring programs for WAG 6 include the ORNL RCRA Compliance Monitoring Program, the RCRA ICM Monitoring Program, and the DOE Order 5820.2A Performance Assessment Monitoring Program. The following paragraphs describe each program.

**WAG 6 ORNL RCRA Compliance Monitoring Program.** As part of the RCRA 3004(u) assessment of the need for corrective actions at SWMUs, ORNL installed a series of groundwater quality monitoring wells around the perimeter of SWSA 6 and began a contaminant detection monitoring program to determine if the site is a source of continuing releases of hazardous constituents. The well installation and sampling are discussed in Sect. 2, and data are discussed in Sects. 3 and 4 of this RFI report.

The RCRA-detection monitoring program identified off-site migration of hazardous constituents in groundwater to the east. Four additional RCRA quality wells were installed, and ORNL is now conducting compliance monitoring in this area. Results from this sampling are described in Sect. 4.

**WAG 6 RCRA ICM Monitoring Program.** As previously described, the RCRA closure plan approved for SWSA 6 specified installation of RCRA ICM caps. Because of the considerable earthwork, pre- and post-implementation monitoring was conducted to determine construction impacts on stream sediment size and distributions and contamination of sediments and surface water. Groundwater monitoring was also performed in the vicinity of the capped areas to aid in assessing the effectiveness of the ICM.

**DOE Order 5820.2A, Performance Assessment Monitoring Program.** DOE Order 5820.2A requires ongoing monitoring to assess the performance of active disposal areas. ORNL maintains such a program, which includes the Tumulus Project Environmental Monitoring and the Waste Disposal Silo Monitoring within SWSA 6.

### 1.3.4 Demography

As illustrated in Fig. 1.1, WAG 6 is located on the federally owned ORR. Because SWSA 6 is an active facility, ORNL workers are on-site daily during the work week and frequently on weekends. Activities performed by these workers include construction of disposal units, waste transportation and disposal, technology demonstrations, and site maintenance and monitoring. All workers are required to have undergone site safety training in accordance with ORNL ES&H Procedures.

At the closest point, WAG 6 is approximately 1 mile from the ORNL Main Plant Area, where the majority of ORNL's approximately 5300 regular employees and 2000 subcontractor personnel work. Within 1/2 mile of the boundary of WAG 6, all land is federally owned, and there are no residents. The two-lane State Highway 95 runs through the ORR and passes along the western side of WAG 6 within 1/2 mile of its boundary. WAG 6 is approximately 0.42 miles from the north bank of the Clinch River, which forms a portion of the boundary of the ORR. The Clinch River, also known as Watts Bar Lake at this location, is open to recreational uses such as boating, fishing, and duck and goose hunting, as permitted by the State of Tennessee.

Within a 1-mile boundary extension of WAG 6, there are approximately 25 residents; all are located across the Clinch River southwest of WAG 6. The closest resident is 0.56 miles from the WAG 6 boundary. Within a 5-mile radius of WAG 6, there are an estimated 580 residents, and within a 10-mile radius, there are an estimated 9900 residents. There are two major population centers for the area. The closest, Oak Ridge, is approximately 10 miles from WAG 6 and in 1986 had an estimated population of 26,920. Knoxville, the largest local population center, is approximately 20 miles from WAG 6 and had a 1986 population of 173,210 (CBER 1989).

## 1.4 PURPOSE AND SCOPE OF THE WAG 6 RFI

The objectives of the WAG 6 RFI were derived from the goals of the EPA RCRA Corrective Action Program and the EPA CERCLA program. The goals are:

- To characterize the nature and extent of contamination associated with WAG 6 sufficiently to achieve the next two goals

- To assess potential impacts of disposed wastes and environmental contamination on human health and the environment

- To identify preliminary site closure and remediation objectives and perform the initial development and screening of alternatives.

- To provide data to support the development of site closure and corrective action alternatives

The WAG 6 RFI addresses existing waste disposal units at WAG 6 and examines contamination of groundwater, surface water, sediment, soil, and air. The baseline human health and environmental evaluations assess the potential health impacts if the site were not closed and remediated. The alternatives assessment includes the preliminary development and screening of alternatives for site closure and for remediation of environmental problems that have been identified through the site characterization and the baseline risk assessment.

## 1.5 REPORT ORGANIZATION

### 1.5.1 Main Document Sections and Appendixes

For the convenience of the reader, the essential descriptions of WAG 6 RFI activities, results, assessments, and conclusions are presented in relatively brief sections (1 through 9) that comprise the main body of this WAG 6 RFI report. Each report section has one or more associated appendixes (e.g., Appendix 1A and 1B; 3A, 3B, 3C, 3D, and 3E) that present more detailed descriptions, additional data, or specific, focused discussions. These appendixes may be consulted as desired by the reader.

The contents of each section are briefly described below. Table 1.4 lists each section and its associated appendixes and their titles.

- Section 1, "Introduction," presents essential regulatory background and site information, plus report organization guidance.

- Section 2, "Summary of RCRA Facility Investigation," describes the WAG 6 RFI field activities.

- Section 3, "Physical Characteristics of the Study Area," describes the physical characteristics of the site that most affect or are most pertinent to assessing the nature and extent of contamination and developing and evaluating alternatives.

- Section 4, "Nature and Extent of Contamination," presents the results of WAG 6 RFI and previous field investigations conducted to determine the characteristics of the contamination discovered.

- Section 5, "Fate and Transport of Contamination," presents a conceptual hydrogeologic model of the site based on data collected during field investigations and previous investigations, and describes fate and transport modeling performed to support the baseline risk assessment.

- Section 6, "Baseline Human Health Evaluation," assesses the potential effects of sources and contamination on the public for present and future exposure scenarios.

- Section 7, "Baseline Environmental Evaluation," presents an assessment of potential ecological impacts of WAG 6 contaminants.

- Section 8, "Preliminary Development and Screening of Alternatives," presents preliminary identification of remedial action objectives and development and screening of alternatives.

- Section 9, "Summary and Conclusions," summarizes the results of the investigation.

### 1.5.2 Treatment of Tables and Figures

As another step to make this report as readable as possible and to prevent the numerous tables and figures from interfering with the flow of the text, all tables and figures have been placed at the end of their appropriate section. Table and figure groupings are clearly marked with dividers so readers can easily refer to them when necessary.

### 1.5.3 References

This report contains a separate References section for all source materials cited herein. The References section appears at the end of the main document (after Sect. 9) and contains all references for the entire report, including the appendixes (i.e., the appendixes do not contain separate reference pages).

# Section 1 Tables

## Table 1.1. WAG 6 waste disposal units

| Type of unit | Number as of 12/90 | Projected number for period 1/91-5/92 | Approximate area (acres) | Inventory[a] (curies) | Description |
|---|---|---|---|---|---|
| Trenches | 498 | 3 | 16 | 19,054 | Trenches were used for disposal of large waste packages and assorted bulky items. Dimensions of trenches, although variable, were generally 50 ft long by 10 ft wide by 13 to 20 ft deep. Beginning in 1975, trench depth was limited to approximately 15 ft or less, with the floor of the trench being at least 2 ft above the documented high water table. Minimum spacing between trenches was 5 ft. When the waste level reached approximately 3 ft below the top, the trench was backfilled with soil, generally from the excavation of the next trench. The cover was then seeded to minimize erosion. |
| Auger holes | 591 | 0 | 1.5 | 208,660 | Auger holes were used for disposal of small waste packages with surface activities exceeding 200 mR/hr. Auger holes were generally located in the higher elevations of SWSA 6. Diameters ranged from 1 to 4 ft, with depths up to 20 ft. In April 1986, the use of unlined auger holes was discontinued. Ten auger holes have diameters of 9 ft. Spacing between auger holes was generally at least 3 ft. Three or four disposals were routinely made in each auger hole. Wastes were disposed in various sized containers up to 55-gal drums. After waste disposal, if the radiation reading at the ground surface was greater than 100 mR/h, soil was placed in the auger hole until the radiation reading was reduced. |
| Greater Confinement Disposal Silos | 146 | 118 | 1.0 | 575 | Silos are concrete-lined waste disposal units and were used after May 1986. They represent the evolution from the shallow land burial techniques described above to greater confinement disposal (GCD) techniques. A typical concrete silo is constructed of two 15-gauge corrugated steel pipes arranged concentrically. The smaller pipe is 8 ft in diameter and the larger pipe is 4 ft in diameter. The length of the pipes is 14 to 20 ft. The annular space between the two pipes is filled with concrete. The bottom of the silo is a 12- to 18-in. wire-reinforced thick concrete pad. To facilitate even greater confinement of waste in the silo, the inside diameter of some concrete silos have a geometric array of vertically-placed cast iron pipes. Usually the silos are placed in the trenches. The majority of silos are equipped with 3-in. diameter monitoring wells for detection and sampling of waste leachate in the silos. |
| GCD auger holes or silo wells | 84 | 29 | 0.35 | 581,777 | These auger holes have heavy-wall (3 to 4 in.) cast iron pipe wells or double-walled corrugated steel pipe wells vertically placed in a drilled auger hole, with the surrounding space backfilled with soil. The pipes are usually 20 ft long with inside diameters of 20 to 25 in. The bottom of the auger holes have a 12 in. thick concrete pad. There are 86 such auger holes in the SWSA 6 area. They were constructed after May 1986. |
| Quadrex boxes | 10 | 0 | 0.03 | 3 | Quadrex boxes are large shipping containers that are filled with low-activity compactible wastes. |

**Table 1.1. (continued)**

| Type of unit | Number as of 12/90 | Projected number for period 1/91-5/92 | Approximate area (acres) | Inventory[a] (curies) | Description |
|---|---|---|---|---|---|
| Tumulus I-II | 486 casks | 0 | 0.6 | 83 | There are two Tumulus disposal units within SWSA 6, referred to as Tumulus I and Tumulus II. Low-activity waste is prepackaged in 55-gal drums or 100-ft$^3$ metal boxes and then sealed in concrete and epoxy-coated, steel-reinforced casks (5.5 ft x 5.5 ft x 8 ft). The voids between casks are grouted. A precast concrete lid is placed on the vault and it is placed on the concrete Tumulus pad. The entire facility will be covered with a low permeability cap during closure and remediation of WAG 6. The pad is equipped with an underdrain to collect any water that might seep through the pad. Water collected from the pad underdrain is analyzed for contaminants. |
| Interim Waste Management Facility (IWMF) | Under construction | – | 0.5 | – | The IWMF is currently under construction and uses the Tumulus technology. The IWMF will consist of 6 to 8 tumulus pads, with an equal extent of ≈32,000 ft$^2$. Because the IWMF has not yet received any wastes, it is not included within the scope of the WAG 6 RFI. |
| <u>Experimental</u> | | | | | |
| Hill Cut Test Facility | 27 boxes | – | 0.3 | 50 | There are four groups of waste disposal units constructed at SWSA 6 for experimental purposes; these are listed at left. The Hill Cut Test Facility was created as a demonstration project to evaluate the use of hillslope cuts for disposal of high-activity LLW. The ETF was established as a field-scale demonstration site to carry out various investigations for improved shallow land burial (SLB) technology. The EPICORE-II research site is being used to evaluate the long-term leachability of solidified radioactively contaminated ion exchange resin. The Polymer Trenches were created as part of a study to evaluate the application of grouting to trench wastes. |
| Engineered Test Facility (ETF) | 9 trenches | – | 0.25 | b | |
| EPICORE | – | – | – | b | |
| Polymer Trenches | 4 trenches | – | 0.3 | b | |
| Low Hazard Contaminated Waste Landfill | – | – | 0.4 | b | The Low Hazard Contaminated Waste Landfill is used for wastes thought to be free of radioactive contamination; however, due to inability to verify this (for example, inability to survey interiors of pipes), the wastes are disposed at SWSA 6. |

[a]Inventories are approximate due to ongoing decay and/or incomplete records.
[b]No records.

**Table 1.2. SWSA 6 technology demonstrations**

| Demonstration | Description |
|---|---|
| Trench Grouting "Polymer" trenches (#349, 350, 351) | Field studies of trench grouting have also been conducted in the Polymer Trench Area of SWSA 6. Spalding, Hyder, and Munro (1985) excavated three pilot-scale trenches (349, 350, and 351) measuring 10 ft by 10 ft by 5 ft. Each trench was fitted with eight poly vinyl chloride (PVC) well casings and a central grout injection well. The trenches were filled with suspect solid waste including concrete blocks, tires, pipes, discarded equipment, wooden pallets, shipping cartons, and paper and backfilled with soil. To measure the hydraulic conductivity of the soils, four boreholes were placed around each trench.<br><br>Trenches 349 and 350 were grouted with sodium silicate in August and September 1982, respectively; Trench 351 was grouted with acrylamide in October 1982. The three trenches were situated so that they had different depths to groundwater. Trench 349 penetrated the water table so wastes were saturated for most of the year; Trench 350 was above the seasonal high point of the water table, and Trench 351 was intermediate between the two. |
| Trench Grouting Trench 150 | In August 1986, particulate grout was injected under pressure into Trench 150 as a remedial action demonstration to assess the effect of this type of grouting on trench subsidence and radionuclide behavior (Spence, Godsey, and McDaniel, 1987). Besides the benefit of filling large voids and preventing subsidence, particulate grouts may immobilize and encapsulate most of the radioisotopes close to the waste, may redirect water flow away from the waste, and may offer the advantage of using natural materials that withstand the rigors of weather and time. Components used in this grout were Type I Portland cement (39 percent), Eastern Class C fly ash (55.5 percent), and bentonite (5.5 percent). A concrete mixing truck was used to mix the solids with water and the set retarder/dispersing agent. The grout was pumped through lances driven into the trench. A total of approximately 8,100 gal of grout, with represents about 19 percent of the total trench volume and most of the void volume, was successfully injected into Trench 150. |
| ISV Demonstration | The ISV demonstration site is located in the northern portion of SWSA 6, southwest of TARA I. The demonstration, which was the second pilot-scale test, used a one-half scale model of trench 7 and pilot-scale ISV equipment from Pacific Northwest Laboratory (PNL). The test was conducted during May 1991.<br><br>A minimum amount of radioactive waste was placed in the trench to track the behavior of radionuclides when subjected to the new pilot ISV. This new ISV system was intended to demonstrate reduced cesium-137 volatility and evaluate seismic imaging and advanced thermometric methods for monitoring the progression of melting (Jacobs and Spalding, 1990).<br><br>Samples of off-gas scrub solutions were collected during the demonstration and analyzed by ORNL. After vitrification is completed, samples of the solid mass will be analyzed for their leachability and composition. |

**Table 1.2. (continued)**

| Demonstration | Description |
|---|---|
| Hill Cut Test Facility | Described in Appendix 1A. |
| EPICORE II | Described in Appendix 1A. |
| Engineered Test Facility | Described in Appendix 1A. |
| Dynamic Compaction Trench 271 | Trench subsidence is a major problem in remediating shallow land disposal sites. Subsidence depressions not only create catchments for surface runoff and precipitation but also channel water into contact with buried waste. Furthermore, surface stability is necessary for almost all infiltration and intrusion barriers. Spalding (1986) conducted a demonstration in SWSA 6 to evaluate the degree of consolidation that could be achieved by dynamic compaction of a closed burial trench in a cohesive soil formation. Trench 271 in the northern portion of SWSA 6 was selected for this demonstration. Waste disposal records indicate that the trench was operational from March to June 1978, during which time about 880 $ft^3$ of waste weighing approximately 8,500 lb were disposed. The waste consisted primarily of contaminated equipment, demolition debris, and dry solids, with a small amount of biological waste. Packaging was variable. The inventory of radioisotopes, totaling about 80 Ci, included mostly strontium-90, with smaller amounts of cesium-137, samarium-151, thorium-232, uranium-238, technetium-99, cesium-134, ruthenium-106, cerium-144, iridium-192, cobalt-60, iron-59, manganese-54, californium-252, curium-244, and tin-121.<br><br>Compaction was accomplished by repeatedly dropping a 4-ton, steel-reinforced concrete cylinder from heights of 12 to 25 ft using the whipline of a 70-ton crane. The ground surface was depressed an average of 2.6 ft. with some areas depressed as much as 6.5 ft. The surveyed volumetric depression totaled 64 percent of the measured trench void space. Neither trench cap bulk density nor permeability was affected by compaction, indicating that the consolidation was primarily subsurface. |
| Dynamic Compaction/Grouting Test Area for Remedial Actions | The proposed Test Area for Remedial Activities (TARA) Phase 1 involved dynamic compaction and grouting of 19 selected trenches. The area chosen for this demonstration is a hillock of approximately 1 acre in the northeastern part of SWSA 6. This area was selected for several reasons including its hydrologic isolation, the likelihood of its having few containers of liquid hazardous waste, and the ease of monitoring for contaminant release through a suite of perimeter wells (ASG, 1987). Experience gained during TARA Phase 1 will be used in the design of TARA Phase 2 to assess the impacts of dynamic compaction on saturated trenches and on the release of contaminants to groundwater. During compaction, downgradient groundwater will be monitored and, as required, extracted and treated. |

**Table 1.3 Waste items detonated at the explosives detonation trench**

| | |
|---|---|
| picric acid | aluminum chloride |
| picryl chloride | aluminum metal |
| 2, 4-dinitrophenyl hydrazine | magnesium metal |
| picramide | phosphorus pentasulfide |
| phosphorous | methyl acrylate |
| zinc peroxide | titanium trichloride |
| nitromethane | potassium azide |
| 2, 4-dinitrophenol | phosgene |
| hydrazine solution | zinc metal |
| barium peroxide | phthalic anhydride |
| hydrogen peroxide | cobalt metal |
| sodium azide | chromium metal |
| charcoal solution | niobium powder |
| thionyl chloride | neodymium |
| ammonium nitrate | zirconium metal |

Source: ORNL (1985)

**Table 1.4. WAG 6 RFI report sections and associated appendixes**

| Section | Appendixes | |
|---|---|---|
| 1. Introduction | 1A. | SWSA 6 Waste Inventory |
| | 1B. | Previous Investigation and Ongoing Monitoring Program |
| 2. Summary of RCRA Facility Investigation | 2A. | Sample Information Management System |
| 3. Physical Characteristics of the Study Area | 3A. | Site Geology |
| | 3B. | Groundwater Hydrology |
| | 3C. | Surface Water Hydrology |
| | 3D. | Hydrogeologic Data |
| | 3E. | Bird, Mammal, Reptile, and Amphibian Species Found in the ORR |
| 4. Nature and Extent of Contamination | 4A. | Data Quality |
| | 4B. | Statistical Analysis |
| | 4C. | Nature and Extent of On-Site Contamination by Medium |
| 5. Fate and Transport of Contamination | 5A. | Surface Water Modeling |
| | 5B. | Analysis and Results of April to May 1990 Storm Sampling |
| | 5C. | Surface/Subsurface Water Contaminant Fate and Transport Model |
| | 5D. | Surface/Subsurface Water Fate and Transport Modeling in WAG 6 |
| | 5E. | Air Modeling—Models Used, Application, and Results |
| 6. Baseline Human Health Evaluation | 6A. | Selection of Inventory |
| | 6B. | Screening and Modeling of WAG 6 Radionuclides |
| | 6C. | Samples Used to Identify Chemicals of Potential Concern |
| | 6D. | Evaluation of Tentatively Identified Compounds |
| | 6E. | Consideration and Analyses Affecting Designation of Specific Chemicals as Contaminants of Potential Concern |
| | 6F. | Upper Confidence Limits for Contact Concentrations of Chemicals |

**Table 1.4. (continued)**

| Section | Appendixes |
|---|---|
| 6. Baseline Human Health Evaluation (continued) | 6G. Radiological Risk Assessment Methodology and Results<br>6H. Concentrations of Contaminants of Potential Concern in Surface Water and Soil Off-WAG<br>6I. Chemical Risk Assessment Methodology<br>6J. Toxicological Effects Associated with Human Exposure to Contaminants of Potential Concern<br>6K. Identification of Uncertainties |
| 7. Baseline Environmental Evaluation | 7A. Results of Surveys for Threatened and Endangered Species and Sensitive Environments<br>7B. Exposure Scenarios<br>7C. Exposure and Toxicity Assessments for Terrestrial Species<br>7D. Exposure and Toxicity Assessments for Aquatic Species |
| 8. Preliminary Development and Screening of Alternatives | 8A. Potential ARARs<br>8B. Screening of Response Actions, Technologies, and Process Options<br>8C. Worker Exposure Assessment for WAG 6 |
| 9. Summary and Conclusion | |
| References | |

# Section 1 Figures

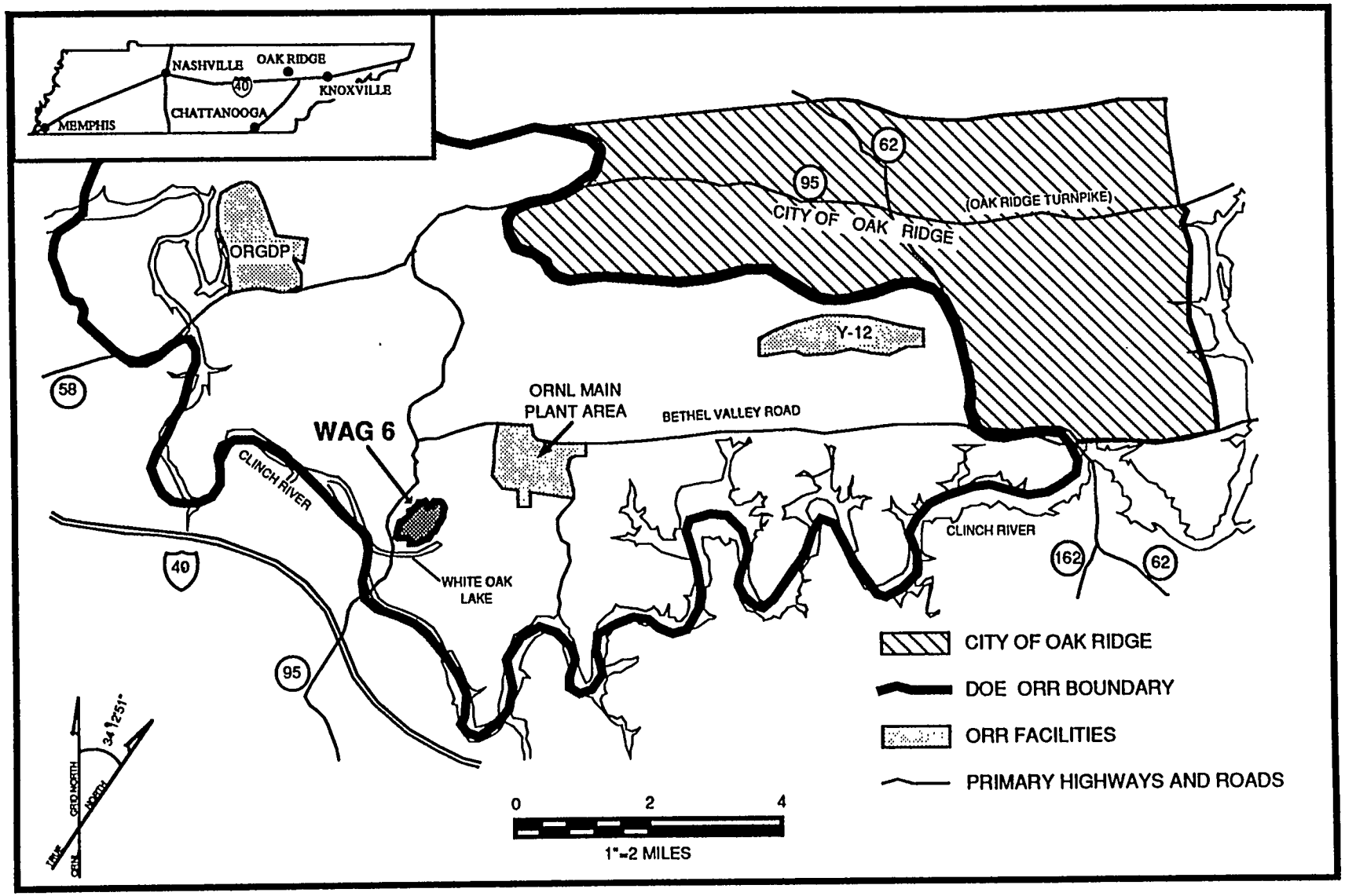



Fig. 1.1. DOE Oak Ridge Reservation.

5.18 4104.7

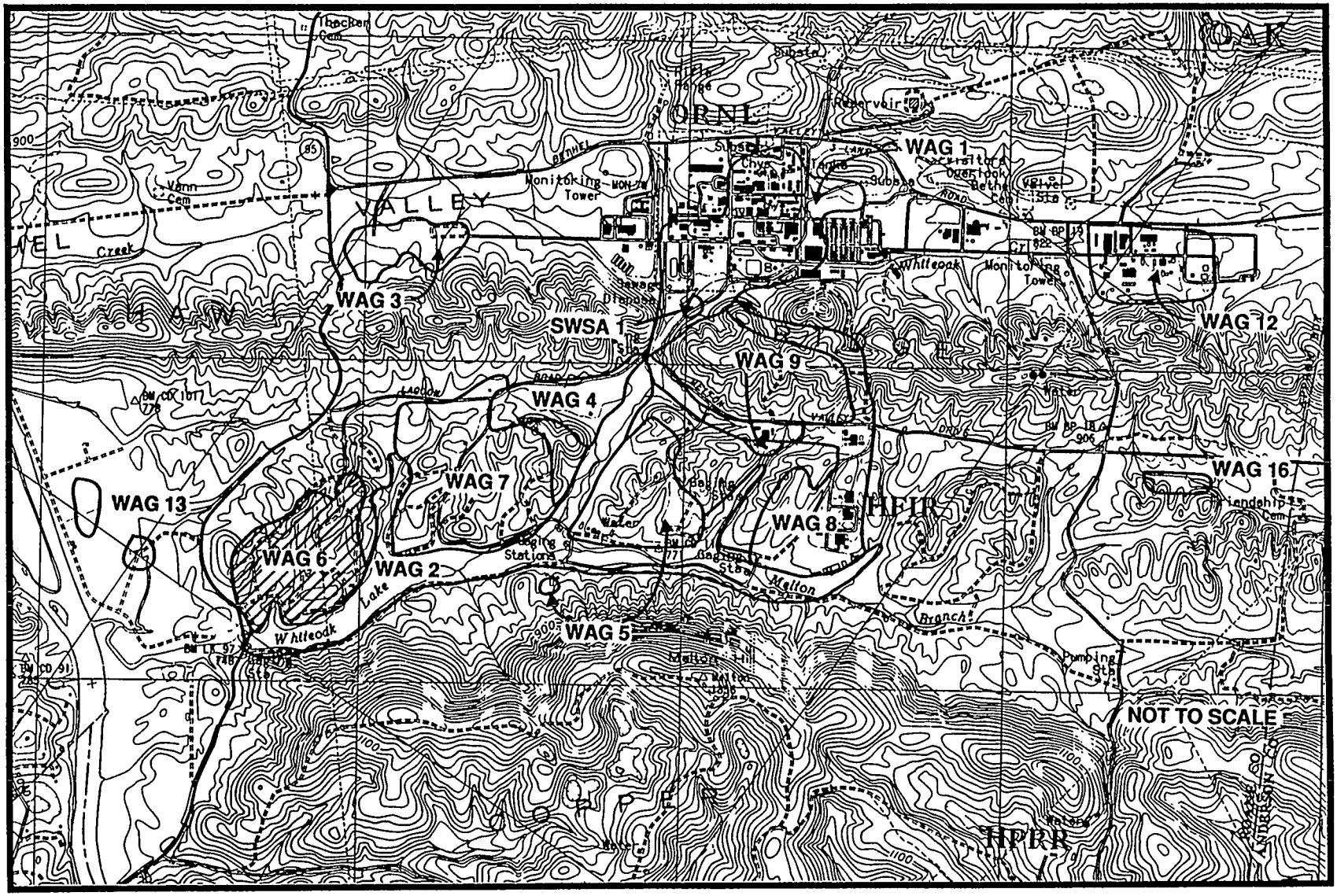
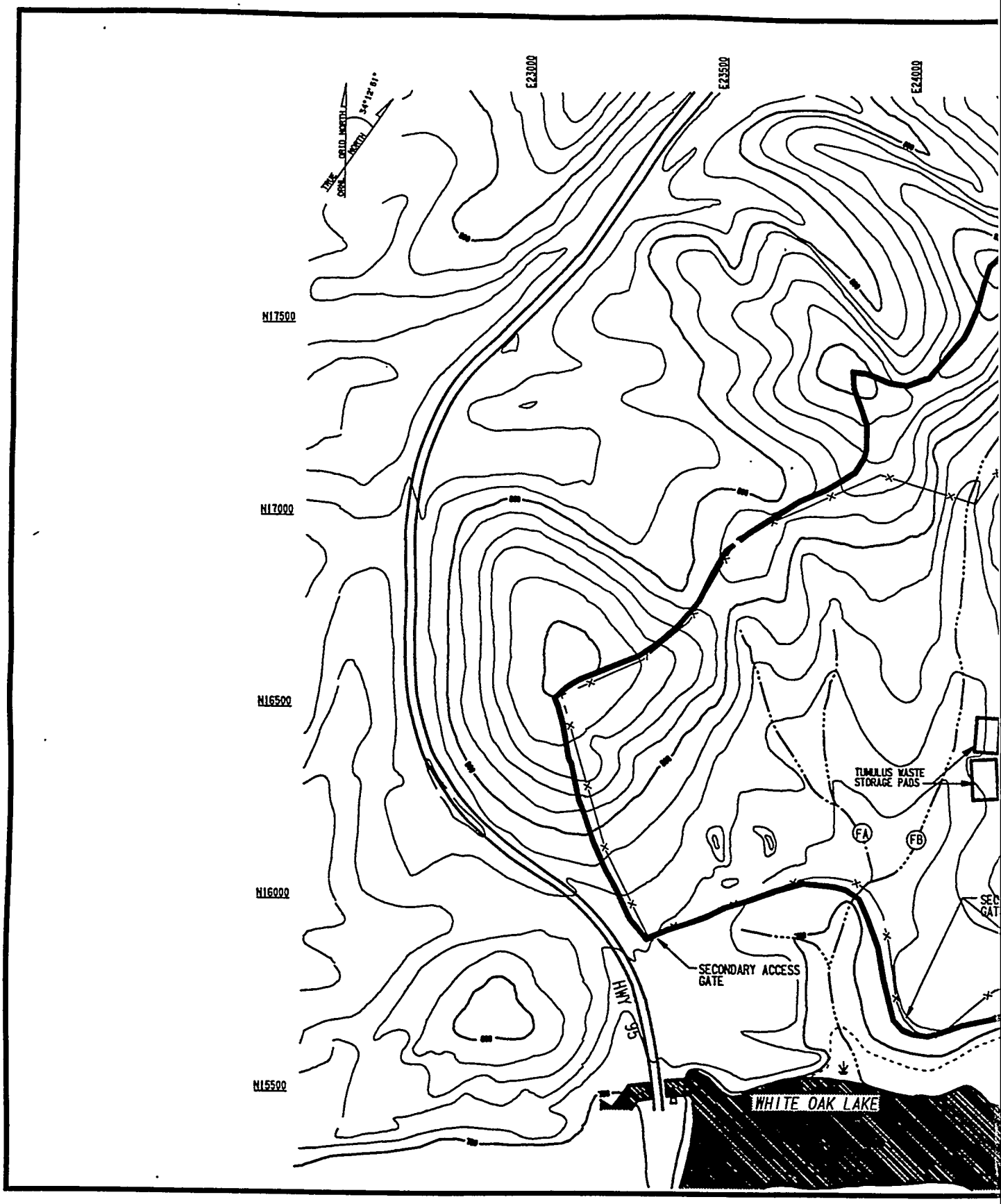



Fig. 1.2. ORNL waste area groupings.

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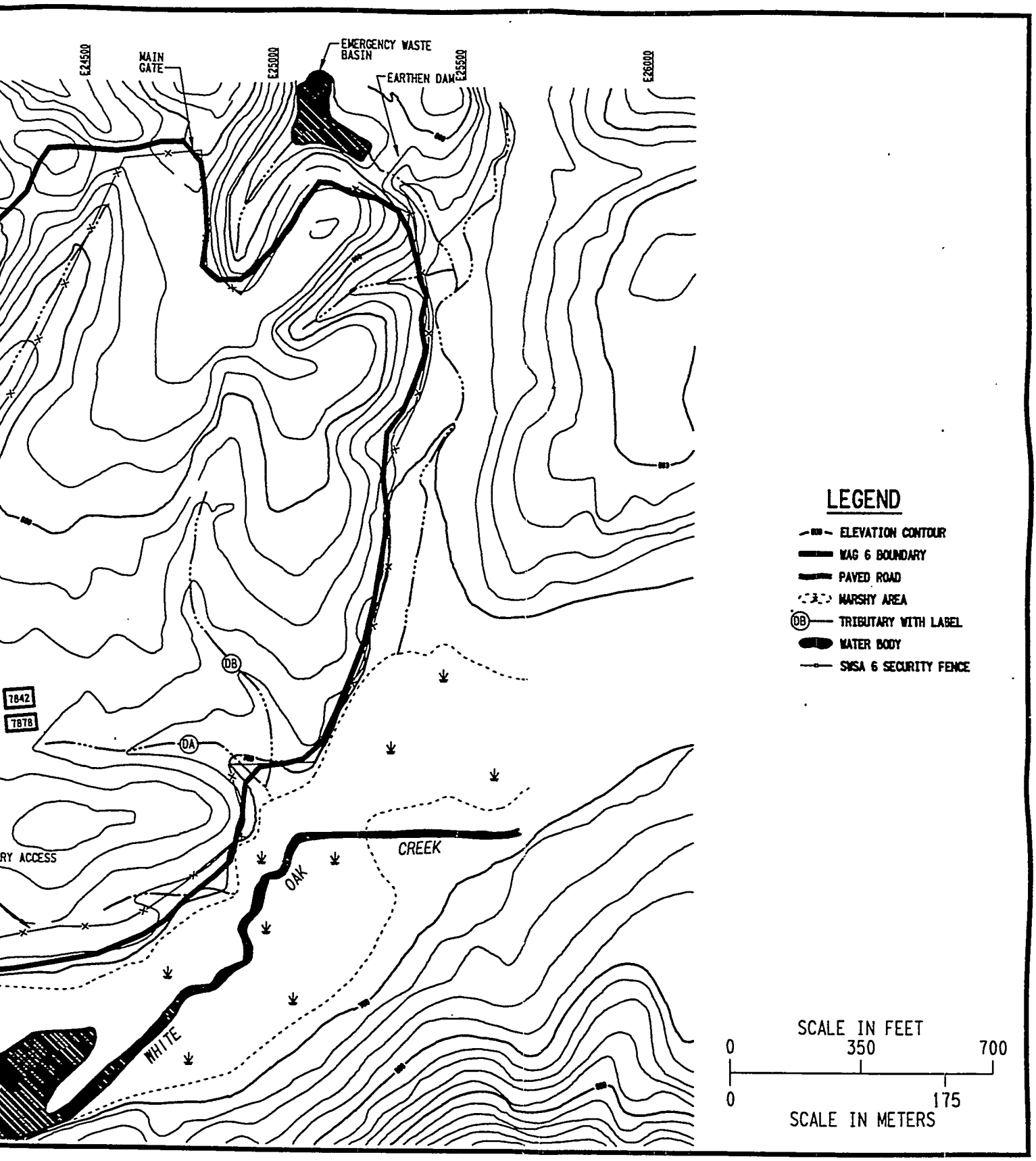



**Fig. 1.3. WAG 6 topography and drainage.**

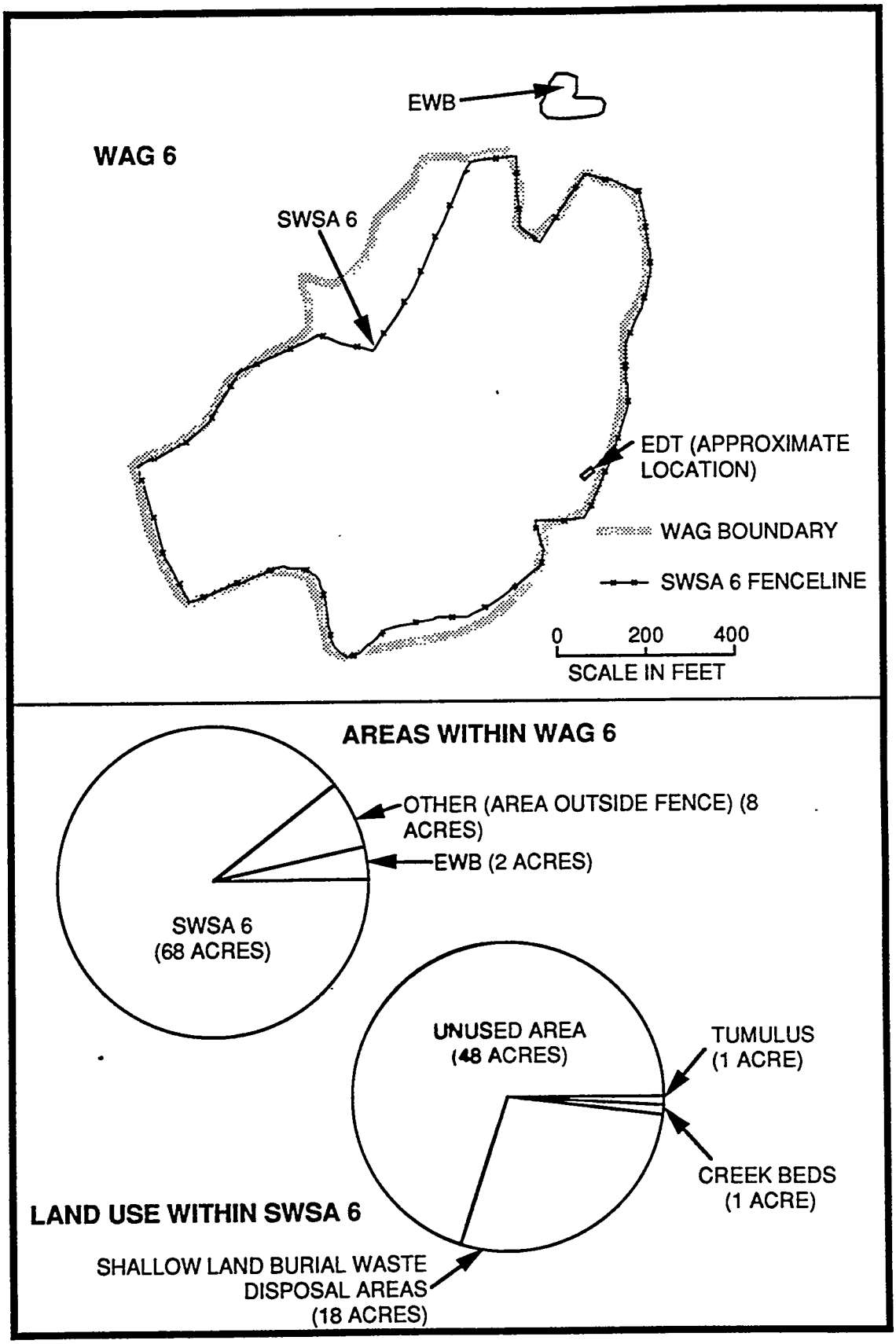
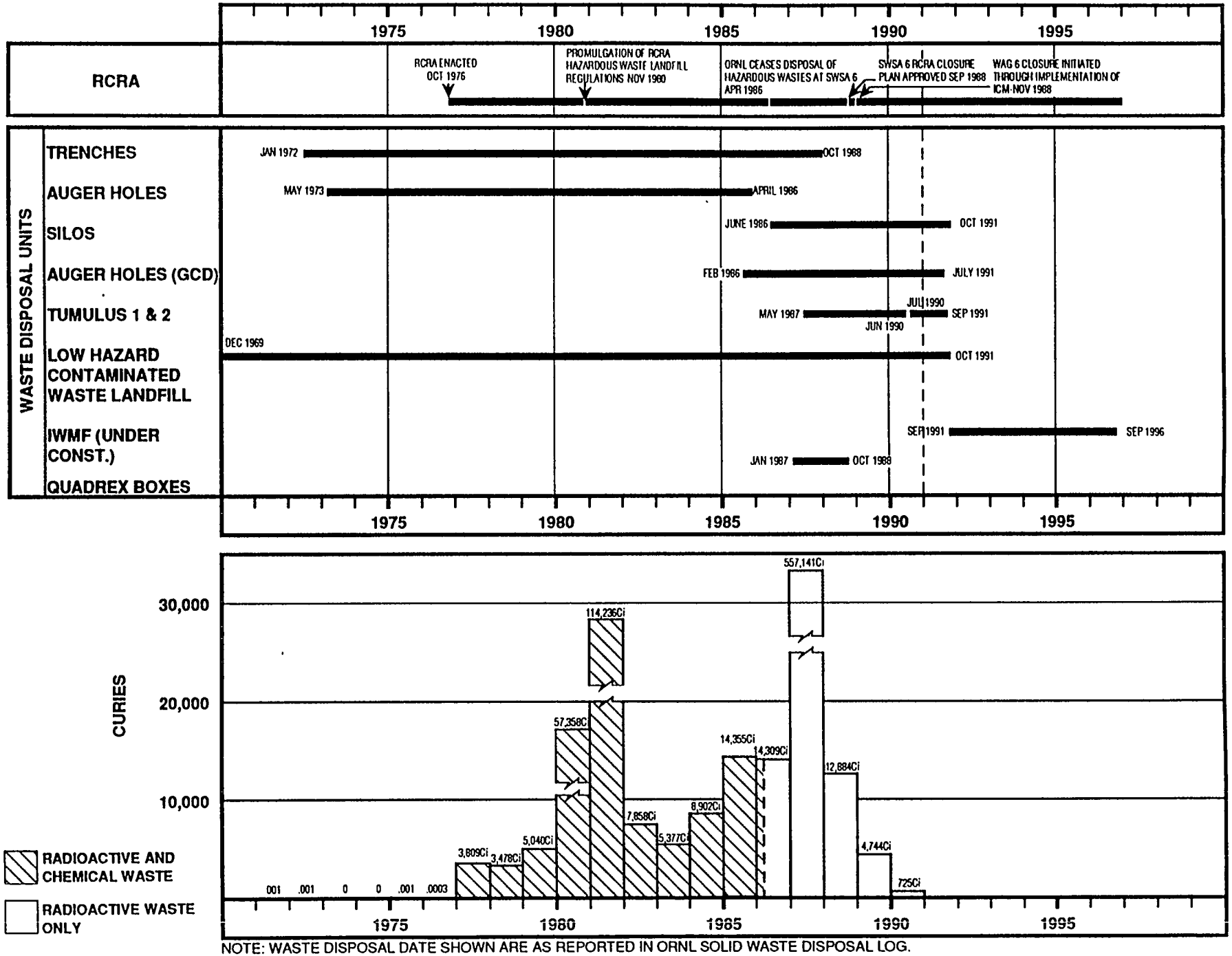



**Fig. 1.4. WAG 6 solid waste management units.**

5.18 4104.8

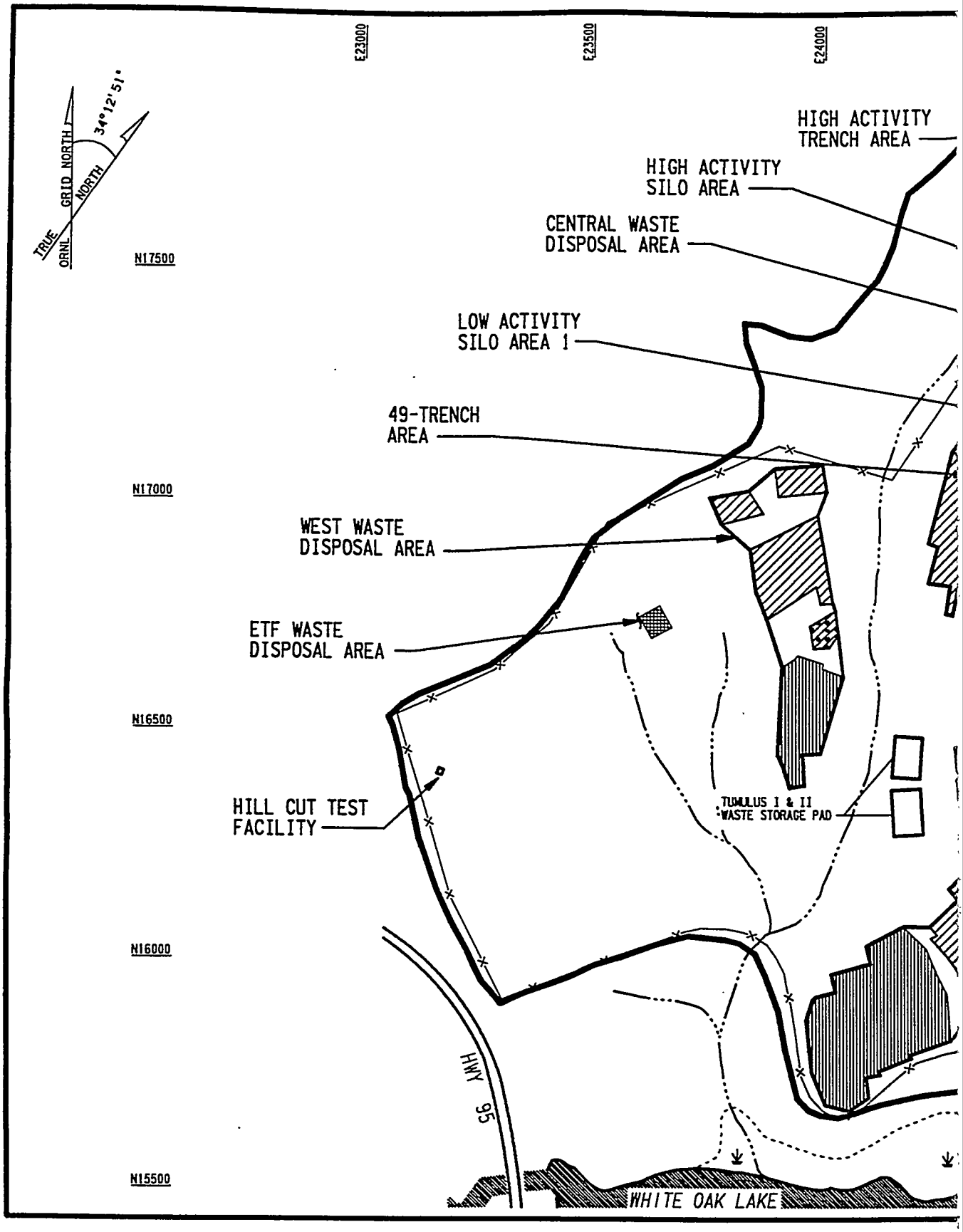
WAG6 06F245.DGN




NOTE: WASTE DISPOSAL DATE SHOWN ARE AS REPORTED IN ORNL SOLID WASTE DISPOSAL LOG.

5.17 3967.1

**Figure 1.5. WAG 6 waste disposal operations.**




WAG 6 06F247.DGN

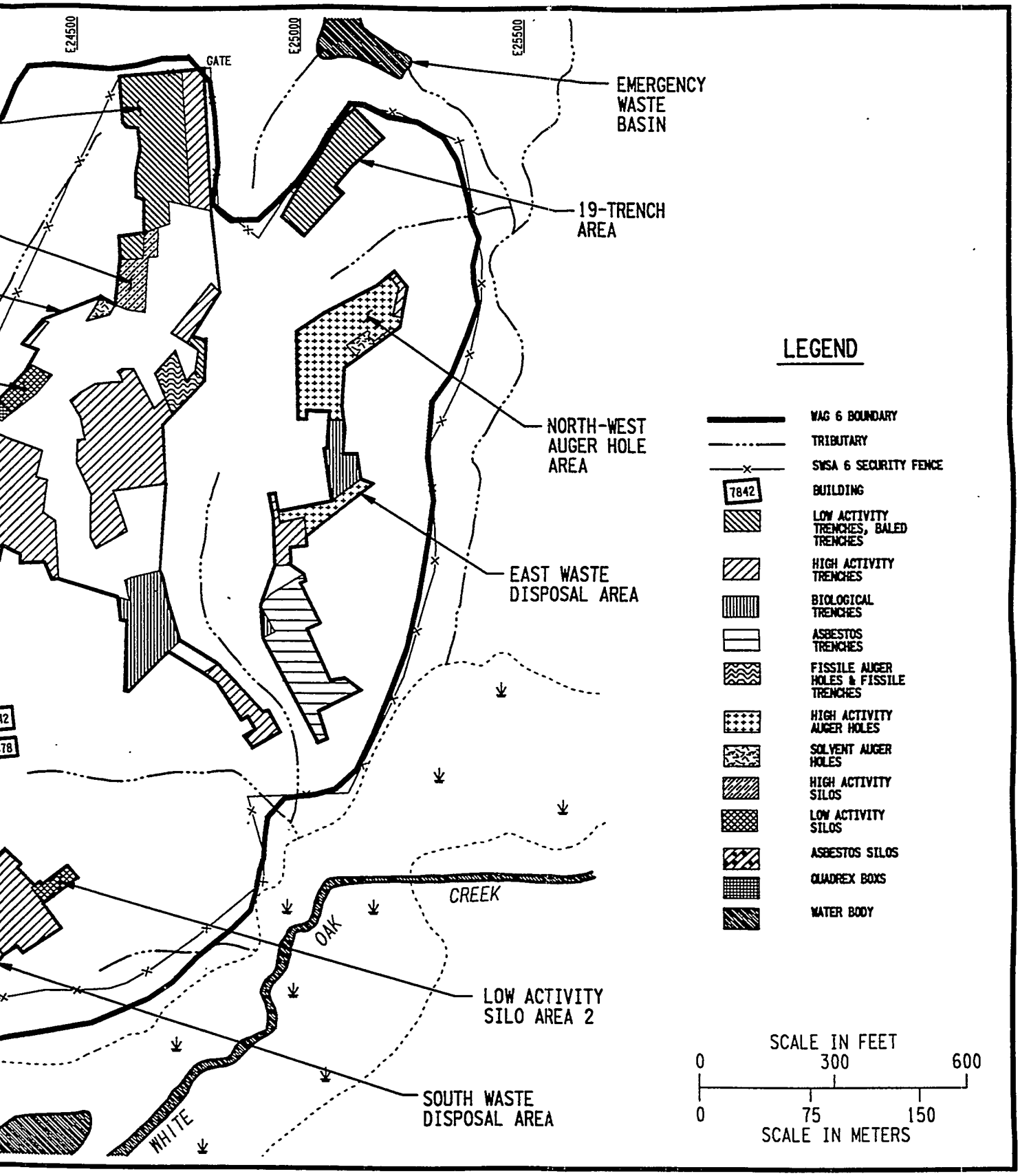



**Fig. 1.6. Waste disposal unit locations.**

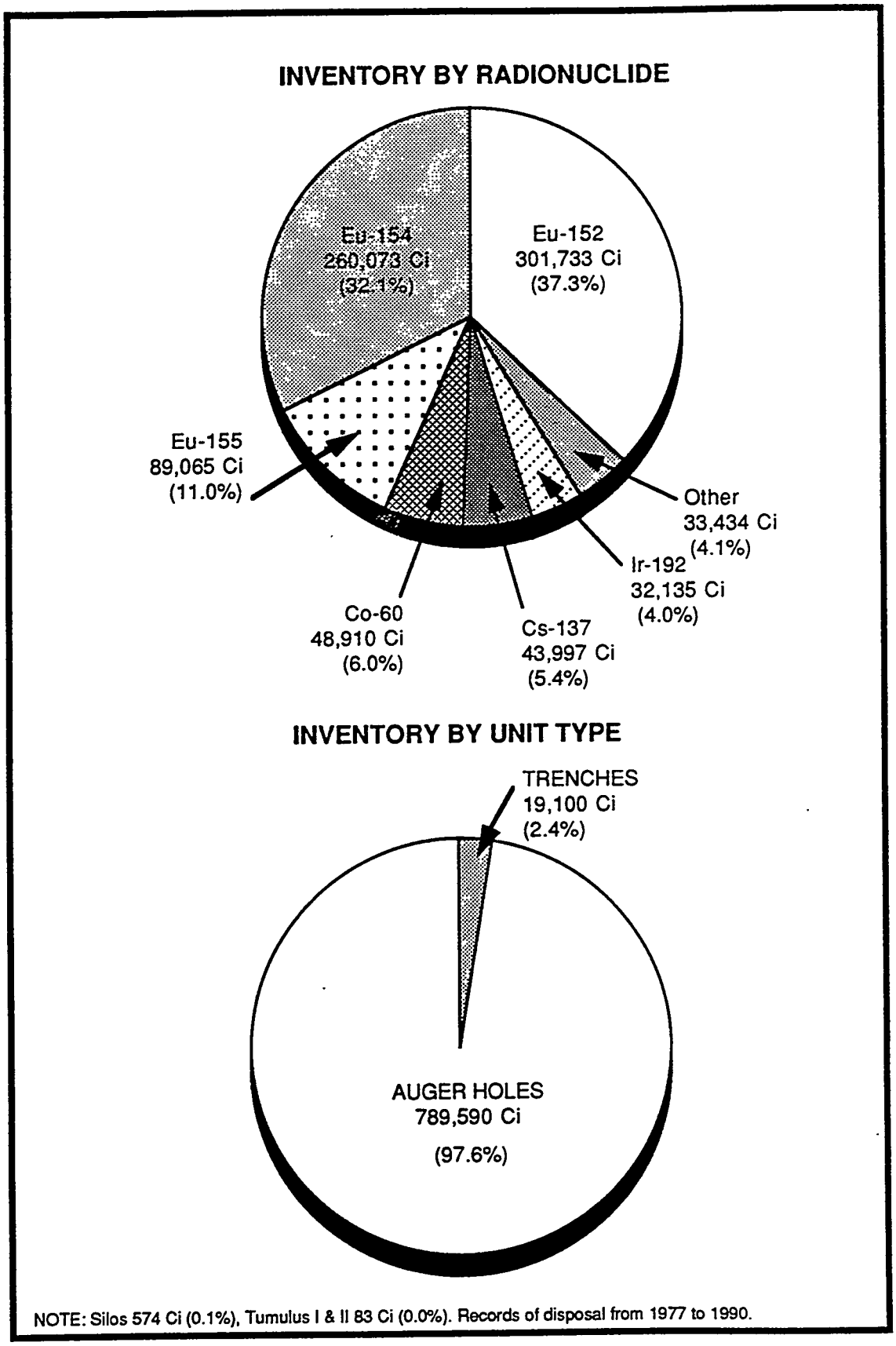
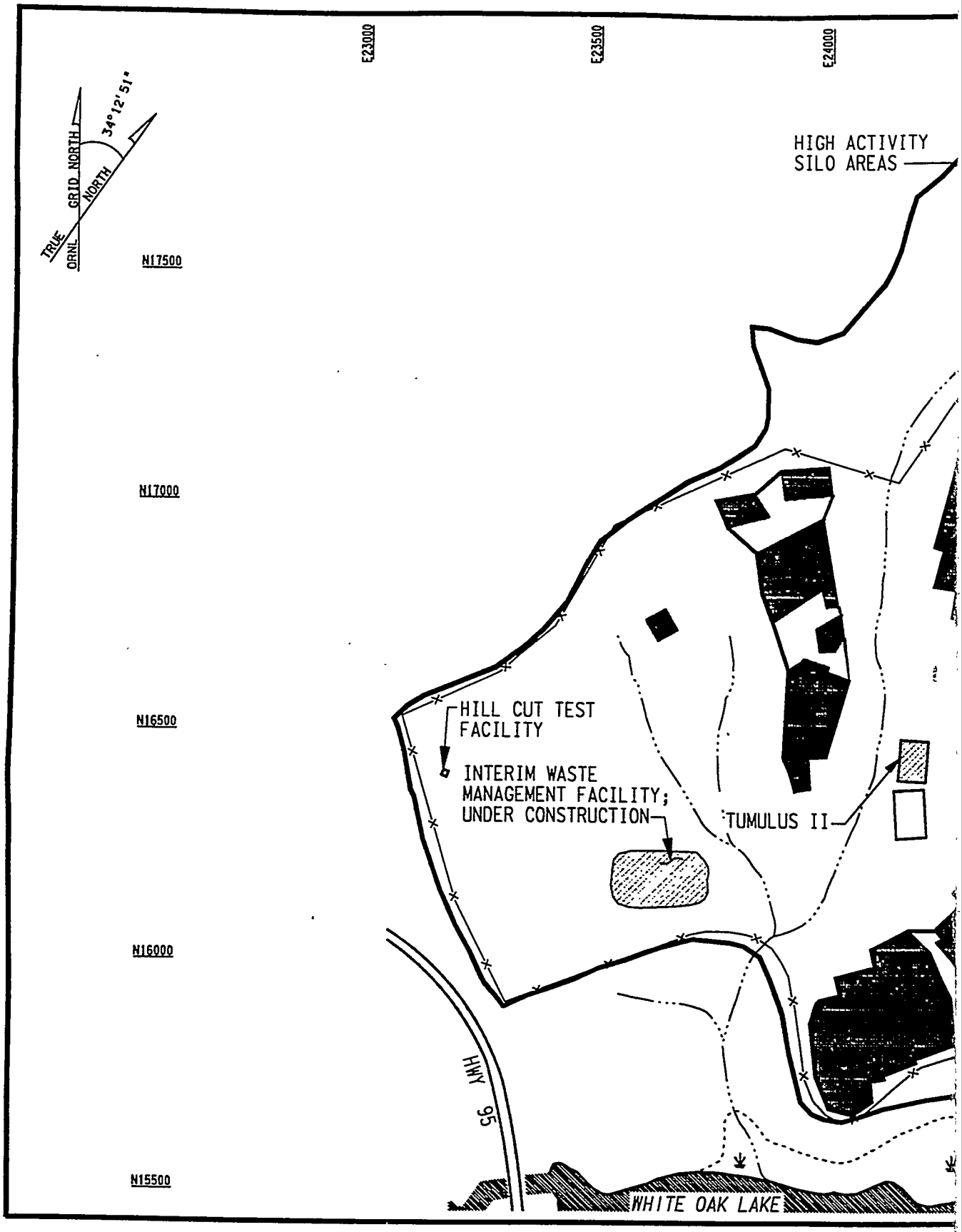



**Fig. 1.7. Summary of radioactive waste disposal log for SWSA 6.**

5 17 3967.3




WAG 6 06F247.DGN

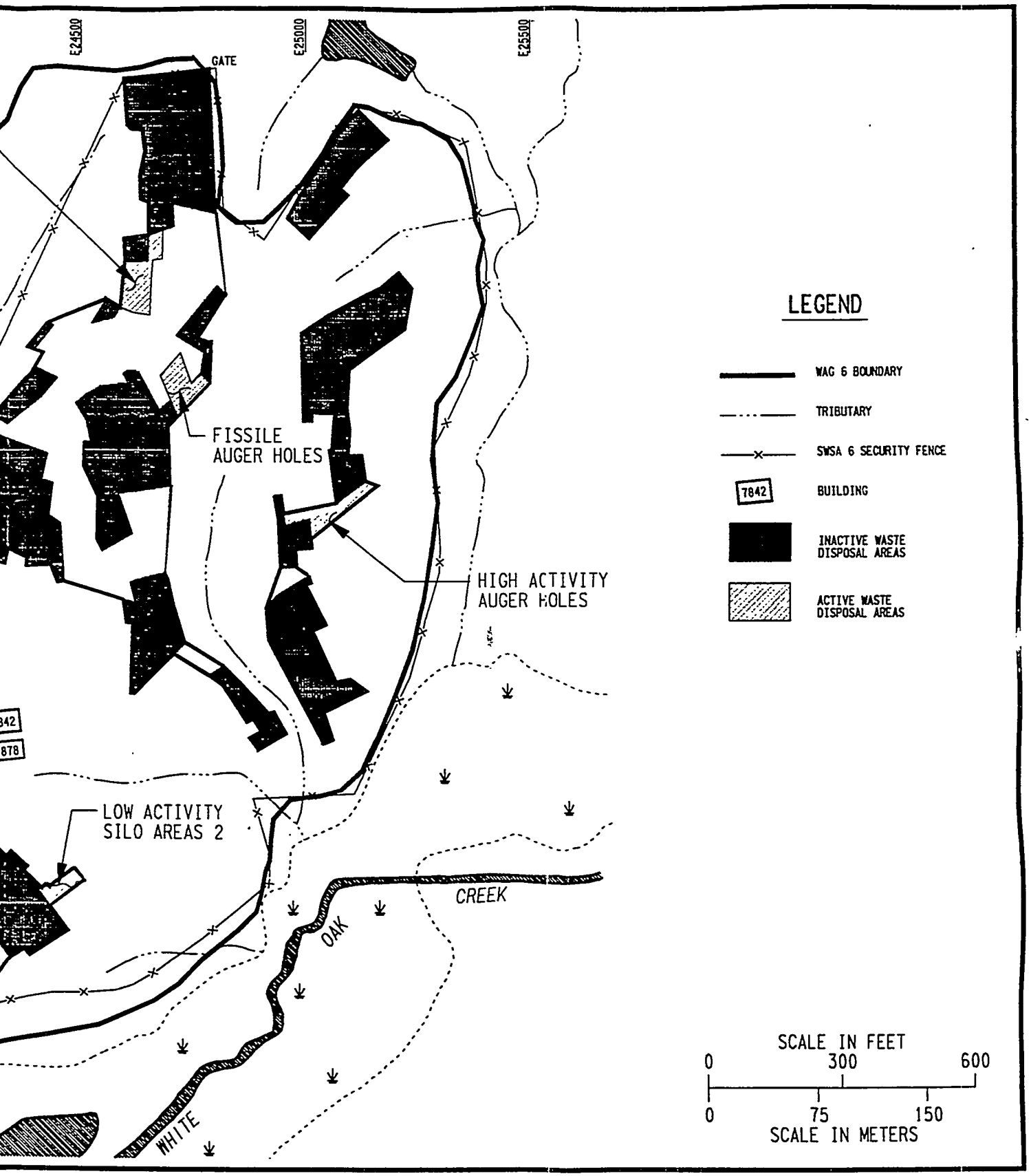
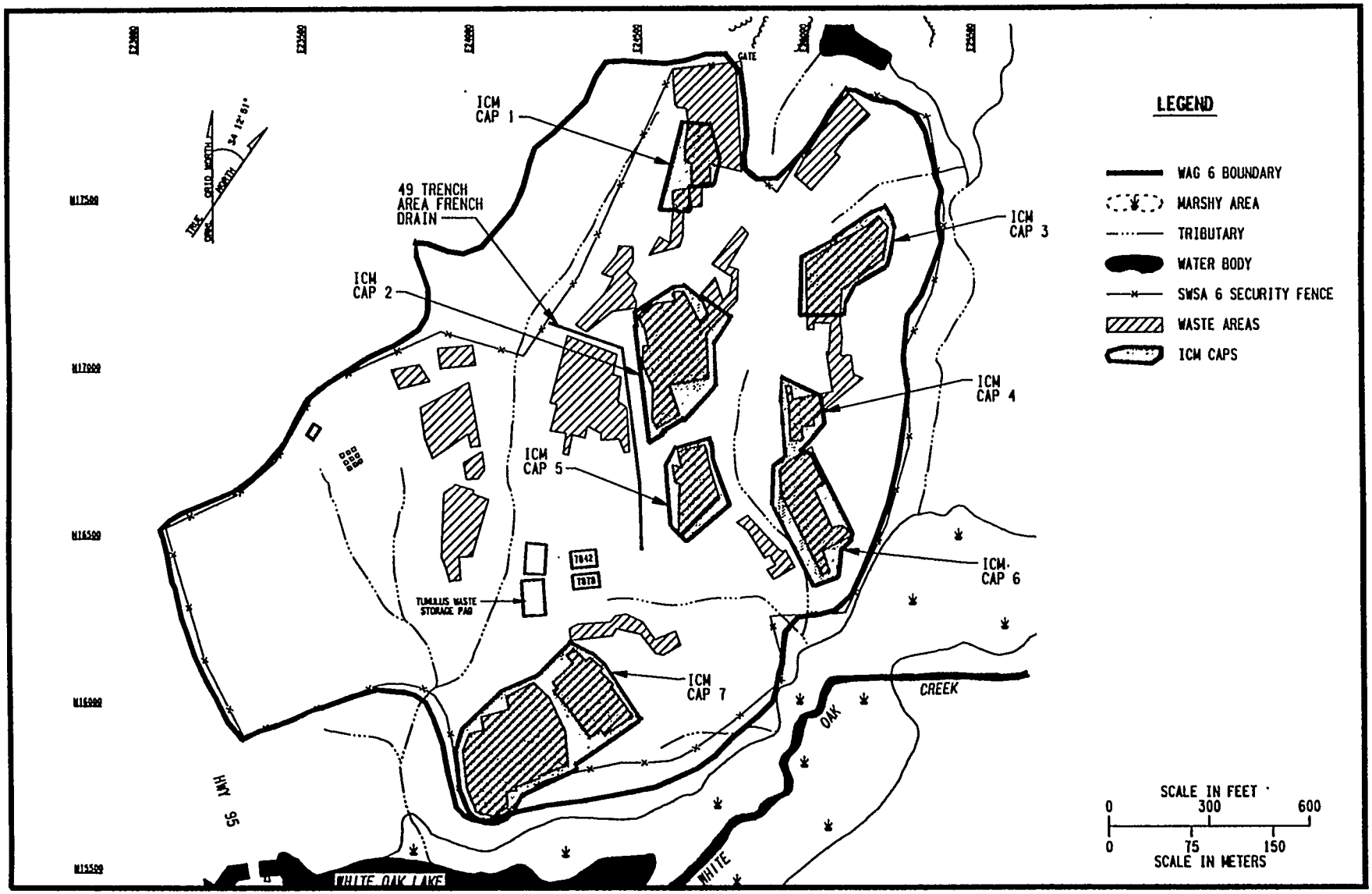



**Fig. 1.8. General areas of ongoing waste disposal at SWSA 6.**




19118 06F107.DGN CAPS

Fig. 1.9. SWSA 6 ICM caps.

# 2. FIELD INVESTIGATION SUMMARY

## 2.1 INTRODUCTION

This section summarizes the field activities performed specifically for the WAG 6 RFI and outlines pertinent activities from other programs that have contributed to the overall understanding of the site. Interpretations of data collected and descriptions of other, nonfield, activities of the RFI are provided in Sects. 3, 4, and 5.

Field activities conducted during the RFI were specified in the WAG 6 RFI Plan (BNI 1989), which was reviewed by EPA and TDC. For the project, a close support laboratory (CSL) was set up at the ORNL RI/FS program Field Operations Facility to permit field radiological screening of environmental samples for gross alpha and gross beta activity. Screening results were used to determine sample shipping and laboratory handling requirements. For the field activities, health and safety hazardous work permits were prepared for individual work tasks. Workers were briefed on potential hazards, and then each day signed onto and off the appropriate activity-specific hazardous work permits. Investigation-derived wastes were handled according to the ORNL RI/FS Waste Management Plan (BNI 1988b) and approved procedures.

Technical memorandums were prepared for key field activities. These documents summarized sampling and measurement activities (such as equipment used, procedures followed, samples collected, and analyses performed) and analytical results. As described in the introduction, WAG 6 RFI field investigations were conducted in two parts, referred to as Activity 1 and Activity 2. Table 2-1 lists the technical memorandums prepared for WAG 6 RFI field activities and indicates whether they were prepared for Activity 1 or 2. Activity 1 technical memorandums were published in the WAG 6 Site Characterization Summary Report (BNI 1990a). Activity 2 technical memorandums are to be published in a separate document.

### 2.1.1 Scope

The goals of the WAG 6 RFI were:

- To characterize the nature and extent of contamination associated with WAG 6 sufficiently to achieve the next two goals
- To assess potential impacts of disposed wastes and environmental contamination on human health and the environment
- To identify preliminary site closure and remediation objectives and perform the initial development and screening of alternatives
- To provide data to support the development of site closure and corrective action alternatives

The investigation included compiling and evaluating historical data associated with past waste disposal activities and data from other investigations of site conditions. WAG 6 RFI field investigations were designed specifically to verify and/or fill gaps in the historical data and to thereby accumulate sufficient data to perform baseline human health and ecological

evaluations and a CMS. The following field activities were conducted by Energy Systems and its subcontractors. Each activity is described in subsequent subsections.

- Surface radiological survey (and gamma radiation exposure rate survey)
- Surface geophysical survey
- Soil gas and well headspace surveys
- Evaluation of existing wells
- Installation of monitoring wells
- Groundwater sampling
- Measurement of groundwater levels
- Installation of flumes on four main drainageways
- Surface water storm flow measurements
- Surface water and sediment sampling
- Surface and subsurface soil sampling
- Biohazard investigation
- Borehole geophysical logging
- Survey for threatened and endangered species
- Wetlands survey
- Reference (background) sampling

Unless otherwise noted, RFI sampling was performed in accordance with ORNL procedures for environmental surveillance. When planned activities were not addressed by existing ORNL procedures, special project-specific procedures were prepared and used. Because of their volume, the project procedures are not included in this report, but copies of any or all procedures can be obtained by contacting DOE/Energy Systems.

The sample management plan for the WAG 6 RFI (Appendix 2A) provides summary descriptions of the sample containers, preservatives, holding times, and quality control (QC) samples. Analytical protocols for samples collected during the RFI are summarized in Tables 2.2 through 2.8, as follows:

- Table 2.2, "Target Compound List as Defined in 1988 Contract Laboratory Program (CLP) Statement of Work—VOCs"
- Table 2.3, "Target Compound List as Defined in the 1988 CLP Statement of Work—Semivolatiles"
- Table 2.4, "Target Compound List as Defined in 1988 CLP Statement of Work—Pesticides and PCBs"
- Table 2.5, "Target Analyte List as Defined in 1988 CLP Statement of Work"
- Table 2.6, "Radiological Analytical Parameters"
- Table 2.7, "Field Parameters and Major Ions for Water Samples"
- Table 2.8, "RCRA Appendix IX Constituents"

### 2.1.2 Data Quality Review

To ensure that data quality objectives (DQOs) were achieved for all RFI samples collected, quality control (QC) levels were assigned to all samples submitted for analysis. These QC levels determined the frequency or percentage of QC to be performed with each sample analysis. QC levels also determined the amount of supporting documentation, regarding the analysis of the sample, that would be submitted by the laboratory with each sample result package. All data received from the analytical laboratory was reviewed for contract compliance and was thus submitted for validation. Sample results were qualified (flagged) by the data reviewer to indicate problems or a reduced level of data quality as a result of either field or analytical deficiencies. Appendix 4A presents a detailed assessment of the quality of WAG 6 RFI environmental data.

## 2.2 SURFACE RADIOLOGICAL SURVEY

Surface radiological surveys were performed during both Activity 1 and Activity 2. The survey for Activity 1 was performed over most of SWSA 6, while the Activity 2 survey was performed on a portion of WAG 2 and the EWB. Both surveys consisted of a surface scan and discrete measurements made at locations shown in Fig. 2.1.

For both surveys four types of measurements were made:

- A continuous near-surface gamma radiation measurement, made with a sodium-iodide detector within 15 cm of the ground surface
- Fixed-position gamma radiation measurements, made with a sodium-iodide detector in a cone shield 30 cm above the ground surface
- Total beta-gamma radiation measurements, made with a pancake Geiger-Muller detector contacting the ground surface
- Gamma radiation exposure rate measurements, made with a pressurized ionization chamber (PIC) 1 m above the ground surface

### 2.2.1 Activity 1 Radiological Survey

Between July 16, 1988, and September 11, 1988, a walkover survey was conducted on approximately 74% of WAG 6 (49 acres). The remainder of the site was inaccessible because of dense undergrowth or ongoing waste disposal operations. The survey characterized radioactive contamination of surface soils and helped define site-specific worker health and safety requirements for implementation of the RCRA ICM and RFI field activities. The survey identified a number of locations at which surface radiation levels were higher than three times daily background (which was measured off the WAG). These areas were field marked for remediation during site preparation for placement of the ICM caps. Gamma radiation exposure rate measurements were used to support the baseline human health risk assessment.

### 2.2.2 Activity 2 Radiological Survey

Between December 5, 1989, and February 16, 1990, an additional walkover survey was performed for the EWB area and a portion of WAG 2. Isolated areas of above-normal surface radiation were identified in the northern area of the EWB and in the WOC area. These were field marked radiation survey readings provided input to selection of soil sampling locations and also were used to determine appropriate health and safety requirements for RFI workers.

## 2.3 GEOPHYSICAL SURVEY

An electromagnetic terrain conductivity (EM) survey was performed during Activity 1 in November 1988. The survey objectives were to help identify potential contaminant plumes, to guide the siting of groundwater wells and soil borings, and to delineate the trench areas and the areas for surface soil investigation.

Twenty-three survey lines, oriented east-west on the ORNL grid system and spaced 30.05 m (100 ft) apart, covered the area inside the SWSA 6 security fence. At 3.05 m (10-ft) intervals along the lines, data were collected. A Geonics EM 34 terrain conductivity meter was employed in the survey. Figure 2.2 shows the survey lines and electromagnetic contour lines.

The EM survey data were interpreted based on general conductivity values; locations showing conductivity anomalies were noted. The EM data revealed considerable cultural interferences from fences, power lines, and metallic materials at the ground surface (e.g., piping and debris). Due to this interference, the EM survey was unable to clearly define the trench area boundaries or any contaminant plumes that might have been present.

## 2.4 SOIL GAS SURVEY

Soil gas surveys were performed during Activity 1 and Activity 2. Each is discussed separately in the following subsections.

### 2.4.1 Activity 1 Soil Gas Survey

The Activity 1 soil gas survey was conducted within SWSA 6 to detect the presence of volatile organic compounds (VOCs) around the perimeter of selected trench areas. The survey was conducted in three phases. During the first phase, conducted between March 7, 1989, and March 29, 1989, 84 soil and well gas (headspace) samples were collected and measured for VOC concentrations with flame ionization and photo ionization field analytical instruments. In the second phase, conducted between April 3 through 7, 1989, 41 of the earlier sampling locations that had shown elevated VOC concentrations were resampled, and the samples were analyzed with a portable gas chromatograph (GC). In general, soil gas sample depths ranged from 4 to 9 ft. During the third phase, 10 nonintrusive VOC sampling devices were placed, retrieved, and analyzed April 5 through 11, 1989, by Quadrel Services, Inc. Figure 2.3 shows soil gas sampling locations for Activity 1. Results were used (with

other data) to identify potential VOC contaminant plumes and to help select locations for soil sampling and installation of groundwater monitoring wells.

### 2.4.2 Activity 2 Soil Gas Survey

During Activity 2, a soil gas investigation was conducted from December 1989 through January 1990 in the EWB area and in four areas within SWSA 6, as shown in Fig. 2.4. This survey's purpose also was to detect the potential presence of VOCs and, in conjunction with other nonintrusive surveys, to locate soil sampling points.

Because of wet conditions during Activity 2, extraction of soil gas in situ was not feasible. Instead, soil samples were collected from a depth of 12 in. to 18 in. for soil headspace analysis. Samples were then collected and taken to the CSL for GC analysis. The soil headspace samples analytical results indicated the presence of VOCs in the soil, and this information was used to identify additional well locations. Well headspace samples were also collected during Activity 2; after collection and equilibration, these were returned to the CSL for analysis by GC.

## 2.5 GROUNDWATER INVESTIGATION

This section discusses the groundwater monitoring that was performed during Activity 1 and Activity 2 of the RFI. The groundwater investigation utilized two groups of wells: the 800 series, which are the ORNL RCRA Compliance Program wells, and the 1200 series, which were installed specifically as part of the WAG 6 RFI.

There are 30 RCRA compliance wells and 22 RFI wells. All 52 wells were installed between June 1987 and June 1990. All were constructed with stainless steel screens and casing and were drilled and installed in general conformance with RCRA Groundwater Monitoring Technical Enforcement Guidance Document (TEGD) (EPA 1986a).

### 2.5.1 ORNL RCRA Groundwater Compliance Program

The 30 ORNL RCRA compliance wells were installed to sample the shallow portion of the water table aquifer, which, as described in Sect. 3, comprises the majority of active groundwater flow. For compliance purposes, 21 of the 30 wells have been designated to serve as the actual RCRA monitoring network, which consists of 14 perimeter wells and 7 upgradient wells that serve as the reference wells. The remaining nine wells are located within SWSA 6 and are used for characterization purposes only.

With few exceptions, wells designated as part of the compliance monitoring network were installed as well pairs. The shallow well of each pair generally is screened to monitor the zone of fluctuation of the water table, while the deeper well is installed below the water table completely within the zone of saturation. The locations of ORNL RCRA compliance wells are shown in Fig. 2.5.

### 2.5.2 WAG 6 RFI Monitoring Well Installation

The 22 WAG 6 RFI groundwater monitoring wells were installed to improve upon the definition of groundwater contamination that could be provided by the RCRA compliance network alone. Nine of the RFI wells (1225 through 1233) are shallow wells and were installed in March 1989 as part of Activity 1. The remaining 13 wells, consisting of 4 deep bedrock wells (1234, 1236, 1238, 1239), 6 intermediate-depth bedrock wells (1249, 1237, 1241, 1242, 1244, and 1245) and 3 additional shallow wells (1235, 1240, 1243) were installed as part of Activity 2 between January and May 1990. RFI well locations are shown in Fig. 2.6. Details of the RFI well installations for Activity 1 and Activity 2 are provided in the following subsections.

#### 2.5.2.1 Activity 1 well installation

Eight well points and nine wells were installed in SWSA 6 during Activity 1 of the WAG 6 RFI. The well points were installed before well installation to determine the depths for positioning the well screens. The well points depths ranged from 7.8 ft to 35.5 ft. The well depths, selected on the basis of water levels measured in the well points, ranged from 7.5 ft to 24.0 ft. Screened intervals ranged from 2.0 ft to 22.5 ft.

Three of these first nine RFI wells were installed as storm flow zone wells. (For a discussion of storm flow, see Sect. 3.) The six other wells were installed to allow sampling of the shallowest groundwater.

#### 2.5.2.2 Activity 2 well installation

Thirteen additional RFI groundwater monitoring wells were installed from January through May 1990. Well locations and completion depths were selected based on analysis of data collected during previous investigations. Monitoring well completion depths were 23.6 ft to 27.2 ft in the shallow overburden (regolith), 27.32 ft in the contact zone, 24.09 ft to 70.5 ft in the intermediate bedrock, and 147 ft to 160 ft in the deep bedrock. Screen intervals ranged from 15 ft to 20 ft. (Rock cores were obtained from Deep Well 1234 and from a portion of Well 1237.)

### 2.5.3 Geophysical Logging of RFI Bedrock Wells

The four deepest bedrock monitoring wells (1234, 1236, 1238, and 1239) were used to assess the groundwater quality and hydrology of the lower flow component of the shallow aquifer system. Following drilling and before well installation, all four open boreholes were geophysically logged by ORNL. Table 2.10 summarizes the borehole geophysical logging program. The primary objectives of the geophysical logging were: (1) to identify water-bearing fractured bedrock to aid in selecting well screen intervals and depths for future well installations; (2) to further characterize local bedrock geology and hydrogeology; and (3) to allow stratigraphic and structural comparisons with existing geophysical logs for Hydraulic Head Monitoring Station (HHMS) wells located within SWSA 6. The HHMS well logs

displayed evidence of faulting (Dreier and Toran 1989). The geophysically logged wells are shown in Fig. 2.6.

### 2.5.4 Groundwater Sampling and Analysis

Sampling and analysis of groundwater was conducted to investigate the nature, extent, and concentrations of contaminants present in the groundwater, to evaluate groundwater geochemistry, and to help determine the potential for contaminant migration from WAG 6. Beginning in June 1988, 10 distinct sampling events were conducted among the monitoring wells at WAG 6, either as part of ORNL RCRA compliance monitoring or WAG 6 RFI activities. Table 2.11 indicates the wells that were sampled during each sampling event, and Tables 2.12 and 2.13 indicate analytical suites for each well for each round. Along with the sampling event, water level measurements were collected prior to purging the well.

As indicated in Table 2.11, the first WAG 6 RFI groundwater sampling event occurred in April through May 1989, which coincided with the fourth sampling event of the RCRA compliance monitoring program. The RFI sampling included Activity 1 RFI wells installed in 1989 and the nine interior RCRA compliance program wells not previously sampled by the RCRA Compliance Monitoring Program. During storm events (May 9 through 11 and June 8 through 9, 1989), two sampling rounds were conducted on the RFI wells and selected interior RCRA compliance site characterization wells to assess the effects of precipitation on shallow groundwater chemistry. The nine RFI wells and nine interior ORNL wells were sampled in August of 1989 to assess groundwater quality under seasonal low groundwater conditions.

Following the installation of the additional 13 RFI monitoring wells during Activity 2, an additional sampling round was conducted from May 9 through 30, 1990, on the newly installed wells and on those RFI wells for which samples had not been obtained in previous sampling rounds because the wells were dry. Again, sampling events coincided with the ORNL semiannual compliance monitoring sampling event. WAG 6 RFI project personnel accompanied ORNL sampling crews to collect supplemental samples (geochemical analyses) from select perimeter and upgradient well pairs. Sample splits were also collected from some compliance wells to provide a basis for comparison of laboratory analytical results from the ORNL Analytical Chemistry Division, which analyzed ORNL RCRA compliance program samples, and IT Corporation, which analyzed RFI samples. Samples were also collected from three existing PVC piezometers from the ETF area to be analyzed for geochemical parameters only. During the tenth sampling event (June 11 through 20, 1990) wells were sampled for metals (total and dissolved), anions, (carbonate/bicarbonate), and alkalinity. Wells 1226, 1230, and 1232 remained dry during all sampling events and consequently have never been sampled.

## 2.6 SURFACE WATER INVESTIGATION

This section discusses the surface water sampling events for Activities 1 and 2 of the WAG 6 RFI. The general objectives of the surface water investigation were to characterize surface water contamination, provide data to support evaluation of interactions between

surface water and groundwater, and provide flow data and contaminant characterization data to support modeling of contaminant flux at the WAG 6 boundary.

### 2.6.1 Reference Surface Water Sampling

On May 22, 1990, two reference samples were collected from locations on the headwaters of Melton Branch (Fig. 2.7) and analyzed for Target Compound List (TCL) volatile organic compounds (VOCs), base neutral and acid extractables (BNAEs), and pesticides/PCBs, and Target Analytes List (TAL) metals, cyanide, and radionuclides. One sample was analyzed for Appendix IX constituents. This creek is in an area well separated from any waste management areas and represents an uncontaminated area of the ORR. Reference samples help determine what constitutes site contamination at WAG 6.

### 2.6.2 Site Surface Water Sampling

Surface water samples and measurements were taken during both Activity 1 and 2. Each is discussed below.

#### 2.6.2.1 Activity 1 surface water sampling

In February, April, and May 1989, surface water samples were collected at 16 locations on intermittent streams within the WAG, at one location in the EWB, and at one seep (Fig. 2.8). Conditions existing during each sampling event were as follows:

- February 1989: Base flow during high groundwater level; before installation of the ICM caps
- April 1989: Base flow during high groundwater level; after installation of the ICM caps
- May 1989: Storm event flow during high groundwater level
- September 1989: Under conditions of low base flow and storm flow during low groundwater table.

During the pre-ICM cap sampling, only 11 of the locations contained water enough to obtain a sample; under the high water table conditions, only 6 locations were sampled; during the storm event, 14 of the sites were sampled. Therefore, a total of 31 samples were collected and analyzed for TCL organics, TAL inorganics, radioactive constituents, anions, total dissolved solids (TDS), sulfide, alkalinity, chemical oxygen demand (COD), total organic carbon (TOC), total kjeldahl nitrogen (TKN), biochemical oxygen demand (BOD), and fecal coliforms.

#### 2.6.2.2 Activity 2 surface water sampling

To provide data for calibrating the surface water contaminant transport model, surface water flow measurements were made and samples were collected during two storm events during Activity 2. To allow flow measurements to be taken, Parshall and trapezoidal flumes were installed at the locations shown in Fig. 2.8. For the storm events, eight automatic samplers controlled by the four electronic data loggers were placed on the four main

drainages of WAG 6. The ORNL Environmental Science Division's (ESD) Hydrology Group and WAG 6 RFI personnel collected discharge data and operated electronic data loggers and automatic sequential water samplers. At each automatic sampler location, 48 grab samples were collected and analyzed for TAL metals and radioactive constituents.

## 2.7 SOILS INVESTIGATION

This section discusses the WAG 6 RFI soil investigation, which was conducted during both Activity 1 and Activity 2. The primary objectives of the soil investigation were to help define the extent of soil contamination in WAG 6, aid in defining contaminant migration pathways, and provide soils data to support development of remedial action alternatives. Sampling activities, including reference sampling, are discussed in the following sections.

### 2.7.1 Reference Soil Sampling

From October through December 1989, 20 reference soil samples were collected from four boreholes (one to four samples per borehole and 10 shallow soil sampling locations) (Fig. 2.7). Samples were analyzed for TCL VOCs, BNAEs, pesticides, PCBs, TAL metals, and radionuclides.

### 2.7.2 Site Soil Sampling

Site soil sampling was conducted during both Activity 1 and Activity 2 of the WAG 6 RFI, as discussed in the following subsections. Figure 2.9 shows soil sampling locations.

#### 2.7.2.1 Activity 1 soil sampling

Between December 1988 and January 1989, 53 borings were drilled to auger refusal. Boring depths ranged from 1.65 m to 15.6 m (5.4 ft to 51.2 ft), and sampling was performed continuously. As samples were collected, they were surveyed for chemical and radiological contamination using field instruments. Based on the results of the field screening, 63 samples were submitted for laboratory analysis of TCL organics, TAL inorganics, and radioactive constituents.

The soil borings were conducted only around the perimeters of the waste disposal areas. There were no attempts to drill into the waste disposal trenches and auger holes themselves, both because of the difficulty in characterizing heterogeneous waste materials and the hazards presented by drilling into unknown waste materials.

#### 2.7.2.2 Activity 2 soil sampling

Between December 1989 and March 1990, in conjunction with well installation, eight soil borings were drilled and continuously sampled until auger refusal. Boring depths ranged from 4.97 m to 14.7 m (16.3 ft to 48.25 ft). As samples were collected, they were surveyed for chemical and radiological contamination using field instruments. Based on the field

screening results, 17 samples were submitted for full TCL and TAL analysis and for selected radiological analyses.

## 2.8 SEDIMENTS INVESTIGATION

Sediment sampling was performed during both Activity 1 and Activity 2 to define the nature and extent of sediment contamination on WAG 6. The following sections summarize sediment sampling activities, including reference sampling.

### 2.8.1 Reference Sediment Sampling

Reference sediment samples were collected under base flow conditions May 24 and 25, 1990, from four locations chosen because they are hydrologically separated from ORNL waste management activities yet contain sediments derived from Conasauga Group material. Reference samples are employed in the determination of what constitutes site contamination at WAG 6. Samples were analyzed for TCL VOCs, BNAEs, pesticides/PCBs, TAL metals, cyanide, and radionuclides. Reference sampling locations are shown in Fig. 2.10.

### 2.8.2 Site Sediment Sampling

Sediment sampling was conducted during Activity 1 and Activity 2 at locations shown in Fig. 2.11. During the Activity 1 period, sediment samples were collected by ORNL in conjunction with the ICM cap construction. During Activity 2, in February and March 1990, sediment samples were collected at 31 locations within WAG 6, including 16 samples from the EWB. The objective of this sampling was to collect contaminant and concentration level data to support the baseline risk assessment. Samples were analyzed for the full TCL and TAL regime and for radionuclide constituents. Select samples were analyzed for the full suite of Appendix IX chemicals.

## 2.9 ECOLOGY INVESTIGATION

ORNL's ESD conducted surveys for threatened and endangered species and sensitive environments in WAG 6. From May through September 1990, surveys were conducted for fish, invertebrates, birds, mammals, plants, and wetlands. No threatened or endangered species or sensitive environments were found. No other ecological investigation was performed as part of the RFI field sampling activities.

## 2.10 BIOHAZARD INVESTIGATION

The biohazard investigation was conducted during both Activity 1 and Activity 2 to determine if the microbiological content of the soils, surface water, and groundwater at WAG 6 are of normal character (e.g., standard plate, total coliforms, fecal coliform, colony morphology). Samples were analyzed primarily for bacteria content. Activities are described in the following sections.

### 2.10.1 Activity 1 Biohazard Sampling

Sixteen soil samples, all downgradient of the biological waste trench areas, were taken at depths up to 1 m (3 ft). Forty-four water samples were taken. Groundwater samples were taken from existing RCRA monitoring wells, and surface water samples were taken at the gaging stations existing in August and November 1988 and at the WOL control structure. Soil sampling locations are shown in Fig. 2.12. Groundwater and surface water sampling locations are shown in Fig. 2.13.

### 2.10.2 Activity 2 Biohazard Sampling

The Activity 2 biohazard investigation was a follow-up to biohazard sampling conducted during Activity 1, during which an unidentified bacteria was noted in SWSA 6 groundwater. The objective of Activity 2 sampling was to:

- Confirm the continued presence of the unidentified bacteria in SWSA 6 groundwater
- Determine if the organism was present in areas immediately adjacent to SWSA 6
- Determine if the organism was present in other ORR and ORNL areas

Surface water samples were collected from four locations outside ORNL and the ORR to determine if the organism were generally present in local waterways (Fig. 2.14). At one location, a sediment sample was collected. In addition, during July 1990, groundwater samples were collected from 49 wells located throughout ORR. These sampling locations are shown in Fig. 2.15.

# Section 2 Tables

Table 2.1. WAG 6 RFI Technical Memorandums

| Technical Memorandum | Title |
|---|---|
| Activity 1 TMs[a] | |
| 06-01 | RI/FS Data Quality Review |
| 06-02 | RFI Well Evaluation |
| 06-03 | Soil Gas Investigation |
| 06-04 | Surface Radiological Investigation |
| 06-05 | Surface Water Investigation |
| 06-06 | Electromagnetic (EM) Survey |
| 06-07 | Validation of Existing ORNL Groundwater Data |
| 06-08 | Monitoring Well Installation |
| 06-09 | Groundwater Investigation |
| 06-10 | Biohazard Investigation |
| 06-11 | Waste Management |
| 06-12 | Soil Investigation |
| Activity 2 TMs | |
| 06-03A | Soil Gas Survey (Phase 1, Activity 2) |
| 06-04A | Surface Radiological Investigation for WAG 6, SWMU 6.2, EWB (Phase 1, Activity 2) |
| 06-05A[b] | Surface Water and Sediment Sampling for the ORNL WAG 6 RFI (Phase 1, Activity 2) |
| 06-08A | WAG 6 RFI Well Installation (Phase 1, Activity 2) |
| 06-09A[b] | Groundwater Sampling at WAG 6 |
| 06-10A[b] | WAG 6 Biohazard Investigation Results (Phase 1, Activity 2) |
| 06-11A | Waste Management |
| 06-12A | Soil Sampling for the ORNL WAG 6 RFI (Activity 1, Activity 2) |
| 06-13 | WAG 6 Borehole Geophysical Logging |
| 06-14 | Demographic Data to Support WAG 6 RFI |
| 06-15 | Reference Sampling for the ORNL WAG 6 RFI |

[a]These Activity 1 TMs were included in *WAG 6 Site Characterization Summary Report* (BNI 1990a). All other TMs describe Activity 2 actions.
[b]These TMs summarize Activity 1 and Activity 2 data.

**Table 2.2. Target compound list as defined in 1988 CLP statement of work—VOCs**

| Volatiles | CAS number | Quantitation limits[a] soil (μg/kg)[b] water (μg/L) |
|---|---|---|
| Chloromethane | 74-87-3 | 10 |
| Bromomethane | 74-83-9 | 10 |
| Vinyl chloride | 75-01-4 | 10 |
| Chloroethane | 75-00-3 | 10 |
| Methylene chloride | 75-09-2 | 5 |
| Acetone | 67-64-1 | 10 |
| Carbon disulfide | 75-15-0 | 5 |
| 1,1-Dichloroethene | 75-35-4 | 5 |
| 1,1-Dichloroethane | 75-35-3 | 5 |
| 1,2-Dichloroethene (total) | 540-59-0 | 5 |
| Chloroform | 67-66-3 | 5 |
| 1,2-Dichloroethane | 107-06-2 | 5 |
| 2-butanone | 78-93-3 | 10 |
| 1,1,1-Trichloroethane | 71-55-6 | 5 |
| Carbon tetrachloride | 56-23-5 | 5 |
| Vinyl acetate | 108-05-4 | 10 |
| Bromodichloromethane | 75-27-4 | 5 |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | 5 |
| 1,2-Dichloropropane | 78-87-5 | 5 |
| cis-1,3-Dichloropropene | 10061-01-5 | 5 |
| Trichloroethene | 79-01-6 | 5 |
| Dibromochloromethane | 124-48-1 | 5 |
| 1,1,2-Trichloroethane | 79-00-5 | 5 |
| Benzene | 71-43-2 | 5 |
| trans-1,3-Dichloropropene | 10061-02-6 | 5 |
| Bromoform | 75-25-2 | 5 |
| 2-Hexanone | 591-78-6 | 10 |
| 4-Methyl-2-pentanone | 108-10-1 | 10 |
| tetrachloroethene | 127-18-4 | 5 |
| Toluene | 108-88-3 | 5 |
| Chlorobenzene | 108-90-7 | 5 |
| Ethyl benzene | 100-41-4 | 5 |
| Styrene | 100-42-5 | 5 |
| Xylenes (total) | 133-02-7 | 5 |

[a]Quantitation limits are highly matrix dependent. The quantitation limits listed are provided for guidance and may not always be achievable.

[b]Quantitation limits for soil are based on wet weight. The quantitation limits calculated by the laboratory for soil sediment are calculated on a dry-weight basis.

**Table 2.3 Target compound list as defined in 1988 CLP statement of work—semivolatiles**

| Semivolatiles | CAS number | Quantitation limits[a] water (μg/L) | soil (μg/kg)[b] |
|---|---|---|---|
| Phenol | 108-95-2 | 10 | 330 |
| bis(2-Chloroethyl)ether | 111-44-4 | 10 | 330 |
| 2-chlorophenol | 95-57-8 | 10 | 330 |
| 1,3-Dichlorobenzene | 541-73-1 | 10 | 330 |
| 1,4-Dichlorobenzene | 106-46-7 | 10 | 330 |
| Benzyl alcohol | 100-51-6 | 10 | 330 |
| 1,2-Dichlorobenzene | 95-50-1 | 10 | 330 |
| 2-Methylphenol | 95-48-7 | 10 | 330 |
| bis(2-Chloroisopropyl)ether | 39638-32-9 | 10 | 330 |
| 4-Methylphenol | 106-44-5 | 10 | 330 |
| N-Nitroso-Dipropylamine | 621-64-7 | 10 | 330 |
| Hexachloroethane | 67-72-1 | 10 | 330 |
| Nitrobenzene | 98-95-3 | 10 | 330 |
| Isophorone | 78-59-1 | 10 | 330 |
| 2-Nitrophenol | 88-75-5 | 10 | 330 |
| 2,4-Dimethylphenol | 105-67-9 | 10 | 330 |
| Benzoic acid | 65-85-0 | 50 | 1600 |
| bis(2-chloroethoxy)methane | 111-91-1 | 10 | 330 |
| 2,4-Dichlorophenol | 120-83-2 | 10 | 330 |
| 1,2,4-Trichlorobenzene | 120-82-1 | 10 | 330 |
| Naphthalene | 91-20-3 | 10 | 330 |
| 4-Chloroaniline | 106-47-8 | 10 | 330 |
| Hexachlorobutadiene | 87-68-3 | 10 | 330 |
| 4-Chloro-3-methylphenol (para-chloro-meta-cresol) | 59-50-7 | 10 | 330 |
| 2-Methylnaphthalene | 91-57-6 | 10 | 330 |
| Hexachlorocyclopentadiene | 77-47-4 | 10 | 330 |
| 2,4,6-Trichlorophenol | 88-06-2 | 10 | 330 |
| 2,4,5-Trichlorophenol | 95-95-4 | 50 | 1600 |
| 2-Chloronaphthalene | 91-58-7 | 10 | 330 |
| 2-Nitroaniline | 88-74-4 | 50 | 1600 |
| Dimethyl phthalate | 131-11-3 | 10 | 330 |
| Acenaphthylene | 208-96-8 | 10 | 330 |
| 2,6-Dinitrotoluene | 606-20-2 | 10 | 330 |
| 3-Nitroaniline | 99-09-2 | 50 | 1600 |
| Acenaphthene | 83-32-9 | 10 | 330 |
| 2,4-Dinitrophenol | 51-28-5 | 50 | 1600 |
| 4-Nitrophenol | 100-02-7 | 50 | 1600 |
| Dibenzofuran | 132-64-9 | 10 | 330 |
| 2,4-Dinitrotoluene | 121-14-2 | 10 | 330 |

Table 2.3 (continued)

| Semivolatiles | CAS number | Quantitation limits[a] water (μg/L) | soil (μg/kg)[b] |
|---|---|---|---|
| Diethylphthalate | 84-66-2 | 10 | 330 |
| 4-Chlorophenyl phenyl ether | 7005-72-3 | 10 | 330 |
| Fluorene | 86-73-7 | 10 | 330 |
| 4-Nitroaniline | 100-01-6 | 50 | 1600 |
| 4,6-Dinitro-2-methylphenol | 534-52-1 | 50 | 1600 |
| N-nitrosodiphenylamine | 86-30-6 | 10 | 330 |
| 4-Bromophenyl-phenylether | 101-55-3 | 10 | 330 |
| Hexachlorobenzene | 118-74-1 | 10 | 330 |
| Pentachlorophenol | 87-86-5 | 50 | 1600 |
| Phenanthrene | 85-01-8 | 10 | 330 |
| Anthracene | 120-12-7 | 10 | 330 |
| Di-n-butylphthalate | 84-74-2 | 10 | 330 |
| Fluoranthene | 206-44-0 | 10 | 330 |
| Pyrene | 129-00-0 | 10 | 330 |
| Butyl benzyl phthalate | 85-68-7 | 10 | 330 |
| 3,3'-Dichlorobenzidine | 91-94-1 | 20 | 660 |
| Benzo(a)anthracene | 56-55-3 | 10 | 330 |
| Chrysene | 218-01-9 | 10 | 330 |
| bis(2-ethylhexyl)phthalate | 117-81-7 | 10 | 330 |
| Di-n-octyl phthalate | 117-84-0 | 10 | 330 |
| Benzo(b)fluoranthene | 205-99-2 | 10 | 330 |
| Benzo(k)fluoranthene | 207-08-9 | 10 | 330 |
| Benzo(a)pyrene | 50-32-8 | 10 | 330 |
| Indeno(1,2,3-cd)pyrene | 193-39-5 | 10 | 330 |
| Dibenz(a,h)anthracene | 53-70-3 | 10 | 330 |
| Benzo(g,h,i)perylene | 191-24-2 | 10 | 330 |

[a]Quantitation limits are highly matrix dependent. The quantitation limits listed are provided for guidance and may not always be achievable.

[b]Quantitation limits for soil are based on wet weight. The quantitation limits calculated by the laboratory for soil sediment are calculated on a dry-weight basis.

Table 2.4 Target compound list as defined in 1988 CLP statement of work—pesticides/PCBs

| Pesticides/PCBs | CAS number | Quantitation limits[a] water (μg/L) | Quantitation limits[a] soil (μg/kg)[b] |
|---|---|---|---|
| alpha-BHC | 319-84-6 | 0.05 | 8.0 |
| beta-BHC | 319-85-7 | 0.05 | 8.0 |
| delta-BHC | 319-86-8 | 0.05 | 8.0 |
| gamma-BHC (Lindane) | 58-89-9 | 0.05 | 8.0 |
| Heptachlor | 76-44-8 | 0.05 | 8.0 |
| Aldrin | 309-00-2 | 0.05 | 8.0 |
| Heptachlor Epoxide | 1024-57-3 | 0.05 | 8.0 |
| Endosulfan I | 959-98-8 | 0.05 | 8.0 |
| Dieldrin | 60-57-1 | 0.10 | 16.0 |
| 4,4'-DDE | 72-55-9 | 0.10 | 16.0 |
| Endrin | 72-20-8 | 0.10 | 16.0 |
| Endosulfan II | 33213-65-9 | 0.10 | 16.0 |
| 4,4'-DDD | 72-54-8 | 0.10 | 16.0 |
| Endosulfan Sulfate | 1031-07-8 | 0.10 | 16.0 |
| 44'-DDT | 50-29-3 | 0.10 | 16.0 |
| Endrin ketone | 53494-70-5 | 0.10 | 16.0 |
| Methoxychlor | 72-43-5 | 0.5 | 80.0 |
| alpha-chlordane | 5103-71-9 | 0.5 | 80.0 |
| gamma-chlordane | 5103-74-2 | 0.5 | 80.0 |
| Toxaphene | 8001-35-2 | 1.0 | 160.0 |
| Aroclor-1016 | 12674-11-2 | 0.5 | 80.0 |
| Aroclor-1221 | 11104-28-2 | 0.5 | 80.0 |
| Aroclor-1232 | 11141-16-5 | 0.5 | 80.0 |
| Aroclor-1242 | 53469-21-9 | 0.5 | 80.0 |
| Aroclor-1248 | 12672-29-6 | 0.5 | 80.0 |
| Aroclor-1254 | 11097-69-1 | 1.0 | 160.0 |
| Aroclor-1260 | 11096-82-5 | 1.0 | 160.0 |

[a]Quantitation limits are highly matrix dependent. The quantitation limits listed are provided for guidance and may not always be achievable.

[b]Quantitation limits for soil are based on wet weight. The quantitation limits calculated by the laboratory for soil sediment are calculated on a dry-weight basis.

**Table 2.5. Target analyte list as defined in 1988 CLP statement of work**

| Metals | CAS number | Quantitation limits[a] water (μg/L) | soil (μg/kg)[b] |
|---|---|---|---|
| Aluminum | 7429-90-5 | 200.0 | 40,000 |
| Antimony | 7440-36-0 | 60.0 | 12,000 |
| Arsenic | 7440-38-2 | 10.0 | 2,000 |
| Barium | 7440-39-3 | 200.0 | 40,000 |
| Beryllium | 7440-41-7 | 5.0 | 1,000 |
| Cadmium | 7440-43-9 | 5.0 | 1,000 |
| Calcium | 7440-70-2 | 5000.0 | 1,000,000 |
| Chromium | 7440-47-3 | 10.0 | 2,000 |
| Cobalt | 7440-48-4 | 50.0 | 10,000 |
| Copper | 7440-50-8 | 25.0 | 5,000 |
| Iron | 7439-89-6 | 100.0 | 20,000 |
| Lead | 7439-92-1 | 5.0 | 1,000 |
| Magnesium | 7439-95-4 | 5000.0 | 1,000,000 |
| Manganese | 7439-96-5 | 15.0 | 3,000 |
| Mercury | 7439-97-6 | 0.2 | 40,000 |
| Nickel | 7440-02-0 | 40.0 | 8,000 |
| Potassium | 7440-09-7 | 5000.0 | 1,000,000 |
| Selenium | 7782-49-2 | 5.0 | 1,000 |
| Silver | 7740-22-4 | 10.0 | 2,000 |
| Sodium | 7440-23-5 | 5000.0 | 1,000,000 |
| Thallium | 7440-28-0 | 10.0 | 2,000 |
| Vanadium | 7440-62-2 | 50.0 | 10,000 |
| Zinc | 7440-66-6 | 20.0 | 4,000 |
| **Other** | | | |
| Cyanide | 57-12-5 | 10.0 | – |

[a]Quantitation limits are highly matrix dependent. The quantitation limits listed are provided for guidance and may not always be achievable.

[b]Quantitation limits for soil are based on wet weight. The quantitation limits calculated by the laboratory for soil sediment are calculated on a dry-weight basis.

**Table 2.6. Radiological analytical parameters**

| Analyte | Detection limit goals |
|---|---|
| Americium-241 | (1.0 pCi/L) |
| Cadmium/Indium-115 | (-) |
| Calcium-45 | (6 pCi/L) |
| Carbon-14 | (100 pCi/L) |
| Curium isotopic | (1 pCi/L) |
| Gamma isotopic | (20 pCi/L Cs-137) |
| Gross alpha - total | (pCi/L - <500 ppm solids) |
| Gross beta | total (4 pCi/L - <500 ppm solids) |
| Iodine-129 | (10 pCi/L) |
| Iodine-131 | (1 pCi/L) |
| Iron-55 | (100 pCi/L) |
| Lead-210 | (20 pCi/L) |
| Neptunium-237 | (1.0 pCi/L) |
| Nickel-63 | (100 pCi/L) |
| Plutonium isotopic | (1 pCi/L) |
| Plutonium isotopic (including Pu-241) | (Pu 241: 10 pCi/L) |
| Polonium-219 | (1 pCi/L) |
| Promethium-147 | (50 pCi/L) |
| Radium-226 | (1.0 pCi/L) |
| Radium-226,228 | (1.0 pCi/L, 3.0 pCi/L) |
| Radon-220 | (volume dependent) |
| Radon-220/222 | (10 pCi/L) |
| Ruthenium-106 | (150 pCi/L) |
| Strontium-89/90 | (10 pCi/L, 5 pCi/L) |
| Strontium-90 | (5 pCi/L) |
| Technitium-99 | (30 pCi/L) |
| Thorium isotopic | (1.0 pCi/L) |
| Thorium isotopic (including Th-234) | (10 pCi/L, Th-234) |
| Tritium | (500 pCi/L) |
| Uranium - total (Fluorometric) | (5 ug/l) |
| Uranium isotopic | (1.0 pCi/L) |
| Uranium isotopic (including U-32) | (1 pCi/L, U-232) |
| Gross alpha/beta (total) | |

**Table 2.7. Field parameters and major ions for water samples**

| Field parameters | Major Ions |
|---|---|
| Eh[a] | Alkalinity |
| pH | Bicarbonate (from alkalinity) |
| Specific electrical conductance | Carbonate (from alkalinity) |
| Temperature | Calcium |
| DO[b] | Chloride |
| | Magnesium |
| | Nitrate |
| | Potassium |
| | Sodium |
| | Sulfate |
| | Sulfide |

[a]Oxidation-reduction potential was not always measured as part of the field parameters.
[b]Dissolved oxygen: was measured only in surface water samples.

Table 2.8. RCRA Appendix IX Constituents

| Compounds/Elements | CAS number | Water CRDLs[a] (μg/L) |
|---|---|---|
| **VOLATILES** | | |
| Acetone | 67-64-1 | 10 |
| Acetonitrile (Methyl cyanide) | 75-05-8 | 1000 |
| Acrolein | 107-02-8 | 10 |
| Acrylonitrile | 107-13-1 | 10 |
| Ally chloride (3-Chloropropene) | 107-05-1 | 5 |
| Benzene | 71-43-2 | 5 |
| Bromodichloromethane | 75-27-4 | 5 |
| Bromoform | 75-25-2 | 5 |
| Carbon disulfide | 75-15-0 | 5 |
| Carbon tetrachloride | 56-23-5 | 5 |
| Chlorobenzene | 108-90-7 | 5 |
| Chloroethane | 75-00-3 | 10 |
| Chloroform | 67-66-3 | 5 |
| Chloroprene | 126-99-8 | 5 |
| Dibromochloromethane | 124-48-1 | 5 |
| 1,2-Dibromo-3-chloropropane | 96-12-8 | 10 |
| 1,2-Dibromoethane | 106-93-4 | 5 |
| trans-1,4-Dichloro-2-butene | 110-57-6 | 100 |
| Dichlorodifluoromethane | 75-71-8 | 200 |
| 1,1-Dichloroethane | 75-34-3 | 5 |
| 1,2-Dichloroethane | 107-06-2 | 5 |
| 1,1-Dichloroethylene | 75-35-4 | 5 |
| trans-1,2-Dichloroethylene | 156-60-5 | 5 |
| 1,2-Dichloropropane | 78-87-5 | 5 |
| cis-1,3-Dichloropropene | 10061-01-55 | 5 |
| trans-1,3-Dichloropropene | 10061-02-65 | 5 |
| 1,4-Dioxane | 123-91-1 | 5000 |
| Ethylbenzene | 100-41-4 | 5 |
| 2-Hexanone | 591-78-6 | 10 |
| Isobutyl alcohol | 78-83-1 | 3000 |
| Methacrylonitrile | 126-98-7 | 10 |
| Methyl bromide (Bromomethane) | 74-83-9 | 10 |
| Methyl chloride (chloromethane) | 74-87-3 | 10 |
| Methylene bromide (Dibromomethane) | 74-95-3 | 10 |
| Methylene chloride (Dichloromethane) | 75-09-2 | 5 |
| Methyl ethyl ketone | 78-93-3 | 10 |
| Methyl iodide (Iodomethane) | 74-88-4 | 5 |
| Methyl methacrylate | 80-62-6 | 10 |
| 4-Methyl-2-pentanone (Methyl isobutyl ketone) | 108-10-1 | 10 |
| Pentachloroethane | 76-01-7 | 20 |
| Propionitrile (Ethyl cyanide) | 107-12-0 | 100 |
| Pyridine | 110-86-1 | 20,000 |

**Table 2.8. (continued)**

| Compounds/Elements | CAS number | Water CRDLs[a] (μg/L) |
|---|---|---|
| **VOLATILES** | | |
| Styrene | 100-42-5 | 5 |
| 1,1,1,2-Tetrachlorethane | 630-20-6 | 5 |
| 1,1,2,2-Tetrachlorethane | 79-34-5 | 5 |
| Tetrachloroethylene | 127-18-4 | |
| Toluene | 108-88-3 | 5 |
| 1,1,1-Trichloroethane | 71-55-6 | 5 |
| 1,1,2-Trichloroethane | 79-00-5 | 5 |
| Trichloroethylene | 79-01-6 | 5 |
| Trichlorofluoromethane | 75-69-4 | 5 |
| 1,2,3-Trichloropropane | 96-16-4 | 5 |
| Vinyl acetate | 108-05-4 | 10 |
| Vinyl chloride | 75-01-4 | 10 |
| Xylene (total) | 1330-20-7 | 5 |
| **SEMIVOLATILES** | | |
| Acenaphthene | 83-32-9 | 10 |
| Acenaphthylene | 208-96-8 | 10 |
| Acetophenone | 98-86-2 | 10 |
| 2-Acetylaminofluorene | 53-96-3 | 10 |
| 4-Aminobiphenyl | 92-67-1 | 50 |
| Aniline | 62-53-3 | 50 |
| Anthracene | 120-12-7 | 10 |
| Aramite | 140-57-8 | 10 |
| Benzo(a)anthracene | 56-55-3 | 10 |
| Benzo(b)fluoranthene | 205-99-2 | 10 |
| Benzo(k)fluoranthene | 207-08-9 | 10 |
| Benzo(g,h,i)perylene | 191-24-2 | 10 |
| Benzo(a)pyrene | 50-32-8 | 10 |
| Benzyl alcohol | 100-51-6 | 20 |
| bis(2-Chloroethoxy)methane | 111-91-1 | 10 |
| bis(2-Chloroethyl)ether | 111-44-4 | 10 |
| bis(2-Chloroisopropyl)ether | 108-60-1 | 10 |
| bis(2-Ethylhexyl) phthalate | 117-81-7 | 10 |
| 4-Bromophenyl phenyl ether | 101-55-3 | 10 |
| Butyl benzyl phthalate | 85-68-7 | 20 |
| 4-Chloroaniline | 106-47-8* | 20 |
| 4-Chloro-3-methylphenol | 59-50-7 | 10 |
| 2-Chloronaphthalene | 91-58-7 | 10 |
| 2-Chlorophenol | 95-57-8 | 10 |
| 4-Chlorophenylphenyl ether | 7005-72-3 | 10 |
| m-Cresol | 108-39-4 | 10 |
| o-Cresol | 95-48-7 | 10 |
| p-Cresol | 106-44-5 | 10 |

Table 2.8. (continued)

| Compounds/Elements | CAS number | Water CRDLs[a] (μg/L) |
|---|---|---|
| **SEMIVOLATILES** | | |
| Chrysene | 218-01-9 | 10 |
| Diallate | 2303-16-4 | 10 |
| Dibenzo(a,h)anthracene | 53-70-3 | 10 |
| Dibenzofuran | 132-64-9 | 10 |
| Di-n-butyl phthalate | 84-74-2 | 10 |
| 1,2-Dichlorobenzene | 95-50-1 | 10 |
| 1,3-Dichlorobenzene | 541-73-1 | 10 |
| 1,4-Dichlorobenzene | 106-46-7 | 10 |
| 3,3-Dichlorobenzidine | 91-94-1 | 20 |
| 2,4-Dichlorophenol | 120-83-2 | 10 |
| 2,6-Dichlorophenol | 87-65-0 | 10 |
| Diethyl phthalate | 84-66-2 | 10 |
| p-Dimethylaminoazobenzene | 60-11-7 | 30 |
| 7,12-Dimethylbenz(a)anthracene | 57-97-6 | 20 |
| 3,3'-Dimethylbenzidine | 119-93-7 | 80 |
| a,a-Dimethylphenethylamine | 122-09-8 | 10 |
| 2,4-Dimethylphenol | 105-67-9 | 10 |
| Dimethyl phthalate | 131-11-3 | 10 |
| m-Dinitrobenzene | 99-65-0 | 10 |
| 4,6-Dinitro-o-cresol (2-Methyl-4,6-dinitrophenol) | 534-52-1 | 50 |
| 2,4-Dinitrophenol | 51-28-5 | 50 |
| 2,4-Dinitrotoluene | 121-14-2 | 10 |
| 2,6-Dinitrotoluene | 606-20-2 | 10 |
| 2-Sec-butyl-4,6-dinitrophenol (Dinoseb) | 88-85-7 | 20 |
| Di-n-octyl phthalate | 117-84-0 | 10 |
| Diphenylamine | 122-39-4 | 10 |
| Ethyl methacrylate | 97-63-2 | 10 |
| Ethyl methanesulfonate | 62-50-0 | 10 |
| Fluoranthene | 206-44-0 | 10 |
| Fluorene | 86-73-7 | 10 |
| Hexachlorobenzene | 118-74-1 | 10 |
| Hexachlorobutadiene | 87-68-3 | 10 |
| Hexachlorocyclopentadiene | 77-47-4 | 10 |
| Hexachloroethane | 67-72-1 | 10 |
| Hexachlorophene | 70-30-4 | 500 |
| Hexachloropropene | 1888-71-7 | 20 |
| Indeno(1,2,3-cd)pyrene | 193-39-5 | 10 |
| Isophorone | 78-59-1 | 10 |
| Isosafrole | 120-58-1 | 10 |
| Methapyrilene | 91-80-5 | 40 |
| 3-Methylcholanthrene | 56-49-5 | 30 |
| Methyl methanesulfonate | 66-27-3 | 10 |
| 2-Methylnaphthalene | 91-57-6 | 10 |
| Naphthalene | 91-20-3 | 10 |

Table 2.8. (continued)

| Compounds/Elements | CAS number | Water CRDLs[a] (μg/L) |
|---|---|---|
| **SEMIVOLATILES** | | |
| 1,4-Naphthoquinone | 130-15-4 | 10 |
| 1-Naphthylamine | 134-32-7 | 120 |
| 2-Naphthylamine | 91-59-8 | 170 |
| o-Nitroaniline | 88-74-4 | 50 |
| m-Nitroaniline | 99-09-2 | 50 |
| p-Nitroaniline | 100-01-6 | 50 |
| Nitrobenzene | 98-95-3 | 10 |
| o-Nitrophenol | 88-75-5 | 10 |
| p-Nitrophenol | 100-02-7 | 50 |
| 4-Nitroquinoline-1-oxide | 56-57-5 | 10 |
| N-Nitrosodi-n-butylamine | 924-16-3 | 20 |
| N-Nitrosodiethylamine | 55-18-5 | 10 |
| N-Nitrosodimethylamine | 62-75-9 | 10 |
| N-Nitrosodiphenylamine | 86-30-6 | 10 |
| N-Nitroso-di-n-propylamine | 621-64-7 | 10 |
| N-Nitrosomethylethylamine | 10595-95-6 | 10 |
| N-Nitrosomorpholine | 59-89-2 | 10 |
| N-Nitrosopiperidine | 100-75-4 | 10 |
| N-Nitrosopyrrolidine | 930-55-2 | 10 |
| 5-Nitro-o-toluidine | 99-55-8 | 20 |
| Pentachlorobenzene | 608-93-5 | 20 |
| Pentachloroethane | 76-01-7 | 20 |
| 5-Nitro-o-toluidine | 99-55-8 | 20 |
| Pentachlorobenzene | 608-93-5 | 20 |
| Pentachloroethane | 76-01-7 | 20 |
| Pentachloronitrobenzene | 82-68-8 | 20 |
| Pentachlorophenol | 87-86-5 | 50 |
| Phenacetin | 62-44-2 | 10 |
| Phenanthrene | 85-01-8 | 10 |
| Phenol | 108-95-2 | 10 |
| p-Phenylenediamine | 106-50-3 | 50 |
| 2-Picolone | 10-96-8 | 70 |
| Pronamide | 23950-58-5 | 30 |
| Pyrene | 129-00-0 | 10 |
| Safrole | 94-59-7 | 10 |
| 1,2,4,5-Tetrachlorobenzene | 95-94-3 | 10 |
| 2,3,4,6-Tetrachlorophenol | 58-90-2 | 10 |
| Tetraethyldithiopyrophosphate | 3689-24-5 | 20 |
| o-Toluidine | 95-53-4 | 20 |
| 1,2,4-Trichlorobenzene | 120-82-1 | 20 |
| 2,4,5-Trichlorophenol | 95-95-4 | 50 |
| 2,4,6-Trichlorophenol | 88-06-2 | 10 |
| O,O,O-Triethylphosphorothioate | 126-68-1 | 10 |
| sym-Trinitrobenzene | 99-35-4 | 10 |

Table 2.8. (continued)

| Compounds/Elements | CAS number | Water CRDLs[a] (μg/L) |
|---|---|---|
| **ORGANOCHLORINE PESTICIDES** | | |
| Aldrin | 309-00-2 | 0.050 |
| alpha-BHC | 319-84-6 | 0.050 |
| beta-BHC | 319-85-7 | 0.050 |
| gamma-BHC (Lindane) | 58-89-9 | 0.050 |
| delta-BHC | 319-86-8 | 0.050 |
| Chlorobenzilate | 510-15-6 | 0.10 |
| Chlordane | 57-74-9 | 0.50 |
| 4,4'-DDD | 72-54-8 | 0.10 |
| 4,4'-DDE | 72-55-9 | 0.10 |
| 4,4'-DDT | 50-29-3 | 0.10 |
| Dieldrin | 60-57-1 | 0.10 |
| Endosulfan-I | 959-98-8 | 0.050 |
| Endosulfan II | 33213-65-9 | 0.10 |
| Endosulfan sulfate | 1031-07-8 | 0.10 |
| Endrin | 72-20-8 | 0.10 |
| *Endrin aldehyde | 7421-93-4 | |
| *Endrin ketone | 53494-70-5 | 0.10 |
| Heptachlor | 76-44-8 | 0.050 |
| Heptachlor epoxide | 1024-57-3 | 0.050 |
| Isodrin | 465-73-6 | 0.050 |
| Kepone | 143-50-0 | 0.10 |
| Methoxychlor | 72-43-5 | 0.50 |
| Toxaphene | 8001-35-2 | 1.00 |
| **PCBs** | | |
| Aroclor-1016 | 12674-11-2 | 0.50 |
| Aroclor-1221 | 11104-28-2 | 0.50 |
| Aroclor-1232 | 11141-16-5 | 0.50 |
| Aroclor-1242 | 53469-21-9 | 0.50 |
| Aroclor-1248 | 12672-29-6 | 0.50 |
| Aroclor-1254 | 11097-69-1 | 1.00 |
| Aroclor-1260 | 11096-82-5 | 1.00 |
| **ORGANOPHOSPHORUS PESTICIDES** | | |
| O,O-Diethyl-O-(2-pyrazinyl)(Thionazin) | 297-97-2 | 1.0 |
| Dimethoate | 60-51-5 | 1.0 |
| Disulfoton | 298-04-4 | 1.0 |
| Famphur | 52-85-7 | 2.0 |
| Parathion | 56-38-2 | 1.0 |
| Parathion methyl | 298-00-0 | 1.0 |
| Phorate | 298-02-2 | 1.0 |

Table 2.8. (continued)

| Compounds/Elements | CAS number | Water CRDLs[a] (μg/L) |
|---|---|---|
| **CHLORINATED HERBICIDES** | | |
| 2,4-D (2,4-Dichlorophenoxyacetic acid) | 94-75-7 | 0.16 |
| Dinoseb | 88-85-7 | 0.04 |
| 2,4,5-TP (Silvex) | 93-72-1 | 0.04 |
| 2,4,5-T (2,4,5-Trichlorophenoxyacetic acid) | 93-76-5 | 0.04 |
| **DIOXINS** | | |
| 2,3,7,8-Tetrachlorodinbenzo-dioxin (TCDD) | 1746-01-6 | 0.36 |
| Tetrachlorodibenzo-dioxins (TCDDs) | | 0.26 |
| Pentachlorodibenzo-dioxins (PeCCDs) | | 0.49 |
| Hexachlorodibenzo-dioxins (HeCDDs) | | 0.55 |
| **FURANS** | | |
| Tetrachlorodibenzo-furans (TCDFs) | | 0.42 |
| Pentachlorodibenzo-furans (PeCDFs) | | 0.16 |
| Hexachlorodibenzo-furans (HxCDFs) | | 0.14 |
| **MISCELLANEOUS PARAMETERS** | | |
| Cyanide | 57-12-5 | 10 |
| Sulfide | 18496-25-8 | 100 |

[a]There are no Contract Required Detection Limit (CRDLs) for Appendix IX constituents for soils/sediments.
*IT analyzes for Endrin Ketone rather than Endrin Aldehyde.

**Table 2.9 RCRA Appendix IX constituents—metals**

| Metals | CAS number | CRDLs water (μg/L) | CRDLs soil (μg/kg)[b] |
|---|---|---|---|
| Aluminum | 7429-90-5 | 200 | 40,000 |
| Antimony | 7440-36-0 | 60 | 12,000 |
| Arsenic | 7440-38-2 | 10 | 2,000 |
| Barium | 7440-39-3 | 200 | 40,000 |
| Beryllium | 7440-41-7 | 5 | 1,000 |
| Cadmium | 7440-43-9 | 5 | 1,000 |
| Calcium | 7440-70-2 | 5000 | 1,000,000 |
| Chromium | 7440-47-3 | 10 | 2,000 |
| Cobalt | 7440-48-4 | 50 | 10,000 |
| Copper | 7440-50-8 | 25 | 5,000 |
| Iron | 7439-89-6 | 100 | 20,000 |
| Lead | 7439-92-1 | 5 | 1,000 |
| Magnesium | 7439-95-4 | 5000 | 1,000,000 |
| Manganese | 7439-96-5 | 15 | 3,000 |
| Mercury | 7439-97-6 | 0.2 | 40,000 |
| Nickel | 7440-02-0 | 40 | 8,000 |
| Osmium | 7440-40-2 | 500 | 100,000 |
| Potassium | 7440-09-7 | 5000 | 1,000,000 |
| Selenium | 7782-49-2 | 5 | 1,000 |
| Silver | 7740-22-4 | 10 | 2,000 |
| Sodium | 7440-23-5 | 5000 | 1,000,000 |
| Thallium | 7440-28-0 | 10 | 2,000 |
| Tin | 7440-31-5 | 50 | 10,000 |
| Vanadium | 7440-62-2 | 50 | 10,000 |
| Zinc | 7440-66-6 | 20 | 4,000 |

**Table 2.10. WAG 6 borehole geophysical logging program summary**

| | Well | | | | |
|---|---|---|---|---|---|
| Log type | 1234 | 1236 | 1238 | 1239 | CH-2* |
| Natural Gamma Ray | (a) | C | C | C | C |
| Caliper | (a) | C | C | C | C |
| Temperature | (a) | C | C | C | C |
| Differential Temperature | (a) | C | C | C | C |
| Spontaneous Potential (SP) | (a) | C | C | C | C |
| Borehole Televiewer (BHTV) | (b) | O | O | O | O |
| Variable Density Acoustic Log (VDL) | (c) | | | | |
| Short Guard Resistivity | O | C | C | C | C |
| Short/Long Normal Resistivity | (a) | C | C | C | C |
| Fluid Resistivity | C | C | C | C | C |
| Lateral Log Resistivity | C | C | C | C | C |
| Single Point Resistance (SPR) | (a) | C | C | C | C |
| Deviation Survey | (b) | B | B | B | B |
| Gamma-gamma Density | (c) | | | | |
| BHC Density | C | C | C | C | C |
| Epithermal Neutron | (c) | | | | |
| BHC Neutron | C | C | C | C | |
| Sonic | (c) | | | | |
| BHC Sonic | C | C | C | C | |

NOTES:

O - Logging performed by ORNL.
C - Logging performed by Century Geophysics.
B - Logging performed by both ORNL and Century.
(a) - ORNL logged the original corehole; Century logged the reamed/deepened borehole.
(b) - ORNL originally logged corehole and subsequently logged the entire reamed/deepened hole.
(c) - Original Well 1234 corehole logging by ORNL.
(*) - Quality Control well located in the ORNL Main Plant area.

Table 2.11. WAG 6 grou .er sampling program summary

| | Sampling Event | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Well No. | 1st Quarter RCRA Monitoring 5/5-7/2/88 | 2nd Quarter RCRA Monitoring 10/4-11/4/88 | 3rd Quarter RCRA Monitoring 1/12-2/13/89 | 4th Quarter RCRA Monitoring 4/11-5/11/89 | Storm Event 5/9-11/89 | Storm Event 6/8-9/89 | Dry Season 8/28-9/5/89 | Dry Season 9/26-28/89 | Semi-Annual RCRA Monitoring 5/9-30/90 | Semi-Annual RCRA Monitoring 6/11-20/90 |
| 1225 | --- | --- | --- | B | B | B | B | B | --- | --- |
| 1226 | --- | --- | --- | Dry | Dry | Dry | Dry | Dry | --- | --- |
| 1227 | --- | --- | --- | B | B | B | --- | B | --- | --- |
| 1228 | --- | --- | --- | B | B | B | B | B | B | B |
| 1229 | --- | --- | --- | B | B | B | B | B | B | B |
| 1230 | --- | --- | --- | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| 1231 | --- | --- | --- | B | B | --- | B | B | --- | --- |
| 1232 | --- | --- | --- | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| 1233 | --- | --- | --- | B | B | B | B | B | --- | --- |
| 1234 | --- | --- | --- | --- | --- | --- | --- | --- | B | B |
| 1234A* | --- | --- | --- | --- | --- | --- | --- | --- | O/B | |
| 1235 | --- | --- | --- | --- | --- | --- | --- | --- | Dry | Dry |
| 1236 | --- | --- | --- | --- | --- | --- | --- | --- | B | B |
| 1237 | --- | --- | --- | --- | --- | --- | --- | --- | B | B |
| 1238 | --- | --- | --- | --- | --- | --- | --- | --- | B | B |
| 1239 | --- | --- | --- | --- | --- | --- | --- | --- | B | B |
| 1240 | --- | --- | --- | --- | --- | --- | --- | --- | B | B |
| 1241 | --- | --- | --- | --- | --- | --- | --- | --- | B | B |
| 1242 | --- | --- | --- | --- | --- | --- | --- | --- | B | B |
| 1243 | --- | --- | --- | --- | --- | --- | --- | --- | B | B |
| 1244 | --- | --- | --- | --- | --- | --- | --- | --- | B | B |
| 1245 | --- | --- | --- | --- | --- | --- | --- | --- | B | B |
| 745 | O | O | O | O | --- | --- | --- | --- | O/B | B |
| 831 | O | O | O | O | --- | --- | --- | --- | O/B | B |
| 832 | O | O | O | O | --- | --- | --- | --- | O/B | B |
| 833 | O | O | O | O | --- | --- | --- | --- | O/B | B |
| 835 | O | O | O | O | --- | --- | --- | --- | O | --- |
| 836 | O | O | O | O | --- | --- | --- | --- | O | --- |
| 837 | Dry | Dry | O | O | --- | --- | --- | --- | O | --- |
| 838 | O | O | O | O | --- | --- | --- | --- | O/B | B |
| 839 | O | O | O | O | --- | --- | --- | --- | O/B | B |
| 840 | O | O | O | O | --- | --- | --- | --- | O/B | B |
| 841 | O | O | O | O | --- | --- | --- | --- | O/B | B |
| 842 | O | O | O | O | --- | --- | --- | --- | O/B | B |
| 843 | O | O | O | O | --- | --- | --- | --- | O/B | B |
| 844 | O | O | O | O | --- | --- | --- | --- | O/B | B |

Table 2.11. (continued)

| Well No. | Sampling Event 1<br>1st Quarter RCRA Monitoring 5/5-7/2/88 | 2<br>2nd Quarter RCRA Monitoring 10/4-11/4/88 | 3<br>3rd Quarter RCRA Monitoring 1/12-2/13/89 | 4<br>4th Quarter RCRA Monitoring 4/11-5/11/89 | 5<br>Storm Event 5/9-11/89 | 6<br>Storm Event 6/8-9/89 | 7<br>Dry Season 8/28-9/5/89 | 8<br>Dry Season 9/26-28/89 | 9<br>Semi-Annual RCRA Monitoring 5/9-30/90 | 10<br>Semi-Annual RCRA Monitoring 6/11-20/90 |
|---|---|---|---|---|---|---|---|---|---|---|
| 845 | O | O | O | B | --- | --- | B | --- | --- | --- |
| 846 | O | O | O | O | --- | --- | --- | --- | --- | --- |
| 847 | O | O | O | O | --- | --- | --- | --- | --- | --- |
| 848 | O | O | O | B | --- | --- | B | --- | --- | |
| 849 | O | O | O | B | B | --- | B | --- | --- | --- |
| 850 | O | O | O | B | --- | --- | B | --- | --- | --- |
| 851 | O | O | O | B | B | --- | B | --- | --- | --- |
| 852 | O | O | O | B | B | --- | B | --- | --- | --- |
| 853 | O | O | O | B | B | --- | B | --- | --- | --- |
| 854 | O | O | O | B | B | --- | B | --- | --- | --- |
| 855 | O | O | O | O | --- | --- | --- | --- | O/B | B |
| 856 | O | O | O | O | --- | --- | --- | --- | O/B | B |
| 857 | O | O | O | O | --- | --- | --- | --- | O/B | B |
| 858 | O | O | O | O | --- | --- | --- | --- | O/B | B |
| 859 | Dry | Dry | O | O | --- | --- | --- | --- | O/B | B |
| 860 | O | O | O | O | --- | --- | --- | --- | O/B | B |
| ETF-13 | --- | --- | --- | --- | --- | --- | --- | --- | B | B |
| ETF-14 | --- | --- | --- | --- | --- | --- | --- | --- | B | B |
| ETF-15 | --- | --- | --- | --- | --- | --- | --- | --- | B | B |

Notes:

O Sampled by ORNL crews as part of compliance monitoring.

B Sampled by RFI personnel.

--- Not sampled.

O/B Well sampled by ORNL crew as part of compliance monitoring; additional samples collected at time of sampling by RFI personnel for geochemical parameters.

* Well 1234A has subsequently been redesignated # 1249 by ORNL.

Table 2.12. WAG 6 grou .r analytical program summary

| | | Sample Event | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Well No. | Date Installed | 1st Quarter RCRA 6/5-7/2/88 | 2nd Quarter RCRA 10/4-11/4/88 | 3rd Quarter RCRA 1/12-2/13/89 | 4th Quarter RCRA 4/11-5/11/89 | Storm Event 5/9-11/89 | Storm Event 6/8-9/89 | Dry Season 8/28-9/5/89 | Dry Season 9/26-28/89 | Semi-Annual RCRA Monitoring 5/9-30/90 | Semi-Annual RCRA Monitoring 6/11-19/90 |
| 1225 | 3/24/89 | --- | --- | --- | A | A | A | A | B1 | --- | --- |
| 1226 | 3/27/89 | --- | --- | --- | Dry | Dry | Dry | Dry | Dry | --- | --- |
| 1227 | 3/28/89 | --- | --- | --- | A | A | A | --- | B | --- | --- |
| 1228 | 3/28/89 | --- | --- | --- | A | A | A | A | B | C | F |
| 1229 | 3/29/89 | --- | --- | --- | A | A | A | A | B | C | F |
| 1230 | 3/17/89 | --- | --- | --- | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| 1231 | 3/22/89 | --- | --- | --- | A | A | --- | A1 | B | --- | --- |
| 1232 | 3/16/89 | --- | --- | --- | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| 1233 | 3/15/89 | --- | --- | --- | A | A | A | A | B | --- | --- |
| 1234 | 5/14/90 | --- | --- | --- | --- | --- | --- | --- | --- | D | F |
| 1234A* | 5/1/90 | --- | --- | --- | --- | --- | --- | --- | --- | C,F | --- |
| 1235 | 1/12/90 | --- | --- | --- | --- | --- | --- | --- | --- | Dry | Dry |
| 1236 | 5/3/90 | --- | --- | --- | --- | --- | --- | --- | --- | C1 | F1 |
| 1237 | 4/5/90 | --- | --- | --- | --- | --- | --- | --- | --- | C | F |
| 1238 | 4/30/90 | --- | --- | --- | --- | --- | --- | --- | --- | C | F |
| 1239 | 5/7/90 | --- | --- | --- | --- | --- | --- | --- | --- | C | F |
| 1240 | 3/19/90 | --- | --- | --- | --- | --- | --- | --- | --- | C | F |
| 1241 | 4/12/90 | --- | --- | --- | --- | --- | --- | --- | --- | C | F |
| 1242 | 4/18/90 | --- | --- | --- | --- | --- | --- | --- | --- | C | F |
| 1243 | 4/18/90 | --- | --- | --- | --- | --- | --- | --- | --- | C | F |
| 1244 | 4/9/90 | --- | --- | --- | --- | --- | --- | --- | --- | C1 | F1 |
| 1245 | 4/13/90 | --- | --- | --- | --- | --- | --- | --- | --- | D | F |
| 745 | 8/5/87 | G | G | G | G | --- | --- | --- | --- | H,F | F |
| 831 | 2/26/87 | G | G | G | G | --- | --- | --- | --- | H,F | F |
| 832 | 6/16/87 | G | G | G | G | --- | --- | --- | --- | H,F | F |
| 833 | 8/5/87 | G | G | G | G | --- | --- | --- | --- | H,F | F |
| 835 | 9/30/87 | G | G | G | G | --- | --- | --- | --- | H | --- |
| 836 | 9/15/87 | G | G | G | G | --- | --- | --- | --- | H | --- |
| 837 | 7/29/87 | Dry | Dry | G | G | --- | --- | --- | --- | H | --- |
| 838 | 7/29/87 | G | G | G | G | --- | --- | --- | --- | H,F | F |
| 839 | 7/31/87 | G | G | G | G | --- | --- | --- | --- | H,F | F |
| 840 | 10/20/87 | G | G | G | G | --- | --- | --- | --- | H,F | F |
| 841 | 7/17/87 | G | G | G | G | --- | --- | --- | --- | H,F,E2 | F |
| 842 | 7/17/87 | G | G | G | G | --- | --- | --- | --- | H,F,E2 | F |
| 843 | 7/28/87 | G | G | G | G | --- | --- | --- | --- | H,F | F |

Table 2.12 (continued)

| | | Sample Event | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Well No. | Date Installed | 1st Quarter RCRA 6/5-7/2/88 | 2nd Quarter RCRA 10/4-11/4/88 | 3rd Quarter RCRA 1/12-2/13/89 | 4th Quarter RCRA 4/11-5/11/89 | Storm Event 5/9-11/89 | Storm Event 6/8-9/89 | Dry Season 8/28-9/5/89 | Dry Season 9/26-28/89 | Semi-Annual RCRA Monitoring 5/9-30/90 | Semi-Annual RCRA Monitoring 6/11-19/90 |
| 844 | 7/2/87 | G | G | G | G | --- | --- | --- | --- | H,F | F |
| 845 | 10/30/87 | G | G | G | A | --- | --- | A | --- | --- | --- |
| 846 | 10/14/87 | G | G | G | G | --- | --- | --- | --- | --- | --- |
| 847 | 12/11/87 | G | G | G | A | --- | --- | --- | --- | --- | --- |
| 848 | 11/20/87 | G | G | G | A | --- | --- | A | --- | --- | --- |
| 849 | 11/5/87 | G | G | G | A | A | --- | A | --- | --- | --- |
| 850 | 11/20/87 | G | G | G | A | --- | --- | A | --- | --- | --- |
| 851 | 11/23/87 | G | G | G | A | A | --- | A | --- | --- | --- |
| 852 | 11/23/87 | G | G | G | A | A | --- | A | --- | --- | --- |
| 853 | 8/3/87 | G | G | G | A | A | --- | A | --- | --- | --- |
| 854 | 9/28/87 | G | G | G | A | A | --- | A | --- | --- | --- |
| 855 | 6/22/87 | G | G | G | G | --- | --- | --- | --- | H,F,E2 | F |
| 856 | 11/23/87 | G | G | G | G | --- | --- | --- | --- | H,F,E2 | F |
| 857 | 11/23/87 | G | G | G | G | --- | --- | --- | --- | H,F | F |
| 858 | 11/23/87 | G | G | G | G | --- | --- | --- | --- | H,F | F |
| 859 | 8/17/87 | Dry | Dry | G | G | --- | --- | --- | --- | H,F | F |
| 860 | 8/11/87 | G | G | G | G | --- | --- | --- | --- | H,F | F |
| ETF-13 | ?/86 | --- | --- | --- | --- | --- | --- | --- | --- | F | F |
| ETF-14 | ?/86 | --- | --- | --- | --- | --- | --- | --- | --- | F | F |
| ETF-15 | ?/86 | --- | --- | --- | --- | --- | --- | --- | --- | F | F |

Notes:
Sample analytical suites A-F are associated with WAG 6 RFI sampling. Samples analyzed by IT Corporation.

Sample analytical suites G and H are the parameters analyzed by ORNL in RCRA detector monitoring. Suite H reflects the reduced parameter as specified for semi-annual RCRA assessment monitoring in the GWQAP. Samples analyzed by the ORNL Analytical Chemistry Division (ACD) laboratory.

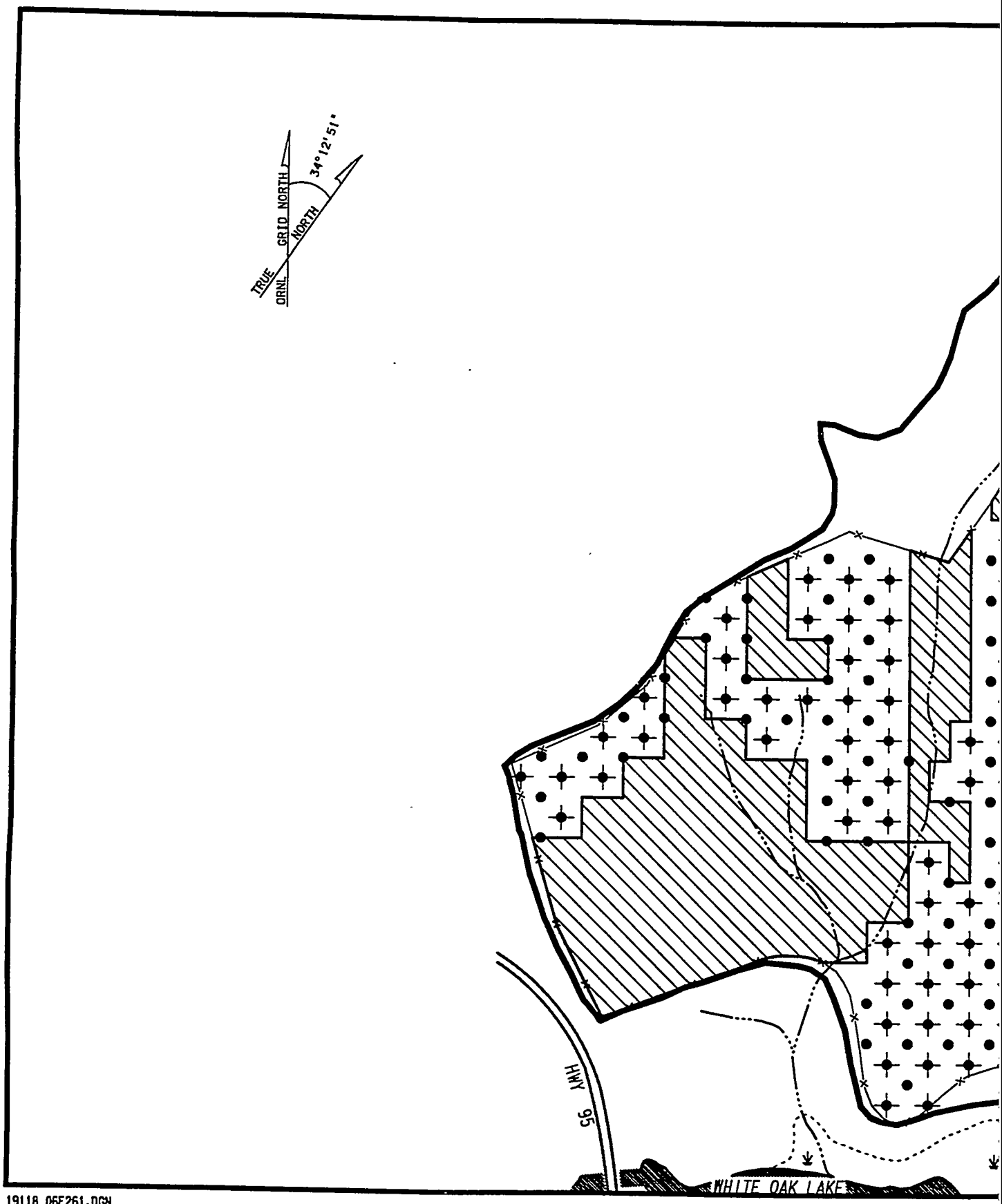
1Denotes duplicate samples collected at a rate of 10%.
2Denotes sample splits analyzed by both ORNL ACD laboratory and WAG 6 RFI contract laboratory (IT Corporation).
*Well 1234A has subsequently been redesignated # 1249 by ORNL.

**Table 2.13. Analytical suite summary**

| Parameter | A[a] | B[a] | C[a] | D[a] | E[a] | F[a] | G[b] | H[b] |
|---|---|---|---|---|---|---|---|---|
| TCL VOCs | X | X | X | - | X | - | X | X[c] |
| Appendix IX VOCs | - | - | - | X | - | - | - | - |
| TCL BNAEs | X | X | X | - | - | - | X | - |
| Appendix IX BNAEs | - | - | - | X | - | - | - | - |
| Phenols | | | | | | | X | |
| TCL Pesticides, PCBs | X | X | X | - | - | - | X | - |
| Appendix IX Pesticides, PCBs | - | - | - | X | - | - | - | - |
| Appendix IX (OP) Pesticides | - | - | - | X | - | - | - | - |
| TCL Chlor. Herbicides | | | | | | | X | |
| Appendix IX Chlor. Herbicides | - | - | - | X | - | - | - | - |
| Appendix IX Dioxins/Furans | - | - | - | X | - | - | - | - |
| TAL Metals | X | X | X | - | - | X | - | - |
| Appendix IX Metals | - | - | - | X | - | - | - | - |
| ICP Metals | - | - | - | - | X | - | X | X |
| TCL Cyanide | X | X | X | - | - | - | - | - |
| Appendix IX Cyanide | - | - | - | X | - | - | - | - |
| Sulfides | X | - | - | - | - | - | - | - |
| Anions | X | - | X | X | - | X | X | X |
| Carbonate/Bicarbonate | X | - | X | X | - | X | - | - |
| Alkalinity (as CaCO3) | - | - | X | X | - | X | - | X |
| COD | X | - | - | - | - | - | - | - |
| Biochemical Oxygen Demand (BOD) | X | - | - | - | - | - | - | - |
| (TKN) | X | - | - | - | - | - | - | - |
| Total Dissolved Solids (TDS) | X | - | - | - | - | - | - | - |
| TOX | X | - | - | - | - | - | X | - |
| TOC | X | - | - | - | - | - | X | - |
| Fecal Coliform | X | - | - | - | - | - | X | - |
| Turbidity | | | | | | | X | |
| Gross Alpha | X | X | X | X[d] | X | - | X | X |
| Gross Beta | X | X | X | X[d] | X | - | X | X |
| Gamma Isotopic | X | X | X | | X | - | X | X |
| Tritium | X | X | X | X | X | - | X | X |
| Ra-226/228 | X | X | X | | - | - | X | - |
| Sr-90 | X | X | X | | X | - | X | X |
| Am-241 | - | - | X | | - | - | - | - |
| Th Isotopic | X | X | X | X | - | - | - | - |
| Pu Isotopic | - | - | X | | - | - | - | - |
| U Isotopic | X | X | X | | - | - | - | - |
| Co-60 | - | - | - | - | - | - | - | X |

[a]Analyses performed by IT Corporation lab as part of the BNI WAG 6 RFI.
[b]Analyses performed by ORNL Analytical Chemical Division lab as part of RCRA compliance monitoring program for SW 6.
[c]Samples analyzed for VOCs using Method SW-8240 Only nine target compounds identified in the RCRA Groundwater Quality Assessment Plan for Solid Waste Storage Area 6 (ORNL 1989).
[d]Samples analyzed for gross alpha and gross beta at the field Close Support Lab (CSL).

# Section 2 Figures




19118 06F261.DGN

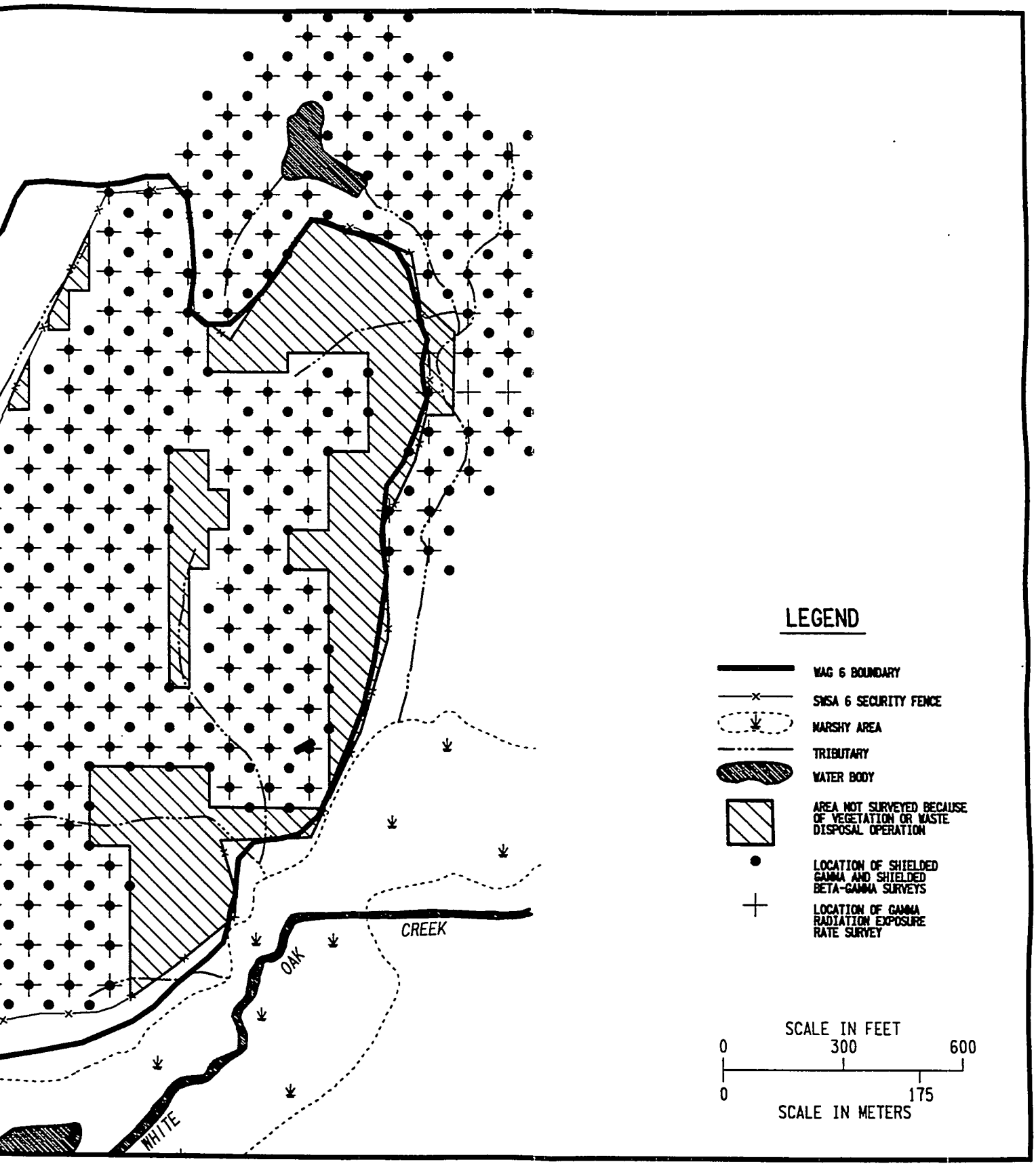
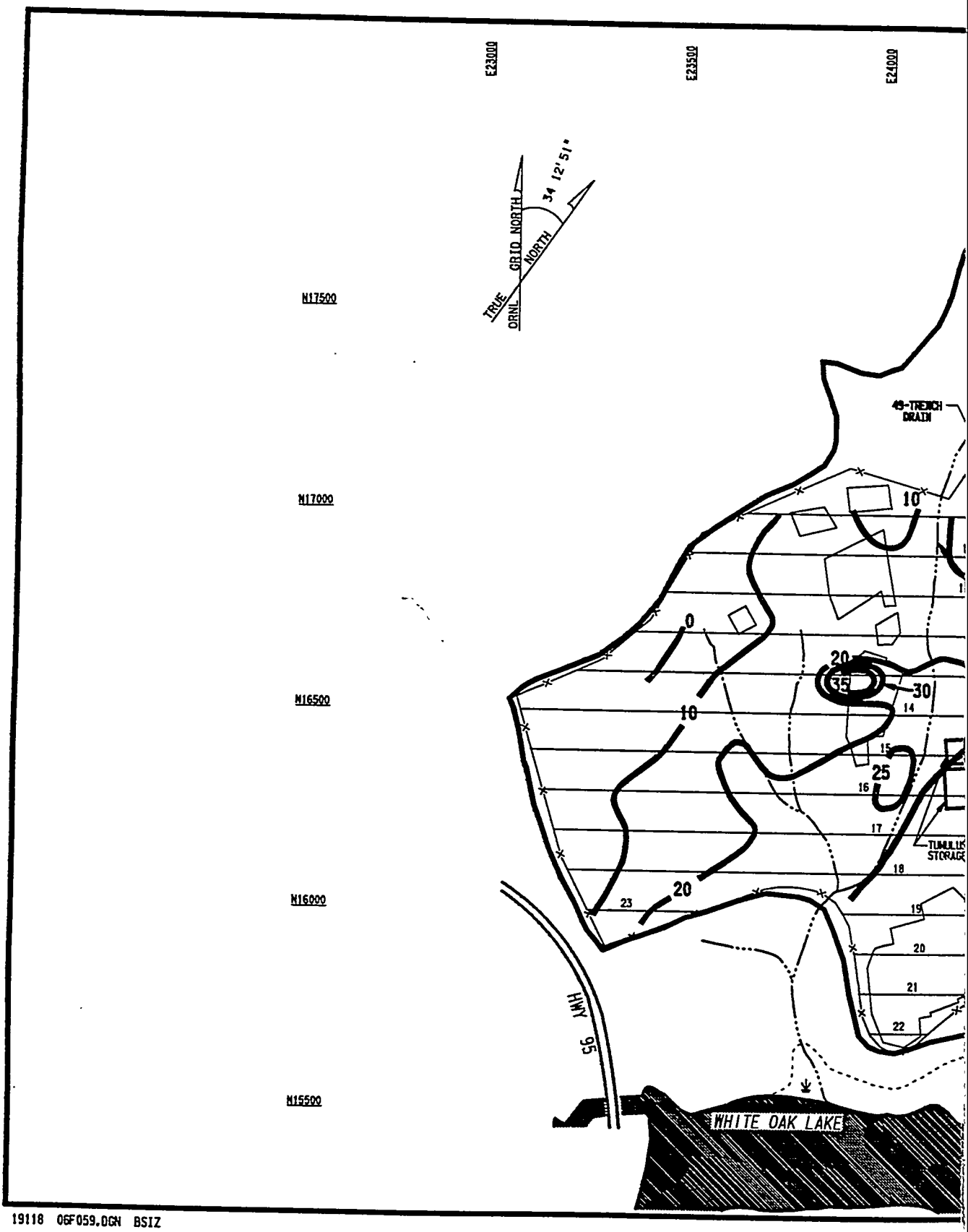



**Fig. 2.1. Radiation walkover survey.**




19118 06F059.DGN BSIZ

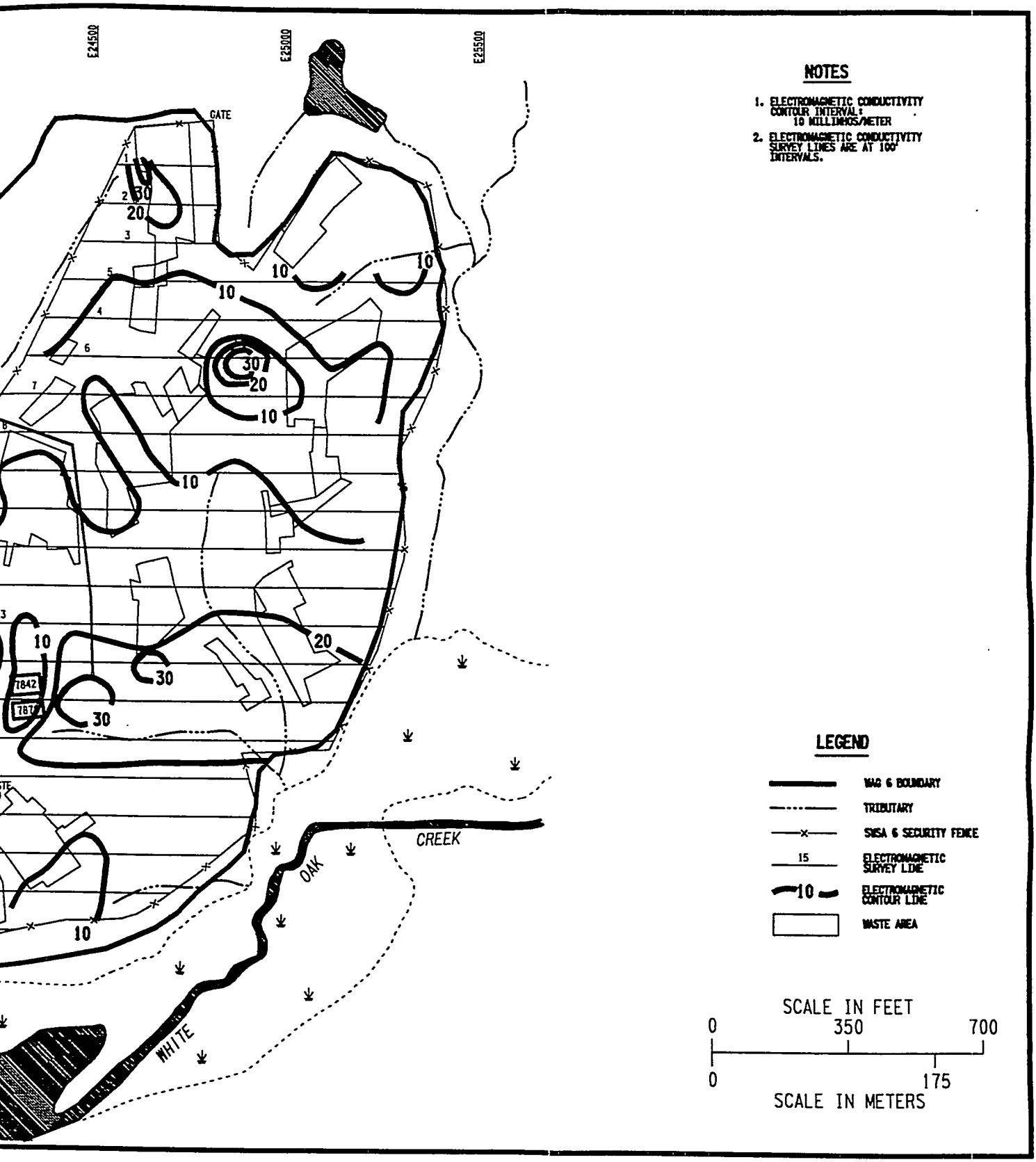
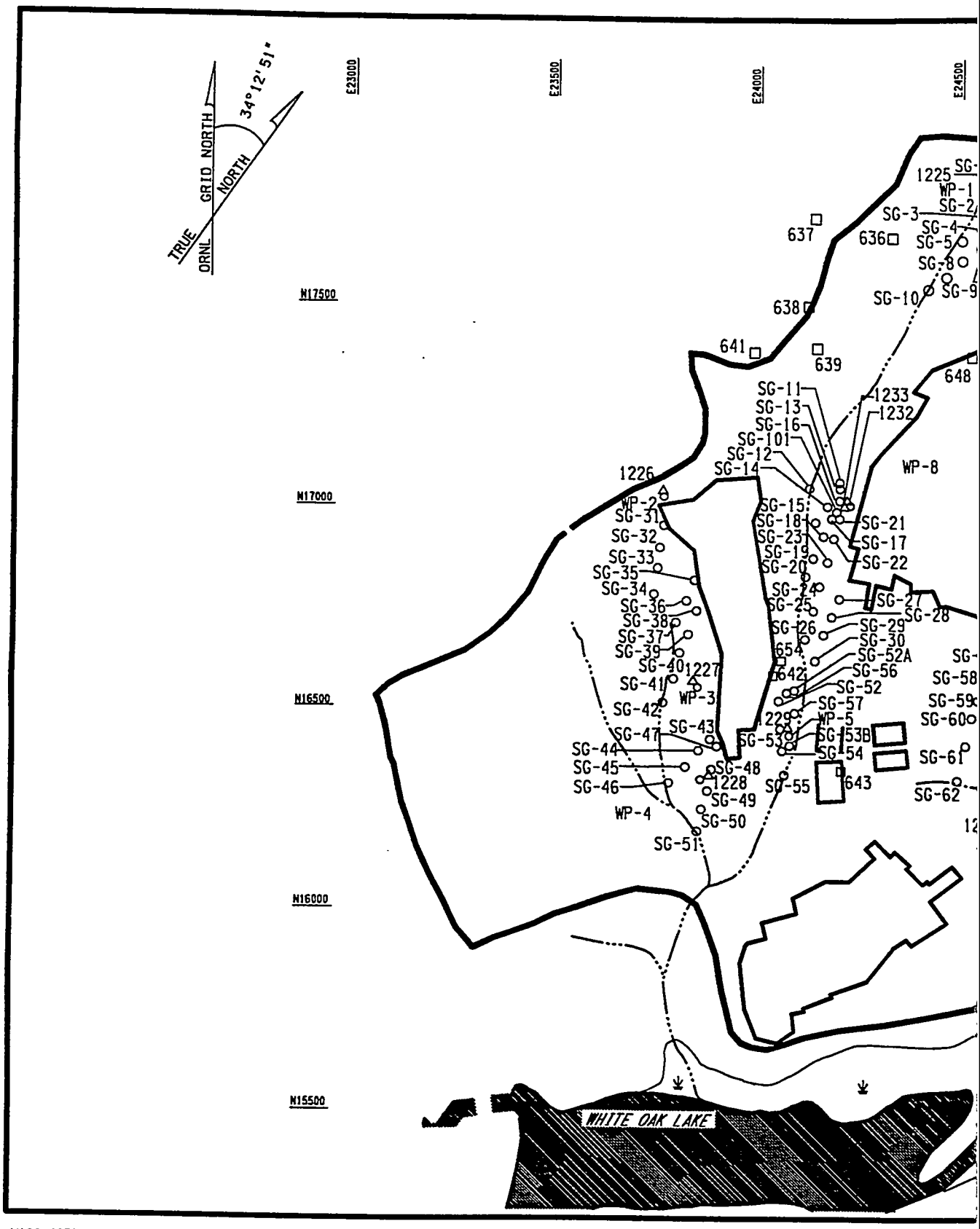



**Fig. 2.2. Electromagnetic conductivity survey contour map.**




WAG6 06F303.DGN

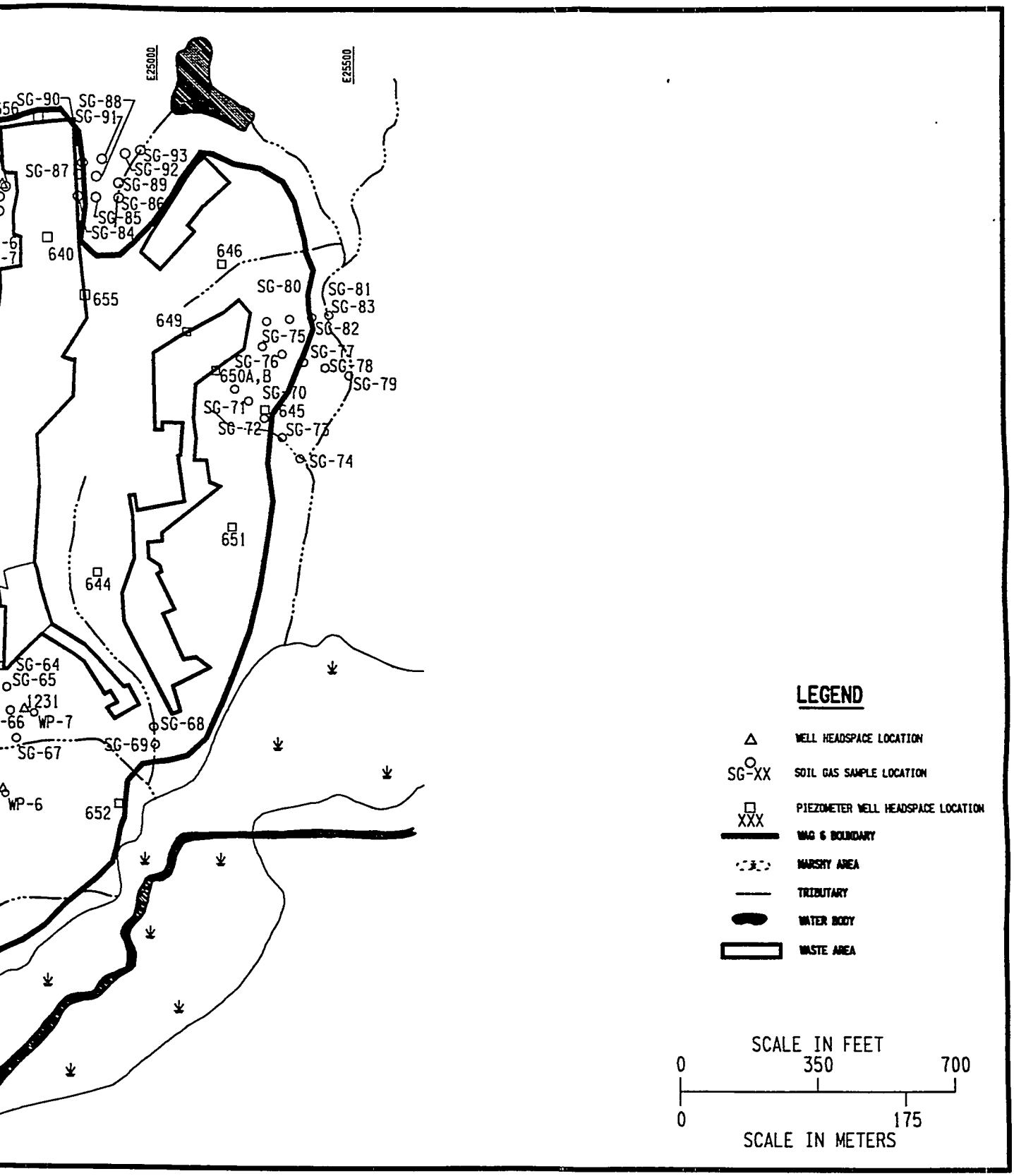
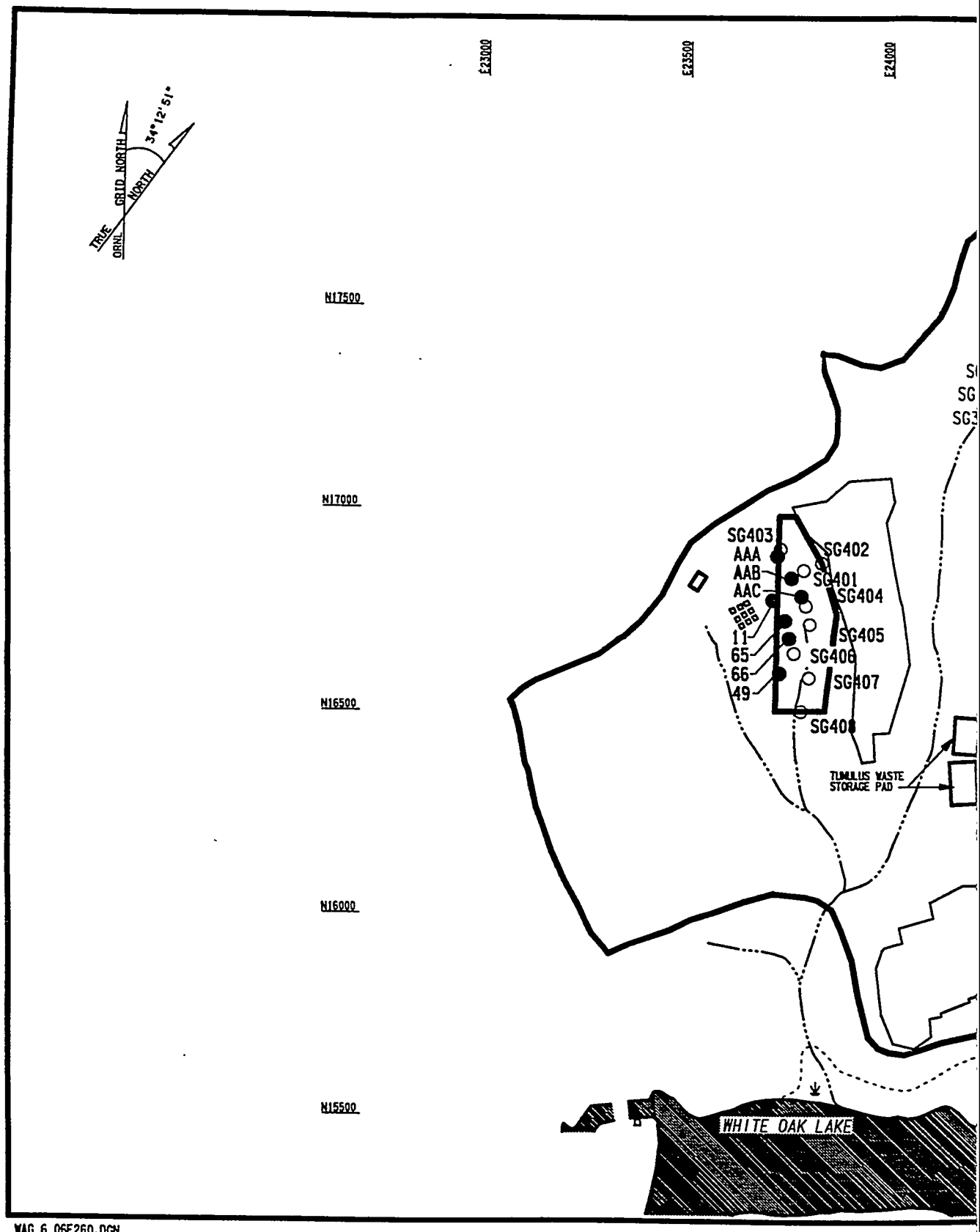



**Fig. 2.3. Soil gas survey locations, Activity 1.**




WAG 6 06F260.DGN

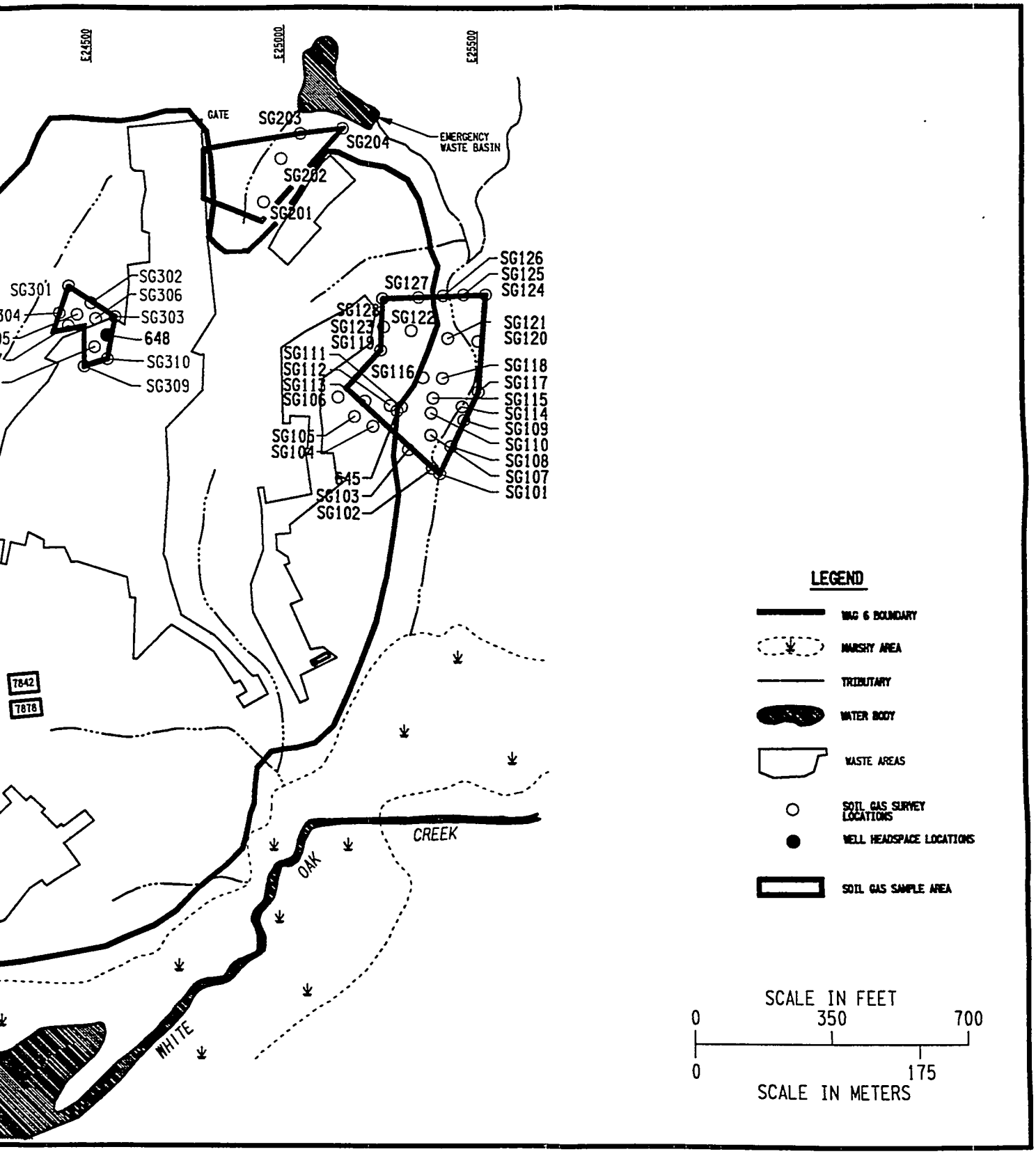
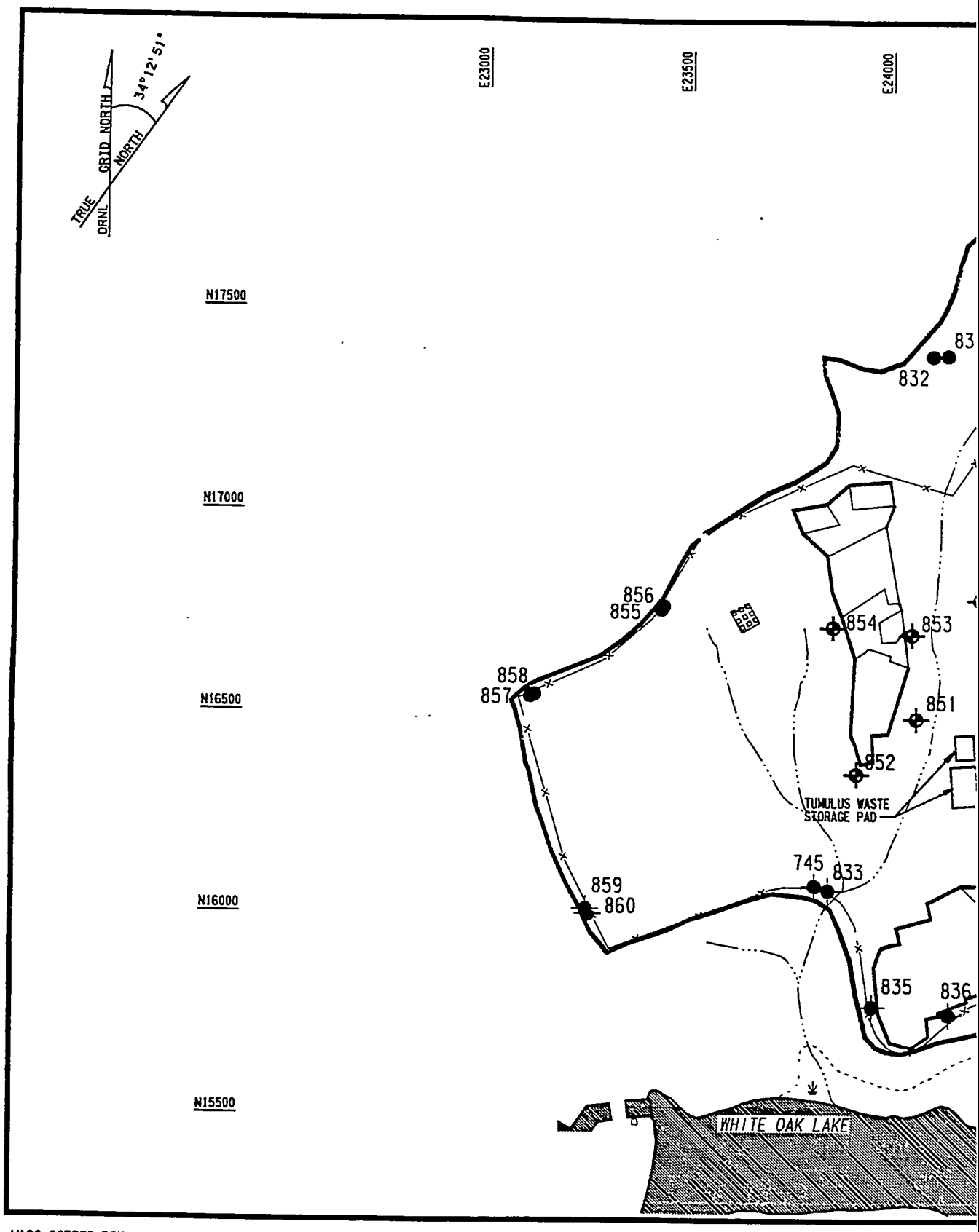



**Fig. 2.4. Soil gas survey locations, Activity 2.**

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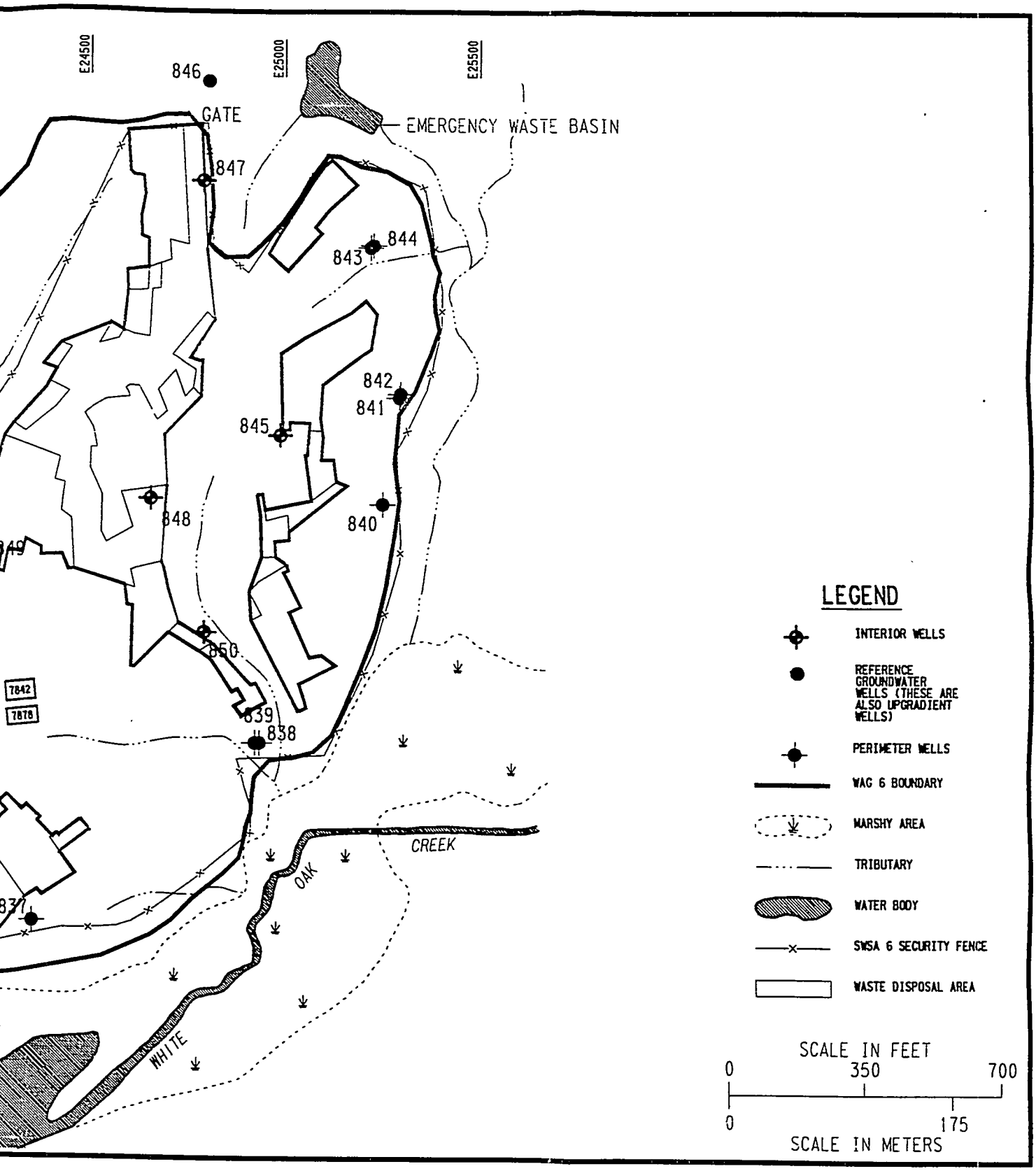
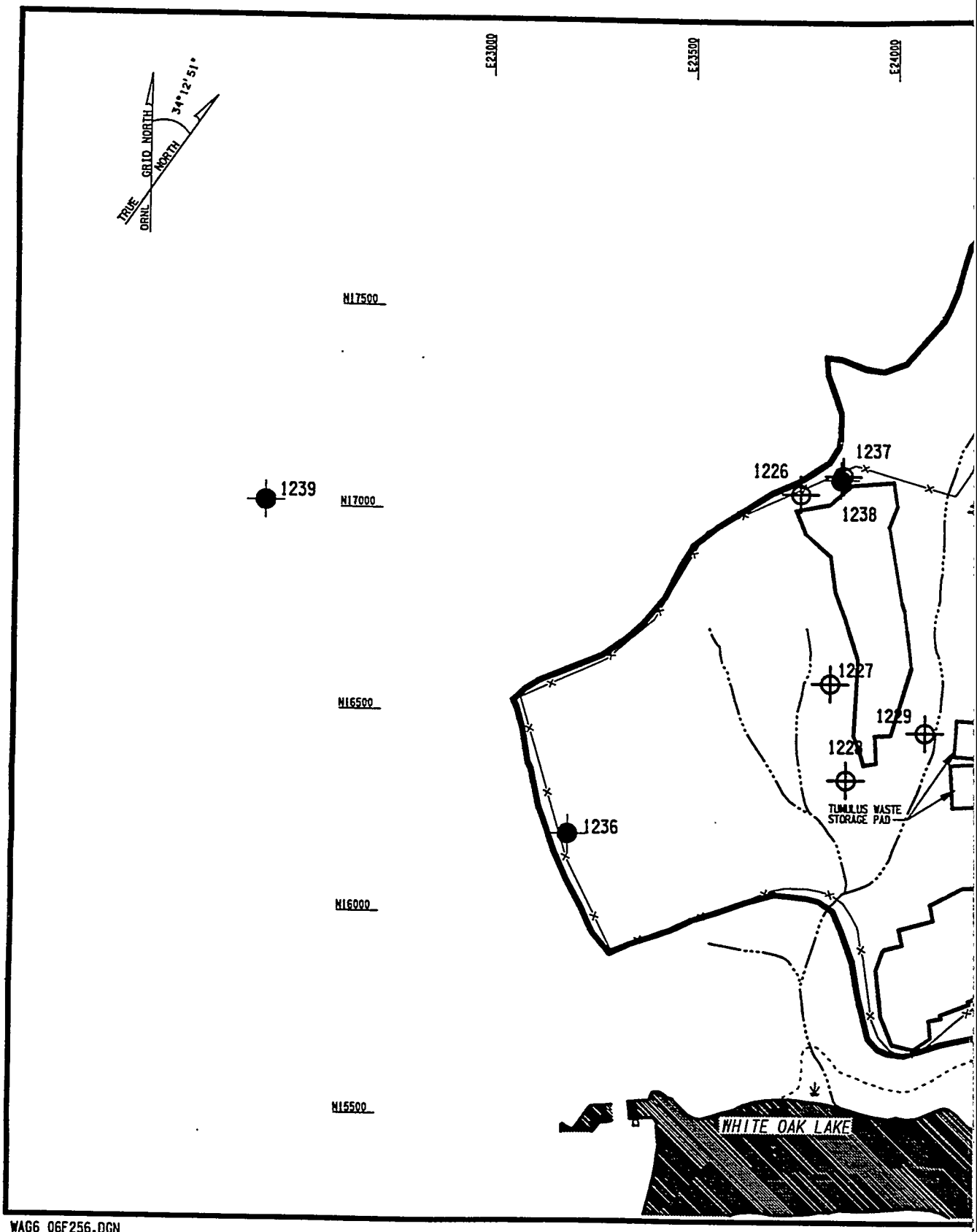



**Fig. 2.5. ORNL RCRA compliance well locations.**




WAG6 06F256.DGN

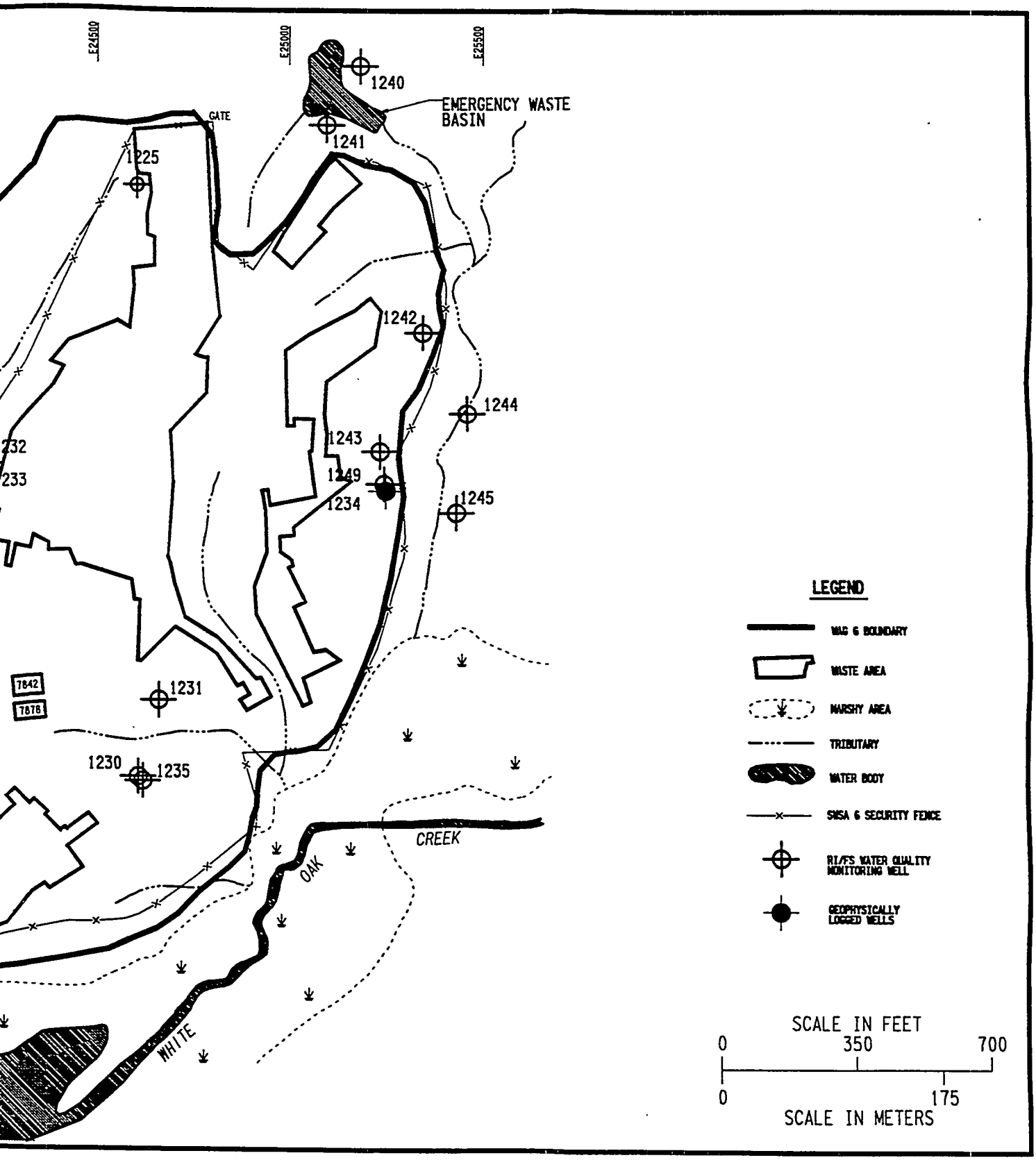
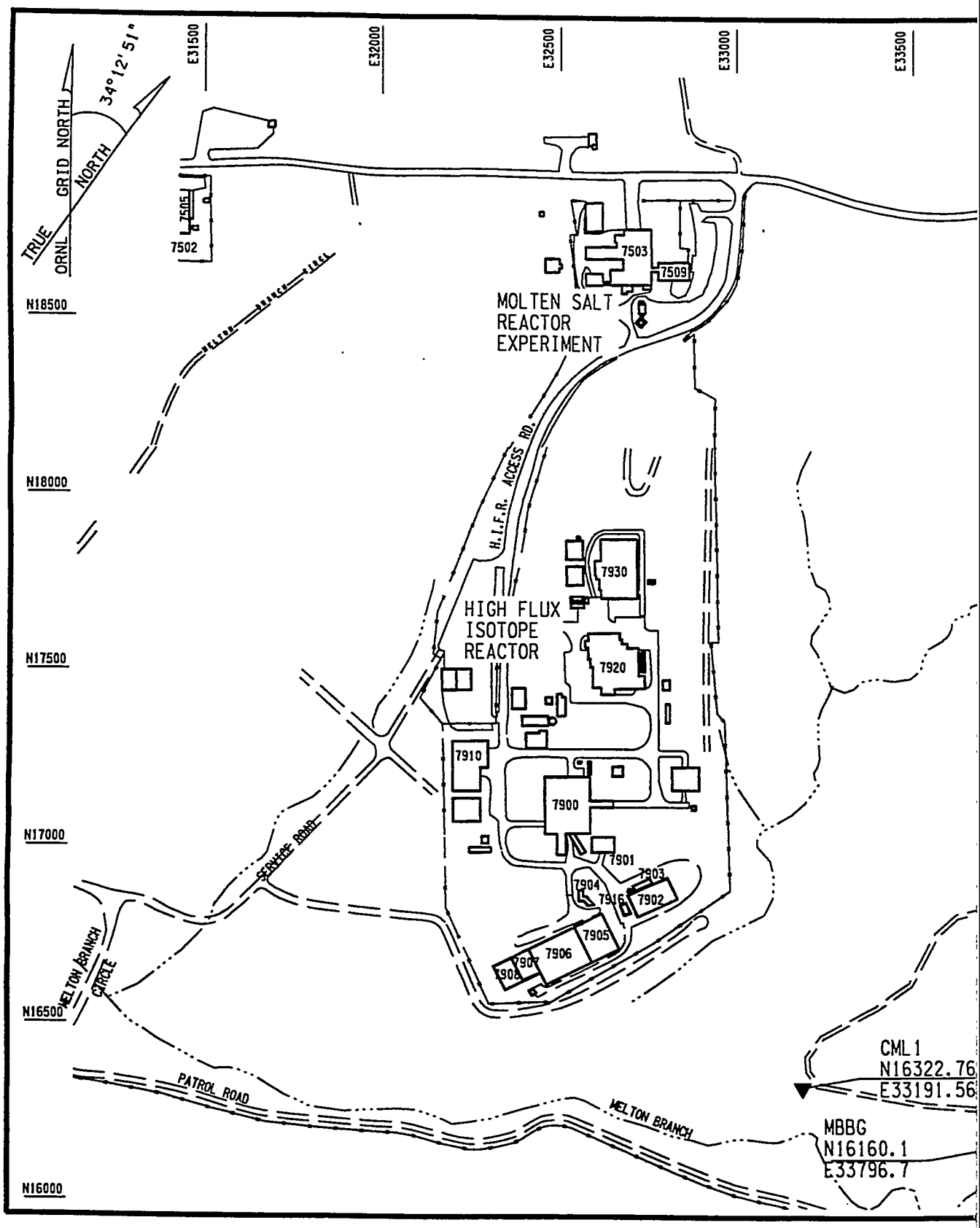



**Fig. 2.6. WAG 6 RFI groundwater well locations.**




WAG6 06F230.DGN

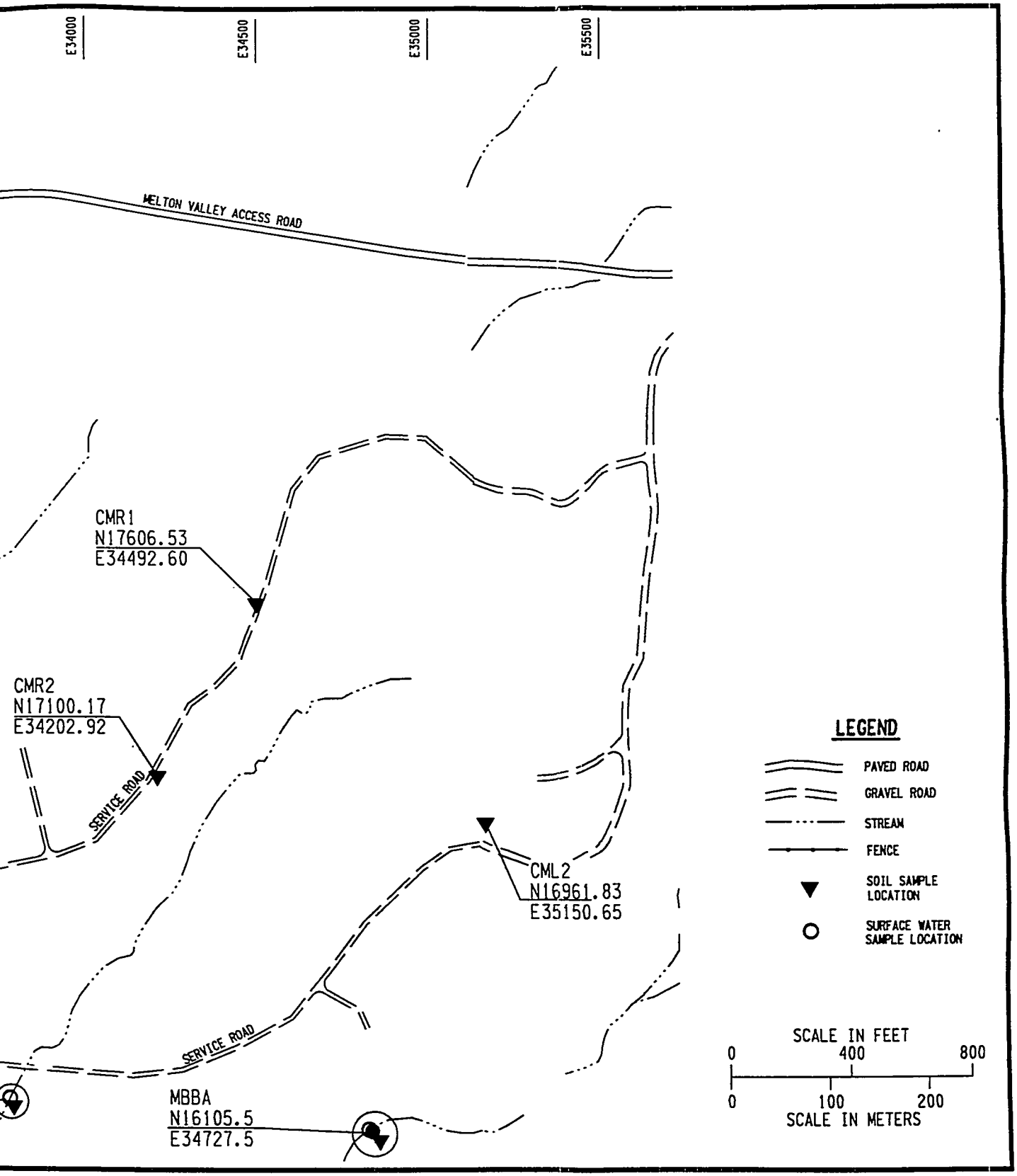
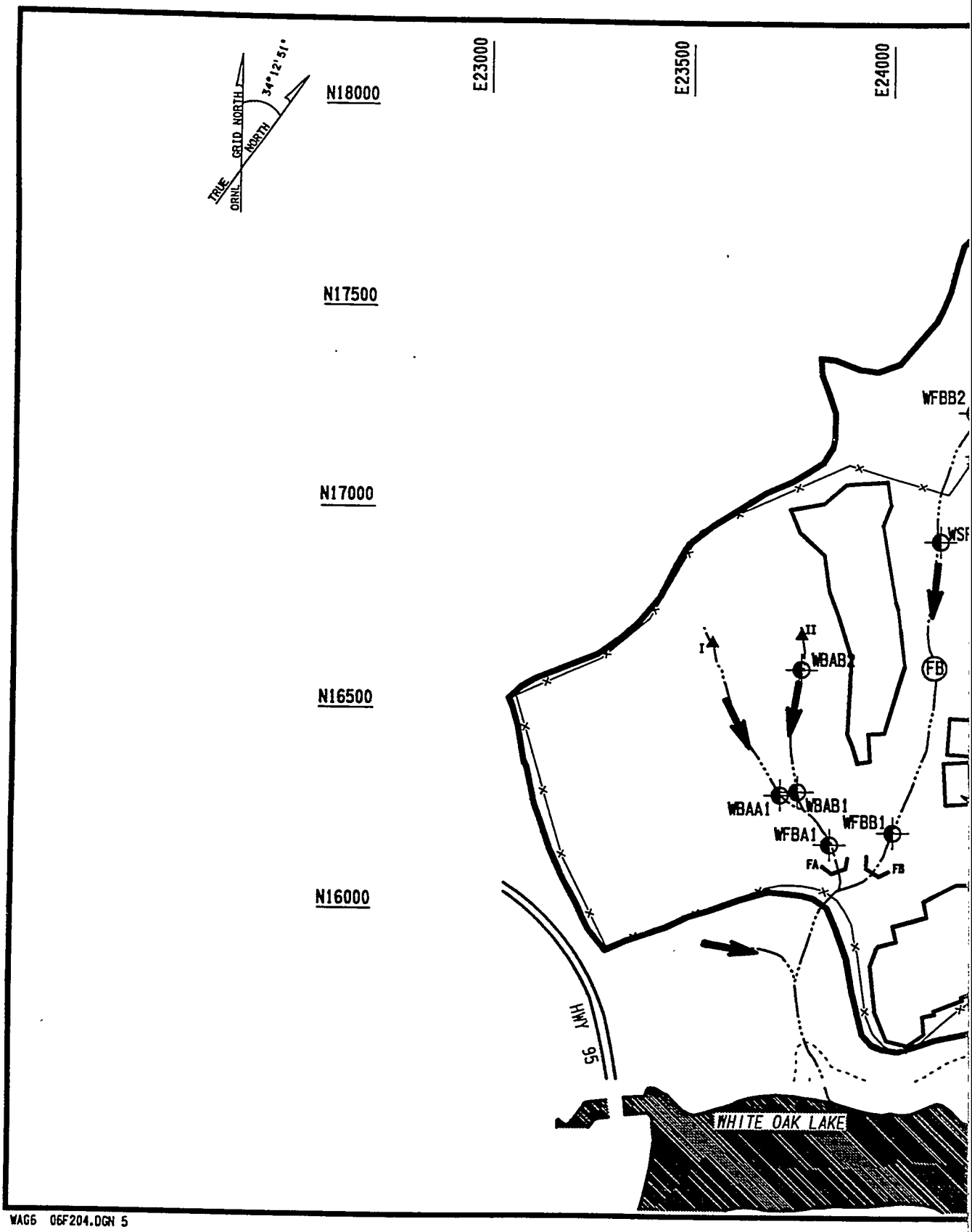



**Fig. 2.7. WAG 6 reference surface water and soil sampling locations (in proposed SWSA 7).**




WAG6 06F204.DGN 5

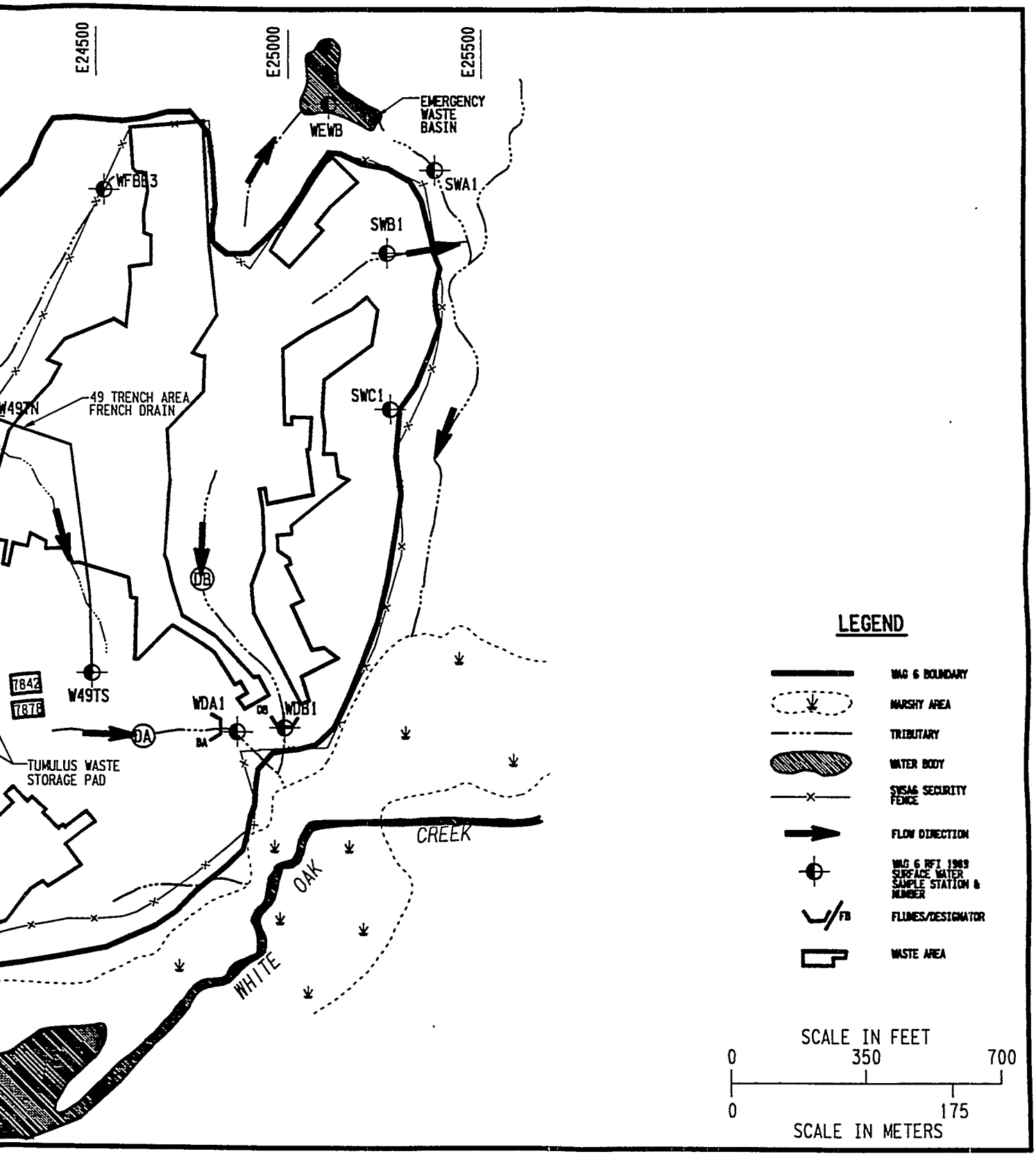
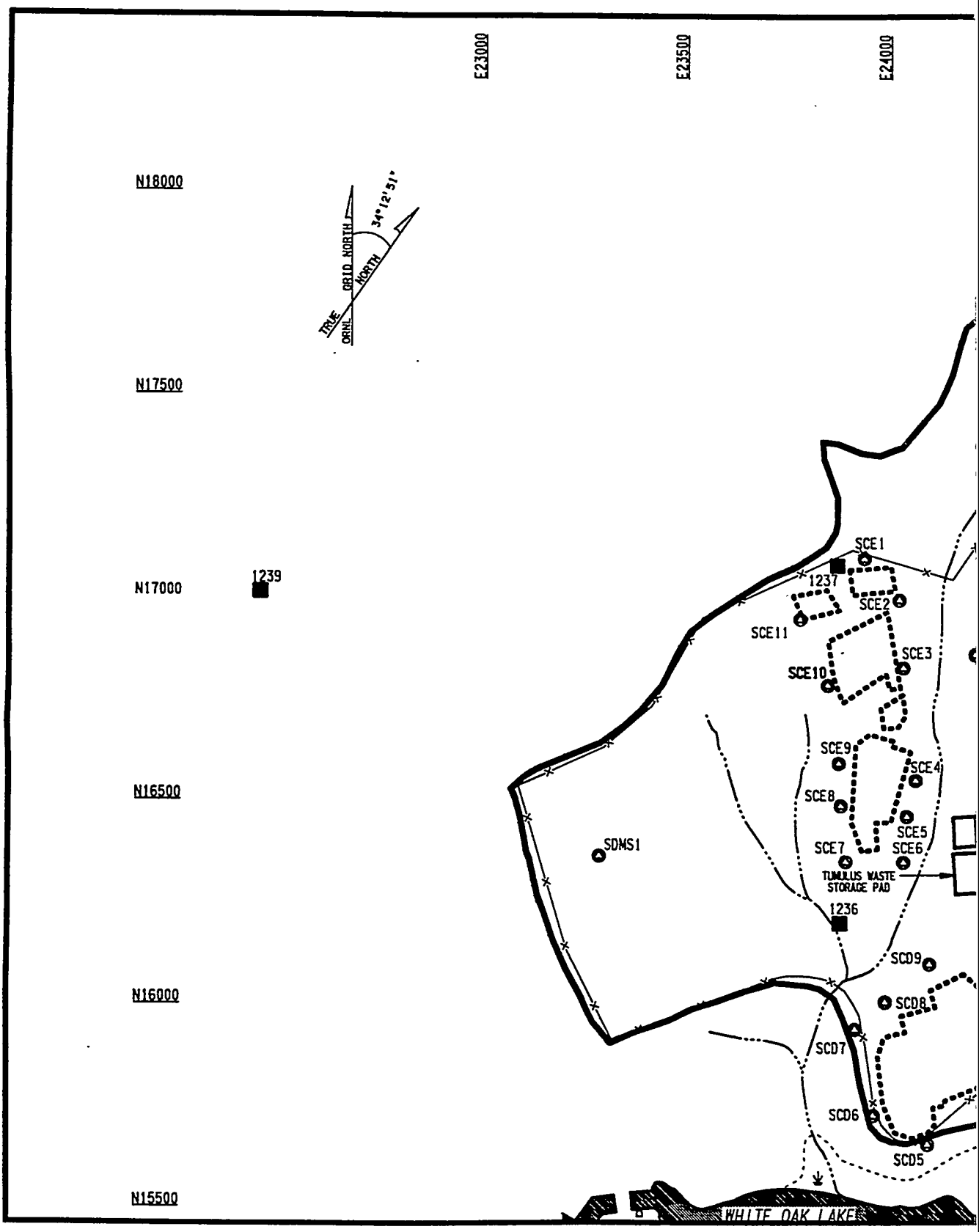



**Fig. 2.8. Surface water sampling locations.**




WAG6 06F250.DGN

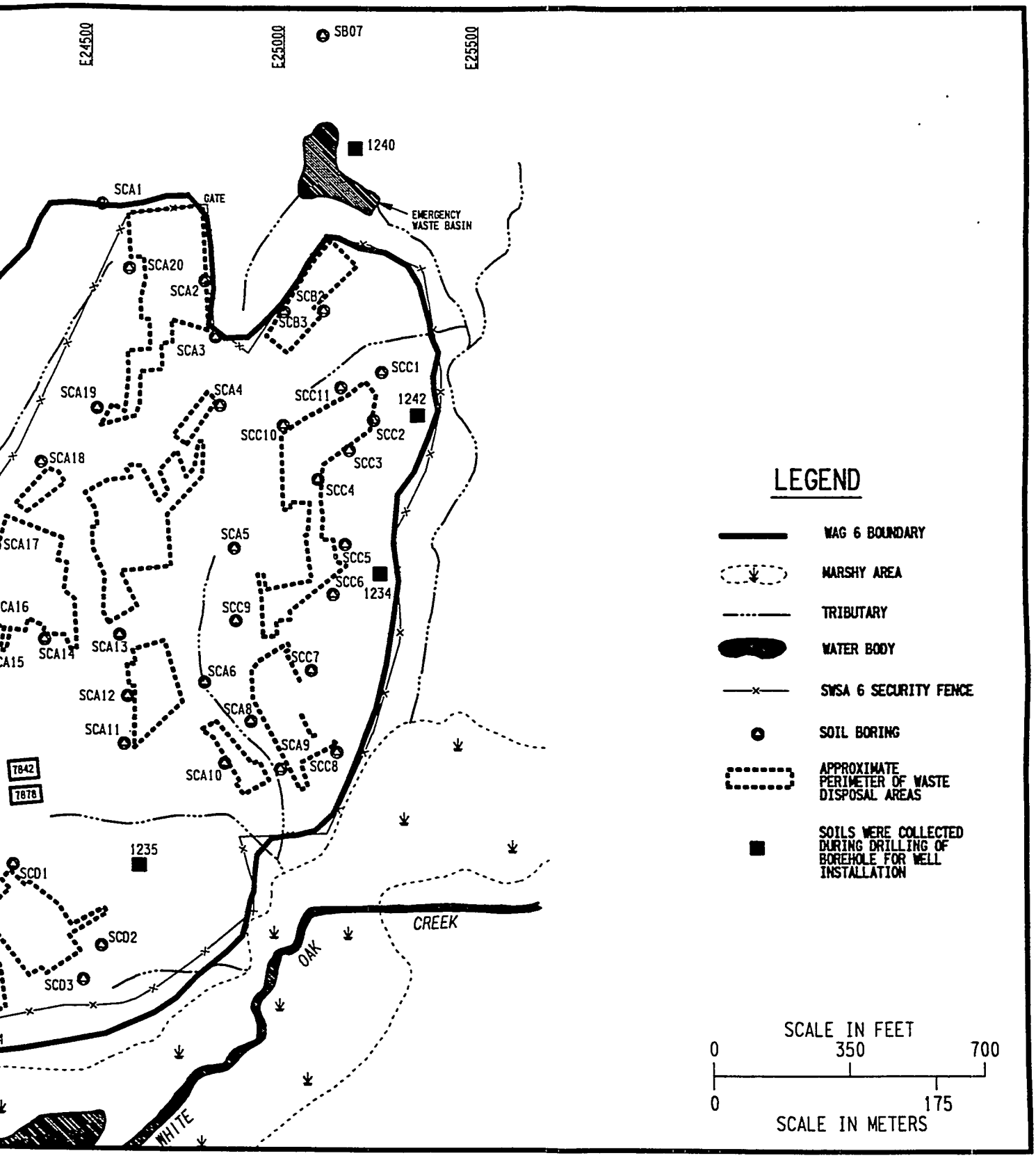



**Fig. 2.9. Soil sampling locations.**

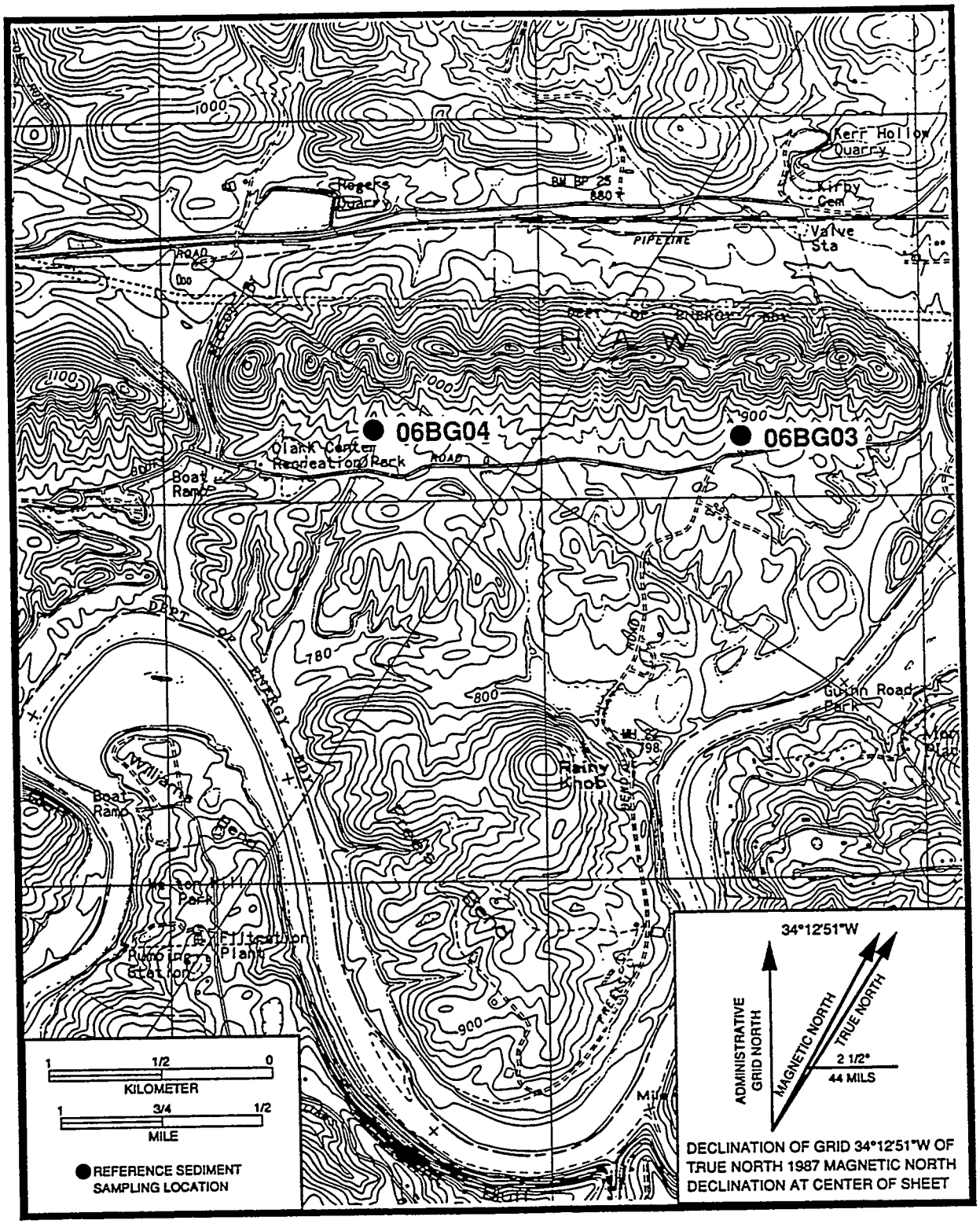
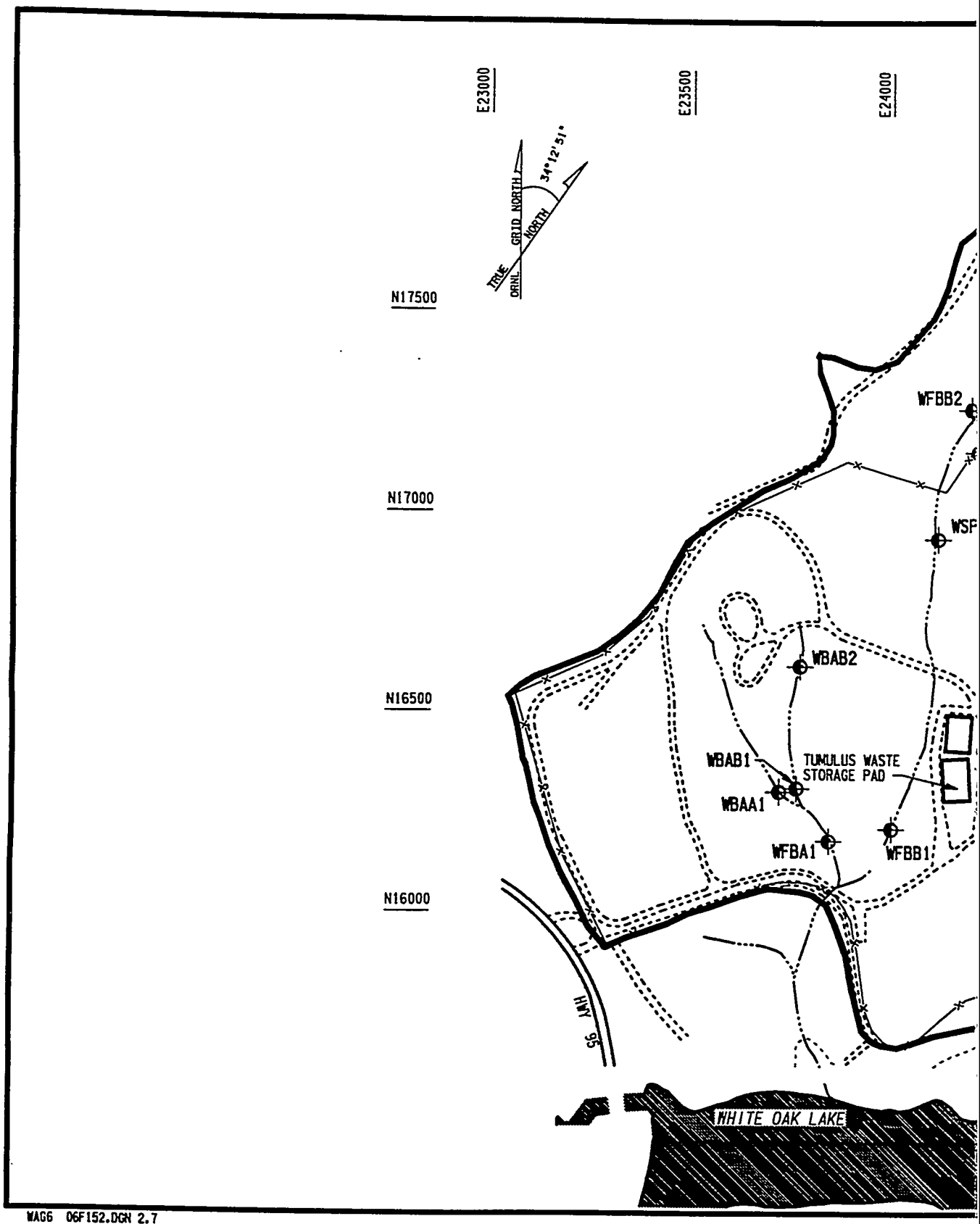



**Fig. 2.10. Reference sediment sampling locations in Melton Valley north of Park Road.**
*SOURCE:* Map prepared by Tennessee Valley Authority for U.S. DOE (1986).




WAG6 06F152.DGN 2.7

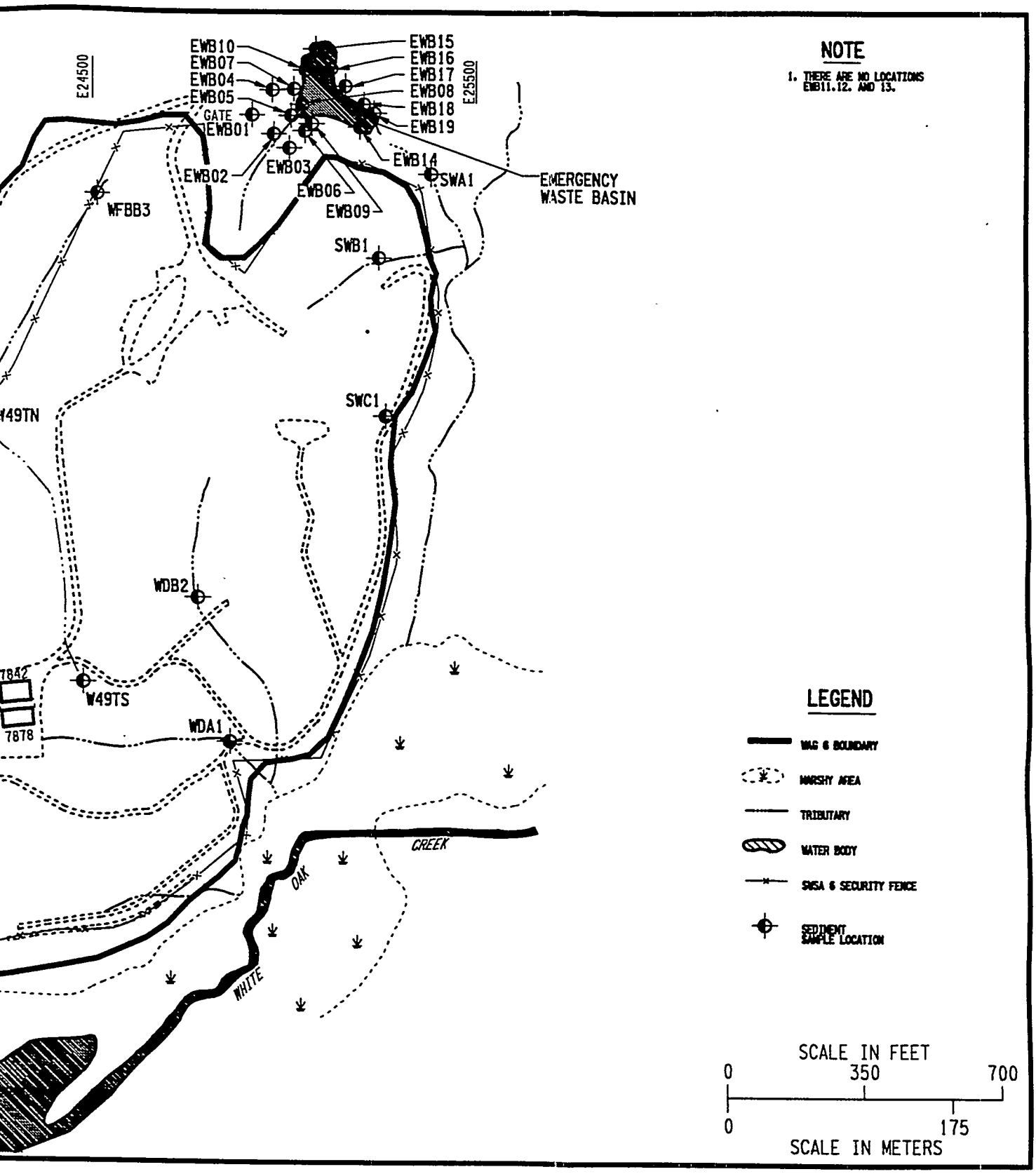
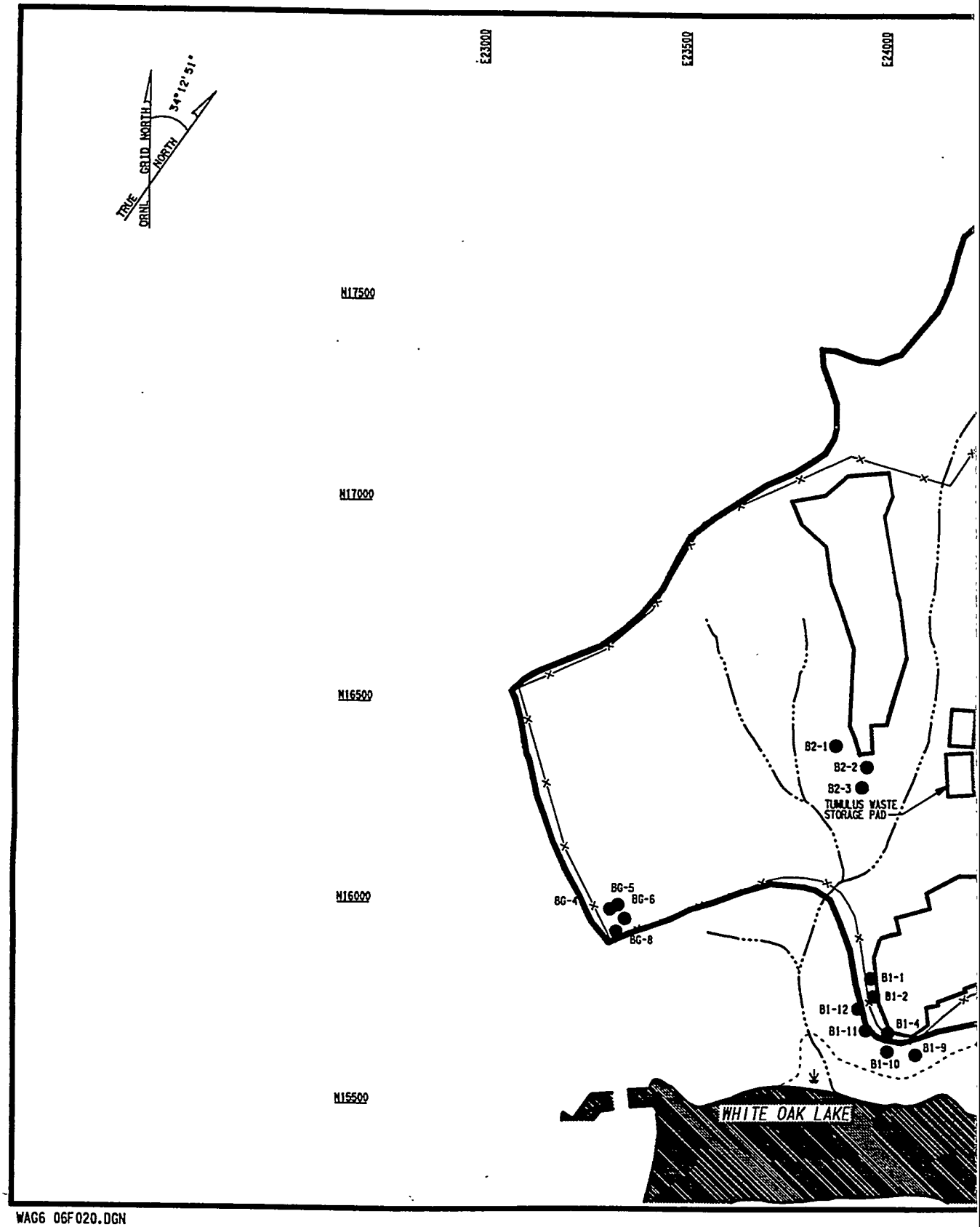



**Fig. 2.11. WAG 6 sediment sampling locations.**




WAG6 06F020.DGN

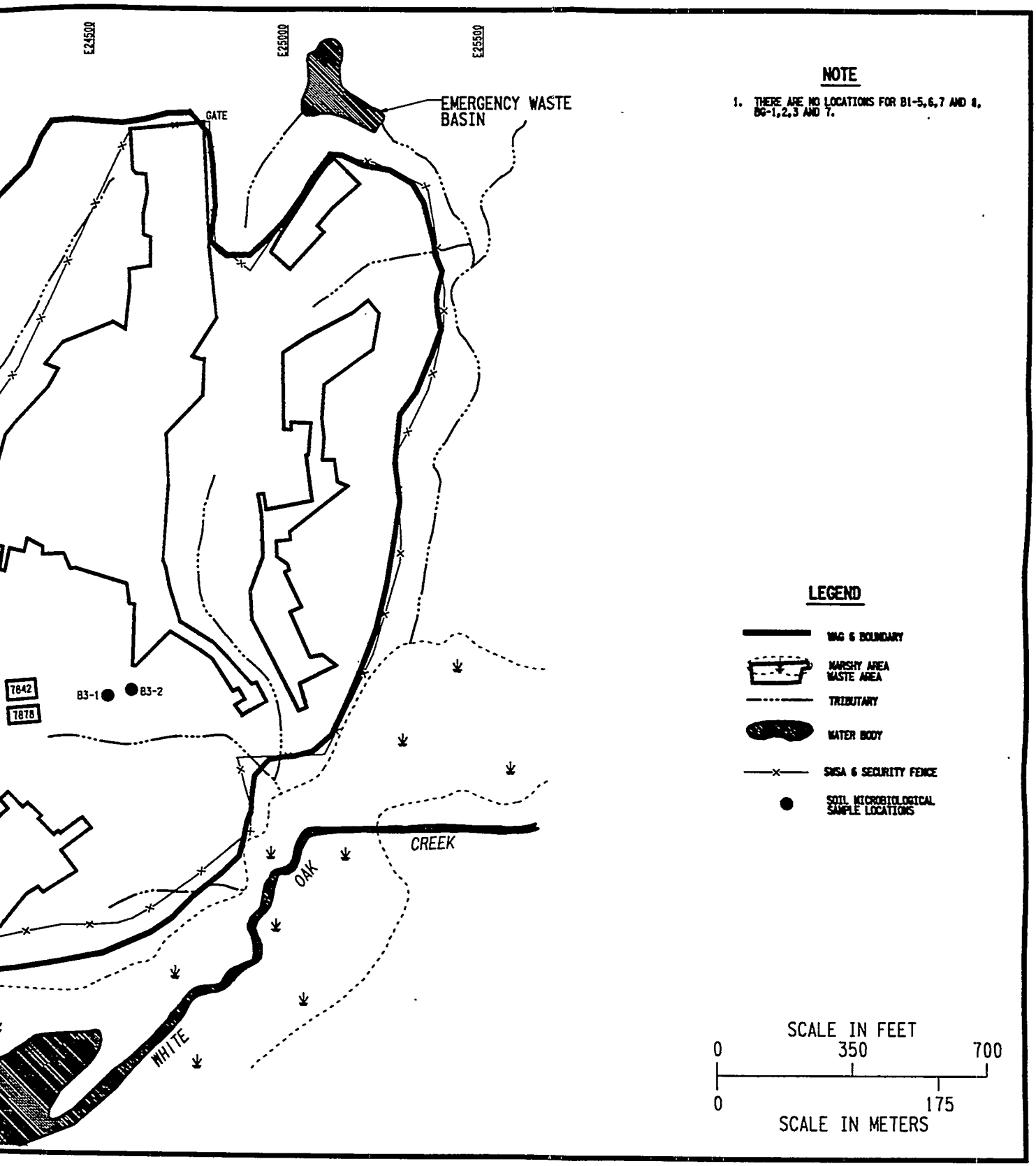
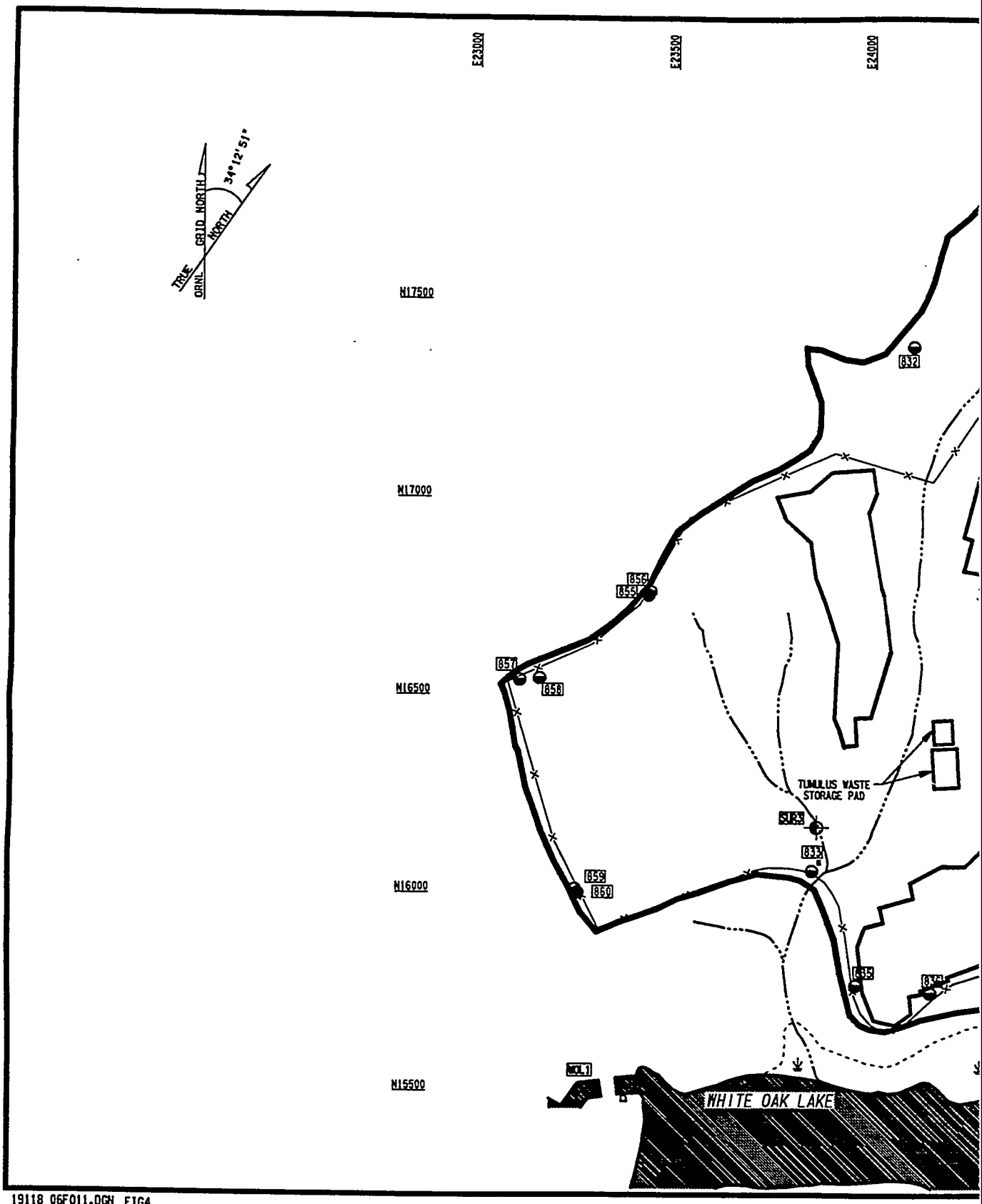



**Fig. 2.12. Soil microbiological sampling locations, Activity 1.**




19118 06F011.DGN FIG4

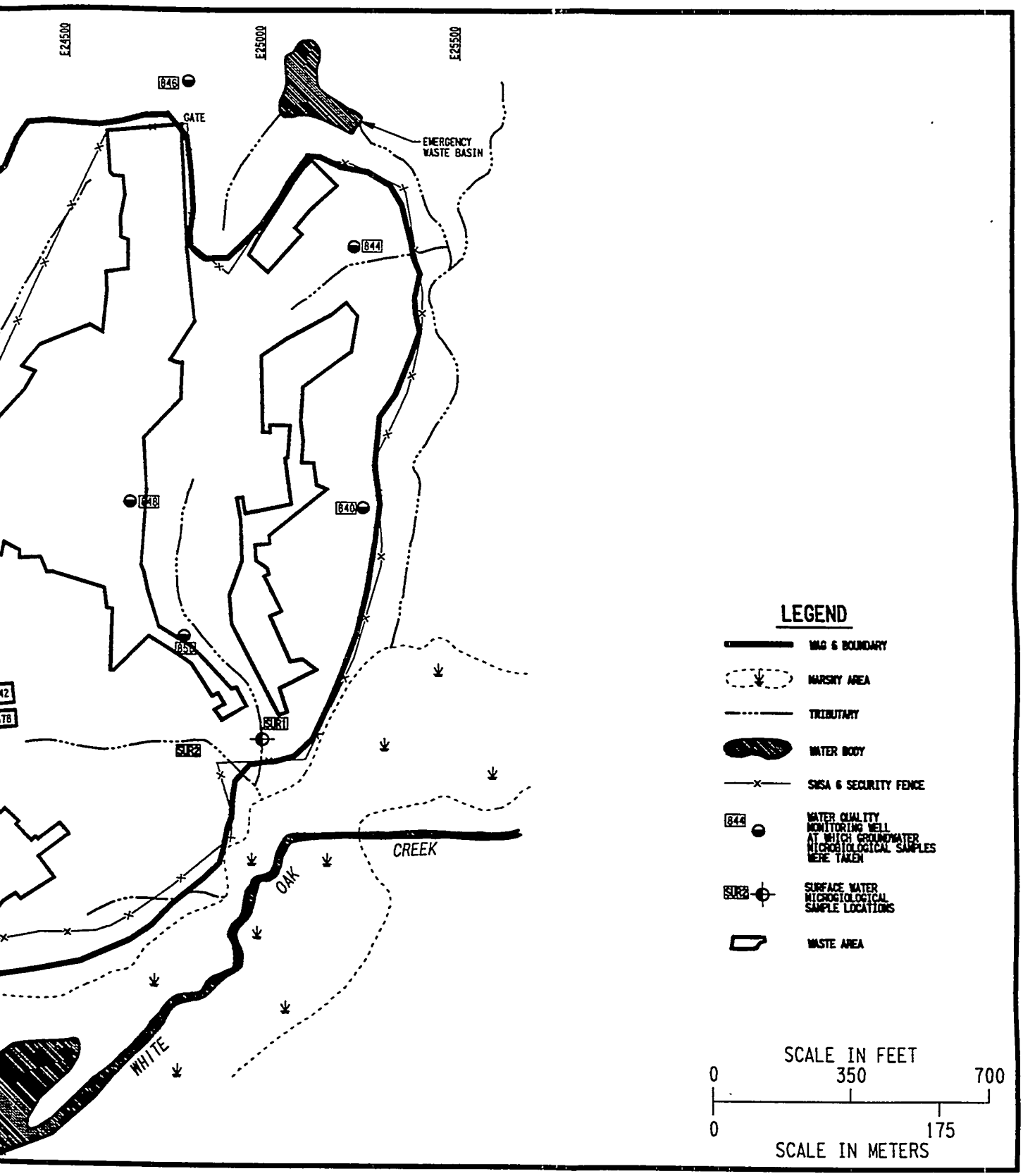



**Fig. 2.13. Groundwater and surface water microbiology sampling locations, Activity 1.**

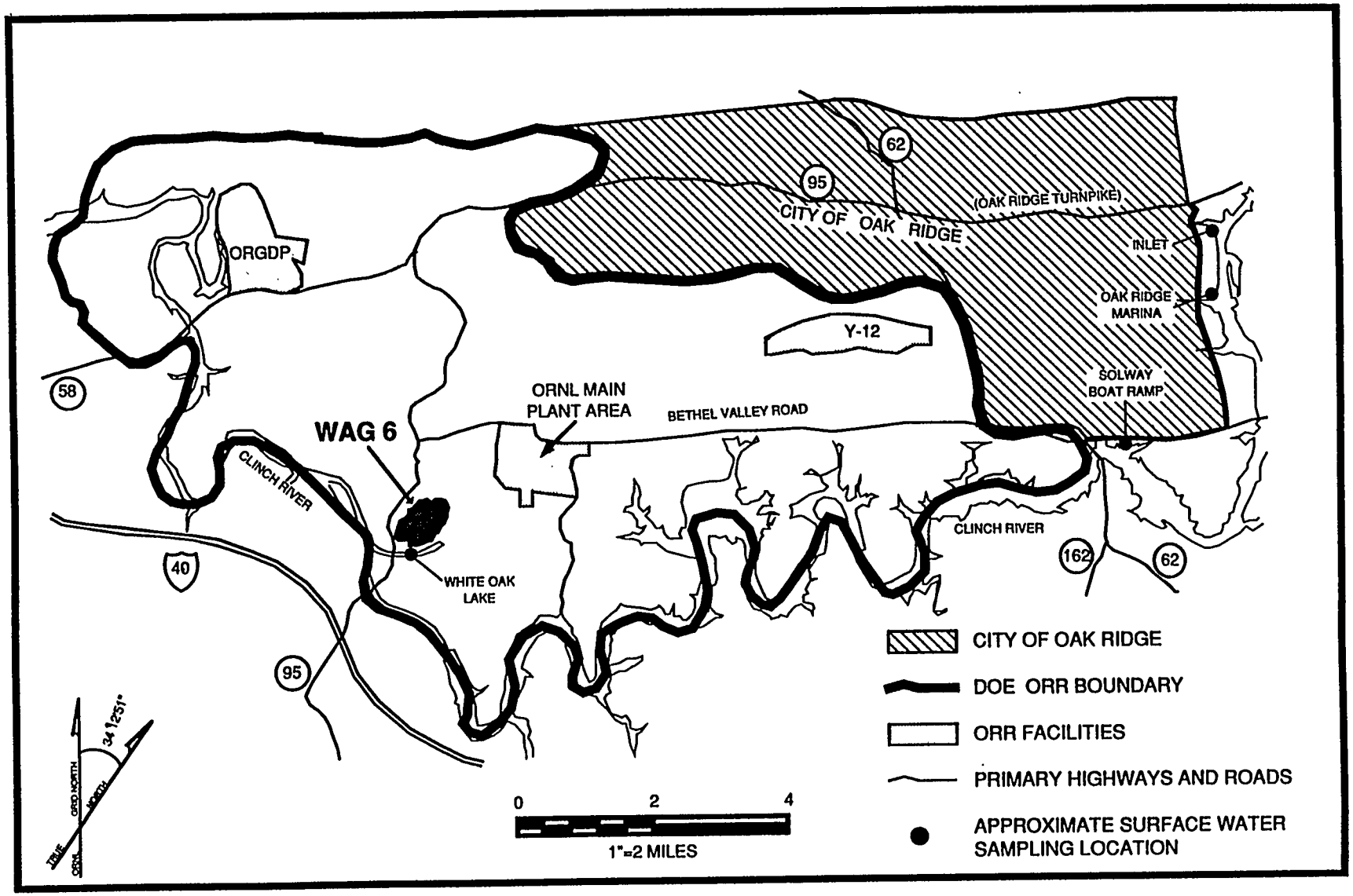
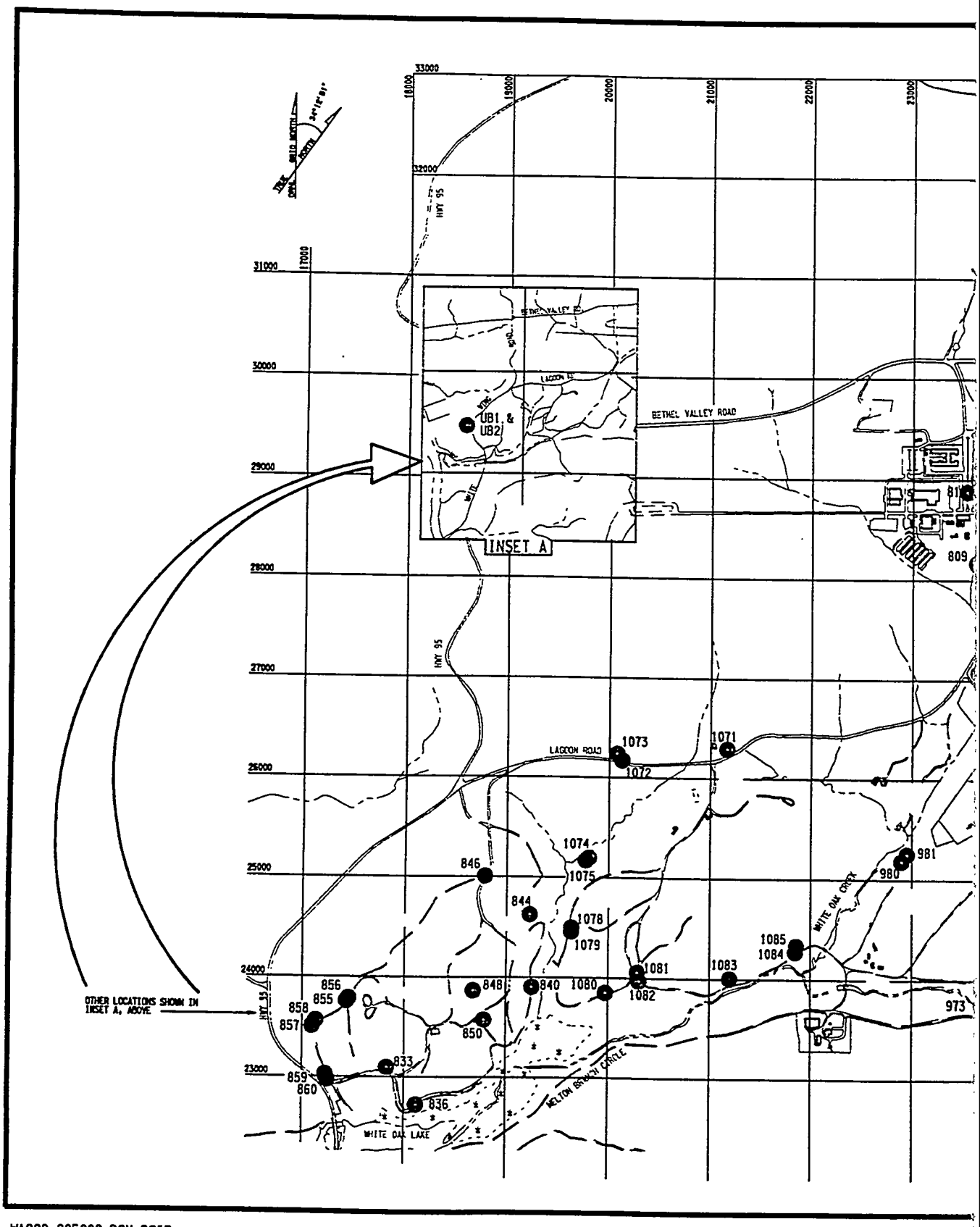



**Fig. 2.14. Approximate microbiological surface water sampling locations, Activity 2.**

5.18F 4104.177




WAG99 99F029.DGN BSIZ

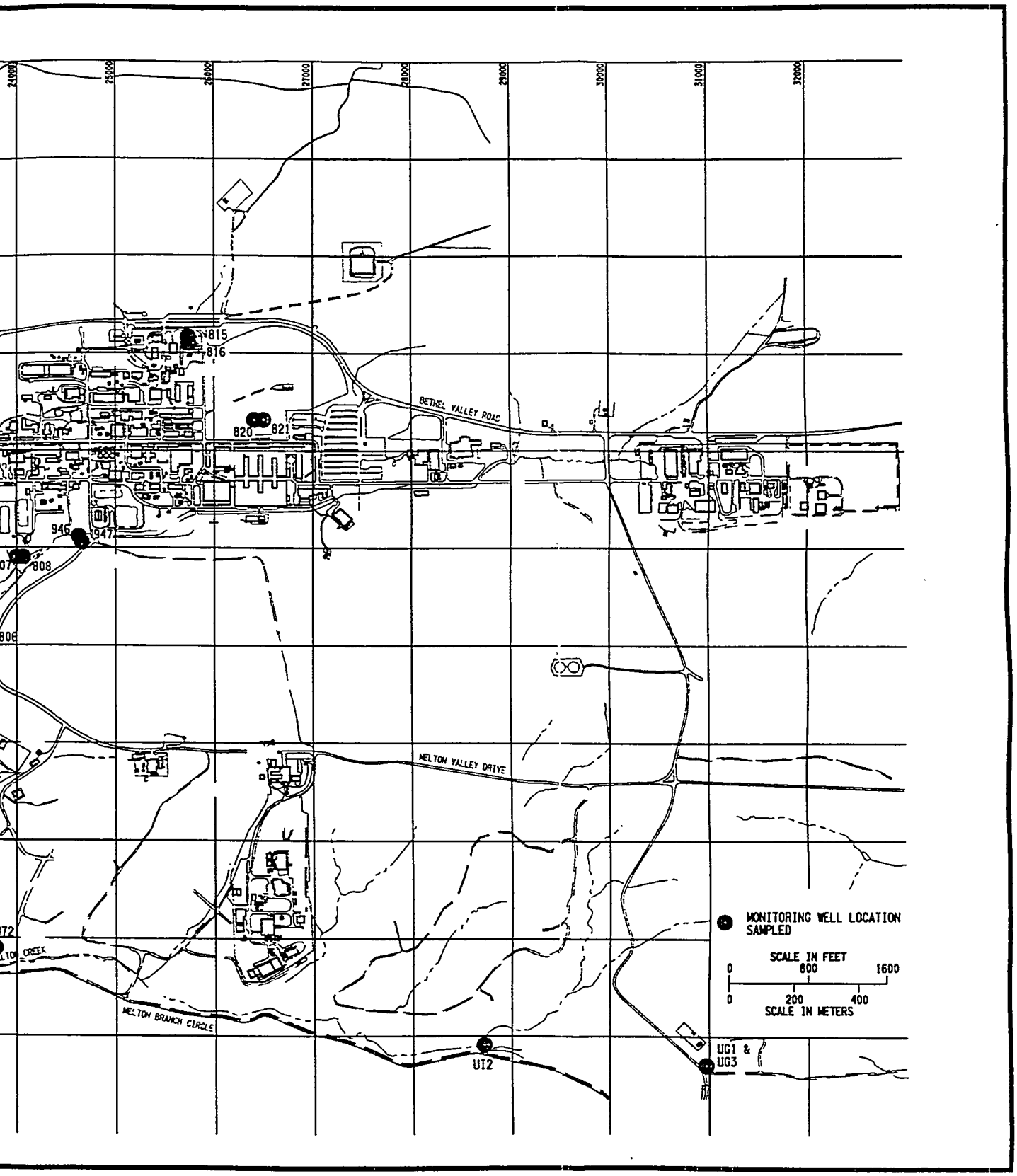



**Fig. 2.15. Groundwater biohazard sampling locations, Activity 2.**

# 3. PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section of the WAG 6 RFI Report provides a summary description of the physical characteristics of the site relevant to identification and evaluation of potential transport pathways, mechanisms, and receptors. This information supports subsequent sections that pertain to nature and extent of contamination and contaminant fate and transport (Sects. 4 and 5, respectively). Additionally, key findings relevant to development and screening of potential remedial action alternatives are included.

This section is organized into five subsections: Sect. 3.1, Site Topography, Climate and Meteorology; Sect. 3.2, Site Geology; Sect. 3.3, Groundwater Hydrology; Sect. 3.4, Surface Water Hydrology; Sect. 3.5, Ecology. A summary of key findings relevant to each section is presented at the conclusion of each of the above listed subsections.

The following summary description is intended to provide an overview of pertinent information regarding physical characteristics. However, WAG 6 has for many years been the focus of numerous research investigations conducted by ORNL, the USGS, and others. Consequently, considerable site characterization data exists. More detailed discussions of Site Geology, Groundwater Hydrology, and Surface Water Hydrology are presented as Appendix 3A, 3B, and 3C, respectively. Additionally, Appendix 3D presents a summary tabulation of WAG 6 subsurface and hydrogeologic data, and Appendix 3E presents data in support of Sect. 3.5.

## 3.1 SITE TOPOGRAPHY, CLIMATE, AND METEOROLOGY

This section discusses the topography, climate, and meteorology of WAG 6. Section 3.1.1 describes the topography and physical features of the site; Sect. 3.1.2 discusses climate and meteorology and the interplay among precipitation, ambient air temperatures, evapotranspiration, and winds. Section 3.1.3 summarizes the key information presented in this section.

### 3.1.1 Topography and Site Features

WAG 6 is located at the southwestern end of Melton Valley, a northeast-southwest trending valley roughly 1.2 miles wide that lies between Haw Ridge to the north and Copper Ridge to the south. Crest elevations along Haw Ridge and Copper Ridge reach 1000 ft and 1356 ft, respectively. A line of lower hills with crest elevations of approximately 850 ft occur near the center of Melton Valley. WAG 6 is situated on the southeast flank of one of these hills.

Ground surface elevations within WAG 6 range from about 745 ft (MSL) adjacent to WOL at the southern WAG boundary and eastern perimeter of the site to greater than 850 ft (MSL) at the crest of the series of knobs along the northwest boundary. Maximum topographic relief across the site is 105 ft. Slopes within WAG 6 are variable and range from 10 to 57%. The greatest irregularity of terrain and the steepest slopes occur in the

northern and northeastern parts of the site adjacent to the SWSA 6 access road and along the eastern perimeter road.

As Fig. 3.1 shows, the WAG 6 topography is dissected by four principal surface water drainages, FA, FB, DB, and DA. With the exception of stream DA, which trends grid east-west, streams in WAG 6 are oriented roughly grid north-south. The resulting undulating topography and relief plays an important role in the hydrogeologic framework of WAG 6 (Sect. 3.3).

Comparisons of historical (pre-ORNL) and recent air photographs of the site reveal that modifications of the land surface for waste disposal have not significantly altered the original surface drainage patterns or slope configuration. However, site records do indicate that the thin site soils have been highly disturbed, reworked, or removed over much of the site during past waste trench excavation, construction activities (involving cut and fill operations), and site grading. Air photographs from 1935 indicate the WAG 6 area was originally cleared and used for agriculture; several farmhouses existed on or adjacent to the present-day site. Old growth timber remained along the low-lying or steep areas not suited for agriculture. By 1952, following acquisition of the land by the Atomic Energy Commission (later DOE), the farmhouses had been removed and the site had become overgrown by secondary growth timber--to the extent that prior to waste disposal operations, the WAG 6 area was heavily wooded. Following initiation of waste disposal operations, trees were removed from waste disposal areas. Stands of trees remained along the principal drainage paths until the ICM capping work, which was completed in 1989. This work required removal of the trees along the eastern two interior drainages (DA and DB). Dense stands of mixed deciduous and conifer timber still exist along the northern boundary and in the western portions of WAG 6. Historical air photographs indicate that the area immediately north and northwest of WAG 6 (outside the SWSA 6 fence) has never been used for waste disposal purposes.

### 3.1.2 Climate and Meteorology

The WAG 6 climatic and meteorological information are pertinent in characterizing the potential for atmospheric transport of contaminants in the risk assessment and are integral factors in the dynamics of site hydrogeology.

The nearby Cumberland and Great Smoky mountains have a moderating influence on the climate of the area. In general, this results in warm, humid summers and cool winters, with no noticeable extremes in precipitation, temperature, or winds.

#### 3.1.2.1 Precipitation

Abundant site-specific precipitation data are available from the gaging stations established at three locations within SWSA 6 (at the ETF, the EPICORE facility, and in the 49 Trench area). Rainfall has been recorded at these stations since 1981. Additional data are available from four meteorological towers established at ORNL in 1982 (in particular, MET Tower 4, located in Melton Valley). Long-term records are available from the National Oceanic and

Atmospheric Association (NOAA) weather station at Norris Dam (1947 to present) and the Atmospheric Turbulence and Diffusion Division Lab (ATDD) located in Oak Ridge (1959-present). Generally, rainfall records for individual precipitation events recorded at different stations are similar (within 0.5 in.), although the Valley and Ridge topography yields some variation from location to location.

Precipitation for WAG 6 for the period 1988 through June 1990 as recorded at the ETF station is shown in Fig. 3.2. The area's climate is humid with frequent rain; periods of 5 days or more without precipitation occur on average only 4 to 5 times per year (Boegly 1984). Maximum monthly precipitation occurs January through March and is associated with winter storms that are generally of low intensity but long duration. Light snow occurs November through March, but most snowfalls amount to only a trace. Average annual snowfall for the period 1951-1988 was 9.8 in. (MMES 1989). A second peak in rainfall occurs in July, when short, heavy rainfalls associated with thunderstorms are common (Davis et al. 1984). The driest period of the year typically occurs from September through October, when, typically, slow-moving high pressure cells suppress rain and provide clear, dry weather.

The long term average annual precipitation recorded at the NOAA Oak Ridge station for the period 1948-1990 was 54 in. An estimate of the long-term average annual precipitation at WAG 6 was determined by using the long-term Oak Ridge station data (1948 to 1990) to extend the existing 1981-1990 record for the ETF station (see Sect. 5). The average annual precipitation for the extended record was computed to be 51.2 in. Consequently, a reasonable estimate of the long-term average annual precipitation for WAG 6 can be considered to be 52 in.

Annual precipitation actually recorded at the ETF station for each year from 1981 through 1988 (excluding 1982) was below the estimated long-term average for WAG 6, indicating drought conditions prevailed. During these years, the drought conditions resulted in reduced stream flows and depressed water levels. The lowest annual precipitation occurred in 1986 when the annual precipitation (38.5 in.) was 26% below the estimated average reference value for WAG 6. However, annual precipitation for the 1989 and 1990 water years measured 64.5 and 63.5 in., respectively, exceeding the estimated WAG 6 average annual precipitation by 12.78 and 11.45 in., respectively. This suggests that 1989 and 1990 were wet years relative to the historical average.

### 3.1.2.2 Temperature

The mean annual temperature for the Oak Ridge area is 58°F (Webster and Bradley 1988). The coldest month is usually January, with temperatures averaging approximately 38°F but occasionally dipping as low as 0°F. However, differences between December through February are minor. Although there is little difference between June and August, July is the hottest month, with temperatures averaging 77°F but occasionally peaking at over 100°F. Average daily temperatures fluctuate 53.6°F over the course of the year (Davis et

al. 1984). Figure 3.3 shows the temperature fluctuation recorded at the ATDD station in Oak Ridge from 1988 through June 1990.

#### 3.1.2.3 Evapotranspiration

Regionally, annual evaporation has been estimated to range from 32 to 35 in., or 60 to 65% of rainfall (Farnsworth et al. 1982). Evapotranspiration in the Oak Ridge area is 29 to 30 in., or 55 to 56% of annual rainfall (TVA 1972; Moore 1988; Hatcher et al. 1989). These estimates may be high for WAG 6, because much of the site's vegetation has been removed. Boegly (1984) reports that actual values are more likely 20 to 23 in. per year or 20 to 30% of annual precipitation.

Although evapotranspiration rates are probably reduced due to recent clearing of site vegetation, soil evapotranspiration is occurring. As part of the RFI effort, water balance calculations for WAG 6 were performed for the period 1981-1990 and indicated an average annual evapotranspiration of 29.4 in. (See Sect. 5 for details), the majority of which occurs during the growing season (average 220 days from April through September). Moore (1988) suggests 75% of evapotranspiration occurs during this period and often exceeds the rate of precipitation, such that soil moisture levels are lowest during this time.

#### 3.1.2.4 Winds

Winds in the Oak Ridge area are controlled in large part by the valley and ridge topography. Prevailing winds are either up-valley (northeasterly) or down-valley (southwesterly). Davis et al. (1984) note that daytime winds generally blow up-valley, while nighttime winds usually blow down-valley. This pattern is apparent in Fig. 3.4, which is a wind rose representing winds measured at the 300-ft level of MET station 4 in Melton Valley for the period January 1988 through June 1990. This figure shows the relative frequency (as a percentage) of occurrence of winds by compass orientation and wind speed. Wind speeds are represented by the telescoping bar scale. Tornadoes and high-velocity winds are rare; wind speeds are less than 7.4 mph 75% of the time, and wind speeds exceeding 18.5 mph are rare.

### 3.1.3 Summary of Key Findings

Pertinent findings regarding WAG 6 topography, climate, and meteorology are summarized below.

- WAG 6 displays up to 105 ft of topographic relief across the site; four internal streams dissect the site forming an undulating topography with slopes that range from 10 to 57% (i.e., vertical grades of 10 to 57 ft per 100 ft horizontally).

- Historical air photographs indicate that the area immediately north and northwest of WAG 6 (outside the SWSA 6 fence) has never been used for waste disposal purposes.

- Site records indicate that the thin site soils have been highly disturbed, reworked, or removed over much of the site during past waste trench excavation, construction activities (involving cut and fill operations), and site grading.

- Maximum precipitation occurs during January to March, with a secondary peak in rainfall in July; the driest period of the year is September to October.

- The mean annual precipitation from 1948 to 1990 was 54 in. Drought conditions prevailed from 1981 through 1988, with 1986 being the driest year. Annual precipitation for 1989 and 1990 exceeded the 1948-1990 mean, indicating relatively wet years.

- Evapotranspiration at WAG 6 ranges from 20-30 in. annually (37 to 56% of annual rainfall).

- Maximum evapotranspiration occurs during the growing season (April through September) and is lowest during the winter.

- Seasonal patterns of evapotranspiration and precipitation have a pronounced effect on soil moisture levels and groundwater levels. The water table and soil moisture levels are highest from January to March, when precipitation is high and evapotranspiration is minimal. Water table and soil moisture levels are lowest from August through October, when precipitation is low and evapotranspiration is high.

- Prevailing winds at WAG 6 are northeasterly during the day and southeasterly during the night; speeds are generally less than 7 mph.

## 3.2 SITE GEOLOGY

The geology of the site has a controlling influence on the occurrence of groundwater and contaminant transport and impacts the selection and design of remedial action alternatives. This section provides a summary description of site geology and identifies key features and aspects that affect the fate and transport of contaminants and bear on potential remedial action alternatives.

This section is organized into three subsections. Section 3.2.1 presents WAG 6 in the context of its regional geologic setting. Section 3.2.2 describes the site-specific geology, providing detailed discussion of the stratigraphy, structural geology, and physical and chemical properties of geologic materials of WAG 6. Section 3.2.3 summarizes the key geologic findings that aid in understanding the aquifer skeleton and that support the needs of the RFI. A more detailed description of site geology is presented in Appendix 3A.

### 3.2.1 Regional Setting

WAG 6 is situated in the Tennessee Valley and Ridge Province, which is part of the Appalachian fold and thrust belt. A series of northeast-trending thrust faults generated by

mountain building processes in Permian-Pennsylvanian time (roughly 250 million years ago) duplicate the Paleozoic rock sequences as bedrock motion along the thrust faults transposed older rocks above younger rocks in a shingled effect. Subsequent differential erosion resulted in a series of alternating valleys and ridges that parallel the surface traces of the thrust faults. Rocks resistent to weathering form the ridges whereas rocks that are more readily weathered underlie the valley floors. Because of the complex mountain-building processes that affected the area, local geology is influenced by structural features at all scales including regional and local thrust faults, normal and tear faults, local folding, and widespread fracture development.

### 3.2.2 Site Geology

WAG 6 is situated in Melton Valley above the Copper Creek Thrust Fault (Fig. 3.5), which lies approximately 1000 ft below WAG 6. Motions along this fault have placed the older, middle to late Cambrian Conasauga Group and underlying Rome Formation rocks above the younger Ordovician Chickamauga Group rocks. Erosional processes and varying degrees of in-place weathering of bedrock have produced a geologic sequence above the Copper Creek Fault that consists of, in ascending order:

- Unweathered, consolidated bedrock (lower Conasauga Group and Rome formations)
- An interval of weathered, unconsolidated bedrock or "saprolite"
- A veneer of alluvial (transported by water), colluvial (transported by gravity), or residual (formed in place by chemical/physical weathering) soils

Because the saprolite and soils formed in place as weathering products of the underlying bedrock, this section first provides a description of the bedrock parent material, followed (in ascending order) by descriptions of WAG 6 saprolite and soils.

#### 3.2.2.1 Bedrock

The geology of bedrock underlying WAG 6 is complex, owing to patterns of initial deposition and highly variable subsequent structural deformation. Bedrock has been encountered at depths ranging from 2.5 to 51 ft below grade within WAG 6. The bedrock surface configuration, based on existing subsurface control and information from the 54 soil borings and 22 wells installed during the WAG 6 RFI, is shown on Fig. 3.6 (depth to bedrock data is tabulated in Appendix 3D). Generally, bedrock is encountered at shallow depths in topographically lower areas and along drainages and at greater depths on hilltops. The average depth to bedrock observed was 19 ft. Depth to bedrock along the perimeter of WAG 6 was found to be 20-25 ft below grade along the northern WAG boundary, an average of 10 ft below grade along the eastern perimeter (ranging from 2.5-21 ft depending on relief), and generally more than 23 ft deep along the southern WAG boundary adjacent to White Oak Lake.

**Stratigraphy.** The Conasauga Group within Melton Valley ranges up to 1800 ft thick (Boegly 1984) and consists of six distinct formations. These are, in ascending order, the

Pumpkin Valley Shale, Rutledge Limestone, Rogersville Shale, Maryville Limestone, Nolichucky Shale, and Maynardville Limestone. Lithologic descriptions for each of the Conasauga Group formations are presented in Table 3.1. At WAG 6, the Maynardville Limestone is not present.

Only the Maryville Limestone and Nolichucky Shale bedrock occur in the near-surface beneath WAG 6, and they generally are not exposed at the surface. The Maryville Limestone underlies the northern half of the site and the Nolichucky Shale underlies the southern half. The contact between the Maryville Limestone and Nolichucky Shale, shown on Fig. 3.7, was determined in part based upon correlations from deep well control on or immediately around WAG 6. It should be noted however, that the contact between the Nolichucky and Maryville formations is gradational. Consequently, the actual contact may vary somewhat from that shown.

The Nolichucky Shale is the youngest formation underlying WAG 6 and ranges up to 550 ft thick. However, a complete Nolichucky section was not encountered at WAG 6, and from deep well control it appears that only the lower Nolichucky underlies WAG 6. Although no Nolichucky rock cores have been obtained within WAG 6, borehole geophysical logs indicate that the Nolichucky within WAG 6 consists of limy shales and mudstones interbedded with thin silty or shaley limestones. The contact between the Nolichucky Shale and underlying Maryville Limestone is marked by an overall increase in limestone content in the upper Maryville.

The Maryville Limestone beneath WAG 6 ranges up to approximately 415 ft thick. WAG 6 rock cores reveal the Maryville to be composed of limestone beds of variable thickness (but generally thin), interbedded with silty, limy mudstones and dark shales. In general, the limestone beds are more abundant, thicker and pure in the upper portion of the Maryville, whereas mudstone are more prevalent in the lower Maryville—as noted in cores and geophysical logs.

The Rogersville Shale, although not exposed near the surface, underlies the Maryville Limestone and was encountered at WAG 6 in only two deep boreholes (at depths of 297 and 352 ft below land surface).

Much of the Conasauga Group bedrock was deposited in a complex transitional marine environment characterized by periodic inundation and retreat of shallow seas. These fluctuating marine/non-marine conditions produced the alternating thin limestone and limy shale or siltstone bedding typical of Conasauga formations. Further, rock cores reveal bedrock lithologies indicative of deposition in association with storms. The environment of deposition for these rocks result in rapid vertical and lateral changes in bedrock lithology. The lack of continuity of individual beds, coupled with post-depositional structural deformation, makes correlations of individual bedrock beds problematic, even when using rock cores or borehole geophysical logs.

**Structural geology**. Generally, the bedrock beneath WAG 6 strikes N55°E, parallel to the trend of the Copper Creek Thrust Fault (roughly grid east-west), and dips 20-25° to the southeast (grid south). However, rock cores and deep well borehole televiewer logs show dips changing frequently in relatively short vertical distances in association with small-scale kink and drag folds and minor faults (see Appendix 2E). Dips observed in cores and logs range from 30° to near vertical, oriented in nearly all directions. Due to the absence of surface bedrock exposures, structural mapping has been limited to mapping structures observed in saprolite zones exposed in shallow trenches. This mapping has shown that structural complexity increases from north to south across WAG 6.

**Faulting**. The principal feature controlling much of the subsidiary structure and stratigraphy within Melton Valley is the Copper Creek Thrust Fault, which is exposed at the surface on the north flank of Haw Ridge north of WAG 6. It then dips relatively gently to the southeast, so that at WAG 6 the fault zone lies roughly 1000 ft below the ground surface. At this depth, the fault does not likely impact WAG 6 groundwater flow or contaminant transport.

Faulting is widespread in the subsurface at WAG 6. Rock cores from WAG 6 and surrounding areas display four types of faults: bedding plane faults, high angle normal and reverse faults, and intraformational thrust faults. None of the faults at WAG 6 are active.

Bedding plane faults are generally small-scale and are ubiquitous throughout the Conasauga Group bedrock. They characteristically occur at contacts between different lithologies and are most abundant in thin- to medium-bedded intervals of limestone or siltstone and mudstone. High-angle normal and reverse faults have been documented in cores from the nearby ORNL-JOY #2 and WOL-1 coreholes (Davis et al. 1987; Haase, Walls, and Farmer 1985), and in shallow trenches and the French Drain excavation (Dreier and Beaudoin 1986; Davis and Stansfield 1984). These faults typically show small displacements (30-40 ft) and are accompanied by minor folding in a zone of deformation up to 5 ft thick.

Two intraformational thrust faults were identified by Dreier and Toran (1989) in WAG 6 in two HHMS-series wells. Figure 3.8 depicts a structural cross section oriented grid north-south (dip parallel) across the central part of WAG 6. This cross section is based upon deep well control afforded by the HHMS well clusters and shows the two thrust faults, "A" and "B", identified in well HMMS-8A and -5A, respectively. These faults are not evidenced at the surface; the near surface leading edge of these two faults are shown on Fig. 3.7. These two faults show relatively small displacements — approximately 250 ft for Fault A and 20 to 75 ft for Fault B (Dreier and Toran, 1989).

During the WAG 6 RFI, four deep (150 to 170 ft) wells were located and installed to assess the extent of these faults and evaluate the potential impact on groundwater flow at WAG 6. However, rock core and borehole geophysical log evidence revealed a fault in only one borehole, Well 1234; it is believed this fault correlates with Fault A observed in well HHMS-8A.

Although it can not be proven because of the limited deep well control and structural complexity at WAG 6, it is likely that other faults may exist. Faulting results in either thickened stratigraphic sections (in the case of reverse and thrust faults) or a loss of section (as in normal faults), making correlations of individual beds between wells problematic. Nine WAG 6 hydrogeologic cross sections were constructed at orientations parallel and perpendicular to bedding strike; these are presented in Appendix 3A. These cross sections incorporate all available subsurface information and display the extent of known faulting identified in deep wells at WAG 6. Based upon available deep well control, is it not possible to evaluate the effects of a given fault on site hydrology (i.e., groundwater flow and contaminant transport) without uncertainty. A fault identified in a single well may act as a conduit, facilitating groundwater flow along the fault plane or fault zone; in another location, the same fault may act as a barrier to flow.

**Folding.** Minor folding is common, particularly in thin-bedded shale and mudstone intervals, and is highly variable in continuity and intensity. Generally, individual structures cannot be correlated with any certainty from well to well. As shown in Fig. 3.7, the folding is most common in the southern half of the site and appears to coincide with the leading edge of the two identified thrust faults, A and B.

**Fractures.** Although the Conasauga Group bears little or no matrix (i.e., bulk rock) porosity, bedrock is highly fractured throughout Melton Valley. Therefore, fractures form the most significant element in groundwater flow. As many as five distinct fracture orientations have been identified at WAG 6. As portrayed in Fig. 3.9, the fracture sets intersect to form a complex, tortuous groundwater flow network that precludes prediction of contaminant transport in bedrock with certainty.

The most prominent fracture orientations are parallel to local geologic strike and include bedding plane parallel and strike-parallel fractures. Less-prominent and less-penetrative fractures are oriented perpendicular and oblique to local strike and bedding.

Fracture density varies with lithology but generally decreases with depth. The highest bedding plane fracture density occurs in intervals of interbedded silty shales and limestones. Coarse limestone breccia zones had the lowest fracture density; the few present were oblique to bedding. Further, high-angle fractures observed in limestone units appear to terminate abruptly at the contact with shale or mudstone units. Although fractures are widespread, they are generally short, being less than 3 ft long (Moore 1988), such that distinct fractures or groups of fractures cannot be correlated between wells with any certainty.

Open fractures are most common in the upper 150 ft of bedrock and decrease with depth (Dreier et al. 1987). Sledz and Huff (1981) reported that fracture porosity decreases roughly 8.2% for every 50 ft below land surface. Dreier and Foreman (1990) suggest that two systems of fractures exist in Melton Valley: an older tectonic system that generally occurs below depths of 150 ft and that is characterized by abundant healed fractures; the younger system generally occurring at depths less than 150 ft and that contains more open fractures (formed in response to erosional unloading).

Fractures (some chemically widened) range up to 6 in. diameter, although most are less than 0.01 in. wide. Solution enlargement of fractures is most common in carbonate-rich portions of the Nolichucky Shale, particularly parallel to bedding planes. However, no large-scale solution (or karst) features were noted in WAG 6 cores or televiewer logs, although some small-scale (less than 0.9 in.) solution cavities have been documented in shallow bedrock cores from the ETF area.

**Bedrock physical and chemical properties.** The migration of radionuclides and other contaminants through bedrock is controlled in large part by the physical properties of the rock matrix (porosity) and chemical interactions between the contaminants and the rock. Calcium carbonate cements in the Nolichucky and Maryville formations generally preclude any primary matrix porosity. Therefore fluids move through bedrock principally along secondary porosity features (fractures and solution cavities). The key physical and chemical properties of bedrock that affect radionuclide or other contaminant transport include bulk rock properties (porosity, hydraulic conductivity, etc.) and retardation associated with ion exchange and sorption reactions caused by interaction with the rock along fracture planes.

Physical and chemical properties of the bedrock that potentially impact the fate and transport of radionuclides were determined for rock cuttings from a 115-ft deep Maryville borehole and a 25-ft deep Nolichucky borehole, both of which were located in SWSA 7 (Davis et al. 1984; Rothschild et al. 1984b). The results are presented in Appendix 3A, but in general, porosity and the capacity for ion exchange and sorption decrease with depth, coinciding with a decrease in rock weathering with depth.

#### 3.2.2.2 Saprolite

Saprolite, formed from in-place weathering of bedrock, directly overlies competent, unweathered bedrock and is a significant component of the aquifer system where saturated. Under unsaturated conditions, the saprolite is further significant in that this is the interval in which, by design, the majority of waste disposal trenches terminate. This section describes saprolite occurrence within WAG 6, its significant characteristics, and its physical and chemical properties.

**Saprolite occurrence.** The Maryville and Nolichucky bedrock weather to form a saprolite indicative of the lithologies of the parent formations. Saprolite in areas underlain by limestone-rich bedrock (the northern part of WAG 6), is principally a clay. Usually in these areas, the transition from saprolite to bedrock is abrupt. Silty limestone or siltstone/shale bedrock weathers to a porous siltstone saprolite, with a gradational transition to competent bedrock noted by an increase in rock fragments with depth. Bedrock consisting of interbedded limestone and shale yields a saprolite with alternating hard and soft beds.

The overall thickness of the saprolite layer throughout WAG 6 varies with topographic position. The 54 soil borings and 22 boreholes drilled during the WAG 6 RFI revealed that the saprolite ranged from 3 to 45 ft thick; saprolite was thicker on hilltops and thinner along valleys and surface water features.

The original bedrock structural fabric is preserved in the saprolite. Consequently, the saprolite is structurally complex, and tight folds, fractures, and minor faults are commonplace, particularly in the southern half of WAG 6. Further, weathering and differential movement of water through the saprolite fractures has in some cases enhanced these relict features in siltstones and shales.

**Physical and Chemical Properties of Saprolite.** The physical and chemical properties of the saprolite have been studied at WAG 6 and in similar settings at WAG 7 (Rothschild et al. 1984a; Ammons et al. 1987) and are summarized in Appendix 3A. In general, the saprolite has considerably more porosity than the underlying consolidated bedrock (up to 40%), as bulk rock (matrix) porosity is developed through weathering and leaching of carbonate cements. The degree of weathering (and therefore porosity development) in the saprolite is variable but decreases with depth, accompanied by an increase in clay content. The saprolite also has a higher ion exchange capacity and higher sorption capacity (for cesium and strontium) than unweathered bedrock. The upper portion of the saprolite is typically leached and is acidic; acidity decreases with depth.

### 3.2.2.3 Soils

This section provides a summary of the soils at WAG 6 and their physical and chemical properties that relate to contaminant transport.

**Soil types and distribution.** Detailed soil mapping at WAG 6 was performed by Lietzke and Lee (1986) and Ammons et al. (1987) using soil test pits and soil cores; 11 distinct soil types were identified. Figure 3.10 depicts these soil types and their distribution at WAG 6.

Soil development is related to the composition of the parent material, the depth and degree of weathering, and topographic position. These soils were developed largely in place from three major parent materials: saprolite and unweathered bedrock (soil units 2, 3, 4, and 10); colluvium or alluvium (soil units 5, 6, 7, 8, and 11); and ancient alluvium (soil unit 9). As noted previously, weathering persists to greater depths on hilltops than in low-lying areas. Consequently, thin residual soils occur on the hilltops but are absent in the low areas (where thick alluvial deposits are found). Ammons et al. (1987) and Lietzke and Lee (1986) reported soil thickness ranging from 1.3 to 9.8 ft thick, but soils generally are less than 3 ft thick.

As reported in Sect. 3.1, much of the surface soil at WAG 6 has either been disturbed, reworked, removed, or replaced with fill materials imported from outside WAG 6. Ammons et al. (1987) report that during clearing activities, most of the soils in the trench areas were pushed off into drainageways or were buried under leached/unleached saprolite excavated from the disposal trenches. In these and other cases, operational activities have altered the natural fabric, composition, and distribution of site soils, creating zones of variable and unpredictable permeability.

Where present, organic surface soil is thin (less than 1.6 in. thick). Underlying A- and B-horizon soils, where present, average 8.5 and 34.5 in., respectively. The surficial soils are, in turn, underlain by a C-horizon consisting of 1 to 13.5 ft of silty clay, which marks the transition between the soils and saprolite.

Recent alluvial and colluvial soils are developing in low areas and along drainageways in WAG 6. In the northwest corner of WAG 6, ancient alluvial soils are evidenced by well-rounded quartzite from the distant Unaka Mountains as well as subrounded Knox chert fragments.

**Soil physical and chemical properties.** Information regarding the physical and chemical nature of WAG 6 soils is principally provided by Ammons et al. (1987) and Davis et al. (1984). Additional soil properties information is presented in Rothschild et al. (1984a) for soils in nearby SWSA 7. Data from these sources is summarized in Appendix 3A.

WAG 6 soils are thin, acidic, and highly leached. Organic content is typically low (less than 4.3 percent) and decreases with depth; clay content increases with depth in the soil horizons and clay-filled upper saprolite. Consequently, soil bulk density generally increases with depth; porosity correspondingly decreases, in part because of the clay plugging and also because of manganese and iron oxide precipitation.

In some areas, water will percolate directly through the soil to enter the saprolite or bedrock fracture system. In others, water evidently flows laterally along the soil/bedrock interface (as in soil type 10), or, due to impermeable fragipan layers (common to soil unit 5), may serve to perch shallow water locally.

Available data show no discernible trends in radionuclide sorption capacity with depth, but WAG 6 soils appear to have high sorption capacities for retarding the migration of cobalt, strontium, and uranium. Ion exchange capacity is also high.

### 3.2.3 Summary of Findings Regarding Site Geology

The distribution and physical characteristics of the geology saprolite, (bedrock, saprolite, and soils) at WAG 6 constitute the aquifer skeleton and in large part control the site's groundwater hydrology (discussed in Section 3.3). The following key findings about site geology are fundamental to understanding groundwater hydrology at WAG 6 and recognizing the limitations the site geology imposes on defining contaminant fate and transport.

- **Bedrock**

— The Maryville Limestone and Nolichucky Shale bedrock underlie the northern and southern parts of the site, respectively. These formations were deposited in an environment whereby rapid lateral and vertical variations in lithology are common. Consequently, correlations of individual beds within these formations from well to well are uncertain.

— Although bedrock generally strikes grid east-west and dips towards grid south (i.e., true northeast strike and southeast dip), due to local structural complexities a wide range in bedding strike and dip has been documented at WAG 6. Site borehole televiewer logs and rock cores show that strikes and dips change rapidly in relatively short vertical distances.

— Minor folding (i.e., kink folds) and normal, reverse, and thrust faults are widespread. Two principal thrust faults have been identified trending roughly east-west across WAG 6. Other faults and fault splays are also possible. Faults may act as either conduits or impediments to groundwater flow (i.e., a given fault or fault zone may in one location facilitate groundwater flow and in another, serve as a barrier to flow). However, faults at WAG 6 are not active faults.

— Structural complexity increases from north to south across WAG 6 and is likely related to the occurrence of the two principal thrust faults.

— Little or no primary porosity exists in the bedrock. However, fractures (secondary porosity) are widespread. As many as five distinct fracture sets may be encountered at a given location at WAG 6. Principal fracture orientations include strike parallel and bedding plane parallel fractures (generally trending ORNL grid east-west) and a high-angle fracture set oriented perpendicular to bedding.

— Most fractures are short (less than 3 ft long) but interconnected so as to form a complicated network (i.e., stair-stepping patterns in all directions) for groundwater flow.

— Open fracture density decreases with depth.

— Depth to bedrock varies with topography, ranging from 2.5 to 51 ft below land surface. Along the perimeter of WAG 6 the depth to bedrock was found to be 20-25 ft below grade an average 10 ft below grade along the eastern perimeter (ranging from 2.5 to 21 ft); and greater than 23 ft along the southern boundary adjacent to WOL.

- **Saprolite**

— Saprolite overlies bedrock throughout the site and is formed in place from weathering of underlying bedrock.

— Saprolite thickness varies across the site with degree and depth of weathering; it is generally thicker on hilltops.

— Relict bedrock structural fabric is preserved, and in some cases (owing to movement of fluids through the saprolite), porosity associated with the structural feature is either enhanced or occluded.

— Weathering has further resulted in dissolution of calcium carbonate cements such that the saprolite shows considerably more matrix (primary) porosity than underlying unweathered bedrock.

- **Soils**

— Eleven different soil types have been delineated at WAG 6.

— WAG 6 soils are typically thin and acidic and in many areas have been removed, reworked, or otherwise altered during site operations. This has created discontinuous zones of variable and somewhat unpredictable permeability, both laterally and vertically.

— Although thin and variable, WAG 6 soils have high sorptive capacities for retaining cobalt, strontium, and uranium.

- **Overall**

— The geology of the site is complex, being a product of original depositional patterns in the bedrock, severe and variable structural deformation, weathering, and human activities. Consequently, there is considerable uncertainty in determining hydrogeologic processes on a local scale, such as assessing specific flow paths from a particular trench source to a well or surface water.

## 3.3 GROUNDWATER HYDROLOGY

Groundwater is a significant pathway for transport of contaminants at WAG 6. Consequently, a thorough understanding of site groundwater hydrology is relevant to support risk assessment, evaluate the nature and extent of contamination, and develop remedial action alternatives. This section of the report provides a summary description of site groundwater hydrology, focusing on information relevant to the support of other aspects of the RFI. Appendix 3B presents a more detailed discussion of groundwater hydrology at WAG 6.

This section provides a brief description of groundwater hydrology of WAG 6 and is organized into three subsections. Section 3.3.1 describes the existing network of wells and piezometers used to evaluate WAG groundwater hydrology. Section 3.3.2 describes groundwater occurrence at WAG 6, aquifer geochemistry, hydraulic properties of the aquifer, and groundwater flow. Key findings regarding groundwater hydrology are summarized in Section 3.3.3. Hydrogeologic data for WAG 6 wells and piezometers are tabulated in Appendix 3D.

### 3.3.1 Monitoring Network

SWSA 6 has long been the focus of ORNL and USGS investigations, site characterization research, remedial technology demonstrations, and regulatory compliance monitoring. Available records indicate a total of 355 groundwater wells and/or piezometers

have been drilled and installed within WAG 6. Additionally, as many as 600 trench piezometers have been installed in and between most of the waste disposal trenches in SWSA 6 to monitor trench water levels and trench water/leachate chemistry. The RFI investigation identified 226 existing WAG 6 groundwater wells or piezometers and 72 existing WAG 6 intra-trench piezometers for which records are available. Well construction data for these wells and piezometers are summarized in Appendix 3D. Figure 3.11 shows the locations of all identified wells or piezometers within or immediately adjacent to WAG 6. Details regarding RFI well installation are presented in Appendix 2E. Well construction details for ORNL RCRA compliance monitoring wells are presented in Mortimore and Ebers (1988). Sources for additional well and piezometer construction data are summarized in Appendix 3B.

Most WAG 6 wells and piezometers were constructed using methods or materials that predate current standards for use in regulatory compliance water quality monitoring. However, they provide valuable information regarding groundwater potentiometric levels; data from these wells has been used to the extent practical in the RFI. Limited groundwater sampling has been performed on many of the piezometers in conjunction with research projects conducted in WAG 6 over the years. Analytical results are presented in Appendix 1B, and have been incorporated as appropriate in the assessment of the nature and extent of contamination (Sect. 4).

It should be noted that following completion of the WAG 6 RFI, wells not required to support activities leading to site closure will be plugged and abandoned. ORNL is preparing a detailed well plugging and abandonment plan and plugging and abandoning will be conducted as an activity separate from the remedial action, prior to completion of the Record of Decision.

### 3.3.2 Groundwater Occurrence

Groundwater at WAG 6 occurs in both the unsaturated (i.e., vadose) zone and saturated zone. In the saturated zone, groundwater occurs principally under unconfined water table conditions in the regolith and bedrock. No major aquitards have been identified; groundwater occurs as a continuum from the water table surface to depth in bedrock. Perched water conditions occur locally in WAG 6 within the unsaturated or vadose zone. Transient saturated conditions associated with shallow subsurface storm flow in the uppermost unsaturated zone also occur. Figure 3.12 conceptually illustrates the various elements of groundwater occurrence at WAG 6.

Sections 3.3.2.1 and 3.3.2.2 describe the occurrence and characteristics of groundwater in the saturated and unsaturated zones, respectively. Section 3.3.2.3 describes aquifer geochemistry; Section 3.3.2.4 summarizes hydraulic properties of the aquifer based upon existing site data; and Section 3.3.2.5 qualitatively and quantitatively describes groundwater flow at WAG 6.

### 3.3.2.1 Saturated zone

The water table marks the top of the saturated zone at WAG 6 and occurs at depths ranging from less than 1 ft below grade (in low-lying topographic areas and along surface water drainages crossing WAG 6) to as much as 55 ft below grade (on hilltops). Adjacent to WOL along the southern boundary of WAG 6, the seasonal high water table occurs in the unconsolidated regolith at an average depth of 19 ft below grade.

The water table fluctuates in response to seasonal patterns of precipitation and evapotranspiration. Climatic factors (described in Sect. 3.1) impact water levels, which are generally highest from January to March (peaking in February), when precipitation is high and evapotranspiration is minimal; water levels are lowest from August through October, when precipitation is low and evapotranspiration is high. Water level fluctuations are more pronounced in higher topographic areas; in low-lying areas (particularly along surface water drainages) water table elevations maintain more consistent levels. Because of this, hydraulic gradients are generally steepest during the wet season, becoming more subdued during the dry season.

Hydrographs for shallow wells at WAG 6 show water levels respond rapidly to precipitation events; water levels increase in response to rainfall within several hours up to 12 hours. Conversely, hydrographs for two deep HHMS-series wells (completed at depths of 380 to 400 ft) show a lack of water level fluctuation in response to rainfall events. Additionally, hydrographs for all but one of the HHMS deep wells show that water levels are still increasing, suggesting that these wells have not reached equilibration since installation in 1987.

Within a 24-hr period in February 1990, water levels were measured at all wells and piezometers in existence at that time in and adjacent to WAG 6. It is believed that these data are representative of peak seasonal high water table elevation conditions. (These water level measurements are tabulated in Appendix 3D.) The February 1990 water table potentiometric map for WAG 6, presented in Fig. 3.13, shows the water table surface as a subdued replica of site topography (see Fig. 3.1); water table gradients indicate local flow to WAG 6 surface water drainages and overall southerly flow towards WOL. The potentiometric map further indicates that the topographic highs along the northwest boundary of WAG 6 form a groundwater divide.

A key feature recognizable on Fig. 3.13 is the linear drawdown pattern in the central part of WAG 6 associated with the 49 Trench area French Drain. This drain, installed into bedrock in late 1983, was designed to intercept groundwater from upgradient areas and lower the water table below the base elevation of the 49 Trench area disposal trenches, thereby decreasing the generation and potential mobilization of leachate. The French Drain discharges directly to surface water features within WAG 6. Figure 3.13 clearly shows that the French Drain is effective in intercepting groundwater, particularly in the immediate vicinity of the drain. Further details regarding the effectiveness of the 49 Trench Area French Drain are presented in Appendix 3B.

Because Fig. 3.13 represents seasonal (wet season) high water table conditions, the hydraulic gradients shown represent expected maximums; hydraulic gradients during the dry season would be somewhat less. Water level elevations representative of dry season, low water table conditions were not obtained from all wells at WAG 6. However, evaluation of historical water level records available for 118 WAG 6 wells or piezometers revealed an average maximum (i.e., average worst case) water table fluctuation of 6.67 ft. This suggests that the water table could, on average, fluctuate 6.67 ft annually across WAG 6. Although the historical data reflect that water level fluctuations vary with topographic position, this provides a reasonable estimation of worst case conditions.

Overlaying the February 1990 potentiometric map (Fig. 3.13) with the top of bedrock surface presented in Fig. 3.7 (Sect. 3.2), shows that even during high water table conditions the water table occurs below the top of competent, unweathered bedrock. In other areas of WAG 6, the water table occurs in the regolith. As water table elevations decline (seasonally or with drought) the extent of bedrock exposed above the water table would increase and the saturated thickness of the regolith would decrease. Figure 3.14 shows areas where the water table occurs totally within the bedrock. This has implications with respect to groundwater flow, as will be discussed further in subsequent sections.

Recharge to groundwater is principally from precipitation (estimated to be 7 to 9% of annual precipitation) and, as such, occurs throughout the site. However, the undulating topographic relief and presence of intervening surface water drainages results in very localized shallow flow systems with classic proximal recharge and discharge areas all within WAG 6. Recharge areas coincide with topographically higher areas while discharge appears to occur along drainages and to WOL.

Head differences observed in well pairs and clusters for the most part confirm this assessment. In recharge areas, the shallow well of the pairs typically shows higher potentiometric head than the deeper well, indicating downward components of flow associated with recharge. Conversely, in discharge areas, such as along the unnamed surface water drainage bounding WAG 6 on the east, potentiometric head observed in the deep well of the pair exceeds that of the shallow well, indicating an upward vertical flow component characteristic of groundwater discharge areas.

Head differences observed in well pairs and clusters represent either upward or downward vertical gradients that can largely be related to the recharge-discharge relationship discussed. Vertical gradients observed range from 0.008 to 0.23 ft/ft and reflect the potential for both upward and downward components of flow. Vertical gradients suggest there exists the **potential** for vertical components of flow, but, as will be discussed further, site data suggest there is little or no vertical groundwater flow from shallow to deep zones, and the topographic relief at WAG 6 is sufficient to induce nearly all of WAG 6 recharge to remain in the shallow, uppermost part of the aquifer.

### 3.3.2.2 Unsaturated zone

The unsaturated zone at WAG 6 comprises the interval from ground surface to the water table and primarily consists of soil and saprolite, although, the uppermost competent bedrock is also locally unsaturated where it protrudes above the water table. This interval is significant because, by design, the majority of waste burial trenches terminate in the unsaturated zone. Groundwater occurs within the unsaturated zone as localized lenses of perched water and as transient perched water in the storm flow zone. This section discusses active processes in the unsaturated zone and trench hydrology.

**Perched water.** Perched water conditions have been observed locally within the unsaturated zone in generally isolated wells and piezometers. Perched conditions are not unexpected due to the nature of the regolith (as previously described) and due to the number of waste disposal trenches that commonly retain infiltrating water, creating a bathtubbing effect. However, well control suggests these perched zones are of limited extent (generally only in the vicinity of the well where encountered) and are relatively insignificant to overall WAG 6 groundwater hydrology.

**Storm flow.** Recent research efforts at ORNL have emphasized the significance of the subsurface storm flow or interflow zone as a mechanism and pathway for shallow transport of infiltrating water and contaminants in the unsaturated zone. The storm flow zone consists of the macropores and mesopores in the root zone of shallow soil horizons and, depending on local conditions, comprises a shallow interval from ground surface to a depth of up to 6 ft (see Fig. 3.12). Conceptually, storm flow may occur wherever the infiltration rate and capacity of surface soils exceeds the peak rainfall intensity. Infiltrating water is then transmitted laterally downslope, following short flow paths towards adjacent drainages. Flow in this zone is transient (on the order of hours or days), and is generated in response to precipitation events of sufficient duration and intensity to produce a transient perched zone in the storm flow zone. Consequently, the storm flow zone can act as both a pathway and a secondary source of contamination. Leakage occurs along the base of the zone such that recharge to the water table occurs along the length of the saturated storm flow zone. Near perennial streams, the water table is considerably higher; in these areas, the storm flow zone and water table are indistinguishable. The storm flow zone and water table may also be connected locally on steep hillsides where wet-weather seeps can occur.

Research published by Moore (1988, 1989a) suggests that in undisturbed forest soil settings at ORNL, 90 to 95% of rainfall infiltrating into the subsurface (approximately 39 to 41% of annual rainfall) is conducted through the storm flow zone. This concept conflicts with the traditional belief that the majority of contaminant transport is by the steady, low-velocity movement of groundwater through the saturated zone to discharge points at streams. Other studies (Solomon et al. 1989) in Melton Valley have shown that the storm flow accounts for only an estimated 44% of total dry season discharge (groundwater discharge plus storm flow).

Attempts during the WAG 6 RFI to evaluate the storm flow zone failed to encounter it. This illustrates that, at WAG 6, the storm flow zone is at best, highly variable and likely is not laterally continuous. Considering the degree and extent of surface soil and saprolite disturbance and the occurrence of 11 distinct soil types at WAG 6, this would not be unexpected. Further, over 1000 piezometers, wells, auger holes and disposal trenches, and the 49 Trench French Drain perforate the storm flow zone, providing infiltration galleries that bypass lateral storm flow. Additionally, approximately 15% of the surface area of WAG 6 is presently covered with impermeable membrane ICM caps, which prevent recharge to storm flow zone in these areas. Where soil infiltration data are available within WAG 6, it appears the peak rainfall intensity would in many cases exceed the soil infiltration capacity, resulting in overland runoff.

These factors illustrate that considerable uncertainty exists, and that it is neither practical nor feasible to assess the impact of the storm flow zone on a site-wide basis. However, as evidenced by trench hydrology data, storm flow does occur at WAG 6, although likely along discontinuous, discrete flow pathways. Due to the uncertainties associated with characterizing the extent and significance of storm flow at WAG 6, recognition of the **potential** for storm flow is sufficient to support the remedial alternatives development process. Remedial strategies should include components that address storm flow.

**Trench hydrology**. Unlined waste trenches at WAG 6 are typically 10 ft wide by 50 ft long by 15 ft deep. Unlined auger holes are typically up to 5 ft in diameter and 23 ft deep. Although they were initially designed so that their bottoms would be above the water table, an interesting consequence of shallow trench waste burial operations is that precipitation tends to infiltrate into trenches either directly or via storm flow, creating bathtubbing conditions, wherein water perches in the trenches above the water table. In other areas of WAG 6, the water table intersects the trenches perennially and/or when seasonal or episodic high water table conditions persist, causing further inundation of the trenches.

Earlier studies (Davis et al. 1987; Solomon et al. 1988) reported on trench hydrology conditions prior to placement of the ICM caps. They found that 10% of monitored trenches were either bathtubbing or inundated perennially, while 84% displayed intermittent bathtubbing or inundation. Bathtubbing trenches provide for generation of leachate, which is either transported via storm flow or infiltrates downward through the unsaturated zone towards the water table. Where trenches are inundated by the water table, there is a greater chance for immediate release.

Therefore, an attempt was made as part of the WAG 6 RFI to evaluate the current state of trench/groundwater interaction after ICM cap construction. This information supports the screening of remedial alternatives intended to either depress the water table below the trench bottom elevations or limit infiltration to trenches thereby preventing bathtubbing.

To evaluate current trench/groundwater interaction, it was assumed that across the site, the average trench is 15 ft deep except in the biological trench areas, where trench depth ranges from 7 to 12 ft deep, (10 ft average depth was assumed). Based on these assumptions

(which are consistent with operational records) an elevation map was created to show the elevation of the bottom of the trenches in the vicinity of the disposal areas. The February 1990 potentiometric map, which illustrates high seasonal water table conditions (Fig. 3.13), was then overlain on the trench bottom map to identify areas where the water table is intersecting the trenches (i.e., exceeds the trench elevation). Using this method, a number of trench areas were determined to be inundated during high seasonal water table conditions, whereas others were clearly unsaturated. Figure 3.15 displays the resulting hydrologic conditions of trenches in February 1990. Actual trench water levels measured in intratrench piezometers confirm the mapped groundwater trench interactions. Where the trenches are clearly above the high water table but water was encountered in the intra-trench piezometer, bathtubbing is occurring. Because the high seasonal potentiometric surface map was used, it is believed Fig. 3.15 represents a worst-case scenario.

Of the 59 trench wells monitored, 21 were dry, 18 were inundated, and 20 displayed bathtubbing. As Fig. 3.15 shows, the French Drain had been effective in dewatering some trenches that otherwise would have been inundated. Comparing pre-ICM capping conditions with post-capping conditions shows the construction of Caps 4, 5, and 6 have apparently had little effect on preventing bathtubbing or preventing trench groundwater interactions (Ashwood and Spalding 1990). Capping has only been effective in two areas, Caps 2 and 8. It is believed that in these two areas, the caps were extensive enough to prevent upgradient recharge of the storm flow zone. Conversely, in other areas where trenches are above the water table (most of which were constructed on hillslopes) bathtubbing persisted, although direct infiltration was prevented by the caps. This suggests that storm flow is actively occurring in these areas and is maintaining bathtubbing conditions.

Ashwood and Spalding (1990) found that in Cap 8, located adjacent to WOL, two intratrench piezometers displayed inundated conditions indicative of interaction with the water table. Further, they found that the trench piezometer water levels fluctuated with lake stage fluctuations in nearby WOL. These two trenches are deeper than the other of Cap 8 trenches, which are typically less than 15 ft deep. Therefore, trenches less than 15 ft deep would not likely be impacted by lake/water table fluctuations because the trench bottoms lie well above the 100-year flood stage elevation for WOL (754 ft). These findings illustrate the need to prevent trench interactions with groundwater in low-lying areas adjacent to the lake.

#### 3.3.2.3 Aquifer geochemistry

Aquifer geochemical data indicate the groundwater at WAG 6 is stratified. Groundwater age-dating results provide support of the geochemical stratification observed. The combination of geochemical stratification and groundwater age-dating results indicates there is little or no circulation or mixing between the shallow, active flow component and deeper, more stagnant groundwater zones. From these results, it is believed that active groundwater flow at WAG 6 is limited to depths less than 150 ft.

As Fig. 3.16 shows, the aquifer appears to be stratified into three distinct zones: a shallow, neutral to acidic, calcium-bicarbonate type water; an intermediate zone of alkaline (pH > 8.5) sodium-carbonate or bicarbonate water; and a deep zone of alkaline to neutral, sodium-chloride type water typical of deeper groundwater observed elsewhere in Melton Valley at depths greater than 600 ft (Haase, Walls, and Farmer 1985). These different zones are shown on the nine WAG 6 hydrogeologic cross sections presented in Appendix 3A.

In general, pH and specific conductance increase linearly with depth (Fig. 3.17). The increased specific conductance and geochemical stratification are indicative of more mineralized water, believed to be developed due to longer residence time in the rock (thereby suggesting little or no flow occurs at depth).

The transitions are significant in that they appear to be distinct, indicating little or no circulation or mixing of waters between zones. Further, the aquifer stratifications apparently transect both structural and stratigraphic features (see hydrogeologic cross-sections in Appendix 3A). Groundwater geochemical zones are consistent across mapped thrust faults and the three distinct Conasauga Group formations encountered beneath WAG 6. It should be noted, however, that 86% of the wells with geochemical data are shallow; deeper stratification is based on limited deep well control.

Tritium is ubiquitous in the shallow groundwater at WAG 6 and within Melton Valley in general. Therefore, tritium can be used as both a tracer for contaminant migration and for age dating because it moves at the same rate as groundwater. Dreier and Toran (1989) reported tritium concentrations near or below detection limits in the WAG 6 HHMS intermediate and deep wells. Tritium was not detected in the four deep RFI monitoring wells. Conversely, in the shallow flow system near waste disposal trenches, tritium has been reported in groundwater at levels ranging up to 10,000,000 pCi/L. The overall lack of deep groundwater contamination by tritium further suggests that active groundwater flow is limited to shallow depths and that little or no circulation between deep and shallow components of the aquifer is occurring.

Measurements of heavy isotopes of oxygen (oxygen-18) and hydrogen (deuterium) in deep WAG 6 groundwater samples reported by Dreier and Toran (1989) further indicate a difference between the intermediate zone and deep zone chemistry. Heavy isotope signatures for deeper, sodium-chloride type waters reflect older, more stagnant water. Further details are provided in Appendix 3B.

Tritium, with a half-life of 12.3 years, decays radioactively to helium, an inert gas. Consequently, the measurement of relative ratios of helium and tritium can be used to date groundwater. Poreda, Cerling, and Solomon (1988) and Solomon (1988) conducted tritium-helium and krypton-85 age dating of WAG 6 groundwater samples collected at depths less than 126 ft and found that all groundwater samples analyzed ranged from 0.1 to 6.0 years in age, indicative of the very short residence times in the aquifer as well as the short flow path lengths. Since residence time is a function of depth and hydraulic gradient, WAG 6 groundwater was found to be younger in areas with higher hydraulic gradients and shallow

depths and older (i.e., at the high end of the age range reported) in areas of low gradient and greater depths. For comparison, carbon-14 age dating of deeper groundwater elsewhere in Melton Valley (Toran et al. 1991) show groundwater ages indicative of stagnant water (i.e., on the order of 3,000 to 40,000 years old) trapped in the rock at the time of deposition.

### 3.3.2.4 Aquifer hydraulic properties

Considerable site characterization research has been conducted at WAG 6, much of which has contributed information regarding site aquifer hydraulic properties. Within WAG 6, a total of 109 individual well slug tests, four tracer tests, and one pump test have been performed. The existing data have been incorporated to form the basis of understanding of hydraulic properties of the aquifer at WAG 6. Because of the nature of the geologic materials comprising the aquifer skeleton, aquifer properties vary between the soil, saprolite, and bedrock, and with depth.

This section summarizes pertinent information regarding aquifer hydraulic properties. A more detailed discussion is presented in Appendix 3B. Slug test hydraulic conductivity data are tabulated in Appendix 3D.

**Soil.** The infiltration rates of site soils are of significance in efforts to model the unsaturated zone. For purposes of comparison, infiltration rates (normally reported in units of in./hr) and hydraulic conductivities both are presented in units of cm/sec.

Site-specific infiltration data for WAG 6 soils have been acquired by Davis et al. (1984) and Clapp (1990). Their results showed infiltration rates ranging from 1.8E-3 cm/sec (Clapp 1990) to 6.0E-6 cm/sec (Davis et al. 1984), respectively. The three-orders-of-magnitude range is not unexpected, because soils vary widely as a result of both natural factors (such as degree or weathering, slope position, and vegetation) and demographic factors (such as soil removal, trenching, etc). It should be noted that the range of soil infiltration rates is exceeded by the peak rainfall intensity ($2.3E^{-3}$ cm/sec) reported by McMaster (1967). This suggests that in many areas of the site, overland runoff would prevail.

The total porosity of WAG 6 soils ranges from 42 to 50%. Davis et al. (1984) further suggest that in the shallow soil interval (0 to 8 in.) , soil effective porosity[1] is roughly equivalent to total porosity (i.e., effective porosity = 0.5), but for deeper soils, the effective porosity probably approaches 0.05 or less. The RCRA RFI Guidance (EPA 1989d) suggests effective porosities of 0.01 to 0.15 could be expected for clayey and silty clay soils typical of WAG 6.

[1]Whereas total porosity is a measure of total pore volume, effective porosity describes the interconnection of pores and the effective volume available for movement of water; consequently, this is a measure of the porosity that will contribute to fluid migration through a media.

**Saprolite.** Because groundwater occurs in the saprolite over much of the southern half of WAG 6, hydraulic properties including hydraulic conductivity[2], effective porosity, and saturated thickness are important factors in assessing the rate of groundwater movement through the saprolite in the saturation zone. Physical properties of saprolite are also significant as the majority of waste disposal trenches terminate in this interval in the unsaturated zone. Values of these properties have been determined from slug test data and from several aquifer tests that have been conducted at WAG 6 within the saprolite in the saturated zone.

Of the 109 slug tests performed in WAG 6, 25 were conducted in the saturated saprolite. These tests determined that hydraulic conductivities range from 3.7E-3 to 9.61E-6 cm/sec, with a geometric mean hydraulic conductivity of 2.0E-4 cm/sec. It should be noted that, based upon available site data, little difference is observed between the range of soil infiltration rates and hydraulic conductivities for the underlying saprolite at WAG 6. Using the geometric mean hydraulic conductivity and mapped saturated regolith thickness from Fig. 3.14, the transmissivity[3] of the regolith ranges from 0 (where unsaturated) to 0.21 $cm^2$/sec ($2.3E^{-3}$ $ft^2$/day).

Two tracer tests were performed in the saprolite at WAG 6. From a tracer test conducted in 1976 in the vicinity of the biological trenches near the southern boundary of WAG 6, Tamura et al. (1980) calculated an average linear velocity[4] of 0.4 to 0.6 m/day and an effective porosity of 2% to 3% (0.02 to 0.03) for the saprolite at this location. Further, it was observed that initial and maximum tracer breakthrough occurred in an observation well directly downgradient of the injection well, suggesting flow in the saprolite at this location is dominated by hydraulic gradient rather than relict structure.

Additional constant head tracer tests were performed in unsaturated saprolite at two test sites near the southwest end of the 49 Trench area (Dreier et al. 1987) adjacent to previously mapped exploratory trenches. Aquifer properties were not quantified, but the tracer results showed strong asymmetric distribution of the tracer in a preferred direction perpendicular to hydraulic gradient, but not quite parallel to mapped fracture orientations. This suggests that flow in the regolith at this location is controlled by a combination of secondary porosity features and hydraulic gradient.

**Bedrock.** There is virtually no primary matrix (i.e., intergranular) porosity in bedrock of the Conasauga Group; therefore, groundwater flow within bedrock is principally along

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[2]A measure of the rate at which water can move through a 1 $ft^2$ cross section of a permeable medium under a unit hydraulic gradient. Consequently, this describes the permeability of the medium.

[3]The rate at which water is transmitted through a unit width of the aquifer and a vertical thickness equivalent to the saturated thickness; it is equivalent to the product of hydraulic conductivity and saturated aquifer thickness.

[4]Defined on page 3-26.

secondary porosity features such as fractures and solution features. Consequently, aquifer properties determined from aquifer testing primarily describe the fracture network.

The results of 68 slug tests performed in bedrock at WAG 6 revealed a consistent trend of decreasing hydraulic conductivity with depth (Fig. 3.18). As shown, hydraulic conductivity varies two to three orders of magnitude at any given depth (as well as laterally). The slug test results show that hydraulic conductivity for the bedrock as a whole at WAG 6 ranges from 1.85E-3 to 1.90E-9 cm/sec, with a geometric mean hydraulic conductivity of 3.1E-5 cm/sec.

Little difference was observed between geometric mean hydraulic conductivity for Nolichucky and Maryville bedrock, although Maryville bedrock appears to exhibit a wider range of values. Both formations display a decrease in hydraulic conductivity with depth. This decrease is related to the density of open fractures with depth and is believed to limit active groundwater flow to shallow depths.

Both a tracer test and a pump test have been performed in the shallow Maryville bedrock at the ETF site. The results for both showed nonradial responses with both tracer and drawdown patterns that approximate the trend of fractures associated with two minor folds. Combining the results of the slug tests, pump tests, and tracer tests at the ETF site, Davis et al. (1984) calculated an effective porosity of 0.03 for the shallow Maryville bedrock at this location. Although this effective porosity is higher than default values suggested in the RFI Guidance (EPA 1989d) for fractured carbonate rocks (0.001) and assumed ranges of 0.0001 to 0.007 presented in various reports (Moore 1988; Vaughan et. al. 1985; Sledz and Huff 1981), this effective porosity was empirically derived using actual WAG 6 aquifer testing data. Therefore, it is believed this value is representative. From evaluation of the pump test data, Vaughan (1982) determined the saturated aquifer thickness to be on the order of 80 ft thick at the ETF site. Using this saturated thickness and the geometric mean bedrock hydraulic conductivity, the transmissivity of the bedrock portion of the aquifer is 0.09 $cm^2$/sec ($9.7E^{-4}$ $ft^2$/day). As hydraulic conductivity decreases with depth, aquifer transmissivity at depth would be much lower. No pump tests were performed in the Nolichucky bedrock within WAG 6. However, aquifer tests performed in similar bedrock in areas of Bear Creek Valley found comparable results in terms of response to pumping and parameter values. Storativity[5] for the bedrock is low, ranging from 0.01 to 0.001, with a geometric mean storativity of 0.005.

The results of aquifer testing in both the saprolite and shallow bedrock of WAG 6 indicate effective porosities of the same magnitude (ie, = .03). Because these values were empirically derived from WAG 6 aquifer testing, it is believed these values are representative.

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[5]The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in hydraulic head and is equal to the specific yield.

The transmissivities, storativities, and effective porosities reported indicate a low-yield aquifer with limited storage capacity principally related to fractures. Although the Conasauga Group bedrock aquifer does supply a few area domestic wells, the hydraulic conductivity of the aquifer is generally too low to encourage extensive use as a water supply aquifer. Yields from bedrock at WAG 6 are typically less than 1 gpm (based upon the less than 1 gpm pumping rates required to perform pump tests in these materials).

Overall, the nonradial responses to pumping, somewhat unpredictable tracer responses, and low aquifer yield (based upon pump test rates) reflects the complexity of the aquifer system and suggests that pump and treat remedial strategies likely would not be feasible.

### 3.3.2.5 Groundwater flow

The portion of precipitation that is not accounted for by surface runoff or evapotranspiration infiltrates into the subsurface and follows complex pathways in both the unsaturated and saturated zones, as described below. Figure 3.19 diagrammatically illustrates combined unsaturated and saturated flow paths at WAG 6.

**Unsaturated zone flow.** Except in areas of WAG 6 where wastes are in direct contact with the water table, a portion of the contaminant travel pathway occurs in the unsaturated zone. Contaminated fluids exiting waste disposal trenches or auger holes are generally under positive pressure. Thus, the downward hydraulic gradients will cause much of the contaminated water from trenches to flow from the trenches either via storm flow or downward percolation to the water table. After exiting the trenches, contaminated fluids move through the unsaturated zone along discrete but established features such as fractures, relict bedding planes, and soil fragipan horizons (Ammons et al. 1987).

Actual storm flow has not been quantified in any form at WAG 6. Where prevalent at WAG 6, flow along the storm flow zone would follow surface topography. However, as discussed earlier, the storm flow zone likely is laterally discontinuous at WAG 6 due to site disturbances; therefore, discrete storm flow pathways likely exist at WAG 6. Storm flow paths are short, on the order of 160 to 330 ft from points of infiltration to discharge at streams or seeps (Moore 1988). Also, because storm flow is transient, perched water in the storm flow zone will infiltrate downward in the unsaturated zone all along the storm flow path during and after precipitation events. Therefore, the storm flow zone likely serves as both a transport mechanism and a secondary source of contamination to the water table.

**Saturated zone flow.** Although the groundwater in the saturated zone at WAG 6 is a continuum from the water table to depth in bedrock, groundwater flow is complex because the geologic materials comprising the saturated zone (i.e., regolith and bedrock) are distinctly different.

Groundwater flow in the regolith occurs through matrix porosity (resulting from weathering) and along secondary porosity features such as fractures and relict bedrock structures, which may be either locally enhanced by solution enlargement or occluded due

to clay plugging or precipitation of iron and manganese oxides. Groundwater flow in the regolith is largely gradient dominated, particularly in the upper, more-weathered portion of the regolith, where the regolith behaves more like an isotropic media. Anisotropy increases with depth in the regolith as the degree of weathering decreases and the significance of relict bedrock structural fabric becomes more prevalent.

Groundwater flow in the unweathered bedrock is principally along secondary porosity features such as fractures, solution cavities, and faults. Bedrock flow paths are associated principally with strike-parallel and bedding plane fractures (trending generally east-west across the site) or with the intersection of bedding plane fractures with other conjugate fracture sets. The result is a tortuous, stair-stepping flow path in three dimensions that may vary with depth (as shown on Fig. 3.19). As explained in Section 3.2.2.1, up to five distinct fracture sets have been identified in WAG 6 bedrock.

Groundwater flow at WAG 6 is local rather than regional and appears to occur predominantly in the shallow subsurface, where it follows short flow paths from points of recharge to points of discharge. Groundwater discharges to intermittent streams within and adjacent to WAG 6, which ultimately discharge to WOL (Webster and Bradley 1988; Lomenick and Wyrick 1965). However, along the southern boundary of WAG 6, groundwater flows directly to the lake (Boegly et al. 1985).

Three conceptual groundwater flow diagrams were constructed across WAG 6 using potentiometric data for February 1990 (Figs. 3.20, 3.21, and 3.22). Two of the flow diagrams (A-A' and C-C') are oriented north-south across the site (i.e., perpendicular to formation strike) and the other (F-F') is oriented east-west across WAG 6 (parallel to formation strike). The three flow diagrams coincide with three of the nine hydrogeologic cross sections presented in Appendix 3A. The north-south diagrams show shallow flow from points of recharge in WAG 6 to discharge to WOL. The east-west flow diagram demonstrates that within WAG 6, flow is local, with recharge occurring in higher topographic areas and discharge occurring to intervening drainages within or adjacent to WAG 6.

Results of modelling (Tucci 1991) indicate 90 to 98% of all groundwater flow at WAG 6 occurs in the upper 50 to 100 ft of the aquifer, with virtually no flow occurring below a depth of 250 ft. From site characterization data presented in this report, a preponderance of evidence exists to supports these results:

- Geochemical data indicate the aquifer at WAG 6 is distinctly stratified, suggesting little or no circulation between zones. These data indicate the shallow active flow system is limited to the upper 150-170 ft of the aquifer.
- Groundwater age dating results show that shallow groundwater is young, on the order of 0.1 to 6.0 years, which indicates short residence times and short flow paths. Within the range given, the age increased with depth. This suggests that most active groundwater circulation occurs at shallow depths.

- Hydraulic conductivities decrease dramatically with depth (related to a decrease in fracture density), to the extent that active circulation at depth is improbable.
- Tritium analytical results for wells at WAG 6 show a lack of tritium contamination below a depth of 100 ft, further supporting a lack of active circulation at depth.

Some vertical flow component is possible, as indicated by the vertical gradients discussed previously. However, topographic relief at WAG 6 is great enough to induce virtually all recharge to remain in the shallow, local flow system. Therefore, if deep flow does occur within WAG 6, it probably involves only a very small fraction of WAG 6 groundwater (Boegly et al. 1985).

Flow directions and rates in saturated regolith and upper bedrock to a depth of 100 ft are the product of hydraulic gradient and the orientation, density, and interconnection of fractures. While it is accepted that strike-parallel flow dominates, it can be assumed that, to a depth of 65 ft in bedrock, flow is in the direction of hydraulic gradient, as represented by a water table potentiometric map (ORNL 1989). Depending on the local orientation of fractures, groundwater flow in bedrock may occur directly between two points. However, features that control groundwater flow in bedrock are so variable laterally that flow prediction between two points cannot be determined with certainty.

To provide an estimate of groundwater flow rates in both saturated regolith and bedrock in various areas of WAG 6, average linear groundwater velocities (or seepage velocities) were calculated along a number of hypothetical but representative flow lines (Fig. 3.23). Average linear velocity was determined by:

$$\text{Velocity} = \frac{\text{(hydraulic conductivity x hydraulic gradient)}}{\text{effective porosity}}$$

An effective porosity of 0.03 was used for both regolith and bedrock (as equivalent values were empirically derived from aquifer testing conducted in the regolith and bedrock within WAG 6). Geometric mean hydraulic conductivities for regolith or bedrock were determined by using the appropriate hydraulic conductivities (i.e., only conductivities measured for the saprolite or uppermost 50 ft of bedrock were used) for each aquifer unit along or near each flow line shown on Fig 3.23. The hydraulic gradient was determined from the February 1990 potentiometric map (Fig. 3.13). In areas where mapping indicated flow was solely in the shallow bedrock, only bedrock velocities were calculated. Conversely, in areas where mapping indicated saturated regolith conditions exist, flow rates were determined for both hydrologic units. Table 3.2 summarizes the average linear velocity calculations for each flow line shown on Fig 3.23.

Groundwater flow rates in the regolith range from 0.10 m/day to 2.28 m/day. The overall geometric mean linear velocity for the regolith is 0.33 m/day (386 ft/year). This value compares well with the average mid-season flow rate of 0.25 m/day (Webster and Bradley 1988) and the WAG 6 tracer test flow rate of 0.40 to 0.60 m/day (Tamura et al.

1980). The tracer test was conducted in the area of flowing Iz where the average linear velocity was determined to be 0.31 m/day.

Average linear velocities calculated for the shallow bedrock ranged from 0.04 m/day to 0.49 m/day. The overall geometric mean linear velocity for the shallow bedrock is 0.15 m/day (180 ft/year). This value compares well with the 0.18 m/day flow rate from the tracer test performed in the ETF area (Davis et al. 1986).

Flow velocities in the regolith are approximately twice those in the bedrock, owing to the order of magnitude difference in hydraulic conductivities between the two hydrologic units. However, flow in the bedrock actually may be considerably faster or slower than the velocities shown; flow in bedrock follows tortuous paths, and rates between two points are not directly proportional to the heads measured at any two points (Moore 1988). In areas where hydraulic gradient direction is parallel to strike and a preferential fracture flow path, flow rates may be significantly faster than areas where the hydraulic gradient is normal to strike, because in the latter case flow paths would be longer and more tortuous.

Groundwater flow in deeper portions of the aquifer in WAG 6 cannot be predicted with certainty, but it is estimated to be towards the south or southeast based upon mapping using WAG 6 deep well potentiometric data. Flow rates through deeper bedrock in the active zone of circulation are expected to be slower due to longer flow paths, lower hydraulic gradients, and decreasing hydraulic conductivity with depth.

### 3.3.3 Summary of Findings Regarding Groundwater Hydrology

Key findings and conclusions regarding the groundwater hydrology at WAG 6 are presented below.

- **Groundwater Occurrence and Flow**

— In the saturated zone, groundwater occurs under water table conditions in the regolith and/or shallow bedrock. No major aquitards or confining layers are present, so that groundwater is a continuum from the water table to depth in bedrock.

— Perched water occurs in the unsaturated zone at WAG 6 but appears to be of limited extent and significance.

— Transient storm flow occurs in the unsaturated zone at WAG 6. However, the storm flow zone is highly variable and likely discontinuous due to considerable removal or reworking of surficial soils, the lack of vegetative cover, ICM capping over approximately 15% of the site, and other physical features resulting from waste disposal activities. Therefore, storm flow paths are likely discrete but short from point of infiltration to discharge along streams or seeps within WAG 6.

— Considerable uncertainty exists with respect to the impact of the storm flow zone on WAG 6 hydrology, and it is neither feasible nor practical to characterize storm flow on a site-wide basis. However, storm flow serves as both a transport mechanism and a secondary source of contamination, and even the potential for storm flow dictates remedial alternatives that address the uncertainties.

— The water table configuration mimics topography, indicating groundwater flow towards WAG 6 surface water features and in an overall southerly direction towards WOL.

— The water table occurs below the top of unweathered bedrock over much of the northern half of WAG 6 for all or most of the year. Groundwater flow in these areas is solely through fractured bedrock. Conversely, the water table occurs in the regolith in the southern half of the site, such that shallow groundwater flow occurs both in the saturated regolith and uppermost fractured bedrock.

— The water table adjacent to WOL fluctuates proportional to lake stage fluctuations. Disposal trenches greater than 15 ft deep adjacent to WOL are inundated, and water levels in these trenches also fluctuate with lake levels. Shallower trenches are apparently unaffected.

— Groundwater flow diagrams (analogous to flownets) indicate groundwater flow is local rather than regional. Groundwater follows short flow paths within WAG 6, flowing from higher elevation points of recharge to discharge along intervening surface water drainages.

— Hydraulic conductivity in the regolith or bedrock varies by several orders of magnitude laterally and at any given depth, but shows a marked decrease with depth. The decrease in hydraulic conductivity is related to the decreasing density of open fractures with depth.

— Aquifer testing results indicate the bedrock aquifer is a low yield aquifer (less than 1 gpm), with limited storage capacity principally related to fractures; well yields are generally too low to encourage use as a potable water supply.

— Aquifer testing (pump and tracer tests) in bedrock showed considerable nonradial, anisotropic response, which illustrates the difficulty in predicting groundwater flow between two points with confidence and suggests that remedial alternatives involving groundwater extraction by pumping are likely to prove ineffective.

— A preponderance of evidence exists to support the conclusion that a majority of groundwater flow at WAG 6 occurs in the upper 50 to 100 ft of the aquifer with virtually no flow occurring below 250 ft.

— Groundwater flow in the regolith, where saturated, is through a combination of matrix porosity and secondary porosity features and generally is expected to follow mapped hydraulic gradient on a larger scale. However, the degree of anisotropy increases with

depth in the regolith in proportion to the degree of weathering. Consequently, some uncertainty remains in predicting local groundwater flow between two points.

— In the unweathered bedrock, groundwater flow occurs along secondary permeability features, principally fractures. Principal groundwater flow direction in bedrock follows strike parallel and bedding plane fractures except where crossing secondary fractures with different orientations and lower heads. This results in tortuous, stair-stepping flow paths in three dimensions.

— Flow directions and rates in the saturated regolith and upper bedrock are controlled by a combination of the hydraulic gradient, and the orientation, density, and degree of interconnecting fractures. While strike-parallel flow dominates in the bedrock, it can be assumed that on a larger scale, flow is in the direction of hydraulic gradient as determined from potentiometric mapping. Nonetheless, there is considerable uncertainty in predicting flow between two given points at WAG 6.

— Groundwater flow rates (average linear velocities) in the regolith range from 0.10 m/day to 2.28 m/day, with an overall geometric mean linear velocity of 0.33 m/day (386 ft/year). Flow rates in the shallow bedrock range from 0.04 to 0.49 m/day, with a geometric mean linear velocity of 0.15 m/day (180 ft/year). The difference is largely related to the order of magnitude difference in hydraulic conductivities between the two.

- **Existing Remedial Measures Performance**

— The 49 Trench French Drain installed in 1983 has been effective in intercepting groundwater and lowering the water table below trench bottoms over portions of the 49 Trench disposal area.

— Comparing pre- and post-ICM capping maps, the construction of ICM caps 4, 5, and 6 have apparently had little effect on dewatering trenches or preventing bathtubbing and/or inundation of the trenches (largely due to the position on slopes and limited size). Conversely, Ashwood and Spalding (1990) report that ICM caps 2 and 8 are effective due to the significant reduction of the storm flow recharge area upgradient of the trenches. None of the caps had any effect on groundwater levels.

## 3.4 SURFACE WATER HYDROLOGY

Surface water at WAG 6 is significant because, as described in Section 3.3, the majority of contaminant transport, either via storm flow or groundwater discharge, is to the surface water features in and surrounding WAG 6. Because of this, surface water is a principal pathway for contaminant transport off of WAG 6 and is of concern with respect to potential health risks associated with exposure. Consequently, an understanding of surface water dynamics at WAG 6 is integral to delineation of the nature and extent of contamination, fate and transport of contaminants, and assessment of risk to receptor populations.

This section presents a summary description of the surface water hydrology of WAG 6 and the water bodies that receive surface water drainage. The section is organized into four subsections. Section 3.4.1, Regional Surface Water Setting, details the drainage features of WAG 6 and characterizes the receiving waters impacted by contaminants released from WAG 6. Section 3.4.2, Stream Flow Data, summarizes the available WAG 6 stream flow data, including the continuous measurements of flow, storm events, and sporadic measurements of dry-weather flows. Section 3.4.3, Precipitation and Runoff Relationships, summarizes the runoff characteristics of the WAG 6 basins based on analyses of available stream flow data and results of previous studies. This section also describes WAG 6 runoff processes, storm response, and stream base flow characteristics. A detailed discussion of surface water hydrology at WAG 6 is presented in Appendix 3C.

### 3.4.1 Regional Surface Water Setting

WAG 6 is situated on a hillside within the WOC basin just north of WOL, which is an impounded segment of WOC. Outflow from WOL is controlled at a dam located about 0.6 miles upstream of the confluence of WOC and the Clinch River. All of the WAG 6 area drains into the WOL floodplain either directly or via the several drainages located within the WAG 6 boundary and along its eastern boundary. WOC joins the Clinch River at Clinch River Mile 21.0. The receiving waters of WAG 6 are the EWB, WOL and the WOC Embayment, WOC, the Clinch River, and an unnamed tributary to WOC that flows along the eastern side of WAG 6. Each of these is described further in Appendix 3C.

#### 3.4.1.2 Site Drainage Characteristics

The existence of several streams located within WAG 6 results in short overland flow lengths. Land surface slopes vary from 20 to 57% around the ridges and from 2 to 12% in the valleys. Despite the modifications to the site vegetation, soils, and surfaces related to the site's use for disposal, no major changes have occurred in the overall topography of WAG 6, and runoff characteristics and drainage features of the site have remained consistent. However, several features constructed at WAG 6 have impacted the overall surface water hydrology of the site:

- The 49 Trench French Drain constructed in the central part of the site to intercept groundwater discharges directly to surface water drainages within WAG 6 via two outfalls at the termination of the north and east limbs. Although discharge from the north limb of the French Drain is intermittent and low (< 1.0 gpm), the east limb has sustained discharges to drainage DA ranging from 0.3 to 20 gpm.

- In April and May of 1989, as part of the ICM, six large areas (covering approximately 15% of the site) were capped with HDPE to reduce infiltration. Around the capped areas, trapezoidal drainage channels or berms were constructed. Channels are 1 ft deep and 1 ft wide at the bottom and have 3:1 side slopes lined with an impermeable membrane and 6- to 8-in. riprap. To avoid erosion from accelerated runoff from capped areas, conveyance channels and attenuation channels were installed as energy dissipators

(Eiffe et al. 1988). The conveyance channels lead to nearby streams; attenuation channels spread runoff over the land surface. Where these channels cross service roads, six old culverts were replaced with new culverts with increased hydraulic capacity. All culverts were designed to pass flows from a storm of 25-year frequency and 24-hr duration. Figure 3.24 shows the capped areas and their drainage features. The caps have increased the site's surface runoff volumes and the peak flow rates. Storm runoff volumes and rates have also been increased due to addition of other impervious areas such as tumulus pass and several buildings.

WAG 6 is divided into 10 subareas that define drainage areas associated with surface streams, bounded by topographic divides. These subareas, shown in Fig. 3.25, are described in detail in Appendix 3C.

### 3.4.2 Stream Flow Data

Stream flow data have not been systematically collected at WAG 6. However, limited data are available from past ORNL research activities and from the WAG 6 RFI surface water sampling events. Available data include short-term continuous flow and storm runoff measurements. These data are presented in Appendix 3C.

### 3.4.3 Precipitation and Runoff Relationships

#### 3.4.3.1 Components of runoff

Four runoff components are considered to contribute to stream flow in WAG 6. These include Hortonian overland flow, which occurs when the rainfall intensity exceeds the infiltration rates of the land surface; subsurface storm flow (described in Section 3.3); saturated overland flow, which occurs when precipitation falls on saturated slopes next to a stream channel; and base flow, which is the discharge of groundwater into the stream.

The relative amount of water contributed to stream flow by each of the runoff processes identified above is dependent on the physical characteristics of the individual drainage basins and precipitation. Whereas precipitation can be assumed to be equal across WAG 6, areal variations in site soils and land vegetative cover are highly variable across the site, as described previously. Because of these conditions, the relative amount of water contributed to stream flow by each of the four runoff processes cannot be determined with certainty and therefore have not been quantified.

#### 3.4.3.2 Storm hydrographs

The storm hydrographs (presented in Appendix 3C) are representative of the responses of WAG 6 basins to storm rainfalls. While it is not possible to separate the storm hydrographs into each of the four runoff components described above, it is possible to determine the surface runoff and base flow components. Overland flow, saturated overland flow, and some of the subsurface storm flow will contribute to surface runoff. By drawing

a line between the flow rates at the beginning of the storm hydrograph and a point on the recession portion of the hydrograph, base flow can be isolated, and it can be seen that base flow represents a small portion of storm runoff volume.

The lag time of the storm event hydrographs, which is the time between the centroid of rainfall excess and the hydrograph peak, has been calculated to be 30 minutes. This computed lag time is typical of hydrographs dominated by overland flow and suggests that, during storm events, the majority of rainfall is conducted to streams via overland flow at WAG 6.

#### 3.4.3.3 Dry weather flows

Streams in WAG 6 are predominantly intermittent. Under high water table conditions during winter months, stream flow is sustained by discharge from the groundwater. During dry periods, when the water table elevation drops below the bottom of the stream channel or when the groundwater gradient toward the stream decreases, base flow ceases and streams become dry. Along their reaches, streams in WAG 6 are expected to behave as effluent (gaining) in the wet season or influent (losing) in the dry season. However, gaining and losing reaches for WAG 6 streams have not been determined.

### 3.4.5 Elements of Water Balance

The hydrologic water balance for the entire WAG 6 site can be simplistically described by:

$$P = RO + ET$$

where,

P = input to the system by precipitation
RO = losses from runoff processes (described in Sect. 3.4.3.1)
ET = losses from the system due to evapotranspiration

There is considerable uncertainty as to the exact magnitude of the various components of the annual water balance for WAG 6, mainly because of the lack of adequate measurements of ET and the runoff components. However, using the estimated average annual precipitation (52.2 in.) and evapotranspiration (30 in.) suggested by Moore (1989a), the average annual runoff would be 22.2 in. For comparison, the estimated mean annual runoff for the 1936-1960 period reported by McMaster (1967) for 19 small drainage basins in the Oak Ridge area ranged from 21.7 to 25.9 in.

A water balance study was performed as part of the WAG 6 fate and transport modelling (see Sect. 5) using the CREAMS model (a field-scale model for Chemicals, Runoff, and Erosion from Agricultural Management Systems) and input data for WAG 6 for the 1981-1990 period. Modelled yearly water balance values for this period are shown in Table 3.3. The surface runoff values given in Table 3.3 are assumed to include overland flow and saturated overland flow. Similarly, the deep percolation values are assumed to include both

groundwater discharge and subsurface storm flow. Total runoff (RO) is the sum of the surface runoff and deep percolation components.

For 1982 and 1984, years in which precipitation was close to the computed long-term average for WAG 6, surface runoff and ET values are comparable to those presented by Moore (1989a) and McMaster (1967). However, during dry years surface runoff decreases roughly 7%, accompanied by an approximate 7% increase in deep percolation. For the 1981-1990 period as a whole, ET accounts for 61% of the annual precipitation while total runoff (surface runoff plus deep percolation) is 39% of the average annual precipitation for this period. Surface runoff and deep percolation account for 23% and 16% of the annual water budget, respectively, or 59% and 41% of the total runoff (RO) component, respectively.

McMaster (1967) reported runoff (surface runoff and deep percolation components) varies seasonally, as follows:

October to December - 17%
January to March - 51%
April to June - 22%
July to September - 10%

The runoff is greatest in January through March, when ET is minimal, precipitation is high, and high soil moisture levels prevail. Lowest runoff occurs in July through September, when ET is high, precipitation is low, and soil moisture levels are low (thereby allowing for increased infiltration). Similar patterns are evident for wet versus dry years as evident from Table 3.3.

Separating the deep percolation into subsurface storm flow and groundwater discharge components cannot be done accurately given the inherent uncertainties previously described. Likewise, the exact amount of groundwater discharge that occurs as baseflow to on-site streams or discharge to WOL could not be determined. Estimates of groundwater discharge reported in the literature show considerable variation. For example, Moore (1989a) asserts that in the Oak Ridge area, groundwater discharge totals 1.26 in. (roughly 2.4%) of annual precipitation; most of it is lost as deep evapotranspiration, with the remaining portion discharged at springs and streams. Conversely, Davis et al. (1986, 1987) in a water balance study for the ETF site (July 1986 to June 1987) observed that 24% of precipitation could be accounted for by overland flow, with the remaining 76% attributed to combined evapotranspiration and groundwater discharge. Assuming 52 in. of annual precipitation and 30 in. of annual evapotranspiration, groundwater discharge using the Davis et al. (1986, 1987) percentages would suggest groundwater discharge accounts for approximately 10 in. annually (or 20% of annual precipitation).

In the northern and eastern part of the site groundwater discharge occurs entirely to the streams as baseflow. In the southwestern and southern parts of WAG 6, portions of the

groundwater discharges to site streams as baseflow and the remaining portion discharges to WOL beyond the WAG 6 boundary.

### 3.4.6 Surface Water Quality

The water in the streams is of the calcium-bicarbonate type, is moderately hard to very hard, and has low sodium, potassium, and chloride content. The pH of the water is between 6.6 and 7.6, indicating neutral to slightly acidic waters. Because surface water features on or adjacent to WAG 6 are receptors for contaminated water from runoff processes, the chemistry of the waters varies from location to location based on degree of contamination. The nature and extent of contamination of WAG 6 surface waters is discussed in detail in Sect. 4.

### 3.4.7 Summary of Findings Regarding Surface Water Hydrology

Key findings and conclusions regarding the surface water hydrology at WAG 6 are summarized below:

- The surface waters of WAG 6 include seven streams (4 principal streams and 3 secondary streams), all originating within WAG 6. Portions of the site drain into the EWB in the north, to the unnamed tributary on the east boundary, and to the WOL in the south.

- The waste management and research activities at the site since the 1970s have impacted the surface water hydrology of WAG 6. Flow paths have been altered due to construction of service roads, culverts, the 49 Trench French Drain, and the drainage features associated with the ICM caps over eight waste areas. This increase in impervious surfaces, plus clearing of some wooded areas, has increased overall flow rates and volumes; however, the increase is small.

- Streams in WAG 6 are intermittent. They are mostly dry during summer months except for some groundwater discharge.

- The stream density of the site is considered high; streams are short, the longest being about 1900 ft. Therefore, potential for dissolved contaminant migration from WAG 6 via surface waters is high.

- While steep slopes in WAG 6 promote fast response to rainfall events, high vegetative cover and variability in soil infiltration rates across the site moderate the storm response somewhat.

- The flow of the streams includes surface runoff (overland flow, saturated overland flow, subsurface storm flow) and base flow components. Adequate data do not exist to assess the relative percents of each these flow components. However, the storm hydrographs at the stream outlets at the site boundary exhibit storm peaks occurring within one hour

of the onset of the storm rainfall. Therefore it can be stated that overland flow and saturated overland flow dominate the storm hydrograph shape and the storm volume.

- The long term (1948 to 1990) annual precipitation as measured at the Oak Ridge Station is 54 in. The average annual precipitation for WAG 6 (ETF site) has been estimated to be 52 in. The average annual evapotranspiration is 30 in. The balance, 22 in., is the average annual discharge from WAG 6. The average annual amount of groundwater discharged to on-site streams and into WOL can not be accurately quantified. Estimated average annual recharge to groundwater ranges from 1.3 to 10 in. (3 to 20% of precipitation).

- Seasonal runoff distribution is proportional to variations in precipitation and evapotranspiration. During the wet season, precipitation is highest and ET is minimal, but soil moisture content is quite high such that runoff is high. Just the opposite occurs in dry periods; much of the precipitation infiltrates into the subsurface and runoff is low. In WAG 6, runoff ranges from 10% during dry periods (July through September) to 51% in wet months (January through March). Similar trends occur in wet versus dry years.

- The natural water in the streams is of the calcium-bicarbonate type, is moderately hard to very hard, and has low sodium, potassium, and chloride content. The pH of the water is neutral to slightly acidic (between 6.6 and 7.6).

## 3.5 ECOLOGY

This section of the report summaries the ecology of WAG 6 and describes the characteristics of the ecosystem components and critical habitats. This information will be used in later sections to determine potentially affected ecosystems.

This section is organized into three subsections. Sections 3.5.1 and 3.5.2 describe flora and fauna commonly found on the ORR, it is believed these same species are represented at WAG 6. Section 3.5.3 summarizes key findings regarding site ecology. Appendix 3E presents tables listing species found on the ORR.

### 3.5.1. Flora

The terrestrial ecology of the ORR has been summarized in several ORNL publications (e.g., Kitchings and Mann 1976; Boyle et al. 1982). Areas of WAG 6 that remain undisturbed are typical of habitat found throughout the ORR. However, most of the site has been altered because it is an active disposal area and an area for research and development of waste storage and disposal techniques. Much of WAG 6 has also been covered with temporary impermeable caps. Currently, the site consists primarily of fields planted in fescue and relatively young wooded areas along drainages, which have moderately steep terrain. The forested areas, shown in Figure 3.26, are generally oak-hickory hardwood stands interspersed among the areas used for waste disposal.

Plant communities at WAG 6 are characteristic of those found in the intermountain regions of Appalachia from the Allegheny Mountains to the southern extension of the Cumberland Mountains. The predominant oak-hickory association often includes stands of mixed yellow pines as well as other hardwoods. Nearly pure stands of yellow poplar (*Liriodendron tulipifera*) are found on well-drained bottomlands and lower slopes, while willow (*Salix* spp.), sycamore (*Platanus occidentalis*), and boxelder (*Acer negundo*) occur adjacent to streams and on poorly drained floodplains. A floral association, which often occurs in coves and on sheltered slopes, is comprised of species such as beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), magnolia (*Magnolia* spp.), buckeye (*Aesculus sylvatica*), and basswood (*Tilia americana*).

A field survey for rare plant species was conducted in May 1990 on WAG 6. This included a walkover of all currently undisturbed areas, but no rare species were found (Cunningham 1990a). In addition, in July 1990 a wetlands survey was conducted of the stream drainages within the fenced area at SWSA 6. Although a few wetland species were found, there was essentially no wetland community development.

### 3.5.2 Fauna

Approximately 60 species of reptiles and amphibians, 150 species of birds, and 40 species of mammals have been recorded on the ORR (see Appendix 3E). The great variety of wooded and open areas, as well as extensive edge communities, provide favorable habitats for a broad range of species. Individual habitat parameters or combinations of parameters can be used to predict the occurrence of species in different habitats. Small mammals may be confined to a single habitat type, while larger species or more mobile species may range over several types of habitats. Most of the animals found on the ORR are capable of adapting to a variety of habitats.

The fauna at WAG 6 are typical of those associated and maintained and forested areas. During a cursory survey of WAG 6 in June 1990, 33 bird species and 1 mammal species were observed (Kroodsma 1990). However, most of the bird, mammal, reptile, and amphibian species listed by Kitchings and Mann (1976) could be present at some time (even if only temporarily) on WAG 6.

No threatened or endangered bird or mammal species listed by the U.S. Fish and Wildlife Service or critical habitats are known to be present on the ORR. Therefore, none should be present on WAG 6. Some species listed by the State of Tennessee as threatened or endangered, such as the Cooper's hawk (*Accipiter cooperii*) and sharp-shinned hawk (*A striatus*), may occasionally hunt for prey on the site. However, these species are not known to nest on WAG 6, nor would they be expected to do so. A lack of suitable habitat and the ongoing disturbances on SWSA 6 would be preventing factors (Kroodsma 1990).

Aquatic communities on the ORR are typical of lake and stream systems in East Tennessee. Within SWSA 6, three relatively small, intermittent streams comprise the

principal aquatic communities. Distinct habitats within the streams consist of riffles, pools, and leaf packs. A habitat evaluation based upon comparisons with similarly sized streams on the ORR indicated that the east tributary did not contain sufficient quality habitat to maintain a fish population (Ryon 1990). The two branches of the west tributary had pools of sufficient depth, appropriate undercut banks, and established pool-riffle sequences to support some fish species; however, none were found during a fish survey in May 1990.

In September 1990, personnel from the Environmental Sciences Division surveyed the EWB by electrofishing and found five fish, all of which were bass (*Micropterus* spp.), and several frogs of undetermined species (Ryon 1990).

In May 1990, a survey was conducted of invertebrate species within the streams in SWSA 6 (Smith 1990). The three distinct habitat types (i.e. riffles, pools, and leaf packs), were sampled and the samples were examined for species listed by the State of Tennessee or the U.S. Fish and Wildlife Service as threatened or endangered. None of the listed freshwater invertebrates are known to exist on the ORR and none were found in the streams in SWSA 6.

### 3.5.3 Summary of Findings Regarding Ecology

Key findings and conclusions regarding the ecology of WAG 6 are presented below:

- A field survey of flora indicated that no rare plant species are present in SWSA 6.
- A wetlands survey along stream drainages within SWSA 6 indicated essentially no wetland community development.
- No threatened or endangered bird or mammal species listed by the U.S. Fish and Wildlife Services are present at WAG 6.
- No invertebrate species listed as threatened or endangered by the State of Tennessee or the U.S. Fish and Wildlife Service have been found in the streams within SWSA 6.

# Section 3 Tables

Table 3.1. Gen[illegible]d stratigraphic column at WAG 6

| Age | Group | Formation/Unit | Description | Thickness (ft) | Thickness at WAG 6 |
|---|---|---|---|---|---|
| MIDDLE CAMBRIAN | CONASAUGA GROUP | **Maynardville** Limestone | Upper (Chances Branch Mbr.) — limestone and dolomitic limestone in thick massive beds. | 140 | Not Present |
| | | | Lower (Low Hollow Mbr.) — dolomitic limestone in thick massive beds. Light gray to buff. | 200 | Not Present |
| | | **Nolichucky** Shale | Upper — shale and limestone in thin to thick beds. Shale dark gray or maroon. Limestone light gray, oolitic, wavy-bedded, or massive. | 60-140 | Not Present |
| | | | Lower — shale and limestone in medium to thick beds. Shale dark gray, olive gray or maroon. Limestone light gray, oolitic, glauconitic, wavy-bedded, and intraclastic. | 430-450 | 460 |
| | | **Maryville** Limestone | Upper — predominantly limestone, silty limestone, intraclastic, oolitic and fossiliferous. | 320-410 | 460 |
| | | | Lower — interbedded limey mudstones, silty limestones and shales. | | |
| | | **Rogersville** Shale | Shale and argillaceous limestone. Laminated to thin bedded, maroon, dark gray, and light gray. | 80-110 | 131 |
| | | **Rutledge** Limestone | Limestone and shale in thin beds. Limestone light to olive gray. Shale gray or maroon. | 100-120 | Unknown |
| | | **Pumpkin Valley** Shale | Upper — shale and calcareous siltstone. Laminated to very thin-bedded. Shale reddish brown, reddish-gray, or gray. Calcareous siltstone light gray or glauconitic. | 130-150 | Unknown |
| | | | Lower — shale and siltstone or silty sandstone. Thin-bedded. Shale reddish-brown or gray to greenish gray. Siltstone and silty sandstone light gray. | 175 | |
| LOWER CAMBRIAN | **Rome Fm.** | | Sandstone with thin shale interbeds. Sandstone fine-grained, light gray or pale maroon. Shale maroon or olive gray. Lower portion more shaley. | Unknown | Unknown |

**Table 3.2. Summary of calculated WAG 6 groundwater flow rates**

| | Average Linear Velocity (m/day) | |
|---|---|---|
| Flowline[a] | Regolith | Bedrock[b] |
| A | 0.21 | 0.13 |
| B1 | 0.10 | 0.25 |
| B2 | 0.24 | 0.22 |
| B3 | 0.34 | 0.34 |
| C1 | 0.16 | 0.10 |
| C2 | 2.28 | 0.10 |
| C3 | 1.62 | 0.10 |
| D | U | 0.07 |
| E1 | U | 0.1 |
| E2 | U | 0.12 |
| E3 | U | 0.09 |
| F | U | 0.34 |
| G | U | 0.42 |
| H1 | U | 0.34 |
| H2 | U | 0.12 |
| I1 | 0.16 | 0.10 |
| I2 | 0.31 | 0.31 |
| I3 | 0.29 | 0.18 |
| J1 | 0.31 | 0.16 |
| J2 | U | 0.49 |
| MEAN | 0.33 | 0.15 |

[a] - Correspond to labelled flowlines on Figure 3.23
[b] - For the uppermost 25 ft of bedrock only
U - Regolith is unsaturated in these locations

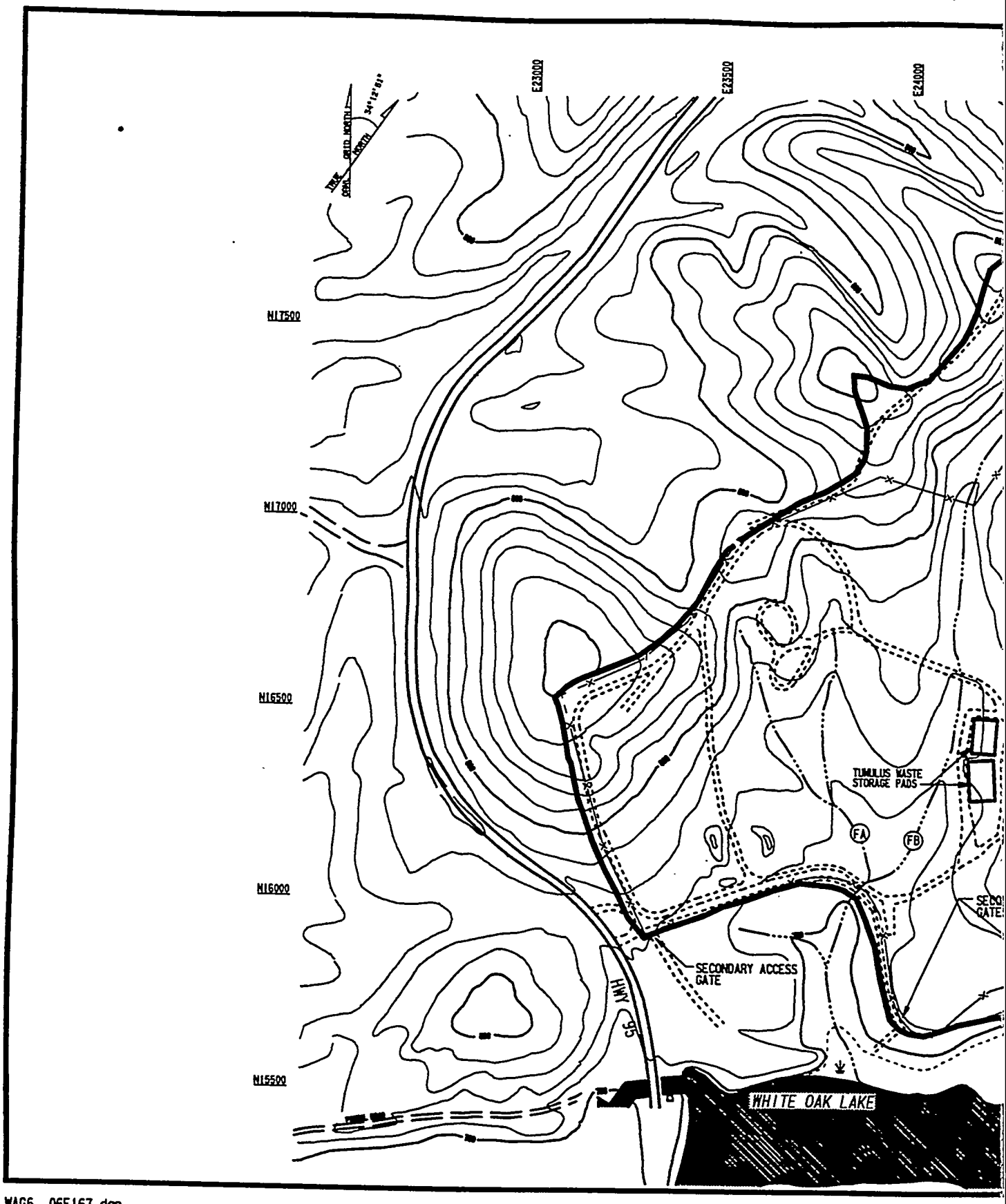
Note:
1 m/day ≈ 1197 ft/yr

**Table 3.3. Yearly water balance values**

| Year | Precipitation (in.) | Surface Runoff (in.) | ET (in.) | Deep Percolation (in.) | Surface Runoff Plus Deep Percolation (in.) |
|---|---|---|---|---|---|
| 1981 | 40.7 | 5.4 | 30.0 | 4.2 | 6.9 |
| 1982 | 52.6 | 11.7 | 30.3 | 10.9 | 22.7 |
| 1983 | 41.6 | 8.8 | 26.3 | 6.4 | 15.2 |
| 1984 | 50.9 | 14.3 | 29.3 | 7.5 | 21.8 |
| 1985 | 39.8 | 6.6 | 29.5 | 3.4 | 10.0 |
| 1986 | 38.5 | 7.2 | 26.7 | 5.1 | 12.3 |
| 1987 | 45.3 | 9.9 | 28.3 | 7.1 | 17.0 |
| 1988 | 45.1 | 10.8 | 28.5 | 4.8 | 15.6 |
| 1989 | 64.5 | 17.3 | 32.7 | 14.6 | 31.9 |
| 1990 | 63.5 | 19.2 | 32.4 | 11.6 | 30.8 |
| MEAN | 48.3 | 11.1 | 29.4 | 7.8 | 18.9 |

ET - Evapotranspiration

# Section 3 Figures




WAG6 06F167.dgn

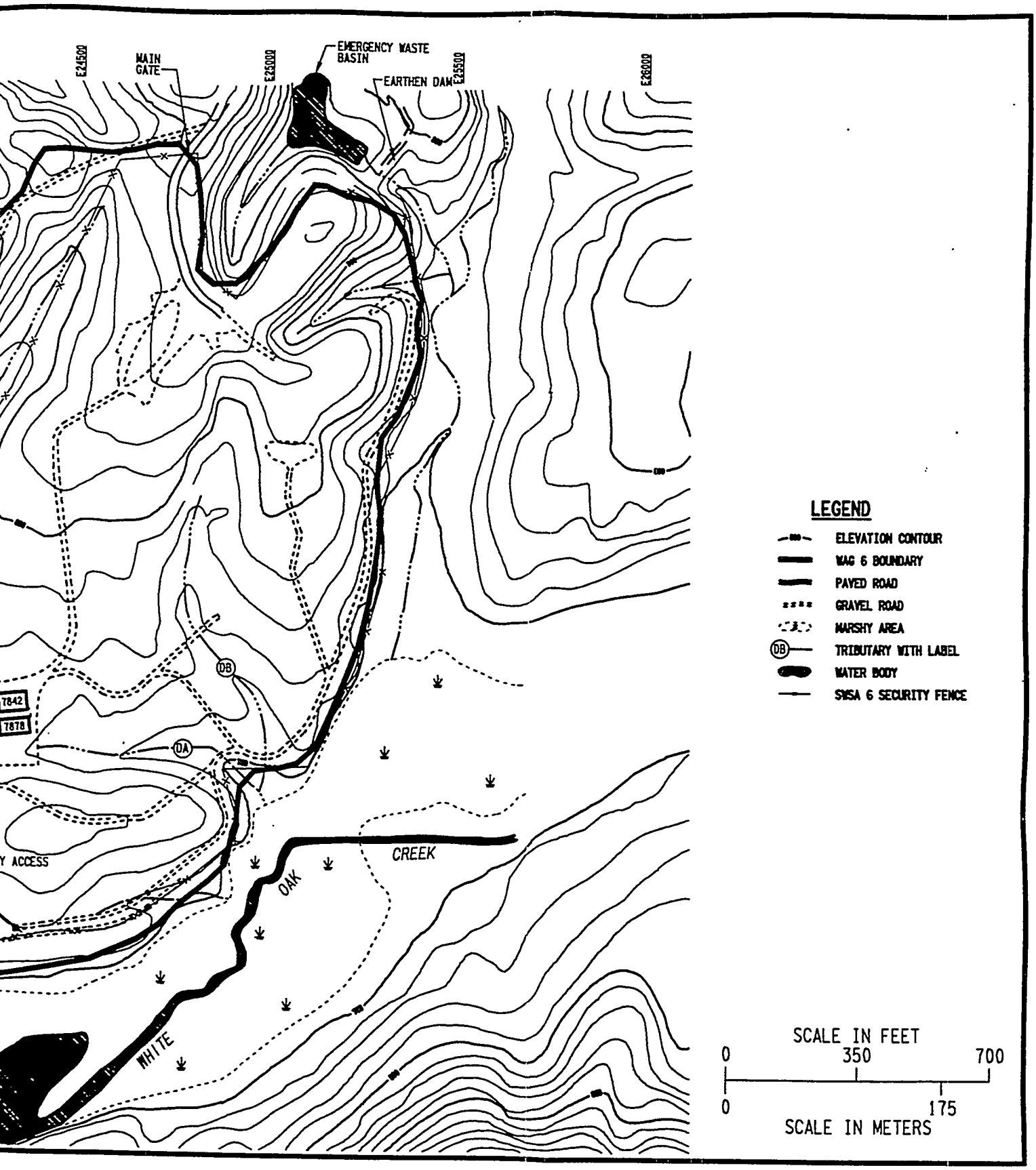
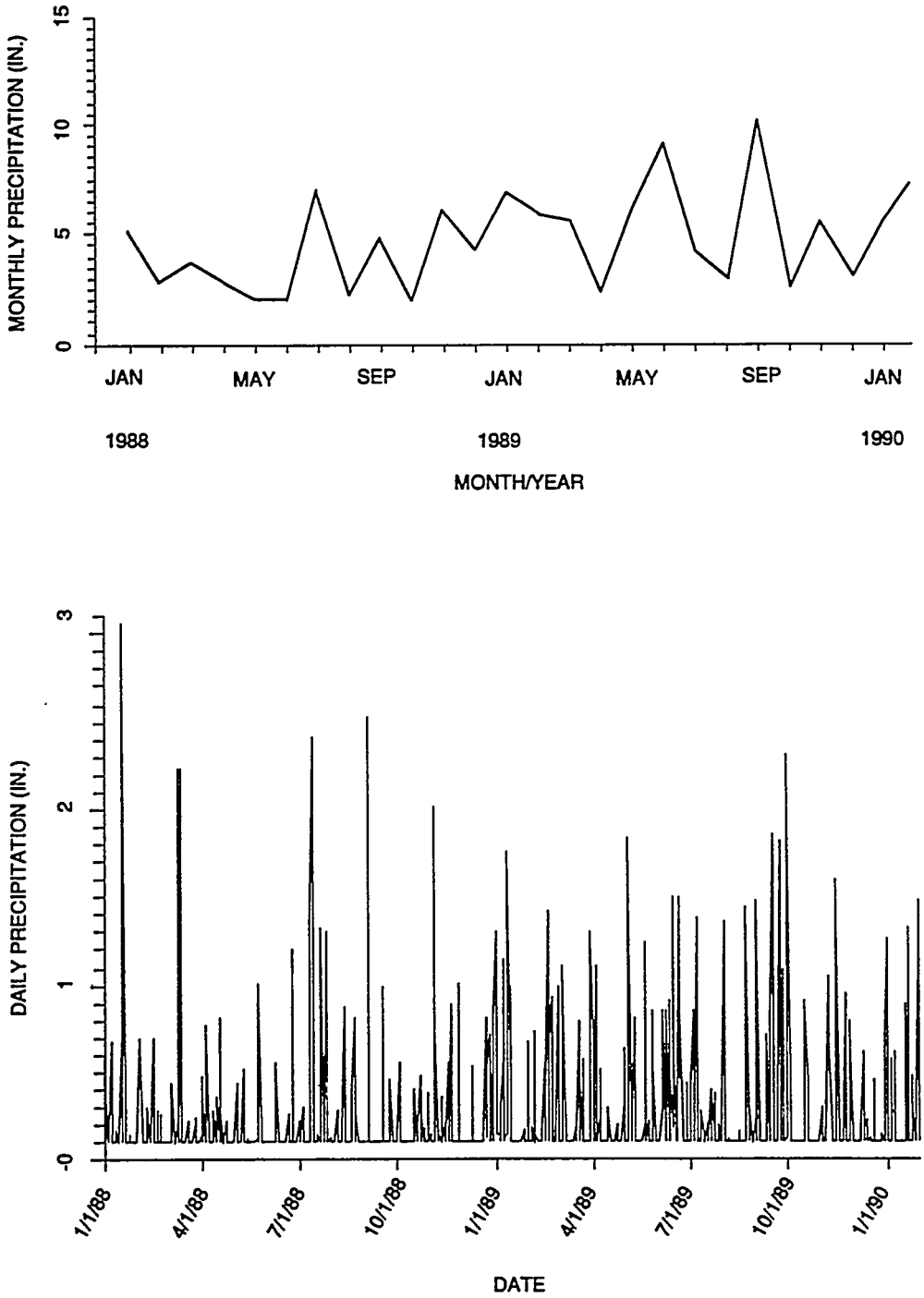


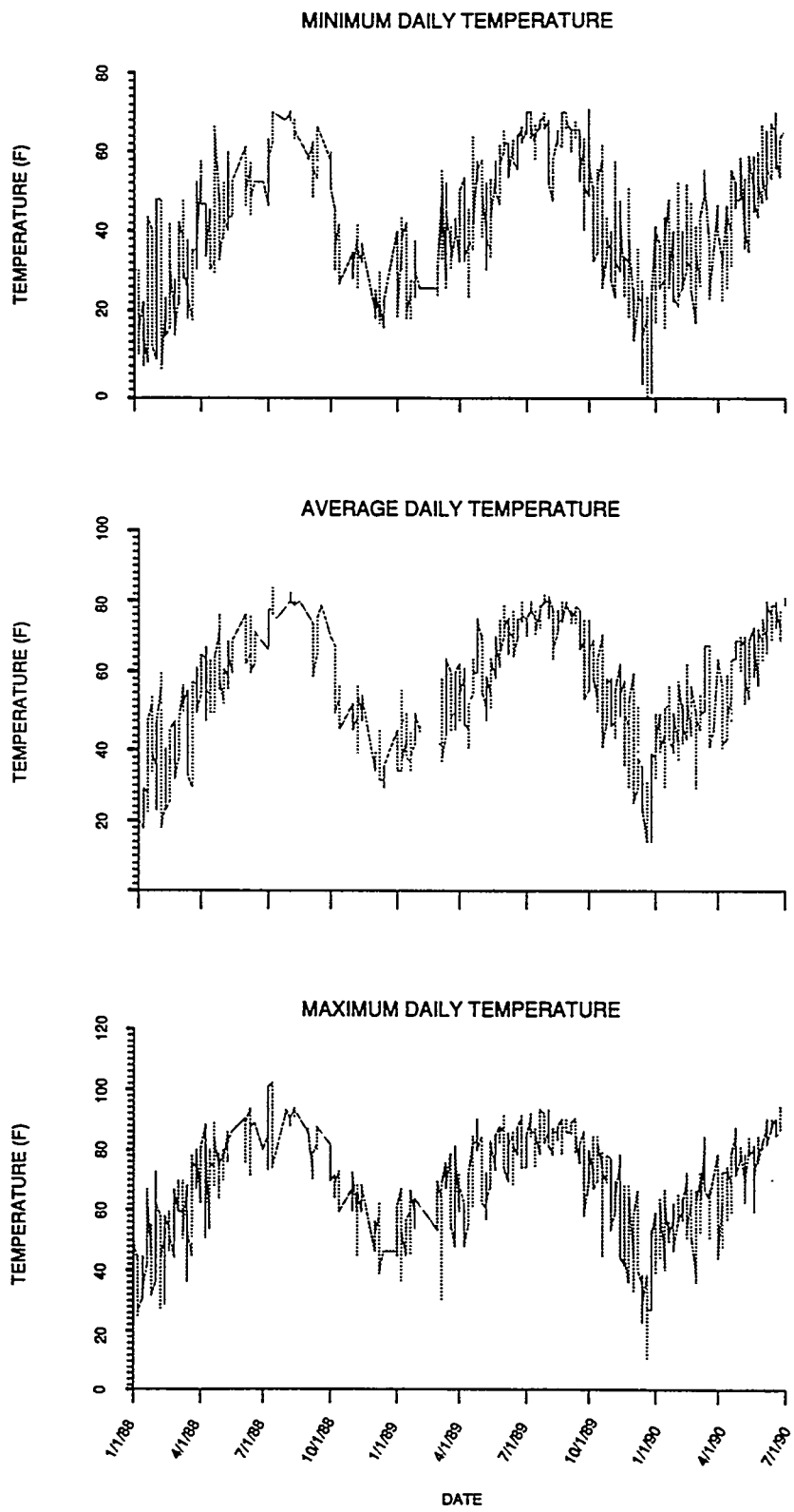

**Fig. 3.1. WAG 6 topography.**




*SOURCE:* GREGORY (1990).

**Fig. 3.2. WAG 6 daily and monthly precipitation for period 1/88 - 1/89 (as measured at the ETF station).**

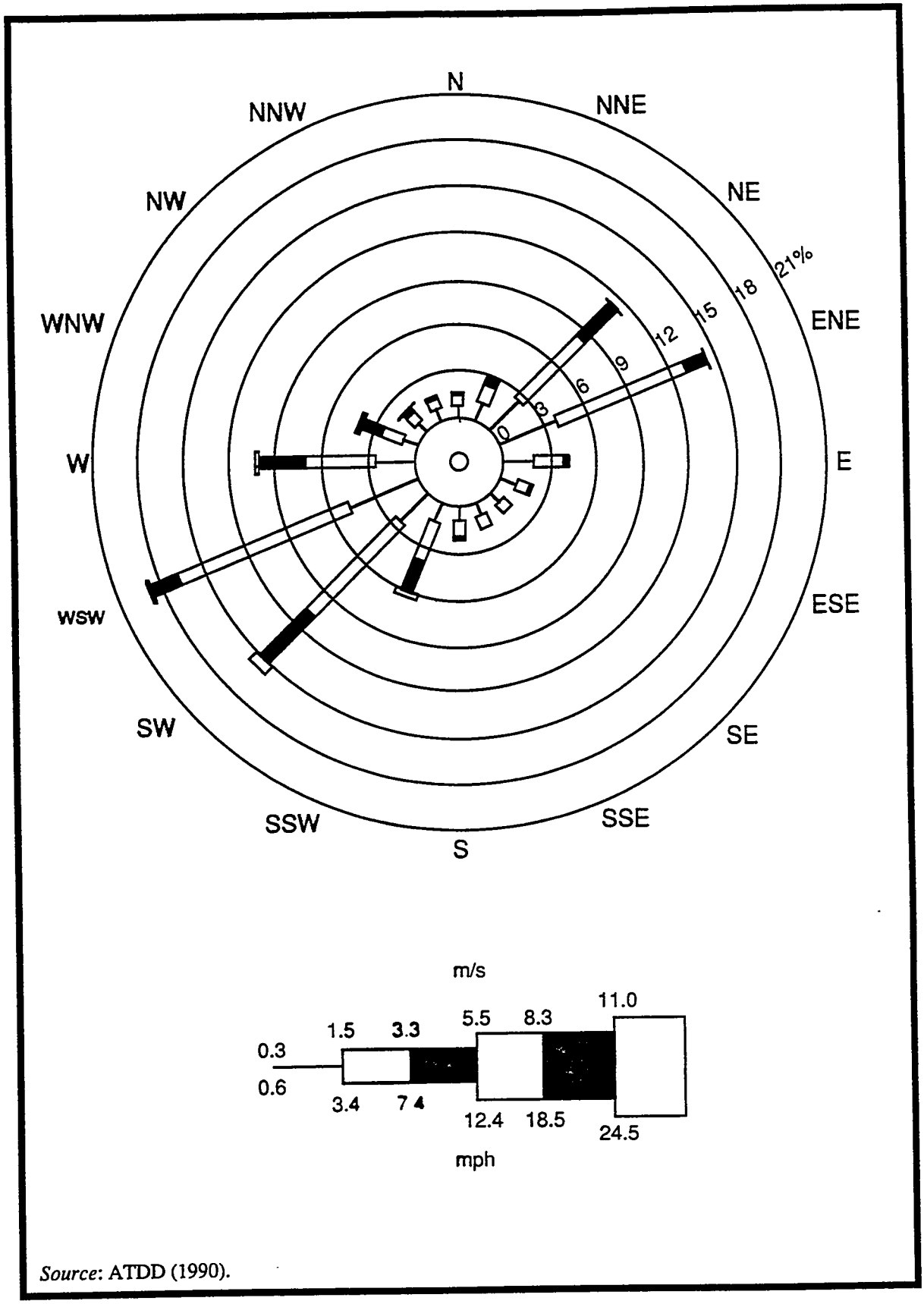
5.18F 4104.172
Adapted from WAG 6 06F141.DGN




*SOURCE:* ATDD (1990).

**Fig. 3.3 WAG 6 minimum, maximum, and average daily temperature for period 1/88-1/90 (as measured at the ATDD station).**

5.18E 4104.137
Adapted from WAG 6 06F144.DGN




*Source*: ATDD (1990).

**Fig. 3.4. Wind rose for period January 1988 through June 1990.**
Measured at meteorological tower A (at 300-ft level) in Melton Valley.

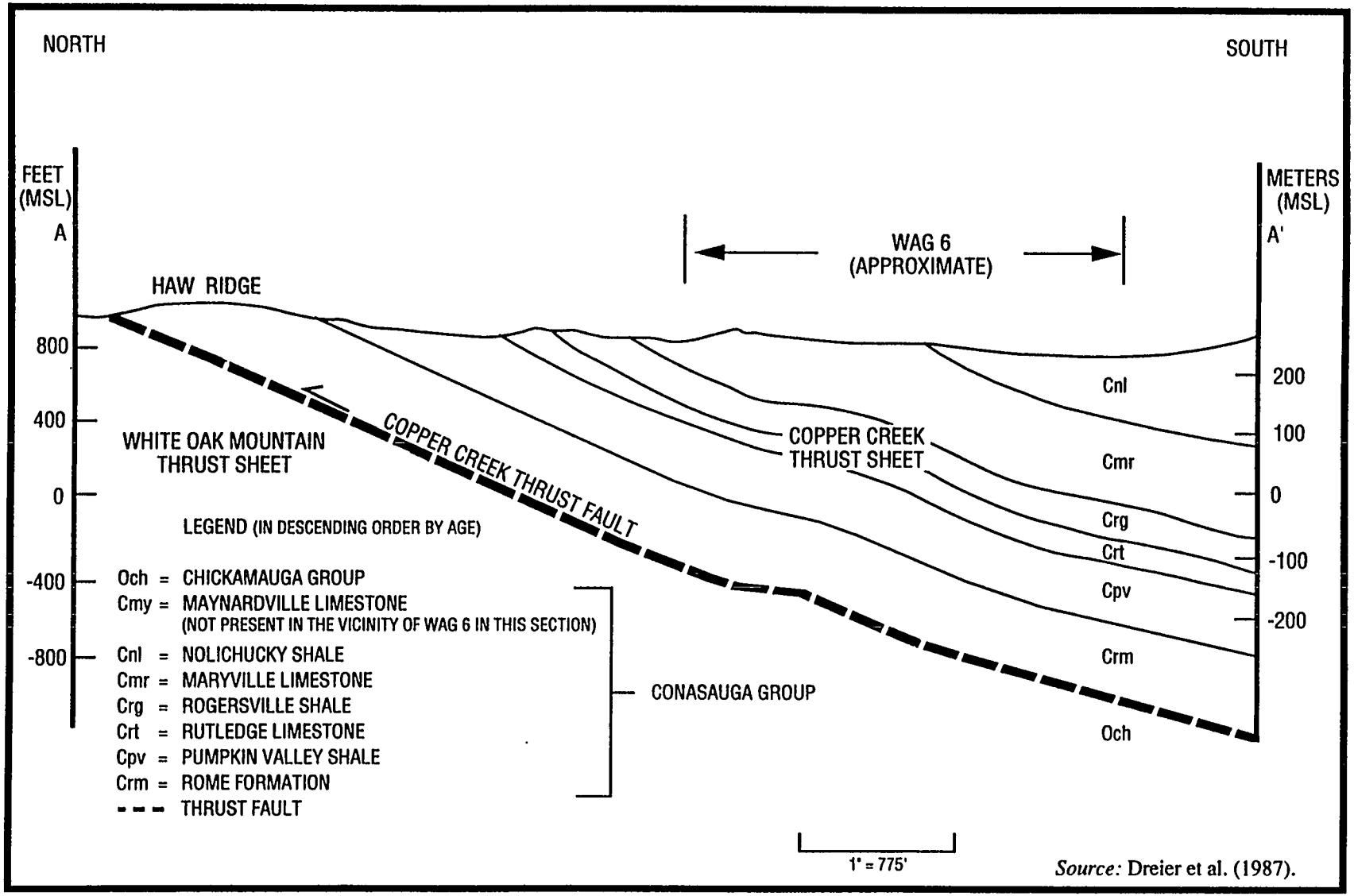
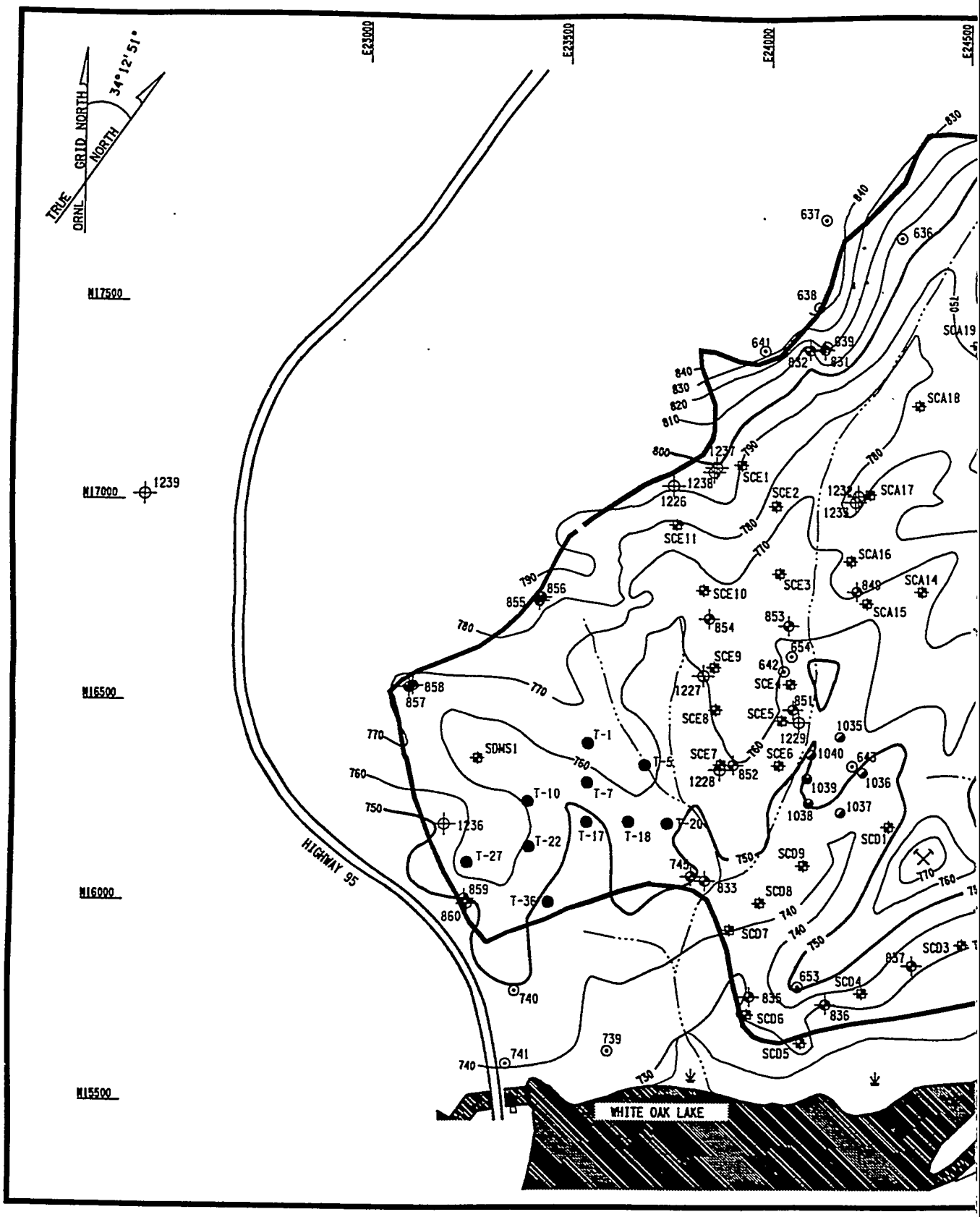



**Fig. 3.5. WAG 6 regional structural setting.**

5.18 4104.4




WAG6 W6BRE.DGN VI=FIG37

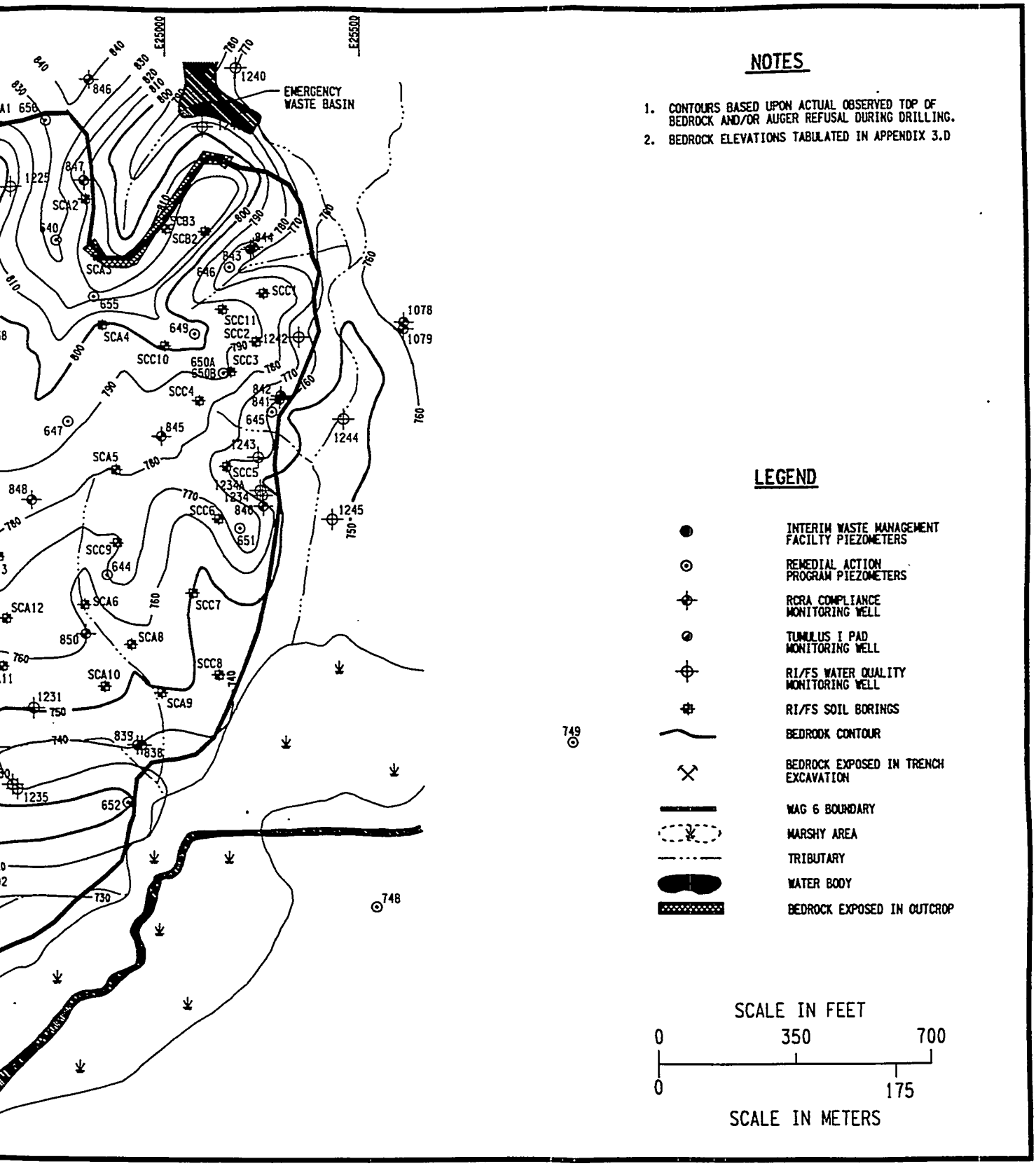
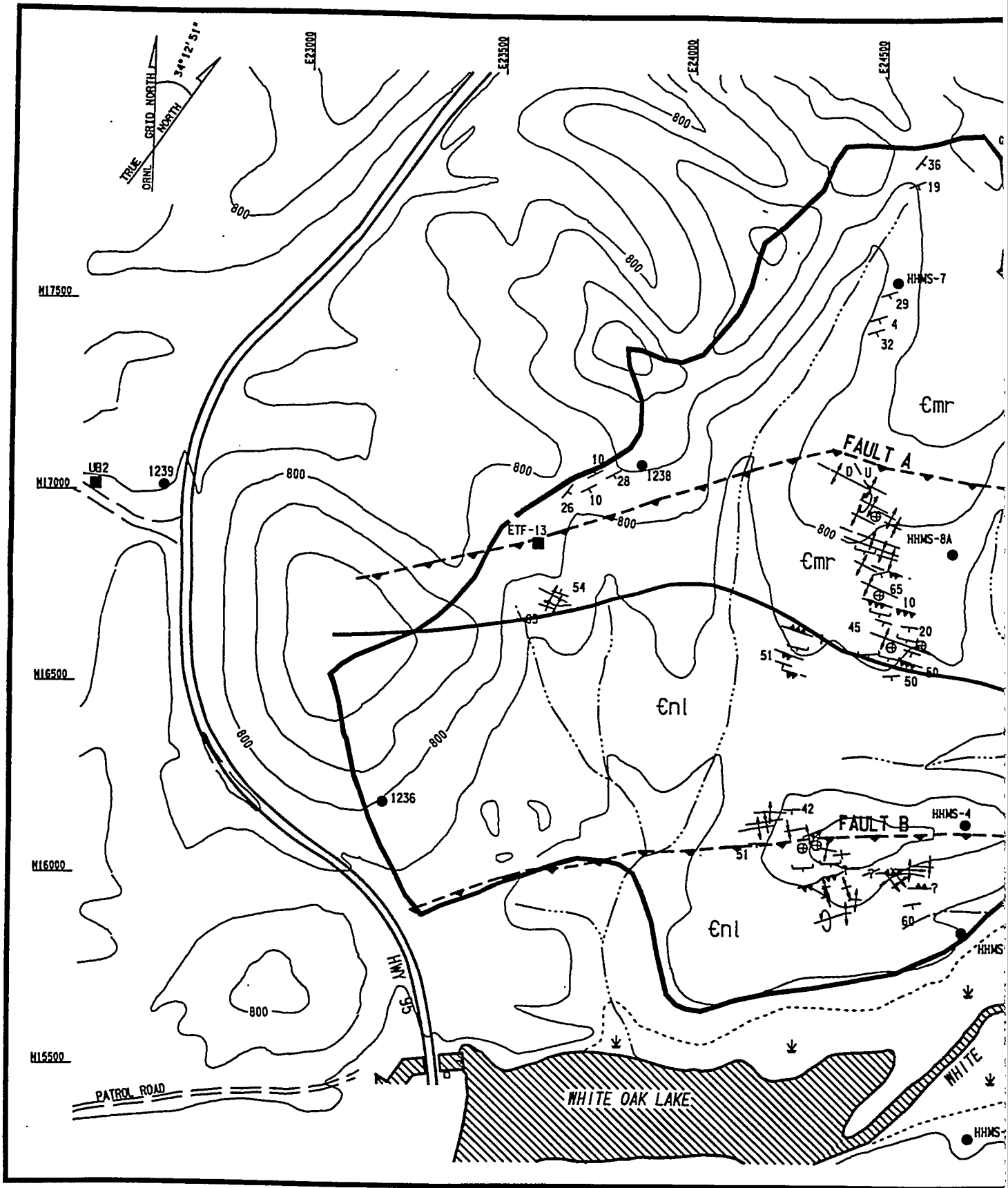



**Fig. 3.6. WAG 6 bedrock elevation contour map.**




WAG6 GE06.DGN

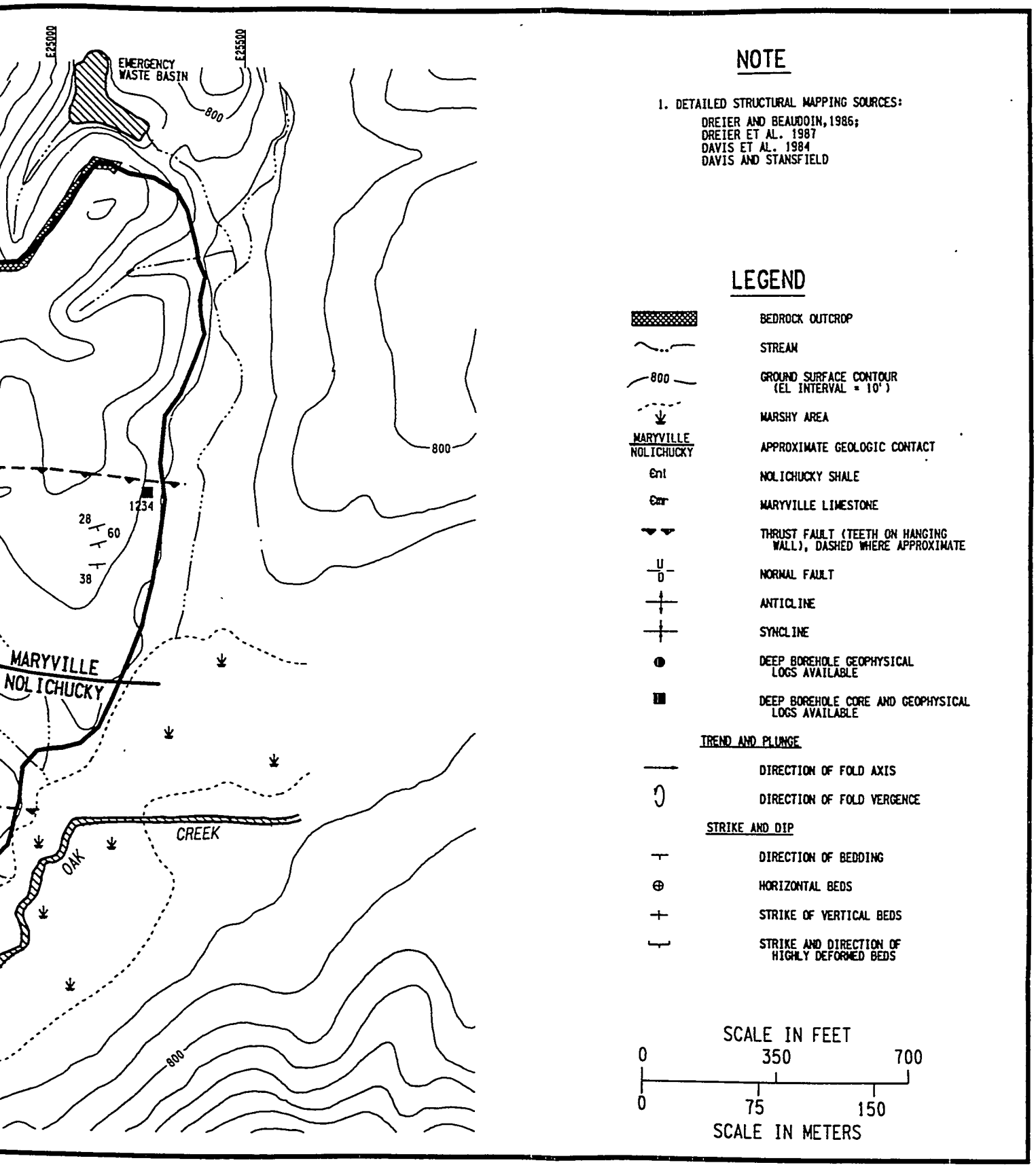
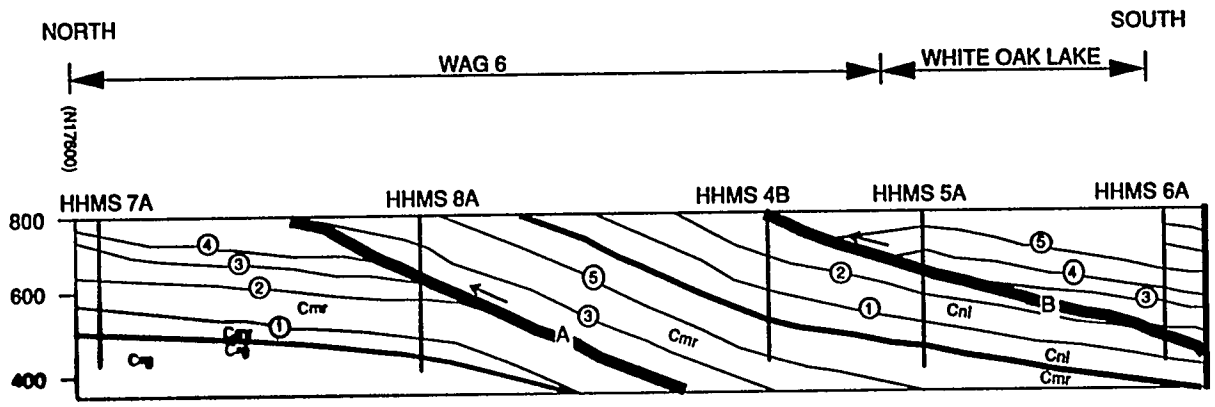



**Fig. 3.7. Geologic map of WAG 6.**




NOTES

1. STRIKE-PERPENDICULAR GEOLOGIC CROSS SECTION THROUGH SWSA 6 AND WHITE OAK LAKE.

2. STRATIGRAPHIC AND STRUCTURAL DATA FROM HHMS A BOREHOLES FROM SITE 4 THROUGH 8, WOL-1, ARE PROJECTED ALONG A GRID-EAST DIRECTION TO THE LINE OF SECTION.

LEGEND

| | |
|---|---|
| Cnl | NOLICHUCKEY SHALE |
| Cmr | MARYVILLE LIMESTONE |
| Crg | ROGERSVILLE SHALE |
| —①— | INTERNAL MARYVILLE AND NOLICHUCKEY STRATIGRAPHIC MARKER HORIZONS |
| ▬ | THRUST FAULTS |
| Cmr / Crg | FORMATION CONTACT |

*SOURCE:* DREIER & TORAN (1989)

**Fig. 3.8. WAG 6 north-south deep well structural cross section.**

5.18E 4104.141
Adapted from WAG 6 06F137.DGN

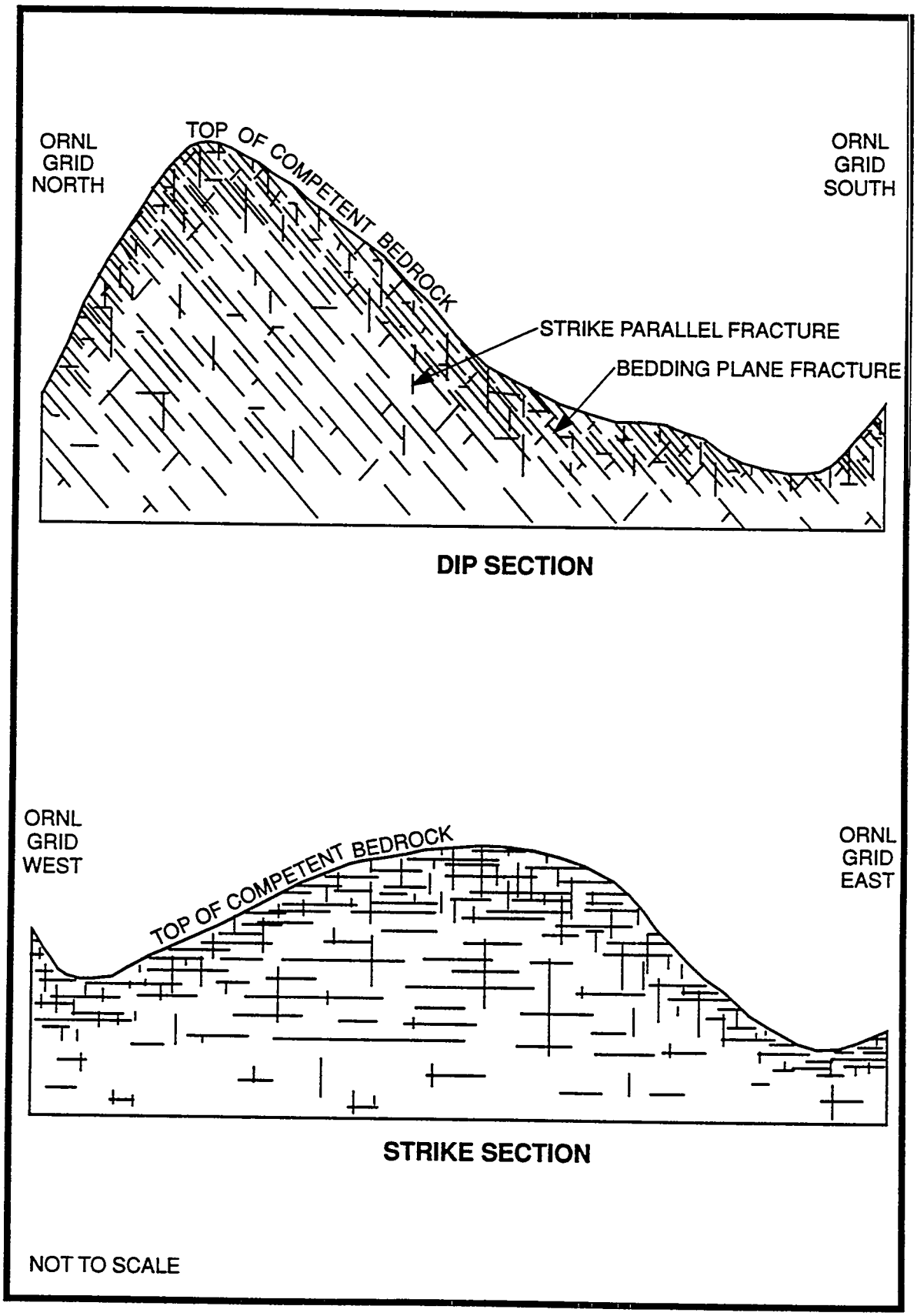
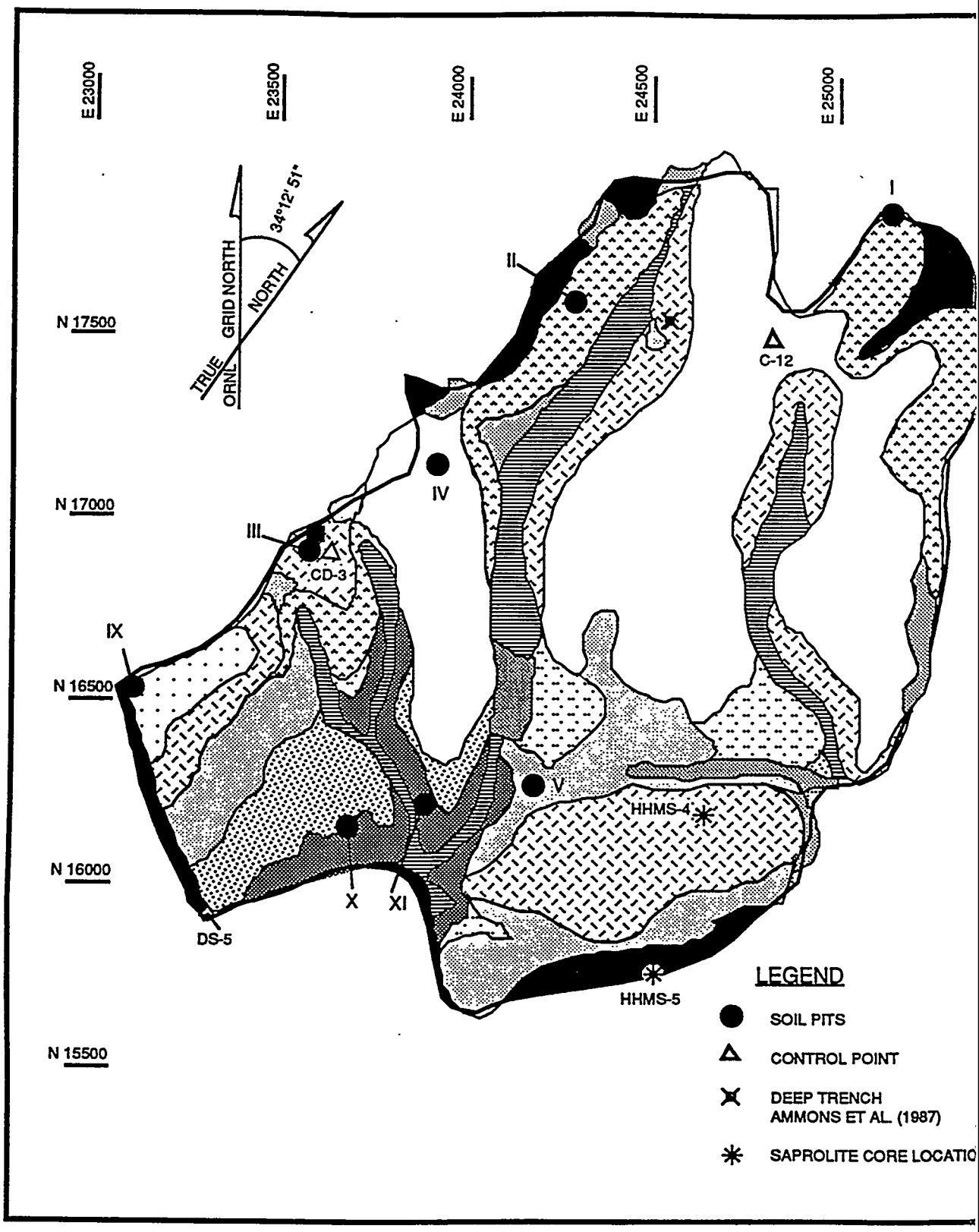



**Fig. 3.9. Conceptual diagram of bedrock fracturing** (Modified after Moore 1991).

5.18 4104.2

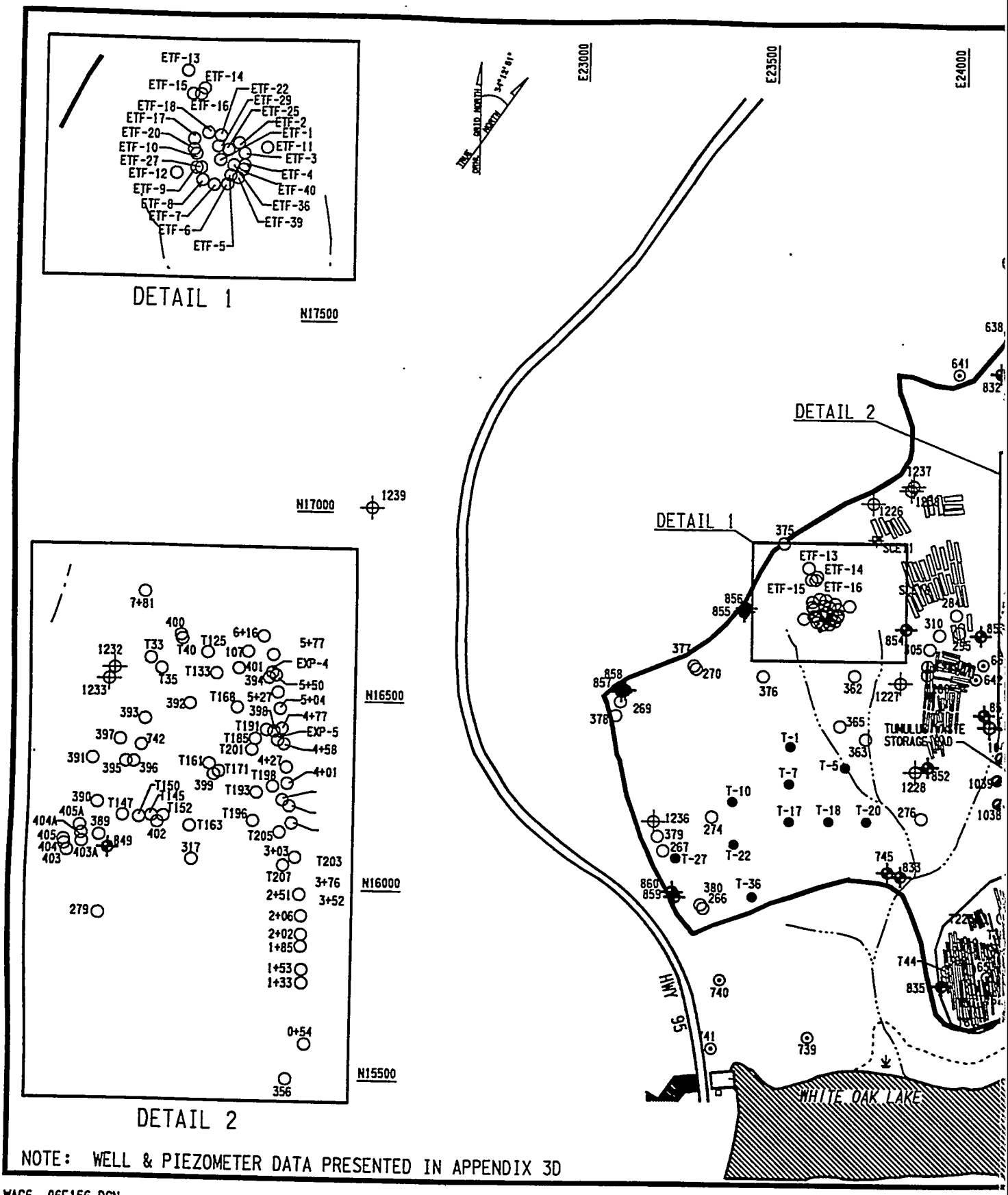



5.18F 4104.173
Adapted from WAG6 06F168.DGN

| MAP UNIT | SOIL TAXONOMY |
|---|---|
| 1 | TYPIC DYSTROCHREPTS; LOAMY-SKELETAL, MIXED, THERMIC, SHALLOW. |
| 2 | STEEP AND VERY STEEP SIDE SLOPES WITH DOUBLY CONVEX SLOPES. SOILS ARE MOSTLY TYPIC DYSTROCHREPTS; LOAMY-SKELETAL, MIXED, THERMIC. (BERKS-VARIANT SERIES). |
| 3 | LONG NARROW SIDE SLOPES WITH SLOPE GRADIENTS MORE THAN 12% AND NARROW DOUBLY CONVEX UPLAND SUMMITS. SOILS ARE MOSTLY RUPTIC-ULTIC DYSTROCHREPTS; LOAMY-SKELETAL, MIXED THERMIC (MUSE SERIES). |
| 4 | BROAD UPLAND SUMMITS AND BROAD SIDE SLOPES WITH SLOPE GRADIENTS BETWEEN 6 AND 12%, AND DOUBLY CONVEX SLOPE CONFIGURATION. SOILS ARE MOSTLY TYPIC HAPLUDULTS; CLAYEY, MIXED, THERMIC (MUSE SERIES). |
| 5 | FOOT-SLOPES WITH MOSTLY DOUBLY CONCAVE SLOPE CONFIGURATION. SLOPES RANGE FROM 6 TO 20%. SOILS ARE TYPIC FRAGIDULTS; FINE-SILTY, MIXED, THERMIC (LEADVALE SERIES) AND TYPIC HAPLUDULTS; FINE-SILTY, MIXED, THERMIC (SHELOCTA SERIES). |
| 6 | DRAINAGEWAYS WITH MOSTLY WET ALLUVIAL SOILS THAT CLASSIFY AS TYPIC OR AERIC FLUVAQUENTS; FINE-SILTY, MIXED, THERMIC (SERIES NOT DESIGNATED). |
| 7 | DRAINAGEWAYS THAT HAVE BEEN FILLED WITH DEBRIS FROM LAND CLEARING ACTIVITIES OR WITH EARTH MATERIALS FROM TRENCHING OPERATIONS (UDORTHENTS). |
| 8 | FOOT-SLOPE LANDFORMS THAT HAVE BEEN FILLED WITH DEBRIS FROM LAND CLEARING ACTIVITIES OR WITH EARTH MATERIALS FROM TRENCHING OPERATIONS (UDORTHENTS). |
| 9 | BROAD, NEARLY LEVEL UPLAND SUMMIT, PLUS SHOULDER AND SIDE SLOPES WITH GRADIENTS OF 6 TO 20%. THE SUMMIT SOILS FORMED IN LOESS/ALLUVIUM/SHALE RESIDUUM, WHEREAS THE SIDE-SLOPE SOILS FORMED IN ALLUVIUM/SHALE. SOILS ARE TYPIC PALEUDULTS; FINE-SILTY AND CLAYEY, SILICEOUS AND MIXED, THERMIC (TURBEVILLE SERIES). |
| 10 | LOW UPLAND WITH SLOPE GRADIENTS BETWEEN 6 AND 12% AND MOSTLY DOUBLY CONVEX SLOPE CONFIGURATION. SOILS ARE MOSTLY RUPTIC-AQUULTIC DYSTROCHERPTS; LOAMY-SKELETAL AND CLAYEY, MIXED THERMIC (SERIES NOT DESIGNATED). |
| 11 | TOE-SLOPES WITH SLOPE GRADIENTS OF 2 TO 6% AND DOUBLY CONCAVE SLOPE CONFIGURATION. SOILS ARE MOSTLY AQUIC HAPLUDULTS; CLAYEY, MIXED, THERMIC. (TUPELO SERIES) |

SOURCES: LIETZKE & LEE (1986)
AMMONS ET AL. (1987)

**Fig. 3.10 WAG 6 soil map.**




NOTE: WELL & PIEZOMETER DATA PRESENTED IN APPENDIX 3D

WAG6 06F156.DGN

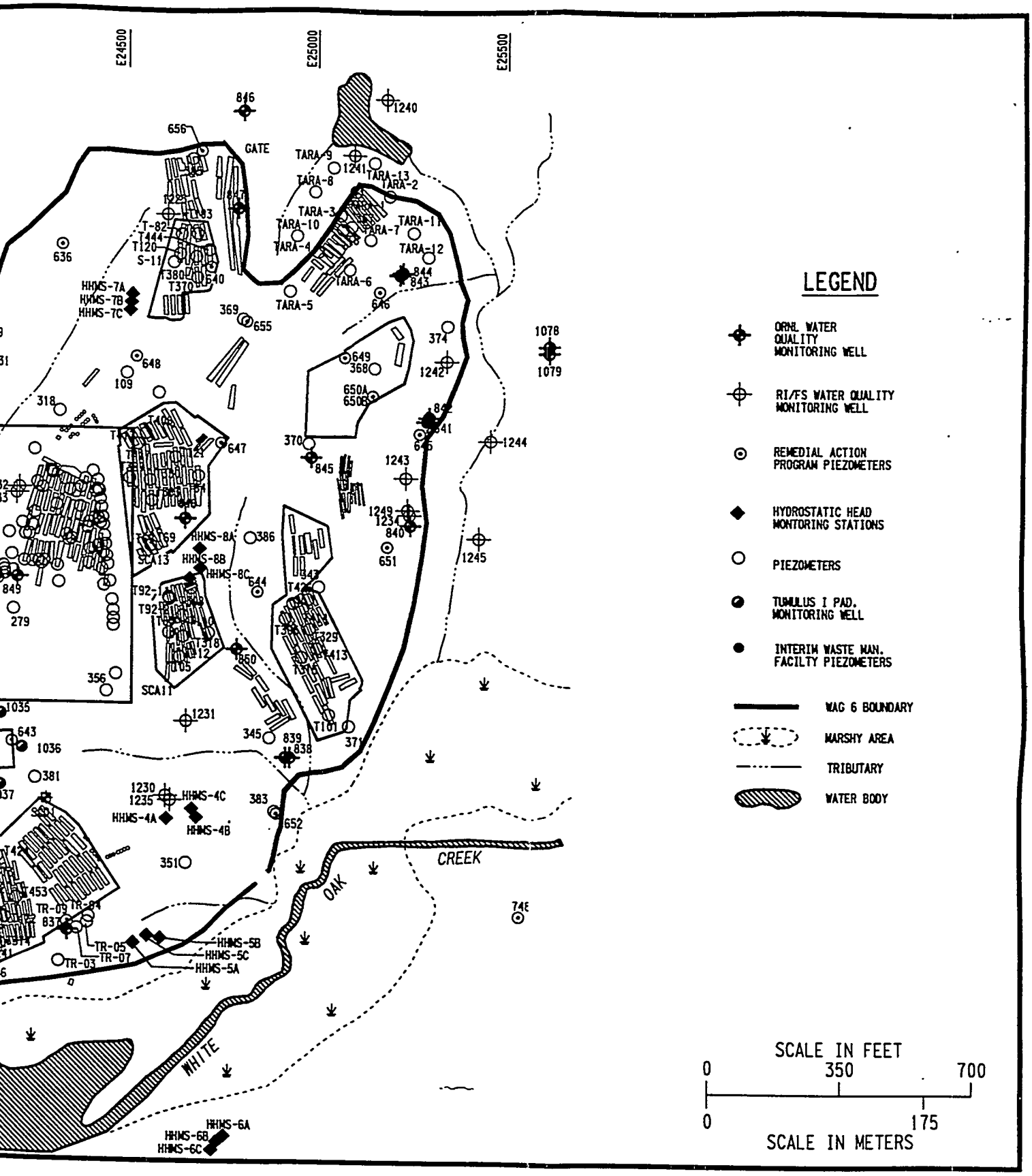
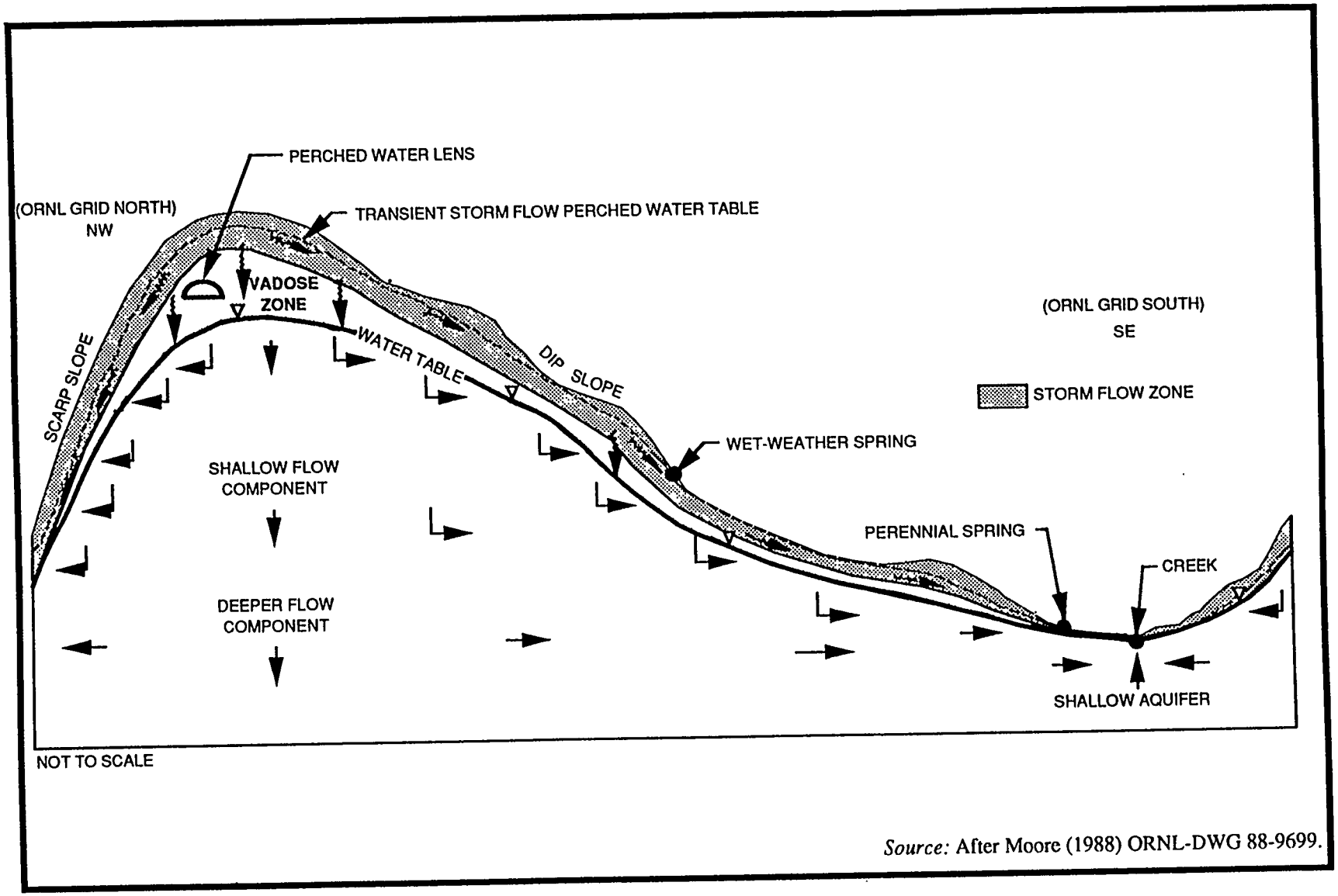


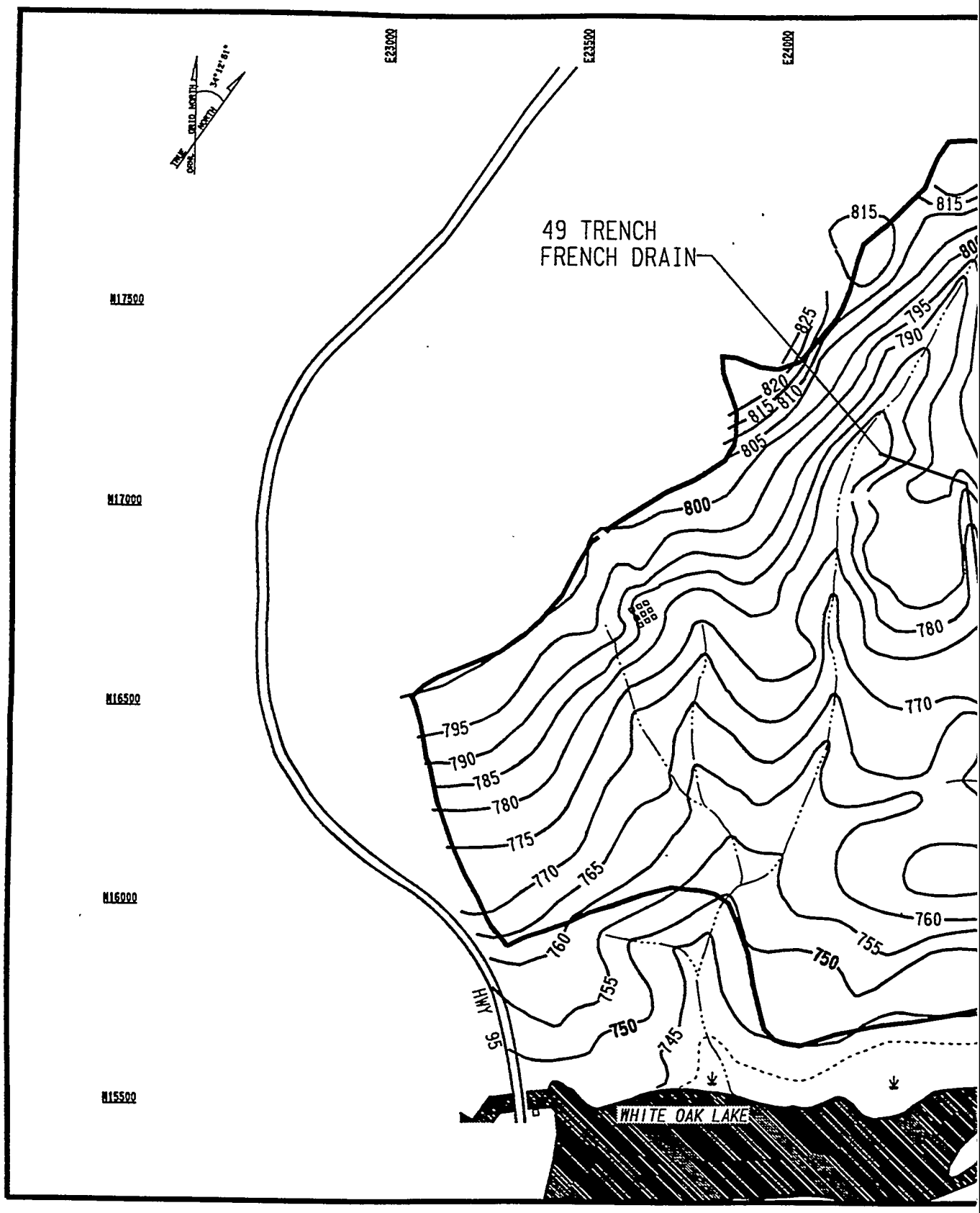

**Fig. 3.11. Existing wells and piezometers at WAG 6 as of June 1990.**




*Source:* After Moore (1988) ORNL-DWG 88-9699.

**Fig. 3.12. Conceptual groundwater occurrence at WAG 6.**

5.18E 4104.147
Adapted from WAG6 06F257 DGN




WAG 6 W6WLEA.DGN

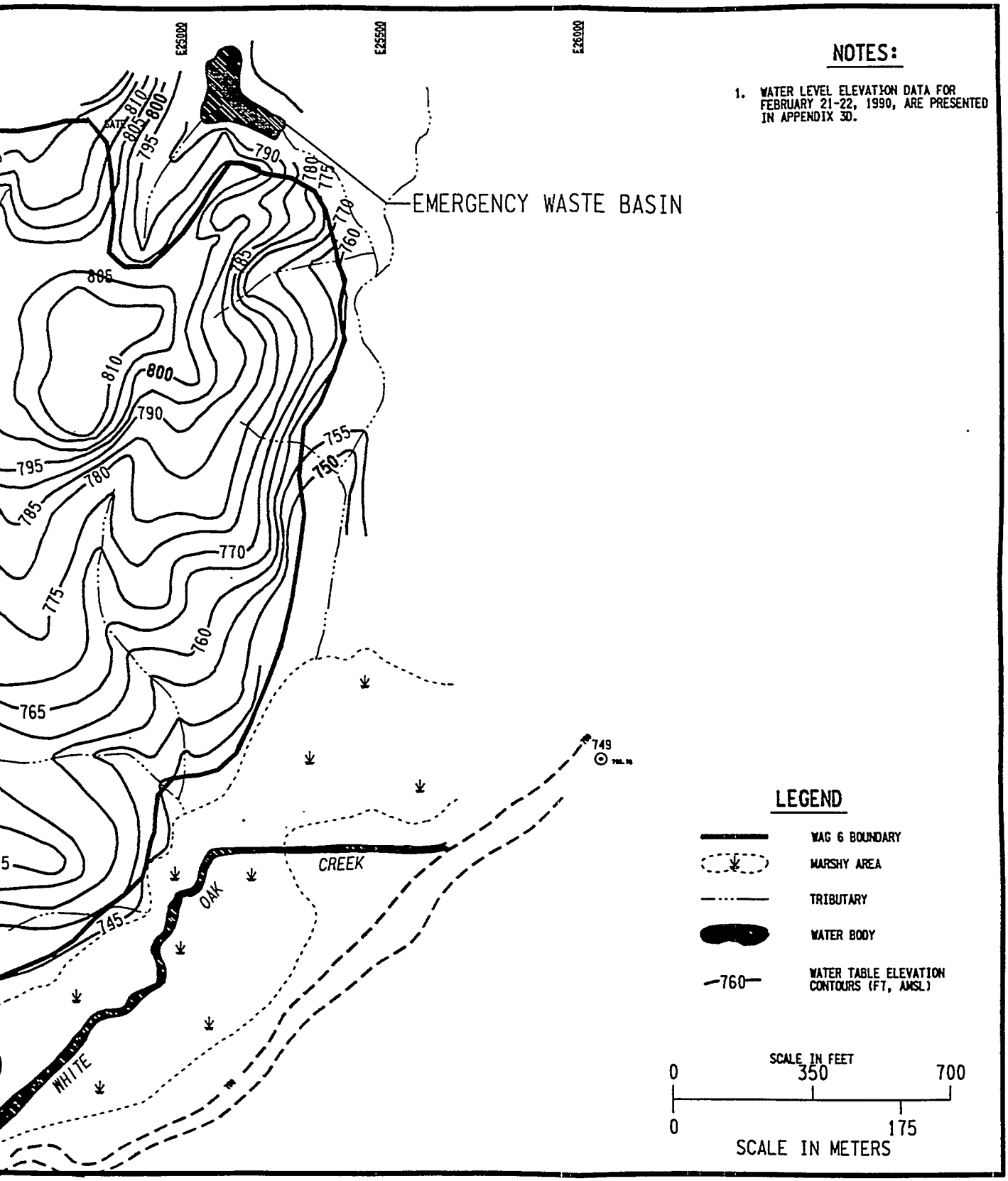
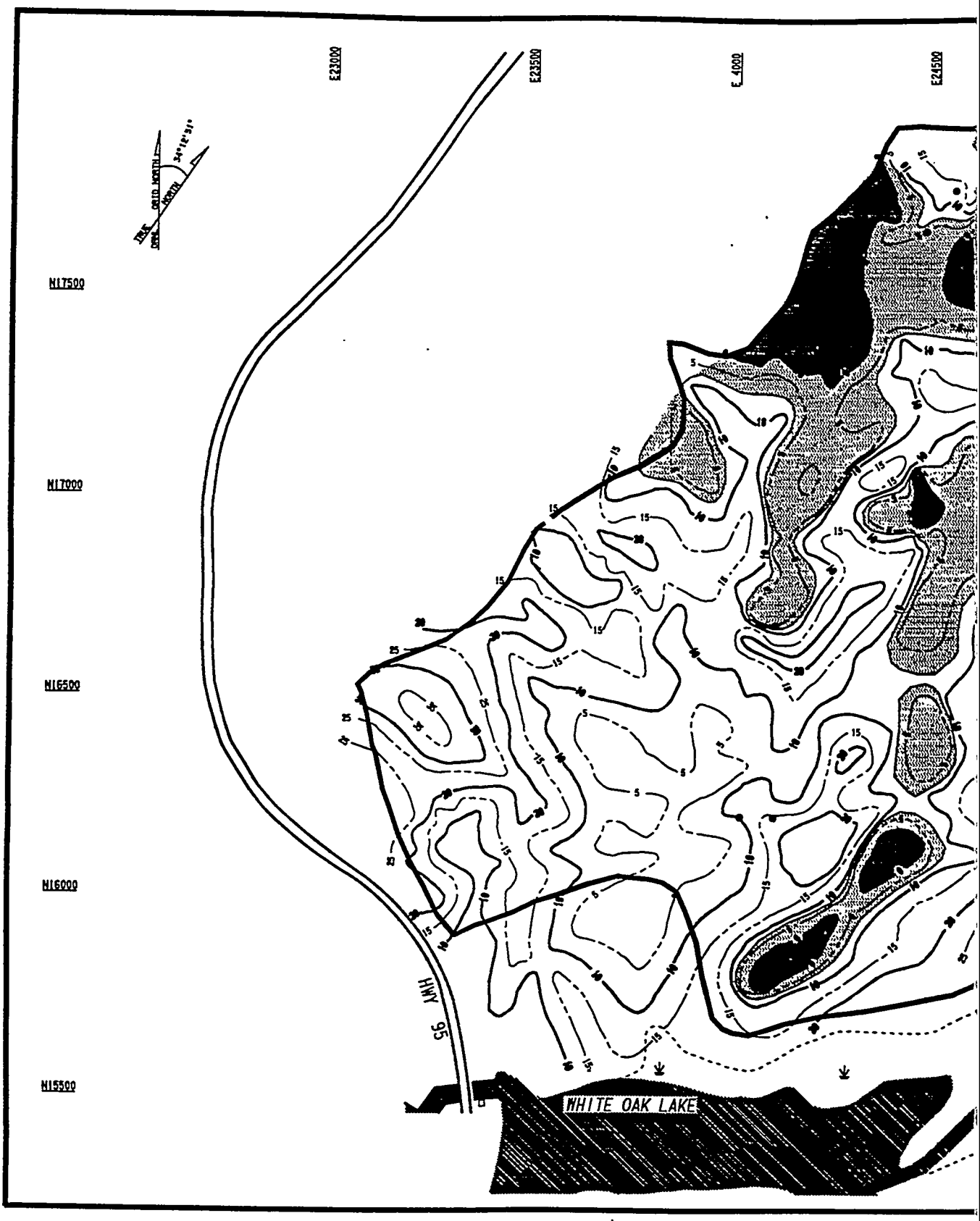



**Fig. 3.13. WAG 6 potentiometric map for February 21-22, 1990.**




WAG6 W6SAT.DGN

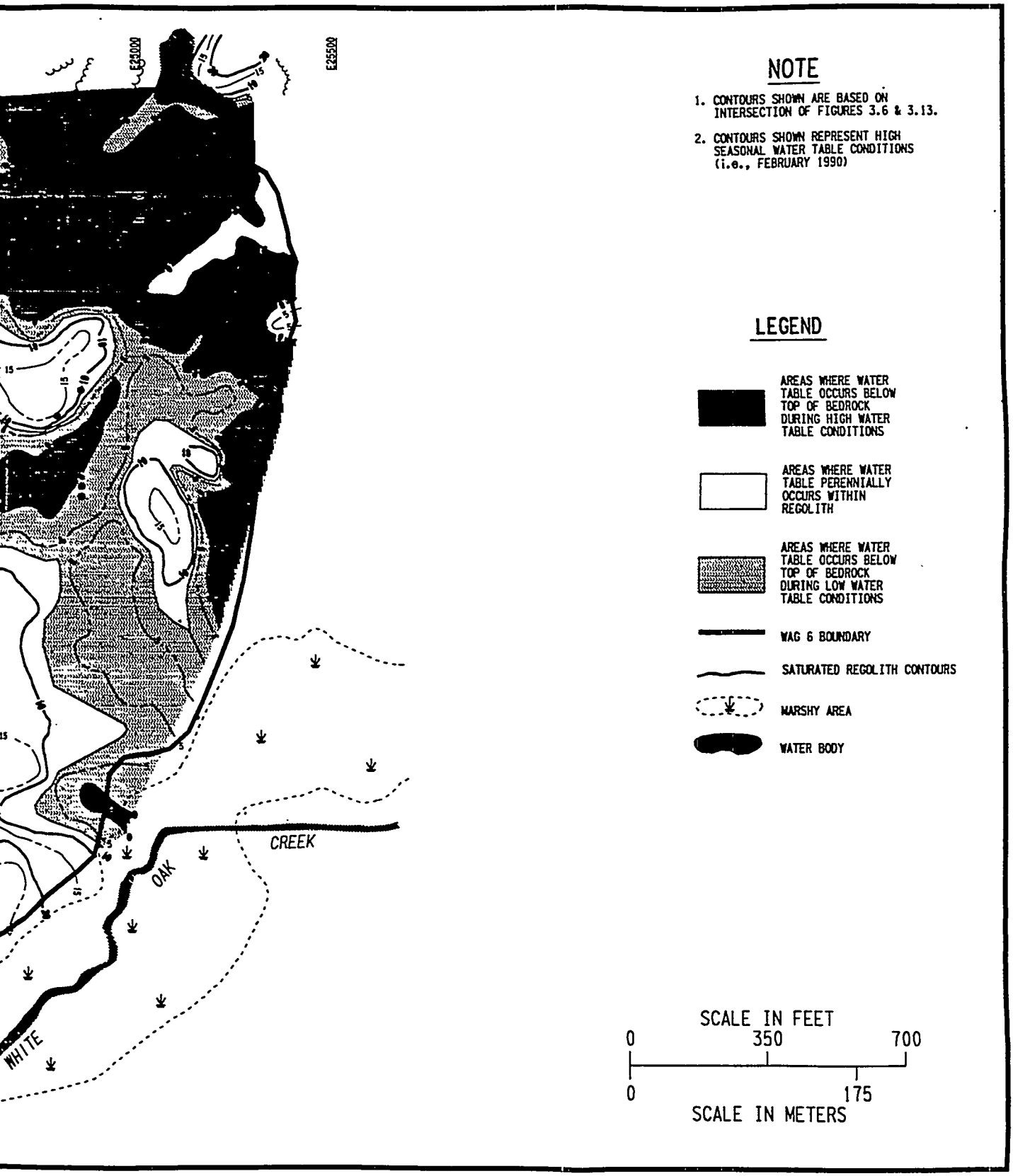
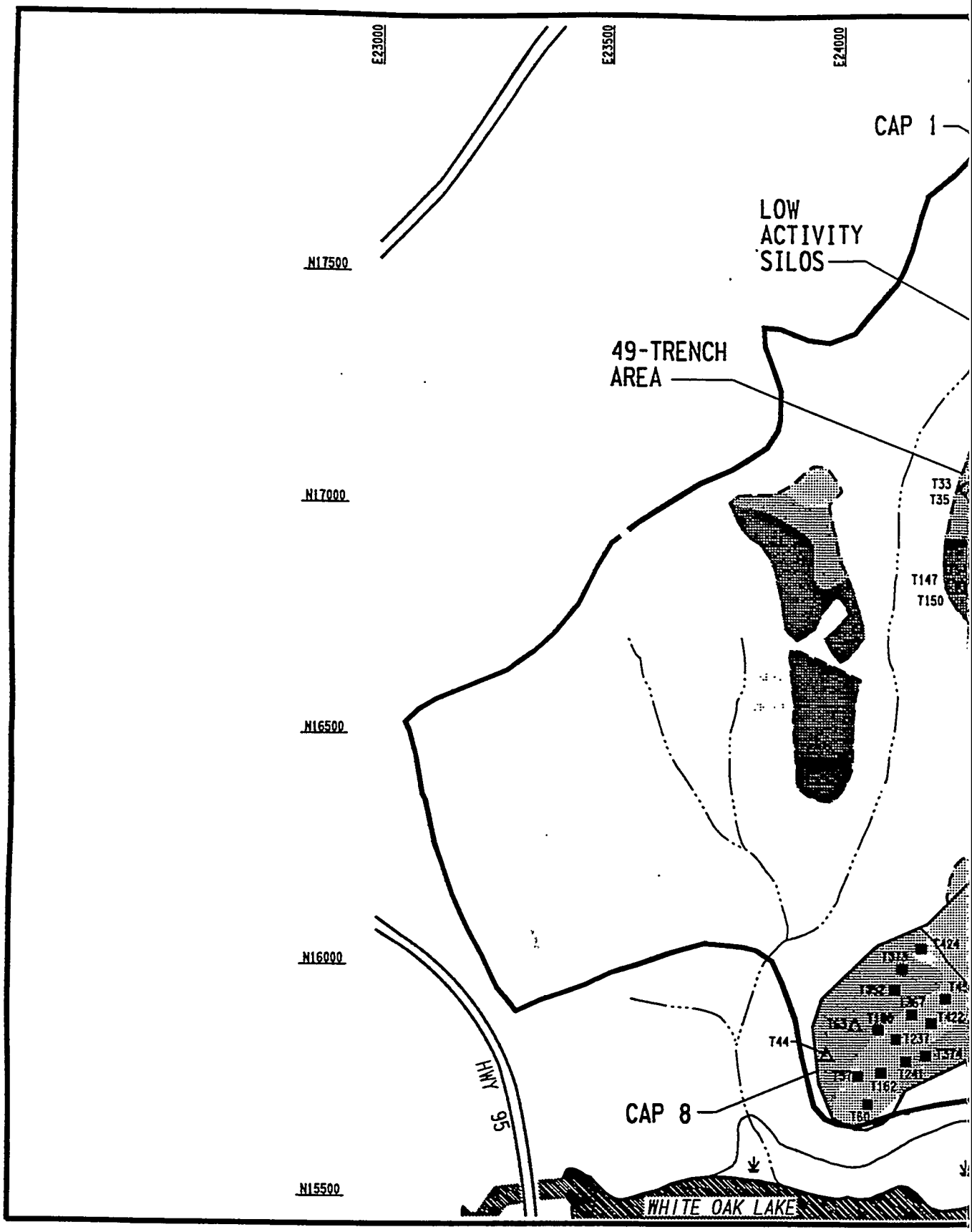



**Fig. 3.14. WAG 6 saturated regolith thickness, February 21-22, 1990.**




WAG6 06F128.DGN

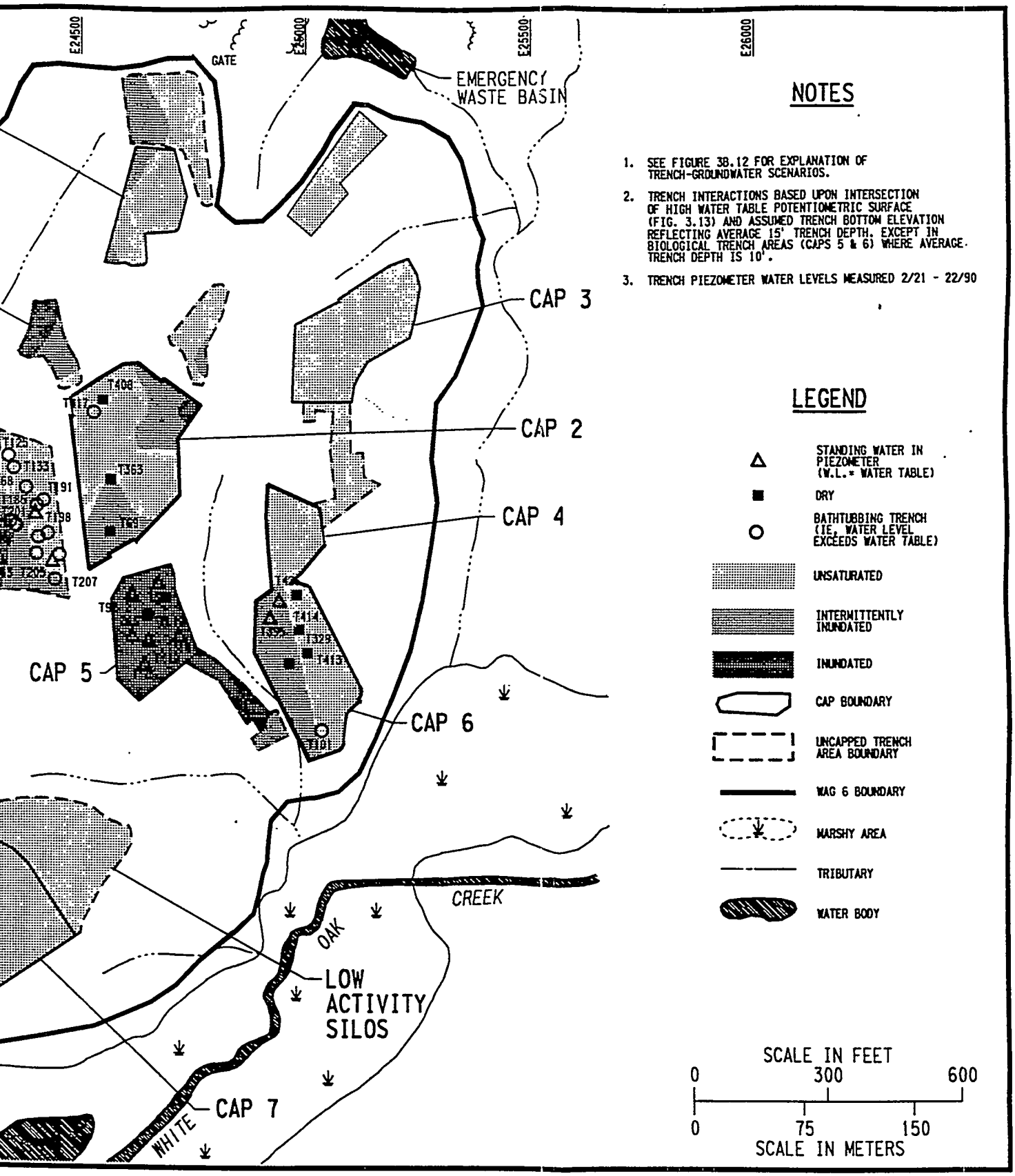



**Fig. 3.15. WAG 6 trench-groundwater interaction map, February 1990.**

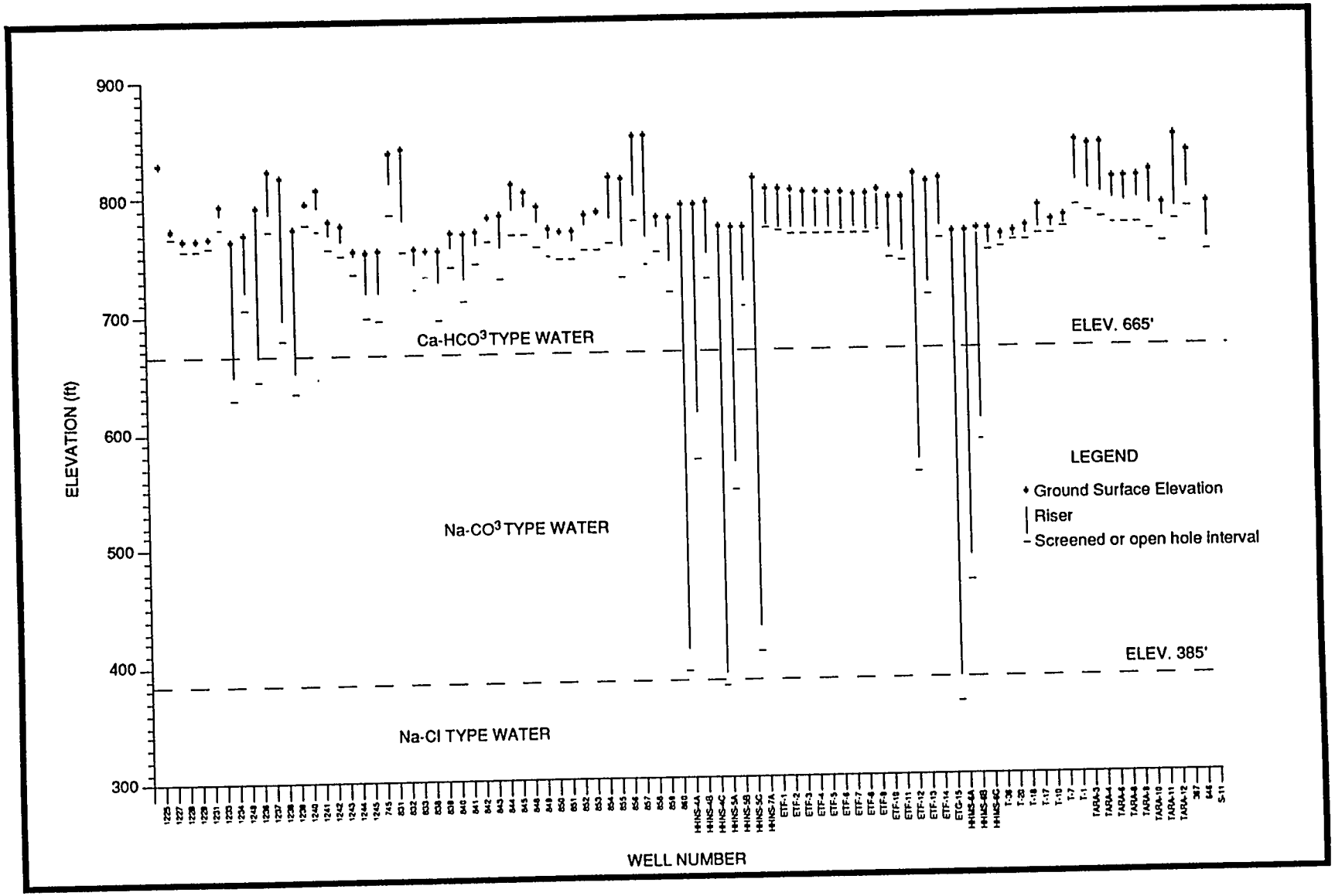



Fig. 3.16. Relation of screened interval to geochemical zone.

5.18E 4104.143
Adapted from WAG 6 06F171 DGN

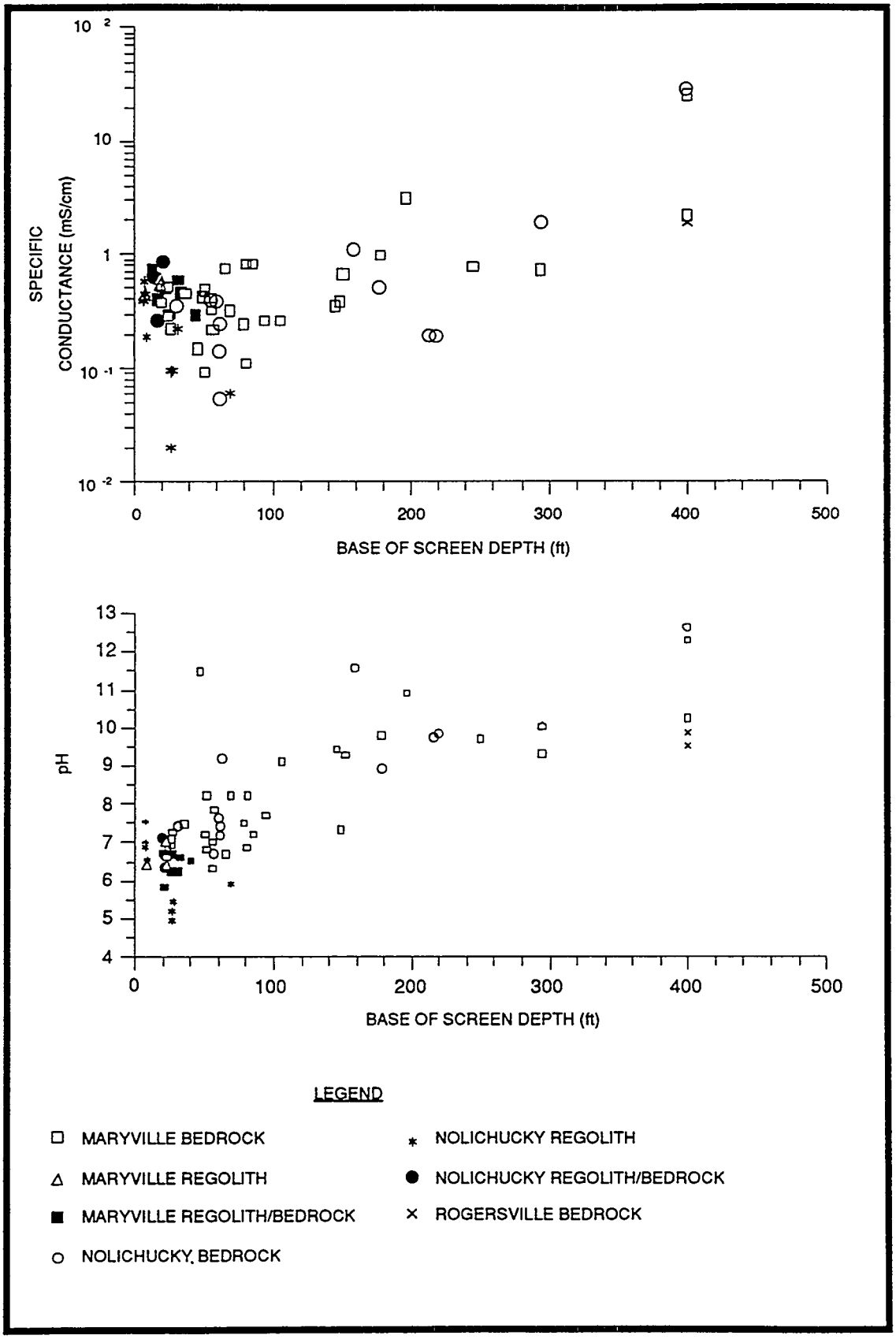



**Fig. 3.17. WAG 6 groundwater pH and specific conductance versus depth.**

5.18F 4104.178

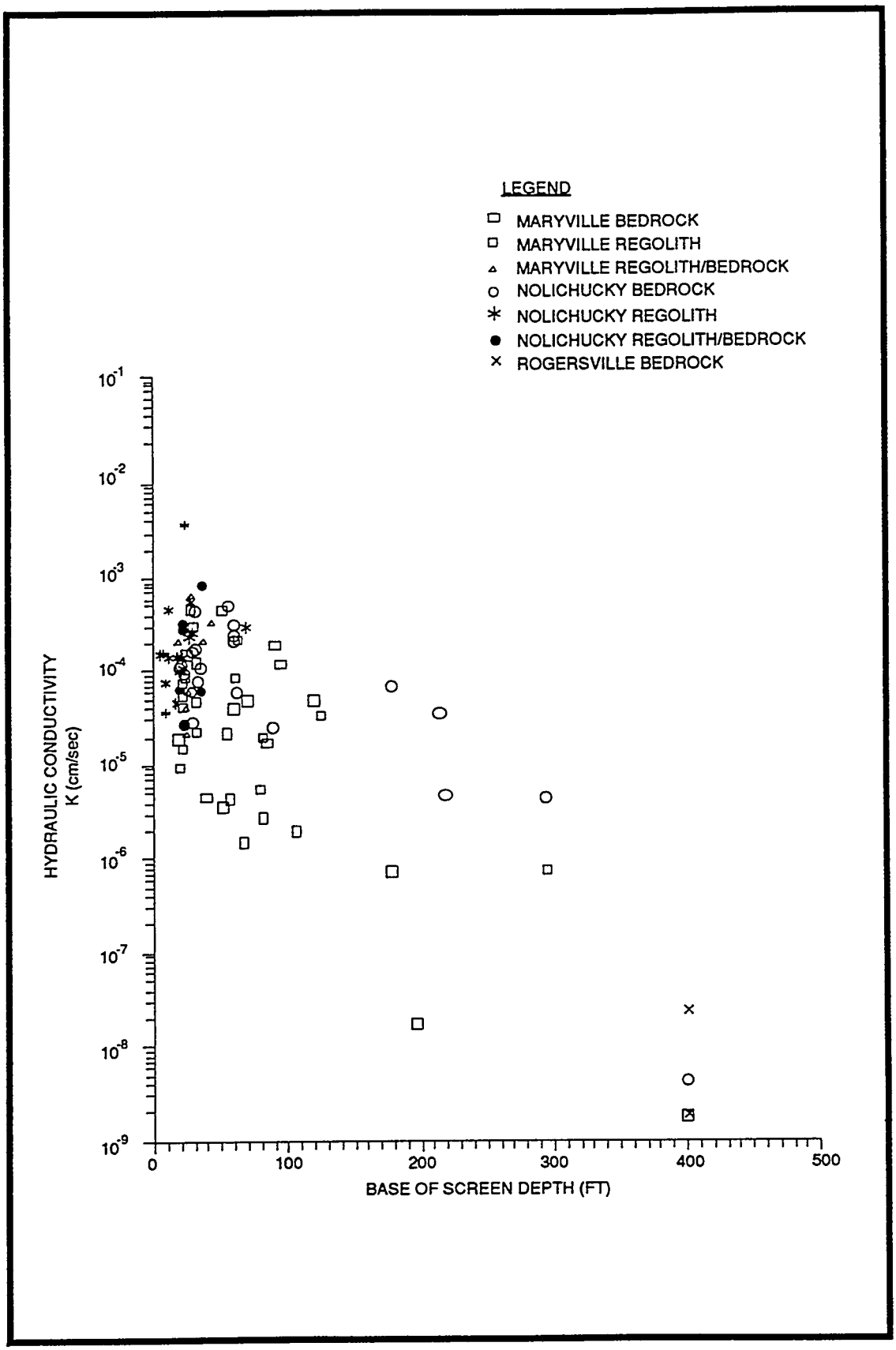



**Fig. 3.18. WAG 6 hydraulic conductivity versus depth plot.**

5.18F 4104.174
Adapted from WAG 6 06F172 DGN

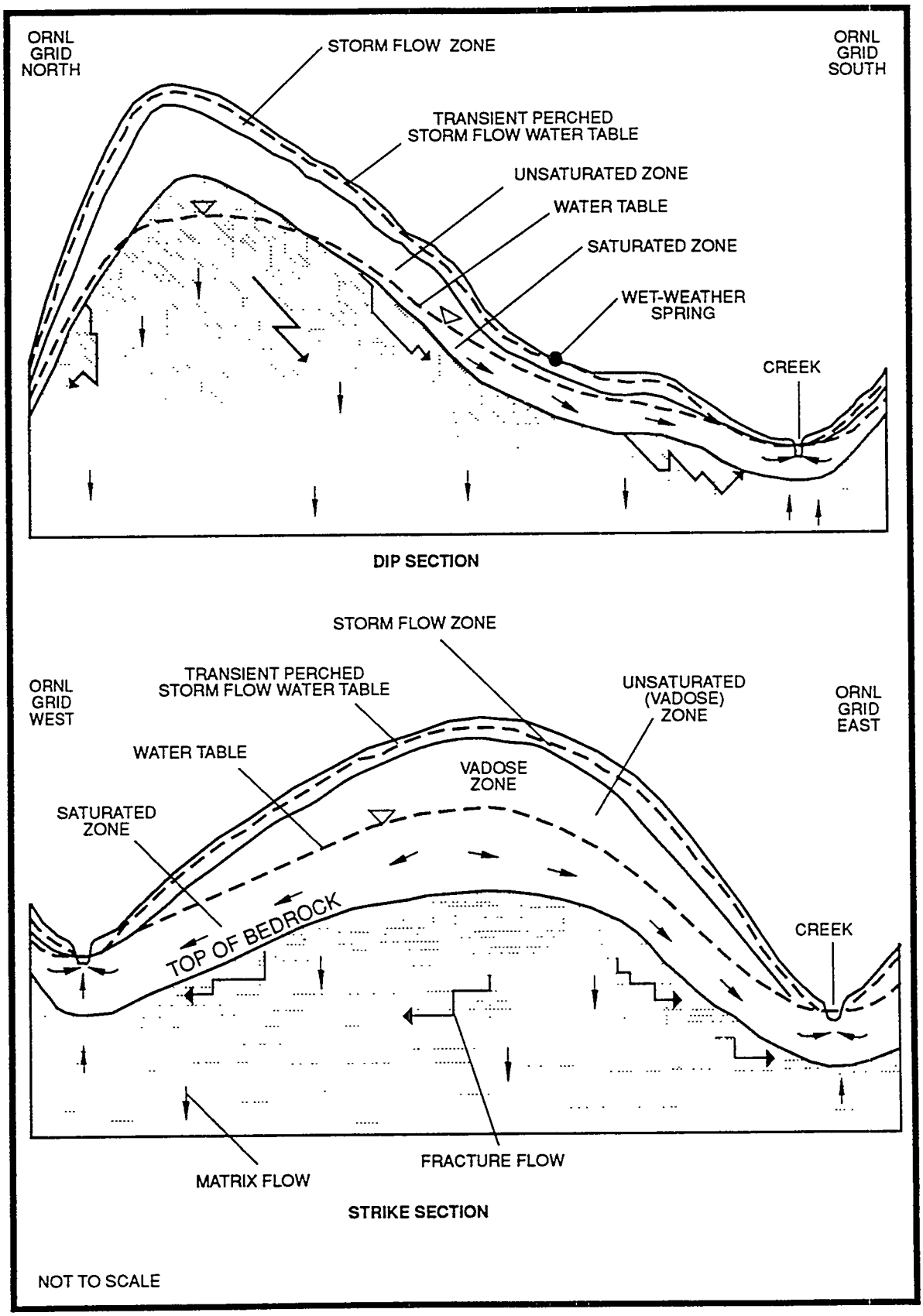
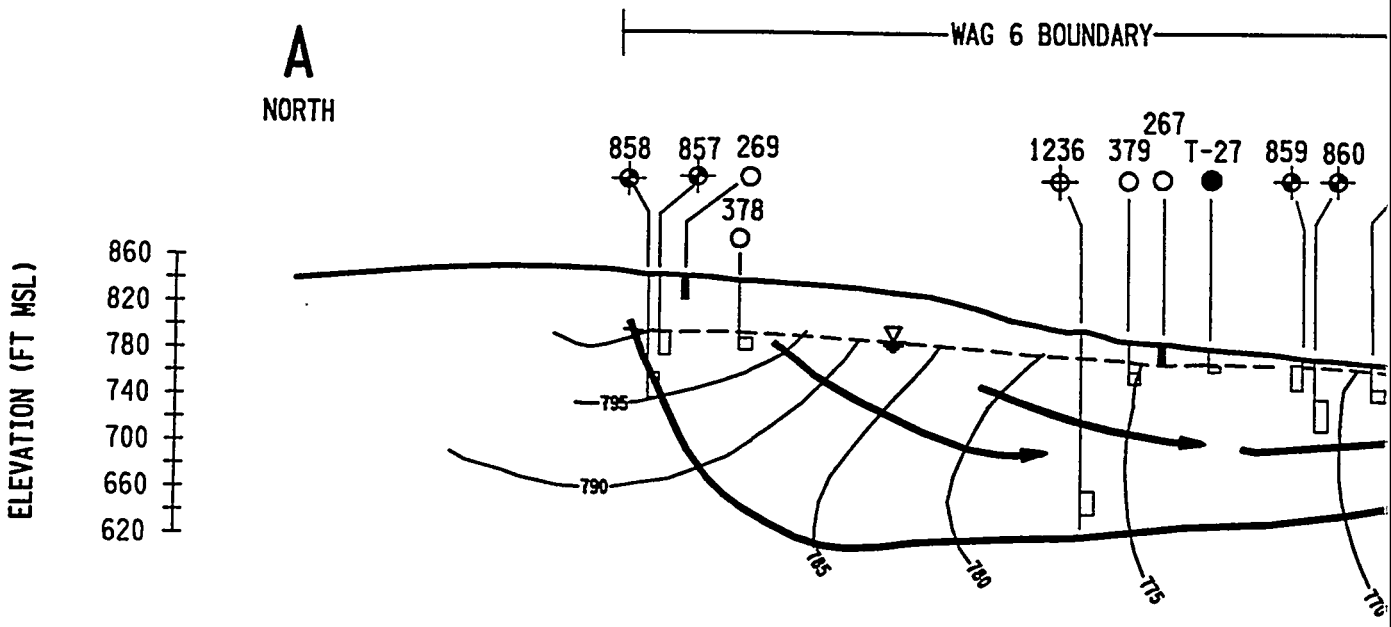



**Fig. 3.19. Groundwater flow at WAG 6** (Modified after Moore 1991).

5.18 4104.9




WAG6 06F183.DGN

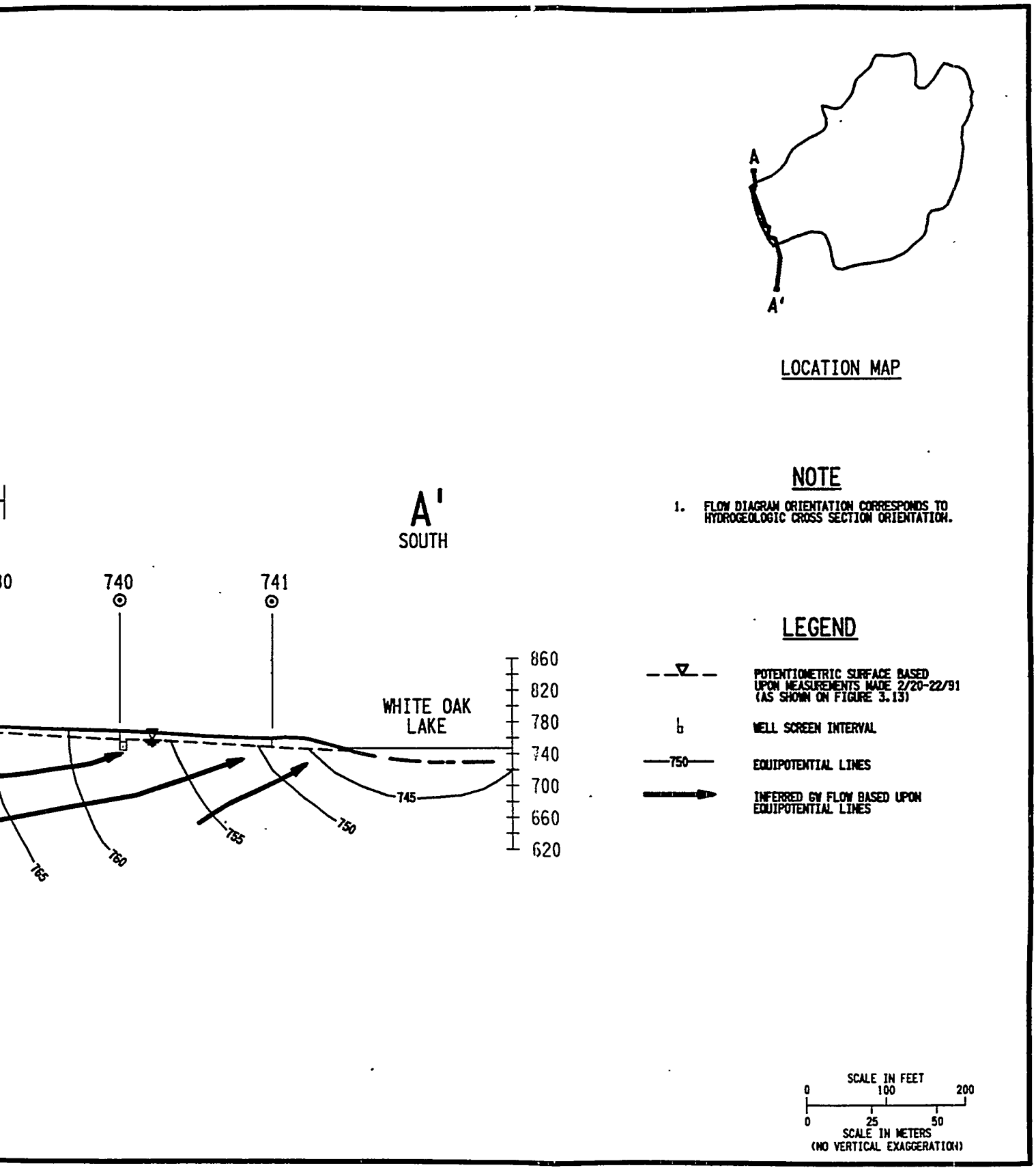
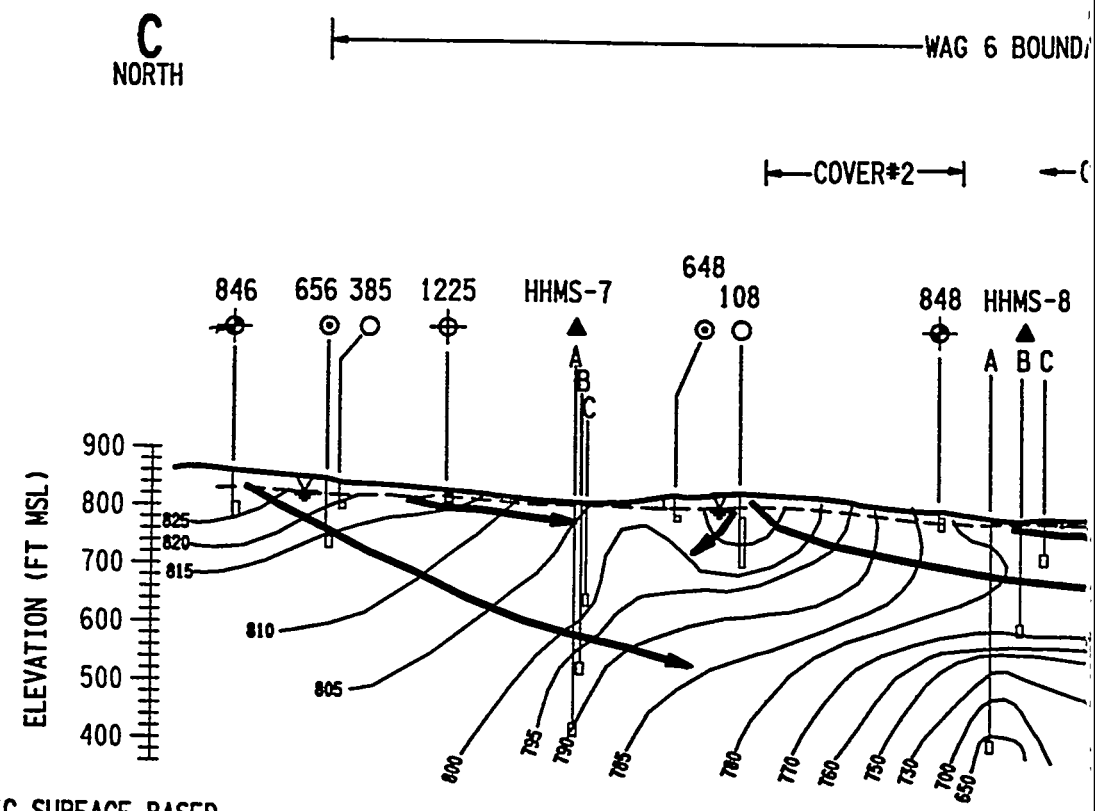



**Fig. 3.20. WAG 6 north-south conceptualized groundwater flow diagram A-A'.**




LEGEND

- POTENTIOMETRIC SURFACE BASED UPON MEASUREMENTS MADE 2/20-22/91 (AS SHOWN ON FIGURE 3.13)
- WELL SCREEN INTERVAL
- 750 EQUIPOTENTIAL LINES
- INFERRED GW FLOW BASED UPON EQUIPOTENTIAL LINES

WAG6 06F182.DGN

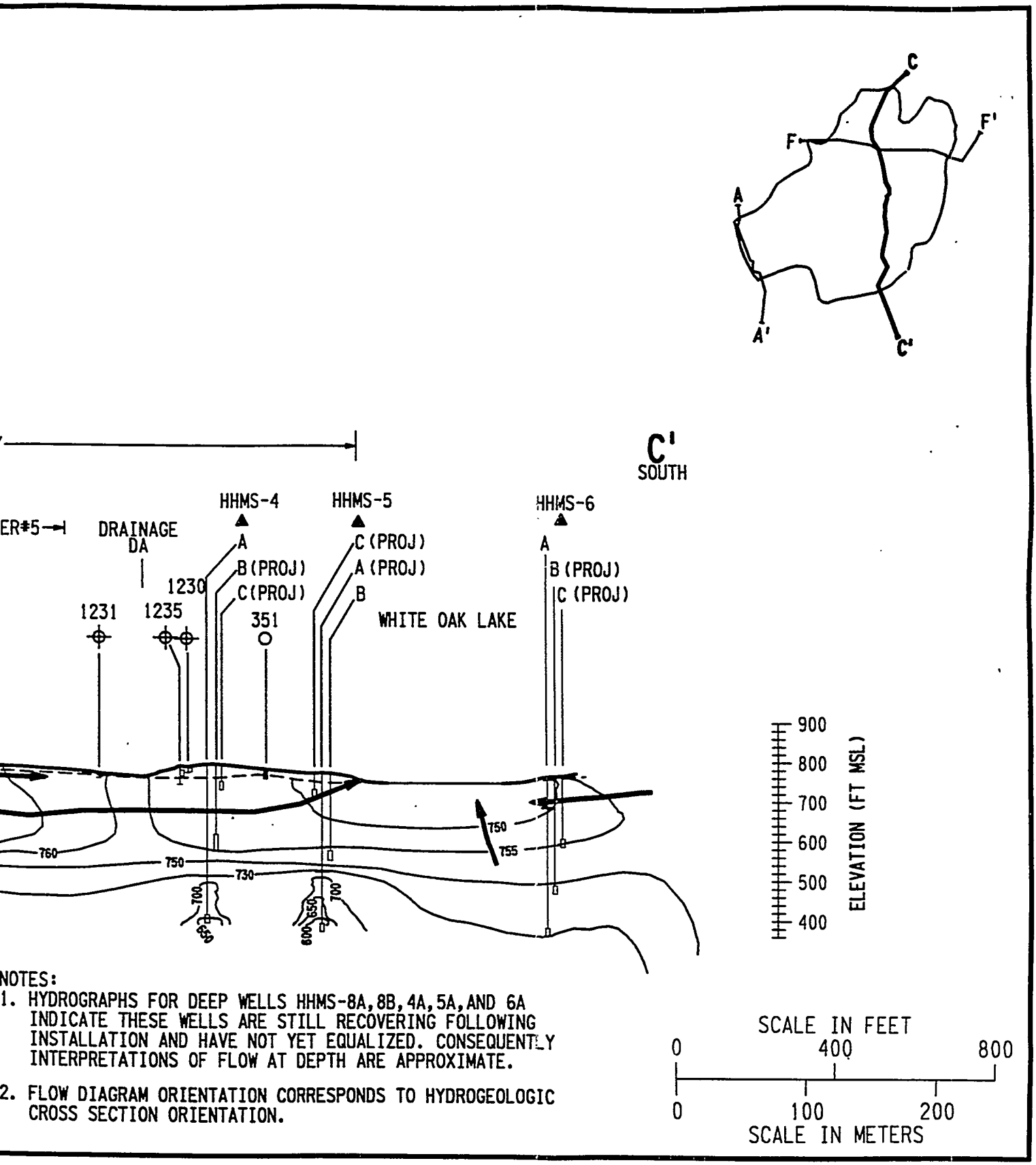
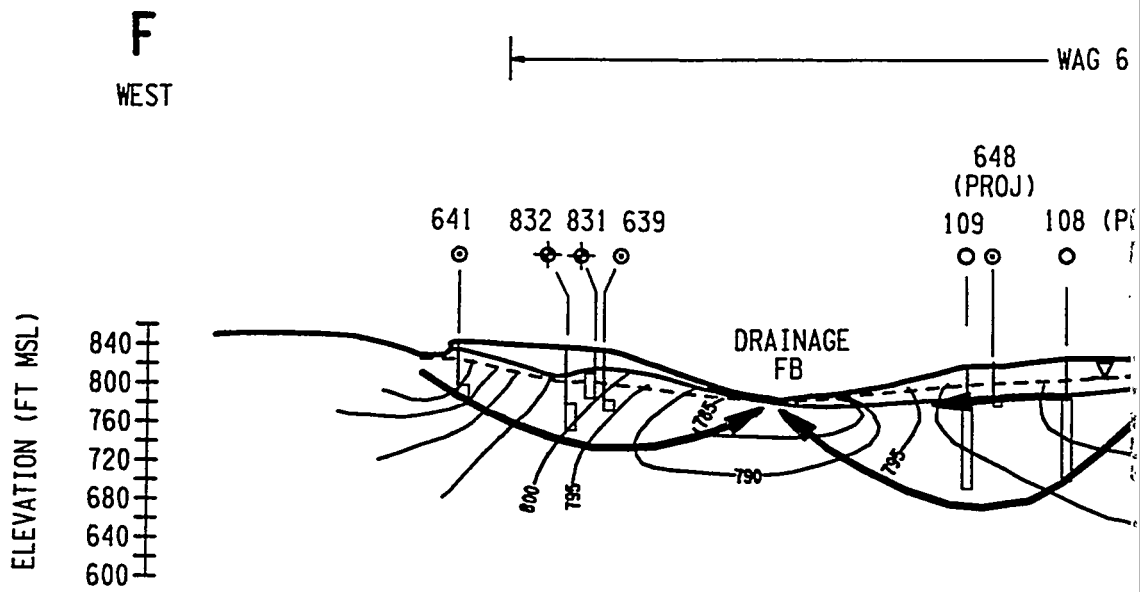



**Fig. 3.21. WAG 6 north-south conceptualized groundwater flow diagram C-C'.**




LEGEND

- POTENTIOMETRIC SURFACE BASED UPON MEASUREMENTS MADE 2/20-22/91 (AS SHOWN ON FIGURE 3.13)
- WELL SCREEN INTERVAL
- EQUIPOTENTIAL LINES
- INFERRED GW FLOW BASED UPON EQUIPOTENTIAL LINES

NOTE: FLOW DIAGRAM ORIENTATION CORRESPONDS TO HYDROGEOLOGIC CROSS SECTION ORIENTATION.

WAG6 06F181.DGN

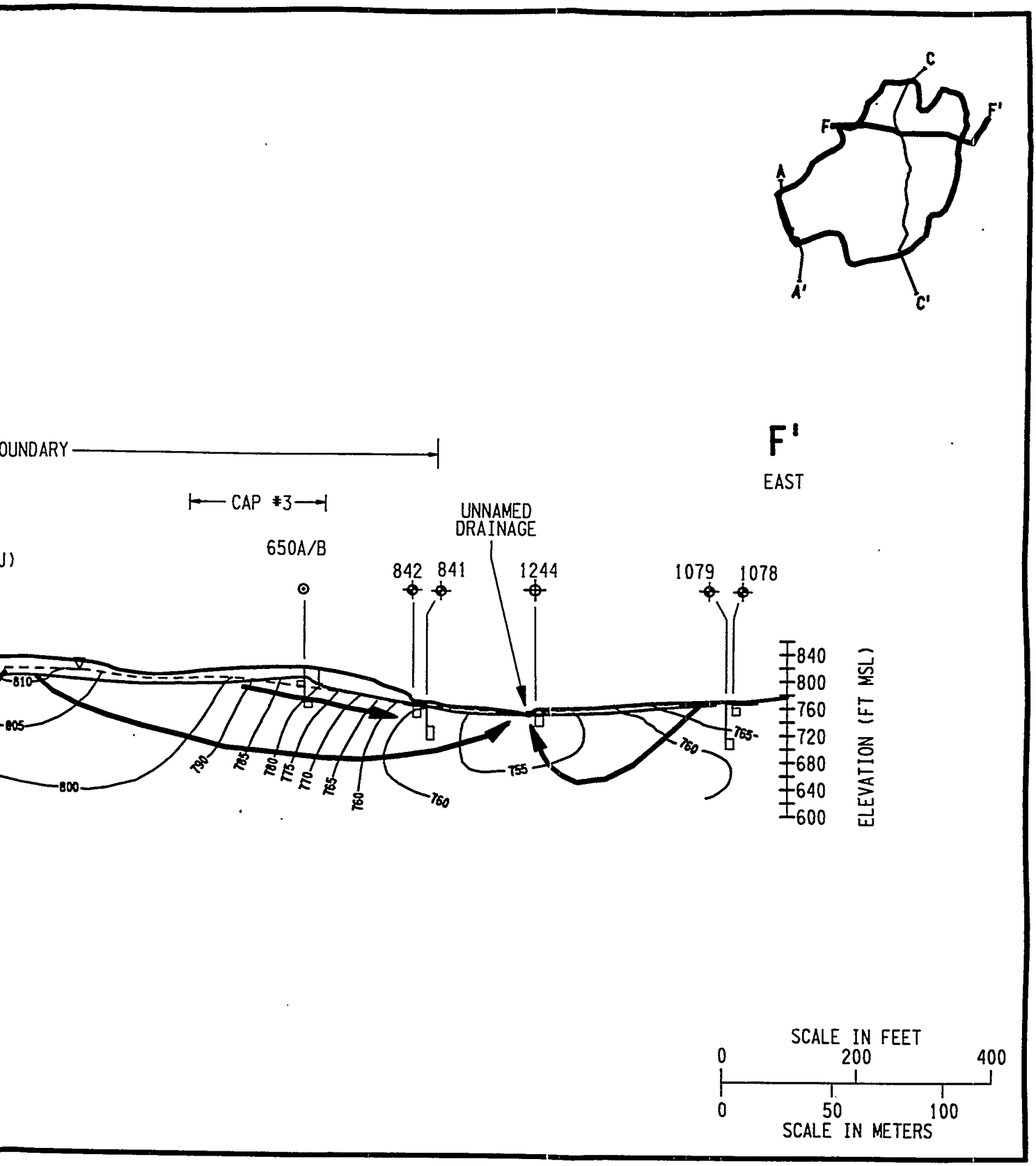
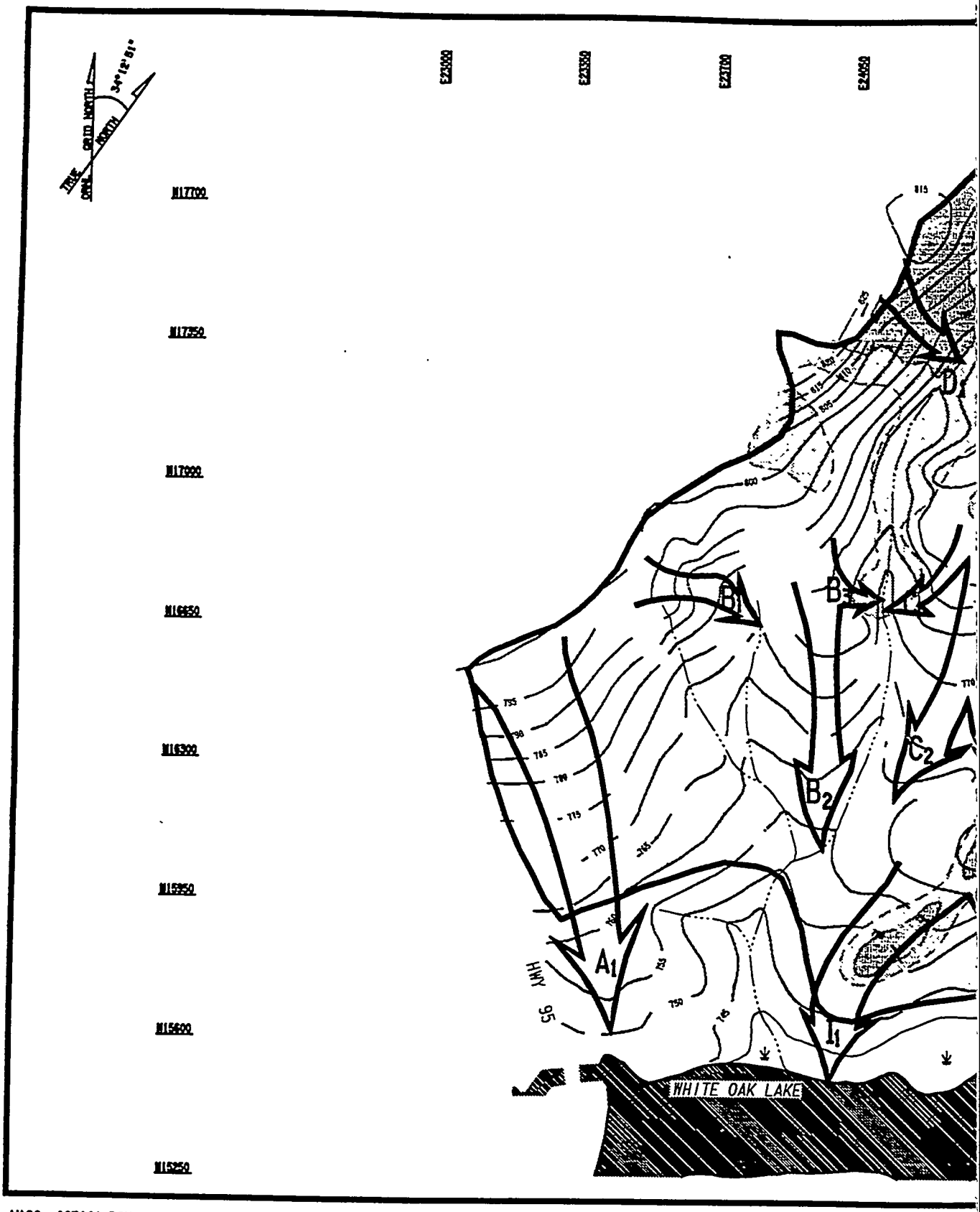



**Fig. 3.22. WAG 6 north-south conceptualized groundwater flow diagram F-F'.**




MAG6 06F161.DGN B

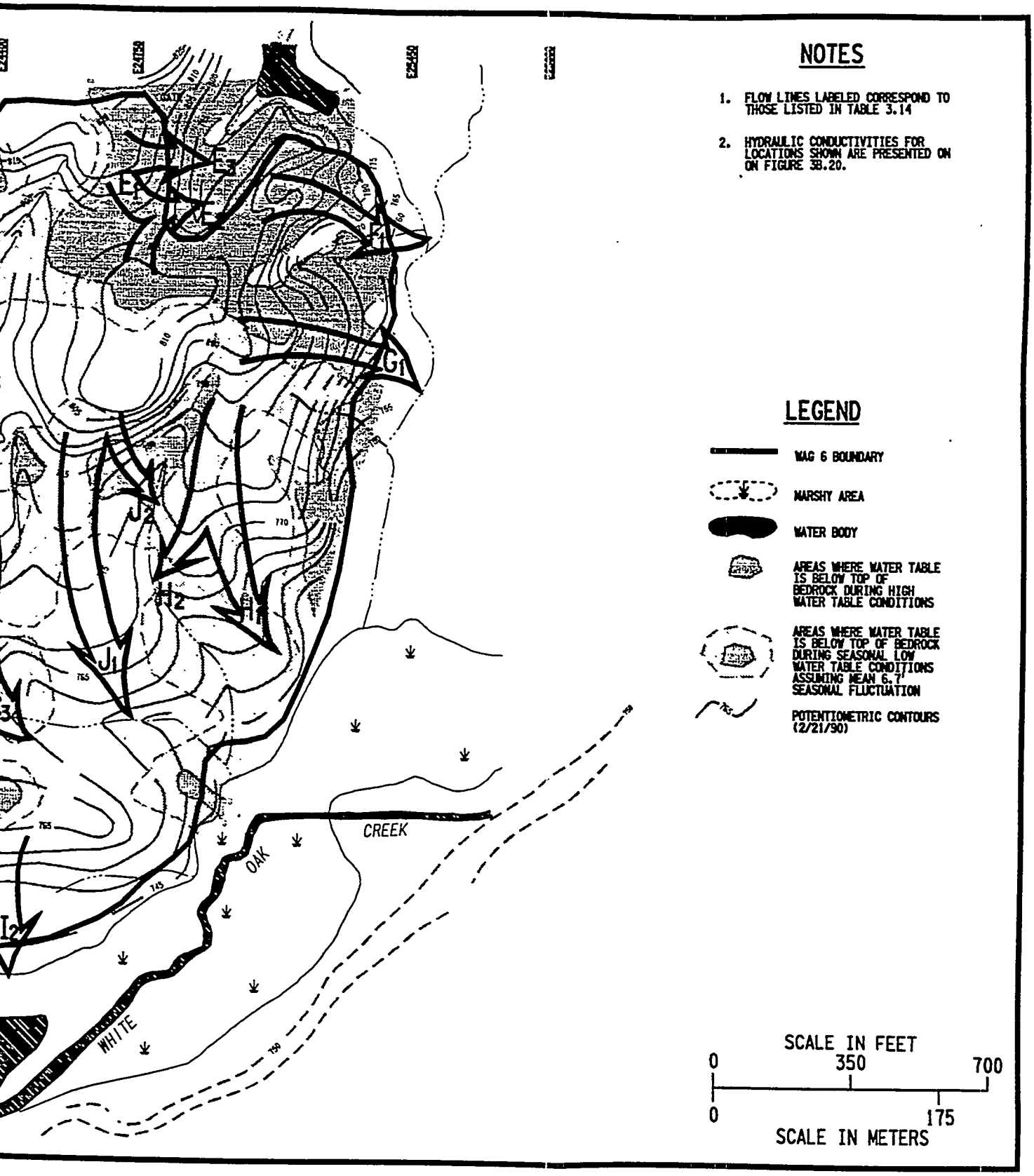
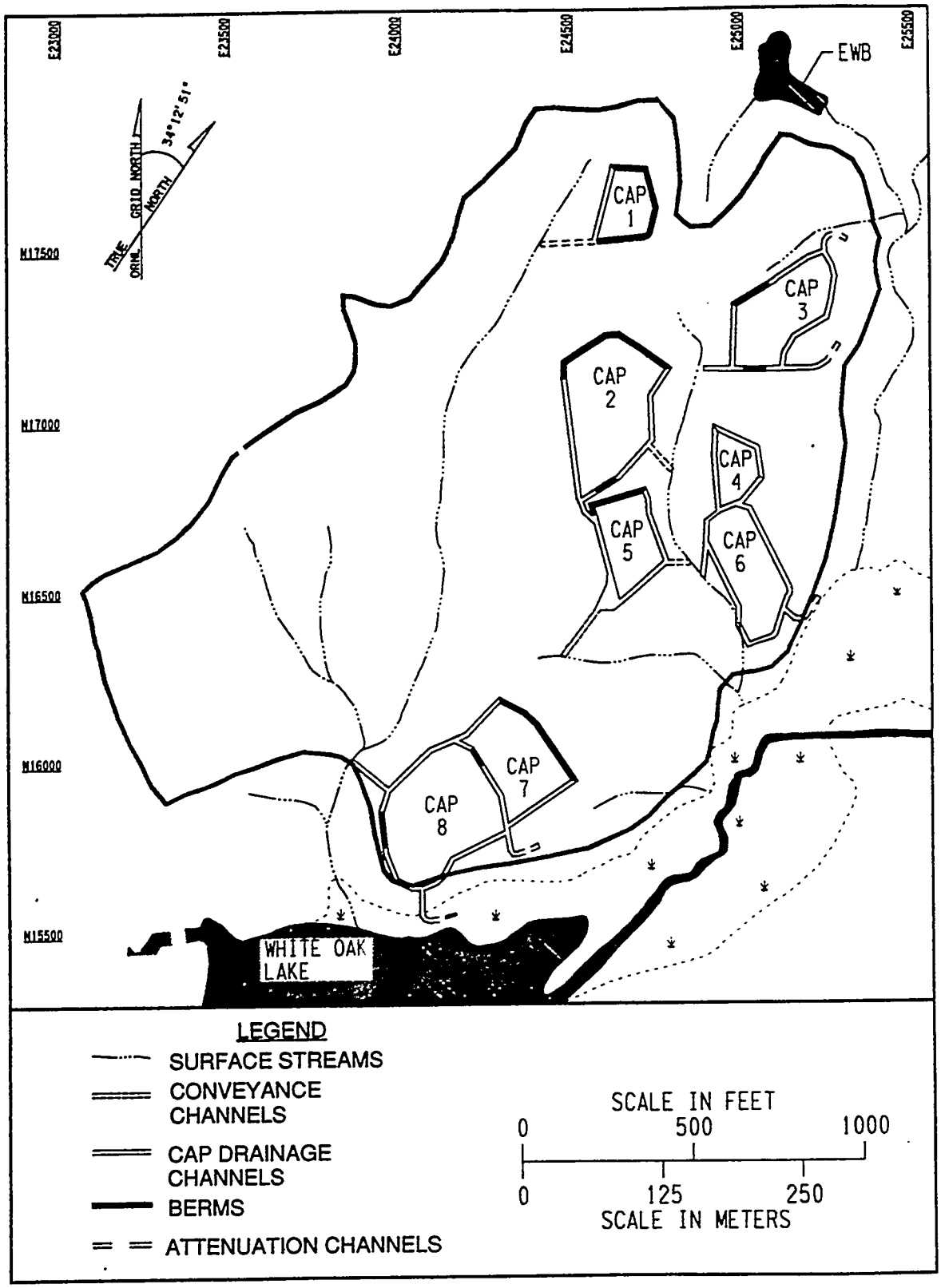
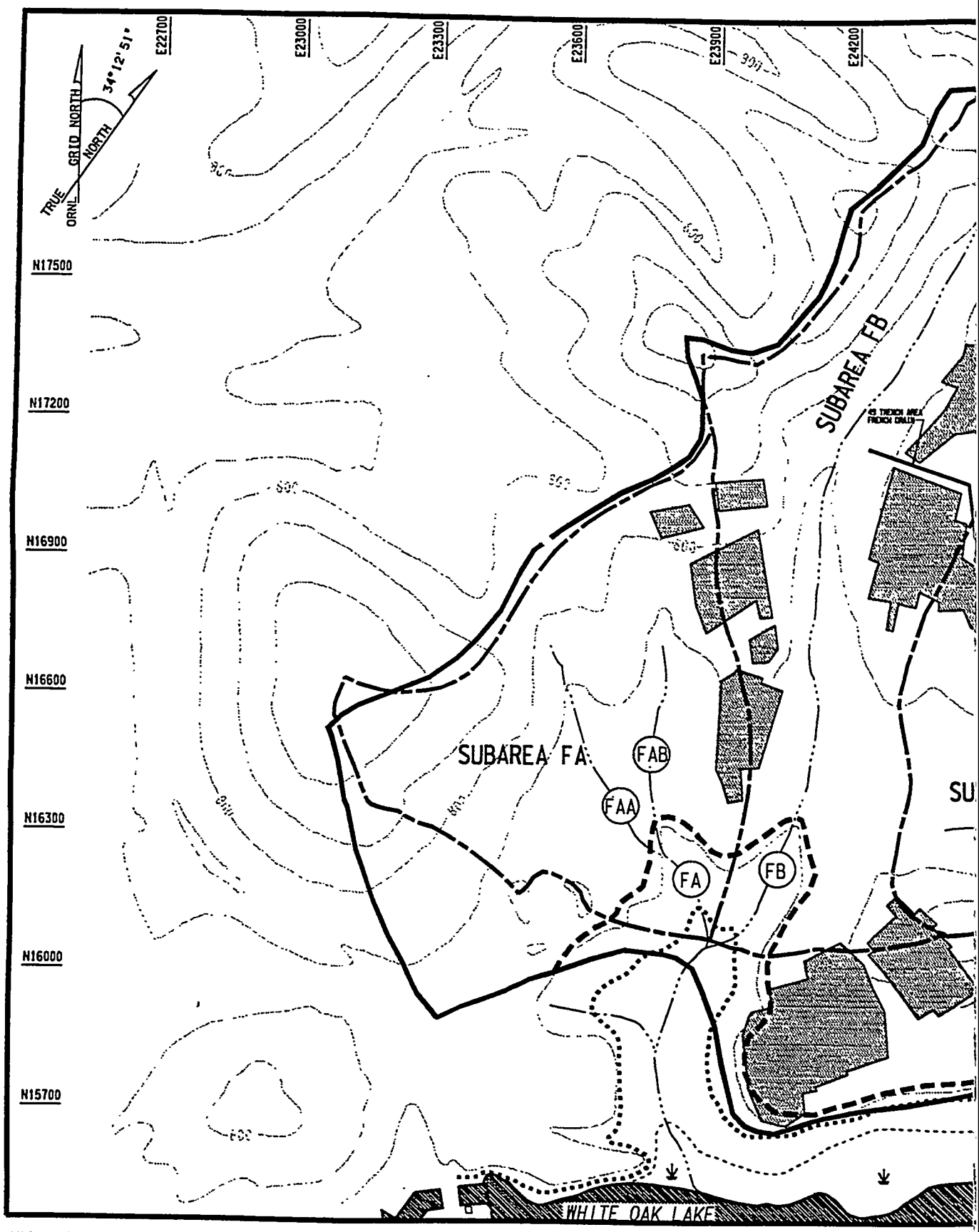



Fig. 3.23. WAG 6 shallow groundwater flow lines.




WAG6 06F189.DGN

**Fig. 3.24. Temporary cap drainage features.**




WAG6 06F231.DGN

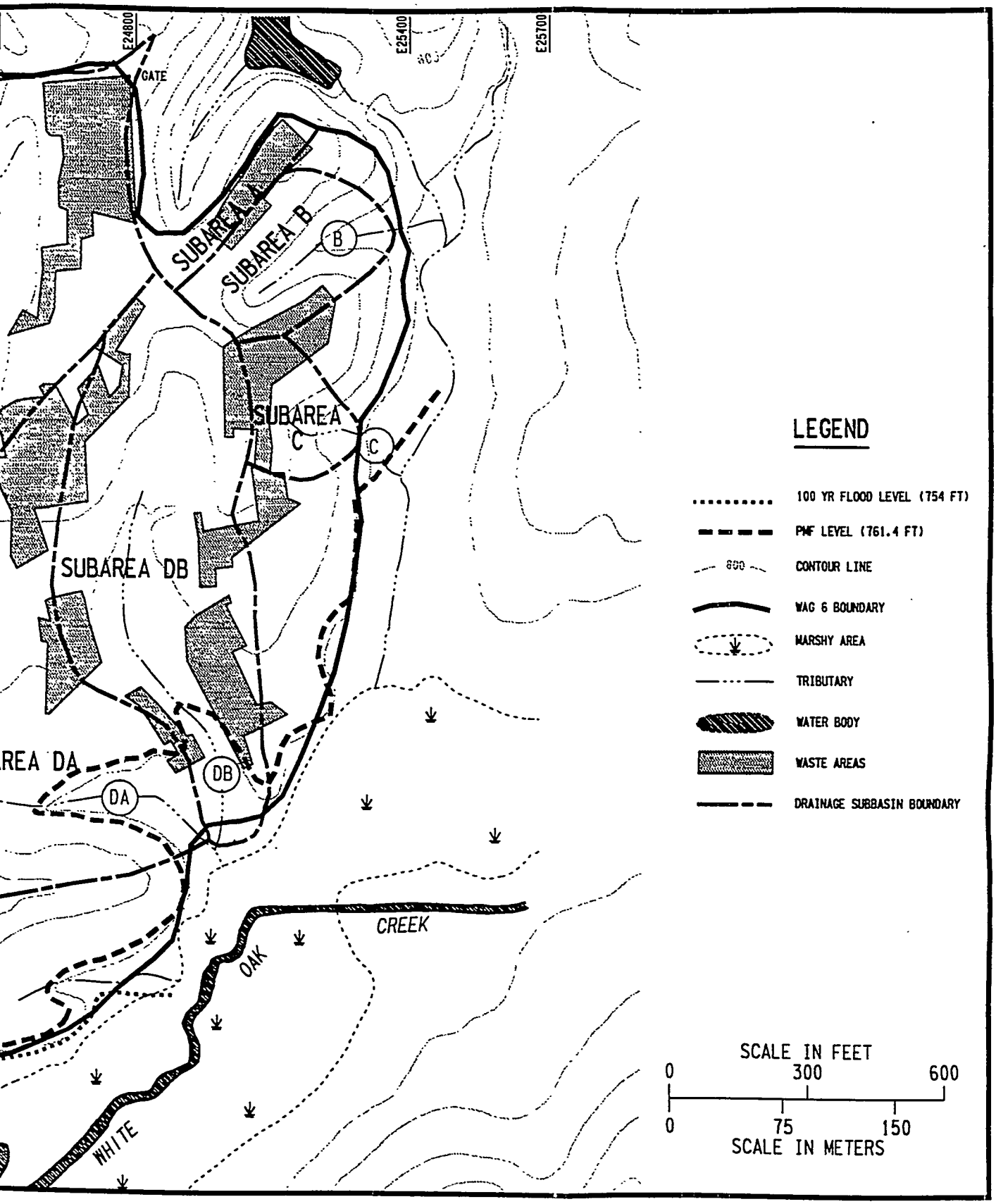
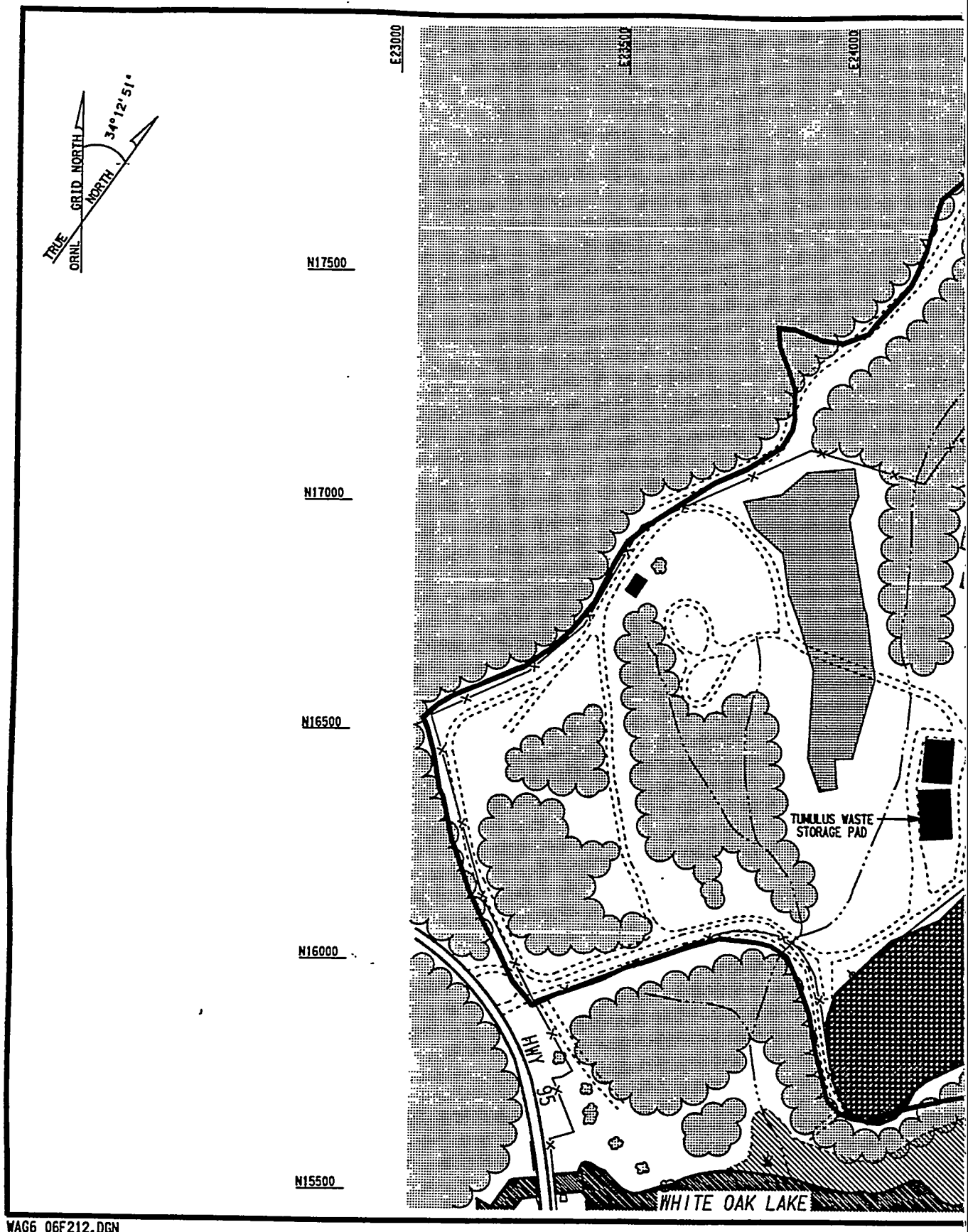



**Fig. 3.25. WAG 6 site drainage characteristics.**




WAG6 06F212.DGN

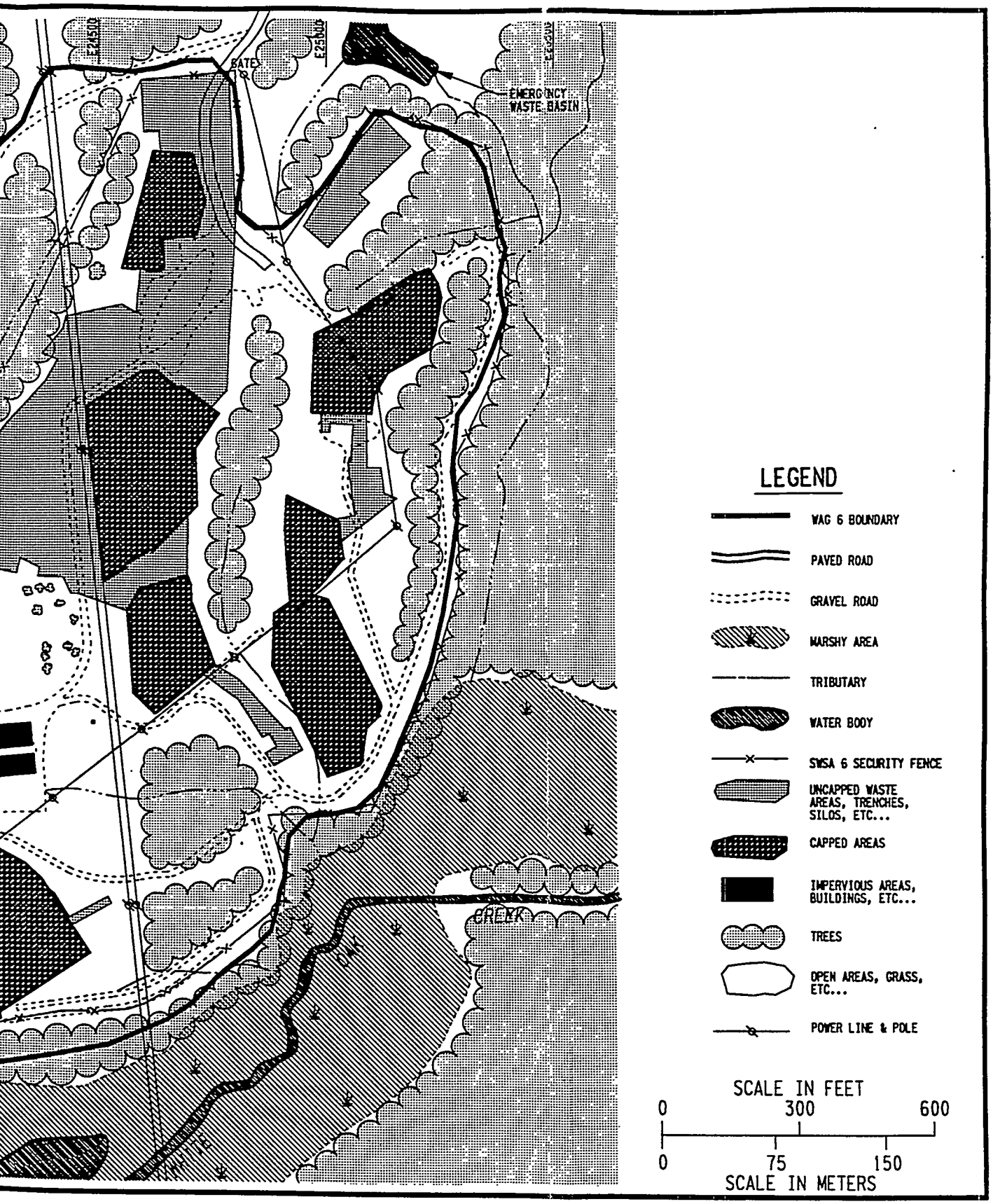



**Fig. 3.26. WAG 6 land usage map.**

# 4. NATURE AND EXTENT OF CONTAMINATION

## 4.1 INTRODUCTION

Section 4 describes the type, concentration, and spatial distribution of contamination at WAG 6, as developed from RFI data, ORNL RCRA compliance monitoring data, and data from previous investigations. Past waste disposal activities in WAG 6 created a complex contaminant source through which releases occur to the surrounding environment. Migration of contaminated environmental media has occurred resulting in contaminants, in many cases, being present beyond their original disposal area. The information in this section forms the basis for the assessment of human health and environmental impacts; it also contributes to the definition of the scope of site closure and corrective action alternatives.

Section 4.1 provides an overview of WAG 6 environmental data, including a description of the WAG 6 database and an evaluation of data quality. Environmental data consist of results from chemical or radiological analysis of samples from various media. Section 4.1 also identifies specific contaminants detected and describes general observations made regarding the data. Inventory information related to source areas is summarized in Sect. 4.2. Section 4.3 summarizes the nature and extent of on-site contamination by environmental media (groundwater, surface water, sediments and soil). Section 4.4 summarizes potential off-site migration of contaminants along the WAG boundary. Appendix 4A is an assessment of contaminant sampling and data analysis. Appendix 4B is a statistical analysis of detected contaminants designed to supplement the information presented in Sect. 4.1.2. And Appendix 4C is a detailed discussion of the nature and extent of on-site contamination incorporating separate discussions of radiological and chemical contaminants by medium.

### 4.1.1 WAG 6 RFI Environmental Data

#### 4.1.1.1 Database

The WAG 6 analytical database consists of two elements: the environmental data base, which contains the actual analytical data, and the sample tracking record. The environmental database is recorded in the separately published Technical Memorandums associated with this RFI report. Table 4.1 lists the matrices and the appendixes in which data can be found.

The two categories of analytical data collected are radiological and chemical. Radiological data include gross alpha and gross beta activity, tritium, and specific radionuclide isotopic analyses. Chemical data included analytical results for Target Compound List (TCL) organic compounds and Target Analyte List (TAL) inorganic analytes; selected samples were analyzed for RCRA Appendix IX analytes. TAL, TCL, and Appendix IX analytes are listed in Sect. 2.

Radiological data for liquid samples are reported in picoCuries per liter (pCi/L). For solid samples, data are reported in picoCuries per gram (pCi/g). Both units are measurements of the level of radioactivity for a given radionuclide (or group of radionuclides

in the case of gross alpha and beta) in the sample matrix. Radioactivity is determined as the rate at which an unstable radionuclide decays, or disintegrates. One picoCurie is equivalent to 2.22 disintegrations per minute (dpm). A direct equivalence between radioactivity and chemical concentration (i.e., the concentration of the radionuclide on a weight basis) can be calculated only on a radionuclide-specific basis.

In this report, WAG 6 RCRA and RFI radiological results are generally reported with an accompanying error factor. The error factor represents a statistical value that is equal to two standard deviations of the sample's activity. Absence of the error term means that the radiological result reported is the Minimum Detectable Activity (MDA) for that analyte in that sample. The actual activity is some value less than the MDA. The MDA is a function of the measurement instrument background and will vary from sample to sample. The best estimate of the radioactivity in a sample is the reported value. The range of what that value may be, with 95% confidence, can be estimated by adding the error factor to the reported value to obtain the upper limit and by subtracting the error factor from the reported value to obtain the lower limit. For example, if the results are reported as 10 +/- 5 pCi/g, the best estimate for the value is 10 pCi/g, and the range of what that value may be, with 95% confidence, is 5 to 15 pCi/g. If the error factor is greater than the reported value, the activity of that radionuclide is statistically indistinguishable from zero and the result is considered a non-detect. Typically, error factors are included in the tables in the report and appendices but are not included in the figures.

Chemical data for liquid samples, such as samples of groundwater or surface water, are presented in units of micrograms of the analyte per liter of liquid ($\mu$g/L). Chemical data for solid samples, such as samples of soil or sediment, are presented in units of micrograms of the analyte per kilogram of solid ($\mu$g/kg) on a dry weight basis. Both $\mu$g/L and $\mu$g/kg are approximately equivalent to one part in a billion parts (ppb) by weight. Where appropriate, chemical data for liquids and solids are also reported in milligrams per liter (mg/L) and in milligrams per kilogram (mg/kg), respectively . Both mg/L and mg/kg are approximately equivalent to one part in a million parts (ppm) by weight.

Frequently, a concentration of an organic constituent is reported as, for example, "<5 $\mu$g/L." This indicates that the constituent was not detected at or above the detection limit for that constituent (in this case, 5 $\mu$g/L).

#### 4.1.1.2 Data quality assessment

An assessment of the quality of WAG 6 RFI environmental data was performed to provide data users with insight regarding the usability of the data. Data generated by the ORNL RCRA compliance monitoring program, which is discussed in subsequent sections, was not evaluated in this assessment. Both chemical and radiological data were evaluated by assessing the following data quality indicators: precision, accuracy, representativeness, completeness and comparability (PARCC) (EPA Guidelines for Data Useability in Risk Assessment 1990a). A detailed presentation of the findings and conclusions of this assessment appears in Appendix 4A.

All chemical data generated during the WAG 6 RFI was submitted for validation. Any problems associated with the analytical procedure which were felt to affect the integrity of the data were dealt with through the use of reviewer qualifiers. Qualifiers revealed problems associated with the analysis such as blank contamination, violation of holding times, poor analytical accuracy, and low precision. In the validation process, trip blank and method blank contamination were evaluated to ensure that false positive detects would not be reflected in the analytical data. Spike recoveries and relative percent differences (RPD) between duplicate analyses were used to evaluate accuracy and precision. The guidance documents used in the assessment and qualification of chemical data are the Laboratory Data Validation Functional Guidelines For Evaluating Organic Analysis and the Laboratory Data Validation Functional Guidelines For Evaluating Inorganic Analysis (EPA 1988b, c). Validated data which was rejected or deemed unusable was not included in this report.

Subsequent to the validation and PARCC review of RFI chemical and radiological data, limitations or uncertainties associated with the data were evaluated. This evaluation was performed to determine whether deficiencies identified would have a significant impact on the ability to characterize and quantify the contaminants present on-site. Based on this evaluation (Appendix 4A), it was determined that there were sufficient chemicals and radiological data of known quality to describe the nature and extent of contamination and to perform the baseline risk assessment.

### 4.1.2 Contaminants Detected

Tables 4.2, 4.3, 4.4, 4.5, 4.6 and 4.7 summarize the concentration range (by medium) of TCL organic compounds, TAL inorganic analytes, Appendix IX constituents, and radiological constituents detected at least once in environmental samples collected either as part of the WAG 6 RFI or the ORNL RCRA compliance monitoring program. These tables also summarize the total number of times a given compound or analyte was detected and the number of times it was analyzed for. Reference sample results are included in the tables. Rejected data and tentatively identified compounds (TICs) are not included in the summaries. Rejected data are those which have been judged unusable by the data validation process (Appendix 4A). TICs are not included since there are no bases for comparison in either environmental criteria or reference samples The following sections of Sect. 4 do present results for TICs wherever nature and extent are important considerations. One example is ethyl ether, a TIC which is included in the groundwater discussion since it is a component of scintillation fluids.

In Tables 4.2 through 4.7, minimum and maximum concentrations for both reference and site samples are listed by medium for comparison to each other and various environmental and health based criteria. For radionuclides, these health based criteria derived concentrations correspond to a one-in-a-million (i.e., 10E-6) excess total lifetime cancer risk and are based on pathway-specific unit risk factors provided for drinking water and soil in EPA's Health Effects Assessment Summary Tables (EPA 1990b). For chemical and radionuclide contaminants, the following criteria are also included:

- Safe Drinking Water Act (SDWA) Maximum Contaminant Limits (MCLs)

- Proposed SDWA MCLs
- Tennessee Secondary Drinking Water Standards
- Federal Ambient Water Quality Criteria for the protection of freshwater organisms
- Proposed RCRA Subpart S, Appendix A action levels for water and soil

The proposed RCRA Action Levels are derived from those given in Appendix A of proposed RCRA Subpart S (EPA 1990b). The assumptions, methodology and health based criteria (slope factors, reference doses) used to derive the Appendix A values are given in Appendixes D, E, and F respectively of proposed Subpart S. These health-based criteria were checked against those published by ORNL in Toxicity Values from the U. S. EPA Integrated Risk Information System and Health Effects Assessment Summary Table (ORNL 1991a). If a health-based criterion for a compound had changed, the RCRA Action Level was re-calculated using the Subpart S Appendix D and E assumptions and methodology with the new health based criterion.

From evaluation of Tables 4.2 through 4.7, it is evident that although a large number of contaminants was detected in WAG 6 samples, many were detected only once or at concentrations below concentration criteria and in estimated concentrations (i.e., reported as estimated below the method detection limit). To identify contaminants for evaluation during the nature and extent analysis, a three-part screening methodology was employed. This methodology is described in the following paragraphs.

- First, a statistical comparison was made to determine which contaminants were present at statistically greater concentrations in WAG 6 samples as compared to reference samples. The reference sampling program is described in Sect. 3. Any contaminant that was present at a statistically greater concentration in the on-site samples for a given medium was included for consideration in the nature and extent. The statistical comparison was limited to those sampling locations and samples used in the human risk assessment (Sect. 6). For on-site, this included 34 of 45 monitoring wells, all of the base flow surface water results, all of the shallow (0 to 6 ft.) soil samples, and sediment samples from the EWB. The monitoring wells not included were the four deep wells (no contaminants detected), one well where no sampling was performed, three shallow wells which were always dry, one well north of the EWB, and two wells east of the branch of White Oak Creek along the eastern side of WAG 6 meant to detect cross-stream movement of contaminants. The statistical analysis is reported in Appendix 4B.

- Second, to ensure that no contaminants which should be evaluated for nature and extent were excluded from the statistical analysis, any contaminant which had a maximum concentration anywhere across the entire WAG greater than the maximum concentration for the samples included in the risk assessment statistical analysis was subjected to an additional screening against the reference values. If the maximum concentration of a contaminant was an order of magnitude greater than the reference value, it was included for consideration in the nature and extent.

- Third, various environmental criteria and health-based, criteria-derived concentrations were compared. The criteria used were explained previously in this section and are included in Tables 4.2 through 4.7. A contaminant was included in the group to evaluate during the nature and extent analysis if its maximum concentration was greater than any of the criteria or criteria derived values. Table 4.8 summarizes the results of the contaminant screening for WAG 6 groundwater, surface water, soils, and sediments.

Inorganics were further screened by removing those constituents which are essential human nutrients from the evaluation group during the nature and extent analysis (Table 4.8).

The naturally occurring radionuclides were retained in the group since the concentrations detected in the environment are often greater than the health-based, criteria-derived concentrations. However, because only thorium-230 is statistically greater than referenced, discussion of these constituents will be limited in the nature and extent.

The resulting list of volatile and semivolatile organic compounds and inorganic analytes and radiological constituents for evaluation for nature and extent is summarized in Tables 4.8 and 4.9. The human risk assessment (Sect. 6) and the environmental evaluation (Sect. 7) produce their own lists of contaminants for consideration in their respective analyses. The special needs and methods of these assessments produce lists of contaminants for consideration which may be longer (human risk assessment) or shorter (environmental evaluation) than the list evaluated in this section.

Most of the contaminants listed in Table 4-9 are discussed in the remainder of this section. Those that are not discussed were found to be of little significance to the nature and extent discussion.

### 4.1.3 General Observations Pertaining to Nature and Extent

During compilation and analysis of site data to develop an understanding of the nature and extent of contamination, certain fundamental observations regarding the data were noted. These observations and general comments regarding data interpretation are described here to provide a framework for understanding data presented in subsequent sections.

#### 4.1.3.1 On-site contamination and off-site migration

Environmental sampling during the WAG 6 RFI focused both on assessing on-site contamination and evaluating potential off-site contaminant migration at the WAG 6 boundary. The characterization of the nature and extent of on-site contamination provides the basis for the assessment of human health and environmental impacts to on-site receptors. Additionally, it supports scoping of alternatives for closure and corrective action by delineating primary release areas and areas where contaminant concentrations may exceed action levels.

Characterization of migration of contaminants off WAG 6 provides the basis for assessment of the contribution of contamination from WAG 6 to WAG 2 and allows an assessment of potential human health and environmental impacts to receptors located at the WAG 6 boundary and beyond. In addition, description of the off-site migration of contaminants supports regulatory compliance program monitoring.

Data collected during the WAG 6 RFI and during previous investigations clearly indicate the release of contaminants from source areas to the environment on-site, and the subsequent migration of some of these contaminants off-site.

#### 4.1.3.2 Vertical distribution of contamination

Inspection review of the data indicate that there is very little radiological contamination of surface soils at WAG 6. The radiation walkover survey conducted for SWSA 6 and the EWB areas indicated some isolated surface soil "hot spots," defined as radiation readings above background. (The on-site SWSA 6 "hot spots" were removed as part of site preparation activities for construction of the ICM caps; the EWB hot spots were flagged by survey personnel and the areas were roped off by ORNL ES&H personnel.) The observed absence of radiological contamination of the ground surface at WAG 6 is consistent with site waste disposal methods and practices (i.e., wastes were disposed below ground level in trenches and auger holes in a controlled manner and subsequently covered with a soil cover several feet thick).

The primary zone of contamination at WAG 6 is the zone below the surface soil cover (i.e., below about 3 ft) including the regolith in both the saturated and unsaturated zones and the shallow bedrock primarily at locations downgradient to waste disposal areas. Numerous groundwater samples and subsurface soil samples indicate radiological and chemical contamination in these zones. There are discernible areal patterns to the contamination, as will be discussed in subsequent subsections. A significant observation regarding subsurface contamination is the decrease in contamination with depth. This trend is most apparent in groundwater as exemplified in Fig. 4.1, which plots tritium concentrations with depth. (Tritium is by far the most ubiquitous and mobile contaminant at WAG 6.) This trend is consistent with the understanding of the hydrogeologic system as described in Sect. 3, namely, that active groundwater flow is local and restricted to the uppermost saturated interval in regolith and bedrock.

#### 4.1.3.3 Variation of groundwater contaminant concentrations with time

As described in Sect. 2, the majority of WAG 6 groundwater monitoring wells have been sampled at least four times. From review of analytical results for these wells, no clearly defined temporal trends or relationships to physical variations in the hydrogeologic system (such as seasonal and episodic water level fluctuations, increased leaching associated with precipitation, etc.) are identifiable. Rather, contaminant concentrations show an apparently random fluctuation from sampling event to sampling event.

The lack of temporal trends and patterns is consistent with the conclusions drawn by Solomon et al. (1988) who noted that, based upon repeated sampling of leachate from selected trenches, there were large and erratic variations in radionuclide concentrations within a given trench. It is likely that the variations noted in trench leachate concentrations are related to the sporadic breakdown of containers and varying rates of water infiltration into the trenches.

#### 4.1.3.4 Delineation of contaminant plumes

A contaminant plume is a discrete zone of contamination that typically results from the flow of subsurface water through a source area. Contaminants are transported from the source in the direction of subsurface flow; the resulting zone of subsurface contamination – the contaminant plume – develops a geometry that is controlled by site specific conditions including, most importantly, the site hydrogeologic regime.

Contaminant data collected during the RFI and presented in this section indicate widespread contamination of shallow groundwater on-site, generally at low concentrations. Within this shallow groundwater system, there are discernible areas where particular contaminants predominate and there are areas of relatively elevated contaminant concentrations.

As described in Sect. 3, the hydrogeologic framework of WAG 6 is complex. Groundwater flow at WAG 6 is local, with short flow paths from recharge points in higher elevation areas to discharge points along site streams and low areas or to White Oak Lake.

Groundwater flow is controlled by a combination of prevailing hydraulic gradient and primary or relict fractures in the bedrock and regolith; groundwater flows along fractures from areas of higher head to areas of lower head. This results in tortuous flow paths (stair-stepping in three dimensions). Fracture orientations and density are variable both laterally and vertically at WAG 6 thereby precluding prediction of groundwater flow directions and rates with any certainty on a local (ie., point to point) basis. Further, the complexity imposed by the fracture network results in highly discrete contaminant transport along fractures that cannot be predicted from well to well. Consequently, detection of contamination in a given monitoring well (regardless of screen length) is extremely fortuitous and probably does not correlate to adjacent wells which may or may not have intercepted the same fracture network.

Although precise delineation of plumes is not feasible (see the description of the hydrogeologic regime presented in Sect. 3 and summarized above), areas of interest have been identified. Should collection of contaminated groundwater be required at WAG 6 it should be possible to develop a remedial design based on the available data, which also accommodates potential deviations from expected conditions.

#### 4.1.3.5 Intermedia transfer of contaminants

An understanding of intermedia transfer of site contaminants (e.g., transfer of contaminants from leachate to groundwater to surface water) is a prerequisite for the effective identification, definition, and evaluation of remedial alternatives. Considerable discussion related to this topic is presented in the analysis of contaminant fate and transport in Sect. 5, based upon data gathered during the RFI.

The primary interactions discussed are the leaching of contaminants from buried wastes to groundwater; the discharge of contaminated groundwater to surface water; and the transfer of contaminants between surface water and sediments.

## 4.2 SOURCE AREAS

Appendix 1A presented information regarding WAG 6 source areas, including information on waste disposal units and locations, waste types and packaging, and available waste inventory data. As a precursor to discussion of site contamination, the following paragraphs recap key information and concepts regarding source areas.

The ORNL Waste Disposal Log documents the radionuclide contents of each disposal trench and auger hole; however, the activities entered into the log generally represent estimated values only. The waste disposal log indicates, that as of December 1990, greater than 85 percent of the waste disposed of at SWSA 6 was disposed of in auger holes. Consequently, from a radiological perspective, SWSA 6 may be viewed as consisting of several small areas of high activity waste (primarily auger holes) located in a much larger area containing low-activity waste (primarily trenches) (ORNL 1986). Figure 4.2 illustrates the major classifications of radiological waste disposal areas and repeats the labeling of waste disposal areas and drainages employed in this report.

Chemical wastes are known to have been disposed both in auger holes and trenches. Oils, cleaning solutions, alcohols, paint thinners, kerosene, jet fuel, acids, sodium, and miscellaneous solvents and other chemicals were disposed in a set of auger holes classified as "solvent auger holes" (ORNL 1986). Some chemical wastes were poured into the auger holes and others were placed in the auger holes in containers; container sizes ranged from small bottles to 55-gal drums. The exact nature and volume of waste disposed in each solvent auger hole is unknown. Limited waste disposal records indicate that biological trenches were known to have received waste scintillation fluids which are composed of various aromatic hydrocarbons. Records indicate that from 1972 through May 1983, approximately 48,000 liters of scintillation fluids were disposed. Thirty-five biological trenches are identified in waste disposal records as having received scintillation fluids. Figure 4.3 illustrates areas where chemical wastes are known to have been disposed.

Trench leachates sampling has been conducted in past environmental sampling to aid in chemical and radiological characterization of source areas. Previous investigations conducted at WAG 6 that involved trench leachate sampling are summarized in Appendix 1B.

Key previous investigations that produced radiological data relevant to characterization of source term concentrations are:

- Tamura et al. (1980) sampled leachate from 26 trenches and analyzed the leachate for strontium-90, cobalt-60, and cesium-137.

- Solomon et al. (1988) sampled leachate from eight trenches and analyzed the samples for tritium as well as strontium-90, cobalt-60, and cesium-137.

- Davis et al. (1989) collected soil samples from five trenches located in the northeastern portion of the WAG (19 trench area). Soils were analyzed for cobalt-60, cesium-137, and strontium-90.

- As part of the Ashwood and Spalding (1990) collected trench leachate samples from 26 intratrench piezometers in the eight ICM capped areas. Samples were analyzed for gross alpha, gross beta, tritium, strontium-90, cesium-137, and cobalt-60.

Past environmental sampling to aid in chemical characterization of source areas has also been limited primarily to sampling of trench leachates or trench bottom soils:

- Solomon et al. (1988) sampled leachate from eight trenches and analyzed the samples for the EPA TCL. Ten VOCs and six SVOCs were identified.

- Ashwood and Spalding (1990) analyzed samples collected from 26 intratrench piezometers for TCL VOCs and SVOCs, and TAL metals.

- Davis et al. (1989) analyzed four trench bottom soil samples collected in the 19-Trench area for VOCs and SVOCs.

Trench leachate and trench soil sampling results are discussed where appropriate in the following sections. Trench leachate concentrations should be interpreted with the following caution: trench leachate data collected by Solomon et al. (1988) showed large and erratic variations in radionuclide concentrations with changing hydraulic conditions. Furthermore, the data indicated no correlation between the concentrations detected in trench leachates and the concentrations reported for those trenches in the ORNL waste disposal log. The variability of trench leachate data with time combined with the large number of trenches at WAG 6 lead Solomon et al. (1988) to conclude that trench leachate sampling was not a reliable method of characterizing source term for modeling.

In conclusion, release rates will likely increase or decrease unpredictably in the future for different contaminants in different areas of the SWSA. These variations would correspond to the unpredictable rates at which different types of waste packages disposed in the SWSA deteriorate. Based on ORNL experience at SWSA 4, it may be anticipated that, on a site-wide basis, WAG 6 environmental contamination will continue to increase in the near term (assuming no closure or corrective action). In the very long term, however, (i.e.,

hundreds of years), radioactive decay and chemical decomposition will result in lowered concentrations.

## 4.3 NATURE AND EXTENT OF ON-SITE CONTAMINANTS BY MEDIUM

This section summarizes the major findings related to the investigation of the nature and extent of radionuclide and chemical contamination in WAG 6 groundwater, surface water, sediments, and soil. The detailed discussion of nature and extent, with supporting figures, appears in Appendix 4C.

### 4.3.1 Groundwater

#### 4.3.1.1 Radionuclides

Both man-made and naturally occurring radionuclides were detected in groundwater samples at WAG 6. Of these radionuclides, tritium was the most prevalent. Except for wells located along the western boundary, tritium has been detected in groundwater samples exceeding the 20,000 pCi/L MCL from wells adjacent to all major waste disposal areas. Concentrations have exceeded 1,000,000 pCi/L in a few wells. The highest concentration detected has been over 4,000,000 pCi/L. Off-site migration of tritium in the groundwater system is probable. The areas of WAG 6 where tritium is most likely migrating off-site include the northern and eastern boundaries.

Additional man-made radionuclides detected in WAG 6 groundwater samples include cobalt-60, strontium-90, cesium-137, and the transuranic radionuclides americium-241, curium-244, plutonium-238, and plutonium-239/240. These radionuclides have been detected at relatively low concentrations, when compared to tritium, and have not been detected in many groundwater samples. Waste disposal areas in the northeastern section of WAG 6 appear to have released cobalt-60 to the groundwater system. Releases of strontium-90 have been detected in groundwater samples from the northern-most waste disposal. There have been other isolated occurrences of strontium-90 and cesium-137; however, detection of these radionuclides in these wells has been sporadic. All four previously mentioned transuranic radionuclides have been detected in groundwater samples from one well located in the northwestern part of WAG 6. Americium-241 has been detected in four other wells on site but in low concentrations (2.39 pCi/L or less).

#### 4.3.1.2 Chemicals

Organic compounds, both VOCs and SVOCs, have been detected in groundwater samples from WAG 6. SDWA MCLs for some VOCs have been exceeded in various wells. The distribution of VOCs is similar to that of tritium, having been detected in wells adjacent to all major waste disposal areas. Highest concentrations of VOCs have been associated with solvent auger hole areas and biological trench areas. Groundwater samples from some upgradient wells have also had VOCs detected; however, concentrations have been low (22 $\mu$g/L or less), are usually estimated values below 5 $\mu$g/L, and in two instances have been common laboratory contaminants. SVOCs that have been detected are few (limited to 3

compounds) and have been detected in groundwater samples in which VOCs have also been detected. Off-site migration of organic compounds in the groundwater system is likely along the northern, eastern and southeastern boundaries of WAG 6.

Metals have been detected exceeding various criteria in a limited number of wells at WAG 6. Of these metals, lead and barium are the most widely detected. Wells in which metals concentrations exceeded various criteria are positioned in the interior of WAG 6. It appears that migration of metals in the groundwater system has not advanced far beyond the boundaries of the waste disposal areas near which they were detected.

### 4.3.2 Surface Water

#### 4.3.2.1 Radionuclides

Both man-made and naturally occurring radionuclides have been detected in surface water samples from WAG 6. Naturally occurring radionuclides have been detected, but do not exceed reference (background) concentrations. Of the man-made radionuclides detected, tritium and strontium-90 are the most prevalent and have been detected at concentrations exceeding their respective MCLs. The highest concentration of tritium detected on site (14,000,000 pCi/L) was collected from a surface water sample from the outfall of the 49-Trench area French Drain. Tritium has been detected in all drainages at WAG 6 and in the majority of samples, the MCL has been exceeded.

Cobalt-60 has been detected only once in a surface water sample from Drainage C located in the northeastern section of WAG 6 and adjacent to where cobalt-60 has been detected in groundwater and soil samples. The concentration at which it was detected exceeded the MCL. Strontium-90 has been detected at concentrations exceeding the MCL in several drainages at WAG 6. Highest concentrations have been detected in surface water samples collected from Drainage FB which flows nearly the whole length of WAG 6 from the north to the south. Strontium-90 has also been detected in groundwater from Well 1225 located near the headwaters of Drainage FB. Transuranic radionuclides have been detected; however, they were detected in only two samples.

#### 4.3.2.2 Chemicals

Organic compounds (VOCs and SVOCs) have been detected in surface water samples from WAG 6. MCLs were exceeded for some VOCs. Of the VOCs detected three compounds are the most common: 1,2-dichloroethene, tetrachloroethene, and trichloroethene. Concentrations are generally less than 200 $\mu$g/L and except in samples collected from the outfall of the 49-Trench area French Drain where tetrachloroethene was detected at 2,200 $\mu$g/L. Organic compounds detected in downstream samples are generally lower in concentration than upstream samples.

The SVOCs that have been detected are generally at low concentrations and are commonly laboratory contaminants. The SVOCs are not considered to be a significant contaminant of surface water at WAG 6.

Barium and cadmium concentrations exceeded reference or MCL values but for only two samples.

### 4.3.3 Sediments

#### 4.3.3.1 Radionuclides

Both man-made and naturally occurring radionuclides were detected in sediment samples from WAG 6. Naturally occurring radionuclides were detected at concentrations within reference (background) ranges and are not considered site contaminants. Of the man-made radionuclides detected (cobalt-60, strontium-90, cesium-137, and tritium), cesium-137 was the most frequently detected. Except for the one detection of strontium-90, which exceeded ingestion limits, concentrations of the other radionuclides did not exceed any action levels (Table 4.7). Transuranic radionuclides were not detected in any soil samples that were analyzed. The potential for off-site migration of strontium-90 in sediment from Drainage FB does exist. Strontium-90 was detected in the sample location closest to the southern boundary of WAG 6.

#### 4.3.3.2 Chemicals

Except for one sampling location, organic compounds – primarily VOCS, were detected in every sediment sample collected at WAG 6. The most frequently detected VOCs include chloroform, acetone and toluene in sediments from the Emergency Waste Basin, and trichloroethene, toluene, and chloroform from sediment samples collected in drainages from WAG 6. The SVOCs that were detected were few and consisted of common laboratory contaminants. Ingestion concentrations for VOCs were not exceeded in any sample. Surface water detects for VOCs have been adjacent to locations where VOCs have been detected in relatively high concentrations in groundwater.

No sediment sampling results indicated any metals concentrations significantly above reference concentrations.

### 4.3.4 Soil

#### 4.3.4.1 Radionuclides

Radiological contamination in soil at WAG 6 is limited to the man-made radionuclides strontium-90 and cobalt-60. Areal extent of each radionuclide was limited to three soil borings each. The maximum concentration of strontium-90 did not exceed ingestion limits (Table 4.7). Ingestion limits for cobalt-60 have not been established.

#### 4.3.4.2 Chemicals

Although various organic compounds (both VOCs and SVOCs) have been detected in soil samples from WAG 6, some of the compounds are suspected sampling- or laboratory-induced contaminants. These compounds are acetone, 2-butanone, methylene chloride,

toluene, and bis(2-ethylhexyl) phthalate. Concentrations detected for these compounds were typically below 100 $\mu$g/L. Proposed Subpart S RCRA concentration criteria were not exceeded for any organic compound detected in soil.

Metal contamination of soil at WAG 6 appears to be very localized. Arsenic, lead, mercury, and cobalt have been detected in a few samples at concentrations significantly above background.

## 4.4 OFF-SITE MIGRATION

The preceding "media by media" discussion focused primarily on describing on-site releases and contamination. In the following paragraphs, conclusions regarding off-site migration of contamination are summarized to support assessment of impacts to off-site receptors.

### 4.4.1 Summary of Off-Site Transport Mechanisms

The primary media by which contaminants are transported off-site are groundwater and surface water. There is some transport off-site via sediments, soils, and air; however, these appear to be relatively minor pathways. Sediments, although contaminated, are not transported off-site at significant rates due to the intermittent nature of the streams and due to erosion control features implemented in conjunction with the RCRA ICM cap. Erosion of surface soils off-site via surface water runoff from waste disposal areas is not considered significant; the radiological walkover survey revealed minimal surface soil contamination, and erosion is controlled by the regularly maintained vegetative cover over the waste disposal areas and by the RCRA ICM caps where installed. Air, although not sampled during the RFI is not expected to be a significant pathway due to the vegetative cover over the waste areas (controlling suspension of soil particles) and the general absence of surface soil contamination. Volatilization of contaminants from surface water may be a significant pathway and is included in the fate and transport analysis (Sect. 5.)

### 4.4.2 Off-Site Migration Patterns

Figures 4.4 and accompanying Table 4.10, and 4.5 and accompanying Table 4.11, illustrate the primary off-site releases identified during the RFI for radionuclides and chemicals, respectively. The figures divide the perimeter of the site into three small classifications:

- Areas where off-site migration is likely (designated by H)
- Areas where off-site migration is not likely (designated L)
- Areas of uncertainty for off-site migration (designated U)

Areas where off-site migration is likely are defined as regions along the boundary of WAG 6 where groundwater and/or surface water features in proximity to the boundary have been shown to contain various contaminants. Unless downstream sampling indicated otherwise, if contamination was detected upstream in any of the drainages on-site, it was

assumed that these contaminants are likely migrating off-site. If wells close to any boundary contained contaminants and groundwater flow directions indicated possible off-site flow, these areas were also labeled as likely areas of
off-site migration.

Areas not likely for off-site migration are defined as those areas that lack any waste disposal facility in the vicinity (such as the southwestern region of WAG 6); those that are upgradient to any waste disposal facility and whose collected samples show little, if any, contamination; and areas downgradient to waste disposal areas where sampling and an understanding of flow characteristics suggest that this area is not a possible exit point from the WAG.

Areas of uncertainty for off-site migration of contaminants include regions along the perimeter of WAG 6 where no direct evidence to support off-site migration exists.

# Section 4 Tables

**Table 4.1 Summary of database**

| Media Sampled | TM Number | TM Title |
|---|---|---|
| Groundwater | 06-094 | Groundwater Investigation |
| Surface Water Sediment | 06-05A | Surface Water and Sediment Investigation |
| Soil | 06-12A | 06-12A Soil Investigation |

**Table 4.9. Constituents for consideration in nature and extent**

| Analyte | CAS No. | Groundwater | Surface water | Soil | Sediment |
|---|---|---|---|---|---|
| Volatile organic compounds | | | | | |
| 1,2–Dichloroethane | 107–06–2 | X | | | |
| 1,2–Dichloroethene | 540–59–0 | X | X | | |
| 2–Butanone | 78–93–3 | | | | X |
| Acetone | 67–64–1 | X | | | X |
| Benzene | 71–43–2 | X | | | |
| Carbon Tetrachloride | 56–23–5 | X | | | |
| Chloroform | 67–66–3 | X | X | | X |
| Ethylbenzene | 100–41–4 | X | | | |
| Methylene Chloride | 75–09–2 | X | | | |
| Tetrachloroethene | 127–18–4 | X | X | | |
| Toluene | 108–88–3 | X | | | X |
| Trichloroethene | 71–55–6 | X | X | | X |
| Vinyl Chloride | 75–01–4 | X | X | | |
| Xylene, total | 1330–20–7 | X | | | |
| Semi–volatile organic compounds | | | | | |
| Benzoic Acid | 65–85–0 | | | | X |
| Bis(2–Ethylhexyl)Phthalate | 117–81–7 | X | X | | |
| Inorganics | | | | | |
| Aluminium | 7429–90–5 | X | X | X | |
| Antimony | 7440–36–0 | X | | | |
| Arsenic | 7440–38–2 | X | X | X | |
| Barium | 7440–39–3 | X | X | | |
| Beryllium | 7440–41–7 | X | X | X | |
| Cadmium | 7440–43–9 | X | X | | |
| Chromium | 7440–47–3 | X | X | X | |
| Cobalt | 7440–48–4 | X | | | |
| Copper | 7440–50–8 | X | X | | |
| Lead | 7439–92–1 | X | X | | |
| Manganese | 7439–96–5 | X | X | | |
| Mercury | 7439–97–6 | X | X | X | |
| Nickel | 7440–02–0 | X | | | |
| Osmium | 7440–04–2 | | | | X |
| Selenium | 7782–49–2 | | | X | |
| Silver | 7440–22–4 | X | X | | X |
| Strontium | 7440–26–6 | X | | | |
| Thallium | 7440–28–0 | X | | X | |
| Titanium | 7440–32–6 | X | | | |
| Vanadium | 7440–62–2 | X | X | X | |
| Zinc | 7440–66–6 | X | X | | |

**Table 4.9. (continued)**

| Analyte | CAS No. | Groundwater | Surface water | Soil | Sediment |
|---|---|---|---|---|---|
| Gross alpha and gross beta | | | | | |
| Gross Alpha | 12587-46-1 | X | X | | |
| Gross Beta | 12587-47-2 | X | X | | X |
| Manmade Radionuclides | | | | | |
| Tritium | 10028-17-8 | X | X | | X |
| Cobalt-60 | 10198-40-0 | X | X | X | X |
| Strontium-89 | 14158-27-1 | | | X | |
| Strontium-90 | 10098-97-2 | X | X | X | X |
| Cesium-137 | 10045-97-3 | X | X | | |
| Americium-241 | 14596-10-2 | X | | | |
| Plutonium-238 | 13981-16-3 | X | X | | |
| Plutonium-239/240 | 0-013 | X | X | | |
| Curium-244 | 13981-15-2 | X | | | |
| Naturally Occurring Radionuclides | | | | | |
| Potassium-40 | 13966-61-1 | X | X | X | X |
| Uranium Series | | | | | |
| Uranium-238 | 7440-61-1 | X | | | |
| Thorium-234 | 15065-10-8 | X | X | X | X |
| Uranium-234 | 13966-29-5 | X | | | X |
| Thorium-230 | 14269-63-7 | X | X | | |
| Radium-226 | 13982-63-3 | X | | X | X |
| Thorium Series | | | | | |
| Thorium-232 | 7440-29-1 | X | X | | |
| Radium-228 | 15262-20-1 | X | X | | |
| Thorium-228 | 14274-82-9 | X | X | X | X |
| Radium-224 | 13233-32-4 | X | X | X | X |

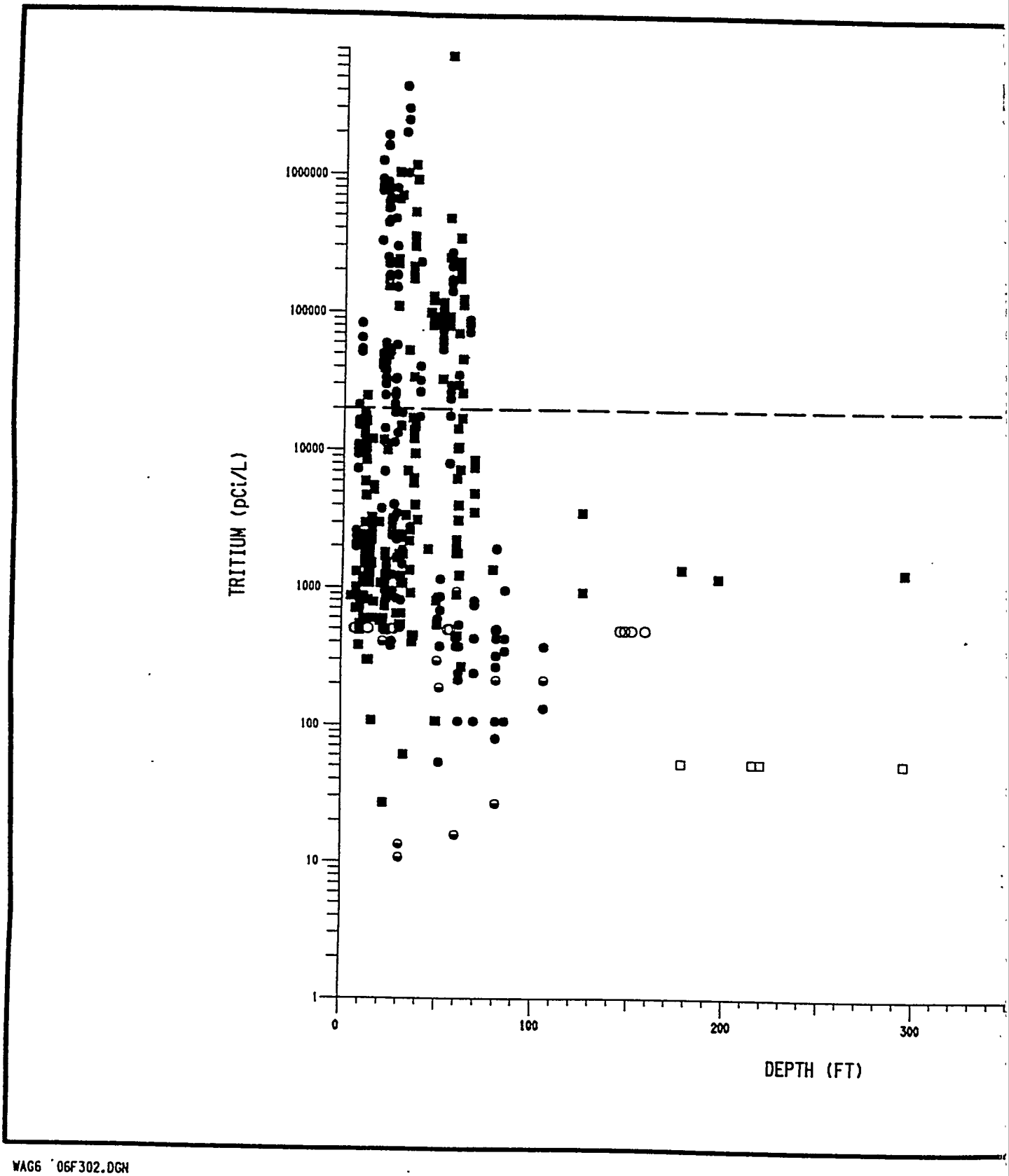
**Table 4.10. Migration of radionuclides off-site**

| Perimeter segment | Radionuclides | Discussion |
|---|---|---|
| | Areas likely for off-site migration of contaminants | |
| H-1 | Surface Water<br>Tritium<br>Strontium-90 | Storm flow sampling identified significant flux of contaminants off-site in surface water. |
| | Groundwater<br>Tritium<br>Strontium-90 | Wells upgradient are contaminated. |
| H-2 | Surface Water<br>Tritium | Storm flow sampling identified significant flux of tritium off site. |
| | Groundwater<br>Tritium | Concentrations exceeding MCL detected in several upgradient wells. |
| H-3 | Groundwater<br>Tritium<br>Cobalt-60<br>Strontium-90 | Compliance and RFI monitoring data indicate presence of radionuclides in groundwater. |
| | Areas not likely for off-site migration of contaminants | |
| L-1 | | Upgradient to waste disposal areas |

**Table 4.11. Migration of chemicals off-site**

| Perimeter segment | Chemicals | Discussion |
|---|---|---|
| | Areas likely for off-site migration of contaminants | |
| H-1 | Surface water<br>none | No significant VOC concentrations detected during storm flow sampling |
| | Groundwater<br>VOCs | Upgradient wells contaminated, monitor unconsolidated zone and bedrock zone. Groundwater wells in this vicinity monitor bedrock zone only. |
| H-2 | Surface water<br>VOCs | Low concentration detected during storm flow. |
| | Groundwater<br>None | Well positioned between creeks DA and DB have had relatively low concentrations of VOCs detected in it. |
| H-3 | Surface water<br>None | No surface water features in this area. |
| | Groundwater<br>VOCs | VOCs detected during compliance and RFI monitoring. |
| | Areas not likely for off-site migration of contaminants | |
| L-1 | Surface and Groundwater<br>None | Upgradient to any waste disposal area |
| L-2 | Surface water<br>None | No contamination detected. |
| | Groundwater<br>VOCs | VOCs have been detected; however, in relatively low concentrations. |

# Section 4 Figures

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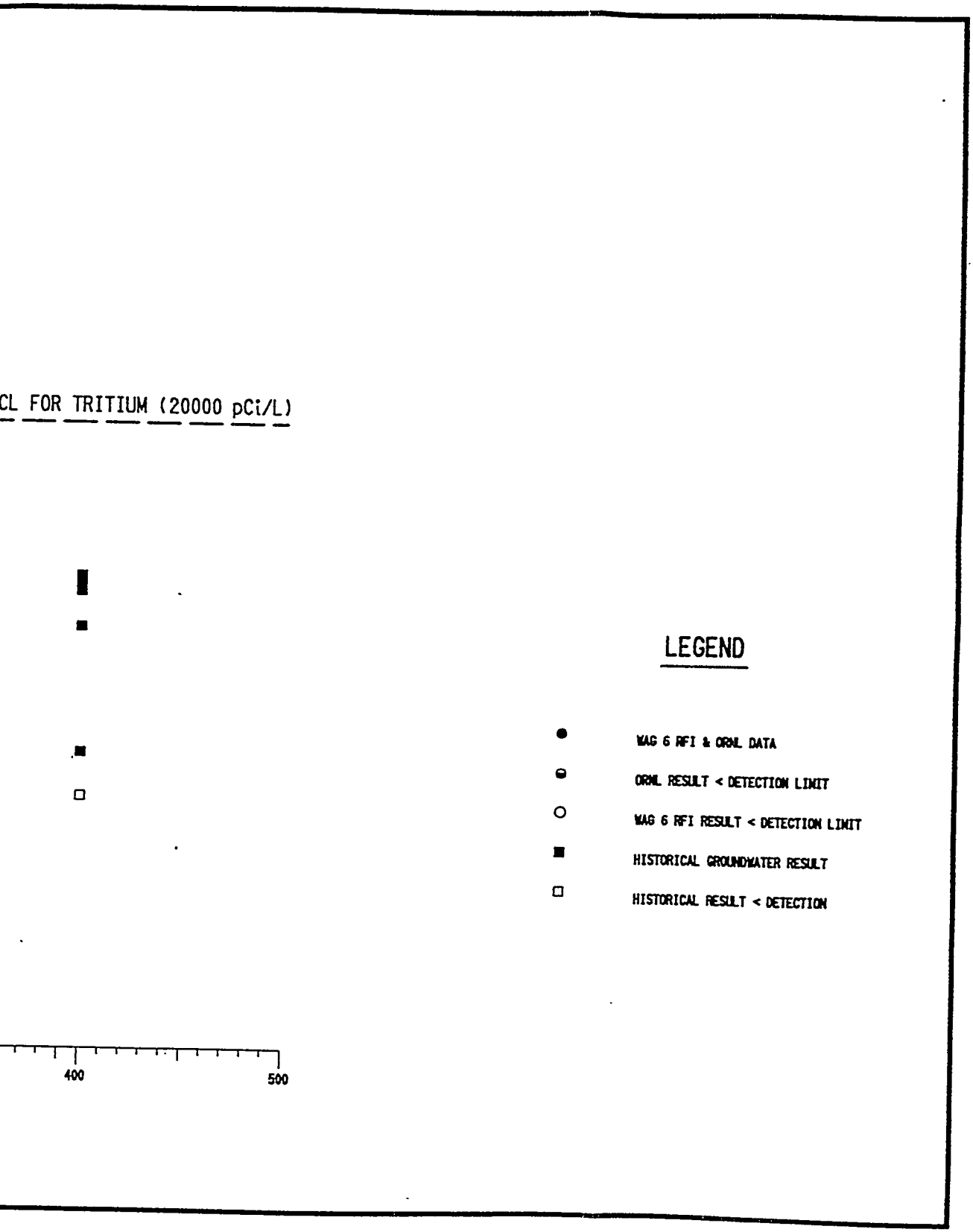
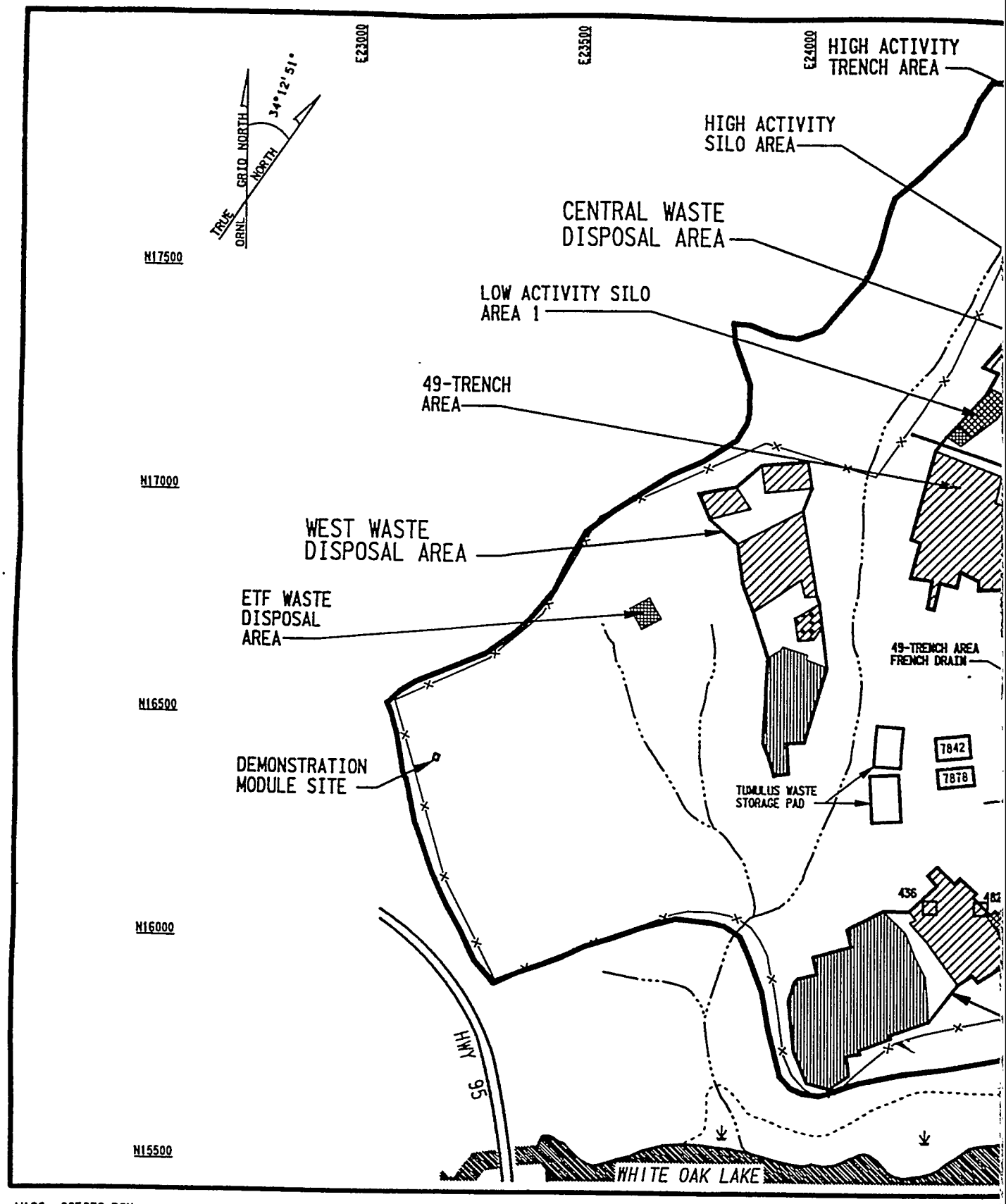



**Fig. 4.1. Vertical distribution of tritium in WAG 6 groundwater.**

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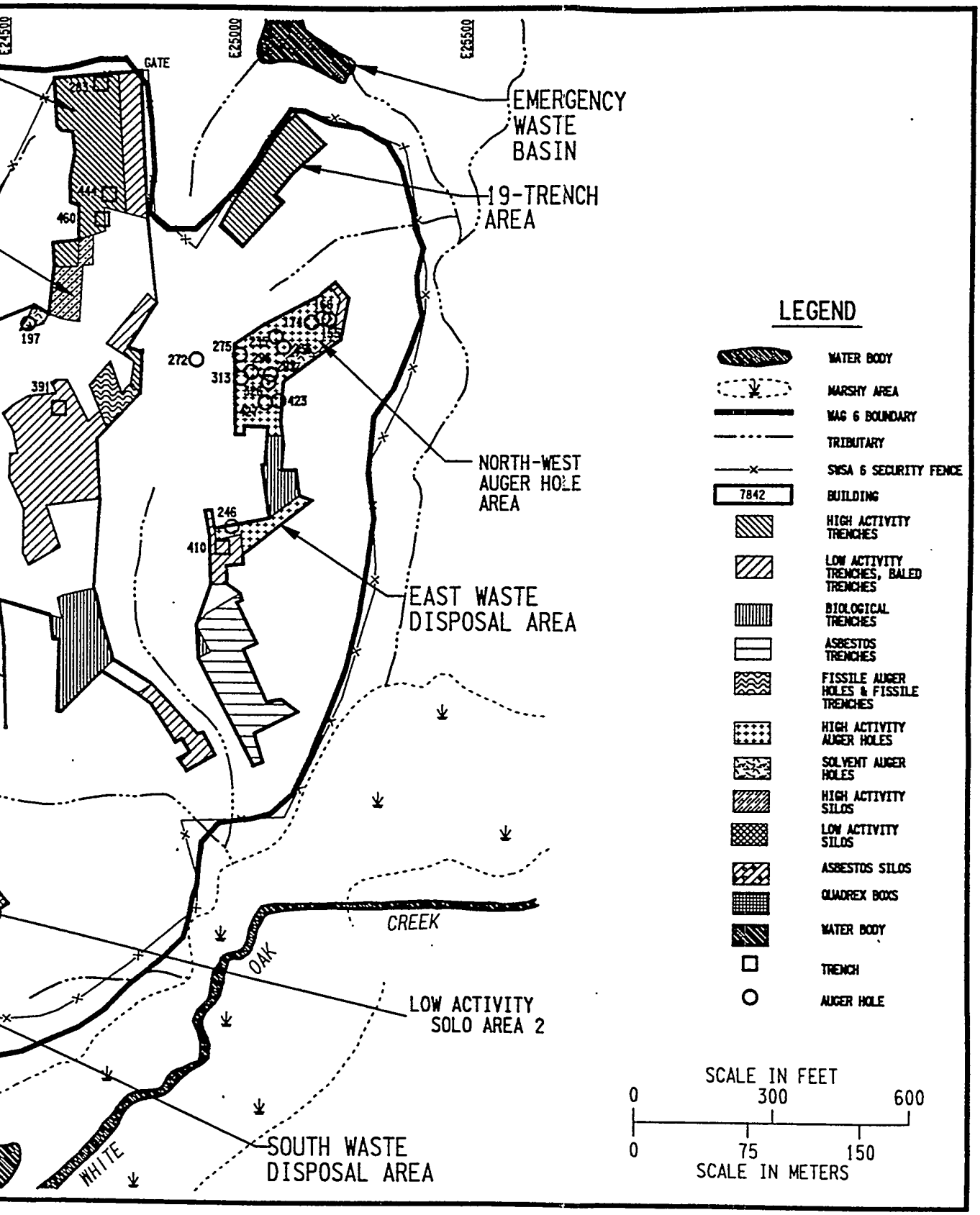
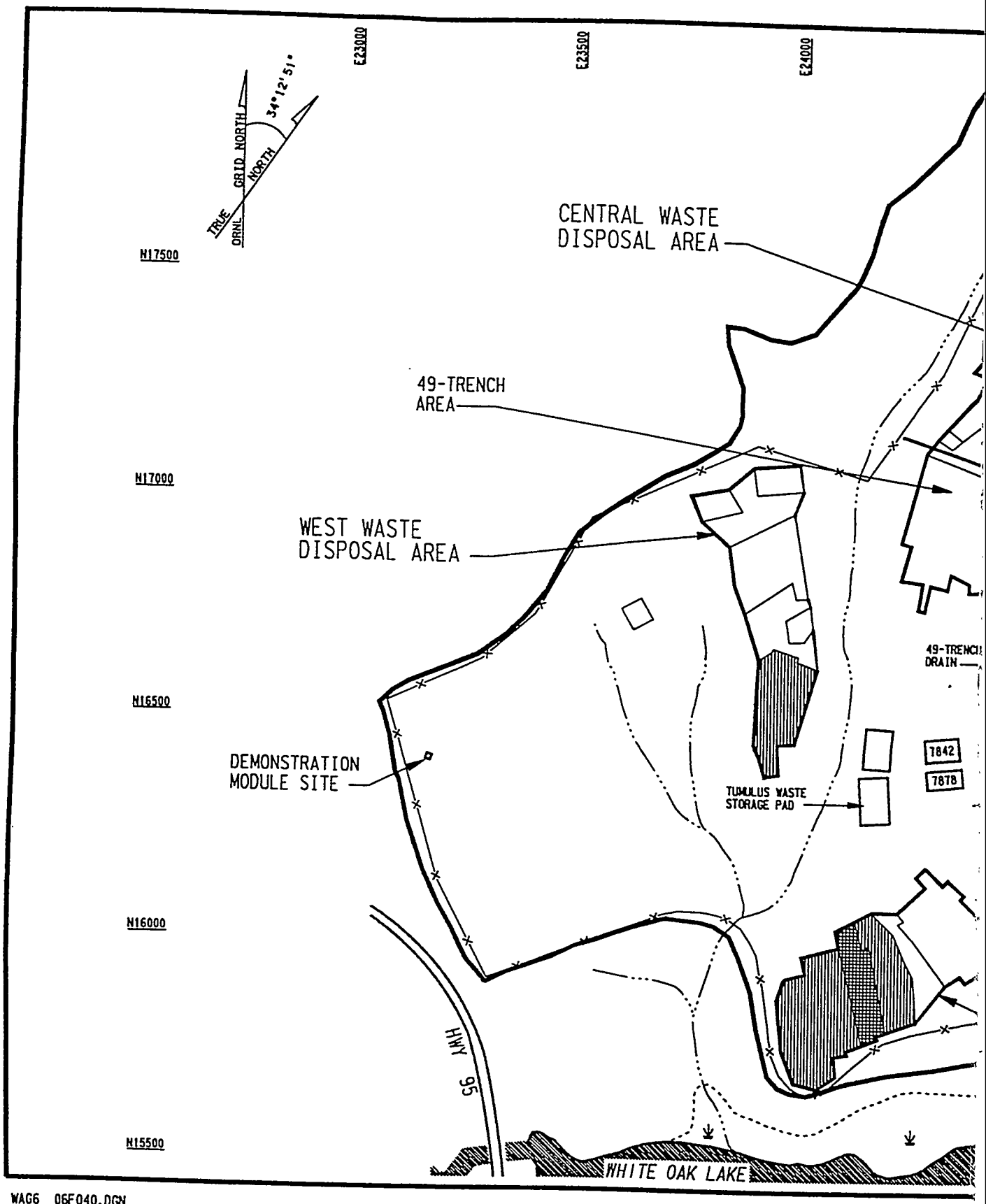



**Fig. 4.2. WAG 6 waste disposal areas.**

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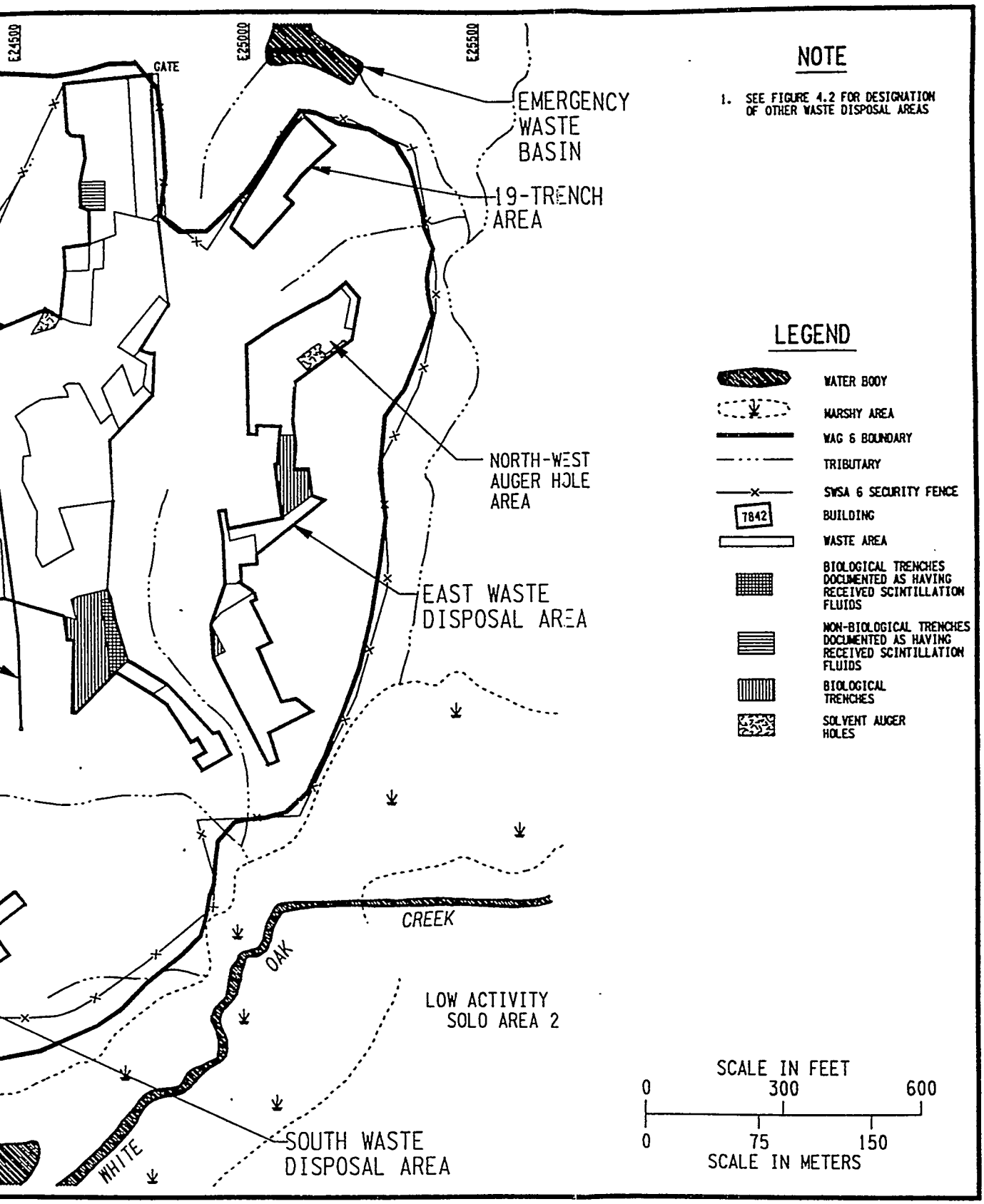
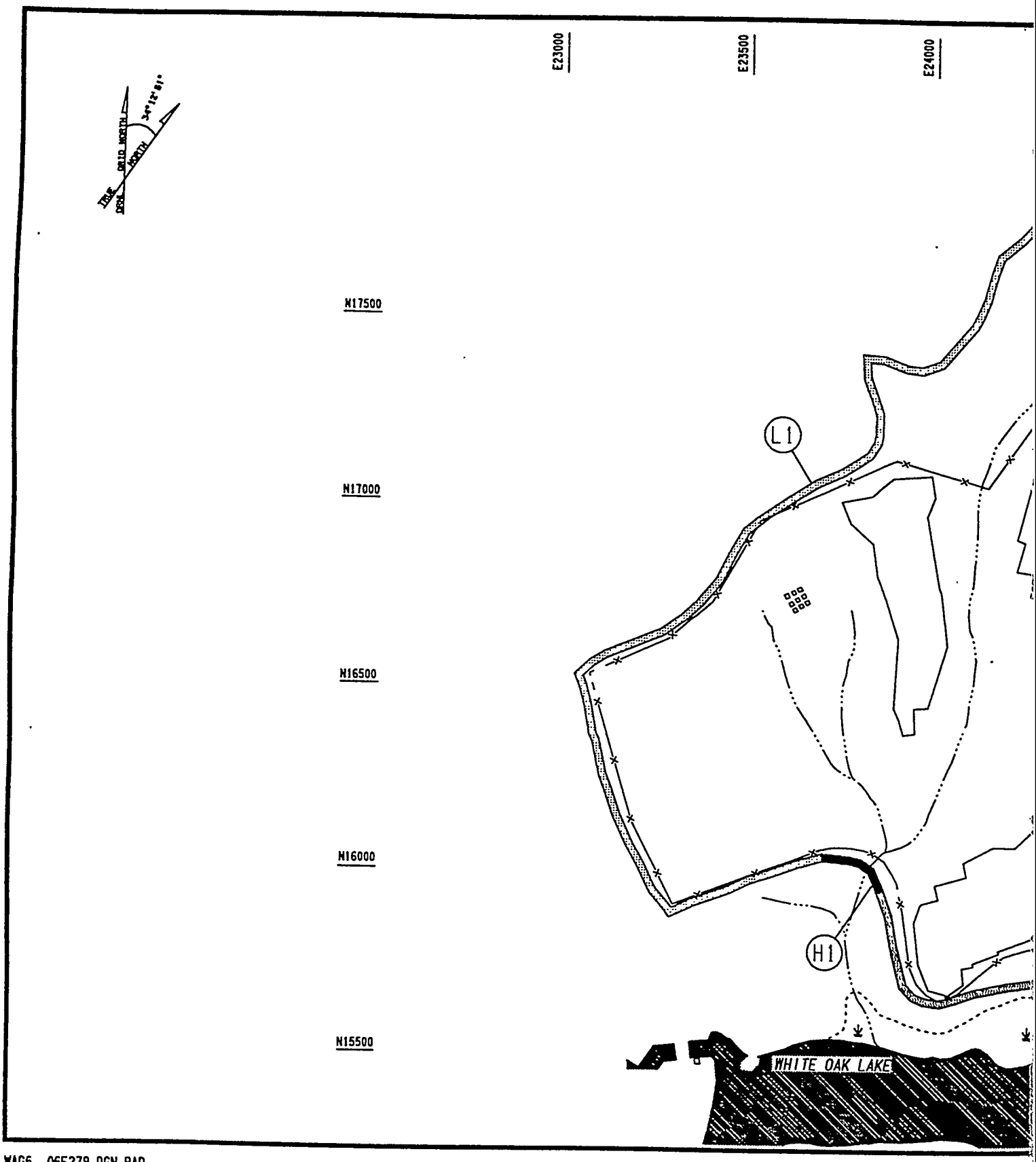



**Fig. 4.3. WAG 6 solvent auger hole and biological trench areas.**




WAG6 06F279.DGN RAD

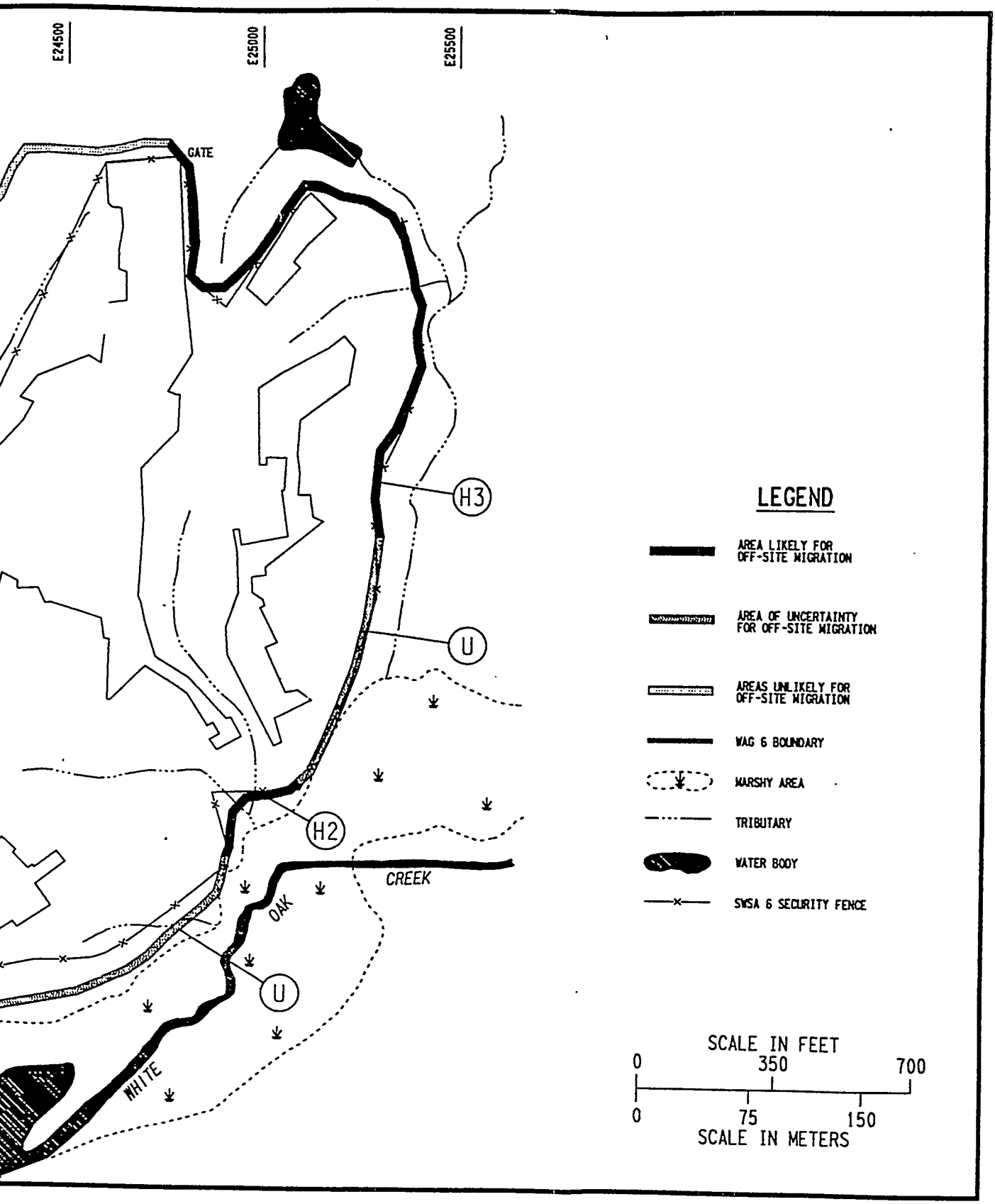
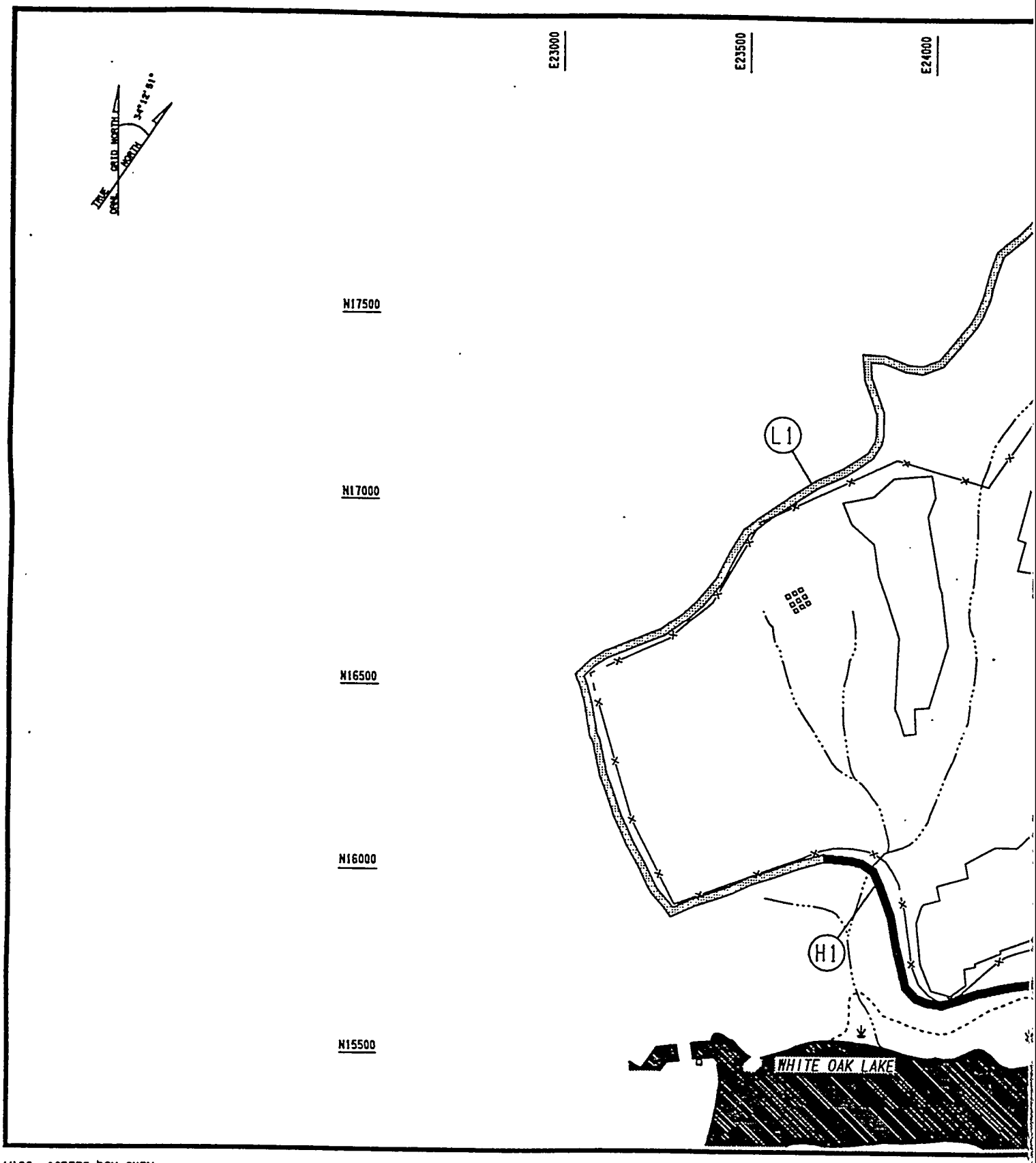



**Fig. 4.4. Off-site migration of radionuclides.**




WAG6 06F335.DGN CHEM

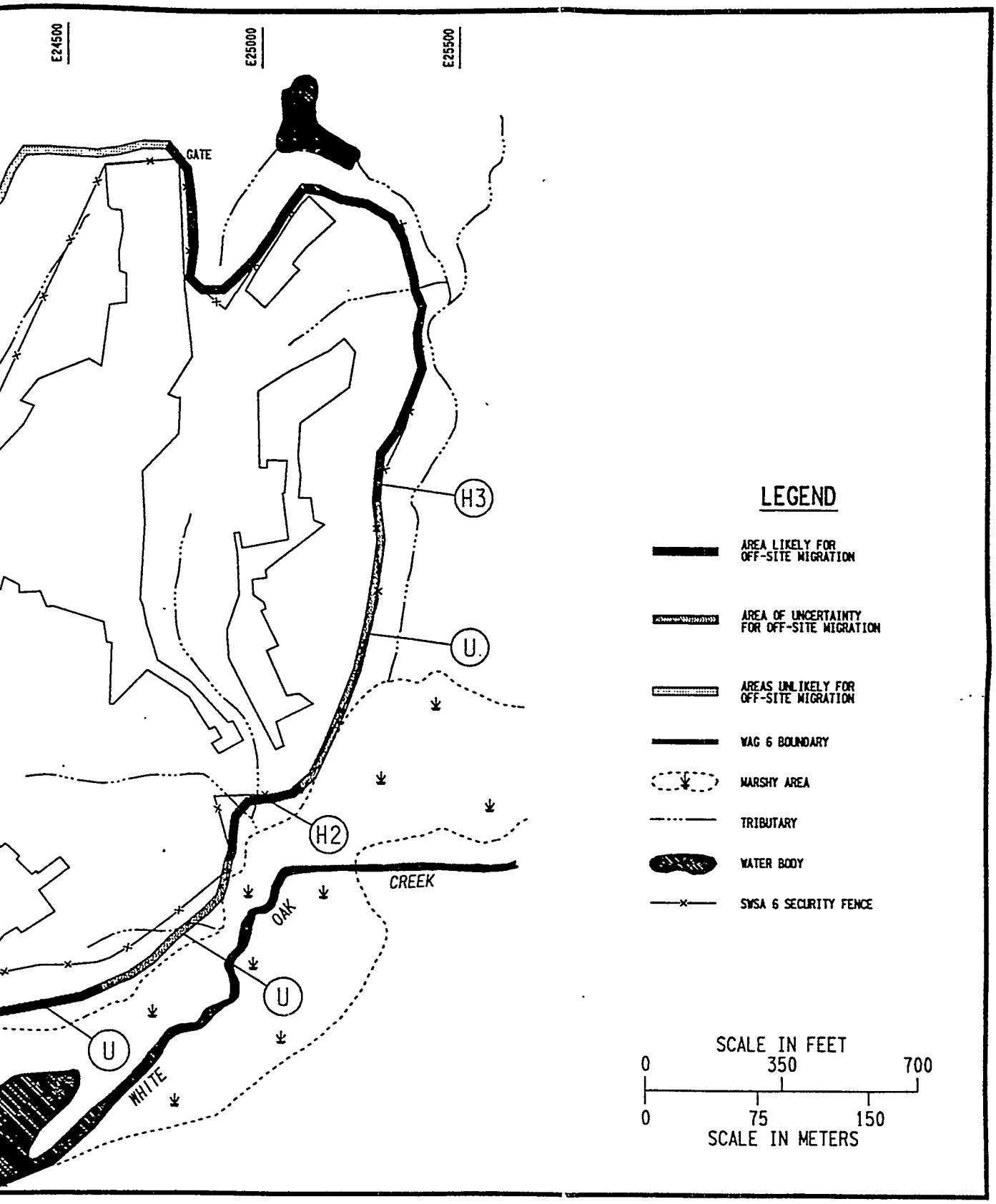



**Fig. 4.5. Off-site migration of chemicals.**

# 5. CONTAMINANT FATE AND TRANSPORT

## 5.1 INTRODUCTION

### 5.1.1 Scope of the Analysis

Contaminant fate and transport modeling was conducted to support the baseline human health evaluation and to aid in definition of remedial alternatives. The baseline human health evaluation (Sect. 6) considers hypothetical present day and future on-site and off-site receptors. For on-site receptors, predictions of contaminant concentrations in groundwater, surface water, sediment, soil, and air are required. For the off-site receptor, contaminant flux via surface water to WOL is assumed; this flux is used to calculate a corresponding concentration downstream in the Clinch River, adjacent to the location of the hypothetical off-site receptor.

To fulfill these data requirements, the fate and transport analysis described in this section quantified:

- Release rates of the contaminants from source areas into the environmental media
- Remaining quantities of the contaminants in source areas
- Persistence of contaminants in environmental media into which they are being released
- Transformation (decay and degradation) of contaminants in media, and their transfer between media
- Transport and migration of contaminants off of WAG 6

Modeling to predict future concentrations and fluxes was performed for radionuclides. Due to a lack of inventory data, prediction of future concentrations and fluxes for chemicals was not possible. However, fluxes of chemicals for current conditions were computed.

### 5.1.2 Methodology and Content

The methodology developed for the fate and transport analysis included computer modeling of contaminants in water and air. Because soil and sediment concentrations are a function of the transport of contaminants in water and air, no specific modeling methodology was developed for these media.

Computer modeling was chosen as the appropriate analytical tool for the analysis because it provided an exploratory as well as predictive capability. The exploratory capability of the modeling stemmed from the quantitative relationships developed which linked the observed contaminant concentrations to site and source characteristics. The predictive capability allowed for the estimation of future contaminant concentrations and fluxes which could not otherwise be derived from monitored concentrations alone.

The site conceptual model for WAG 6 is discussed in Sect. 5.2, prior to the discussion of the fate and transport analysis. The site conceptual model identifies the potential environmental pathways through which humans could be exposed to the radionuclides and chemicals. The model provided the basis for the analysis of fate and transport; also, exposure pathways identified in the model were used as the basis for performing the baseline risk assessment presented in Sect. 6, and for identifying potential remedial measures.

Section 5.3 summarizes the surface/subsurface water fate and transport analysis methodology, application, and results. Section 5.4 summarizes the air modeling methodology, application, and results, and the conclusions of the fate and transport analysis appear in Sect. 5.5. In-depth accounts of the analysis are provided in the following appendixes:

- Appendix 5A, Surface Water Modeling in WAG 6
- Appendix 5B, Analysis and Results of April-May 1990 Storm Sampling
- Appendix 5C, Surface/Subsurface Water Fate and Transport Model
- Appendix 5D, Surface/Subsurface Water Fate and Transport Modeling in WAG 6
- Appendix 5E, Air Modeling-Models Used, Application, Results

## 5.2 SITE CONCEPTUAL MODEL

The site conceptual model was the framework within which environmental pathways of potential concern for WAG 6 were identified and illustrated. Figure 5.1 is a conceptual model of WAG 6 which illustrates the environmental pathways by which humans can be exposed to contaminants released from the source areas where contaminants have been placed. The following paragraphs discuss the basic elements of the conceptual model.

The term source areas refers to the shallow land burial waste disposal units described in Sect. 1. In Fig. 5.2, these units are illustrated schematically within the general hydrologic setting.

A contaminant release mechanism is defined as any process that results in migration of the contaminant from a source area into the immediate environment. Contaminants may be released via the mechanisms identified in Fig. 5.1 into the primary transport media: groundwater, surface water/sediments, soil, and air. As discussed in Sect. 4, the occurrence of contamination in all media except air was determined by observation. Air was included in the conceptual model since it can be a potential pathway, and air modeling was performed to characterize it.

Contaminants in source areas and in the environmental media are subject to transformation processes which degrade the contaminant concentrations. For the radionuclides, the process is radioactive decay; for organic chemicals it involves photochemical, biological, and chemical degradation processes.

Once in the environment, contaminants can be transferred among media (Fig. 5.3), and transported out of WAG 6. Humans are exposed to contaminant concentrations via the exposure routes of inhalation of air, and via ingestion and direct contact in other media. The environmental pathways involving each primary transport media shown in Fig. 5.1 are discussed in the following subsections.

### 5.2.1 Groundwater Pathway

As discussed in Sect. 4, migration of contaminants was identified in WAG 6, extending from specific source areas toward site streams, the WAG 6 boundary, and WOL. The groundwater release mechanisms were identified as percolation and direct contact. In trenches saturated or partially saturated due to the rising water table, contaminants were in direct contact with groundwater. In disposal units located above the normal water table leachate is generated when infiltrating moisture mixes with the waste material and then percolates to the groundwater.

Intermedia transfer of contaminants occurred between groundwater, soil, and surface water. Some contaminants in groundwater moved at velocities much lower than the characteristic flow velocity of groundwater because they were retarded by interaction with the solid matrix of the aquifer (sorption). When the groundwater intersected the streams, groundwater contaminants were transferred to surface waters by groundwater discharge. Seepage from the stream beds also transferred contaminants in surface water to the groundwater.

Contaminants can be transported in groundwater by advection and dispersion. Advection is the movement of contaminants at flow velocity. Dispersion occurs because of local velocity variations induced by the complex geometry of the actual flow path. It depends on the mean flow velocity and is greater in the direction of flow than transverse to the flow. Therefore, a contaminant plume spreads in the direction of advection, resulting in longitudinally elongated plumes. As discussed in Sect. 3, the hydrogeology of WAG 6 is complex, and contaminant transport occurs through secondary porosity features such as fractures. Flow and transport characteristics of the media were not fully characterized.

Extensive refinement of the groundwater pathway conceptual model was not appropriate due to the considerable uncertainty associated with contaminant release rates and hydrogeologic parameters. As described in Sect. 4.2, because source areas comprise heterogeneous units with heterogeneous waste forms, packaging, and containers, contaminant release rates may vary unpredictably as random disintegration of waste containment occurs. Hydrogeology exhibited characteristics of both porous media and fractured rock; these characteristics could not be readily characterized by field measurements on a local scale across the site and therefore were not modeled numerically.

### 5.2.2 Surface Water Pathway

Elevated levels of tritium, strontium-90, and chlorinated alkenes and alkanes were observed along the streams in WAG 6, and were being transported off of the site, as discussed in Sect. 4. The potential mechanisms identified for the release of these contaminants from the source areas were trench overflow and subsurface storm flow. Trench overflow occurs when a trench is saturated and spills leachate. Trench overflow mixes with overland flow and is carried into streams. Contaminant release into surface water may also occur via subsurface storm flow (Sect. 3.3). Leachate in bathtubbing trenches or in trenches within the groundwater table could mix with these subsurface storm flows, move laterally with the flows, and be discharged into the streams.

From surface waters, intermedia transfers occurred to air via volatilization, to groundwater via seepage from stream beds, and to soil via seepage. Stream widths in WAG 6 are relatively small, and streams carry water intermittently, therefore volatilization of contaminants is minimal. In the upper reaches of the streams, seepage into soil and groundwater occurred. Contaminants in stream water were also transferred to sediments in suspension and/or on the stream-bed.

Contaminants were also transferred into surface waters from air via precipitation/deposition; from soil via runoff including overland flow, saturated overland flow, and subsurface storm flow; and from groundwater via groundwater discharge (baseflow).

Transport of contaminants out of WAG 6 appeared relatively rapid since streams exiting the site are quite short. Contaminant flux out of WAG 6 via streamflow was the major component of the total contaminant flux exiting WAG 6, since most of the flux from groundwater was discharged into site streams.

Further refinement of the surface water pathway was not appropriate because contaminant release rates into surface waters for the different release mechanisms discussed could not be measured. No models exist that address subsurface storm flow. As discussed in Sect. 3, subsurface storm flow may exist in only parts of WAG 6. The stream flows in WAG 6 consist of overland flows, saturated overland flows, subsurface storm flows, and base flows. These individual flow components and of contaminant concentrations associated with them were not estimated because it is the contaminant flux out of WAG 6 that is of primary interest for surface water, and that can be monitored at stream outlets.

### 5.2.3 Soil Pathway

Since most of the source areas in WAG 6 contained disposal units located in the vadose zone, contaminants were released into soil by direct contact, diffusion, percolating water, and subsurface storm flows. Vertical and lateral movement of the advancing soil moisture front, especially from the unlined trenches, spread the dissolved contaminants in the vadose zone

soil. As discussed in Sect. 4, contamination in the vadose zone was fairly limited and did not appear to represent significant secondary source areas. Contamination of surface soils appeared minimal.

From soil, contaminants were transferred to air via volatilization and particulate suspension; to groundwater via percolation; and to surface water via runoff and groundwater discharge. Also, contaminants were transferred to soil via precipitation/deposition from air; via sorption from groundwater; and via seepage from surface water.

No specific transport mechanism was considered for soil, since soil acts as a storage medium in which transport occurs mostly via water.

### 5.2.4 Air Pathway

Air was determined to be a minor pathway. Volatilization and particulate emissions (due to upwind erosion of source area soils) are the two mechanisms for contaminant releases to air. Other than the soil gas survey conducted during RFI activities at the perimeter of selected trench areas (to assess the presence and migration of VOCs), no database was developed to quantify these release rates. Volatilization rates are contaminant-specific and vary according to waste characteristics, the characteristics of the waste units, natural and engineered barriers, and climatic and meteorological conditions. Biological trenches were identified as the areas where gas generation would most likely occur due to biological, chemical, and physical decomposition of the wastes.

Particulate emissions due to source area soil erosion would likely be minimal because of high annual rainfall, low wind speeds, extensive grass cover, and the rapid regrowth of vegetation in temporarily disturbed areas.

Contaminants released into the air could be transferred to both surface waters and soil surface by deposition (dry settling) and precipitation, thereby creating diffuse secondary sources which lead to further contamination of other media. For example, from the soil surface, infiltrating rainwater could carry the contaminants into the vadose zone, and from there into the groundwater. Air-soil and air-water transfers are functions of solubility, adsorption, particle size, and precipitation. Transport of contaminants in air occur by advection and dispersion, in the predominant wind directions of southwest and northeast.

## 5.3 SURFACE/SUBSURFACE WATER CONTAMINANT FATE AND TRANSPORT

Surface water/subsurface water contaminant transport modeling methodology was developed consistent with the site conceptual model of WAG 6. The methodology developed provided for a simplified quantitative analysis of the fate and transport.

- **Uncertainties in the evaluation of source terms.** Substantial uncertainties existed concerning the quantities of contaminants placed in the waste areas in WAG 6. The waste areas exhibited highly heterogeneous waste forms, packaging, containers, and modes of disposal, and accurately predicting the rates at which contaminants were released from individual waste areas was not feasible.

- **Complexity of release mechanisms.** Trenches and auger holes across the site exhibited varying interactions with surface water and groundwater on a storm-by-storm basis. Furthermore, disintegration mechanisms of various containers were not known, and the date of a disposal unit's loss of integrity could not be estimated accurately.

- **Complexity of the site hydrogeology.** Unsaturated and saturated zones in WAG 6 exhibited characteristics of both porous media and of fractured rock. Flow and transport characteristics of the site could not be characterized in detail on a local scale.

The next five subsections present modeling assumptions, contaminants modeled, modeling methodology, results, and a discussion of the results.

### 5.3.1 Modeling Assumptions

The surface water/subsurface water modeling methodology included the following assumptions:

- **Time step.** A time step of one year was considered appropriate for the transport modeling objectives, which focused on the long-term predictions of contaminant concentrations.

- **Steady-state assumption.** A steady-state approach was taken to model the surface and groundwater flows. An average year was assumed to repeat for the simulation period.

- **Lumped source area.** Waste area sites were grouped into manageable units according to burial methods and waste types and forms. For modeling purposes, the waste areas in WAG 6 were divided into 26 source areas (Areas A to Z). These are shown in Fig. 5.4.

- **Surface water generation.** Since no long-term continuous flow measurements were available to define the WAG 6 streamflows, flows for an average climatic year were generated using a water balance model, shown in Appendix 5A.

- **Groundwater flows.** Groundwater flow and water table data generated in Sect. 3 were used as the steady-state groundwater input for the transport modeling.

- **Surface water transport.** A conceptual empirical modeling approach was formulated based on field calibration which related the source term to observed concentrations.

- **Groundwater transport.** A one-dimensional analytical model was used to model contaminant transport in the vadose zone and the saturated zone. The model was calibrated against analytical sampling data from wells downgradient of the source area and considered first-order decay, sorption, dilution, and dispersion.

### 5.3.2 Contaminants Modeled

Modeling was performed for selected radionuclides based on dose considerations discussed in Sect. 6. These included tritium, cobalt-60, strontium-90, cesium-137, europium-152, europium-154, uranium-233, uranium-238, and thorium-232. No modeling was performed for chemicals since source inventories for them were unknown.

### 5.3.3 Modeling Methodology

The transport model developed to perform the analysis of fate and transport in surface waters and subsurface water was executed within a Monte Carlo simulation framework, where the uncertainty of the model parameters was directly incorporated into the modeling process. The theoretical basis of the model and its features are given in Appendix 5C. The model was calibrated, where possible, for each of the 26 source areas and for each of the radionuclides. The model calibration was based on the sampled radionuclide concentration data in surface water and groundwater, and on the radionuclide source inventory. For each of the modeled areas, the model output included 160 years of radionuclide inventory; flux in surface runoff; and groundwater flux, and concentrations at calibration wells and points downgradient of wells within WAG 6.

Radionuclide flux in streams was computed by combining the flux in the surface runoff of the tributary areas with the flux of groundwater discharging into streams. Radionuclide concentration in streams was then computed by dividing the stream radionuclide flux by the streamflow rate. The radionuclide plumes from source areas were superimposed to compute groundwater radionuclide flux and concentration at the WAG 6 boundary.

The model input data, selection of model parameters, calibration of the model for source areas, and modeling output and analysis are presented in Appendix 5D.

### 5.3.4 Results

The model output for each of the 26 areas for each of the radionuclides included predicted annual time-series of radionuclide inventory, concentration in the calibration well, and the flux in the surface runoff. Both the time-series of mean values and the time-series of the 95 percentile of the mean values are shown in the computer printout. Since the 95 percentile of the mean value was required as input to the risk analyses, only the 95 percentile values are presented in this report.

As an example, the output is presented for cobalt-60 for Area A: Fig. 5.5 shows the time-history of the cobalt-60 concentration in Well 1242; the time-history of the cobalt-60 inventory remaining in Area A; and the cobalt-60 flux in the surface runoff from Area A. In Appendix 5D, similar results are shown for cobalt-60, cesium-137, europium-152, tritium, and strontium-90 for Areas A, B, C, M, and Y.

The year in which a radionuclide occurred the first time in the well (breakthrough year), its concentration that year, its peak concentration, and the year when the peak concentration occurred in the well representing the source area, are summarized in Tables 5.1 through 5.9 for cobalt-60, tritium, strontium-90, cesium-137, europium-152, europium-154, uranium-233, uranium-238, and thorium-232, respectively. These tables also show the inventory of radionuclides and their average year of emplacement. The depleted radionuclide inventories in all of the 26 areas are shown in Table 5.10 for the years 2020 and 2120.

To provide the necessary data for the risk analysis, the average concentrations of radionuclides in the streams were determined at various points along the streams for three time periods. The time periods considered were 1990-2019, 1990-2059, and 2100-2129. The results for cobalt-60, cesium-137, europium-152, europium-154, tritium, strontium-90, thorium-232, uranium-233 and uranium-238 are shown in Appendix 5D.

The time-histories of annual fluxes in surface waters for the nine radionuclides that exit the WAG 6 boundary and those that discharge into the EWB also are shown in Appendix 5D. The predicted peak annual fluxes and the years of their occurrence are presented in Table 5.11. The time-histories of the annual groundwater fluxes that exit all of WAG 6, and those that discharge into the EWB, are also shown in Appendix 5D. The predicted peak annual fluxes and years of their occurrence are contained in Table 5.12.

### 5.3.5 Discussion

#### 5.3.5.1 Radionuclides in groundwater

Present-day and predicted future concentrations of the modeled radionuclides in groundwater (Tables 5.1 through 5.9) are discussed below. Cobalt-60 and tritium concentrations in groundwater were predicted to deplete monotonically over time due to decreasing leachate flux and radioactive decay. Maximum concentrations of cobalt-60 have already occurred and no significant peaks were predicted in the future. Except in areas F, N, Q, and V, the observed tritium concentrations in the wells were the maximum expected concentrations.

The peak strontium-90 concentrations in most wells were predicted to occur after the year 2032. The predicted peaks were within an order of magnitude of concentrations observed during field sampling. The present-day concentration of strontium-90 in groundwater was highest in area C. Also, existing groundwater plumes from Areas Z and L showed significant strontium-90 concentrations. Because strontium-90 complexes with

organics less readily than cobalt-60, it has relatively high retardation. Strontium-90 behaves as does calcium in competing for cationic adsorption sites in clays and minerals and has a longer half-life than cobalt-60 or tritium. Thus, in several areas with high strontium inventory (such as Areas A, B, F, G, H, and P), the groundwater concentration was predicted to show a peak in the future after containers are breached. With the plumes from Areas C, D, and H, there was a significant strontium-90 flux in groundwater discharging to stream FB.

There were relatively high concentrations of cesium-137 in the contaminant plumes downgradient of Areas A, B, C, L, M, N, O, and P. The cesium concentration should decrease with time in most places except for the plume from Area P; peak concentration was predicted to occur in the year 2051, with about three times the present-day concentration.

Europium-152 and europium-154 were not present in most of the groundwater plumes. Most europium was placed in lined auger holes with control plates composed of a europium oxide-aluminum cermet clad with aluminum. The lining in the auger holes and the aluminum cladding has delayed and reduced leaching. There were high inventories of europium-152 in Areas B and P and of europium-154 in Areas B, K, and P. Significant concentrations of europium-152 were predicted to be present in the receptor wells downgradient of Areas B and P around the year 2000. Around the same period, contaminant plumes from Areas B, K, and P may show elevated levels of europium-154. Concentration peaks for europium were predicted to occur between 2030 and 2040, after the auger aluminum claddings were assumed to be ineffective.

Concentrations of uranium in wells appeared negligible. There was a large inventory of uranium-233 reported for Areas L, M, N, and Y. Uranium-238 is present in large quantities in Areas E, N, V, and Y. For the source Area L, sampling well 848 was predicted to have a uranium-233 concentration of approximately 20 pCi/L in the year 2025. In Area Y, sampling well 837 was predicted to have a uranium-233 concentration of approximately 30 pCi/L and a uranium-238 concentration of approximately 84 pCi/L in year 2091. Peak concentrations of uranium-233 and uranium-238 were predicted to occur beyond the year 2180.

Thorium-232 inventory was high in Areas P (6003 Ci) and N (16.2 Ci). The thorium-232 concentrations, like those of uranium, continue to increase for a long time (as thorium-232 has a very long half-life). However, retardation of thorium is almost an order of magnitude higher than retardation of the other radionuclides analyzed. Therefore, it should reach the wells or receptor points very slowly; its detected concentrations were negligible.

#### 5.3.5.2 Depletion of radionuclide inventories

The fate of the radionuclides in the source areas discussed below was based on the remaining source inventory data presented in Table 5.10.

Within 55 years, cobalt-60 inventory was predicted to be depleted in all waste areas in WAG 6 except Area P, which had the largest inventory. Cobalt-60 inventory was predicted to be completely depleted within 72 years; and tritium inventory in all areas except in Area L within 65 years (with complete depletion in 96 years). Strontium-90 has a longer half-life, and depletes slowly. By the year 2120 (within 129 years) only Areas A, B, C, D, F, and P were predicted to have significant strontium-90 activity. Cesium-137 was predicted to remain in significant quantities in Areas A, B, J, P and Q by the year 2120.

Europium-152 and europium-154 were present in Areas A, B, K, and P. Europium-152 has a half-life of 13.6 years and was predicted to be present at significant levels in all source areas in the year 2120, when europium-154 (half-life of 8.8 years) would be depleted in all areas except Area P.

Uranium and thorium were present at significant levels in a few areas (see Table 5.10). Relatively high levels of uranium-233 were present in Areas L, M, N, and Y, and high levels of uranium-238 were present in areas M, N, and Y. High thorium-232 activity (6003 Ci) existed only in Area P. The source inventory of uranium-233, uranium-238, and thorium-232 was predicted to undergo little depletion by the year 2100 because of slow leaching. Since these radionuclides have long half-lives, depletion of the existing source through decay will take a long time.

## 5.4 ANALYSIS OF ATMOSPHERIC FATE

For the baseline risk assessment, air modeling was performed to determine the average annual airborne contaminant concentrations over the WAG 6 area for four periods. The modeling was limited to a screening level analysis of emissions and of atmospheric dispersion of the contaminants of concern, including tritium and selected VOCs. Tritium was found in surface waters of WAG 6 and was assumed to be emitted to the atmosphere as water evaporates. VOCs were assumed to be emitted from the waste burial grounds in WAG 6.

Air emissions were estimated by using EPA's landfill emissions estimation model, CHEMDAT7 (EPA 1989). Dispersion modeling was performed using EPA's Industrial Source Complex Long Term (ISCLT) atmospheric dispersion model (EPA 1987b). The data used in the modeling included the sampling data for tritium and VOCs plus meteorological data from ORNL's station TA, which is located near WAG 6, for the 5-year period (1986-1990).

The data input for the model, the models used in the analysis, the application of the models to the site, and the modeling results are presented in Appendix 5E; summaries are provided below.

### 5.4.1 Emission Modeling

#### 5.4.1.1 Tritium

Tritium emissions were assumed to originate primarily from surface water. Emission rates were developed for the four periods required by the baseline risk assessment: (1) the present; (2) 1990-2019; (3) 1990-2059; and (4) 2100-2129. The air emissions for the present were based on the maximum tritium concentrations measured during four sampling events in 1989. For the other periods, modeled concentrations in surface waters (presented in Appendix 5D) were used.

Air emissions were estimated assuming that dissolved tritium evaporated at the same rate as water. The volume of water evaporated from each stream equaled the product of the source surface area and the annual evaporation rate. Evaporation rates for perennial source areas were calculated assuming that 39 in. of water evaporated per year. Evaporation rates for intermittent streams were based on the predicted number of days that the stream contained water.

#### 5.4.1.2 VOCs

VOC emissions were assumed to originate primarily from the waste burial areas. For modeling purposes, 89 source areas were identified. The CHEMDAT7 model was used to generate steady-state emission rates for the chemicals found in WAG 6. The CHEMDAT7 model applied in this analysis was confined to the "closed landfill" model. This section of the model was designed to estimate emissions from dilute aqueous sources contained in a closed (no longer active) landfill that generally included an earthen layer or cap covering the landfill.

### 5.4.2 Dispersion Modeling

EPA's ISCLT model was designed to calculate average concentrations or total deposition values produced by emissions from multiple stack, volume, and area sources. The concentrations or total deposition values can be calculated on a seasonal or annual basis for an unlimited number of sources. ISCLT is capable of producing seasonal and/or annual results for each source as well as combined results from groups of multiple sources. Calculations were performed for an input set of receptor coordinates defining a fixed receptor grid system and/or for discrete (arbitrarily placed) receptor points. All points were relative to a user-defined grid origin in either a Cartesian or polar coordinate system.

Input data for the ISCLT model consisted of four categories: meteorological data, source data, receptor data, and program control parameters. Each is briefly described below.

#### 5.4.2.1 Meteorological data

Meteorological data required for ISCLT consisted of an annual joint frequency table, mixing height data, and temperature data. A joint frequency table is a matrix containing the frequencies of occurrence of 6 wind speed classes, 16 wind direction sectors, and 6 atmospheric stability categories. Mixing height data are required for each wind speed, stability category, and season. Temperature data are required for each stability category and season.

#### 5.4.2.2 Source data

The program accepts three types of sources: point, area, and volume. Source data inputs included the location (in relation to a user-defined origin), elevation, and emission rate. For area sources, the horizontal dimension and effective emission height were also required.

#### 5.4.2.3 Receptor data

Receptor data consisted of grid and discrete receptors. Grid receptors, spaced along a 25-meter, Cartesian coordinate grid, were used to determine on-site concentrations. Hypothetical receptors were placed along the site boundary to determine concentrations at the site fenceline.

#### 5.4.2.4 Program control parameters

Program control parameters and options allow the user to choose one or more of the model options. These options define the types of sources, receptors, and output to be used in each model run; they also allow the user to change model default values.

### 5.4.3 Results

The predicted surface water tritium emissions are shown in Table 5.13. Predicted VOC emissions are shown in Table 5.14. Both tritium and VOC annual concentrations were calculated for fenceline receptors and on-site receptors. Table 5.15 lists the maximum concentrations for tritium for hypothetical receptors at the boundary and on-site for all four time periods; for VOCs, Table 5.15 shows steady-state concentrations.

#### 5.4.3.1 Tritium results

With the exception of the EWB, all other sources had minimal impacts on ambient concentrations. The predominant winds in the area caused concentrations to follow a southwest-northeast direction. Emissions based on 1989 sampling data resulted in the highest concentrations, occurring a few meters east of the French Drain. Due to radioactive decay, concentrations of tritium decreased during the later time periods.

### 5.4.3.2 VOC results

The predominant winds for the WAG 6 area caused concentrations to generally elongate along a southwest-northeast axis. Table 5.15 lists the maximum concentrations for both fenceline and on-site receptors.

## 5.5 CONCLUSIONS

The conclusions of the fate and transport analysis which included the modeling of water and air in WAG 6 are summarized below.

- Water was the major transport mechanism for off-site migration of contaminants and most of the radionuclide flux out of WAG 6 was expected to continue to occur via surface water
- Cobalt-60, tritium, strontium-90, and cesium-137 were in most of the wells in WAG 6. Thorium-232 was in area M wells
- The first occurrences of europium and uranium in groundwater were predicted to be in years 1998 and 2025.
- Peak future groundwater concentrations were predicted to be within two orders of magnitude of the present-day concentrations
- Air modeling, which was performed conservatively, indicated that air pathway contributed negligible amounts of exposure-point concentrations of contaminants on-site and off-site
- Radioactive decay was the major mechanism for the depletion of source inventories of the radionuclides with short half-lives
- Source inventories of cobalt-60 and tritium were predicted to be depleted in about 100 years in WAG 6
- Source inventories of strontium-90 in Areas A, B, C, D, F, and P were predicted to still be significant in the year 2120
- Source inventories of cesium-137 in Areas A, B, J, P, and Q were predicted to still be significant in the year 2120

- Europium was present in source areas A, B, K, and P. By the year 2120, while europium-152 inventory was predicted to remain in significant quantities, europium-154 was expected to be depleted in all source areas except area P

- Radionuclides with long half-lives, such as uranium and thorium-232, were predicted to remain in the source areas far beyond the year 2120

# Section 5 Tables

**Table 5.1 Predicted cobalt-60 concentration**

| | Inventory | | Breakthrough concentration | | Peak concentration | |
|---|---|---|---|---|---|---|
| Area | Ci | Year | pCi/L | Year[a] | pCi/L | Year[b] |
| A | 3357 | 1978 | 7.6 | | 17.6 | 2024 |
| B | 1305 | 1978 | 1030 | | | |
| C | 15.2 | 1977 | 37.3 | | | |
| D | 3521 | 1982 | 590 | | | |
| E | 16.2 | 1973 | 9.6 | | | |
| F | 14.5 | 1974 | 7.4 | | | |
| G | 4.13 | 1975 | 105 | | | |
| H | 82.2 | 1988 | 57.6 | 1998 | | |
| I | 1.9 | 1988 | 8.6 | 1999 | | |
| J | 250 | 1987 | 96.6 | 1990 | | |
| K | 20.9 | 1981 | 7.56 | | | |
| L | 7.2 | 1982 | 2.0 | | | |
| M | 198 | 1975 | 2.7 | | | |
| N | 645 | 1978 | 3.3 | 2024 | | |
| O | 391 | 1978 | 3.2 | | | |
| P | 21064 | 1985 | 8210 | | | |
| Q | 377 | 1974 | 34.6 | | | |
| R | 1001 | 1983 | 82 | | | |
| S | .005 | 1979 | -- | | | |
| T | .001 | 1978 | -- | | | |
| U | .004 | 1980 | -- | | | |
| V | 16.2 | 1979 | 1.7 | | | |
| W | .173 | 1982 | -- | | | |
| X | 25.7 | 1979 | 3.4 | | | |
| Y | 6436 | 1985 | 8.8 | | 60 | 2024 |
| Z | .855 | 1988 | -- | | | |

[a] Unless indicated, breakthrough year was 1989.
[b] Unless indicated, peak occurred in the breakthrough year.

**Table 5.2. Predicted tritium concentration**

| | Inventory | | Breakthrough concentration | | Peak concentration | |
|---|---|---|---|---|---|---|
| Area | Ci | Year | pCi/L | Year[a] | pCi/L | Year[b] |
| A | 1.6 | 1978 | 31600 | | | |
| B | 32.8 | 1978 | 656000 | | | |
| C | 1071 | 1977 | 2.8E+6 | | | |
| D | 13.3 | 1982 | 1.04E+6 | | | |
| E | 50.4 | 1973 | 114000 | | | |
| F | 45.5 | 1974 | 4700 | | 35000 | 2009 |
| G | 13 | 1975 | 1.39E+6 | | | |
| H | 10 | 1988 | 84300 | | | |
| I | 4.9 | 1988 | 54200 | | | |
| J | 5 | 1987 | 116000 | | | |
| K | 0.35 | 1981 | 10000 | | | |
| L | 2488 | 1982 | 7.0E+6 | | | |
| M | 618 | 1975 | 3.4E+6 | | | |
| N | 452 | 1978 | 4000 | | 154000 | 2011 |
| O | 284 | 1978 | 292000 | | 563000 | 2026 |
| P | 2700 | 1985 | 1.8E+6 | | 3.05E+6 | 2020 |
| Q | 6.2 | 1974 | 123000 | | 1.6E+6 | 2024 |
| R | 19 | 1983 | 49500 | | | |
| S | 30 | 1979 | 38000 | | | |
| T | 34.5 | 1978 | 97000 | | | |
| U | 61.6 | 1980 | 33000 | | | |
| V | 50.4 | 1979 | 17900 | | 52600 | 2014 |
| W | 3.5 | 1982 | 169000 | | | |
| X | 177 | 1979 | 45000 | | | |
| Y | 805 | 1985 | 26300 | | | |
| Z | 9.5 | 1988 | 477000 | | | |

[a] Unless indicated, breakthrough year was 1989.
[b] Unless indicated, peak occurred in the breakthrough year.

**Table 5.3. Predicted strontium-90 concentration**

| | Inventory | | Breakthrough concentration | | Peak concentration | |
|---|---|---|---|---|---|---|
| Area | Ci | Year | pCi/L | Year[a] | pCi/L | Year[b] |
| A | 416 | 1978 | 4.6 | | 718 | 2052 |
| B | 284 | 1978 | 4.3 | | 418 | 2052 |
| C | 105 | 1977 | 5640 | | | |
| D | 68 | 1982 | 41 | 2055 | 117 | 2116 |
| E | 3.2 | 1973 | 4.3 | | 17.2 | 2049 |
| F | 93.3 | 1974 | 8.02 | | 268 | 2032 |
| G | 26.7 | 1975 | 4.5 | | 496 | 2053 |
| H | 45 | 1988 | 163 | 1998 | 419 | 2058 |
| I | 20.4 | 1988 | 561 | 2013 | | |
| J | 43.7 | 1987 | 53.6 | 1990 | 130 | 2049 |
| K | 6.8 | 1981 | 13.7 | | | |
| L | 38 | 1982 | 59 | | 75 | 2045 |
| M | 39 | 1975 | 7.3 | | 100 | 2051 |
| N | 25 | 1978 | 8.5 | | 46.2 | 2050 |
| O | 19.1 | 1978 | 8.6 | | 39.4 | 2050 |
| P | 129 | 1985 | 12.0 | | 201 | 2048 |
| Q | 50 | 1974 | 9.3 | | 79.2 | 2051 |
| R | 21 | 1983 | 22.8 | | | |
| S | .001 | 1979 | -- | | | |
| T | .005 | 1978 | -- | | | |
| U | .012 | 1980 | -- | | | |
| V | 3.2 | 1979 | 7.5 | | 15.8 | 2045 |
| W | .021 | 1982 | -- | | | |
| X | 11.1 | 1979 | 6.2 | | 41 | 2049 |
| Y | 34.4 | 1985 | 4.6 | | 48.3 | 2049 |
| Z | 10.6 | 1988 | 62 | 2049 | | |

[a] Unless indicated, breakthrough year was 1989.
[b] Unless indicated, peak occurred in the breakthrough year.

**Table 5.4. Predicted cesium-137 concentration**

| | Inventory | | Breakthrough concentration | | Peak concentration | |
|---|---|---|---|---|---|---|
| Area | Ci | Year | pCi/L | Year[a] | pCi/L | Year[b] |
| A | 1646 | 1978 | 12.2 | | | |
| B | 771 | 1978 | 12.4 | | 12.5 | 2045 |
| C | 34.1 | 1977 | 23.7 | | | |
| D | 53.3 | 1982 | 0.62 | 2126 | 1.4 | 2187 |
| E | 12.5 | 1973 | 5.2 | | | |
| F | 47.1 | 1974 | 20 | | | |
| G | 13.5 | 1975 | 2.9 | | | |
| H | 106 | 1988 | 0.7 | 2080 | 1.1 | 2140 |
| I | 10.4 | 1988 | .03 | 2359 | | |
| J | 702 | 1987 | 3.7 | 2016 | 7.5 | 2077 |
| K | 18.8 | 1981 | .17 | 2010 | .36 | 2072 |
| L | 159 | 1982 | 11.5 | | | |
| M | 152 | 1975 | 11 | | | |
| N | 35.4 | 1978 | 12.7 | | | |
| O | 115 | 1978 | 13.3 | | | |
| P | 5822 | 1985 | 37 | | 92 | 2051 |
| Q | 265 | 1974 | 3.4 | | | |
| R | 41 | 1983 | .1 | 2025 | .24 | 2086 |
| S | .011 | 1979 | -- | | | |
| T | .001 | 1978 | -- | | | |
| U | .002 | 1980 | -- | | | |
| V | 12.5 | 1979 | 4.4 | | | |
| W | .021 | 1982 | -- | | | |
| X | 16.6 | 1979 | 3.6 | | | |
| Y | 40.6 | 1985 | 2.8 | | | |
| Z | 20.2 | 1988 | .12 | 2597 | | |

[a] Unless indicated, breakthrough year was 1989.
[b] Unless indicated, peak occurred at breakthrough year.

**Table 5.5. Predicted europium-152 concentration**

| | Inventory | | Breakthrough concentration | | Peak concentration | |
|---|---|---|---|---|---|---|
| Area | Ci | Year | pCi/L | Year | pCi/L | Year |
| A | 4175 | 1978 | 7.7 | 1998 | 32.4 | 2033 |
| B | 16270 | 1978 | 15.8 | 2000 | 85.2 | 2036 |
| K | 26801 | 1981 | .17 | 2010 | .36 | 2072 |
| P | 250865 | 1985 | 163 | 2005 | 850 | 2040 |

**Table 5.6. Predicted europium-154 concentration**

| | Inventory | | Breakthrough concentration | | Peak concentration | |
|---|---|---|---|---|---|---|
| Area | Ci | Year | pCi/L | Year | pCi/L | Year |
| A | 1558 | 1978 | 0.85 | 1998 | 2.2 | 2028 |
| B | 22305 | 1978 | 47.7 | 2000 | 85.4 | 2029 |
| K | 48701 | 1981 | 48.8 | 1996 | 23.5 | 2021 |
| P | 187368 | 1985 | 321 | 2005 | 584 | 2036 |

**Table 5.7. Predicted uranium-233 concentration**

| | Inventory | | Breakthrough concentration | | Peak concentration | |
|---|---|---|---|---|---|---|
| Area | Ci | Year | pCi/L | Year | pCi/L | Year |
| C | 4.8 | 1977 | 7.6 | 2131 | 201 | 2290 |
| D | 2.8 | 1982 | 2.5 | 2219 | 61.4 | 2378 |
| E | 4.6 | 1973 | 7.3 | 2038 | 149 | 2197 |
| F | 4.1 | 1974 | 2.5 | 2217 | 60.6 | 2376 |
| G | 1.2 | 1975 | 4.1 | 2671 | 100 | 2830 |
| L | 101 | 1982 | 19.7 | 2025 | 524 | 2184 |
| M | 56.1 | 1975 | 27 | 2150 | 780 | 2309 |
| N | 25 | 1978 | 8.3 | 2057 | 221 | 2216 |
| V | 4.6 | 1979 | 2.24 | 2064 | 59 | 2223 |
| Y | 124.7 | 1985 | 28.9 | 2091 | 695 | 2250 |

**Table 5.8. Predicted uranium-238 concentration**

| | Inventory | | Breakthrough concentration | | Peak concentration | |
|---|---|---|---|---|---|---|
| Area | Ci | Year | pCi/L | Year | pCi/L | Year |
| E | 7.7 | 1973 | 19 | 2038 | 400 | 2197 |
| L | 1.72 | 1982 | 0.3 | 2025 | 8.7 | 2184 |
| N | 16.3 | 1978 | 4.9 | 2057 | 144 | 2216 |
| O | 1.12 | 1978 | 0.4 | 2055 | 8.2 | 2215 |
| V | 7.7 | 1979 | 3.5 | 2064 | 100 | 2223 |
| Y | 209 | 1985 | 84 | 2091 | 1240 | 2250 |

**Table 5.9. Predicted thorium-232 concentration**

| | Inventory | | Breakthrough concentration | | Peak concentration | |
|---|---|---|---|---|---|---|
| Area | Ci | Year | pCi/L | Year | pCi/L | Year |
| M | 1.14 | 1975 | 0.4 | 1989 | 0.83 | 2148 |
| N | 16.2 | 1978 | 4.9 | 2057 | 144 | 2216 |
| O | 1.0 | 1978 | -- | -- | -- | -- |
| P | 6003 | 1985 | 57.8 | 2948 | 1080 | 3107 |

**Table 5.10. Predicted radionuclide inventories (Ci) in source areas in years 2020 and 2120**

| Area A | | | | | | |
|---|---|---|---|---|---|---|
| Year | Co-60 | H-3 | Sr-90 | Cs-137 | Eu-152 | Eu-154 |
| 2020 | 16.6 | 6.8 | 168 | 768 | 581 | 65.6 |
| 2120 | -- | -- | 14.6 | 76.2 | 3.2 | -- |
| Year of depletion | 2042 | 2044 | >2138 | >2138 | >2138 | 2074 |
| **Area B** | | | | | | |
| Year | Co-60 | H-3 | Sr-90 | Cs-137 | Eu-152 | Eu-154 |
| 2020 | 6.44 | 2.0 | 128 | 343 | 1960 | 894 |
| 2120 | -- | -- | 11.1 | 34.1 | 10.8 | 0.3 |
| Year of depletion | 2035 | 2030 | >2138 | >2138 | >2138 | 2106 |
| **Area C** | | | | | | |
| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 | |
| 2020 | -- | 35.9 | 46.1 | 14.4 | 5.56 | |
| 2120 | -- | -- | 4.04 | 1.43 | 5.53 | |
| Year of depletion | 1999 | 2042 | 2137 | 2136 | >2137 | |
| **Area D** | | | | | | |
| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 | |
| 2020 | 29.4 | 1.04 | 32.8 | 26.0 | 3.28 | |
| 2120 | -- | -- | 2.8 | 2.6 | 3.27 | |
| Year of depletion | 2046 | 2021 | >2142 | >2142 | >2142 | |
| **Area E** | | | | | | |
| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 | U-238 |
| 2020 | -- | 1.0 | 1.24 | 4.76 | 5.54 | 9.59 |
| 2120 | -- | -- | -- | 0.5 | 5.52 | 9.59 |
| Year of depletion | 1996 | 2021 | 2029 | 2088 | >2133 | >2133 |
| **Area F** | | | | | | |
| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 | |
| 2020 | -- | .5 | 39 | 18.2 | 4.79 | |
| 2120 | -- | -- | 3.4 | 1.8 | 4.77 | |
| Year of depletion | 1996 | 2017 | >2134 | >2134 | >2134 | |

Table 5.10. (continued)

**Area G**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 |
|---|---|---|---|---|---|
| 2020 | -- | 0.65 | 11 | 5.4 | 1.37 |
| 2120 | -- | -- | 0.95 | 0.5 | 1.36 |
| Year of depletion | 1988 | 2015 | 2118 | 2093 | >2135 |

**Area H**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | 1.25 | 1.29 | 23.6 | 57.8 |
| 2120 | -- | -- | 2.0 | 5.7 |
| Year of depletion | 2022 | 2024 | >2148 | >2148 |

**Area I**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | -- | 0.6 | 11.5 | 5.66 |
| 2120 | -- | -- | 1.00 | 0.56 |
| Year of depletion | 1994 | 2013 | 2121 | 2096 |

**Area J**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | 3.33 | 0.68 | 22.4 | 375 |
| 2120 | -- | -- | 1.97 | 37.2 |
| Year of depletion | 2030 | 2014 | >2147 | >2147 |

**Area K**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | Eu-152 | Eu-154 |
|---|---|---|---|---|---|---|
| 2020 | .14 | -- | 3.0 | 8.7 | 4100 | 2860 |
| 2120 | -- | -- | 0.26 | 0.87 | 22.6 | 1.08 |
| Year of depletion | 2005 | -- | 2066 | 2114 | >2141 | 2122 |

**Area L**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-238 | U-238 |
|---|---|---|---|---|---|---|
| 2020 | -- | 249 | 25.7 | 16.2 | 11.7 | 2.18 |
| 2120 | -- | -- | -- | 1.36 | 11.6 | 2.18 |
| Year of depletion | 1998 | 2087 | 2056 | 2133 | >2142 | >2142 |

Table 5.10. (continued)

**Area M**

| Year | Co-60 | H-3 | Sr-90 | C-137 | U-233 | U-238 |
|---|---|---|---|---|---|---|
| 2020 | 0.63 | 25.7 | 16.2 | 61.4 | 71.1 | 103 |
| 2120 | -- | -- | 1.36 | 6.1 | 70.8 | 103 |
| Year of depletion | 2017 | 2056 | 2133 | 2135 | >2135 | >2135 |

**Area N**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 | U-238 |
|---|---|---|---|---|---|---|
| 2020 | 3.05 | 3.93 | 11.2 | 15.3 | 29.0 | 20.7 |
| 2120 | -- | -- | 0.95 | 1.5 | 28.9 | 20.7 |
| Year of depletion | 2029 | 2024 | 2118 | 2138 | >2138 | >2138 |

**Area O**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 | Th-232 |
|---|---|---|---|---|---|---|
| 2020 | 1.85 | 22.1 | 8.55 | 49.7 | 1.41 | 1.01 |
| 2120 | -- | -- | 0.71 | 4.93 | 1.41 | 1.01 |
| Year of depletion | 2025 | 2055 | 2107 | 2138 | >2138 | >2138 |

**Area P**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | Eu-152 | Eu-154 |
|---|---|---|---|---|---|---|
| 2020 | 261 | 283 | 67.3 | 2930 | 47700 | 15000 |
| 2120 | -- | -- | 5.88 | 290 | 263 | 5.66 |
| Year of depletion | 2063 | 2047 | >2145 | >2145 | >2145 | 2143 |

**Area Q**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | 1.1 | 0.26 | 20 | 104 |
| 2120 | -- | -- | 1.75 | 10.3 |
| Year of depletion | 2021 | 2004 | >2137 | >2137 |

**Area R**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | 9.1 | 2.4 | 10.7 | 20.1 |
| 2120 | -- | -- | 0.94 | 2.0 |
| Year of depletion | 2037 | 2033 | 2118 | >2143 |

Table 5.10. (continued)

**Area S**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | -- | 0.37 | -- | -- |
| 2120 | -- | -- | -- | -- |
| Year of depletion | -- | 2017 | -- | -- |

**Area T**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | -- | 2.1 | -- | -- |
| 2120 | -- | -- | -- | -- |
| Year of depletion | -- | 2035 | -- | -- |

**Area U**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 | U-238 |
|---|---|---|---|---|---|---|
| 2020 | -- | 4.1 | -- | -- | 5.31 | 9.79 |
| 2120 | -- | -- | -- | -- | 5.29 | 9.79 |
| Year of depletion | -- | 2032 | -- | -- | >2139 | >2139 |

**Area V**

| Year | Co-60 | H-3 | Sr-90 | CS-137 |
|---|---|---|---|---|
| 2020 | -- | 2.0 | 1.44 | 5.5 |
| 2120 | -- | -- | -- | 0.5 |
| Year of depletion | 2002 | 2024 | 2035 | 2094 |

**Area W**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | -- | 0.3 | -- | -- |
| 2120 | -- | -- | -- | -- |
| Year of depletion | -- | 2004 | -- | -- |

**Area X**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | 0.14 | 3.7 | 5.05 | 1.65 |
| 2120 | -- | -- | 0.4 | -- |
| Year of depletion | 2005 | 2025 | 2086 | 2046 |

**Table 5.10. (continued)**

| Area Y | | | | | | |
|---|---|---|---|---|---|---|
| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 | U-238 |
| 2020 | 80.5 | 61.3 | 18.3 | 20.4 | 14.6 | 2.55 |
| 2120 | -- | -- | 1.54 | 2.0 | 14.6 | 255 |
| Year of depletion | 2054 | 2035 | 2138 | >2145 | >2145 | >2145 |

| Area Z | | | | |
|---|---|---|---|---|
| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
| 2020 | -- | 1.28 | 5.86 | 10.9 |
| 2120 | - | -- | 0.5 | 1.08 |
| Year of depletion | -- | 2024 | 2093 | 2173 |

| Tumulus I | | | | |
|---|---|---|---|---|
| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
| 2020 | 157 | .44 | 5.63 | 7.01 |
| 2120 | -- | -- | 0.049 | 0.7 |
| Year of depletion | 2006 | 2006 | 2092 | 2105 |

**Table 5.11. Predicted peak annual flux in surface waters in WAG 6**

| | Peak flux exiting WAG 6 | | Peak flux discharge to EWB | |
|---|---|---|---|---|
| Radionuclide | μCi | Year | μCi | Year |
| H-3 | 60,000,000 | 2018 | 820,000 | 2028 |
| Co-60 | 7700 | 2026 | 12 | 1990 |
| Sr-90 | 43,000 | 2042 | 3,400 | 2038 |
| Cs-137 | 3200 | 1990 | 120 | 1990 |
| Eu-152 | 930 | 2020 | - | - |
| Eu-154 | 430 | 2024 | - | - |
| Th-232[a] | 5,000 | 2130 | - | - |
| U-233[a] | 2,200 | 2130 | 46 | 2130 |
| U-238[a] | 6,000 | 2130 | 18 | 2130 |

[a]Peak occurs after 2130.

**Table 5.12. Predicted peak annual flux in groundwater discharge in WAG 6**

| | Peak flux exiting WAG 6 | | Peak flux discharge to EWB | |
|---|---|---|---|---|
| Radionuclide | μCi | Year | μCi | Year |
| H-3 | 2,750,000 | 1992 | 4,480 | 2007 |
| Co-60 | 1,700 | 1990 | 0.2 | 1995 |
| Sr-90 | 450 | 2052 | 13 | 2043 |
| Cs-137 | 62 | 2050 | 0.3 | 1995 |
| Eu-152 | 200 | 2050 | - | - |
| Eu-154 | 52 | 2036 | - | - |
| Th-232 | 0.4 | 2064 | - | - |
| U-233[a] | 92 | 2205 | 2 | 2205 |
| U-238[a] | 160 | 2210 | 3 | 2205 |

[a]Peak occurs after 2205.

**Table 5.13. Surface water tritium emissions to air ($g/m^2$-s)**

| Source[a] | 1989 | 1990-2019 | 1990-2059 | 2100-2129 |
|---|---|---|---|---|
| FA1 | 6.95E-18 | 3.81E-18 | 2.34E-18 | 1.28E-21 |
| FA2 | 6.95E-18 | 1.91E-18 | 1.18E-18 | 6.75E-22 |
| FAA1 | 4.71E-20 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| FAA2 | 4.71E-20 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| FAA3 | 4.71E-20 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| FAA4 | 4.71E-20 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| FAB1 | 7.44E-18 | 3.65E-18 | 2.25E-18 | 1.08E-21 |
| FAB2 | 5.78E-18 | 3.65E-18 | 2.25E-18 | 1.08E-21 |
| FAB3 | 4.12E-18 | 1.36E-18 | 8.37E-19 | 3.98E-22 |
| FAB4 | 2.46E-18 | 1.36E-18 | 8.37E-19 | 3.98E-22 |
| FB1 | 4.49E-18 | 1.88E-17 | 9.57E-18 | 7.09E-23 |
| FB2 | 3.21E-18 | 1.34E-17 | 6.84E-18 | 5.06E-23 |
| FB3 | 6.73E-18 | 2.07E-17 | 1.05E-17 | 1.77E-22 |
| FB4 | 1.53E-17 | 3.35E-17 | 1.70E-17 | 3.22E-22 |
| FB5 | 1.53E-17 | 3.35E-17 | 1.70E-17 | 3.22E-22 |
| FB6 | 1.53E-17 | 1.87E-17 | 9.48E-18 | 1.61E-22 |
| FB7 | 4.25E-17 | 1.87E-17 | 9.48E-18 | 1.61E-22 |
| FB8 | 6.97E-17 | 1.87E-17 | 9.48E-18 | 1.61E-22 |
| FB9 | 9.69E-17 | 2.05E-17 | 1.01E-17 | 4.02E-22 |
| FB10 | 1.24E-16 | 2.05E-17 | 1.01E-17 | 4.02E-22 |
| FB11 | 1.51E-16 | 2.05E-17 | 1.01E-17 | 4.02E-22 |
| FB12 | 2.06E-16 | 2.36E-17 | 1.16E-17 | 4.63E-22 |
| FB13 | 1.42E-16 | 1.27E-17 | 6.24E-18 | 2.23E-22 |
| FB14 | 1.61E-16 | 1.27E-17 | 6.24E-18 | 2.23E-22 |
| FB15 | 1.80E-16 | 1.27E-17 | 6.24E-18 | 2.23E-22 |
| FB16 | 1.99E-16 | 1.27E-17 | 6.24E-18 | 2.23E-22 |
| FB17 | 3.07E-16 | 1.69E-17 | 8.60E-18 | 3.14E-22 |
| FB18 | 3.07E-16 | 1.69E-17 | 8.60E-18 | 3.14E-22 |
| FB19 | 3.07E-16 | 1.69E-17 | 8.60E-18 | 3.14E-22 |
| FD1 | 4.73E-14 | 9.01E-15 | 5.17E-15 | 4.65E-18 |
| DA1 | 8.24E-17 | 1.50E-17 | 8.54E-18 | 7.32E-21 |
| DA2 | 8.24E-17 | 1.17E-17 | 6.65E-18 | 5.68E-21 |
| DA3 | 8.24E-17 | 7.69E-18 | 4.39E-18 | 3.76E-21 |
| DB1 | 4.25E-18 | 4.26E-17 | 4.07E-17 | 1.16E-22 |
| DB2 | 4.25E-18 | 4.71E-17 | 3.84E-17 | 9.89E-21 |

**Table 5.13. (continued)**

| Source[a] | 1989 | 1990-2019 | 1990-2059 | 2100-2129 |
|---|---|---|---|---|
| DB3 | 4.25E-18 | 4.71E-17 | 3.84E-17 | 9.89E-21 |
| DB4 | 4.25E-18 | 3.19E-17 | 2.60E-17 | 6.92E-21 |
| DB5 | 4.25E-18 | 2.85E-17 | 2.31E-17 | 6.05E-21 |
| DB6 | 4.25E-18 | 2.85E017 | 2.31E-17 | 6.05E-21 |
| DB7 | 4.25E-18 | 2.12E-17 | 1.71E-17 | 4.48E-21 |
| B1 | 7.67E-20 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| B2 | 7.67E-20 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| B3 | 7.67E-20 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| B4 | 7.67E-20 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| A21 | 1.44E-19 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| A22 | 1.44E-19 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| A23 | 1.44E-19 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| A24 | 1.44E-19 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| WB1 | 6.41E-16 | 5.12E-17 | 2.37E-17 | 0.00E+00 |
| WB2 | 6.41E-16 | 5.12E-17 | 2.37E-17 | 0.00E+00 |
| WB3 | 6.41E-16 | 5.12E-17 | 2.37E-17 | 0.00E+00 |

[a]Locations are shown in Fig. 5E.4, Appendix 5E

Table 5.14. Baseline CHEMDAT7 sources and emissions

| Area[a] | Total area ($cm^2$) | No. of sources | Receptor no. | X (m) | Y (m) | Emissions rate ($g/m^2$-s) |
|---|---|---|---|---|---|---|
| 49-Trench | 69,675,000 | | | | | 1.18E-10 |
| | | 10 | 1 | 244 | 366 | 1.18E-11 |
| | | | 2 | 274 | 366 | 1.18E-11 |
| | | | 3 | 244 | 396 | 1.18E-11 |
| | | | 4 | 274 | 396 | 1.18E-11 |
| | | | 5 | 305 | 396 | 1.18E-11 |
| | | | 6 | 244 | 427 | 1.18E-11 |
| | | | 7 | 274 | 427 | 1.18E-11 |
| | | | 8 | 305 | 427 | 1.18E-11 |
| | | | 9 | 244 | 46 | 1.18E-11 |
| | | | 10 | 274 | 46 | 1.18E-11 |
| West Disposal Area | 92,900,000 | 14 | | | | 1.58E-10 |
| | | | 11 | 244 | 244 | 1.13E-11 |
| | | | 12 | 213 | 27 | 1.13E-11 |
| | | | 13 | 244 | 274 | 1.13E-11 |
| | | | 14 | 183 | 305 | 1.13E-11 |
| | | | 15 | 213 | 305 | 1.13E-11 |
| | | | 16 | 244 | 305 | 1.13E-11 |
| | | | 17 | 122 | 335 | 1.13E-11 |
| | | | 18 | 152 | 335 | 1.13E-11 |
| | | | 19 | 183 | 335 | 1.13E-11 |
| | | | 20 | 213 | 366 | 1.13E-11 |
| | | | 21 | 122 | 366 | 1.13E-11 |
| | | | 22 | 152 | 366 | 1.13E-11 |
| | | | 23 | 183 | 366 | 1.13E-11 |
| | | | 24 | 152 | 396 | 1.13E-11 |
| Central Disposal Area | 11,612,500 | 3 | | | | 1.97E-11 |
| | | | 25 | 427 | 396 | 6.57E-12 |
| | | | 26 | 457 | 396 | 6.57E-12 |
| | | | 27 | 488 | 396 | 6.57E-12 |
| North-East Disposal Area | 18,580,000 | 4 | | | | 3.16E-11 |
| | | | 28 | 427 | 549 | 7.90E-12 |
| | | | 29 | 457 | 549 | 7.90E-12 |
| | | | 30 | 396 | 579 | 7.90E-12 |
| | | | 31 | 427 | 579 | 7.90E-12 |
| 17-Trench | 20,902,500 | 3 | | | | 3.55E-11 |
| | | | 32 | 305 | 701 | 1.18E-11 |
| | | | 33 | 305 | 732 | 1.18E-11 |

Table 5.14. (continued)

| Area[a] | Total area ($cm^2$) | No. of sources | Receptor no. | X (m) | Y (m) | Emissions rate ($g/m^2$-s) |
|---|---|---|---|---|---|---|
| | | | 34 | 305 | 762 | 1.18E-11 |
| HATA | 20,902,500 | 3 | | | | 3.55E-11 |
| | | | 35 | 183 | 671 | 1.18E-11 |
| | | | 36 | 183 | 701 | 1.18E-11 |
| | | | 37 | 213 | 701 | 1.18E-11 |
| Groundwater | 27,870,000 | 4 | | | | 4.74E-11 |
| | | | 38 | 427 | 671 | 1.19E-11 |
| | | | 39 | 427 | 701 | 1.19E-11 |
| | | | 40 | 46 | 701 | 1.19E-11 |
| | | | 41 | 427 | 732 | 1.19E-11 |
| South Disposal Area | 137,027,500 | 18 | | | | 2.33E-10 |
| | | | 42 | 335 | 122 | 1.29E-11 |
| | | | 43 | 335 | 152 | 1.29E-11 |
| | | | 44 | 366 | 61 | 1.29E-11 |
| | | | 45 | 366 | 91 | 1.29E-11 |
| | | | 46 | 366 | 122 | 1.29E-11 |
| | | | 47 | 366 | 152 | 1.29E-11 |
| | | | 48 | 366 | 183 | 1.29E-11 |
| | | | 49 | 366 | 213 | 1.29E-11 |
| | | | 50 | 396 | 61 | 1.29E-11 |
| | | | 51 | 396 | 61 | 1.29E-11 |
| | | | 52 | 396 | 122 | 1.29E-11 |
| | | | 53 | 396 | 152 | 1.29E-11 |
| | | | 54 | 396 | 183 | 1.29E-11 |
| | | | 55 | 396 | 213 | 1.29E-11 |
| | | | 56 | 427 | 122 | 1.29E-11 |
| | | | 57 | 427 | 152 | 1.29E-11 |
| | | | 58 | 427 | 183 | 1.29E-11 |
| | | | 59 | 427 | 213 | 1.29E-11 |
| South-Central Disposal Area | 41,805,000 | 5 | | | | 7.10E-11 |
| | | | 60 | 366 | 396 | 1.42E-11 |
| | | | 61 | 366 | 427 | 1.42E-11 |
| | | | 62 | 396 | 366 | 1.42E-11 |
| | | | 63 | 396 | 396 | 1.42E-11 |
| | | | 64 | 396 | 427 | 1.42E-11 |

Table 5.14. (continued)

| Area[a] | Total area ($cm^2$) | No. of sources | Receptor no. | X (m) | Y (m) | Emissions rate ($g/m^2$-s) |
|---|---|---|---|---|---|---|
| Middle Central Disposal Area | 74,320,000 | 9 | | | | 1.26E-10 |
| | | | 65 | 274 | 488 | 1.40E-11 |
| | | | 66 | 274 | 518 | 1.40E-11 |
| | | | 67 | 305 | 457 | 1.40E-11 |
| | | | 68 | 305 | 488 | 1.40E-11 |
| | | | 69 | 305 | 518 | 1.40E-11 |
| | | | 70 | 305 | 549 | 1.40E-11 |
| | | | 71 | 335 | 427 | 1.40E-11 |
| | | | 72 | 335 | 457 | 1.40E-11 |
| | | | 73 | 335 | 488 | 1.40E-11 |
| North-Central Disposal Area | 23,225,000 | 2 | | | | 3.95E-11 |
| | | | 74 | 213 | 640 | 1.98E-11 |
| | | | 75 | 244 | 640 | 1.98E-11 |
| South-East Disposal Area | 71,997,500 | 8 | | | | 1.22E-10 |
| | | | 76 | 427 | 488 | 1.53E-11 |
| | | | 77 | 427 | 518 | 1.53E-11 |
| | | | 78 | 457 | 457 | 1.53E-11 |
| | | | 79 | 457 | 488 | 1.53E-11 |
| | | | 80 | 488 | 427 | 1.53E-11 |
| | | | 81 | 488 | 457 | 1.53E-11 |
| | | | 82 | 518 | 396 | 1.53E-11 |
| | | | 83 | 518 | 427 | 1.53E-11 |
| North-West Auger Hole Area | 55,740,000 | 6 | | | | 9.47E-11 |
| | | | 84 | 366 | 610 | 1.58E-11 |
| | | | 85 | 366 | 640 | 1.58E-11 |
| | | | 86 | 366 | 671 | 1.58E-11 |
| | | | 87 | 396 | 610 | 1.58E-11 |
| | | | 88 | 396 | 640 | 1.58E-11 |
| | | | 89 | 396 | 671 | 1.58E-11 |

[a]Locations are shown in Fig. 5E.5, Appendix 5E.

**Table 5.15. Predicted maximum concentrations of tritium and VOCs**

| Tritium | | | | |
|---|---|---|---|---|
| | Maximum fenceline receptor | | Maximum on-site receptor | |
| | Concentration | | Concentration | |
| Period | (picograms/m$^3$) | (picocuries/m$^3$) | (picograms/m$^3$) | (picocuries/m$^3$) |
| 1989 (present) | 620 | 5,952,000 | 64,670 | 620,832,000 |
| 1990-2019 | 109 | 1,046,400 | 12,326 | 118,329,600 |
| 1990-2059 | 64 | 614,400 | 7,077 | 67,939,200 |
| 2100-2129 | 0.05 | 480 | 6 | 57,600 |

| VOCs | | |
|---|---|---|
| | Maximum fenceline receptor | Maximum on-site receptor |
| Case | Concentration (picograms/m$^3$) | Concentration (picograms/m$^3$) |
| Baseline | 64 | 166.5 |

# Section 5 Figures

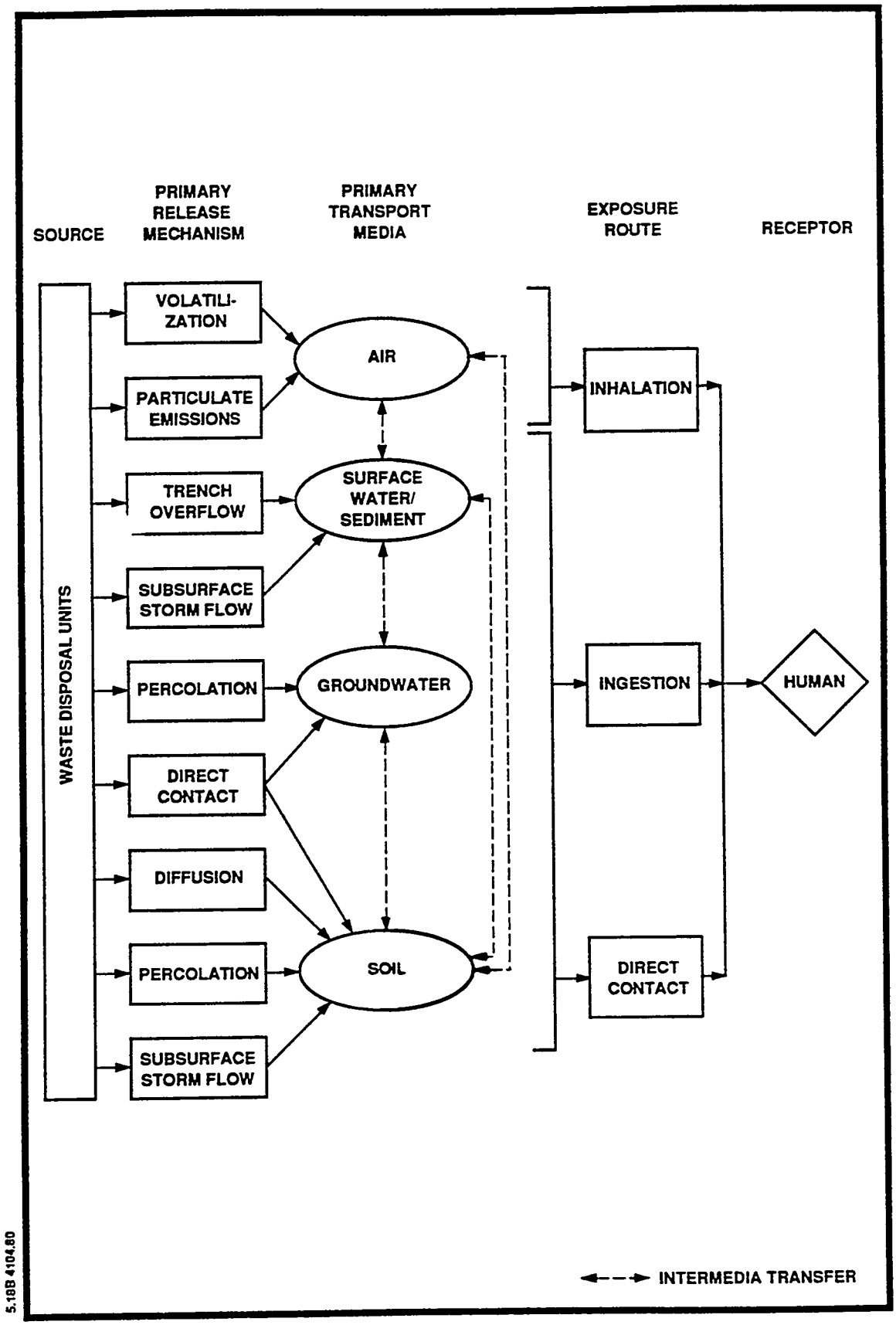



Fig. 5.1. Site conceptual model.

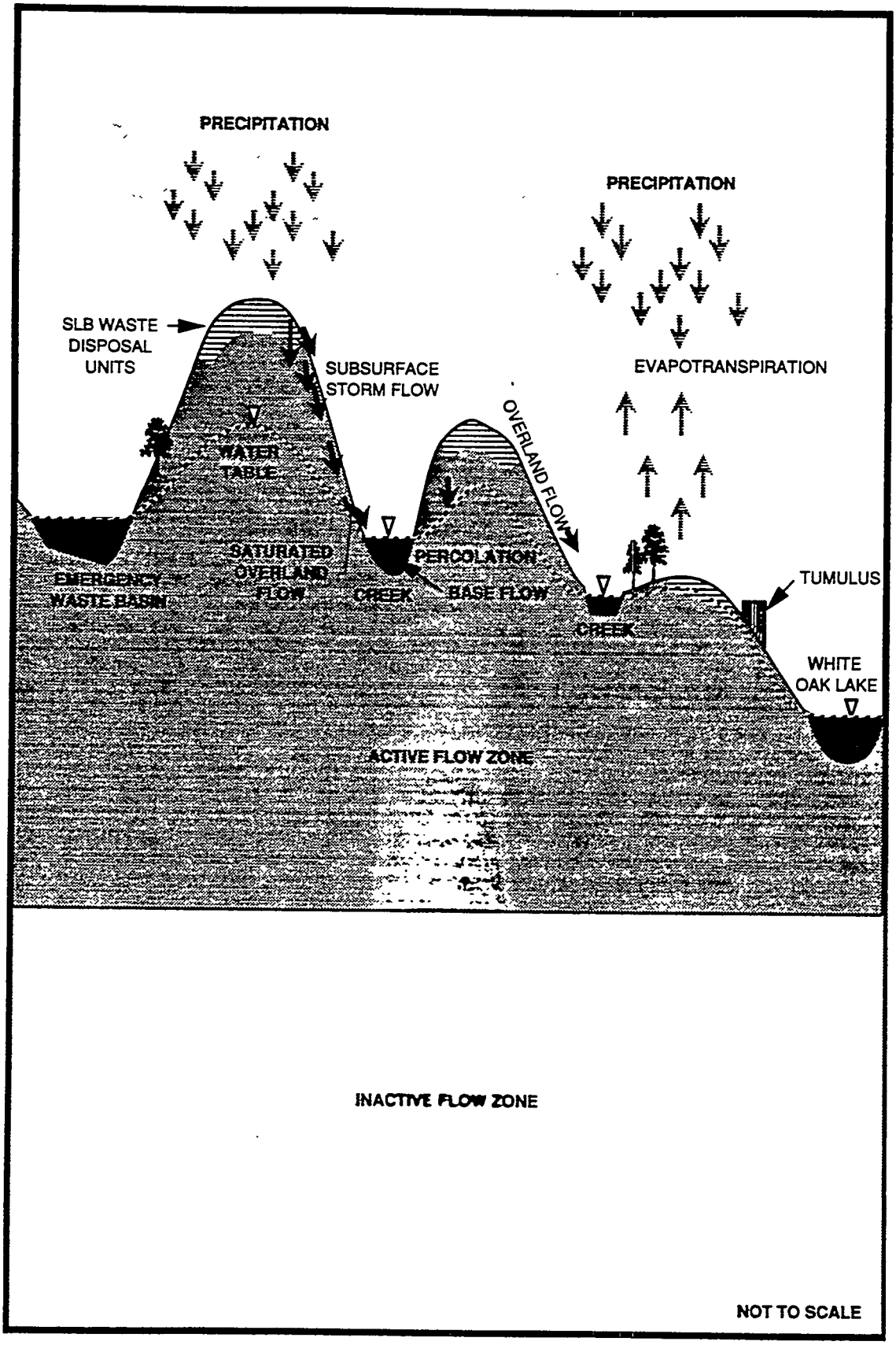



Fig. 5.2. Hydrologic features of WAG 6.

5.18 4104.16

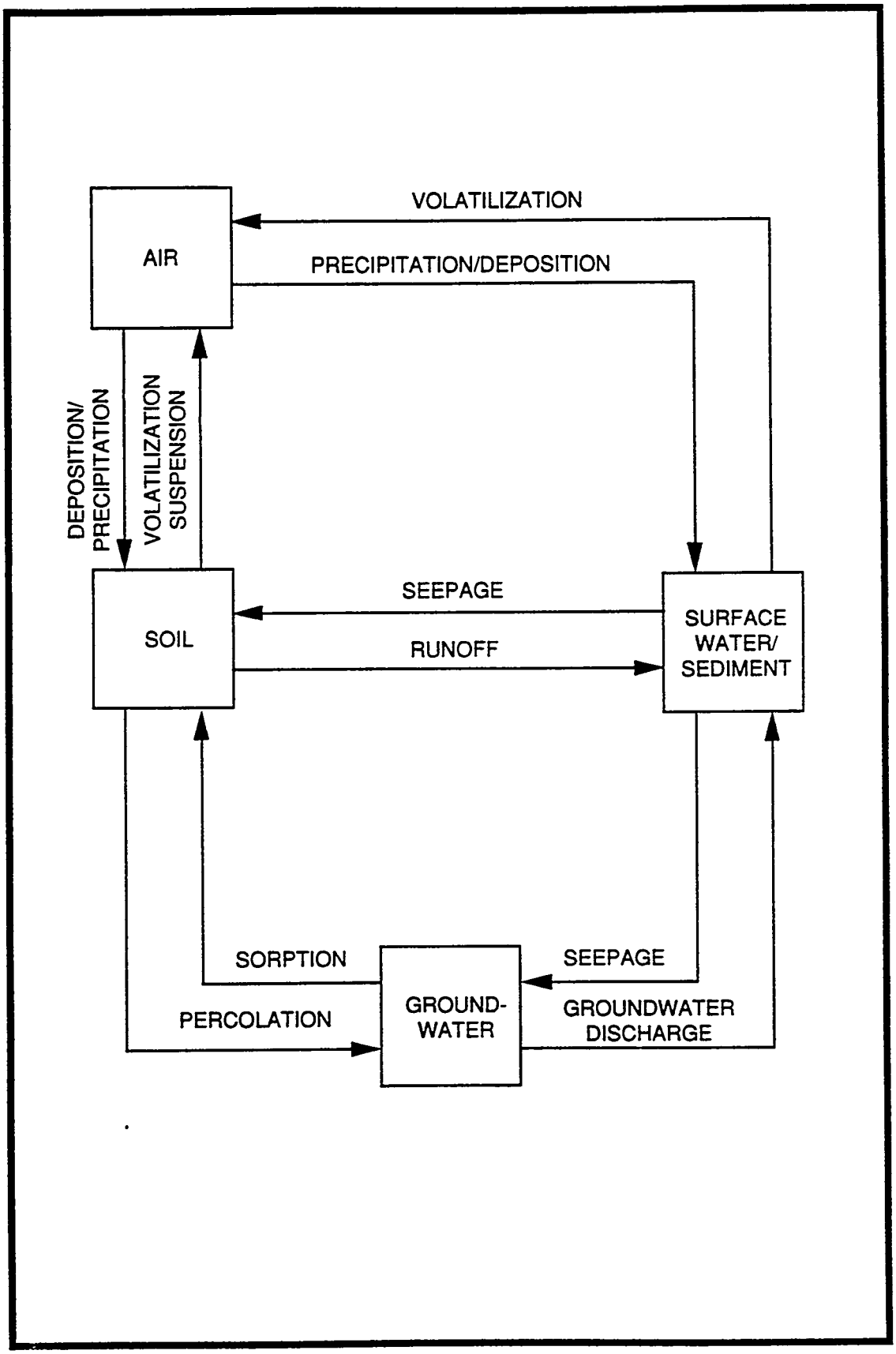
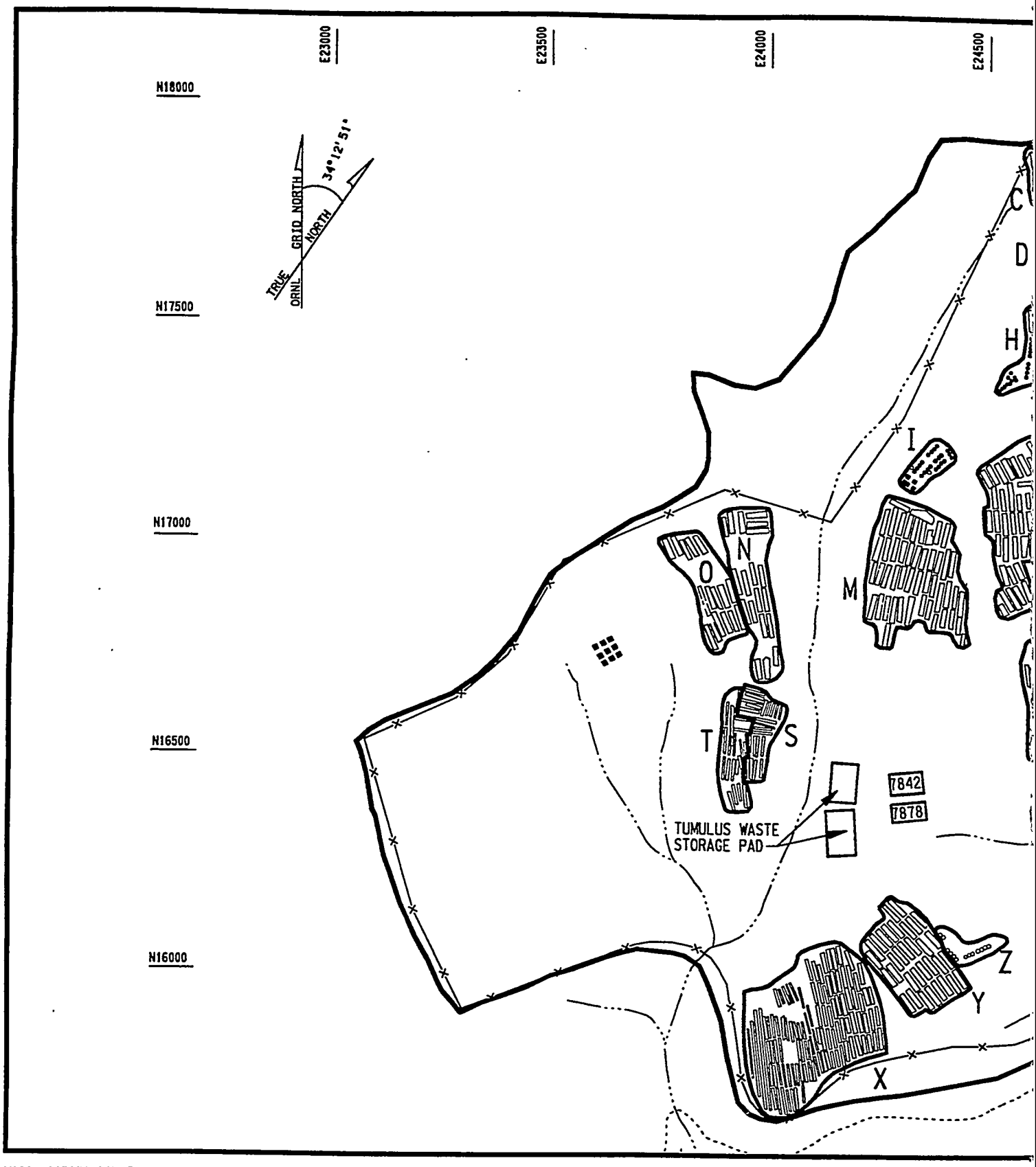



Fig. 5.3. Intermedia transfer processes.

5.18 4104.17




WAG6 06F270.DGN 5.4

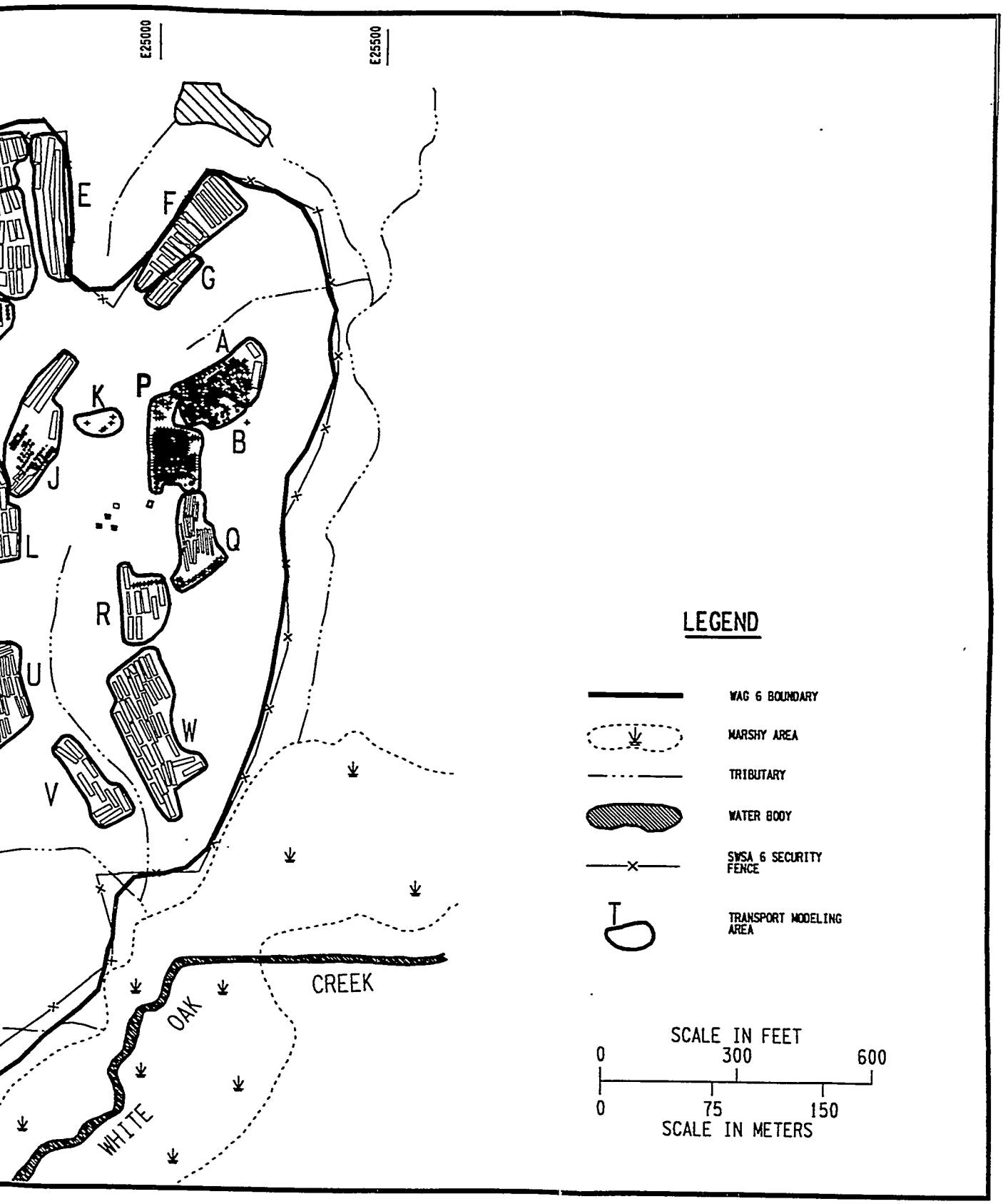



Fig. 5.4. WAG 6 transport modeling areas

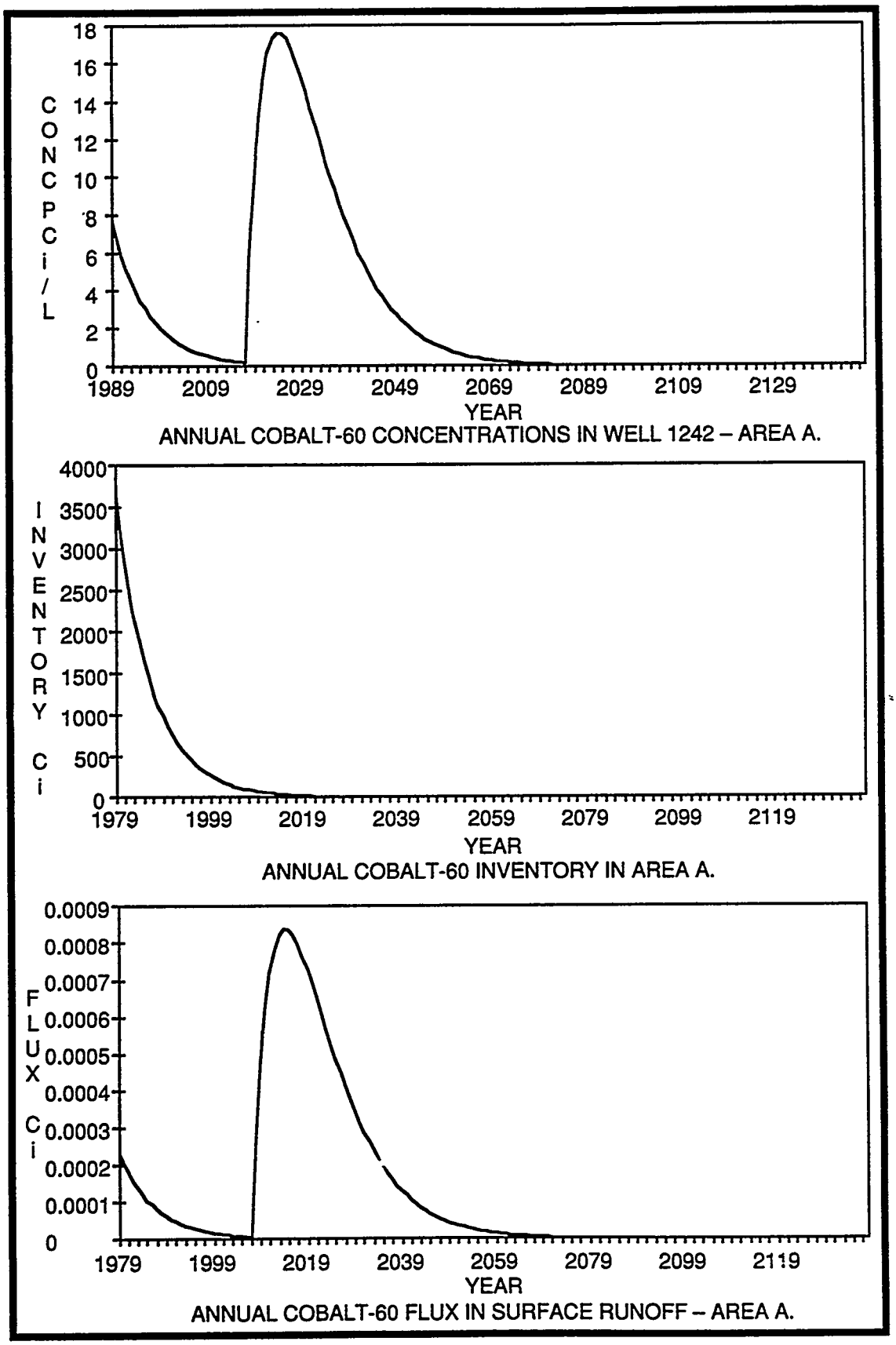



**Fig. 5.5. Modeling output for cobalt-60, Area A.**

# 6. BASELINE HUMAN HEALTH EVALUATION

## 6.1 INTRODUCTION

This section addresses the process and results of quantifying human health hazards associated with contamination at WAG 6 in terms of risk to the recipient. It is termed a *baseline* human health evaluation because all data and analyses are not discounted in any way to reflect an improvement in conditions that might occur if remediation of the WAG were undertaken. The evaluation was developed using standard guidance documents, primarily the *Risk Assessment Guidance for Superfund, Vol. I: Human Health Evaluation Manual (Part A)* (EPA 1989b) and "Supplemental Region IV Risk Assessment Guidance" (EPA 1991a). The data on which it is based were collected during the RFI and are presented in Sect. 4, 5, Appendix 6C of this report, and separately published Technical Memorandums.

Figure 6.1 illustrates the steps comprising the evaluation process. Section 6.2, Selecting Contaminants of Potential Concern, identifies the radionuclides and chemicals selected for study and describes the selection process. Section 6.3, Exposure Assessment, establishes a framework for quantifying human exposure to these contaminants by combining assumptions regarding conditions at the WAG (scenarios); example recipients (hypothetical receptors); concentrations of contaminants in environmental media and biota; and mechanisms by which the recipients would become exposed to the contaminants (exposure pathways). In Sect. 6.4, Toxicity Assessment, each contaminant of concern is classified as to the type of hazard it presents (e.g. carcinogenic or noncarcinogenic effects) and the toxicity factors typically used to quantify these hazards are specified. In Sect. 6.5, Risk Characterization, exposure values and toxicity parameters are combined to quantify the risk to a human resulting from each of the radionuclides and chemicals characterized. Section 6.6, Summary and Conclusions, presents the results of the human health evaluation.

## 6.2 SELECTING CONTAMINANTS OF POTENTIAL CONCERN

This section describes the manner in which radioactive and chemical contaminants at WAG 6 were evaluated to identify those that are of potential concern to human health.

### 6.2.1 Radioactive Contaminants

In determining the radionuclides of concern to human health, no field sampling data were used as direct input to the evaluation. Sampling of the underground waste disposal areas in WAG 6 would have resulted in excessive worker exposure; instead, existing information on the WAG 6 waste disposal inventory was used as a source term. (Section 1 addresses WAG 6 waste disposal practices and the associated inventory information.) The inventory information identifies 82 different radionuclides disposed of below ground, with a total activity (decayed to January 1991) of 571,710 curies. The inventory for the above ground and future units represents less than 2 percent of the below ground unit inventory and was thus not used for this baseline human health evaluation (see Appendix 6A).

The radionuclides in the below ground inventory were screened to identify those of potential concern. The relative dose from each radionuclide was estimated for three exposure routes: ingestion, inhalation, and external exposure from an infinitely thin area source.

Radionuclides contributing potentially approximately 98 percent of the total relative dose were identified. In addition, tritium, which is a known WAG 6 contaminant exhibiting extreme environmental mobility, was identified as being of potential concern. Detail on the final selection of radionuclides of potential concern is provided in Appendix 6B. Table 6.1 lists 17 radionuclides of potential concern at WAG 6.

### 6.2.2 Chemical Contaminants

Because sampling of the underground waste disposal area was not possible and no chemical inventory information was available, field sampling data around waste disposal areas were used to identify chemicals of potential concern to human health. Seventy-three chemicals were detected in the soil, sediment, surface water, and groundwater samples considered for use in the baseline human health evaluation (Appendix 6C). These comprised 45 organics and 28 inorganics, each detected at least once. Many inorganics are naturally occurring chemicals and were detected frequently at WAG 6. The organics, however, are generally man-made and were detected less frequently, many only once.

All data used underwent data review, as described in Appendix A6. Samples were analyzed for TCL and TAL, or RCRA Appendix IX, constituents identified in Section 2. As discussed in Appendix 6D, tentatively identified compounds (TICs) were evaluated as part of the sample analyses.

All volatile organic chemicals were assumed to be of potential concern as a conservative measure to discount volatilization (Appendix 6E). Semi-volatile chemicals and inorganic chemicals detected in each of the four environmental media were statistically evaluated to determine which ones exhibited significant differences between concentrations obtained on-site and reference concentrations (Appendix 6E). These statistically significant chemicals were also identified as being of potential concern. However, those inorganic chemicals that are essential human nutrients (Appendix 6E) and that were detected at concentrations below the recommended dietary allowances were eliminated from further consideration.

Some semivolatile organic chemicals not found to be statistically significantly different were included from the list of contaminants of concern. As a conservative measure, those for which any of the following were true were included in the list:

- A field sampling concentration was detected in excess of the contract required detection limit
- The chemical was statistically significant in other media
- The chemical was a known WAG 6 contaminant (Teasley 1990)
- A field sampling concentration was detected in excess of a health-based criterion

Table 6.2 lists the 44 chemicals of potential concern identified from the above evaluations. The list comprises 32 organics and 12 inorganics, most of which occurred only in groundwater.

## 6.3 Exposure Assessment

An individual's exposure (i.e., potential for intake of contaminants) is a function of the environmental conditions under which that person operates, the activities that person pursues, and the length of time that person conducts these activities within the environment. Consequently, to arrive at estimated intakes attributable to contaminants at WAG 6, assumptions (or scenarios) were established regarding the operation of the site, hypothetical receptors pertinent to each scenario were identified, and periods of evaluation were specified (Table 6.3). For each receptor, exposure pathways (e.g., ingestion of contaminated water, inhalation of particulates) were selected; contaminant concentration values in environmental media (e.g., air, water) were derived from field data and modeled data and evaluated in the context of these pathways. Intakes are not presented in this section as end products in themselves, but are assessed in combination with toxicity values derived in Sect. 6.4 to characterize the overall health risk to each receptor in Sect. 6.5.

### 6.3.1 Exposure Scenarios

Two hypothetical scenarios were assumed for WAG 6. The first, termed the no-action scenario, assumed that DOE's current access restrictions for the site became ineffective immediately. Site fencing, warning signs, patrols, and institutional controls were assumed to disappear. Although this is not a reasonable scenario for the WAG, evaluation thereof is required under Section 300.68(f) (1) (v) of the National Contingency Plan (NCP). The second scenario assumed that DOE would continue to use WAG 6 as a disposal site for LLW for the next 10 years and that this operational period would be followed by a 100-year institutional control period. This scenario corresponds to DOE's operational and institutional control plans for WAG 6 for the next 110 years; it does not assume, however, that DOE will perform site closure or remediation other than maintenance of the existing soil cover and vegetation over the disposal units.

### 6.3.2 Hypothetical Receptors

Given the two scenarios described above, hypothetical receptors were selected. For the no-action scenario that assumed free access to the waste disposal areas, only a homesteader who lived in a house built directly on top of the burial grounds was assessed for current exposure since this would represent the greatest risk value for that scenario. *(TM 06-14 Demographic Data to Support WAG 6 RFI* showed that no residents live closer than 0.56 miles from the WAG boundary and that these residents live on the opposite bank of the Clinch River. Consequently, actual exposure estimates for these residents were not used since they would not be representative of exposure to a resident on the WAG.)

For the institutional control scenario, one hypothetical on-site receptor and three hypothetical off-site receptors were assessed for current exposure, the latter to represent exposure to the public in general. Since site controls would eliminate the feasibility of on-site homesteading, an on-WAG homesteader was assessed only for the future, post-control phase of this scenario (i.e., beginning in 2100). An ORNL employee conducting maintenance activities at the WAG was assessed because the WAG is still an operating disposal site. An individual hunting deer nearby was evaluated because hunting occurs at specified times of the year in designated areas within the ORR Wildlife Management Area

south and west of the WAG. A person stationed at the fence that surrounds most of the WAG was assessed because certain sections of the fence are accessible to the public. Finally, a homesteader resident downstream along the Clinch River was examined because contamination could potentially be migrating from the WAG. These four individuals were not assessed for future exposure because the future exposure of the on-WAG homesteader would represent the greatest risk value for that phase of the institutional control scenario.

### 6.3.3 Exposure Pathways

Associated with each hypothetical receptor were a variety of potential pathways by which that individual could potentially be exposed to contaminants from WAG 6. An exposure pathway consists of four elements: a source; a transport medium by which contaminants move from the source to a receptor; a point of potential contact with the contaminated medium (e.g, on top of a waste disposal area); and an exposure route (e.g., ingestion) whereby contaminants may affect the receptor (Fig. 6.2). Potential pathways for the various receptors considered in this evaluation are listed in Table 6.4. Table 6.5 illustrates the significant receptor/pathway combinations selected for assessment and the periods for which they were evaluated. Assumptions made about each receptor and the pathways evaluated are presented in Table 6.6.

### 6.3.4 Quantification of Exposure

The final step in assessing radiological and chemical exposures to a hypothetical receptor was to determine the intake to the receptor from each pathway associated with that individual. This quantification of exposure was a two-stage process: first, the contaminant concentrations to which the receptor would be exposed in different media were estimated. Second, these concentrations were combined with other variables, such as exposure frequency and duration, to yield pathway-specific intakes.

When quantifying exposure for a given pathway variables used are selected so that the combination of all variables result in an estimate of the reasonable maximum exposure for that pathway (EPA 1989b). The goal of the reasonable maximum exposure is to combine upper-bound and average exposure factors so that the result represents an estimate of exposure that is both protective and reasonable, not the worst possible case (EPA 1991). Thus not all variables used in this evaluation (e.g., body weight, contaminant concentrations) were at their individual maximums, but when used in combination with other variables resulted in reasonable estimates of maximum exposure.

#### 6.3.4.1 Estimation of contaminant concentrations in media

To provide a reasonable estimate of maximum exposure, potential contact concentrations for each contaminant were calculated at the upper 95 percentile confidence interval. For radionuclides, 26 individual subareas within the WAG were studied. For chemicals, two study areas were defined: the entire WAG and the high-activity auger hole area in which 85 percent of the radioactivity at the WAG was disposed. The results for radionuclides at the upper 95 percentile confidence interval around the mean are presented in Appendix 5D. The method and results for chemicals at the upper 95 percentile confidence limit around the median are presented in Appendixes 4B and 6F.

**Derivation of radionuclide concentrations.** Figure 6.3 illustrates the process used to estimate concentrations of radionuclides for various routes of exposure. Concentrations in environmental media were estimated using fate and transport modeling.

The radionuclides modeled were those identified as contaminants of concern in Sect. 6.2.1. The two models used were a surface/subsurface water model (the water model) and an air model, both of which were discussed in Sect. 5 and associated appendixes. Groundwater and surface water contaminant concentrations from the water model were calibrated by comparing them with field sampling data from groundwater wells and surface water sources. Contaminant concentrations in soil were determined from the water model by accounting for leaching and decay of radionuclides out of the soil. From these concentrations in soil, the concentrations of airborne radionuclide particulates were calculated. The air model used tritium concentrations in surface water from the water model as source data to calculate the maximum annual average concentration of tritium in air. Appendix 6G lists the concentrations of radionuclides used in assessing exposures to hypothetical receptors.

Radionuclide concentrations in vegetables and fruits, beef, deer meat, milk, and fish were predicted from contaminant concentrations in surface water, groundwater, and soil, using a food chain transport model (Appendix 6G).

Concentrations of radionuclides in surface water at the WAG boundary were determined from the water model (Appendix 5D). The dilution factor at Mile 9.5 (ORNL 1991b) was applied to modeled surface water values to obtain the concentrations of contaminants at this point on the Clinch River (Appendix 6H). Off-WAG concentrations of radionuclides in soil (Appendix 6H) and biota were also calculated from surface water values for Clinch River Mile 9.5.

**Derivation of chemical concentrations.** Figure 6.4 illustrates the process used to estimate concentrations of chemicals for various exposure routes. Chemicals evaluated WAG-wide and in the high-activity auger hole area were those listed in Sect. 6.2.2 as being of potential concern. Field sampling results were used directly to calculate estimated concentrations for groundwater, surface water, sediment, and soil. Modeled data were used to determine concentrations of volatile organics in air across the entire WAG. The air model is discussed in Sect. 5 and Appendix 5E.

Chemical concentrations in vegetables, fruit, beef, deer meat, milk, and fish were calculated using field data for soil, groundwater, and surface water and modeled data for air. Appendix 6I presents a detailed discussion of the calculation methods and results.

As with radionuclide concentrations, surface water concentrations downstream on the Clinch River were calculated using the surface water values at the WAG boundary and Clinch River dilution factors (ORNL 1991b). From the surface water results at Clinch River Mile 9.5, concentrations in soil, air (particulates), and biota were calculated. The results of and method for calculating these concentrations are presented in Appendix 6H for soil and Appendix 6I for air and biota.

As stated in Sect. 6.2.2, no chemical source data were available. Therefore, future concentrations of chemicals in waste disposal areas could not be modeled and the conservative assumption was made that concentrations of chemicals in the environment would not change over time so that exposure intakes to a future on-WAG homesteader would be the same as those for the current on-WAG homesteader.

#### 6.3.4.2 Calculation of pathway-specific intakes

Once contaminant concentrations were estimated for all environmental media and biota, reasonable maximum intakes were calculated for radioactive and chemical contaminants within identified pathways. Appendixes 6G and 6I detail calculation variables, methods, and results for radionuclides and chemicals, respectively. Upper-bound (90 percentile) and average values were used for equation variables to yield reasonable maximum intakes to each receptor. Results of intake calculations are discussed as part of the overall estimation of risk to receptors presented in Sect. 6.5, Risk Characterization.

## 6.4 TOXICITY ASSESSMENT

This section summarizes the toxicity assessment process, which consisted of two steps. First, hazards were identified and second, toxicity parameters were identified that quantified these hazards. These toxicity parameters express a dose-response relationship (i.e., they quantify whether or not a relationship exists between the dose of a contaminant administered or received and the incidence of adverse health effects in the exposed population). These dose-response values were then used in combination with intake values (Sect. 6.3) to characterize risk (Sect. 6.5).

### 6.4.1 Radionuclide toxicity assessment

#### 6.4.1.1 Hazard identification

All radionuclides have carcinogenic effects and have been formally classified as such by the US EPA Carcinogenic Assessment Group (EPA 1986c) or the International Agency for Research on Cancer (IARC 1982). Exposure to radionuclides with carcinogenic effects can cause or induce cancer. Further information on these and other potential effects from exposure to radionuclides is provided in Appendix 6J. Table 6.1 lists the 17 radionuclides of potential concern at WAG 6.

#### 6.4.1.2 Dose-response evaluation for radionuclides

Toxicity parameters used to quantify the dose-response relationship associated with the 17 radionuclides were dose conversion factors (typically used to express occupational exposure) and slope factors (used in risk assessment studies to express cancer risk). Values for both parameters were available for the external exposure, inhalation, and ingestion routes of exposure; however, slope factors were not available for contamination at depth (i.e., for subsurface contamination with a surface layer of clean soil). The values used are listed in Appendix 6J.

### 6.4.2 Chemical Toxicity Assessment

#### 6.4.2.1 Hazard identification

The chemicals of potential concern at WAG 6 exhibit noncarcinogenic and carcinogenic effects. Exposure to noncarcinogenic chemicals may result in numerous health effects, ranging from effects on specific organ systems (e.g., neurotoxicity) to effects on reproduction and offspring (e.g., fetotoxicity). Chemicals considered to be potential carcinogens may also capable of causing noncarcinogenic effects. Further information on chemical hazard identification is provided in Appendix 6J.

In Sect. 6.2, 44 chemicals of potential concern were identified for WAG 6 (Table 6.2). Of these, 16 are classified as known or probable human carcinogenic chemicals by the EPA Carcinogenic Assessment Group or the International Agency for Research on Cancer and 31 are noncarcinogenic chemicals (Table 6.7). Toxicity profiles for these chemicals are summarized in Appendix 6J. Nine chemicals exhibit both noncarcinogenic and carcinogenic effects.

#### 6.4.2.2 Dose-response evaluation for chemicals

Toxicity parameters used to quantify hazards associated with chemicals were reference doses and slope factors. Reference doses were used to express the dose-response relationship for noncarcinogenic chemicals; slope factors expressed the relationship for carcinogenic chemicals. Reference doses and slope factors were available for the inhalation and ingestion routes of exposure. In the absence of specific toxicity values for the dermal route of exposure, reference doses and slope factors for ingestion were modified to express dose-response relationships (Appendix 6J). For reference doses, the critical effect (e.g., neurotoxicity, fetotoxicity) was also indicated. These toxicity parameters are listed in Appendix 6J.

## 6.5 RISK CHARACTERIZATION

In the risk characterization step of the baseline human health evaluation, results from the exposure assessment (Sect. 6.3) and toxicity assessment (Sect. 6.4) were summarized and integrated into quantitative risk estimates. To quantify risk from exposure to carcinogenic chemicals, probabilities that a hypothetical receptor developed cancer over a lifetime of exposure were estimated from projected intakes and contaminant-specific dose-response information. To quantify risk from exposure to noncarcinogenic chemicals, direct comparisons were made between projected exposure levels and toxicity values. The following sections address these two types of risk for the hypothetical receptors associated with WAG 6. As stated in Sect. 6.4, carcinogenic risk was quantified for the radionuclides of potential concern; both types of risk were calculated for chemical contaminants of potential concern. Uncertainties associated with the quantification of risk are in this evaluation discussed and identified in Appendix 6K.

### 6.5.1 Quantification of Carcinogenic Risk

For carcinogenic chemicals, risks were estimated as the excess probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen via a specific pathway. A slope factor was used to convert estimated daily intakes averaged over a lifetime to a value expressing incremental risk. For the inhalation and ingestion pathways, risk associated with each radionuclide or chemical was estimated by multiplying the appropriate slope factor by the estimated intake of the substance in question. Risk from the external exposure pathway (relevant only to radionuclides) was computed as the product of the slope factor, the concentration in soil, and the duration of exposure to the radionuclide under study.

Simultaneous exposures to several radionuclides and chemicals via more than one pathway were also assessed. The risk of developing cancer from simultaneous exposure to several contaminants is based on the assumption that carcinogenic risks are additive (EPA 1989b). Appendix 6G presents calculations that express risk from exposure to multiple radionuclide carcinogens across several pathways and the values resulting from these calculations. Appendix 6I presents similar information for chemical carcinogens.

The on-WAG ORNL employee and the boundary receptor were exposed to only undisturbed subsurface contamination. As stated in Sect. 6.4.1, slope factors do not exist for contamination at depth; therefore, risk was quantified in terms of radiation dose (Appendix 6G). As suggested by EPA (1989b), radiation dose values were also calculated for each of the other receptors for the current and future time periods; these results are also presented in Appendix 6G.

Risk to the on-WAG homesteader was characterized in two ways: using data from the entire WAG and data specifically from the high-activity auger hole area (i.e., northeast auger hole area as illustrated in Fig. 1.6). For risk from exposure to radionuclides, contaminant concentrations calculated at the 95 percentile confidence interval for each of the 26 study areas were averaged to yield a "WAG-wide" risk. Similarly, the radionuclide contaminant concentrations calculated for the study areas comprising the auger hole area were averaged to estimate risk specific for this area.

Calculated risks from exposure to radionuclides and chemicals were compared to EPA's target risk range of 1E-6 to 1E-4 (EPA 1990c). That is, any risk values greater than 1E-4 (1 in 10,000 chance of developing cancer) are unacceptable and any risk values less than 1E-6 (1 in 1,000,000 chance of developing cancer) are acceptable by EPA. As shown in Fig. 6.5, the current day receptors with the highest cancer risk from radionuclides were the on-WAG homesteaders, whose risks were characterized based on data from the WAG. These individuals exhibited a risk of 1 (i.e., a 100 percent probability of developing cancer). Cancer risk for the off-WAG homesteader was within the EPA's target range at 6E-5, and for the hunter and boundary receptor was less than 1E-6. The future on-WAG homesteader whose risk was characterized using data from the auger hole area exhibited a risk of 9E-1, while the future on-WAG homesteader characterized using data from the entire WAG exhibited a lesser risk of 3E-1. The on-WAG ORNL employee showed an even lower risk of 1E-3. Tables 6.8 and 6.9 illustrate the exposure pathways contributing to these risks,

which are above or within EPA's target risk range. Exposure pathways for receptors with risks below the lower end of the risk range are presented in Appendix 6G.

As discussed in Appendix 6K, the assumption that waste is exhumed and mixed in the garden and yard had a significant impact on the risk values from radionuclides to the on-WAG homesteaders. In order to put the importance of this assumption in perspective, risk values were calculated for the on-WAG homesteaders assuming no waste exhumation. For this case, risk values were still above the upper limit of EPAs target risk range, yet considerably less (3 orders-of-magnitude) than those calculated previously assuming waste exhumation.

As shown in Figure 6.5, the adult on-WAG homesteader exhibited a cancer risk from chemicals of 4E-4 based on data from the entire WAG and a risk of 3E-4 based on data from the high-activity auger hole area. These values and those for the child homesteader in both cases slightly exceed the upper limit (1E-4) of EPA's target range. Table 6.10 illustrates the exposure pathways contributing to these risks that exceeded EPA's target risk range. Risks to the other receptors were all less than 1E-6. Tables illustrating the pathways contributing to these risks are in Appendix 6I.

### 6.5.2 Quantification of Noncarcinogenic Risk

The potential for noncarcinogenic effects on health was evaluated by comparing an exposure level with a reference dose. This ratio of exposure to toxicity is called a hazard quotient. The hazard quotient assumes that a level of exposure exists [reference dose (RfD)] below which it is unlikely for a receptor to experience adverse health effects. If the exposure level (E) exceeds this threshold (i.e., if E/RfD exceeds unity), the potential exists for noncarcinogenic effects to develop.

Exposures to noncarcinogenic chemicals may involve potential exposure to several chemicals simultaneously for a critical effect. To assess the overall potential for noncarcinogenic effects in such circumstances, a hazard index (HI) specific to a critical effect is used. The HI is equal to the sum of the hazard quotients. Thus, the HI can exceed unity even if no single chemical exposure exceeds the RfD for that chemical. Naturally, any single chemical with an estimated daily intake greater than the corresponding RfD will cause the HI to exceed unity. When the HI exceeds unity, adverse critical effects on human health may develop.

Figure 6.6 shows that the receptors whose hazard index for a critical effect exceeded unity were the on-WAG homesteader adult and child whose risks were characterized for the high-activity auger hole area. The hazard index for total effects exceeded or approached unity for the child and adult homesteaders, respectively, whose risks were characterized WAG-wide; the hazard index for these receptors never exceeded unity for a specific critical effect. Table 6.11 details the exposure pathways and chemicals contributing to these health hazards that had a critical effect specific hazard index exceeding 1. Exposure pathways for receptors with effect specific hazard indices less than 1, and total hazard indices are presented in Appendix 6G.

## 6.6 SUMMARY AND CONCLUSIONS

The baseline human health evaluation quantified potential carcinogenic and noncarcinogenic effects on hypothetical receptors of exposure to WAG 6 radionuclides and chemicals. The objective of the evaluation was to determine whether or not human health is threatened if no remedial action is undertaken at the WAG. Incremental lifetime cancer risks were estimated on the basis of total dose received from all possible exposure routes. However, these calculated "excess" lifetime cancer risks do not reflect, in any manner, actual risks to the exposed population in the vicinity of the WAG. Rather, they are conservative estimates of the reasonable maximum risk to hypothetical receptors, using assumptions within the framework of accepted health risk assessment methodologies.

Data on radionuclide and chemical contaminants at the WAG were summarized for groundwater, surface soil, surface water, and sediment. Information on the WAG 6 radionuclide inventory was screened to identify radionuclides of potential concern. Models were then used to calculate current and future concentrations of these radionuclides in groundwater, soil, surface water, and air. Statistical methods were used to identify potential chemicals of concern in addition to organics, which were evaluated further. Models were used to determine concentrations of chemicals in surface water and concentrations of volatile organic chemicals in air.

An on-WAG homesteader, an on-WAG ORNL employee, a hunter near the WAG, a boundary receptor at the fenceline of the WAG, and an off-WAG homesteader were evaluated as hypothetical receptors. Exposure routes analyzed for these receptors were ingestion of groundwater, surface water, fruit, vegetables, milk, beef, and deer meat; incidental ingestion of surface water, soil, and sediment; inhalation of suspended particulates and volatiles from ambient air and showering; dermal contact with soil, surface water, sediment, and groundwater; and external exposure from soil. Intakes of contaminants from these exposure pathways were then used in conjunction with toxicity parameters (or dose-response values) for the potential contaminants of concern to quantify the risk of developing carcinogenic and noncarcinogenic health effects.

### 6.6.1 Carcinogenic Risk

Carcinogenic risk was quantified for all the radionuclides of concern and the 16 chemicals classified as carcinogens. Under the toxicological and exposure assumptions used in the evaluation, the radionuclide-related excess lifetime cancer risk of the on-WAG homesteader and on-WAG ORNL employee exceeded the upper limit of EPA's target range (1E-6 to 1E-4).

The off-WAG homesteader exhibited radionuclide-related excess lifetime cancer risk within EPA's target range. Risks calculated for the hunter and boundary receptors were both less than 1E-8.

Chemical-related excess lifetime cancer risk was highest for the on-WAG homesteader, slightly exceeding the upper limit of EPA's target range. The on-WAG ORNL employee, hunter near the WAG, boundary receptor, and off-WAG homesteader all exhibited risks less than 1E-10.

### 6.6.2 Noncarcinogenic Risk

In the case of noncarcinogens, the risk of developing adverse health effects was expressed by the degree to which the effect-specific HI exceeded one. Only the on-WAG homesteader in the auger-hole subarea exhibited a critical effect specific hazard index exceeding one.

# Section 6 Tables

**Table 6.1. Radionuclides of potential concern - WAG 6**

| Radionuclide | Radionuclide |
|---|---|
| Am-241 | Pa-234[a] |
| Ba-137m[a] | Pa-234m[a] |
| Cm-244 | Sr-90 |
| Co-60 | Th-232 |
| Cs-137 | Th-234[a] |
| Eu-152 | U-233 |
| Eu-154 | U-238 |
| Eu-155 | Y-90[a] |
| H-3 | |

[a] Short-lived daughter assumed to be in equilibrium with parent and therefore also considered in the quantitative analysis of risk.

**Table 6.2. Rationale for inclusion of chemicals as contaminants of concern - WAG 6**

| | | Medium | | | |
|---|---|---|---|---|---|
| Chemical | CAS number | Soil | Groundwater | Sediment | Surface water |
| **Organics** | | | | | |
| Carbon Tetrachloride | 56-23-5 | | V | | |
| Acetone | 67-64-1 | V | V | V | V |
| Chloroform | 67-66-3 | | V | SS | V |
| Benzene | 71-43-2 | | V | | |
| 1,1,1-Trichloroethane | 71-55-6 | | V | | |
| Ethyl Chloride | 75-00-3 | | V | | |
| Vinyl Chloride | 75-01-4 | | V | | |
| Methylene Chloride | 75-09-2 | V | V | V | |
| Carbon Disulfide | 75-15-0 | | V | | V |
| 1,1-Dichloroethane | 75-34-3 | | V | | |
| 1,1-Dichloroethene | 75-35-4 | | V | | |
| Trichlorofluoromethane | 75-69-4 | | | V | |
| 2-Butanone | 78-93-3 | | V | SS | |
| 1,1,2-Trichloroethane | 79-00-5 | | V | | |
| Trichloroethene | 79-01-6 | V | V | V | V |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | | V | | |
| Diethylphthalate | 84-66-2 | | O | | |
| Di-N-Butylphthalate | 84-74-2 | | O | | |
| Napthalene | 91-20-3 | | O | | |
| 2,4,5-TP | 93-72-1 | | O | | |
| 2,4,5-T | 93-76-5 | | O | | |
| 2,4-D | 94-75-7 | | O | | |
| 2-Methlyphenol | 95-48-7 | | O | | |
| Ethylbenzene | 100-41-4 | V | SS | | |
| Benzyl Alcohol | 100-51-6 | O | | | |
| 1,2-Dichloroethane | 107-06-2 | | V | | |
| Toluene | 108-88-3 | V | V | V | |
| Bis (2-Ethylhexyl) phthalate | 117-81-7 | | O | | |
| Tetrachloroethene | 127-18-4 | | V | | V |
| 1,2- Dichloroethylene | 540-59-0 | V | SS | | V |
| Xylene (total) | 1330-20-7 | V | V | | |
| Arochlor 1254 | 11097-69-1 | | O | | |

Table 6.2. (continued)

| Chemical | CAS number | Medium | | | |
|---|---|---|---|---|---|
| | | Soil | Groundwater | Sediment | Surface water |
| **Inorganics** | | | | | |
| Aluminum | 7429-90-5 | SS | | | |
| Manganese | 7439-96-5 | | SS | | |
| Mercury | 7439-97-6 | | SS | | |
| Nickel | 7440-02-0 | | SS | | |
| Silver | 7440-22-4 | | SS | SS | SS |
| Strontium | 7440-24-6 | | SS | | |
| Thallium | 7440-28-0 | SS | | | |
| Titanium | 7440-32-6 | | SS | | |
| Cadmium | 7440-43-9 | | SS | | |
| Chromium | 7440-47-3 | SS | SS | | |
| Cobalt | 7440-48-4 | | SS | | |
| Vanadium | 7440-62-2 | SS | SS | | |

SS = Statistically significant
V = Volatile
O = Other - (in excess of contract required detection limit; statistically significant in other media; in excess of health-based criterion; known WAG contaminant)

**Table 6.3. Scenarios, receptors, and periods of evaluation studied**

| Scenario | Hypothetical receptor | Evaluation period |
|---|---|---|
| No action | On-WAG homesteader[a] | Current[b] |
| Institutional control | On-WAG homesteader[a] | Future[c] |
| Institutional control | On-WAG ORNL employee | Current |
| Institutional control | Hunter near WAG | Current |
| Institutional control | Boundary receptor | Current |
| Institutional control | Off-WAG homesteader[a] | Current |

[a] Homesteader assumes adult receptor for exposure to radionuclides and assumes adult and child receptors for exposure to chemicals.
[b] Beginning in 1990.
[c] Beginning in 2100.

Table 6.4. Potential exposure pathways for WAG 6 receptors

| Receptor | Exposure medium | Exposure route | Pathway evaluated | Reason for selection or exclusion |
|---|---|---|---|---|
| Hunter | Deer | Ingestion (R,C) | Yes | Contaminants detected in deer killed on ORR |
| Boundary receptor | Air | Inhalation - Vapors (R,C) | Yes | Volatile organics and tritium present in soil on WAG |
| | | - Particulates (R,C) | No | No surface contamination since waste areas covered by 1 ft. of clean cover material |
| | Soil | External Exposure (R) | Yes | Gamma emitters present in disposal units |
| On-WAG ORNL employee | Air | Inhalation-Vapors (R,C) | Yes | Volatile organics present in soil on WAG; tritium present in surface water on WAG |
| | | - Particulates (R,C) | No | No surface contamination since waste areas covered by 1 ft. of clean cover material |
| | Soil | External Exposure (R) | Yes | Gamma emitters present in disposal units |
| | | Dermal contact (C) | No | No surface contamination since waste areas covered by 1 ft. of clean cover material |
| | Surface water | Dermal contact (C) | No | Not in contact with surface water bodies |
| | Sediment | External exposure (R) | No | Not in contact with surface water bodies |
| | | Dermal contact (C) | No | Not in contact with surface water bodies |
| On-WAG homesteader | Air | Inhalation-Vapors (R,C) | Yes | Volatile organics present in soil on WAG; tritium present in surface water on WAG |
| | | - Particulates (R,C) | Yes | Waste material present in garden and yard |
| | Soil | External exposure (R) | Yes | Gamma emitters present in waste material in garden and yard |
| | | Incidental ingestion (R,C) | Yes | Waste material present in garden and yard |
| | | Dermal contact (C) | Yes | Waste material present in garden and yard |
| | Ground-water | Inhalation-Vapors while showering (C) | Yes | Volatile organics present in groundwater |
| | | Ingestion (R,C) | Yes | Contaminants present in groundwater |

Table 6.4. (continued)

| Receptor | Exposure medium | Exposure route | Pathway evaluated | Reason for selection or exclusion |
|---|---|---|---|---|
| | | Dermal contact (C) | Yes | Waste materials present in groundwater |
| | Surface water | Incidental ingestion (C) | Yes | While swimming in EWB |
| | | Dermal contact (C) | Yes | While swimming in EWB |
| | Sediment | External exposure (R) | No | Insignificant compared to soil exposures |
| | | Incidental ingestion (C) | Yes | While swimming in EWB |
| | | Dermal contact (C) | Yes | While swimming in EWB |
| | Biota | Ingestion (R,C) | Yes | Vegetables/fruits from garden; milk/meat from cows |
| Off-WAG homesteader | Air | Inhalation-Vapors (R,C) | No | Volatile organics insignificant in surface water |
| | | - Particulates (R,C) | Yes | Contaminants present in garden and yard |
| | Soil | External exposure (R) | Yes | Gamma emitters present in garden and yard |
| | | Incidental ingestion (R,C) | Yes | Contaminants present in garden and yard |
| | | Dermal contact (C) | Yes | Contaminants present in garden and yard |
| | Surface water | Inhalation-Vapors while showering (C) | No | Volatile organics insignificant in surface water |
| | | Ingestion (C) | Yes | Contaminants present in surface water |
| | | Incidental ingestion (R,C) | No | Insignificant compared to ingestion of surface water |
| | | Dermal contact (C) | Yes | While swimming in Clinch River and showering |
| | Sediment | External exposure (R) | No | Insignificant compared to soil exposures |
| | | Incidental ingestion (R,C) | No | Insignificant compared to soil exposures |
| | | Dermal contact (C) | No | Insignificant compared to soil exposures |
| | Biota | Ingestion (R,C) | Yes | Vegetables/fruits from garden; milk/meat from cows |

(R) - Radionuclides
(C) - Chemicals

**Table 6.5. Receptor/pathway combinations studied for WAG 6**

| Potential receptors | Pathway evaluated for current assessment[a] 1990 | | Pathway evaluated for future assessment 2100 |
|---|---|---|---|
| | On-WAG | Off-WAG | WAG 6 area[b] |
| Hunter receptor | | Ingestion-deer (R,C) | |
| Boundary receptor[c] | | Inhalation-air (R,C) | |
| | | External exposure-soil (R) | |
| On-WAG ORNL employee[d] | Inhalation-air[e] (R,C) | | |
| | External exposure-soil (R) | | |
| On-WAG homesteader[f,g] | External exposure-soil (R) | | External exposure-soil (R) |
| | Inhalation-air (R,C); SW (R); GW (C) | | Inhalation-air (R,C); SW (R); GW (C) |
| | Ingestion-GW, biota (R,C) | | Ingestion-GW, biota (R,C) |
| | Incidental ingestion-soil (R,C); SW, sediment (C) | | Incidental ingestion-soil (R,C); SW, sediment (C) |
| | Dermal contact-soil, GW, SW, sediment (C) | | Dermal contact-soil, GW, SW, sediment (C) |
| Off-WAG homesteader[f,h] | | External exposure-soil (R) | |
| | | Inhalation-air[i] (R,C) | |
| | | Ingestion-SW, biota (R,C) | |
| | | Incidental ingestion-soil (R,C) | |
| | | Dermal contact-soil, SW (C) | |

[a] GW means groundwater; SW means surface water; R means assessed for radionuclide components; C means assessed for chemical components.

[b] WAG 6 area in future, no WAG boundaries exist; assumes institutional controls of 10-year operational period plus 100-year post-operational period.

[c] Only where WAG does not adjoin other WAGs (i.e., along its western and northern limits).

**Table 6.5. (continued)**

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[d] Assumes normal working conditions and no accident scenarios.

[e] Includes inhalation of volatiles and particulates for air exposure routes.

[f] For radiological assessment evaluated adult only; for chemical assessment evaluated adult and child.

[g] Represents concentrations across the entire WAG and at the high-activity auger hole area.

[h] Off-WAG receptor located downstream at Clinch River Mile 9.5; includes contamination of specific media through irrigation using contaminated Clinch River water.

[i] Assessed for particulates only.

**Table 6.6. Assumptions about receptors and pathways evaluated**

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I. On-WAG Homesteader-Adult and Child (Current and Future)

- Assumptions:
  - homesteader family comprised of two adults and one child [average family size for area surrounding WAG 6 (1990 Census for Roane County)]
  - adult homesteader evaluated for exposure to both radioactive and chemical contaminants; child homesteader evaluated for exposure to chemical contaminants only
  - waste exhumed during construction of a house on the waste disposal area is mixed in the garden and yard; waste in these locations is indistinguishable from native soil
- Pathways:
  - ingestion of contaminated drinking water from a groundwater well near the waste disposal areas
  - ingestion of vegetables/fruit grown in contaminated soil
  - ingestion of milk and beef from dairy and beef cattle that drink contaminated groundwater
  - incidental ingestion of contaminated soil from the vegetable/fruit garden and yard
  - incidental ingestion of contaminated water and sediment while swimming in the EWB
  - external exposure from contaminated soil in the garden and yard
  - inhalation of suspended particulates and volatiles from contaminated soil in the garden and yard
  - inhalation of vapors from groundwater while showering
  - inhalation of tritium from surface water (i.e., on-WAG)
  - dermal contact with soil in the yard and garden
  - dermal contact with ground water while showering
  - dermal contact with surface water and sediment while swimming in the EWB

II. Off-WAG Homesteader-Adult and Child

- Assumptions:
  - homesteader family comprised of two adults and one child [average family size for area surrounding WAG 6 (1990 Census for Roane County)]
  - adult homesteader evaluated for exposure to both radioactive and chemical contamination; child homesteader evaluated for exposure to chemicals contaminants only
  - homesteader located at Clinch River Mile 9.5 downstream of WAG 6
  - contamination at this location is exclusively from surface water leaving WAG 6
  - homesteader uses Clinch River water to:
    - drink
    - irrigate his vegetable/fruit garden and yard
    - provide water for his cattle to drink
    - swim and fish in
- Pathways:
  - external exposure from contaminated soil in garden and yard
  - ingestion of surface water for drinking water
  - ingestion of fruit and vegetables grown in garden irrigated with contaminated surface water
  - ingestion of milk and beef from cattle drinking contaminated surface water
  - ingestion of fish from Clinch River
  - incidental ingestion of contaminated soil from garden and yard
  - inhalation of particulates from contaminated soil from garden and yard
  - dermal contact with soil in the yard and garden
  - dermal contact with surface water while showering

**Table 6.6. (continued)**

III. On-WAG ORNL Employee

- Assumptions:
  - employee does maintenance and surveillance work only (i.e., not involved with disposal of waste materials during the 10-year operational period)
  - employee is not a radiation protection worker (i.e., protective equipment is not required)
  - normal working conditions and no accident scenarios
  - employee is evaluated on waste disposal areas (i.e., not on areas of WAG where no waste disposal occurred)
  - all waste material is covered by a minimum of 1 ft. of clean material
- Pathways:
  - external exposure from soil
  - inhalation of volatiles (including tritium)

IV. Boundary Receptor at Fenceline

- Assumptions:
  - adult only since exposure to child is unlikely due to remote location of WAG
  - receptor is located only along portions of WAG that are not adjacent to another WAG (e.g., WAG 2)
  - exposures are only from waste disposal areas nearest fence (i.e., average value from entire WAG will not be used)
  - waste disposal areas are covered by a minimum of 1 ft. of clean material
- Pathways:
  - external exposure from soil on-WAG
  - inhalation from volatiles (including tritium)

V. Hunter - Off-WAG

- Assumptions:
  - hunter kills deer that drink contaminated water exclusively from EWB and other contaminated ephemereal surface water streams on WAG 6
  - hunter is at least 100 yards from WAG 6; therefore, is not exposed directly to WAG 6 contaminants at the boundary
- Pathways:
  - ingestion of contaminated deer meat

Table 6.7. Chemicals of potential concern exhibiting carcinogenic effects and noncarcinogenic effects

| Chemical | CAS number | Carcinogen | Noncarcinogen |
|---|---|---|---|
| **Organics** | | | |
| Carbon Tetrachloride | 56-23-5 | X | X |
| Acetone | 67-64-1 | | X |
| Chloroform | 67-66-3 | X | X |
| Benzene | 71-43-2 | X | |
| 1,1,1-Trichloroethane | 71-55-6 | | X |
| Ethyl Chloride | 75-00-3 | | X |
| Vinyl Chloride | 75-01-4 | X | |
| Methylene Chloride | 75-09-2 | X | X |
| Carbon Disulfide | 75-15-0 | | X |
| 1,1-Dichloroethane | 75-34-3 | | X |
| 1,1-Dichloroethene | 75-35-4 | X | X |
| Trichlorofluoromethane | 75-69-4 | | X |
| 2-Butanone | 78-93-3 | | X |
| 1,1,2-Trichloroethane | 79-00-5 | X | X |
| Trichloroethylene | 79-01-6 | X | |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | X | |
| Diethylphthalate | 84-66-2 | | X |
| Di-N-Butylphthalate | 84-74-2 | | X |
| Napthalene | 91-20-3 | | X |
| 2,4,5-TP | 93-72-1 | | X |
| 2,4,5-T | 93-76-5 | | X |
| 2,4-D | 94-75-7 | | X |
| 2-Methlyphenol | 95-48-7 | X | |
| Ethylbenzene | 100-41-4 | X | |
| Benzyl Alcohol | 100-51-6 | | X |
| 1,2-Dichloroethane | 107-06-2 | X | |
| Toluene | 108-88-3 | | X |
| Bis (2-Ethylhexyl) phthalate | 117-81-7 | X | X |
| Tetrachloroethylene | 127-18-4 | X | X |
| 1,2- Dichloroethylene[a] | 540-59-0 | | |
| Xylene (total) | 1330-20-7 | | X |
| Arochlor 1254[a] | 11097-69-1 | | |

Table 6.7. (continued)

| Chemical | CAS number | Carcinogen | Noncarcinogen |
|---|---|---|---|
| **Inorganics** | | | |
| Aluminum[a] | 7429-90-5 | | |
| Manganese | 7439-96-5 | | X |
| Mercury | 7439-97-6 | | X |
| Nickel | 7440-02-0 | | X |
| Silver | 7440-22-4 | | X |
| Strontium[a] | 7440-24-6 | | |
| Thallium | 7440-28-0 | | X |
| Titanium[a] | 7440-32-6 | | |
| Cadmium | 7440-43-9 | X | X |
| Chromium VI | 18540-29-9 | X | X |
| Cobalt[a] | 7440-48-4 | | |
| Vanadium | 7440-62-2 | | X |

[a] No EPA-approved dose-response relationship available; not further evaluated in risk characterization.

**Table 6.8. Radionuclide risk and dose estimated for the on-WAG homesteader under the no-action scenario**

| | Homesteader WAG-wide | | | Homesteader auger-hole area | | |
|---|---|---|---|---|---|---|
| Pathway | Risk[a] | Dose[b] | Percentage of total dose[c,d] | Risk[a] | Dose[b] | Percentage of total dose[c,d] |
| External exposure | 1E+2 | 2E+5[f] | 99 | 7E+2 | 1E+6[g] | 98 |
| Inhalation | 6E-1 | 3E+3 | 1 | 4E+0 | 2E+4 | 2 |
| Ingestion of food[e] | 3E-3 | 3E+1 | <1 | 2E-2 | 2E+2 | <1 |
| Ingestion of groundwater | 6E-4 | 1E+0 | <1 | 8E-4 | 1E+0 | <1 |
| Ingestion of soil | 5E-3 | 9E+1 | <1 | 3E-2 | 7E+2 | <1 |
| Totals | 1E+2 | 2E+5 | | 7E+2 | 1E+6 | |
| Total one-hit risk | 1E+0[h] | | | 1E+0[h] | | |

[a] Excess probability of individual developing cancer calculated using linear low-dose cancer equation.
[b] Expressed in units of rem.
[c] Dose attributable to the specific pathway divided by receptor's total dose.
[d] Sum of percents may be greater than 100 due to rounding.
[e] Includes ingestion of fruits and vegetables, milk, and meat.
[f] 1E+5 rem from europium-152 and 9E+4 rem from europium-154.
[g] 8E+5 rem from europium-152 and 5E+5 from europium-154.
[h] Calculated using one-hit equation for high carcinogenic risk levels.

**Table 6.9. Radionuclide risk and dose estimated for the on-WAG ORNL employee, on-WAG homesteader, and off-WAG homesteader under the institutional control scenario**

| | On-WAG ORNL employee | | | Homesteader WAG-wide | | | On-WAG homesteader, auger hole area | | | Off-WAG homesteader | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pathway | Risk[a] | Dose[b] | Percent[c,d] | Risk[a] | Dose[b] | Percent[c,d] | Risk[a] | Dose[b] | Percent[c,d] | Risk[a] | Dose[b] | Percent[c,d] |
| External exposure | 1E-3 | 2E+0[e] | 98 | 4E-1 | 6E+2 | 18 | 2E+0 | 4E+3 | 15 | 6E-5 | 1E-1[f] | 90 |
| Inhalation | 7E-9 | 5E-6 | 2 | 6E-2 | 3E+3[g] | 79 | 5E-1 | 2E+4 | 83[h] | 4E-8 | 6E-4 | <1 |
| Ingestion of food[i] | | | | 3E-4 | 2E+1 | <1 | 2E-3 | 2E+2 | <1 | 1E-6 | 5E-3 | 4 |
| Ingestion of water | | | | 3E-4 | 7E-1 | <1 | 2E-4 | 8E-1 | <1 | 3E-6 | 6E-3 | 5 |
| Ingestion of soil | | | | 1E-3 | 8E+1 | 2 | 6E-3 | 7E+2 | 2 | 2E-8 | 7E-5 | <1 |
| Totals | 1E-3 | 2E+0 | | 4E-1 | 4E+3 | | 3E+0 | 3E+4 | | 6E-5 | 1E-1 | |
| Total one-hit risk | | | | 3E-1[j] | | | 9E-1[j] | | | | | |

[a] Excess probability of an individual developing cancer calculated using the linear low dose cancer equation.
[b] Expressed in units of rem.
[c] Percent of pathways dose divided by receptors total dose.
[d] Sum of percent may be greater than 100 due to rounding.
[e] Dose is attributable to europium-152, europium-154, europium-155, cobalt-60 and cesium-137.
[f] 6E-2 rem from cobalt-60 and 3E-2 rem from barium-137.
[g] 3E+3 rem from thorium-232.
[h] 2E+4 rem from thorium-232.
[i] Includes ingestion of fruits and vegetables, milk, and meat.
[j] Calculated using the one-hit equation for high carcinogenic risk levels.

**Table 6.10. Chemical risk for the on-WAG homesteader**

| Pathway | WAG-wide, adult | | WAG-wide, child | | Auger hole area, adult | | Auger hole area, child | |
|---|---|---|---|---|---|---|---|---|
| | Risk[a] | Percent[b,c] | Risk[a] | Percent[b,c] | Risk[a] | Percent[b,c] | Risk[a] | Percent[b,c] |
| Ingestion of soil and sediment | 2E-10 | <1 | 4E-10 | <1 | 3E-11 | <1 | 6E-11 | <1 |
| Vapor phase inhalation | 3E-10 | <1 | 1E-10 | <1 | 3E-10 | <1 | 1E-10 | <1 |
| Vapor phase inhalation while showering | 7E-5 | 17 | 7E-5 | 30 | 1E-4 | 37 | 1E-4[d] | 58 |
| Ingestion of groundwater | 3E-4[e] | 80 | 2E-4[f] | 70 | 2E-4[g] | 59 | 8E-5[h] | 44 |
| Ingestion of food[i] | 1E-6 | <1 | 1E-6 | <1 | 4E-8 | <1 | 3E-8 | <1 |
| Dermal contact w/groundwater | 1E-5 | 3 | 4E-6 | <1 | 5E-6 | <1 | 2E-6 | <1 |
| Dermal contact with soil and sediment | 8E-8 | <1 | 6E-8 | <1 | 7E-8 | <1 | 3E-8 | <1 |
| Totals | 4E-4 | | 2E-4 | | 3E-4 | | 2E-4 | |

[a] Excess probability of an individual developing cancer.
[b] Risk attributable to the specific pathway divided by receptor's total risk.
[c] Sum of percent may be greater than 100 due to rounding.
[d] Risk of 3.8E-5 from carbon tetrachloride and 3.1E-5 from trichloroethene.
[e] Risk of 2.3E-4 from vinyl chloride and 3.7E-5 from 1,1 dichloroethene.
[f] Risk of 1.2E-4 from vinyl chloride and 1.9E-5 from 1,1 dichloroethene.
[g] Risk of 8.3E-5 from carbon tetrachloride and 4.3E-5 from trichloroethene.
[h] Risk of 4.2E-5 from carbon tetrachloride and 2.2E-5 from trichloroethene.
[i] Includes ingestion of fruits and vegetables, milk, and meat.

**Table 6.11. Noncarcinogenic effects for the on-WAG homesteader**

| | Auger hole area, adult[a] | | Auger hole area, child[a] | | Auger hole area, child[b] | |
|---|---|---|---|---|---|---|
| Pathway | Hazard index | Percent[c,d] | Hazard index | Percent[c,d] | Hazard index | Percent[c,d] |
| Ingestion of soil and sediment | 3E-7 | <1 | 3E-6 | <1 | 4E-2 | 4 |
| Ingestion of groundwater | 2E+0[e] | 96 | 5E+0[f] | 98 | 8E-1[g] | 84 |
| Ingestion of food[h] | 4E-4 | <1 | 1E-3 | <1 | 1E-2 | 1 |
| Dermal contact with groundwater | 7E-2 | 3 | 1E-1 | 2 | 1E-2 | 1 |
| Dermal contact with soil and sediment | 8E-4 | <1 | 1E-3 | <1 | 1E-1 | 13 |

[a] Critical effect is to the liver.
[b] Critical effect is to the kidney.
[c] Critical effect hazard index attributable to the subject pathway divided by the receptors total critical effect hazard index.
[d] Sum of percents may be greater than 100 due to rounding.
[e] A hazard index of 2E+0 is from carbon tetrachloride.
[f] A hazard index of 5E+0 is from carbon tetrachloride.
[g] A hazard index of 6E-1 is from cadmium and 1E-1 is from vanadium.
[h] Includes ingestion of fruits and vegetables, milk, and meat.

# Section 6 Figures

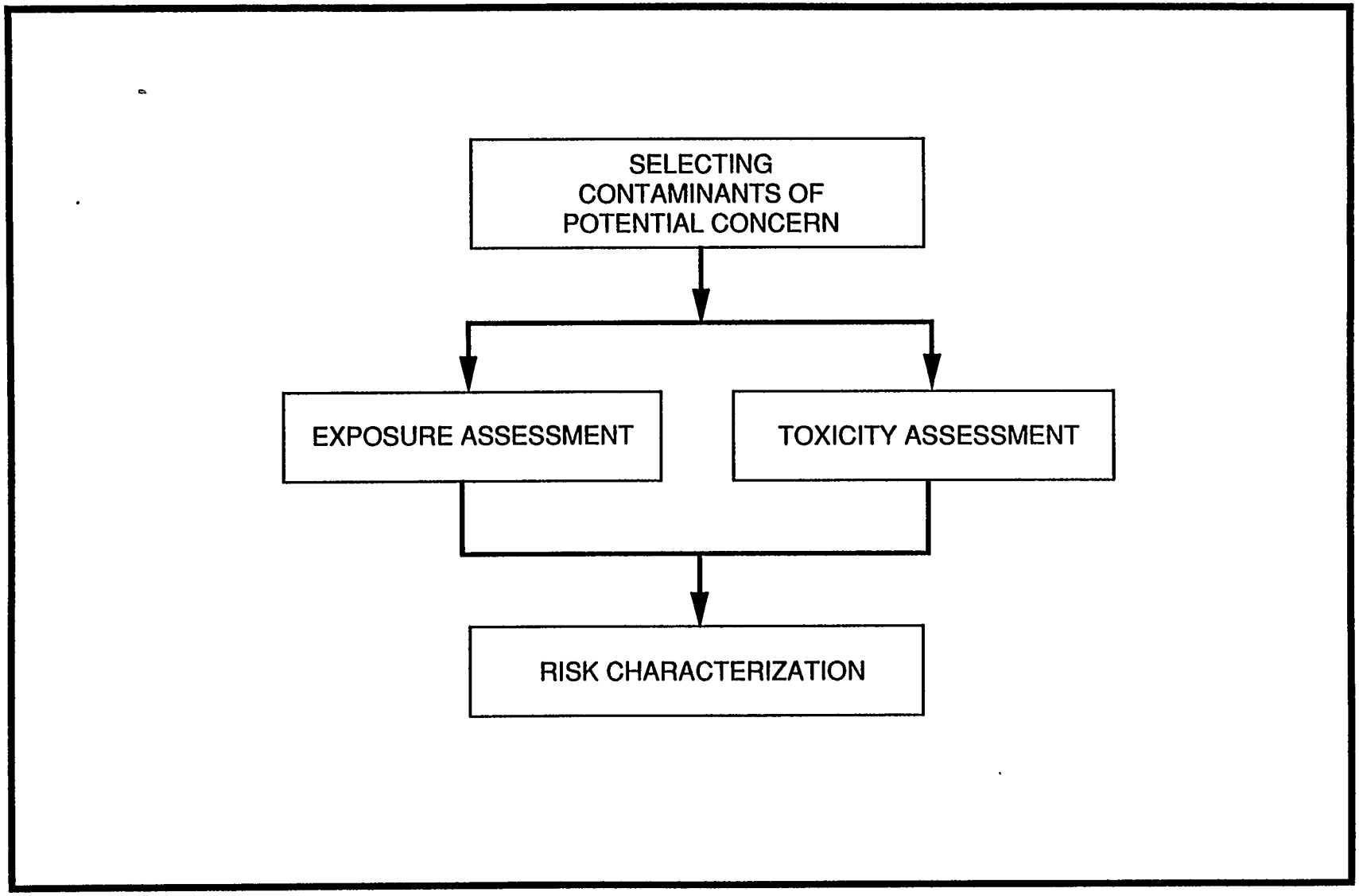



**Fig. 6.1. Steps in the human health evaluation process.**

5.19F 4104.169

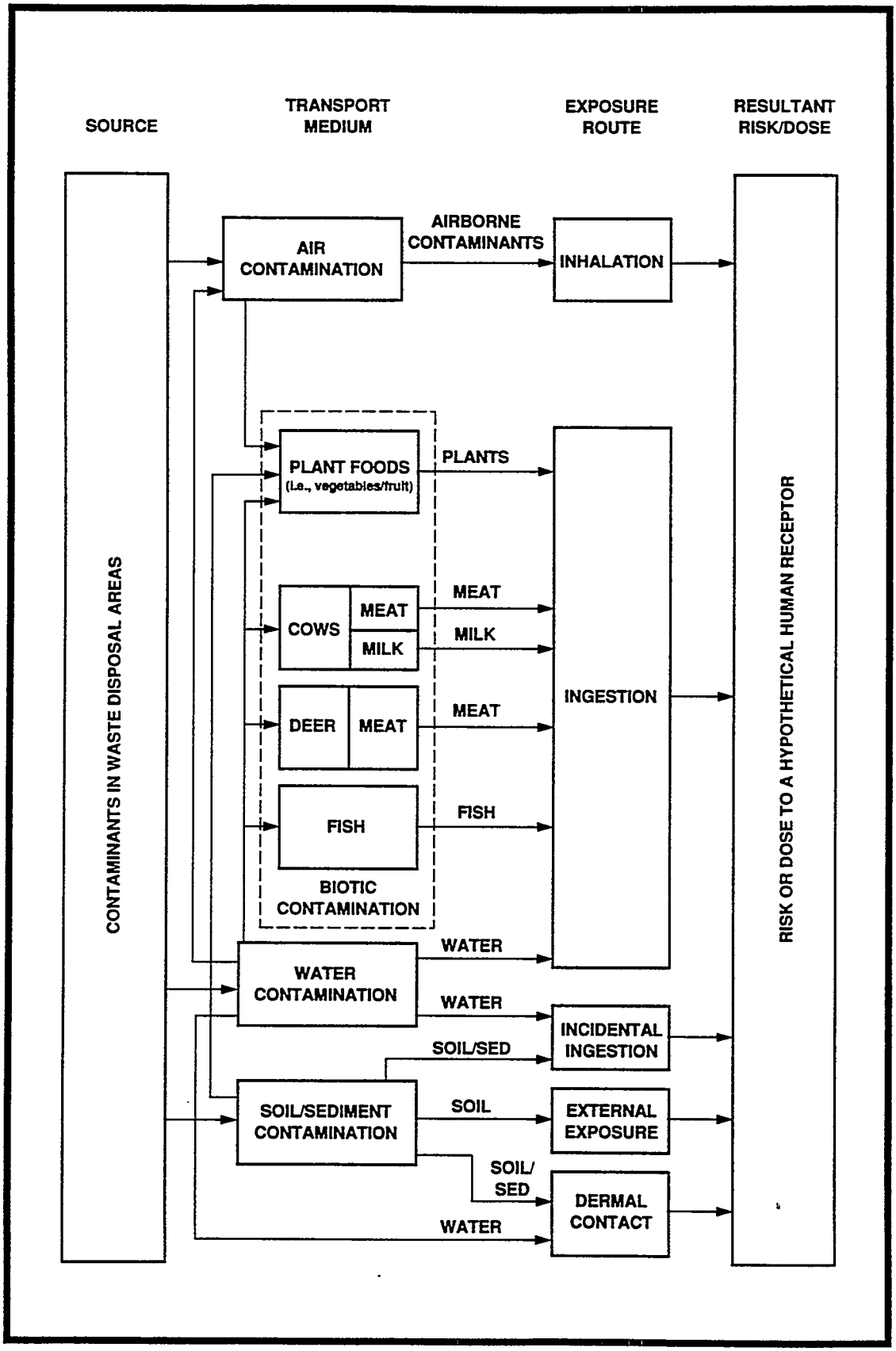



Fig. 6.2. Flow diagram of exposure pathways for WAG 6.

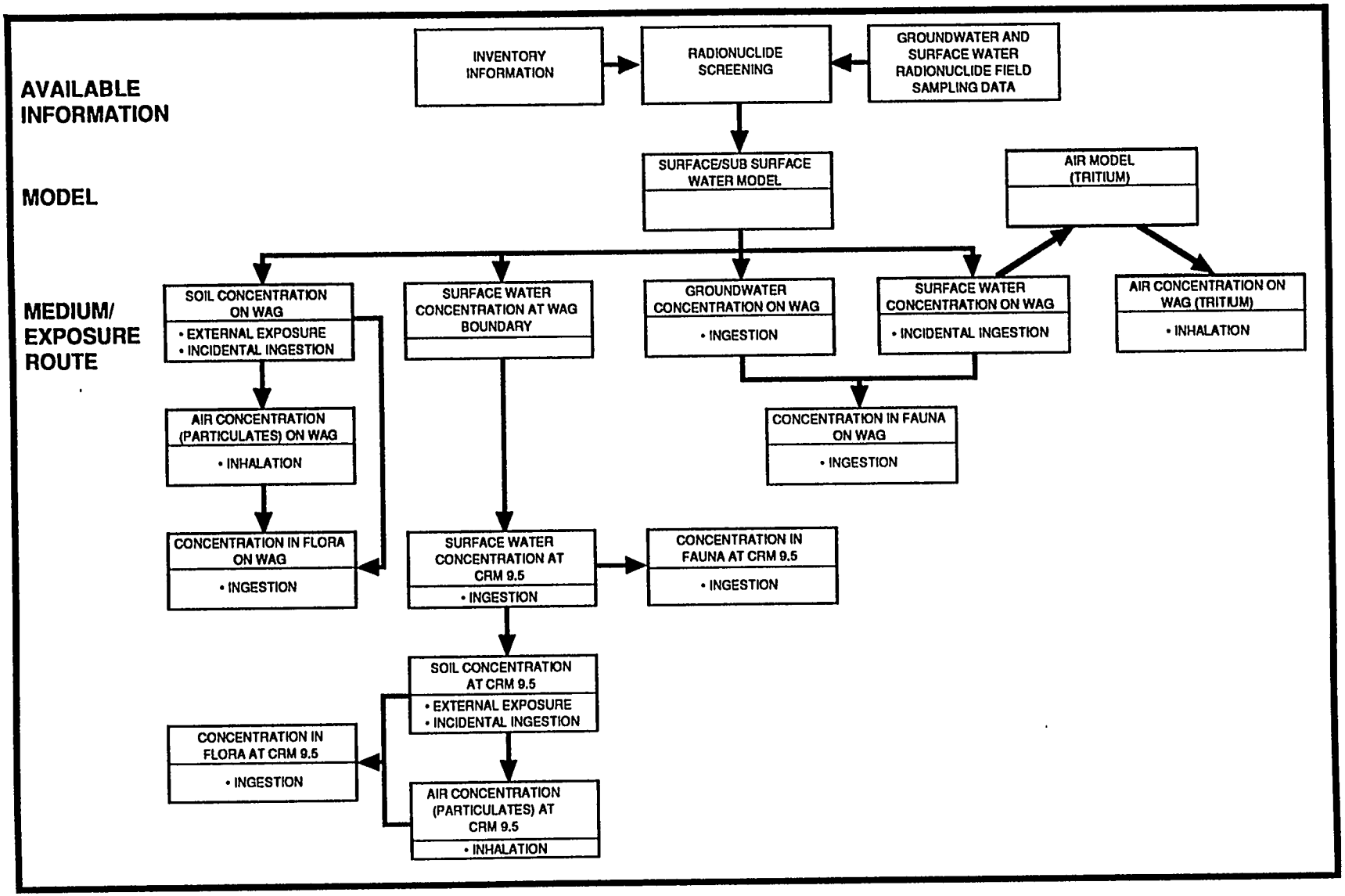



**Fig. 6.3. Process used to estimate media concentrations of radionuclides for various routes of exposure.**

5.18F 4104.170

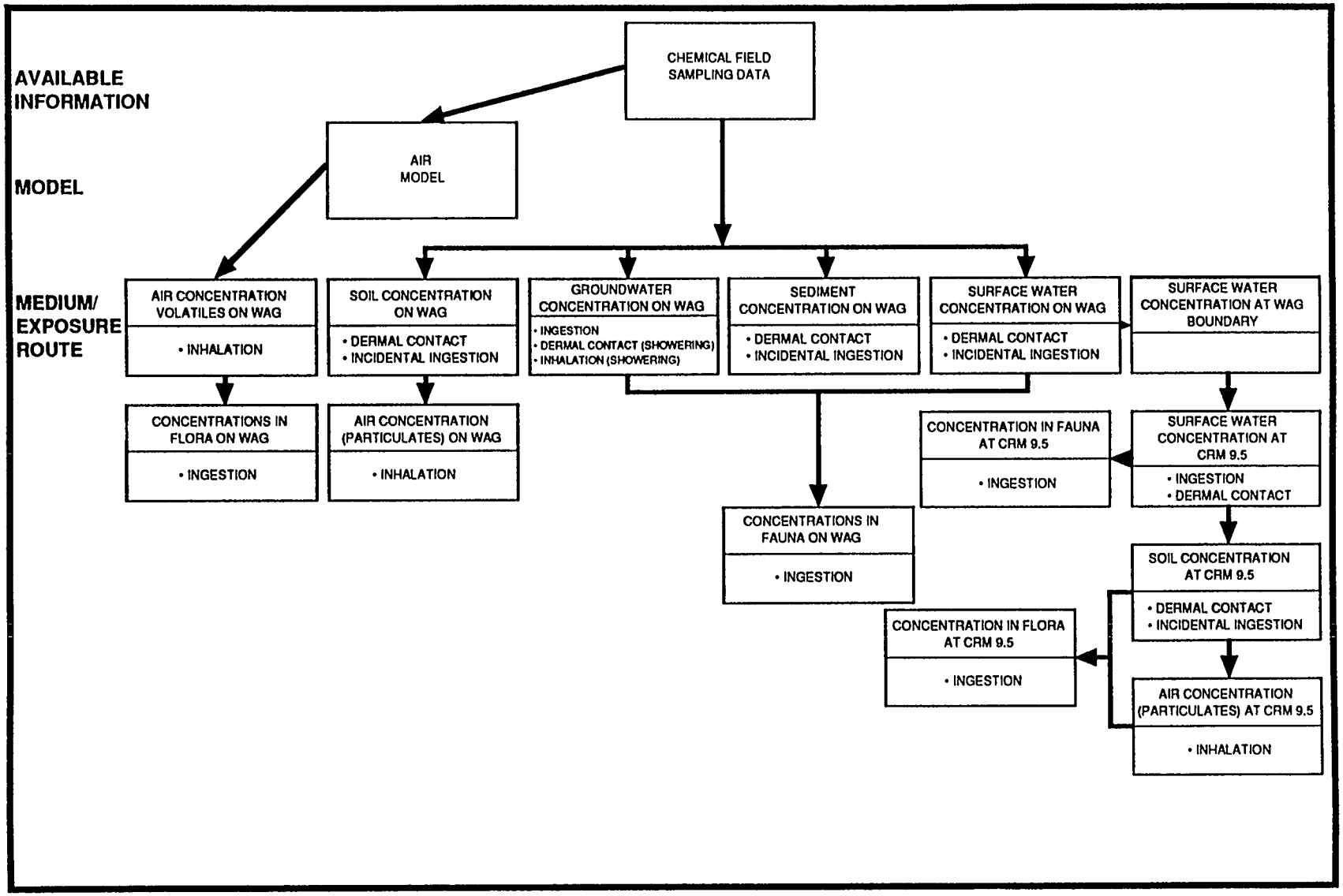



**Fig. 6.4. Process used to estimate media concentrations of chemicals for various routes of exposure.**

5.18F 4104.171

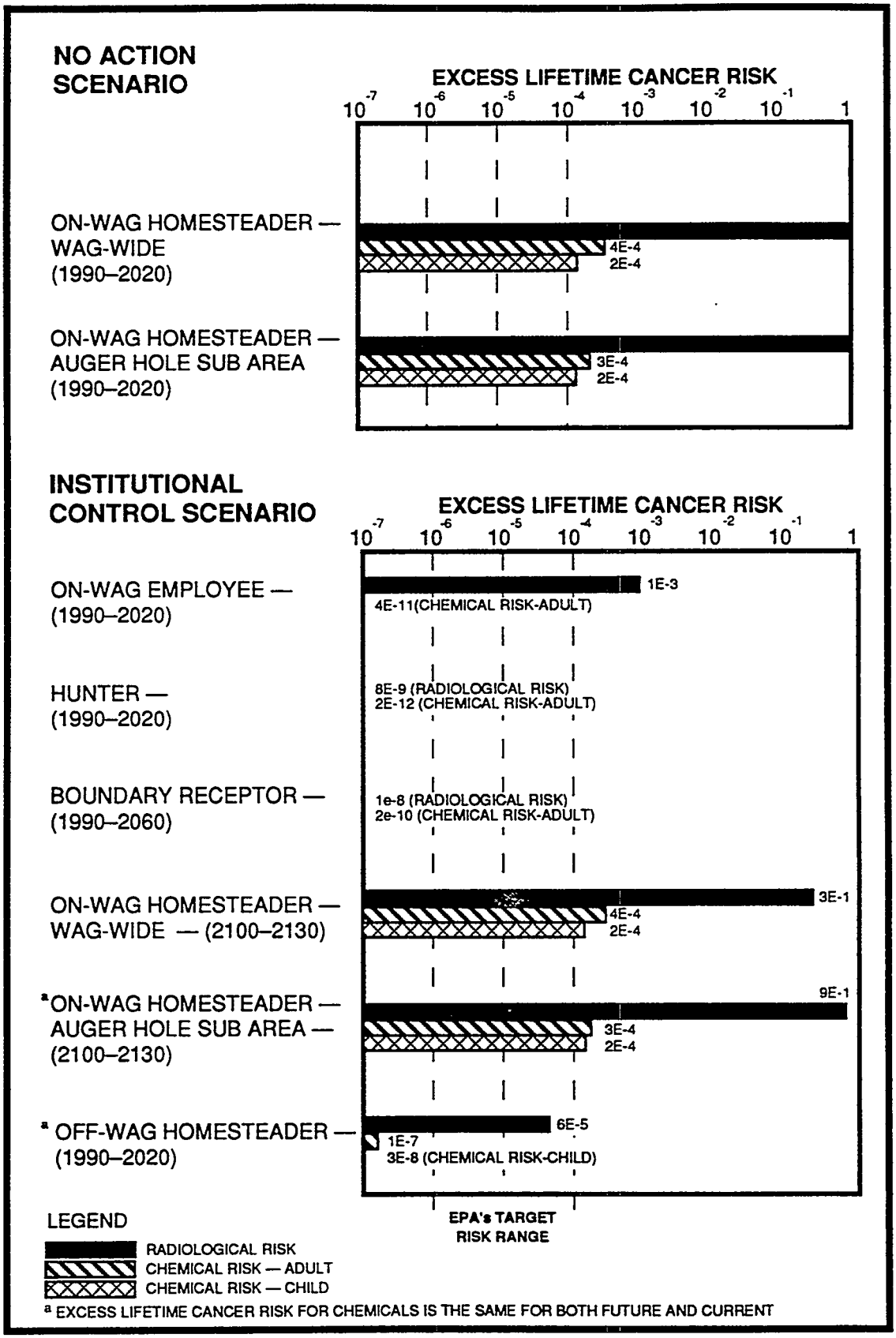



**Fig. 6.5. Summary of carcinogenic risk values.**

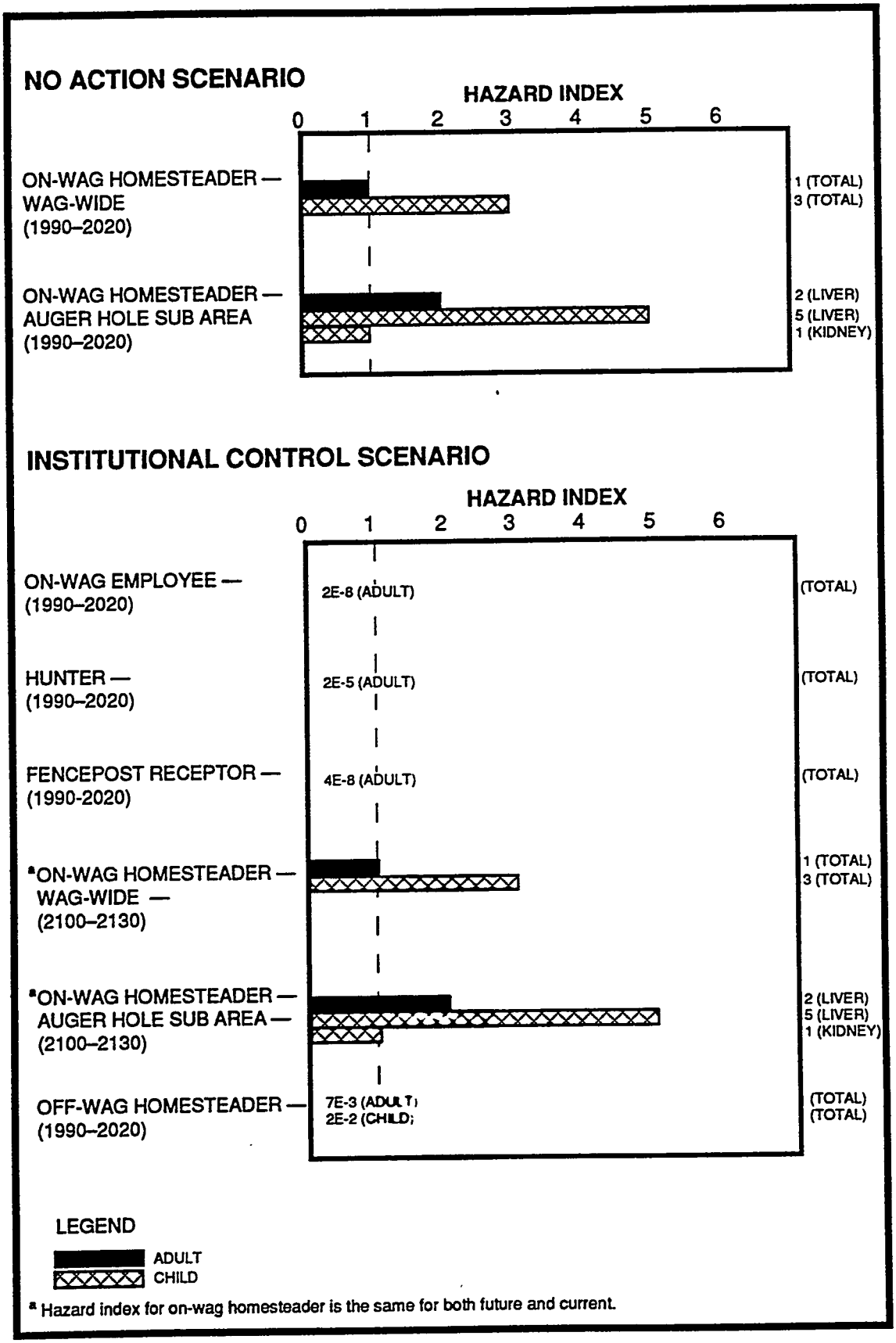



**Fig. 6.6. Summary of noncarcinogenic effects.**

5.18F 4104.168

# 7. BASELINE ENVIRONMENTAL EVALUATION

## 7.1 INTRODUCTION

A baseline environmental evaluation is generally intended to assess the type and magnitude of risk to ecological receptors associated with a given site, assuming no site remediation and assuming that site operations and access restrictions are discontinued. This hypothetical "no action" scenario corresponds to that considered in the human health evaluation in Sect. 6. Typically, an environmental evaluation first identifies general classes of receptors, based on site surveys, and then selects appropriate target species for further assessment. Next, the target species are sampled to determine contaminant uptakes and to observe contaminant effects. The evaluation then characterizes the probable risks to the target species.

Because large areas of WAG 6 have been cleared for waste disposal, very little natural wildlife habitat remains. Wildlife that might be expected to occupy cleared land has been discouraged from doing so by regular mowing and maintenance and by the frequent traffic associated with ongoing site operations. For these reasons, sampling of site biota is not feasible. Therefore, to assess potential environmental impacts to WAG 6 under a no action scenario, the general approach described in Sect. 7.3 was adopted.

The protection of wildlife, fisheries, threatened and endangered species, and important habitats is required by CERCLA as amended by SARA and other statutes. An environmental evaluation of hazardous waste sites is the avenue through which pertinent information is gathered, and it utilizes these data to evaluate potential impacts to environmental values and resources. Guidelines for conducting this environmental evaluation are provided by EPA in Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual (EPA 1989c).

The purpose of this evaluation is to determine whether there is a present or potential risk of detrimental effects to the environment from contaminants at WAG 6; it, and the human health evaluation presented in Sect. 6, together constitute the WAG 6 baseline risk assessment.

## 7.2 ORGANIZATION OF THE ENVIRONMENTAL BASELINE EVALUATION

Section 7.3 presents the methodology and approach used for this evaluation. Section 7.4 discusses potentially affected habitats and exposed populations in the environmental setting, and Sect. 7.5 summarizes the risk assessments for terrestrial flora and fauna and aquatic vertebrates and invertebrates. The results of the ORNL Environmental Sciences Division (ESD) survey of threatened and endangered species are contained in Appendix 7A. The detailed discussion of exposure scenarios for target species (including exposure assessments,

toxicity assessments, and risk characterizations) appears in Appendix 7B. The comprehensive literature review of toxic effects on terrestrial species and aquatic species is presented in Appendixes 7C and 7D, respectively.

## 7.3 METHODOLOGY AND APPROACH FOR WAG 6

Aquatic and terrestrial surveys were conducted for threatened and endangered species, and a wetlands survey was conducted. (No threatened and endangered species were identified and no wetland community development was found.) Based on knowledge of the environment surrounding WAG 6, hypothetical target species were selected to evaluate potential impacts under a no action scenario. For each of the hypothetical target species, exposure pathways were identified and contaminants of potential concern were selected. For each target species, impacts were estimated to the extent feasible given the available data. The evaluation estimated potential effects on the WAG 6 environment under hypothetical circumstances where fences were down and animals were free to move off and on site at will.

An environmental evaluation can be either a qualitative or quantitative appraisal of the actual or potential effects of a hazardous waste site on plants and animals other than humans and domesticated species. This environmental evaluation is primarily qualitative because of a lack of quantitative information. Therefore, it was necessary to make inferences and extrapolations from similar species and other locations with sufficient quantitative information. For example, results of a laboratory study using white rats might serve as the basis for assuming similar responses in wild rodents.

With more than 1500 vascular plants and 250 vertebrate animal species present on the ORR, it was impractical to consider all exposure pathways or potential receptors. Therefore, representative exposure pathways were selected that included different aquatic and terrestrial trophic levels that were composed of species likely to be found in the WAG 6 environment.

This evaluation encompassed a comprehensive review of available literature, which included examination of hundreds of bibliographic entries and the subsequent in-depth review of approximately 400 scientific reports of special relevance. This literature review encompassed several tiers: 1) information specific to WAG 6, 2) information from the ORR, 3) studies conducted at other DOE facilities, 4) studies from other contaminated sites, and 5) general scientific literature.

### 7.3.1 Hypothetical Target Species

Target species were selected for terrestrial flora and fauna and for aquatic vertebrates and invertebrates. The target species selected were the tu poplar, representing terrestrial flora; the white-tailed deer, red-tailed hawk, and raccoo representing terrestrial fauna; bluegill and fathead minnow, representing aquatic vertebrates; and benthic macroinvertebrates representing aquatic invertebrates.

### 7.3.2 Contaminants Considered in the Environmental Evaluation

Factors influencing the selection of contaminants were: (1) their potential to cause ecological effects, (2) their occurrence and potential levels based on site characterization data collected during the RFI and/or historical records about quantities disposed, (3) regulatory standards and guidelines, and (4) the availability of uptake and dose-response information in the literature for the target species or similar species.

Results from RFI sampling events provided recent information about the contaminants in the media and at the locations sampled. Because source areas are expected to release contaminants unpredictably at different times and in different areas of the site in the future, including contaminants not yet detected in environmental media, data presented in management records and earlier characterization studies were considered.

For terrestrial species, three radionuclides (strontium-90, cesium-137, and tritium), four VOCs (trichloroethene, tetrachloroethene, toluene, xylene), and two metals (cadmium and chromium) were selected. For aquatic species, a reduced number of contaminants was considered; two radionuclides (strontium-90 and cesium-137), two VOCs (toluene and xylene), and two metals (cadmium and copper). Concentrations of radionuclides considered in this evaluation included those detected during site sampling. As with the human health evaluation, the environmental evaluation assumed a steady-state condition for chemicals. The chemical concentrations in the environment were presumed constant over time so that risk from exposure to chemicals would not change.

### 7.3.3 Selection of Exposure Pathways

Exposure pathways incorporate the affected media, potential routes of exposure, and the ecological receptors.

Certain criteria were used in selecting exposure pathways for the environmental risk assessment. First, the target species selected represent different tropic levels and various exposure pathways. Second, it was essential that relevant information be available regarding effects of the selected contaminants of concern on the selected organisms.

The media affected by WAG 6 disposal units were determined to be groundwater, surface water, sediments, soil, and, to a much lesser extent, air. The evaluation assumed that the tulip poplar grew on WAG 6 and that the raccoon and deer had established home ranges on site. The evaluation also assumed that the hawk consumed prey on site and that the fathead minnow, bluegill, and benthic macroinvertebrates were found inhabiting WAG 6 tributaries or the EWB.

### 7.3.4 Risk Characterization

Where feasible, potential impacts to target species were characterized using contaminant uptake data and data on the probable effects of contaminants on target species. These data were largely derived from the literature search previously cited. In some cases, e.g., tulip poplar, it was not possible to predict the biological effects of contaminant uptake.

## 7.4 ENVIRONMENTAL SETTING

### 7.4.1 Potentially Affected Habitats

Several WAG 6 habitats have the potential to be affected by site contamination. WAG 6 consists primarily of fields planted in fescue and of young wooded areas growing along drainages. Both the fields and wooded areas are habitats subject to contamination by discharge of contaminated groundwater to surface water and by surface runoff. Another mode of transport that will affect open areas through soil displacement is animal burrowing. Arthur and Markham (1983) reported that during 1978 and 1979 small burrowing mammals displaced about 27 pounds of subterranean soil to the surface at an 89-acre solid radioactive waste disposal area. This mode of transport is of particular importance to WAG 6 because of the potential for shrews, voles, and groundhogs inhabiting the site.

The aquatic habitat at WAG 6 is limited to the EWB and two intermittent streams, Drainages DB and FA, draining the western and east-central portions of the area (see Sect. 3). These streams drain directly into WOL. Runoff is seasonal, with highest flows in the winter. Investigations at WAG 6 have determined that leaching of contaminants from disposal areas and subsequent surface or shallow subsurface flow represent the primary mode of contaminant transport to the WAG 6 streams.

Drainage DB lacks adequate habitat for fish (Ryon 1990); although Drainage FA contains pools, undercut banks, and pool-riffle sections suitable for minnows native to the area, no fish were found during an electroshocking survey (Ryon 1990). Both drainages support benthic macroinvertebrate communities, at least in sections containing water much of the year. The EWB has reportedly never been used to store wastes; thus, its muddy bottom should support macroinvertebrates. During an electroshocking survey of the EWB in September 1990, five bass were present (Ryon 1991).

### 7.4.2 Potentially Exposed Populations

Under a no action scenario, WAG 6 would provide habitats for a diversity of terrestrial and aquatic flora and fauna. Thirty-seven species of mammals, 151 species of birds, and 61 species of reptiles and amphibians have been observed on the ORR (Kitchings and Mann 1976; Boyle et al. 1982). It is assumed that most of these species could be present at some time on WAG 6, if only temporarily. The bird, mammal, reptile, and amphibian species found on the ORR are listed in Appendix 3E.

In the WAG 6 wooded areas, the floristic populations that may be exposed to contamination are the mixed mesophytic association of trees, including such predominant overstory species as oak (Quercus spp.), tulip poplar (Liriodendron tulipifera), beech (Fagus grandiflora), sugar maple (Acer saccharum), red maple (Acer rubrum), magnolia (Magnolia spp.), buckeye (Aesculus octandra), and basswood (Tilia americana). The understory species include dogwood (Cornus florida), red maple, black cherry (Prunus sylvatica), and sweet gum (Liquidamber styraciflua). Examples of herbaceous species growing in association with the upland hardwood forests found on WAG 6 are greenbriar (Smilax spp.), honeysuckle (Lonicera japonica), bracken fern (Pteridium aquilinum), and strawberry bush (Euonymus spp.). In the maintained areas, the predominant grass cover is fescue (Festuca elatior).

The populations of fauna that may inhabit the forested areas on WAG 6 include small mammals, such as the white-footed mouse (Peromyscus leucopus), chipmunk (Tamias striatus), golden mouse (Ochrotomys nuttalli), shorttail shrew (Blarina brevicauda), and house mouse (Mus musculus). They provide prey for predators such as red and grey foxes (Vulpes fulva and Urocyon cinereoargenteus, respectively), striped skunks (Mephitis mephitis), bobcats (Lynx rufus), and weasels (Mustela frenata). White-tailed deer (Odocoileus virginianus) also inhabit the forested areas and graze along the edges of fields where food is plentiful and tree cover is available.

Different bird species prefer different habitats, and the WAG 6 wooded areas and their edges provide many habitat types that can support the avian species presumed to be present. Examples of species of birds that prefer habitats in the wooded areas are yellow-shafted flickers (Colantes auratus), red-bellied woodpeckers (Centurus carolinus), hairy and downy woodpeckers (Dendrocopes villosus and D. pubescens, respectively), blue jays (Cyanocitta cristata), Kentucky warblers (Oporonis formosus), and ovenbirds (Seiurus aurocapillus). Species that prefer the shrubby forest edges are brown thrashers (Toxostoma rutum), rufous-sided towhees (Pipilo erythrophthalmus), and Carolina wrens (Thryothorus ludovicianus). Predatory birds that may utilize the woodlands for nesting and hunting are the red-tailed hawk (Buteo jamaicensis), broad-winged hawk (Buteo platypterus), great horned owl (Bubo virginianus), screech owl (Otus asio), and barred owl (Strix varia).

According to Kitchings and Mann (1976), there are several taxonomic groups of forest arthropods on the ORR that might be affected by WAG 6 site contamination: spiders (Aranoe), centipedes (Chilopoda), beetles (Coleoptera), millipedes (Diplopoda), flies and mosquitos (Diptera), bees and ants (Hymenoptera), butterflies (Lepidoptera), and grasshoppers (Orthoptera). According to Johnson (1964), anurans (frogs and toads) and most of the reptiles are found in old field areas on the ORR. Reptiles and amphibians that may inhabit WAG 6 forested areas include frogs (Bufo spp.), salamanders (Eurycea spp.), eastern box turtles (Terrapene carolina), northern copperheads (Agkistrodon contortix), timber rattlesnakes (Crotalus horridus), black rat snakes (Elaphe obsoleta), and fence lizards (Sceloporus undulatus).

In the grassy areas, the mammal species are similar to those inhabiting old field areas, whether the vegetative cover is tree seedlings and shrubs or fescue grass such as that covering portions of WAG 6. Small mammals on these grassy fields include cotton rats (Sigmodon hispidus), white-footed mice, shorttail shrews, and eastern harvest mice (Reithrodontomys humulis). Another larger mammal that may inhabit the expanse of WAG 6 fields is the groundhog (Marmota monax). White-tailed deer also graze the fields. Use of field areas by bird species is based on the presence of shrubs and low-growing herbaceous plants that thrive on the edges of fields and forests. These herbaceous species provide food and nesting areas for birds such as sparrows, towhees, blue grosbeaks (Guiraca caerulea), and brown thrashers. The maintained fields in WAG 6 may be used for courtship displays and breeding purposes by some birds such as quail (Colinus virginianus) or woodcocks (Philohela minor). Raptors may also hunt in those areas.

Fish common in the upper reaches of the WOC watershed, which may potentially exist at WAG 6, primarily include minnows (Cyprinidae) and sunfish (Centrarchidae). Creek chubs (Semotilus atromaculatus) and blacknose dace (Rhinichthys atratulus) are two common native minnows. Fathead minnows (Pimephales promelas), a widely introduced species, are also common in WOC. All three species inhabit small streams with pool-riffle areas and spawn during the summer. The fathead minnow is more tolerant of turbidity, high temperatures, and low dissolved oxygen than the chub or dace. Several species of sunfish inhabit the WOC watershed, including the redbreast sunfish (Lepomis auritus), largemouth bass (Micropterus salmoides), and bluegill sunfish (L. macrochirus). All three species mature in 2 to 3 years and spawn in nests during spring and summer. All are fairly hardy and are desirable sport fish.

The smaller headwater tributaries of the WOC watershed contain a wide variety of benthic macroinvertebrates, predominantly insect larvae, crustaceans, oligochaetes, and molluscs. During a May 1990 ESD survey of the DB and FA Drainages in WAG 6, nine orders of Insecta, four orders of Crustacea, molluscs, and aquatic worms (Oligochaeta) were collected. In Drainage DB, oligochaetes, the isopod Lirceus (Crustacea), and several dipteran groups accounted for most of the benthic organisms collected (Smith 1990). In Drainage FA, the isopod Lirceus accounted for 62 to 92% of the total population at the three stations sampled. The amphipod Crangonyx and stonefly Amphineura were abundant at one station.

In conjunction with the WAG 6 RFI environmental evaluation, ESD at ORNL conducted surveys for threatened and endangered species and sensitive environments in WAG 6. Results of these surveys are provided in Appendix 7A. The fish survey consisted of qualitative electrofishing sampling and assessing the presence of potential fish habitat. No fish were found in the tributaries within the SWSA 6 boundaries, possibly due to the intermittent nature of the streams and their isolation. Drainage DB did not contain sufficient quality habitat to maintain fish populations; however, the two branches of Drainage FA did contain suitable habitat for species such as creek chubs and black-nose dace. Electrofishing at the EWB, as cited earlier, produced five bass (Micropterus spp.).

Surveys of macroinvertebrates revealed no threatened or endangered species within WAG 6. The most notable difference between samples collected from streams within WAG 6 and those from reference areas was the low relative abundance or absence of Ephemeroptera, Plecoptera, and Tricoptera (EPT) from WAG 6 sites. Because most EPT taxa are very sensitive to adverse changes in water quality, this lack of abundance or absence is an indication that streams in WAG 6 are impacted. The most obvious cause of impact is from past physical disturbances (e.g., stream channel modification, vegetation removal/alteration, and siltation), although degraded water quality due to contaminants from waste disposal sites in WAG 6 cannot be excluded as a possible cause for the observed impacts (Smith 1991). Survey results and maps showing study sites and reference areas are presented in Appendix 7A.

A brief survey was conducted for threatened and endangered bird and mammal species at WAG 6, and none were found. Thirty-three bird and one mammal species were actually observed, although many other species probably occur. The site also appears to be relatively unimportant for species listed as threatened, endangered, or in need of management by the state of Tennessee (e.g., Cooper's hawk, sharp-shinned hawk, black vulture, and red-shouldered hawk). These species may occasionally hunt for prey at the site, but SWSA 6 does not appear to have suitable habitat for nesting (Kroodsma 1990).

A survey was conducted for rare plant species known to exist on the ORR as well as any unknown taxa, but no rare species were found (Cunningham 1990a). Similarly, a survey for wetland communities within the fenced area revealed a few wetland species (Scirpus and Carex) but essentially no wetland community development (Cunningham 1990b).

## 7.5 SUMMARY RISK ASSESSMENT

Because this environmental risk assessment was limited by a lack of site-specific quantifiable data and toxicological data, assumptions and extrapolations were made using data available in the literature. Generally, these data in the literature were derived using laboratory animals or agricultural crop species. Plants and animals in the natural environment tend to have longer exposures than those in the laboratory due to life span, multiple exposure pathways, and differences in metabolism. Therefore, a conservative approach was taken for this environmental evaluation.

Certain specific factors influenced this assessment - most importantly that WAG 6 is:

- A highly disturbed site with limited natural habitat
- An active waste disposal site
- An active center for environmental restoration research and development operations

Because of these factors, the collection of biota and the determination of contaminant levels were not warranted for WAG 6. Therefore, the general approach to this risk

assessment was to conduct a comprehensive review of pertinent literature, conduct aquatic and terrestrial field surveys for threatened and endangered species, determine representative exposure pathways for target species, select contaminants of concern, delineate expected responses based upon contaminant levels, and characterize the environmental risk. This risk analysis is ultimately an integrated evaluation of historical, chemical, analytical, environmental, and toxicological data that are as site-specific as possible. Each step in the risk analysis is biased toward conservative estimations using maximum concentrations.

### 7.5.1 Potential Contaminants of Concern

Approximately 65 contaminants of concern were identified for WAG 6. A reduced number (three radionuclides, four volatile organic compounds, and three metals), were selected for this environmental risk assessment. Each contaminant was analyzed within the context of each exposure pathway according to its known or suspected potential to cause ecological harm, its known or suspected level (based on results of field sampling during the RFI or historical records about quantities disposed there), and the availability of dose response information in the literature for target or similar species.

### 7.5.2 Terrestrial Flora

The tulip poplar was selected as the target species in the exposure scenario of terrestrial flora because it is a tree that is ubiquitous on the ORR, it is commonly found in disturbed areas such as WAG 6, and it has been used in studies of radioisotope uptake, accumulation, and recycling. A tulip poplar (like all vegetation growing on WAG 6) can be contaminated by assimilation from the soil, gas exchange with the atmosphere, bioaccumulation from surface water, and surface deposition (see Fig. 7.1).

The important pathways through a tulip poplar tree to the forest floor are rain leaching and especially passage through the root system. Transfers of the tagged radionuclide cesium-137 occurred rapidly throughout the tree.

The data in the literature concerning selected WAG 6 contaminants do not include effects on or concentration levels in vegetation. The data are derived from research on accumulation, recycling, and distribution of contaminants throughout a floristic organism. Thus, no risk characterization was possible on tulip poplar trees because of the lack of information describing the effects of known concentrations of contaminants on the terrestrial flora exposure scenario.

### 7.5.3 Terrestrial Fauna

Three target species were selected to describe the risk to the terrestrial fauna exposure scenarios of WAG 6: white-tailed deer, red-tailed hawk, and raccoon. There are three routes of exposure for each species, only one of which, ingestion, can be addressed because

no available data exist for the routes of inhalation and direct contact (see Figs. 7.2 through 7.4).

These target species were chosen to represent different trophic levels and various exposure pathways. The white-tailed deer is a large herbivorous mammal, while the red-tailed hawk is a carnivorous raptor. The raccoon is omnivorous, consuming vegetation and both aquatic and terrestrial prey. Another important factor in selecting these as target species in a pathways analysis was the availability of relevant information regarding effects of the selected contaminants on the organisms.

Of the three radionuclides selected for this environmental evaluation, strontium-90 likely poses the greatest threat to wildlife at WAG 6. As an analog of calcium, it is readily absorbed and deposited in bone tissue, where it can result in bone tumors and leukemia. Because of the large inventory of strontium-90 at WAG 6, species from the lower trophic levels such as rabbits and shrews are likely to suffer adverse effects, to bioconcentrate strontium-90 in their bone tissue, and subsequently to result in contamination of red-tailed hawks and raccoons that prey upon them. There are no data about vegetation concentrations of strontium-90 for WAG 6; however, data from SWSA 5 indicate that concentrations of strontium-90 in honeysuckle and blackberry are at significant levels so that the strontium-90 level in the bone of a 45-kg deer that regularly browses these plants over a period of 1 week to 1 year could easily exceed the confiscation limit of 30 pCi/g.

The most probable avenue through which cesium-137 may enter the food chain is from earthworms ingesting contaminated soil. They can be eaten by shrews, which are then consumed by red-tailed hawks. Concentrations of cesium-137 are relatively low when compared to those of strontium-90. However, there are no regulatory standards for cesium-137, and no information could be found in the literature to indicate the likely effects of the concentrations detected in WAG 6 on soft tissue (where it accumulates) of the target species, which precluded an assessment of the environmental risks for this radionuclide. Levels of tritium far exceeded the SDWA MCL, but the primary adverse effects are expected to result from ionizing radiation and not from bioaccumulation.

Of the metal contaminants selected for the terrestrial environmental evaluation, cadmium is likely to pose a greater threat than chromium. Cadmium levels were higher, exceeding the SDWA MCL and suggested standards from the U.S. Fish and Wildlife Service. This metal is also known to bioconcentrate in liver and kidney tissue of shrews by factors ranging from 15 to 33 times the levels found in the soil. Not only can cadmium adversely affect the soft tissues of shrews but also those of red-tailed hawks that feed upon them. The greatest potential for adverse effects to raccoons is through ingestion of contaminated surface water by raccoons themselves and by voles upon which they prey and from ingestion of contaminated aquatic organisms such as crayfish and fish. Cadmium is closely associated with soil and is not known to bioaccumulate in plants; therefore, it is not expected to have adverse effects on the herbivorous white-tailed deer.

While results from studies on humans and laboratory animals indicate that volatile organic compounds could pose a potential risk to wildlife at WAG 6 if there were extensive or persistent releases, they should volatilize fairly rapidly from surface water or soils and should not present a major risk. However, toxicological data about effects of these contaminants on terrestrial wildlife are not available, which precludes an assessment of their true environmental risk.

### 7.5.4 Aquatic Environment—Fish

Of the six contaminants addressed in this assessment, cadmium, copper, and strontium-90 would be the most likely to affect fish populations because of prevailing concentrations reported in the WAG 6 tributaries and indications found in scientific literature that these contaminants can cause chronic effects at relatively low ppb concentrations. Cadmium and copper exceed the ambient water quality criteria for these two metals for protection of aquatic organisms and could adversely affect fish within WAG 6. Strontium-90 is a concern because surface water has been reported to contain strontium-90, concentrations of strontium-90 in WOL fish are elevated, and strontium-90 tends to concentrate in bone tissues where the biological half-life may be long. The uptake of strontium-90 in fish has been known to cause morphological abnormalities (Appendix 7B). Cesium-137 would be potentially hazardous, but no significant levels of cesium-137 have been reported for WAG 6 surface waters. Toluene and xylene do not pose as great a potential hazard because concentrations causing chronic effects in fish are in the ppm rather than ppb range, and these organics will quickly volatilize from the shallow surface waters at WAG 6.

### 7.5.5 Aquatic Environment—Benthic Macroinvertebrates

Of the six selected contaminants in this assessment, cadmium and copper are most likely to impact the macroinvertebrate communities. These two metals produce chronic effects at concentrations ranging from 0.01 mg/L up to 30-32 mg/L and higher. Stoneflies and caddisflies are relatively resistant to cadmium and copper in comparison to other macroinvertebrate groups, but chronic toxicity occurs in the 1 to 100 mg/L range for many species.

Toluene and xylene will volatilize relatively rapidly from the shallow surface waters at WAG 6 and they are also less toxic than cadmium and copper.

Strontium-90 has been reported in two or more seeps at WAG 6, but the bioconcentration of this radionuclide by macroinvertebrates is expected to be low because of their short life cycle and frequent molting. Bioconcentration of cesium-137, if it occurs in significant concentrations, may also be offset by losses due to molting and elimination. Polikarpov (1966) indicated that cesium-137 was eliminated fairly rapidly by freshwater invertebrates.

# Section 7 Figures

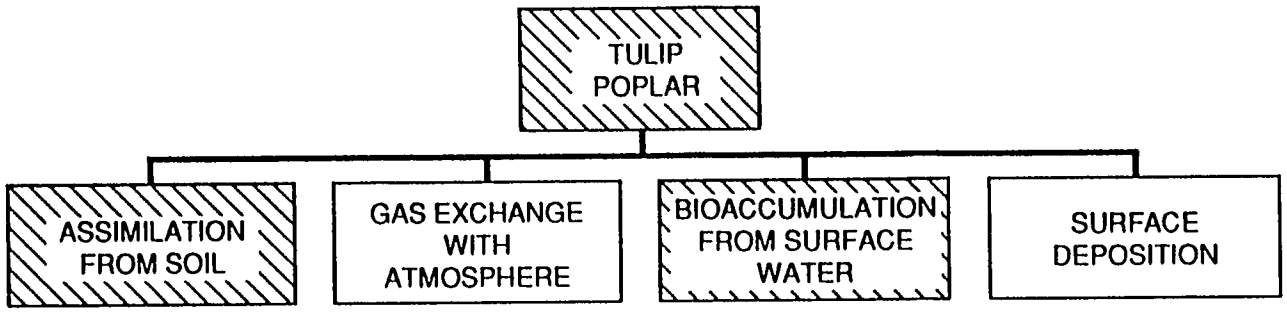



Fig. 7.1. Exposure scenario with the tulip poplar as the target species. (Highlighted boxes indicate primary exposure routes.)

5 18B 4104 78

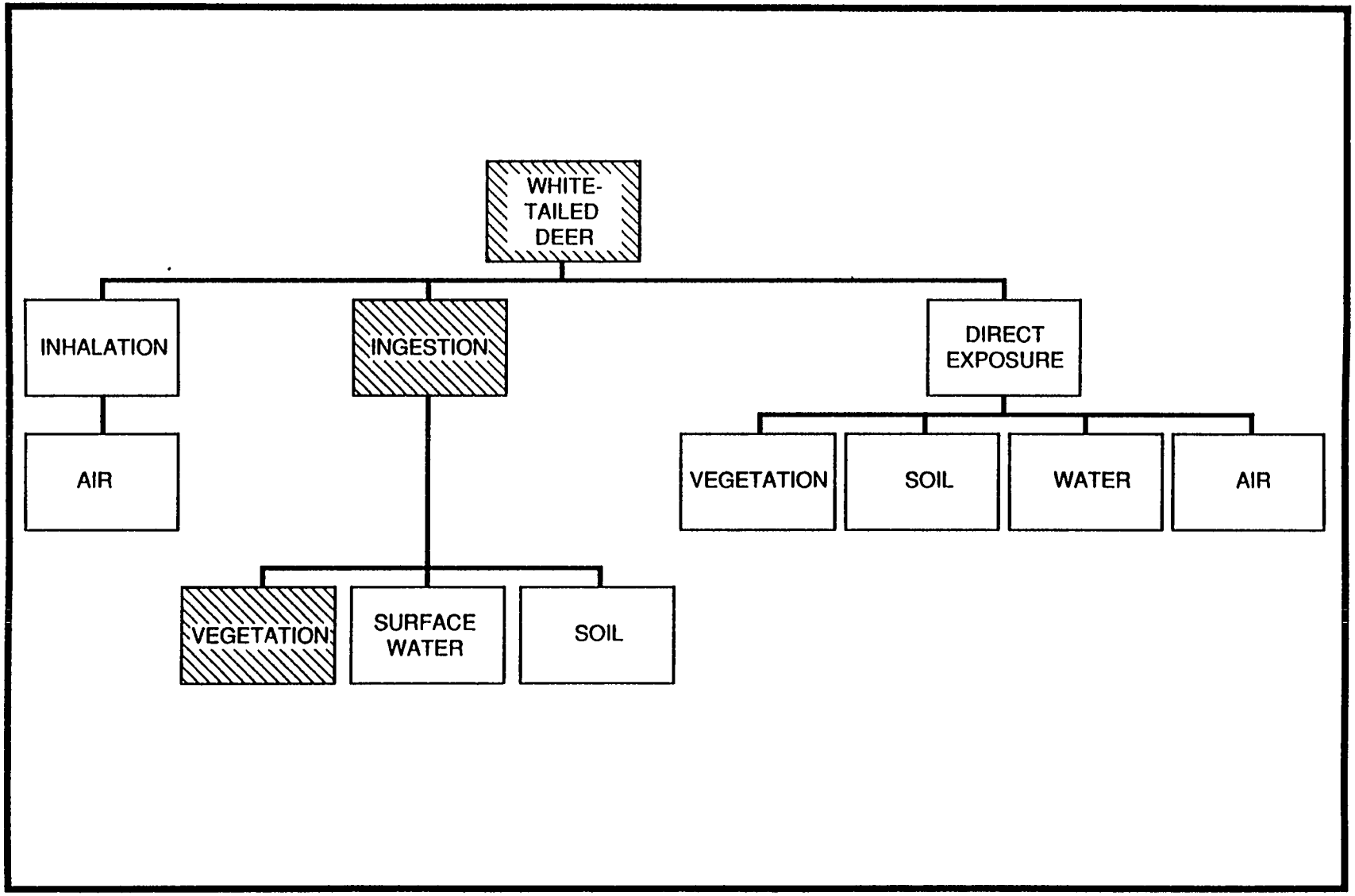



**Fig. 7.2. Exposure scenario with the white-tailed deer as the target species. (Highlighted boxes indicate primary exposure routes.)**

5.18B 4104 76

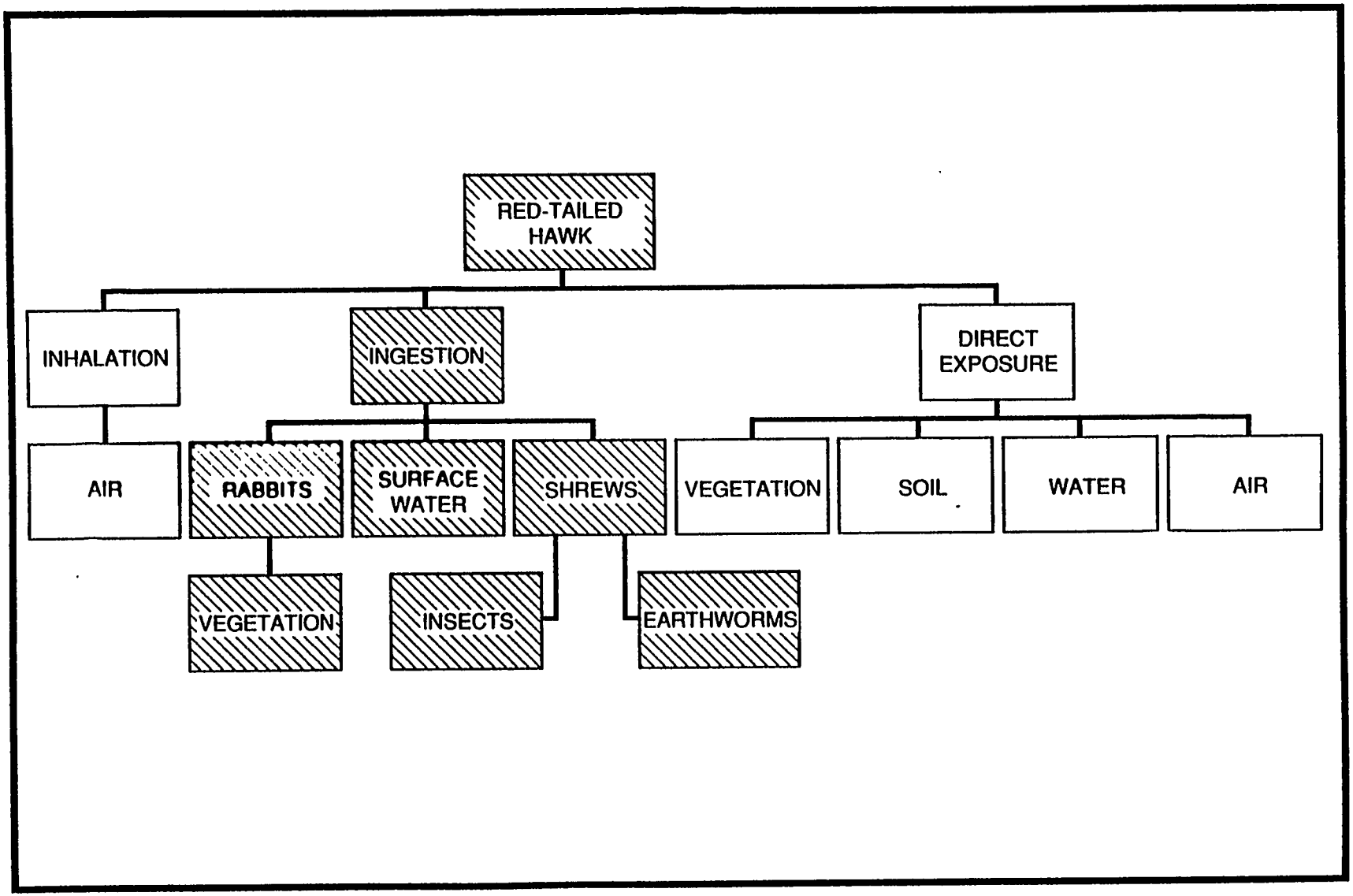



Fig. 7.3. Exposure scenario with the red-tailed hawk as the target species. (Highlighted boxes indicate primary exposure routes.)

5.18B 4104.77

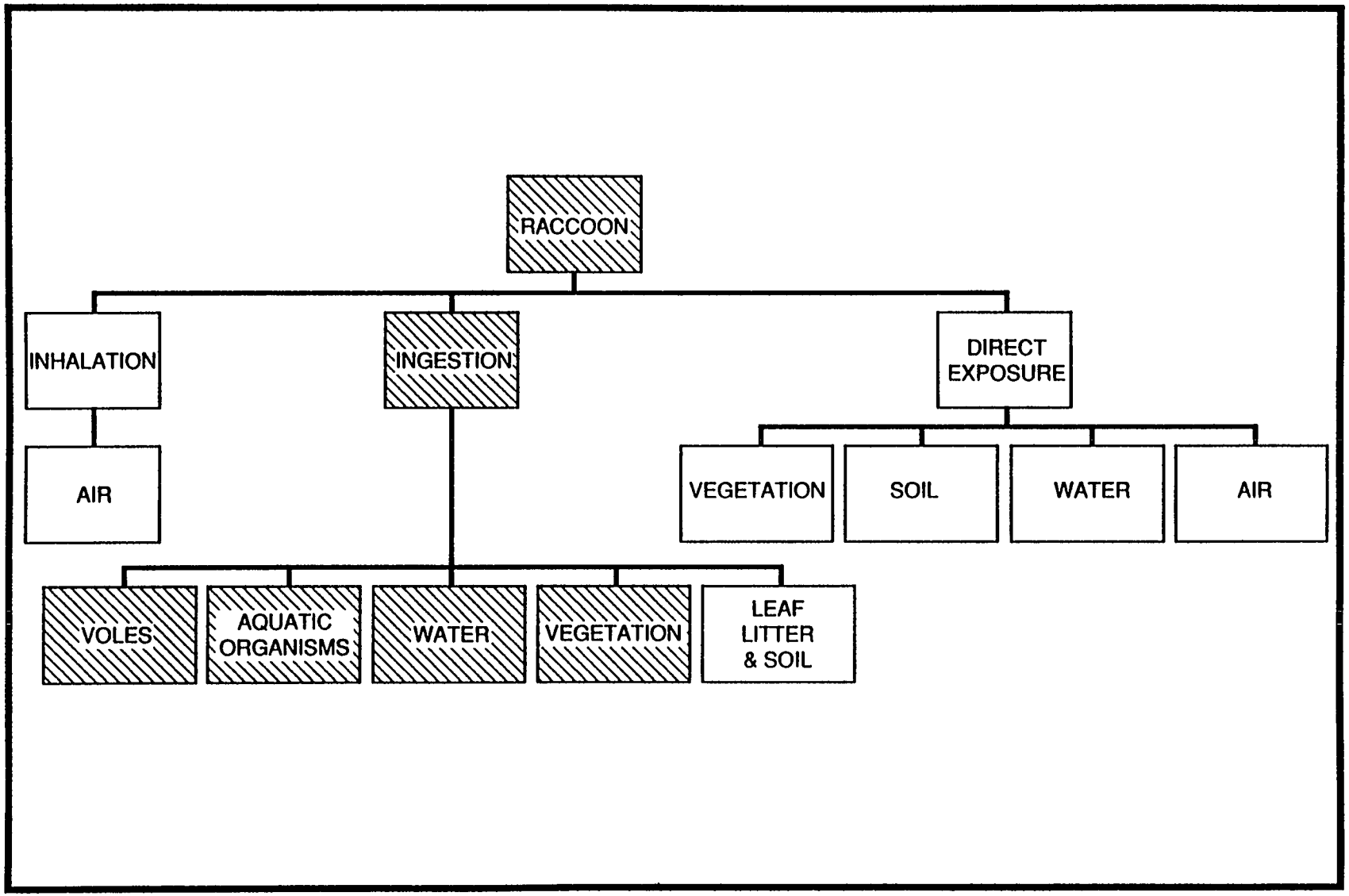



**Fig. 7.4. Exposure scenario with the raccoon as the target species. (Highlighted boxes indicate primary exposure routes.)**

# 8. PRELIMINARY DEVELOPMENT AND SCREENING OF ALTERNATIVES

## 8.1 INTRODUCTION

The purpose of this section is to develop alternatives that will meet the remedial action objectives for WAG 6. While this section concludes with a preliminary list of site-wide alternatives, the work begun here will continue. Each alternative will be defined and evaluated in detail in the FS/CMS/EA (anticipated to be submitted to EPA in February 1992). The EPA Superfund process was employed to develop the alternatives for RCRA closure and corrective action for WAG 6. The process is described in detail in the "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA 1988a). The guidance is substantially the same as the guidance for RCRA corrective actions as described in "RCRA Corrective Action Plan" (EPA 1988f). The process of developing alternatives is consistent with NEPA requirements.

### 8.1.1 Alternative Assessment Process

The following is a generalized discussion of the steps followed in performing the alternative development and assessment process for WAG 6, which is begun in this section and will be finalized in the FS/CMS/EA. The process is illustrated in Fig. 8.1.

Based on the information gathered during the RFI, objectives for the remediation of the site have been formulated. The goal of this section of the report is to develop a range of alternatives that can meet those objectives so that a cost-effective remedy can be identified. To accomplish this, many remediation technologies and process options have been identified and evaluated for technical feasibility. They were then screened to eliminate those obviously not suited to WAG 6 conditions or contaminants (see Sect. 8.3 and Appendix 8B). The retained technology process options were then combined into alternatives for waste sources and groundwater. These alternatives were evaluated for implementability, effectiveness, and cost to reduce the number of alternatives (Sect. 8.4) and yet retain a range of reasonable alternatives. The last phase of the alternative assessment presented in this report is the assembly of waste source and groundwater alternatives into site-wide alternatives.

This alternative assessment for WAG 6 recognizes that changes or differences may occur in anticipated site conditions or in the expected performance of an alternative so that modifications or adjustments to the alternative are required. These changes may be the result of different interpretations or changing site conditions. Because there are numerous potential interpretations concerning existing and future site conditions and a variety of alternative responses for each, it is not feasible to specifically address all potential interpretations. The most credible interpretation and major variations on this interpretation have been considered while developing the alternatives. Monitoring of site conditions to identify changes or variations in site conditions will be part of every developed alternative.

### 8.1.2 Scope of Alternative Assessment

Based on the description of site contamination presented in Sect. 4 and the results of the baseline risk assessment (Sects. 6 and 7), the alternative assessment has focused on the following.

- **Sources.** WAG 6 has both aboveground disposal units (Tumulus) and shallow land burial (SLB) units, including high-activity trenches, low-activity trenches, biological trenches, asbestos trenches, silos, auger holes, and test areas. These buried sources and the Tumulus will be considered separately. Although many different types of waste are buried in a variety of containers, it is felt that technologies considered will be similar because the sources are all buried. To simplify the alternatives assessment, all buried wastes and corresponding soil and leachate will be considered together, although they may not all be remediated by the same technology. The IWMF is not included under the scope of this RFI.

- **Groundwater.** Site characterization data presented in Sect. 4.1 show that the groundwater contains volatiles (notably vinyl chloride, 1,1-dichloroethene, 1,2-dichloroethene, and trichloroethene) at levels exceeding MCLs and health-based levels. Metals, especially barium, beryllium, and cadmium, were also detected above MCLs and site reference levels. Also detected were radionuclides, with tritium, strontium-90, and cobalt-60 being most frequently detected above levels of concern. Remedial actions for groundwater will not focus on off-WAG remediation since that is part of the cleanup of other WAGs (WAGs 2 and 7).

## 8.2 REMEDIAL ACTION OBJECTIVES

The general goal of WAG 6 closure and remedial action is to protect human health and the environment by providing a long-term closure of the disposal units to segregate the waste from the environment for as long as the waste remains a threat to human health and the environment and by remediating unacceptable levels of environmental contamination. This is consistent with the RCRA requirements [40 CFR 265 Subpart G (265.111)] presented in the RCRA Closure Plan that a facility be closed in a manner that controls, minimizes, or eliminates, to the extent required to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous waste decomposition products into the environment. Alternatives are to be developed for the Tumulus, the SLB wastes, and groundwater.

Objectives for waste sources and groundwater are as follows.

- Tumulus and SLB wastes: to provide protection of public health and the environment by limiting direct contact/emissions, surface runoff, and leachate generation from on-site sources and associated contaminated leachate and soil.

- Groundwater: to provide protection of public health and the environment by mitigating the effects of the migration of contaminants off-site and prevent future use of on-site contaminated groundwater.

During the development of alternatives for site closure and remediation (including the definition of action levels and treatment options), a variety of regulations and standards must be considered. This requirement to consider all applicable or relevant and appropriate requirements (ARARs) is driven by §121 of CERCLA. The potential ARARs for WAG 6 are presented in Appendix 8A.

## 8.3 SCREENING OF RESPONSE ACTIONS, TECHNOLOGIES, AND PROCESS OPTIONS

Response actions and associated technologies that might be applied to the waste sources and groundwater at WAG 6 are described in Appendix 8B, which also explains the process used to screen these technologies and associated process options. The response actions and associated technologies that pass the screening process form the basic components of the remedial alternatives that are described and evaluated in greater detail in Sect. 8.4.

The technology and process option screening process produced the process options and technologies listed in Table 8.1. Secondary technologies are those that are needed to support a technology that addresses the objectives. These include pre- and post-treatment, dust control, etc. These secondary technologies and process options have not been included in the table and will not be discussed again until final alternatives are developed.

## 8.4 PRELIMINARY DEVELOPMENT OF ALTERNATIVES

Specific remedial alternatives for waste sources and groundwater on the WAG 6 site are described and screened in this section. The alternatives represent a range of treatment and containment combinations specifically applicable to SLB disposal units and groundwater. The alternatives vary from the No Action alternative, in which no remedial efforts would be undertaken, to more aggressive and permanent alternatives.

The objective of the preliminary alternatives screening is to identify the alternatives that best meet the tests for effectiveness, implementability, and cost. The alternatives carried forward for incorporation into site-wide alternatives will provide a range of possible actions with respect to cost and degree of active remediation.

Effectiveness is primarily defined in terms of an alternative's ability to protect potential human and environmental receptors during and after remedial activities and in terms of its long-range reliability.

In assessing implementability, each alternative is evaluated in terms of both technical and administrative feasibility during construction, operation, and maintenance. Technical feasibility refers to the ability to construct, reliably operate, and meet technology-specific regulations for

the remedial technology options. Administrative feasibility considers the procedure required to obtain approval or cooperation from federal, state, and/or local government agencies.

Relative costs, as used in this evaluation process, are for comparative purposes only and reflect judgment based on experience with the technologies in other situations. Cost of a remedial alternative is estimated as low, moderate, or high relative to other alternatives for each media. Those identified as being more costly without providing significant additional benefits may not be carried forward.

### 8.4.1 Development and Evaluation of Media-Specific Remedial Alternatives

This section begins with a brief description of the waste sources or groundwater at WAG 6. It also briefly examines the technology options retained from the technology screening and describes the rationale used to develop alternatives. Also in this section, waste source and media-specific alternatives developed from these technologies are presented and evaluated with respect to their effectiveness, implementability, and comparative cost. This results in a range of viable alternatives that can be combined into site-wide alternatives.

Only two alternatives are being considered for the Tumulus: no action and capping. Because there is no known technology for destroying radionuclides, only containment and disposal at a different location were considered. Because of the issues surrounding off-site disposal and because the Tumulus is the state-of-the-art in LLW disposal, only no-action and on-site containment in the Tumulus are viable. These will be described in later sections of the alternative assessment as components of site-wide alternatives. In the subsections that follow, alternatives for SLB wastes and groundwater are developed and evaluated.

#### 8.4.1.1 Shallow land burial waste alternatives

Source control alternatives are methods for protecting public health and the environment by limiting direct contact/emissions, surface runoff, and leachate generation from on-site sources and associated contaminated leachate and soil. For SLB wastes, the general response actions and process options carried forward to this phase include:

- No Action
- Institutional Controls
  - Deed Restrictions
  - Fences
- Containment
  - Multilayered Cap
  - Surface Controls
  - Dynamic Compaction
  - In Situ Grouting
- Removal
  - Solids Excavation
  - Liquid Collection (leachate)
- Treatment

- In Situ Vitrification
- Incineration

- Disposal
  - On-Site
  - Existing ORNL Liquid Waste Treatment System (leachate)

For the SLB wastes, alternatives have been developed to represent a range including no action, Institutional Controls, containment, and treatment. Not all possible combinations of technologies have been developed into alternatives, because many combinations essentially accomplish the same objective with virtually no difference in effectiveness, implementability, or cost. Also, alternatives that are not technically feasible have not been developed.

Not considered, for instance, is complete excavation of the sources. Much of the waste previously disposed of at WAG 6 is mixed waste. Currently, ORNL stores mixed waste as it is produced, awaiting the development of a mixed waste disposal facility. There is no existing DOE or commercial facility where the mixed waste at WAG 6 could be disposed of.

The other reason for not considering complete excavation is the potential for unacceptable worker exposure to radiation that could result while excavating many of the disposal units. Calculations (Appendix 8C) indicate that unacceptable radiation exposure to workers would be associated with excavation of many of the sources, even with 40-mm shielding (over the limit of reasonable shielding possible for heavy equipment). The calculated exposure levels exceed DOE orders for worker exposure and are counter to DOE orders requiring ALARA whenever possible. The use of remotely operated equipment is technically feasible but adds enormous costs to a site the size of WAG 6.

Also, specific containment or treatment technologies identified in each alternative will not necessarily be applied to all sources on the site. Instead, as part of defining the alternative, some sources will be assigned different technologies based on technical considerations. Thus, both dynamic compaction and in situ grouting are considered as waste structural stabilization technologies. Considering the wide variety of waste types and disposal methods at WAG 6, detailed alternatives would likely need to use more than one waste stabilization technology to address source characteristic differences. If an alternative containing stabilization is carried forward to the detailed evaluation, specific process options will be defined for the specific sources at that point.

Except for No Action or Institutional Controls, all developed alternatives have an element that removes the southern trenches that are hydraulically connected to WOL. This is accomplished either by consolidation or excavation and incineration. Negative aspects of evaluation to be addressed in the FS/CMS/EA are the odor impacts on the community and the potential exposure of workers. All alternatives also include consolidation of the Hill Cut Test Facility and the ETF.

The following alternatives have been developed and are evaluated in this section.

1. No Action
2. Institutional Controls
3. Surface Controls, Capping, Consolidation
4. Surface Controls, Cap, Consolidation, Structural Stabilization
5. Surface Controls, Cap, Consolidation, Structural Stabilization, In Situ Vitrification
6. Surface Controls, Cap, Consolidation, Incineration, Structural Stabilization

These are briefly described below and then evaluated and compared with respect to their effectiveness, implementability, and comparative cost. Except for No Action, all alternatives include performance monitoring to assess their effectiveness during and after implementation. Performance monitoring will also be included in each of the detailed alternatives, as an integral part of the total approach to remediation. Each detailed alternative also will define the appropriate monitoring and the appropriate contingent action to allow systematic, logical progress of remedial action.

**SLB Alternative 1: No Action.** In accordance with EPA guidance, No Action is evaluated under the assumption that WAG 6 has been abandoned, that there would be no Institutional Controls, and that the fence would no longer be effective in limiting access to the sources. This alternative provides no protection against existing and future hazardous material releases. As determined in the Baseline Risk Assessment, risk to human health (see Sect. 6) and the environment (see Sect. 7) would occur through leachate production and subsequent release to the groundwater or to the surface. Future risk would also occur if the existing soil cover were eroded.

The No Action alternative is the least expensive, as no costs would be incurred. The alternative will be carried forward for consideration to meet regulatory requirements of CERCLA, SARA, and NEPA to provide a baseline comparison for other retained alternatives.

**SLB Alternative 2: Institutional Controls.** Two variations of Institutional Controls are considered. The first provides continued use of existing Institutional Controls through a 10-year operational period and a 100-year post-operational period. During the combined periods, the existing covers would be maintained, minimizing erosion. After 110 years, the Institutional Controls would be lifted and the facility abandoned. However, the Baseline Risk Assessment (Sect. 6) indicates that after 110 years, without active remediation the site would still pose a risk to human health. Therefore, such Institutional Controls alone will no longer be considered because they would not be effective in protecting public health.

The second variation of Institutional Controls requires controls for as long as the sources present a threat to public health (more than 110 years into the future). During the site's operational and post-operational periods, existing Institutional Controls (access controls) would be maintained. After the post-operational period, the access controls would be continued, with deed restrictions banning disturbance of the site and requiring continued maintenance of the existing covers. Although effectively implemented Institutional Controls would protect against exposure to humans, they would not protect the environment from future contaminant releases

associated with leachate production. Also, they are also not as reliable as more active measures.

Institutional Controls would be fairly easy to implement at WAG 6, because most already exist. Also, Institutional Controls may have relatively low capital costs. However, the operational and maintenance costs may be comparable to those for a more active alternative. The existing covers need to be maintained during waste subsidence. In addition, the fences need to be maintained and patrolled.

Because of the high operation and maintenance costs and the possibility of failure of the controls before the risk from the site ends, and because they would not protect the environment from future contaminant releases, Institutional Controls will not be carried forward as an individual alternative. Instead, Institutional Controls will be considered as a part of the more active source control alternatives.

**SLB Alternative 3: Surface Controls with Capping and Consolidation.** Alternative 3 contains small caps with associated surface controls and consolidation of the southern biological trenches. The caps included in Alternative 3 are small, waste area-specific caps. Fig. 8.2 shows their approximate locations. The purpose of these caps would be to limit infiltration through the waste, limit contaminant movement through surface runoff, and protect against direct exposure to the waste. In a detailed alternative, shallow drains may be combined with the caps to collect stormflow before it interacts with the wastes. However, no attempt is made to use the caps to lower the groundwater table below the bottom of the SLB waste units. As opposed to using any of the structural stabilization methods retained from the technology screening phase, this alternative would include a cap design to make repairs or replacement feasible as waste trenches subside over time. A grid mesh over the waste may help reduce the impact on the cap from waste subsidence by providing more support to the cap. Monitoring the condition of the cap and providing maintenance is an integral part of this alternative.

Surface controls also include grading and revegetation. The caps and surrounding areas would be graded to eliminate any surface ponding, and slopes would be graded to limit erosion. Upon completion of grading, disturbed areas would be revegetated.

Also under this alternative, disposal units inundated with groundwater as a result of direct contact with WOL, the Hill Cut Test Facility, and the ETF would be excavated and consolidated elsewhere on-site with other wastes Depending on the types of waste from each disposal unit, the waste would either be placed under the cap at a higher elevation or, for non-RCRA waste, would be disposed in the Tumulus. Figure 8.2 shows the material being consolidated in the area of the existing landfill. The RCRA land disposal restrictions are not invoked under this scenario because the entire WAG is considered an area of contamination; the movement of waste from one area of the site to another area is not considered "placement" under RCRA. However, rather than just dispersing the trench wastes into other disposal areas it may be necessary to construct a disposal unit that is more protective. Most space appropriate for disposal is already in use. The on-site disposal possibilities will be defined and evaluated in detail in the FS/CMS/EA report.

The soil adjacent to the trenches remaining after excavation of the inundated waste would be left in place and the trenches would be backfilled. Without complete remediation of WOL, any soil placed below the flood level of the lake is expected to be contaminated by WOL. Therefore, no attempt will be made to remove all contaminated soil. Neither would the area be capped. This will permit flexibility for future actions at WOL, which may require access to the southern portion of WAG 6. (The consolidation described herein is also considered as part of Alternatives 4 and 5.)

Also in Alternative 3, French drains are included in selected areas of the site to intercept stormflow prior to its entering the disposal units. Since there will be no contact with the waste, it is expected that water collected during a storm event would be clean and would not require treatment. More detailed development of Institutional Controls, monitoring, and contingent actions will be provided in the FS/CMS/EA.

Under this alternative, some continued contamination of the groundwater may occur, because the smaller caps likely will not permanently lower the groundwater table significantly. However, intercepting stormflow prior to its contacting the wastes decreases continuing degradation of the groundwater quality. In addition, the caps will protect against direct contact with the waste and will minimize infiltration into the waste. The alternative can effectively meet the objectives of the remedial action. However, in the long term, the caps may need to be replaced because the waste would not have been stabilized and subsidence might undermine the caps.

Alternative 3 is one of the most easily implemented alternatives; none of the technologies require difficult construction techniques or unusually difficult worker protection. The alternative has relatively low capital costs compared to other alternatives, but maintenance costs may be relatively high if significant subsidence of the waste damages the caps. The consolidation component of the technology adds construction cost and complexity, but this is a component of all remaining alternatives. Alternative 3 will be carried forward to the detailed site-wide alternatives to allow a comparison of the merits of smaller caps versus larger caps (presented in other alternatives).

**SLB Alternative 4: Surface Controls, Capping, Consolidation, and Structural Stabilization.** Alternative 4 contains large caps (Figure 8.3) with previous structural stabilization of the trenches and necessary surface water controls. Also, as in Alternative 3, the southern trenches would be excavated and consolidated with other waste. The caps of this alternative would be designed to virtually eliminate recharge to the capped area, including recharge by stormflow, and consequentially would lower the water table. Caps sufficient in size to cover the recharge area also would reduce leachate generation caused by groundwater and/or infiltrating precipitation interacting with the waste, which would further reduce release to or transport via groundwater.

Studies conducted at WAG 6 indicate that interim caps 2 and 8, which were placed as part of the interim closure of the RCRA units, have been effective in reducing or preventing trench bathtubbing by stopping infiltration and by preventing recharge to the trenches via shallow stormflow. However, other caps have not prevented bathtubbing effects and some

capped waste disposal areas continue to be inundated by groundwater (Ashwood and Spalding 1990). This indicates that even if direct infiltration is reduced locally, some existing caps are not large enough area to prevent trench bathtubbing caused by stormflow seepage or interaction with the water table. Smaller caps would not significantly impact the water table level. Therefore, Alternative 4 will involve the larger caps. If further evaluation during the detailed alternative development shows that the caps alone do not lower the water table below the waste, interception drains upgradient of the disposal area may be included.

The degree of structural instability of the trenches and their contents has been documented in a report (Ashwood and Spalding 1990) that concluded that burial trenches in all areas of the site are inherently unstable and subject to substantial settlement under existing and newly imposed loads. Because the larger caps would be more difficult to replace in the event of failure then the smaller caps, all trenches would be stabilized by dynamic compaction or in situ grouting before the caps are constructed.

Dynamic compaction has been demonstrated to be effective in reducing the void volume in a trench as discussed in Sect. 1. Using a weight to compress the waste material does not in itself add much additional cost to capping. The negative aspect of this technology is that compaction could break containers, accelerating the release of contaminants to the subsurface. To date, monitoring wells have not detected any increase in contamination of the groundwater due to the dynamic compaction pilot studies. However, it is unclear if the demonstration trenches contained containerized wastes or whether sufficient time has elapsed for contamination to reach the monitoring wells.

Dynamic compaction would be used on trenches anticipated to have lower levels of contamination and a low likelihood of significant biodegradation. Even after compaction, biodegradation can result in significant subsidence. In this case, in situ grouting, which would limit biodegradation, would be the preferred technology. Future cap maintenance would be needed since any biodegradation would cause waste subsidence.

In situ grouting is also included in Alternative 4 as a process option for improving stability of trench waste. Prior to grouting, leachate present in the trenches may be removed through vacuum collection and transported to the ORNL liquid waste treatment system for treatment and disposal. ORNL performed a treatability study to test the capabilities for treating trench leachate using existing processes in the treatment system (Robinson 1990). This study indicated that the trench leachate could be effectively treated by the system. (The study results will be discussed in more detail as part of groundwater alternatives containing this option.) Alternately, the trench leachate may be used as part of the makeup water for the grout.

As discussed in Sect. 1, testing at ORNL also has shown grouting technology to be implementable and effective in stabilizing waste (Tallent et al. 1987; Spence et al. 1987). Preliminary unit cost estimates provided in the test report showed in situ grouting to be much more expensive than dynamic compaction. Monitoring of the groundwater near the trench has been initiated and is continuing to assess the effectiveness of the grout on reducing mobility of contaminants in the waste.

Grouting would be used on the more highly contaminated trenches. Because grouting could leave some voids unfilled and because the grout itself could physically deteriorate, its reliability in the long-term may be less than that of dynamic compaction.

Alternative 4 is anticipated to provide better long-term effectiveness than Alternative 3, primarily because the caps would be more reliable and would offer improvements in protection from further contamination of groundwater. Alternative 4 is anticipated to be more difficult to implement due to the use of grouting and the construction of a large cap that will require significant earth-moving activities. Even though Alternative 4 may have higher capital costs than Alternative 3, the operational and maintenance costs are expected to be lower. To determine the benefit of the increased effectiveness versus the additional implementation difficulties and possible costs, Alternative 4 will be retained for further consideration during definition of detailed site-wide alternatives.

**SLB Alternative 5: Consolidation, Surface Controls, Capping, Structural Stabilization, and In Situ Vitrification.** Alternative 5 incorporates many of the same process options or technologies as Alternative 4 (surface controls, capping, grouting, and/or dynamic compaction) and Alternative 3 (consolidation). It also includes in situ vitrification, which would be used on some of the highest activity trenches in place of structural stabilization. Other disposed waste of high activity would also be vitrified. (The actual disposal units selected for vitrification will be described during definition of the site-wide alternatives in the FS/CMS/EA report.)

In theory, and based on the demonstration tests described in Sect. 1, full-scale in situ vitrification appears to reduce the mobility of many of the radionuclides in addition to destroying the organic chemicals. The resulting vitrified matrix is structurally and biologically stable and should be reliable for a long time into the future. Proper worker protection against volatilized cesium would be required. The long-term effectiveness of this technology is unknown.

In situ treatment has inherent implementation difficulties, especially with a varied waste matrix. Significant operational modifications may be necessary for different disposal areas. Significant field testing would be required. However, the technology does not require excavation of the buried material; therefore, the costs and hazards associated with materials handling are considerably less than with incineration (discussed below in this section).

The costs of full-scale in situ vitrification are not well understood. There are reports that energy costs are very high, yet the process is probably less expensive than incineration and may be comparable to in situ grouting. Alternative 5 is anticipated to be in the same order of magnitude in cost as Alternative 4.

Alternative 5 will be carried forward to evaluate the added benefit of treatment versus the added implementation difficulties.

**SLB Alternative 6: Consolidation, Surface Controls, Capping, Structural Stabilization, and Incineration.** The surface control, capping, and structural stabilization aspects of Alternative 6 were discussed in Alternative 4. Under Alternative 6 waste contaminated with high levels of organics or containing combustible material (biological trenches) would be excavated and incinerated to reduce the volume of contamination and to destroy organic contaminants. A sufficient amount of waste must be considered for incineration to justify the extremely high mobilization costs.

Contaminated soil immediately surrounding the waste would be excavated. The volume of soil accumulated will depend on the excavation technique and on the contaminant concentrations, but volumes would be minimized as much as possible. Soil in the southern portion of the site would be left to be remediated along with WAG 2, because cleaned soil in the area would be recontaminated by the lake. The soil around the solvent auger holes would also be excavated as needed to remove the waste. Remaining contaminated areas would be backfilled and covered by the site cap.

Under this alternative, only an on-site mobile incinerator is considered. Although permanent off-site incinerators exist in the area [Scientific Ecology Group (SEG) incinerator and K-25 incinerator], they either are not permitted for mixed waste or do not have the capacity for the varied wastes found at WAG 6. (The only wastes under consideration for incineration from WAG 6 contain both radionuclides and RCRA organic wastes.) In addition, on-site incineration eliminates troublesome transportation considerations involved with off-site incinerators. Mobile incinerators currently are not present at ORNL, and one would need to be procured. Any existing incinerator would require considerable retrofitting since its design would not have been based on WAG 6 waste characteristics. It would also require up to 2 years lead time to set up, conduct trial burns, and obtain permits. This is a significant schedule delay over the other alternatives.

The effectiveness of Alternative 6 in protecting public health and the environment is not significantly improved over other alternatives. Although some of the organic contaminants may be destroyed, most of the risk from the site is from radionuclides, which are not affected by incineration. Waste sources selected for incineration include the biological trenches and solvent auger holes. This waste is assumed to be combustible and would not present too great a hazard if excavated. However, extreme costs and mobilization efforts would be spent, only to achieve some volume reduction or to only destroy some of the organics on WAG 6. The majority of the waste at the facility would remain unaltered and hazardous (inorganics and radionuclides).

This alternative is considerably more difficult to implement than previous alternatives. Considerable materials handling and solids processing would be required before the excavated material could be incinerated. Large objects, including concrete pipes, would need to be crushed or segregated. Material excavated from beneath the existing groundwater table would need to be drained on drying beds to minimize moisture in the incinerator. Material might need to be separated and stored until there is sufficient volume of like material to warrant modifying the incinerator operating conditions, as not all waste could be incinerated using the same conditions.

After incineration, the ash and solids from emission controls would require disposal. Under the best conditions, the solids would be contaminated with radionuclides and could be disposed on-site in an above-ground Tumulus. Due to the fairly low volume reduction anticipated (no more than 50%) a considerable amount of LLW would require disposal. The on-site disposal units have very little future capacity, and there is no room on-site for new low-level disposal units. To dispose of the ash and noncombusted material under the cap would result in up to 4 to 5 years' delay in cap installation. Off-WAG disposal at a low-level disposal facility might be required. Under the most likely conditions, the residue would contain radionuclides and RCRA inorganics, making it a mixed waste. Because there are no existing on-site or off-site final disposal facilities for mixed waste, the material would have to be stored until an off-site facility becomes available. Any disposal of treated material also involves the land ban restrictions of RCRA. The extensive materials handling make this alternative very expensive to implement, both in terms of capital and operation and maintenance (O&M) costs, and the issues surrounding disposal of the incinerated material and the air pollution control residue make this alternative almost impossible to implement.

Alternative 6 will not be carried forward for incorporation into site-wide alternatives because of the high cost, difficult implementation, and minimal additional effectiveness.

#### 8.4.1.2 Results of shallow land burial wastes alternatives

As a result of this alternative screening, the remedial alternatives for source control that will be carried forward include:

| | |
|---|---|
| Alternative 1. | No Action |
| Alternative 3. | Surface Controls, Small Caps, Consolidation |
| Alternative 4. | Surface Controls, Large Caps, Consolidation, Structural Stabilization |
| Alternative 5. | Surface Controls, Large Caps, In Situ Vitrification, Structural Stabilization |

A summary of this evaluation is presented in Table 8.2.

#### 8.4.1.3 Groundwater alternatives

As defined in Sect. 6 of this report, radionuclides and volatile organics with respect to groundwater are the contaminants of primary concern at WAG 6. These contaminants have exceeded various federal standards, are migrating off-site, and are of risk to future potential users of the groundwater. The hydrogeologic setting at WAG 6 creates complex groundwater flow paths. Groundwater flow in the saturated soil and saprolite above competent bedrock is generally controlled by a combination of primary matrix porosity of the weathered saprolite and secondary porosity caused by relict bedrock structural features such as fractures and solution cavities. Groundwater flow in the soil and saprolite is somewhat predictable and follows the hydraulic gradient indicated by potentiometric mapping. Conversely, there is little or no primary porosity associated with the competent bedrock. Flow in this zone occurs along fractures, following a tortuous path related to intersecting fractures. As there are up to five distinct fracture orientations recognized at any one location within WAG 6, prediction of

groundwater flow in the bedrock is not possible. Although groundwater contamination has been detected in many of the WAG 6 interior and perimeter monitoring wells, distinct on-site groundwater plumes related to specific sources are not recognizable. Alternatives for remediation of groundwater must recognize the unknowns associated with the subsurface. As part of the alternative evaluation process performed in the FS/CMS/EA, the alternatives will be compared with respect to how effectively they can respond to varying conditions.

Because of the site's topographic relief, groundwater flow of most concern within WAG 6 originates primarily on-site. It flows from points of recharge (generally topographically higher areas) within WAG 6 to points of discharge also within or adjacent to WAG 6 (typically in low lying areas and surface water drainages), which ultimately flow into WOL. Adjacent to WOL, groundwater appears to discharge directly to the lake. A principal point of groundwater discharge appears to occur along the stream in the low area outside the eastern boundary of WAG 6. Site characterization data suggest that in the northern half of the site, the water table is below competent bedrock surface for most of the year such that groundwater flow does occur in the bedrock in this area.

General response actions and process options selected thus far for carrying forward to this phase include:

- No Action
- Institutional Controls
  - Deed Restrictions
  - Fences
- Collection
  - Drains
- Disposal
  - ORNL Liquid Waste Treatment System
  - Discharge to Surface Water

Remedial actions for groundwater will not focus on restoration of on-site groundwater to specified levels because of the difficulty of characterizing on-site contaminant plumes and groundwater flow patterns and because all source alternatives include the permanent disposal of wastes on-site. Alternatives developed here will address the mitigation of the impacts of off-site migration of contaminated groundwater and preventing the public from using on-site groundwater. Except for No Action, all of the developed alternatives include monitoring and the necessary Institutional Controls to prevent access to on-site contaminated water.

The following alternatives are under consideration for groundwater:

1. No Action
2. Institutional Controls, Monitoring
3. Institutional Controls, Monitoring, Future Decision
4. Boundary Collection, ORNL Liquid Waste Treatment System, Surface Water Disposal, Monitoring

These alternatives are evaluated below with respect to their effectiveness, implementability, and cost.

**Groundwater Alternative 1: No Action.** Under Alternative 1, the contamination moving off-site will not be controlled. The baseline risk assessment and environmental assessment (Sections 6 and 7, respectively) have illustrated the effects on public health and the environment of no action on the groundwater. Although no action is easy to implement technically, this alternative will not protect public health or the environment. Alternative 1 has no associated costs. The No Action alternative will be carried forward for consideration to meet CERCLA, SARA, and NEPA requirements and to provide a baseline comparison for other alternatives.

**Groundwater Alternative 2: Institutional Controls, Monitoring.** Institutional Controls and monitoring, as with the Institutional Control alternative for sources, contains two variations. The first variation assumes that the ORNL facility will remain operational for 10 years. That period will be followed by a post-operational period of 100 years, during which existing Institutional Controls will remain in effect. After that time, all Institutional Controls on WAG 6 will be removed. Institutional Controls for this variation are primarily access controls such as fences and patrols. The risk assessment has indicated that the groundwater will remain a threat to public health beyond 110 years. Therefore, this first variation on Institutional Controls would not be effective in protecting public health and will not be carried forward for further evaluation.

The second variation uses the existing Institutional Controls through the post-operational period but extends the controls to as long as the groundwater remains a threat to public health. After the post-operational period, deed restrictions on the WAG 6 land would be added to the controls, limiting use of the land and of the groundwater beneath the site. In addition, monitoring would continue to assess when the controls can be lifted.

As with no action, there would be no mitigation of continued off-site migration of contaminated groundwater, but the effect on public health would be minimized by not allowing access to the on-site contaminated groundwater. Institutional Controls may not be effective over a long period; typical controls resulting from hazardous waste remediation have not been in place long enough to assess long-term effectiveness, and it is anticipated that Institutional Controls may fail over time as the reason for the controls is forgotten. However, this may be more true for controls on private land than for controls on federal facilities.

Institutional Controls on DOE property are easy to implement, and most of the controls necessary for WAG 6 are already in place. They need only to be extended in time, and they would have a relatively low capital cost. However, the operational and maintenance costs may be higher than typically anticipated because of the need to continue patrolling the area.

Because of the low cost as compared to a more active alternative and the ease of implementation, Institutional Controls will be carried forward for further consideration.

**Groundwater Alternative 3: Institutional Controls, Monitoring, and Future Decision.** Alternative 3 includes Institutional Controls, monitoring, and a future decision concerning groundwater remediation. The groundwater underlying individual WAGs, including WAG 6, is not isolated and is part of the overall hydrologic system prevalent in Melton Valley. Consequently, groundwater at WAG 6 interacts with groundwater and surface water from adjacent WAGs, and decisions to address each independently may result in redundancy in collection and treatment systems or may even result in lowering the effectiveness of individual actions through interference. Cleanup levels or action levels need to be consistent across adjoining WAGs, especially with WOL cleanup since the groundwater from WAG 6 ultimately discharges there. Because of the interdependence of groundwater in and around WAG 6 with groundwater and surface water associated with other WAGs, and because of the timing of the work at each WAG, it is not possible to define, evaluate, implement, or monitor separate groundwater remediation actions for WAG 6 and adjacent WAGs. At this stage, it is only possible to control migration between WAGs. This is the objective for Alternative 4. However, Alternative 3 allows the groundwater at WAG 6 to be addressed as part of a larger area-wide groundwater action. In the meantime, Institutional Controls would be implemented over WAG 6 to prevent use of on-site groundwater until sufficient information is known about the adjacent WAGs to select an area-wide groundwater remedial action.

Alternative 3 provides the same degree of immediate protection of public health and the environment as Alternative 2; yet it does not preclude the use of active restoration as a future action. Where there is a significant risk from the use of groundwater, most active remediation alternatives are more effective in protecting public health and the environment in the long-term than Institutional Controls. The implementation of this alternative may best be accomplished by addressing WAG 6 groundwater and other connected groundwater as another operable unit.

It is not possible to assign costs to WAG 6 from a future decision. However, greater protection at a lower cost would be possible across the WAGs under this alternative than with active restoration or migration control alternatives at each WAG.

Alternative 3 will be carried forward for evaluation with respect to other alternatives.

**Groundwater Alternative 4.** Alternative 4, the final groundwater alternative developed, includes collection of contaminated groundwater and disposal to the existing ORNL liquid waste treatment system for treatment and ultimate surface water discharge through the system's permitted discharge.

A drain was installed in the 49-Trench area in bedrock in 1983. Initially the 826 foot drain resulted in depressing the water table 10 feet (13 feet maximum). The drawdown area extended almost 200 feet from the centerline (Davis and Marshall 1988). Until the drain started clogging, it clearly demonstrated the effectiveness of trench drains at WAG 6.

ORNL has conducted treatability studies on the technologies contained in their process waste treatment and non-rad waste treatment plants. One of the conclusions of the report was that the plants can successfully treat the leachate found at WAG 6 to meet NPDES effluent

requirements. The existing treatment capabilities will be explored more thoroughly during the detailed definition of alternatives.

Because the future areas of groundwater contamination passing the boundary are unknown, the collection system would be designed to address the areas at the facility boundary that are contaminated now, as illustrated in Sect. 4. Monitoring would be used to identify future boundary locations that may become incorporated into the boundary collection system. Any groundwater collection system would need to be integrated with any groundwater diversion drain system used as part of the source control alternative.

The components of this alternative have been tested at ORNL and found to be effective in achieving their respective purposes. Alternative 4 is more effective in the long-term for protecting public health and the environment than the no action alternative and than Institutional Controls. This is primarily due to the removal of contaminants from the groundwater. As risk from exposure of groundwater is lessened, so are the consequences of a collection system failure in the long-term. Alternative 4 probably has the same degree of protection and reliability as Alternative 3, which would include area-wide remediation.

The necessity to excavate collection trenches into the bedrock to collect contaminated groundwater at the northern and eastern boundary of the site make Alternative 4 difficult to implement. The depth of bedrock excavation will be determined in the FS/CMS/EA, but the objective is to collect groundwater contaminated above unacceptable levels from the aquifer. However, the treatment component would be fairly easy to implement, even compared to Institutional Controls, as it would only be necessary to transfer groundwater to the existing treatment systems. However, if the existing plants need to be expanded, the difficulty of implementing the treatment component would be higher. This will be discussed further in the FS/CMS/EA.

The cost of this alternative is the highest of the groundwater alternatives. Drains in the northern portion of the site may need to be installed deep in bedrock since the water table is below the bedrock surface contributing significantly to the capital costs. In addition, operation and maintenance costs of collecting the groundwater and monitoring the system would continue for a very long time. It may be necessary to add drains to the system in the future, causing future significant cost impacts.

Because of its treatment component, its implementability, its protectiveness of the environment and public health from the further release of contaminated groundwater off-site, and its long-term reliability compared to Institutional Controls, Alternative 4 will be carried forward for development into site-wide alternatives.

#### 8.4.1.4 Results of groundwater alternatives screening

As a result of the above screening process, all of the groundwater remedial alternatives developed (listed below) will be carried forward. A summary of the evaluation is presented in Table 8.3.

1. No Action
2. Institutional Controls, Monitoring
3. Institutional Controls, Delayed Decision, Monitoring
4. Collection, ORNL Liquid Waste Treatment System, Surface Water Discharge, Monitoring

### 8.4.2 Assembly of Site-Wide Alternatives

The waste sources and groundwater alternatives have been combined to satisfy the remedial response objectives for the site. While these alternatives will be defined in more detail in the FS/CMS/EA report, they are presented in this section of the RFI to allow the reader to review how the media-specific alternatives may be combined to address all of WAG 6. After further technical evaluation, some of these alternatives may be modified.

Table 8.4 illustrates the major components of the assembled alternatives. The Tumulus will be closed with a cap under all alternatives except the no-action alternative. The design of the cap will be discussed as part of the definition of alternatives presented in the FS/CMS/EA report.

# Section 8 Tables

**Table 8.1. Retained primary process options ORNL WAG 6**

| General response action | Technology | Process option |
|---|---|---|
| No Action | | |
| Institutional Controls | Access/Use Restrictions | Deed Restrictions<br>Fences<br>Permits |
| Containment | Cap<br>Vertical Barrier<br>Surface Controls | Multilayered Cap<br>Drains<br>Grading/Revegetation<br>Diversion/Collection<br>Dynamic Compaction<br>In Situ Grouting |
| Collection | Excavation<br>Groundwater Collection<br>Vapor/Gas Collection | Solids<br>Drains<br>Passive<br>Active |
| Treatment | In Situ Treatment<br>Thermal Treatment | In Situ Vitrification<br>Incineration |
| Disposal | Wastewater Discharge | ORNL Liquid Waste Treatment Systems<br>Surface Water |
| | Solids Disposal | On-Site |

**Table 8.2. Summary of evaluation of SLB waste alternatives**

| Alternative | Major components | Effectiveness | Implementability | Cost | Retained |
|---|---|---|---|---|---|
| 1 | No Action | No protectiveness. | | Low | Yes |
| 2 | Institutional Controls | Protects public health, but limited reliability for long-term. Little protection of environment. | Easy. Most controls already in existence and in place. | Medium | No |
| 3 | Small caps, consolidation | Protects public health with improved reliability. Improved effectiveness for environment. | Except for consolidation, technically easy. | Medium | Yes |
| 4 | Large caps, structural stabilization, consolidation | Protects public health and environment. Long-term reliability still a concern. | Somewhat difficult technically, but not excessive. | High | Yes |
| 5 | Large caps, structural stabilizaiton, consolidation, in situ vitrification | Protects public health and environment. Long-term reliability still a concern. | More difficult than Alts. 3 and 4. Not too difficult. | High | Yes |
| 6 | Large caps, structural stab., consolidation, incineration | Worker exposure a concern. Not much effectiveness improvement. | Technically difficult if not impossible due to disposal issues. Difficult administratively. | Very high | No |

**Table 8.3. Summary of evaluation of groundwater alternatives**

| Alternative | Major components | Effectiveness | Implementability | Cost | Retained |
|---|---|---|---|---|---|
| 1 | No Action | Not effective in protecting public health or environment. | Nothing to implement. | Low | Yes |
| 2 | Institutional Controls | Protects public health, but limited reliability. No improvement in environmental quality. | Easy. Most controls already in existence and in place. | Low | Yes |
| 3 | Future decision | Most effective as objectives of remediation are for entire area and consistent. | No interference between WAG remedial actions. Should be technically straightforward. Administratively, best to address as area-wide operable unit. | Low, but not definable | Yes |
| 4 | Boundary collection, treatment at ORNL system | Protects public health and improves environmental conditions. Fairly reliable. | Construction of trenches in bedrock is difficult. | Medium | Yes |

**Table 8.4. WAG 6 alternative assessment preliminary site-wide alternatives**

| Components | Alternatives | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| SLB Waste | | | | | | | |
| Small Caps | N | X | X | | | | |
| Large Caps | O | | | X | X | X | X |
| Structural Stabilization | | | | X | X | X | X |
| In Situ Vitrification | A | | | | | | X |
| Consolidation | C | X | X | X | X | X | X |
| Groundwater | T I O N | | | | | | |
| Monitoring | | X | X | X | X | X | X |
| Institutional Controls | | X | X | X | X | X | X |
| Future Decision | | X | | | X | | |
| Boundary Drains | | | X | | | X | X |
| ORNL Liquid Waste Treatment Systems | | | X | | | X | X |
| Tumulus | | | | | | | |
| Cap | | X | X | X | X | X | X |

# Section 8 Figures

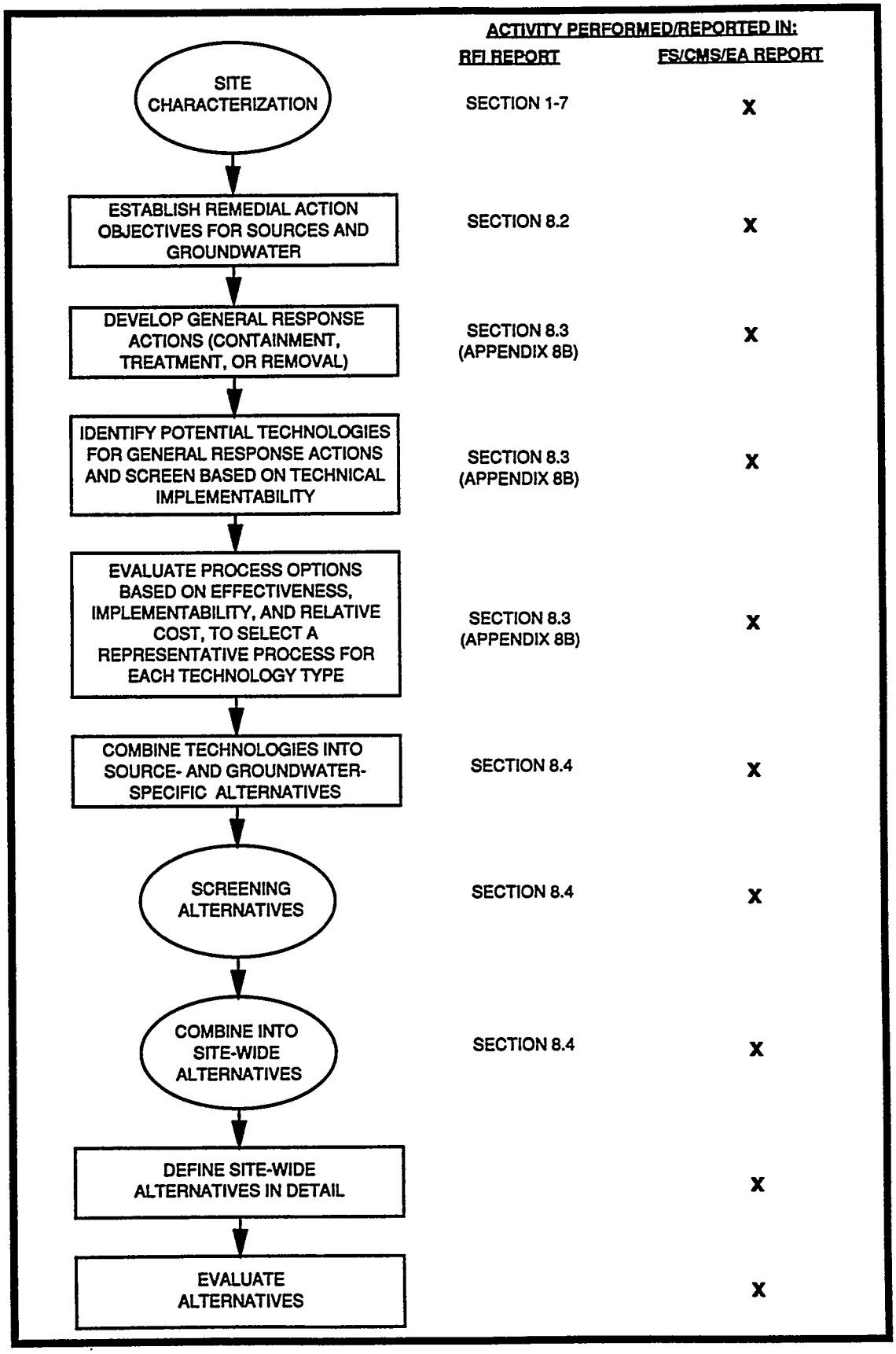
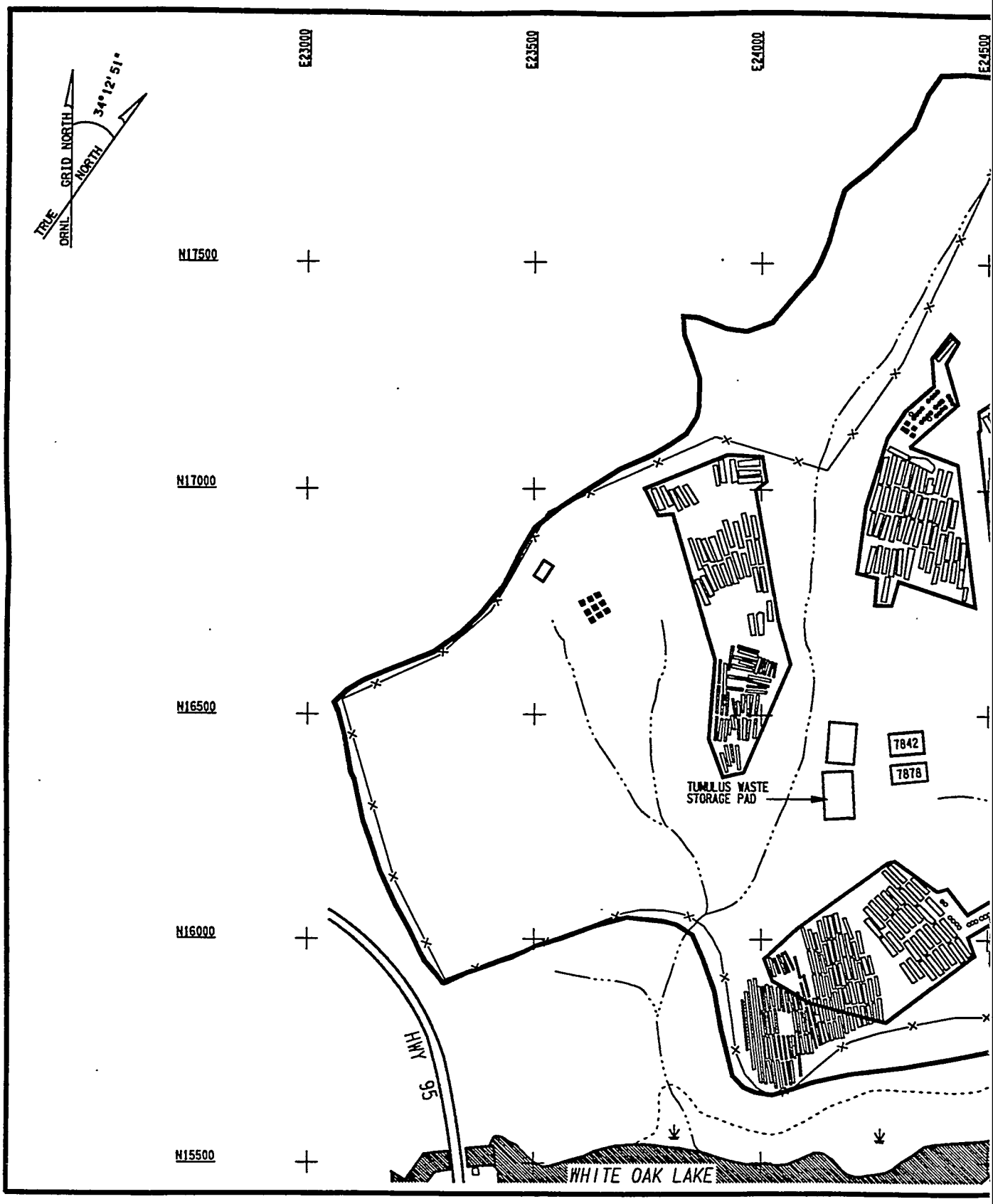



**Fig. 8.1. Alternative development and evaluation process.**




WAG6 06F160.DGN

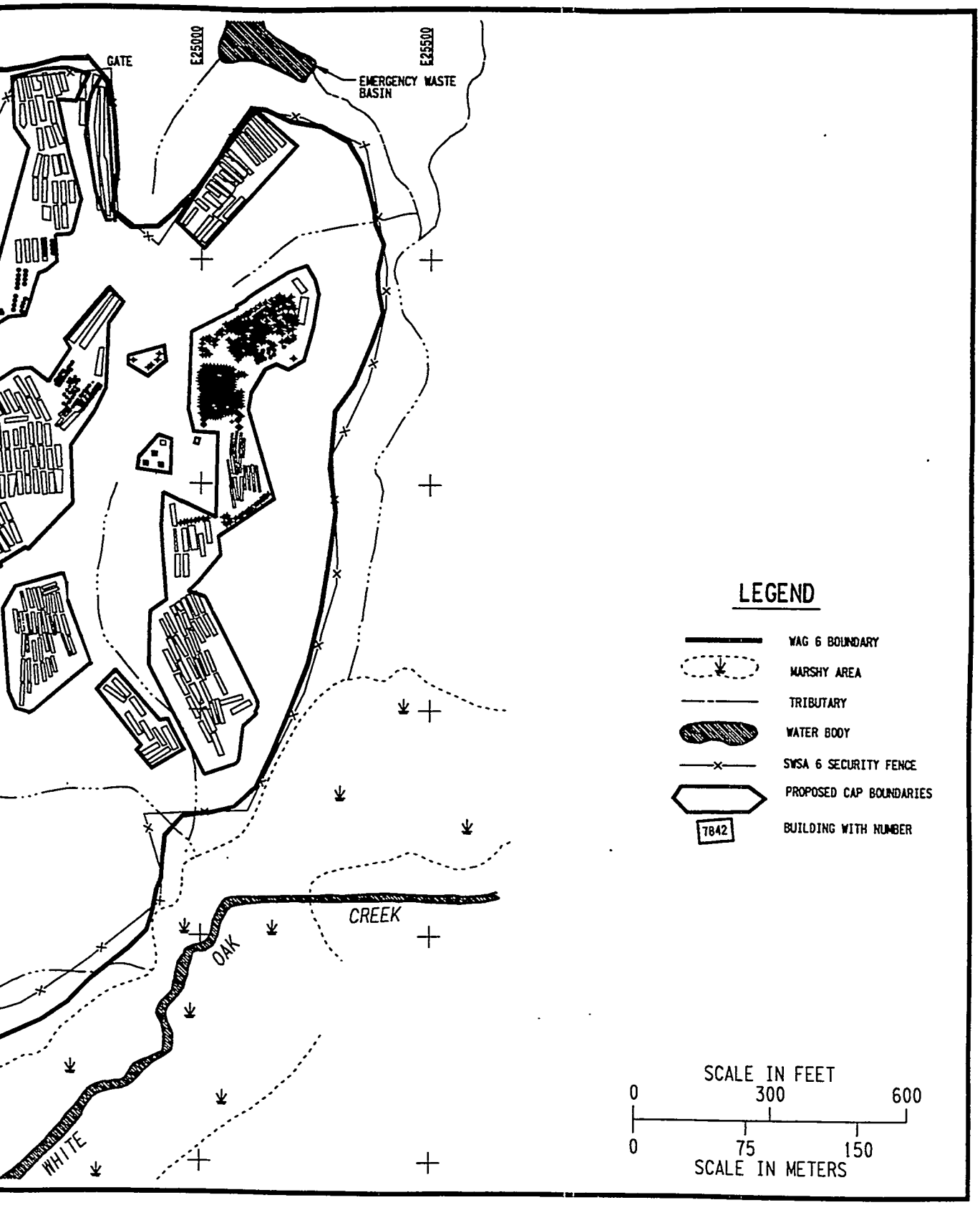



**Fig. 8.2. Approximate location of small area caps, WAG 6.**

WAG6 06F227.DGN

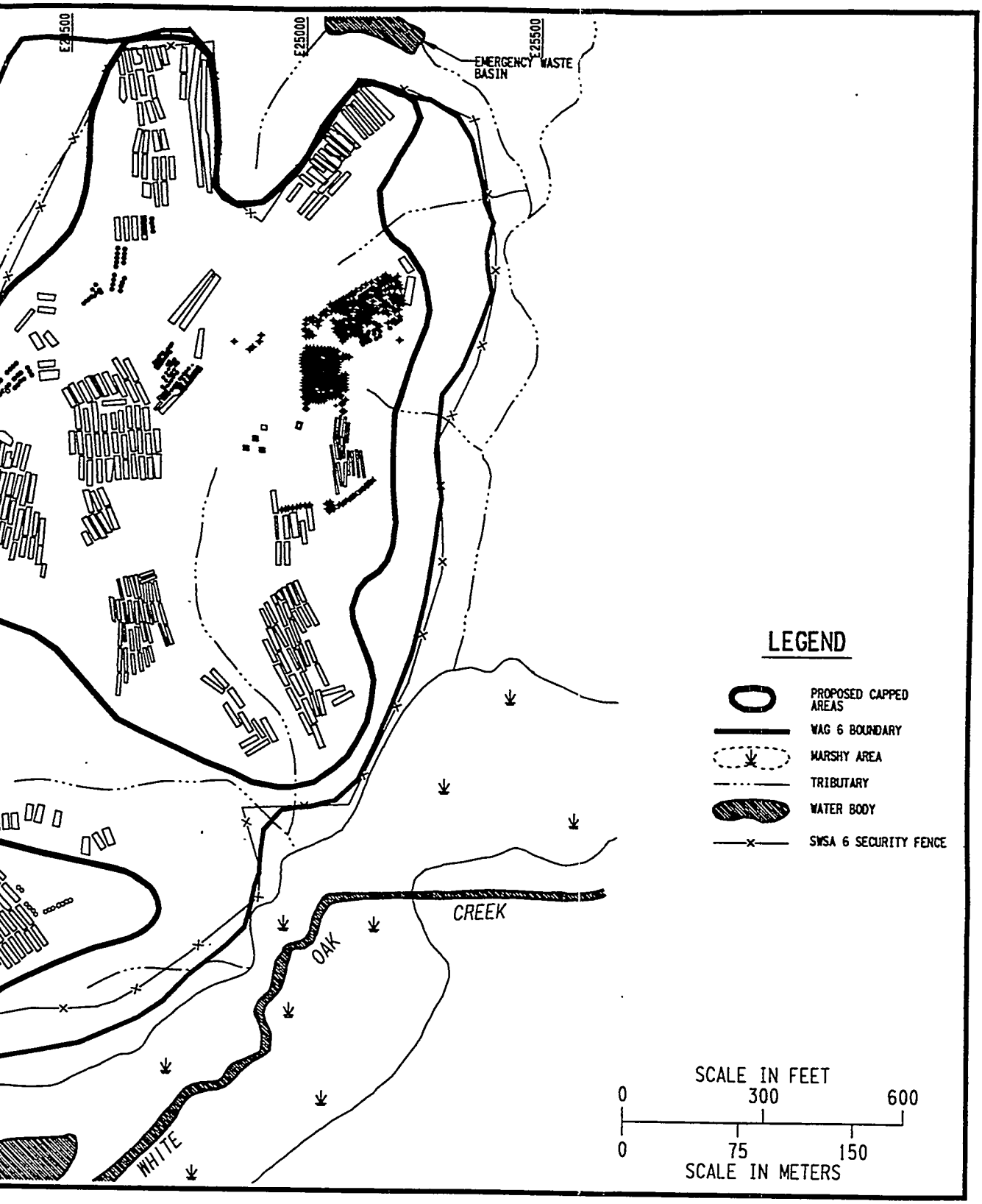



**Fig. 8.3. Approximate location of large area caps, WAG 6.**

# 9. SUMMARY AND CONCLUSIONS

## 9.1 NATURE AND EXTENT OF CONTAMINATION

Contaminant data collected during the RFI indicated that contaminants were widespread downgradient of source areas; however, specific contaminants were generally detected infrequently and/or were at low concentrations. Within the site, there were areas where particular contaminants were detected at elevated concentrations.

### 9.1.1 Groundwater

Both man-made and naturally occurring radionuclides were detected in groundwater at WAG 6. Tritium was by far the most prevalent contaminant and frequently exceeded the 20,000 pCi/L MCL in locations adjacent to waste disposal areas. Additional man-made radionuclides detected included cobalt-60, strontium-90, and cesium-137; however, these were detected far less frequently and at relatively low concentrations. Cobalt-60 detections were generally in the northeastern corner of the site and strontium-90 was primarily associated with the high activity trench area. Transuranics were detected only infrequently and at low concentrations in groundwater.

Like tritium, VOCs were detected in groundwater adjacent to most waste disposal areas throughout the site. The highest concentrations, frequently exceeding MCL's, were associated with the biological trench areas and the solvent auger hole areas. Few SVOCs were detected in groundwater. Of metals detected that exceeded criteria identified in Sect. 4, lead and barium were the most common. Metals contamination appears to be primarily restricted to areas immediately adjacent to waste disposal units.

### 9.1.2 Surface Water

In surface water, as for groundwater, tritium was the most frequently detected contaminant. Tritium was detected in all drainages and, in the majority of samples, the MCL was exceeded. Cobalt-60 was detected only once in surface water, adjacent to where it was detected in groundwater and in soils. Strontium-90 was detected at concentrations exceeding the MCL in several drainages; the highest concentrations were detected in Drainage FB which appears to be receiving strontium-90 from the high activity trench area.

The primary VOCs detected at levels exceeding MCL's were 1,2-dichloroethene, tetrachloroethane, and trichloroethene. SVOCs detected were generally at low concentrations and were frequently common laboratory contaminants. Barium and cadmium concentrations exceeded reference or MCL values, but only for two samples.

### 9.1.3 Sediments

Cesium-137 was the most frequently detected man-made radionuclide in sediments. Apart from one cobalt-90 detection, concentrations of other man-made radionuclides did not exceed criteria identified in Sect. 4. Strontium-90 was detected in sediments in Drainage FB, the same drainage in which surface water appears to be receiving strontium-90 from the high activity trench area.

VOCs were detected in most sediment sampling locations, but at concentrations less than the criteria identified in Sect.4. SVOCs were detected infrequently and were typically common laboratory contaminants. Metals concentrations in sediments did not appear to be significantly elevated relative to reference concentrations.

### 9.1.4 Soils

The radiological walkover survey and the soil sampling program indicated minimal surface soil contamination and the absence of gross soil contamination adjacent to source areas.

Radiological contaminants detected in soils were limited primarily to strontium-90 and cobalt-60; each was detected in three soil borings. The maximum concentration of strontium-90 did not exceed criteria identified in Sect.4. Comparable criteria for cobalt-60 are unavailable.

Both VOCs and SVOCs were detected in soil samples. Compounds detected were frequently laboratory contaminants; concentrations did not exceed proposed RCRA Subpart S RCRA criteria. Metal contamination of soil at WAG 6 appears to be very localized. Arsenic, lead, mercury, and cobalt were detected in a few samples at concentrations significantly above background.

## 9.2 CONTAMINANT FATE AND TRANSPORT

Simplified contaminant fate and transport modeling was conducted to predict on-site radionuclide concentrations in groundwater, surface water, sediment and soil, and to predict the flux of contaminants off-site. Contaminant fluxes were used to calculate contaminant concentrations downstream in the Clinch River, where a hypothetical off-site receptor was assumed to be located.

Modeling was performed using essentially two models: an integrated surface/subsurface water contaminant fate and transport model, and an air model. Time series predictions of concentrations for each contaminant modeled were generated and employed in the baseline risk assessment.

Selected conclusions of the fate and transport analysis are summarized below.

- Water was the major transport mechanism for off-site migration of contaminants and most of the radionuclide flux out of WAG 6 was expected to continue to occur via surface water

- Tritium, cobalt-60, strontium-90, and cesium-137 were predicted to occur in most of the wells in WAG 6. Peak future groundwater concentrations were predicted to be within two orders of magnitude of the present-day concentrations

- The first occurrences of europium and uranium in groundwater were predicted to be in years 1998 and 2025, respectively

- Air modeling, which was performed conservatively, indicated that the air pathway contributed negligible exposure-point concentrations of contaminants on-site and off-site

## 9.3 BASELINE RISK ASSESSMENT

A baseline risk assessment was performed to assess the potential impacts of contaminants at WAG 6 on human health and the environment if no remedial actions are taken. The baseline risk assessment comprised a human health evaluation and an environmental evaluation.

### 9.3.1 Human Health Evaluation

Two hypothetical scenarios were assumed for WAG 6. The first, termed the "no-action" scenario, assumed that DOE's current access restrictions for the site become ineffective immediately. The second hypothetical scenario assumed that DOE would continue to use WAG 6 as an LLW disposal site for the next 10 years and that this operational period would be followed by a 100 year institutional control period (institutional control scenario). Under the toxicological and exposure assumptions used in the evaluation, the lower limit of EPA's target range (1E-4 to 1E-6) was exceeded for the following receptors:

No Action Scenario
- On-WAG homesteader (1990-2020)

Institutional Control Scenario
- On-WAG ORNL worker (1990-2020)
- Off-WAG (Clinch River) homesteader (1990-2020)
- On-WAG homesteader (2100-2130)

Results for each scenario are briefly discussed in the following paragraphs.

#### 9.3.1.1 Receptor risks for no action scenario

**On-WAG homesteader (evaluated for 1990).** The estimated radionuclide and chemical carcinogen risks for the current day on-WAG receptor evaluated for site average concentrations were 1 and 4E-4, respectively. Ninety-nine percent of the radiological risk was associated with external exposure, with the majority of the dose resulting from radioisotopes of europium. The majority of the chemical risk was due to ingestion of groundwater and inhalation of water vapor while showering. Vinyl chloride and 1,1-dichloroethene were the predominant contributors to this risk.

Critical effect-specific hazard indexes computed for non-carcinogens were greater than 1 for the on-site homesteader (adult and child).

#### 9.3.1.2 Receptor risks for institutional control scenario

**Worker receptor (1990-2020).** The estimated radionuclide risk for the maintenance receptor was 1E-3. The radionuclide risk was almost exclusively attributable to an estimated external radiation dose of 2 rem accumulated over 30 years. Because the scenario assumed the worker spends 8 hours per day for 30 years working over SWSA 6 waste disposal areas, the risk estimate is conservative.

**Off-WAG homesteader (1990-2020).** The estimated radionuclide risk for the off-WAG homesteader was 6E-5. This risk was primarily a result of external radiation exposure from cobalt-60 and cesium-137 that have accumulated in soils as a result of crop irrigation over a period of decades. The contribution to radionuclide risk from assumed ingestion of surface water was 3E-6. Because heavy irrigation is highly unlikely given the abundant rainfall in the region, and because a homesteader is most likely to use groundwater as a drinking water source rather than surface water, this scenario was conservative.

**On-WAG homesteader (2100-2130).** The estimated radionuclide risk for the future on-WAG receptor evaluated for site average concentrations was 3E-1. As for the on-WAG homesteader, the majority of the radionuclide risk was associated with external exposure from isotopes of europium. Due to the assumption of steady state conditions for chemicals, chemical risks were the same as computed for the no action scenario on-WAG homesteader (1990 - 2020).

### 9.3.2 Environmental Evaluation

As an operating solid waste disposal facility, the majority of WAG 6 has been cleared of natural habitat. Regular site mowing and ongoing construction have discouraged reestablishment of natural habitats and wildlife communities. Aquatic and terrestrial surveys conducted at WAG 6 revealed no threatened and endangered species nor any developed wetland communities.

Potential impacts on target species were evaluated, including the tulip poplar, representing terrestrial flora; the white-tailed deer, red-tailed hawk, and racoon, representing

terrestrial fauna; bluegill and fathead minnows, representing aquatic vertebrates; and benthic macroinvertebrates representing aquatic invertebrates. These are species found on the ORR, and as such, might be expected on WAG 6 under a no action scenario.

The tulip poplar would likely uptake cesium-137; however, prediction of specific effects was not possible due to a lack of information in the literature.

Strontium-90 would likely pose a significant threat to wildlife at WAG 6. It is readily absorbed and deposited in bone tissue, where it can result in bone tumors and leukemia. Species from lower trophic levels such as rabbits and shrews are likely to suffer adverse effects, to bioconcentrate strontium-90 in their bone tissue, and subsequently to contaminate red-tailed hawks and raccoons that prey upon them.

Cadmium, copper, and strontium-90 could potentially affect fish populations. Cadmium and copper exceeded ambient water quality criteria for protection of aquatic organisms. Strontium-90 may accumulate in bone tissues; the uptake of strontium-90 in fish has been known to cause morphological abnormalities.

Macroinvertebrate communities could potentially be affected by cadmium and copper. These two metals produce chronic effects at concentrations ranging from 0.01 mg/L up to 30-32 mg/L and higher. Stoneflies and caddisflies are relatively resistant to cadmium and copper in comparison to other macroinvertebrate groups, but chronic toxicity occurs in the 1 to 100 mg/L range for many species. Bioconcentration of strontium-90 by macroinvertebrates is expected to be low because of their short life cycle and frequent molting.

### 9.3.3 Conclusions of the Baseline Risk Assessment

Evaluation of hypothetical on-WAG homestead receptors demonstrated that the no-action scenario could result in unacceptable risks to the public. Calculations further showed that if a receptor unknowingly excavated into one of the small number of high activity auger holes in which reactor control plates have been disposed, radiation doses could cause acute effects. If the control plates were removed, however, residual risks associated with the remaining inventory were still predicted to exceed EPA's target range.

It is emphasized that the no-action scenario is not a realistic scenario and was evaluated solely to define a baseline against which to compare alternatives for site closure and remediation. The location of SWSA 6 on the U.S. government owned ORR adjacent to an operating facility (ORNL), and the existence of site fencing and security patrols make it highly unlikely that a member of the public could occupy the site and remain undetected.

Estimated risks for hypothetical public receptors associated with the institutional control scenario did not exceed the upper limit of EPA's target risk range. For the off-WAG (Clinch River) receptor, risks fell within the lower end of the range; however, due to the conservative assumptions associated with this scenario, this result should not be the sole basis

for implementing actions beyond those already inherent in the scenario (e.g., access restrictions, site maintenance).

Evaluation of an on-WAG receptor for the period 2100-2130 indicated unacceptable risks and therefore demonstrated that, without appropriate site closure and remediation, access restrictions should continue beyond the year 2130 to prevent the possibility of on-WAG homesteading.

## 9.4 REMEDIAL ACTION OBJECTIVES

The results of the RFI baseline risk assessment indicate that closure and remedial action is required for source areas and groundwater.

Specific remedial objectives for each of these waste media are as follows:

- **Sources**: protect public health and the environment by limiting direct contact/emissions, surface runoff, and leachate generation from on-site sources and associated contaminated leachate and soil.

- **Groundwater**: protect public health and the environment by mitigating the effects of migration of contaminants off-WAG and by protecting against future use of on-site contaminated groundwater.

## 9.5 CLOSURE AND CORRECTIVE ACTION ALTERNATIVES

Using the methodology recommended in EPA's *Guidance for Conducting Feasibility Studies Under CERCLA* (EPA 1988a), a range of alternatives was developed for addressing source areas and groundwater. The alternatives were developed to span a range of cost and permanence. The alternatives are described in Sect. 8.

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DRAFT

# ORNL WAG 6 RFI REPORT

## VOLUME II: APPENDIXES (1A through 4C)

OAK RIDGE NATIONAL LABORATORY
REMEDIAL INVESTIGATION/FEASIBILITY STUDY

ENVIRONMENTAL RESTORATION
DOCUMENT MANAGEMENT
BLDG 1210 MS 7256

JUNE 1991

Prepared by
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| 4C.7 | Cesium-137 concentrations detected in groundwater samples from ORNL RCRA compliance wells at WAG 6 |
| 4C.8 | Levels of nondetection of cesium-137 from groundwater samples from RFI wells and some ORNL RCRA compliance wells at WAG 6 |
| 4C.9 | Cobalt-60 concentrations detected in groundwater samples from ORNL RCRA compliance wells at WAG 6 |
| 4C.10 | Cobalt-60 concentrations detected in groundwater samples from RFI wells and some ORNL RCRA compliance wells at WAG 6 |
| 4C.11 | Total strontium concentrations detected in groundwater samples from ORNL RCRA compliance wells at WAG 6 |
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| 4C.26 | Maximum VOC concentrations in groundwater, cross section H-H'; west waste disposal area including the 49 Trench area |
| 4C.27 | Maximum VOC concentrations in groundwater, cross section I-I'; west waste disposal area |

FIGURE NO.


| | |
|---|---|
| 4C.28 | Maximum VOC concentrations in groundwater, cross section J-J'; southern waste disposal area |
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# Appendix 1A. SWSA 6 WASTE INVENTORY

ORNL has an information management system for its solid waste disposal operations. This system, known as the ORNL Solid Waste Disposal Log, contains a partial inventory of wastes disposed in SWSA 6. This appendix describes the data management system and presents tabular summaries of inventory data recorded in the system for SWSA 6. The description of the data management system is adapted from Boegly (1984). This appendix also presents, in tabular form, summaries of the types and form of waste received in each of the types of waste disposal units at SWSA 6.

## 1A.1 ORNL SOLID WASTE DISPOSAL LOG

The Documentation Management Center within the Office of Waste Management and Remedial Action maintains the ORNL Solid Waste Disposal Log, a computerized inventory of waste shipments made by ORNL to both internal and external destinations. Prior to contacting the Documentation Management Center for LLW disposal service, individual ORNL waste generators complete a form that identifies the waste classification, type of waste, and the number and type of waste containers. Although this form requests a list of the principal isotopes and associated activities in the waste, in many cases the data provided are only estimates, and past experience has shown that the estimates are often on the high or conservative side. Thus, the total activity obtained by summing the individual disposal records may be higher than what is actually buried.

From the time wastes were first disposed in SWSA 6, the nature of the information entered into the ORNL record system has been modified a number of times. Initially, waste information was entered into the system using what was called MOD 1 input. For MOD 1, only data on waste volumes were stored, although fissile waste was noted and entered separately. MOD 1 input was used for SWSA 6 data from January 1962 to December 1974. Starting in January 1975, inventory data were input using what was called MOD 2, which consisted of information on volume (both combustible or noncombustible and compactible or noncompactible) and the activity of the waste using certain nuclear material codes. MOD 2 data lack information on radionuclides other than those included on the special nuclear materials lists. MOD 2 was used for only a short time (January 1975 to March 1977).

In March 1977, the National Low-Level Waste Management Program established a nationwide data retrieval system for DOE-generated LLW called the Solid Waste Information Management System (SWIMS). At this time, ORNL initiated MOD 3 data input, which included more detailed information on radioisotopes in the waste and which provided output that was compatible with SWIMS requirements. SWIMS required that LLW volumes and activity levels be itemized in eight nuclide categories: transuranium (TRU), uranium/thorium, fission product, induced activity, tritium, beta-gamma TRU, alpha, and other. A detailed description of the eight nuclide categories is given by Batchelder (1980). Data on the chemical and physical forms of the radionuclides were not required in the data input. Two of these nuclide categories (TRU and beta-gamma TRU) are retrievably stored in facilities outside of SWSA 6 and are not disposed in SWSA 6.

Although not entered into the computerized inventory system, a written log is maintained by the ORNL Engineering Division. This log documents the dates of excavation of the disposal units (trenches and wells) and the time at which the units are filled and covered. The log also contains information regarding the intended use (such as for storage of high- or low-activity wastes) of the disposal unit.

## 1A.2 SWSA 6 INVENTORY RECORDS

Inventory data recorded in the ORNL Solid Waste Disposal Log for SWSA 6 are summarized in Tables 1A.1 and 1A.2. Table 1A.1 summarizes the total activity disposed in each class of disposal unit by year. Table 1A.2 presents the activities of individual radionuclides disposed each year.

It is emphasized that the information in Tables 1A.1 and 1A.2 is based only on the ORNL Solid Waste Disposal Log, which is known to be incomplete. For example, the early portions of the ORNL inventory system do not record the amount of activity buried. However, based on existing reports, it is estimated that about 470,000 $ft^3$ of waste containing 45,000 Ci was buried during the period prior to 1977 (Boegly 1984).

Since 1977, MOD 3 information on the amount of radioactivity in each of the six nuclide categories (by totals and by individual nuclides) has been required for each waste shipment to the SWSAs. It should also be noted that the 809,347.1 Ci recorded as buried since 1977 is inventoried as follows:

- 650,871 Ci were europium isotopes (80.41%)
- 48,910 Ci were cobalt-60 (6.04%)
- 43,997 Ci were cesium-137 (5.44%)
- 32,135 Ci were iridium (3.97%)
- 7,910 Ci were tritium (0.97%)
- 7,362 Ci strontium-90 (0.91%)

These nuclides make up 97.75 percent of the total activity buried from 1977 to 1990; the remaining 18,210.31 Ci are listed as unidentified or comprise smaller amounts of other nuclides.

## 1A.3 DISPOSAL BY WASTE UNIT TYPE

Tables 1A.3 through 1A.5 provide summary information on the amounts and types of waste disposed in the trenches (Tale 1A.3), auger holes (Table 1A.4), and the active waste disposal units (Table 1A.5). Table 1A.6 briefly describes the WAG 6 experimental areas and the waste disposed therein.

# Appendix 1A Tables

Table 1A1. Total activity disposed in each type of disposal unit in SWSA 6, by year

| | SA | SB | SH | SL | TA | TB | TH | TL | TQ | TUM1 | TUM2 | WF | WH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1971 | | | | | | | | | | | | | 1.00E-03 |
| 1972 | | | | | | | 1.00E-03 | | | | | | |
| 1975 | | | | | | | 1.00E-03 | | | | | 1.00E-05 | |
| 1976 | | | | | | 3.00E-04 | | | | | | | |
| 1977 | | | | | | 5.30E+01 | 8.51E+01 | 4.79E+02 | | | | 1.47E-02 | 3.19E+03 |
| 1978 | | | | | 1.00E-06 | 1.59E+02 | 1.12E+03 | 1.89E+02 | | | | 8.30E-04 | 2.01E+03 |
| 1979 | | | | | 1.00E-03 | 1.09E+02 | 3.28E+01 | 6.28E+02 | | | | 8.20E-02 | 4.27E+03 |
| 1980 | | | | | 2.01E-03 | 1.15E+02 | 7.11E+01 | 1.71E+02 | | | | 3.60E-01 | 5.70E+04 |
| 1981 | | | | | | 9.35E+01 | 8.49E+01 | 5.78E+01 | | | | 7.40E-04 | 1.14E+05 |
| 1982 | | | | | 1.12E-07 | 9.83E+01 | 1.56E+01 | 5.37E+01 | | | | 3.65E-03 | 7.69E+03 |
| 1983 | | | | | 1 10E-03 | 9.46E+01 | 2.03E+00 | 2.43E+03 | | | | 5.04E+00 | 2.84E+03 |
| 1984 | | | | | 1 00E-02 | 1.27E+02 | 5.46E+01 | 6.86E+03 | | | | 1.06E-01 | 1.86E+03 |
| 1985 | | | | | 1.10E+00 | 1.98E+02 | 3.52E+03 | 5.36E+02 | | | | | 1.01E+04 |
| 1986 | (a) | | 1.47E+02 | 1.83E+02 | 1.00E-04 | 3.63E-01 | 6.83E-01 | 1.65E+03 | 2.08E-02 | 9.48E+00 | | 9.16E+02 | 1.14E+04 |
| 1987 | 1.35E-03 | | 6.64E+01 | 5.36E+01 | | 7.74E-03 | | 2.00E-03 | 1.88E+00 | 1.86E+01 | 9.88E-01 | 1.34E-03 | 5.57E+05 |
| 1988 | 4.65E-02 | | 4.49E+01 | 2.35E+01 | | 7.79E-03 | 1.28E+01 | | 9.21E-01 | 1.22E+01 | 1.59E+01 | 1.74E+02 | 1.26E+04 |
| 1989 | 2.63E-03 | | 3.58E+01 | 1.31E+01 | | 5.21E-03 | 1.70E-03 | | | 1.90E+01 | 3.40E+00 | 4.25E+01 | 4.63E+03 |
| 1990 | 3.12E-02 | 5.40E-04 | 6.78E+00 | 2.89E-01 | 1.90E-04 | 5.47E-03 | | | | 4.67E-01 | 2.90E+00 | 5.20E-04 | 7.14E+02 |
| Total[b] | 0.08168 | 0.00054 | 300.88 | 273.489 | 1.1142111 | 1047.789 | 4950.477 | 13054.502 | 2.8218 | 59.747 | 23.188 | 1138.1098 | 789304 |

[a]No entry - implies negligible Ci content
[b]Total activity disposed in all types of disposal units: 810,156.2

SA: Asbestos waste silos
SB: Biological waste silos
SH: High activity waste silos
TA: Asbestos waste trenches
TB: Biological waste trenches
TH: High activity waste trenches
TL: Low activity waste trenches
TQ: Quadrex Boxes
TUM1: Tumulus 1
TUM2: Tumulus 2
WF: Fissile auger holes
WH: High activity waste auger holes

## Table 1A.2 Activities of individual radionuclides disposed in SWSA 6, by year (curies)

| Nuclide | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ag-110m | | | | | | | | | | | | | | | | | 6.5E-02 | | | 0.065 |
| Ag-111m | | | | | | | | | | | | | | | | | 2.2E-01 | | | 0.22 |
| Am-241 | | | | | | 3.1E-03 | 3.3E+00 | 9.7E-03 | | 3.0E-04 | 4.4E-02 | 4.9E-02 | 8.0E-04 | 2.6E-03 | 1.1E-01 | 3.4E-02 | 8.1E-04 | 2.4E-04 | 7.0E-03 | 3.62345 |
| Am-243 | | | | | | 1.1E-05 | | 4.0E-05 | | | | | | 1.0E-04 | 3.0E-05 | 2.0E-05 | 1.1E-03 | 6.1E-03 | | 0.007401 |
| Be-10 | | | | | | | 2.1E-01 | | | | 4.0E+02 | | | 1.0E-06 | | | | 3.2E-03 | | 0.2532 |
| Bi-207 | | | | | | | | | | | | | | | | | 5.0E-01 | | | 0.5 |
| Bk-249 | | | | | | 1.0E-06 | | | | | | | | 1.0E-04 | | 2.0E-05 | | | | 0.000121 |
| Br-82 | | | | | | | | | | | | | | | 2.0E-04 | | | | | 0.0002 |
| C-14 | | | | | | 2.2E+01 | 3.9E+01 | 2.5E+01 | 2.8E+01 | 2.2E+01 | 2.7E+01 | 2.6E+01 | 6.4E+01 | 1.6E+01 | 2.5E-03 | 1.0E-01 | 4.9E-03 | 5.3E-02 | 5.0E-02 | 267.2529 |
| Cd-113m | | | | | | | | | | | | 3.0E+00 | | | | | | | | 3.0 |
| Cf-249 | | | | | | | | | | | | | | | 3.0E-05 | 1.2E-03 | 1.1E-04 | 1.0E-04 | | 0.01155 |
| Cf-252 | | | | | | 5.6E-04 | 1.1E-03 | 2.1E-04 | | | | | 7.3E-03 | 2.1E-03 | | 2.9E-02 | 1.1E-04 | | | 0.04038 |
| Cl-36 | | | | | | | | | | | | | | | | 1.5E-01 | | | | 0.15 |
| Cm-242 | | | | | | 5.0E-06 | | | | | | | | | | | | | | 0.000005 |
| Cm-244 | | | | | | 1.0E+00 | 3.4E+00 | 3.2E-03 | 5.0E-01 | 1.5E-03 | 4.2E-02 | 1.2E-01 | 5.5E-01 | 2.2E+01 | 2.3E-01 | 1.5E-03 | 2.5E-02 | 5.1E-01 | 3.1E-03 | 28.41475 |
| Cm-248 | | | | | | | | | | | | | | | | 1.2E-04 | | | | 0.00012 |
| Co-58 | | | | | | | | | | | | | | | | | | 3.8E+01 | 1.0E-04 | 38.0001 |
| Co-60 | | | | | | 1.6E+03 | 7.9E+01 | 3.6E+02 | 5.6E+02 | 1.6E+04 | 3.0E+03 | 6.9E+02 | 6.2E+03 | 5.0E+03 | 1.9E+03 | 1.0E+04 | 3.1E+02 | 2.1E+03 | 1.0E+01 | 47832.772 |
| Cr-51 | | | | | | | | | | | | | | | 2.6E+01 | | | | | 26.015 |
| Cs-134 | | | | | | 2.1E-02 | 3.9E+00 | 4.7E-01 | 1.8E-02 | | 2.0E-03 | 1.9E-02 | 1.0E-02 | 2.0E-01 | 1.2E+01 | 1.5E+00 | 6.8E-01 | 1.0E+00 | 2.0E-01 | 20.656 |
| Cs-137 | | | | | | 1.1E+02 | 2.0E+02 | 1.3E+02 | 1.4E+03 | 2.4E+02 | 6.9E+02 | 9.3E+02 | 1.2E+03 | 3.2E+03 | 5.1E+03 | 2.6E+04 | 4.1E+03 | 1.1E+03 | 2.5E+02 | 44685.938 |
| Cu-64 | | | | | | | | | | | | | | | 5.0E-05 | | | 6.6E-02 | | 0.07677 |
| Es-253 | | | | | | | | | | | | | | | 1.0E-04 | | | | | 0.0001 |
| Es-254 | | | | | | | | | | | | | | | | 1.1E-04 | | | | 0.00011 |
| Eu-152 | | | | | | 2.0E+00 | 3.0E+00 | 3.5E+03 | 2.0E+04 | 2.7E+04 | 2.0E+01 | 1.1E+02 | 1.4E+02 | 5.1E+01 | 1.3E+03 | 2.5E+05 | 2.6E+03 | 2.9E+02 | 1.0E+02 | 305116.9 |
| Eu-154 | | | | | | 1.5E+03 | 1.0E-04 | 4.0E+00 | 2.2E+04 | 4.9E+04 | 1.4E+01 | 9.5E+00 | 7.9E+01 | 4.7E+01 | 1.3E+03 | 1.8E+05 | 1.4E+03 | 9.4E+00 | 1.1E+02 | 25,654871 |
| Eu-155 | | | | | | | | 5.0E-02 | 1.0E+04 | 2.1E+04 | | | 1.6E+00 | | | 5.8E+04 | | | | 89,001.65 |
| Eu-156 | | | | | | | | | | | | | | | | 3.1E+02 | | | | 310 |
| Fe-55 | | | | | | | 1.0E-06 | 7.5E-01 | 1.0E-06 | | | | 1.0E+01 | | | 1.0E-01 | 7.0E-05 | 1.7E-03 | | 10.857 |
| Fe-59 | | | | | | | | | | | | | | | 4.5E+00 | 1.8E+00 | 7.6E-02 | 2.9E+01 | 1.0E-04 | 35.426 |
| Ga-67 | | | | | | | | | | | | | | | 2.0E-03 | | | | | 0.002 |
| Gd-153 | | | | | | | | | | | | | | | 2.0E+02 | 4.2E+03 | 3.8E-01 | 6.6E-01 | 8.3E-02 | 4402.2923 |

## Table 1A.2 (continued)

| Nuclide | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Co-67 | | | | | | | | | | | | | | | 5.0E-05 | | | | | 1.2099 |
| Co-68 | | | | | | | | | | | | | | | | 3.4E-04 | | | | 0.00034 |
| H-3 | | | | | | 7.6E+01 | 1.0E+03 | 5.8E+02 | 7.3E+01 | 2.4E+01 | 2.7E+03 | 2.3E+03 | 3.1E+02 | 5.2E+02 | 3.4E+00 | 1.3E+00 | 2.5E+02 | 2.0E+01 | 8.5E-03 | 7861.9041 |
| I-125 | | | | | | | | | | | | | | | 7.3E-04 | 2.8E-04 | 1.2E-03 | 6.4E-04 | 5.1E-04 | 0.0887 |
| I-131 | | | | | | | | | | | | | | | 1.1E-03 | 6.9E-02 | 4.0E-03 | 1.1E+00 | | 1.21338 |
| In-111 | | | | | | | | | | | | | | | 3.1E-04 | | | | | 0.03959 |
| Ir-192 | | | | | | | | | | | | | | | 4.1E+03 | 2.5E+04 | 2.2E+03 | 2.7E+01 | 2.8E-01 | 31331.347 |
| K-40 | | | | | | | | | | | | | | | 6.4E-04 | | | 1.7E-03 | | 0.00234 |
| Kr-85 | | | | | | | | | | | | | | | 1.0E+00 | | 1.7E-02 | | | 1.0406 |
| Mn-54 | | | | | | | | | | | | | | | 6.0E-05 | | 7.6E-02 | 3.3E+01 | 1.0E-03 | 53.09206 |
| Na-22 | | | | | | 5.3E-01 | 1.1E-02 | | | | | | | | | 1.5E-03 | | 2.3E-04 | | 0.55973 |
| Nb-93m | | | | | | | | | | | | | | | 4.0E-02 | | | | | 0.04 |
| Ni-63 | | | | | | | 1.0E-03 | 2.0E-06 | | | | | | | | 2.3E-01 | 5.8E-02 | 8.3E-02 | | 0.574 |
| Np-237 | | | | | | | 3.0E-07 | | | 1.5E-04 | 2.3E-04 | 7.0E-05 | | 5.0E-04 | | 6.0E-05 | | | | 0.009 |
| Os-191 | | | | | | | | | | | | | | | 2.4E-01 | 1.0E-05 | 3.5E-02 | | 5.3E-02 | 0.09774 |
| Other | | | | | | | 2.5E-03 | 5.0E-03 | | | | | | | | | | | | 0.0075 |
| P-32 | | | | | | | | | | | | | | | 1.0E-03 | | | | 8.0E-05 | 0.00108 |
| Pd-103 | | | | | | | | | | | | | | | | | 2.2E+00 | 2.4E+00 | 2.8E-01 | 4.88142 |
| Pd-107 | | | | | | | | | | | | | | | | | 6.5E-02 | | | 0.065 |
| Pm-147 | | | | | | 5.0E+01 | 8.5E+01 | 1.0E-03 | 9.0E+00 | 5.0E-01 | | 2.0E-01 | | | 2.0E+01 | 1.2E-01 | 4.8E+01 | 2.2E-02 | 2.0E-05 | 212.329 |
| Pt-195 | | | | | | | | | | | | | | | | | | | 2.0E-05 | 0.00055 |
| Pu-238 | | | | | | 1.0E-02 | 1.7E-02 | | 1.0E-07 | 1.0E-06 | 2.0E-03 | 1.3E-05 | 1.0E-06 | | | 6.1E-04 | 1.9E-03 | 1.3E-04 | | 0.032745 |
| Pu-239 | | | | | | 1.2E-02 | 8.3E-04 | 9.7E-03 | 1.8E-06 | 5.1E-04 | 2.2E-03 | 1.0E-01 | 9.2E-03 | 2.1E-02 | 2.0E-01 | 4.2E-02 | 2.9E-03 | 1.1E-03 | | 0.85492 |
| Ra-226 | | | | | | | | | | | | | | | 1.0E-03 | | 8.5E-04 | | | 0.00355 |
| Ra-229 | | | | | | | | | | | | | | | | | | 3.2E-03 | | 0.0032 |
| Ru-106 | | | | | | | 1.0E+01 | 2.0E-02 | 5.0E-07 | | | | | 3.3E+03 | | 1.0E-05 | | | | 3310.0202 |
| Sm-151 | | | | | | 5.5E+01 | 1.6E+01 | 1.5E+01 | 1.1E+02 | 7.0E+00 | | | | | | | | | | 203 |
| Sn-121m | | | | | | 2.0E+00 | 7.5E+00 | | | | | | | | | | | | | 9.5 |
| Sr-85 | | | | | | | | | | | | | | | 1.2E-03 | 1.0E-03 | | | | 0.0052 |
| Sr-89 | | | | | | | | | | | | | | | | 5.1E+00 | | | | 5.1 |
| Sr-90 | | | | | | 9.5E+00 | 1.9E+02 | 9.8E+01 | 2.4E+03 | 1.5E+02 | 5.1E+01 | 2.6E+01 | 1.5E+01 | 3.1E+01 | 1.3E+02 | 1.2E+03 | 1.8E+03 | 1.0E+03 | 2.5E+02 | 7369.124 |
| Ta-179 | | | | | | | | | | | | | | | | | | 8.3E-02 | 1.7E-03 | 0.0847 |

## Table 1A.2 (continued)

| Nuclide | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ta-182 | | | | | | | | | | | | | | | 3.0E+02 | 3.1E+00 | 3.6E+00 | 2.1E+00 | | 808.975 |
| Tc-99 | | | | | 3.0E-04 | 2.0E-03 | 1.8E+00 | 3.3E+01 | 1.0E-01 | 1.1E-02 | 1.0E-07 | 8.0E-01 | 1.0E+00 | 2.0E-01 | | 1.1E-01 | 1.0E-03 | 4.1E-01 | | 37.52357 |
| Th-228 | | | | | | | | | | | | | | | | 2.4E-04 | | 1.0E-05 | | 0.00725 |
| Th-229 | | | | | | | | | | | | | | | | | | | 7.5E-03 | 0.0075 |
| Th-230 | | | | | | | | | | | | | | | | | 3.0E-03 | | | 0.0030 |
| Th-232 | | | | | | 2.0E-103 | 1.0E+00 | 3.4E-02 | 4.3E-01 | 3.3E-04 | 2.2E-02 | 5.2E-01 | 5.2E-01 | 8.5E-04 | 1.1E-04 | 1.2E-01 | 1.5E-03 | 5.0E-05 | 1.8E-04 | 2.65166 |
| Th-234 | | | | | | | | | | | | | | | | | 4.9E-04 | | | 0.00049 |
| U-232 | | | | | | | | | | | | | | | 2.8E-04 | 1.1E-02 | | | | 0.01139 |
| U-233 | | | | | | 2.2E-02 | 3.3E+00 | 1.1E-02 | 1.2E-03 | 3.0E+00 | 5.0E-01 | 1.2E-01 | 2.2E+02 | 1.2E-02 | 1.6E-01 | 9.4E-02 | 1.1E-02 | 1.5E-03 | 6.0E-04 | 227.321 |
| U-234 | | | | | | | | | | | | | | | | 1.0E-05 | | | | 0.00001 |
| U-235 | | | 1.8E-03 | 4.7E-103 | | 4.6E-03 | 1.7E-03 | 9.8E-04 | 5.3E-03 | 2.6E-04 | 1.0E-01 | 5.0E-02 | 4.0E-01 | 3.6E-04 | 2.3E-04 | 1.5E-03 | 1.2E-02 | 3.5E-04 | 5.2E-04 | 0.34287 |
| U-236 | | | | | | | | | | | | | | | | | | 7.0E-05 | | 0.00007 |
| U-238 | | | 5.0E-02 | 3.5E-01 | 1.2E-08 | 1.4E-01 | 1.0E+00 | 2.2E-01 | 4.3E-01 | 5.2E-01 | 6.0E-01 | 1.1E-01 | 2.0E+02 | 6.0E-02 | 1.4E-02 | 2.7E-02 | 1.4E-02 | 5.1E-03 | 1.0E-02 | 203.558 |
| Unid | 1.0E-03 | 7.5E-01 | | 5.0E+00 | | 4.1E+02 | 1.8E+03 | 3.6E+02 | 6.5E+02 | 8.7E+02 | 1.1E+03 | 1.2E+03 | 4.6E+02 | 4.2E+02 | 4.0E-02 | | 5.1E-03 | | | 7275.80 |
| Y-90 | | | | | | | | | | | | | | | 4.0E-01 | 2.4E+00 | 5.0E+01 | 2.7E-03 | 1.7E+00 | 54.7379 |
| Zn-65 | | | | | | | | | | | | | | | | | 1.5E+01 | | | 15.0 |
| Zr-93 | | | | | | 5.1E-03 | 1.0E+01 | 5.9E+00 | 7.3E+00 | | | | | | | | | | | 14.2051 |
| Zr-95 | | | | | | | | | | | | | | | 1.0E-04 | | | | | 0.00016 |
| TOTAL | 1.0E-03 | 7.5E-01 | 5.2E-02 | 5.4E+00 | 3.0E-04 | 3.9E+03 | 3.5E+03 | 5.1E+03 | 5.8E+04 | 1.1E+05 | 8.0E+03 | 5.3E+03 | 8.9E+03 | 1.3E+04 | 1.4E+04 | 5.6E+05 | 1.3E+04 | 4.7E+03 | 7.2E+02 | |
| S-35* | | | | | | | | | | | | | | | | | | | | 0.00115 |
| K-43* | | | | | | | | | | | | | | | | | | | | 0.00083 |
| Mfp* | | | | | | | | | | | | | | | | | | | | 0.00033 |
| Ge-68* | | | | | | | | | | | | | | | | | | | | 0.0586 |
| Ar-39* | | | | | | | | | | | | | | | | | | | | 0.0013 |
| Ce-141* | | | | | | | | | | | | | | | | | | | | 0.00018 |
| Hg-203* | | | | | | | | | | | | | | | | | | | | 0.00054 |
| Pb-210* | | | | | | | | | | | | | | | | | | | | 0.0171 |
| Sr-119m* | | | | | | | | | | | | | | | | | | | | 0.035 |
| U-204* | | | | | | | | | | | | | | | | | | | | 0.05 |
| W-188* | | | | | | | | | | | | | | | | | | | | 0 0017 |
| Tc-95m* | | | | | | | | | | | | | | | | | | | | 0.0001 |

*Year-by-year activities for these rare radionuclides are not provided because of their negligible amounts. An estimated total is provided for each.

## Table 1A.3. Trench disposal units

| Category | Number as of 12/90 | Projected number for period 1/91-5/92 | Approximate area (acres) | Inventory[a] (curies) | Description |
|---|---|---|---|---|---|
| High activity | 49 | 0 | 2.50 | 4950 | High-activity trenches were used for disposal of wastes with a radiation reading on the surface of the container equal to or greater than 200 mR/h. In general, this waste contained low-level beta/gamma activity and/or non-fissile alpha activity. Wastes disposed in the high-activity trenches include wastes from inside hot cells and glove boxes used for work on pure beta emitters; these packages may read less than 200 mR/h on the package surface. After being placed in the trench, wastes were covered with sufficient soil to lower the radiation reading at the ground surface to 100 mR/h or less. The period of active disposal for each trench was approximately 6 to 8 months. |
| Low activity | 190 | 0 | 7.0 | 13,054 | The low-activity trench wastes were used to dispose of waste with radiation readings on the container surface of less than 200 mR/h. This waste contained a wide variety of materials including metal, wood, construction debris, concrete, paper, plastic, gloves, and shoe covers. Prior to June 1985, materials were just dumped into trenches; after that time, most waste was either packaged in plywood boxes and stacked in the trenches or packed in 208-L mild steel drums and stacked in a horizontal array in the trench. Contaminated soil and concrete from excavation projects have also been dumped into low-activity trenches. Two trenches (TL 120 and TL 346) have been reported to have received installation fluids. In addition to radioactive waste, certain low-activity trenches are known to have received waste containing lead containers, lead shielding, and lead packaging. Low-activity trenches were usually active for a period of 6 to 8 weeks. |
| Biological | 203* | 3 | 4.50 | 1,048 | Biological trenches were used for disposal of carcasses, bedding, excreta, and any material associated with a biomedical laboratory, such as gloves, blotter paper, and shoe covers. Waste contained in the biological trenches is predominantly very low-activity, non-alpha contaminated waste with surface radiation readings of less than or equal to 200 mR/h, with most at approximately 5 mR/h. To conserve trench space, vertical metal dividers were placed about 8 ft apart to prevent soil cover over wastes in one portion of a trench from sloughing into unused trench space. Biological trenches were generally active for approximately 6 weeks. |

**Table 1A.3 (continued)**

| Category | Number as of 12/90 | Projected number for period 1/91-5/92 | Approximate area (acres) | Inventory[a] (curies) | Description |
|---|---|---|---|---|---|
| Asbestos | 36 | 0 | 1.20 | 1.114 | The asbestos trenches have been used for disposal of both radioactively contaminated and non-contaminated asbestos from ORNL. The wastes include a variety of materials, such as bagged asbestos insulation, asbestos pipe and pipe insulation, and construction rubble from renovation and demolition of buildings and equipment. To conserve trench space, vertical metal dividers were placed about 8 ft apart to prevent soil cover over wastes from sloughing into unused portions of the trench. |
| Baled | 16 | 0 | 0.60 | 451 | Compactible radioactive waste is a special category of low-activity, low-level waste consisting of non-alpha, radioactively contaminated material such as plastic bags, sheets, blotter paper, rubber, gloves, shoe covers, rags, and soft plastic bottles. The waste was compacted into bales weighing approximately 650 lb each. The compaction process resulted in a volume reduction ratio of approximately 8 to 1. |
| Fissile | 4 | 0 | 0.05 | No records | Waste containing U-235 or the waste that contains other isotopes such as Cs-137, U-238, or Sr-90 mixed with U-235. |

[a]Inventory is appropriate due to ongoing radionuclides decay and incomplete records.

*Four of the 203 biological trenches were active during August 1988 to June 1990.

## Table 1A.4. Auger hole disposal units

| Category | Number as of 12/90 | Approximate area (acres) | Inventory[a] (curies) | Description |
|---|---|---|---|---|
| High Activity | 454 | 1.10 | 789,304 | High activity auger hole wastes contain any high-activity wastes not classified as fissile. Physical characteristics of t high-activity waste dictated whether it would be disposed in the high- activity trenches or auger holes. If the waste cou physically fit in an auger hole, it was placed there. Large boxes, equipment, or other debris too large for auger holes were put into trenches. |
| Fissile | 100 | 0.27 | 1138.1 | Any material that contains U-235 is classified as fissile was In addition to U-235, fissile waste may also contain other isotopes such as Cs-137, U-238 or Sr-90. |
| Solvent | 37 | 0.1 | ≈1000 | Solvent auger holes received a variety of chemical wastes before 1986, some of which were radioactively contaminate Wastes disposed in solvent auger holes included oils, cleani solutions, alcohols, paint thinners, kerosene, jet fuel, acids, sodium, and miscellaneous solvents and other chemicals. Containers for chemical wastes ranged from small bottles an cans up to 208-L drums. Some chemical wastes were pour directly into solvent auger holes. |

[a]Inventory is approximate due to ongoing radionuclide deay and in complete records.

**Table 1A.5. Active waste disposal units**

| Category | Number as of 12/90 | Projected number for period 1/91-5/92 | Approximate area (acres) | Inventory[a] (curies) | Description |
|---|---|---|---|---|---|
| Silos: | | | | | Since May 1986, high-activity and low-activity wastes as described above have been placed in GCD units. These units are most frequently referred to as silos. The silos are approximately 8-ft diameter and 20-ft deep with concrete floors and 6-in. concrete walls, and are constructed below grade. Wastes are placed in the silos until the silos are filled within 3 ft of the top. |
| Low activity | 93 | 80 | 0.5 | 273.5 | |
| High activity | 53 | 35 | 0.4 | 300.88 | |
| Asbestos | 3 | 3 | 0.04 | 0.08168 | |
| | | | | | The GCD silos were constructed using 3 different techniques. The initial 12 silos were constructed using precast concrete drainage pipe. Four pipes were placed vertically adjacent to one another in each of three trenches. The trench around the pipes was then backfilled, and a steel-reinforced concrete bottom was poured into each silo. The joint between the concrete silo walls and floor was sealed with tar (Baldwin et al. 1989). |
| | | | | | The second construction technique, which was used to construct 24 silos, consisted of using 2 diameters (8 ft and 9 ft) of corrugated metal pipe as forms for pouring the concrete sidewalls. The 2 pipes were aligned vertically, positioned concentrically, and attached with welded struts. The bottoms were formed by pouring a steel-reinforced concrete floor and sealing the joint between the inner corrugated metal pipe and the concrete floor with tar. |
| | | | | | Early monitoring indicated that some water was present in the silos. The integrity of the joint between the concrete floor and sidewalls was the suspected source (Baldwin et al. 1989). This resulted in development of a third construction technique. As in the previous construction method, corrugated metal piping was used as forms for pouring the concrete sidewalls. However, the inner of the two pipes was raised approximately 1 ft above the outer pipe before being welded in place. The floor was then poured first, using the outer metal pipe as its sidewall. This technique resulted in a concrete-to-concrete joint. |

**Table 1A.5 (continued)**

| Category | Number as of 12/90 | Projected number for period 1/91-5/92 | Approximate area (acres) | Inventory (curies) | Description |
|---|---|---|---|---|---|
| GCD Auger Holes or Silo Wells | 84 | 29 | 0.35 | 581,777 | A variation of the GCD silo as described above is the GCD silo well. These wells are constructed by placing vertical iron pipes within the silo and grouting the annular space between the outer silo wall and the iron pipes. Wastes are placed within the pipes (or "wells") and subsequently covered with shielding until the pipes are filled to within several feet of the top. The wells are then grouted to the surface and covered with a concrete cap.<br><br>GCD silo wells are used for disposal of fissile wastes and for the disposal of radioactively contaminated asbestos. Fissile waste is waste contaminated with uranium-235 and may also contain other radionuclides such as cesium-137, uranium-238, or strontium-90 mixed with uranium-235. Asbestos wastes consist of a variety of materials such as bagged asbestos insulation and asbestos pipe. These wastes are generated during renovation and demolition of buildings and equipment. |
| Tumulus | 1 | 1 | 0.35 | 82.94 | There are two tumulus facilities at SWSA 6: Tumulus I and Tumulus II. The tumulus technology involves sealing prepackaged waste in concrete vaults, stacking the vaults on a concrete pad, and then covering the vaults with a low permeability cap. The wastes placed in the tumulus are initially packaged in 55-gal drums or 100-cubic ft metal boxes. The packages have surface radiation readings of less than 200 mR/h. These waste packages are then placed in 5.5 ft square by 8 ft tall concrete casks. The casks are constructed of high-strength concrete reinforced with epoxy-coated steel. Radiation readings at the surface of the casks range from 1 to 30 mR/h. After the waste containers are placed in the vault, voids between containers are grouted. A precast concrete lid is then placed on the vault and the vault is transferred to the pad. When the pad is fully loaded with vaults, the tumulus will be covered with a low permeability cap.<br><br>The Tumulus I pad is loaded to capacity and temporarily covered with a plastic tarp, and the Tumulus II pad is currently being loaded. |

**Table 1A.5 (continued)**

| Category | Number as of 12/90 | Projected number for period 1/91-5/92 | Approximate area (acres) | Inventory[a] (curies) | Description |
|---|---|---|---|---|---|
| IWMF | NA | NA | 0.5 | NA | The IWMF will use the tumulus technology described for Tumulus I and II. The facility, which is expected to begin operations in September 1991 and close in September 1996, will consist of up to 6 tumulus pads measuring approximately 4,500 sq ft. The wastes placed in the IWMF will be Class II solid LLW. Class II waste is defined as fission-product material which will be environmentally acceptable after 100-300 years of radioactive decay. The IWMF may also accommodate high range waste and incorporate shielding in order to meet ALARA standards. |
| Low Hazard Contaminated Waste Landfill | NA | NA | 0.4 | [b] | "Low hazard contaminated waste" or "suspect waste" is waste that has no measurable surficial contamination, but has been judged by the generator to be radioactively contaminated above ORNL "Health Physics material Transfer Clearance Tag" (free of radiation or contamination hazard) limits, or to be such that all surfaces of the waste cannot be surveyed (such as the inside of a pipe). As feasible, the waste is shredded to reduce its volume before landfilling. Landfill waste is then covered with soil, often with soil excavated for disposal trenches or silo construction. |

[a]Inventory is approximate due to ongoing radionuclide decay and incomplete records.
[b]Negligible.

## Table 1A.6 Experimental areas

| Category | Aprpoximate Area (Acres) | Inventory[a] (Curies) | Description |
|---|---|---|---|
| Hill Cut Disposal Test Facility (HCDTF) | 0.3 | ≈50 | The HCDTF, located in the northwest corner of SWSA 6, was created as a demonstration project to evaluate the use of hillslope cuts for disposal of high activity, low-level radioactive waste and to determine the resultant degree of hydrologic isolation.<br><br>The HCDTF is comprised of a 15 by 15 ft concrete pad and a runoff collection system placed in a cut on the side slope of a hill. For the demonstration, 27 concrete boxes were stacked on the pad in a 3 × 3 × 3 array. Each box measures 3.5 ft wide, 4.5 ft long and 3.5 ft high. The HCDTF concrete boxes contain solid LLW; 8 or 9 of the boxes contain soil contaminated with radioactive isotopes of europium. The total radioactivity based upon available records is 39 Ci for 23 of the 27 boxes. No data are available for 4 of the boxes. Surface radiation readings were recorded for all boxes. One box had a maximum reading of 2,200 mrem/hr and 9 more had maximum readings greater than 100 mrem/hr. The mean reading was 110 mrem/hr. Boxes with the highest activity were placed at the bottom of the stack. Information from the Solid Waste Management System database indicates that the low-level waste contained in the concrete boxes consists of cesium-137, strontium-90, europium-152, europium-154, and other isotopes. Once stacked, these boxes were covered with soil (Clapp 1989).<br><br>The project, which began in 1981, was discontinued in 1982 but reactivated in 1985 as a joint Operations Division and Low Level Waste Disposal Development and Demonstration (LLWDDD) project. At that time, the HCDTF was considered the best available test method for disposing of high activity, low-level waste. The demonstration provided LLWDDD the opportunity to evaluate the use of hillslope cuts as potential sites for future engineered disposal facilities. Wastes were loaded and runoff and water levels monitored beginning in August and September, 1986. In early 1987, LLWDDD discontinued its support because the overall scope of the project was too limited (Clapp 1989). |
| Engineered Test Facility (ETF) | 0.25 | Negligible | The ETF, a field-scale demonstration site consisting of 9 trenches, was established in SWSA 6 to carry out investigations for improved SLB technology. ETF wastes consist of low-activity baled wastes originating from waste packages with surface radiation readings of less than 200 mR/h. Three of these trenches have been grouted, 3 are lined with an impermeable liner, and 3 were backfilled with soil (i.e., no special trench preparation or waste treatment). Originally, the investigations were to focus on waste grouting prior to cover emplacement and on waste isolation with trench liners to prevent the waste from contacting water, thus minimizing waste leaching (Davis et al. 1984). The grouting demonstrations were eventually conducted elsewhere. |

**Table 1A.6 (continued)**

| Category | Approximate Area (Acres) | Inventory[a] (Curies) | Description |
|---|---|---|---|
| Engineered Test Facility (ETF) (Continued) | 0.25 | Negligible | The ETF was characterized in order to construct a hydrologic model based on geology, soils, and hydrology (Davis et al. 1984). Site characterization activities were initiated in 1981 with emphasis on geological characterization at shallow depths where the waste lie. Radionuclide, chemical, and physical properties were determined using core samples taken nearby at depths ranging from 16 to 115 ft. |
| EPICORE | 0.30 | Negligible | The EPICORE-II research site is located on the north side of SWSA 6 and covers approximately 1250 $ft^2$ (Rogers et al. 1990). This site has been used to evaluate the long-term leachability of solidified radioactively-stressed ion exchange resin samples from EPICOR-II prefilter liners. The resin samples originated from EPICOR-II prefilter liners PF-7 and PF-24, which were used to decontaminate water from the Auxiliary and Fuel Handling Building at Three Mile Island Unit-2 (Davis et al. 1986).<br><br>In January 1985, a 35-ft by 6-ft trench was excavated and filled with crushed stone to prepare the site for the installation of an 11- to 12-in. thick concrete pad and five 10.25-ft diameter lysimeters (Davis et al. 1986). The lysimeters were filled with solidified ion exchange resin and soil and sealed at the bottom. The lysimeters were opened to precipitation in August 1985 to allow water to pass through and collect in a leachate collection reservoir. The first leachate sampling was completed in September 1985 and indicated that no detectable levels of radionuclides had yet migrated from the solidified resin samples (Davis et al. 1986). This is a long-term experiment (planned for approximately 20 years). |
| "Polymer" Trenches | 0.04 | No record | Trenches 349, 350, and 351 (designated as "polymer" trenches) were created as part of a study to evaluate the application of grouting to various soils used as trench backfills. The 3 trenches, 10 ft by 10 ft by 5 ft deep, were excavated on the eastern slope of the east disposal area. Each trench was filled with low hazard contaminated waste to within 1 ft of the ground surface. The waste included concrete blocks, tires, pipes, scrap metal, discarded electronic equipment, wood pallets, assorted shipping cartons, and paper waste (Spalding et al. 1985). Trenches 349 and 350 were grouted with sodium silicate, and Trench 351 was grouted with acrylamide.<br><br>Adjacent to the above trenches is Trench 399, which is documented to contain approximately 1 Ci of radioactive waste. All 4 trenches lie near the toe of the low hazard contaminated waste landfill (described above), and will soon be covered by landfill wastes. |

[a]Inventories are estimates.

# APPENDIX 1B. PREVIOUS INVESTIGATIONS AND ONGOING MONITORING PROGRAMS

This appendix gives an overview of previous investigations and ongoing monitoring programs that contribute significantly to the understanding of WAG 6. Integration of data developed in these investigations with data developed during the WAG 6 RFI is presented in Section 3, "Site Physical Characteristics," and Section 4, "Nature and Extent of Contamination."

Section 1B.1 lists the general administrative or regulatory programs under which the investigations and monitoring were conducted. Section 1B.2 describes studies that present data primarily regarding site physical characteristics (e.g., geological profiles, groundwater levels and geochemistry, rainfall data). Studies that present significant data on radiological and chemical contamination are described in Section 1B.3. Studies for which the scope included both site physical characteristics and site contamination data are identified in more than one section.

## 1B.1 GENERAL PROGRAMS OF SITE INVESTIGATION

Most previous investigations, studies, and monitoring programs performed at SWSA 6 have been conducted under the auspices of general investigatory or regulatory programs. Some of these investigations focused exclusively on WAG 6; others focused on other areas of ORNL, but included all or parts of WAG 6 within their scope.

General programs of investigation include the following.

- **Study of ORNL contaminant releases to WOC watershed.** In April 1983, a program was initiated to assess radioactive contaminant contributions to the Clinch River from wastes buried in the WOC watershed and to implement appropriate corrective measures. The scope of work included SWSAs 5 and 6 and Seepage Trench 7 (in WAG 7). Site characterization activities conducted as part of this program are reported in periodic status reports (e.g., Duguid 1976; Tamura et al. 1980).

- **ETF site characterization.** As part of DOE research and development activities, ORNL designed and constructed an experimental facility to investigate and demonstrate the application of improved techniques for shallow land burial of LLW. One of the major program objectives was to evaluate a variety of site characterization techniques and to develop data regarding site physical characteristics. Numerous site characterization activities were conducted in support of this objective, and these activities are reported in Davis et al. (1984).

- **DOE Order 5820.2A, site characterization activities.** When SWSA 6 was opened in 1969, little guidance was provided on site characterization requirements for new LLW disposal sites. When such site characterization guidance was established (DOE Order 5820.2A and NRC 10 CFR, Part 61), ORNL compiled existing SWSA 6 site information (Boegly 1984) and subsequently prepared a characterization plan for SWSA 6 to satisfy outstanding data needs (Boegly et al. 1985). The characterization's primary emphasis was

to collect geologic and hydrologic data needed to understand the physical and geochemical environment of the SWSA. The approach taken to characterize the disposal environment focused on hydrology, geochemistry, geology, and soils. During these activities, the events described in the following paragraph transpired and resulted in a redirection of the SWSA 6 characterization activities.

- **SWSA 6 RI site preliminary characterization activities.** In May 1986, SWSA 6 was closed to burial operations by DOE, pending investigation of the disposal of RCRA-regulated wastes in the SWSA. It was determined that approximately 25% of the landfill area of the site may have been used for the disposal of RCRA-regulated wastes. In April 1986, ORNL had revised its RCRA Part A permit application to reflect that hazardous wastes had been disposed in SWSA 6 since 1980. In July 1986, the site was reopened for disposal of LLW only, and SWSA 6 was designated as a RCRA-regulated mixed waste site due to the hazardous wastes disposed there between 1980 and May 1986.

  A draft RCRA closure plan was subsequently prepared for the site and submitted to the regulatory agencies (IT 1986). The closure plan was updated and revised in 1988 (BNI 1988a) and subsequently approved. The original closure plan specified preparation and implementation of an RI plan. In December 1986, the draft RI plan was completed (ORNL 1986). The plan was submitted to the regulatory agencies for review, and ORNL began implementation of certain portions of the plan. Data collected are presented in Davis et al. (1987). In 1987, ORNL reevaluated its RI Plan and subsequently revised it.

- **Demonstration of potential closure technologies.** With the objective of developing techniques applicable to the closure of LLW shallow land burial facilities, ORNL has conducted a number of field trials of potential closure techniques. These trials have included trench dynamic compaction (Spalding 1986; Davis et al. 1989); in situ grouting of trenches (Spence, Godsey, and McDaniel, 1987; Spalding, Hyder, and Munro 1985); and ISV (Spalding and Jacobs 1989). Spalding, Jacobs, and Davis (1989) summarized most of these demonstrations in a single document. For some of these field trials, site characterization data were developed and reported in the field trial documentation. These data generally pertain to the geochemistry of trench waters and surrounding soils and, in some cases, include data pertaining to trench water and soil contaminants.

  General monitoring programs included:

- WAG 6 RCRA Compliance Monitoring Program
- RCRA ICM Monitoring Program
- DOE Order 5820.2A, Performance Assessment Monitoring Program
- SWSA 6 Active Sites Monitoring (Tumulus, LLW and Asbestos Silos, Solvent Auger Areas)

## 1B.2 SITE PHYSICAL CHARACTERISTICS

During the last two decades, a large number of studies have been performed at SWSA 6 which have generated data and information on site physical characteristics. Table 1B.1 lists specific types of data and information included in these reports.

This section describes the general scope of specific investigations that yielded site physical characteristics data. This information is presented in Tables 1B.2 through 1B.5 as follows:

- Table 1B.2, Source Areas
- Table 1B.3, Geology and Soils
- Table 1B.4, Groundwater Hydrology
- Table 1B.5, Surface Water Hydrology

Specific data not presented in this appendix are discussed in the appropriate subsections of Section 3 of the RFI report.

## 1B.3 CONTAMINANT CHARACTERIZATION DATA

The following paragraphs provide brief descriptions of the scope of investigations and ongoing monitoring programs that have yielded radiological and chemical site characterization data. Where appropriate, figures showing sampling locations and tables summarizing the data are referenced. All figures and tables referenced appear at the end of the appendix.

### 1B.3.1 Source Information—Trench Leachate Sampling

Trench leachate sampling has been performed as part of several investigations conducted by ORNL. The trenches sampled during each of these investigations are illustrated in Figure 1B.1, and the corresponding trench leachate data are tabulated in Tables 1B.6 (radiological data) and 1B.7a through 1B.7d (chemical data). A brief statement of the scope of the individual investigations is provided in the following paragraphs.

- Ashwood and Spalding (1990) conducted a multiactivity investigation to evaluate the performance of HDPE caps installed as a RCRA ICM for SWSA 6. One of the activities involved the April 1989 sampling of leachates from 22 trenches. Radiochemical analyses included gross alpha, gross beta, tritium, carbon-14, strontium-90, cesium-137, and cobalt-60. Analyses were performed for inductively coupled plasma (ICP) elements, as well as Hg, K, and Na. Volatile and semivolatile compounds were analyzed for using EPA methods 8240 and 8250, respectively. Total organic carbon, and major cations and anions were determined.

- Tamura et al. (1980) collected leachate samples from 26 trenches within SWSA 6 during 1976, as part of an ongoing ORNL project to characterize contaminants released from ORNL waste burial grounds to the Clinch River. The concentrations of strontium-90, cobalt-60, and cesium-137 were determined for each sample.

- Solomon et al. (1988) gathered trench leachate and groundwater data to help develop contaminant source terms for use in modeling future site performance. Leachate was analyzed from 14 trenches. In the laboratory, chemical analyses were performed for ICP elements, mercury, ammonia, inorganic and total carbon, and major cations and anions. For seven of the trenches, analyses were also performed for the EPA TCL. Radiological analyses included gross alpha and gross beta; specific alpha- and beta-emitting radionuclides (if indicated by gross analysis results); tritium, carbon-14, and technetium-99; and determination of gamma-emitting radionuclides by gamma spectroscopy. In addition, four of the trenches (41, 92, 257, and 288) were sampled on three separate dates to examine time-variations in radioactive contaminant concentrations and water chemistry. A comparison of trench leachate contaminant concentrations with ORNL waste disposal records indicated no useful correlation between the two.

- Spalding (1986) conducted a field demonstration of dynamic compaction on trench 271 within SWSA 6 during 1985. Water being pumped into the trench for the determination of void space and samples of the resulting trench leachate were collected and analyzed for pH, electrical conductivity, dissolved solids, hardness, alkalinity, and gross alpha and beta activity. Samples of groundwater from wells around the trench were collected prior to pumping water into the trench and were analyzed for the same parameters.

### 1B.3.2 Trench Bottom Soil, Cap Soil, and Leachate Sampling

- Davis et al. (1989) As part of studies connected with field scale demonstrations of trench closure techniques, soil samples were collected on July 1, 1988 from the bottom of trenches 2, 3, 4, 5, and 6, and from the cap of Trench 3. Samples were screened in the field for gross beta/gamma activity and were analyzed in the ORNL laboratory for cesium-137, cobalt-60, and strontium-90. Between October 27 and November 20, 1987, during trench void space determination, trench water samples were collected for analyses. The samples were of waters injected into the trenches during trench void space determination. They were characterized by measuring pH, electrical conductivity, dissolved solids, hardness, alkalinity, and gross alpha and gross beta activities. These analyses were also performed on a sample of water from the EWB, which served as the source of water employed during the trench void space determinations.

### 1B.3.3 Groundwater Investigations

The following paragraphs briefly describe previous WAG 6 groundwater investigations yielding contaminant data. The wells sampled during each of these investigations are illustrated in Figure 1B.2, and the corresponding groundwater data is tabulated in Table 1B.8 (radiological data) and 1B.9 (organic chemical data).

#### 1B.3.3.1 ETF groundwater investigations

- Davis et al. (1984) The framework for the ETF studies is described in Section 1. The ETF site characterization program included considerable efforts to evaluate aquifer characteristics, water table fluctuations and the groundwater flow system, and water

chemistry. The investigation of aquifer characteristics included tracer tests, pumping tests, and a series of slug tests. Water levels were continuously monitored in 15 wells located on the ETF site, and approximately 30 months of the data were recorded. Groundwater chemistry was evaluated by collecting monthly groundwater samples from 12 wells. All samples were analyzed for major cations and anions, as well as trace metals and radionuclides. No samples were analyzed for organics. Aquifer characteristics determined in this study are included in Section 3.0. These data and groundwater chemistry data will be employed, as appropriate, in contaminant transport modeling during Phase I, Activity II of the RFI.

- Vaughan et al. (1982) report on interim progress results of site characterization investigations at the ETF site and present groundwater quality data for twelve shallow ETF piezometers (ETF-1 through -12). Samples were collected 4/81 and 8/81 and analyzed for cations and anions, alkalinity, tritium, cesium-137, cobalt-60, strontium-90, and gross alpha activity. No samples were analyzed for organics.

### 1B.3.3.2 Hydraulic head measuring station (HHMS) program

- Dreier and Toran (1989) present a summary of data from the HHMS program. This program has three objectives: 1) to characterize hydraulic head levels at ORNL selected waste management areas, 2) to characterize Melton Valley geology, and 3) to assess groundwater quality and aquifer stratification. This work has contributed to the current understanding of hydrogeologic systems underlying SWSA 6. The program involved the installation of 11 well clusters, each consisting of a shallow well (approximately 80 ft deep), an intermediate well (approximately 200 ft deep) and a deep well (approximately 400 ft deep). Four of these clusters are located within the boundaries of WAG 6. Aquifer testing was performed on the wells. Groundwater samples were collected and analyzed to assess groundwater geochemistry (alkalinity, cations/anions, TOC), groundwater quality (tritium, gross alpha, gross beta, gamma activity, strontium-90 and uranium-thorium), and heavy isotopes (oxygen-18, deuterium). Samples were collected in February and July 1987 for most wells; cluster HHMS-8 and wells HHMS-7B and -7C were installed later and sampled in August 1988. However, with the exception of tritium results, radiological results for groundwater samples collected and analyzed were not included in this report.

- Toran (1989) supplied radionuclide analytical (gross alpha, gross beta, tritium, strontium-90, gamma activity)results for HHMS series wells within WAG 6 that were not previously reported in Dreier and Toran (1989).

### 1B.3.3.3 TARA groundwater investigations

- Davis et al. (1989) The TARA project involved the installation of 13 PVC groundwater wells. Water level data sufficient to construct hydrographs for each well from the period April 1987 to August 1988 are presented in this report. Response of monitoring wells to trench water pumping tests conducted in July and October 1987 is included on the hydrographs. Groundwater sampling was conducted between November 18 and 23, 1987, and included collection of samples from each of the 15 wells. Field measurements

included temperature, pH, dissolved oxygen, and electrical conductivity. In addition, samples were submitted for laboratory analysis for elements using ICP analysis, hardness, alkalinity, total organic carbon (TOC), total dissolved solids (TDS), 91 semivolatile organic compounds (SVOCs), radionuclides, mercury, potassium, and major anions. To determine how groundwater quality changed with time, additional samples were collected from the 15 wells in May 1987, November 1987, June 1988, and August 1988. These samples were analyzed for pH, electrical conductivity, hardness, alkalinity, dissolved solids, tritium, and gross beta and gross alpha radioactivity. Methods, procedures, and data are presented in Davis et al. (1989). These data were considered in the assessment of the nature and extent of contamination in WAG 6.

### 1B.3.3.4 IWMF investigations

Prior to commencement of construction of the IWMF in SWSA 6, a series of shallow piezometers were installed, aquifer testing (slug tests) were performed, and groundwater samples collected in order to characterize the site. Several reports summarize site characterization progress and results obtained:

- Morrissey (1990) presents a summary of IWMF site characterization data including as-built well construction information, potentiometric data, aquifer testing results, and groundwater chemical and radiological data for 10 IWMF piezometers (T-1, T-5, T-7, T-10,T-17, T-18, T-20, T-22, T-27, and T-36) and 3 existing adjacent piezometers (274, 379, 380). Slug testing results are presented for all 10 IWMF piezometers; continuous water level measurement data were collected for five of the IWMF piezometers but not presented in this letter report. Groundwater samples were collected from the IWMF piezometers on 10/25/89 and 10/26/89 and analyzed for basic water quality parameters (cations/anions, alkalinity, TOC, TIC, TOX), field parameters (temp., pH, dissolved oxygen, and Eh), and radiological parameters (gross alpha, gross beta, cobalt-60, cesium-137, strontium-90, and tritium). No organic analyses were performed.

- Huff (1988a) presents interim analytical results of cesium-137 analyses performed on groundwater samples collected from six IWMF piezometers (T-1, T-5, T-7, T-17, T-18, and T-20) in October 1988.

- Huff (1988b) presents additional analytical results for tritium and strontium-90 for the six IWMF piezometer groundwater samples collected in October 1988.

### 1B.3.3.5 Active sites groundwater monitoring program investigations

An Active Sites Environmental Monitoring Program (ASEMP) was established by ORNL to provide for early detection and performance monitoring of active LLW disposal sites and transuranic waste storage areas at ORNL. At SWSA 6 this monitoring includes: Tumulus I and II groundwater and pad runoff monitoring and sampling, quarterly monitoring and sampling of a total of 57 intratrench piezometers installed in the LLW silos, auger holes, fissile wells and asbestos silos areas; and, runoff and groundwater monitoring and sampling at the Hillcut Disposal Test Facility. Numerous monthly and semi-annual reports present the

monitoring results for these areas, including: Ashwood 1990a, b; Ashwood 1991; Wickliff, Morrissey, and Ashwood 1991a-c. Groundwater radiological data (gross alpha, gross beta, cobalt-60, cesium-137, and tritium) are available for Tumulus wells 1036 through 1040 from June 1987. Groundwater sampling results for active sites intratrench wells is available beginning February 1990. No analyses have been preformed for organic compounds.

### 1B.3.3.6 Other groundwater investigations

- Solomon et al. (1988) gathered trench leachate and groundwater data to help develop contaminant source terms for use in modeling future site performance. A single groundwater sample was collected from 5 wells (S-11, 647, 648, 649, and 650) between January and July 1987. Groundwater samples were analyzed for inductively coupled plasma (ICP) elements, mercury, ammonia, inorganic and total carbon, and major cations and anions, EPA Target Compound List (TCL) organic compounds, gross alpha and gross beta, tritium, carbon-14, technetium-99; and a gamma scan.

- Poreda, Cerling, and Solomon (1988) performed age dating of shallow groundwater samples in SWSA 6 by comparing relative ratios of tritium and its daughter product helium. As part of this study, groundwater samples were collected from 13 shallow piezometers (108, 109, 345, 347, 370, 371, 373, 374, 381, 382, 383, 386, and 388) in September 1986 and July 1986 and analyzed for tritium and helium. The results are discussed further in Section 3.0, but indicate shallow groundwater is young, on the order of 0.6 to 6 years old, suggestive of short residence times and local flow systems.
- Solomon (1988) reports the results of tritium-helium and Kr-85 age dating of shallow groundwater sampled from three wells in Melton Valley and a surface water sample collected from Melton Hill Lake. Groundwater samples were collected from piezometer 741 in the southwest corner of WAG 6 and analyzed for tritium. Results support the findings of Poreda, Cerling, and Solomon (1988); groundwater from this well is apparently 1.5 years old.

- Sherwood and Borders (1987) summarize hydrologic data collected from the White Oak Creek watershed during various investigations conducted as part of the ORNL Remedial Action Program and continued monitoring by the ORNL Environmental Monitoring and Compliance Department (1940-1986). Data are presented for meteorology/climate, surface water flow and water quality of White Oak Creek, aquifer hydraulic testing results, and groundwater sampling of selected RAP piezometers along the WOC floodplain. Groundwater samples were collected from one of these piezometers, 739, located within WAG 6 in 1986 and analyzed for cations/anions, cobalt-60, cesium-137, gross alpha, gross beta, tritium, and strontium-90.

- Doyle and Taylor (1986) present results of a scoping survey of contaminants in selected ORNL waste disposal areas. SWSA 6 wells sampled during the survey included Wells 272, 279, 305, 371, 380, and 382. The samples were analyzed for anions/cations and radioisotopes (i.e., strontium-90, cobalt-60, and cesium-137).

### 1B.3.4 Surface Water

The following paragraphs describe previous site-specific surface water sampling investigations for SWSA 6. The surface water sampling locations described are shown in Figure 1B.3.

### 1B.3.4.1 ETF surface water investigations

As part of a study to assess the performance of selected site characterization techniques, a test site, the Engineering Test Facility (ETF) was established in the western portion of SWSA 6.

- Davis et al. (1984) reports on the surface water data collection associated with the ETF program. The characterization of surface water hydrology included both an evaluation of the quality and the quantity of surface water flow. Water quality and radionuclide analyses were performed once a quarter to determine baseline conditions at the site. Surface water sampling included the collection of a mixture of proportional and grab samples from both streams over an extended period of time from. In addition, weekly grab samples were collected and monitored for pH and electrical conductivity. Parshall flumes equipped with automated flowmeters and flow proportional water samplers were placed in both channels draining the ETF site. Surface water flow data were collected over a 30-month period extending from October 1980 to March 1983. In addition to surface water flow measurements and sampling, an investigation of surface water infiltration rates was completed. This involved the installation of a group of six infiltrometers around the ETF site. Surface water sampling locations are shown in Figure 1B.3. Surface water radionuclide data have been considered in assessing the nature and extent of contamination at WAG 6.

- Boegly (1984) presents radionuclide analytical results for 22 surface water samples collected from the ETF Flume II between March 1981 and June 1981. Sample collected were analyzed for gross alpha, cobalt-60, cesium-137, strontium-90, and tritium. Analytical results are presented in Table 1B.10.

### 1B.3.4.2 49 Trench area French Drain sampling

- Davis and Marshall (1988) reported on the effectiveness of the 49 Trench area drain, which was installed to suppress the groundwater table in that area. Water samples were collected representing discharge from the outlets to the north and east legs of the drain. Eight samples were collected from the east leg outfall between September 1983 and October 1986; a single sample was collected from the north leg outfall in February 1984. Additionally, seven surface water samples were collected from the 49 Trench area west creek seep between November 1982 and October 1986. All water samples were analyzed for tritium, strontium-90, cesium-137, and cobalt-60. These data are considered in the assessment of the nature and extent of contamination in Section 5.0, and presented in Tables 1B.8 (drain outfalls) and 1B.11 (west seep). Outfall and seep sampling locations are shown in Figures 1B.2 and 1B.3, respectively.

### 1B.3.4.3 Interim Corrective Measures monitoring

- Miller, Black, and Craig (1989) performed environmental monitoring and sampling to evaluate the performance of the ICM capping measures at SWSA 6 to detect and quantify the effects of the ICM caps on radionuclide migration and to determine methods for long term performance monitoring. Groundwater levels beneath the caps were monitored periodically from 19 piezometers and continuously in 7 piezometers. Surface water samples were collected generally every 300 feet along WAG 6 interior surface water drainages over five distinct sampling periods (a single pre-cap, 3 events during cap construction, and 2 post-cap events) between October 1988 and June 1989. Samples were analyzed for gross alpha, gross beta, a gamma scan, strontium-90, tritium, total suspended solids, TDS, and TOC. The analytical results are presented in Table 1B.12.

#### 1B.3.4.4 Other investigations

- Davis et al. (1987). In order to assess and quantify the effects of stormflow on surface water discharge and contaminant flux, a series of surface water samples were collected from 4 principal drainages at WAG 6 during three separate storms between February and April 1987. Samples collected were analyzed for tritium and dissolved silica. Tritium analytical results are presented in Table 1B.13.

- Davis et al. (1989). As part of the characterization activities at the TARA area, a single surface water sample was collected from the Emergency Waste Basin on 11/14/87 and analyzed for gross alpha and gross beta. No gross beta was detected; gross alpha was measured at 162 pCi/L.

### 1B.3.5 Sediments

#### 1B.3.5.1 1981 WOC and tributaries streambed contaminant survey

- Cerling and Spalding (1981) completed a comprehensive assessment of strontium-90, cobalt-60, and cesium-137 concentrations in streambed gravel from contaminated drainages in WOC. In addition to the WOC main channel and the major tributaries, several samples were collected from the minor tributaries in SWSA 6. A total of 30 sediment samples were collected from drainages within and adjacent to SWSA 6 in October and November 1978 and analyzed for cobalt-60, cesium-137, and strontium-90. Radionuclide distribution coefficients were also determined. Radionuclide concentrations in WAG 6 sediments are discussed in Section 4.0. Sediment radiological results are presented in Table 1B.14.

#### 1B.3.5.2 Investigation of bedload transport of contaminated gravel

- Cerling & Huff (1985) reported on an investigation of sediment contamination within the WOC drainage. Three locations were sampled within SWSA 6 in July and August 1985. Samples were analyzed for strontium-90, cobalt-60, and cesium-137. Additionally, a single sample from one location within the SWSA was analyzed for selected metals, including copper, potassium, zinc, manganese, and iron. Radioisotope analytical results are presented in Table 1B.15. Radionuclide concentrations in WAG 6 sediments are discussed in detail in Section 4.0.

- Huff (1986) presents the results of sediment sampling at 6 locations along surface water drainages in or adjacent to WAG 6. Samples were collected in 1978 and 1985 and analyzed for cobalt-60, strontium-90, and cesium-137. Analytical results are presented in Table 1B.16.

### 1B.3.5.3 Interim Corrective Measures monitoring

- Miller, Black, and Craig (1989) As part of the ICM capping performance evaluation, sediment samples were collected simultaneously with surface water at a total of 18 locations. Samples were collected representing fine and course sediment fractions at each location and analyzed for gross alpha, gross beta, gamma scan, and strontium-90. Additionally, grain size determinations were performed on sediment samples to evaluate the impacts of the capping measures on erosion and deposition in site streams. Analytical data are presented in Table 1B.17.

### 1B.3.6 Soils

The following paragraphs describe some of the previous investigations that resulted in site soils and geological information. With a few exceptions, only site-specific investigations are described; however, there have been numerous projects conducted by ORNL that have yielded geologic and soils information for Melton Valley in general.

### 1B.3.6.1 Other soils investigations

Other investigations that resulted in collection of soils and geologic information pertinent to SWSA 6 are briefly described in the following paragraphs. In general, these investigations focused on other topics and yielded only minor soils and geologic data, or were not specific to SWSA 6 but yielded data pertinent to SWSA 6. Results of the investigations described below have been used as applicable in Sections 3.0 and 4.0. During Phase I, Activity II of the RFI, data regarding soil physical and chemical characteristics will be used, as appropriate, to support contaminant transport modeling.

- Spalding, Hyder, and Munro (1985) describe a field trial of grouting three small test trenches within SWSA 6. As part of the project, measurements of hydraulic conductivity were made in four borings around the three test trenches. In addition, soils encountered during the excavation of the trenches were described.

- Spalding (1986) dynamically compacted Trench 271 within SWSA 6. In conjunction with this project, trench cover soil bulk density and moisture contents were measured. In addition, surface water infiltration rates were measured for the trench cover soils, both before and after dynamic compaction.

- Davis et al. (1989) collected considerable site characterization data at the TARA site. Trench cover soil bulk density and moisture contents were measured both before and after dynamic compaction. Around the trenches, 39 Standard Penetration Tests (SPTs) were performed and soil samples collected at several depth intervals. Samples of trench bottom

soil were collected from five trenches and screened for radioactivity in the field. The samples were subsequently dried and submitted for determination of cesium-137, cobalt-60, and strontium-90. Of the samples collected, those with the 10 highest readings were analyzed for volatile organic compounds (VOCs) in addition to radionuclides. The soils analytical data are presented in Table 1B.18.

- Yager and Craig (1989) present quarterly analytical data for soils collected as part of the environmental monitoring for the Tumulus Demonstration Project. Soils were collected of the uppermost 7-10 in. of soil at eleven sampling locations around the Tumulus pad between February 1987 and July 1988. Soil samples were analyzed for gross alpha, gross beta, cobalt-60, cesium-137, beryllium-7, and potassium-40. Analytical results are presented in Table 1B.19.

Other studies which provide useful information regarding soils of the area but no additional radioisotope or chemical contaminant data are presented in:

- Lomenick et al. (1983) described an initial evaluation of the ORNL area for potential SWSA sites. This investigation primarily involved reviewing existing information and involved only minor amounts of field work. The investigation focused on Melton Valley, underlain by the Conasauga Group, and contains descriptions of Melton Valley soils, but no chemical data.

- Rothschild et al. (1984a) provided a soils characterization of the proposed SWSA 7 site. The study included a soil survey, determination of mineralogy, and an assessment of soil hydraulic properties, radionuclide adsorption properties, chemical properties, engineering properties, and erosion potential.

- Friedman and Kelmers (1990) describe investigations to measure the sorption properties of several radionuclides in SWSA 6 soils to support modeling of radionuclide mobility. No additional soil contaminant assessment data is presented in this report. These data are considered in the evaluation of the contaminant fate and transport.

# Appendix 1B Tables

**Table 1B.1. Data typically available in reports of previous investigations**

Facility Characteristics:

- Source locations
- Containment/disposal methods
- Engineered Structures
- Drainage control/discharge points
- Historical aerial photography

Waste Characteristics:

- Trench/waste disposal inventory

Geology:

- Soil types/distribution
- Soil physical properties
- Soil chemical properties
- Lithology/thickness of saprolite
- Lithology/thickness of bedrock
- Structural features and orientations
- Fracture density and orientations
- Saprolite physical properties
- Saprolite chemical properties
- Bedrock physical properties
- Bedrock chemical properties

Hydrology:

- Meteorological data
- Aquifer hydraulic properties
- Aquifer geochemistry
- Groundwater age-dating data
- Potentiometric/gradient data
- Engineered features performance
- Surface water flow/discharge data
- Surface water chemistry
- Lake stage data (White Oak Lake)
- Trench hydrology
- Trench leachate chemistry

Ecological:

- Land use
- Ecosystem components
- Critical habitats

**Table 1B.2. Source areas**

| Study/Investigation | Description |
|---|---|
| Kelmers and Hightower (1987) | This report characterizes potential release rates of radionuclides from High Flux Isotope Reactor (HFIR) wastes placed in SWSA 6. The study included a review of the HFIR waste radionuclide inventory, a description of the wastes and the placement technique, and geochemical conditions at SWSA 6. The information presented was used in support of contaminant transport modeling for the RFI. |
| Davis et al. (1986) | ORNL took photographs and recorded geologic information for 17 trenches opened from July 1984 through September 1985. Information collected includes photos of trench contents and selected trench walls, a brief geologic description of the profile revealed by the excavation, a range of depths of soil cover, average geologic strike of strata, an estimated range of geologic dip of strata, and the presence of water in the trench. This information has aided in the understanding of site geology, which is described in Section 3.0. The photos of typical waste forms will aid in appropriate modeling of contaminant release and in evaluating remediation alternatives during the CMS. |

## Table 1B.3. Geology and soils

| Study/Investigation | Description |
|---|---|
| Dreier and Foreman (1990) | Presents evidence for two distinct fracture systems at ORNL: an older, largely healed fracture system at depth and a younger open fracture system formed in response to tectonic unloading. The transition between the two systems is believed to control the depth of active groundwater circulation. |
| Dreier and Toran (1989) | The objective of this study was to characterize the geology in Melton Valley, to characterize potentiometric head levels in and near waste disposal areas, and to evaluate water quality at the monitoring locations. The study involved the drilling and logging of a series of three well clusters aligned in two transects across Melton Valley, performing aquifer testing, and performing geochemical and heavy isotope analyses of groundwater from the wells. This study provides considerable information regarding stratigraphy and structural geology of bedrock underlying WAG 6 as determined from 5 HHMS-series well clusters in and adjacent to WAG 6. Petrophysical log data allows for identification of larger scale thrust faulting features as well as small scale stratigraphic and structural features evident in borehole logs. |
| Haase, Walls, and Farmer (1985) | The objective of this study was to provide detailed stratigraphic and structural information regarding Conasauga Group bedrock based upon rock cores from within Melton Valley. This study provides information regarding the environment of deposition for the formations of the Conasauga Group. |
| Tucci and Witherspoon-Hanchar (1989) | This investigation presents rock core lithologic descriptions and borehole geophysical logs for nineteen USGS deep and shallow wells installed within Melton Valley. Provides a basis for stratigraphic and structural correlation with other deep WAG 6 wells. |
| Hasson and Haase (1988) | This investigation discusses the regional stratigraphy of the Conasauga Group and provides a discussion of the environments of deposition of these rock units, describing in detail the various depositional facies. |

**Table 1B.3 (continued)**

| Study/Investigation | Description |
|---|---|
| Ammons et al. (1987) | This report summarizes an investigation of soil and saprolite characteristics in SWSA 6. The objective was to collect general information regarding the chemical, mineralogical, physical, and engineering properties of soils and saprolite within SWSA 6. Soil and saprolite samples were collected from five soil profiles within the SWSA. Physical analyses included size distribution, Atterberg limits, bulk densities, and specific gravity. Mineralogical analyses included x-ray diffraction and differential scanning colorimetry. Micromorphological analyses included petrographic analysis on thin section samples and examination with a scanning electron microscope. Chemical analyses included soil pH, organic carbon, calcium carbonate equivalent (CCE), exchangeable bases, exchangeable acids, and CEC. As noted for the soil survey conducted by Lietzke and Lee (1986), this investigation supports a better understanding of WAG 6 surficial geology and may be used in support of geotechnical remedial design. |
| Davis et al. (1986) | See Table 1B.2 |
| Dreier and Beaudoin (1986) | The general objective of this investigation was to characterize the orientation and density of fracture networks in saprolite in SWSA 6 through shallow trench mapping. Ten investigation trenches were constructed. Trenches were aligned as close to parallel or perpendicular to geologic strike as possible. Each trench was mapped at a scale of 1:120. All bedding, fracture, fault, and fault orientation data were recorded and plotted on maps. In addition, fracture densities were measured at 10-ft increments in the trenches. Results of this study have contributed to the current understanding of WAG 6 surficial geology. |
| Lietzke and Lee (1986) | This report summarizes results of a 1986 soil survey of SWSA 6. During this survey, soil mapping was accomplished at a scale of 1:1200 by walking over the entire site, making periodic observation of landforms and soils. As a result, SWSA 6 soils were segregated into nine different map units. For each map unit, a record was made of soil genesis, soil classification, soil color, and pH. This soil classification has supported a better understanding of the surficial geology of WAG 6 (Section 4.0) and may be employed in support of geotechnical design of WAG 6 remedial and closure measures. |
| Boegly (1984) | The objective of this report was to collect and compile existing site information regarding SWSW 6 for use in future environmental assessments of the site No original site characterization activities were performed, but considerable site characterization data from other studies is presented. |

**Table 1B.3 (continued)**

| Study/Investigation | Description |
|---|---|
| Davis et al. (1984) | ETF (Engineered Test Facility) Geologic and Soils Investigations. The framework for the ETF project is described in Section 1.2.2.1. ETF soils investigations reported included evaluation of radionuclide adsorption properties, soil chemical properties, soil physical properties, and morphology. Radionuclide distribution coefficients were determined in the laboratory for americium-241, strontium-90, cesium-137, cobalt-60, iodine-125, iron-59, and chromium-51.<br><br>For soil chemical properties, exchangeable cations were determined by elemental analyses of calcium, magnesium, potassium, and sodium. Exchangeable acidity and cation exchange capacity (CEC), percent base saturation, percent organic matter, pH, and hardness were also determined. Soil physical properties reported include bulk densities and approximate particle size distributions. For the soil morphological descriptions, parameters such as soil color, texture, aggregate structure, and plant root density and penetration were noted.<br><br>The investigation of site-specific geology included examination of lithology, structure, and chemical properties of the underlying geologic formation. Information was collected by coring eight boreholes drilled for installation of wells at the ETF. The investigation of lithology included visual classification of the rock cores, x-ray diffraction of selected core samples to determine clay mineralogy, and geophysical logging of the boreholes. Geophysical logging included natural gamma and neutron attenuation logs. Structure was investigated by observation of trench excavations, evaluation of surface geophysical data, and visual observation of drill samples. The surface geophysical investigation to characterize geology included three surface geophysical methods: shallow electrical resistivity, shallow seismic refraction, and ground penetrating radar (GPR). |
| Davis and Stansfield (1984) | This report documents the background, design and construction of the 49 Trench French Drain, including a separate evaluation of the geologic conditions encountered. The lithology of the weathered bedrock and soil materials encountered during the investigation are documented. This report provides further information regarding the depth to bedrock in this area; key relict structural features identified are depicted on maps and documented by photographs. Cross-sectional profiles of the drain provide as-built construction details and depict the installation of piezometers along the drain centerline |
| Sledz and Huff (1981) | This report documents the occurence, orientations, frequency, and density of fractures in the Conasauga bedrock through detailed mapping of local bedrock outcrops. As such, this report provides vital information regarding fracturing and jointing within Melton Valley. |

**Table 1B.3 (continued)**

| Study/Investigation | Description |
|---|---|
| Vaughan et al. (1982) | This interim status report summarizes ETF site characterization activities and provides information regarding soils, bedrock stratigraphy and structural geology, results of surface geophysical investigations, meteorological data, results of a groundwater investigation and aquifer testing results. |
| Lomenick and Wyrick (1965) | This report documents a geohydrologic site assessment conducted prior to the use of SWSA 6 for waste disposal. Wells were installed to depths of up to 20 ft during the investigation. Soils and geologic information was collected during drilling, and this information has been considered in the development of the description of site geology, as presented in Section 3.0. |

## Table 1B.4. Groundwater hydrology

| Study/Investigation | Description |
|---|---|
| Ashwood and Spalding, 1990 | This report summarizes SWSA 6 Interim Corrective Measures environmental activities for FY 1990 and presents results of a characterization study to evaluate the performance of the ICM capping measures and document current trench hydrology conditions. This study provides hydrographs (covering the period August 1988 to October 1990) for 25 shallow groundwater piezometers located adjacent to capped areas and 45 intratrench piezometers within capped areas (covering the periodNovember 1988 to June 1989). Additionally provides White Oka Lake stage hydrographs to demonstrate the relation of trench water levels to fluctuating lake stage levels. |
| Clapp, pers. comm., 1990 | Soil infiltration rate data from an unpublished study performed on WAG 6 soils by the author. |
| Morrissey, 1990 | This report summarizes IWMF site characterization data and presents shallow soil and saprolite boring logs and well construction details, potentiometric data, slug testing results, and aquifer geochemical data for ten piezometers installed. |
| Black, 1989 | This report provides details of the 49 Trench French Drain performance as applied to design of the IWMF french drain. This report provides hydrographs for wells within the vicinity of the French Drain, evaluates drain performance (water table suppression), and presents drain discharge/flow figures. |
| Davis et al., 1989 | This report summarizes the site characterization activities conducted in the TARA area of SWSA 6 and provides information regarding well construction, geology, aquifer geochemical data, slug test results, and groundwater quality results for 13 wells installed in this study as well as other local wells included. |
| Dreier and Toran, 1989 | This report provides substantial information regarding the overall hydrogeology of Melton Valley as determined from HHMS well clusters, including aquifer testing results, aquifer geochemical data and heavy isotope data useful in interpreting aquifer stratification, hydrographs for HHMS wells and information regarding vertical gradients in Melton Valley. |
| Davis and Marshall, 1988 | This report presents the results of several years of monitoring the performance of the 49 Trench French Drain and provides insight into the hydrogeology of this area of WAG 6 impacted by the drain. This report discusses the effects of the cap on the local hydrologic system and presents drain outflow discharge data and water chemistry information. |
| Mortimer and Ebers, 1988 | This report documents the installation of the RCRA water quality monitoring network at SWSA 6, and includes well construction data, limited water level data, and hydraulic conductivity testing results conducted on these wells. |
| Poreda, Cerling, and Solomon 1988 | This paper presents the results of helium-tritium age dating of groundwater from shallow wells within WAG 6 and provides support for a local rather than regional groundwater flow system at WAG 6. Results indicate shallow groundwaters are young (0.6 to 6 years old) suggesting short residence times within the aquifer. |

**Table 1B.4. (continued)**

| Study/Investigation | Description |
|---|---|
| Moore, 1988 and 1989a,b | These papers summarize a recently completed comprehensive analysis of existing hydrologic data in the ORNL area and discusses the role and significance of stormflow in understanding active hydrologic processes, particularly, the interaction of surface and groundwater and processes governing contaminant flux to streams. Although not specifically addressing WAG 6, these papers present considerable hydrogeologic information and contribute to the overall understanding of site hydrogeology. |
| Solomon, 1988 | This report presents the results of additional helium-tritium and $Kr^{85}$ groundwater age dating performed in piezometer 741 within WAG 6. Results indicate groundwater in this well is approximately 1.5 years old at time of sampling, confirming results of Poreda, Cerling, and Solomon (1988). |
| Solomon et al., 1988 | This report summarizes the results of trench leachate and groundwater sampling conducted in FY 1986 and 1987 provides groundwater geochemical data in addition to water quality analytical results (raf=diological and organic compounds). |
| Yager and Craig, 1989<br>Yager et al., 1989 | These reports present groundwater quality and water table data collected in conjunction with Tumulus environmental monitoring and water table elevation data collected in conjunction with ICM environmental monitoring. Water table data from both the Tumulus and ICM programs contributes to the understanding of local hydrologic conditions in WAG 6. |
| Webster and Bradley, 1988 | This report integrates existing geologic and hydrologic data pertaining to SWSAs 4, and 6, all located in Melton Valley and presents conclusions regarding the general hydrology of Melton Valley and implication for contaminant transport. Surface water, regolith, and bedrock hydrology are discussed individually. The authors concluded that the two primary modes of contaminant transport are by dissolution in circulating ground-water and the overflow of trench leachate and subsequent flow across the ground surface. |
| Davis et al., 1987 | As part of the activities specified in ORNL's draft SWSA 6 RI plan (ORNL 1986), several constant head tracer tests were conducted in the fall of 1986 and 1987 during similar hydrologic conditions The test configuration consisted of a central injection hole and six boreholes arranged around the injection hole each of which contained two piezometers, one deep and one shallow. Water with a tracer was injected in the central hole, and water levels and the presence of tracer were monitored in the piezometers. |
| Mortimore 1987 | This report documents the ORNL Remedial Action Program piezometer installation program which entailed the installation of 21 piezometers in SWSA 6. During installation, cuttings were monitored for radioactivity, and samples of water and soil cuttings were submitted for laboratory radiological and chemical analyses. Hydrologic testing was performed on the piezometers and water level data have been recorded. |
| Tucci, 1984 | This report presents the preliminary results of USGS 3D modelling efforts in Melton Valley and provides a summary of hydrologic properties. Although not specifically addressing WAG 6, this report provides general insight regarding groundwater flow in Melton Valley. |

**Table 1B.4. (continued)**

| Study/Investigation | Description |
|---|---|
| Luxmoore, Spalding, and Munro 1981 | This report presents infiltration rates and physico-chemical data (CEC, exchangeable cations, bulk density) for subsoil (saprolite) materials in a disturbed setting typical of WAG 6. A total of 48 infiltration tests were performed on a 2 $m^2$ grid. |
| Smith and Vaughan, 1985a, b<br>Vaughan et al., 1982 | These reports present the interpretation of ETF Maryville limestone pump test data and Nolichucky pump test data from Bear Creek Valley using non-radial analytical solutions, and provide information regarding bedrock aquifer hydraulic properties. |
| Davis et al., 1984 | See Table 1B.3 |
| Davis and Stansfield, 1984 | Data Developed During Construction of the 49-Trench Drain. During construction of a French drain for diversion of groundwater in the 49 Trench area in SWSA 6, geologic and soils data were collected from the trench excavation. The thickness and nature of surficial soils and the lithology of the consolidated strata were recorded. Fracture density and orientation, folds, and a fault were documented. The geologic and soils data developed during this project have aided the overall understanding of the geology of WAG 6, which is described in Section 3.0. |
| Tamura et al., 1980 | This report summarizes studies conducted at SWSA 1, 2, 3, 4, 5, and 6 between October 1975 and September 1977. This report documents the results of a tracer study performed in saprolite materials near the southern boundary of SWSA 6 in 1976, and provides hydrologic information regarding groundwater flow in saprolite materials. |
| Webster et al. 1980<br>Webster et al. 1982 | USGS Hydrologic Data Collection. Data are summarized for the period 1975 to 1979 for approximately 100 wells installed at SWSA 6. The data include an inventory of wells, measurements of water levels, well hydrographs, and a map showing the location of the wells. Webster et al (1982) summarize precipitation data for January 1976 through December 1980 for two stations; one each in SWSA 5 and SWSA 6. Daily, monthly, and annual values are reported. |
| Lomenick and Wyrick 1965 | See Table 1B.3 |
| Rothschild et al., 1984a,b | A hydrogeologic investigation was performed for the proposed SWSA 7 located in Melton Valley to the east of SWSA 6. Because the proposed SWSA 7 has similar topography and is located over the same geologic formation (Conasauga Group) and in the same hydrogeologic setting, this site characterization data may be of use in understanding the hydrogeology of SWSA 6. |
| McMaster 1971, 1972 | Off-site field investigations that may provide supplemental information of value for characterizing SWSA 6 hydrogeology include pumping tests performed in 1971 and 1972 by McMaster. |
| Spalding, Hyder, and Munro 1985 | This report describes a field trial of grouting three small test trenches within SWSA 6. As part of the project, measurements of hydraulic conductivity in the unperturbed soil formation in four borings around the three test trenches were performed. |

**Table 1B.5. Surface water hydrology**

| Study/Investigation | Description |
|---|---|
| Webster et al. 1982 | Summarizes precipitation data for January 1976 through December 1980 for two stations; one each in SWSA 5 and SWSA 6. Daily, monthly, and annual values are reported. |
| Webster and Bradley 1988 | See Table 1B.4 |
| Stewart 1989 | Samples representative of both wet and dry seasons were collected from a stream at the east side and a stream on the west side of SWSA 6. A bioassay was performed on the water samples to assess toxicity. Aside from the "wet weather" sample collected from the stream on the west side of SWSA 6, the water samples did not show evidence of toxicity. |

## Table 1B.6. WAG 6 historical trench leachate radiological analytical data

| Well No. | Date Sampled | Gross Alpha (pCi/L) | | Gross Beta (pCi/L) | | CO-60 (pCi/L) | | CS-137 (pCi/L) | | SR-90 (pCi/L) | | Tritium (pCi/L) | | Data Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error | |
| T2 | 10/30/87 | 3159 | | 5400 | | NA | | NA | | NA | | NA | | Ashwood & Spalding, 1990 |
| T2 | 03/29/89 | 270 | | 2781 | | NA | | NA | | NA | | 29970 | | Ashwood & Spalding, 1990 |
| T2 | 09/27/89 | NA | | 46359 | | NA | | NA | | NA | | 18684 | | Ashwood & Spalding, 1990 |
| T3 | 03/29/89 | 270 | | 12339 | | NA | | NA | | NA | | 75870 | | Ashwood & Spalding, 1990 |
| T3 | 09/27/89 | NA | | NA | | NA | | NA | | NA | | 18684 | | Ashwood & Spalding, 1990 |
| T4 | 11/03/87 | 1350 | | 9361872 | | NA | | NA | | NA | | NA | | Ashwood & Spalding, 1990 |
| T4 | 06/21/89 | NA | | NA | | NA | | NA | | NA | | 65340 | | Ashwood & Spalding, 1990 |
| T5 | 10/27/87 | 84159 | | 19359 | | NA | | NA | | NA | | NA | | Ashwood & Spalding, 1990 |
| T5 | 03/29/89 | 189 | | 13824 | | NA | | NA | | NA | | NA | | Ashwood & Spalding, 1990 |
| T5 | 09/27/89 | NA | | NA | | NA | | NA | | NA | | 2320 | | Ashwood & Spalding, 1990 |
| T6 | 10/30/87 | ND | | 115668 | | NA | | NA | | NA | | NA | | Ashwood & Spalding, 1990 |
| T8 | 03/29/89 | NA | | 14275827 | | NA | | NA | | NA | | NA | | Ashwood & Spalding, 1990 |
| T11 | 02/15/90 | 0.86 | | 56.7 | | 13.5 | | NA | | 0.54 | | 15390 | | Ashwood & Spalding, 1990 |
| T13 | 08/11/89 | 148.5 | | 297000 | | <14.85 | | <1485 | | NA | | NA | | Ashwood & Spalding, 1990 |
| T13 | 02/15/90 | 0.78 | | 1.08 | | 16.2 | | ND | | 0.54 | | 67500 | | Ashwood & Spalding, 1990 |
| T16 | 02/15/90 | 1.54 | | 21.33 | | 16.2 | | 5.4 | | 8.1 | | 40500 | | Ashwood & Spalding, 1990 |
| T44 | 04/06/89 | NA | | NA | | 26190 | | NA | | NA | | NA | | Ashwood & Spalding, 1990 |

**Table 1B.6. (continued)**

| Well No. | Date Sampled | Gross Alpha (pCi/L) | | Gross Beta (pCi/L) | | CO-60 (pCi/L) | | CS-137 (pCi/L) | | SR-90 (pCi/L) | | Tritium (pCi/L) | | Data Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error | |
| T57 | 04/10/89 | ND | | 351 | | NA | | NA | | NA | | 178200 | | Ashwood & Spalding, 1990 |
| T60 | 04/10/89 | ND | | 405 | | NA | | NA | | NA | | 17280 | | Ashwood & Spalding, 1990 |
| T69 | 04/05/89 | 675 | | 6399 | | NA | | NA | | NA | | 22950000 | | Ashwood & Spalding, 1990 |
| T82 | 04/06/89 | ND | | 29700 | | ND | | 324 | | 17820 | | 864 | | Ashwood & Spalding, 1990 |
| T85 | 04/06/89 | ND | | 378 | | ND | | 207.9 | | 89.1 | | 23220 | | Ashwood & Spalding, 1990 |
| T92-1 | 04/05/89 | ND | | 145.8 | | ND | | ND | | 62.1 | | 25110 | | Ashwood & Spalding, 1990 |
| T92-2 | 04/05/89 | ND | | 202.5 | | ND | | 70.2 | | 23.76 | | 23760 | | Ashwood & Spalding, 1990 |
| T101 | 04/06/89 | 16.2 | | 67.5 | | ND | | ND | | 23.76 | | 4050 | | Ashwood & Spalding, 1990 |
| T105 | 04/06/89 | NA | | NA | | 48600 | | NA | | NA | | NA | | Ashwood & Spalding, 1990 |
| T110 | 04/05/89 | ND | | 2781 | | NA | | NA | | NA | | 81000 | | Ashwood & Spalding, 1990 |
| T112 | 04/06/89 | ND | | 1485 | | ND | | 729 | | 20.79 | | 72900 | | Ashwood & Spalding, 1990 |
| T180 | 04/06/89 | ND | | 405 | | ND | | 94.5 | | 40.5 | | 12690 | | Ashwood & Spalding, 1990 |
| T225 | 04/06/89 | ND | | 621 | | NA | | NA | | NA | | 78300 | | Ashwood & Spalding, 1990 |
| T237 | 04/06/89 | ND | | 324 | | ND | | 64.8 | | 3.78 | | 72900 | | Ashwood & Spalding, 1990 |
| T252 | 02/15/90 | 0.95 | | 2.97 | | ND | | 32.4 | | 0.54 | | 8910 | | Ashwood & Spalding, 1990 |
| T275 | 02/15/90 | 1.32 | | 0.27 | | 32.4 | | <2.7 | | 0.27 | | 2700 | | Ashwood & Spalding, 1990 |
| T279 | 08/11/89 | 27 | | 2457 | | ND | | 972 | | 945 | | 25650 | | Ashwood & Spalding, 1990 |

**Table 1B.6. (continued)**

| Well No. | Date Sampled | Gross Alpha (pCi/L) | | Gross Beta (pCi/L) | | CO-60 (pCi/L) | | CS-137 (pCi/L) | | SR-90 (pCi/L) | | Tritium (pCi/L) | | Data Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error | |
| T279 | 02/15/90 | 0.95 | | 2.7 | | ND | | ND | | 0.54 | | 8100 | | Ashwood & Spalding, 1990 |
| T284 | 02/15/90 | 1.57 | | 11.61 | | ND | | ND | | ND | | 11610 | | Ashwood & Spalding, 1990 |
| T285 | 02/15/90 | 2.05 | | 7.56 | | 43.2 | | 21.6 | | 1.62 | | 2538 | | Ashwood & Spalding, 1990 |
| T288 | 08/11/89 | 15.12 | | 702 | | ND | | 40.5 | | 378 | | 6750 | | Ashwood & Spalding, 1990 |
| T288 | 02/15/90 | ND | | 14.58 | | ND | | ND | | 2.43 | | 9450 | | Ashwood & Spalding, 1990 |
| T318 | 04/06/89 | 21.6 | | 124.2 | | ND | | ND | | 1.08 | | 40500 | | Ashwood & Spalding, 1990 |
| T329 | 04/06/89 | ND | | 72.9 | | ND | | ND | | 21.6 | | 32400 | | Ashwood & Spalding, 1990 |
| T363 | 04/05/89 | 540 | | 23760 | | NA | | NA | | NA | | 51300 | | Ashwood & Spalding, 1990 |
| T367 | 04/06/89 | 81 | | 216 | | NA | | NA | | NA | | 167400 | | Ashwood & Spalding, 1990 |
| T395 | 04/06/89 | 81 | | 675 | | NA | | NA | | NA | | 7290 | | Ashwood & Spalding, 1990 |
| T414 | 04/06/89 | 81 | | 135 | | NA | | NA | | NA | | 3510 | | Ashwood & Spalding, 1990 |
| T453 | 04/06/89 | 54 | | 2376 | | NA | | NA | | NA | | 56700 | | Ashwood & Spalding, 1990 |
| T41 | 03/11/86 | 232.2 | 143.1 | 145800 | 2700 | 0 | | 2376 | 162 | 97200 | 2700 | 54000 | 2700 | Solomon et al., 1988 |
| T41 | 12/04/86 | 2970 | 1215 | 486000 | 27000 | <20 | | 3510 | 270 | 83700 | 2700 | 9180000 | 270000 | Solomon et al., 1988 |
| T41 | 03/10/87 | 29.7 | 48.6 | 432000 | 27000 | <20 | | 3780 | 270 | | | 4860000 | 270000 | Solomon et al., 1988 |
| T92 | 04/22/86 | 40.5 | 45.9 | 4050 | 270 | 5.94 | 2.16 | 70.2 | 5.4 | 2322 | 324 | 59400 | 2700 | Solomon et al., 1988 |
| T92 | 12/04/86 | 18.9 | 37.8 | 432 | 108 | <10 | | 8.91 | 7.56 | 22.68 | 5.4 | 70200 | 2700 | Solomon et al., 1988 |
| T92 | 03/10/87 | 27 | 27 | 251.1 | 91.8 | <2.7 | | 15.93 | 3.51 | | | 40500 | 2700 | Solomon et al., 1988 |
| T135 | 04/13/87 | 16.2 | 27 | 145800 | 2700 | 18.9 | 5.94 | 1080 | 27 | | | 891000 | 27000 | Solomon et al., 1988 |

**Table 1B.6. (continued)**

| Well No. | Date Sampled | Gross Alpha (pCi/L) | | Gross Beta (pCi/L) | | CO-60 (pCi/L) | | CS-137 (pCi/L) | | SR-90 (pCi/L) | | Tritium (pCi/L) | | Data Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error | |
| T163 | 04/21/87 | 27 | 45.9 | 702 | 135 | 8.91 | 4.86 | 64.8 | 5.4 | | | 16700 | 1350 | Solomon et al., 1988 |
| T219 | 01/21/87 | <54 | | 540 | 135 | <54 | | 81 | 10.8 | | | 10300 | 1080 | Solomon et al., 1988 |
| T257 | 12/05/86 | 78.3 | 64.8 | 253.8 | 99.9 | <10 | | <10 | | 7.02 | 3.51 | 621000 | 27000 | Solomon et al., 1988 |
| T257 | 01/21/87 | 113.4 | 81 | 29700 | 2700 | 37.8 | 10.8 | 56.7 | 10.8 | | | 105000 | 2700 | Solomon et al., 1988 |
| T257 | 03/10/87 | 54 | 56.7 | 27 | 64.8 | <5 | | <5 | | | | 32400 | 27000 | Solomon et al., 1988 |
| T260-2 | 04/13/87 | 10.8 | 27 | 105.3 | 81 | <5 | | <8.1 | | | | 8370 | 1080 | Solomon et al., 1988 |
| T288 | 03/21/86 | 51.3 | 54 | 132.3 | 78.3 | 23.76 | 7.02 | <2.7 | | | | 13000 | 2430 | Solomon et al., 1988 |
| T288 | 12/05/86 | 67.5 | 62.1 | 1404 | 189 | 11.61 | 7.83 | 32.4 | 8.1 | 324 | 27 | 32400 | 2700 | Solomon et al., 1988 |
| T288 | 03/10/87 | 27 | 54 | 245.7 | 91.8 | <5 | | 7.83 | 2.97 | | | 15400 | 1350 | Solomon et al., 1988 |
| T27 | 1976 | NA | | NA | | 3110 | | ≤380 | | 39600 | | NA | | Tamura et al., 1980 |
| T36 | 1976 | NA | | NA | | ≤110 | | 230 | | 34800 | | NA | | Tamura et al., 1980 |
| T41 | 1976 | NA | | NA | | ≤190 | | ≤220 | | 15700 | | NA | | Tamura et al., 1980 |
| T42 | 1976 | NA | | NA | | ≤100 | | 160 | | 3620 | | NA | | Tamura et al., 1980 |
| T123 | 1976 | NA | | NA | | ≤110 | | 90 | | 8830 | | NA | | Tamura et al., 1980 |
| T127 | 1976 | NA | | NA | | ≤130 | | ≤80 | | 1340 | | NA | | Tamura et al., 1980 |
| T129 | 1976 | NA | | NA | | ≤60 | | ≤280 | | 43100 | | NA | | Tamura et al., 1980 |
| T135 | 1976 | NA | | NA | | ≤130 | | ≤80 | | 17400 | | NA | | Tamura et al., 1980 |
| T137 | 1976 | NA | | NA | | ≤140 | | ≤180 | | 7700000 | | NA | | Tamura et al., 1980 |
| T139 | 1976 | NA | | NA | | ≤130 | | ≤60 | | 5230000 | | NA | | Tamura et al., 1980 |
| T145 | 1976 | NA | | NA | | ≤110 | | 1350 | | 51300 | | NA | | Tamura et al., 1980 |
| T150 | 1976 | NA | | NA | | ≤410 | | 410 | | 1330 | | NA | | Tamura et al., 1980 |
| T152 | 1976 | NA | | NA | | ≤120 | | 4010 | | 739000 | | NA | | Tamura et al., 1980 |
| T153 | 1976 | NA | | NA | | ≤130 | | ≤180 | | 310000 | | NA | | Tamura et al., 1980 |

**Table 1B.6. (continued)**

| Well No. | Date Sampled | Gross Alpha (pCi/L) | | Gross Beta (pCi/L) | | CO-60 (pCi/L) | | CS-137 (pCi/L) | | SR-90 (pCi/L) | | Tritium (pCi/L) | | Data Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error | |
| T156 | 1976 | NA | | NA | | ≤130 | | ≤90 | | 4400 | | NA | | Tamura et al., 1980 |
| T160 | 1976 | NA | | NA | | ≤90 | | ≤80 | | 54100 | | NA | | Tamura et al., 1980 |
| T161 | 1976 | NA | | NA | | ≤170 | | 1120 | | 12400 | | NA | | Tamura et al., 1980 |
| T163 | 1976 | NA | | NA | | ≤90 | | ≤10 | | 8650 | | NA | | Tamura et al., 1980 |
| T166 | 1976 | NA | | NA | | 110 | | ≤120 | | 17000 | | NA | | Tamura et al., 1980 |
| T168 | 1976 | NA | | NA | | ≤130 | | ≤130 | | 6040 | | NA | | Tamura et al., 1980 |
| T171 | 1976 | NA | | NA | | ≤130 | | ≤390 | | 55900 | | NA | | Tamura et al., 1980 |
| T173 | 1976 | NA | | NA | | ≤190 | | ≤200 | | 887000 | | NA | | Tamura et al., 1980 |
| T177 | 1976 | NA | | NA | | ≤170 | | 790 | | 30700 | | NA | | Tamura et al., 1980 |
| T177A | 1976 | NA | | NA | | ≤220 | | ≤90 | | 8470 | | NA | | Tamura et al., 1980 |
| T279 | 1976 | NA | | NA | | ≤80 | | ≤100 | | 3050 | | NA | | Tamura et al., 1980 |
| T317 | 1976 | NA | | NA | | ≤90 | | ≤80 | | 1940 | | NA | | Tamura et al., 1980 |

NOTE: Sampling locations (excluding Tamura et al. trench wells) shown on Figure 1B.1.

**Table 1B.7a. Historical trench leachate chemical data**

| Well no. | Date sampled | Chloroethane (µg/L) | 1,1-DCE (µg/L) | TCE (µg/L) | Benzene (µg/L) | Cis-1,3-DCPE (µg/L) | PCE (µg/L) | Toluene (µg/L) | Data source |
|---|---|---|---|---|---|---|---|---|---|
| T4 | 06/21/89 | <10 | | <5 | <5 | | | <5 | Ashwood & Spalding 1990 |
| T7 | 06/21/89 | <10 | | <5 | <5 | | | <5 | Ashwood & Spalding 1990 |
| T11 | 02/15/90 | <5000 | | <2500 | <2500 | | | 3400 | Ashwood & Spalding 1990 |
| T11 | 07/24/90 | <10 | | <5 | 9 | | | 23 | Ashwood & Spalding 1990 |
| T13 | 08/11/89 | <10 | | <5 | 240 | | | 4300 | Ashwood & Spalding 1990 |
| T13 | 11/09/89 | | | | | | | 6600 | Ashwood & Spalding 1990 |
| T13 | 02/15/90 | <5000 | | <2500 | <2500 | | | 8700 | Ashwood & Spalding 1990 |
| T13 | 07/24/90 | | | | | | | 18 | Ashwood & Spalding 1990 |
| T16 | 02/15/90 | <5000 | | <2500 | <2500 | | | 69000 | Ashwood & Spalding 1990 |
| T16 | 07/24/90 | | | | | | | 18 | Ashwood & Spalding 1990 |
| T44 | 04/06/89 | | | 16JB | | | | 220B | Ashwood & Spalding 1990 |
| T63 | 04/06/89 | | | 4JB | | | | 75B | Ashwood & Spalding 1990 |
| T82 | 04/06/89 | | | | | | | 18 | Ashwood & Spalding 1990 |
| T85 | 04/06/89 | | | 36B | | | | 3200B | Ashwood & Spalding 1990 |
| T85 | 11/09/89 | | | | | | | 18000 | Ashwood & Spalding 1990 |
| T92-1 | 04/05/89 | | | 4JB | | | | 41B | Ashwood & Spalding 1990 |
| T92-2 | 04/05/89 | | | 5JB | | | | 7B | Ashwood & Spalding 1990 |
| T101 | 04/06/89 | | | | 0.6J | | | 83 | Ashwood & Spalding 1990 |
| T105 | 04/06/89 | | | | 12 | | | 3500E | Ashwood & Spalding 1990 |

**Table 1B.7a (continued)**

| Well no. | Date sampled | Chloroethane (µg/L) | 1,1-DCE (µg/L) | TCE (µg/L) | Benzene (µg/L) | Cis-1,3-DCPE (µg/L) | PCE (µg/L) | Toluene (µg/L) | Data source |
|---|---|---|---|---|---|---|---|---|---|
| T105 | 11/09/89 | | | | | | | 74000 | Ashwood & Spalding 1990 |
| T112 | 04/06/89 | | | | 1J | | | 260E | Ashwood & Spalding 1990 |
| T180 | 04/06/89 | | | | 11 | | | 5000E | Ashwood & Spalding 1990 |
| T237 | 04/06/89 | | | | 28 | | | 2500E | Ashwood & Spalding 1990 |
| T252 | 02/15/90 | <5000 | | <2500 | <2500 | | | 2000J | Ashwood & Spalding 1990 |
| T252 | 07/24/90 | <10 | | <5 | <5 | | | 20 | Ashwood & Spalding 1990 |
| T275 | 02/15/90 | | | | | | | 150000 | Ashwood & Spalding 1990 |
| T275 | 07/24/90 | <10 | | <5 | <5 | | | 2J | Ashwood & Spalding 1990 |
| T279 | 08/11/89 | <10 | | <5 | 140 | | | 3400 | Ashwood & Spalding 1990 |
| T279 | 11/09/89 | | | | | | | 9500 | Ashwood & Spalding 1990 |
| T279 | 02/15/90 | | | | | | | 5000 | Ashwood & Spalding 1990 |
| T279 | 07/24/90 | <10 | | <5 | 2J | | | 4J | Ashwood & Spalding 1990 |
| T284 | 02/15/90 | | | | | | | | Ashwood & Spalding 1990 |
| T284 | 07/24/90 | <10 | | <5 | <5 | | | <5 | |
| T285 | 02/15/90 | | | | | | | | Ashwood & Spalding 1990 |
| T285 | 07/24/90 | <10 | | <5 | <5 | | | <5 | Ashwood & Spalding 1990 |
| T288 | 08/11/89 | <10 | | <5 | 2J | | | 180 | Ashwood & Spalding 1990 |
| T288 | 11/09/89 | | | | | | | 180 | Ashwood & Spalding 1990 |
| T288 | 02/15/90 | | | | | | | | Ashwood & Spalding 1990 |
| T288 | 07/24/90 | <10 | | <5 | <5 | | | 15 | Ashwood & Spalding 1990 |

**Table 1B.7a (continued)**

| Well no. | Date sampled | Chloroethane (µg/L) | 1,1-DCE (µg/L) | TCE (µg/L) | Benzene (µg/L) | Cis-1,3-DCPE (µg/L) | PCE (µg/L) | Toluene (µg/L) | Data source |
|---|---|---|---|---|---|---|---|---|---|
| T318 | 04/06/89 | | | | 2J | | | 2500E | Ashwood & Spalding 1990 |
| T318 | 11/09/89 | | | | | | | 8400 | Ashwood & Spalding 1990 |
| T329 | 04/06/89 | | | | 0.8J | | | 670E | Ashwood & Spalding 1990 |
| T92 | 04/22/86 | ND | ND | 2 | 4.4 | ND | ND | ND | Solomon et al. 1988 |
| T135 | 04/13/87 | ND | ND | ND | ND | ND | ND | 14 | Solomon et al. 1988 |
| T163 | 04/21/87 | 49 | 626 | ND | ND | ND | ND | 668 | Solomon et al. 1988 |
| T219 | 01/21/87 | ND | ND | 8 | 929 | 58 | 1182 | ND | Solomon et al. 1988 |
| T257 | 01/21/87 | ND | ND | ND | ND | ND | ND | 35 | Solomon et al. 1988 |
| T260-2 | 04/13/87 | ND | ND | ND | ND | ND | ND | ND | Solomon et al. 1988 |
| T288 | 04/29/86 | ND | ND | ND | 13 | ND | ND | 1940 | Solomon et al. 1988 |

| WELL # | DATE SAMPLED | Ethylbenzene (ug/L) | Styrene (ug/L) | Xylenes (ug/L) | Ph[illegible] (ug/L) | 4-Methylphenol (ug/L) | Acetone (ug/L) | Napthalene (ug/L) | DATA SOURCE: |
|---|---|---|---|---|---|---|---|---|---|
| T4 | 06/21/89 | <5 | | <5 | <11 | <11 | 77B | | Ashwood & Spalding, 1990 |
| T7 | 06/21/89 | <5 | | <5 | <11 | <11 | 6JB | | Ashwood & Spalding, 1990 |
| T11 | 02/15/90 | 3500 | | 1600J | 1800 | 2300 | <5000 | 1400 | Ashwood & Spalding, 1990 |
| T11 | 07/24/90 | <5 | | 9000 | NA | NA | 3270 | | Ashwood & Spalding, 1990 |
| T13 | 08/11/89 | 6000 | | 32000 | 690 | 3900 | 140B | 4000 | Ashwood & Spalding, 1990 |
| T13 | 11/09/89 | 3300 | | 2800 | 140 | 1800 | 2800 | 3000 | Ashwood & Spalding, 1990 |
| T13 | 02/15/90 | 14000 | | 6400 | <100 | 420 | <5000 | 2300 | Ashwood & Spalding, 1990 |
| T13 | 07/24/90 | | | 486 | | | 16 | | Ashwood & Spalding, 1990 |
| T16 | 02/15/90 | 170000 | | 77000 | 18J | 140 | 3800J | | Ashwood & Spalding, 1990 |
| T16 | 07/24/90 | | | 56600 | | | 37 | | Ashwood & Spalding, 1990 |
| T44 | 04/06/89 | | | | | | 100B | 270 | Ashwood & Spalding, 1990 |
| T63 | 04/06/89 | | | | | | 16B | | Ashwood & Spalding, 1990 |
| T82 | 04/06/89 | | | | | | 6600BE | | Ashwood & Spalding, 1990 |
| T85 | 04/06/89 | 80 | | 1900E | 19 | | 8300BE | 830E | Ashwood & Spalding, 1990 |
| T85 | 11/09/89 | | | 12000 | 16J | 500 | 3100 | 2200 | Ashwood & Spalding, 1990 |
| T92-1 | 04/05/89 | | | 19 | | | 130B | | Ashwood & Spalding, 1990 |
| T92-2 | 04/05/89 | | | | | | 5400BE | | Ashwood & Spalding, 1990 |
| T101 | 04/06/89 | | | 31 | | | 55B | | Ashwood & Spalding, 1990 |
| T105 | 04/06/89 | 130 | | 3000E | | 1200E | 3200BE | 3000E | Ashwood & Spalding, 1990 |
| T105 | 11/09/89 | | | 21000 | 760 | 4600 | 12500 | 8800 | Ashwood & Spalding, 1990 |
| T112 | 04/06/89 | 65 | | 400E | | | 3600BE | | Ashwood & Spalding, 1990 |
| T180 | 04/06/89 | 69 | | 730E | | | 20B | 3600E | Ashwood & Spalding, 1990 |
| T237 | 04/06/89 | 190 | | 1700E | <11 | | 51B | 240 | Ashwood & Spalding, 1990 |
| T252 | 02/15/90 | 3400 | | 1500J | <100 | <100 | 5600 | 160 | Ashwood & Spalding, 1990 |
| T252 | 07/24/90 | <5 | | 28 | NA | NA | 5J | | Ashwood & Spalding, 1990 |
| T275 | 02/15/90 | 3200 | | 1500J | | | 5700 | 820 | Ashwood & Spalding, 1990 |
| T275 | 07/24/90 | <5 | | 60 | NA | NA | 3J | | Ashwood & Spalding, 1990 |
| T279 | 08/11/89 | 280 | | 820 | 38 | 120 | <10 | | Ashwood & Spalding, 1990 |
| T279 | 11/09/89 | | | 2500 | <130 | 69J | 1200 | 1100 | Ashwood & Spalding, 1990 |
| T279 | 02/15/90 | 2300J | | | | | 8300 | 810 | Ashwood & Spalding, 1990 |
| T279 | 07/24/90 | <5 | | 42300 | NA | NA | 3J | | Ashwood & Spalding, 1990 |
| T284 | 02/15/90 | | | | | | 13000 | | Ashwood & Spalding, 1990 |
| T284 | 07/24/90 | <5 | | 1J | NA | NA | 1J | | |
| T285 | 02/15/90 | | | | | | 50000 | | Ashwood & Spalding, 1990 |
| T285 | 07/24/90 | <5 | | 2J | NA | NA | <10 | | Ashwood & Spalding, 1990 |
| T288 | 08/11/89 | <5 | | 480 | 2J | 25 | 4JB | 57 | Ashwood & Spalding, 1990 |

| WELL # | DATE SAMPLED | Ethylbenzene (ug/L) | Styrene (ug/L) | Xylenes (ug/L) | Phenol (ug/L) | 4-Methylphenol (ug/L) | Acetone (ug/L) | Napthalene (ug/L) | DATA SOURCE: |
|---|---|---|---|---|---|---|---|---|---|
| T288 | 11/09/89 | | | 420 | <13 | | 220JB | 18 | Ashwood & Spalding, 1990 |
| T288 | 02/15/90 | | | | | | <10000 | 32J | Ashwood & Spalding, 1990 |
| T288 | 07/24/90 | <5 | | 7300 | NA | NA | 108 | | Ashwood & Spalding, 1990 |
| T318 | 04/06/89 | 140 | | 3400E | | | 19B | 760E | Ashwood & Spalding, 1990 |
| T318 | 11/09/89 | | | 9600 | 36J | 740 | 130B | 1100 | Ashwood & Spalding, 1990 |
| T329 | 04/06/89 | 41 | | 510E | 40 | 600E | 64B | 170 | Ashwood & Spalding, 1990 |
| T92 | 04/22/86 | ND | ND | ND | ND | ND | ND | 51 | Solomon etal, 1988 |
| T135 | 04/13/87 | ND | ND | ND | ND | ND | ND | ND | Solomon etal, 1988 |
| T163 | 04/21/87 | ND | ND | ND | 12 | 91 | ND | ND | Solomon etal, 1988 |
| T219 | 01/21/87 | 67 | 7 | 3696 | ND | 34 | ND | 354 | Solomon etal, 1988 |
| T257 | 01/21/87 | ND | ND | 11 | ND | ND | ND | ND | Solomon etal, 1988 |
| T260-2 | 04/13/87 | ND | ND | ND | ND | ND | ND | ND | Solomon etal, 1988 |
| T288 | 04/13/87 | 720 | ND | ND | 13 | ND | ND | 1704 | Solomon etal, 1988 |

| WELL # | DATE SAMPLED | 4-methyl-2-Pentanone (ug/L) | 2-Methyl Phenol (ug/L) | Benzoic Acid (ug/L) | Di[illegible] Phthalate (ug/L) | Di-n-butyl Phthalate (ug/L) | | | DATA SOURCE: |
|---|---|---|---|---|---|---|---|---|---|
| T4 | 06/21/89 | | | | <10 | <5 | <5 | <5 | Ashwood & Spalding, 1990 |
| T7 | 06/21/89 | | | | 450B | <5 | <5 | | Ashwood & Spalding, 1990 |
| T11 | 02/15/90 | | | | <2500 | <2500 | <2500 | <5000 | Ashwood & Spalding, 1990 |
| T11 | 07/24/90 | | | | <5 | <10 | <5 | <10 | Ashwood & Spalding, 1990 |
| T13 | 08/11/89 | 260 | | | 50B | <5 | 35 | | Ashwood & Spalding, 1990 |
| T13 | 11/09/89 | | | | 390JB | | | | Ashwood & Spalding, 1990 |
| T13 | 02/15/90 | | | | <2500 | <2500 | <2500 | <5000 | Ashwood & Spalding, 1990 |
| T13 | 07/24/90 | | | | <5 | | | | Ashwood & Spalding, 1990 |
| T16 | 02/15/90 | | | | 440J | <2500 | <2500 | <5000 | Ashwood & Spalding, 1990 |
| T16 | 07/24/90 | | | | <5 | | | | Ashwood & Spalding, 1990 |
| T44 | 04/06/89 | | | | 12JB | | 4J | | Ashwood & Spalding, 1990 |
| T63 | 04/06/89 | | | | 4JB | | 0.6J | | Ashwood & Spalding, 1990 |
| T82 | 04/06/89 | | | | 19B | | 8 | | Ashwood & Spalding, 1990 |
| T85 | 04/06/89 | | | | 12JB | | 16J | | Ashwood & Spalding, 1990 |
| T85 | 11/09/89 | | | | 280JB | | | | Ashwood & Spalding, 1990 |
| T92-1 | 04/05/89 | | | | 5JB | | 3J | 0.5J | Ashwood & Spalding, 1990 |
| T92-2 | 04/05/89 | | | | 5B | | | | Ashwood & Spalding, 1990 |
| T101 | 04/06/89 | | | | 5B | | | | Ashwood & Spalding, 1990 |
| T105 | 04/06/89 | 210 | | | 45B | 0.6J | 560E | 18B | Ashwood & Spalding, 1990 |
| T105 | 11/09/89 | 160 | | | 2900JB | | 5300 | | Ashwood & Spalding, 1990 |
| T112 | 04/06/89 | | | | 8B | | 1J | 95B | Ashwood & Spalding, 1990 |
| T180 | 04/06/89 | | | | 5JB | | 14 | | Ashwood & Spalding, 1990 |
| T237 | 04/06/89 | 20 | | | 7B | 0.7J | | 19B | Ashwood & Spalding, 1990 |
| T252 | 02/15/90 | | | | 550J | <2500 | <2500 | <5000 | Ashwood & Spalding, 1990 |
| T252 | 07/24/90 | | | | <5 | <10 | <5 | <10 | Ashwood & Spalding, 1990 |
| T275 | 02/15/90 | | | | 520J | 890J | | | Ashwood & Spalding, 1990 |
| T275 | 07/24/90 | | | | <5 | <10 | <5 | <10 | Ashwood & Spalding, 1990 |
| T279 | 08/11/89 | 27 | | | 7B | <5 | 5J | | Ashwood & Spalding, 1990 |
| T279 | 11/09/89 | | | | 107J | | | | Ashwood & Spalding, 1990 |
| T279 | 02/15/90 | | | | 430J | | | | Ashwood & Spalding, 1990 |
| T279 | 07/24/90 | | | | <5 | <10 | <5 | <10 | Ashwood & Spalding, 1990 |
| T284 | 02/15/90 | | | | 1000J | 2800 | | | Ashwood & Spalding, 1990 |
| T284 | 07/24/90 | | | | <5 | <10 | <5 | <10 | |
| T285 | 02/15/90 | | | | 14OOJ | | | | Ashwood & Spalding, 1990 |

| WELL # | DATE SAMPLED | 4-methyl-2-Pentanone (ug/L) | 2-Methyl Phenol (ug/L) | Benzoic Acid (ug/L) | Diethyl Phthalate (ug/L) | Di-n-butyl Phthalate (ug/L) | | | DATA SOURCE: |
|---|---|---|---|---|---|---|---|---|---|
| T285 | 07/24/90 | | | | <5 | <10 | <5 | <10 | Ashwood & Spalding, 1990 |
| T288 | 08/11/89 | 17 | | | 3JB | <5 | <5 | | Ashwood & Spalding, 1990 |
| T288 | 11/09/89 | | | | 37J | | | | Ashwood & Spalding, 1990 |
| T288 | 02/15/90 | | | | 790J | | | | Ashwood & Spalding, 1990 |
| T288 | 07/24/90 | | | | <5 | | <5 | <10 | Ashwood & Spalding, 1990 |
| T318 | 04/06/89 | 20 | | | 19B | | 1J | | Ashwood & Spalding, 1990 |
| T318 | 11/09/89 | 380 | | | 120JB | | | | Ashwood & Spalding, 1990 |
| T329 | 04/06/89 | | | | 4JB | | | 20B | Ashwood & Spalding, 1990 |
| T92 | 04/22/86 | ND | ND | ND | ND | ND | ND | ND | Solomon etal, 1988 |
| T135 | 04/13/87 | ND | ND | ND | ND | ND | ND | ND | Solomon etal, 1988 |
| T163 | 04/21/87 | ND | ND | ND | ND | ND | ND | ND | Solomon etal, 1988 |
| T219 | 01/21/87 | ND | ND | ND | ND | ND | ND | ND | Solomon etal, 1988 |
| T257 | 01/21/87 | ND | ND | ND | ND | ND | ND | ND | Solomon etal, 1988 |
| T260-2 | 04/13/87 | ND | ND | ND | ND | ND | ND | ND | Solomon etal, 1988 |
| T288 | 04/13/87 | 32 | 26 | 141 | ND | ND | ND | ND | Solomon etal, 1988 |

| WELL # | DATE SAMPLED | 2,4-Dimethylphenol (ug/L) | o-Cresol (ug/L) | p-Cresol (ug/L) | Methylene Chloride (ug/L) | Carbon Disulfide (ug/L) | Chloroform (ug/L) | 2-Butanone (ug/L) | DATA SOURCE: |
|---|---|---|---|---|---|---|---|---|---|
| T4 | 06/21/89 | | | | <10 | <5 | <5 | <5 | Ashwood & Spalding, 1990 |
| T7 | 06/21/89 | | | | 450B | <5 | <5 | | Ashwood & Spalding, 1990 |
| T11 | 02/15/90 | | | | <2500 | <2500 | <2500 | <5000 | Ashwood & Spalding, 1990 |
| T11 | 07/24/90 | | | | <5 | <10 | <5 | <10 | Ashwood & Spalding, 1990 |
| T13 | 08/11/89 | 260 | | | 50B | <5 | 35 | | Ashwood & Spalding, 1990 |
| T13 | 11/09/89 | | | | 390JB | | | | Ashwood & Spalding, 1990 |
| T13 | 02/15/90 | | | | <2500 | <2500 | <2500 | <5000 | Ashwood & Spalding, 1990 |
| T13 | 07/24/90 | | | | <5 | | | | Ashwood & Spalding, 1990 |
| T16 | 02/15/90 | | | | 440J | <2500 | <2500 | <5000 | Ashwood & Spalding, 1990 |
| T16 | 07/24/90 | | | | <5 | | | | Ashwood & Spalding, 1990 |
| T44 | 04/06/89 | | | | 12JB | | 4J | | Ashwood & Spalding, 1990 |
| T63 | 04/06/89 | | | | 4JB | | 0.6J | | Ashwood & Spalding, 1990 |
| T82 | 04/06/89 | | | | 19B | | 8 | | Ashwood & Spalding, 1990 |
| T85 | 04/06/89 | | | | 12JB | | 16J | | Ashwood & Spalding, 1990 |
| T85 | 11/09/89 | | | | 280JB | | | | Ashwood & Spalding, 1990 |
| T92-1 | 04/05/89 | | | | 5JB | | 3J | 0.5J | Ashwood & Spalding, 1990 |
| T92-2 | 04/05/89 | | | | 5B | | | | Ashwood & Spalding, 1990 |
| T101 | 04/06/89 | | | | 5B | | | | Ashwood & Spalding, 1990 |
| T105 | 04/06/89 | 210 | | | 45B | 0.6J | 560E | 18B | Ashwood & Spalding, 1990 |
| T105 | 11/09/89 | 160 | | | 2900JB | | 5300 | | Ashwood & Spalding, 1990 |
| T112 | 04/06/89 | | | | 8B | | 1J | 95B | Ashwood & Spalding, 1990 |
| T180 | 04/06/89 | | | | 5JB | | 14 | | Ashwood & Spalding, 1990 |
| T237 | 04/06/89 | 20 | | | 7B | 0.7J | | 19B | Ashwood & Spalding, 1990 |
| T252 | 02/15/90 | | | | 550J | <2500 | <2500 | <5000 | Ashwood & Spalding, 1990 |
| T252 | 07/24/90 | | | | <5 | <10 | <5 | <10 | Ashwood & Spalding, 1990 |
| T275 | 02/15/90 | | | | 520J | 890J | | | Ashwood & Spalding, 1990 |
| T275 | 07/24/90 | | | | <5 | <10 | <5 | <10 | Ashwood & Spalding, 1990 |
| T279 | 08/11/89 | 27 | | | 7B | <5 | 5J | | Ashwood & Spalding, 1990 |
| T279 | 11/09/89 | | | | 107J | | | | Ashwood & Spalding, 1990 |
| T279 | 02/15/90 | | | | 430J | | | | Ashwood & Spalding, 1990 |
| T279 | 07/24/90 | | | | <5 | <10 | <5 | <10 | Ashwood & Spalding, 1990 |
| T284 | 02/15/90 | | | | 1000J | 2800 | | | Ashwood & Spalding, 1990 |
| T284 | 07/24/90 | | | | <5 | <10 | <5 | <10 | |
| T285 | 02/15/90 | | | | 14OOJ | | | | Ashwood & Spalding, 1990 |
| T285 | 07/24/90 | | | | <5 | <10 | <5 | <10 | Ashwood & Spalding, 1990 |

| WELL # | DATE SAMPLED | 2,4-Dimethylphenol (ug/L) | o-Cresol (ug/L) | p-Cresol (ug/L) | Methylene Chloride (ug/L) | Carbon Disulfide (ug/L) | Chloroform (ug/L) | 2-Butanone (ug/L) | DATA SOURCE: |
|---|---|---|---|---|---|---|---|---|---|
| T288 | 08/11/89 | 17 | | | 3JB | <5 | <5 | | Ashwood & Spalding, 1990 |
| T288 | 11/09/89 | | | | 37J | | | | Ashwood & Spalding, 1990 |
| T288 | 02/15/90 | | | | 790J | | | | Ashwood & Spalding, 1990 |
| T288 | 07/24/90 | | | | <5 | | <5 | <10 | Ashwood & Spalding, 1990 |
| T318 | 04/06/89 | 20 | | | 19B | | 1J | | Ashwood & Spalding, 1990 |
| T318 | 11/09/89 | 380 | | | 120JB | | | | Ashwood & Spalding, 1990 |
| T329 | 04/06/89 | | | | 4JB | | | 20B | Ashwood & Spalding, 1990 |
| T92 | 04/22/86 | ND | ND | ND | ND | ND | ND | ND | Solomon etal, 1988 |
| T135 | 04/13/87 | ND | ND | ND | ND | ND | ND | ND | Solomon etal, 1988 |
| T163 | 04/21/87 | ND | ND | ND | ND | ND | ND | ND | Solomon etal, 1988 |
| T219 | 01/21/87 | ND | ND | ND | ND | ND | ND | ND | Solomon etal, 1988 |
| T257 | 01/21/87 | ND | ND | ND | ND | ND | ND | ND | Solomon etal, 1988 |
| T260-2 | 04/13/87 | ND | ND | ND | ND | ND | ND | ND | Solomon etal, 1988 |
| T288 | 04/13/87 | 32 | 26 | 141 | ND | ND | ND | ND | Solomon etal, 1988 |

## Table 1B.8. Historical groundwater radiological data (pCi/L)

| Well # | Date Sampled | Gross Alpha | | Gross Beta | | CO-60 | | CS-137 | | SR-90 | | Tritium | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | |
| 108 | 09/09/86 | | | | | | | | | | | 946 | | Poreda, 1988 |
| 109 | 09/09/86 | | | | | | | | | | | 3617 | | Poreda, 1988 |
| 109 | 08/29/83 | 8.10 | | | | <2.16 | | 4.32 | | 0.00 | | | | Boegly, 1984 |
| 272 | 1985? | | | | | 6.48 | | 148.5 | | 13.23 | | ND | | Taylor & Doyle, 1986 |
| 279 | 1985? | | | | | | | | | 2.16 | | ND | | Taylor & Doyle, 1986 |
| 284 | 08/30/83 | | | | | <0.81 | | <5.40 | | 0.00 | | 0 | | Boegly, 1984 |
| 296 | 08/30/83 | | | | | <5.40 | | <2.70 | | 0.00 | | 0 | | Boegly, 1984 |
| 305 | 1985? | | | | | | | 16.47 | | 2.70 | | ND | | Taylor & Doyle, 1986 |
| 313 | 12/12/83 | 7.02 | | | | 14.85 | | 32.40 | | 10.26 | | <1080 | | Boegly, 1984 |
| 313 | 08/30/83 | 5.40 | | | | <0.54 | | 6.21 | | 5.40 | | 567 | | Boegly, 1984 |
| 318 | 03/08/82 | 51.30 | | | | 2.43 | | 1.38 | | 3780.00 | | 3240 | | Boegly, 1984 |
| 318 | 12/12/83 | 0.00 | | | | | | 0.00 | | 5130.00 | | 0 | | Boegly, 1984 |
| 345 | 08/29/83 | 1.62 | | | | <8.10 | | <5.40 | | 24.84 | | 18090 | | Boegly, 1984 |
| 345 | 06/25/84 | | | | | | | 70.20 | | <18.90 | | 12987 | | Boegly, 1984 |
| 345 | 12/13/83 | 21.87 | | | | 4.86 | | 10.26 | | 35.10 | | 14040 | | Boegly, 1984 |
| 345 | 09/10/86 | | | | | | | | | | | 16726 | | Poreda, 1988 |
| 347 | 09/10/86 | | | | | | | | | | | 5522 | | Poreda, 1988 |
| 347 | 09/10/86 | | | | | | | | | | | 5166 | | Poreda, 1988 |
| 355 | 12/12/83 | | | | | | | | | 783.00 | | 0 | | Boegly, 1984 |
| 355 | 06/12/84 | | | | | | | 229.77 | | 4695.30 | | 2997 | | Boegly, 1984 |
| 355 | 03/15/84 | | | | | 2.13 | | 224.10 | | 2970.00 | | 0 | | Boegly, 1984 |
| 356 | 08/30/83 | | | | | <5.40 | | 3.78 | | | | 0 | | Boegly, 1984 |
| 367 | 04/08/87 | | | | | | | | | | | 3604 | | Davis et al., 1989 |
| 367 | 08/29/88 | | | | | | | | | | | 4955 | | Davis et al., 1989 |
| 367 | 11/04/87 | | | 324.00 | | | | | | | | 8559 | | Davis et al., 1989 |
| 367 | 11/20/87 | | | | | 0.19 | | <2.7 | | 17.55 | | 7560 | | Davis et al., 1989 |
| 367 | 06/24/88 | 351.00 | | | | | | | | | | 8108 | | Davis et al., 1989 |
| 370 | 09/09/86 | | | | | | | | | | | 52956 | | Poreda, 1988 |
| 370 | 08/29/83 | | | | | <2.16 | | <1.89 | | 0.00 | | 0 | | Boegly, 1984 |
| 371 | 1985? | | | | | | | | | 2.43 | | ND | | Taylor & Doyle, 1986 |
| 371 | 09/09/86 | | | | | | | | | | | 14950 | | Poreda, 1988 |
| 372 | 08/29/83 | | | | | 5.40 | | <5.40 | | 0.00 | | 0 | | Boegly, 1984 |

## Table 1B.8. (continued)

| Well # | Date Sampled | Gross Alpha | | Gross Beta | | CO-60 | | CS-137 | | SR-90 | | Tritium | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | |
| 373 | 09/09/86 | | | | | | | | | | | 7136 | | Poreda, 1988 |
| 374 | 09/10/86 | | | | | | | | | | | 2454 | | Poreda, 1988 |
| 376 | 06/25/84 | | | | | | | 29.70 | | 10.80 | | 2198 | | Boegly, 1984 |
| 380 | 1985? | | | | | | | 67.5 | | | | ND | | Taylor & Doyle, 1986 |
| 381 | 08/30/83 | | | | | <5.40 | | <2.70 | | 0.00 | | 0 | | Boegly, 1984 |
| 381 | 07/15/86 | | | | | | | | | | | 1350 | | Poreda, 1988 |
| 381 | 09/15/86 | | | | | | | | | | | 2619 | | Poreda, 1988 |
| 382 | 1985? | | | | | 5.4 | | | | 2.43 | | ND | | Taylor & Doyle, 1986 |
| 382 | 09/10/86 | | | | | | | | | | | 11754 | | Poreda, 1988 |
| 382 | 12/12/83 | 5.40 | | | | <5.40 | | 6.21 | | 17.28 | | 567 | | Boegly, 1984 |
| 382 | 06/25/84 | | | | | | | 99.90 | | 29.70 | | 38961 | | Boegly, 1984 |
| 383 | 09/10/86 | | | | | | | | | | | 3390 | | Poreda, 1988 |
| 386 | 09/09/86 | | | | | | | | | | | 4682 | | Poreda, 1988 |
| 388 | 06/25/84 | | | | | | | 18.90 | | 18.90 | | 11988 | | Boegly, 1984 |
| 388 | 08/29/83 | 2.97 | | | | <5.40 | | <5.40 | | 4.32 | | 24570 | | Boegly, 1984 |
| 388 | 07/15/86 | | | | | | | | | | | 8428 | | Poreda, 1988 |
| 388 | 12/12/83 | <0.81 | | | | 4.59 | | 43.20 | | 12.42 | | 10260 | | Boegly, 1984 |
| 388 | 09/09/86 | | | | | | | | | | | 16080 | | Poreda, 1988 |
| 646 | 11/20/87 | | | | | <2.7 | | <2.7 | | 20.25 | | | | Davis et al., 1989 |
| 646 | 08/29/88 | | | | | | | | | | | | | Davis et al., 1989 |
| 646 | 04/08/87 | | | | | | | | | | | | | Davis et al., 1989 |
| 646 | 11/04/87 | 243.00 | | 1647.00 | | | | | | | | 3153 | | Davis et al., 1989 |
| 646 | 06/24/88 | | | | | | | | | | | | | Davis et al., 1989 |
| 647 | 07/10/86 | 43.20 | 54.00 | 143.10 | 81.00 | <2.70 | | 2.70 | | | | 918 | 567 | Solomon et al., 1988 |
| 648 | 01/21/87 | <54.00 | | <81.00 | | <81.00 | | <8.10 | | | | 1917 | 648 | Solomon et al., 1988 |
| 649 | 03/11/87 | 27.00 | 54.00 | <54.00 | | <13.50 | | <10.80 | | | | 405 | 540 | Solomon et al., 1988 |
| 650 | 03/11/87 | 27.00 | 27.00 | 70.20 | 70.20 | <2.70 | | <2.70 | | | | 702000 | 27000 | Solomon et al., 1988 |
| 739 | 1987 | 2.30 | | <3.00 | | <0.20 | | <0.10 | | 0.13 | | 61 | | Sherwood & Borders, 1987 |
| 741 | 0.06 | | | | | | | | | | | 1067 | | Solomon, 1988 |
| 1035 | 06/18/87 | 1.08 | 1.35 | 6.48 | 2.16 | <8.10 | | <8.10 | | | | 2700 | 810 | Yager & Craig, 1989 |
| 1035 | 08/11/87 | 40.50 | 51.30 | 51.30 | 67.50 | <8.10 | | <5.40 | | | | 2700 | 837 | Yager & Craig, 1989 |
| 1035 | 12/17/87 | 70.20 | 32.40 | 15.93 | 2.43 | <5.40 | | <5.40 | | | | 2214 | 864 | Yager & Craig, 198 |

## Table 1B.8. (continued)

| Well # | Date Sampled | Gross Alpha | | Gross Beta | | CO-60 | | CS-137 | | SR-90 | | Tritium | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | |
| 1035 | 03/18/88 | | | 11.88 | 1.62 | <2.70 | | <2.70 | | | | 2565 | 891 | Yager & Craig, 1989 |
| 1035 | 06/28/88 | 8.64 | 5.94 | 10.80 | 5.40 | | | | | | | 3240 | 810 | Yager & Craig, 1989 |
| 1035 | 09/27/88 | 10.80 | 19.98 | 1.89 | 9.45 | | | | | | | 2970 | | Yager & Craig, 1989 |
| 1035 | 01/18/89 | 3.51 | 19.71 | 5.94 | 11.34 | <2.70 | | <2.70 | | | | 1485 | 918 | Yager & Craig, 1989 |
| 1035 | 01/18/89 | 14.85 | 14.04 | 22.14 | 20.79 | <5.40 | | <4.86 | 3.24 | | | 11880 | 1350 | Yager & Craig, 1989 |
| 1035 | 01/18/89 | 10.80 | 13.77 | | | <2.70 | | <2.43 | | | | 1512 | 918 | Yager & Craig, 1989 |
| 1036 | 06/18/87 | 1.89 | 1.62 | 9.45 | 2.43 | <8.10 | | <5.40 | | | | 837 | 810 | Yager & Craig, 1989 |
| 1036 | 08/11/87 | 10.80 | 37.80 | 40.50 | 64.80 | <5.40 | | <5.40 | | | | 486 | 675 | Yager & Craig, 1989 |
| 1036 | 12/17/87 | 2.43 | 1.62 | 7.83 | 1.62 | <2.70 | | <2.70 | | | | 1215 | 837 | Yager & Craig, 1989 |
| 1036 | 03/18/88 | | | 4.05 | 1.08 | <5.40 | | <5.40 | | | | 1458 | 864 | Yager & Craig, 1989 |
| 1036 | 06/28/88 | 3.24 | 3.51 | 3.78 | 3.24 | | | | | | | 1539 | 864 | Yager & Craig, 1989 |
| 1036 | 09/27/88 | 29.70 | 32.40 | 43.20 | 32.40 | | | | | | | 9990 | | Yager & Craig, 1989 |
| 1036 | 01/18/89 | 5.40 | 9.99 | | | <5.40 | | <5.40 | | | | 48600 | 2700 | Yager & Craig, 1989 |
| 1036 | 01/18/89 | 17.82 | 2.97 | 7.83 | 15.39 | <2.70 | | <2.70 | | | | 54000 | 2700 | Yager & Craig, 1989 |
| 1036 | 09/89 | | | | | | | | | | | 168750 | 2700 | Ashwood, 1989 |
| .36 | 12/89 | | | | | | | | | | | 153900 | 5400 | Ashwood, 1989 |
| 1036 | 05/90 | | | | | | | | | | | 226800 | 5400 | Ashwood, 1989 |
| 1037 | 06/18/87 | 1.08 | 1.35 | 4.32 | 2.16 | 8.10 | | 5.40 | | | | 1701 | 864 | Yager & Craig, 1989 |
| 1037 | 08/11/87 | 5.40 | 32.40 | 18.90 | 64.80 | 5.40 | | 5.40 | | | | 972 | 756 | Yager & Craig, 1989 |
| 1037 | 12/17/87 | 1.89 | 1.08 | 2.70 | 1.08 | 2.70 | | 2.70 | | | | 1809 | 864 | Yager & Craig, 1989 |
| 1037 | 03/18/88 | 0.27 | 0.27 | 4.59 | 1.35 | 5.40 | | 2.70 | | | | 1188 | 837 | Yager & Craig, 1989 |
| 1037 | 06/28/88 | 0.00 | 0.54 | 7.29 | 4.32 | <5.40 | | <5.40 | | | | 1242 | 864 | Yager & Craig, 1989 |
| 1037 | 09/27/88 | 0.81 | 5.67 | 35.10 | 29.70 | | | | | | | 729 | | Yager & Craig, 1989 |
| 1037 | 01/18/89 | 3.51 | 10.26 | 21.87 | 24.03 | 5.40 | | 5.40 | | | | 1080 | 918 | Yager & Craig, 1989 |
| 1037 | 01/18/89 | 0.54 | 0.54 | 0.27 | 0.54 | 10.80 | | 8.10 | | | | 27 | 864 | Yager & Craig, 1989 |
| 1038 | 06/18/87 | 0.54 | 1.08 | 4.32 | 2.16 | 2.70 | | 2.70 | | | | 1242 | 837 | Yager & Craig, 1989 |
| 1038 | 08/12/87 | 10.80 | 37.80 | 40.50 | 64.80 | 5.40 | | 2.70 | | | | 1944 | 756 | Yager & Craig, 1989 |
| 1038 | 12/17/87 | 0.27 | 0.54 | 1.35 | 0.81 | 5.40 | | 2.70 | | | | 1647 | 864 | Yager & Craig, 1989 |
| 1038 | 03/18/88 | | | 6.75 | 1.62 | 5.40 | | 5.40 | | | | 1728 | 864 | Yager & Craig, 1989 |
| 1038 | 06/28/88 | 1.62 | 2.43 | 5.67 | 3.78 | <5.40 | | <5.40 | | | | 1458 | 864 | Yager & Craig, 1989 |
| 1038 | 09/27/88 | 0.54 | 1.62 | 0.00. | 2.70 | <8.10 | | <8.10 | | | | 2025 | 1323 | Yager & Craig, 1989 |
| 1038 | 01/13/89 | | 0.54 | 2.97 | 1.89 | 2.16 | | 6.48 | 3.24 | | | 810 | 1215 | Yager & Craig, 1989 |

## Table 1B.8. (continued)

| Well # | Date Sampled | Gross Alpha | | Gross Beta | | CO-60 | | CS-137 | | SR-90 | | Tritium | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | |
| 1038 | 01/13/89 | 1.08 | 0.81 | 1.89 | 1.35 | 1.08 | | 0.81 | 648.00 | | | 297 | 1215 | Yager & Craig, 1989 |
| 1039 | 06/18/87 | 0.81 | 1.08 | 2.16 | 1.89 | 5.40 | | 5.40 | | | | 2187 | 864 | Yager & Craig, 1989 |
| 1039 | 08/12/87 | 29.70 | 48.60 | 32.40 | 64.80 | 5.40 | | 5.40 | | | | 1593 | 810 | Yager & Craig, 1989 |
| 1039 | 12/17/87 | | | 2.97 | 1.08 | 5.40 | | 5.40 | | | | 2430 | 891 | Yager & Craig, 1989 |
| 1039 | 03/18/88 | 0.54 | 0.81 | 0.81 | 0.54 | 2.70 | | 2.70 | | | | 1971 | 864 | Yager & Craig, 1989 |
| 1039 | 06/28/88 | 4.05 | 4.05 | | | <5.40 | | <5.40 | | | | 1755 | 864 | Yager & Craig, 1989 |
| 1039 | 09/27/88 | | | 6.75 | 27.00 | <5.40 | | <5.40 | | | | 1485 | 1296 | Yager & Craig, 1989 |
| 1039 | 01/13/89 | 0.81 | 0.81 | 3.51 | 1.89 | 2.16 | | 4.59 | | | | 2187 | 1269 | Yager & Craig, 1989 |
| 1039 | 01/13/89 | 1.62 | 1.08 | 2.16 | 1.62 | 0.27 | | 1.08 | | | | 2970 | 1350 | Yager & Craig, 1989 |
| 1039 | 03/89 | | | | | | | | | | | 5940 | 1080 | Ashwood, 1989 |
| 1039 | 06/89 | | | | | | | | | | | 11340 | 1350 | Ashwood, 1989 |
| 1039 | 09/89 | | | | | | | | | | | 9990 | 1080 | Ashwood, 1989 |
| 1039 | 12/89 | | | | | | | | | | | 10530 | 1350 | Ashwood, 1989 |
| 1039 | 05/90 | | | | | | | | | | | 17550 | 1350 | Ashwood, 1989 |
| 1040 | 06/18/87 | 1.62 | 1.35 | 3.24 | 1.89 | 5.40 | | 5.40 | | | | 1377 | 837 | Yager & Craig, 1989 |
| 1040 | 08/12/87 | 24.30 | 45.90 | 108.00 | 70.20 | 5.40 | | | | | | | | Yager & Craig, 1989 |
| 1040 | 12/17/87 | 1.08 | 0.81 | 1.89 | 0.81 | 2.70 | | 2.70 | | | | 1755 | 837 | Yager & Craig, 1989 |
| 1040 | 03/18/88 | | | 4.32 | 1.35 | 2.70 | | 2.70 | | | | 1944 | 864 | Yager & Craig, 1989 |
| 1040 | 06/28/88 | 2.97 | 3.51 | 7.29 | 4.32 | <5.40 | | <5.40 | | | | 1944 | 864 | Yager & Craig, 1989 |
| 1040 | 09/27/88 | 1.35 | 2.43 | 5.67 | 3.78 | <8.10 | | <5.40 | | | | 1242 | 1269 | Yager & Craig, 1989 |
| 1040 | 01/13/89 | | 0.54 | 1.35 | 1.35 | 5.67 | | 1.89 | | | | 1080 | 1242 | Yager & Craig, 1989 |
| 1040 | 01/13/89 | 0.81 | 0.81 | 3.24 | 1.62 | 2.97 | | 2.43 | | | | 297 | 1215 | Yager & Craig, 1989 |
| ETF-1 | 04/81 | 13.23 | 14.04 | | | <0.81 | | <8.1 | | <54.00 | | 1647 | 1080 | Vaughan et al., 1982 |
| ETF-1 | 08/81 | 5.40 | 10.80 | | | 2.51 | 2.38 | <2.16 | | 27.00 | 81.00 | 648 | 1242 | Vaughan et al., 1982 |
| ETF-2 | 08/81 | 8.10 | 10.80 | | | 7.56 | [illegible] | [illegible] | | <81.00 | | 1755 | 1350 | Vaughan et al., 1982 |
| ETF-2 | 04/81 | 7.29 | 11.61 | | | <2.7 | | <2.43 | | <54.00 | | 1080 | 891 | Vaughan et al., 1982 |
| ETF-3 | 08/81 | 5.40 | 8.10 | | | <2.16 | | <1.62 | | 27.00 | 81.00 | 648 | 1242 | Vaughan et al., 1982 |
| ETF-3 | 04/81 | 21.60 | 15.39 | | | <2.7 | | <2.16 | | <54.00 | | 540 | 864 | Vaughan et al., 1982 |
| ETF-4 | 08/81 | 14.58 | 15.12 | | | 2.48 | 2.32 | <1.89 | | 27.00 | 81.00 | 1215 | 1296 | Vaughan et al., 1982 |
| ETF-4 | 04/81 | 11.61 | 11.88 | | | <2.7 | | <1.89 | | <54.00 | | 1080 | 891 | Vaughan et al., 1982 |
| ETF-5 | 04/81 | 24.84 | 19.44 | | | <2.7 | | <2.16 | | <54.00 | | 1647 | 918 | Vaughan et al., 1982 |
| ETF-5 | 08/81 | 8.10 | 10.80 | | | 2.97 | 1.35 | <1.08 | | 27.00 | 81.00 | 1215 | 1296 | Vaughan et al., 1982 |

## Table 1B.8. (continued)

| Well # | Date Sampled | Gross Alpha | | Gross Beta | | CO-60 | | CS-137 | | SR-90 | | Tritium | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | |
| ETF-6 | 08/81 | 16.20 | 16.20 | | | 8.37 | 1.35 | 0.81 | 0.81 | 27.00 | 81.00 | 648 | 1242 | Vaughan et al., 1982 |
| ETF-6 | 04/81 | 11.88 | 14.58 | | | <2.7 | | <2.16 | | <54.00 | | 540 | 864 | Vaughan et al., 1982 |
| ETF-7 | 08/81 | 8.10 | 13.50 | | | 4.86 | 0.81 | 1.08 | 0.81 | <81.00 | | 1755 | 1350 | Vaughan et al., 1982 |
| ETF-7 | 04/81 | 15.12 | 10.80 | | | <1.89 | | <1.35 | | <54.00 | | 540 | 864 | Vaughan et al., 1982 |
| ETF-8 | 04/81 | 6.48 | 7.83 | | | <1.89 | | <1.35 | | <54.00 | | 1647 | 918 | Vaughan et al., 1982 |
| ETF-8 | 08/81 | <54.00 | | | | <0.54 | | <2.7 | | <81.00 | | 1755 | 1350 | Vaughan et al., 1982 |
| ETF-9 | 04/81 | 7.29 | 11.34 | | | <2.7 | | <2.7 | | <54.00 | | 1080 | 891 | Vaughan et al., 1982 |
| ETF-9 | 08/81 | 24.30 | 24.30 | | | 13.77 | 5.94 | <2.7 | | <81.00 | | 1755 | 1350 | Vaughan et al., 1982 |
| ETF-10 | 08/81 | 27.00 | 24.30 | | | 24.03 | 6.21 | <2.7 | | 70.20 | 94.50 | 2322 | 1377 | Vaughan et al., 1982 |
| ETF-10 | 04/81 | 5.13 | 9.45 | | | <1.89 | | <1.35 | | <54.00 | | 1080 | 891 | Vaughan et al., 1982 |
| ETF-11 | 04/81 | 3.24 | 9.18 | | | <1.62 | | <1.62 | | <54.00 | | <810.00 | | Vaughan et al., 1982 |
| ETF-11 | 08/81 | 8.10 | 13.50 | | | <2.7 | | <2.43 | | <81.00 | | 108 | 1215 | Vaughan et al., 1982 |
| ETF-12 | 08/81 | 24.30 | 21.60 | | | 78.30 | 10.80 | <2.7 | | 27.00 | 81.00 | 108 | 1215 | Vaughan et al., 1982 |
| ETF-12 | 04/81 | 5.94 | 10.53 | | | <2.7 | | <2.7 | | <54.00 | | 540 | 891 | Vaughan et al., 1982 |
| HHMS-4A | 2/87 | | | | | | | | | | | 108 | | Dreier & Torsn, 1989 |
| HHMS-4A | 07/28/87 | 1.08 | 7.83 | 32.40 | 10.80 | <0.1 | | <2.70 | | 2.16 | 3.51 | 1755 | 918 | Dreier & Torsn, 1989 |
| HHMS-4B | 07/21/87 | 2.97 | 5.94 | 29.70 | 8.10 | <0.20 | | <5.40 | | 13.23 | 8.10 | <1431 | | Dreier & Torsn, 1989 |
| HHMS-4B | 2/87 | | | | | | | | | | | 54 | | Dreier & Torsn, 1989 |
| HHMS-4C | 2/87 | | | | | | | | | | | 1242 | | Dreier & Torsn, 1989 |
| HHMS-4C | 07/20/87 | 6.21 | 6.21 | 83.70 | 13.50 | <0.30 | | <8.10 | | 2.16 | 3.78 | 7290 | 1080 | Dreier & Torsn, 1989 |
| HHMS-5A | 2/87 | | | | | | | | | | | 783 | | Dreier & Torsn, 1989 |
| HHMS-5A | 07/28/87 | 15.66 | 12.42 | 378.00 | 54.00 | <0.20 | | <5.40 | | 3.78 | 2.70 | 1566 | 918 | Dreier & Torsn, 1989 |
| HHMS-5B | 2/87 | | | | | | | | | | | 54 | | Dreier & Torsn, 1989 |
| HHMS-5B | 07/23/87 | <5.40 | | 25.92 | 9.18 | <0.1 | | <2.70 | | 3.24 | 4.05 | <1431 | | Dreier & Torsn, 1989 |
| HHMS-5C | 2/87 | | | | | | | | | | | 270 | | Dreier & Torsn, 1989 |
| HHMS-5C | 07/23/87 | 3.24 | 6.75 | 17.82 | 8.64 | <0.20 | | <5.40 | | 2.70 | 3.24 | <1431 | | Dreier & Torsn, 1989 |
| HHMS-6A | 07/28/87 | 7.83 | 11.61 | 270.00 | 54.00 | <0.30 | | <8.10 | | 0.27 | 3.78 | <1431 | | Dreier & Torsn, 1989 |
| HHMS-6A | 2/87 | | | | | | | | | | | 54 | | Dreier & Torsn, 1989 |
| HHMS-6B | 2/87 | | | | | | | | | | | 54 | | Dreier & Torsn, 1989 |
| HHMS-6B | 07/24/87 | 2.16 | 5.67 | 7.56 | 7.56 | <0.20 | | <5.40 | | 2.70 | 3.24 | <1431 | | Dreier & Torsn, 1989 |
| HHMS-6C | 2/87 | | | | | | | | | | | 54 | | Dreier & Torsn, 1989 |
| HHMS-6C | 07/24/87 | 4.86 | 5.94 | 25.38 | 8.91 | <0.20 | | <5.40 | | 2.16 | 2.97 | <1431 | | Dreier & Torsn, 1989 |

## Table 1B.8. (continued)

| Well # | Date Sampled | Gross Alpha | | Gross Beta | | CO-60 | | CS-137 | | SR-90 | | Tritium | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | |
| HHMS-7A | 2/87 | | | | | | | | | | | 54 | | Dreier & Torres, 1989 |
| HHMS-7A | 07/21/87 | 2.70 | 6.75 | 16.20 | 8.64 | <0.1 | | <2.7 | | <2.70 | | <1431 | | Dreier & Torres, 1989 |
| HHMS-7B | 08/22/88 | | | | | | | | | | | <1350 | | Dreier & Torres, 1989 |
| HHMS-7C | 08/04/88 | | | | | | | | | | | | | Dreier & Torres, 1989 |
| HHMS-7C | 08/22/88 | | | | | | | | | | | <1404 | | Dreier & Torres, 1989 |
| HHMS-8A | 08/23/88 | | | | | | | | | | | <1377 | | Dreier & Torres, 1989 |
| HHMS-8A | 08/04/88 | | | | | | | | | | | | | Dreier & Torres, 1989 |
| HHMS-8B | 08/23/88 | | | | | | | | | | | <1215 | | Dreier & Torres, 1989 |
| HHMS-8B | 08/04/88 | | | | | | | | | | | | | Dreier & Torres, 1989 |
| HHMS-8C | 08/23/88 | | | | | | | | | | | <1377 | | Dreier & Torres, 1989 |
| HHMS-8C | 08/04/88 | | | | | | | | | | | | | Dreier & Torres, 1989 |
| S-11 | 03/17/86 | 207.90 | 72.90 | 126.90 | 78.30 | 23.49 | 8.91 | 2.70 | | | | 99900 | 5400 | Solomon et al., 1988 |
| TARA-1 | 04/08/87 | | | | | | | | | | | 2252 | | Davis et al., 1989 |
| TARA-1 | 06/24/88 | | | | | | | | | | | 1802 | | Davis et al., 1989 |
| TARA-1 | 11/04/87 | | | 108.00 | | | | | | | | 6306 | | Davis et al., 1989 |
| TARA-1 | 08/29/88 | | | | | | | | | | | 450 | | Davis et al., 1989 |
| TARA-1 | 11/20/87 | | | | | <5.4 | | <5.4 | | 6.21 | | 1998 | | Davis et al., 1989 |
| TARA-2 | 06/24/88 | 729.00 | | | | | | | | | | 14414 | | Davis et al., 1989 |
| TARA-2 | 11/04/87 | | | 783.00 | | | | | | | | 71171 | | Davis et al., 1989 |
| TARA-2 | 11/20/87 | | | | | <2.7 | | <2.7 | | 22.95 | | 29700 | | Davis et al., 1989 |
| TARA-2 | 08/29/88 | 108.00 | | 432.00 | | | | | | | | 10360 | | Davis et al., 1989 |
| TARA-2 | 04/08/87 | | | | | | | | | | | 901 | | Davis et al., 1989 |
| TARA-3 | 04/08/87 | | | | | | | | | | | 109009 | | Davis et al., 1989 |
| TARA-3 | 11/20/87 | | | | | <0.89 | | 0.31 | | 37.80 | | 118800 | | Davis et al., 1989 |
| TARA-3 | 06/24/88 | 108.00 | | 108.00 | | | | | | | | 96396 | | Davis et al., 1989 |
| TARA-3 | 08/29/88 | | | | | | | | | | | 85135 | | Davis et al., 1989 |
| TARA-3 | 11/04/87 | | | 324.00 | | | | | | | | 32883 | | Davis et al., 1989 |
| TARA-4 | 04/08/87 | | | | | | | | | | | 248648 | | Davis et al., 1989 |
| TARA-4 | 06/24/88 | 162.00 | | 324.00 | | | | | | | | 80631 | | Davis et al., 1989 |
| TARA-4 | 11/04/87 | | | | | | | | | | | 480180 | | Davis et al., 1989 |
| TARA-4 | 11/20/87 | | | | | <0.43 | | <2.7 | | 0.00 | | 7290000 | | Davis et al., 1989 |
| TARA-4 | 08/29/88 | | | 81.00 | | | | | | | | 93694 | | Davis et al., 1989 |

**Table 1B.8. (continued)**

| Well # | Date Sampled | Gross Alpha | | Gross Beta | | CO-60 | | CS-137 | | SR-90 | | Tritium | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | |
| TARA-5 | 08/29/88 | 162.00 | | | | | | | | | | 450 | | Davis et al., 1989 |
| TARA-5 | 04/08/87 | | | | | | | | | | | 1802 | | Davis et al., 1989 |
| TARA-5 | 06/24/88 | 108.00 | | | | | | | | | | 3153 | | Davis et al., 1989 |
| TARA-5 | 11/20/87 | | | | | <2.7 | | <2.7 | | 10.53 | | 10530 | | Davis et al., 1989 |
| TARA-5 | 11/04/87 | | | | | | | | | | | 4054 | | Davis et al., 1989 |
| TARA-6 | 04/08/87 | | | | | | | | | | | 344594 | | Davis et al., 1989 |
| TARA-6 | 11/20/87 | | | | | <0.51 | | <2.7 | | 78.30 | | 202500 | | Davis et al., 1989 |
| TARA-6 | 08/29/88 | 297.00 | | | | | | | | | | 176576 | | Davis et al., 1989 |
| TARA-6 | 06/24/88 | 243.00 | | | | | | | | | | 231982 | | Davis et al., 1989 |
| TARA-6 | 11/04/87 | 108.00 | | | | | | | | | | 181081 | | Davis et al., 1989 |
| TARA-7 | 04/08/87 | | | | | | | | | | | 113964 | | Davis et al., 1989 |
| TARA-7 | 11/20/87 | | | | | <5.4 | | <5.4 | | 21.06 | | 45900 | | Davis et al., 1989 |
| TARA-7 | 08/29/88 | | | 108.00 | | | | | | | | 17117 | | Davis et al., 1989 |
| TARA-7 | 06/24/88 | 405.00 | | | | | | | | | | 26126 | | Davis et al., 1989 |
| TARA-7 | 11/04/87 | | | | | | | | | | | 125225 | | Davis et al., 1989 |
| TARA-8 | 04/08/87 | | | | | | | | | | | 17117 | | Davis et al., 1989 |
| TARA-8 | 11/20/87 | | | | | <5.4 | | <2.7 | | | | 189000 | | Davis et al., 1989 |
| TARA-8 | 08/29/88 | 54.00 | | | | | | | | | | 175225 | | Davis et al., 1989 |
| TARA-8 | 06/24/88 | 162.00 | | | | | | | | | | 188739 | | Davis et al., 1989 |
| TARA-8 | 11/04/87 | | | | | | | | | | | 212162 | | Davis et al., 1989 |
| TARA-9 | 11/04/87 | | | | | | | | | | | 13964 | | Davis et al., 1989 |
| TARA-9 | 11/20/87 | | | | | <2.7 | | <2.7 | | 13.23 | | 12150 | | Davis et al., 1989 |
| TARA-9 | 06/24/88 | 351.00 | | | | | | | | | | 6306 | | Davis et al., 1989 |
| TARA-9 | 04/08/87 | | | | | | | | | | | 450 | | Davis et al., 1989 |
| TARA-9 | 08/29/88 | | | | | | | | | | | 5856 | | Davis et al., 1989 |
| TARA-10 | 06/24/88 | 243.00 | | | | | | | | | | 528378 | | Davis et al., 1989 |
| TARA-10 | 11/04/87 | | | | | | | | | | | 297297 | | Davis et al., 1989 |
| TARA-10 | 08/29/88 | | | | | | | | | | | 1167116 | | Davis et al., 1989 |
| TARA-10 | 04/08/87 | | | | | | | | | | | 33784 | | Davis et al., 1989 |
| TARA-10 | 11/20/87 | | | | | <5.4 | | <5.4 | | 1.24 | | 351000 | | Davis et al., 1989 |
| TARA-11 | 08/29/88 | 405.00 | | 513.00 | | | | | | | | 93694 | | Davis et al., 1989 |
| TARA-11 | 11/20/87 | | | | | <1.30 | | <2.7 | | 4.59 | | 89100 | | Davis et al., 1989 |

## Table 1B.8. (continued)

| Well # | Date Sampled | Gross Alpha | | Gross Beta | | CO-60 | | CS-137 | | SR-90 | | Tritium | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | |
| TARA-11 | 04/08/87 | | | | | | | | | | | 131531 | | Davis et al., 1989 |
| TARA-11 | 11/04/87 | | | 135.00 | | | | | | | | 122522 | | Davis et al., 1989 |
| TARA-11 | 06/24/88 | 243.00 | | 405.00 | | | | | | | | 81081 | | Davis et al., 1989 |
| TARA-12 | 06/24/88 | 108.00 | | | | | | | | | | 658558 | | Davis et al., 1989 |
| TARA-12 | 04/08/87 | | | | | | | | | | | 238288 | | Davis et al., 1989 |
| TARA-12 | 08/29/88 | | | | | | | | | | | 1029278 | | Davis et al., 1989 |
| TARA-12 | 11/04/87 | | | | | | | | | | | 109910 | | Davis et al., 1989 |
| TARA-12 | 11/20/87 | | | | | <0.24 | | <2.7 | | 1.89 | | 221400 | | Davis et al., 1989 |
| TARA-13 | 06/24/88 | 162.00 | | | | | | | | | | 9459 | | Davis et al., 1989 |
| TARA-13 | 11/04/87 | | | 27.00 | | | | | | | | 4054 | | Davis et al., 1989 |
| TARA-13 | 04/08/87 | | | | | | | | | | | 450 | | Davis et al., 1989 |
| TARA-13 | 08/29/88 | | | | | | | | | | | 14865 | | Davis et al., 1989 |
| TARA-13 | 11/20/87 | | | | | <5.4 | | 0.15 | | 7.56 | | 918000 | | Davis et al., 1989 |
| T-1 | 10-26-89 | 1.08 | 2.70 | 3.24 | 6.21 | -1.62 | 9.45 | 0.27 | 7.29 | 5.67 | 5.13 | 378 | 837 | Morrissey, 1990 |
| T-1 | 10/25/89 | 1.35 | 2.43 | 0.54 | 5.40 | 2.70 | 7.29 | 1.35 | 8.37 | -1.62 | 12.15 | 702 | 864 | Morrissey, 1990 |
| T-1 | 10/10/88 | | | | | | | 148.00 | 40 | 102 | 28 | 842 | 256 | Huff, 1988a, b |
| T-10 | 10/25/89 | 1.35 | 2.70 | -2.16 | 5.67 | -9.99 | 15.93 | -5.40 | 14.31 | -1.35 | 4.32 | 594 | 837 | Morrissey, 1990 |
| T-10 | 10/26/89 | 0.27 | 1.89 | 1.35 | 5.67 | -3.78 | 19.98 | 3.51 | 14.85 | -0.81 | 3.78 | 594 | 837 | Morrissey, 1990 |
| T-17 | 10/26/89 | 1.08 | 2.70 | 5.67 | 5.94 | -2.16 | 14.58 | -5.94 | 17.28 | 2.43 | 3.78 | 594 | 837 | Morrissey, 1990 |
| T-17 | 10/10/88 | | | | | | | [illegible] | 38 | 2700 | 52 | 857 | 258 | Huff, 1988 |
| T-17 | 10/25/89 | 0.27 | 1.89 | 0.27 | 1.89 | 3.51 | 8.10 | [illegible] | 12.69 | 1.89 | 6.75 | 1188 | 891 | Morrissey, 1990 |
| T-18 | 10/26/89 | 0.54 | 2.16 | 2.16 | 5.40 | 9.18 | [illegible] | [illegible] | 15.12 | -8.10 | 11.61 | 702 | 864 | Morrissey, 1990 |
| T-18 | 10/10/88 | | | | | | | [illegible] | 41 | 225 | 30 | 1304 | 268 | Huff, 1988 |
| T-18 | 10/25/89 | -0.54 | 0.27 | 17.01 | 8.10 | -3.51 | [illegible] | [illegible] | 17.28 | -0.54 | 6.75 | 999 | 864 | Morrissey, 1990 |
| T-20 | 10/25/89 | 0.27 | 2.16 | 0.54 | 5.13 | 1.89 | [illegible] | [illegible] | 7.02 | -1.08 | 3.51 | 864 | 891 | Morrissey, 1990 |
| T-20 | 10/26/89 | 0.54 | 2.16 | -0.54 | 4.32 | -7.02 | [illegible] | [illegible] | 11.88 | -2.97 | 3.78 | 1107 | 864 | Morrissey, 1990 |
| T-20 | 10/10/88 | | | | | | | [illegible] | 36 | n.d. | | 1080 | 262 | Huff, 1988 |
| T-22 | 10/26/89 | 0.00 | 1.89 | -2.16 | 4.89 | 6.21 | [illegible] | [illegible] | 12.42 | 3.51 | 7.02 | 594 | 837 | Morrissey, 1990 |
| T-22 | 10/25/89 | 0.27 | 1.89 | 1.08 | 6.21 | -4.59 | 16.74 | [illegible] | 14.04 | -0.27 | 4.05 | 108 | 783 | Morrissey, 1990 |
| T-36 | 10/26/89 | 1.89 | 2.70 | 4.05 | 6.48 | 2.79 | 9.45 | [illegible] | 13.50 | 4.86 | 4.86 | 783 | 864 | Morrissey, 1990 |
| T-36 | 10/25/89 | 0.27 | 1.89 | 1.62 | 5.67 | 2.16 | 7.29 | 0.81 | 7.56 | 3.24 | 2.97 | 594 | 837 | Morrissey, 1990 |
| T-5 | 10/10/88 | | | | | | | 225 | 35 | 73 | 28 | 866 | 256 | Huff, 1988 |

## Table 1B.8. (continued)

| Well # | Date Sampled | Gross Alpha | | Gross Beta | | CO-60 | | CS-137 | | SR-90 | | Tritium | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | |
| T-7 | 10/10/88 | | | | | | | 178 | 45 | 174 | 29 | 736 | 256 | Huff, 1988 |
| T-7 | 10/26/89 | 0.00 | 1.89 | 3.51 | 6.21 | 2.70 | 10.53 | 4.86 | 12.69 | -0.27 | 14.31 | 486 | 864 | Morrissey, 1990 |
| T-7 | 10/25/89 | -0.81 | 0.27 | -3.78 | 4.32 | 7.56 | 8.10 | 4.32 | 8.91 | 3.51 | 4.32 | 540 | 864 | Morrissey, 1990 |
| 4 | 02/07/91 | | | | | | | <67.5 | | | | | | Wickliff, 1991 |
| 4 | 02/12/90 | 2.16 | 2.16 | 21.06 | 4.05 | <67.5 | | <67.5 | | | | | | Ashwood, 1990 |
| 5 | 09/20/90 | 4.32 | 2.97 | 19.71 | 6.48 | | | 24.30 | 70.20 | | | | | Wickliff, 1991 |
| 5 | 02/07/91 | -2.97 | 1.08 | 8.64 | 18.09 | | | <67.5 | | | | | | Wickliff, 1991 |
| 5 | 02/12/90 | 1.35 | 1.62 | 31.59 | 4.59 | <67.5 | | <67.5 | | | | | | Ashwood, 1990 |
| 6 | 02/07/91 | -22.68 | 0.86 | 72.90 | 27.00 | | | <67.5 | | | | | | Wickliff, 1991 |
| 6 | 09/20/90 | 1.32 | 1.78 | 12.69 | 4.59 | | | -32.40 | 132.30 | | | | | Wickliff, 1991 |
| 6 | 02/12/90 | 2.43 | 2.43 | 16.74 | 3.78 | <67.5 | | <67.5 | | | | | | Ashwood, 1990 |
| 7 | 02/12/90 | 1.62 | 2.16 | 26.19 | 4.59 | <67.5 | | <67.5 | | | | | | Ashwood, 1990 |
| 7 | 09/19/90 | 0.41 | 1.19 | 14.58 | 4.59 | | | 16.20 | 48.60 | | | | | Wickliff, 1991 |
| 8 | 02/12/90 | 0.81 | 0.54 | 50.76 | 4.86 | <67.5 | | <67.5 | | | | | | Ashwood, 1990 |
| 8 | 09/19/90 | 13.23 | 15.39 | 64.80 | 37.80 | | | 16.20 | 86.40 | 14.58 | 11.88 | | | Wickliff, 1991 |
| 8 | 02/07/91 | 1.89 | 6.75 | 20.25 | 21.33 | | | <67.5 | | | | | | Wickliff, 1991 |
| 8 | 12/07/90 | 1.62 | 2.43 | 24.30 | 7.56 | | | -5.40 | 48.60 | 2.70 | 54.00 | | | Wickliff, 1991 |
| 9 | 02/07/91 | 2.16 | 7.29 | 56.70 | 24.30 | | | <67.5 | | | | | | Wickliff, 1991 |
| 10 | 09/20/90 | 1.40 | 1.65 | 6.21 | 4.05 | | | 10.80 | 99.90 | | | | | Wickliff, 1991 |
| 10 | 02/07/91 | 1.62 | 4.32 | 0.27 | 9.99 | | | <67.5 | | | | | | Wickliff, 1991 |
| 11 | 12/07/90 | 3.51 | 3.24 | 17.82 | 6.75 | | | <67.5 | | <67.5 | | | | Wickliff, 1991 |
| 11 | 02/12/90 | 0.54 | 1.89 | 18.63 | 4.05 | <67.5 | | <67.5 | | | | | | Ashwood, 1990 |
| 11 | 09/20/90 | 0.73 | 1.32 | 15.93 | 4.59 | | | 64.80 | 51.30 | | | | | Wickliff, 1991 |
| 11 | 02/07/91 | 4.32 | 8.37 | 20.79 | 20.25 | | | 48.60 | 10.80 | | | | | Wickliff, 1991 |
| 12 | 02/12/90 | -0.27 | 1.62 | 4.32 | 2.70 | <67.5 | | <67.5 | | | | | | Ashwood, 1990 |
| 12 | 09/20/90 | 1.54 | 1.81 | 13.77 | 4.86 | | | -8.10 | 102.60 | | | | | Wickliff, 1991 |
| 12 | 02/07/91 | 7.56 | 6.48 | 17.28 | 11.61 | | | 29.70 | 10.80 | | | | | Wickliff, 1991 |
| 13 | 09/20/90 | 18.90 | 32.40 | 251.10 | 94.50 | | | -62.10 | 186.30 | | | | | Wickliff, 1991 |
| 13 | 02/12/90 | 0.81 | 0.81 | 60.21 | 5.40 | <67.5 | | <67.5 | | | | | | Ashwood, 1990 |
| 15 | 02/07/91 | 9.45 | 12.15 | 21.60 | 23.22 | | | <67.5 | | | | | | Wickliff, 1991 |
| 15 | 12/07/90 | 6.48 | 5.40 | 5.94 | 5.67 | | | <67.5 | | <67.5 | | | | Wickliff, 1991 |
| 15 | 09/20/90 | 2.97 | 17.55 | 13.50 | 48.60 | | | 21.60 | 70.20 | | | | | Wickliff, 1991 |

**Table 1B.8. (continued)**

| Well # | Date Sampled | Gross Alpha | | Gross Beta | | CO-60 | | CS-137 | | SR-90 | | Tritium | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | |
| 18 | 02/07/91 | 2.97 | 4.32 | 16.47 | 11.34 | | | <67.5 | | | | | | Wickliff, 1991 |
| 19 | 09/20/90 | 19.44 | 25.38 | 1350.00 | 162.00 | | | 37.80 | 94.50 | | | | | Wickliff, 1991 |
| 19 | 12/07/90 | 2.43 | 3.24 | 2295.00 | 0.00 | | | <67.5 | | <67.5 | | | | Wickliff, 1991 |
| 19A | 02/22/91 | 1.89 | 4.05 | 1188.00 | 0.00 | | | <67.5 | | 513.00 | 108.00 | | | Wickliff, 1991 |
| 19B | 02/22/91 | -1.59 | 0.54 | 864.00 | 0.00 | | | <67.5 | | 513.00 | 81.00 | | | Wickliff, 1991 |
| 20 | 02/07/91 | 2.70 | 7.29 | 10.53 | 18.63 | | | <67.5 | | | | | | Wickliff, 1991 |
| 22 | 02/07/91 | 2.16 | 4.86 | 10.80 | 10.53 | | | <67.5 | | | | | | Wickliff, 1991 |
| 23 | 02/07/91 | 1.08 | 3.51 | 10.80 | 10.80 | | | 37.80 | 10.80 | | | | | Wickliff, 1991 |
| 24 | 02/07/91 | -2.16 | 5.67 | 5.40 | 21.33 | | | <67.5 | | | | | | Wickliff, 1991 |
| 25 | 09/20/90 | 2.16 | 1.89 | 7.83 | 4.86 | | | -21.60 | 110.70 | | | | | Wickliff, 1991 |
| 25 | 02/22/91 | -0.54 | 5.40 | 13.50 | 18.63 | | | <67.5 | | | | | | Wickliff, 1991 |
| 25 | 12/07/90 | 1.08 | 2.16 | 35.10 | 8.10 | | | <67.5 | | <67.5 | | | | Wickliff, 1991 |
| 26 | 02/07/91 | 1.35 | 3.78 | 18.36 | 13.50 | | | <67.5 | | | | | | Wickliff, 1991 |
| 27 | 09/20/90 | 1.97 | 2.30 | 18.63 | 5.40 | | | 54.00 | 159.30 | | | | | Wickliff, 1991 |
| 27 | 02/22/91 | 1.08 | 3.78 | -1.35 | 8.37 | | | <67.5 | | | | | | Wickliff, 1991 |
| 27 | 12/12/90 | 6.75 | 7.29 | 13.77 | 10.80 | | | <67.5 | | <67.5 | | | | Wickliff, 1991 |
| 28 | 02/07/91 | -0.54 | 5.40 | 23.22 | 21.33 | | | <67.5 | | | | | | Wickliff, 1991 |
| 28 | 09/20/90 | 0.78 | 1.46 | 17.01 | 4.86 | | | 54.00 | 132.30 | | | | | Wickliff, 1991 |
| 28 | 12/12/90 | -0.54 | 0.27 | 37.80 | 8.10 | | | -2.70 | 54.00 | 32.40 | 62.10 | | | Wickliff, 1991 |
| 30 | 09/20/90 | 1.11 | 1.81 | 10.26 | 4.32 | | | 8.10 | 102.60 | | | | | Wickliff, 1991 |
| 30 | 02/07/91 | -2.27 | 0.89 | 2.97 | 15.39 | | | <67.5 | | | | | | Wickliff, 1991 |
| 30 | 12/12/90 | 0.27 | 1.35 | 7.02 | 5.40 | | | <67.5 | | <67.5 | | | | Wickliff, 1991 |
| 32 | 12/12/90 | -19.71 | 17.82 | 51.30 | 10.80 | | | 18.90 | 75.60 | -5.40 | 110.70 | | | Wickliff, 1991 |
| 32 | 09/20/90 | -8.91 | 3.51 | 21.60 | 45.90 | | | -10.80 | 153.90 | | | | | Wickliff, 1991 |
| 32 | 02/07/91 | -1.35 | 0.51 | 14.85 | 11.07 | | | <67.5 | | | | | | Wickliff, 1991 |
| 35 | 09/20/90 | 13.23 | 22.14 | 59.40 | 51.30 | | | 5.40 | 70.20 | | | | | Wickliff, 1991 |
| 35 | 12/12/90 | 2.70 | 4.32 | 21.60 | 8.10 | | | <67.5 | | | | | | Wickliff, 1991 |
| 36 | 09/20/90 | 37.80 | 35.10 | -5.40 | 54.00 | | | 64.80 | 159.30 | | | | | Wickliff, 1991 |
| 36 | 02/07/91 | -0.54 | 5.40 | 18.09 | 25.65 | | | 8.10 | 21.60 | | | | | Wickliff, 1991 |
| 38 | 02/07/91 | 7.56 | 9.72 | 54.00 | 27.00 | | | <67.5 | | | | | | Wickliff, 1991 |
| 38 | 09/20/90 | 0.54 | 13.50 | 121.50 | 64.80 | | | -18.90 | 102.60 | 35.10 | 16.20 | | | Wickliff, 1991 |
| 38 | 12/12/90 | 1.62 | 3.24 | 40.50 | 8.10 | | | <67.5 | | | | | | Wickliff, 1991 |

## Table 1B.8. (continued)

| Well # | Date Sampled | Gross Alpha | | Gross Beta | | CO-60 | | CS-137 | | SR-90 | | Tritium | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | |
| 39 | 02/07/91 | -1.54 | 0.51 | -2.97 | 7.56 | | | <67.5 | | | | | | Wickliff, 1991 |
| 40 | 02/07/91 | -2.70 | 5.13 | 6.48 | 18.90 | | | <67.5 | | | | | | Wickliff, 1991 |
| 40 | 12/12/90 | 0.27 | 1.62 | 7.56 | 5.67 | | | <67.5 | | | | | | Wickliff, 1991 |
| 41 | 02/07/91 | 2.70 | 7.02 | -0.81 | 16.74 | | | <67.5 | | | | | | Wickliff, 1991 |
| 42 | 09/20/90 | 2.46 | 2.54 | 24.03 | 5.67 | | | 8.10 | 110.70 | | | | | Wickliff, 1991 |
| 42 | 12/12/90 | -0.27 | 2.70 | 56.70 | 13.50 | | | 29.70 | 70.20 | 21.60 | 78.30 | | | Wickliff, 1991 |
| 42 | 02/07/91 | -2.38 | 0.92 | 12.42 | 23.22 | | | <67.5 | | | | | | Wickliff, 1991 |
| 43 | 12/12/90 | 4.32 | 4.32 | 2.43 | 5.67 | | | <67.5 | | <67.5 | | | | Wickliff, 1991 |
| 43 | 02/07/91 | 3.24 | 5.67 | 20.52 | 14.31 | | | <67.5 | | | | | | Wickliff, 1991 |
| 44 | 02/07/91 | 4.59 | 8.91 | 3.78 | 17.01 | | | <67.5 | | | | | | Wickliff, 1991 |
| 45 | 02/07/91 | | 0.00 | | 0.00 | | | 67.50 | 29.70 | | | | | Wickliff, 1991 |
| 46 | 02/07/91 | 2.70 | 7.29 | 15.39 | 19.17 | | | <67.5 | | | | | | Wickliff, 1991 |
| AUG 48 | 02/22/91 | | 0.00 | | 0.00 | | | <67.5 | | | | | | Wickliff, 1991 |
| AUG 48 | 12/12/90 | 1.62 | 2.70 | 4.59 | 4.86 | | | <67.5 | | <67.5 | | | | Wickliff, 1991 |
| UG 49 | 09/14/90 | 1.08 | 1.08 | 4.59 | 1.89 | | | <67.5 | | | | | | Wickliff, 1991 |
| 49 | 02/22/91 | | 0.00 | | 0.00 | | | <67.5 | | | | | | Wickliff, 1991 |
| AUG 50 | 02/22/91 | | 0.00 | | 0.00 | | | <67.5 | | | | | | Wickliff, 1991 |
| AUG 51 | 02/22/91 | | 0.00 | | 0.00 | | | <67.5 | | | | | | Wickliff, 1991 |
| AUG W536 | 02/22/91 | 0.27 | 3.24 | 19.71 | 14.04 | | | <67.5 | | | | | | Wickliff, 1991 |
| AUG W540 | 02/22/91 | 1.62 | 4.05 | 4.32 | 9.18 | | | <67.5 | | | | | | Wickliff, 1991 |
| AUG W559 | 02/22/91 | -1.70 | 0.57 | 1.89 | 8.37 | | | <67.5 | | | | | | Wickliff, 1991 |
| AUG W7 | 02/22/91 | | 0.00 | | 0.00 | | | <67.5 | | | | | | Wickliff, 1991 |
| C520 | 12/12/90 | 5.67 | 4.32 | 29.70 | 8.10 | | | [illegible] | 26.19 | -10.80 | 29.70 | | | Wickliff, 1991 |
| C520 | 02/07/91 | -0.54 | 4.59 | 9.45 | 20.25 | | | <67.5 | | | | | | Wickliff, 1991 |
| C595 | 02/07/91 | 37.80 | 18.90 | 12.69 | 21.60 | | | <67.5 | | | | | | Wickliff, 1991 |
| C595 | 12/12/90 | 7.83 | 5.40 | 21.60 | 7.83 | | | [illegible] | 35.10 | 10.80 | 37.80 | | | Wickliff, 1991 |
| FIS 102 | 02/07/91 | 1.08 | 5.40 | 43.20 | 24.30 | | | <67.5 | | | | | | Wickliff, 1991 |
| FIS 102 | 12/12/90 | 4.86 | 3.78 | 32.40 | 8.10 | | | [illegible] | 35.10 | 43.20 | 27.00 | | | Wickliff, 1991 |
| FIS ? | 02/07/91 | -0.27 | 3.51 | 27.00 | 13.50 | | | <67.5 | | | | | | Wickliff, 1991 |
| FIS ? | 12/12/90 | 2.43 | 2.97 | 18.63 | 7.83 | | | [illegible] | 26.19 | -8.10 | 35.10 | | | Wickliff, 1991 |
| FD-North | 02/29/84 | 54.00 | 27.00 | | | <18.9 | | <16.2 | | 51.30 | 24.30 | 5940 | 50 | Davis & Marshall, 1988 |
| -East | 09/29/83 | 54.00 | 27.00 | | | <16.2 | | <13.5 | | 14.58 | 7.56 | 513000 | 27000 | Davis & Marshall, 1988 |

## Table 1B.8. (continued)

| Well # | Date Sampled | Gross Alpha | | Gross Beta | | CO-60 | | CS-137 | | SR-90 | | Tritium | | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | Conc. | Err | |
| FD-East | 02/29/84 | 124.20 | 97.20 | | | <1.90 | | <1.35 | | 48.60 | 24.30 | 729000 | 27000 | Davis & Marshall, 1988 |
| FD-East | 04/30/84 | <27.00 | | | | <2.70 | | <2.70 | 21.60 | 7.83 | 5.94 | 2133000 | 27000 | Davis & Marshall, 1988 |
| FD-East | 05/17/85 | | | | | | | <1.62 | | 4.86 | 4.59 | 8910000 | 270000 | Davis & Marshall, 1988 |
| FD-East | 10/25/85 | <54.00 | | | | | | | <54.0 | 4.32 | 4.05 | 7830000 | 270000 | Davis & Marshall, 1988 |
| FD-East | 01/14/86 | 78.30 | 35.10 | | | | | | 35.10 | 40.50 | 8.10 | 8910000 | 270000 | Davis & Marshall, 1988 |
| FD-East | 03/21/86 | | | | | | | <1.35 | | 11.34 | 4.86 | 4590000 | 270000 | Davis & Marshall, 1988 |
| FD-East | 10/30/86 | | | | | <2.70 | | <2.70 | | 2.62 | 2.16 | 4860000 | 270000 | Davis & Marshall, 1988 |
| FD-East | 02/26/87 | | | | | | | | | | | 4510000 | | Davis et al., 1987 |
| FD-East | 02/27/87 | | | | | | | | | | | 3850000 | | Davis et al., 1987 |
| FD-East | 02/27/87 | | | | | | | | | | | 3530000 | | Davis et al., 1987 |
| FD-East | 02/27/87 | | | | | | | | | | | 3040000 | | Davis et al., 1987 |
| FD-East | 02/27/87 | | | | | | | | | | | 3100000 | | Davis et al., 1987 |
| FD-East | 02/27/87 | | | | | | | | | | | 3750000 | | Davis et al., 1987 |
| FD-East | 02/28/87 | | | | | | | | | | | 2780000 | | Davis et al., 1987 |
| FD-East | 02/28/87 | | | | | | | | | | | 1620000 | | Davis et al., 1987 |
| FD-East | 02/28/87 | | | | | | | | | | | 1760000 | | Davis et al., 1987 |
| FD-East | 03/01/87 | | | | | | | | | | | 2460000 | | Davis et al., 1987 |
| FD-East | 04/14/87 | | | | | | | | | | | 7310000 | | Davis et al., 1987 |
| FD-East | 04/14/87 | | | | | | | | | | | 7080000 | | Davis et al., 1987 |
| FD-East | 04/14/87 | | | | | | | | | | | 6950000 | | Davis et al., 1987 |
| FD-East | 04/15/87 | | | | | | | | | | | 3300000 | | Davis et al., 1987 |
| FD-East | 04/15/87 | | | | | | | | | | | 3150000 | | Davis et al., 1987 |
| FD-East | 04/15/87 | | | | | | | | | | | 5360000 | | Davis et al., 1987 |

NOTE:FD-North = 49 Trench French Drain north limb outfall
FD-South = 49 Trench French Drain east limb outfall

Sampling/well locations shown on Figure 1.b.2

**Table 1B.9. Historical VOC analytical data for groundwater**

| Well # | Date Sampled | Methylene Chloride (ug/l) | 1,1-DCA (ug/l) | Chloroform (ug/l) | 1,2-DCA (ug/l) | 1,1,2,2-PCE (ug/l) | TCE (ug/l) | Data Source |
|---|---|---|---|---|---|---|---|---|
| S-11 | 03/17/86 | ND | ND | ND | ND | ND | 2 | Solomon et al., 1988 |
| 647 | 07/10/87 | 256 | 10 | ND | ND | ND | ND | Solomon et al., 1988 |
| 648 | 01/21/87 | ND | ND | 85 | 23 | 55 | 2323 | Solomon et al., 1988 |
| 649 | 03/11/87 | 40 | ND | ND | ND | ND | ND | Solomon et al., 1988 |
| 650A | 03/11/87 | ND | ND | ND | ND | ND | ND | Solomon et al., 1988 |

| Well # | Date Sampled | Benzene (ug/l) | PCE (ug/l) | Toluene (ug/l) | Total Xylenes (ug/l) | Phthalate* (ug/l) | Data Source |
|---|---|---|---|---|---|---|---|
| S-11 | 03/17/86 | ND | ND | ND | ND | 13 | Solomon et al., 1988 |
| 647 | 07/10/87 | ND | ND | ND | ND | ND | Solomon et al., 1988 |
| 648 | 01/21/87 | 70 | 1973 | 10 | 6 | ND | Solomon et al., 1988 |
| 649 | 03/11/87 | ND | ND | ND | ND | ND | Solomon et al., 1988 |
| 650A | 03/11/87 | ND | ND | ND | ND | ND | Solomon et al., 1988 |

SEE FIGURE 1B.2 FOR SAMPLING LOCATIONS.

**Table 1B.10. Historical surface water radiological dataanalytical data - Flume II[a]**

| Date | Gross Alpha (pCi/L) | | CO-60 (pCi/L) | | CS-137 (pCi/L) | | SR-90 (pCi/L) | | H-3 (pCi/L) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error |
| 03-16-81 | 102.6 | 132.3 | <18.9 | | <13.5 | | 5.7 | 9.2 | 675000.0 | 27000.0 |
| 03-23-81 | 67.5 | 75.6 | <13.5 | | <10.8 | | 4.9 | 9.7 | 648000.0 | 27000.0 |
| 03-30-81 | 83.7 | 124.2 | <13.5 | | <8.1 | | 5.4 | 9.7 | 297000.0 | 27000.0 |
| 04-05-81 | 102.6 | 126.9 | 297.0 | 54.0 | <21.6 | | 4.9 | 9.7 | 126900.0 | 5400.0 |
| 04-05-81 | 29.7 | 75.6 | <10.8 | | <13.5 | | 6.5 | 11.6 | 240300.0 | 8100.0 |
| 04-07-81 | 59.4 | 116.1 | 14.0 | 12.2 | <10.8 | | 3.0 | 10.8 | 45900.0 | 2700.0 |
| 04-14-81 | 118.8 | 137.7 | 19.2 | 18.1 | <13.5 | | 12.2 | 11.9 | 567000.0 | 27000.0 |
| 04-20-81 | 159.3 | 121.5 | <21.6 | | <16.2 | | 7.3 | 11.3 | 121500.0 | 5400.0 |
| 04-20-81 | 102.6 | 129.6 | <13.5 | | <8.1 | | 20.8 | 19.7 | 145800.0 | 8100.0 |
| 04-20-81 | 29.7 | 75.6 | <10.8 | | <8.1 | | 2.2 | 8.9 | 253800.0 | 8100.0 |
| 04-20-81 | 108.0 | 116.1 | <16.2 | | <13.5 | | 13.8 | 11.6 | 297000.0 | 27000.0 |
| 04-27-81 | 64.8 | 102.6 | 24.3 | | <13.5 | | 7.8 | 11.9 | 540000.0 | 27000.0 |
| 05-04-81 | 145.8 | 153.9 | <21.6 | | <16.2 | | 9.5 | 11.1 | 567000.0 | 27000.0 |
| 05-11-81 | 105.3 | 97.2 | <18.9 | | <16.2 | | 7.6 | 11.1 | 540000.0 | 27000.0 |
| 05-18-81 | 116.1 | 140.4 | 17.0 | 11.3 | 10.5 | 8.9 | 10.3 | 12.7 | 83700.0 | 5400.0 |
| 05-25-81 | 64.8 | 116.1 | <10.8 | | 14.6 | 9.5 | 0.3 | 0.5 | 405000.0 | 27000.0 |
| 05-26-81 | 140.4 | 148.5 | <18.9 | | <13.5 | | 10.0 | 11.6 | 405000.0 | 27000.0 |
| 05-27-81 | 72.9 | 81.0 | <16.2 | | <13.5 | | 6.8 | 11.9 | 78300.0 | 5400.0 |
| 05-30-81 | 108.0 | 132.3 | <10.8 | | <10.8 | | 3.5 | 10.5 | <2700 | |
| 05-30-81 | 59.4 | 94.5 | <10.8 | | <8.1 | | 24.3 | 32.4 | 56700.0 | 5400.0 |
| 05-31-81 | 78.3 | 97.2 | <16.2 | | <13.5 | | 3.2 | 9.7 | 108000.0 | 5400.0 |
| 06-02-81 | 118.8 | 162.0 | <18.9 | | <16.2 | | 5.4 | 10.5 | 270000.0 | 27000.0 |

[a]Source: Boegly 1984

NOTE: See Figure 1B.3 for location.

## Table 1B.11. Historical surface radiological water analytical data - 49 Trench Area West Creek Seep[a]

| Date | Gross Alpha (pCi/L) | | CO-60 (pCi/L) | CS-137 (pCi/L) | | SR-90 (pCi/L) | | H-3 (pCi/L) | |
|---|---|---|---|---|---|---|---|---|---|
| | Result | Error | Result | Result | Error | Result | Error | Result | Error |
| 11-05-82 | 75.60 | 43.20 | <18.9 | <1.6 | | 864.00 | 27.00 | N/A | |
| 07-27-83 | 18.90 | 32.40 | <16.2 | <1.6 | | 324.00 | 27.00 | 3.2e+06 | 2.7e+05 |
| 04-30-84 | 2.97 | 19.44 | <18.9 | <1.6 | | 253.80 | 24.30 | 2.7e+06 | 2.7e+05 |
| 10-25-85 | <2 | | N/A | N/A | | 7830.00 | 270.00 | 7.0e+05 | 2.7e+04 |
| 01-14-86 | 64.80 | 32.40 | N/A | N/A | | 83.70 | 10.80 | 1.4e+06 | 2.7e+04 |
| 03-21-86 | N/A | | N/A | 3.24 | 2.43 | 3240.00 | 270.00 | 2.6e+06 | 2.7e+04 |
| 10-30-86 | N/A | | <2.7 | <2.7 | | 253.80 | 16.20 | 4.1e+06 | 2.7e+05 |

[a]Source: Davis & Marshall 1988

N/A = analysis not performed

NOTE: See Figure 1B.3 for location.

## Table 1B.12. Historical surface water analytical data - ICM monitoring[a]

| Sample/Location | Date | Gross Alpha (pCi/L) | | Gross Beta (pCi/L) | | CO-60 (pCi/L) | | CS-137 (pCi/L) | | SR-90 (pCi/L) | | H-3 (pCi/L) | | TSS | TDS | TOC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error | (mg/L) | (mg/L) | (µg/L) |
| 102 | 10-88 | 13.23 | | 78.3 | | 5.4 | | 5.4 | | 9.45 | | 8.37e+04 | | 7 | 304 | 4 |
| 102 | 01-89 | 0.54 | | 21.33 | | 29.7 | | -2.7 | | 12.69 | | 2.46e+05 | | 17 | 254 | 3.2 |
| 102 | 03-89 | 1.728 | | 37.8 | | 0.81 | | -2.16 | | 6.21 | | 1.59e+05 | | 69 | 205 | 0.9 |
| 102 | 06-89 | 1.566 | | 54 | | 5.4 | | -21.6 | | 12.15 | | 1.08e+05 | | 116 | 279 | 4.9 |
| 103 | 01-89 | 0.54 | | 19.44 | | -5.4 | | 8.1 | | 8.91 | | 3.24e+05 | | 18 | 278 | 3 |
| 103 | 03-89 | 4.05 | | 35.1 | | -2.7 | | -1.35 | | 11.34 | | 1.81e+05 | | 142 | 206 | 0.9 |
| 103 | 06-89 | 1.296 | | 27 | | 21.6 | | -16.2 | | 10.8 | | 1.30e+05 | | 62 | 255 | 5.2 |
| 104 | 03-89 | 0.918 | | 24.03 | | 0.27 | | 0.81 | | 8.37 | | 1.57e+05 | | 38 | 185 | 1.3 |
| 104 | 06-89 | 1.35 | | 37.8 | | -10.8 | | 13.5 | | 7.02 | | 8.10e+04 | | 36 | 230 | 5.1 |
| 201 | 10-88 | 1.89 | | 45.9 | | 5.4 | | 5.4 | | 59.4 | | 9.99e+05 | | 7 | 202 | 5.4 |
| 201 | 01-89 | 2.7 | | 7.02 | | 21.6 | | -10.8 | | 3.24 | | 1.30e+06 | | 5 | 162 | 1.4 |
| 201 | 03-89 | 1.674 | | 7.83 | | 7.29 | | 4.05 | | 2.403 | | 1.43e+06 | | 17 | 137 | 2.3 |
| 201 | 04-89 | 2.97 | | 16.74 | | -24.3 | | 10.8 | | 6.48 | | 2.03e+06 | | 15 | 145 | 2.9 |
| 201 | 06-89 | 0.486 | | 14.85 | | 10.8 | | 48.6 | | 0.81 | | 8.91e+05 | | 14 | 199 | 4.5 |
| 201 | ? | 10.8 | | 43.2 | | 1.62 | | 1.35 | | 1.62 | | 1.86e+06 | | 5 | 171 | 2.3 |
| 301 | 10-88 | 7.56 | | 224.1 | | 5.4 | | 5.4 | | 108 | | 2.08e+05 | | 10 | 208 | 10 |
| 302 | 10-88 | 2.7 | | 232.2 | | 2.7 | | 2.7 | | 99.9 | | 3.51e+05 | | 14 | 250 | 4.1 |
| 303 | 10-88 | 13.77 | | 248.4 | | 5.4 | | 5.4 | | 140.4 | | 3.78e+05 | | 5 | 254 | 4.9 |
| 303 | 01-89 | 0.54 | | 378 | | -5.4 | | -10.8 | | 167.4 | | 2.30e+06 | | 13 | 184 | 2 |
| 303 | 03-89 | 5.13 | | 351 | | 2.43 | | 0.54 | | 205.2 | | 1.27e+06 | | 216 | 160 | 2.7 |
| 303 | 04-89 | 4.86 | | 486 | | 16.2 | | -27 | | 218.7 | | 2.59e+06 | | 20 | 226 | 2.6 |
| 303 | 06-89 | 1.728 | | 513 | | 2.7 | | -5.4 | | 259.2 | | 1.65e+06 | | 141 | 196 | 4.9 |
| 303 | ? | 18.9 | | 4860 | | -0.81 | | -0.81 | | 351 | | 2.62e+06 | | 7 | 164 | 3.8 |
| 304 | 10-88 | 1.89 | | 405 | | 8.1 | | 8.1 | | 270 | | 1.73e+06 | | 23 | 277 | 4.3 |

Table 1b. - (continued)

| Sample/Location | Date | Gross Alpha (pCi/L) | | Gross Beta (pCi/L) | | CO-60 (pCi/L) | | CS-137 (pCi/L) | | SR-90 (pCi/L) | | H-3 (pCi/L) | | TSS | TDS | TOC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error | (mg/L) | (mg/L) | (µg/L) |
| 304 | 03-89 | 4.05 | | 459 | | 2.16 | | -0.27 | | 226.8 | | 1.38e+06 | | 34 | 138 | 0.5 |
| 304 | 04-89 | 5.67 | | 702 | | 43.2 | | -35.1 | | 324 | | 3.24e+06 | | 107 | 212 | 3.1 |
| 304 | 06-89 | 13.5 | | 594 | | 27 | | -21.6 | | 226.8 | | 1.78e+06 | | 36 | 192 | 4.7 |
| 304 | ? | 62.1 | | 8910 | | 0.27 | | -0.27 | | 567 | | 5.13e+06 | | 7 | 249 | 3.7 |
| 305 | 10-88 | 17.82 | | 432 | | 10.8 | | 10.8 | | 324 | | 2.97e+06 | | 106 | 290 | 5 |
| 305 | 01-89 | 1.35 | | 459 | | 24.3 | | 27 | | 245.7 | | 3.78e+06 | | 7.5 | 185 | 0.7 |
| 305 | 03-89 | 3.24 | | 513 | | 1.08 | | -2.16 | | 261.9 | | 1.46e+06 | | 29 | 130 | 0.5 |
| 305 | 04-89 | 5.94 | | 756 | | 27 | | -8.1 | | 324 | | 4.05e+06 | | 3.7 | 229 | 2.9 |
| 305 | 06-89 | 2.7 | | 594 | | 5.4 | | 2.7 | | 297 | | 1.92e+06 | | 16 | 195 | 4.5 |
| 305 | ? | 3.78 | | 10800 | | 0.27 | | 0.27 | | 702 | | 5.40e+06 | | 6 | 274 | 3.6 |
| 306 | 10-88 | 17.82 | | 108 | | 13.5 | | 10.8 | | 51.3 | | 1.73e+06 | | 28 | 256 | 2.7 |
| 306 | 01-89 | 0.81 | | 183.6 | | -8.1 | | -18.9 | | 89.1 | | 2.97e+05 | | 12 | 176 | 0.5 |
| 306 | 03-89 | 5.67 | | 378 | | 0.54 | | 2.43 | | 172.8 | | 1.27e+05 | | 59 | 141 | 0.5 |
| 306 | 04-89 | 4.05 | | 270 | | -24.3 | | 5.4 | | 113.4 | | 8.91e+05 | | 22 | 199 | 2.4 |
| 306 | 06-89 | 3.51 | | 351 | | 21.6 | | -21.6 | | 178.2 | | 2.11e+05 | | 3.7 | 189 | 3.5 |
| 306 | ? | 143.1 | | 3510 | | -1.62 | | -0.54 | | 167.4 | | 1.27e+06 | | 5 | 257 | 3.6 |
| 308 | 10-88 | 7.56 | | 270 | | 10.8 | | 8.1 | | 170.1 | | 4.59e+04 | | 9 | 315 | 2.6 |
| 321 | 01-89 | 1.35 | | 5.13 | | 32.4 | | 8.1 | | -1.89 | | 3.78e+04 | | 30 | 159 | 2.1 |
| 321 | 03-89 | 2.322 | | 6.48 | | 0.27 | | 0.54 | | 1.323 | | 4.86e+04 | | 47 | 112 | 1.4 |
| 321 | 04-89 | 7.56 | | 18.36 | | 18.9 | | 10.8 | | 2.97 | | 1.11e+05 | | 125 | 176 | 3.1 |
| 321 | 06-89 | 1.053 | | 9.72 | | -10.8 | | -21.6 | | -1.35 | | 5.94e+04 | | 57 | 170 | 5.2 |
| 321 | ? | 3.78 | | 156.6 | | 0.54 | | -1.89 | | 1.701 | | 8.91e+04 | | 60 | 226 | 3.6 |
| 322 | 10-88 | 15.93 | | 32.4 | | 13.5 | | 10.8 | | 1.35 | | 1.32e+03 | | 43 | 209 | 3.3 |

*Source: Miller et al. 1989
NOTE: See Figure 1B.3 for location.

**Table 1B.13. Historical surface water analytical data--storm events[a]**

| Monitoring Station | Date | H-3 (pCi/L) | Monitoring Station | Date | H-3 (pCi/L) |
|---|---|---|---|---|---|
| MS 1 | 4/14/87 | 3.90e+05 | MS 2 | 4/16/87 | 1.40e+06 |
| MS 1 | 4/15/87 | 1.30e+05 | MS 2 | 4/16/87 | 1.67e+06 |
| MS 1 | 4/15/87 | 1.70e+05 | MS 3 | 2/26/87 | 3.52e+06 |
| MS 1 | 4/15/87 | 2.20e+05 | MS 3 | 2/26/87 | 9.80e+05 |
| MS 1 | 4/15/87 | 2.50e+05 | MS 3 | 2/27/87 | 4.90e+05 |
| MS 1 | 4/15/87 | 2.90e+05 | MS 3 | 2/27/87 | 6.60e+05 |
| MS 1 | 4/15/87 | 3.10e+05 | MS 3 | 2/27/87 | 8.50e+05 |
| MS 1 | 4/16/87 | 3.70e+05 | MS 3 | 2/27/87 | 1.00e+06 |
| MS 2 | 2/26/87 | 2.07e+06 | MS 3 | 2/27/87 | 7.90e+05 |
| MS 2 | 2/26/87 | 2.09e+06 | MS 3 | 2/27/87 | 1.02e+06 |
| MS 2 | 2/27/87 | 6.10e+05 | MS 3 | 2/28/87 | 1.54e+06 |
| MS 2 | 2/27/87 | 4.20e+05 | MS 3 | 2/28/87 | 1.16e+06 |
| MS 2 | 2/27/87 | 2.40e+05 | MS 3 | 2/28/87 | 2.60e+05 |
| MS 2 | 2/27/87 | 3.90e+05 | MS 3 | 2/28/87 | 4.10e+05 |
| MS 2 | 2/27/87 | 3.00e+05 | MS 3 | 2/28/87 | 2.90e+05 |
| MS 2 | 2/27/87 | 1.23e+06 | MS 3 | 2/28/87 | 4.60e+05 |
| MS 2 | 2/28/87 | 1.88e+06 | MS 3 | 3/1/87 | 1.69e+06 |
| MS 2 | 2/28/87 | 8.50e+05 | MS 3 | 3/24/87 | 3.22e+06 |
| MS 2 | 2/28/87 | 1.41e+06 | MS 3 | 3/24/87 | 2.03e+06 |
| MS 2 | 2/28/87 | 5.20e+05 | MS 3 | 3/24/87 | 2.78e+06 |
| MS 2 | 2/28/87 | 8.00e+05 | MS 3 | 3/24/87 | 2.24e+06 |
| MS 2 | 2/28/87 | 1.11e+06 | MS 3 | 3/24/87 | 1.89e+06 |
| MS 2 | 3/1/87 | 1.62e+06 | MS 3 | 3/24/87 | 2.06e+06 |
| MS 2 | 3/1/87 | 1.20e+06 | MS 3 | 3/25/87 | 2.43e+06 |
| MS 2 | 4/14/87 | 2.52e+06 | MS 3 | 3/25/87 | 2.31e+06 |

Table 1B.13 (continued)

| Monitoring Station | Date | H-3 (pCi/L) | Monitoring Station | Date | H-3 (pCi/L) |
|---|---|---|---|---|---|
| MS 2 | 4/14/87 | 2.30e+06 | MS 3 | 3/25/87 | 3.00e+06 |
| MS 2 | 4/14/87 | 2.31e+06 | MS 3 | 4/14/87 | 3.33e+06 |
| MS 2 | 4/14/87 | 2.31e+06 | MS 3 | 4/14/87 | 3.41e+06 |
| MS 2 | 4/15/87 | 3.40e+05 | MS 3 | 4/15/87 | 9.40e+05 |
| MS 2 | 4/15/87 | 4.10e+05 | MS 3 | 4/15/87 | 8.40e+05 |
| MS 2 | 4/15/87 | 7.40e+05 | MS 3 | 4/15/87 | 3.80e+05 |
| MS 2 | 4/15/87 | 1.44e+06 | MS 3 | 4/15/87 | 1.53e+06 |
| MS 2 | 4/15/87 | 1.69e+06 | MS 3 | 4/15/87 | 1.53e+06 |
| MS 2 | 4/15/87 | 2.01e+06 | MS 3 | 4/16/87 | 1.81e+06 |
| MS 2 | 4/16/87 | 1.93e+06 | MS 3 | 4/16/87 | 8.60e+05 |
| MS 2 | 4/16/87 | 2.07e+06 | MS 3 | 4/16/87 | 9.10e+05 |
| MS 2 | 4/16/87 | 1.65e+06 | MS 3 | 4/16/87 | 1.90e+06 |
| MS 3 | 4/16/87 | 9.30e+05 | | | |
| MS 3 | 4/16/87 | 3.70e+05 | | | |
| MS 3 | 4/16/87 | 6.70e+05 | | | |
| MS 3 | 4/16/87 | 5.20e+05 | | | |
| MS 3 | 4/16/87 | 8.20e+05 | | | |
| MS 3 | 4/17/87 | 1.77e+06 | | | |

[a]Source: Davis and Marshall 1988
See Figure 1B.3 for location.

Table 1B.14. Historical sediment analytical data -- Cerling & Spalding 1981

| Sample Location[a] | Date Sampled | CO-60 (pCi/g) | CS-137 (pCi/g) | SR-90 (pCi/g) |
|---|---|---|---|---|
| 234 | 10-78 | 6.76 | 3.87 | 13.74 |
| 235 | 10-78 | 6.40 | 4.37 | 18.25 |
| 236 | 10-78 | 6.49 | 3.02 | 19.01 |
| 237 | 10-78 | 164.88 | 2.12 | 16.62 |
| 238 | 10-78 | 300.03 | 6.76 | 14.87 |
| 239 | 10-78 | 285.62 | 0.41 | 13.52 |
| 240 | 10-78 | 320.76 | 0.45 | 15.59 |
| 241 | 10-78 | 349.59 | 3.92 | 17.97 |
| 242 | 10-78 | 398.69 | 6.53 | 15.27 |
| 341 | 11-78 | 0.00 | 0.09 | 0.50 |
| 342 | 11-78 | 0.00 | 0.00 | 0.72 |
| 343 | 11-78 | 0.00 | 0.32 | 0.50 |
| 344 | 11-78 | 0.00 | 0.36 | 66.09 |
| 345 | 11-78 | 0.00 | 0.00 | 75.23 |
| 346 | 11-78 | 0.00 | 1.04 | 99.65 |
| 347 | 11-78 | 0.00 | 0.90 | 84.92 |
| 348 | 11-78 | 0.00 | 0.14 | 79.33 |
| 349 | 11-78 | 0.00 | 0.63 | 80.86 |
| 350 | 11-78 | 0.00 | 1.04 | 58.97 |
| 351 | 11-78 | 0.00 | 4.91 | 1.76 |
| 352 | 11-78 | 0.00 | 1.85 | 1.49 |
| 353 | 11-78 | 0.00 | 0.59 | 0.63 |
| 354 | 11-78 | 0.00 | 0.18 | 0.50 |
| 355 | 11-78 | 0.00 | 0.14 | 0.27 |
| 356 | 11-78 | 0.00 | 0.27 | 0.72 |
| 357 | 11-78 | 0.00 | 0.68 | 0.72 |
| 358 | 11-78 | 0.00 | 0.68 | 0.59 |
| 359 | 11-78 | 0.00 | 1.04 | 1.35 |
| 360 | 11-78 | 0.00 | 0.54 | 0.72 |
| 361 | 11-78 | 0.00 | 0.54 | 0.72 |

[a]Locations shown on Figure 1B.4.

Table 1B.15. Historical sediment analytical data -- Cerling & Huff 1986

| Sampling Location | Site | Date Sampled | C0-60 (pCi/L) | CS-137 (pCi/L) | SR (pC |
|---|---|---|---|---|---|
| 15 | W. SEEP | 7-8/85 | 1.323 | 0.135 | 2 |
| 16 | SWSA 6 (1&2) | 7-8/85 | | | |
| 17 | SWSA 6 (3) | 7-8/85 | 0.135 | 0.135 | 5. |

See Figure 1B.4 for location.

**Table 1B.16. Historical sediment analytical data – Huff 1986**

| Sampling Location | Year | CO-60 (pCi/g) | | CS-137 (pCi/g) | | SR-90 (pCi/g) | |
|---|---|---|---|---|---|---|---|
| | | Result | Error | Result | Error | Result | Error |
| 6 | 1978 | 353.70 | 40.50 | 3.65 | 3.11 | 16.20 | 1.49 |
| 6 | 1985 | 70.20 | 3.78 | 3.48 | 1.19 | 6.08 | 0.19 |
| 6 | SORB | 1.32 | 0.19 | 0.14 | 0.08 | 2.70 | 0.54 |
| 7 | 1978 | <0.14 | | 0.59 | 0.43 | 72.90 | 12.15 |
| 7 | 1985 | <0.14 | | 0.49 | 0.05 | 20.52 | 1.89 |
| 7 | SORB | <0.14 | | 0.14 | | 5.13 | 0.81 |
| 34 | 1978 | 4.70 | 1.84 | 4.00 | 1.89 | 20.79 | 2.97 |
| 34 | 1985 | 5.54 | 2.70 | 3.65 | 0.95 | 8.64 | 0.81 |
| 35 | 1978 | <0.14 | | 0.14 | | 0.62 | |
| 35 | 1985 | 2.62 | | 10.53 | | 0.30 | |
| 36 | 1978 | <0.14 | | 1.03 | | 1.35 | |
| 36 | 1985 | 2.70 | | 20.52 | | 0.78 | |
| 37 | 1978 | <0.14 | | 0.19 | 0.14 | 0.57 | 0.14 |
| 37 | 1985 | di | | | | | |

di = data incomplete

See Figure 1B.4 for location.

Table 1B.17. Historical sediment analytical data -- Miller, Black, and Craig 1989

| Sample/ Location[1] | Date | Gross Alpha (pCi/gm) | | Gross Beta (pCi/gm) | | CO-60 (pCi/gm) | | CS-137 (pCi/gm) | | SR-90 (pCi/gm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error |
| 101 | 10-88 | 9.72 | | 351 | | 25.38 | | 567 | | 4.59 | |
| 101 | 01-89 | 9.99 | | 221.4 | | 17.55 | | 405 | | 2.403 | |
| 101 | 03-89 | 5.4 | | 148.5 | | 11.34 | | 324 | | 0.999 | |
| 101 | 04-89 | 10.53 | | 324 | | 20.25 | | 513 | | 2.079 | |
| 101 | 06-89 | 12.42 | | 351 | | 17.28 | | 432 | | 2.187 | |
| 102 | 10-88 | 4.05 | | 11.61 | | 0.486 | | 1.593 | | 0.891 | |
| 102 | 10-88 | 7.83 | | 14.85 | | 0.0081 | | 0.459 | | 2.295 | |
| 102 | 01-89 | 6.75 | | 9.45 | | -0.0162 | | 2.97 | | 0.2403 | |
| 102 | 01-89 | 3.78 | | 7.56 | | 0.0054 | | 2.079 | | 0.54 | |
| 102 | 03-89 | 3.24 | | 4.05 | | 0.054 | | 0.999 | | 0.1485 | |
| 102 | 03-89 | 3.78 | | 3.51 | | 0.108 | | 1.026 | | 0.1755 | |
| 103 | 10-88 | 2.43 | | 5.13 | | 0.081 | | 0.378 | | 0.972 | |
| 103 | 01-89 | 4.86 | | 5.4 | | -0.0351 | | 0.0594 | | 0.2052 | |
| 103 | 03-89 | 0.54 | | 1.512 | | 0.0081 | | 0.0621 | | 0.1053 | |
| 104 | 10-88 | 8.1 | | 17.82 | | 0.216 | | 1.377 | | 1.62 | |
| 104 | 01-89 | 6.48 | | 21.6 | | 0.0351 | | 1.35 | | 1.215 | |
| 104 | 03-89 | 2.241 | | 6.21 | | 0.1404 | | 1.107 | | 0.459 | |
| 104 | 04-89 | 5.94 | | 15.66 | | 0.162 | | 1.431 | | 0.837 | |
| 104 | 06-89 | 7.83 | | 17.55 | | 0.1701 | | 1.323 | | 0.891 | |
| 201 | 10-88 | 4.32 | | 9.18 | | 0.2511 | | 6.48 | | 0.675 | |
| 201 | 10-88 | 4.05 | | 11.34 | | 0.2025 | | 6.75 | | 1.512 | |
| 201 | 01-89 | 4.32 | | 6.48 | | 0.2565 | | 1.431 | | 0.27 | |
| 201 | 01-89 | 3.51 | | 6.21 | | 0.135 | | 0.567 | | 0.1566 | |
| 201 | 03-89 | 1.215 | | 2.457 | | 0.324 | | 0.405 | | 0.0378 | |
| 201 | 03-89 | 2.16 | | 3.24 | | 0.0621 | | 0.513 | | 0.1269 | |
| 201 | 04-89 | 6.75 | | 8.1 | | 0.0945 | | 0.783 | | 0.27 | |
| 201 | 04-89 | 3.24 | | 6.21 | | 0.0162 | | 0.918 | | 0.1998 | |
| 201 | 06-89 | 2.97 | | 5.13 | | 0.0432 | | 0.621 | | 0.0945 | |
| 201 | 06-89 | 4.32 | | 7.02 | | 0.0513 | | 0.81 | | 0.297 | |
| 202 | 10-88 | 4.05 | | 4.86 | | -0.0297 | | 0.324 | | -0.054 | |

**Table 1B.17. (continued)**

| Sample/ Location[1] | Date | Gross Alpha (pCi/gm) | | Gross Beta (pCi/gm) | | CO-60 (pCi/gm) | | CS-137 (pCi/gm) | | SR-90 (pCi/gm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error |
| 202 | 01-89 | 4.59 | | 5.4 | | -0.0378 | | 0.324 | | 0.0621 | |
| 202 | 03-89 | 2.457 | | 3.51 | | 0.0027 | | 0.486 | | -0.0027 | |
| 202 | 04-89 | 3.51 | | 4.86 | | 0.0162 | | 0.54 | | 0.135 | |
| 202 | 06-89 | 4.86 | | 4.86 | | 0.0189 | | 0.972 | | 0.1782 | |
| 301 | 10-88 | 5.67 | | 75.6 | | 3.51 | | 67.5 | | 9.72 | |
| 301 | 01-89 | 5.4 | | 54 | | 2.646 | | 54 | | 10.26 | |
| 301 | 03-89 | 2.187 | | 35.1 | | 2.97 | | 102.6 | | 4.86 | |
| 301 | 04-89 | 4.86 | | 64.8 | | 2.97 | | 67.5 | | 13.23 | |
| 301 | 06-89 | 6.48 | | 59.4 | | 2.7 | | 64.8 | | 9.99 | |
| 302 | 10-88 | 3.78 | | 56.7 | | 0.027 | | 45.9 | | 12.96 | |
| 302 | 01-89 | 7.29 | | 40.5 | | 0.081 | | 26.19 | | 11.88 | |
| 302 | 03-89 | 1.647 | | 23.76 | | 0.1188 | | 25.65 | | 6.21 | |
| 302 | 04-89 | 5.4 | | 62.1 | | 0.0864 | | 32.4 | | 17.28 | |
| 302 | 06-89 | 4.32 | | 54 | | 0.0621 | | 11.61 | | 14.85 | |
| 303 | 10-88 | 3.78 | | 14.85 | | 0.0513 | | 0.2106 | | 4.05 | |
| 303 | 10-88 | 7.29 | | 17.55 | | 0.0081 | | 0.189 | | 5.67 | |
| 303 | 01-89 | 4.05 | | 14.58 | | -0.0297 | | 0.297 | | 4.32 | |
| 303 | 01-89 | 2.403 | | 10.8 | | 0.0297 | | 0.27 | | 5.4 | |
| 303 | 03-89 | 2.106 | | 8.1 | | 0.0594 | | 0.27 | | 2.97 | |
| 303 | 03-89 | 2.376 | | 11.61 | | 0.0918 | | 0.1998 | | 4.05 | |
| 303 | 04-89 | 4.05 | | 14.04 | | -0.0351 | | 0.351 | | 5.13 | |
| 303 | 04-89 | 3.51 | | 18.63 | | 0.0891 | | 0.2376 | | 7.02 | |
| 303 | 06-89 | 7.29 | | 26.73 | | 0.0243 | | 0.378 | | 9.99 | |
| 303 | 06-89 | 6.21 | | 32.4 | | 0.1134 | | 0.432 | | 10.53 | |
| 304 | 10-88 | 9.72 | | 62.1 | | 0.1512 | | 0.2214 | | 25.38 | |
| 304 | 01-89 | 5.67 | | 51.3 | | 0.0324 | | 0.297 | | 24.84 | |
| 304 | 03-89 | 3.51 | | 35.1 | | 0.0459 | | 0.1674 | | 14.85 | |
| 304 | 04-89 | 5.94 | | 70.2 | | 0.0621 | | 0.1323 | | 29.7 | |
| 304 | 06-89 | 8.37 | | 86.4 | | 0.0675 | | 0.1971 | | 35.1 | |
| 305 | 10-88 | 8.37 | | 51.3 | | -0.081 | | 0.27 | | 23.76 | |

**Table 1B.17. (continued)**

| Sample/ Location[1] | Date | Gross Alpha (pCi/gm) | | Gross Beta (pCi/gm) | | CO-60 (pCi/gm) | | CS-137 (pCi/gm) | | SR-90 (pCi/gm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error |
| 305 | 01-89 | 5.13 | | 72.9 | | 0.0405 | | 0.1836 | | 32.4 | |
| 305 | 03-89 | 1.701 | | 29.7 | | 0.0567 | | 0.189 | | 12.42 | |
| 305 | 04-89 | 2.592 | | 70.2 | | 0.162 | | 0.1782 | | 32.4 | |
| 305 | 06-89 | 3.51 | | 67.5 | | 0.1161 | | 0.1593 | | 27 | |
| 306 | 10-88 | 6.21 | | 17.82 | | 0.324 | | -0.027 | | 3.51 | |
| 306 | 01-89 | 4.32 | | 20.25 | | 0.0108 | | 0.27 | | 2.7 | |
| 306 | 03-89 | 1.296 | | 14.04 | | 0.0432 | | 0.162 | | 3.78 | |
| 306 | 04-89 | 3.24 | | 29.7 | | 0.1566 | | 0.324 | | 5.94 | |
| 306 | 06-89 | 6.75 | | 25.38 | | 0.0135 | | 0.243 | | 5.67 | |
| 307 | 10-88 | 6.75 | | 59.4 | | 0.405 | | 0.648 | | 29.7 | |
| 307 | 01-89 | 6.48 | | 75.6 | | 0.432 | | 0.675 | | 32.4 | |
| 307 | 03-89 | 2.97 | | 32.4 | | 0.2457 | | 0.567 | | 14.58 | |
| 307 | 04-89 | 7.83 | | 94.5 | | 0.27 | | 0.756 | | 43.2 | |
| 307 | 06-89 | 8.64 | | 124.2 | | 0.405 | | 0.837 | | 48.6 | |
| 308 | 10-88 | 1.62 | | 25.11 | | 0.2349 | | 0.2322 | | 11.88 | |
| 308 | 01-89 | 6.21 | | 32.4 | | -0.0081 | | 0.1431 | | 11.61 | |
| 308 | 03-89 | 3.24 | | 15.39 | | 0.1296 | | 0.1809 | | 5.94 | |
| 308 | 04-89 | 4.86 | | 27 | | 0.054 | | 0.351 | | 8.37 | |
| 308 | 06-89 | 3.78 | | 29.7 | | 0.1215 | | 0.351 | | 10.53 | |
| 309 | 10-88 | 4.32 | | 27 | | 0.1944 | | 0.297 | | 16.2 | |
| 309 | 01-89 | 4.05 | | 32.4 | | 0.0999 | | 0.1485 | | 14.58 | |
| 309 | 03-89 | 2.43 | | 40.5 | | 0.1539 | | 0.1539 | | 18.09 | |
| 309 | 04-89 | 5.13 | | 54.7 | | 0.2484 | | 0.1188 | | 22.95 | |
| 309 | 06-89 | 4.32 | | 54.7 | | 0.2187 | | 0.243 | | 19.98 | |
| 310 | 10-88 | 4.86 | | 270 | | 0.378 | | 0.54 | | 140.4 | |
| 310 | 01-89 | 4.05 | | 240.3 | | 0.594 | | 0.783 | | 116.1 | |
| 310 | 03-89 | 2.97 | | 135 | | 0.378 | | 0.297 | | 64.8 | |
| 310 | 04-89 | 6.75 | | 324 | | 0.837 | | 0.648 | | 143.1 | |
| 310 | 06-89 | 3.24 | | 237.6 | | 0.675 | | 0.54 | | 124.2 | |
| 321 | 10-88 | 6.48 | | 5.67 | | 0.0648 | | 0.2538 | | 0.081 | |

Table 1B.17. (continued)

| Sample/ Location[1] | Date | Gross Alpha (pCi/gm) | | Gross Beta (pCi/gm) | | CO-60 (pCi/gm) | | CS-137 (pCi/gm) | | SR-90 (pCi/gm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Result | Error | Result | Error | Result | Error | Result | Error | Result | Error |
| 321 | 01-89 | 8.64 | | 8.64 | | -0.0216 | | 0.1053 | | 0.1728 | |
| 321 | 03-89 | 3.24 | | 3.24 | | -0.0243 | | 0.135 | | 0.2106 | |
| 321 | 06-89 | 5.13 | | 5.94 | | 0.0297 | | 0.1755 | | 0.0567 | |
| 403 | 10-88 | 116.1 | | 135 | | 51.3 | | 2.133 | | 11.88 | |

[1]Locations shown on Figure 1B.4.

Table 1B.18. Historical soil analytical data -- Davis et al. 1989

| Sample Location[a] | Depth (inches) | Volatile Organic Compounds (ug/kg)[b] | | | | | Radionuclides (pCi/g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | VOC A | VOC B | VOC C | VOC D | VOC E | CO-60 | CS-137 | SR-90 |
| 1 | 0-18 | na | na | na | na | na | <0.3 | 13.7 | 86.7 |
| 1 | 18-36 | na | na | na | na | na | <0.3 | <0.3 | 34.4 |
| 1 | 36-54 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 1 | 54-72 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 1 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 1 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 1 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 2 | 0-18 | na | na | na | na | na | <0.3 | 54.9 | <0.5 |
| 2 | 18-36 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 2 | 36-54 | na | na | na | na | na | <0.3 | <0.3 | 60.1 |
| 2 | 54-72 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 2 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 2 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | 7.3 |
| 2 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 2 | 126-144 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 2 | 144-162 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 2 | 162-180 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 3 | 0-18 | na | na | na | na | na | <0.3 | <0.3 | 52.8 |
| 3 | 18-36 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 3 | 36-54 | na | na | na | na | na | <0.3 | 13.4 | 3.5 |
| 3 | 54-72 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 3 | 72-90 | na | na | na | na | na | <0.3 | 1.3 | <0.5 |
| 3 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 3 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 3 | 126-144 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 3 | 144-162 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 3 | 162-180 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 4 | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 4 | 18-36 | na | na | na | na | na | <0.3 | <0.3 | 20.9 |
| 4 | 36-54 | na | na | na | na | na | 4.3 | <0.3 | <0.5 |

**Table 1B.18. (continued)**

| Sample Location[a] | Depth (inches) | Volatile Organic Compounds (ug/kg)[b] | | | | | Radionuclides (pCi/g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | VOC A | VOC B | VOC C | VOC D | VOC E | CO-60 | CS-137 | SR-90 |
| 4 | 54-72 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 4 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | 55.2 |
| 5 | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 5 | 18-36 | na | na | na | na | na | <0.3 | 1623.8 | 667.4 |
| 5 | 36-54 | na | na | na | na | na | <0.3 | <0.3 | 162.0 |
| 5 | 54-72 | na | na | na | na | na | <0.3 | 1.9 | 17.8 |
| 5 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 5 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 5 | 108-126 | na | na | na | na | na | <0.3 | 191.9 | <0.5 |
| 6 | 0-18 | na | na | na | na | na | <0.3 | <0.3 | 14.7 |
| 6 | 18-36 | na | na | na | na | na | <0.3 | 26.5 | 1.7 |
| 6 | 36-54 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 6 | 54-72 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 6 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 6 | 90-108 | na | na | na | na | na | <0.3 | 19.5 | <0.5 |
| 6 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 6 | 126-144 | 97.0 | 103B | 130J | 28.0J | 87.0B | <0.3 | <0.3 | <0.5 |
| 6 | 144-162 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 6 | 162-180 | na | na | na | na | na | <0.3 | 1.6 | <0.5 |
| 7 | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 7 | 18-36 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 7 | 36-54 | na | na | na | na | na | <0.3 | <0.3 | 1.2 |
| 7 | 54-72 | na | na | na | na | na | <0.3 | <0.3 | 18.4 |
| 7 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 7 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 7 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 8 | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 8 | 18-36 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 8 | 36-54 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 8 | 54-72 | 53.0 | 38.0B | nd | 28.0J | 840.0B | <0.3 | <0.3 | <0.5 |

Table 1B.18. (continued)

| Sample Location[a] | Depth (inches) | Volatile Organic Compounds (ug/kg)[b] | | | | | Radionuclides (pCi/g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | VOC A | VOC B | VOC C | VOC D | VOC E | CO-60 | CS-137 | SR-90 |
| 8 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 9 | 0-18 | na | na | na | na | na | <0.3 | 27.1 | <0.5 |
| 9 | 18-36 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 9 | 36-54 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 9 | 54-72 | 65.0 | 44.0B | 145.0J | 26.0J | 600.0B | <0.3 | 3.8 | 27.2 |
| 9 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 9 | 90-108 | na | na | na | na | na | <0.3 | 4.5 | <0.5 |
| 9 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 9 | 126-144 | na | na | na | na | na | 4.3 | <0.3 | <0.5 |
| 9 | 144-162 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 9 | 162-180 | na | na | na | na | na | 3534.7 | <0.3 | 84018.9 |
| 10 | 0-18 | na | na | na | na | na | <0.3 | <0.3 | 176.6 |
| 10 | 18-36 | na | na | na | na | na | <0.3 | 7.7 | <0.5 |
| 10 | 36-54 | na | na | na | na | na | <0.3 | <0.3 | 25.8 |
| 10 | 54-72 | na | na | na | na | na | <0.3 | 0.6 | 50.6 |
| 10 | 72-90 | na | na | na | na | na | <0.3 | 14.1 | 50.6 |
| 10 | 90-108 | na | na | na | na | na | <0.3 | 1.3 | <0.5 |
| 10 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 10 | 126-144 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 10 | 144-162 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 10 | 162-180 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 11 | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 11 | 18-36 | na | na | na | na | na | <0.3 | 23.9 | <0.5 |
| 11 | 36-54 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 11 | 54-72 | na | na | na | na | na | <0.3 | 1.9 | <0.5 |
| 11 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 11 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 11 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 11 | 126-144 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 11 | 144-162 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |

Table 1B.18. (continued)

| Sample Location[a] | Depth (inches) | Volatile Organic Compounds (ug/kg)[b] | | | | | Radionuclides (pCi/g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | VOC A | VOC B | VOC C | VOC D | VOC E | CO-60 | CS-137 | SR-90 |
| 11 | 162-180 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 12 | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 12 | 18-36 | na | na | na | na | na | <0.3 | 10.54 | <0.5 |
| 12 | 36-54 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 12 | 54-72 | na | na | na | na | na | <0.3 | <0.3 | 30.7 |
| 12 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 12 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 12 | 108-126 | 17.0 | 22.0B | 83.0J | 39.0J | 390.0B | <0.3 | <0.3 | 26.9 |
| 12 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 12 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | 26.9 |
| 12 | 162-180 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 13 | 0-18 | na | na | na | na | na | <0.3 | 0.9 | 3.5 |
| 13 | 18-36 | 96.0 | 27.0B | 161.0J | nd | 1050.0B | <0.3 | <0.3 | <0.5 |
| 13 | 36-54 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 13 | 54-72 | na | na | na | na | na | <0.3 | <0.3 | 8.6 |
| 13 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 13 | 90-108 | na | na | na | na | na | <0.3 | 14.1 | <0.5 |
| 13 | 108-126 | na | na | na | na | na | <0.3 | 9.3 | <0.5 |
| 13 | 126-144 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 13 | 144-162 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 13 | 162-180 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 14 | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 14 | 18-36 | na | na | na | na | na | <0.3 | 7.1 | <0.5 |
| 14 | 36-54 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 14 | 54-72 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 14 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 14 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 14 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 14 | 126-144 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 14 | 144-162 | na | na | na | na | na | <0.3 | 6.4 | <0.5 |

Table 1B.18. (continued)

| Sample Location[a] | Depth (inches) | Volatile Organic Compounds (ug/kg)[b] | | | | | Radionuclides (pCi/g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | VOC A | VOC B | VOC C | VOC D | VOC E | CO-60 | CS-137 | SR-90 |
| 14 | 162-180 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 15 | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 15 | 18-36 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 15 | 36-54 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 15 | 54-72 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 15 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 15 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 15 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 15 | 126-144 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 15 | 144-162 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 15 | 162-180 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 16 | 0-18 | na | na | na | na | na | 238.9 | 213.6 | 545.5 |
| 16 | 18-36 | na | na | na | na | na | 50.1 | 60.7 | 185.1 |
| 16 | 36-54 | na | na | na | na | na | <0.3 | 48.2 | <0.5 |
| 16 | 54-72 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 16 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 16 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 16 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 16 | 126-144 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 17 | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 17 | 18-36 | na | na | na | na | na | <0.3 | 0.3 | 34.3 |
| 17 | 36-54 | na | na | na | na | na | <0.3 | 26.8 | <0.5 |
| 17 | 54-72 | na | na | na | na | na | <0.3 | <6.7 | <0.5 |
| 17 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 17 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 17 | 108-126 | na | na | na | na | na | 7.5 | <0.3 | <0.5 |
| 17 | 126-144 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 17 | 144-162 | na | na | na | na | na | <0.3 | 0.9 | <0.5 |
| 17 | 162-180 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 18 | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |

Table 1B.18. (continued)

| Sample Location[a] | Depth (inches) | Volatile Organic Compounds (ug/kg)[b] | | | | | Radionuclides (pCi/g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | VOC A | VOC B | VOC C | VOC D | VOC E | CO-60 | CS-137 | SR-90 |
| 18 | 18-36 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 18 | 36-54 | na | na | na | na | na | 19.2 | 349.3 | 99.2 |
| 18 | 54-72 | na | na | na | na | na | <0.3 | 37.0 | 7.3 |
| 18 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 18 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 18 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 18 | 126-144 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 18 | 144-162 | na | na | na | na | na | 14.9 | <0.3 | 66.3 |
| 18 | 162-180 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 19 | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 19 | 18-36 | na | na | na | na | na | <0.3 | 17.3 | <0.5 |
| 19 | 36-54 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 19 | 54-72 | na | na | na | na | na | <0.3 | 0.6 | <0.5 |
| 19 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 19 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 19 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 19 | 126-144 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 19 | 144-162 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 19 | 162-180 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 20 | 0-18 | na | na | na | na | na | <0.3 | 8.6 | <0.5 |
| 20 | 18-36 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 20 | 36-54 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 20 | 54-72 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 20 | 72-90 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 20 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 20 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 20 | 126-144 | na | na | na | na | na | <0.3 | <0.3 | 117.9 |
| 20 | 144-162 | na | na | na | na | na | <0.3 | 9.9 | 0.5 |
| 20 | 162-180 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 21 | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |

Table 1B.18. (continued)

| Sample Location[a] | Depth (inches) | Volatile Organic Compounds (ug/kg)[b] | | | | | Radionuclides (pCi/g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | VOC A | VOC B | VOC C | VOC D | VOC E | CO-60 | CS-137 | SR-90 |
| 21 | 18-36 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 21 | 36-54 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 21 | 54-72 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 21 | 72-90 | na | na | na | na | na | 6.4 | <0.3 | <0.5 |
| 21 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 21 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 21 | 126-144 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 22 | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 22 | 18-36 | na | na | na | na | na | <0.3 | 41.5 | <0.5 |
| 22 | 36-54 | na | na | na | na | na | 9.1 | <0.3 | <0.5 |
| 22 | 54-72 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 22 | 72-90 | 74.0 | 64.0B | 130.0J | 26.0J | 500.0B | <0.3 | 2.3 | <0.5 |
| 22 | 90-108 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 22 | 108-126 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 22 | 126-144 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 22 | 144-162 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 22 | 162-180 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 2A | 0-18 | na | na | na | na | na | <0.3 | 22.7 | 8.8 |
| 2A | 18-36 | na | na | na | na | na | <0.3 | 3504.7 | <0.5 |
| 2B | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 2B | 18-36 | na | na | na | na | na | <0.3 | 290.5 | <0.5 |
| 2C | 0-18 | na | na | na | na | na | <0.3 | 17.6 | <0.5 |
| 2C | 18-36 | na | na | na | na | na | <0.3 | 0.3 | <0.5 |
| 3A | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 3A | 18-36 | 78.0 | 44.0B | 172.0J | 21.0J | 1530.0B | <0.3 | <0.3 | <0.5 |
| 3B | 0-18 | na | na | na | na | na | <0.3 | 5.1 | <0.5 |
| 3B | 18-36 | na | na | na | na | na | <0.3 | 385.6 | <0.5 |
| 3C | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 3C | 18-36 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 4A | 0-18 | na | na | na | na | na | <0.3 | 3.5 | <0.5 |

**Table 1B.18. (continued)**

| Sample Location[a] | Depth (inches) | Volatile Organic Compounds (ug/kg)[b] | | | | | Radionuclides (pCi/g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | VOC A | VOC B | VOC C | VOC D | VOC E | CO-60 | CS-137 | SR-90 |
| 4A | 18-36 | 81.0 | 48.0B | 126.0J | nd | 4025.0B | <0.3 | <0.3 | <0.5 |
| 4B | 0-18 | na | na | na | na | na | <0.3 | 5.4 | 40.7 |
| 4B | 18-36 | na | na | na | na | na | <0.3 | 4.8 | <0.5 |
| 4C | 0-18 | na | na | na | na | na | <0.3 | 7.0 | 56.5 |
| 4C | 18-36 | na | na | na | na | na | <0.3 | 48.2 | <0.5 |
| 5A | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 5A | 18-36 | 107.0 | 66.0B | 82.0J | nd | 82.0B | <0.3 | 49.8X | 253.8X |
| 5B | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 5B | 18-36 | na | na | na | na | na | <0.3 | 565.4 | <0.5 |
| 5C | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 5C | 18-36 | na | na | na | na | na | 15.5 | 565.4 | <0.5 |
| 6A | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 6A | 18-36 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 6B | 0-18 | 82.0 | 24.0B | nd | nd | 1050.0B | <0.3 | 12.8 | 41.5 |
| 6B | 18-36 | na | na | na | na | na | 13.3 | 145.3 | 238.3 |
| 6C | 0-18 | na | na | na | na | na | <0.3 | <0.3 | <0.5 |
| 6C | 18-36 | na | na | na | na | na | <0.3 | 1207.2 | <0.5 |

[a]NOTES:

VOC Compound Key

VOC A = Methylene Chloride
VOC B = Acetone
VOC C = Diethylphthalate
VOC D = Di-n-butylphthalate
VOC E = bis-(2-Ethylhexyl)-phthalate

na = not analyzed
nd = not detected
B = This data qualifier appears for a compound which was detected in both the sample and its associated blank.
J = Indicates that the quantitative value is estimated. It appears after a value which is below the quanitation limit but above the detection limit.
X = Conflicting data from source report.

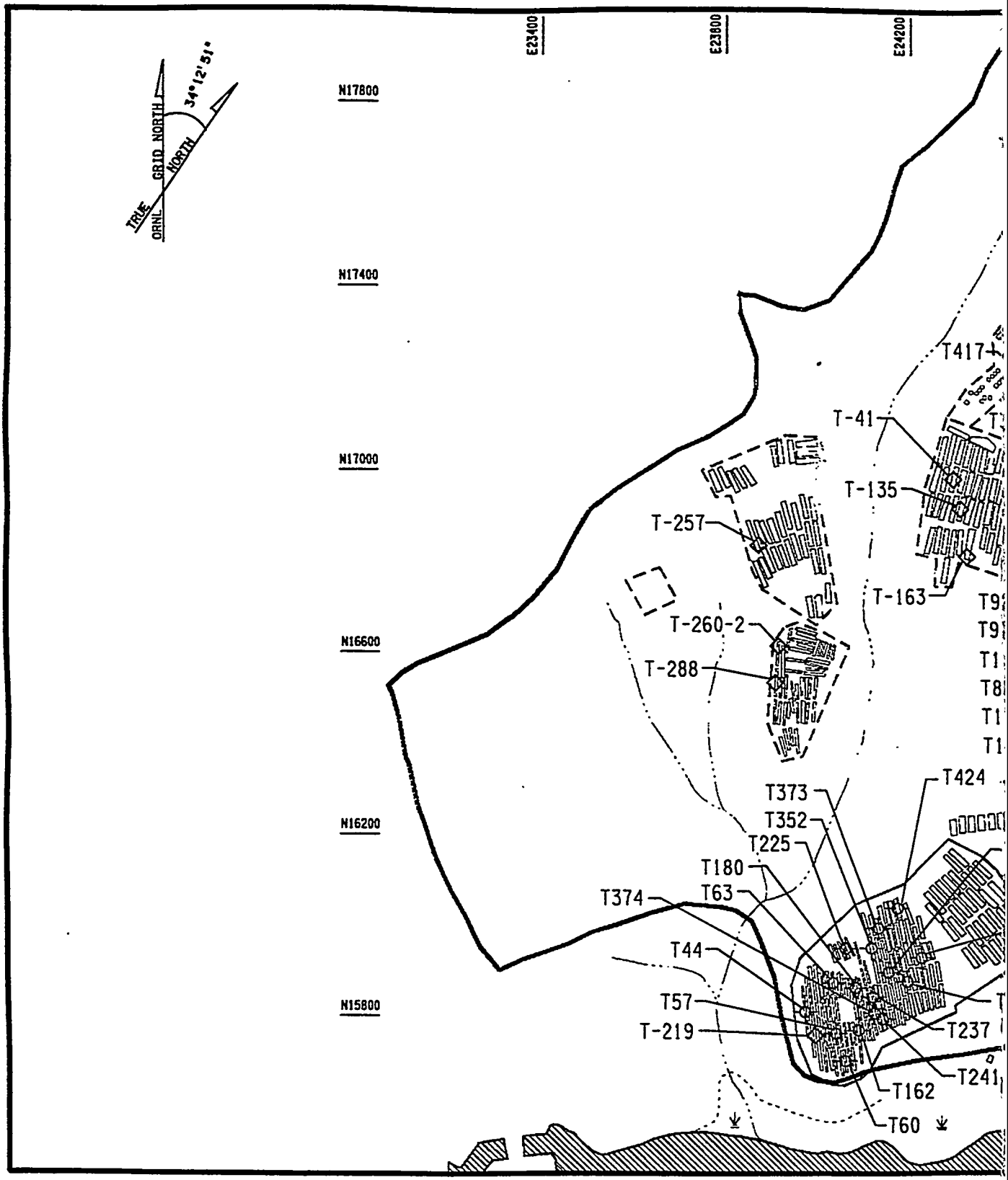
[b]Sample locations shown on Figure 1B.5.

Table 1B.19. Historical soil analytical data -- Yager & Craig 1989

| Location[a] | Date Sampled | Gross Alpha (pCi/g) | Gross Beta (pCi/g) | CO-60 (pCi/g) | CS-137 (pCi/g) |
|---|---|---|---|---|---|
| 1/2C | 02/26/87 | 8.37 | 27 | <0.027 | 0.189 |
| 1/2C | 09/21/87 | 20.52 | 24.57 | 0.0054 | 0.0135 |
| 1/2C | 12/18/87 | 18.63 | 32.4 | 0.0864 | 0.2322 |
| 3 | 02/26/87 | 23.49 | 27 | <0.027 | 0.297 |
| 3 | 12/18/87 | 11.61 | 26.73 | 0 | 0.1647 |
| 3 | 03/17/88 | 3.51 | 2.97 | <0.054 | 0.2619 |
| 3 | 07/06/88 | 8.37 | 16.74 | <0.054 | 0.2349 |
| 4 | 02/26/87 | 17.55 | 45.9 | <0.054 | 0.1404 |
| 4 | 09/21/87 | 12.96 | 17.55 | <0.054 | 0.2619 |
| 4 | 12/18/87 | 17.28 | 37.8 | 0 | 0.378 |
| 4 | 03/17/88 | 3.24 | 2.97 | <0.081 | 0.405 |
| 4 | 07/06/88 | 5.4 | 12.42 | <0.027 | 0.2241 |
| 5 | 09/21/87 | 37.8 | 56.7 | <0.081 | <0.108 |
| 5 | 3/17/88 | 2.97 | 2.376 | <0.054 | <0.054 |
| 5 | 07/06/88 | 4.05 | 24.3 | <0.054 | <0.054 |
| 5/6C | 02/26/87 | 14.85 | 17.55 | <0.027 | <0.027 |
| 5/6C | 12/18/87 | 20.79 | 35.1 | 0 | <0.027 |
| 6 | 09/21/87 | 14.04 | 45.9 | <0.081 | <0.081 |
| 6 | 03/17/88 | 4.05 | 3.24 | <0.054 | 0.1809 |
| 6 | 07/06/88 | 9.72 | 40.5 | <0.054 | <0.054 |
| 7/8C | 12/18/87 | 5.4 | 45.9 | 0 | 0.702 |
| 7/8C | 03/17/88 | 2.97 | 2.7 | <0.054 | 0.1647 |
| 7/8C | 07/06/88 | 9.45 | 22.41 | <0.054 | 0.1728 |
| 9 | 09/21/87 | 6.21 | 25.65 | <0.081 | 0.1134 |
| 9 | 12/18/87 | 11.88 | 26.46 | 0 | 0.297 |
| 9 | 03/17/88 | 3.51 | 2.592 | <0.054 | 0.2619 |
| 9 | 07/06/88 | 22.95 | 45.9 | <0.054 | 0.0891 |
| 10/11C | 03/17/88 | 4.05 | 4.05 | <0.054 | 0.2619 |
| 10/11C | 07/06/88 | 4.32 | 21.6 | <0.054 | 0.432 |

[a]See Figure 1B.5 for sampling locations.

# Appendix 1B Figures




WAG6 06F255.DGN

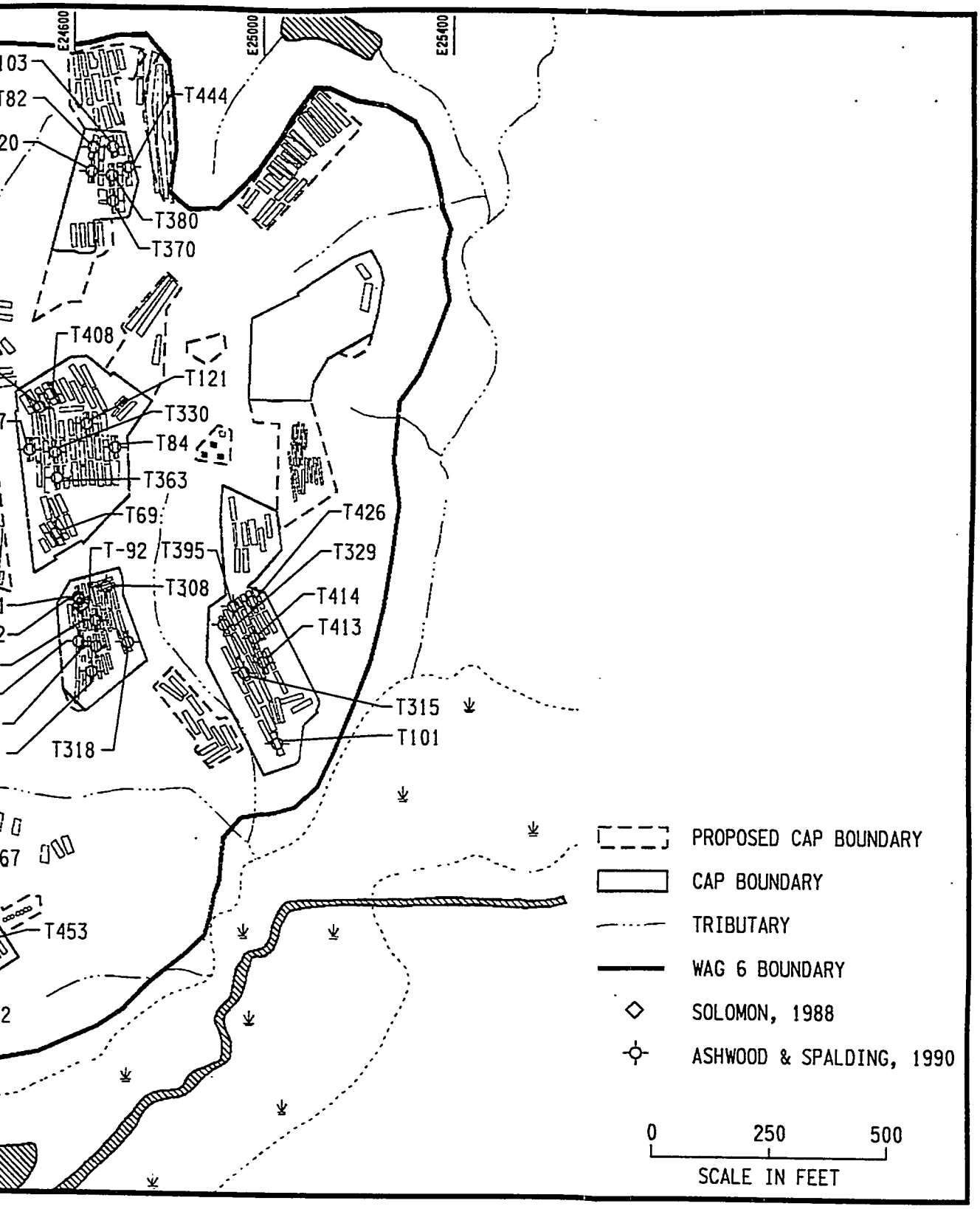
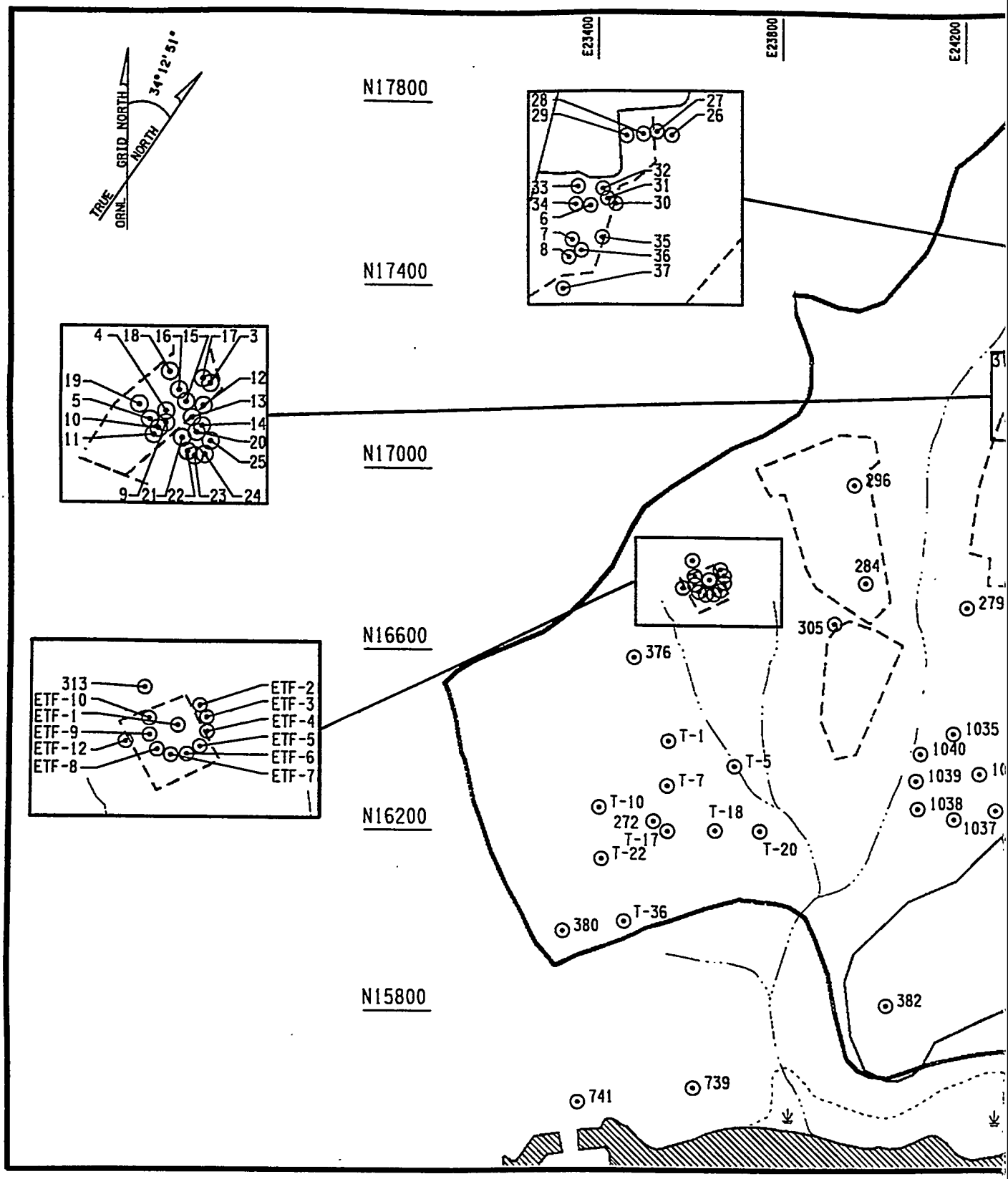



**Fig. 1B.1. Historical trench leachate sampling locations.**




WAG6 06F258.DGN

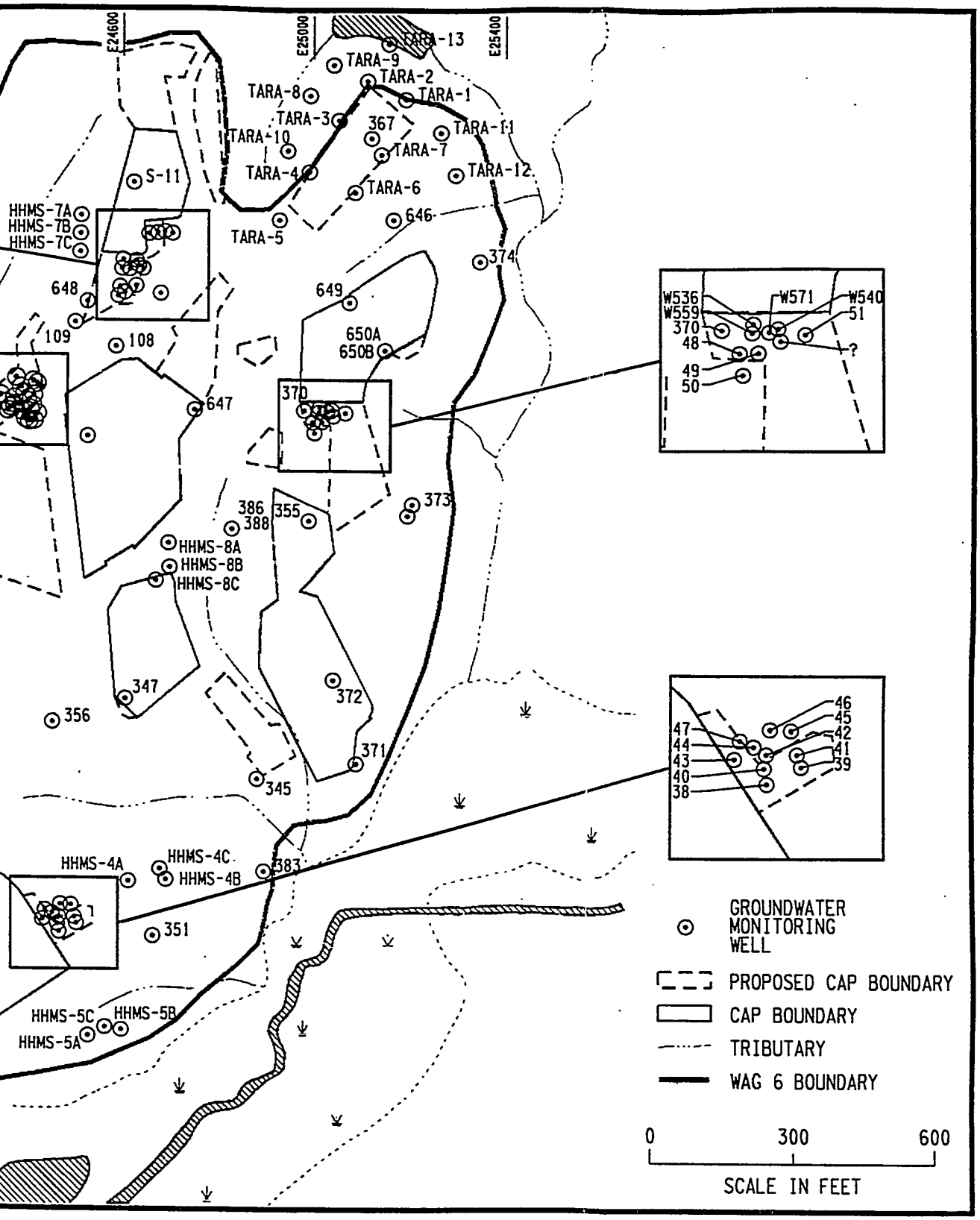
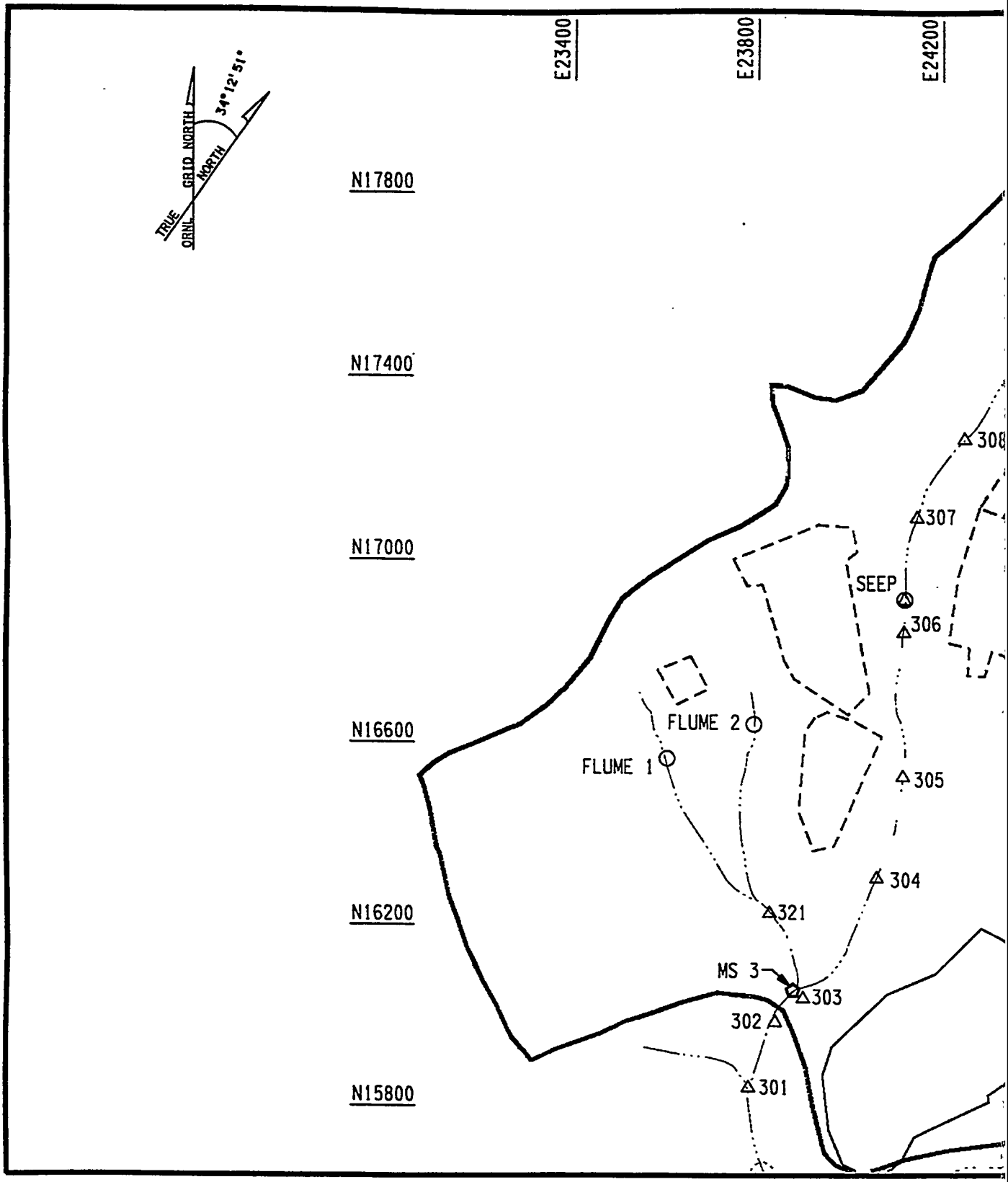



**Fig. 1B.2. Historical groundwater sampling locations.**




WAG6 06F253.DGN

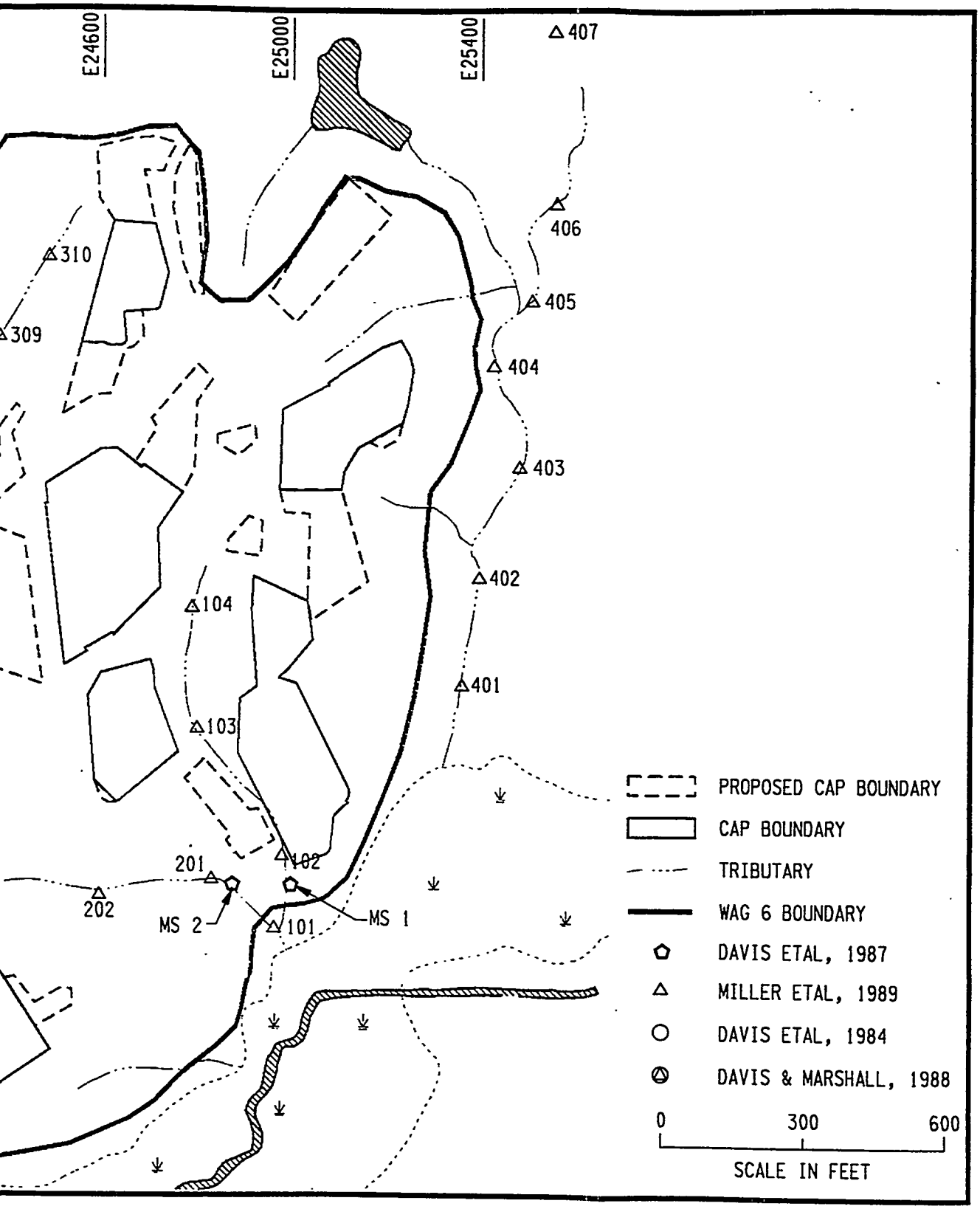
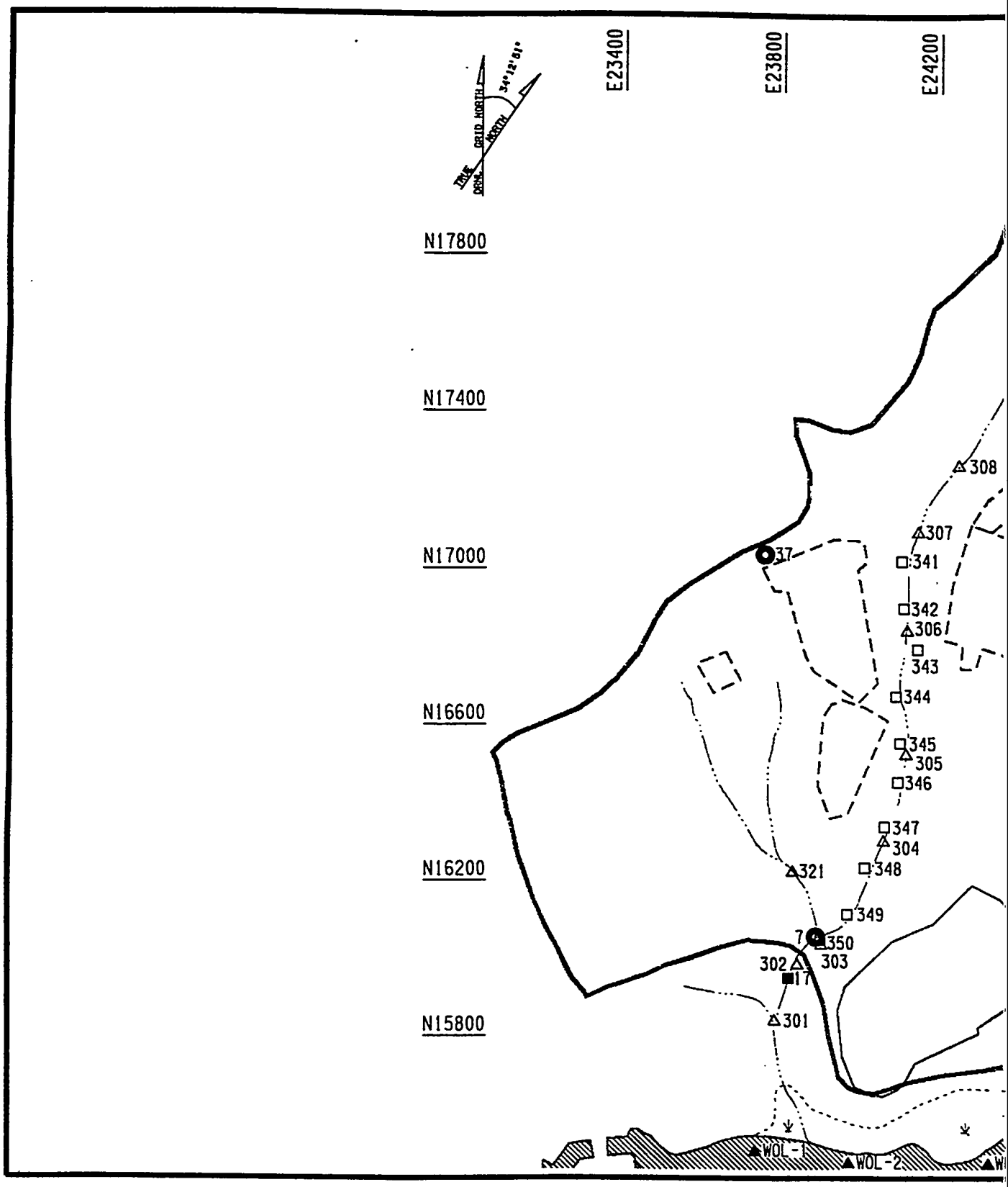



**Fig. 1B.3. Historical surface water sampling locations.**




WAG6 06F252.DGN

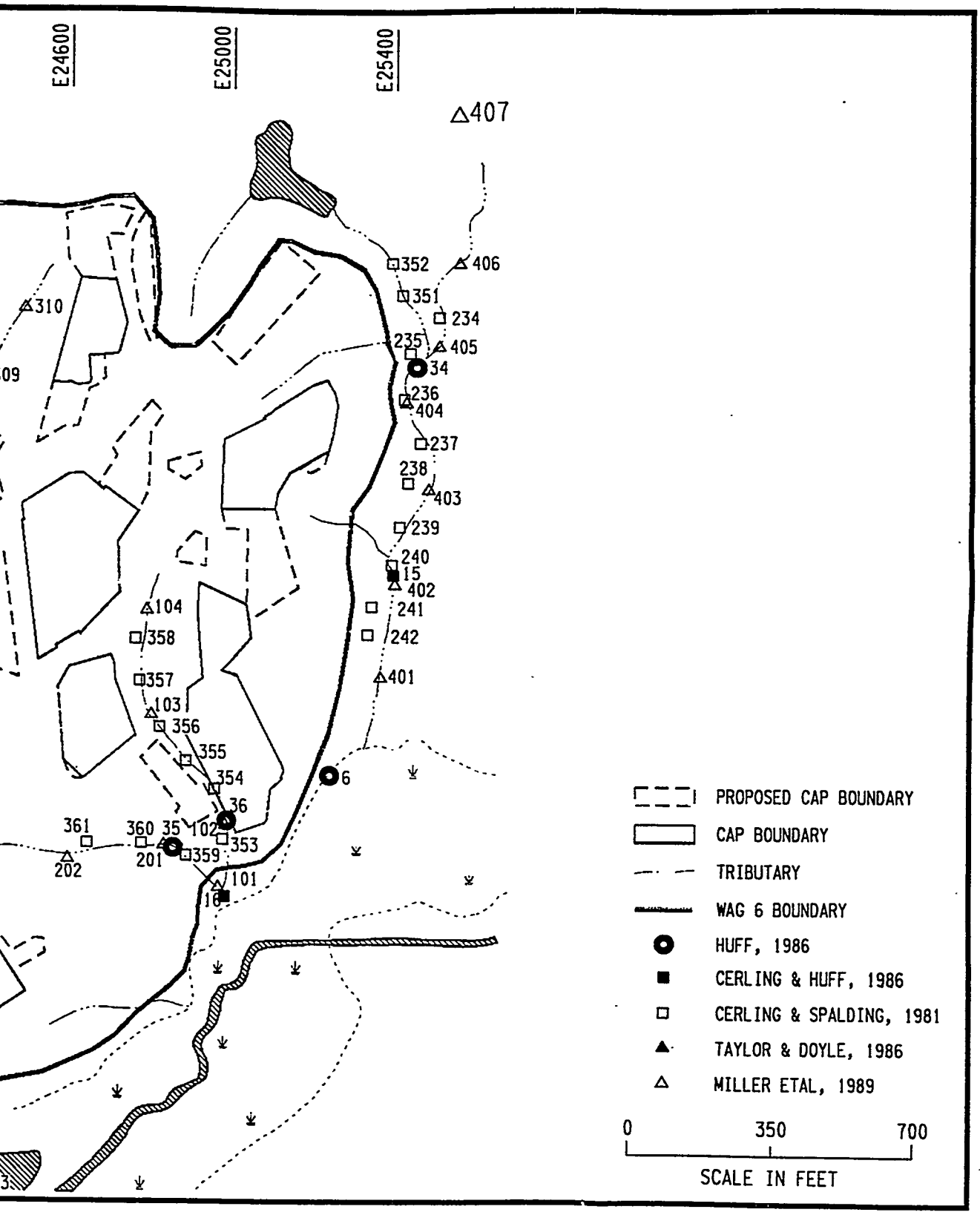
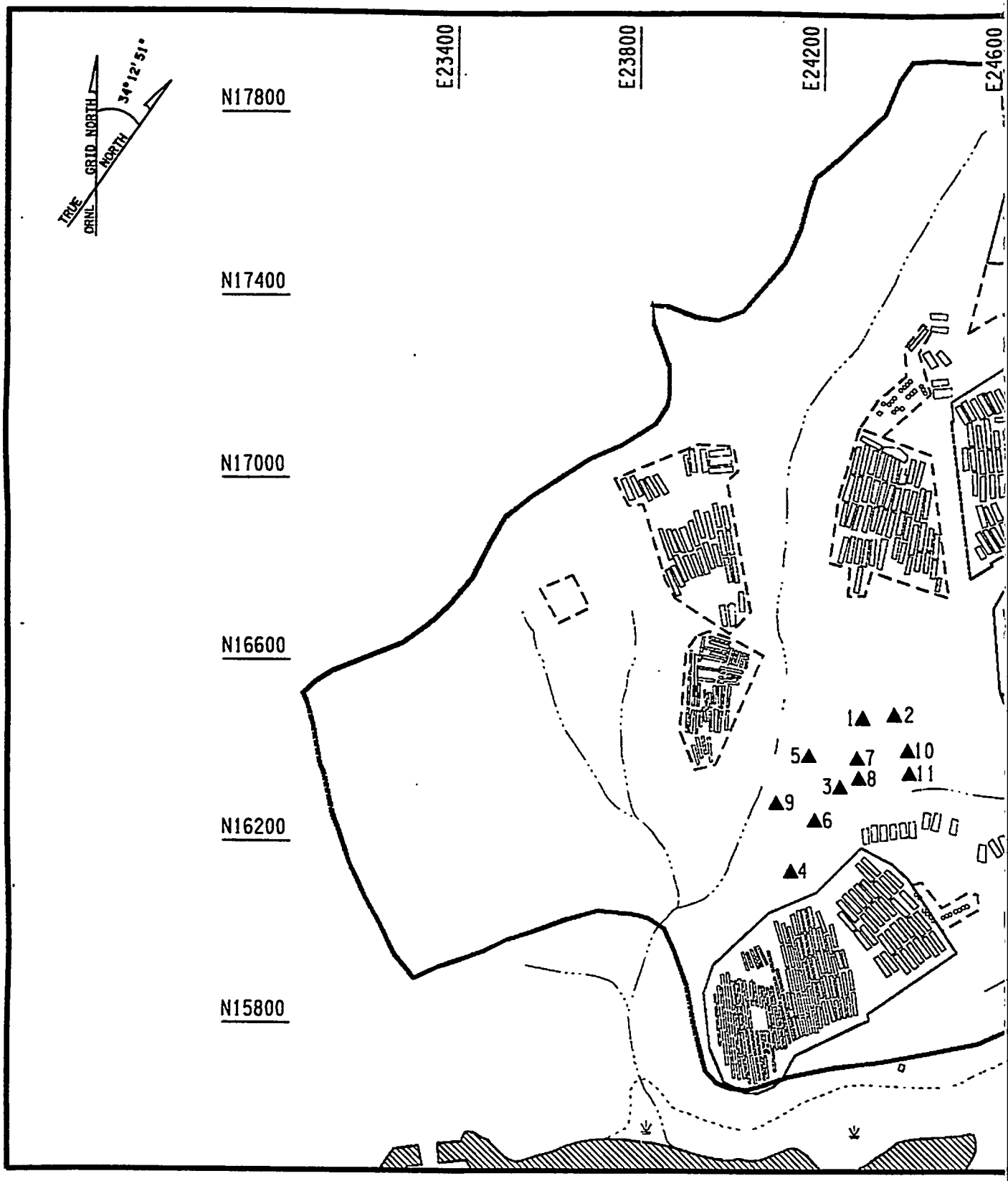



**Fig. 1B.4. Historical sediment sampling locations.**




WAG6 06F254.DGN

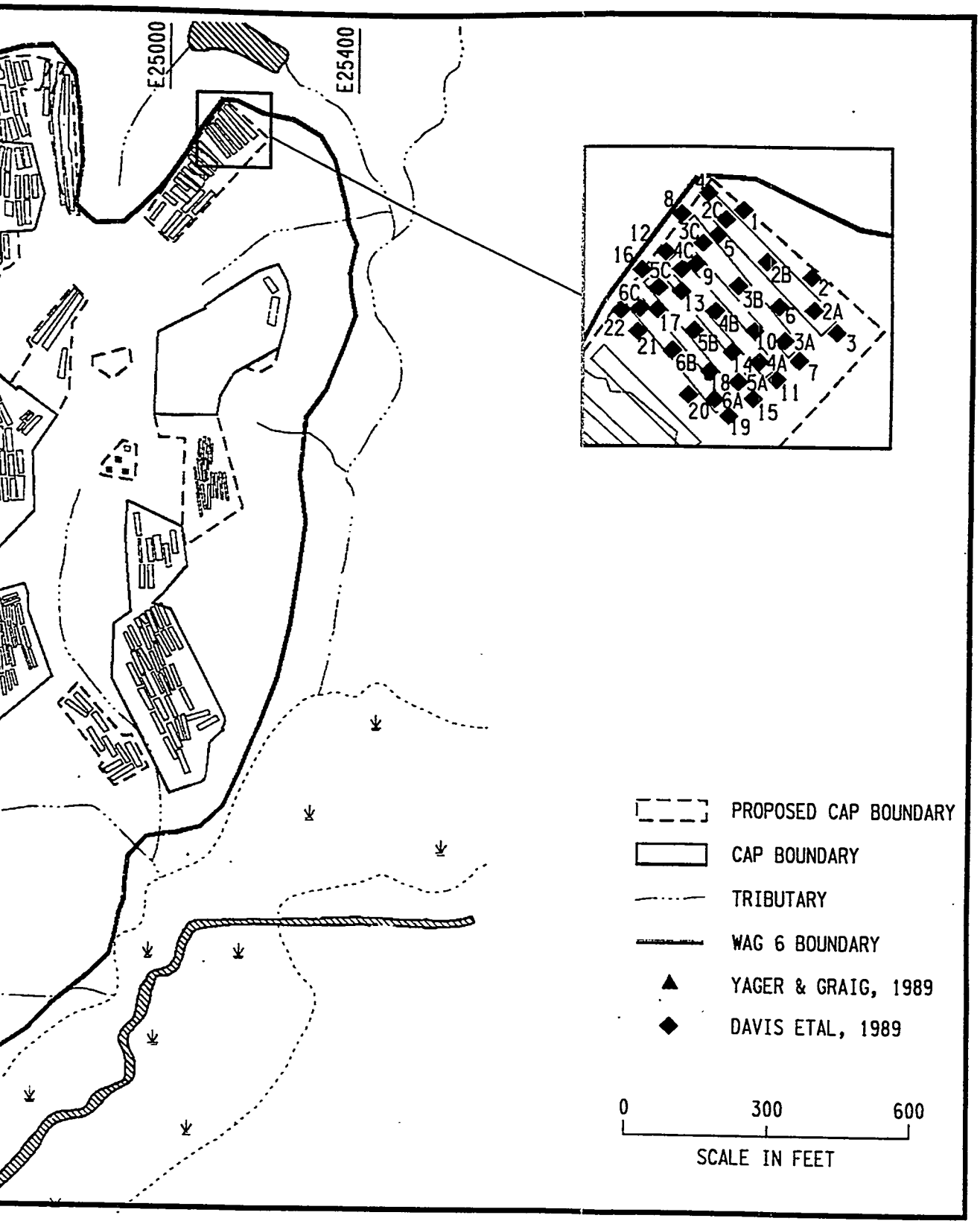



**Fig. 1B.5. Historical soil sampling locations.**

# APPENDIX 2A

# SAMPLE INFORMATION MANAGEMENT SYSTEM

TITLE: SAMPLE INFORMATION MANAGEMENT SYSTEM (SIMS)

DOCUMENT NUMBER: 1603

REVISION NUMBER: B

DATE: 12/04/89

PROJECT: ORNL RI/FS

JOB NO.: 19118

PREPARED: Andrea S. Mavridal — Data Base Supervisor — 1/29/90 Date

REVIEWED: Bob Pearcol — Project Quality Assurance Supervisor — 1/29/90 Date

APPROVED: RDSle — Program Manager — 1/29/90 Date

# SAMPLE INFORMATION MANAGEMENT SYSTEM

## 1.0 PURPOSE

This procedure provides methodology for use of the Sample Information Management System (SIMS) protocols for sample accumulation and tracking functions.

## 2.0 SCOPE

This procedure applies to all ORNL RI/FS project field sampling activities.

## 3.0 DEFINITIONS

Custody - A sample or other physical evidence is considered to be in custody if the possession of the sample can be traced from the time of collection until the sample analytical data is introduced as evidence in legal proceedings. For example:

- it is in the field investigator's or the transferee's possession; or
- it is in the field investigator's or the transferee's view, after being in his/her physical possession; or
- it was in the field investigator's or the transferee's physical possession, and then he/she secured it to prevent tampering; or
- it is placed in a designated secure area.

Sample - Physical evidence collected from a facility/site or the environment for monitoring purposes. Evidence includes collected environmental material, photographs, remote sensing data, and in situ field measurements and analyses, whether taken directly from a collected sample or made with field instruments.

Sample Identification Documents (Sample Documents) - Any form, report, or record prepared to maintain chain of custody (COC), including, but not limited to, the following:

- Request for Analysis (RFA) Form (Attachment 1)

- Custody Seals (Attachment 2)
- Field notebooks (see PP 1631, "Logbook Protocols")
- Photographic logs (see PP 1110.1, "Field Photography and Control")
- Forms used in commercial transport (i.e., Federal Express Airbills and Hazardous Cargo Manifests) of samples for analysis at other than the Analytical Laboratory Subcontractor (ALS) facility
- Specialized sample identification and management forms or modified RFA forms required by the WAG field sampling plan or QA project procedures

## 4.0 PROCEDURES

The following major activity functions shall be completed for each sample, or group of samples, taken.

### 4.1 ELECTRONIC DATA TRANSFER

#### 4.1.1 Laboratory Notification

The sampling event must be initiated by the WAG manager's request for analysis, issued to the Laboratories Manager and the Field Sample Coordinator (FSC) at the RI/FS project Field Operations Facility (FOF). The request is made on a Sample Event Initiation Request (SEIR) form (Attachment 3). Requests are to be made and forwarded to the ALS at least seven working days prior to the anticipated sampling event. It is the responsibility of the Laboratories Manager to notify the ALS by providing them a copy of the SEIR form. In addition, the FSC and Laboratories Manager must ensure that an adequate stock of the various containers and preservative reagents is continuously available for all sampling events.

#### 4.1.2 Container Preparation

Upon receipt of the SEIR form, the FSC must coordinate preparation of all sample containers necessary to fulfill the SEIR form requirements. Each container must be equipped with a unique bar code label consisting of four digits to identify sampling location and two digits to ensure uniqueness in container identification. All containers with the same first

four digits comprise a sample set (to be taken from the same location). Prior to sampling, the Close Support Laboratory (CSL) Supervisor will affix a second bar code label to each container identifying the preservative added to the container.

Using bar code readers and software, the FSC will prepare an ASCII file of container preparation parameters for each sample to be collected. The file consists of a prefix (CP) to indicate the container preparation software module; a user I.D. (Martin Marietta badge number for the employee/scanned from badge); date and time of transaction (automatic entry); container ID (scanned from label on container); and pay item numbers to identify requested analyses (scanned from bar coded menu cards). All such ASCII files are to be uploaded from bar code readers to personal computers at the FOF and then transmitted to BNI's Digital VAX computer system using modems and communications software. All bar code files are loaded into ORACLE tables for sample tracking. Electronic tracking is begun by matching uploaded container preparation files to SEIR forms.

### 4.1.3 Preparation for Sampling

A designated sampling team member must obtain those containers, preservatives, packaging materials, coolers, bar code readers, etc., necessary for that day's scheduled sampling events from the FSC. All coolers will contain a bar code label identifying sample location which consists of four digits (matching the first four digits on all container labels belonging to that sample set).

Prior to initiation of sampling activities, the names of all sampling team members must be entered into the field logbook. If team members leave the sampling area at any time during the shift or if new team members arrive, the times of departure/arrival must also be entered into the field logbook.

Menu cards for all data collection are prepared and issued to sample team leaders prior to sampling. Menu cards include bar code labels specifying sampling location; sample matrix; sample type (e.g., regular, field blank, duplicate, etc.); and depth intervals for soil samples.

All bar code labels and menu cards are printed at the FOF using personal computers and printers and graphics software packages. All labels used on menu cards or affixed to containers and coolers will be checked for accuracy using the label check option

available on the portable bar code readers. Should any labels fail to read correctly, replacements will immediately be printed and substituted for those failing the check.

### 4.1.4 Sample Collection

In preparation for the collection of a sample, a designated team member must use the Sample Structure Module of BNI's bar code software to record the following information:

- Prefix (SS) to identify module for transaction (automatic entry)
- Team member's (individual using the bar code reader or the sampler) Martin Marietta badge number (scanned from badge)
- Date and time stamp for transaction (automatic entry)
- Sampling location site (e.g., well/hole number - scanned from menu card)
- Container ID (scanned from label on container)
- Sample matrix code (scanned from menu card)
- Preservatives added or NONE (scanned from container label)
- Sample Type (scanned from menu card)
- Depth interval (soil samples only/scanned from menu card)

Upon successful completion of the foregoing bar code reader entries, the designated team member must enter the container identification (bar code label on the container) into the field logbook. Immediately after this entry, the team member must make those entries required by the provisions of PP 1631, "Logbook Protocols."

### 4.1.5 Custody Transfer

The container transfer module of the bar code software must be used each time that the containers change hands to ensure a complete record of COC. The CT files contain:

- Prefix (CT) to identify module (automatic entry)

- User I.D. (scanned Martin Marietta badge number of employee relinquishing custody)
- Date and time for transaction (automatic entry)
- Container ID (scanned from label on container)
- Location of origin (scanned from menu card)
- Location for transfer (scanned from menu card)
- Custodian ID (scanned Martin Marietta badge number of individual receiving samples)

When a custody transfer involves placing samples into storage (e.g., interim or archival storage), all sample containers shall be stored in secure areas designated for that purpose. Access to storage facilities shall be strictly controlled by the Field Services and Support (FSS) Manager and monitored by the Field Environmental Safety and Health Supervisor.

Custody transfers outside the BNI Team and use of manual COC must be performed in accordance with the provisions of this procedure using the RFA form shown in Attachment 1.

4.1.6 Shipment of Samples to the ALS

The Shipping Officer (SO) must ensure that samples are packaged, labeled, marked, placarded, and have appropriate shipping papers, in accordance with the provisions of the PP 1260 series, "Hazardous Materials Transportation."

The final bar code container transfer transaction prior to shipping (e.g., custody transfer to vehicle driver) must include a "shipping event" indicator. Prior to actual shipping, the FSC must ensure that the bar code reader (see Paragraph 4.1.7 below) is uploaded to the FOF microcomputer (PC) and that an RFA form is generated. The FSS Manager must sign and date the completed form, indicating an authorized BNI Team request for analysis. The FSS Manager must ensure that the completed form is attached to the shipping papers. The shipment of the samples to the ALS laboratory facilities may then be executed.

4.1.7 Uploading Bar Code Readers to Computers

Information collected by each hand-held bar code reader must be transferred (uploaded) to RI/FS project PCs at the end of each work shift and should be uploaded more frequently if large numbers of high volume transactions are executed (e.g., at the lunch break and at the end of the shift).

### 4.1.8 Information Backup

Transactions uploaded to RI/FS project PCs during a single calendar day (midnight to midnight) are written to a single flexible disk (floppy) and journalized on the internal hard disk that is unique to that particular PC and for that particular day. This backup function is executed automatically at the completion of each individual bar code reader upload transaction. The FSC must ensure that each day's uploaded data for a given PC is stored on a separate floppy disk that is free of any other data.

At the conclusion of each working day, the PC operator must print the directory for each floppy disk. The PC operator must also label each printed directory with location, PC identifier, and the date. The PC operator must then sign each such record to attest to the accuracy of contained information and file the labeled floppy disk in a secure location.

Upon completion of the foregoing backup operations, the PC operator will use modems and communications software to upload that day's transactions from the PC to the VAX computer system located at Bechtel's Oak Ridge Office. If for any reason the data communications links cannot be established, the PC operator must back up the floppy disk (copy entire contents onto another floppy disk) and forward the backup copy of the floppy disk to the Data Base Supervisor. The Data Base Supervisor must ensure that the data contained on the floppy disk(s) are loaded onto the VAX computer sytem (RI/FS project data base) within 24 hours of receipt of the diskette. The Data Base Supervisor must notify the FSS Manager if any data could not be successfully loaded into the RI/FS data base or if any data should look suspect. Necessary changes, additions, or deletions must be documented on a Data Base Change Request form (Attachment 5) before actual alteration of any data. Logbook entries should be consulted prior to approval of change requests.

## 4.2 MANUAL SAMPLE MANAGEMENT AND CHAIN OF CUSTODY

### 4.2.1 General

Manual methods for the management of samples will be used whenever bar code equipment is unavailable or when the automated procedures are impractical. Sample identification, field records, and COC records will be recorded in waterproof, non-erasable ink. If errors are made in any of these documents, BNI Team members should make correction by crossing a single line through the error, entering the correct information, and initialing and dating the correction. If possible, corrections should be made by the individual who made the error, or the individual who made the error should be advised of the correction.

### 4.2.2 Sample Identification

The provisions of Section 4.1 are followed in obtaining sample containers, in reserving analytical capacity in the laboratory, and in preparation for field sampling.

### 4.2.3 Field Measurements

Those samples that consist of field measurements and analyses, such as temperature, pH, Eh, conductivity, flow measurements, geophysical measurements, radiological measurements, surveying measurements, and ambient air characterization measurements (i.e., oxygen/combustible gas levels, organic vapor levels, concentrations of toxic gases, etc.), are identified by recording the information in a bound field logbook (which may contain specialized forms). Temperature, pH, and specific conductivity are also recorded on Sampling Point Location forms (Attachment 4) which are provided to the Data Base Supervisor after each sampling event.

### 4.2.4 Sample Identification

Environmental Samples

Sample identification forms (Attachment 6) are provided to the BNI Team by the FSC, along with sample containers, preservatives, and other items for sample collection and management.

Samples, other than those collected for in situ field measurements or analyses, are identified by using a standard sample field tag (Attachment 6) which is attached to the sample container. In some cases, such as rock cores, the sample field

label may have to be included with or wrapped around the sample. The sample field labels are sequentially numbered and are accountable documents after they are completed and attached to a sample or other physical evidence.

The sample field label can be filled out prior to obtaining the sample, leaving only the date/time and sampler's signature blank. The sample field tag (Attachment 6) is completed with the following information:

- Project Name: ORNL RI/FS (specify WAG or project name, such as "WAG 10 P&A").
- Project Number: Use the BNI project number and work release number (e.g., 19118-X022).
- Sample Number: A unique identifying number consisting of numbers and letters. The sample number is determined by the WAG Manager.
- Collection Date/Time: Use the following notation:

MO/DA/YR/HR:MN:SC

where: MO is a two-digit numeral representing the month. Use zeros as the first digit where appropriate.

DA is a two-digit numeral representing the day. Use zeros as the first digit where appropriate.

YR is a two-digit numeral representing the last two digits of the year.

Either slashes (/) or dashes (-) may be used to separate the dates. Colons are used to separate the time elements,

where: HR is a two digit numeral representing the hour. Use military (24-hr) notation, with the hours after noon represented by the numbers 13 (1 p.m.) through 23 (11 p.m.). Midnight is expressed as 00:00 hours, noon as 12:00. Use zeros as the first digit where appropriate.

MN is a two-digit numeral representing the minutes. Use zeros as the first digit where appropriate.

SC is a two-digit numeral representing the seconds. Use only when required. Use zeros as the first digit where appropriate.

- Collector's Name: PRINT your name [if more than one person is collecting samples, provide the actual collector's name, the name of the person bearing on-site responsibility for the sampling effort, or the names of the entire sampling team (usually two names)]. Whenever possible, add the sampler's ORNL identification badge number.

- Sample Location: Provide sufficient detail to enable the same location to be resampled at a later date.

- Sample Type/Depth/Description: The sample is either a grab or a composite. Specify depth taken for groundwater, surface water, soils, lagoons, or impoundments, waste piles, etc. Describe the media sampled (groundwater, etc.) and briefly specify hazards (high hazard, rad hazard, environmental sample). Specify the sample as a field or travel blank (FB or TB), a duplicate (DUP), or a non-QC replicate (REP). QC samples, such as replicates, submitted to the laboratory at the direction of the Laboratoris Manager are an exception and will be submitted as a "blind" to the laboratory, marked as a normal sample.

- Preservative: The type of preservative used will be filled in by the Close Support Laboratory (CSL) Supervisor. See PP 1632, "Sample Containers and Preservatives."

- Request for Analysis Number: The type of analysis is determined by the WAG Manager in conjunction with the Laboratories Manager prior to collecting the sample. The RFA number corresponds to the RFA form (Attachment 1) filed in by the laboratory. The type of preservative, size and type of jar, and RFA number are interdependent. The sampler fills the container with the correct sample based on the three items.

| | |
|---|---|
| Bottle ___ of ___ | Used to indicate samples in more than one container, such as a water sample in two one-liter bottles. |
| Filtered/Nonfiltered | Check the appropriate item. |

The information recorded on the sample label (with the exception of sampler's signature) must also be recorded in the field

logbook. In particular, the serialized sample label number must be linked to the sample number. The field logbook will serve as the prime sample tracking mechanism in the manual system.

Other Physical Evidence

Sample labels are also used for labeling and tracking physical evidence other than sample jars, such as charts, or air and soil gas sample collection tubes or bags. If a label cannot be applied, a unique identifying number should be etched, written, scratched, or marked on the item (55-gal drum, pressure vessel, etc.) and the information required for a sample label recorded in the logbook. A completed sample tag can be forwarded with the item for analysis in a clear plastic bag, attached to the item by whatever means work.

Prior to decontamination of the sample, the sample label should be covered with clear tape to avoid smearing the entries. If the samples are enclosed in an outer package (paint can, core box), a duplicate (but not serialized) sample label should be filled out, attached to the outer container, and covered with clear, water-resistant tape.

4.2.5 Chain of Custody Record

The possession of samples or other physical evidence shall be traceable from the time they are obtained until they are introduced as evidence in legal proceedings. RFA forms (Attachment 1) are used to trace samples. A lapse in COC is usually grounds for the data relating to the sample to be dismissed as "tainted."

Samples taken for the ORNL RI/FS project must remain in the possession of the field investigator until transferred to the ALS representative or to the possession of the FSS manager. The samples must be transferred to the ALS representative to transport as soon as possible after collection, but no later than 24 hrs. If samples must be retained overnight, the samplers must surrender custody of the sample to the FSS Manager, using the RFA form. The FSS Manager is responsible for securing and maintaining samples and transferring custody to the ALS as soon as practical.

The RFA form (Attachment 1) is used to record the custody of all samples or other physical evidence collected and maintained by

BNI Team personnel. This form also serves as a sample logging and tracking mechanism for the ALS sample custodian.

The following information must be supplied in the indicated spaces in detail to complete the RFA form:

- The project name and number
- The lab designation, previously determined by the Laboratories Manager, FSS Manager, and WAG Manager
- All designated signature blocks must be signed
- The sample number, sample matrix, container I.D., preservative, pay item numbers, requested testing programs, priority level, and QC level are included for each sample. Only one sample is described on each line. This information is obtained from the sample labels, the container preparation module of the bar code transaction files, and the SEIR form.

The "special instructions" line is used to list any additional testing requested or to clarify above items. Whenever possible, samples requiring similar analyses should be listed on the same RFA form and shipped together. The "Possible Hazard Identification" line is used to alert laboratory personnel to take special precautions when opening the sample shipment package. If the sample is surrendered to an on-site laboratory, the name and employee number of the sample custodian for that laboratory must be entered in the "Samples Received By" slot.

The sample custodian maintains custody throughout the analytical process. When the sample is first received, the "condition on receipt" is noted. If the containers are broken, damaged, empty, or if custody seals have been broken (see below), the sample custodian will set the sample aside and inform the Laboratories Manager, who will contact the FSS Manager and WAG Manager to determine if analysis should proceed or if resampling is indicated. The sample custodian will complete the RFA form when analysis is completed and the sample is disposed and will return a copy of the completed form to the Laboratories Manager for distribution to the permanent project record.

### 4.2.6 Custody Seals

Samples will be sealed immediately upon collection, utilizing the custody seal shown in Attachment 2, bridging the lid/bottle gap,

so that the seal will be broken if the container is opened. Seals are also placed on boxes or coolers used to transport samples to the laboratory. Any time the custody seal is broken by investigators in the field to get access to the sample, a notation is made on the RFA form, and a new seal applied. The laboratory sample custodian will note any broken custody seals and inform the SAL Coordinator.

### 4.2.7 Request for Analysis

The RFA form (Attachment 1) is sent to the laboratory by FOF personnel. Information regarding the sample/container number, sample type/matrix, preservative, pay items, priority and QC levels is recorded on the RFA form under the direction of the Laboratories Manager. The information required can be taken from the bar code container preparation files for each container, with the exception of priority and QC levels. The corresponding SEIR form provides that information.

RFA forms accompany the samples listed on the forms to the laboratory.

### 4.2.8 General Considerations

A RFA form must be completed for all samples or physical evidence collected. A separate form is necessary for each laboratory utilized during the inspection or investigation and for the final destination of the sample (archived or disposed).

During the course and at the end of the field work, the WAG manager, Laboratories Manager, and Field QC Supervisor determine whether these procedures have been followed and if the collection of additional samples is required.

In general, BNI Team personnel must not accept samples from other sources (i.e., Energy Systems, Rust Engineering, etc.) unless the sample collection procedures used are known to be acceptable, can be documented, and the sample COC can be established. Typically, the requirements can be met by having a BNI Team member observe the sampling effort. If such samples are accepted by BNI Team members, a standard sample tag containing relevant information and a RFA form must be completed for each set of samples.

When samples are split with a state or federal regulatory agency, the regulatory agency representative signs the RFA form.

## 5.0 RESPONSIBILITIES

The Program Manager is responsible for ensuring overall compliance with this procedure.

The WAG managers are responsible for timely notification to the Laboratories Manager of sampling requirements and close coordination with the FSS Manager for authorization/approval for analysis of opportunistic samples.

The Laboratories Manager is responsible for timely coordination with the ALS, for ensuring that the ALS responds to programmatic needs of the project in a timely and cost-effective manner, and for ensuring that the ALS utilizes the SIMS in accordance with this procedure and contractual directives.

The FSS Manager is responsible for field control of sample container stocks, storage/maintenance/issuance of bar code readers, and field data transfers.

The Data Base Supervisor is responsible for ensuring the quality and timeliness of SIMS and related data bases maintained on the VAX computer system and for technical inspections and surveillances of field and laboratory operations to ensure that data are collected in an appropriate and quality manner.

The Field QC Supervisor is responsible for inspecting field activities to determine compliance with this procedure.

## 6.0 REFERENCES

(1) Oak Ridge National Laboratory, "ORNL SAS Data Sets," 1987.

(2) Bechtel National, Inc. Team, "Project Management Plan for the Oak Ridge National Laboratory Remedial Investigation/ Feasibility Study," ORNL/RAP/Sub-87/99053/1, September 1987.

(3) Martin Marietta Energy Systems, Inc., "Environmental Surveillance Procedure Quality Control Program," ESH/Sub/87-21706/1 DRAFT, September 1988.

## 7.0 ATTACHMENTS

Attachment 1: Request For Analysis

Attachment 2: Custody Seal

Attachment 3: Sample Event Initiation Request

Attachment 4: Sampling Point Location Data Input Form

Attachment 5: Data Base Change Request Form

Attachment 6: Sample Field Label

REQUEST FOR ANALYSIS

PROJECT NAME: BECHTEL/ORNL RI/FS
PROJECT NUMBER: 19118
PROJECT MANAGER: R. D. GLENN
SUB CONTRACT NUMBER 19118-SC-04

ADDRESS: BECHTEL NATIONAL, INC.
800 OAK RIDGE TURNPIKE
OAK RIDGE, TENNESSEE 37830

BILLING: S. L. PRIEST
LAB REPORT: PDCC 19118

BECHTEL CONTACT: R. D. BROOKSBANK
482-0404

SE NO. _____

WORK RELEASE NO. _____

DATE SAMPLE COLLECTED: _____
DATE OF CUSTODY TRANSFER: _____
DATE SAMPLE SHIPPED: _____
SHIPMENT NO: _____
LAB DESTINATION: OAK RIDGE
LABORATORY CONTACT: J. T. HARVEY

SAMPLE DISPOSAL: RETURN TO CLIENT

| K-SERIES | SAMPLE NUMBER | MATRIX/ DATA CODE | CONTAINER ID | PRESERVATIVE | PAY ITEM NUMBER | REQUESTED TESTING PROGRAM | PRIORITY LEVEL | QC LEVEL |
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SPECIAL INSTRUCTIONS:
Perform additional radiological testing for alpha and beta emitters if gross values indicate presence, reference BNI CCN 004975, W.C. Borden to J. Harvey 9/25/89.

POSSIBLE HAZARD IDENTIFICATION:

NONHAZARD X FLAMMABLE SKIN IRRITANT HIGHLY TOXIC RAD HAZARD BIO HAZARD OTHER

REPORT PREPARED BY: _____ DATE: _____
SAMPLES RECEIVED BY: _____ DATE: _____

SAMPLES RELINQUISHED BY: _____ DATE: _____
TIME: _____

CUSTODY SEAL

L A B O R A T O R Y

S A M P L E S

# SAMPLE EVENT INITIATION REQUEST

Bechtel National, Inc.

Interoffice Memorandum

SAL Coordinator

WAG Manager's Sample Event Initiation Request

FSS Manager
RI/FS Manager

WAG ___ Manager

RI/FS Project - 19118

Oak Ridge, TN

Work Release No. _____
SE No. _____
SC _____

Sampling of the indicated media for the following analyses will be initiated on or about _____ and be completed on or about _____.

| Number of Samples | Matrix/ Data Code | ALS Contract Pay Item No. | Analyte or Analyte Class | QC Level | Priority Level |
|---|---|---|---|---|---|
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SAMPLE

COMMENTS:

Authorized by: WAG Mgr. _____ Date _____

# SAMPLING POINT LOCATION DATA INPUT FORM

## RI/FS DATA INPUT FORM/SSV105

## SAMPLING POINT LOCATION DATA

WAG _____ LOCATION ID _____

GRID SYSTEM _____ EASTING _____.__ NORTHING _____.__

GROUND SURFACE ELEVATION _____._ _ CIVIL SURVEY DATE __/__/__

SAMPLE COLLECTED? __ Y __ N SAMPLE TYPE (MATRIX) _____

SAMPLE DATE __/__/__

| | TIME 1 | TIME 2 | TIME 3 | TIME 4 |
|---|---|---|---|---|
| | __:__ | __:__ | __:__ | __:__ |
| PH | | | | |
| SPECIFIC CONDUCTANCE | | | | |
| TEMPERATURE | | | | |

DATA COLLECTED BY (NAME) _____

REMARKS _____

_____

COMPLETED DATA COLLECTION FORM CHECKED BY: _____

VERIFICATION CODE: __ UNVERIFIED __ VERIFIED/INVALID
__ VERIFIED/LIMITED USE __ VERIFIED/VALID

WORK RELEASE NO. _____

# DATA BASE CHANGE REQUEST FORM

DATA FILE NAME _____

DATE OF DATA COLLECTION __/__/__

CHANGE REQUESTED BY (NAME) _____

ITEM TO BE CHANGED _____

EXISTING ENTRY _____

CORRECTED ENTRY _____

CORRECTION APPROVED BY (NAME) _____

DATE OF CHANGE REQUEST __/__/__

# SAMPLE FIELD LABEL

PROJECT NAME _____

PROJECT NO. _____

SAMPLE NO. _____

COLLECTION DATE/TIME _____

COLLECTOR'S NAME _____

SAMPLE LOCATION _____

SAMPLE TYPE/DEPTH/DESCRIPTION _____

_____

PRESERVATIVE _____

RFA NO. _____

BOTTLE _____ OF _____

FILTERED _____ NONFILTERED _____

# APPENDIX 3A. SITE GEOLOGY

The geology of the site has a controlling influence on the occurrence of groundwater and contaminant transport and impacts the selection and design of remedial action alternatives. This appendix provides a detailed description of the geology of WAG 6 and identifies key features and aspects that affect the fate and transport of contaminants and bear on potential remedial action alternatives. Section 3A.1 presents WAG 6 in the context of its regional geologic setting. Section 3A.2 describes the site-specific geology of WAG 6, providing detailed discussion of the stratigraphy, structural geology, and physical and chemical properties of geologic materials. Section 3A.3 summarizes key geologic findings presented in previous sections relevant to understanding the aquifer system and to support the needs of the RFI.

## 3A.1 REGIONAL SETTING

WAG 6 is situated in the Tennessee Valley and Ridge Province, part of the Appalachian fold and thrust belt, which is characterized by a succession of northeast-trending thrust faults that structurally stack and duplicate the Paleozoic rocks in this area. As a result of thrusting associated with the Permian-Pennsylvanian Alleghenian Orogeny and subsequent differential erosion, a series of valleys and ridges have formed that parallel the surface traces of thrust faults. Variable resistance to weathering and erosion of the dipping strata have caused parallel alignment of ridges and valleys such that resistant formations (generally siltstones, sandstones, and dolomite units) form the ridges while more readily weathered and eroded formations (principally shales and shaley carbonates) underlie the valley floors.

Situated in a foreland fold and thrust belt, local geology is influenced by structural features at all scales including regional thrust faults, local thrust, normal, and tear faults, local folding, and widespread fracture development.

## 3A.2 SITE GEOLOGY

WAG 6 is situated in Melton Valley on the Copper Creek Thrust Sheet (Fig. 3A.1). The middle to late Cambrian Conasauga Group and underlying Rome Formation constitute the lowest stratigraphic interval on the Copper Creek Thrust within Melton Valley. The stratigraphic sequence underlying WAG 6 consists of the following, in ascending order:

- Unweathered, consolidated Conasauga Group bedrock
- Regolith
  - An interval of weathered, unconsolidated bedrock or saprolite
  - A veneer of alluvial, colluvial, or residual soils

Because saprolite and soils are weathering products of the underlying bedrock, this section is organized to provide a detailed description of bedrock parent material, followed in ascending order by saprolite and soil discussions.

### 3A.2.1 Bedrock

This section describes in detail the stratigraphy, structural geology, and chemical properties of bedrock underlying WAG 6 based upon existing and RFI data.

#### 3A.2.1.1 Stratigraphy

The Conasauga Group is a complex sequence of clastic-rich units alternating with carbonate-rich units deposited as part of a major marine transgression over a subsiding carbonate-rimmed tidal flat. This depositional setting is believed to mark the regional transition from the shallow shelf environment to the northwest to the deeper marine environment to the southeast (Hasson and Haase 1988; Haase, Walls, and Farmer 1985).

The Conasauga Group within Melton Valley ranges up to 1800 ft thick (Boegly 1984) and comprises six distinct formations. These are, in ascending order: the Pumpkin Valley Shale, Rutledge Limestone, Rogersville Shale, Maryville Limestone, Nolichucky Shale, and Maynardville Limestone. Lithologic descriptions for each of the Conasauga Group formations are presented in Table 3A.1. These lithologic descriptions are derived from Haase, Walls, and Farmer (1985) and are based primarily upon continuous rock cores from the 2700-ft deep ORNL-JOY # 2 corehole located approximately 3.5 miles east-southeast of WAG 6. The composite borehole geophysical log was developed from a series of 400-ft deep HHMS-series wells within or adjacent to WAG 6 (Dreier and Toran 1989). Although there are abundant wells within WAG 6, the majority were drilled using air-rotary drilling methods and containment boxes and consequently do not provide much detailed site-specific stratigraphic information. However, site-specific stratigraphic control is afforded by rock cores and borehole geophysical logs from deep wells within or adjacent to WAG 6. These deep borehole and core control points are indicated in Fig. 3A.2. Borehole geophysical logs for the four deep wells drilled and logged at WAG 6 as part of the RFI are presented and evaluated in TM-06-13A.

#### 3A.2.1.2 WAG 6 borehole geophysical logging

The Maryville Limestone underlies the northern half of the site, while the overlying Nolichucky Shale underlies the southern half of the site. Bedrock is generally not exposed at the surface. However, the Maryville Limestone does outcrop in the extreme northeastern part of WAG 6 in the embankment on the north side of the TARA area. The contact between the Maryville Limestone and Nolichucky Shale, as shown on Fig. 3A.2, was determined in part based upon three-point problem solutions using deep well control on or immediately around WAG 6. The contact between the Nolichucky and underlying Maryville is gradational, marked by an increase in limestone content in the lower Nolichucky (Haase, Walls, and Farmer 1985). Consequently, there is some range of error associated with this interpretation.

The Maryville Limestone beneath WAG 6 ranges up to approximately 415 ft thick, as shown by deep borehole geophysical log correlations. Descriptions of the lithology of the Maryville Limestone are provided by rock cores from the ETF area (wells ETF-1, -3, -4,

-5, -6, -11, -13, and the 240-ft deep ETF-16); USGS corehole UB-2 (located immediately west of Highway 95 and WAG 6); and two cores from Wells 1234 and 1238 (drilled as part of the WAG 6 RFI). Generally, the Maryville within WAG 6 is characterized by massive to ribbon-bedded silty, intraclastic (flat pebble), oolitic and pelloidal limestones up to 1 ft thick, interbedded with silty, calcareous mudstones and dark shales (Vaughan et al. 1982; Tucci and Withington-Hanchar 1989; Haase, Walls, and Farmer 1985; and TM-06-08A, WAG 6 Well Installation). Limestone lenses are more abundant and pure in the upper portion of the Maryville in the northern half of the site, whereas mudstone units are more prevalent in the Lower Maryville, as noted in cores and geophysical logs.

The Maryville stratigraphy observed in site cores shows rapid lithologic changes vertically and laterally. As reported in Haase, Walls, and Farmer (1985) and observed in WAG 6 RFI rock cores, the limestones within the upper Maryville display upward-coarsening cycles that are clearly indicative of a higher energy environment within a subtidal setting, possibly associated with storm deposition. This setting commonly yields laterally discontinuous depositional patterns and may contribute to the difficulty encountered in correlating individual beds from well to well. Further, structural deformation within both the Maryville and Nolichucky formations produces wide variations in formation and internal stratigraphic interval thicknesses from one location to another. Consequently, it is difficult to correlate individual or groups of limestone beds between wells, even using borehole geophysical logs.

Locally, the Nolichucky Shale is approximately 550 ft thick as observed in the ORNL-JOY #2 corehole (Haase, Walls, and Farmer 1985). However, a complete Nolichucky section was not encountered in the southern half of WAG 6 and it appears that only the lower Nolichucky underlies WAG 6. Cores have not been obtained from the Nolichucky Shale within WAG 6. Borehole geophysical logs (in particular, borehole televiewer logs) from the HHMS-series deep wells and from WAG 6 RFI Well 1236 are the principal source of lithologic information for the Nolichucky within WAG 6. These logs indicate that the Nolichucky within WAG 6 consists of thin shaley limestone beds interbedded with carbonate shales and mudstones. Similar lithologies were observed in lower Nolichucky cores from USGS coreholes UG2 and UF2, located further up Melton Valley in an equivalent stratigraphic position (Tucci and Withington-Hanchar 1989).

The lithologies observed and reported for the Nolichucky suggest that the Nolichucky deposition marks either a transition from shallow to deeper shelf conditions or a marine transgressive pulse. Like the Maryville, rapid lateral facies changes or post-depositional structural deformations make tenuous any lateral correlations of observed Nolichucky stratigraphy based on logs or cores.

The Rogersville Shale, although not exposed near the surface at WAG 6, was encountered at depths between 297 and 352 ft below land surface in two deep HHMS wells (Wells HHMS-7A and -8A, respectively) located in the northern half of WAG 6.

Bedrock has been encountered at depths ranging from 2.5 to 51 ft below grade in WAG 6. This information is based on existing subsurface control (provided in Davis et al.

1984; Davis et al. 1986; Davis et al. 1987; Davis et al. 1989; Davis and Stansfield 1984; Spalding - Pers. Comm., 1990; Morrissey, 1990; Dreier and Toran, 1989; Mortimore, 1987; Mortimore and Ebers, 1988) and information from the 54 soil borings and 22 wells installed during the WAG 6 RFI.

The average depth to bedrock observed was 19 ft. Generally, bedrock is encountered at shallow depths in topographically lower areas and along drainages and at greater depths on hilltops. Bedrock occurs at depths of 20 to 25 ft below grade in the vicinity of the WAG 6 main gate; 2.5 to 21 ft below grade along the eastern perimeter of WAG 6 (10 ft on average); 7 to 8 ft below grade along the drainage bounding WAG 6 on the east; and at depths generally greater than 23 ft (ranging up to 39 ft) along the southern boundary of WAG 6 in the vicinity of the biological trenches.

Figure 3A.3 shows the bedrock surface configuration generated using available subsurface information, including bedrock tops from boring logs, auger refusal depths, and actual elevations of bedrock exposed in trenches. Given the available subsurface data, the bedrock surface shown is a reasonable approximation. However, due to the variety in types and sources of bedrock surface information, the bedrock configuration shown is only an approximation and in any single location may show more or less relief than is actually present.

In an attempt to better define the bedrock surface, ORNL performed a shallow refraction seismic survey across WAG 6 (Dreier, Selfridge, and Beaudoin 1987). However, after processing two test lines (2A-2G and 1A-1G), the study was terminated short of completion and the remainder of the data were not processed. The test line data showed good correlation with bedrock depths known from well data. Figure 3A.4 shows the location of the seismic lines. If determined necessary to support the corrective measures study, improved definition of the bedrock surface could be provided through further processing and evaluation of these data.

### 3A.2.1.3 Structural geology

As shown in Fig. 3A.1, WAG 6 is situated on the Copper Creek Thrust Sheet, the principal structural feature controlling much of the subsidiary structure and stratigraphy within Melton Valley. The Copper Creek Thrust Fault separates the Copper Creek Thrust Sheet formations from the underlying WOC Sheet formations such that the Cambrian Rome Formation overlies the younger Ordovician Chickamauga Group. Trending N50-60° E, the Copper Creek Fault is exposed at the surface on the north flank of Haw Ridge north of WAG 6. It then dips relatively gently to the southeast, so that at WAG 6 the fault zone lies roughly 1000 ft below the ground surface. At this depth, the Copper Creek Thrust does not likely impact groundwater flow or contaminant fate and transport.

The Conasauga Group bedrock on the Copper Creek Thrust Sheet generally strikes N55°E and dip 20-25° to the southeast (i.e., striking roughly ORNL grid east-west and dipping grid south). However, within WAG 6, dips are generally steeper, on the order of

30-40°, and highly variable due to complex local structural deformation (Webster and Bradley 1988).

This high degree of structural complexity is evidenced in cores and deep well borehole televiewer logs from WAG 6. Dips change frequently in relatively short vertical distances in association with small-scale kink and drag folds and minor faults (Tucci and Withington-Hanchar 1989; Drier and Toran 1989; and TM-06-13A, WAG 6 Borehole Geophysical Logging). Dips observed in cores and logs range from 30° to near vertical, with strikes oriented in nearly all directions. Minor folding is common, particularly in thin-bedded shale and mudstone intervals, and is highly variable in continuity and intensity (Webster and Bradley 1988). Because deep well and/or core subsurface control within WAG 6 is limited, individual structures cannot be correlated with any certainty from well to well.

Due to the absence of surface bedrock exposures, structural mapping within WAG 6 has been limited to mapping structures observed in saprolite zones exposed in shallow trenches. Dreier and Beaudoin (1986) documented structural complexity through shallow trench mapping on a scale of 1:125. In that study, 10 shallow (4-ft deep) trenches were excavated in a band trending roughly north-south across the central portion of WAG 6. The trenches were aligned to allow for mapping structures and fracture densities in the saprolite perpendicular and parallel to overall formation strike. In general the study revealed that formation strike is variable (N35-70°E) across the site but is approximately oriented grid east-west. Conversely, formation dips reflect increasing structural complexity from north to south across the site. In the northern part of WAG 6, bedding was found to dip 22° to 33° to the southeast with gentle warping of the beds. In the central part of the site, small folds and faults have been identified. In the southern part of the site (on the hill adjacent to WOL), the trenches revealed more intense deformation marked by small-scale thrusting and overturned folds.

Davis et al. (1984) observed two sharp folds in the bedrock at the ETF site. The fold axes are roughly 18 ft apart and trend north-northeast. The folds are asymmetric, with steeper dips observed on the southeast flanks. Dips ranged from 12° to 65°. Structural mapping in saprolite above the Maryville formation was also performed during excavation and construction of the 49-Trench French Drain. Davis and Stansfield (1984) found that the bedding dips locally from horizontal up to 60° to the southeast due to folding of the strata. Structural measurements from all of these studies are presented in Fig. 3A.2. As can be seen, structural complexity increases from north to south across the site.

**Faulting.** Faulting is widespread in the shallow subsurface and in deeper bedrock at WAG 6. Cores from WAG 6 and surrounding areas identified four types of faults: bedding plane faults, high angle normal and reverse faults, and intraformational thrust faults. Bedding plane faults are ubiquitous throughout the Conasauga Group bedrock but are generally small-scale, with only slight horizontal displacement. They characteristically occur at contacts between different lithologies and are most abundant in thin- to medium-bedded intervals of limestone or siltstone and mudstone (Haase, Walls, and Farmer 1985). High angle normal and reverse faults have been identified in cores from the nearby ORNL-JOY #2 and WOL-1 coreholes (Davis et al. 1987; Haase, Walls, and Farmer 1985). These faults

typically show small vertical displacements (30-40 ft) and are accompanied by minor drag folds and a zone of deformation up to 5 ft thick. Many high angle faults were observed in shallow trenches in SWSA 6 and during the French Drain construction (Davis and Stansfield 1984), suggesting that such faults are quite common in the subsurface at WAG 6.

Intraformational thrust faults have also been encountered in cores from within Melton Valley. Two intraformational thrust faults were observed in the ORNL-JOY #2 corehole, accompanied by a 16- to 65-ft thick zone of chaotic bedding (Haase, Walls, and Farmer 1985). Within WAG 6, Dreier and Toran (1989) identified two low-angle thrust faults in two of the four deep HHMS well clusters (wells HHMS-5A and HHMS-8A). Their findings were based upon stratigraphic thickening, abrupt dip changes in televiewer logs, temperature log anomalies, and other supporting borehole geophysical log evidence.

Figure 3A.5 depicts a structural cross section oriented grid north-south across the central part of WAG 6. This cross section is based upon deep well control afforded by the HHMS well clusters and shows the two thrust faults, "A" and "B", identified in HHMS well 8A and 5A, respectively. Dreier and Toran (1989) report displacements of approximately 250 ft for Fault A and 20 to 75 ft for Fault B. The fault zone associated with Fault A in well HHMS-8A ranges up to 23 ft thick. The occurrence of these faults is believed related to changes in the shape of the underlying Copper Creek Thrust Fault at depth.

During the WAG 6 RFI, four deep (150-170 ft) wells were installed to evaluate the deeper flow component of the shallow aquifer system (TM-06-08A, WAG 6 Well Installation). With guidance from ORNL researchers (Dreier - Pers. comm. 1989), the locations of the four wells were selected to intercept the two identified thrust faults and assess their impact on groundwater flow. Continuous rock cores were obtained from RFI Well 1234, located on the eastern perimeter of WAG 6, and from the upper 20 ft of Well 1238, located in the northwest portion of the site. Evaluations of the core from these two wells and the full suite of borehole geophysical logs subsequently run on all four boreholes (BNI 1990a) revealed faulting in only one deep borehole, Well 1234. The fault plane in this well was encountered at a depth of 56 ft below land surface; an accompanying 20-ft thick fault zone occurred from 50 to 70 ft. The fault is evidenced in the core by a brecciated zone straddled by intervals of chaotic bedding on either side. Further evidence includes temperature and fluid resistivity anomalies noted in borehole geophysical logs. A repeated stratigraphic section typical of thrust faults was not observed, but the fault was encountered just below the base of surface casing, thereby precluding acquisition of adequate geophysical logs above that point. It is believed this fault correlates with Fault A observed in Well HHMS-8A. Thrust faults commonly diverge to form imbricate splays (i.e., subsidiary fault slivers off a main fault). Based upon the structural complexity observed in the shallow mapping and deformation observed in borehole televiewer loss, it is possible that other thrust faults or fault splays could exist at WAG 6.

Figure 3A.2 shows the subcrop leading edge of the two principal thrust faults identified. Figures 3A.6 through 3A.16 present hydrogeologic cross sections that depict the generalized structural framework underlying WAG 6 and incorporate the faults identified. From examination of Fig. 3A.2, it appears that the structural complexity noted in the

southern half of WAG 6 can be attributed to the imbricate thrust faulting. North of the mapped edge of Fault A, the degree of complexity diminishes and bedding orientations are more consistent.

**Fractures.** Conasauga Group bedrock has little or no matrix (i.e., bulk rock) porosity but is highly fractured throughout Melton Valley. Consequently, fractures form the most significant element in groundwater flow in the bedrock. Fractures may have developed at any time from the Ordovician (associated with compaction during or immediately after deposition) to the present. However, the present fracture network was principally developed in response to the Alleghenian Orogeny. At least two, but as many as five, fracture sets have been identified in cores from the Maryville and Nolichucky bedrock within and around WAG 6. Based upon extensive outcrop mapping in Melton Valley, Sledz and Huff (1981) documented two major fracture orientations in weathered lower Conasauga Group shales. From statistical analysis of fracture orientations, Sledz and Huff (1981) identified one principal set of fractures/joints oriented parallel to formation strike (N54°E) dipping roughly parallel to bedding, and a second principal set oriented normal to formation strike (N45°W) but oblique to bedding, dipping at angles up to 82°. Similar fracture patterns were encountered in coreholes at the ETF site (Davis et al. 1984 and 1987), WOL-1 and ORNL-JOY #2 (Haase, Walls, and Farmer 1985), and in WAG 6 RFI cores.

Shallow trench mapping (Dreier and Beaudoin 1986; Davis and Stansfield 1984) in WAG 6 has identified two near-vertical extensional fracture sets present in saprolite in addition to bedding plane fractures. The extensional fractures are oriented roughly perpendicular to each other. Dreier and Foreman (1990) report extensional fracture orientations of N35°W and N55°E in the northern part of WAG 6 and N5°E and N85°W in the southern portion of the site. Other fractures were observed in the ETF area parallel to local folding. It is expected that additional fracture trends associated with local structural features (folds and faults) may be encountered throughout WAG 6.

Fracture density varies with lithology but generally decreases with depth. Sledz and Huff (1981) identified up to 14 fractures per foot in siltstones and shales of the lower Conasauga Group in outcrop. Davis et al. (1987) noted that the highest bedding plane fracture density occurs in intervals of interbedded silty shales and limestones. Coarse limestone breccia zones had the lowest fracture density; the few present were oblique to bedding. Cores and televiewer logs from deep WAG 6 RFI wells support this. Detailed fracture mapping in the shallow saprolite (Dreier et al. 1987) showed that fracture densities appear to be locally independent of fracture type and average 20 to 30 fractures per foot. Although fractures are widespread, they are generally short, being less than 3.3 ft long (Moore 1989b) such that distinct fractures or groups of fractures cannot be correlated between wells with any certainty. However, the various fracture sets intersect to form a tortuous groundwater flow network.

Fractures (some chemically widened) range up to 6 in. in diameter, although most are less than 0.01 in. wide (Vaughan et al. 1982). All WAG 6 RFI cores exhibited fractures; some were open and others were filled with calcite accompanied by lesser amounts of dolomite, pyrite, gypsum, and other minerals. WAG 6 televiewer logs and cores showed that

high-angle fractures in limestone units appear to terminate abruptly at the contact with shale or mudstone units. Large-scale solution cavities were not observed in WAG 6 RFI cores, although some small-scale (less than 0.9 in.) solution cavities were reported in shallow (less than 50 ft deep) Maryville Limestone cores in the ETF area (Davis et al. 1984).

Open fractures are most common in the upper 150 ft of bedrock and decrease with depth (Dreier et al. 1987). Modeling performed by Sledz and Huff (1981) showed that fracture porosity decreased roughly 8.2% for every 50 ft below land surface. Figure 3A.17 schematically portrays the fracture network prevalent at WAG 6 and illustrates the interconnection of various fracture orientations with an overall decrease in fracture density with depth.

### 3A.2.1.4 Bedrock physical and chemical properties

The migration of radionuclides and other contaminants through bedrock is controlled in large part by the physical properties of the rock matrix or secondary porosity features and chemical interactions between the contaminants and the rock. Calcium carbonate cements in the Nolichucky and Maryville formations generally preclude any primary matrix porosity. Therefore fluids move through bedrock principally along secondary porosity features (fractures and solution cavities). Consequently, the key physical and chemical properties of bedrock that affect radionuclide transport include bulk rock properties (porosity, hydraulic conductivity, etc.) and retardation associated with ion exchange and sorption reactions caused by interaction with the rock along fracture planes.

Examination of the borehole geophysical logs for the WAG 6 RFI deep wells shows that the bulk density of the rock increases with depth; this is associated with the decrease in matrix porosity with depth. Davis et al. (1984) reported a mean bulk density of 2.63 g/cc (and calculated mean porosity of 0.018) for the Maryville Limestone observed in a 115-ft deep Maryville borehole at SWSA 7. Generally, the calcium carbonate content increased with depth at the expense of clay particle content, reflecting a vertical decrease in porosity related to decreased weathering and solution of calcium carbonate cements with depth (Table 3A.2). X-ray diffraction studies of selected Maryville rock cores from the ETF area (Davis et al. 1984) indicate that illite, chlorite, and mixed layer illite/vermiculite are the dominant clay minerals present. The pH of shallow bedrock samples generally ranges from 7 to 8.

Although the WAG 6 RFI undertook no specific studies to determine ion exchange and sorption reactions, Kds[1] for five radionuclides, CEC[2], and other physical properties were

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[1]The relative sorption (adsorption and/or absorption) of a given compound or radionuclide by a rock or soil matrix is expressed as the distribution coefficient, Kd. The Kd is related to overall retardation as follows:

$$\text{Retardation factor } (R_f) = 1 + Kd \times (\text{bulk density/porosity})$$

determined for rock cuttings from a 115-ft deep Maryville borehole and a 25-ft deep Nolichucky borehole in SWSA 7 (Rothschild et al. 1984b). Bedrock in SWSA 7, located further east in Melton Valley, is representative of conditions at WAG 6. The results are summarized in Table 3A.3.

Figure 3A.18 summarizes the chemical properties of Maryville limestone with depth. As shown, CEC decreases with depth as a result of decreased rock weathering. The Kds for strontium-85 decrease with depth, which parallels a similar decrease in total hardness (Ca + Mg) Kds and exchangeable Ca with depth. Strontium sorption is principally by ion exchange in competition with Ca and Mg in solution. The parallel decrease in Kds for Ca + Mg and the increase in calcium carbonate content with depth suggests that the Maryville bedrock is increasingly indurated and inert to radionuclide sorption at depth. Webster (1976) noted that cesium-137 interacts with illite clays and is readily sorbed into the illite lattice structure, while cobalt-60 is commonly adsorbed to manganese oxide coatings in fractured or weathered rock. The decreasing Kds for cesium-134 and cobalt-58 observed with depth in the deep Maryville borehole may reflect a decrease in illite content and manganese oxide coatings with depth related to the depth and degree of weathering. No observable pattern was noted for iodine-125 or americium-241 (Davis et al. 1984; Rothschild et al. 1984b). Rock cuttings from the 25-ft deep Nolichucky borehole suggest similar trends, but these remain unsubstantiated due to the limited sampling performed.

It should be noted that the reported Kd values are derived from bulk analysis of disaggregated rock cuttings. However, most transport of radionuclides through the bedrock underlying WAG 6 is via fractures and other secondary porosity features. Sorption in the bedrock would occur where fluids are in contact with the rock. As the surface area of the bedrock is limited to that exposed along the fractures (with some slight matrix interaction), the actual sorptive capacity of the system is finite and is somewhat less than that described by laboratory Kds derived from pulverized material. However, radionuclide transport is further controlled by the hydraulic conductivity of the bedrock and hydraulic gradients. If hydraulic conductivities and gradients are low, even low Kd values are sufficient to retard migration because of the longer residence time.

### 3A.2.2 Saprolite

Saprolite formed from in situ weathering of bedrock directly overlies competent bedrock and is a significant component of the aquifer system where saturated. This section provides a detailed description of the saprolite based upon existing and RFI data. This discussion describes saprolite occurrence and thickness, relict structural features, and physical/chemical properties.

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[2]The cation exchange capacity (CEC) is the sum of the exchangeable cations within a rock or soil profile. The CEC represents the degree of anticipated ion exchange between radionuclides and other ionic substances and the rock or soil matrix.

### 3A.2.2.1 Saprolite occurrence

Throughout Melton Valley, the Maryville and Nolichucky bedrock weather to form a saprolite indicative of the lithologies of the individual parent formations. Saprolite in areas underlain by carbonate-rich bedrock, such as in the northern part of WAG 6, is principally a brownish-yellow illitic clay (Vaughan et al. 1982). Usually in these areas, the transition from saprolite to bedrock is abrupt. Silty limestone or siltstone/shale bedrock weathers to a porous, brown or dull olive-brown siltstone saprolite, with a gradational transition to competent bedrock noted by an increase in rock fragments with depth. Bedrock consisting of interbedded limestone and shale yields a saprolite with alternating hard and soft beds, such as was encountered in drilling in the TARA area at the northern end of WAG 6. Within WAG 6, the upper portion of the saprolite is further weathered to form a silty clay soil layer that ranges from less than 1 ft to 13.5 ft thick (BNI 1990b, 1990c; TM-06-08A, Well Installation Phase 1, Activity 2; TM-06-12A, Soil Investigation Phase 1, Activity 2). This silty clay soil is equivalent to the "C" soil horizons. The contact between the silty clay and saprolite is gradational, marked by an increase in shale fragments and decreased weathering with depth. Contact generally occurs between 5 to 10 ft below grade. Six RFI soil borings (SCA-10, SCA-17, SCC-2, SCC-3, SCE-5, and SCE-6) that were terminated at refusal in limestone bedrock encountered no weathered shale zone, and the silty clay directly overlay the limestone bedrock.

The overall thickness of the saprolite layer throughout WAG 6 is proportional to the depth of bedrock weathering and varies with topographic position. The 54 soil borings and 22 boreholes drilled during the WAG 6 RFI revealed that the saprolite ranged from 3 to 45 ft thick. It was thicker on hilltops and thinner along surface water features in topographically low-lying areas.

The original bedrock structural fabric is preserved in the saprolite. Consequently, fractures and minor faults are commonplace, particularly in the southern half of WAG 6. Saprolite exposures along the east perimeter road (in the vicinity of RFI Well 1234) show considerable kink folding and relict fracturing. From mapping exploratory trenches within WAG 6, Dreier and Beaudoin (1986), Davis and Stansfield (1984), and others have found the saprolite to be highly folded and fractured. Weathering and differential movement of water through the saprolite fractures has in some cases enhanced these relict features in siltstones and shales. In other cases, fracture faces are coated with manganese or iron oxides (Ammons et al. 1987), thereby reducing fracture openings.

### 3A.2.2.2 Physical and chemical properties of saprolite

The physical and chemical properties of the saprolite have been studied at WAG 6 and in similar settings at SWSA 7 and have been reported in Ammons et al. (1987) and Rothschild et al. (1984a). Laboratory Kds have not been determined for WAG 6 saprolite but are available from saprolite developed from Maryville Limestone at SWSA 7 (Rothschild et al. 1984a). Kds are not available for saprolite derived from Nolichucky bedrock, but are expected to be similar to those reported for Maryville saprolite from SWSA 7. Table 3A.4 summarizes the findings of these studies.

Porosity in saprolite is a combination of matrix and secondary porosity, developed through weathering and leaching of carbonate cements and enlargement of fractures. The degree of weathering in the saprolite is variable but decreases with depth as evidenced by:

- An increase in illitic clays with depth and an abundance of iron and manganese oxide clay complexes caused by downward percolation of water through the saprolite;
- The calcium carbonate equivalents are low and decrease with depth;
- Clay content in the saprolite is high in the upper portions but decreases with depth in less weathered saprolite. (In some cases, fractures in the upper portion of the saprolite are clay filled);
- The saprolite becomes less acidic with depth (the contact with unweathered bedrock can sometimes be distinguished by a sharp change to pHs greater than 7.5.)

The chemical properties of in-place saprolite are controlled by iron-manganese clay and oxide complexes coating most fracture and grain surfaces (where weathering has sufficiently enhanced primary matrix porosity). Kds for strontium-85 are higher than observed for unweathered Maryville bedrock, but there is increased competition for exchange sites with calcium and magnesium in solution, which are leached from the saprolite. Kds for cesium-134 are also higher, perhaps related to the increase in illitic clays and extractable manganese and iron over bedrock. (Cesium-134 sorption is higher in the presence of illitic clays, manganese, and iron.) SWSA 7 Kds suggest that there is little difference between the sorption capacity of Nolichucky and Maryville saprolite.

### 3A.2.3 Soils

This section provides a description of the distribution and physical/chemical properties of WAG 6 soils.

#### 3A.2.3.1 Soil types and distribution

WAG 6 soils are principally residual soils developed in situ as weathered products of saprolites of the Maryville Limestone and Nolichucky Shale. In addition, alluvial deposits occur within drainage paths and low-lying areas adjacent to WOL. Colluvium also mantles some hillslopes, particularly in the northwest and southwest portions of WAG 6. Soil development is related to parent rock and/or saprolite composition, degree of weathering, and topographic position. As noted previously, weathering persists to greater depths on hilltops than in low-lying areas. Consequently, thin residual soils occur on the ridges but are absent in the low areas, where thick alluvial deposits are found.

Within most areas of WAG 6, native soils have been removed or reworked and fill materials imported during operational and disposal activities. Soils have been considerably altered or removed in association with construction of the 49 Trench French Drain, Tumulus pads, and most recently the widespread grading in conjunction with construction of the

Interim Waste Management Facility in the southwest part of WAG 6. Ammons et al. (1987) report that during clearing activities, most of the soils in trenched areas were pushed off into the drainage ways or buried under leached/unleached saprolite excavated from the waste disposal trenches. Vaughan (1982) further reports that most of the A and B horizon soils were removed in the ETF area in 1975. In these and other cases, activities at WAG 6 have altered the natural fabric, mineralogy, and distribution of soils, creating zones of variable and unpredictable permeability, both laterally and vertically.

Detailed soil mapping at WAG 6 was performed by Lietzke and Lee (1986) and Ammons et al. (1987) using eight test pits, one deep trench, and soil/saprolite cores from two HHMS-series wells. Eleven distinct soil units were identified. Figure 3A.19 depicts the distribution of the soil units and shows the locations of the test pits and trenches. These soils were developed from three major parent materials: saprolite and unweathered bedrock (soil units 2,3,4,10); colluvium or alluvium (soil units 5, 6, 7, 8, and 11) and ancient alluvium (soil unit 9). Soil taxonomy for the eleven units is summarized in Fig. 3A.19.

The descriptions of eight test pits presented in Lietzke and Lee (1986) revealed total soil thickness ranging from 1.3 to 9.8 ft; generally soil thickness was less than 3 ft. WAG 6 soil organic content is typically low (less than 4.3 percent) and decreases with depth. Where present, organic surface soil is thin (less than 1.6 in. thick).

As described in Sect. 3A.2.2.1, the C-Horizon soils at WAG 6 are typically composed of silty clay, with increasing shale content marking the transition to the underlying weathered shale saprolite (where present). The silty clay ranges from less than 1 to 13.5 ft thick.

Thin, highly acidic A- and B-horizon soils overlie the silty clay C-Horizon. The A-Horizon soil (soil exposed at ground surface) is typically a gray to yellowish-brown silt loam or shaley silt loam with less than 20 percent rock fragments. A-Horizon soil ranges from less than 1 in. to 1 ft thick (with a mean of 8.5 in.). The B-Horizon underlies the A-Horizon soil and averages 34.5 in. in thickness. It is comprised of yellowish-brown or orange-brown shaley silt loam to silty clay and clay loam, with manganese oxide nodules and coatings and an overall increase in rock fragments with depth. The pH of the B Horizon soils ranges from acidic to alkaline (pH 5 to 8). Between 50 and 100 percent of the relict bedrock structure is preserved in the B horizon (Ammons et al. 1987).

The surface water drainages in WAG 6 are believed to be gradually widening and causing parallel slope retreat. As a result, recent alluvial and colluvial soils are developing in low areas and along drainageways in WAG 6. Whereas the reddish-brown or orange color of most WAG 6 soil suggests oxidizing conditions, in the drainage areas the soils are subjected to reducing conditions caused by the fluctuating water levels, which differentially leach manganese, iron, and other ions and leave the soils a pale brown to grayish color.

In the northwest corner of WAG 6, ancient alluvial soils are evidenced by well-rounded quartzite from the distant Unaka Mountains as well as sub-rounded Knox chert fragments. These alluvial deposits indicate that, during the past, the Clinch River flowed across the site (Ammons et al. 1987; Davis et al. 1984).

The maximum depth of root penetration noted in the ETF area was 15 in. (Davis et al. 1984), but Lietzke and Lee (1986) noted fine roots as deep as 4 ft below grade in several test pit locations. Soil unit 5, which typically occurs in foot-of-slope positions, commonly has a fragipan horizon that tends to perch water above it. Flow zones associated with the fragipan layer were evident at depths of 2.3 to 3 ft in test pit V in the vicinity of the biological trenches (Lietzke and Lee 1986). Soils of this type underlie the Tumulus area and biological disposal trenches in the southern part of WAG 6. Lietzke and Lee (1986) encountered a relatively impermeable bedrock underlying soil unit 10 as observed in test pit X and suggest that at this location, water evidently flows laterally along the soil/rock interface in this area, discharging to the stream.

### 3A.2.3.2 Soil physical and chemical properties

Information regarding the physical and chemical nature of WAG 6 soils is principally provided by Ammons et al. (1987) and Davis et al. (1984). Additional soil properties information is presented in Rothschild et al. (1984a) for soils in SWSA 7. Table 3A.5 summarizes the soil properties from these sources. Data from Ammons et al. suggest the shallow soils have higher extractable iron but lower extractable manganese concentrations in comparison with the underlying saprolite. The shallow soils also are more acidic, reflecting a higher degree of soil leaching.

Clay content increases with depth in the soil horizons and clay-filled upper saprolite. Clay minerals identified by X-ray diffraction include kaolinite, illite, smectite, chlorite, and hydroxy-interlayered vermiculite. Soil bulk density generally increases with depth; porosity correspondingly decreases, in part due to clay plugging and the precipitation of manganese and iron oxides.

Bulk Kd analyses were performed on 24 Maryville soil samples collected from three 6.5-ft deep trenches within WAG 6 (Davis et al. 1984). No observable patterns or correlations were identified between Kd values and depth, soil physical properties, or each other. Further, no discernable pattern was noted relating depth to soil bulk density or porosity. CEC was high, averaging 208 meq/kg, and displayed no observable trends either laterally, vertically, or in relation to other properties. Ammons et al. noted that CEC varies between soil horizons with different clay contents. As shown in Table 3A.5, Kds reported for WAG 6 soils from the ETF area (Davis et al. 1984) are significantly higher than those reported for SWSA 7 soils (Rothschild et al. 1984a) for cesium, strontium, and cobalt. An explanation for this is not apparent. Friedman and Kelmers (1990) determined laboratory-measured Kds for soil from a shallow trench in the northern part of WAG 6 and for other WAG 6 soils sampled and described by Lietzke and Lee (1986). Their study revealed the following findings.

- Kds measured varied widely according to soil type. For instance, the Kd for cesium ranged from 151 L/kg for mixed sandstone/shaley clay to 5035 L/kg for claystone soils.
- Organics (EDTA, napthalene, toluene, chloroform, and phthalates) had no effect on the Kd for europium.

- The Kds for europium and uranium increased with increasing pH, but above pH = 5.5 the Kds for uranium began to decline.
- Although thin, WAG 6 soils have a high sorption capacity and are thus capable of retaining appreciable concentrations of cobalt, strontium, and uranium.

## 3A.3 SUMMARY OF FINDINGS REGARDING SITE GEOLOGY

The distribution and physical characteristics of the geology (soils, saprolite, and bedrock) at WAG 6 constitute the aquifer skeleton and in large part control the site's groundwater hydrology (discussed in Appendix 3B). The following brief notes summarize the discussions in previous sections to relate key findings about site geology that are fundamental to understanding groundwater hydrology and recognizing the limitations in defining groundwater flow, or that have significance with respect to the objectives of the RFI.

- **Bedrock**

— The Maryville Limestone and Nolichucky Shale bedrock underlie the north and south parts of the site, respectively. These formations were deposited in an environment whereby rapid lateral and vertical variations in lithology are common. Consequently, correlations of individual beds within these formations from well to well are enigmatic, even using borehole geophysical logs.

— Although bedrock generally strikes grid east-west and dips towards grid south (i.e., true northeast strike and southeast dip), due to local structural complexities a wide range in bedding strike and dip has been documented at WAG 6. From WAG 6 borehole televiewer logs and rock cores, it can be seen that bedrock strikes and dips change rapidly in relatively short vertical distances.

— Minor folding (i.e., kink folds) and faulting are common. Minor normal, reverse, and thrust faults are widespread. Two principal thrust faults have been identified trending roughly east-west across WAG 6. Other faults and fault splays are also possible. Faults may act as either conduits or impediments to groundwater flow (i.e. a given fault or fault zone in one location may facilitate groundwater flow and in another, impede flow). However, faults at WAG 6 are not active faults.

— Structural complexity increases from north to south across WAG 6 and is likely related to the occurrence of the two principal (as well as subsidiary) thrust faults.

— Little or no primary porosity exists in the bedrock. However, fractures are widespread. At least two but as many as five distinct fracture sets may be encountered at a given location at WAG 6. Principal fracture orientations include strike parallel and bedding plane parallel fractures (generally trending ORNL grid east-west) and a high angle fracture set oriented perpendicular to bedding.

— Most fractures are short (less than 3 ft long) but interconnected so as to form a tortuous network (i.e., stair-stepping pattern in three dimensions) for groundwater flow.

— Open fracture density decreases with depth.

— Depth to bedrock varies with topography, ranging from 2.5 to 51 ft below land surface. Along the perimeter of WAG 6, the depth to bedrock was found to be: 20-25 ft below grade along the northern WAG boundary; an average 10 ft below grade along the eastern perimeter (ranging from 2.5-21 ft); and greater than 23 ft along the southern boundary adjacent to WOL.

- **Saprolite**

— Saprolite overlies bedrock throughout the site and is formed in situ from weathering of underlying bedrock.

— Saprolite thickness varies across the site with degree and depth of weathering, but is generally thicker on hilltops.

— Relict bedrock structural fabric is preserved, and in some cases (owing to movement of fluids through the saprolite), porosity associated with structural features is either enhanced or occluded.

— Weathering has further resulted in dissolution of calcium carbonate cements such that the saprolite shows considerably more matrix porosity than underlying unweathered bedrock.

- **Soils**

— Eleven different soil units have been delineated at WAG 6.

— WAG 6 soils are typically thin, acidic, and in many areas have been removed, reworked, or otherwise altered during site operations, creating discontinuous zones of variable and somewhat unpredictable permeability both laterally and vertically.

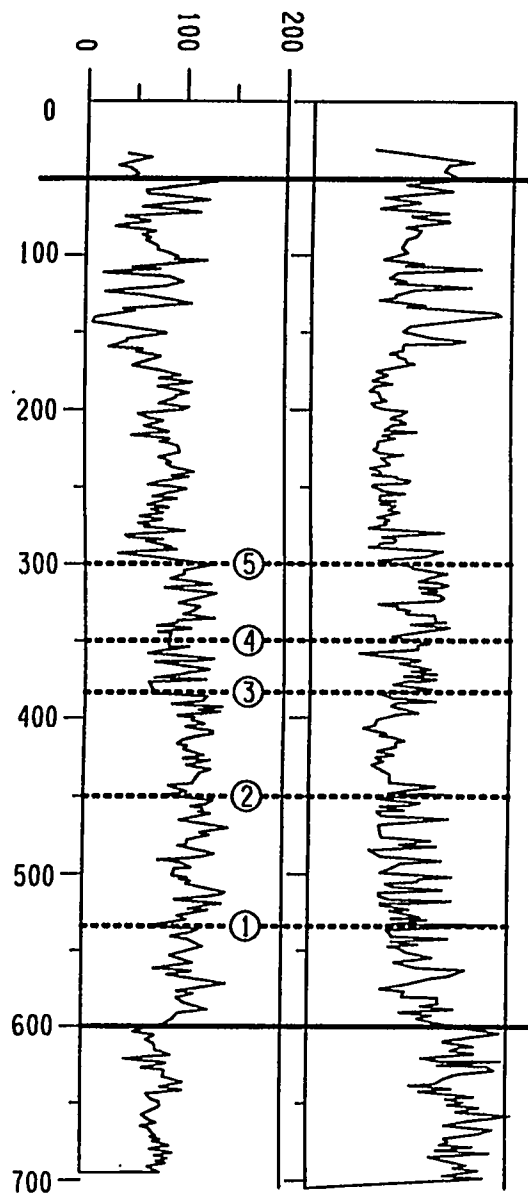
— Although thin and variable, WAG 6 soils have high sorptive capacities for retaining cobalt, strontium, and uranium.

- **Overall**

— The overall geology of the site is highly complex, being a product of original depositional patterns in the bedrock, severe and variable structural deformation, degree and extent of weathering, and anthropogenic processes. Consequently, there is considerable uncertainty in determining hydrogeologic processes on a local scale, such as assessing flowpaths from a particular source to a well or between wells.

# Appendix 3A Tables

Composite Log*

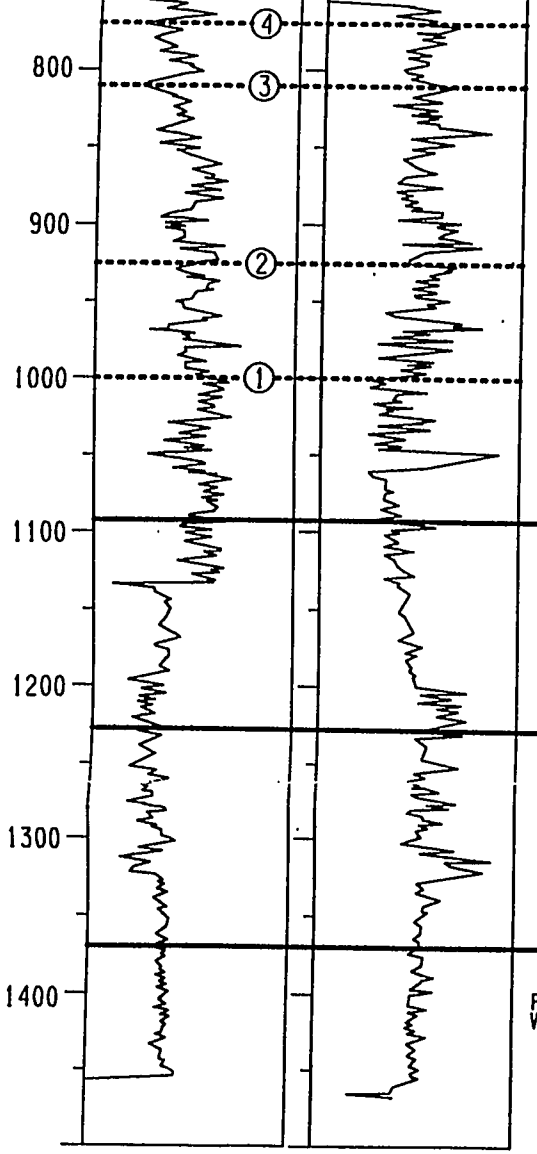



## TABLE 3A-1
## GENERALIZED STRATIGRAPHY OF THE CONASAUGA GROUP

| Formation | Member | Approximate WAG 6 Member Thickness (a) (ft) | Lithologic Description |
|---|---|---|---|
| Maynardville Limestone (Cmy) | Chances Branch | Not Present | Medium to thin-bedded buff and light gray dolostones, ribbon-bedded dolomitic calcarenites, wackstones, and micrites, and medium gray oolitic packstones and grainstones. |
| Nolichucky Shale (Cnl) | Low Hollow | 180 | Wavy to evenly ribbon-bedded calcarenite and micrite alternating with oolitic packstones and grainstones. |
| | Upper Shale | 62 | Interstratified calcareous mudstones and limestones. The medium dark gray to grayish black, locally brownish black mudstones are wavy to evenly stratified and thickly laminated. The light gray limestones are wavy ribbon-bedded to laminated micrites, oolitic fossiliferous wackstones, and packstones. |
| | Bradley Creek | 29 | Predominantly lenticularly to irregularly stratified, light to dark gray algal wackstones and packstones. |
| | Lower Shale | 459 | Numerous repeated cycles of limestone, calcareous mudstone, and shale. The red-brown to maroon or red-gray mudstones are silty calcarenites, oolitic packstones, fossiliferous pelloidal wackstones, and intraclastic packstones and conglomerates. Bedding in the carbonates varies from parallel to wavy to lenticular. |
| | Upper(b) | 246 | Flat-pebble conglomerates interbedded with gray calcareous mudstones, wavy to lenticularly bedded modular micrite and dolomitic wackstones, wavy to lenticularly bedded calcarenite, and fossiliferous pelloidal packstone. |

*NOTE: BREAK IN SECTION; LOG DATA NOT AVAILABLE

WAG 6 06F311.DGN




| | | | |
|---|---|---|---|
| Maryville Limestone (Cmr) | Lower | 213 | Calcareous mudstone interbedded with wackstones, packstones, calcarenites and calcareous siltstones. Carbonate lithologies tend to be critical. Mudstones are thickly to thinly bedded; packstones are massive to thinly bedded. |
| Rogersville Shale (Crg) | | 131 | Massive to laminated calcareous and noncalcareous mudstones and evenly bedded to wavy current-rippled calcarenites and subarkosic siltstones. Mudstones range from red-brown to gray and gray-green. An upper member--Craig--is the limestone-rich interval in the upper portion of this formation. |
| Rutledge Limestone (Crt) | | 102 | Upper and lower separated by a clastic-rich interval. Upper limestones consist of micrites, locally fossilliferous pelloidal wackstones and packstones, and silty calcarenites that are thinly bedded with highly variable stratification patterns. The middle interval consists of red-brown, red-gray, and grey mudstones and shales with interbedded laminae and lenses of subarkosic siltstone. The lowermost limestones are lenticularly bedded to mottled and bioturbated gray to gray-green wackstones and calcarenites interbedded with shales and mudstones. |
| Pumpkin Valley Shale (Cpv) | Upper | 157 | Red-brown, red-gray, and gray mudstones and shales interbedded with subarkosic siltstones. The mudstones are massive to thinly bedded and evenly to wavy parallel stratified. Siltstones exhibit complex stratification that range from thinly laminated to thinly bedded with wavy to evenly parallel to nonparallel stratification. Glauconite pellets are commonly interbedded or found within other beds. |

*COMPOSITE LOG CONSTRUCTED USING, IN DESCENDING ORDER, HHMS-11, -6, -4, -7, -10, -9 LOGS.

(a) Approximate on-site thickness derived from JOY-2 corehole.
(b) Informal, site-specific division into Upper and Lower Members.

①–MARYVILLE LIMESTONE AND NOLICHUCKY SHALE INTERNAL STRATIGRAPHIC MARKERS AS PER DREIER & TORAN, 1989.

Source: Haase, Walls, and Farmer (1985); Dreier & Toran (1989)

**Table 3A.1. Generalized stratigraphy of the Conasauga Group.**

Table 3A.2. Typical Maryville Limestone physical properties with depth[a]

| Depth (ft) | pH | $CaCO_3$(%) | Sand[b]% | Silt[b]% | Clay[b]% | Bulk density (g/cc) |
|---|---|---|---|---|---|---|
| 5 | 5.4 | 0.2 | 63 | 18 | 19 | 2.61 |
| 10 | 7.7 | 6.4 | 68 | 21 | 12 | 2.61 |
| 15 | 7.7 | 18.2 | 74 | 13 | 12 | 2.61 |
| 20 | 7.7 | 27.9 | 72 | 16 | 12 | 2.61 |
| 25 | 7.6 | 21.9 | 66 | 16 | 18 | 2.63 |
| 30 | 7.7 | 5.4 | 59 | 21 | 19 | 2.64 |
| 35 | 7.6 | 27.2 | 67 | 19 | 14 | 2.63 |
| 40 | 7.3 | 25.8 | 66 | 19 | 15 | 2.63 |
| 45 | 7.4 | 18.9 | 67 | 15 | 18 | 2.64 |
| 50 | 7.4 | 16.7 | 73 | 14 | 12 | 2.64 |
| 55 | 7.6 | 10.6 | 77 | 12 | 10 | 2.63 |
| 60 | 7.6 | 7.3 | 75 | 14 | 11 | 2.63 |
| 65 | 7.8 | 6.7 | 79 | 13 | 8 | 2.63 |
| 70 | 7.8 | 9.1 | 80 | 10 | 10 | 2.63 |
| 75 | 7.8 | 18.9 | 81 | 11 | 8 | 2.62 |
| 80 | 7.9 | 26.8 | 82 | 11 | 7 | 2.63 |
| 85 | 7.8 | 26.2 | 82 | 10 | 8 | 2.63 |
| 90 | 7.8 | 26.2 | 86 | 7 | 7 | 2.63 |
| 95 | 8.0 | 22.3 | 90 | 5 | 5 | 2.57 |
| 100 | 7.7 | 26.0 | 82 | 11 | 7 | 2.62 |
| 105 | 7.9 | 11.7 | 82 | 11 | 7 | 2.63 |
| 110 | 7.7 | 21.0 | 87 | 6 | 7 | 2.64 |
| 115 | 7.9 | 10.9 | 80 | 12 | 7 | 2.64 |
| MEAN | 7.6 | 17.1 | 76 | 13 | 11 | 2.63 |

[a]From analysis of cuttings from the 115 deep corehole #10 at SWSA 7 (Rothschild et al. 1984b; Davis et al. 1984).
[b]Based upon sieve analysis of < 2 mm fraction.

Table 3A.3. Bedrock physical and chemical properties

| | | Units | Maryville Limestone[a] | Nolichucky Shale[b] |
|---|---|---|---|---|
| Kds | $Am^{241}$ | L/kg | 27600 | 28400 |
| | $Sr^{85}$ | L/kg | 63.1 | 38 |
| | $Cs^{134}$ | L/kg | 27400 | 26200 |
| | $Co^{58}$ | L/kg | 2720 | 2197 |
| | $I^{125}$ | L/kg | 9.4 | 12.5 |
| | Ca+Mg | L/kg | 56 | 40.8 |
| Exchangeable Ca | | meq/kg | 113 | 119 |
| Exchangeable Mg | | meq/kg | 19.1 | 22 |
| Exchangeable Na | | meq/kg | 0.3 | 0.4 |
| Exchangeable Acidity | | meq/kg | 16.0 | 11.0 |
| CEC | | meq/kg | 149 | 154 |
| pH | | -log[$H^+$] | 7.6 | 7.7 |
| Bulk Density | | g/cc | 2.63 | NA |
| Total Porosity[c] | | % | 1.8 | NA |

[a]Mean of 23 Maryville rock cutting samples (<2mm) from the 115-ft deep Well No. 10 in SWSA 7 (Davis et al. 1984)
[b]Mean of 3 Nolichucky rock cuttings samples from the 25-ft deep Well No. 13 at SWSA 7 (Rothschild et al. 1984b)
[c]Mean total porosity calculated, where: total porosity = ((1-(bulk density/2.68) x 100)
NA - Not Analyzed

Table 3A.4. Saprolite physical and chemical properties

| | | | WAG 6 | | SWSA 7 |
|---|---|---|---|---|---|
| | | Units | Maryville LS[a] | Nolichucky SH[b] | Maryville LS[c] |
| Kds | $Am^{241}$ | L/kg | NA | NA | 20398 |
| | $Sr^{85}$ | L/kg | NA | NA | 202 |
| | $Cs^{134}$ | L/kg | NA | NA | 49766 |
| | $Co^{58}$ | L/kg | NA | NA | 2381 |
| | $I^{125}$ | L/kg | NA | NA | 16.8 |
| | Ca+Mg | L/kg | NA | NA | 117 |
| Exchangeable Ca | | meq/kg | 3.8 | 11.5 | 93.4 |
| Exchangeable Mg | | meq/kg | 11.7 | 50 | 59.9 |
| Exchangeable Na | | meq/kg | 2.9 | 1.2 | 2.5 |
| Exchangeable Acidity | | meq/kg | 63.1 | 33.5 | 52.3 |
| CEC | | meq/kg | 81.5 | 96.2 | 208 |
| pH | | -log[$H^+$] | 5.1 | 6.1 | 6.8 |
| $CaCO_3$ | | % | NA | NA | 2.97 |
| Extractable Fe[d] | | mg/kg | 257.2 | 331 | 282 |
| Extractable Mn[d] | | mg/kg | 1092 | 2842 | 623 |
| Organic Matter | | % | 0.12 | 0.38 | NA |
| Sand Fraction | | % | 31 | 32 | 366 |
| Silt Fraction | | % | 32 | 28 | 22 |
| Clay Fraction | | % | 37 | 40 | 42 |
| Bulk Density | | g/cc | 1.59 | NA | NA |
| Total Porosity[e] | | % | 40.7 | NA | NA |

[a]Mean of 16 C & Cr-horizon saprolite samples from three soil pits (I, III, and IV of Lietzke & Lee) in WAG 6 (Ammons et al. 1987).
[b]Mean of five C & Cr-horizon saprolite samples from test pit X in WAG 6, (Ammons et al. 1987).
[c]Mean of 12 Maryville saprolite samples from four 25-ft deep boreholes at SWSA 7 (Rothschild et. al, 1984a).
[d]Sodium dithionite extractable (CBD).
[e]Total porosity calculated, where: total porosity = ((1-(bulk density/2.68) x 100)).

NA - Not Analyzed.
LS - Limestone.
SH - Shale.

Table 3A.5. Soil physical and chemical properties

| | | WAG 6 | | | SWSA 7 | |
|---|---|---|---|---|---|---|
| | Units | Maryville Soils[a] | Maryville Soils[b] | Nolichucky Soils[c] | Maryville Soils[d] | Nolichucky Soils[e] |
| Kds $Am^{241}$ | L/kg | 5670 | NA | NA | 1213 | 2500 |
| Kds $Sr^{85}$ | L/kg | 494* | NA | NA | 144 | 50.4 |
| Kds $Cs^{134}$ | L/kg | 64100* | NA | NA | 561 | 949 |
| Kds $Co^{58}$ | L/kg | 782* | NA | NA | 80.7 | 84.5 |
| Kds $I^{125}$ | L/kg | 11.7 | NA | NA | 16.1 | 4.0 |
| Kds Ca+Mg | L/kg | NA | NA | NA | 112 | 35.4 |
| Exchangeable Ca | meq/kg | 20 | 59.7 | 14.7 | 42 | 17.5 |
| Exchangeable Mg | meq/kg | 31 | 5.2 | 7.4 | 19 | 5.2 |
| Exchangeable Na | meq/kg | 1 | 0.5 | 0 | 0.1 | 0 |
| Exchangeable Acidity | meq/kg | 154 | 37.6 | 37 | 116 | 92 |
| CEC | meq/kg | 210 | 103 | 86.5 | 177 | 115 |
| Extractable Fe[f] | mg/kg | NA | 2065 | 2414 | NA | NA |
| Extractable Mn[f] | mg/kg | NA | 434 | 412 | NA | NA |
| pH | -log[$H^-$] | 4.4 | 5.6 | 4.9 | 4.9 | 5.3 |
| Organic Matter | % | 0.37 | 1.58 | 0.57 | 3.17 | 4.24 |
| Sand Fraction | % | 36 | 21 | 19 | 40 | 24 |
| Silt Fraction | % | 22 | 53 | 52 | 31 | 23 |
| Clay Fraction | % | 42 | 26 | 29 | 29 | 53 |
| Bulk Density | g/cc | 1.34 | 1.45 | 1.44 | NA | NA |
| Total Porosity[g] | % | 50 | 45.9 | 46.2 | NA | NA |

[a]Mean of 24 [Maryville material] soil samples from three 6.7-ft deep trenches (334, 338, 342) in SWSA 6 (Davis et al. 1984).
[b]Mean of 7 [Maryville material] A & B horizon soil samples from three soil pits (Pits I, III, and IV of Lietzke and Lee, 1986) in SWSA 6 (Ammons et al. 1987).
[c]Mean of 7 [Nolichucky and ancient alluvium material] A & B horizon soil samples from two soil pits (Pits IX and X of Leitzke and Lee, 1986) in SWSA 6 (Ammons et al. 1987).
[d]Mean of 12 B horizon soil samples reported from SWSA 7 (Rothschild et al. 1984a).
[e]Mean of 2 B horizon soil samples reported from SWSA 7 (Rothschild et al. 1984a).
[f]Sodium dithionite extractable (CBD).
[g]Mean total porosity calculated where Total Porosity = ((1-(bulk density/2.68) x 100)).

NA - Not Analyzed.
* - Davis et al. (1984) Kds reported for Cs-137, Co-60, and Sr-90.

# Appendix 3A Figures

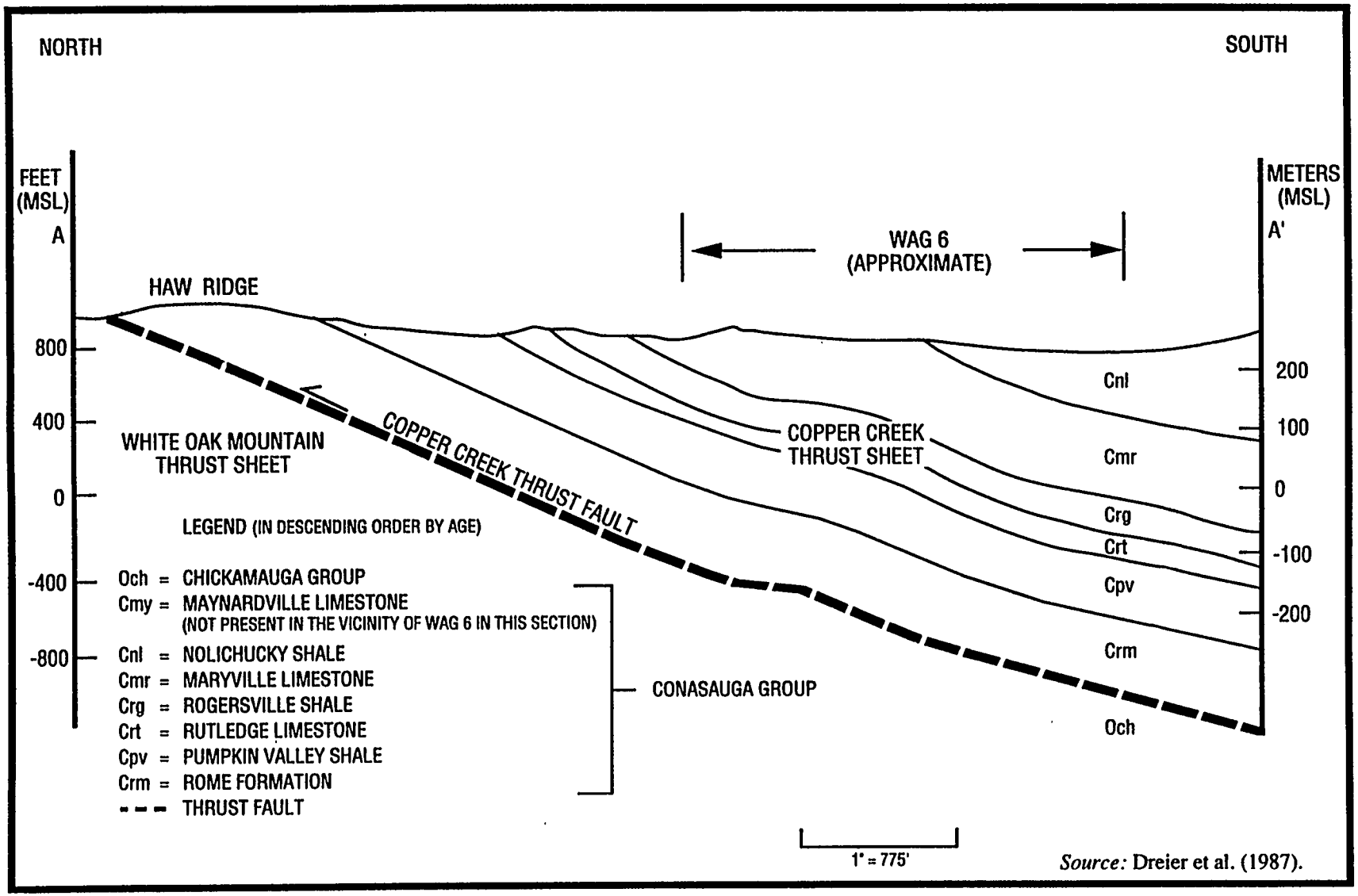
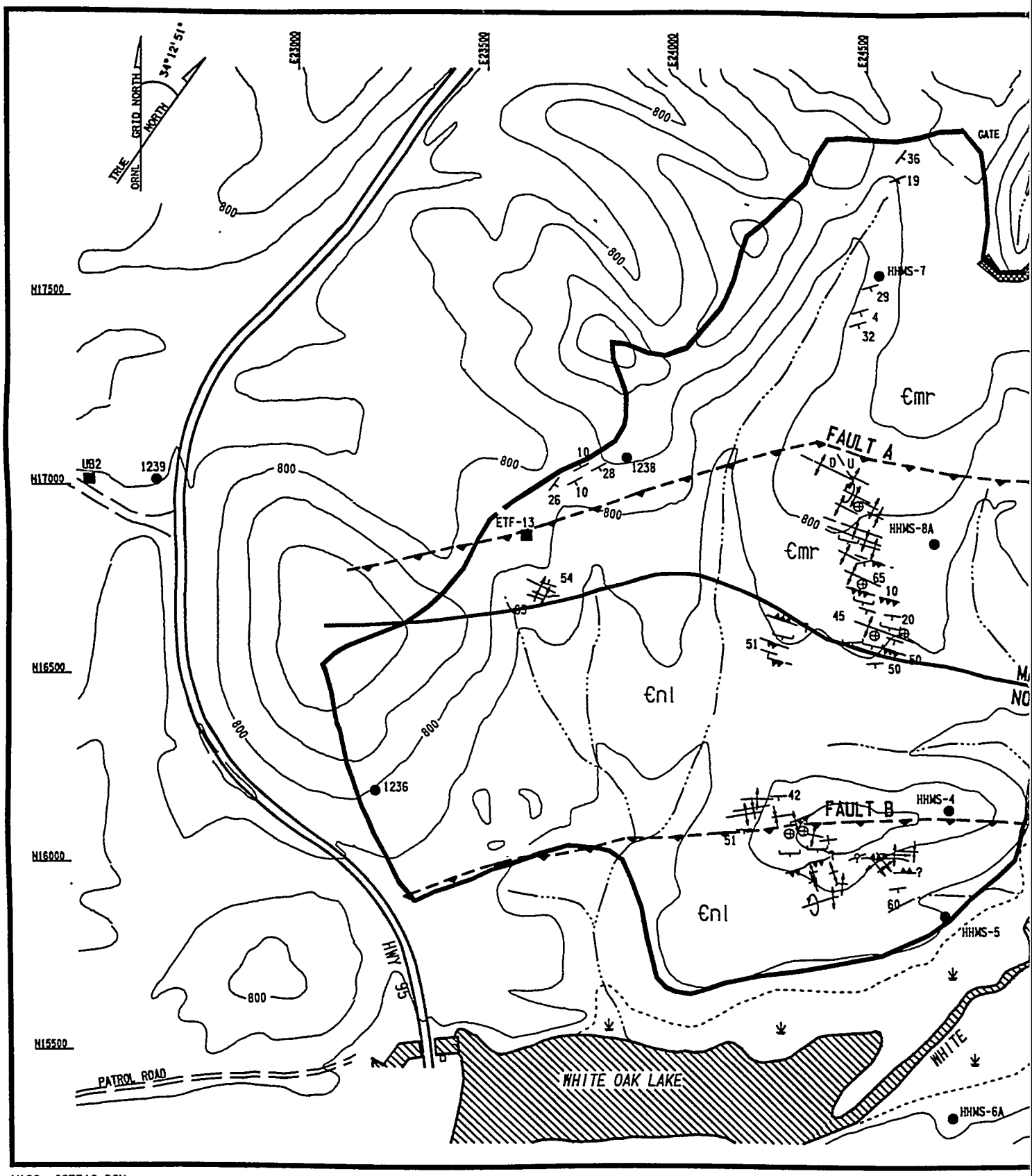



**Fig. 3A.1. WAG 6 regional structural setting.**

5.18 4104.4

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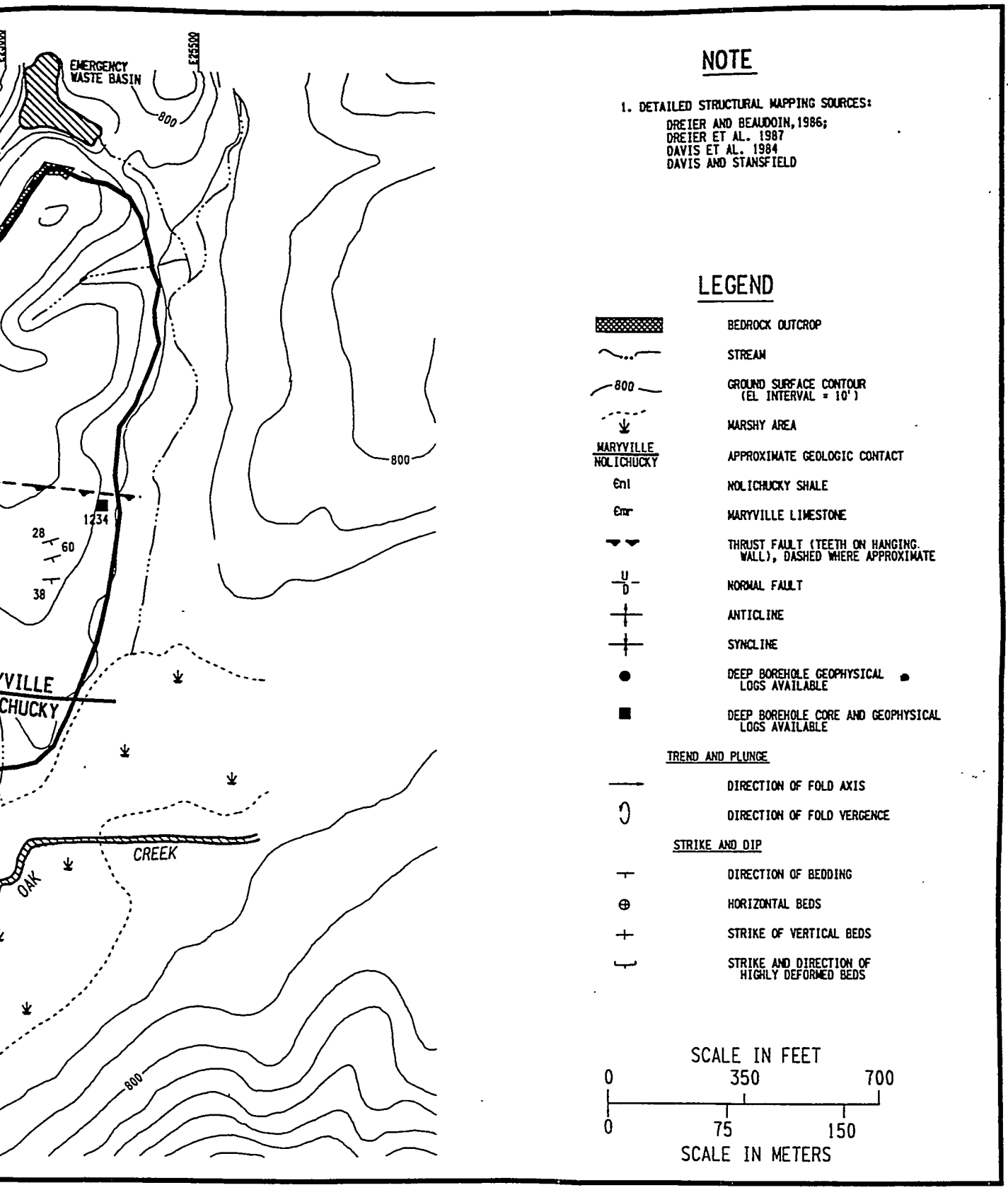
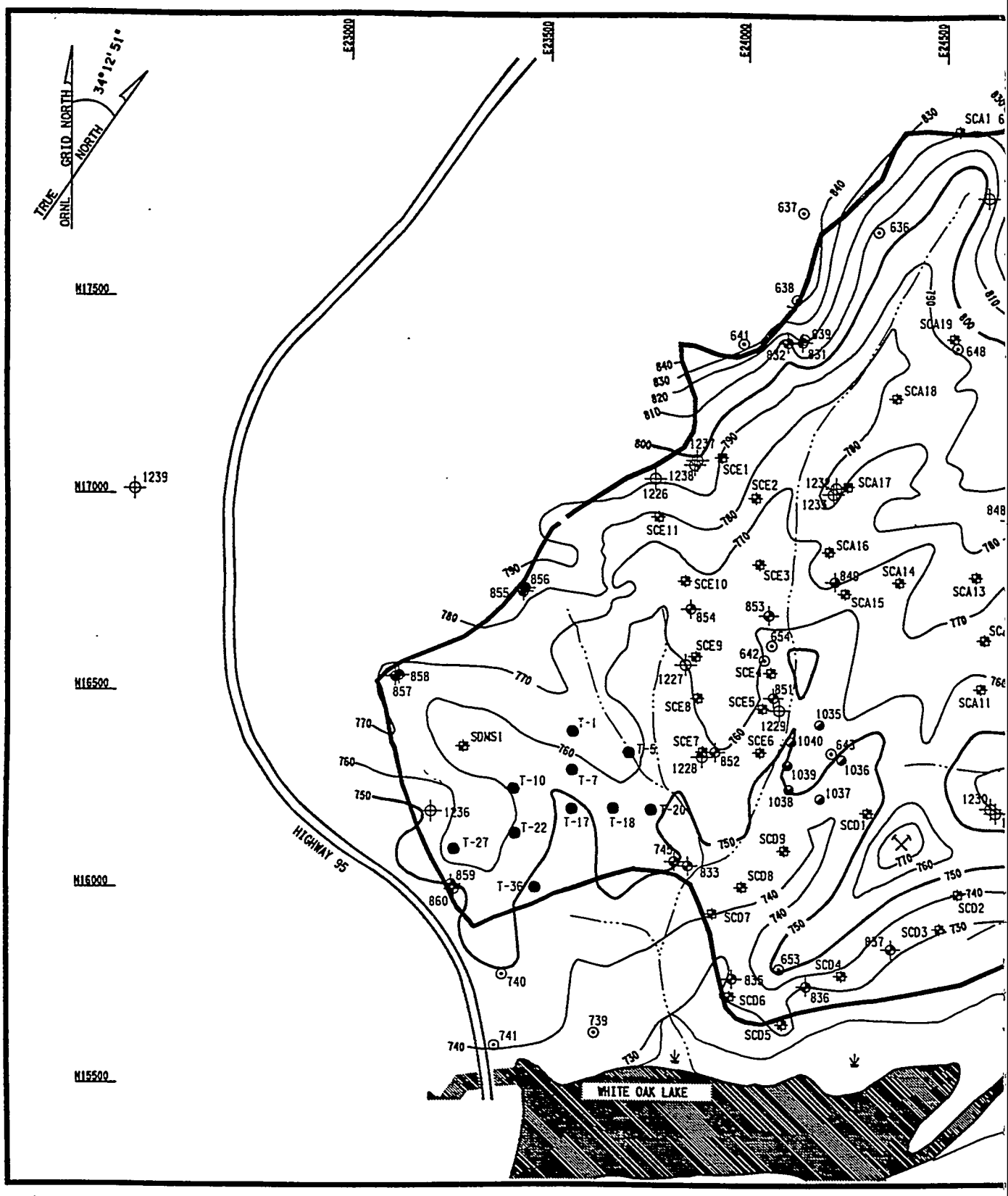



**Fig. 3A.2. Geologic map of WAG 6.**

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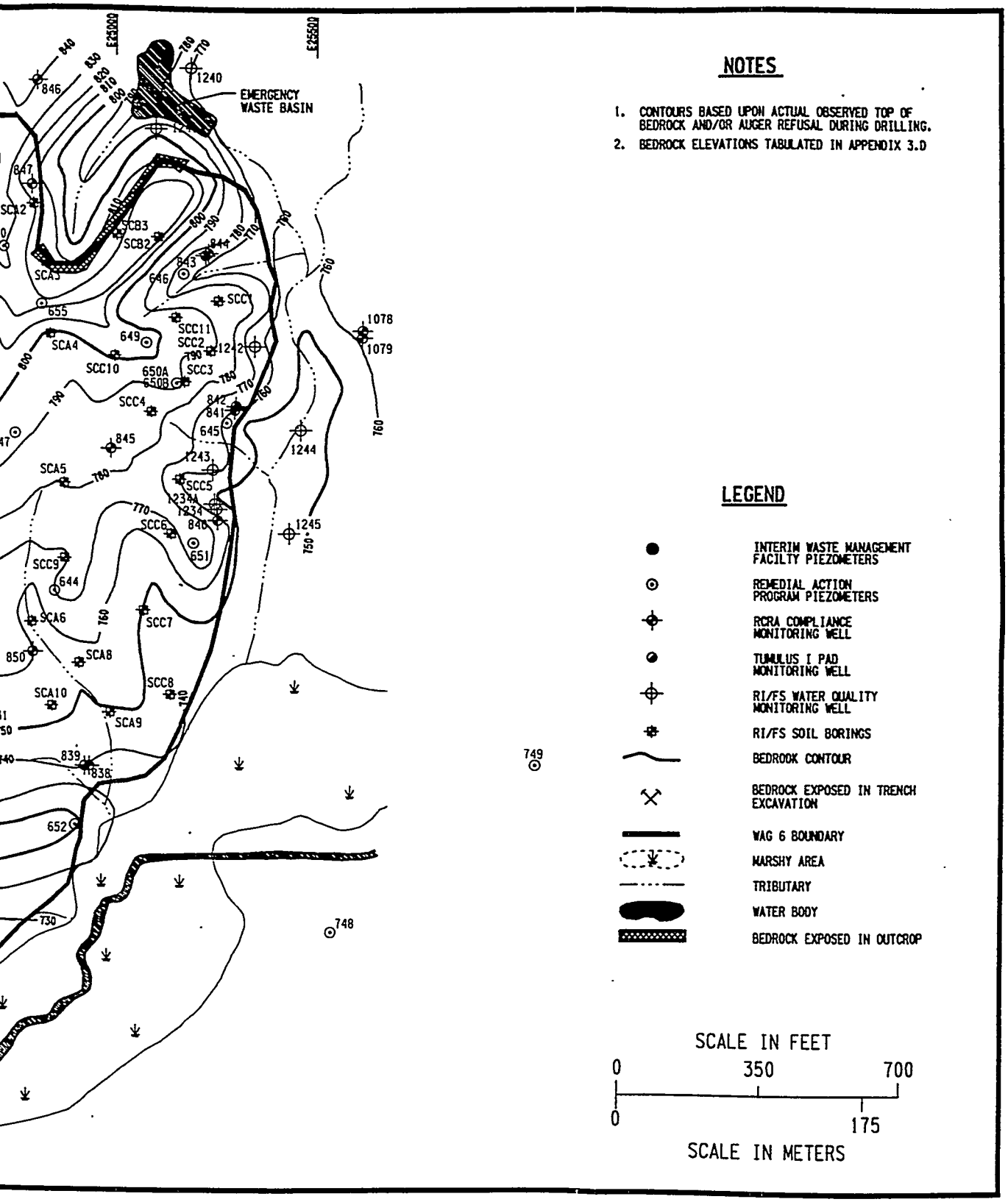
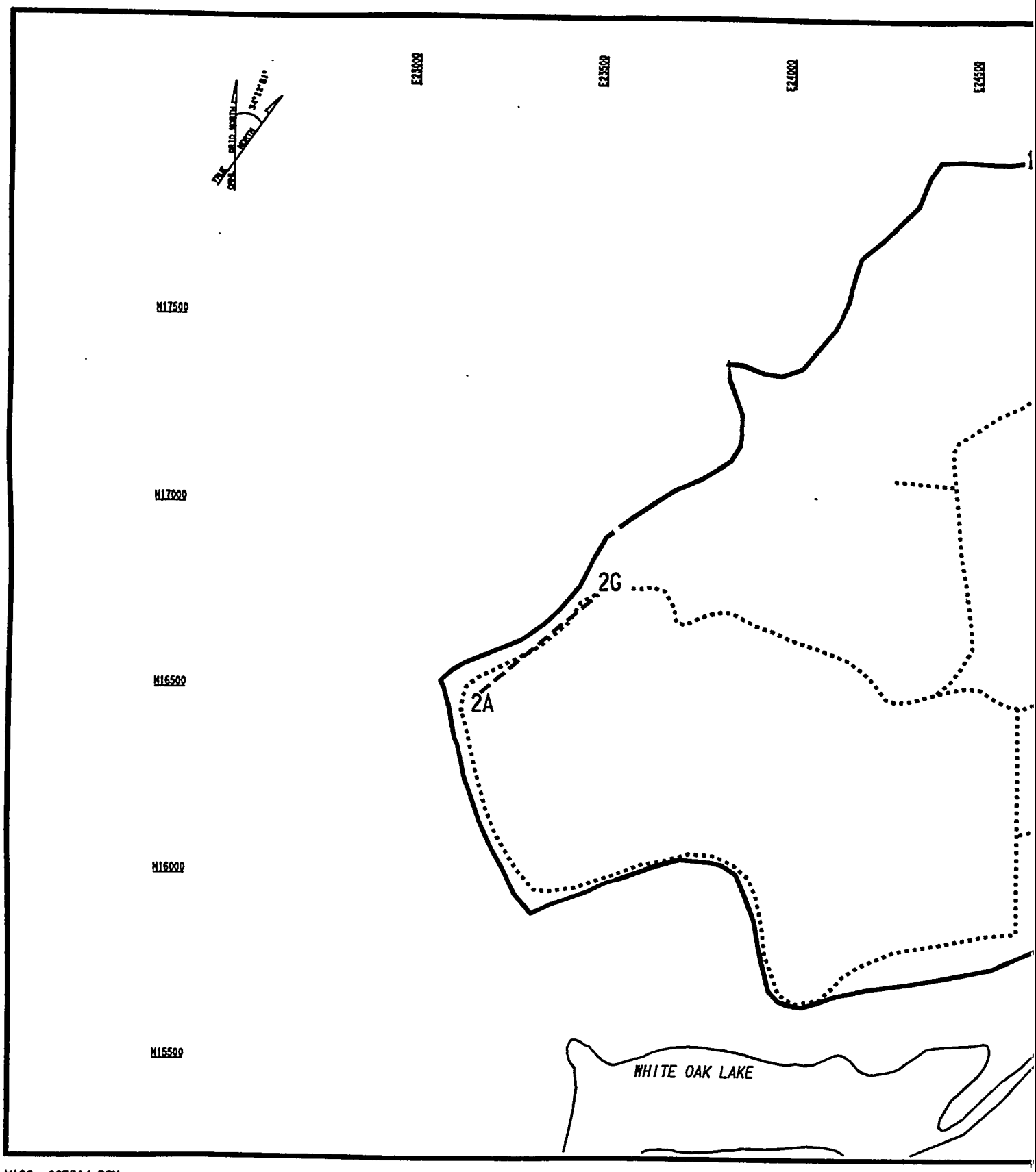



Fig. 3A.3. WAG 6 bedrock elevation contour map.

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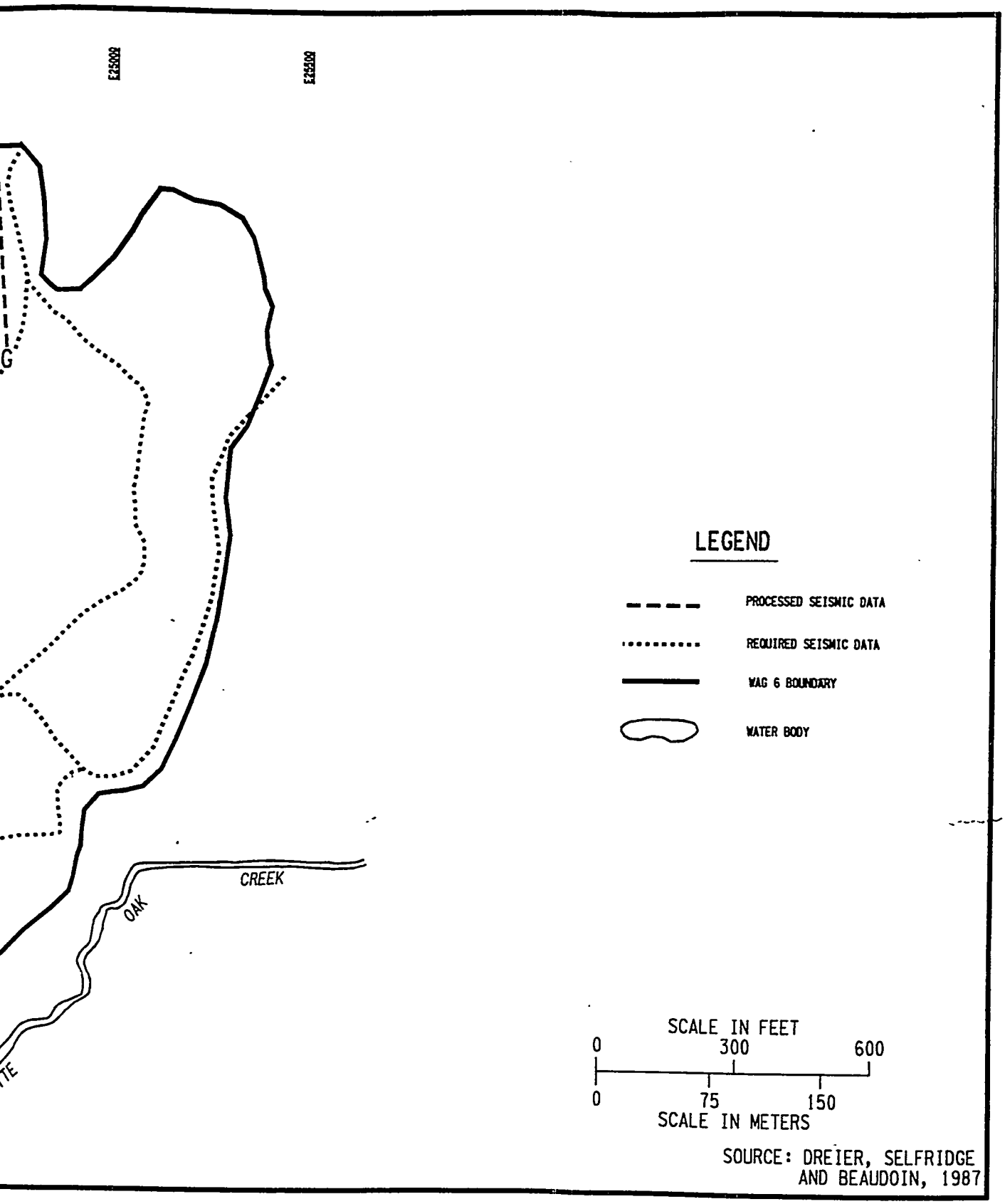
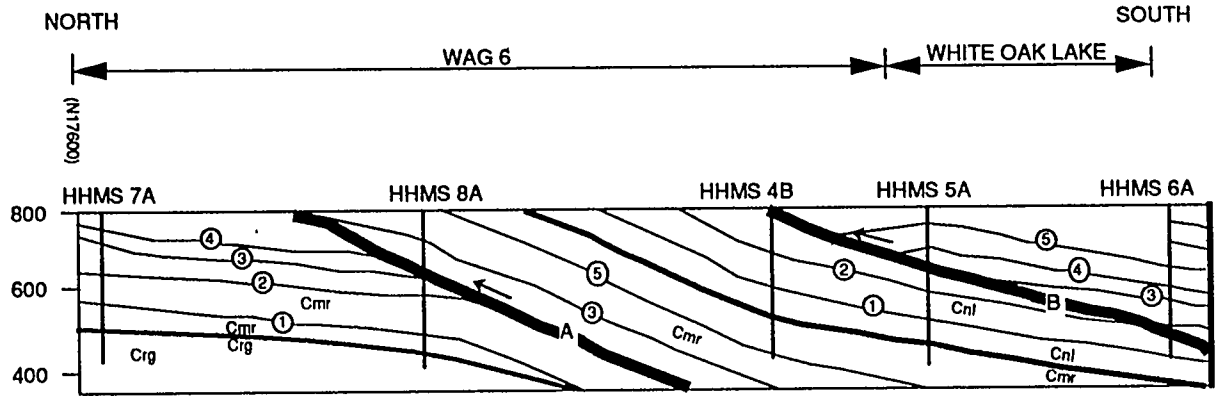



**Fig. 3A.4. ORNL refraction seismic transects at WAG 6.**




NOTES

1. STRIKE-PERPENDICULAR GEOLOGIC CROSS SECTION THROUGH SWSA 6 AND WHITE OAK LAKE.

2. STRATIGRAPHIC AND STRUCTURAL DATA FROM HHMS A BOREHOLES FROM SITE 4 THROUGH 8, WOL-1, ARE PROJECTED ALONG A GRID-EAST DIRECTION TO THE LINE OF SECTION.

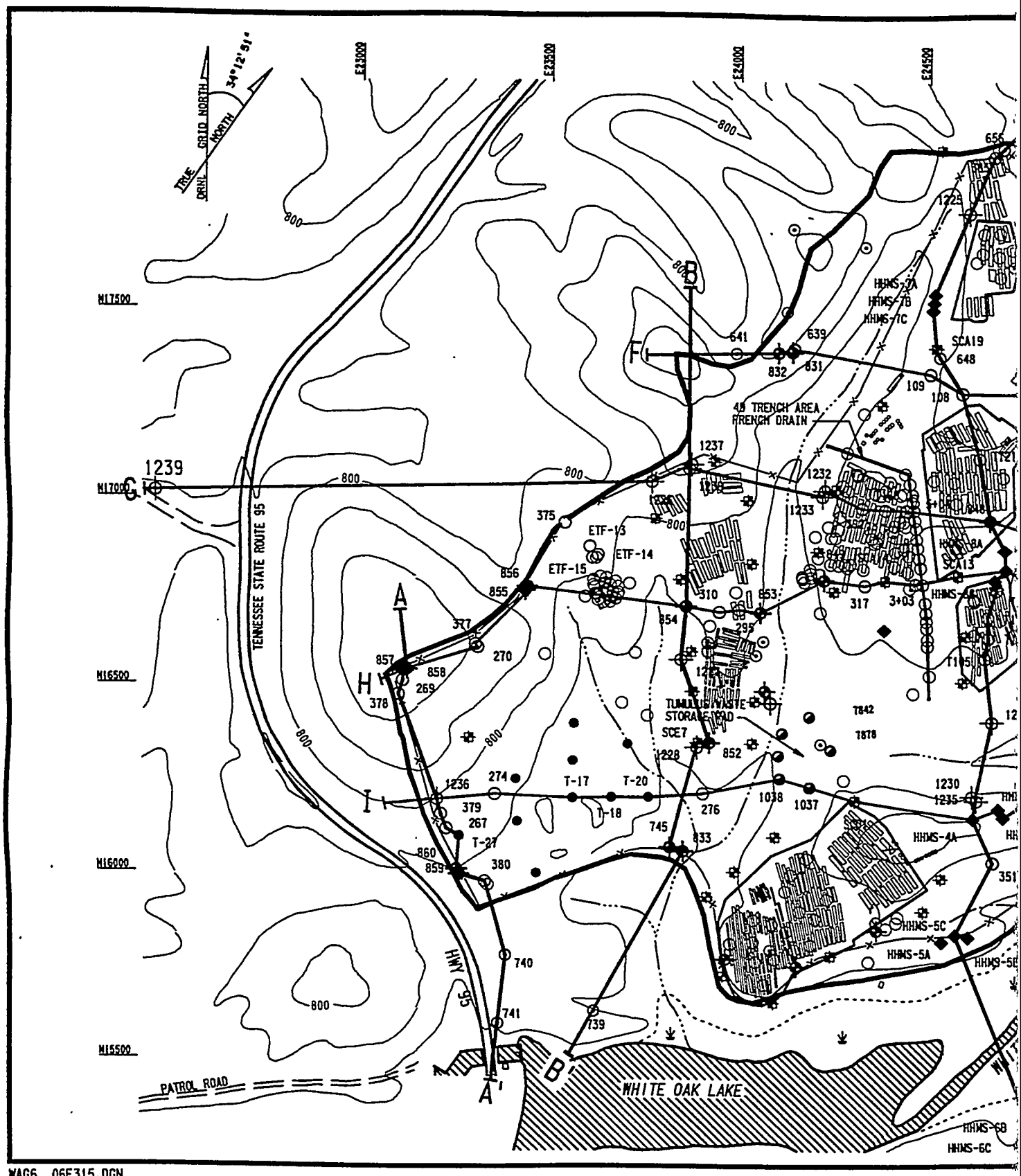
LEGEND

| | |
|---|---|
| Cnl | NOLICHUCKEY SHALE |
| Cmr | MARYVILLE LIMESTONE |
| Crg | ROGERSVILLE SHALE |
| —①— | INTERNAL MARYVILLE AND NOLICHUCKEY STRATIGRAPHIC MARKER HORIZONS |
| ▬ | THRUST FAULTS |
| Cmr / Crg | FORMATION CONTACT |

*SOURCE:* DREIER & TORAN (1989)

**Fig. 3A.5. WAG 6 north-south deep well structural cross section.**

5.18E 4104.141
Adapted from WAG 6 06F137.DGN




WAG6 06F315.DGN

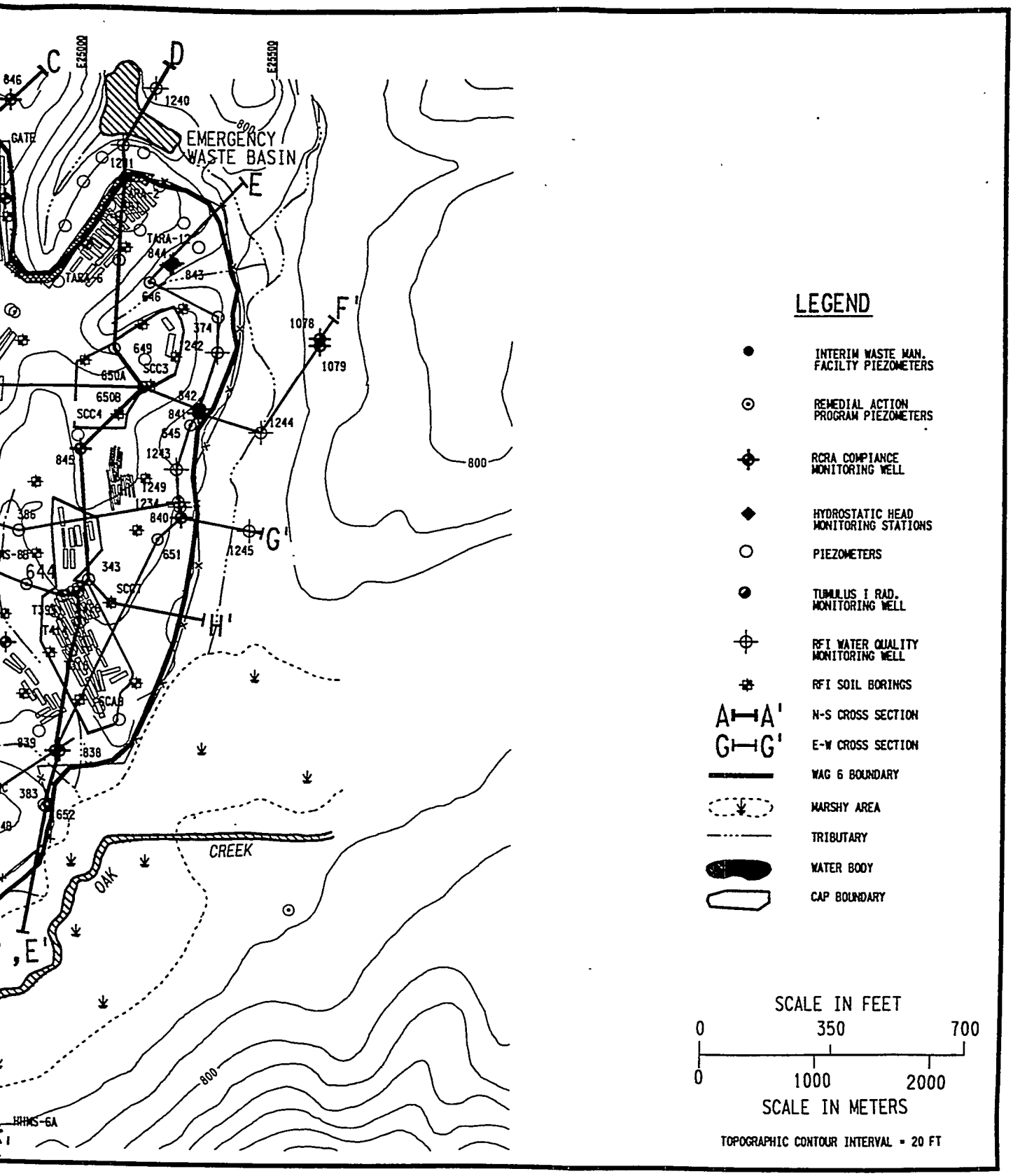
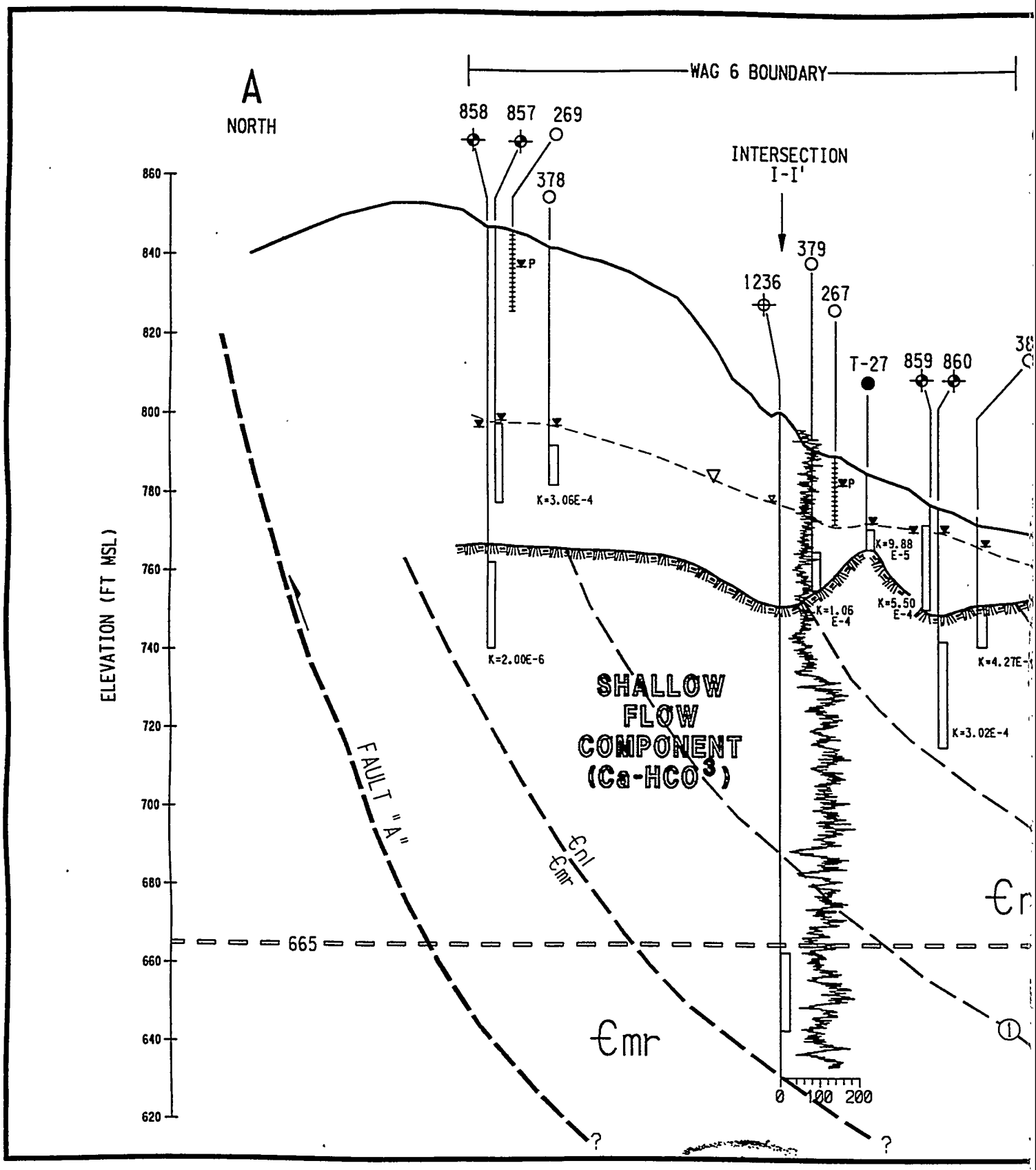



**Fig. 3A.6. WAG 6 hydrogeologic cross section location map.**




WAG6 06F134.DGN VI=STRUC

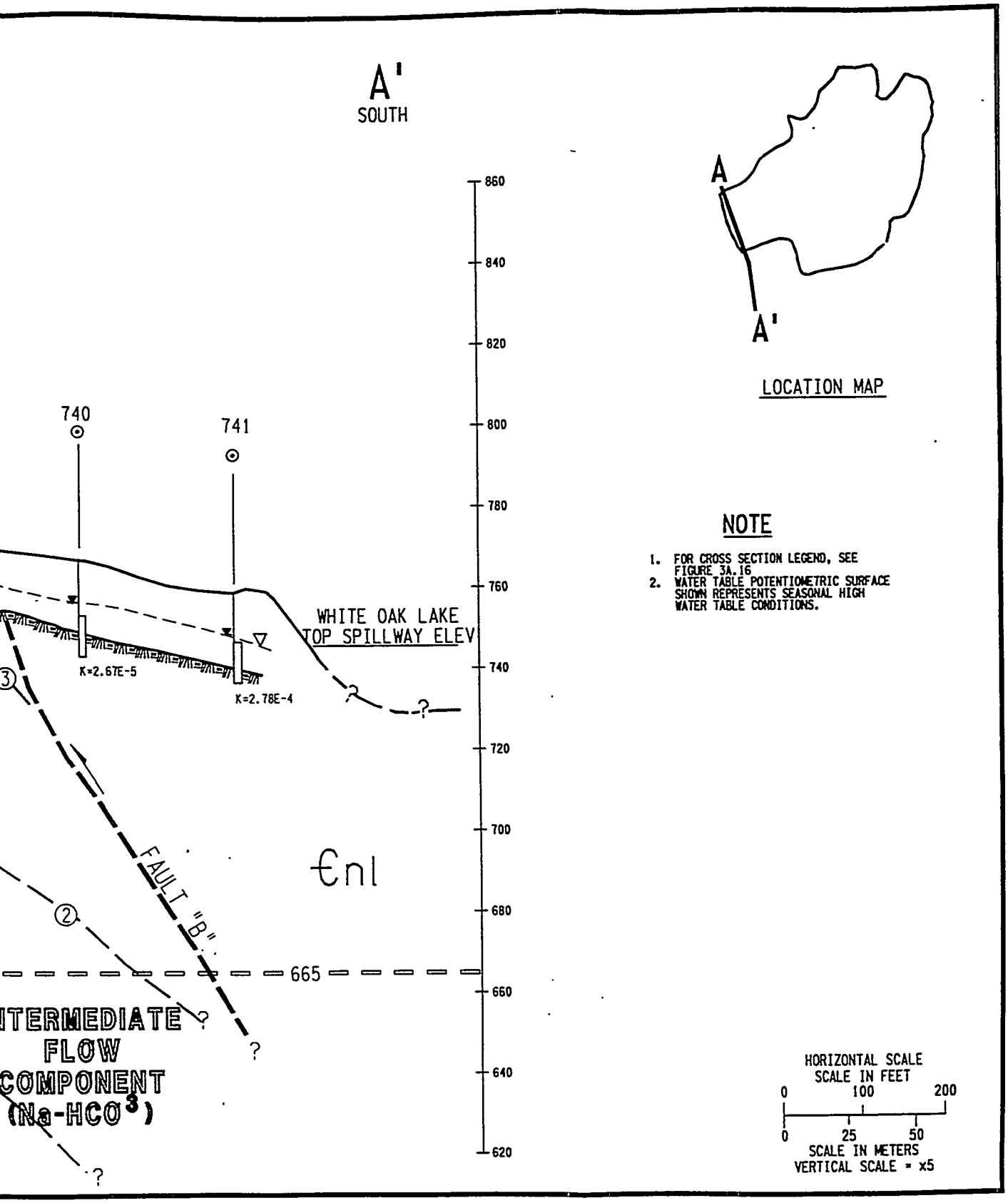
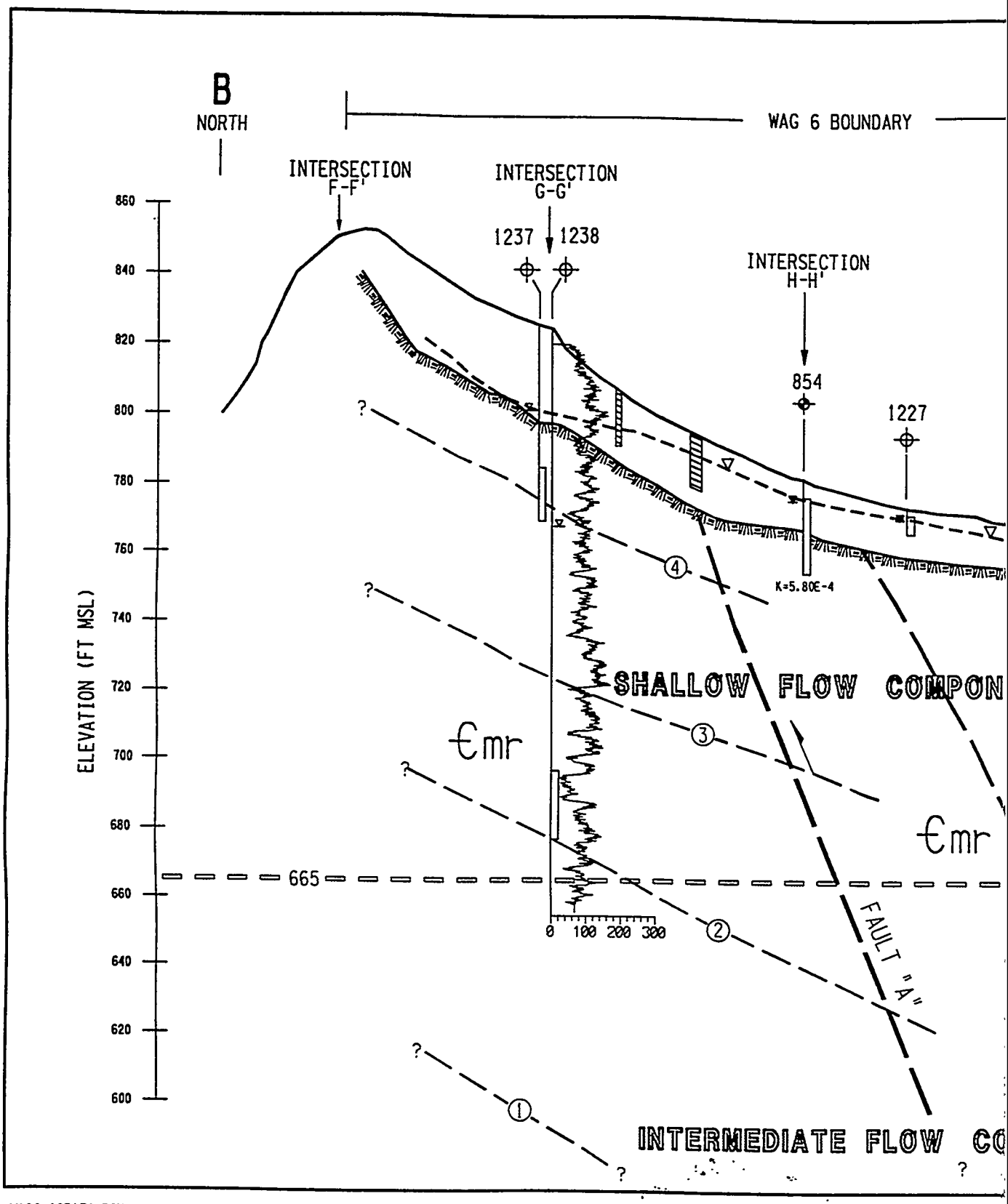



**Fig. 3A.7. WAG 6 hydrogeologic cross section A-A'.**

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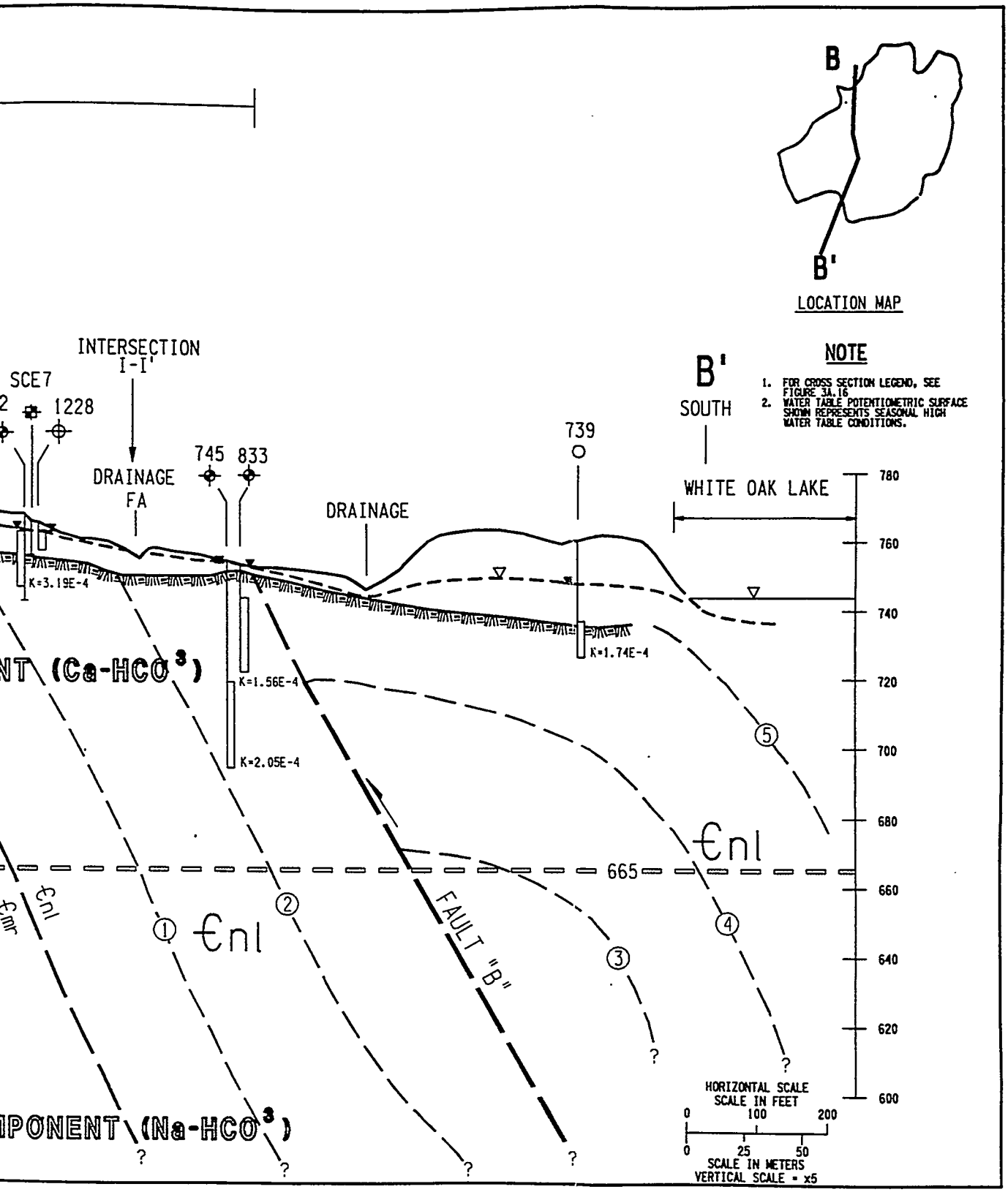
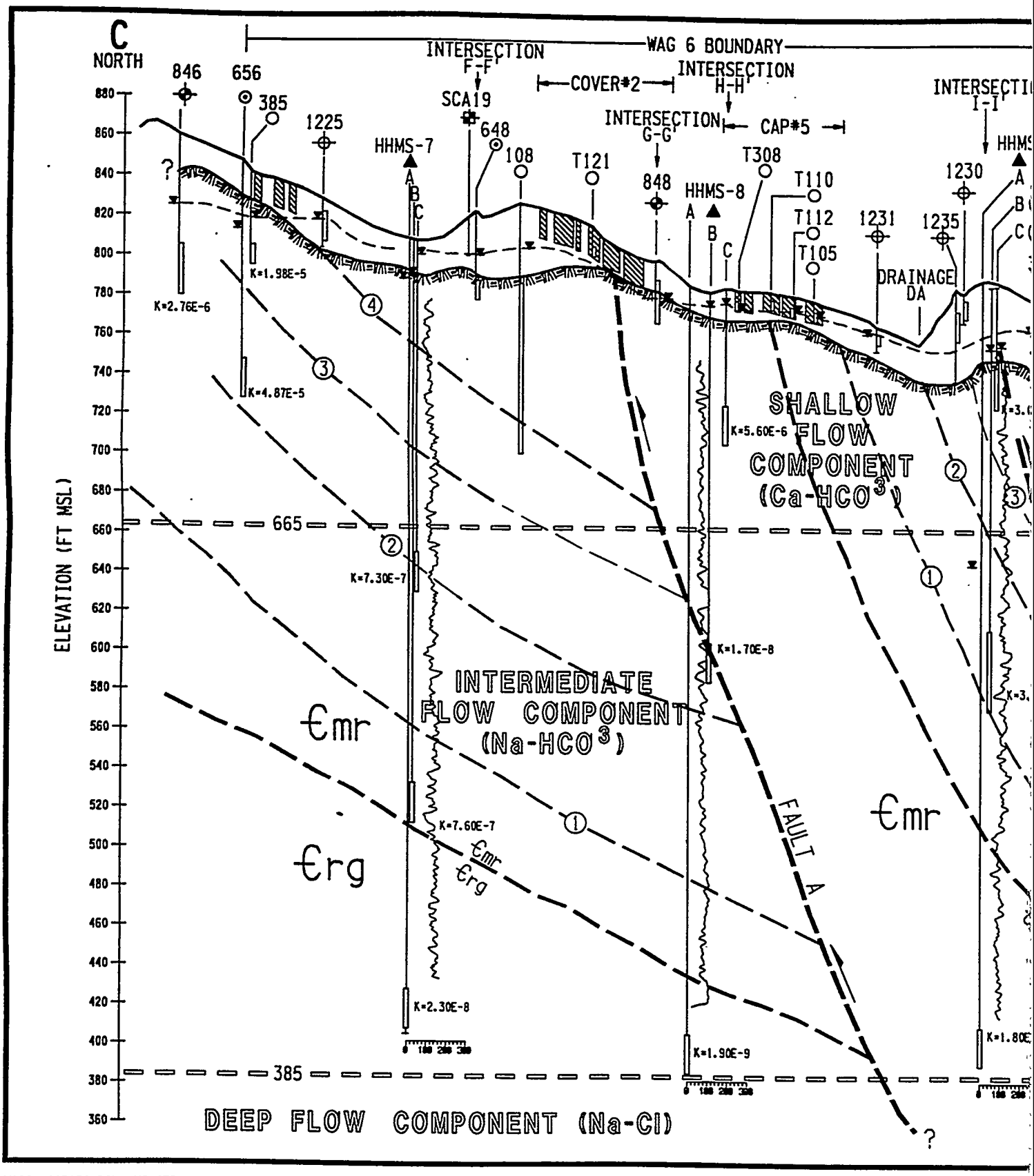



**Fig. 3A.8. WAG 6 hydrogeologic cross section B-B'.**

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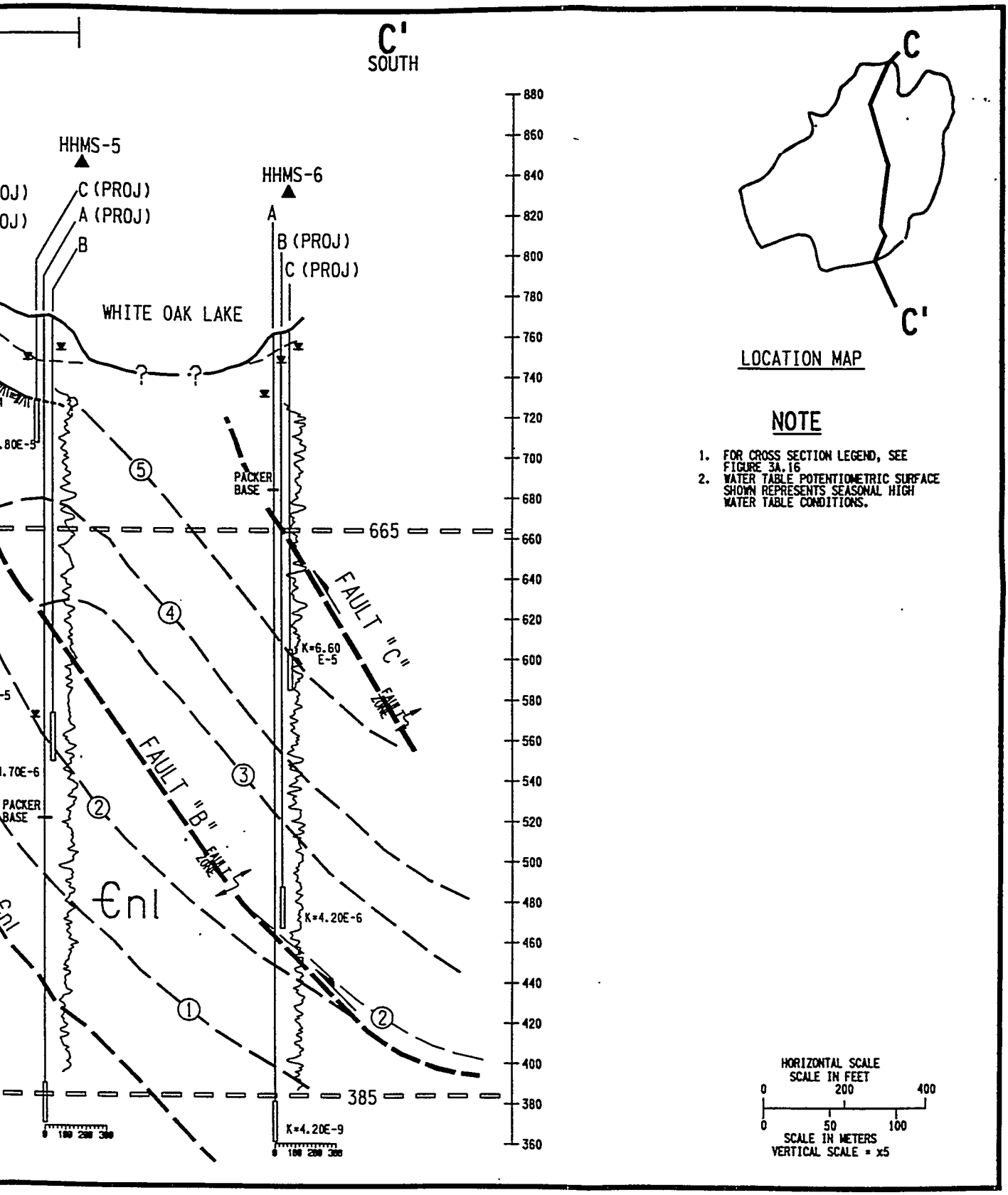
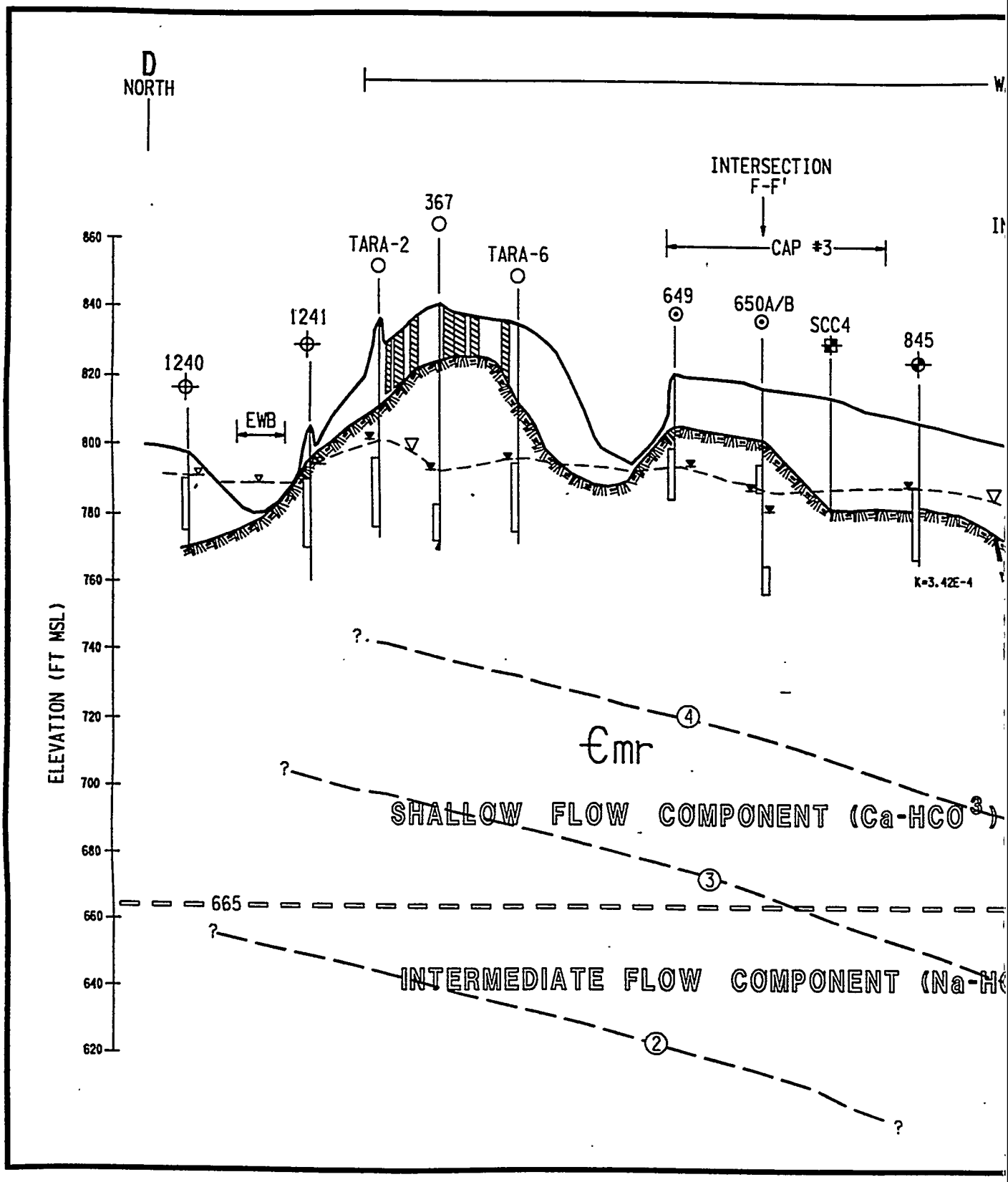



**Fig. 3A.9. WAG 6 hydrogeologic cross section C-C'.**




WAG6 06F316.DGN

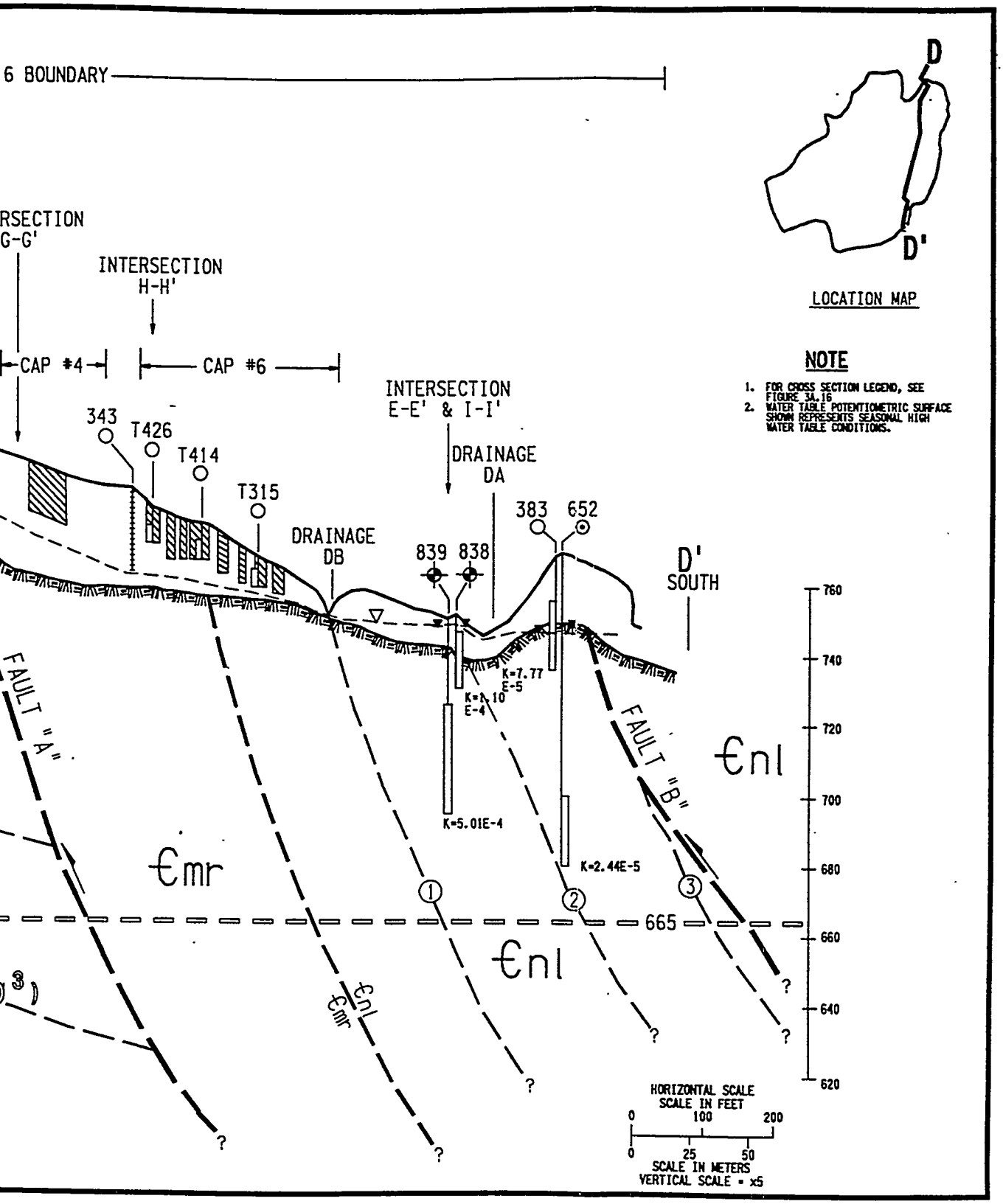
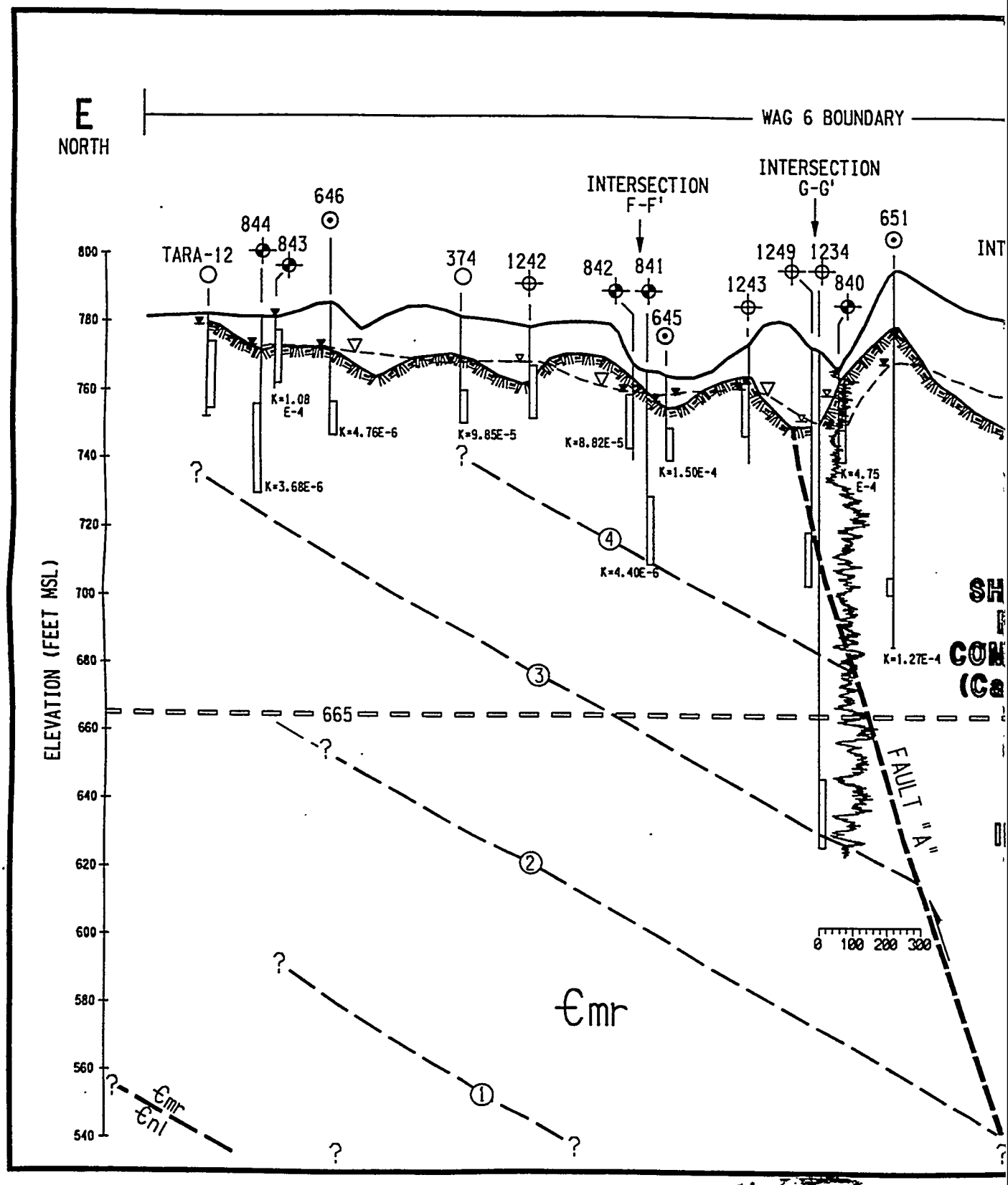



**Fig. 3A.10. WAG 6 hydrogeologic cross section D-D'.**

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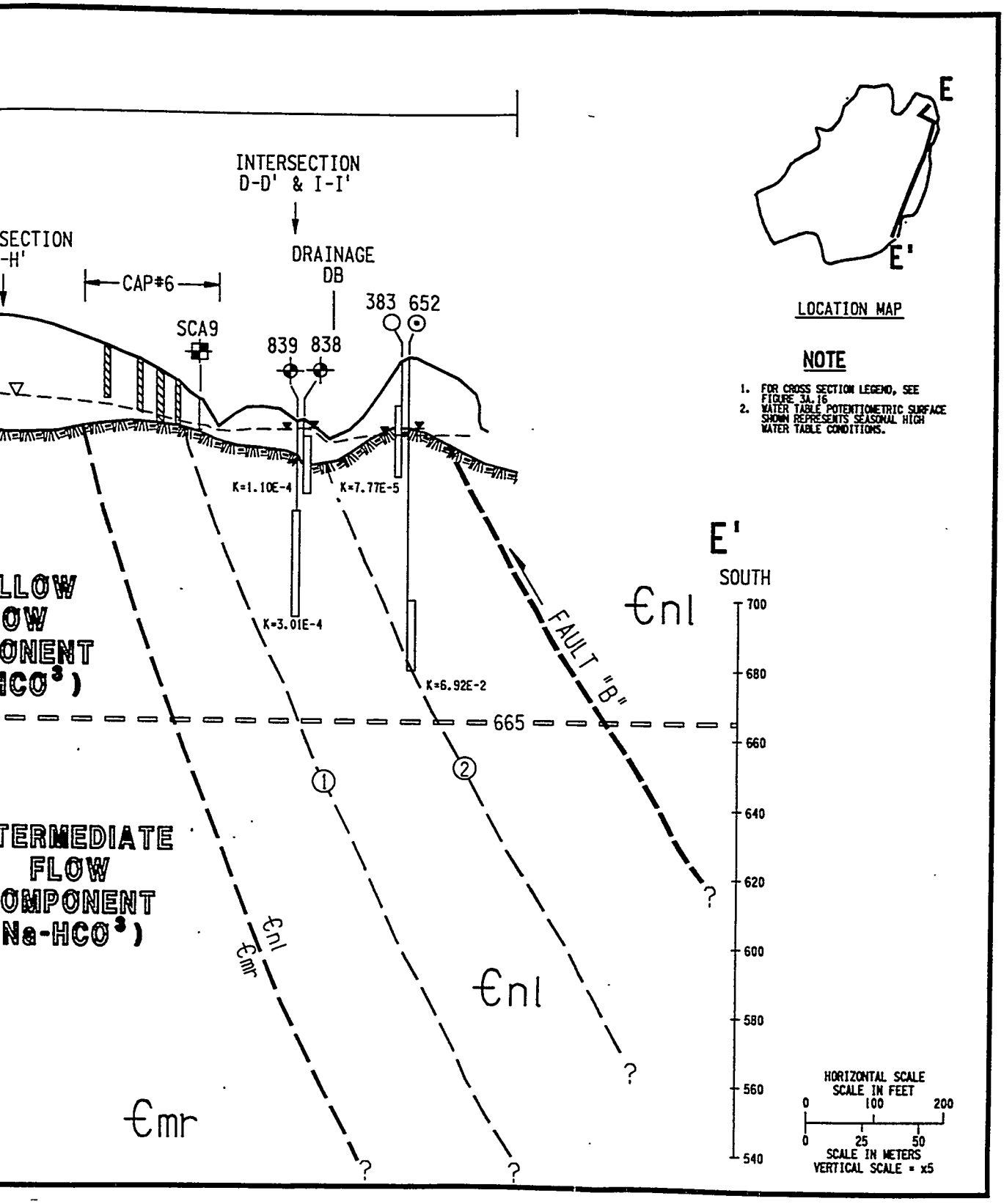
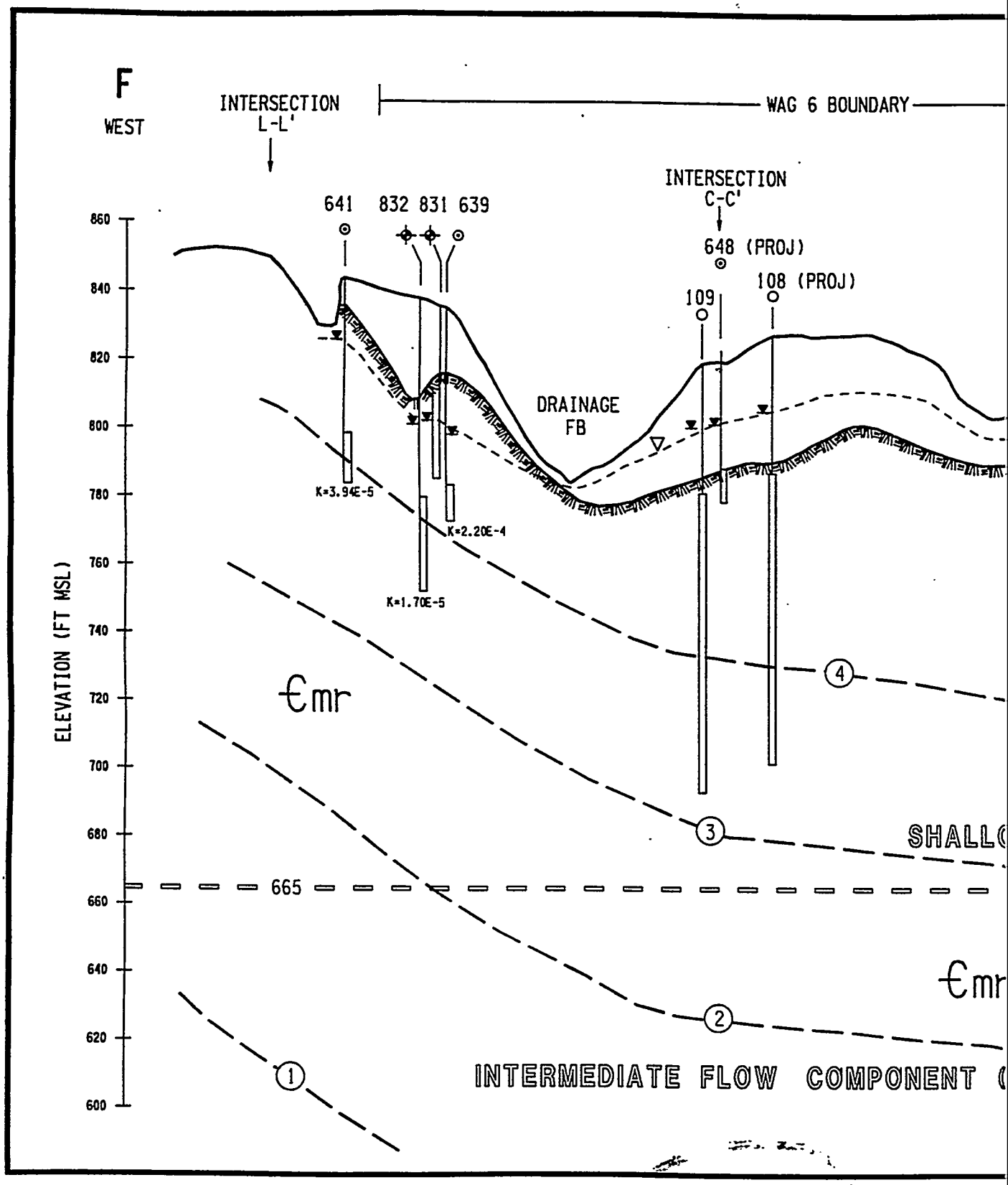



**Fig. 3A.11. WAG 6 hydrogeologic cross section E-E'.**

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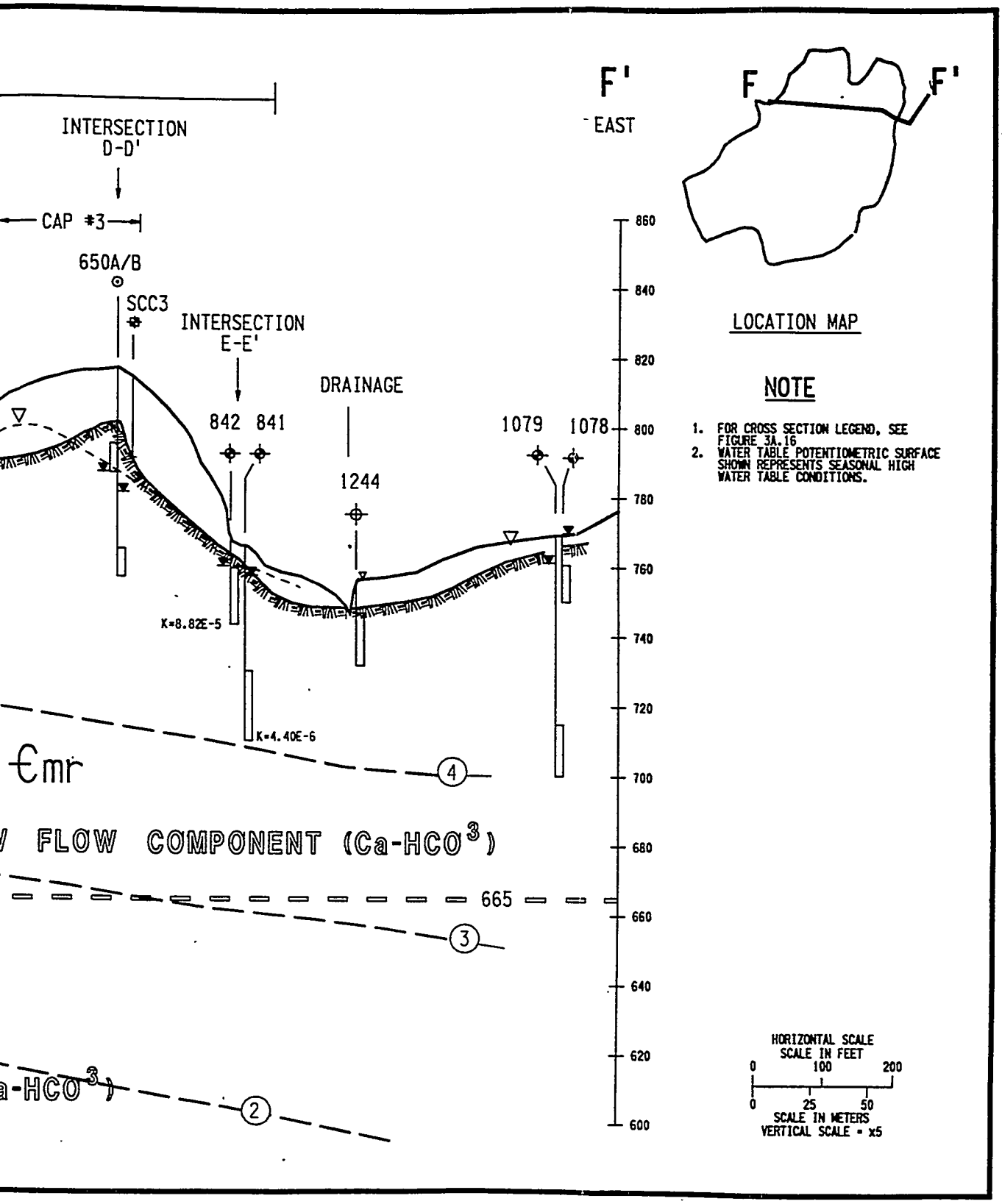
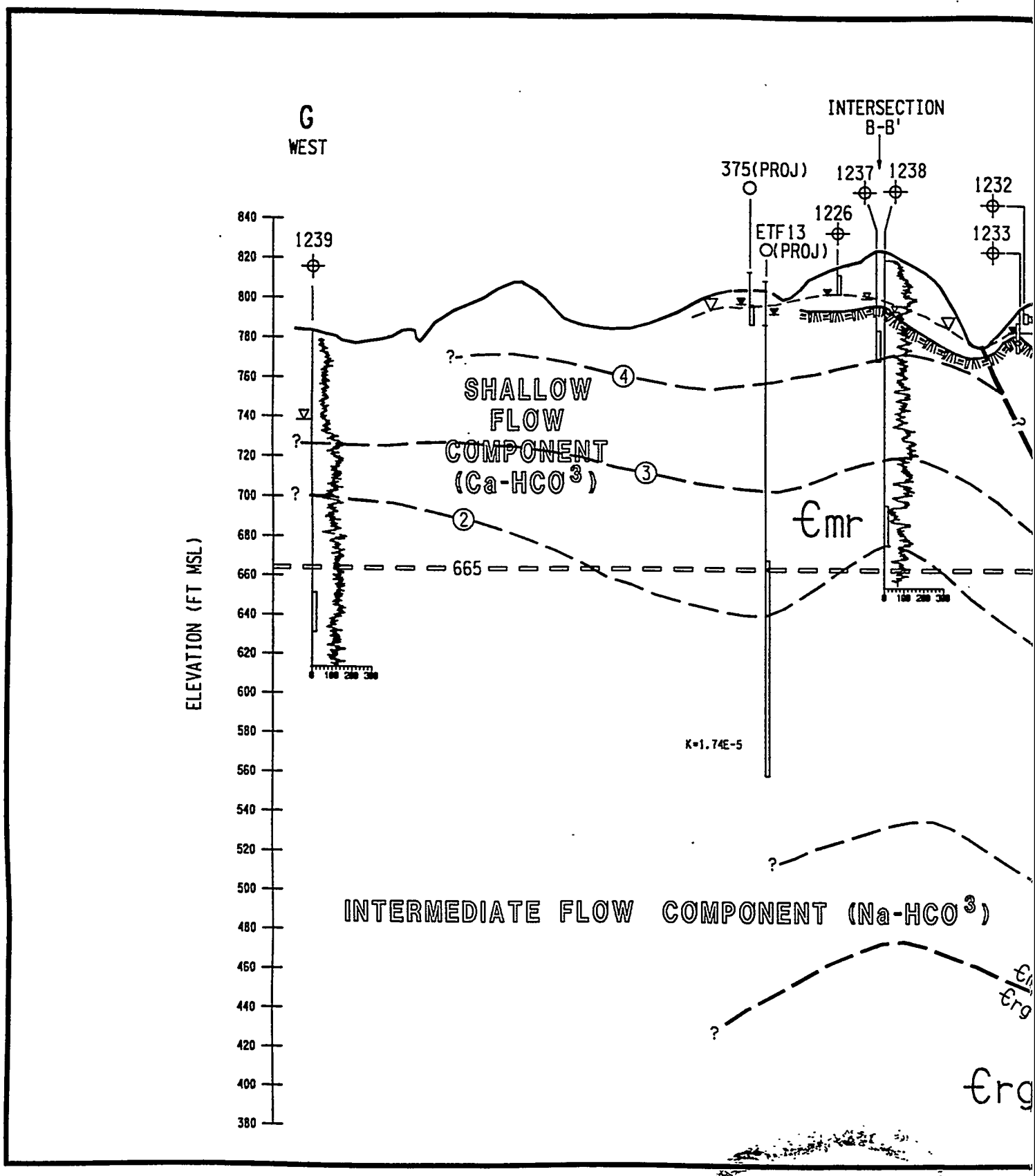



**Fig. 3A.12. WAG 6 hydrogeologic cross section F-F'.**




WAG 6 06F136.DGN VI=STRUC

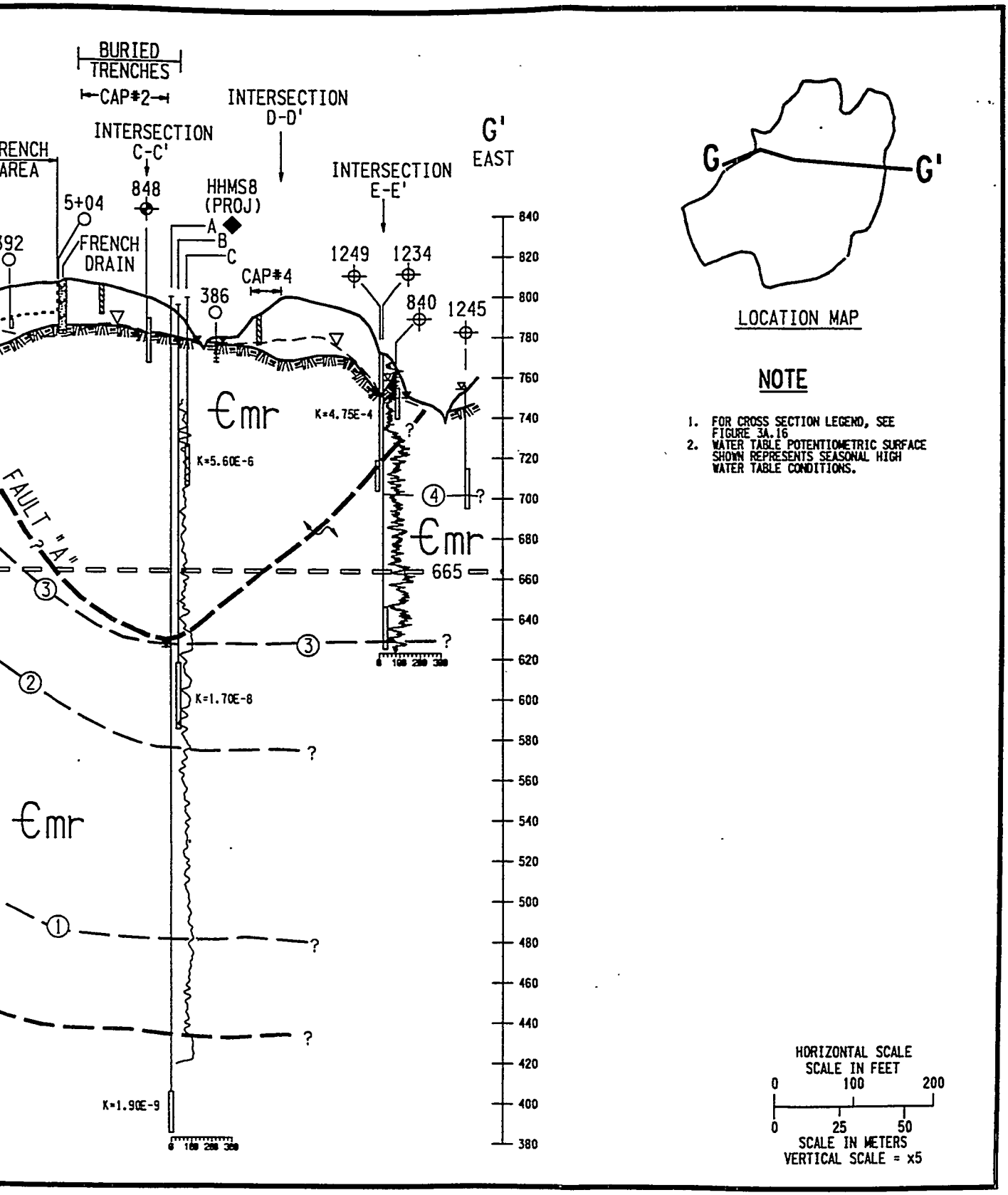
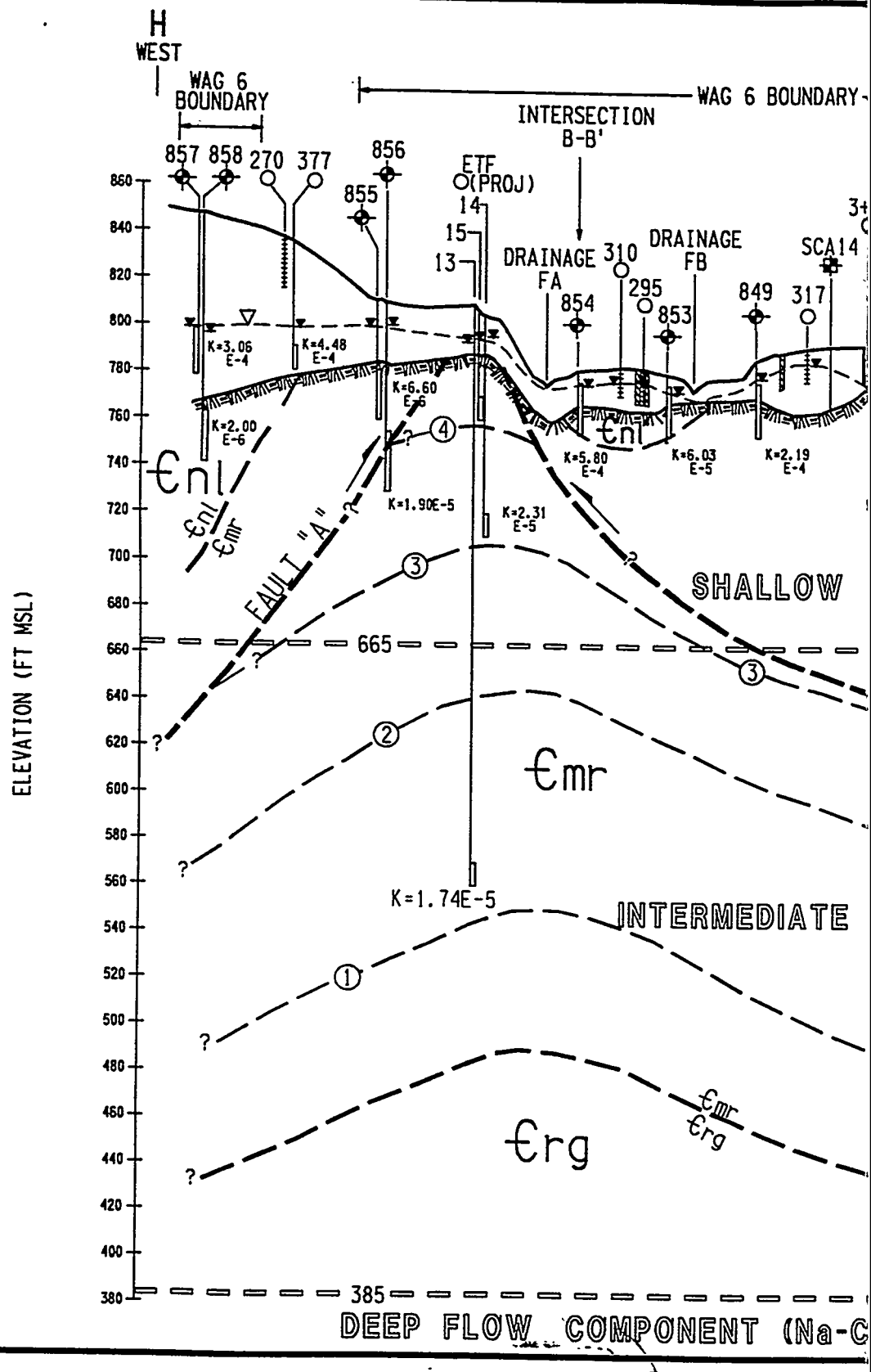



**Fig. 3A.13. WAG 6 hydrogeologic cross section G-G'.**

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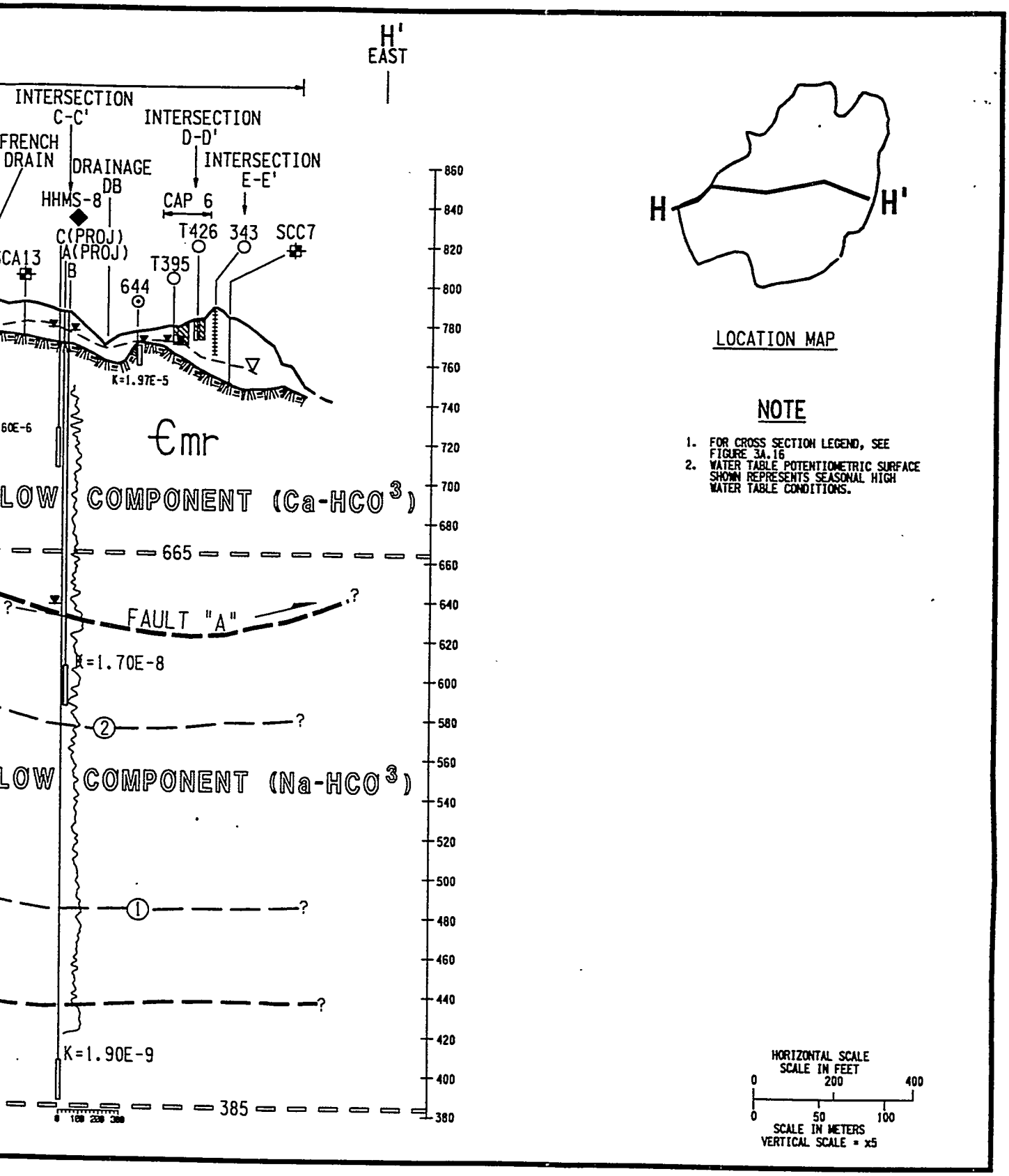
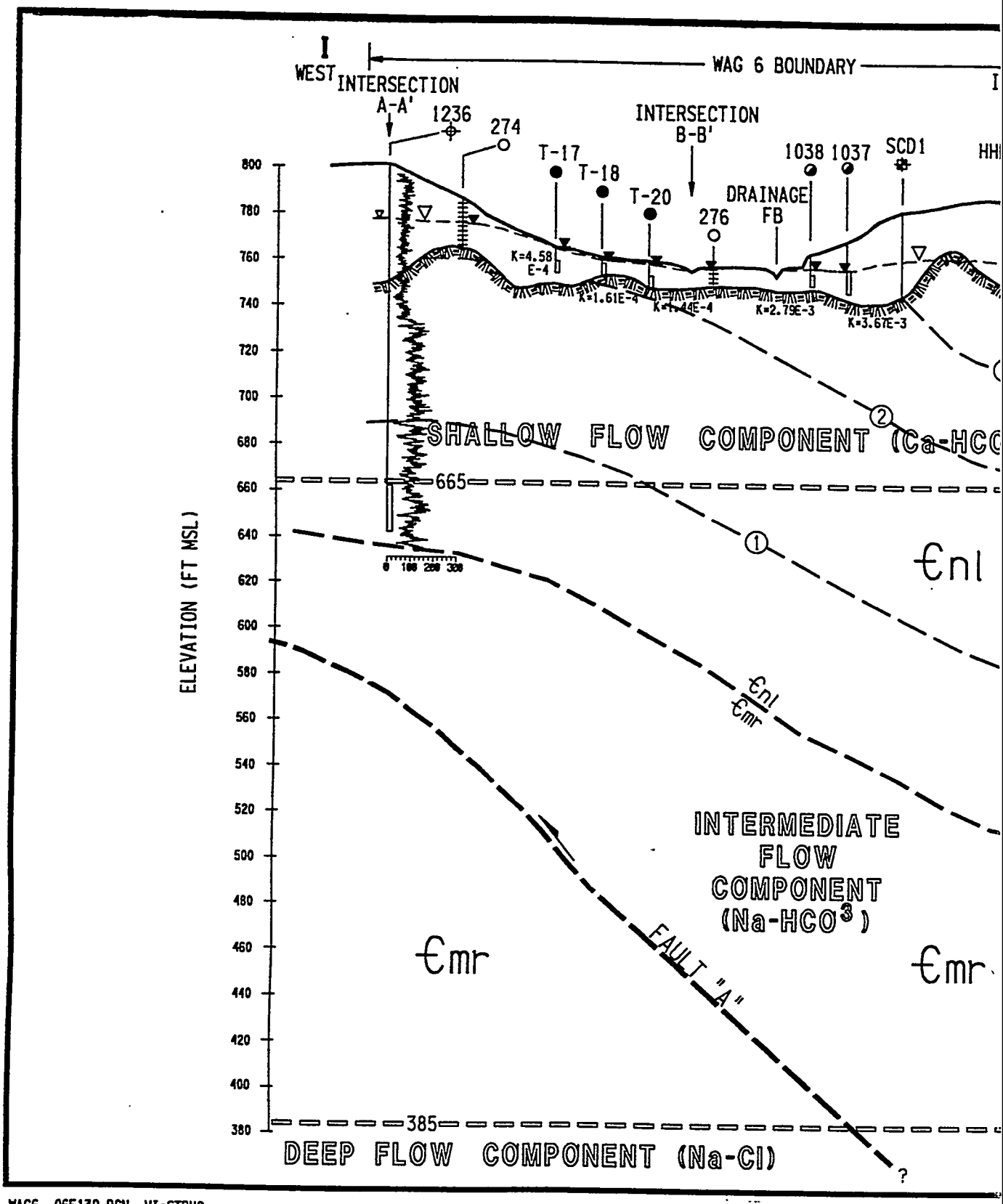



**Fig. 3A.14. WAG 6 hydrogeologic cross section H-H'.**




WAG6 06F130.DGN VI=STRUC

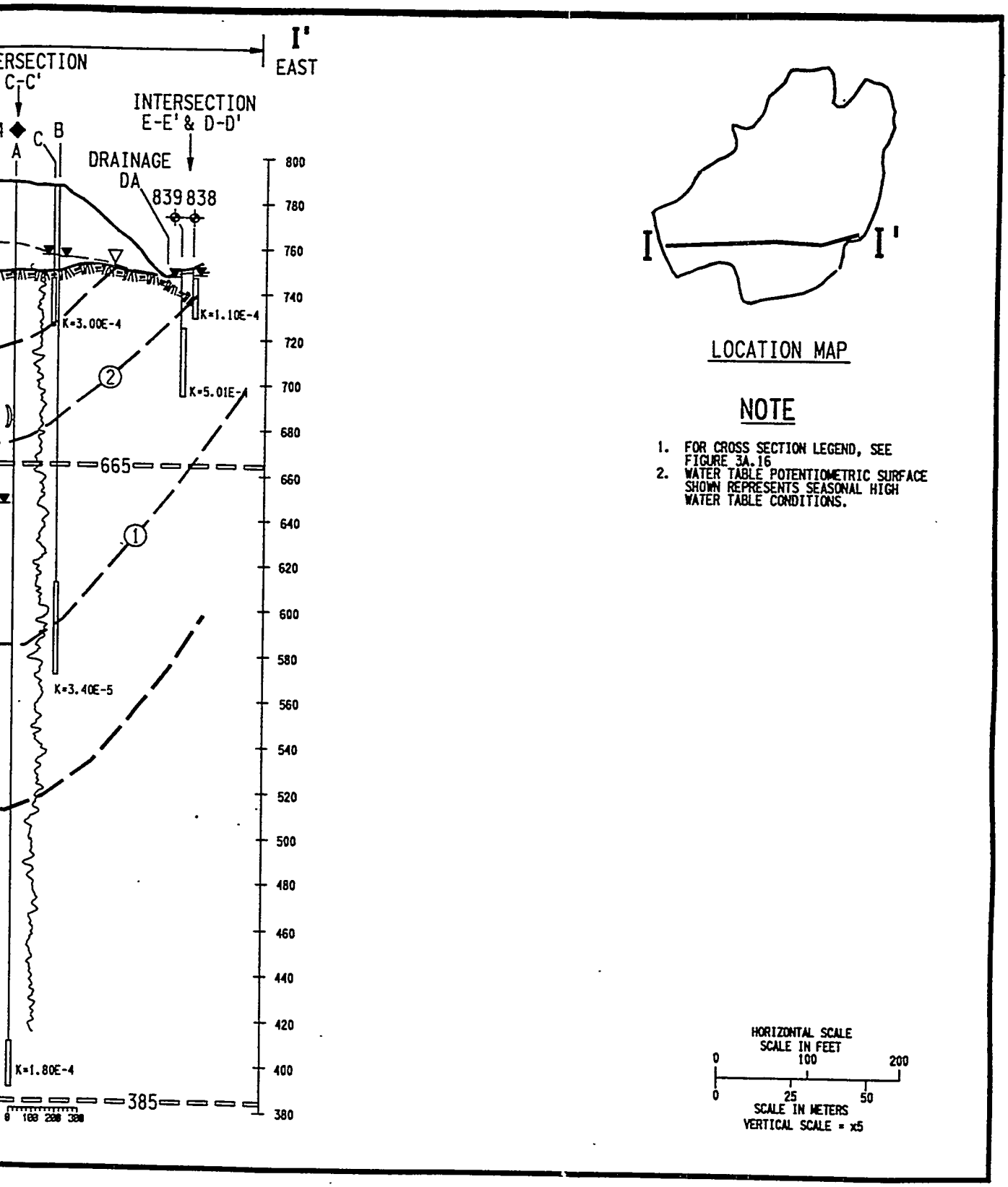



**Fig. 3A.15. WAG 6 hydrogeologic cross section I-I'.**

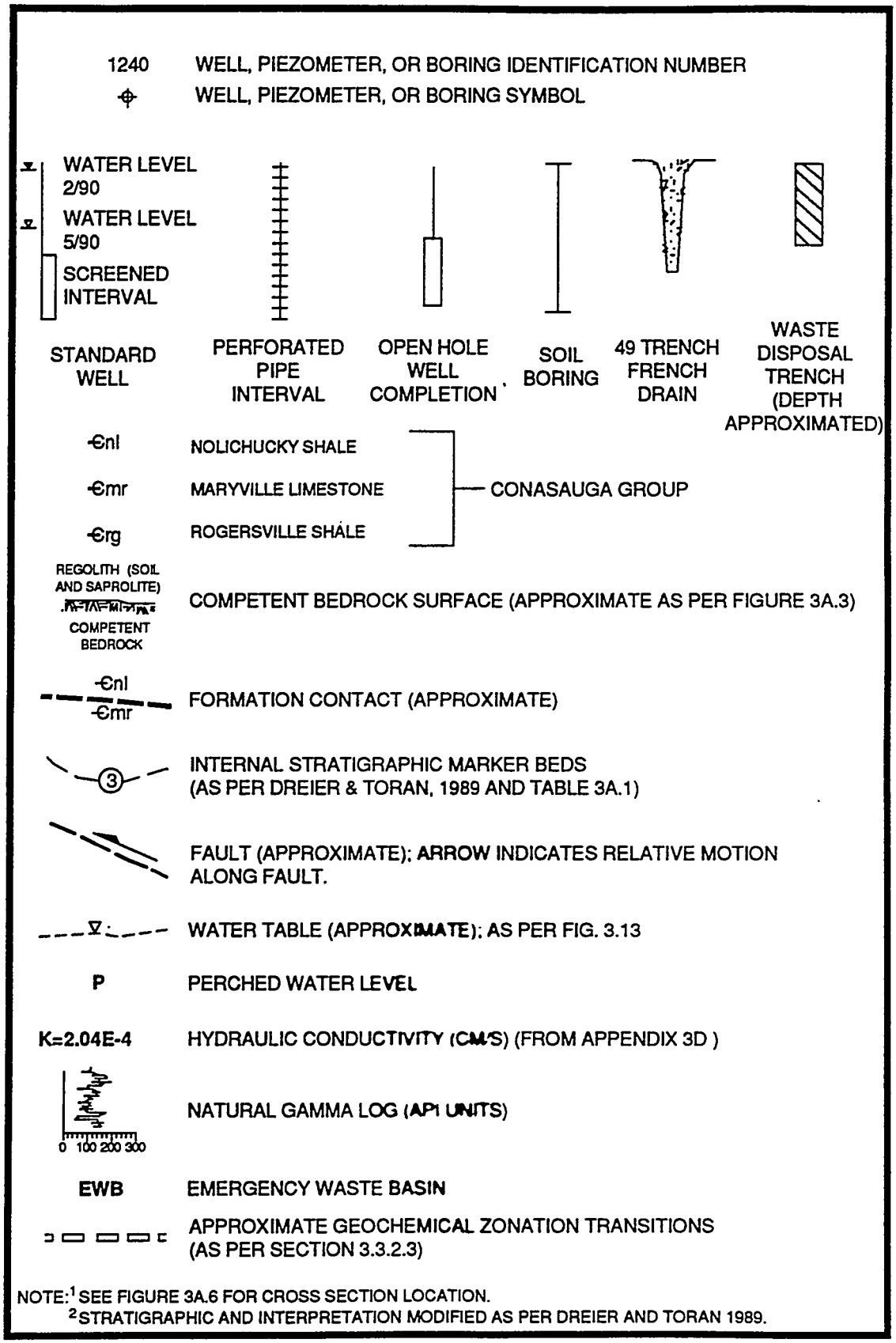



**Fig. 3A.16. Index sheet for hydrogeologic sections.**

5.18F 4104.146
Adapted from WAG6 LEGENDS.DGN

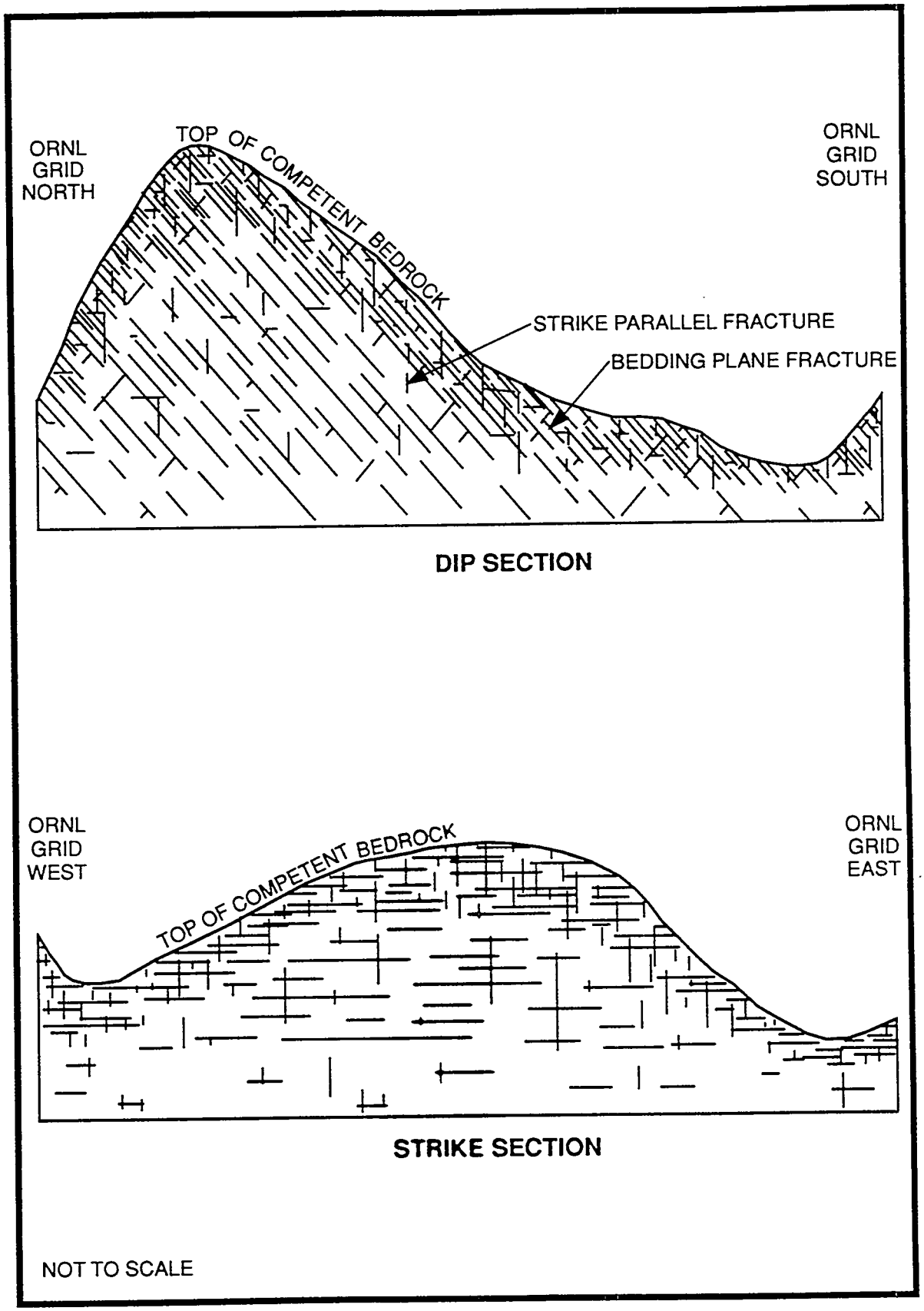
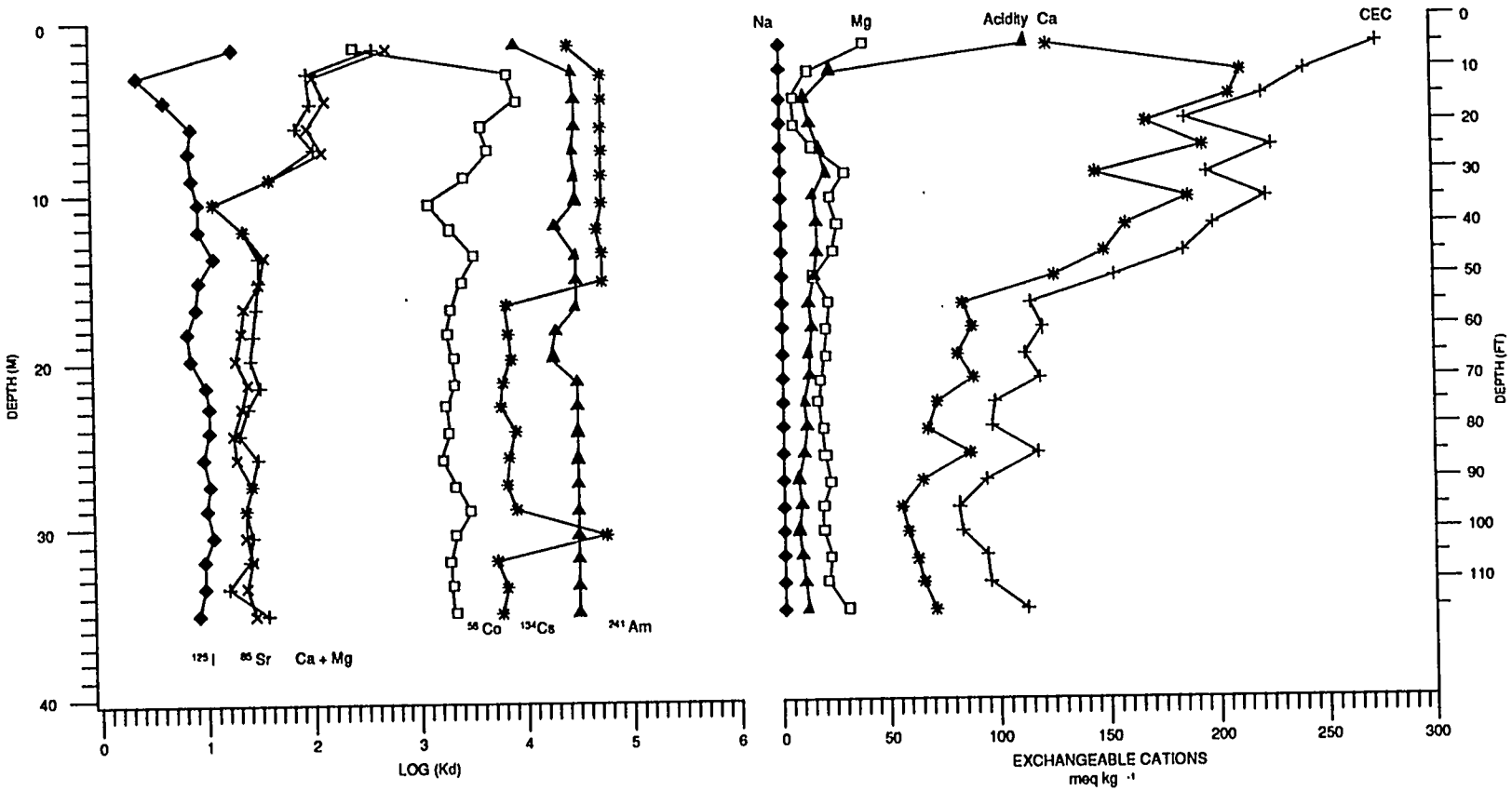



**Fig. 3A.17. Conceptual diagram of bedrock fracturing** (Modified after Moore 1991).

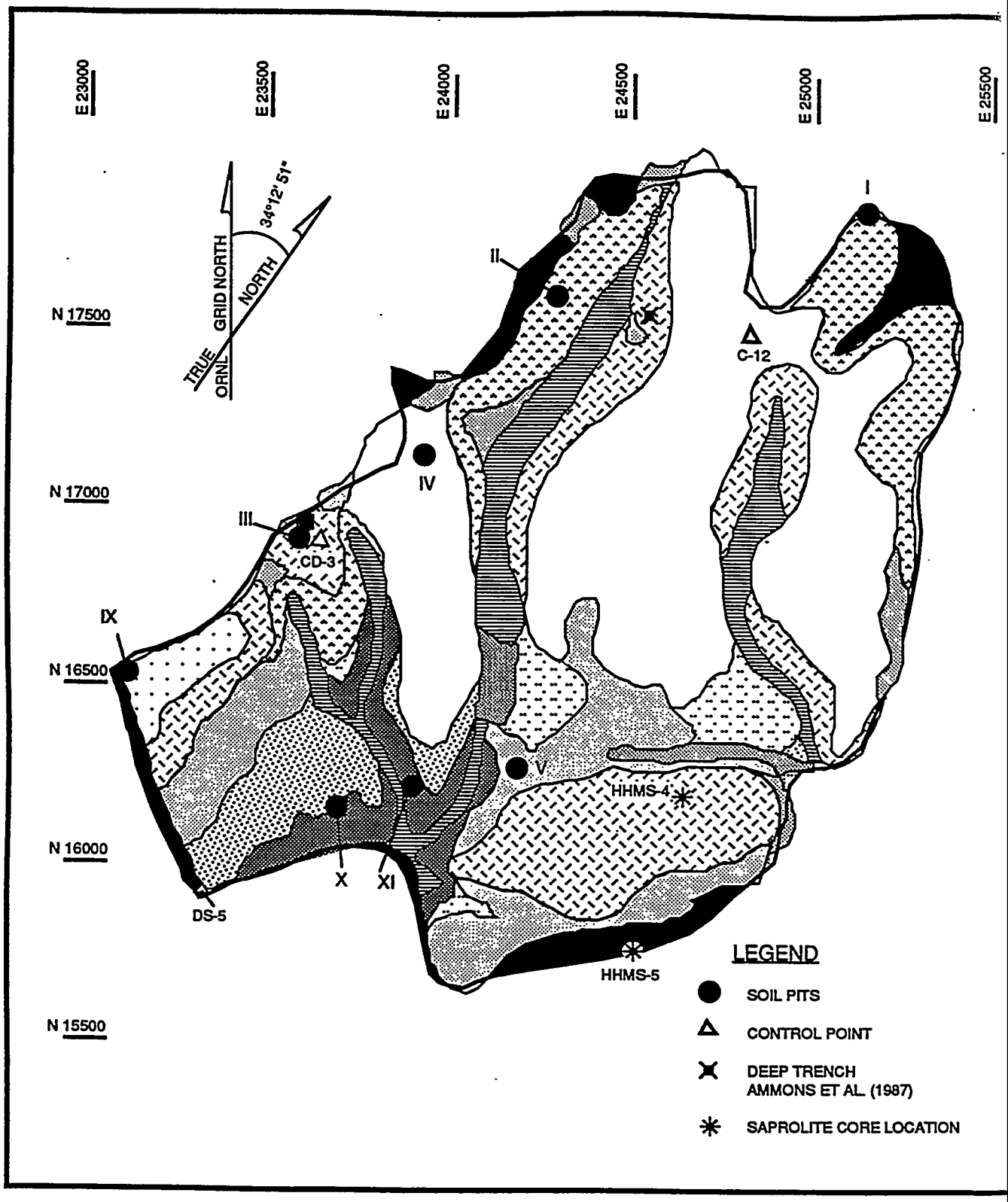
5.18 4104.2




NOTE: REPORTED FOR ROCK CUTTINGS FROM A 115 ft DEEP (WELL 10) MARYVILLE BEDROCK BOREHOLE IN SWSA 7. (ROTHSCHILD et al. 1984b)

**Fig. 3A.18. Chemical properties of Maryville Limestone w/depth.**

5.18E 4104.136
Adapted from WAG 6 06I169.DGN




5.18F 4104.173
Adapted from WAG6 06F168.DGN

| MAP UNIT | SOIL TAXONOMY |
|---|---|
| 1 | TYPIC DYSTROCHREPTS; LOAMY-SKELETAL, MIXED, THERMIC, SHALLOW. |
| 2 | STEEP AND VERY STEEP SIDE SLOPES WITH DOUBLY CONVEX SLOPES. SOILS ARE MOSTLY TYPIC DYSTROCHREPTS; LOAMY-SKELETAL, MIXED, THERMIC. (BERKS-VARIANT SERIES). |
| 3 | LONG NARROW SIDE SLOPES WITH SLOPE GRADIENTS MORE THAN 12% AND NARROW DOUBLY CONVEX UPLAND SUMMITS. SOILS ARE MOSTLY RUPTIC-ULTIC DYSTROCHREPTS; LOAMY-SKELETAL, MIXED THERMIC (MUSE SERIES). |
| 4 | BROAD UPLAND SUMMITS AND BROAD SIDE SLOPES WITH SLOPE GRADIENTS BETWEEN 6 AND 12%, AND DOUBLY CONVEX SLOPE CONFIGURATION. SOILS ARE MOSTLY TYPIC HAPLUDULTS; CLAYEY, MIXED, THERMIC (MUSE SERIES). |
| 5 | FOOT-SLOPES WITH MOSTLY DOUBLY CONCAVE SLOPE CONFIGURATION. SLOPES RANGE FROM 6 TO 20%. SOILS ARE TYPIC FRAGIDULTS; FINE-SILTY, MIXED, THERMIC (LEADVALE SERIES) AND TYPIC HAPLUDULTS; FINE-SILTY, MIXED, THERMIC (SHELOCTA SERIES). |
| 6 | DRAINAGEWAYS WITH MOSTLY WET ALLUVIAL SOILS THAT CLASSIFY AS TYPIC OR AERIC FLUVAQUENTS; FINE-SILTY, MIXED, THERMIC (SERIES NOT DESIGNATED). |
| 7 | DRAINAGEWAYS THAT HAVE BEEN FILLED WITH DEBRIS FROM LAND CLEARING ACTIVITIES OR WITH EARTH MATERIALS FROM TRENCHING OPERATIONS (UDORTHENTS). |
| 8 | FOOT-SLOPE LANDFORMS THAT HAVE BEEN FILLED WITH DEBRIS FROM LAND CLEARING ACTIVITIES OR WITH EARTH MATERIALS FROM TRENCHING OPERATIONS (UDORTHENTS). |
| 9 | BROAD, NEARLY LEVEL UPLAND SUMMIT, PLUS SHOULDER AND SIDE SLOPES WITH GRADIENTS OF 6 TO 20%. THE SUMMIT SOILS FORMED IN LOESS/ALLUVIUM/SHALE RESIDUUM, WHEREAS THE SIDE-SLOPE SOILS FORMED IN ALLUVIUM/SHALE. SOILS ARE TYPIC PALEUDULTS; FINE-SILTY AND CLAYEY, SILICEOUS AND MIXED, THERMIC (TURBEVILLE SERIES). |
| 10 | LOW UPLAND WITH SLOPE GRADIENTS BETWEEN 6 AND 12% AND MOSTLY DOUBLY CONVEX SLOPE CONFIGURATION. SOILS ARE MOSTLY RUPTIC-AQUULTIC DYSTROCHERPTS; LOAMY-SKELETAL AND CLAYEY, MIXED THERMIC (SERIES NOT DESIGNATED). |
| 11 | TOE-SLOPES WITH SLOPE GRADIENTS OF 2 TO 6% AND DOUBLY CONCAVE SLOPE CONFIGURATION. SOILS ARE MOSTLY AQUIC HAPLUDULTS; CLAYEY, MIXED, THERMIC. (TUPELO SERIES) |

SOURCES: LIETZKE & LEE (1986)
AMMONS ET AL. (1987)

**Fig. 3A.19. WAG 6 soil map.**

# APPENDIX 3B. GROUNDWATER HYDROLOGY

Groundwater is a significant pathway for transport of contaminants at WAG 6. Consequently, a thorough understanding of site groundwater hydrology is necessary to risk assessment and development of remedial alternatives. This appendix summarizes the groundwater hydrology of WAG 6. Section 3B.1 discusses prior groundwater investigations conducted at WAG 6 and describes the existing network of wells and piezometers used to evaluate WAG hydrology. Section 3B.2 describes groundwater occurrence at WAG 6 and discusses trench hydrology, the effects of ICM capping, aquifer geochemistry, aquifer hydraulic properties, and groundwater flow. Key findings related to groundwater hydrology at WAG 6 are summarized in Sect. 3B.3.

## 3B.1 PRIOR INVESTIGATIONS/MONITORING NETWORK

SWSA 6 has long been the focus of ORNL and USGS investigations, site characterization research, remedial technology demonstrations, and regulatory compliance monitoring. The first groundwater wells and/or piezometers were installed in 1954 as part of the initial characterization of SWSA 6, 15 years prior to the site's use for disposal. Since then, available records indicate a total of 355 groundwater wells and/or piezometers have been drilled and installed within WAG 6. Additionally, as many as 600 trench piezometers have been installed in and between most of the waste disposal trenches in SWSA 6 to monitor trench water levels and trench water/leachate chemistry. The RFI investigation identified 226 WAG 6 groundwater wells or piezometers and 72 WAG 6 intra-trench piezometers for which records are available. Well construction data for these wells and piezometers are summarized in Appendix 3D.

Table 3.B1 summarizes the history of groundwater well or piezometer installations through June 1990, and identifies those still existing when the WAG 6 RFI was conducted. Figure 3.B1 shows the locations of all identified wells or piezometers within or immediately adjacent to WAG 6.

Since completion of WAG 6 RFI field activities (June 1990), approximately 50 additional monitoring wells, well points, or piezometers have been installed or were to be installed within WAG 6 by ORNL as part of the ongoing Active Site Monitoring Program. These include 31 intratrench wells installed next to the LLW silos; 8 wells installed next to the high activity auger holes; 2 wells installed near the active fissile wells; a well installed adjacent to both asbestos silos; 4 wells planned in the Hill Cut Test Facility area; and 6 new wells around Tumulus Pad 2 (Ashwood 1990a; Ashwood 1990b; Wickliff, Morrissey, and Ashwood 1990). Figure 3B.1 and Appendix 3D do not include those wells installed after June 1990. Also, since June 1990, grading activities associated with the IWMF construction in the southwest part of WAG 6 have resulted in the destruction or abandonment of the 10 IWMF piezometers as well as several other pre-RAP Program piezometers (piezometers 266, 267, 380, 274, 276, 379 and 380).

Most of the still-existing wells and piezometers were constructed using methods or materials that predate current standards for use in regulatory compliance water quality monitoring. However, they provide valuable information regarding groundwater

potentiometric levels, and these data have been used to the extent practical in the RFI. Limited groundwater sampling has been performed on many of the piezometers in conjunction with research projects conducted in WAG 6 over the years. Analytical results are presented in Appendix 1B, and have been incorporated as appropriate in the assessment of the nature and extent of contamination (Sect. 4).

The present groundwater quality monitoring network consists of the 22 RFI monitoring wells (BNI 1990b; TM-06-08A, Well Installation) and 30 ORNL RCRA compliance monitoring wells (Mortimore and Ebers 1988). Figure 3B.2 shows the locations of these 52 water quality monitoring wells. The 22 RFI wells were installed at depths ranging from 3 ft to 170 ft to monitor the shallow storm flow zone, saturated regolith, and shallow and deep bedrock. Details regarding well construction and rationale for well location selection are provided in WAG 6 RFI Well Installation TM 06-08 (BNI 1990b) and 06-08A. Of the 22 wells installed, 3 wells (1226, 1232, and 1235) have remained consistently dry throughout the investigation period.

The ORNL compliance monitoring network consists of upgradient, interior site characterization and perimeter wells and well pairs. Generally, well pairs were constructed to monitor both the water table and the deeper bedrock (i.e., less than 110 ft deep) and are screened in both regolith and/or shallow bedrock. Deep potentiometric control within WAG 6 is afforded by: four HHMS three-well clusters that monitor 20-ft open intervals at three distinct depths to 400 ft; by a four-well cluster at the ETF site to depths of 240 ft; RFI well pair 1237 and 1238; RFI wells 1236 and 1239; and a three-well cluster on the east side of WAG 6 (RFI wells 1234, 1249, and ORNL Well 840).

Following completion of the WAG 6 RFI, wells not required to support activities leading to site closure will be plugged and abandoned to eliminate them as possible sources of cross-contamination. ORNL is preparing a detailed well plugging and abandonment plan, and plugging and abandoning will be conducted as an activity separate from the remedial action prior to completion of the ROD.

## 3B.2 GROUNDWATER OCCURRENCE

Groundwater at WAG 6 occurs principally under unconfined, water table conditions in the regolith and shallow bedrock. No major confining layers or aquitards have been identified, such that groundwater occurs as a continuum from the water table surface depth in bedrock. Perched water conditions occur locally in WAG 6 within the unsaturated zone, or vadose zone. Transient saturated conditions associated with shallow subsurface storm flow in the uppermost unsaturated zone also occur. Figure 3B.3 illustrates the various elements of groundwater occurrence at WAG 6. As shown, near surface water features and in low-lying areas, the storm flow zone and shallow water table are indistinguishable.

### 3B.2.1 Saturated Zone

The water table marks the top of the saturated zone and occurs at depths ranging from less than 1 ft below grade in low-lying topographic areas and along surface water drainages to as much as 55 ft below grade on hilltops. The water table fluctuates in response to episodic and longer-term seasonal patterns of precipitation and evapotranspiration. Water levels are generally highest from January to March (peaking in February), when precipitation is high and evapotranspiration is minimal; water levels are lowest from August through October, when precipitation is low and evapotranspiration is high.

Historical water level data are plentiful for existing wells and piezometers at WAG 6. However, there have been few occasions during which a large number of wells were measured simultaneously, such that it is not possible to construct a potentiometric map for the whole site for a given date using this data. Therefore, in February 1990, water levels were measured at nearly 300 wells and piezometers in existence at that time in and adjacent to WAG 6. These water level measurements are tabulated in Appendix 3D. Additional water level data recorded in association with quarterly sampling of the 30 ORNL compliance monitoring wells and the 22 RFI monitoring wells from 1988 through June 1990, are summarized in TM-06-09A: Groundwater Sampling Phase 1, Activity 2.

A water table potentiometric map for February 1990, is presented in Fig. 3B.4. It is believed this map reflects both seasonal as well as long-term high water table conditions (1990 was a wet year with above average precipitation). Although the majority of WAG 6 wells do not straddle the water table, but potentiometric maps constructed using data from wells screened at or within 50 ft of the water table provide a reliable approximation of the water table. Potentiometric head differences were noted in well pairs consisting of deep and shallow bedrock or regolith wells. Therefore, in preparing Fig. 3B.4, care was exercised to exclude potentiometric data from deeper bedrock wells, deep wells in well pairs or well clusters, and wells encountering obvious perched water conditions. As Fig. 3B.4 shows, the water table surface appears to be a subdued replica of site topography (see Fig. 3.1 in Sect. 3.1), and water table gradients suggest local flow to WAG 6 surface water drainages and overall southerly flow towards WOL. The potentiometric map further indicates the line of topographic highs along the northwest boundary of WAG 6 forms a groundwater divide.

A complete round of water level measurements from all existing wells representing dry season conditions (i.e., September 1990) was not obtained during the WAG 6 RFI field effort. However, existing historic water level data for 118 site wells were evaluated collectively to assess the mean maximum annual water level fluctuation at each location. This information is summarized in Appendix 3D. The maximum historic water level fluctuations recorded in these wells were contoured and are presented as Fig. 3B.5. Typically, water level fluctuations are more pronounced in higher topographic areas; in low-lying areas (particularly along surface water drainages) water table elevations are maintained at more consistent levels. Because of this, hydraulic gradients are generally steepest during the wet season, becoming more subdued during the dry season. As Fig. 3B.5 confirms, the least amount of fluctuation was observed in low-lying areas, while greater than

20 ft of maximum fluctuation occurs in localized areas of generally higher topography in the northern portion of WAG 6. Because Fig. 3B.4 represents seasonal (as well as long-term) high water table conditions, the hydraulic gradients shown represent expected maximums; hydraulic gradients during the dry season would be somewhat less. Evaluation of historical data indicated a mean maximum water table fluctuation of 6.67 ft. Consequently, water level elevations for low water table conditions would be expected to average 6.7 ft lower than those presented for February 1990.

Shallow wells screened in either the bedrock or regolith show rapid response to precipitation events, whereas deep wells show little or no response. Figure 3B.6 presents daily rainfall hyetographs and hydrographs for three shallow WAG 6 wells for which continuous water level data were available. The hydrographs show water level responses from several hours up to 12 hours. Davis et al. (1984) and Davis and Marshall (1988) report response times of 5 to 7 hours with 11.5 hours to peak water level and up to 170 hours for re-equilibration. Hydrographs and hyetographs for other wells (Ashwood and Spalding 1990) show similar trends, although water level data generally were recorded biweekly to weekly and aquifer response to individual precipitation events could not always be measured.

Figure 3B.7 presents hydrographs for two 400-ft deep HHMS-series piezometers for which continuous water level data were available. Two significant features of these hydrographs are noted. First, water levels for both wells indicate these wells have yet to reach equilibration following drilling and installation in 1987. In fact, all but one of the four deep HHMS A wells (HHMS-7A) are still equilibrating. (This is related to the low storativity of the aquifer associated with decreased secondary permeability and hydraulic conductivity at depth in the bedrock.) Second, these hydrographs show a lack of water level fluctuation in response to precipitation events. Although some minor pressure fluctuations are noted in these wells, they cannot readily be correlated to precipitation events. Alternatively, due to the low hydraulic conductivity prevalent in wells of this depth, it is possible that the lag in aquifer response is so great that the minor fluctuations observed are responses to recharge (i.e., precipitation) events occurring prior to the period for which data was recorded. No explanation can be found for the erratic hydrograph response shown for HHMS-6A, which is located outside the WAG 6 boundary on the south side of WOL.

Comparing measured water level elevations with bedrock elevations in wells and piezometers, as shown in the hydrogeologic cross section figures (see Appendix 3A), it is clear that the water table in some areas in WAG 6 occurs in the regolith and in other areas occurs in the bedrock. To separate those areas where water table occurs in bedrock from those where it occurs in the regolith, the top of bedrock elevation map (Fig. 3A.3) was subtracted from the February 1990 potentiometric map (Fig. 3B.4). The resulting intercept values were contoured to represent the regolith-saturated thickness map presented in Fig. 3B.8. Figure 3.B8 also shows areas where, during seasonal high water table conditions, the water table occurs in the bedrock and the overlying regolith is unsaturated.

As shown in Fig. 3B.8, in much of the northern portion of WAG 6 the water table occurs below bedrock at depths ranging up to 30 ft below the regolith/bedrock contact. In

areas where the water table occurs above bedrock, the saturated thickness of the regolith ranges up to 30 ft, but is generally less than 20 ft thick throughout the site. Because the water table declines seasonally, it can be assumed that the extent and thickness of saturated regolith will also decline as more bedrock is exposed above the water table. The anticipated areal extent of saturated regolith and/or bedrock under low water table conditions, as shown on Fig. 3.B8, was interpreted by assuming a 6.7 ft decline in the seasonal high water table elevation (the mean maximum fluctuation observed from historical data), which would expose an additional 6.7 ft of bedrock above the water table. As shown in Fig. 3B.8, during the dry season, a much larger area exists where the water table occurs below the bedrock surface. (The implications of this finding on groundwater flow is pursued further in Sect. 3B.2.4). Because Fig. 3.B.5 shows areas where water table fluctuations could be less than or exceed the assumed average (6.67 ft), the actual extent of areas where the water table occurs below bedrock during dry season conditions could vary from that shown in Fig. 3B.8.

**Groundwater recharge and discharge.** Groundwater recharge is principally from precipitation (estimated to range form 7 to 9% of annual precipitation at WAG 6) and as such, occurs throughout WAG 6. The undulating topographic relief and presence of intervening surface water drainages results in very localized shallow flow systems with classic proximal recharge and discharge areas all within WAG 6. As shown in Fig. 3.B.4, recharge areas coincide with topographically higher areas while discharge appears to occur along drainages and to WOL. Head differences observed in well pairs and clusters for the most part confirm this assessment. In recharge areas, the shallow well of the pairs typically (though not always) show higher potentiometric head than the deeper well indicating downward components of flow associated with recharge. Conversely, in discharge areas, such as along the unnamed surface water drainage bounding WAG 6 on the east, potentiometric head observed in the deep well of the pair exceeds that of the shallow well, indicating an upward vertical flow component characteristic of groundwater discharge areas. This is further confirmed by the artesian conditions observed in RFI wells 1244 and 1245 installed directly adjacent to this drainage. Well pairs installed in hillslope positions somewhere between the hilltop recharge areas and lower relief discharge areas show typical mixed upward and downward vertical gradients depending on location relating to the imaginary line separating recharge and discharge, (i.e., where measured heads would be equal in deep and shallow wells).

Head differences observed in well pairs and clusters represent either upward or downward vertical gradients that can be related to the recharge-discharge relationship discussed. Table 3B.2 summarizes average vertical gradients and directions for WAG 6 well clusters and well pairs based upon available water level data. Figure 3B2 displays the average vertical gradients and indicated gradient direction. Vertical gradients observed range from .008 to .23 ft/ft and reflect the potential for both upward and downward components of flow. A downward component of flow is indicated at the HHMS-7 and ETF-14/15/16 well clusters. At HHMS-7, the vertical gradient increases with depth while the ETF cluster shows a decrease in gradient with depth. Upward vertical gradients were observed between the intermediate and shallow wells at the HHMS-5 well cluster, which is located adjacent to WOL in a groundwater discharge location. Vertical gradients could not be determined

between intermediate and deep wells for HHMS clusters 4, 5, 6, and 8 because potentiometric data indicate the deep wells have not yet equilibrated following drilling and installation (as shown in Fig. 3B.5). It must be noted that the occurrence of vertical gradients does not imply flow in a vertical sense, only the **potential** for vertical components of flow. However, as will be discussed further, site data suggest there is little or no vertical groundwater flow from shallow to deep zones, and the high degree of topographic relief is sufficient to induce virtually all of WAG 6 recharge to remain in the shallow aquifer.

**Effects of the 49 Trench area French Drain.** A key feature recognizable on Fig. 3B.4 is the linear drawdown pattern in the central part of WAG 6 associated with the 49 Trench area French Drain. This drain, installed into bedrock in late 1983, was designed to intercept groundwater from upgradient areas and lower the water table below the base elevation of the 49 Trench area trenches, thereby decreasing the generation and potential mobilization of leachate. The French Drain is lined with a filter fabric and consists of a 226-ft long north leg, which discharges to a catch basin at the western outfall, and a 600-ft long east leg, which discharges to a catch basin at the southern end of this leg. Discharge from the east leg ultimately drains to surface water drainageway DA.

Early post-construction performance monitoring by Davis and Stansfield (1984) showed the French Drain effectively suppressed the water table to a depth of 16 ft below ground surface over 50% of the 49 Trench area. (Previously the water table occurred at a depth of 6 ft below grade.) Drawdown was observed to extend 164 to 196 ft from the trench centerline (out to intertrench Well 400), with a maximum 13-ft suppression at the deepest point in the drain (Davis and Marshall 1988). As a result, 29 of 49 trenches had dried up.

Davis and Marshall (1988) report that discharge from the east leg of the drain during steady state conditions is 0.32 to 0.50 gpm but ranges up to 20 gpm during storm events. Davis and Marshall (1988) report a total of 1,137,909 and 695,903 gal of water were discharged from the east leg during 1984 and 1985, respectively. Discharge from the north leg is intermittent and was observed only five times during Davis and Marshall's 3-year study, and then at a peak discharge of 1 gpm associated with a storm.

Figure 3B.4 clearly shows that the French Drain is effective in intercepting groundwater, particularly in the immediate vicinity of the drain. However an evaluation of precipitation and well hydrographs for the period 1984 to 1988 shows that the French Drain effectiveness is decreasing, probably as a result of clogging of the filter fabric lining (Black 1989). Wells within 40 ft of the drain show 4 to 11 ft of sustained water table suppression, whereas wells beyond 50 ft of the drain centerline now show no drawdown effects.

### 3B.2.2 Unsaturated Zone

The unsaturated zone at WAG 6 extends from ground surface to the water table and primarily consists of soil and saprolite, although, as shown in Fig. 3B.8, the uppermost competent bedrock is also locally unsaturated when it protrudes above the water table. This interval is significant because, by design, the majority of waste burial trenches terminate in

the unsaturated zone. Groundwater occurs within the unsaturated zone as localized lenses of perched water and as transient water in the storm flow zone. This section describes groundwater occurrence in the unsaturated zone and discusses active processes related to waste disposal trench hydrology (bathtubbing, trench-groundwater interactions, effects of ICM capping.)

### 3B.2.2.1 Perched water

Perched conditions have been observed locally within the unsaturated zone in wells and piezometers, specifically in the northwest corner of WAG 6 (in piezometers 269, 267, and 270) and in the 49 Trench area in the central part of WAG 6 (in Well 1232 and Piezometer 317). Perched conditions are not unexpected due to the nature of the regolith (for example, the occurrence of a clayey "C-horizon" as previously described) and the number of waste disposal trenches that commonly retain infiltrating water, creating a bathtubbing effect. Perched water may also occur in areas of WAG 6 underlain by soil unit 5 (see Fig. 3A.19), which commonly displays a fragipan horizon that could act to perch water.

Well control suggests these perched zones are of limited extent (generally only in the vicinity of the well where encountered) and are relatively insignificant. For example, perched water identified in Piezometer 269 in the western part of the site was not observed in Piezometer 378 or wells 857 and 858, which are located within 40-50 ft of Piezometer 269.

### 3B.2.2.2. Storm flow

Recent research efforts at ORNL have emphasized the significance of the subsurface storm flow or interflow zone as a mechanism and pathway for shallow transport of infiltrating water and contaminants in the unsaturated zone to surface streams. The storm flow zone consists of the macropores and mesopores in the root zone of shallow soil horizons and depending on local conditions, comprises the shallow interval from ground surface to a depth of up to 6 feet (see Fig. 3B.3). Conceptually, storm flow may occur wherever the infiltration rate and capacity of surficial soils exceeds the peak rainfall intensity. Consequently, flow in this zone is transient (lasting only hours or days) generated in response to precipitation events of sufficient duration and intensity to saturate this interval and produce a transient perched zone in the storm flow zone. Infiltrating water is then transmitted laterally downslope in response to gravity following short flow paths towards adjacent drainages. Because the base of the zone is not impermeable, recharge to the water table occurs along the length of the saturated storm flow zone. Near perennial streams, the water table is considerably higher; in these areas, the storm flow zone and water table are indistinguishable. The storm flow zone and water table may also be connected locally on steep hillsides where wet-weather seeps can occur.

The occurrence of storm flow is dependant on the infiltration rate of surface soils exceeding both the peak rainfall intensity and permeability of the underlying saprolite such that the majority of precipitation will infiltrate and remain perched in the storm flow zone.

Moore (1988) compared hydraulic conductivity data from slug tests conducted in nearly 400 piezometers at ORNL (including 60 piezometers at WAG 6) to limited soil infiltration data for undisturbed, forested soils in SWSA 7 and determined that the shallow surface soils have significantly higher permeability than the underlying saprolite. Further, Moore reported the infiltration capacity of undisturbed forested soils exceeds the maximum rainfall intensity for the area, such that practically all incident rainfall infiltrates into the soils with little or no overland flow component. From results of storm flow monitoring at SWSA 7, Moore (1988 and 1989a), postulated that in undisturbed areas on the ORR, 90 to 95% of the rain water actually infiltrating into the subsurface (approximately 39 to 41% of annual rainfall) is conducted through this zone to surface water drainages, with only 5 to 10% of precipitation actually recharging the shallow groundwater. This conflicts with the traditional belief that the majority of contaminant transport is by the steady, low-velocity movement of groundwater through the saturated zone.

Other studies (Solomon et al. 1989) conducted in a localized study area similar to WAG 6 at nearby SWSA 5 have shown that storm flow only accounts for an estimated 44% of the total discharge (i.e., groundwater discharge plus storm flow) to adjacent Melton Branch during "dry" years. Further, in this study, tritium detected in soil pore water strongly suggests that the flow path between the waste disposal trenches and the stream may be partially in the storm flow zone, but the contamination is discharged to the stream as groundwater.

During the WAG 6 RFI, three shallow storm flow wells were installed to assess the storm flow zone at locations where expected to be present. All three wells were constructed using RCRA monitoring well construction standards. Wells were screened from 3 to 14 ft below ground surface to intercept the storm flow zone. However, throughout the investigation, two of the three wells (Wells 1226 and 1230) have remained consistently dry during rainfall events monitored. The third well, RFI Well 1232, consistently had water both during periods of precipitation and during dry periods; it likely monitors a localized perched water lense. These results highlight the logistical problems associated with monitoring this zone and the difficulty in predicting the occurrence of the storm flow zone.

The surface soils at WAG 6 have been highly disturbed, reworked, or removed as a result of site clearing and grading, and waste disposal trench excavation and cut and fill work associated with the construction of the ICM caps, Tumulus pads, and IWMF area. Additionally, over 1000 piezometers, wells, auger holes, and disposal trenches perforate the storm flow zone providing infiltration galleries that bypass lateral storm flow. Approximately 15% of the WAG 6 surface area is covered by impermeable ICM caps preventing direct recharge to the storm flow zone. Consequently, the surficial soils at WAG 6 are not representative of undisturbed, forested conditions elsewhere in Melton Valley and the storm flow zone, where prevalent, is likely laterally discontinuous.

Available WAG 6 soil infiltration data (presented in Sect. 3B.2.4) suggests that overall, there is little difference in permeability between site soils and underlying saprolite at the locations where data were collected. Further, site soil infiltration rates (ranging from 1.8E-3

to 6.0E-6 cm/sec) are less than the peak rainfall intensity of 2.3 cm/sec reported by McMaster (1967) for the area. This suggests that once the infiltration capacity of the soils is reached and soils are saturated, the majority of precipitation would be conducted away as overland runoff. However, as discussed in Appendix 3A and shown on Fig. 3A.19, eleven distinct soil units have been identified at WAG 6 and physical and hydraulic properties likely vary laterally within a given soil type as well as between different soil units. Nonetheless, although site soils may display higher infiltration rates elsewhere in WAG 6, in the areas where data were collected, it is unlikely that the storm flow is a significant factor.

Hydrographs for shallow water table wells at WAG 6 show rapid responses to precipitation events (up to 3.5 ft peak increase in water level). If the majority of infiltrating water was attenuated in the storm flow zone, such rapid increases would not be expected to occur. This suggests that the storm flow component may not be present in these locations.

From the preceding discussion, the storm flow zone at WAG 6 is believed to be highly variable and discontinuous, resulting in discrete flow pathways where present. However, as will be discussed in the following section, storm flow does appear to be occurring at WAG 6 as evidenced by trench hydrology data in the vicinity of capped areas, and may be of significance in contaminant transport (both as a pathway and a secondary source of contaminants) at WAG 6. Nonetheless, due to the inherent heterogeneity of the storm flow zone at WAG 6, site-wide characterization of this component is neither practical nor feasible. Consequently, considerable uncertainty exists regarding the impact of storm flow on the hydrologic system and contaminant fate and transport at WAG 6. Due to these uncertainties, simple recognition of the **potential** for storm flow is sufficient to support the remedial alternatives selection process (i.e., although monitoring the storm flow is impractical, remedial strategies should include components that address storm flow).

### 3B.2.2.3 Trench hydrology

Unlined waste trenches at WAG 6 are typically 10 ft wide by 50 ft long by 15 ft deep. However, in the biological trenches, trench depths are shallower, ranging from 7 to 12 ft deep. Unlined auger holes are typically up to 5 ft in diameter and up to 23 ft deep. Although they were initially designed so that their bottoms would be above the water table, an interesting consequence of shallow trench waste burial operations is that precipitation tends to infiltrate into trenches either directly or via storm flow, creating bathtubbing conditions wherein water is perched in the trenches above the water table. In other areas of WAG 6, the water table intersects the trenches perennially and/or when seasonal or episodic high water table conditions persist, causing further inundation of the trenches.

Trench bathtubbing occurs when inflow from these sources along fractures, mesopores, and macropores exceeds outflow through the trench bottoms and side walls, which have lower permeability. Bathtubbing trenches act as infiltration galleries allowing for mobilization of leachate. In the case where trenches are completely filled, outflow can potentially occur via the storm flow zone, where it exists.

Bathtubbing is most pronounced during the winter wet season. During this time, precipitation is at a maximum, evapotranspiration is minimal, water table elevations and soil moisture contents are highest, and water infiltrates into waste disposal trenches faster than it seeps out of the bottom (Tamura et al. 1980).

### 3B.2.2.4 Pre-ICM cap trench hydrologic conditions

Davis et al. (1987) reported on a study conducted by Davis and Solomon to identify the interaction between the shallow water table and trenches. A total of 20 intratrench monitoring wells and six water table wells were monitored over an extended period to define the hydrologic conditions of the trenches in WAG 6. A combination of continuous and manual water level measurements were made beginning in February and March 1986. Existing data from 1985 to 1987 were also included in the study. The water level data showed that trenches could be classified hydrologically according to one of five criteria.

(1) **Unsaturated**—the water table outside the trench was consistently below the trench bottom and standing water was not observed in the trench monitoring well
(2) **Inundated**—the water level elevation in the trench monitoring well is above the trench bottom and equal to the water level elevation observed in adjacent water table monitoring wells
(3) **Intermittently Inundated**—a combination of 1 and 2, due to a fluctuating water table
(4) **Bathtubbing**—the water table elevation adjacent to the trench was consistently less than the water level inside the trench and is below the trench bottom and measurable standing water was observed in the trench monitoring well
(5) **Intermittently Bathtubbing**—the trench bottom is about the seasonal high water table and trench water is only encountered sporadically

The hydrologic condition of trenches in WAG 6 during the study are shown in Fig. 3B.10. Solomon et al. (1988) report only 10% of trenches monitored were either bathtubbing or inundated during the entire monitoring period. Eighty-four percent of SWSA 6 trenches showed either intermittent bathtubbing or were intermittently inundated during this period. Further monitoring of 14 trench wells from 1986-1987 identified only 6 trenches in which bathtubbing occurred for more than one month. Davis et al. (1987) found that only those trenches with water levels within 1.5 ft of the adjacent water table showed any significant response to storm events. When trench well water levels are greater than 1.5 ft above the local water table elevation, the majority of infiltration can be attributed to direct infiltration through the cap or storm flow. However, when the water level difference is less than 1.5 ft, as much as 90% of the total trench influx may occur through pathways other than direct infiltration through the cap, namely, interaction with the water table.

Water level data from 1976 to 1987 indicate that the auger holes are not inundated by a high water table, although standing water was observed during construction of several auger holes (Solomon et al. 1988). The existence of bathtubbing auger holes was not explored because piezometers do not exist in auger holes.

### 3B.2.2.5 Effects of ICM capping on trench hydrology

In 1989, eight high-density polyethylene (HDPE) caps were constructed in WAG 6 as an Interim Corrective Measure; the caps presently cover over 15% of the surface area of WAG 6. Solomon et al. (1988) reported on the hydrologic condition of trenches prior to placement of the caps (Fig. 3B.10). An attempt was made as part of the RFI to evaluate the current state of trench/groundwater interaction.

To accomplish this, it was assumed that across the site, the average trench is 15 ft deep. Based on this assumption (which is consistent with operational records, which indicate that with the exception of the biological waste trenches, most trenches range from 14 to 18 ft deep) an elevation map was created to show the elevation of the bottom of the trenches in the vicinity of the capped areas. This map was created by subtracting 15 ft from the topographic surface (Fig. 3.1). For the biological trenches, a trench depth of 10 ft was assumed (records indicate trenches in these areas range form 7 to 12 ft deep). The February 1990 potentiometric map, which illustrates high seasonal water table conditions, (Fig. 3.B4) was then subtracted from the trench bottom map to identify areas where the water table is intersecting the trenches. Using this method, a number of trench areas were determined to be inundated during high seasonal water table conditions, whereas others appear to be unsaturated as a result of interaction with the water table. Figure 3B.11 displays the resulting hydrologic conditions of trenches in February 1990. Because the high seasonal potentiometric surface map was used, it is believed this figure represents a worst case scenario.

From examination of surface topography (ground surface elevations ranging from 810 to 820 ft) and the February 1990 potentiometric map (elevations 785-800 ft), and assuming all auger holes are at least 20 ft deep (records support this), it appears the auger holes are not in contact with the water table.

To determine the degree of groundwater and trench interaction under dry conditions, the mean maximum water table fluctuation of 6.7 ft was considered. If a trench area is unsaturated during high water table conditions, it should also be unsaturated during the dry season, when the water table would be on average approximately 6.7 ft lower. Conversely, a trench area where mapping indicates wet season inundation of greater than 6.7 ft should remain inundated during the dry season. Trenches where mapping indicates 6.7 ft of intercept or less should be inundated during the wet season but unsaturated during the dry season (intermittently inundated). Figure 3B.12 depicts these scenarios.

Further, trench water elevations measured February 20, 1990, for 59 intratrench wells were compared to the mapped water table elevation for the same date, as shown on Fig. 3B.4. Bathtubbing trenches are those in which there trench water elevations exceed the mapped water level elevation at that location. Inundated trenches show trench water elevations that are equivalent to the mapped water table elevations. Dry trenches are noted by dry intratrench wells. From examination of Fig. 3B.11, some trenches appear to be either bathtubbing or unsaturated in areas designated as inundated. This is related to depths of

individual trench piezometers and indicates that Fig. 3B.11 trench hydrologic conditions shown on Fig. 3B.11 are a reasonable approximation, but actual conditions in individual trenches may vary from those shown.

Of the 59 trench wells, 21 were dry, 18 were inundated, and 20 displayed bathtubbing. The individual trench well conditions are also shown on Fig. 3B.11. The results suggest that in the uncapped 49-Trench area, the French Drain has been effective in lowering the water table to preclude groundwater/trench interactions, but the trenches commonly display bathtubbing conditions resulting from either storm flow or direct precipitation infiltration. Apart from two trench wells (T44 and T63) that reflect trench/groundwater interaction, CAP 8 has apparently been effective in preventing infiltration. As shown on Fig. 3B.10, trenches in the CAP 8 area were found to be intermittently bathtubbing prior to cap placement (Davis et al. 1987). Comparing pre- and post-cap mapping, the construction of Caps 4, 5, and 6 have apparently had little effect on dewatering trenches or preventing bathtubbing and/or inundation of the trenches.

Ashwood and Spalding (1990) have recently summarized the results of monitoring the effects of the ICM caps on groundwater levels and trench water levels. In this study, conducted from 1988 (pre-Cap) through October 1990, water level data were manually and, in some cases, continuously recorded for 25 shallow groundwater wells or piezometers outside the trench areas and 45 intratrench piezometers. Their findings support the previously stated conclusion that the ICM caps have only been effective in preventing bathtubbing for two cap areas, Caps 2 and 8. It is believed that in these two areas the caps significantly reduced the recharge area of the storm flow zone, thereby preventing infiltration to the bathtubbing trenches. Conversely, in other capped areas (most of which were constructed on hillslopes) bathtubbing conditions persisted although direct infiltration by precipitation was precluded by the caps. This indicates that storm flow does occur and should be addressed in closure alternatives intended to prevent bathtubbing.

Ashwood and Spalding (1990) also concluded that recharge to the shallow groundwater was not affected by placement of the caps. Shallow wells monitored still displayed responses to precipitation that are consistent with the range of pre-cap responses.

Ashwood and Spalding (1990) noted that in the Cap 8 area, only two trench wells (T44 and T63) displayed inundated conditions. They found that the lake and trench water elevations in these two trenches are the same, and that the trench water levels fluctuate proportionately with changes in lake stage in response to precipitation events (Fig. 3B.13). In these two cases, the trenches are slightly deeper than the average trench depth near WOL, and the trench bottoms are below the lake stage level of WOL. Other trenches located closer to WOL are typically less than 15 ft deep and would not be impacted by lake stage fluctuations because the trench bottoms are well above the 100-year flood stage elevation (754 ft). It is possible that there ma other deep trenches present in this area. Therefore, closure alternatives may need to address means of preventing interactions with the groundwater in these low-lying areas.

### 3B.2.3 Aquifer Geochemistry

Groundwater geochemistry data acquired either as part of the WAG 6 RFI or prior research indicates the groundwater at WAG 6 is stratified. Groundwater age-dating studies provide support of the geochemical stratification observed.

The combination of geochemical stratification and groundwater age dating results indicates there is little or no circulation or mixing between the shallow, active flow component and deeper, more stagnant groundwater zones. From these results, it is believed that active groundwater flow at WAG 6 is limited to the upper 150 to 170 ft of the aquifer.

#### 3B.2.3.1 Aquifer stratification

During the RFI, groundwater analytical data for samples from 86 WAG 6 wells or piezometers were evaluated to assess the aquifer geochemistry. Existing groundwater data from 40 piezometers were integrated with data from 46 groundwater samples collected and analyzed as part of the RFI. Samples were collected from all of the ORNL RCRA well pairs, the well 840/1234/1249 cluster, and the ETF-13/14/15 piezometer cluster, as well as all other WAG 6 RFI monitoring wells and selected ORNL interior site characterization monitoring wells. Table 3.B3 summarizes the data sources for existing WAG 6 groundwater geochemical data used. Figure 3B.14 shows the locations of all 86 wells.

Groundwater geochemical data were plotted on a trilinear diagram (Piper plot) and are presented as Fig. 3B.15. Further, plots of pH versus depth, specific conductance versus depth, and pH versus specific conductance were prepared and are presented as Figs. 3B.16, 3B.17, and 3B.18, respectively. There are apparent increases in pH and specific conductance with depth in the aquifer that appear directly related to the aquifer geochemistry. Specific conductance and pH form a linear relationship, both increasing with depth. Field measured pH was found to range up to 12.5, but a pH greater than 11 must be considered suspect. Dreier and Toran (1989) suggest that the elevated pH (i.e., above 9) are related to grout contamination. While this may be the case in the two HHMS wells where pH = 12.5, elevated pH values above 10 were observed in other than HHMS wells and in other locations within Melton and Bear Creek Valleys. It is unlikely that all of these wells are contaminated with grout. It is believed that with the exception of wells HHMS-5A and 6A and ETF-13, wells with pH of 9-11 are not grout contaminated, but reflect a natural evolution of groundwater. Details are provided in TM-06-09A, Groundwater Sampling Phase 1, Activity 2. Further, the elevated sodium and chloride concentrations observed in the two deep HHMS-series wells are far in excess of levels representative of grout, and are equivalent to concentrations reported for deep (i.e., > 600 ft deep) saline groundwater encountered in the hydrofracture rock cover wells elsewhere in Melton Valley.

As Fig. 3B.15 shows, the aquifer appears to be stratified into three distinct zones: a shallow, neutral to acidic, calcium-bicarbonate type water; an intermediate zone of alkaline (pH > 8.5) sodium-carbonate or bicarbonate water; and a deep zone of alkaline to neutral, sodium-chloride type water. The sodium-chloride chemistries are interpreted as representing

the upper extent of the deep saline groundwater component observed by Haase, Walls, and Farmer (1985) and Switek et al. (1985) in deep hydrofracture wells in Melton Valley. Further, concentrations of lithium, bromide, and fluoride are comparable to deep saline water chemistries.

Eighty-six percent of the wells studied are shallow and displayed the calcium-bicarbonate chemistries. As seen from Fig. 3B.15, some of the calcium-bicarbonate type waters show elevated percentages of magnesium. This is likely due to a localized increase in dolomite in the vicinity of these wells. The only two outliers to the observed stratification are wells HHMS-5C and RFI well 1244 (data points 49 and 17 on Fig. 3B.15, respectively). Well 1244 is located along the eastern drainage, screened below the water table in an area where depth to bedrock is very shallow (exposed in the stream bed), and potentiometric data indicate artesian conditions prevail at this location.

Groundwater from Well 1244 plots midway between the shallow calcium-bicarbonate and intermediate sodium-carbonate/bicarbonate chemistries. It is unclear whether the resulting geochemistry is indicative of either upward flow from depth (which is consistent with the both the recharge-discharge relationships discussed earlier and the artesian conditions observed) or mixing of shallow groundwater with potentially contaminated surface water. Similarly, groundwater from well HHMS-5C, the shallow well of this cluster (screened interval is from 42 to 62 ft), consistently plots outside the remainder of the data in all three fields of the trilinear diagram. As shown on Table 3B.2, upward vertical gradients are prevalent between the intermediate and shallow wells at this cluster. This suggests there is some mixing of intermediate and shallower groundwater at this location, due to either the indicated upward flow component; alternatively, it may be an artifact of well installation or related to interaction with WOL surface water.

By comparing the different water chemistries to screened interval (as shown in Fig. 3B.19 and summarized in Table 3.B), the transition between the shallow calcium-bicarbonate type water and the intermediate sodium-carbonate/bicarbonate water is seen to occur in WAG 6 at an elevation of approximately 665 ft. This transition can also be identified in borehole geophysical logs for several of the deep RFI wells for which high quality fluid resistivity borehole geophysical logs are available (TM-06-13A, Borehole Geophysical Logging). The transition between the intermediate zone and the underlying sodium-chloride type waters is observed only in the vicinity of WOL in wells HHMS-6A and 5A, and appears to occur at an elevation of 385 ft. The stratification observed is consistent with the findings of Webster and Bradley (1988) for groundwater elsewhere in Melton Valley. Geraghty and Miller (1990) and Haase and King (1988) observed similar stratification of groundwater in the Conasauga Group bedrock aquifer in Bear Creek Valley, although the transition depths between zones varied. These transitions are noted on all WAG 6 RFI hydrogeologic cross sections (Figs. 3A.6 through 3A.16). Depth to these transitions varies across the site owing to topographic relief. It is unlikely that the transitions are totally planar features; they probably fluctuate somewhat across the site perhaps mimicking the structural configuration of Melton Valley. The transitions are significant in that they appear to be distinct, indicating little or no circulation or mixing of waters between zones (except perhaps in the two wells

previously noted). Further, as can be seen in Figs. 3A.6 through 3A.16, the aquifer stratifications observed transect both structural and stratigraphic features. Groundwater geochemical zones are consistent across mapped thrust faults and the three distinct Conasauga Group formations underlying WAG 6. Dreier and Toran (1989) noted 1 to 2 orders of magnitude higher specific conductances for the deep HHMS A wells versus the shallower B and C wells. The increase in specific conductance with depth observed suggests a more highly mineralized groundwater at depth, which is usually related to higher residence time in the bedrock and/or longer flow path lengths.

Tritium is ubiquitous in the shallow groundwater at WAG 6 and within Melton Valley in general (Poreda, Cerling, and Solomon 1988). Therefore, tritium can be used as both a tracer for contaminant migration and for age dating because it moves at the same rate as groundwater. Dreier and Toran (1989) reported tritium concentrations near or below detection limits in the WAG 6 HHMS intermediate and deep wells. Tritium was not detected in the four deep RFI monitoring wells. Conversely, in the shallow flow system near waste disposal trenches, tritium has been reported in groundwater at levels ranging up to 10,000,000 pCi/L. Tritium was reported at 1243 pCi/L in well HHMS-4C, the shallow well of the cluster (which displayed calcium-bicarbonate chemistry indicative of the active flow system), but was not detected in the deeper wells in this cluster in spite of the downward vertical gradients indicated by potentiometric data. The overall lack of deep groundwater contamination by tritium further suggests that little or no circulation (or mixing) occurs between the different geochemical zones, and active flow is restricted to the uppermost parts of the aquifer.

### 3B.2.3.2 Heavy isotope studies and age dating

Dreier and Toran (1989) analyzed samples from WAG 6 wells HHMS-5A, -5B, -5C, -6A, -6B, and -6C for deuterium and oxygen-18 isotopes to fingerprint the aquifer flow components.[1] Generally, oxygen-18 and deuterium ratios decreased with depth indicating the groundwater is heavier at depth (the more negative values indicate lighter water and less negative values indicate heavier waters). The deep "A" wells, which displayed sodium-

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[1]The hydrogen and oxygen isotope values in groundwater are in general determined from the environment in which the groundwater recharged (entered the aquifer). Specifically, temperature, latitude, and elevation influence the isotope values. Thus, if these conditions are different for separate flow systems, the hydrogen and oxygen isotopes will fingerprint water from each system. The isotopes studied are deuterium ($^{2}H$ or D) and $^{18}O$, which have additional neutrons making them heavier than the more common isotopes, $^{1}H$ and $^{16}O$. Because the heavy isotopes occur in very small quantities, the $\delta$ notation is used to report isotope ratios:

$$\delta = ({}^{R}\text{sample}/{}^{R}\text{standard}^{-1}) \times 1000\ ^{o}/oo$$

where R is the ratio of the heavy isotope to the light isotope. The sample is reported as a ratio to standard mean ocean water (SMOW) for D and $^{18}O$). This ratio has 1 subtracted from it to make the standard value 0, and it is multiplied by 1000 to make the number larger and use units of per mil ($^{o}/oo$, analogous to percent).

chloride type chemistries, display subtle differences in isotopic signatures than the sodium-carbonate/bicarbonate type waters of the "B" and "C" wells. This suggests relatively stagnant, older waters. The deep wells showed deuterium ratios ranging from -23 to -27 o/oo (per mil; analogous to percent) and oxygen-18 ranging from -2.6 to -4.1 o/oo. Conversely, the "B" and "C" wells, which have sodium-carbonate geochemical signatures, showed deuterium ranging from -34.5 to -35 o/oo and oxygen-18 ranging from -5.5 to -6.1 o/oo. HHMS-5C, which displayed a geochemical signature indicative of mixing of intermediate and shallow water chemistries, and which has been shown to have upward vertical gradients, displayed deuterium results comparable to the other "B" and "C" well results but had the lowest oxygen-18 ratios (-6.1 o/oo).

The oxygen-18 and deuterium results further indicate that there is stratification between the intermediate and deeper water chemistries and suggest a subtle difference between the intermediate zone and shallow, active flow zone chemistry (although the shallowest well analyzed monitors an apparent mixing zone). However, no samples were analyzed from waters displaying calcium-bicarbonate chemistries indicative of the active flow component.

Tritium, with a half-life of 12.3 years, decays radioactively to helium, an inert gas. Consequently, the measurement of relative ratios of helium and tritium can be used to date groundwater. Poreda, Cerling, and Solomon (1988) sampled 13 WAG 6 wells (108, 109, 345, 347, 370, 371, 373, 374, 381, 382, 383, 386, and 388) in July and September 1986, and analyzed samples for tritium and helium to date the shallow (less than 126 ft deep) groundwater at WAG 6. Poreda, Cerling, and Solomon (1988) found that all groundwater samples analyzed ranged from 0.1 to 6.0 years in age, indicative of the very short residence times in the aquifer as well as the short flow path lengths. Since residence time is a function of depth and hydraulic gradient, WAG 6 groundwater was found to be younger in areas with higher hydraulic gradients and shallow depths and older (i.e., at the high end of the age range reported) in areas of low gradient and greater depths. Poreda, Cerling, and Solomon (1988) reported several wells that did not fit this trend but suggest that the lower residence times indicated by age dating results reflected localized zones of preferential flow.

Additional age dating of WAG 6 groundwater was performed by Solomon (1988) using tritium, helium and krypton-35 techniques. Samples from RAP piezometer 741 in the southwest corner of WAG 6 indicate the groundwater in that well is approximately 1.5 years old. This finding agrees with the results of the Poreda, Cerling, and Solomon (1988) study and further confirms the short residence times in the shallow, active flow component of the aquifer at WAG 6. Conversely, carbon-14/carbon-13 age dating (Toran et al. 1991) of deeper groundwater indicates this water at depth is very old (on the order of 10,000 to 40,000 years old), indicative of extremely long residence time and little movement.

### 3B.2.4 Aquifer Hydraulic Properties

As previously noted, considerable site characterization research has been conducted at WAG 6, much of which has contributed information regarding site aquifer hydraulic properties. Other studies within similar geologic settings in Melton and Bear Creek valleys

have provided further information. Within WAG 6, a total of 109 individual well slug tests, four tracer tests, and one pump test have been performed. Because of the extent of available information, aquifer testing was not conducted as part of the RFI. Rather, the existing data have been incorporated to form the basis of understanding of site hydraulic properties. Because of the nature of the geologic materials comprising the aquifer skeleton, aquifer properties vary between the regolith (soil and/or saprolite) and bedrock, and with depth. This section summarizes pertinent information regarding aquifer hydraulic properties. Table 3B.5 summarizes the aquifer hydraulic properties reported from available sources. Slug test hydraulic conductivities are tabulated in Appendix 3D.

### 3B.2.4.1 Soil hydraulic properties

As noted in Sect. 3B.2.2.3, in uncapped areas, precipitation tends to infiltrate into trenches either directly or via storm flow, creating "bathtubbing" conditions. Therefore, the infiltration rates of site soils are of significance in efforts to model the unsaturated zone. For purposes of comparison, infiltration rates and hydraulic conductivities are both presented in units of cm/sec.

Soil infiltration data have been collected at several locations within the ORR and Melton Valley. Moore (1988) reports that soil infiltration rates for the ORR range from 1.01E-2 to 2.31E-3 cm/sec (28.6 to 6.54 ft/d). Site-specific infiltration data for WAG 6 has been acquired by Davis et al. (1984) in the ETF area, and by Clapp (1990) for three 482-$ft^2$ test plots within SWSA 6. Their results, which showed infiltration rates lower than suggested by Moore, ranged from 1.8E-3 (Clapp, 1990) to 5.6E-6 (Davis et al. 1984) cm/sec (2.6 to 0.008 in./hr, respectively). Their site-specific data are within ranges reported by Luxmoore, Spalding, and Munro (1981) and Rothschild et al. (1984a) for undisturbed soils in similar geologic conditions at SWSA 5 and SWSA 7, respectively. The three-orders-of-magnitude range is not unexpected as soils vary widely as a result of both natural (such as degree or weathering, slope position, and vegetation) and demographic factors (such as soil removal, trenching, etc.). Soil macropores and mesopores together total only 0.2% of the soil volume but account for 96% of the infiltration (Watson and Luxmoore 1986).

Ammons et al. (1987) determined that the total porosity of WAG 6 soils ranges from 42 to 49%, which is within the 30 to 60% range reported by Davis et al. (1984) for undisturbed A and B-horizon soils in the ETF area. Both ranges reported are typical of clayey and silty clay soils. Davis et al. (1984) report a mean total porosity of 50% (0.5) for ETF area soils. They further suggest that in the 0 to 8-in. shallow soil interval, soil effective porosity is roughly equivalent to total porosity (i.e., effective porosity = 0.5) but for deeper soils, the effective porosity probably approaches 0.05 or less. The RCRA RFI Guidance (EPA 1989) suggests effective porosities of 0.01 to 0.15 (depending on degree of secondary porosity) could be expected for clayey and silty clay soils typical of WAG 6.

### 3B.2.4.2 Saprolite hydraulic properties

Because groundwater occurs in the saprolite over much of WAG 6, aquifer properties including hydraulic conductivity and effective porosity are important factors in assessing the rate of groundwater movement through the saprolite in the saturated zone. Physical properties of saprolite are also significant as the majority of waste disposal trenches terminate in saprolite in the unsaturated zone. Values for these properties for WAG 6 have been determined from slug test data and from several aquifer tests that have been conducted at WAG 6 within the saprolite portion of the regolith.

Of the 109 slug tests performed in WAG 6, 25 were conducted in the saturated saprolite. These tests determined that hydraulic conductivities range from 3.7E-3 to 9.61E-6 cm/sec, with a geometric mean hydraulic conductivity of 2.0E-4 cm/sec. Table 3B.6 summarizes the distribution of WAG 6 regolith hydraulic conductivity data from slug tests. Using the geometric mean hydraulic conductivity and mapped saturated thickness of the regolith from Fig. 3B.8, the transmissivity of the regolith ranges from 0 (where unsaturated) to 0.21 $cm^2$/sec (2.3E-3 $ft^2$/day).

The majority of the regolith slug tests were performed in saprolite derived from the underlying Nolichucky bedrock. From Table 3B.6 it can be seen that the saprolite formed from Nolichucky bedrock has a geometric mean hydraulic conductivity that is ten times that observed for saprolite derived from Maryville bedrock. This may be related to the nature of the host rock, in that the Maryville is more carbonate-rich and tends to weather to a clayey saprolite whereas the Nolichucky saprolite is more silty in nature.

Figure 3B.20 shows the distribution of hydraulic conductivity across WAG 6 by hydrogeologic unit. There is little difference between WAG 6 soil infiltration rates and hydraulic conductivities for the underlying saprolite.

From a tracer test conducted in 1976, the vicinity of the biological trenches near the southern boundary of WAG 6, Tamura et al. (1980) observed that initial and maximum tracer breakthrough occurred in an observation well downgradient to the injection well. Using tracer breakthrough time and known distance between the wells, an average linear velocity of 0.4 to 0.6 m/day and an effective porosity of 2% to 3% was calculated for the saprolite at this location. These values are consistent with the range reported in Webster and Bradley (1988).

Additional constant head tracer tests were performed in unsaturated saprolite at two test sites near the southwest end of the 49 Trench area (Dreier et al. 1987) adjacent to previously mapped exploratory trenches. Aquifer properties were not determined, but the tracer results showed strong asymmetric distribution in a preferred direction perpendicular to hydraulic gradient. The orientation of the tracer plume was found to be influenced by the intersection of mapped bedding plane fractures and extensional fractures, but did not approximate the vector sum of the bedding plane fracture orientations as expected. This suggests that flow in the regolith is controlled by a combination of secondary permeability features and

hydraulic gradient. These test sites were revisited later in 1987, and new tests were performed using improved techniques in somewhat deeper pits. Results indicated faster tracer travel times, with the highest tracer concentrations observed in strike-parallel observation wells. However, subsequent excavation of the test site to identify the structural fabric affecting the results revealed a tree root that had grown along and enlarged a relict fracture in the saprolite. This indicates the difficulties involved in confidently predicting groundwater flow paths in the regolith on a local scale. From a larger perspective, however, groundwater flow can be expected to be primarily gradient dominated with secondary control exerted by structural fabric.

### 3B.2.4.3 Bedrock hydraulic properties

There is virtually no primary matrix porosity in bedrock of the Conasauga Group; therefore, groundwater flow within bedrock is principally along secondary permeability features such as fractures and solution cavities. Consequently, aquifer properties determined from aquifer testing primarily describe the fracture network.

Sixty-eight slug tests performed in bedrock at WAG 6 revealed a consistent trend of decreasing hydraulic conductivity with depth, a trend unrelated to stratigraphy (Fig. 3B.21). WAG 6 bedrock hydraulic conductivities are summarized in Table 3B.7 and are presented on Fig. 3B.20, and are also included on the WAG 6 hydrogeologic cross sections (Figs. 3A.7 through 3A.10). The slug test results show that hydraulic conductivity for the bedrock as a whole at WAG 6 ranges from 1.85E-3 to 1.90E-9 cm/sec, with a geometric mean of 3.1E-5 cm/sec. Davis et al. (1984) calculated a hydraulic conductivity of 2.08E-4 cm/sec from tracer test results at the ETF site, of WAG 6 hydraulic conductivity range derived from slug test data.

Little difference can be seen between geometric mean hydraulic conductivities for Nolichucky and Maryville bedrock although Maryville bedrock, appears to exhibit a wider range of values. As Fig. 3B.18 and 3B.19 show, hydraulic conductivities vary several orders of magnitude at any given depth as well as laterally. Both formations display a decrease in hydraulic conductivity with depth. This decrease is related to the depth of active circulation of groundwater and the density of open fractures. As noted previously, Dreier and Foreman (1990) report that two systems of fractures exist in Melton Valley—an older tectonic system that generally occurs below depths of 150 ft and a younger system. The older, deeper system is characterized by abundant healed fractures; the younger system generally occurring at depths less than 150 ft, contains more open fractures (formed in response to erosional unloading). Therefore, the decrease in hydraulic conductivity with depth reflects this transition from younger to older fracture systems. Active groundwater flow is limited to depths less than 150 ft; groundwater flow is increasingly precluded with depth.

Results of a tracer test in shallow Maryville bedrock the ETF area showed initial tracer breakthrough as well as peak concentrations in a direction along strike. However, although the highest tracer concentration was detected along strike from the injection well, it was not detected in the nearest along-strike well (Vaughan et al. 1982). It was found that tracer

patterns were controlled by a combination of matrix porosity and, principally, by strike parallel fractures associated with two sharp anticlinal structures trending approximately along formation strike. This suggests that primary flow in groundwater at WAG 6 is along fractures, but bulk transport via intergranular flow is also a factor. Fractures are important and dominate quick movement, but volumetrically, fractures are less significant than the surrounding rock matrix.

Similar patterns of drawdown were observed in observation wells during a pump test in the same ETF area. Smith and Vaughan (1985) analyzed the pump test data using nonradial solutions and calculated a geometric mean transmissivity of 1.35 $m^2$/day, with a strike-parallel transmissivity five times that of the strike-perpendicular transmissivity (i.e., 5:1 anisotropy). Webster and Bradley (1988) have observed results of pump tests for deep (100-200 ft) Maryville bedrock wells elsewhere within Melton Valley and have reported transmissivities that are up to five orders of magnitude lower than those reported for WAG 6. Storativity ranged from .01 to .001, with a geometric mean storativity of .005. Anisotropy has been reported to range from 3:1 to 23:1 (Kx:Ky) elsewhere in Melton Valley. Combining the results of the slug tests, pump tests, and tracer tests at the ETF site, Davis et al. (1986) calculated an effective porosity of 0.03 for the shallow Maryville bedrock at this location.

Interestingly, results of aquifer testing in both the regolith (saprolite) and shallow bedrock of WAG 6 indicate effective porosities of the same magnitude ($n_e$ =.03). Moore (1988) suggests effective porosity is expected to be orders of magnitude lower at greater depths owing to a decreased density of open fractures. Because those values were empirically derived from actual WAG 6 aquifer testing data, it is believed the values are representative.

The transmissivities, storativities, and effective porosities reported indicate a low-yield aquifer with limited storage capacity principally related to fractures. Although the Conasauga Group bedrock aquifer does supply a few area domestic wells, the hydraulic conductivity of the aquifer is generally too low to encourage extensive use as a water-supply aquifer.

No pump tests were performed in the Nolichucky bedrock within WAG 6. However, Smith and Vaughan (1985a, 1985b) and Law Engineering, Inc. (1983) have reported on aquifer tests performed in similar bedrock in areas of Bear Creek Valley. They separate studies found comparable results in terms of response to pumping and parameter values.

Using aquifer data measured at the ETF site (specifically, transmissivity determined from Theis radial solutions), Davis et al. (1984) calculated an aquifer thickness of roughly 220 ft (where, saturated aquifer thickness is equal to transmissivity/hydraulic conductivity). Substituting the (nonradial) geometric mean transmissivity of Smith and Vaughan (1985a, 1985b), the aquifer appears to be on the order of 81 ft thick. This latter thickness is consistent with the depth of active groundwater flow indicated from the geochemical results.

An earlier pump test attempted at the ETF site was terminated because the pumping rate (1.7 gpm) was too high and rapidly dewatered the fracture system. A subsequent successful pump test required pumping at a rate of less than 0.9 gpm. The nonradial responses to pumping, somewhat unpredictable tracer responses, and low pumping rates reflects the complexity of the aquifer system.

### 3B.2.5 Groundwater Flow

The portion of precipitation that is not accounted for by surface runoff or evapotranspiration infiltrates into the subsurface and follows complex pathways in both the unsaturated and saturated zones, as described below. Figure 3B.22 illustrates combined unsaturated and saturated flow paths at WAG 6.

#### 3B.2.5.1 Unsaturated zone flow

Except in areas of SWSA 6 where wastes are in direct contact with the water table, a portion of the contaminant travel pathway occurs in the unsaturated zone. Due to the "bathtubbing" effect discussed earlier, contaminated fluids exiting waste disposal trenches or auger holes are generally under positive pressure. Thus the downward hydraulic gradients will cause much of the existing contaminated water to be delivered to the water table, although some of the water would move down inclined surfaces (such as bedding planes) to discharge to streams or swales, or as seeps. In intersecting the water table, flow in trenches or along a series of trenches may vary from flow in the intervening area between trenches as water particles would move along the trench and exit at any point of lower head along the trench bottom and/or sidewalls (Webster and Bradley 1988). Once exiting the trench, contaminated fluids flow through the unsaturated zone following discrete but established features such as fractures, relict bedding planes, and soil fragipan horizons (Ammons et al. 1987). Unsaturated flow is generally transient and therefore is slower than flow under saturated conditions. This allows for more contact between fluids and geologic materials, and contaminant retardation (i.e., related to sorption processes) is increased (Ammons et al. 1987).

Where prevalent at WAG 6, flow along the storm flow zone would follow surface topography. Storm flow paths are consequently short, on the order of 160 to 330 ft from points of infiltration to discharge at streams or seeps (Moore 1988). Also, because storm flow is transient, perched water in the storm flow zone will infiltrate downward in the unsaturated zone all along the storm flow path during and after precipitation events.

#### 3B.2.5.2 Saturated zone flow

Although the groundwater at WAG 6 is a continuum from the regolith to depth in bedrock, groundwater flow is complex, as these geologic materials comprising the saturated zone (i.e., regolith and bedrock) are distinctly different.

Groundwater flow in the regolith occurs through porosity (resulting from weathering) and along fractures and relict bedrock structures, which may be either locally enhanced by solution enlargement or occluded due to clay plugging or precipitation of iron and manganese oxides. Groundwater flow in the regolith is largely gradient dominated, particularly in the upper more weathered portion of the regolith, where the degree of weathering is greater and the regolith behaves more like an isotropic media. Anisotropy increases with depth in the regolith as the degree of weathering decreases and the significance of relict bedrock structural fabric becomes more prevalent. Nonetheless, Webster and Bradley (1988) suggest that anisotropy in the regolith is probably not great enough to impair flow rate and directions on a larger scale using hydraulic gradients derived from potentiometric mapping.

Conversely, due to the lack of primary matrix porosity, groundwater flow in the unweathered bedrock is principally along secondary permeability features such as fractures, solution cavities, and possibly, faults. Bedrock flow paths are associated principally with strike-parallel bedding plane fractures (trending generally east-west across the site) or with the intersection of bedding plane fractures with other conjugate fracture sets. As explained in Appendix 3A, up to five distinct fracture sets have been identified in WAG 6 bedrock.

Whereas flow in the regolith is generally controlled by the hydraulic gradient and follows topography, groundwater flow in bedrock is strike-parallel and along bedding, except where crossing secondary fractures with different orientations and lower heads. The result is a tortuous, stair-stepping flow path in three dimensions that may vary with depth (Webster and Bradley 1988).

Depending on the local orientation of fractures and the hydraulic gradient, bedrock groundwater flow may occur directly between two points. However, features that control flow in the bedrock (folds, faults, fractures) are so variable laterally that flow prediction between two points cannot be determined precisely.

Small-scale folds, such as those identified in the ETF area at WAG 6, have been shown to effect significant control on flow direction and rate, generally owing to the increased hydraulic conductivity associated with these features. Depending on orientation, other such features present but not identified at WAG 6 may serve as either conduits or impediments to strike-parallel flow (Boegly et al. 1985).

Groundwater flow at WAG 6 is local rather than regional and appears to occur predominantly in the shallow subsurface, where groundwater flow follows short flow paths from points of recharge to points of discharge, all within WAG 6. Groundwater discharges to nearby intermittent streams, which ultimately discharge to WOL (Webster and Bradley 1988; Lomenick and Wyrick 1965). However, along the southern boundary of WAG 6, surface and groundwater flow is directly to the lake (Boegly et al. 1985). Moore (1988) suggests the shallow flow system has flow paths on the order of 1300 ft long, while Webster and Bradley (1988) report the maximum flow path length in the deeper aquifer is 3300 ft long.

Three conceptual groundwater flow diagrams were constructed across WAG 6 using potentiometric data for February 1990 (Figs. 3B.23, 3B.24, and 3B.25). Two of the flow diagrams are oriented north-south across the site while the third is oriented east-west across WAG 6. The two north-south flow diagrams, A-A' and C-C', show discharge to WOL and shallow flow from points of recharge in WAG 6. The east-west flow diagram, F-F', demonstrates that within WAG 6, flow is local with discharge to drainages within or adjacent to WAG 6. USGS modeling results further support the conclusion that groundwater flow is towards the intervening streams (Tucci 1984). The conceptual flow diagrams illustrate the recharge/discharge relationships observed in individual well pairs or clusters across WAG 6.

Conceptual flow diagram C-C' is somewhat more complex due to the inclusion of potentiometric data for the three deep HHMS-series wells (HHMS-4A, -5A, and -8A), which have not yet reached equilibrium following their installation. The flow diagram as drawn implies flow towards these wells. However, the low hydraulic conductivities reported for these wells, coupled with aquifer geochemical results, suggest there is minimal flow at these depths. As these wells continue to recover, the effects are expected to diminish.

Pressure tests conducted in the Conasauga Group in Melton Valley indicate secondary openings in bedrock are limited to the upper 100 ft of bedrock, restricting active flow to this interval (Webster, 1976; Lomenick and Wyrick, 1965). Further, USGS modeling efforts to date (Tucci 1991) suggest 90% to 98% of all groundwater flow at WAG 6 occurs in the upper 50 to 100 ft of the aquifer, with virtually no flow occurring below 250 ft. From site characterization data presented in this report, a preponderance of evidence exists to indicate that active groundwater flow is limited to the upper 150 ft of the aquifer.

- Geochemical data indicate the aquifer at WAG 6 is distinctly stratified, suggesting little or no circulation occurs between zones. These data indicate the shallow active flow system is limited to the upper 150-170 ft of the aquifer.
- Groundwater age dating results show that shallow groundwater is young, on the order of 0.1 to 6.0 years, which indicates short residence times and short flow paths. Within the range given, the age increased with depth. This suggests that most active groundwater circulation occurs at shallow depths.
- Heavy isotope data suggest deeper groundwater is older and relatively stagnant.
- Hydraulic conductivities decrease dramatically with depth such that active circulation at depth is improbable.
- Hydrographs suggest only shallow wells show demonstrable response to precipitation.
- Tritium analytical results for wells at WAG 6 show a lack of tritium contamination below a depth of 100 ft further supporting a lack of active circulation at depth.

Some vertical flow component is possible, as indicated by the vertical gradients discussed previously. However, topographic relief at WAG 6 is great enough to induce virtually all of WAG 6 recharge to remain in the shallow, local flow system. Therefore, if deep flow does occur within WAG 6, it probably involves only a very small fraction of WAG 6 groundwater (Boegly et al. 1985).

As shown in Fig. 3B.8, during the wet season the water table occurs in the regolith over most of the southern half of WAG 6, and below the regolith/bedrock interface in the shallow bedrock in much of the northern half of the site. During the dry season, the area of regolith saturation decreases and groundwater flow through bedrock is more significant. Likewise, hydraulic gradients decrease during period of seasonal low water table conditions. Therefore, groundwater flow rates calculated from seasonal high water table potentiometric data represent maximum expected flow rates and provide a conservative estimate of groundwater discharge from WAG 6. Groundwater flow velocities during low water table conditions would be somewhat less.

Flow directions and rates in saturated regolith and upper bedrock to a depth of 100 ft are the product of hydraulic gradient and the orientation, density, and interconnection of fractures. While it is accepted that strike-parallel flow dominates, it can be assumed that, to a depth of 65 ft in bedrock, flow is in the direction of hydraulic gradient, as determined from a water table potentiometric map (ORNL 1990).

To provide an estimate of groundwater flow rates in both saturated regolith and bedrock in various areas of WAG 6, average linear groundwater velocities (or seepage velocities) were calculated along 20 major and secondary flowlines labeled A through J, as shown on Fig. 3B.26. Average linear velocity was determined by:

$$\text{Velocity} = \frac{\text{(hydraulic conductivity x hydraulic gradient)}}{\text{effective porosity}}$$

An effective porosity of 0.03 was used for both regolith and bedrock as equivalent values were obtained from aquifer testing conducted in the regolith and bedrock within WAG 6. Geometric mean hydraulic conductivities for regolith or bedrock were determined by using the appropriate hydraulic conductivities along or near each flowline from Fig. 3B.26. The hydraulic gradient was determined from the February 1990 potentiometric map (Fig. 3B.2). In areas where mapping indicates flow is solely in the shallow bedrock, only bedrock velocities are calculated. Conversely, in areas where mapping indicates saturated regolith conditions exist, flow rates were determined for both hydrologic units. The resulting average linear velocities are summarized on Table 3B.8.

As shown on Table 3B.8, groundwater flow rates in the regolith range from 0.10 m/day (flowline $B_1$) to 2.28 m/day (flowline $C_2$). The overall geometric mean linear velocity for the regolith is 0.33 m/day (386 ft/year) This value compares well with the average mid-season flow rate of 0.25 m/day (Webster and Bradley 1988) and the WAG 6 tracer test flow rate of 0.40 to 0.60 m/day (Tamura et al 1980). The tracer test was conducted in the area of flowline $I_2$, where the average linear velocity was determined to be 0.31 m/day.

Average linear velocities calculated for the shallow bedrock ranged from 0.04 m/day (flowline F) to 0.49 m/day (flowline $J_2$). The overall geometric mean linear velocity for the shallow bedrock is 0.15 m/day (180 ft/year). This value compares well with the 0.18 m/day flow rate from the tracer test performed in the ETF area (Davis et al. 1986).

As shown on Table 3B.8, flow velocities in the regolith are approximately twice those in the bedrock, owing to the order of magnitude difference in hydraulic conductivities between the two hydrologic units. However, flow in the bedrock actually may be considerably faster or slower than the velocities shown, because flow in bedrock follows tortuous paths and rates between two points are not directly proportional to the heads measured at any two points (Moore 1988). In areas where hydraulic gradient direction is parallel to strike, flow rates may be significantly faster than areas where the hydraulic gradient is normal to strike, because in the latter case flow paths would be longer and more tortuous.

Groundwater flow in deeper portions of the aquifer in WAG 6 is estimated to be towards the south or southeast based upon mapping using WAG 6 deep well potentiometric data (Fig. 3B.27). As explained earlier, flow rates through deeper bedrock in the active zone of circulation would be slower because longer flow paths, lower hydraulic gradients, and increasing confinement with depth.

## 3B.3 SUMMARY OF FINDINGS REGARDING GROUNDWATER HYDROLOGY

Key findings and conclusions regarding the groundwater hydrology at WAG 6 from previous discussions are presented below.

### 3B.3.1 Groundwater occurrence and flow

- In the saturated zone groundwater occurs as an unconfined, water table aquifer in the regolith and/or shallow bedrock. No major aquicludes or confining layers are present; groundwater is a continuum from the water table to depth in bedrock.

- Localized perched water and transient storm flow occur in the unsaturated zone. Transient storm flow does occur at WAG 6 as evidenced by continued trench bathtubbing beneath ICM capped areas. However, the storm flow zone is highly variable and likely discontinuous at WAG 6 due to considerable removal or reworking of surficial soils, the lack of vegetative cover, ICM capping over approximately 15% of the site, and other physical features on site including the 49 Trench French Drain, numerous wells and piezometers and the waste disposal trenches. Transient storm flow paths are short, from point of infiltration to discharge along streams or seeps all within WAG 6.

- Potentiometric mapping shows the hydraulic gradient mimics topography, indicating groundwater flow towards WAG 6 surface water features and overall, in a southerly direction towards WOL.

- Groundwater flow diagrams (analogous to flownets) indicate groundwater flow is local rather than regional whereby groundwater follows short flow paths within WAG 6, flowing from higher elevation points of recharge to discharge along intervening surface water drainages.

- Vertical gradients have been identified in well pairs and clusters, but WAG 6 topographic relief is great enough to induce virtually all of WAG 6 recharge to remain in the shallow, local flow system.

- Hydraulic conductivity in the regolith or bedrock varies several orders of magnitude laterally and at any given depth, but shows a marked decrease with depth. The decrease in hydraulic conductivity is related to the decreasing density of open fractures with depth.

- Aquifer testing results indicate the bedrock aquifer is a low yield aquifer (less than 1 gpm) with limited storage capacity principally related to fractures; well yields are generally too low to encourage use as a potable water supply.

- Aquifer testing (pump and tracer tests) in bedrock showed considerable non-radial, anisotropic response which illustrates the difficulty in predicting groundwater flow between two points with confidence.

- The USGS modelling results indicate 90 to 98% of all groundwater flow at WAG 6 occurs in the upper 50 to 100 ft of the aquifer, with virtually no flow occurring below 250 ft. A preponderance of evidence exists which supports these results, including:

  - Geochemical data indicate the groundwater is distinctly stratified into three groundwater geochemical types. This stratification suggests little or no mixing of shallow and deep groundwater occurs and that active groundwater flow is limited to depths less than 150 ft.
  - Age dating and heavy isotope data support the geochemical stratification and suggest that active groundwater flow is limited to shallow depths. Shallow groundwater dating shows residence times (0.6 to 6 years) which supports a localized flow system concept. Carbon-14 dating of deeper groundwaters below 180 ft deep indicates these waters are considerably older (several thousand years old) and largely stagnant.
  - The lack of tritium, the most ubiquitous and mobile WAG 6 contaminant, in groundwater below a depth of 100 ft supports the conclusion that active groundwater flow is shallow.
  - The decreasing hydraulic conductivity with depth limits active flow to depths less than 150 ft and precludes groundwater flow at depth.

- Groundwater flow in the regolith, where saturated, is through a combination of primary matrix porosity and relict secondary features and generally is expected to follow mapped hydraulic gradient on a larger scale. However, the degree of anisotropy increases with depth in the regolith in proportion to degree of weathering. Consequently, there remains some uncertainty in predicting local groundwater flow between two points.

- Due to the lack of primary matrix porosity in the indurated bedrock, groundwater flow occurs along secondary permeability features, principally fractures. Principal

groundwater flow directions in bedrock follows strike parallel and bedding plane fractures except where crossing secondary fractures with different orientations and lower heads. The result is a tortuous, stair-stepping flow path in three dimensions.

- Flow directions and rates in the saturated regolith and upper bedrock are controlled by a combination of the hydraulic gradient, and the orientation, density, and degree of interconnecting fractures. While strike parallel flow dominates in the bedrock, it can be assumed that on a larger scale, to a depth of approximately 65 ft in the bedrock, flow is in the direction of hydraulic gradient as determined from potentiometric mapping. Nonetheless, there is considerable uncertainty in predicting flow accurately between two given points at WAG 6.

- Groundwater flow rates (average linear velocities) in the regolith range from 0.10 m/day to 2.28 m/day with an overall geometric mean linear velocity of 0.33 m/day (386 ft/year). Flow rates in the shallow bedrock range from 0.04 to 0.49 m/day with a geometric mean linear velocity of 0.15 m/day (180 ft/year). The difference is largely related to the order of magnitude difference in hydraulic conductivities between the two.

### 3B.3.2 Existing remedial measures performance

- The 49 Trench area French Drain installed in late 1983 has been effective in intercepting groundwater and lowering the water table below trench bottoms over portions of the 49-Trench disposal area. Minimal (i.e., intermittent, $<1.0$ gpm) discharges to surface water occur from the north limb of the drain, but sustained direct discharge to surface water drainage area DA occurs at rates ranging from 0.3 to 20 gpm.

- Comparing pre- and post-ICM capping maps, the construction of ICM caps 4, 5, and 6 have apparently had little effect on dewatering trenches or preventing bathtubbing and/or inundation of the trenches. Ashwood and Spalding (1990) report that ICM caps 2 and 8 are effective due to significant reduction of the storm flow recharge area upgradient of the trench areas. The individual caps have had no effect on the shallow water table levels.

- Trenches greater than 15 ft deep adjacent to WOL are inundated and fluctuate directly with lake stage elevations. Shallower trenches are apparently unaffected by lake level fluctuations.

# Appendix 3B Tables

**Table 3B.1. Summary of existing wells and piezometers identified at WAG 6**

| Date installed | No. of wells installed | Description | No. of wells still existing | Identification of wells still existing | Source |
|---|---|---|---|---|---|
| 1954 | 28 | 6 5/8" perforated, corrugated steel pipe to depths of 20'; open from surface to TD. | 4 | 284, 295, 305, 310 | Webster et al. 1981 |
| 1956 | 4 | 5 1/2" steel cased open hole completion wells to 126'; generally 80' open hole interval. | 3 | 107, 108, 109 | Webster et al. 1981 |
| 1964-76 | 50 | 6 5/8" perforated, corrugated steel pipe to depths of 24'; open from surface to TD. | 9 | 317, 318, 343, 345, 351, 356, 362, 363, 365 | Lomenick & Wyrick 1965 |
| 1976 | 12 | 4" PVC Tracer test piezometers to depths up to 47'. | 5 | TR-03, -04, -05, -07, -09 | Tamura et al. 1980 |
| 1977-78 | 22 | 3" PVC to depths up to 69'. | 17 | 367 through 71, 374 through 83, 385 through 86. | Webster et al. 1980 |
| 1975-84? | 30 | 2" and 3" PVC or SS installed by ORNL. | 25 | 389-405, 403A, 404A, 405A, S-8, S-11, EXP-4, EXP-5 | Solomon et al. 1988; Spalding 1990 |
| 1982-84 | 63 | 3" and 6" PVC piezometers to depths of 240' associated with ETF characterization. | 26[a] | ETF-1 through -18, -20, -22, -27, -29, -36, -39, -40 | Davis et al. 1984 |
| 1983 | 28 | 3" PVC French Drain piezometers. | 20 | 0+54, 1+33, 1+53, 1+85, 2+02, 2+26, 2+51, 3+03, 3+52, 3+76, 4+01, 4+27, 4+58, 4+77, 5+04, 5+77, 5+50, 5+77, 6+16, 7+81 | Davis and Stansfield, 1984 |
| 1986 | 13 | 3" PVC piezometers associated with TARA characterization study. | 13 | TARA-1 through -13 | Davis et al. 1987 |
| 1986 | 25 | 2" PVC (and two SS) RAP piezometers. | 25 | 636 through 655, 739 through 741 | Mortimore 1987 |

**Table 3B.1 (continued)**

| Date installed | No. of wells installed | Description | No. of wells still existing | Identification of wells still existing | Source |
|---|---|---|---|---|---|
| 1987 | 30 | 2" and 4" SS RCRA Groundwater Quality Monitoring Wells. | 30 | 745, 831 through 860 | Mortimore and Ebers 1988 |
| 1987 | 6 | 3" PVC Tumulus I Pad monitoring wells. | 5 | 1036 through 1040 | Morrissey 1990 |
| 1988 | 10 | 2" PVC IWMF area piezometers, 5 to 15' deep. | 10 | T-1, -5, -7, -10, -17, -18, -20, -22, -27, -36 | Morrissey 1990 |
| 1986-88 | 12 | 4" and 6" carbon steel casings with 20' open hole completions; installed as four 3-well clusters to depths of 400'. | 12 | HHMS-4A, -4B, -4C, -5A, -5B, -5C, -7A, -7B, -7C, -8A, -8B, -8C | Dreier and Toran 1989 |
| 1989-90 | 22 | 2" and 4" WAG 6 RFI RCRA-quality Monitoring Wells. | 22 | 1225 through 1245, 1249 | BNI 1990b; TM-06-08A |
| ? | 600?<br>955 | Intra- and inter-trench piezometers. | 72<br>226 | (see Appendix A) | various |

[a]A high number of ETF wells still exist, but only 26 were identified in the field.

SS - Stainless Steel Screen and Riser.
PVC - Polyvinyl Chloride Screen and Riser.

**Table 3B.2. Summary of Vertical Gradients for WAG 6 Well Pairs**

| Well Pair | Position | Head Difference (ft) | Gradient Direction | Vertical Gradient (ft/ft) |
|---|---|---|---|---|
| 745*/833 | D | 1.24[a] | UP[a] | 0.044[a] |
| 831/832* | R | 0.87[a] | UP[a] | 0.094[a] |
| 838/839* | H/D | 0.10[a] | DOWN[a] | 0.003[a] |
| 841*/842 | H/D | 3.78[a] | DOWN[a] | 0.120[a] |
| 843/844* | H | 6.28[a] | DOWN[a] | 0.230[a] |
| 855/856* | R/H | 0.49[a] | UP[a] | 0.008[a] |
| 857/858* | R | 0.84[a] | DOWN[a] | 0.023[a] |
| 859/860* | H/R | 0.91[a] | UP[a] | 0.028[a] |
| 840/1249* | H/D | 2.8[b] | UP[b] | 0.065[b] |
| 1249/1234* | H/D | 7.35[b] | UP[b] | 0.098[b] |
| 1237/1238* | R/H | 4.44[b] | DOWN[b] | 0.049[b] |
| ETF-14*/ETF-15 | R | 0.82[c] | DOWN[c] | 0.017[c] |
| ETF-14/ETF-16* | R | 1.14[c] | DOWN[c] | 0.007[c] |
| HHMS-4B*/HHMS-4C | R | 0.93[c] | DOWN[c] | 0.005[c] |
| HHMS-5B*/HHMS-5C | D | 4.57[c] | UP[c] | 0.029[c] |
| HHMS-7B*/HHMS-7C | H | 9.04[c] | DOWN[c] | 0.005[c] |
| HHMS-7A*/HHMS-7B | H | 2.34[c] | DOWN[c] | 0.022[c] |
| HHMS-8B*/HHMS-8C | H | 2.44[c] | DOWN[c] | 0.020[c] |

*Indicates deep well of pair (e.g., 745*).

[a]Based upon average of water level measurements recorded during quarterly sampling and other sampling performed from 6/88 through 6/90.
[b]Based upon average of water level measurements recorded during 5/90 and 6/90 sampling events.
[c]Based upon water level measurements collected 2/21/90.

R = Well pair located in apparent recharge zone relative to topographic and potentiometric setting.
D = Well pair located in apparent groundwater discharge zone.
H = Well pair situated in hillslope position reflecting transition between inferred groundwater recharge and discharge zones.

**Table 3B.3. Historical sources of WAG 6 groundwater geochemistry data**

| Wells | Data source |
|---|---|
| HHMS-4A, -4B, -4C, -5A, -5B, -5C, -6A, -6B, -6C, -7A | Dreier & Toran 1989, ORNL RAP data base |
| ETF -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12 | Davis et al. 1987 |
| T -1, -7, -10, -17, -18, -20, -36 | Morrissey 1990 |
| TARA-3, -4, -6, -8, -9, -10, -11, -12 | Davis et al. 1989 |
| 367, 646 | Davis et al. 1989 |
| S-11 | Solomon et al. 1988 |

Table 3B.4. Summary of WAG 6 aquifer geochemistry

| Well No. | Water Type | Screen Depth (ft) | Screen Elevation (ft) | Monitored Zone |
|---|---|---|---|---|
| All Others[a] | Calcium-Bicarbonate | <100 | >665 | 1,2,3,4,5,6 |
| 1234 | Sodium-Carbonate/Bicarbonate | 126-146 | 629-649 | 5 |
| 1236 | Sodium-Carbonate/Bicarbonate | 139-159 | 645-665 | 2 |
| 1239 | Sodium-Carbonate/Bicarbonate | 132-152 | 633-653 | 5 |
| HHMS-4A | Sodium-Carbonate/Bicarbonate | 380-400 | 390-410 | 5 |
| HHMS-4B | Sodium-Carbonate/Bicarbonate | 174-215 | 573-614 | 2 |
| HHMS-5B | Sodium-Carbonate/Bicarbonate | 196-219 | 547-570 | 2 |
| HHMS-6B | Sodium-Carbonate/Bicarbonate | 275-295 | 467-487 | 2 |
| HHMS-6C | Sodium-Carbonate/Bicarbonate | 158-178 | 584-604 | 2 |
| HHMS-7A | Sodium-Carbonate/Bicarbonate | 380-400 | 409-429 | 7 |
| ETF-13 | Sodium-Carbonate/Bicarbonate | 241-251 | 559-569 | 5 |
| HHMS-5A | Sodium-Chloride | 380-400 | 367-387 | 2 |
| HHMS-6A | Sodium-Chloride | 380-400 | 364-384 | 2 |

Monitored Zone Key
1 Nolichucky Regolith
2 Nolichucky Bedrock
3 Nolichucky Regolith/Bedrock
4 Maryville Regolith
5 Maryville Bedrock
6 Maryville Regolith/Bedrock
7 Rogersville Bedrock

[a]This includes wells: 1225, 1227, 1228, 1229, 1231, 1233, 1237, 1238, 1240, 1241, 1242, 1243, 1244, 1245, 1249, 745, 831, 832, 833, 838, 839, 840, 841,, 842, 843, 844, 845, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 859, 860, HHMS-4C, HHMS-5C, ETF-1 thru ETF-12, ETF-14, ETF-15, T-36, T-20, T-18, T-17, T-10, T-7, T-1, TARA-3, TARA-4, TARA-6, TARA-8, TARA-9, TARA-10, TARA-11, TARA-12, 367, 646, 5-11.

| | Unit | Davis et al. 1984 | Ammons et al. 1987 | Tamura et al. 1980 | Law 1983 | Sledz and Huff 1981 | Smith and Vaughn 1985[a, b] | Davis et al. 1987 | Moore 1988 | Pored 19 |
|---|---|---|---|---|---|---|---|---|---|---|
| **I. SOILS** | | | | | | | | | | |
| Infiltration Rate (K) | cm/sec | $3.5^{-5}$ to $6.0^{-6}$ b<br>Geom. Mean = $1.56^{-5}$ | — | — | — | — | — | — | $1.10^{-2}$ to $2.31^{-3}$ | |
| Total Porosity | — | .30 - .60[b] | .42 - .492[a] | — | — | — | — | — | — | — |
| Effective Porosity (ne) | — | 0.5 | — | — | — | — | — | — | | |
| **II. SAPROLITE** | | | | | | | | | | |
| Hydraulic Conductivity (K) | cm/sec | $2.0^{-5}$ | — | — | — | — | — | $3.53^{-4}$ to $3.53^{-5}$<br>$5.3^{-5}$ (for N/2 or WAG-6)[l]<br>$2.1^{-4}$ (for near W.O.L)[l] | $4.76^{-6}$ | |
| Total Porosity | — | .30 - .60 | 0.2 - 0.54[a] | — | — | — | — | — | — | — |
| Effective Porosity (ne) | — | <.05 | — | 0.02 - 0.03[h] | — | — | — | — | — | — |
| Average Linear Velocity | m/day | — | — | 0.4 - 0.6[h] | — | — | — | — | — | — |
| Transmissivity (T) | $m^2$/Day | — | — | — | — | — | — | — | — | — |
| **III. BEDROCK** | | | | | | | | | | |
| Hydraulic Conductivity (K) | cm/sec | $2.08^{-4}$ c<br>$6.31^{-5}$ d | — | — | — | — | — | — | $4.74^{-5}$ to $5.1^{-7}$ | $3.33^{-4}$ to 5.<br>$1.8^{-3}$ to 9.7 |
| Transmissivity (T) | $m^2$/Day | 1.8 to 6.28[e]<br>Mean = 3.65<br>0.46 to 2.02<br>(Matrix Only) | — | — | 0.32[p] | — | 1.35 Cmr Geom Mean[j]<br>3.0 Cmr (along Strike)[j]<br>0.6 Cmr ( to Strike)[j]<br>3.11 Cnl (along Strike)[k]<br>1.03 Cnl ( to Strike)[k] | — | — | — |
| Storativity (S) | — | $3.34^{-4}$ to $3.0\text{-}2^{e}$<br>(Mean = $1.0^{-2}$) | — | — | .003[p] | — | $5.0^{-3}$ (Geom. Mean)[i]<br>$1.0^{-2}$ to $1.0^{-3}$<br>$1.1^{-3}$ (Geom. Mean)[k] | — | $1^{-2}$ to $1^{-6}$<br>.0025[o] | — |
| Effective Porosity (ne) | — | 0.007 Fractures[c]<br>0.10 Bulk Matrix[c]<br>0.03[f] | — | — | .002[p] | .0007[r] | — | — | .0005 to .00001<br>.0025[o] | — |
| Anisotropy | KxKy | — | — | — | — | — | 5:1[j]<br>3:1[k] | — | 2.3:1 | — |
| Dispersivity | meters | — | — | — | 10[p] | — | — | — | — | — |
| Average Linear Velocity | m/day | — | — | — | — | — | — | — | — | — |
| Intrinsic Permeability | $m^2$ | $1.4^{-12}$ to $2.8^{-12}$<br>(Fractures)<br>$1.0^{-14}$ to $2^{-14}$<br>(Bulk Matrix) | — | — | — | — | — | — | — | — |
| Aquifer Thickness | m | 67[e] | — | — | — | — | 24.76[g] | — | — | — |
| | ft | 220[e] | — | — | — | — | 81[g] | — | — | — |

a Based on water retention data from seven A&B horizon soil samples from test pits within SWSA-6.
b From undisturbed soil samples at the ETF site.
c Derived from tracer test in Maryville bedrock at the ETF site within WAG 6.
d Mean K from slug tests performed in Maryville bedrock in ETF site wells, WAG 6.
e From two pump tests performed in shallow Maryville bedrock at ETF site using Theis solution.
f Determined using ETF site tracer test velocities (0.17 m/d) and mean slug test K (6.31E-5 cm/sec) and gradient = 0.094.
g Determined from pump test data at ETF site using Winterspoon-Gringarten solution.
h Determined from tracer test performed in southern portion of WAG 6.
i Based on water retention data from seven C-horizon soil analyses from seven test pits in WAG 6.
j From ETF pump test data using non-radial solution for Nolichucky bedrock.
k From Y-12 Nolichucky pump test data using non-radial solution.
l K values used in modelling as original K = 2.1E-4 did not work (dewatered the shallow aquifer).
m Maryville bedrock pump test data from Webster & Bradley for SWSA-5 at depths of 150-200' and 44-100' res
n Derived using ne=.03, K-1.58E-4 cm/sec, gradient=0.555.
o
p
q
r
s
t

5.18/4104.5

**Table 3B.5. Summary of aquifer hydraulic parameters.**

| al. | Clapp 1990 | Luxmoore 1981 | Tucci 1984 | Webster and Bradley 1988 | Connell et al. 1989 | WAG 6 Draft Perform. Assess Modeling 1990 | Roths-child et al. 1984[a] | All Compiled WAG 6 Slug Tests |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | $1.8^{-3}$ to $5.1^{-4}$[y]<br>$9.4^{-4}$ (Geom. Mean) | $1.97^{-4}$ to $3.47^{-4}$ | — | — | — | $3.49^{-3}$ to $5.65^{-5}$ (M)[u]<br>$3.49^{-3}$ to $2.29^{-7}$ (U)[v] | $1.67^{-3}$ to $3.5^{-5}$[t] | — |
| | — | — | — | — | — | 0.39 to 0.476 | — | — |
| | — | — | — | — | — | 0.7 (CALC)[w] | — | — |
| | | | | | | | | |
| | — | — | $3.53^{-6}$ to $3.53^{-4}$ | $1.02^{-6}$ to $2.36^{-3}$<br>$1.58^{-4}$ (Geom. Mean) | $8.47^{-5}$ to $2.3^{-3}$(Cnl)<br>$1.81^{-3}$ to $2.29^{-7}$(Cmr) | — | $2.57^{-5}$[s] | $2.01^{-4}$ (Overall Geom.Mean)<br>$7.62^{-5}$ to $9.61^{-6}$ (Cmr)<br>$3.05^{-5}$ (Geom. Mean Cmr)<br>$3.71^{-3}$ to $3.68^{-5}$ (Cnl)<br>$3.22^{-4}$ (Geom. Mean Cnl) |
| | — | — | — | — | — | — | — | — |
| | — | — | — | 0.03 | — | — | — | — |
| | — | — | — | $2.5^{-1}$[n] | — | — | — | — |
| | — | — | 2.43 to 4.87<br>(8-16 $ft^2$/day) | $1.18^{-1}$ to 6.33 | — | — | — | — |
| | | | | | | | | |
| 5 wells)[x]<br>ell 388)[x] | — | — | $3.52^{-6}$ to $2.3^{-3}$ | — | $5.65^{-5}$ to $3.06^{-4}$ (Cnl)<br>$8.01^{-5}$ to $5.3^{-8}$ (Cmr) | $1.24^{-4}$ | — | $3.01^{-5}$ (Overall Geom.Mean)<br>$1.85^{-3}$ to $1.70^{-8}$ (Cmr)<br>$4.97^{-5}$ (Overall Geom.Mean)<br>$5.01^{-4}$ to $4.20^{-6}$ (Cnl)<br>$8.13^{-5}$ (Cnl Geom. Mean) |
| | — | — | $1.8^{-2}$ to $1.39^{-1}$ | $5.3^{-8}$ to $6.7^{-5}$ | — | $4.8^{-1}$ $m^2$/day | — | — |
| | — | — | — | — | — | 0.001 | — | — |
| | — | — | — | — | — | .02 | — | — |
| | — | — | 3:1 to 20:1 | — | — | 3:1 | — | — |
| | — | — | — | — | — | 3 | — | — |
| | — | — | — | — | — | <$9.15^{-2}$ | — | — |
| | — | — | — | — | — | — | — | — |
| | — | — | — | — | — | — | — | — |
| | — | — | — | — | — | — | — | — |

imes at depth, ne = S.
t tracer tests performed in Conasauga Rocks in Bear Creek Valley.
n pump tests performed in Conasauga Rocks in Bear Creek Valley.
outcrop measurements.
d on slug test data from SWSA-7 wells in similar geologic materials.
d on soils developed on similar parent materials at SWSA-7; results of four pump-in tests in shallow augured
<21' deep.

u Range of K values initially tried based upon measured values for WAG 6.
v Range of K values altered than utilized in modelling to agree with Moore stormflow concept.
w Model results.
x Based on $He^3/He^4$ age dating data.
y Based on infiltration tests in three 402 $ft^2$ plots within WAG 6.

Other: (M) Range of field measure values; Cmr Maryville Fm; (U) Range of values used in modelling; Cnl Nolichucky Fm

Table 3B.6 WAG 6 regolith hydraulic conductivity distribution

| | K (cm/sec) | | | | |
|---|---|---|---|---|---|
| | Maximum | Minimum | Mean | Geometric Mean | Number of Analysis |
| Overall Regolith | $3.71E^{-3}$ | $9.61E^{-6}$ | $7.52E^{-4}$ | $2.01E^{-4}$ | 25 |
| Maryville Regolith | $7.62E^{-5}$ | $9.61E^{-6}$ | $3.98E^{-5}$ | $3.15E^{-5}$ | 5 |
| Nolichucky Regolith | $3.71E^{-3}$ | $3.78E^{-5}$ | $9.30E^{-4}$ | $3.22E^{-4}$ | 20 |

Hydraulic conductivities used for each well in Appendix 3.1.

Note: 1 cm/sec = 2835 ft/d.

**Table 3B.7 WAG 6 bedrock hydraulic conductivity distribution[a]**

| Unit | Depth | K (cm/sec) | | | | Number of Analyses |
|---|---|---|---|---|---|---|
| | | Maximum | Minimum | Mean | Geometric Mean | |
| All Bedrock[b] | | $1.9E^{-3}$ | $1.9E^{-9}$ | $1.0E^{-4}$ | $3.1E^{-5}$ | 68 |
| Maryville LS | (Overall) | $1.9E^{-3}$ | $1.7E^{-8}$ | $1.5E^{-4}$ | $4.9E^{-5}$ | 45 |
| | Upper 50' | $1.9E^{-3}$ | $1.5E^{-6}$ | $1.8E^{-3}$ | $4.8E^{-5}$ | 35 |
| | 51-100' | $2.2E^{-4}$ | $1.5E^{-6}$ | $6.1E^{-5}$ | $2.9E^{-5}$ | 14 |
| | 101-200' | $4.9E^{-5}$ | $1.7E^{-3}$ | $2.1E^{-5}$ | $2.1E^{-6}$ | 4 |
| | ≥ 200' | $2.9E^{-5}$ | $7.6E^{-7}$ | $1.6E^{-5}$ | $7.3E^{-6}$ | 3 |
| Nolichucky Shale | (Overall) | $5.0E^{-4}$ | $4.2E^{-6}$ | $1.5E^{-4}$ | $8.1E^{-5}$ | 19 |
| | Upper 50' | $5.0E^{-4}$ | $2.4E^{-5}$ | $1.8E^{-4}$ | $1.3E^{-4}$ | 15 |
| | 51-100' | $2.1E^{-4}$ | $2.4E^{-5}$ | $1.8E^{-4}$ | $9.7E^{-5}$ | 4 |
| | 101-200' | $6.6E^{-5}$ | $4.7E^{-6}$ | $3.5E^{-5}$ | $2.2E^{-6}$ | 3 |
| | ≥ 200' | $4.7E^{-6}$ | $4.2E^{-6}$ | $4.5E^{-6}$ | $4.4E^{-6}$ | 2 |
| Rogersville Shale[b] | Overall | $2.3E^{-8}$ | $1.9E^{-9}$ | $1.3E^{-8}$ | $6.6E^{-9}$ | 2 |

[a]From WAG 6 slug test data only except where noted; does not include well screens straddling regolith and bedrock.
[b]Includes HHMS well cluster slow recovery data.

1cm/sec = 2935 ft/day

| FLOW LINE[b] | WELLS USED TO DETERMINE GEOMETRIC MEAN CONDUCTIVITY | GEOM. MEAN HYDRAULIC CONDUCTIVITY (cm/sec) | HYDRAULIC GRADIENT[c] (ft/ft) | EFFECTIVE POROSITY[d] (cf/cf) | AVG. LINEAR VELOCITY (m/day) | AVG. LINEAR VELOCITY (m/day) | |
|---|---|---|---|---|---|---|---|
| | REGOLITH | | | | | | |
| A | 740, 741, 857, 859; T-10, -22, -27, -36 | $1.36^{-4}$ | 0.0535 | .03 | 0.21 | 0.21 | 3 |
| $B_1$ | 854; ETF-17, -20, -22, -25, -36, -39, -40 | $5.3^{-5}$ | 0.0714 | .03 | 0.10 | 0.20 | 8 |
| $B_2$ | 851, 852, 853, 854 | $1.8^{-4}$ | 0.0464 | .03 | 0.24 | | 6 |
| $B_3$ | 853, 854 | $1.9^{-4}$ | 0.0625 | .03 | 0.34 | | 6 |
| $C_1$ | 849, 853 | $1.1^{-4}$ | 0.0482 | .03 | 0.16 | 0.84 | 6 |
| $C_2$ | 849, 1036, 1037, 1038, 1039, 1040 | $2.0^{-3}$ | 0.0397 | .03 | 2.28 | | 6 |
| $C_3$ | 849, 1036, 1037 | $1.4^{-3}$ | 0.0403 | .03 | 1.62 | | 3 |
| D | (f) | — | — | — | — | (f) | 6 |
| $E_1$ | (f) | — | — | — | — | (f) | 3 |
| $E_2$ | (f) | — | — | — | — | | 6 |
| $E_3$ | (f) | — | — | — | — | | 6 |
| F | (f) | — | — | — | — | (f) | 8 |
| G | (f) | — | — | — | — | (f) | 3 |
| $H_1$ | (f) | — | — | — | — | (f) | 3 |
| $H_2$ | (f) | — | — | — | — | | 6 |
| $I_1$ | 382, 835, 836 | $1.6^{-4}$ | 0.0360 | .03 | 0.16 | 0.24 | 38 |
| $I_2$ | 382, 835, 836 | $1.6^{-4}$ | 0.0676 | .03 | 0.31 | | 65 |
| $I_3$ | 382, 835, 838 | $1.4^{-4}$ | 0.0714 | .03 | 0.29 | | 38 |
| $J_1$ | 838, 845, 849 | $2.0^{-4}$ | 0.0541 | .03 | 0.31 | 0.31 | 37 |
| $J_2$ | (f) | | | | | | 38 |
| | MEAN | $2.19^{-4}$ | 0.0537 | .03 | 0.33 | — | MI |
| | | OVERALL GEOMETRIC MEAN | MEAN GRADIENT | MEAN EFFECT. POROSITY | OVERALL GEOM. MEAN LINEAR VELOC. (m/d) | | |

[a] *Upper 50 ft of saturated bedrock only.*

[b] *Labels correspond to flow lines shown on Figure 3B.26.*

[c] *Average hydraulic gradient along the length of flow line shown.*

[d] *Effective porosity based upon aquifer testing results (Tamura et al., 1980).*

[e] *Effective porosity based upon aquifer testing results at ETF area (Davis et al., 1984).*

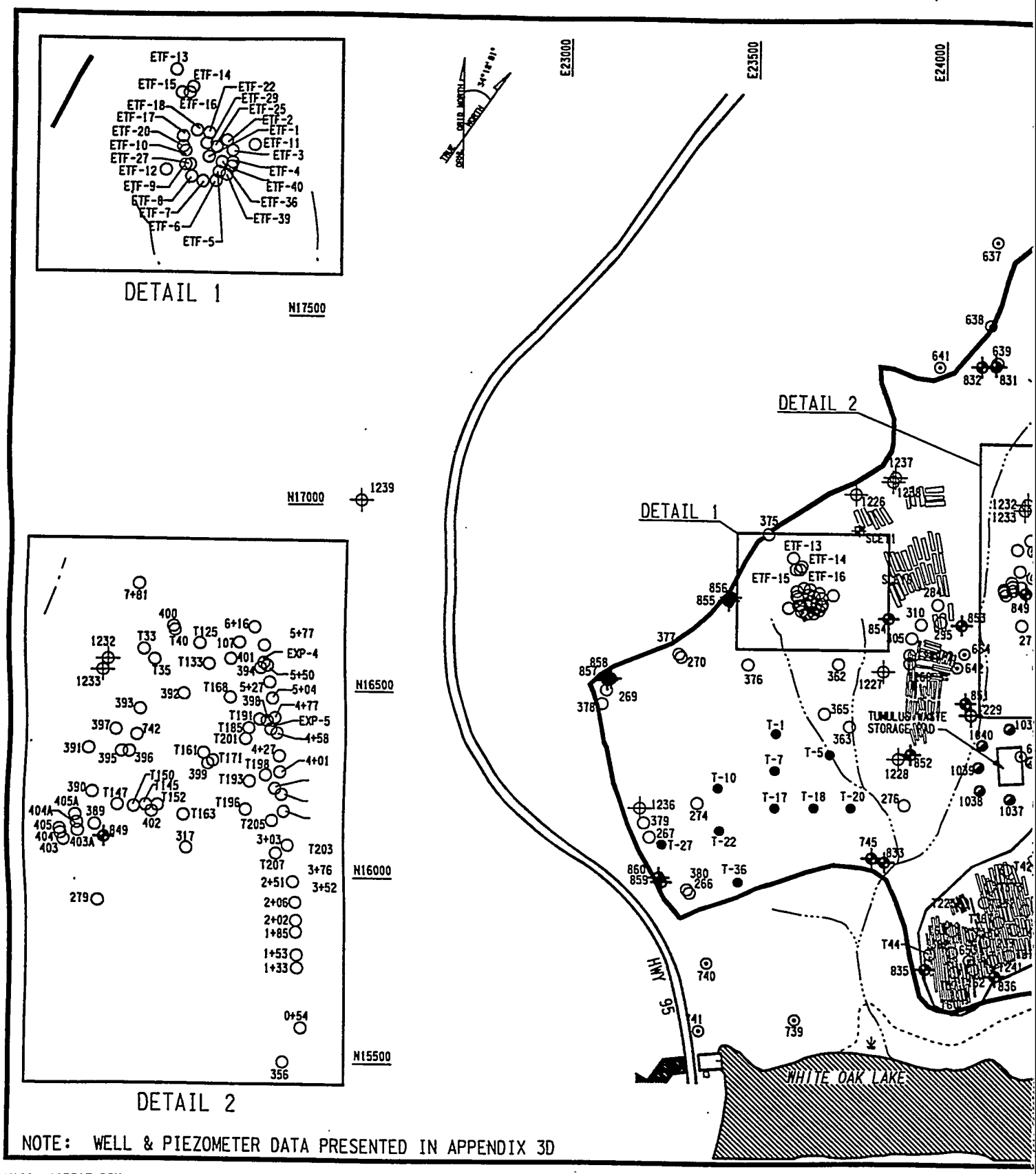
[f] *Groundwater flow only occurs in bedrock in this area.*

5.18/4104.6

**Table 3B.8. WAG 6 average linear velocities by flow line.**

| BEDROCK[a] | | | | | | |
|---|---|---|---|---|---|---|
| WELLS USED TO DETERMINE GEOMETRIC MEAN CONDUCTIVITY | GEOM. MEAN HYDRAULIC CONDUCTIVITY (cm/sec) | HYDRAULIC GRADIENT[c] | EFFECTIVE POROSITY[e] | AVG. LINEAR VELOCITY (m/day) | AVG. LINEAR VELOCITY (m/day) | FLOW LINE[b] |
| 380, 739, 858, 860 | $8.6^{-5}$ | 0.0535 | .03 | 0.13 | 0.13 | A |
| 856, ETF-1 through -9, -11, -12, -15 | $1.2^{-4}$ | 0.0714 | .03 | 0.25 | 0.26 | $B_1$ |
| 745, 833, 654, 851, 852, 854 | $1.6^{-4}$ | 0.0464 | .035 | 0.22 | | $B_2$ |
| 4, 853, 8545 | $1.9^{-4}$ | 0.0625 | .03 | 0.34 | | $B_3$ |
| 849, 851, 853, 854 | $9.4^{-5}$ | 0.0482 | .03 | 0.10 | 0.10 | $C_1$ |
| 654, 381, 849 | $9.0^{-5}$ | 0.0397 | .03 | 0.10 | | $C_2$ |
| 642, 654, 849 | $9.0^{-5}$ | 0.0403 | .03 | 0.10 | | $C_3$ |
| 638, 639, 832 | $2.3^{-5}$ | 0.1000 | .03 | 0.07 | 0.07 | D |
| 640 | $4.1^{-5}$ | 0.0811 | .03 | 0.10 | 0.10 | $E^1$ |
| 655 | $5.3^{-5}$ | 0.0769 | .03 | 0.12 | | $E^2$ |
| 638, 639, 832, 846 | $2.1^{-5}$ | 0.1429 | .03 | .09 | | $E_3$ |
| 844, 374 | $1.2^{-5}$ | 0.1096 | .03 | 0.34 | 0.04 | F |
| 840, 841, 842 | $1.4^{-4}$ | 0.1045 | .03 | 0.42 | 0.42 | G |
| 644, 839, 840, 845 | $1.6^{-4}$ | 0.0769 | .03 | 0.34 | 0.20 | $H_1$ |
| 845 | $8.2^{-5}$ | 0.0513 | .03 | 0.12 | | $H_2$ |
| 882, 653 | $9.5^{-5}$ | 0.0360 | .03 | 0.10 | 0.18 | $I_1$ |
| HHMS-4C, HHMS-5C | $1.6^{-4}$ | 0.0676 | .03 | 0.31 | | $I_2$ |
| 883, 652, 839 | $8.7^{-5}$ | 0.0714 | .03 | 0.18 | | $I_3$ |
| 881, 644, 839, HHMS-4C | $1.0^{-4}$ | 0.0541 | .03 | 0.16 | 0.28 | $J_1$ |
| 881, 644, 839, HHMS-4C | $1.0^{-4}$ | 0.1707 | .03 | 0.49 | | $J_2$ |
| N | $7.81^{-5}$ | 0.07953 | .03 | 0.15 | | |
| | OVERALL GEOMETRIC MEAN | MEAN GRADIENT | MEAN EFFECT. POROSITY | OVERALL GEOM. MEAN LINEAR VELOC. (m/d) | | |

# Appendix 3B Figures




WAG6 06F317.DGN

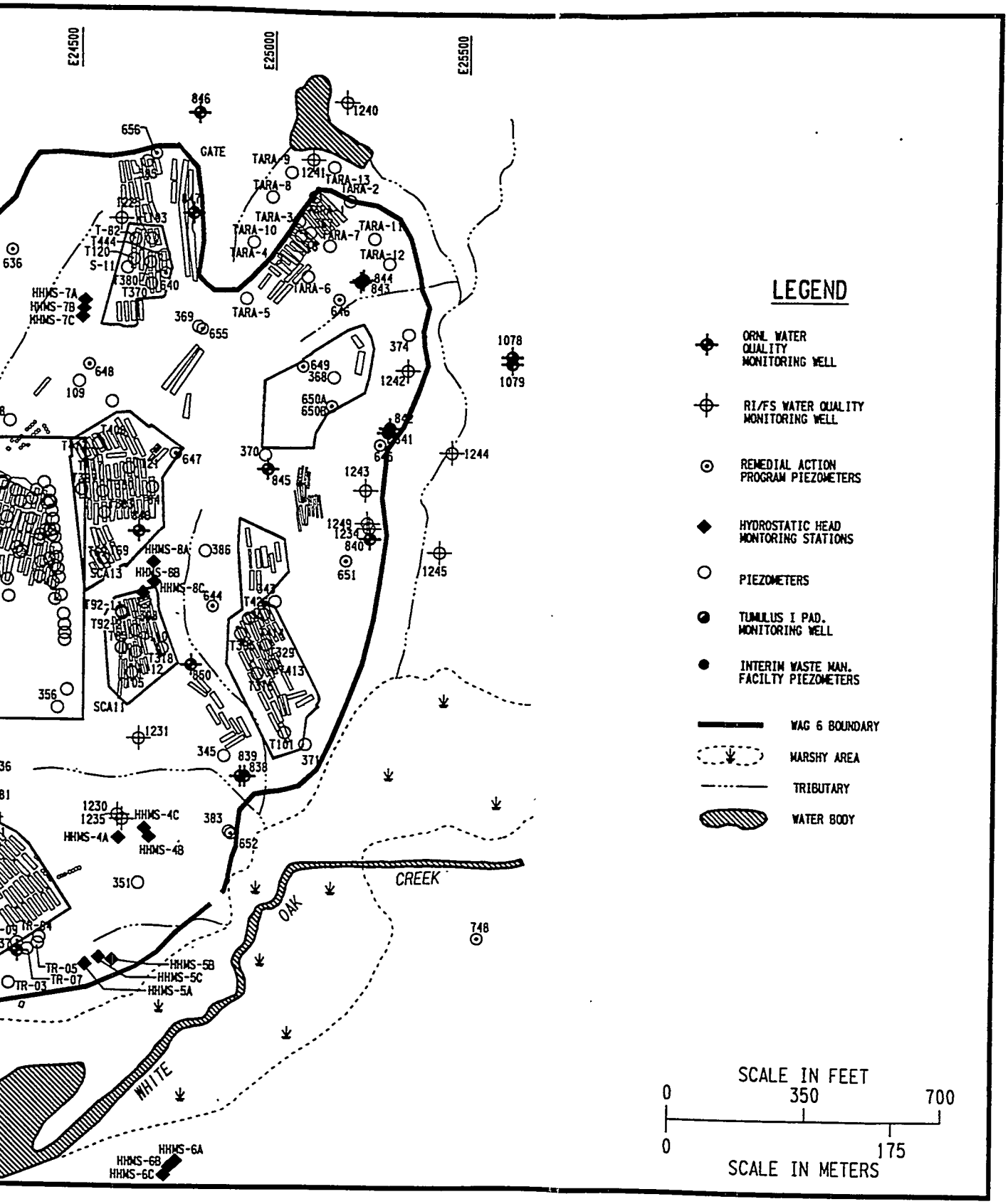
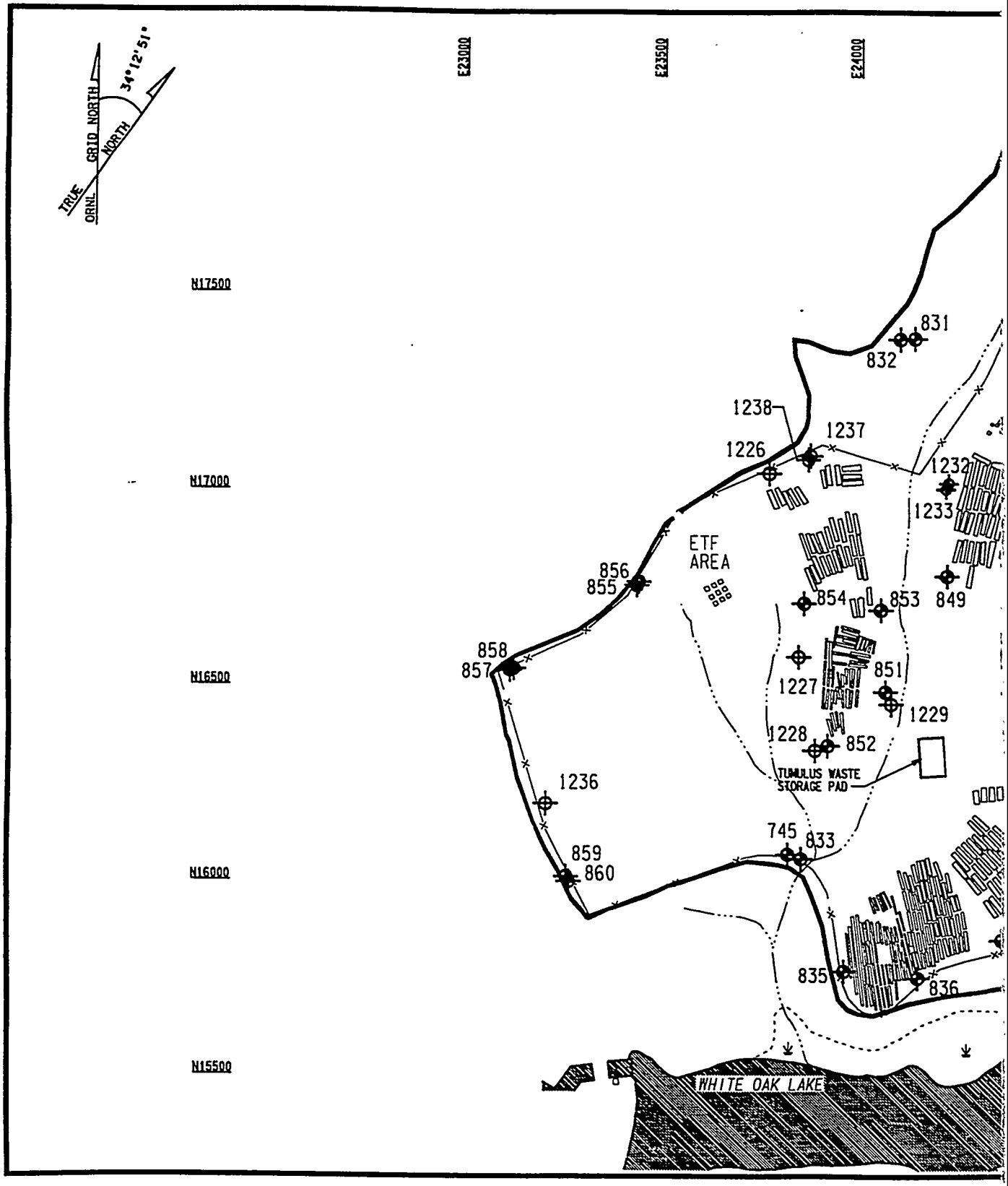



**Fig. 3B.1. Existing wells and piezometers at WAG 6 as of June 1990.**

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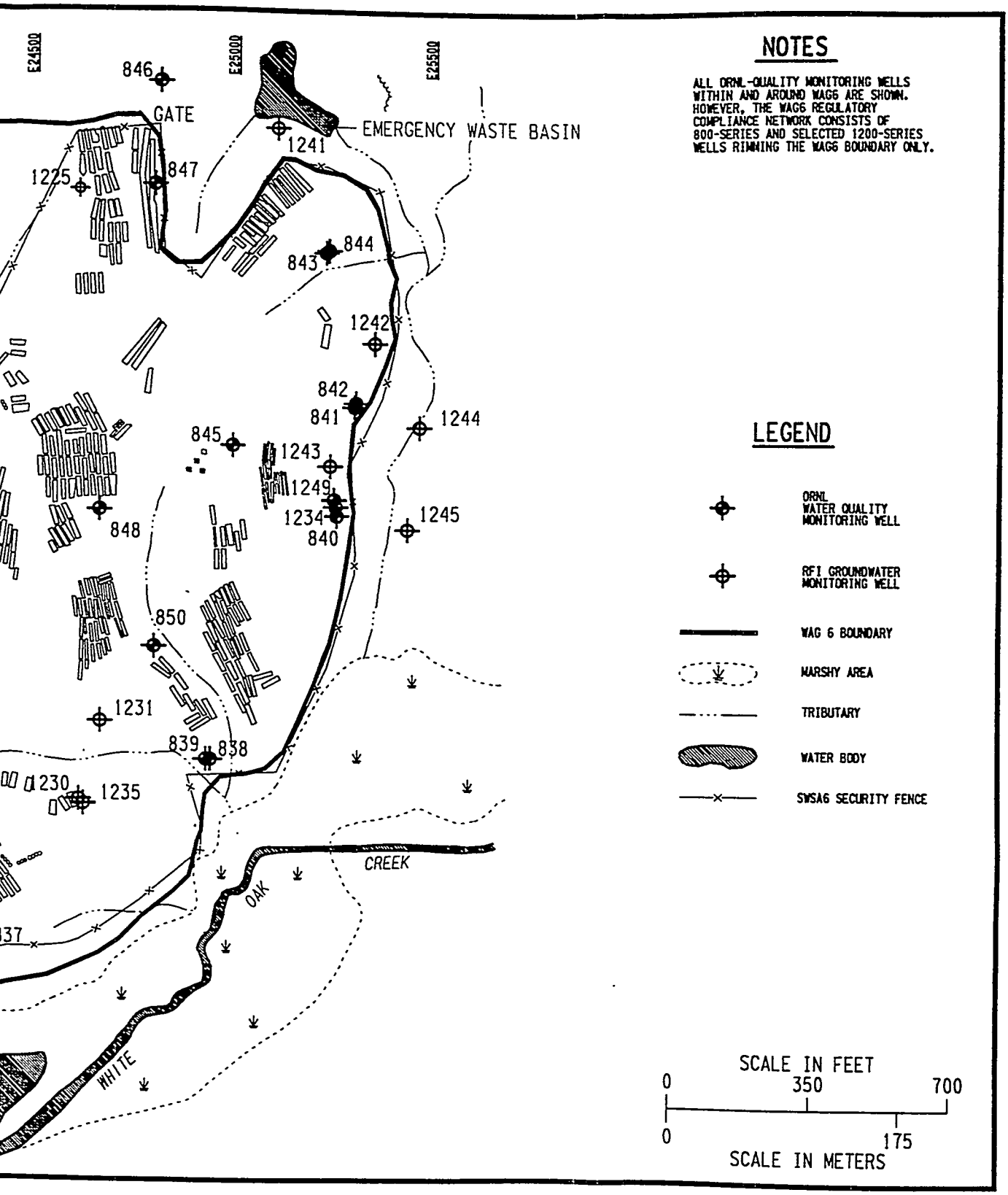
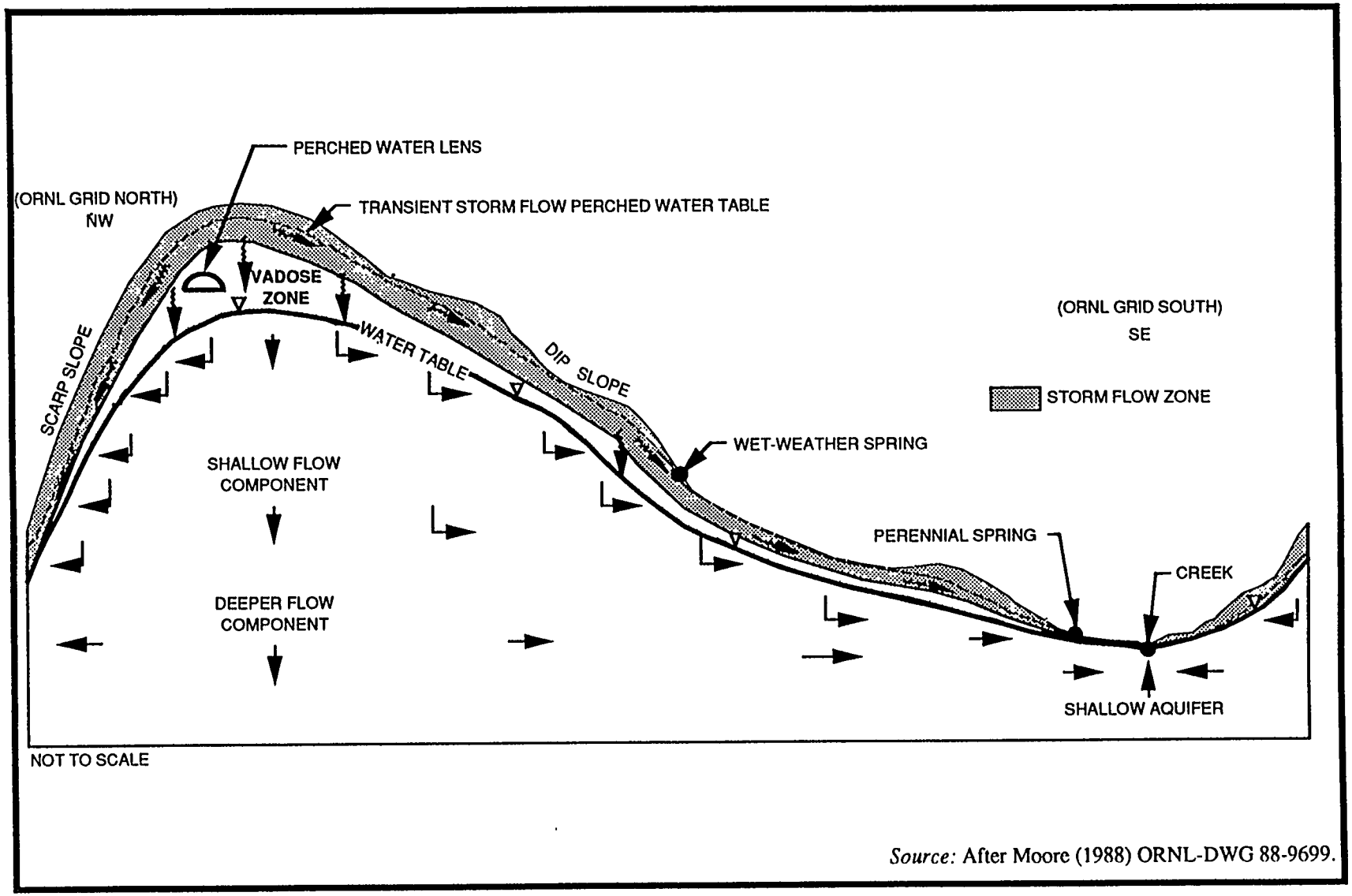


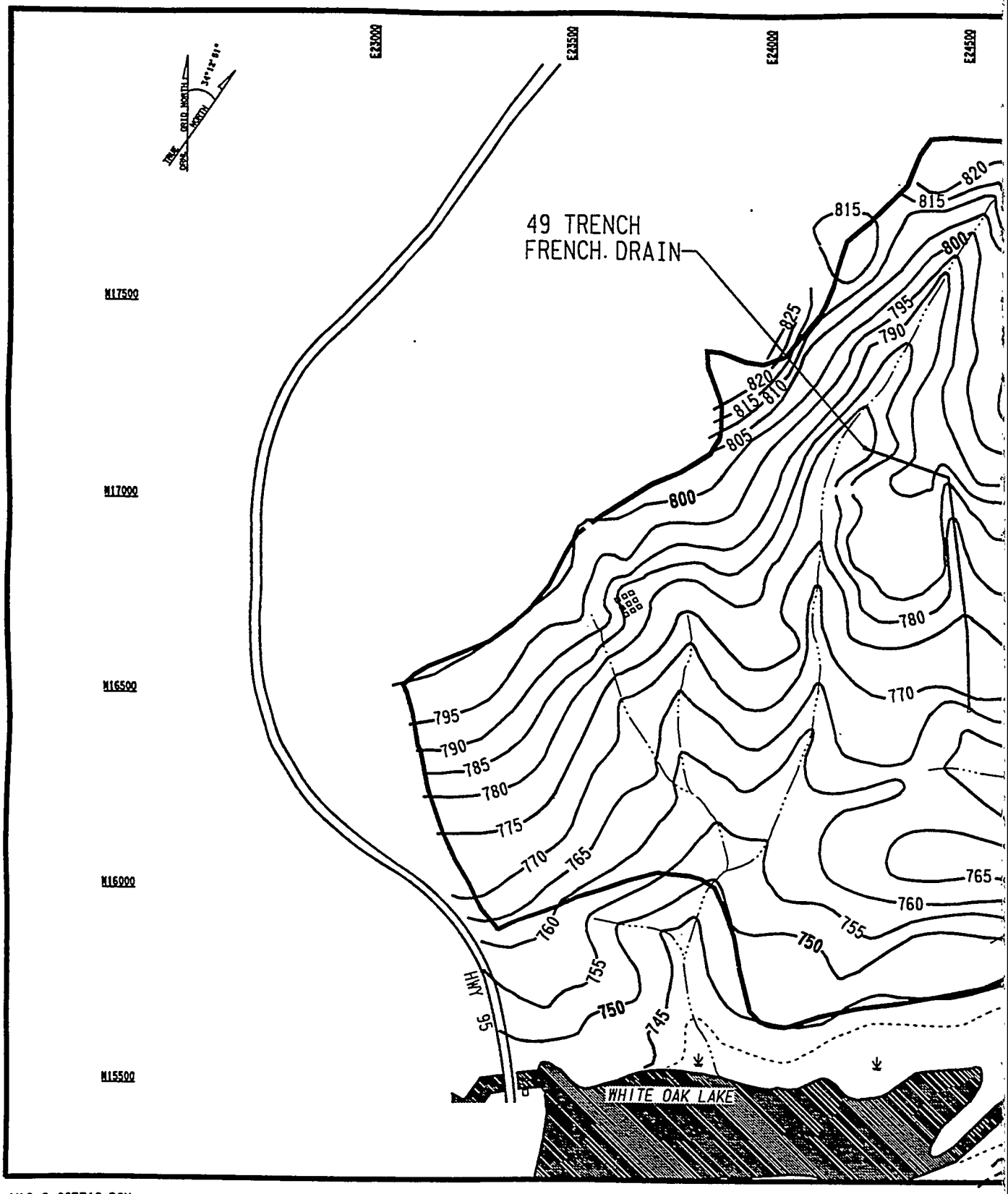

**Fig. 3B.2. WAG 6 groundwater quality monitoring wells.**




*Source:* After Moore (1988) ORNL-DWG 88-9699.

**Fig. 3B.3. Conceptual groundwater occurrence at WAG 6.**

5.18E 4104.147
Adapted from WAG6 06F257.DGN




WAG 6 06F319.DGN

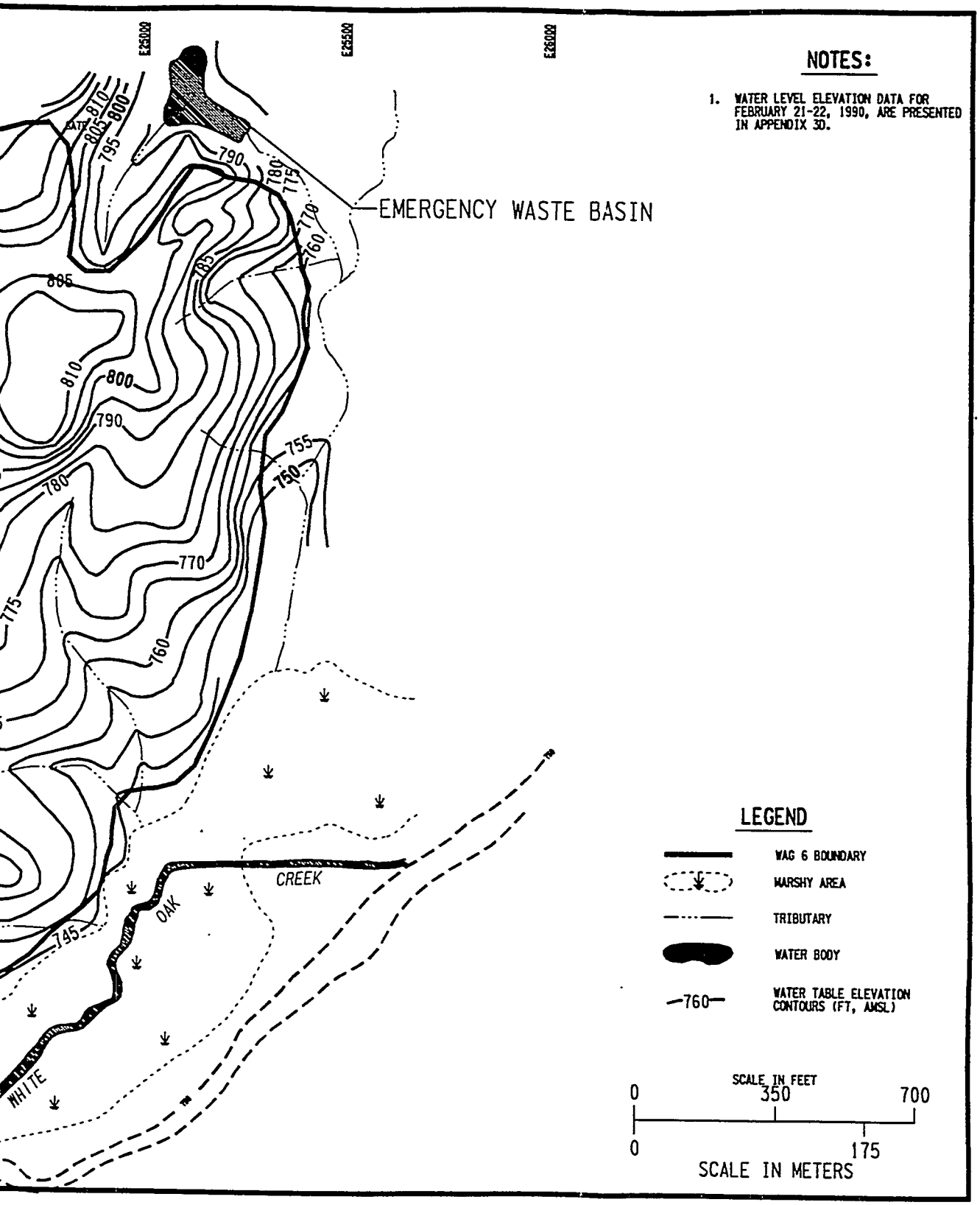
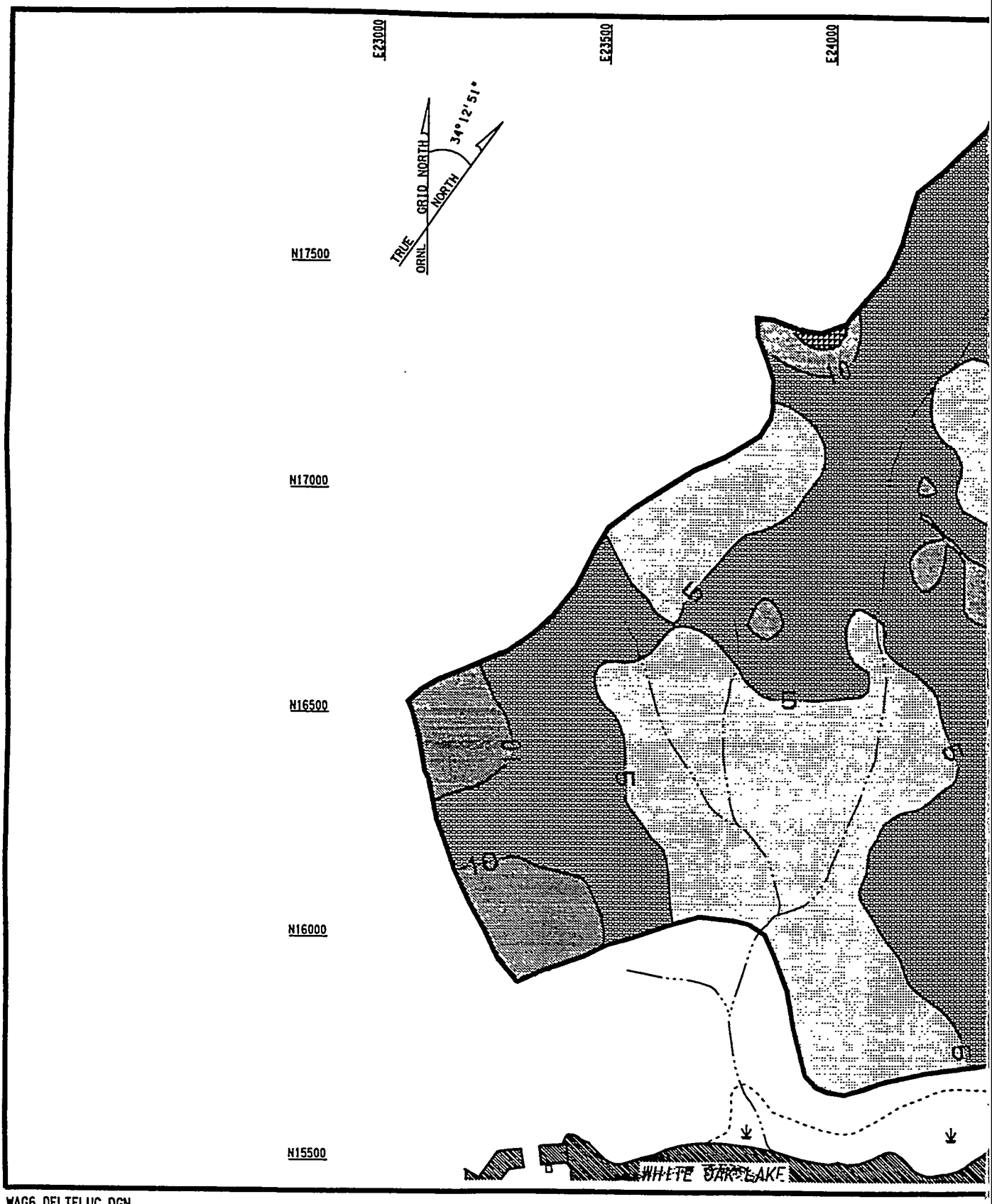



**Fig. 3B.4. WAG 6 potentiometric map for February 21-22, 1990.**




WAG6 DELTFLUC.DGN

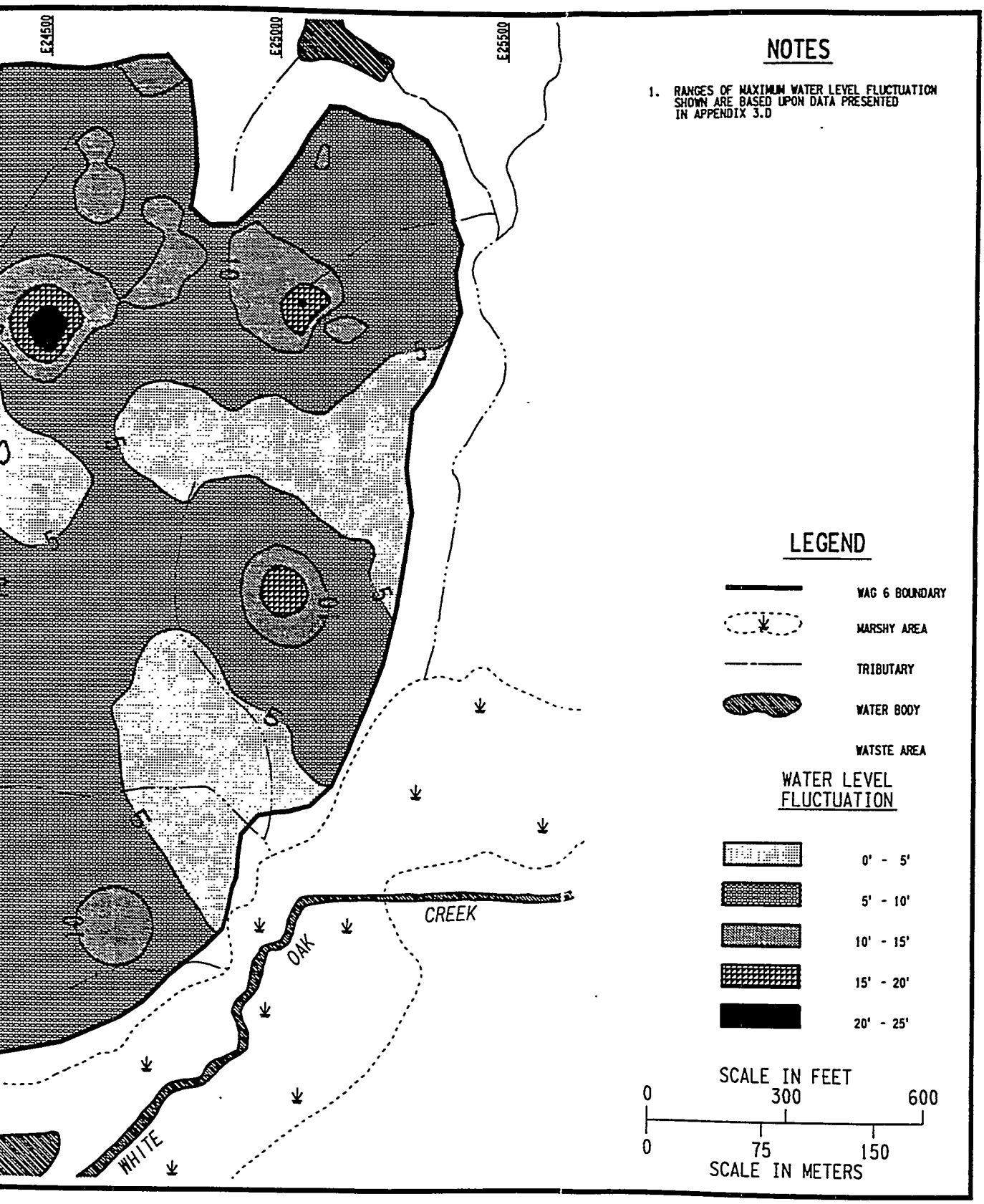



**Fig. 3B.5. WAG 6 maximum historic water level fluctuation.**

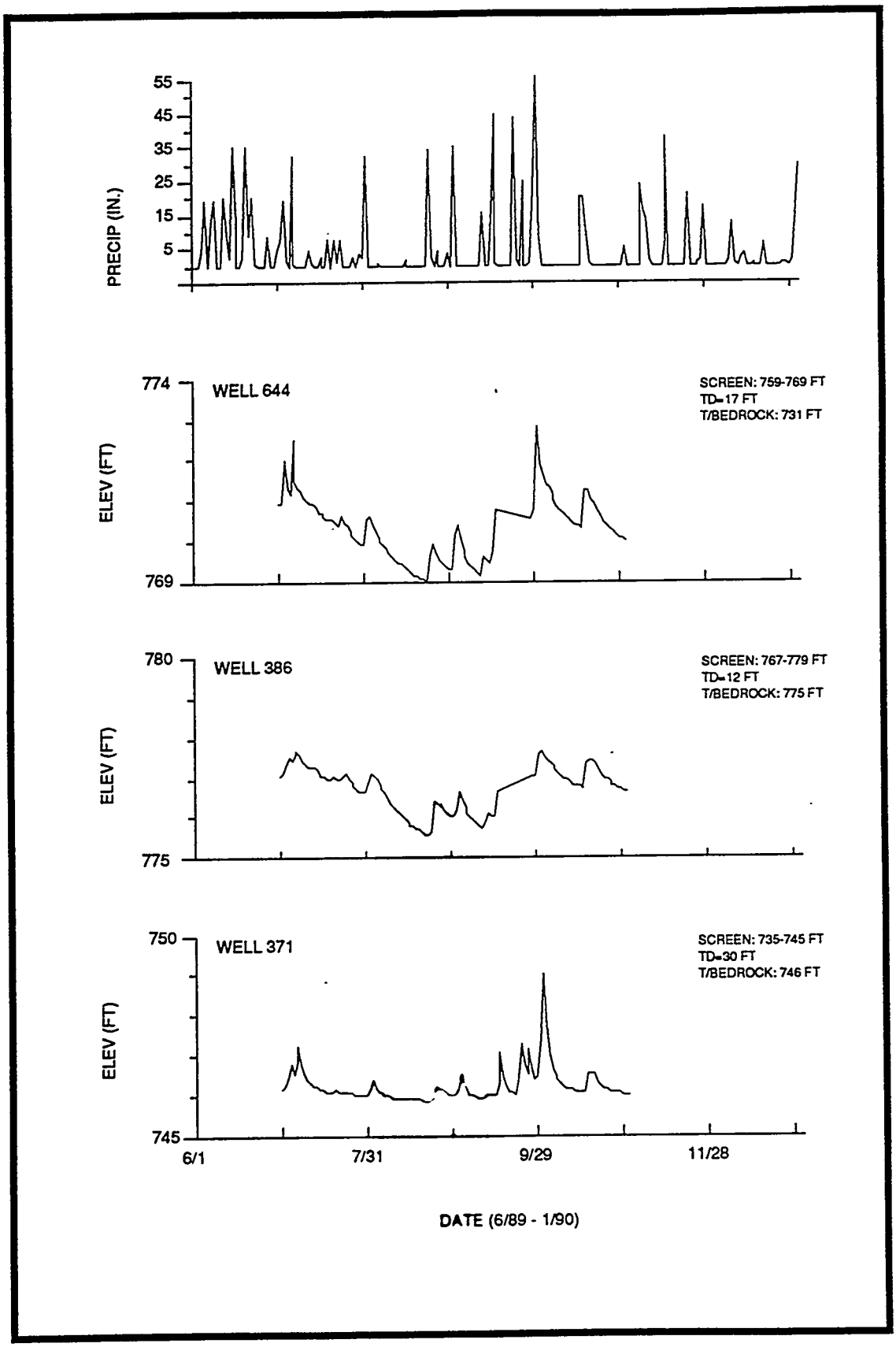



**Fig. 3B.6. WAG 6 shallow well response to precipitation.**

5.18E 4104.140
Adapted from WAG 6 06F145.DGN

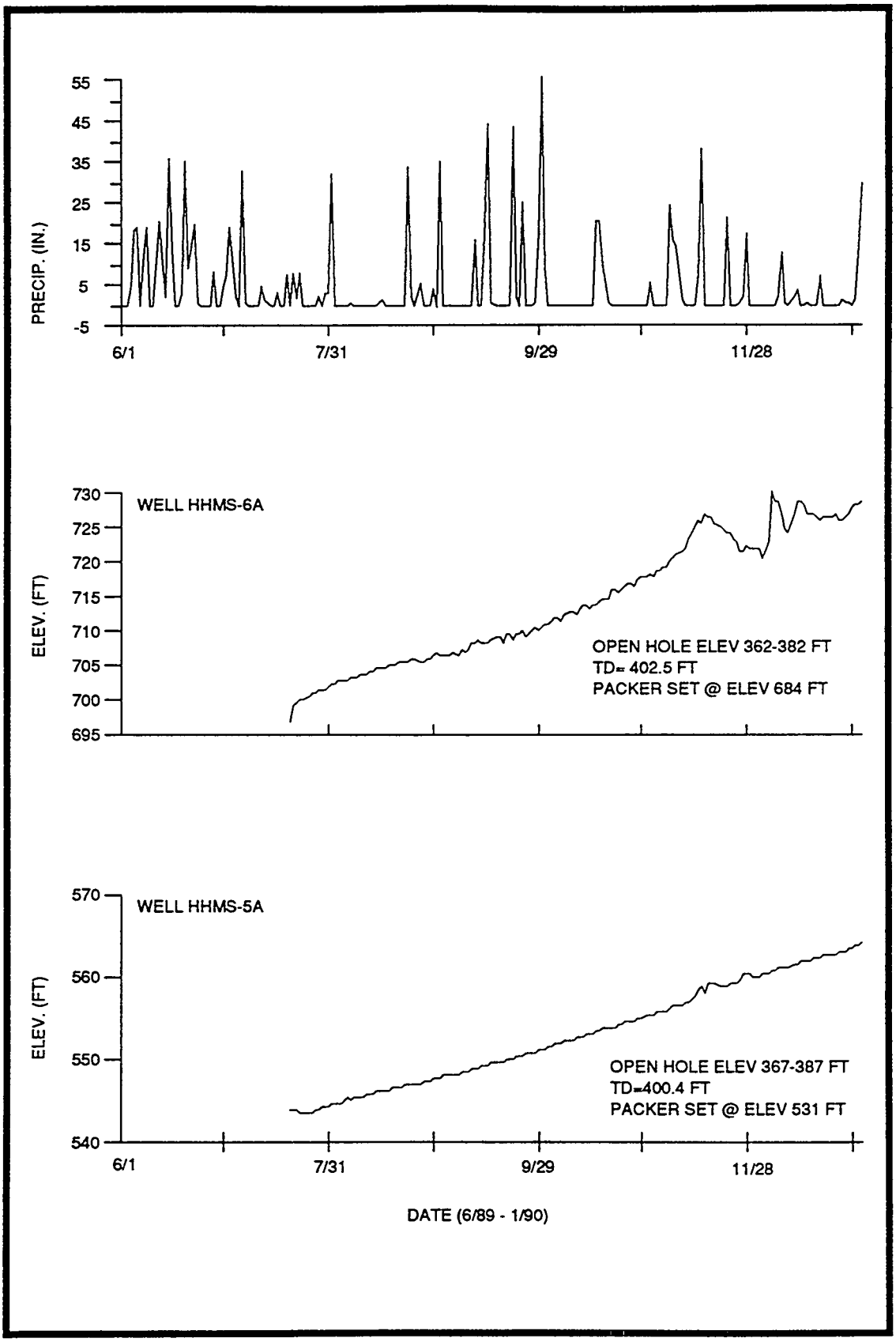



**Fig. 3B.7. WAG 6 deep well response to precipitation.**

4.18E 4104.142
Adapted from WAG 6 06F146.DGN

WAG6 06F320.DGN

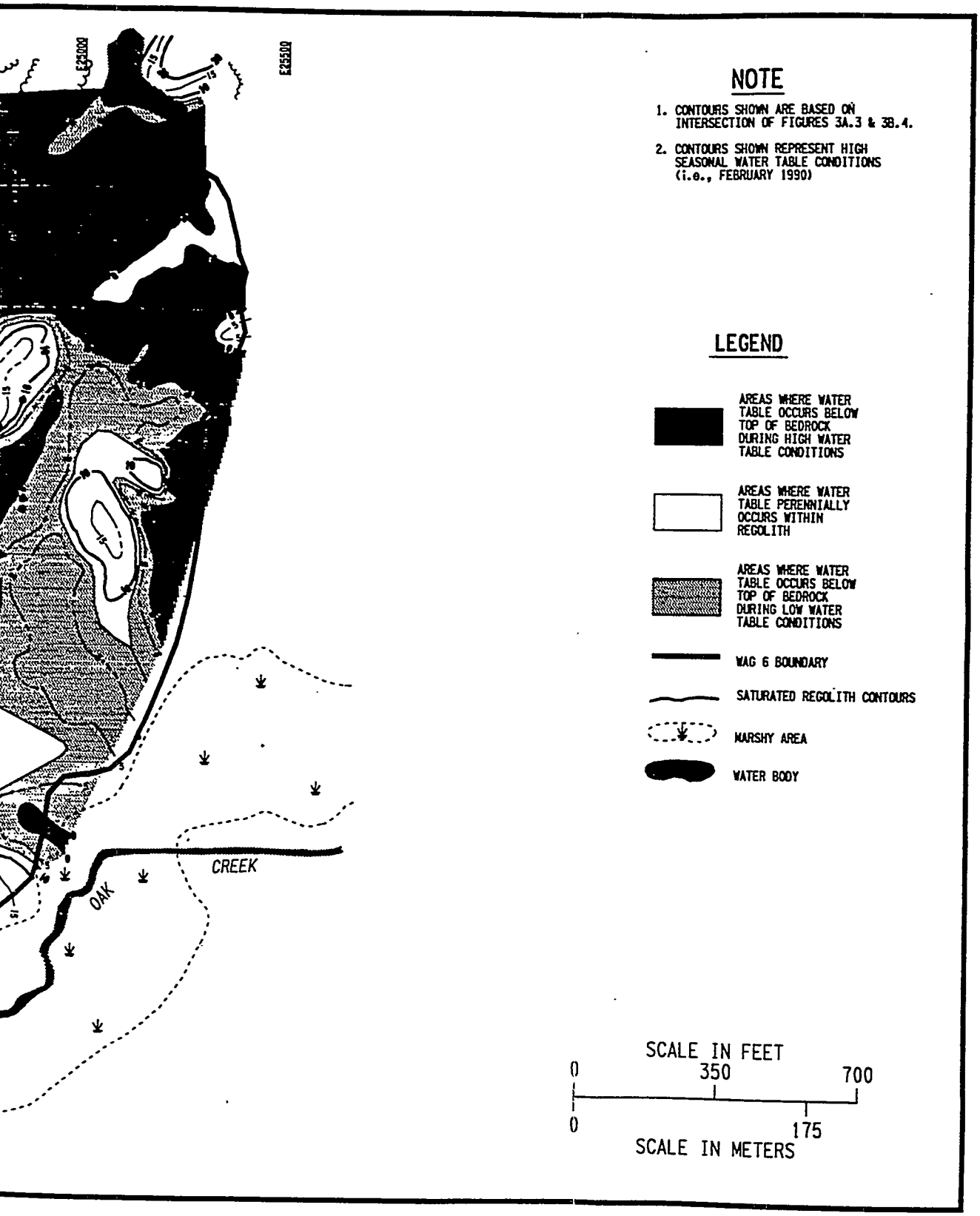
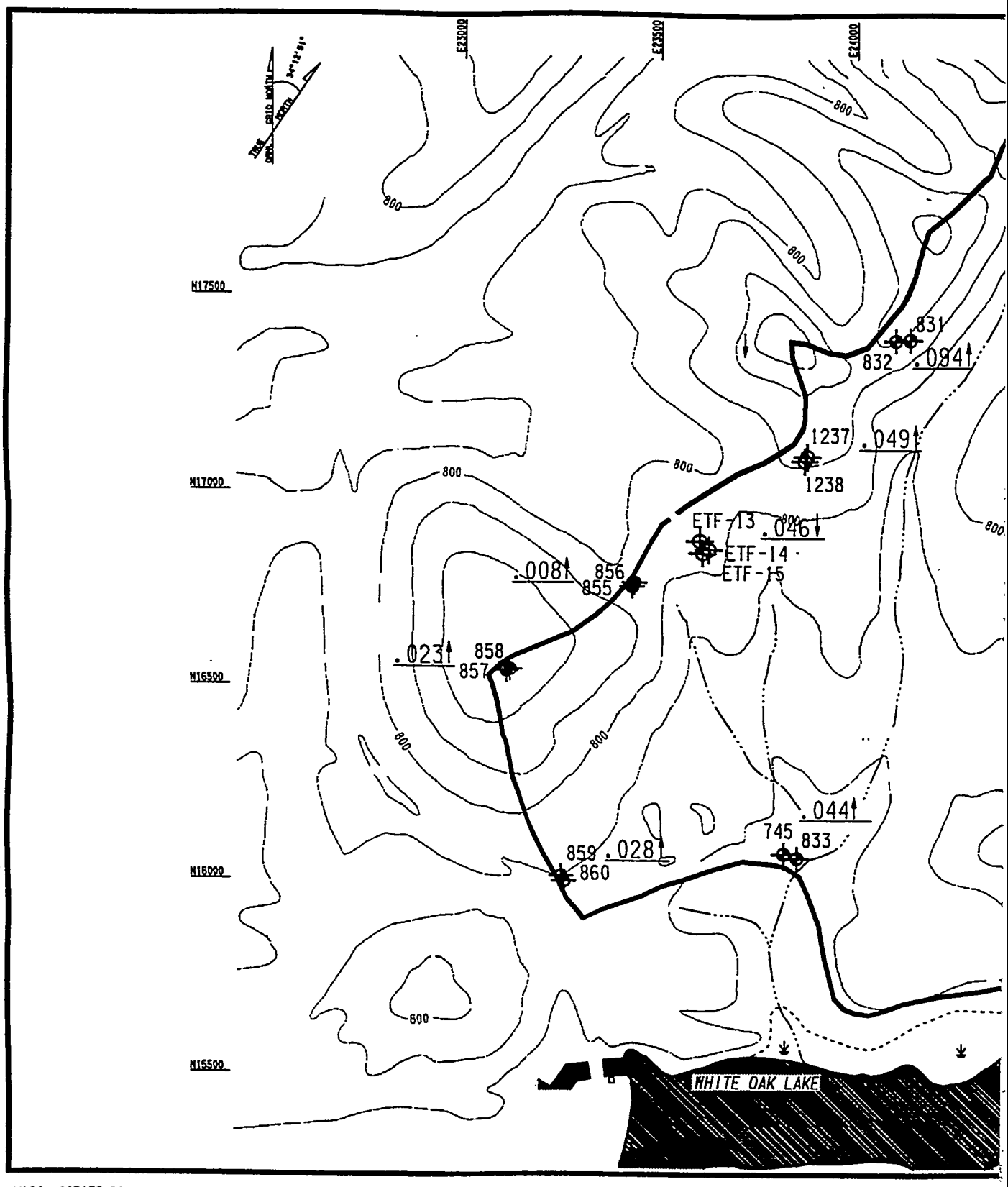



**Fig. 3B.8. WAG 6 saturated regolith thickness, February 21-22, 1990.**




WAG6 06F175.DGN

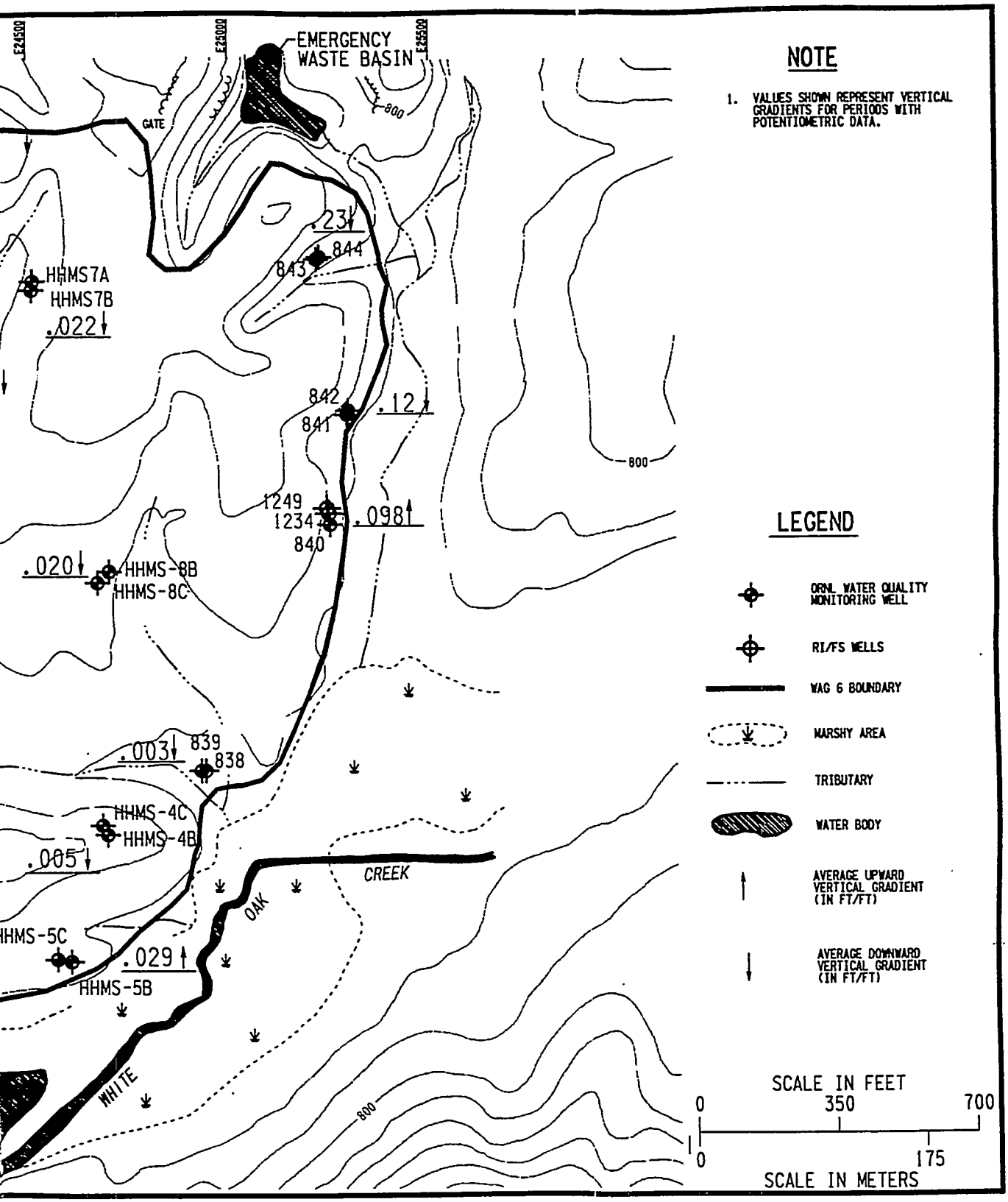
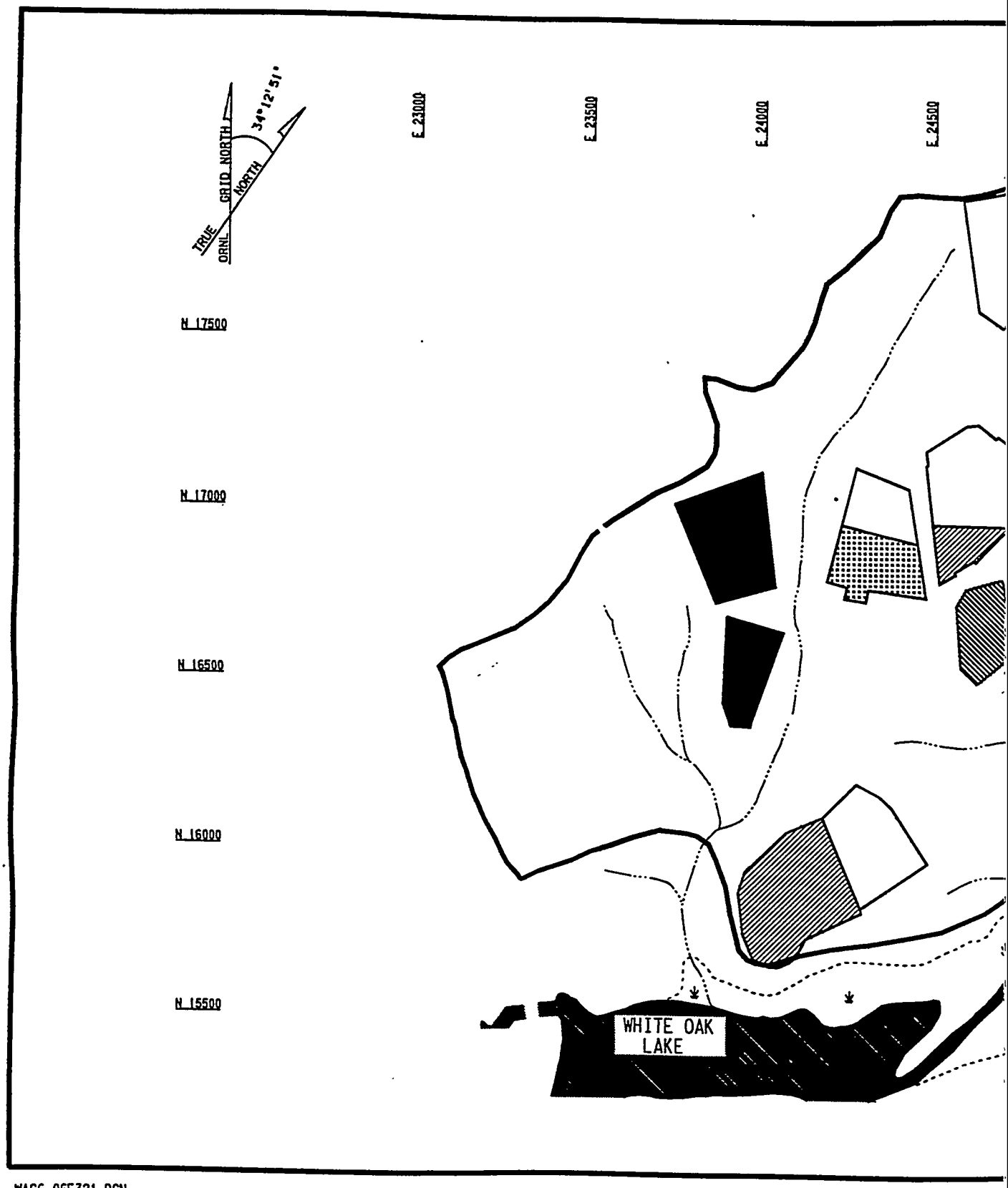



**Fig. 3B.9. WAG 6 vertical hydraulic gradient distribution.**




WAG6 06F321.DGN

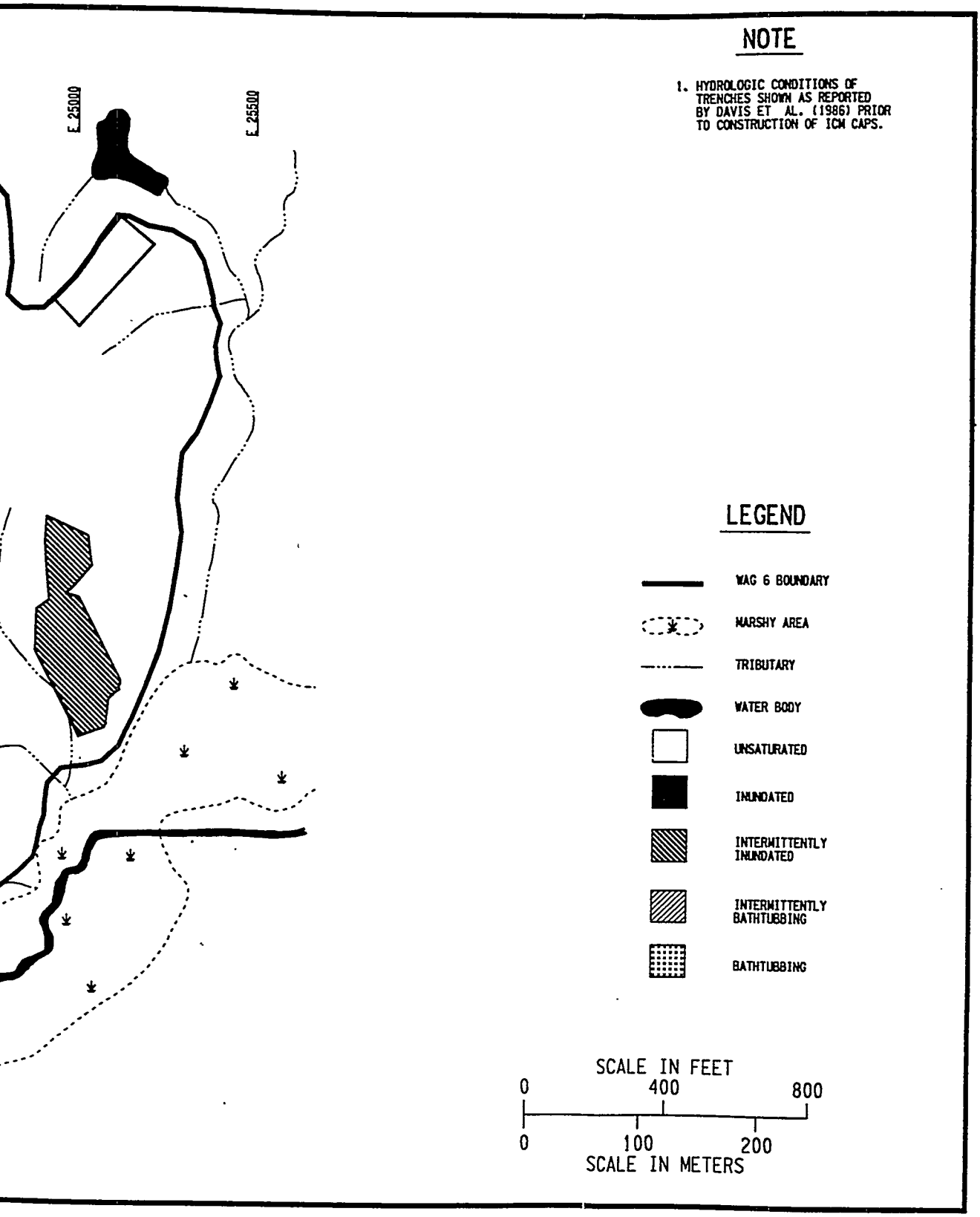
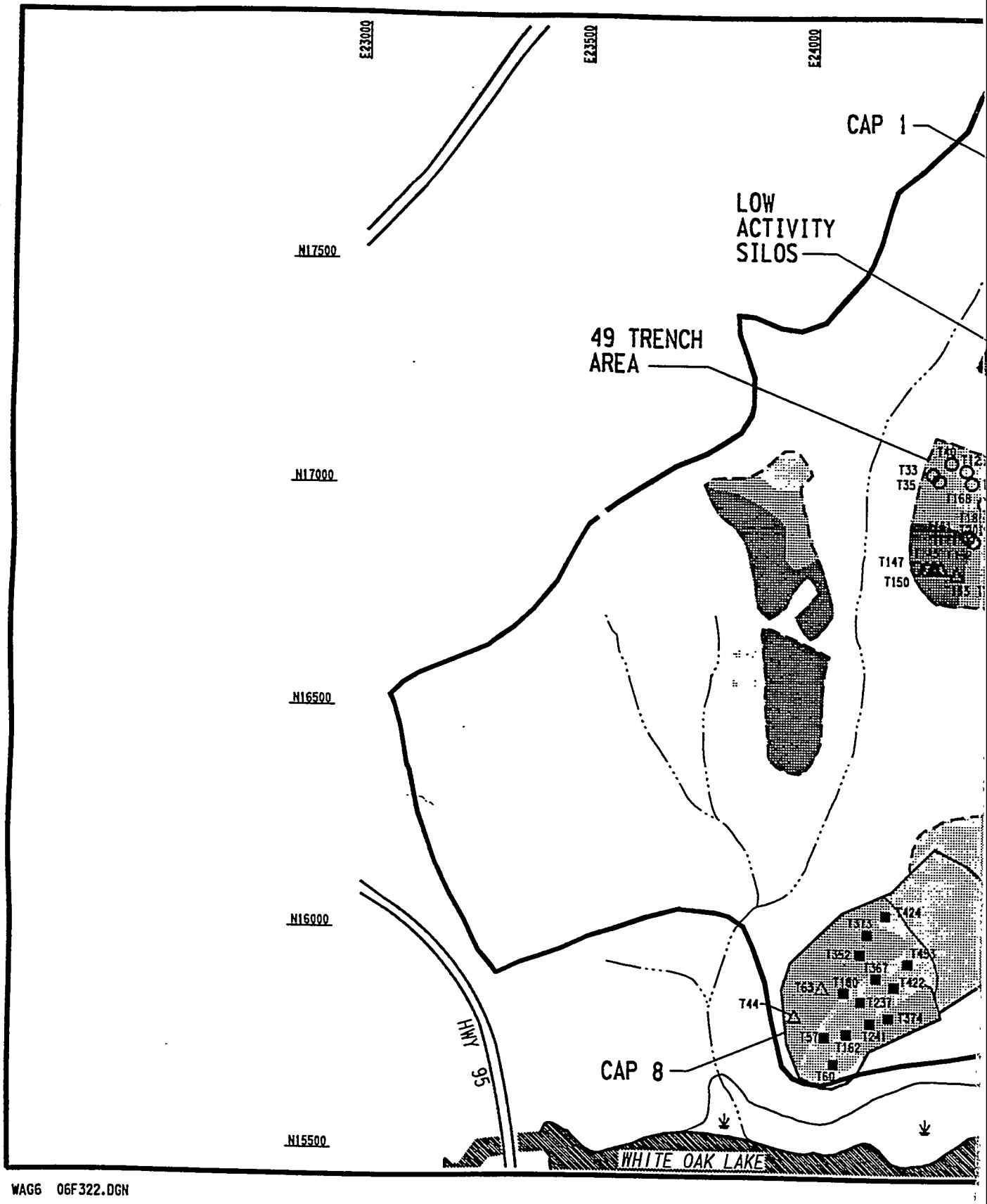



**Fig. 3B.10. Hydrologic condition of trenches in SWSA 6, 1986.**




WAG6 06F322.DGN

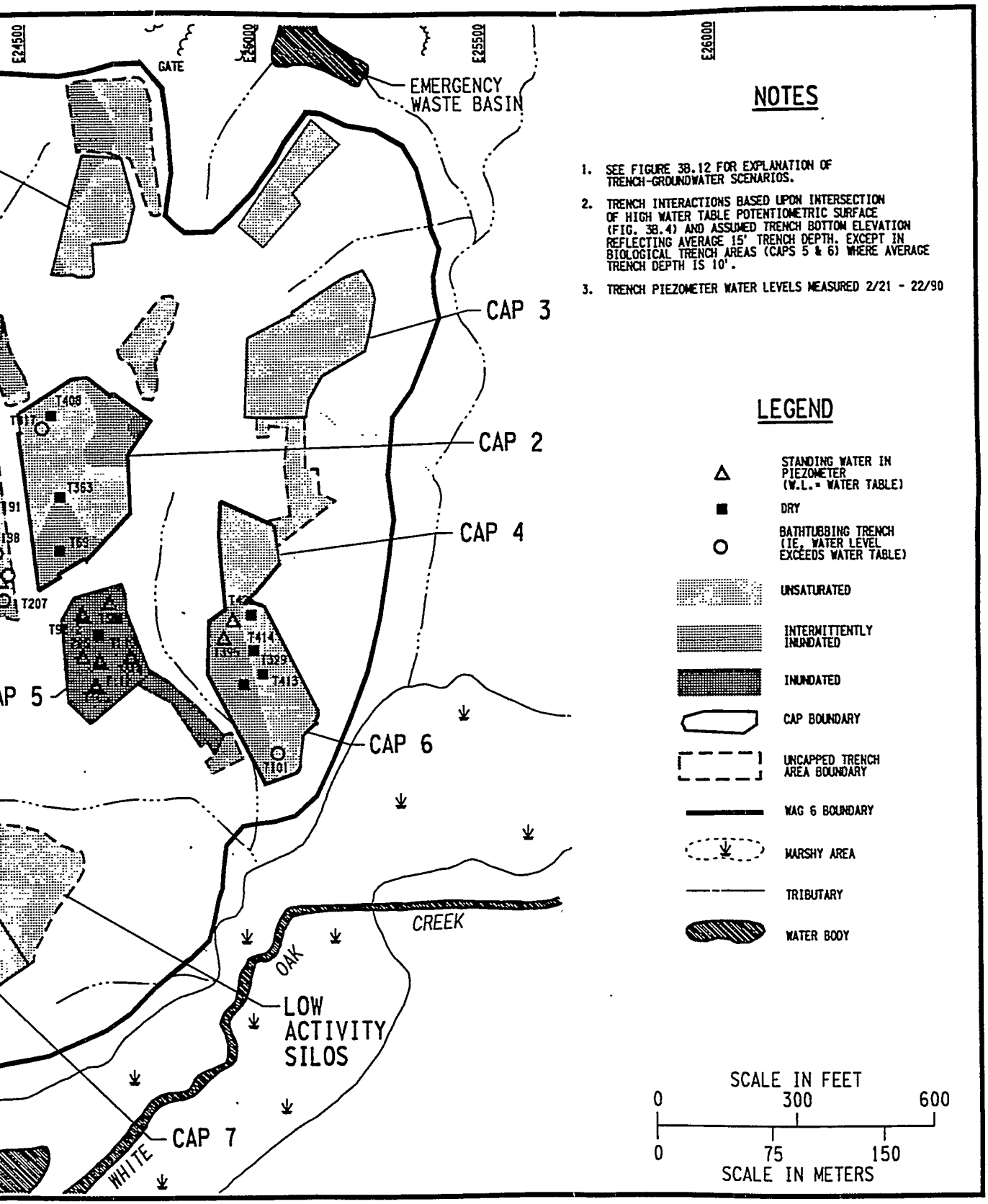
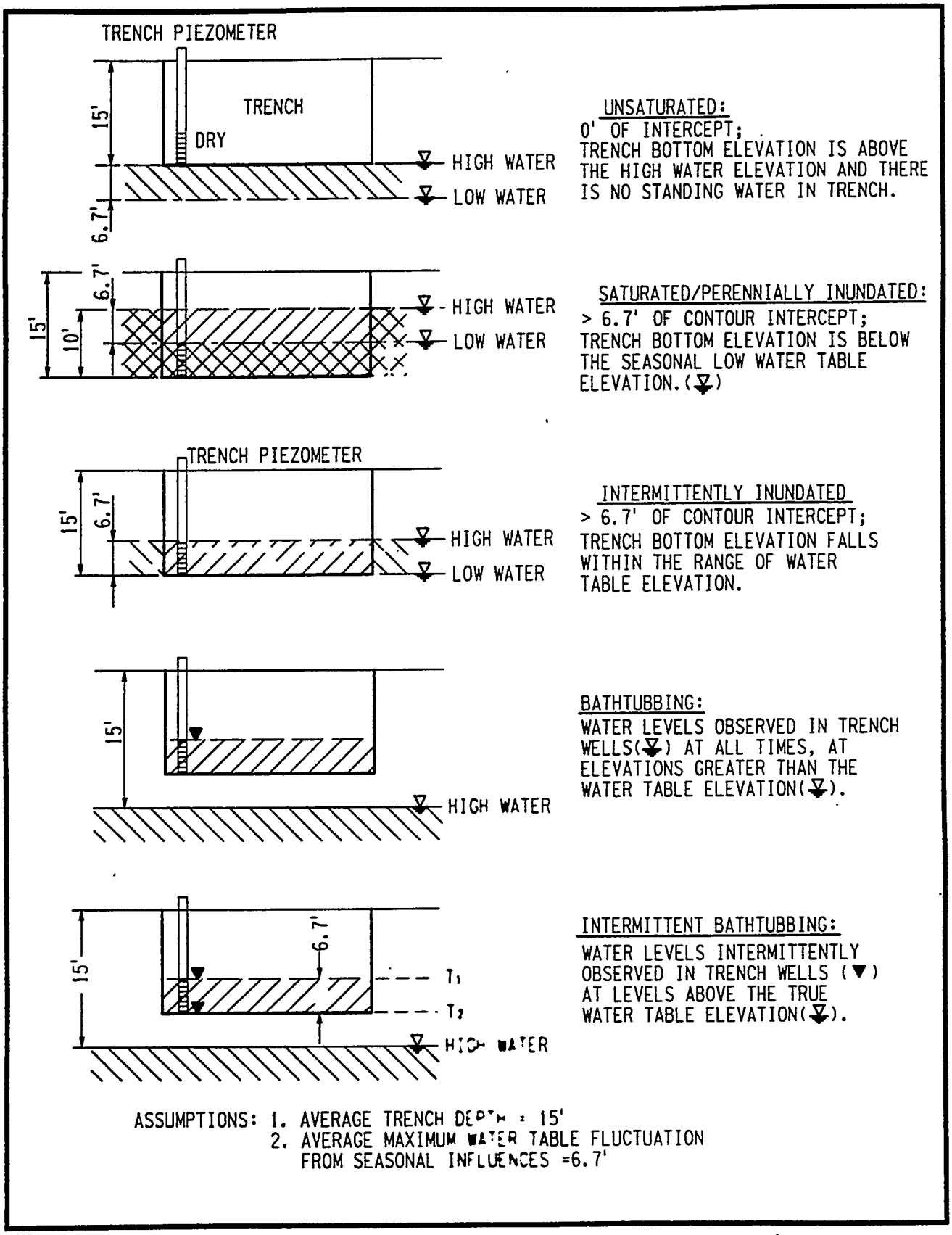
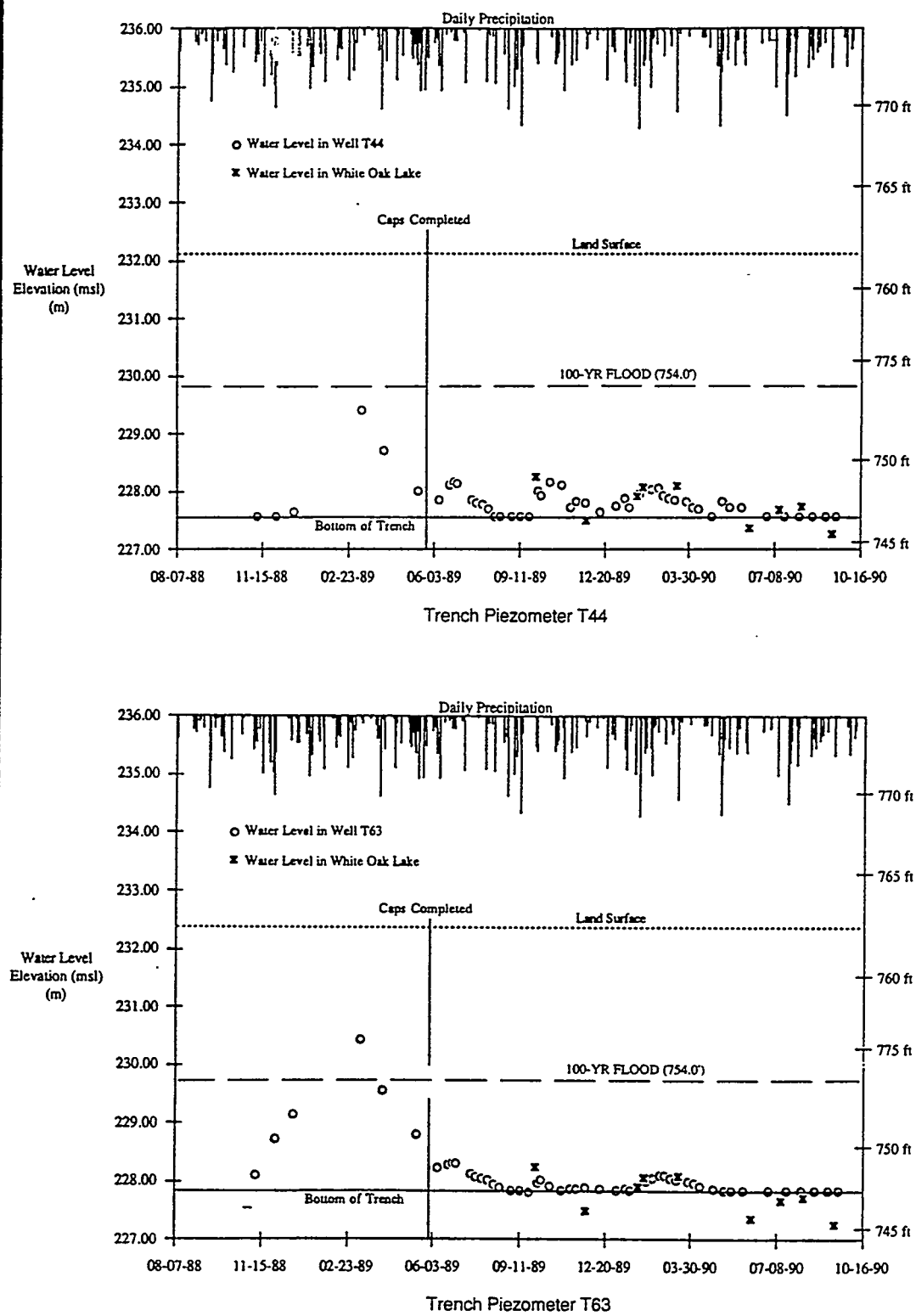



**Fig. 3B.11. WAG 6 trench-groundwater interaction map, February 1990.**



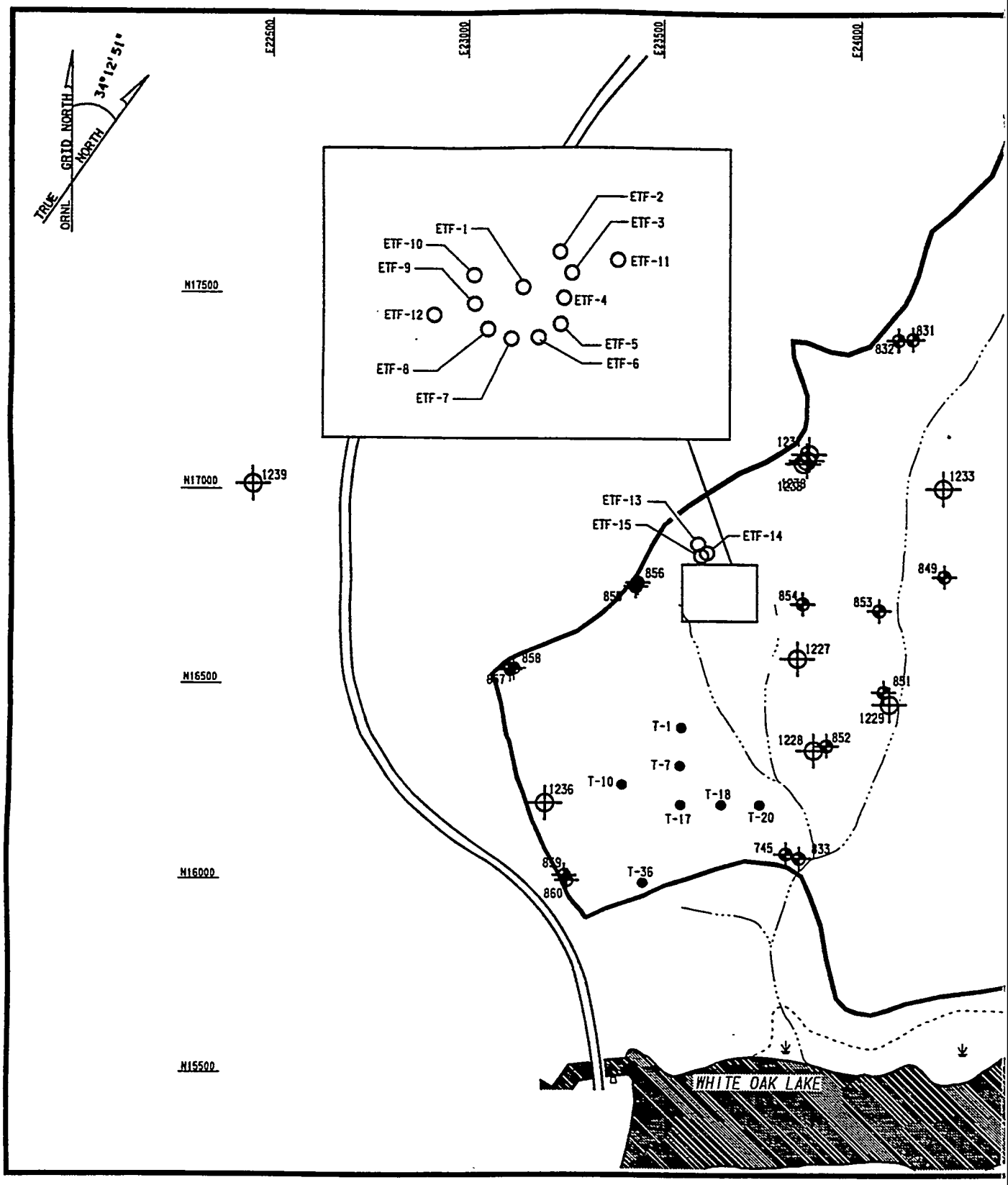

WAG6 06F323.DGN

**Fig. 3B.12. Typical WAG 6 trench-groundwater interaction scenarios.**




*Source: Ashwood & Spalding (1990).*

**Fig. 3B.13. Hydrograph and associated hyetograph for wells T44 and T63.**




WAG6 06F324.DGN

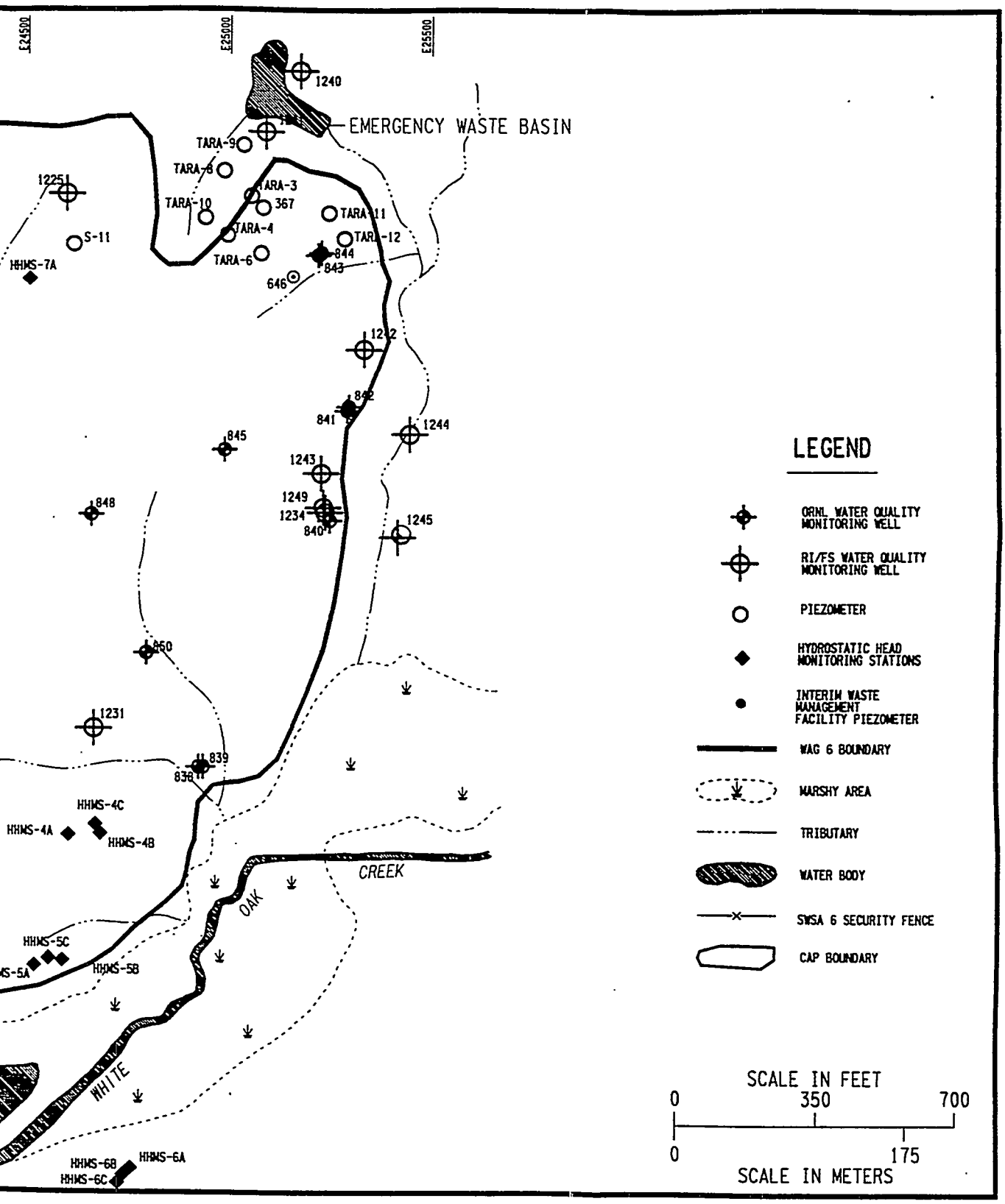
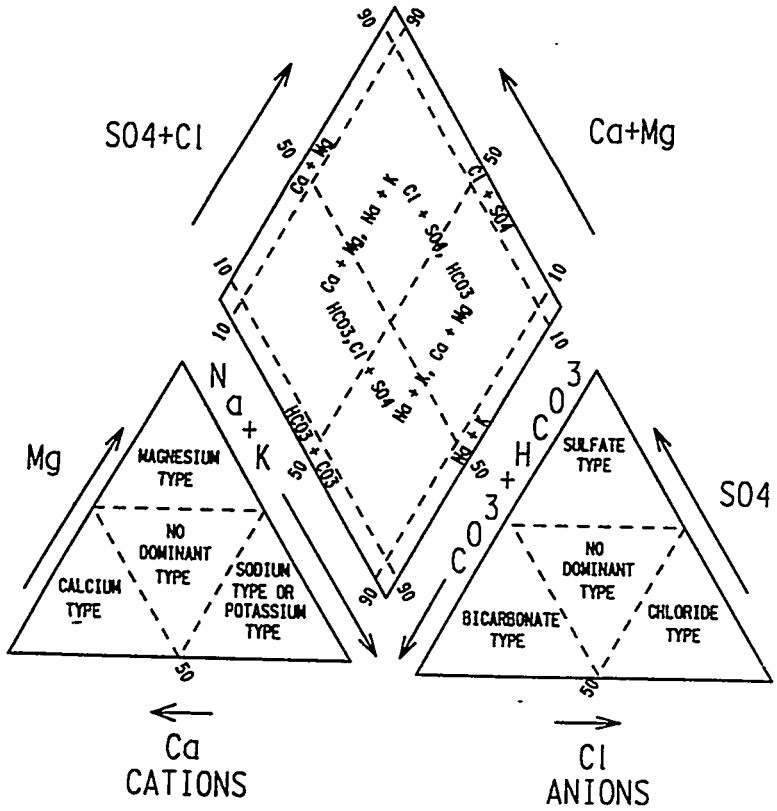



**Fig. 3B.14. WAG 6 aquifer geochemistry sampling locations.**



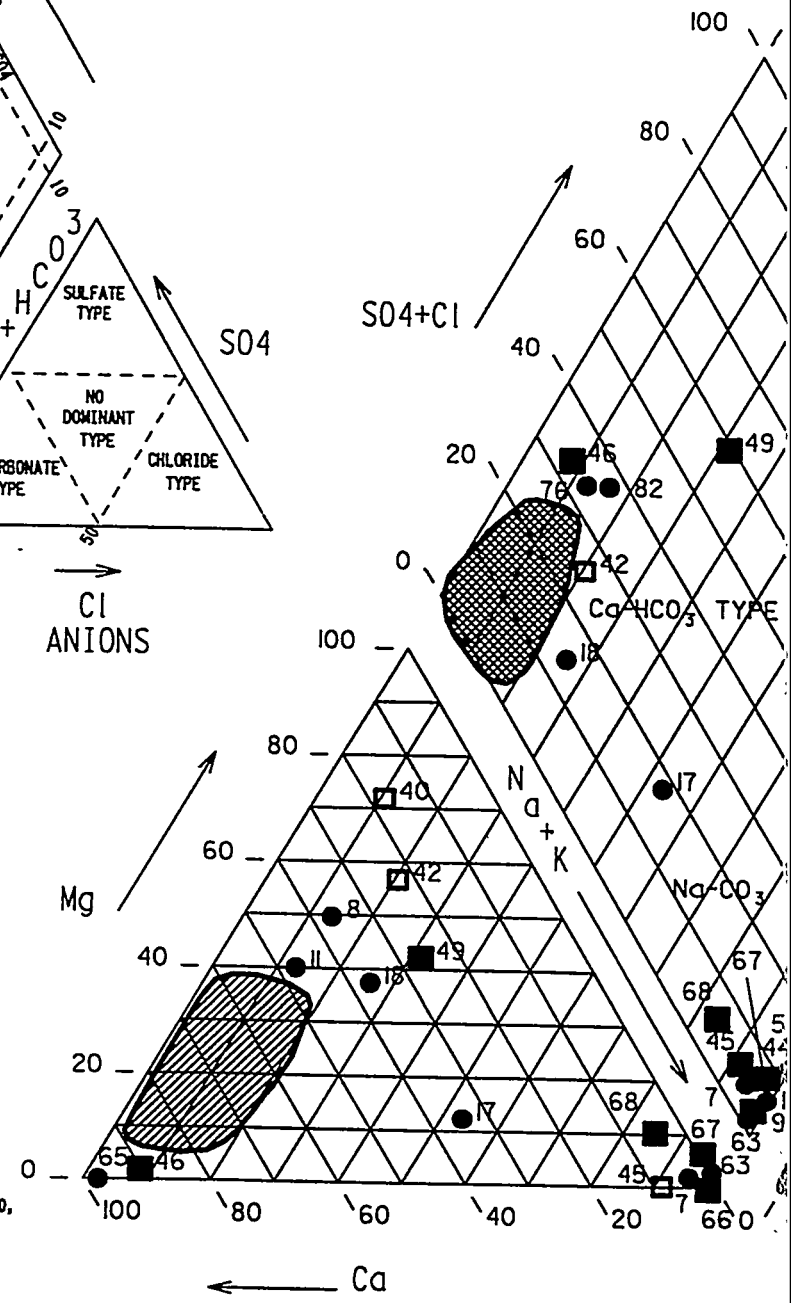

| PLOT SYMBOL | HYDROLOGIC UNIT | HYDROSTRATIGRAPHIC UNIT |
|---|---|---|
| ○ | - 1 - | MARYVILLE REGOLITH |
| ● | - 2 - | MARYVILLE BEDROCK |
| ◐ | - 3 - | BOTH MARYVILLE REGOLITH/BEDROCK |
| □ | - 4 - | NOLICHUCKY REGOLITH |
| ■ | - 5 - | NOLICHUCKY BEDROCK |
| ◧ | - 6 - | BOTH NOLICHUCKY REGOLITH/BEDROCK |
| ▲ | - 7 - | ROGERSVILLE BEDROCK |

DUE TO DENSITY OF DATA POINTS, WELLS ARE CLUSTERED IN STIPLED PATTERNS AS FOLLOWS:

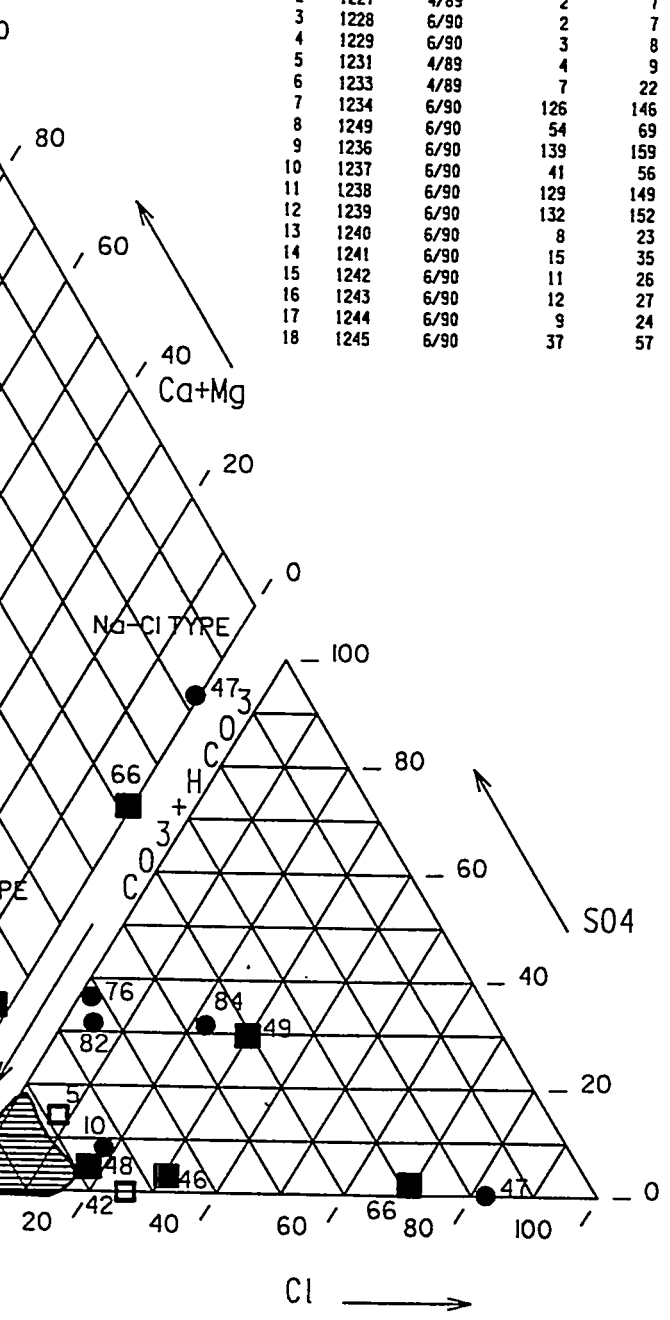
AREA 1 CONTAINS: 1-6,10,13,15,16, 19-39,41,43,51-62,64,69-85

AREA 2 CONTAINS: 1-6,8,10,11,13-16, 19-40, 43,51-57,59-62,64-65, 69-75, 77-81,83-86

AREA 3 CONTAINS: 1-4,6-9,11-41, 43-45,50-65,68-75,77-81,83,85




WAG6/DATA PIPER1.DGN 3.38




| PLOT # | WELL # | DATE SAMPLED | DEPTH (FT) T/SCREEN | DEPTH (FT) B/SCREEN | HYDROLOGIC UNIT |
|---|---|---|---|---|---|
| 1 | 1225 | 4/89 | 7 | 22 | 1 |
| 2 | 1227 | 4/89 | 2 | 7 | 4 |
| 3 | 1228 | 6/90 | 2 | 7 | 4 |
| 4 | 1229 | 6/90 | 3 | 8 | 4 |
| 5 | 1231 | 4/89 | 4 | 9 | 4 |
| 6 | 1233 | 4/89 | 7 | 22 | 2 |
| 7 | 1234 | 6/90 | 126 | 146 | 2 |
| 8 | 1249 | 6/90 | 54 | 69 | 2 |
| 9 | 1236 | 6/90 | 139 | 159 | 5 |
| 10 | 1237 | 6/90 | 41 | 56 | 2 |
| 11 | 1238 | 6/90 | 129 | 149 | 2 |
| 12 | 1239 | 6/90 | 132 | 152 | 2 |
| 13 | 1240 | 6/90 | 8 | 23 | 1 |
| 14 | 1241 | 6/90 | 15 | 35 | 2 |
| 15 | 1242 | 6/90 | 11 | 26 | 2 |
| 16 | 1243 | 6/90 | 12 | 27 | 2 |
| 17 | 1244 | 6/90 | 9 | 24 | 2 |
| 18 | 1245 | 6/90 | 37 | 57 | 2 |
| 19 | 745 | 6/90 | 35 | 60 | 5 |
| 20 | 831 | 6/90 | 24 | 50 | 2 |
| 21 | 832 | 6/90 | 58 | 86 | 2 |
| 22 | 833 | 6/90 | 10 | 31 | 5 |
| 23 | 838 | 6/90 | 5 | 22 | 6 |
| 24 | 839 | 6/90 | 25 | 56 | 5 |
| 25 | 840 | 6/90 | 11 | 27 | 2 |
| 26 | 841 | 6/90 | 36 | 56 | 2 |
| 27 | 842 | 6/90 | 8 | 23 | 2 |
| 28 | 843 | 6/90 | 4 | 19 | 3 |
| 29 | 844 | 6/90 | 25 | 52 | 2 |
| 30 | 845 | 4/89 | 19 | 40 | 3 |
| 31 | 848 | 4/89 | 10 | 32 | 3 |
| 32 | 849 | 4/89 | 11 | 33 | 3 |
| 33 | 850 | 4/89 | 6 | 22 | 3 |
| 34 | 851 | 4/89 | 4 | 20 | 6 |
| 35 | 852 | 4/89 | 5 | 22 | 6 |
| 36 | 853 | 4/89 | 5 | 26 | 3 |
| 37 | 854 | 4/89 | 5 | 27 | 3 |
| 38 | 855 | 6/90 | 30 | 52 | 2 |
| 39 | 856 | 6/90 | 55 | 81 | 2 |
| 40 | 857 | 6/90 | 50 | 70 | 4 |
| 41 | 858 | 6/90 | 85 | 106 | 5 |
| 42 | 859 | 6/90 | 5 | 26 | 4 |
| 43 | 860 | 6/90 | 34 | 62 | 5 |
| 44 | HHMS-4A | 7/87 | 380 | 400 | 2 |
| 45 | HHMS-4B | 7/87 | 174 | 215 | 5 |
| 46 | HHMS-4C | 7/87 | 41 | 62 | 5 |
| 47 | HHMS-5A | 7/87 | 380 | 400 | 2 |
| 48 | HHMS-5B | 7/87 | 196 | 219 | 5 |
| 49 | HHMS-5C | 7/87 | 42 | 63 | 5 |
| 50 | HHMS-7A | 7/87 | 380 | 400 | 7 |
| 51 | ETF-1 | 10/80 | 25 | 29 | 1 |
| 52 | ETF-2 | 10/80 | 28 | 32 | 1 |
| 53 | ETF-3 | 10/80 | 27 | 31 | 1 |
| 54 | ETF-4 | 10/80 | 27 | 31 | 1 |
| 55 | ETF-5 | 10/80 | 26 | 30 | 1 |
| 56 | ETF-6 | 10/80 | 26 | 30 | 1 |
| 57 | ETF-7 | 10/80 | 26 | 30 | 1 |
| 58 | ETF-8 | 10/80 | 25 | 30 | 1 |
| 59 | ETF-9 | 10/80 | 27 | 31 | 1 |
| 60 | ETF-10 | 10/80 | 27 | 31 | 1 |
| 61 | ETF-11 | 10/80 | 42 | 50 | 1 |
| 62 | ETF-12 | 10/80 | 42 | 50 | 1 |
| 63 | ETF-13 | 6/90 | 241 | 251 | 2 |
| 64 | ETF-14 | 6/90 | 85 | 95 | 2 |
| 65 | ETF-15 | 6/90 | 37 | 47 | 2 |
| 66 | HHMS-6A | 7/87 | 380 | 400 | 5 |
| 67 | HHMS-6B | 7/87 | 275 | 295 | 5 |
| 68 | HHMS-6C | 7/87 | 158 | 178 | 5 |
| 69 | T-36 | 10/89 | 12 | 17 | 4 |
| 70 | T-20 | 10/89 | 6 | 11 | 4 |
| 71 | T-18 | 10/89 | 2 | 7 | 4 |
| 72 | T-17 | 10/89 | 6 | 11 | 4 |
| 73 | T-10 | 10/89 | 17 | 22 | 4 |
| 74 | T-7 | 10/89 | 4 | 9 | 4 |
| 75 | T-1 | 10/89 | 4 | 9 | 4 |
| 76 | TARA-3 | 11/87 | 32 | 52 | 2 |
| 77 | TARA-4 | 11/87 | 35 | 55 | 2 |
| 78 | TARA-6 | 11/87 | 41 | 61 | 2 |
| 79 | TARA-8 | 11/87 | 16 | 36 | 2 |
| 80 | TARA-9 | 11/87 | 17 | 37 | 2 |
| 81 | TARA-10 | 11/87 | 17 | 37 | 2 |
| 82 | TARA-11 | 11/87 | 27 | 47 | 2 |
| 83 | TARA-12 | 11/87 | 8 | 28 | 2 |
| 84 | 367 | 11/87 | 59 | 69 | 2 |
| 85 | 646 | 11/87 | 29 | 39 | 2 |
| 86 | S-11 | 3/87 | 30 | 45 | 2 |

Fig. 3B.15. WAG 6 aquifer geochemistry.

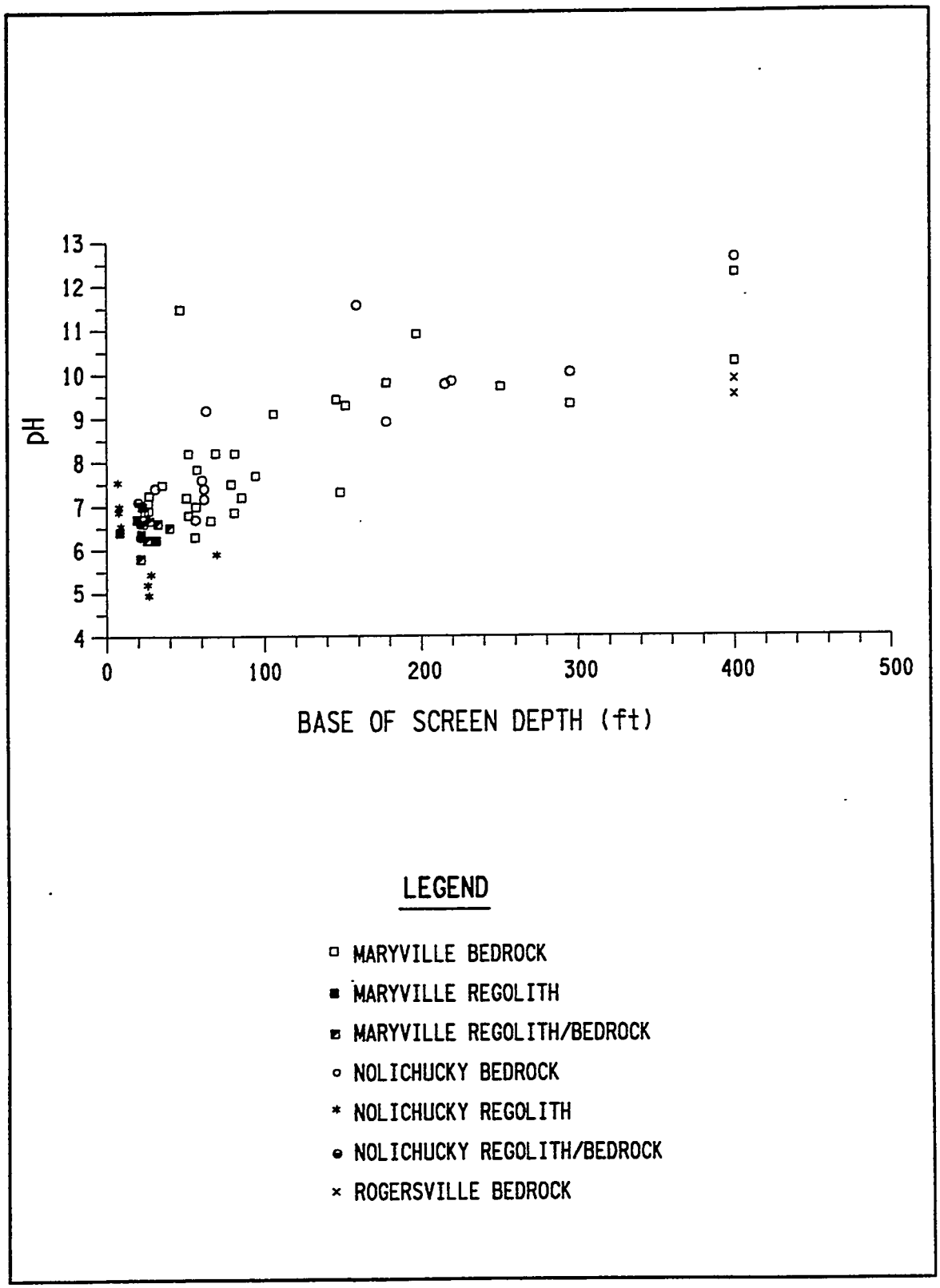



**Fig. 3B.16. WAG 6 groundwater pH versus depth.**

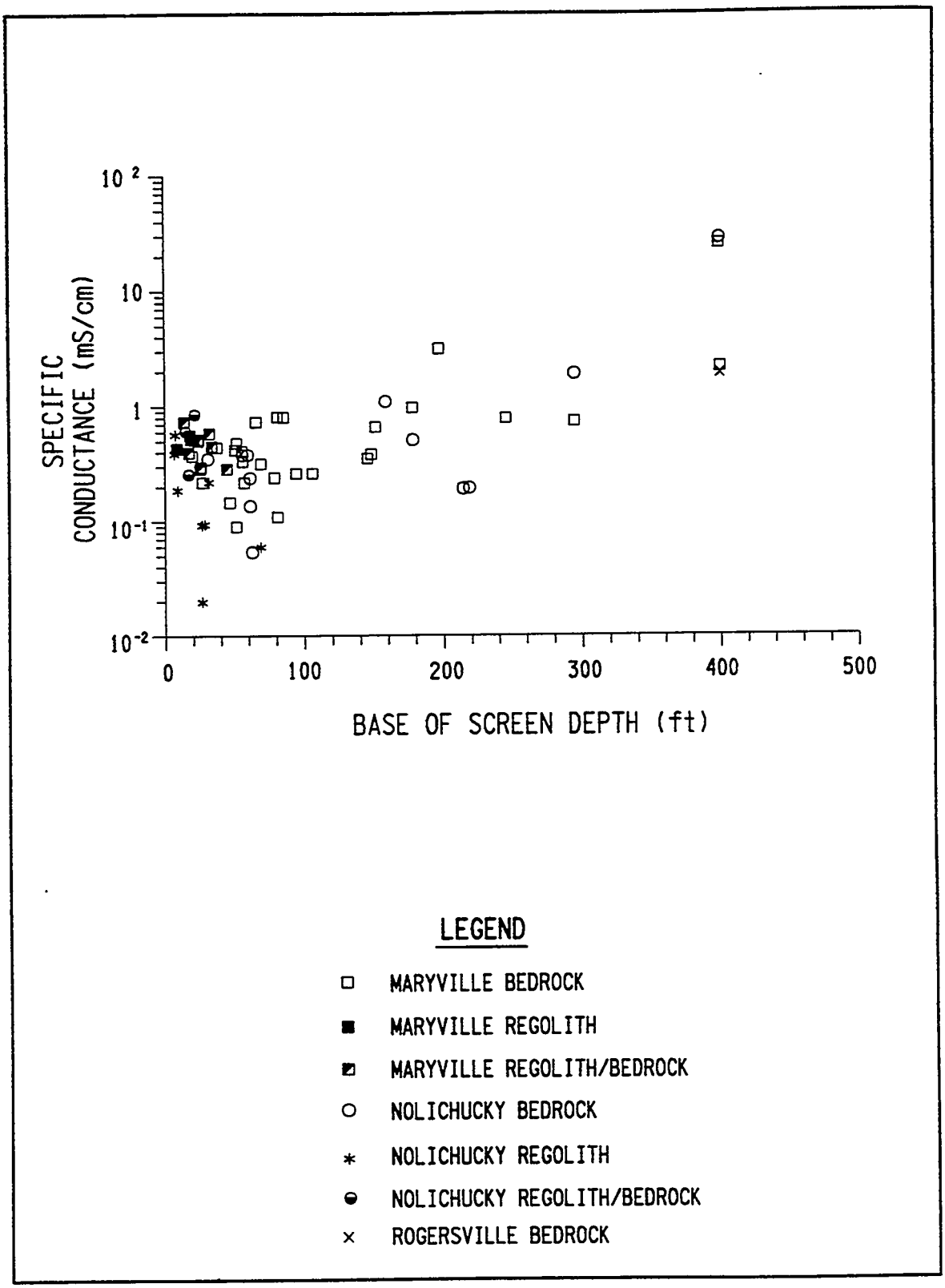
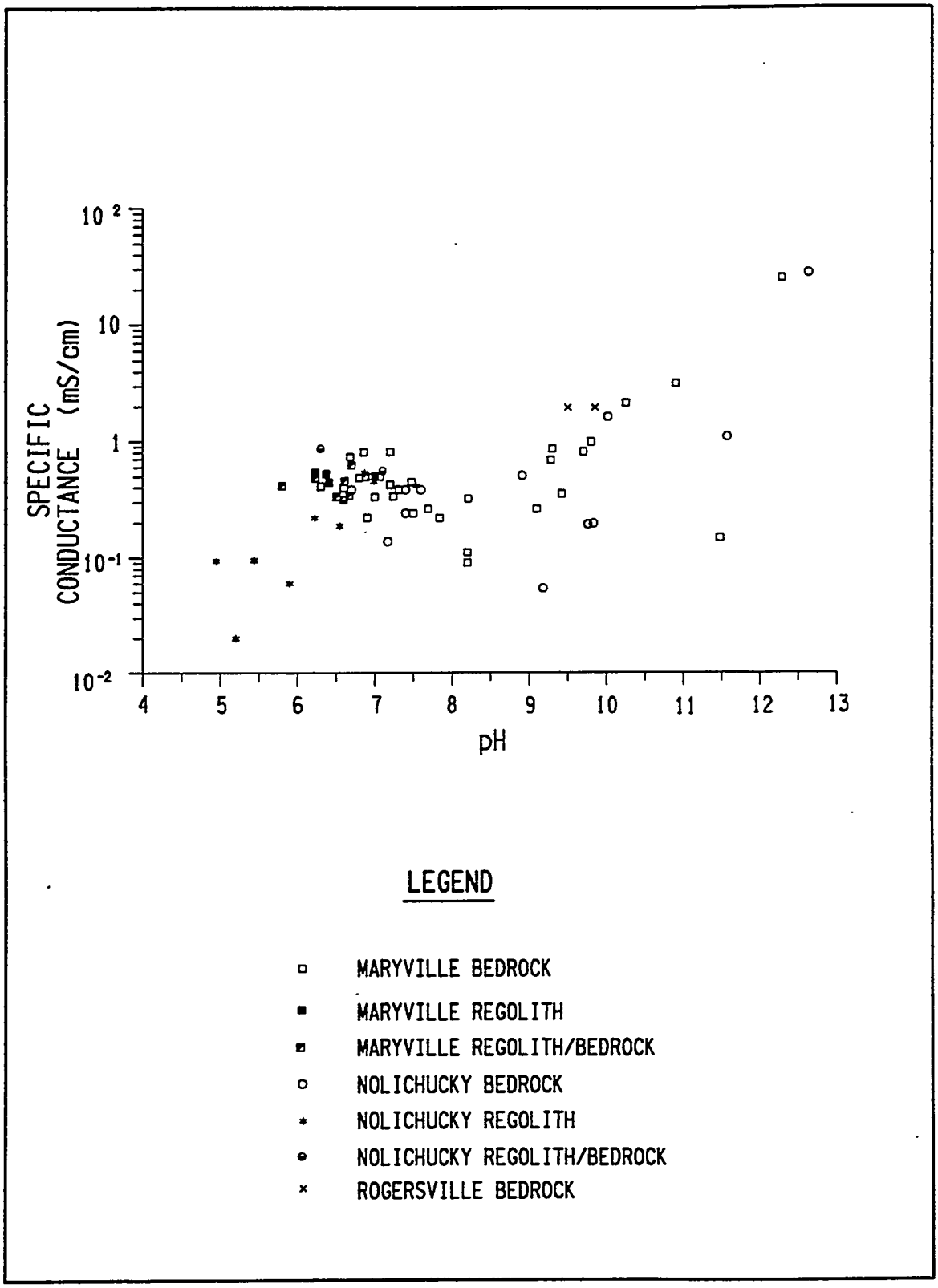



**Fig. 3B.17. WAG 6 groundwater specific conductance versus depth.**




WAG6 06F325.DGN

**Fig. 3B.18. WAG 6 groundwater pH versus specific conductance.**

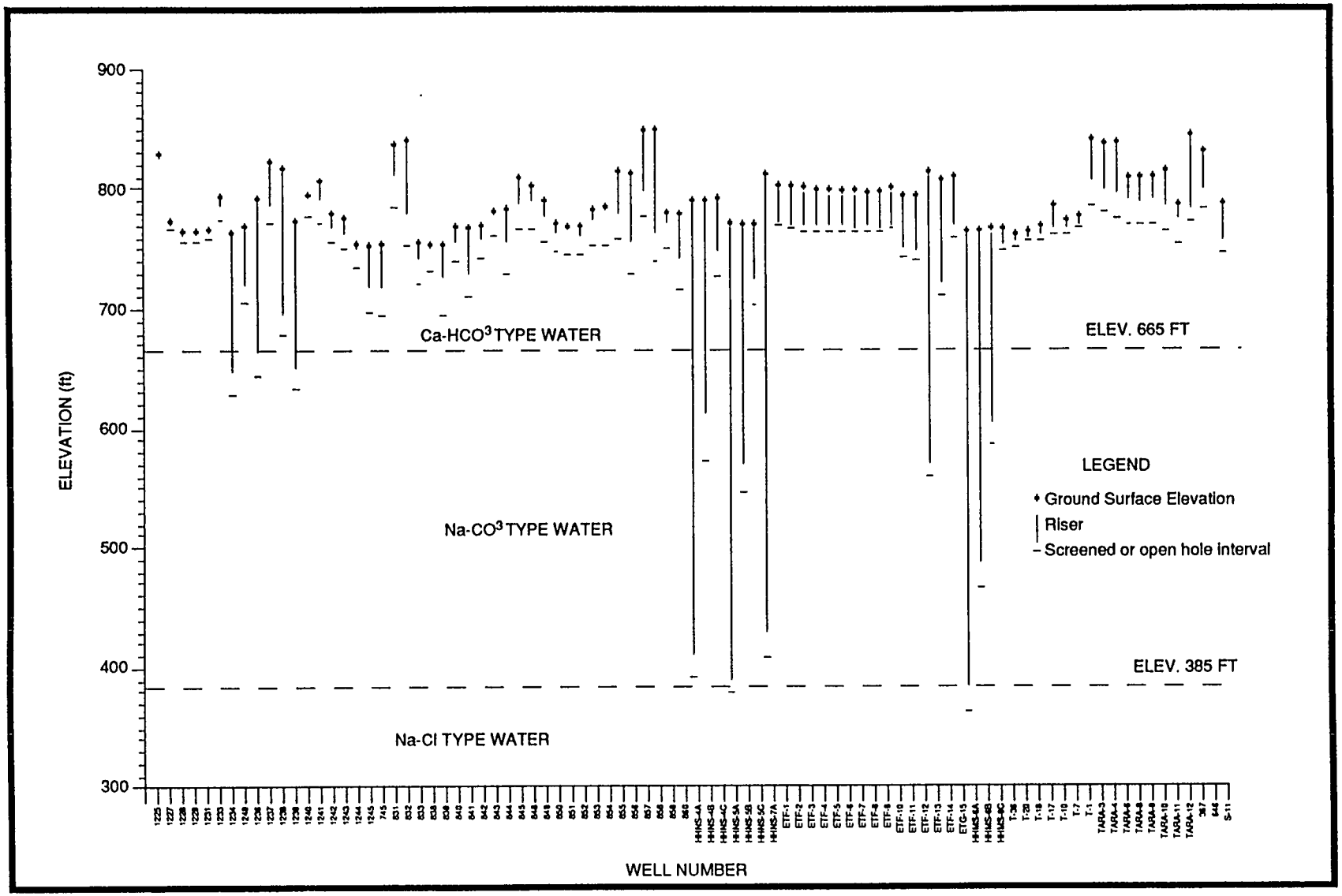
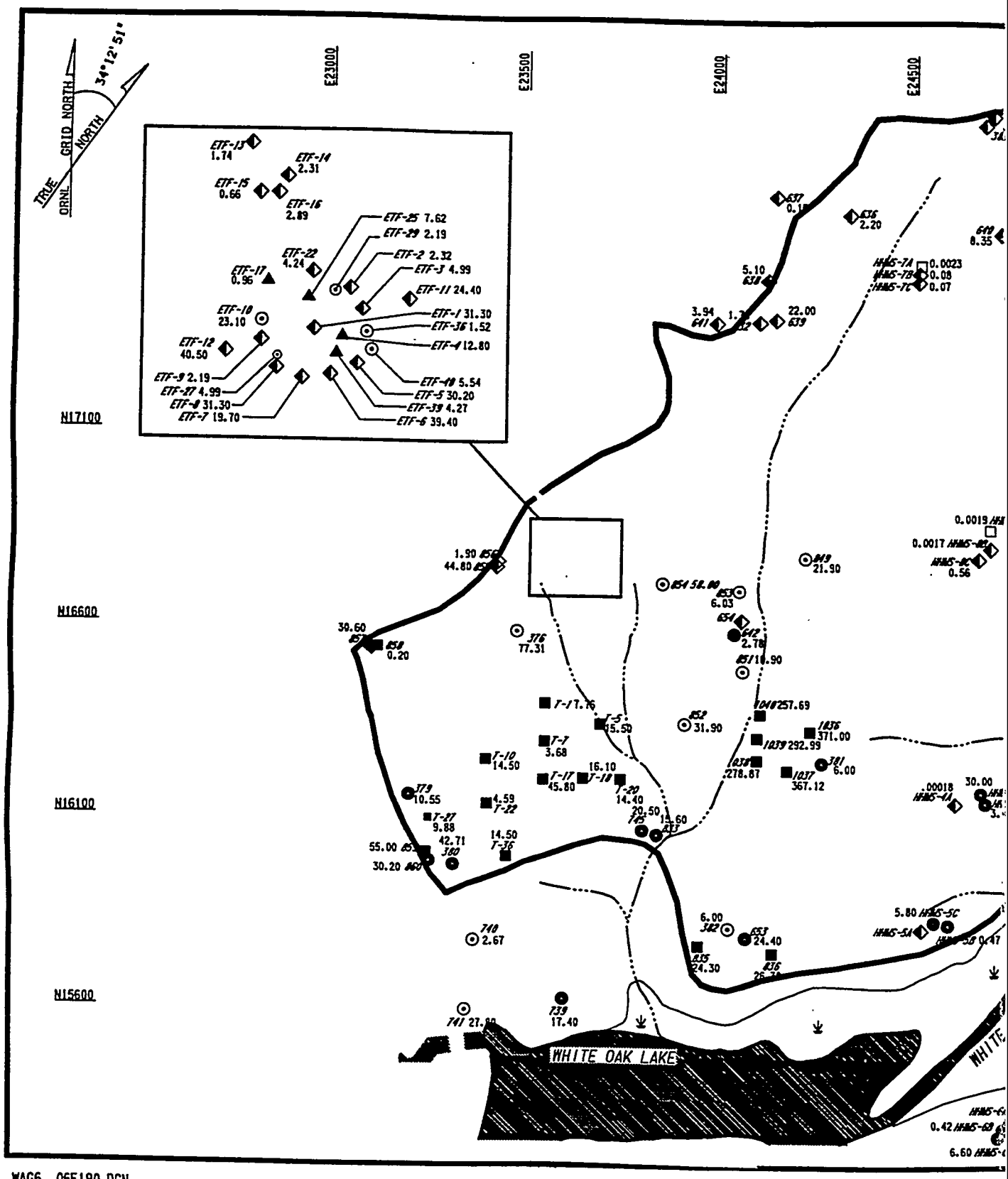



Fig. 3B.19. Relation of screened interval to geochemical zone.

5.18E 4104 143
Adapted AG 6 06F171 DGN




WAG6 06F190.DGN

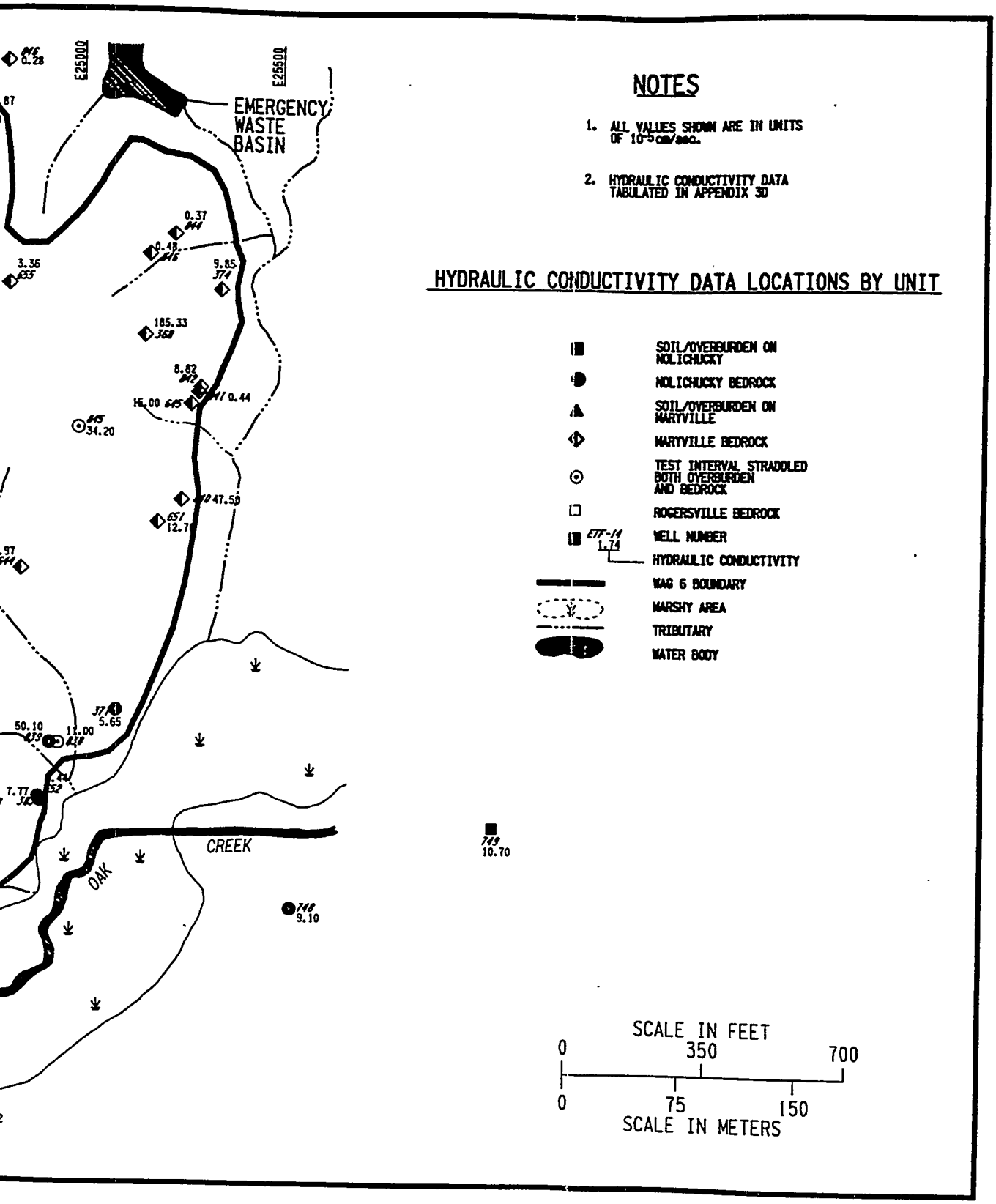



**Fig. 3B.20. WAG 6 hydraulic conductivity distribution map.**

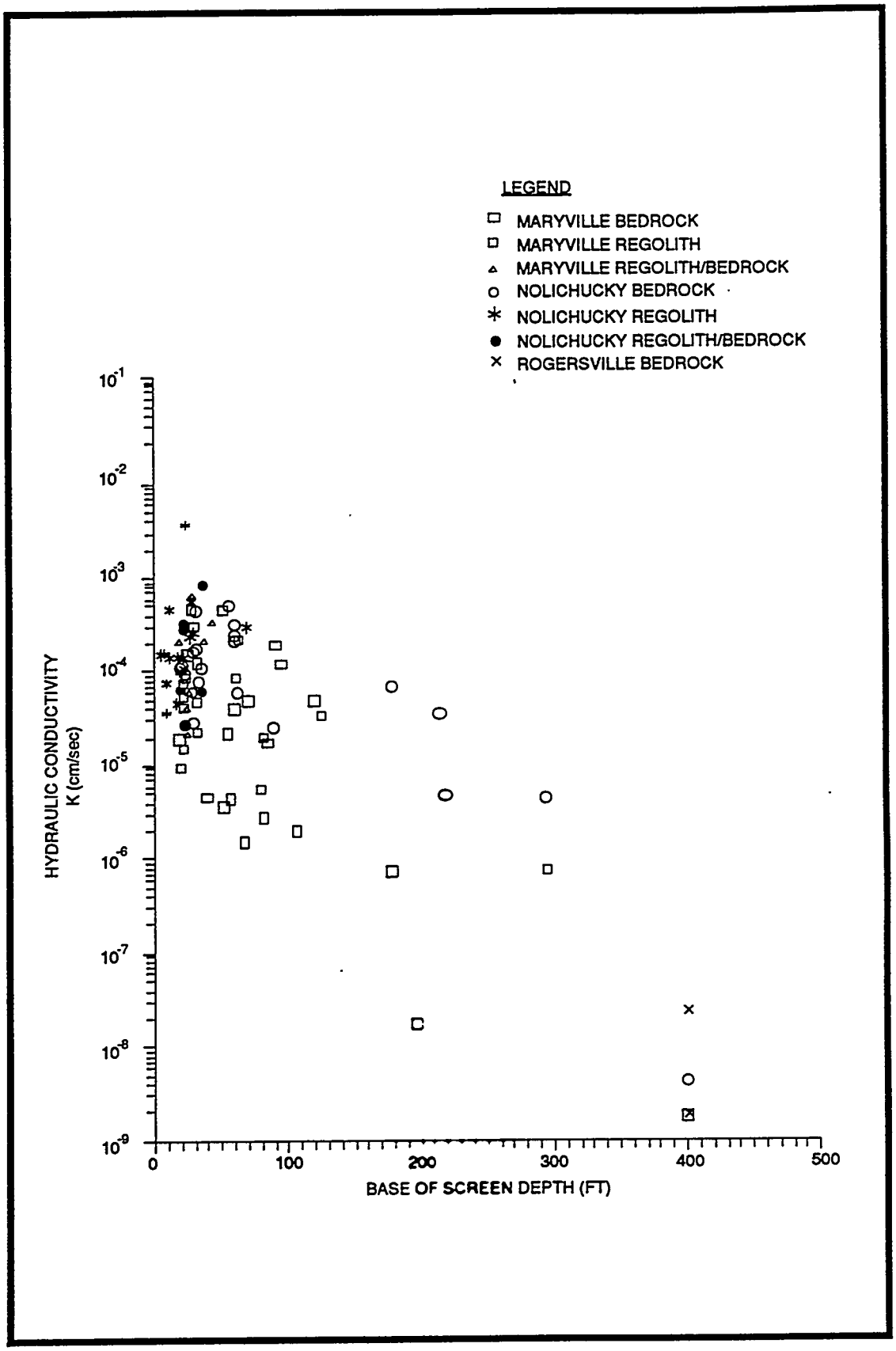



**Fig. 3B.21. WAG 6 hydraulic conductivity versus depth plot.**

5.18F 4104.174
Adapted from WAG 6 06F172.DGN

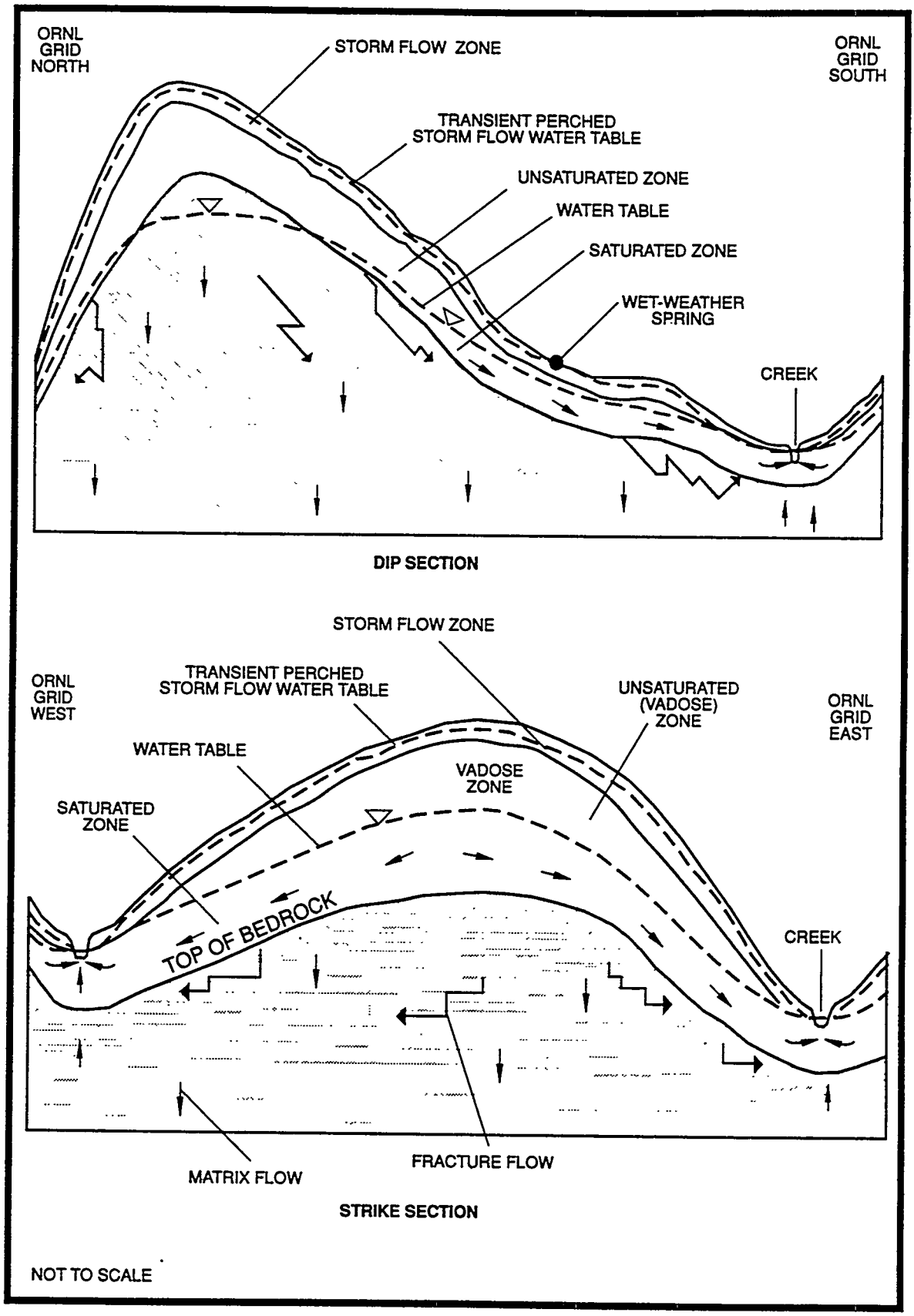
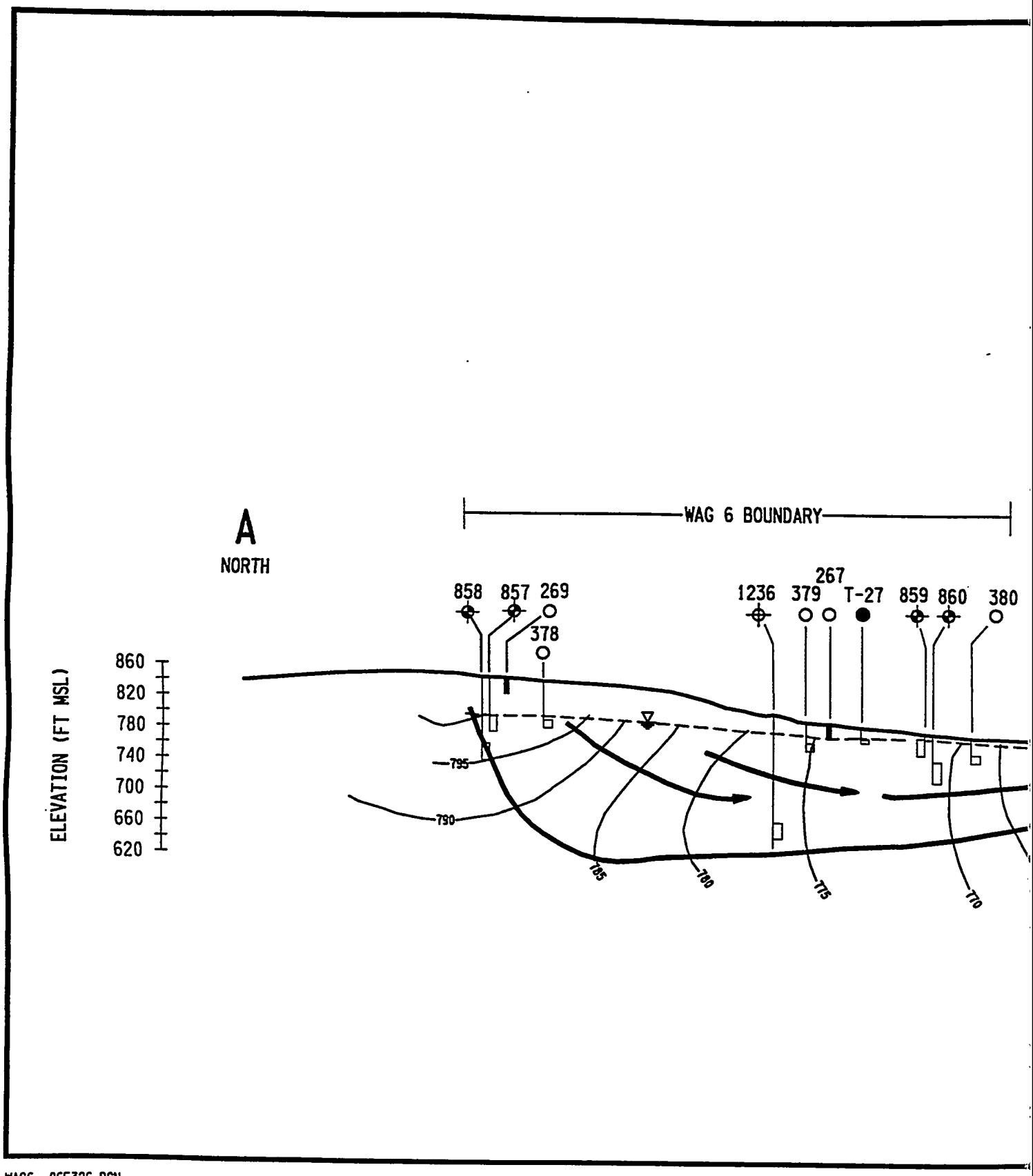



**Fig. 3B.22. Groundwater flow at WAG 6** (Modified after Moore 1991).

5.18 4104.9




WAG6 06F326.DGN

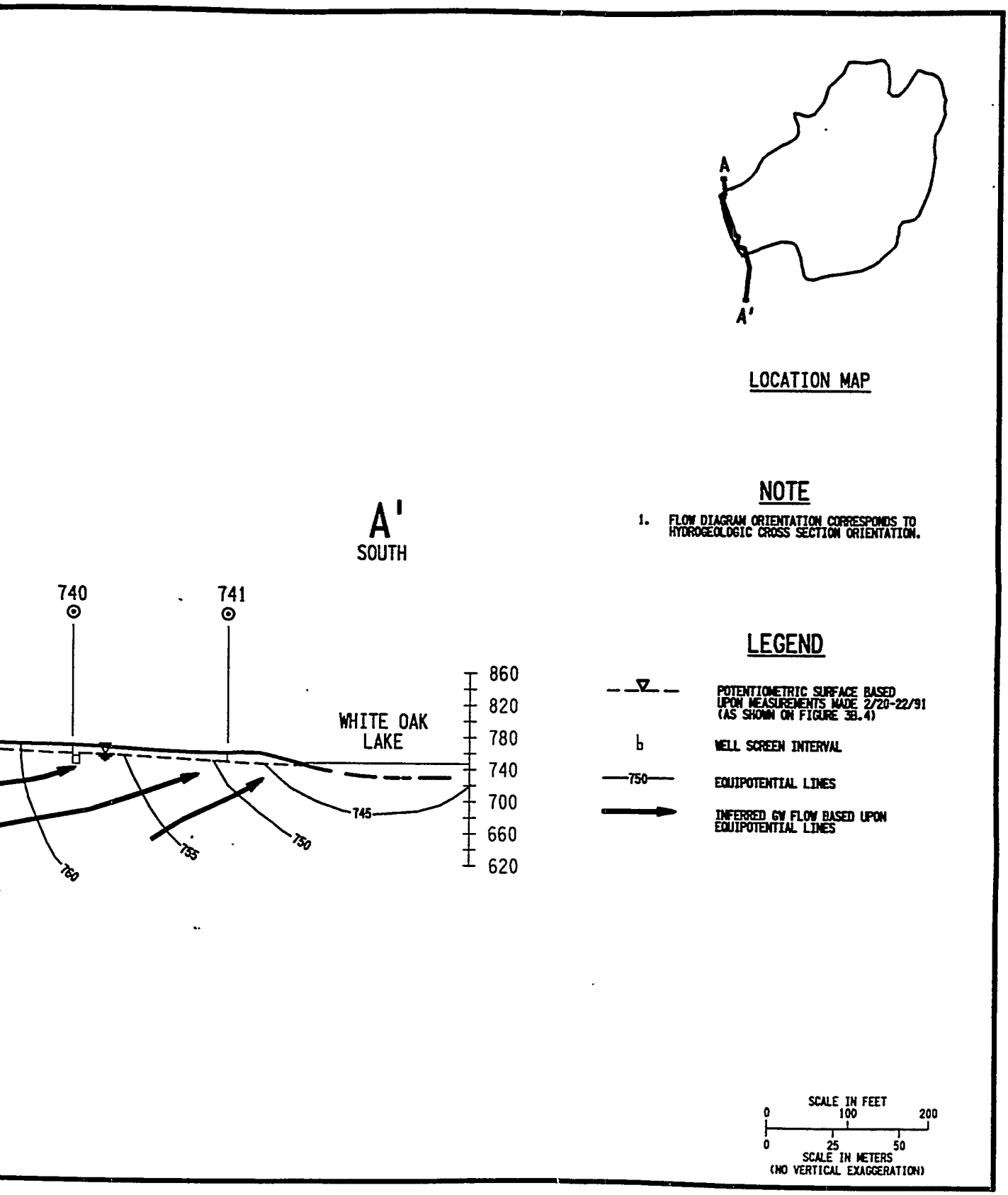
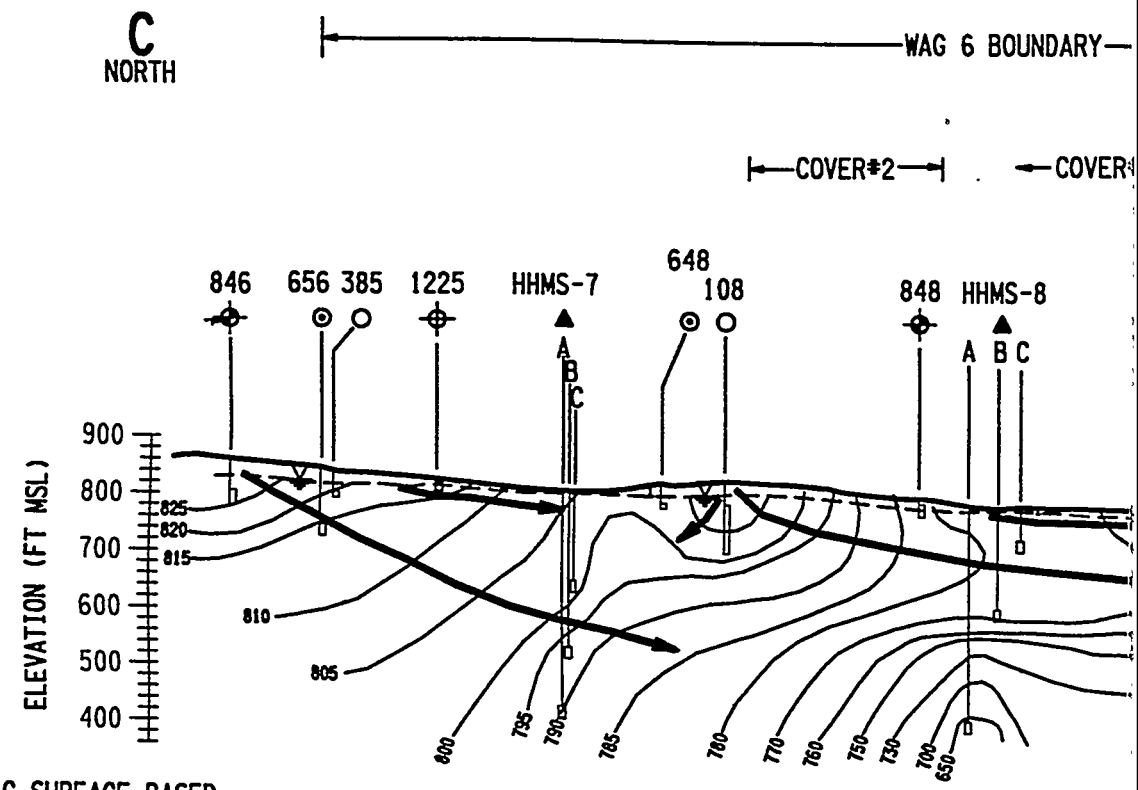



**Fig. 3B.23. WAG 6 north-south conceptualized groundwater flow diagram A-A'.**




## LEGEND

- POTENTIOMETRIC SURFACE BASED UPON MEASUREMENTS MADE 2/20-22/91 (AS SHOWN ON FIGURE 3B.4)
- WELL SCREEN INTERVAL
- 750 EQUIPOTENTIAL LINES
- INFERRED GW FLOW BASED UPON EQUIPOTENTIAL LINES

NOT
1.

2.

WAG6 06F327.DGN

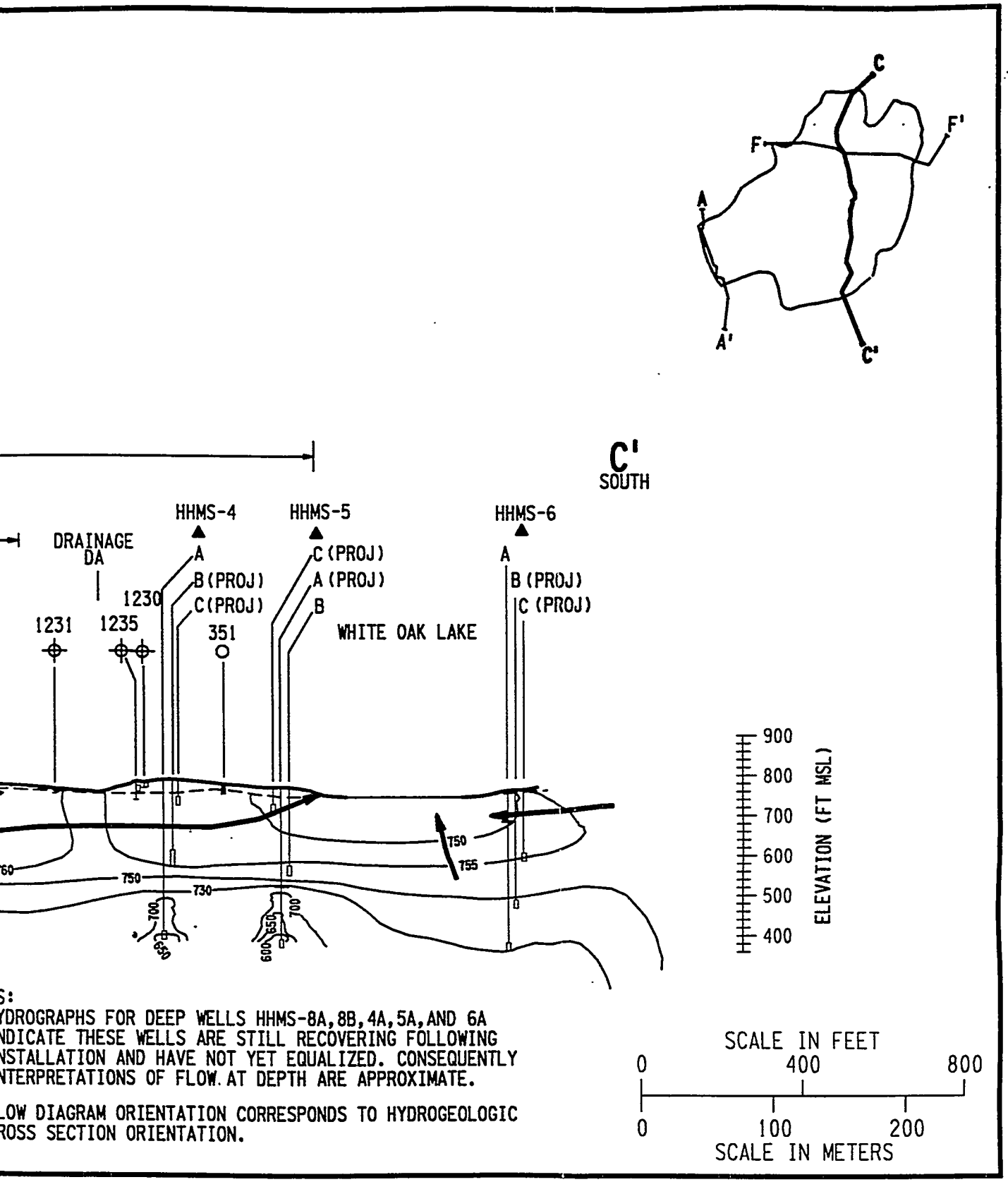
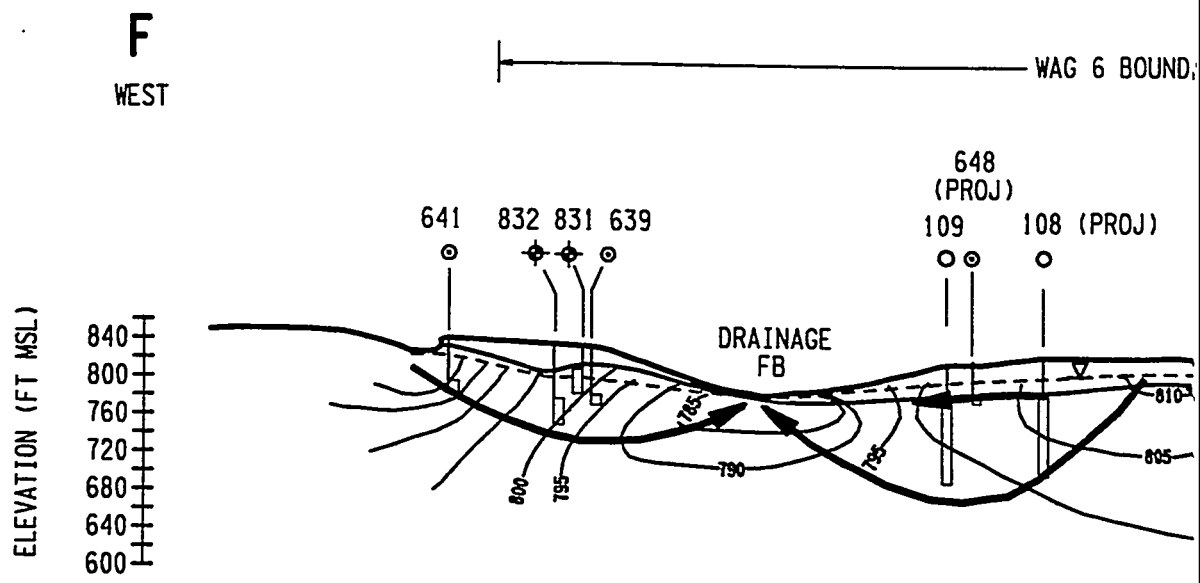



**Fig. 3B.24. WAG 6 north-south conceptualized groundwater flow diagram C-C'.**




LEGEND

POTENTIOMETRIC SURFACE BASED UPON MEASUREMENTS MADE 2/20-22/91 (AS SHOWN ON FIGURE 3B.4)

WELL SCREEN INTERVAL

EQUIPOTENTIAL LINES

INFERRED GW FLOW BASED UPON EQUIPOTENTIAL LINES

NOTE: FLOW DIAGRAM ORIENTATION CORRESPONDS TO HYDROGEOLOGIC CROSS SECTION ORIENTATION.

WAG6 06F328.DGN

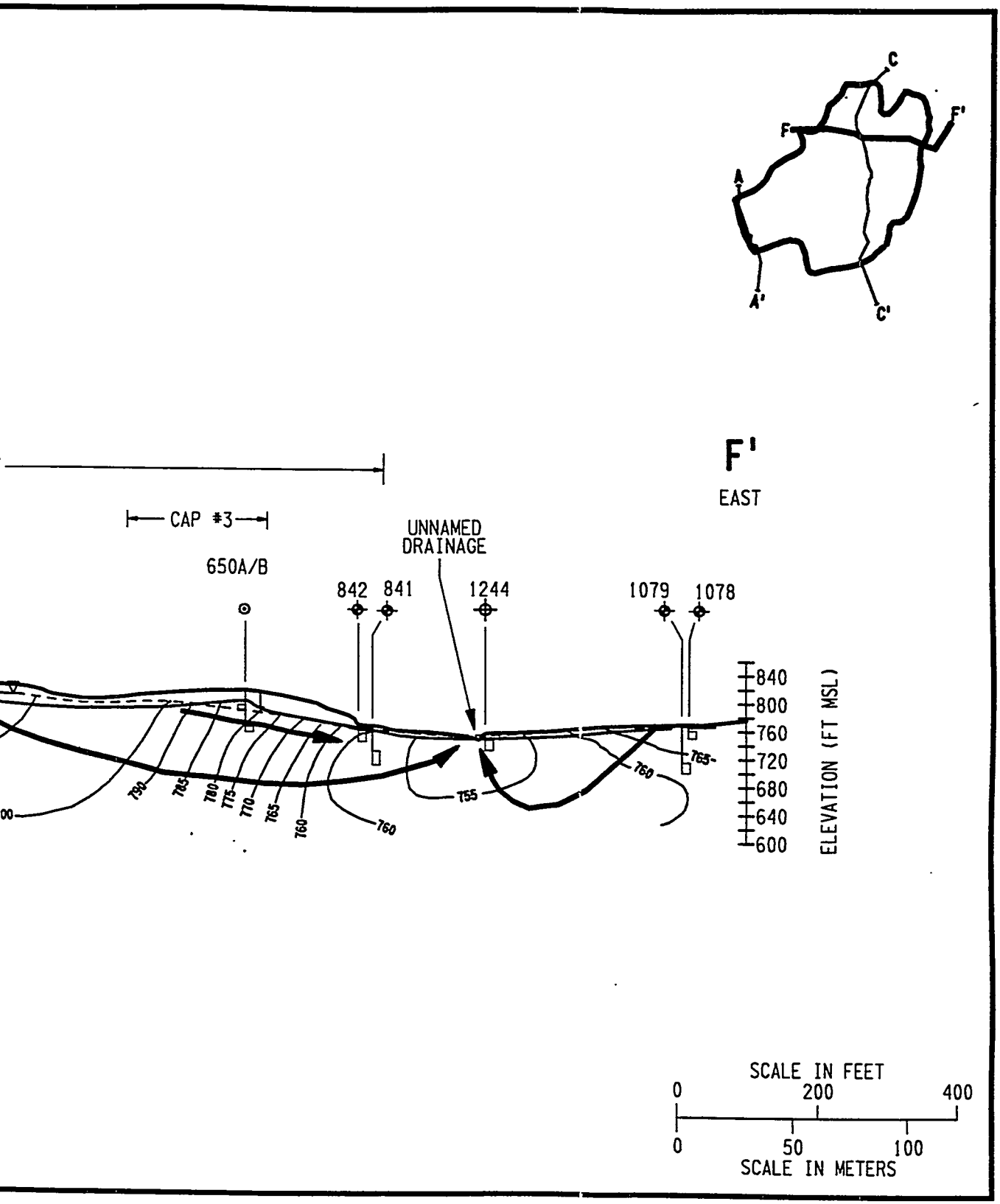



**Fig. 3B.25. WAG 6 north-south conceptualized groundwater flow diagram D-D'.**

WAG6 06F329.DGN B

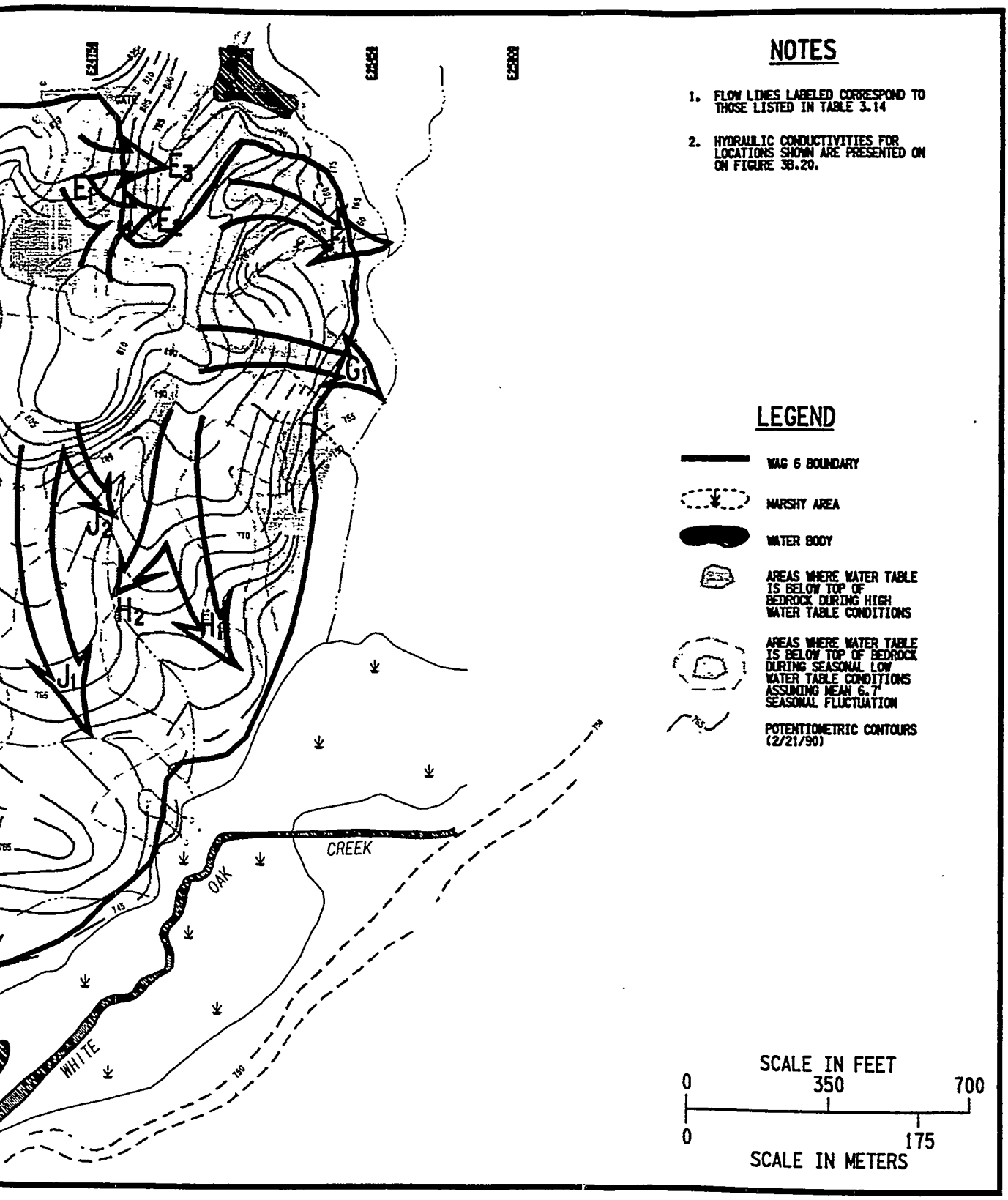
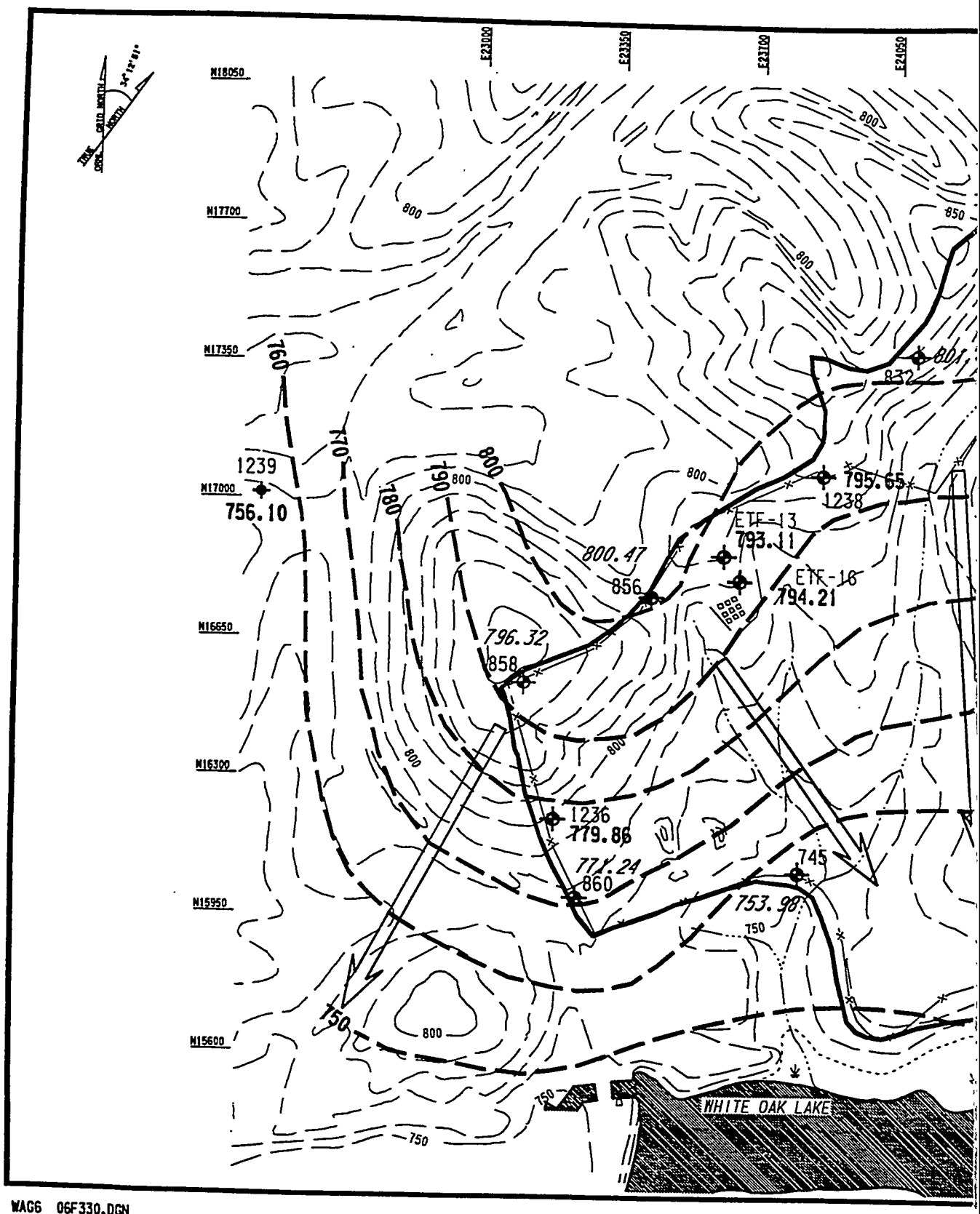



Fig. 3B.26. WAG 6 shallow groundwater flow lines.




WAG6 06F330.DGN

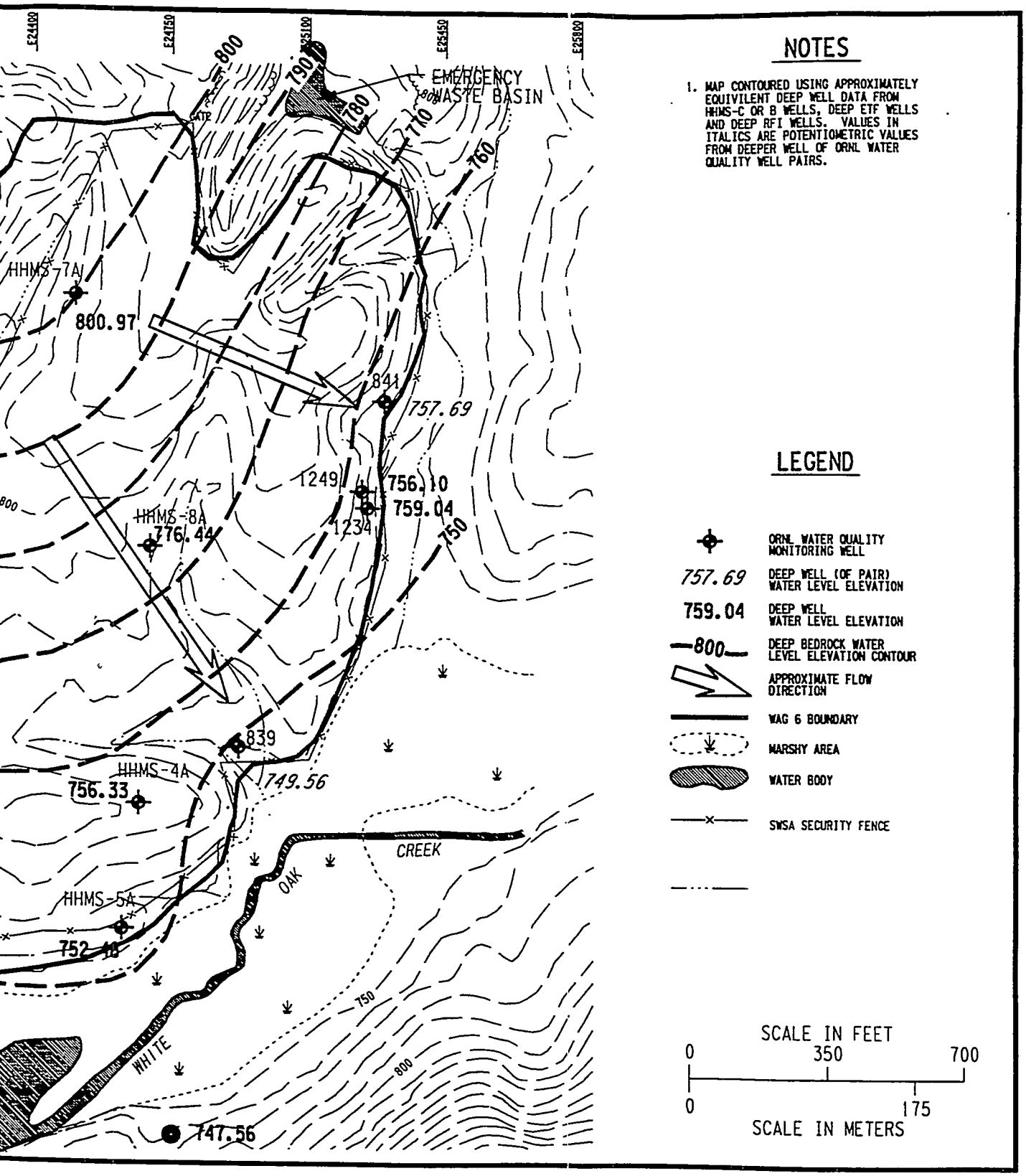



**Fig. 3B.27. WAG 6 approximate deep groundwater potentiometric map, February 20-21, 1990.**

# APPENDIX 3C. SURFACE WATER HYDROLOGY

This appendix describes the surface water hydrology of WAG 6 and the water bodies that receive surface water drainage. Section 3C.1, Surface Water Features, details the drainage features of WAG 6 and characterizes the receiving waters impacted by contaminants released from WAG 6. Section 3C.2, Stream Flow Data, summarizes the available WAG 6 stream flow data, including the continuous measurements of flow, storm events, and sporadic measurements of dry-weather flows. Section 3C.3, Precipitation and Runoff Relationships, summarizes the runoff characteristics of the WAG 6 basins based on analyses of available stream flow data and results of previous studies. This section also describes WAG 6 runoff processes, storm response, and stream base flow characteristics.

Section 3C.4 summarizes the effects of ICM capping on stream flow. Section 3C.5, Elements of Water Balance, provides estimates of average annual precipitation, evapotranspiration, surface runoff, and groundwater discharge. Finally, Sect. 3C.6, Surface Water Quality, describes the natural quality of the surface waters in WAG 6 based on the results of the 1989 WAG 6 RFI surface water sampling activities.

## 3C.1 SURFACE WATER FEATURES

WAG 6 is situated on a hillside within the WOC basin, as shown in Fig. 3C.1. The site is just north of WOL, which is an impounded segment of WOC. Outflow from WOL is controlled at a dam located about 0.6 miles upstream of the confluence of WOC and the Clinch River. All of the WAG 6 area drains into the WOL floodplain through the several drainages located within the WAG 6 boundary and along its eastern boundary. White Oak Creek joins the Clinch River at Clinch River Mile (CRM) 21.0.

### 3C.1.1 Key Local Surface Water Features

The receiving waters of WAG 6 are the EWB, an unnamed tributary to WOC that flows along the eastern side of WAG 6, WOL and the WOC Embayment, WOC, and the Clinch River. Each of these is described below.

#### 3C.1.1.1 Emergency Waste Basin

The Emergency Waste Basin is located just north of the SWSA 6 fence. Runoff from a small area north of the northern drainage divide drains into a natural channel leading to the EWB, which is approximately 40 ft below the level of WAG 6 boundary. The EWB was constructed in 1961-62 to serve as an emergency holding basin for LLW and process waste that ORNL could not release to WOC. The EWB has never been used for its intended purpose.

The bowl-shaped basin has a surface area of 2 acres and a storage capacity of 46 ac-ft (15 million gallons). The surrounding area is generally marshy and covered mostly with high grass and briar. An earth-filled dam on the eastern side controls outflow from the EWB, and any discharge (or seepage) enters a narrow stream draining the area southeast of the dam. Eventually this stream joins the unnamed tributary of WOC that parallels the eastern boundary of WAG 6.

### 3C.1.1.2 Unnamed tributary of WOC

An unnamed tributary parallels the eastern boundary of WAG 6 and runs south into a marshy area that marks the approximate high-water level of WOL. This unnamed tributary receives groundwater and surface water runoff from a 161-acre drainage basin that includes the southeast slopes of Haw Ridge, a portion of the pits and trenches of WAG 7, the EWB, and the eastern flank of WAG 6.

### 3C.1.1.3 White Oak Lake and White Oak Creek embayment

White Oak Lake, located just south of WAG 6, is formed by a low-head earthen dam located 0.6 miles upstream of the confluence of WOC and the Clinch River. Since September 1986, ORNL has recorded water level measurements for WOL at two locations along the upstream side of the dam. Lake stage data are recorded in 15-minute increments by a Stevens (chart) recorder installed in a stilling well mounted to the dam on the south side of the lake. In addition, since May 1988, ORNL has recorded lake stage data using two pressure transducers mounted to a staff gage in a stilling well affixed to the dam on the north side of the lake. Lake level elevations for May 1988 through January 1991 are shown in Fig. 3C.2. The data show a mean lake level for this period of 745.36 ft, which is only 3 ft above the bank-full level of the Clinch River. The maximum flood level recorded to date for WOL is 751.28 ft; it occurred on December 23, 1990, associated with a high-intensity rainstorm. The lowest lake level, 744.81 ft, was recorded November 10, 1990. Daily fluctuations of several feet associated with short-duration rainstorms is not uncommon. From May 1988 to January 1991, the lake level exceeded the mean 25 percent of the time, but reached elevations above 747 ft only 2.7% of the time. The cumulative frequency distribution of lake levels is shown in Fig. 3C.2.

At mean pool level, the lake has a 35.5 ac-ft (1,550,000 $ft^3$) storage capacity. Outflow from the lake is through a weir and a concrete-box culvert located at the dam. The present outlet capacity is estimated to be 2000 cfs (Tschantz 1987). Fitzpatrick (1982) estimated the levels of WOL for 100 and 500 year floods and for the probable maximum flood (PMF), to be 754, 754.9, and 761.4 ft, respectively. The PMF would inundate the animal waste trenches located in the southern part of WAG 6. Changes in the lake level have been shown to impact the water table elevation in the southern part of WAG 6 (Ashwood and Spalding 1990). As discussed previously in Appendix B and shown in Fig. 3B.13, lake level fluctuations are evidenced in water levels recorded in several of the deeper trench piezometers (Wells T44 and T63) adjacent to WOL, which fluctuate in response to lake stage elevation. Shallower trenches showed no response. Generally in the deeper trenches, a response to WOL fluctuation is only observed when lake levels exceed an elevation of 747 ft.

White Oak Lake is the sink for all the contaminants transported in runoff and sediments generated in the WOC basin, and accumulated sediments in the lake contain tritium, cobalt-60, and cesium-137. The lake dynamics greatly impact radionuclide releases into the Clinch River. Resuspended sediments are released from the lake during heavy storms. Dye studies conducted in 1987 by ORNL indicated that travel time through the lake is approximately 27 hours (Borders et al. 1987). The major flow paths appeared to be the old channel beds.

Discharge and water levels below the WOL dam are controlled by the operation of the Melton Hill Dam, which is located on the Clinch River, 2.3 miles upstream of the WOC embayment. The backwater from the Watts Bar reservoir, 21 miles downstream, also affects the stages of Clinch River and the WOC embayment.

### 3C.1.1.4 White Oak Creek

White Oak Creek drains a 6.53 $mi^2$ basin that contains the ORNL Main Plant (WAG 1) in Bethel Valley and all the other WAGs within Melton Valley and Bethel Valley. Elevations in the basin range from 741 ft at the Clinch River confluence to 1356 ft at the crest of Copper Ridge on the southeastern drainage divide. WOC originates at several springs along Chestnut Ridge. The main branch of WOC is 4 miles long, and its major tributaries are the Melton Branch, which drains the Melton Valley, and an unnamed tributary in the northwest part of Bethel Valley.

The WOC flow consists of natural surface runoff, groundwater discharge, and discharge of imported waters. ORNL imports water from outside the WOC basin and discharges an estimated 3.5 cfs of process and waste water into WOC annually (Webster and Bradley 1988). According to Tennessee's water quality criteria and stream use classification for interstate and intrastate streams, WOC's water is intended for freshwater use, for livestock watering, and for wildlife.

Flow characteristics of the streams in the WOC basin vary according to local geology, soils, and vegetative cover. Table 3B.1 shows flow statistics from four USGS flow gaging stations shown in Fig. 3.C1.

### 3C.1.1.5 Clinch River

The Clinch River is the major surface water body receiving discharges from WOC. Three TVA dams, Melton Hill, Norris, and Watts Bar, control the flow of the Clinch River. Norris Dam is about 32 miles from the site; Watts Bar Dam is on the Tennessee River near the lower end of the Clinch River.

At the Melton Hill Dam gaging station, the Clinch River has a drainage area of 3343 $mi^2$. The average annual discharge of the river is about 4600 cfs. The record since 1936 shows extremes ranging from the maximum of 39,600 cfs recorded February 18, 1937, to several zero-flow days recorded since Melton Hill Dam was completed in August 1962 (USGS 1990b).

River stages below Melton Hill Dam are affected by Watts Bar Lake backwater. Since power generation began at Melton Hill Dam in the summer of 1964, the Clinch River flow has corresponded to the power generation pattern. During the peak power generation days, Monday through Friday, releases are made for a 10-to-16 hour period; no releases are made for the remaining off-peak hours. The peak releases vary between 16,000 to 21,000 cfs.

Table 3C.2 shows the monthly flows of the Clinch River recorded at the Melton Hill Dam tailwaters for the 1988-1989 water year.

According to the State of Tennessee stream use classification, the Clinch River water is used for domestic water supply, industrial water, aquatic life, recreation, irrigation, livestock watering, wildlife, and navigation.

### 3C.1.2 Site Drainage Characteristics

The number of streams in WAG 6 result in short overland flow lengths. Land slopes vary from 20 to 57 percent around the ridges and from 2 to 12 percent in the topographic low areas. Despite the modifications to the site vegetation, soils, and surfaces related to the site's use for disposal, site streams and overall topography have not been altered. Gross topographic features remain unchanged.

However, several features constructed at WAG 6 have impacted the overall surface water hydrology of the site:

- The 49 Trench French Drain, constructed in the central part of the site to intercept groundwater, discharges directly to surface water drainages within WAG 6 via two outfalls at the termination of the north and east limbs. Although discharge from the north limb of the French Drain is intermittent and low (<1.0 gpm), the east limb has sustained discharges to drainage DA ranging from 0.3 to 20 gpm.

- In April and May of 1989, as part of the ICM, six large areas (covering approximately 15% of the site) were capped with HDPE to reduce infiltration. Around the capped areas, trapezoidal drainage channels or berms were constructed. Channels are 1 ft deep and 1 ft wide at the bottom and have 3:1 side slopes lined with an impermeable membrane and 6- to 8-in. riprap. To avoid erosion from accelerated runoff from capped areas, conveyance channels and attenuation channels were installed as energy dissipators (Eiffe et al. 1988). The conveyance channels lead to nearby streams; attenuation channels spread runoff over the land surface. Where these channels cross service roads, six old culverts were replaced with new culverts with increased hydraulic capacity. All culverts were designed to pass flows from a storm of 25-year frequency and 24-hr duration. Fig. 3C.3 shows the capped areas and their drainage features. The caps have increased the site's surface runoff volumes and the peak flow rates. Storm runoff volumes and rates have also been increased due to addition of other impervious areas such as Tumulus pads and several buildings.

WAG 6 is divided into 10 subareas that define drainage areas associated with surface streams. These subareas, shown in Fig. 3C.4, are listed below and discussed in the following sections.

| Subarea | Drainage Area (acres) |
|---|---|
| FA | 12.2 |
| FB | 21.6 |
| DA | 9.6 |
| DB | 8.8 |
| A | 0.9 |
| B | 2.5 |
| C | 1.5 |
| South Slopes | 5.9 |
| East Slopes | 2.3 |
| Southwest Slopes | 2.7 |

### 3C.1.2.1 Subarea FA

The western and eastern parts of Subarea FA are drained by separate streams (Streams FAA and FAB). The westernmost stream flows southeasterly, while the easternmost stream flows to the south. Both are about 500 ft long. They join in a low-lying marshy area and from there flow southeasterly as a single stream for about 230 ft; this stream then joins the stream draining Subarea FB. The joined stream passes through a culvert under the service road near the southern boundary of WAG 6 then runs about 500 ft before discharging into WOL.

The average stream channel slope is about 5%. In the upstream reaches, channels are not well-defined, but in the middle reaches the channels are about 8-10 ft wide—although flow is usually confined to a 1.5 ft-wide section. At the basin outlet, the stream channel is about 3 ft wide, and the bankfull depth is about 16 in. The overland slopes range from 2 to 12 percent, and the overland flow distances to the streams are about 150 ft.

### 3C.1.2.2 Subarea FB

A single stream running north to south drains Subarea FB. The stream channel is 1900 ft long and its average slope is about 3%. In the upstream reaches, the channel is 6 to 18 in. wide and the bankfull depth is 1 ft. At the downstream end, the channel width is about 36 in., and the depth is about 16 in. Within this subbasin, the overland flow distances to stream FB range from about 150 to 300 ft.

The north leg of the 49 Trench area French Drain (226 ft long) is located in the northeast part of Subarea FB. The French Drain terminates in a 4 ft by 4 ft concrete settling tank close to the stream. However, records indicate discharge from the French Drain settling basin has been intermittent, (observed only five times from 1984-1985), and peak discharge has been less than 1 gpm (Davis & Marshall 1988).

### 3C.1.2.3 Subarea DA

The L-shaped Subarea DA lies in the middle of WAG 6. The south end of the French Drain terminates in a 4-ft by 4-ft concrete setting tank approximately 200 ft east of Building

7842, which is located on the southwest ridge of Subarea DA. The tank has a 4-in. PVC outlet pipe and discharges directly overland to stream DA.

All of Subarea DA is drained by a natural easterly flowing stream. The stream is 550 ft long and has a channel slope of about 3.7%. The downstream channel is about 3 ft wide and 1 ft deep at bankfull capacity. The stream passes under the service road through a 30-in. culvert, crosses the WAG 6 boundary, and then joins the stream draining Subarea DB. The combined stream then runs into the floodplain of WOL.

### 3C.1.2.4 Subarea DB

Subarea DB, located in the eastern part of WAG 6, is drained by a stream running north to south. The stream is about 750 ft long, and its channel has an average slope of about 4%. Its upstream reach is made up of various channels that are 3 to 6 in. wide and drain a flat floodplain. The stream's downstream reach is a riprap-lined, 2- to 3-ft wide channel. The stream passes through a culvert, crosses the WAG 6 boundary, and joins the stream from Subarea DA.

### 3C.1.2.5 Subarea A

Subarea A is located in the northern part of WAG 6. Overland flow from the west and east slopes of Subarea A drains north into the stream leading to the EWB.

### 3C.1.2.6 Subarea B

Subarea B is located in the northeastern part of WAG 6. A stream 350 ft long drains the area toward the northeast. The stream channel is about 16 in. wide and 6 in. deep. About 75 ft after crossing the WAG 6 boundary, the stream joins another stream flowing south, and together they join the unnamed tributary of WOC that separates WAG 6 and WAG 7 and discharges to the floodplain of WOL.

### 3C.1.2.7 Subarea C

Subarea C is located in the eastern part of WAG 6. A small stream runs east and empties into the WOL floodplain. The high activity solvent waste auger holes are located in Subarea C.

### 3C.1.2.8 Slopes

The easternmost slopes of WAG 6 drain by overland flow into the unnamed tributary that flows east of the WAG 6 boundary. The southern slopes of WAG 6, south of the drainage divide of Subareas FB and DA, discharge directly into the floodplain of WOL. There are no developed stream channels on these slopes. A small area west of the drainage divide of Subarea FA drains southeasterly toward stream FA draining into WOL. Some drainage also occurs toward the perimeter service road and into small channels running towards the WOL.

## 3C.2 STREAM FLOW DATA

Limited stream flow data are available from past ORNL research activities, and, more recently, from the WAG 6 RFI surface water sampling events. Available data are summarized below.

### 3C.2.1 Continuous Flow Measurements

From June 1985 to June 1987, continuous flow measurements were made at three weirs located at road culverts near the southern boundary of WAG 6 (Davis et al. 1986). Stations 1 and 2 were located at the outlet of Subareas DB and DA. Station 3 was located at the outlet of the combined drainages of Subareas FA and FB (Fig. 3C.5). At each site, a combination V-notch and rectangular weir was installed in the upstream end of the 15-in. culvert. Water surface elevation (stage height) was measured using a pressure transducer in a stilling well constructed in the pool upstream of the weir. The stage height was recorded every 15 minutes with a Stevens punch tape water level recorder. Stage height was converted to flow rate with a rating curve. Flows could be measured within the range of 0.09 to 1.07 cfs.

Because of equipment failures, flow measurements were considered unreliable for 7 days for Station 1, for 11 days for Station 2, and for 31 days for Station 3 during the 1985-1987 data period. Daily flow hydrographs for the same period are shown in Figs. 3C.6a and 3C.6b.

### 3C.2.2 Storm Runoff Measurements

#### 3C.2.2.1 October 1980-March 1983 samplings

As part of the ETF site investigation activities initiated in 1980 (Davis et al. 1984), two Parshall flumes with 9-in. throats were constructed in two channels draining the ETF site (FAA and FAB streams in Subarea FA). Flumes I and II have drainage area of 1.6 acres and 2.2 acres, respectively. A PVC liner was placed about 13 ft upstream of each flume at 6.5 ft below the channel bottom so that the subsurface flow could also be passed through the flume. Sixty runoff events were recorded at Flume 1 and 121 at Flume 2 for the 30-month period from October 1980 to March 1983. The peak flows (in cfs) were:

| | Flume I | Flume II |
|---|---|---|
| Maximum Discharge (cfs) | 2.05 | 1.80 |
| Mean Peak Discharge (cfs) | 0.37 | 0.35 |
| Standard Deviation of Peak Discharge (cfs) | 0.42 | 0.38 |

Hydrographs recorded at the flumes for winter (November 1980) and summer (June 1981) storms are shown in Figs. 3C.7a and 3C.7b, respectively.

### 3C.2.2.2 April-May 1990 storm runoff sampling

As part of the WAG 6 RFI activities, storm runoff measurements were made during April-May 1990. Automatic flow monitoring sites were established at four locations (Fig. 3C.5) on the streams draining subareas FA, FB, DA, and DB. A trapezoidal flume with a 2-in. throat and 60° side slopes was installed in the stream channel draining Subarea FA. A Parshall Flume with a 6-in. throat was installed in the drainages of FB and DB. In drainage DA, a Parshall flume with a 18-in. throat was installed. The flume sizes were selected based on channel geometry at bankfull capacity. All of the flumes were prefabricated with fiberglass by Free Flow, Inc. and were equipped with two stilling wells, one upstream and the other downstream of the throat. The stilling wells were equipped with pressure transducers (2 to 5 psi sensitivity range) to measure the water stage. An Easy-Logger Model EL-834 was used to record the stage measurements (TM-06-05A, Surface Water and Sediment Investigation, Phase 1, Activity 2). The stage measurements were converted to flow rates using factory-supplied rating curves. The design characteristics of the flumes are shown in Table 3C.3.

Figures 3C.8a through 3C.8e are storm hydrographs for April 28, May 17, May 20, and May 27, 1990 storms, respectively. A total of two storms were successfully monitored at each site. Table 3C.4 shows the storm rainfall, runoff, and peak flows for each of the storms at each site.

### 3C.2.3 Dry Weather Flows

During April and May of 1983, Davis et al. (1984) made several bucket-and-stopwatch measurements to quantify the dry weather flows at the ETF site. The average of the measured flows was about 0.0014 cfs. Streams were dry most of the time.

As part of surface water sampling for the WAG 6 RFI in 1989, dry-weather (base flow) flows were measured at various stream locations within WAG 6 during the sampling events as well as at seeps and the outfalls from the 49 Trench Area French Drain. Surface water sampling sites are shown in Fig. 3C.5. The dates and prevailing weather conditions for the five surface water sampling events were as follows:

- February 8-9, 1989; high groundwater; pre-cap conditions; dry weather
- April 18-24, 1989; high groundwater; post-cap conditions, dry weather
- May 9, 1989; dry weather following a storm
- September 5-6, 1989; low groundwater; dry weather
- September 25-27, 1989; low groundwater; dry weather following a storm

Flows were measured using the velocity-area method. Flow velocity was measured at a stream depth of 0.6 ft using a Swoffer Model 2100-14 current meter. Water depth was measured using either a ruler or the depth gage on the current meter probe handle. Discharge was then calculated as flow velocity times the flow cross-section area, using the U.S. Geological Survey mid-section method. Flow from the seeps was measured using a beaker and a Huer stopwatch (BNI 1990a).

The results of the base flow measurements are shown in Table 3C.5.

## 3C.3 PRECIPITATION AND RUNOFF RELATIONSHIPS

### 3C.3.1 Components of Runoff

Precipitation reaches a stream channel through various paths, and stream flow hydrographs at any point in a stream can be visualized as a composite of runoff generated by different processes. Four runoff components are considered to contribute to stream flow in WAG 6. These are described below.

(1) Hortonian Overland Flow. Hortonian Overland Flow (overland flow) occurs when the rainfall intensity exceeds the infiltration rates of the land surface. The excess water travels over the surface, collecting in small rivulets and trenches, and flows into stream channels relatively quickly. Flow hydrographs dominated by overland flow exhibit fast rises to peak, high peaks, and sharp recessions. In small areas (less than 100 acres) that are bare or sparsely vegetated, overland flow hydrograph peaks may lag rainfall by 5 to 15 minutes.

(2) Subsurface Storm flow. Also known as interflow, subsurface storm flow is the infiltrated water that travels subsurface to reach a stream channel. Subsurface storm flow occurs in areas where topsoil of high infiltration capacity is underlain by a low permeability strata. Such a mechanism can occur in humid, forested areas where all precipitation infiltrates the soil and essentially no overland flow occurs. Because vertical movement of the infiltrated water is impeded by the underlying low-permeability strata, water accumulates and flows laterally downgradient until discharging as a seep or to a stream channel. Moore (1988) has recorded this phenomenon in an ORNL basin. Subsurface storm flow hydrographs are less peakish and can lag rainfall by 1 to 30 hours. In areas with deep permeable soils, on steep hillslopes and in narrow valley bottoms, most of the volume of the storm runoff is from the subsurface storm flow.

(3) Saturated Overland Flow. Saturated overland flow results when precipitation falls on saturated slopes next to a stream channel; subsurface flow emerges to the surface on the lower parts of slopes. During the passage of the storm, as the groundwater table rises and falls, the degree of saturation of the slopes will also rise and fall. Saturated overland flow dominates the peak flow rates in humid forested areas.

(4) Base Flow. Base flow, also called dry-weather flow, is the discharge of groundwater into the stream when the hydraulically connected water table has a gradient toward the channel. Since groundwater flow is usually very slow, there is considerable lag between precipitation and groundwater flow into the streams. In humid areas during dry periods, groundwater flow accounts for most stream flow.

### 3C.3.2 Areal Variation of Runoff Processes

The relative amount of water contributed to stream flow by each of the runoff processes identified above depends on the physical characteristics of the drainage basin and the precipitation event. Two major physical characteristics of the basin are the soils and land cover.

As shown in Fig. 3A.19, eleven distinct soil units have been delineated at WAG 6. Several soil units present a high potential for subsurface storm flow because they are underlain either by impermeable fragipan horizons (such as in soil unit 5) or by impermeable bedrock, as was encountered in Lietzke and Lee's (1986) soil test pit No. 10. In low-lying areas along drainageways, soils are generally saturated all year (except during summer months), and overland flow prevails in these areas.

Soils in WAG 6 are typically composed of clayey, silty loam. Infiltration rates for WAG 6 soils have been reported on by Clapp (1990) and Davis et al. (1984). Davis (1984) found undisturbed soils in the ETF area to have infiltration rates ranging from 0.008 to 4.9 in./hr (5.6E-6 to 3.5E-3 cm/sec) Clapp (1990) reported WAG 6 soil infiltration rates ranging from 0.72 in./h to 2.6 in./hr ($5.1E^{-4}$ to 1.8E-3 cm/sec). Since the infiltration capacity of soils drops exponentially within 15 to 20 minutes after the onset of rainfall, minimum infiltration rates are expected to prevail as a storm progresses. Rainfall intensities experienced at WAG 6 may exceed these infiltration rates. Therefore, overland flow occurs during most storms in uncapped parts of WAG 6 where infiltration rates are limiting and where the land surface is bare or sparsely vegetated.

### 3C.3.3 Storm Hydrographs

The storm hydrographs shown in Figs. 3C.7a and 3C.7b and Figs. 3C.8a through 3C.8e are representative of the responses of WAG 6 basins to storm rainfalls. While it is not possible to separate the storm hydrographs according to the four runoff components described above, it is possible to determine the surface runoff and base flow components. Overland flow, saturated overland flow, and some of the subsurface storm flow will contribute to surface runoff. By drawing a line between the flow rates at the beginning of the storm hydrograph and a point on the recession portion of the hydrograph, base flow can be isolated, and it can be seen that base flow represents a small portion of storm runoff volume.

A concept useful in defining overland flow hydrographs is the time of concentration, which is the time it takes for water to travel from the furthest point in the basin to the basin outlet. Using the SCS velocity charts for the DA, DB, FA, and FB drainage, the time of concentration was estimated to range from 10 to 75 minutes.

Lag time, which is the time between the centroid of rainfall excess and the hydrograph peak, was also computed for these basins The computed lag times, 60% of the time of concentration, are 6 to 45 minutes. The observed storm hydrographs (Figs. 3C.8a through 3C.8e) exhibit lag times of 25 to 75 minutes, similar to computed lag times. This indicates that overland flow concepts can explain the hyrdograph shapes.

The storm hydrographs for Flume I at the ETF site, shown in Figs. 3C.7a and 3C.7b, exhibit the very short lag times typical of an overland flow hydrograph. The small drainage basin at Flume I has shallow soils and sparse grass cover; therefore, overland flow dominates the peak of the hydrograph. Furthermore, because of saturated soil moisture conditions, the hydrograph peak during the winter storm was also dominated by overland flow, which equaled about 60 percent of the storm precipitation (Davis et al. 1984). The hydrographs for Flume II exhibited a more delayed response to rainfall, but as Davis et al. (1984)

indicate, this was due to the impoundment of water upstream of the culvert where flows were measured.

### 3C.3.4 Dry Weather Flows

Streams in WAG 6 are predominantly intermittent. Under high water table conditions during winter months, stream flow is comprised of discharge from the groundwater. During dry periods, when the water table elevation drops below the bottom of the stream channel or when the groundwater gradient toward the stream decreases, base flow ceases and streams become dry. Along their reaches, streams in WAG 6 are expected to behave as effluent (gaining) in the wet season or influent (losing) in the dry season. As the dry weather flow measurements in Table 3C.5 show, no flow was observed in upstream reaches of the streams during dry weather.

The mean daily flows reported in Davis et al. (1984) for the period June 1985 to July 1986 at basins DA, DB, and F (FA and FB combined) were analyzed to determine the percentage of base flow (i.e., groundwater discharge). Flows during dry days and the portions of flows during wet days that were isolated by visual inspection of the daily flow recessions were summed for the entire period. Computed percentages were 43, 24, and 36 for the DA, DB, and F basins, respectively.

## 3C.4 EFFECT OF ICM CAPPING ON STREAM FLOW

In a recent study by Eiffe et al. (1988), 25-year, 24-hour storm hydrographs were developed at various locations in WAG 6 to help in the design of ICM cap drainage culverts. The storm magnitude was estimated to be 5.48 in., based on the Weather Bureau Technical Paper No. 40 (Hershfield 1961). SCS Type II rainfall distribution was used to define the rainfall distribution (USDA 1985). The 5-min peak rainfall amount was 0.72 in. Using these assumptions, stream flow hydrographs were generated using the HEC-1 (U.S. Army Corps of Engineers 1981) model to simulate the effects of capping. The modeled peak flows and the percent increase in peak flow were:

| Area | Pre-Cap Peak flow (cfs) | Post-Cap Peak flow (cfs) | Percent increase |
|---|---|---|---|
| DA | 117 | 123 | 5 |
| DB | 29 | 33 | 14 |
| F | 33 | 42 | 27 |

## 3C.5 ELEMENTS OF WATER BALANCE

The hydrologic water balance for the entire WAG 6 site or any basin within it can be expressed as a "lumped equation":

$$P = RO + ET + \Delta SM + \Delta GWS$$

where,

P = input to the system by precipitation
RO = losses from runoff processes (described in Sect. 3.4.3.1)
ET = losses from the system due to evapotranspiration
$\Delta SM$ = change in soil moisture
$\Delta GWS$ = change in groundwater storage

Assuming changes in both groundwater storage and soil moisture are negligible, the hydrologic water balance for the entire WAG 6 site can be simplistically described by:

$$P = RO + ET$$

There is considerable uncertainty as to the exact magnitude of the various components of the annual water balance for WAG 6, mainly because of the lack of adequate measurements of ET and the runoff components. However, using the estimated average annual precipitation (52.2 in.) and evapotranspiration (30 in.) suggested by Moore (1989a), the average annual runoff would be 22.2 inches. For comparison, the estimated mean annual runoff for the 1936-1960 period reported by McMaster (1967) for 19 small drainage basins in the Oak Ridge area ranged from 21.7 to 25.9 inches.

A water balance study was performed as part of the WAG 6 fate and transport modeling (see Sect. 5) using the CREAMS model (a field-scale model for Chemicals, Runoff, and Erosion from Agricultural Management Systems). CREAMS is a physically based rainfall runoff model that generates surface runoff, potential evapotranspiration (PET), actual ET (soil and plant evaporation) and deep percolation from the input precipitation, monthly average temperature, and solar radiation. Daily precipitation data for the 1981-1990 period recorded at the ETF station was used to represent WAG 6 precipitation in the water balance study. Flow records available for the F, DA, and DB drainages for June 1986 through July 1987 were used in calibration of the model.

The modeled yearly water balance values for this period are shown in Table 3C.6 (further details are presented in Section 5 of the RFI report). The surface runoff values given in Table 3C.6 are assumed to include overland flow and saturated overland flow. Similarly, the deep percolation values are assumed to include both groundwater discharge and subsurface storm flow. Total runoff (RO) is the sum of the surface runoff and deep percolation components.

Disregarding the results for 1981 because initial conditions affect the first year of simulation, the total runoff and ET values for other years are reasonable. For 1982 and 1984, years in which precipitation was close to the computed long-term average for WAG 6,

surface runoff and ET values are comparable to those presented by Moore (1989a) and McMaster (1967). However, during dry years surface runoff decreases roughly 7%, accompanied by an approximate 7% increase in deep percolation. For the 1981-1990 period as a whole, ET accounts for 61% of the annual precipitation while total runoff (surface runoff plus deep percolation) is 39% of the average annual precipitation for this period. Surface runoff and deep percolation account for 23% and 16% of the annual water budget, respectively, or 59% and 41% of the total runoff (RO) component, respectively.

McMaster (1967) reported runoff (surface runoff and deep percolation components) varies seasonally, as follows:

October to December — 17%
January to March — 51%
April to June — 22%
July to September — 10%

The runoff is greatest in January through March, when ET is minimal, precipitation is high, and high soil moisture levels prevail. Lowest runoff occurs in July through September, when ET is high, precipitation is low, and soil moisture levels are low (thereby allowing for increased infiltration). Similar patterns are evident for wet versus dry years as evident from Table 3.3.

Separating the deep percolation into subsurface storm flow and groundwater discharge components cannot be done accurately given the inherent uncertainties previously described. Likewise, the exact amount of groundwater discharge that occurs as baseflow to on-site streams or discharge to WOL could not be determined. Estimates of groundwater discharge reported in the literature show considerable variation. For example, Moore (1989a) asserts that in the Oak Ridge area, groundwater discharge totals 1.26 in. (roughly 2.4%) of annual precipitation; most of it is lost as deep evapotranspiration, with the remaining portion discharged at springs and streams. Conversely, Davis et al. (1986, 1987) in a water balance study for the ETF site (July 1986 to June 1987) observed that 24% of precipitation could be accounted for by overland flow, with the remaining 76% attributed to combined evapotranspiration and groundwater discharge. Assuming 52 in. of annual precipitation and 30 in. of annual evapotranspiration, groundwater discharge using the Davis et al. (1986, 1987) percentages would suggest groundwater discharge accounts for approximately 10 in. annually (or 20% of annual precipitation.

In the northern and eastern part of the site groundwater discharge occurs entirely to the streams as baseflow. In the southwestern and southern parts of WAG 6, portions of the groundwater discharges to site streams as baseflow and the remaining portion discharges to WOL beyond the WAG 6 boundary.

## 3C.6 SURFACE WATER QUALITY

The natural quality of the surface waters in WAG 6 has been characterized based on the surface water samples collected at various times and locations within WAG 6. Earlier sampling events were limited to the ETF site (Davis et al., 1984). More recently, in 1989 and 1990, as part of the WAG 6 RFI, a more comprehensive surface water quality sampling has been done. The sampling activities and their results are described in Technical Memorandums TM 06-05 (BNI 1990b) and TM 06-05A, Surface Water and Sediment Investigation, Phase 1, Activity 2.

From evaluation of available data, the water in the streams is of the calcium-bicarbonate type, is moderately hard to very hard, and has low sodium, potassium, and chloride content. The pH of the water is between 6.6 and 7.6, indicating neutral to slightly acidic waters. Because surface water features on or adjacent to WAG 6 are receptors for contaminated water associated with runoff from WAG, the chemistry of the surface water varies from location to location based upon degree of contamination. The nature and extent of contamination of WAG 6 surface water is discussed in detail in Sect. 4 of the RFI report.

## 3C.7 SUMMARY OF FINDINGS REGARDING SURFACE WATER HYDROLOGY

Key findings and conclusions regarding the surface water hydrology at WAG 6 are summarized below:

- The surface waters of WAG 6 include seven streams (four principal streams and three secondary streams), all originating within WAG 6. Portions of the site drain into the EWB in the north, to the unnamed tributary on the east boundary, and to the WOL in the south.

- The waste management and research activities at the site since the 1970s have impacted the surface water hydrology of WAG 6. Flow paths have been altered due to construction of service roads, culverts, the French Drain, and the drainage features associated with the ICM caps over eight waste areas. This increase in impervious surfaces, plus clearing of some wooded areas, has increased overall flow rates and volumes; however, the increase is small.

- Streams in WAG 6 are intermittent. They are mostly dry during summer months except for some groundwater discharge.

- The stream density of the site is considered high; streams are short, the longest being about 1900 ft. Therefore, potential for dissolved contaminant migration from WAG 6 via surface waters is quite high.

- While steep slopes in WAG 6 promote fast response to rainfall events, high vegetative cover and variability in soil infiltration rates across the site moderate the storm response somewhat.

- The flow of the streams includes surface runoff (overland flow, saturated overland flow, subsurface storm flow) and base flow components. Adequate data do not exist to assess the relative percents of each of these flow components. However, the storm hydrographs at the stream outlets at the site boundary exhibit storm peaks occurring within one hour of the onset of the storm rainfall. Therefore it can be stated that overland flow and saturated overland flow dominate the storm hydrograph shape and the storm volume.

- The long term (1948 to 1990) annual precipitation as measured at the Oak Ridge Station is 54 in. The average annual precipitation for WAG 6 (ETF site) has been estimated to be 52 in. The average annual evapotranspiration is 30 in. The balance, 22 in., is the average annual discharge from WAG 6. The average annual amount of groundwater discharged to on-site streams and into WOL cannot be accurately quantified. Estimated average annual recharge to groundwater ranges from 1.3 to 10 in. (3 to 20% of precipitation).

- Seasonal runoff distribution is proportional to variations in precipitation and evapotranspiration. During the wet season, precipitation is highest and ET is minimal, but soil moisture content is quite high, such that runoff is high. Just the opposite occurs in dry periods; much of the precipitation infiltrates into the subsurface and runoff is low. In WAG 6, runoff ranges from 10% during dry periods (July through September) to 51% in wet months (January through March). Similar trends occur in wet versus dry years.

- The natural water in the streams is of the calcium-bicarbonate type, is moderately hard to very hard, and has low sodium, potassium, and chloride content. The pH of the water is neutral to slightly acidic (between 6.6 and 7.6).

# Appendix 3C Tables

**Table 3C.1. Statistics of flows at the USGS gaging stations in White Oak Creek Basin through 1981**

| USGS Gaging Station Number | Station Number[a] | Drainage area ($ft^2$) | Type of Gage | Periods(s) of record | Discharge (cfs) Mean | Max. | Min. |
|---|---|---|---|---|---|---|---|
| 035650 | 2 | 22.39 | water-stage recorder | 1950-55 | 3.9 | 616 | 0.7 |
| 035370 | 3 | 11.87 | water-stage recorder and Cipolletti weir | 1950-53<br>1955-64<br>1978-81 | 9.6 | 642 | .9 |
| 035375 | 4 | 4.86 | water-stage recorder and v-notch sharp-crested weir | 1955-64<br>1977-80 | 2.5 | 242 | 0 |
| 035380 | 5 | 19.72 | water-stage recorder | 1953-55<br>1960-64<br>1977-79 | 13.5 | 669 | 0 |

*Source*: Webster and Bradley (1988)

[a]Locations shown on Fig. 3C.1.

NOTE: Mean discharge for stations 3, 4, and 5 includes 3.5 cfs imported water.

**Table 3C.2. Monthly flow statistics of Clinch River at Melton Hill Dam (tailwater), water year 1988-1989**

| Month | Mean (cfs) | Maximum (cfs) | Minimum (cfs) |
|---|---|---|---|
| October 1988 | 1,922 | 5,140 | 400 |
| November 1988 | 1,363 | 5,120 | 0 |
| December 1988 | 1,874 | 4,740 | 400 |
| January 1989 | 6,727 | 11,600 | 2,070 |
| February 1989 | 7,371 | 14,200 | 433 |
| March 1989 | 3,299 | 10,500 | 0 |
| April 1989 | 1,571 | 5,650 | 400 |
| May 1989 | 5,678 | 13,000 | 833 |
| June 1989 | 9,728 | 19,100 | 317 |
| July 1989 | 6,606 | 10,900 | 1,250 |
| August 1989 | 6,099 | 8,380 | 1,270 |
| September 1989 | 6,736 | 10,500 | 0 |
| Annual | 4,895 | 19,100 | 0 |

*Source*: Water Resources Data, Tennessee Water Year 1989, U.S. Geological Survey, Water-Data Report TN-89-1, 1990.

**Table 3C.3. Design characteristics of flumes**

| Drainage | Flume Type | Throat Size, in. | Channel Bankfull Capacity, cfs | Operational Flow Range of Flume, cfs |
|---|---|---|---|---|
| DA | Parshall | 18 | 23.0 | 0.15-21.0 |
| DB | Parshall | 6 | 288.0 | 0.05-3.9 |
| FA | Trapezoidal | 2 | 1.3 | 0.022-0.95 |
| FB | Parshall | 6 | 13.0 | 0.05-3.5 |

**Table 3C.4. Storm rainfall-runoff and peak flow rates**

| | | Storm runoff (in.) | | | | Peak flow (cfs) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Date | Storm rainfall (in.) | DA | DB | FA | FB | DA | DB | FA | FB |
| 4/28/90 | 0.69 | - | - | 0.04 | - | - | - | 0.11 | - |
| 5/17/90 | 0.82 | 0.26 | 0.23 | 0.10 | 0.17 | 4.21 | 2.19 | 0.42 | 2.0 |
| 5/20/90 | 0.33 | - | - | - | 0.04 | - | - | - | 0.19 |
| 5/27/90 | 0.58 | 0.17 | 0.53 | - | - | 2.74 | 1.9 | - | - |

**Table 3C.5. Baseflow measurements, RFI surface water sampling[a]**

| Location | Feb 8-9 | April 18-24 | May 9 | Sept 5-6 | Sept 25-27 |
|---|---|---|---|---|---|
| **Subarea A** | | | | | |
| WEWB | -- | -- | -- | -- | -- |
| SWA1 | -- | -- | -- | -- | -- |
| **Subarea B** | | | | | |
| SWB 1 | -- | 0.02 | 10.7 | -- | -- |
| **Subarea C** | | | | | |
| SWC 1 | -- | -- | -- | -- | -- |
| **Subarea DA** | | | | | |
| W49TS[b] | 0.24 | 0.11 | 0.14 | 0.060 | -- |
| WDA1 | -- | 13.2 | 68.2 | -- | -- |
| **Subarea DB** | | | | | |
| WDB1 | -- | -- | 10.1 | -- | -- |
| **Subarea FA** | | | | | |
| WBAB2 | -- | -- | -- | -- | 3.23 |
| WBAB1 | -- | -- | 0.5 | -- | -- |
| WBAA1 | -- | -- | -- | -- | -- |
| WFBA1 | -- | -- | -- | -- | -- |
| **Subarea FB** | | | | | |
| WFBB3 | -- | -- | -- | -- | -- |
| WFBB2 | -- | -- | 1.3 | -- | -- |
| W49TN | -- | -- | -- | -- | -- |
| WSP1 | -- | -- | 25.3 | -- | 1.32 |
| WFBB1 | -- | -- | 2.9 | -- | -- |

[a]Flow rates are given in liter/second, due to low flow rates; 1L/sec = 3.53E-2 cfs.
[b]French Drain outfall.

-- Not measured.

**Table 3C.6. Yearly water balance values**

| Year | Precipitation (in.) | Surface Runoff (in.) | ET (in.) | Deep Percolation (in.) | Surface Runoff Plus Deep Percolation (in.) |
|---|---|---|---|---|---|
| 1981 | 40.7 | 5.4 | 30.0 | 4.2 | 6.9 |
| 1982 | 52.6 | 11.7 | 30.3 | 10.9 | 22.7 |
| 1983 | 41.6 | 8.8 | 26.3 | 6.4 | 15.2 |
| 1984 | 50.9 | 14.3 | 29.3 | 7.5 | 21.8 |
| 1985 | 39.8 | 6.6 | 29.5 | 3.4 | 10.0 |
| 1986 | 38.5 | 7.2 | 26.7 | 5.1 | 12.3 |
| 1987 | 45.3 | 9.9 | 28.3 | 7.1 | 17.0 |
| 1988 | 45.1 | 10.8 | 28.5 | 4.8 | 15.6 |
| 1989 | 64.5 | 17.3 | 32.7 | 14.6 | 31.9 |
| 1990 | 63.5 | 19.2 | 32.4 | 11.6 | 30.8 |

# Appendix 3C Figures

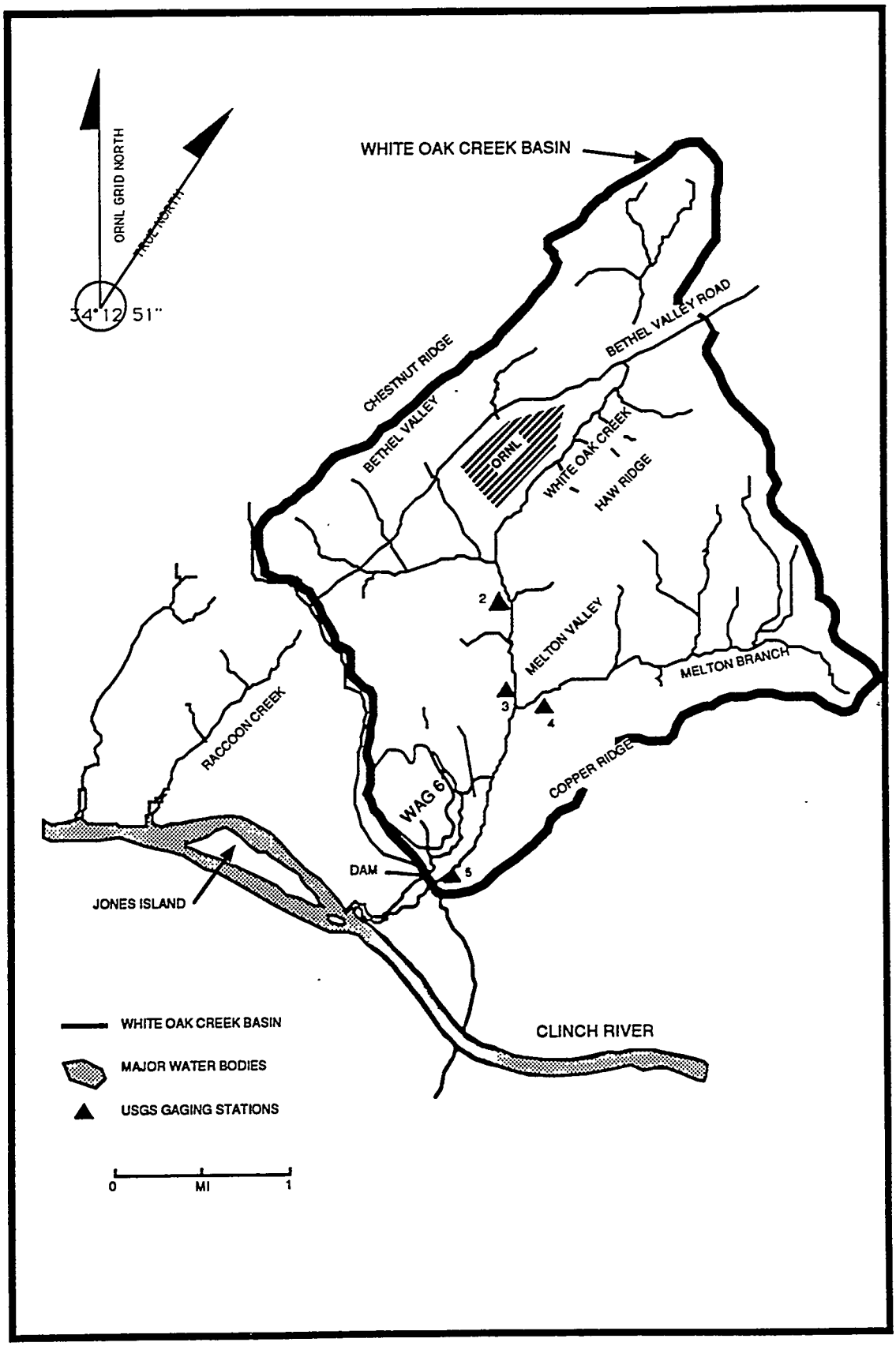



**Fig. 3C.1. White Oak Creek Basin (Showing location of USGS gaging stations).**

5.18E 4104.138A
Adapted from WAG6 06F188.DGN

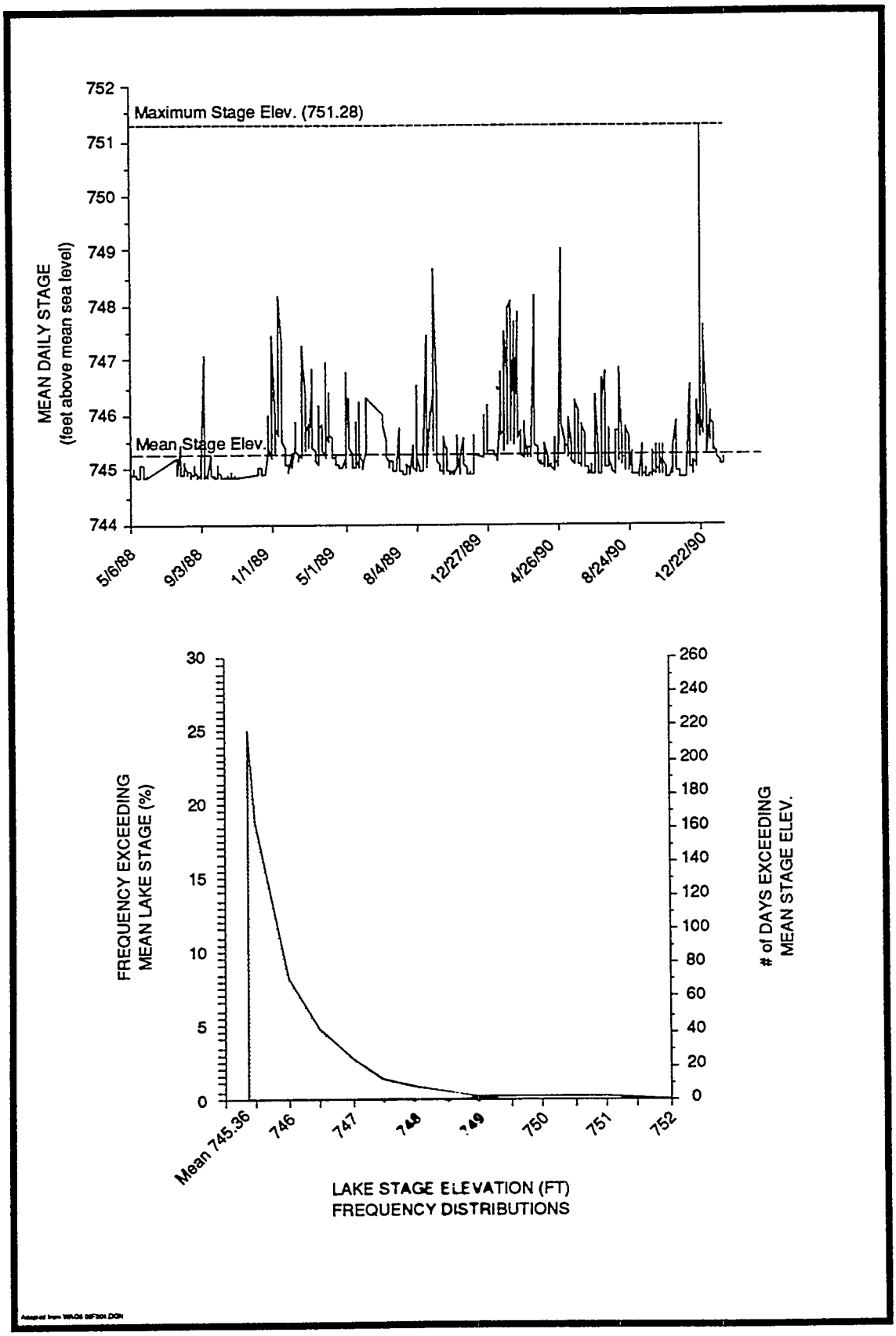
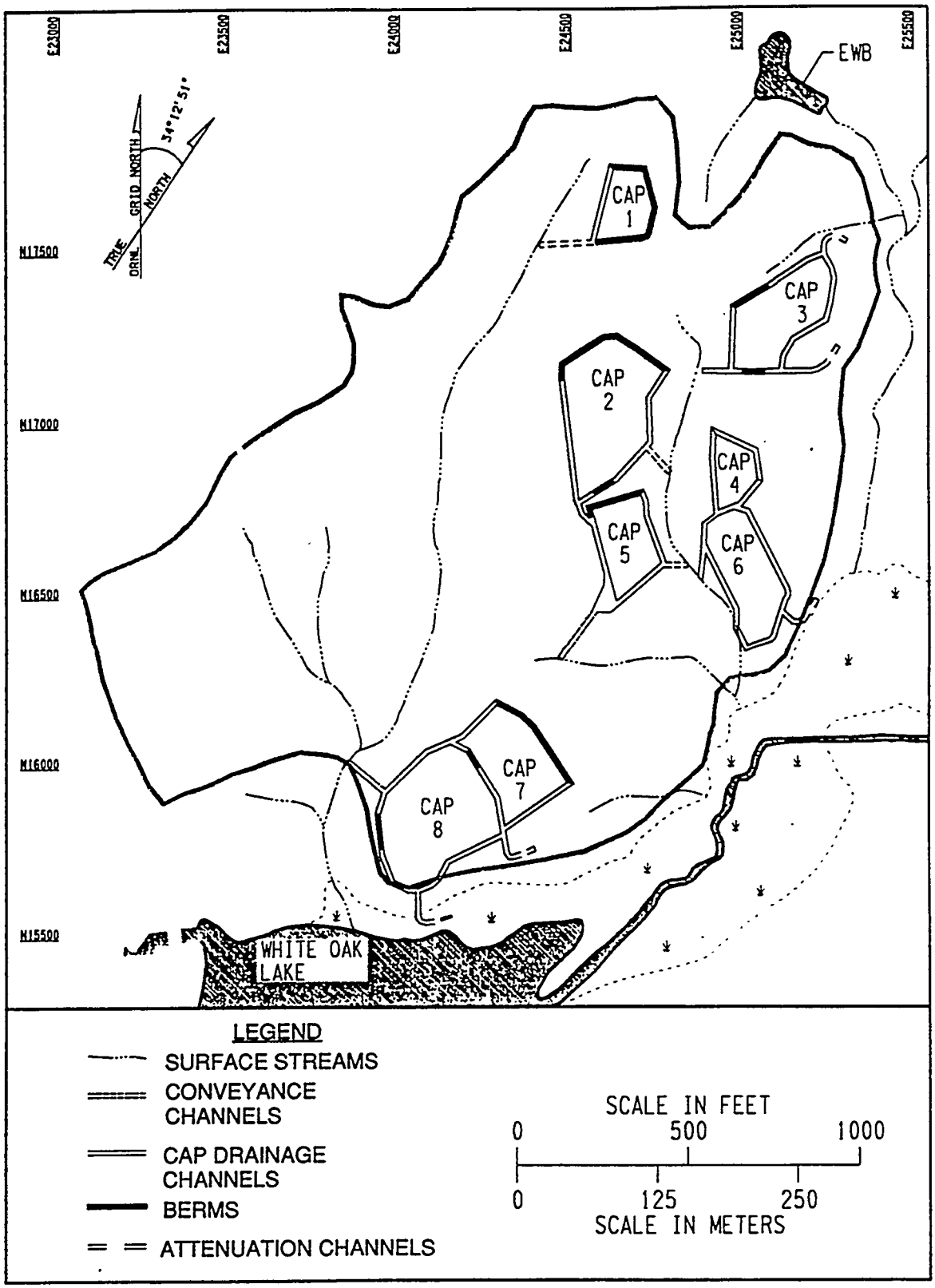
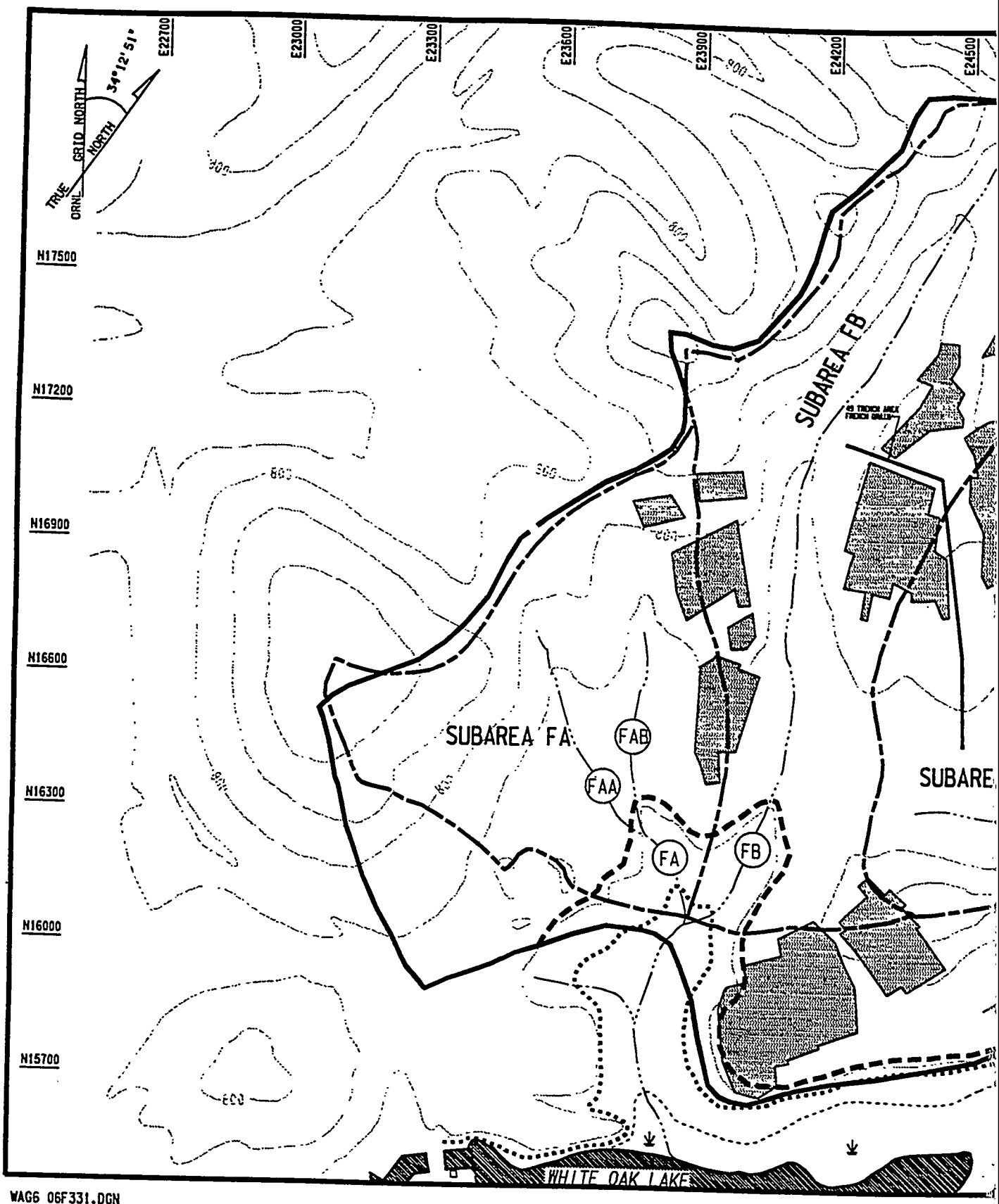



**Fig. 3C.2. Mean daily lake levels and frequency of distribution, White Oak Lake.**




WAG6 06F189.DGN

**Fig. 3C.3 Temporary cap drainage features.**




WAG6 06F331.DGN

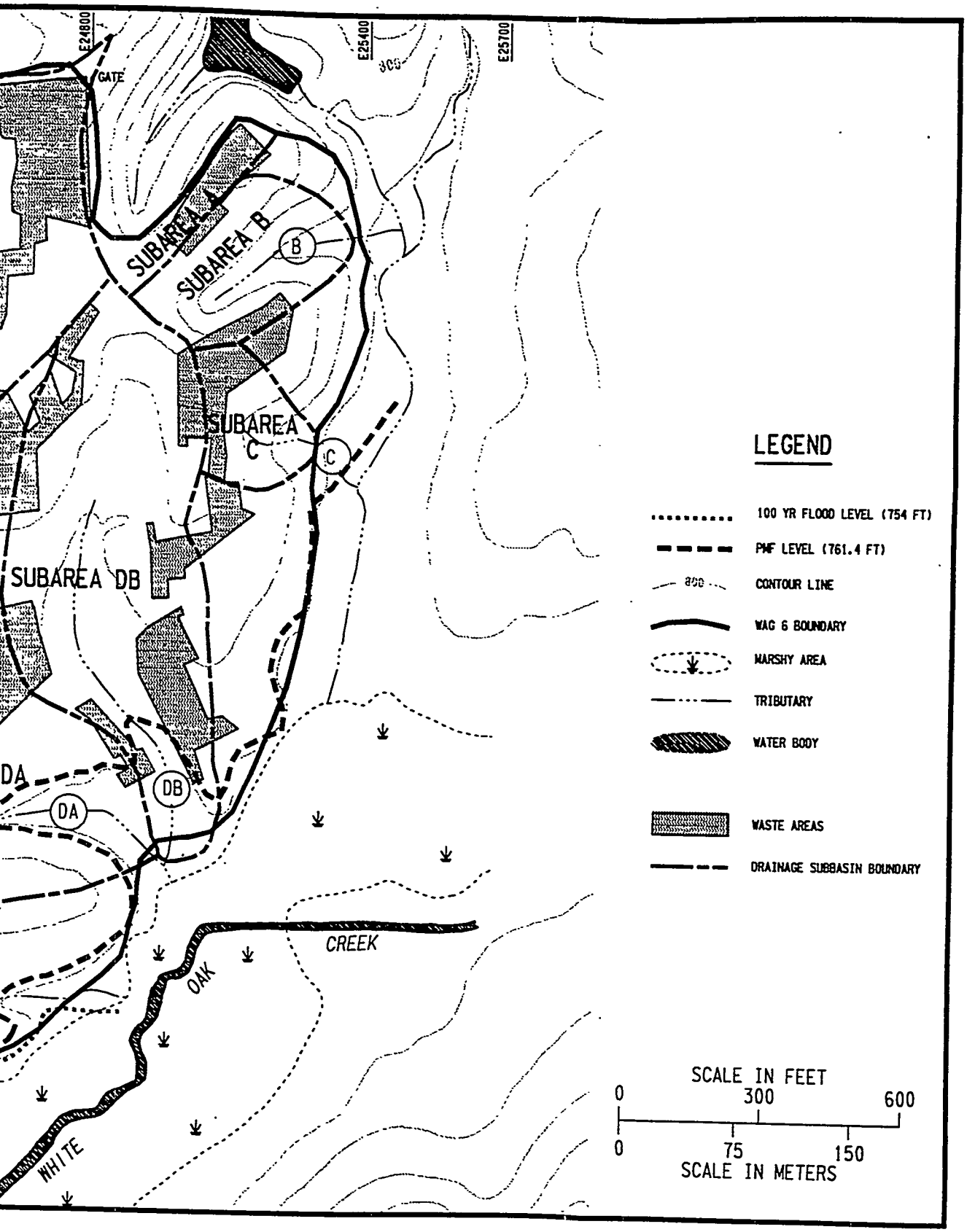
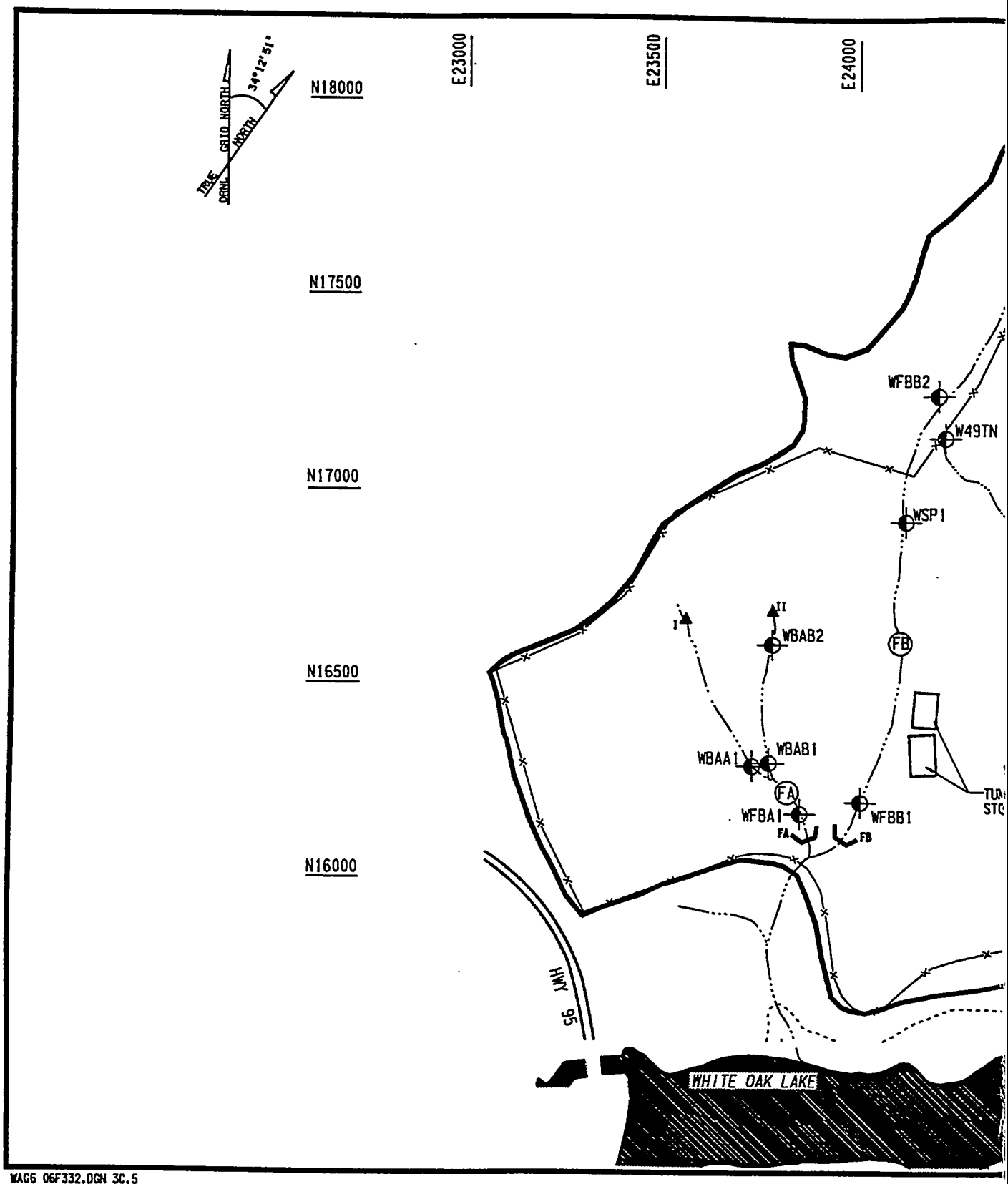



Fig. 3C.4. WAG 6 site drainage areas.




WAG6 06F332.DGN 3C.5

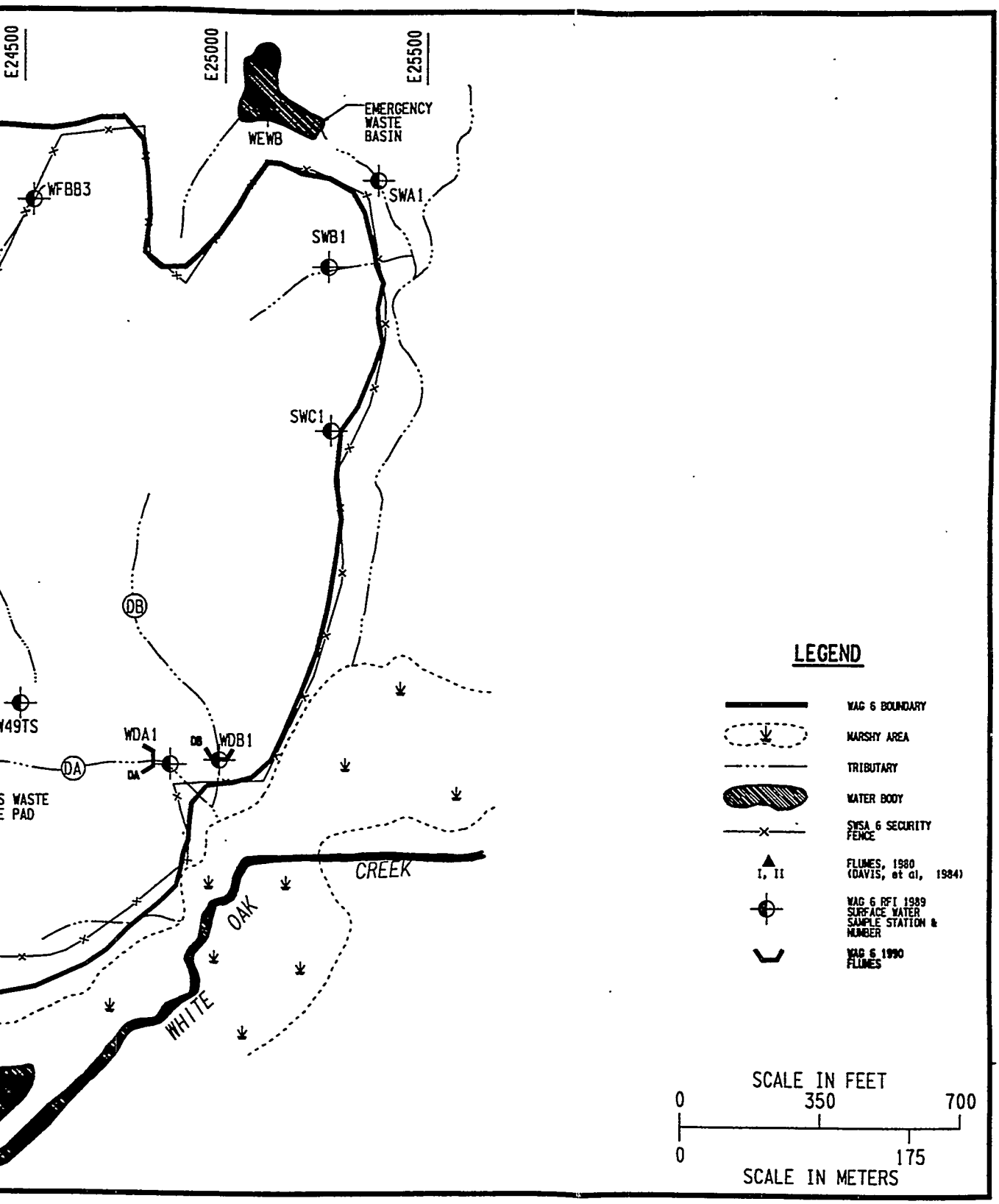



Fig. 3C.5. WAG 6 surface water flow station and sampling site

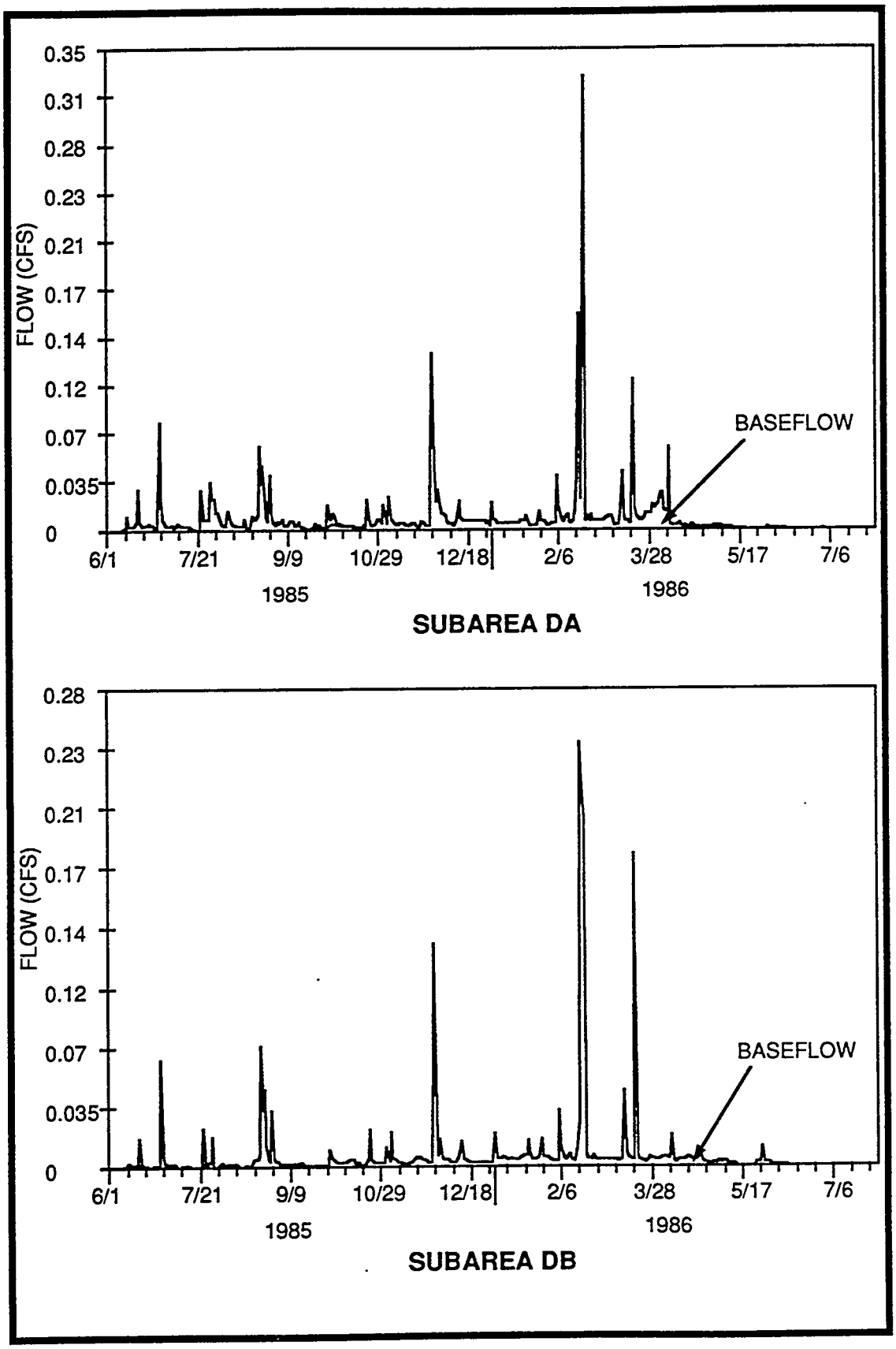



**Fig. 3C.6a. Mean daily flow hydrograph, June 1985-July 1986, Subareas DA and DB.**

5.18 4104.11

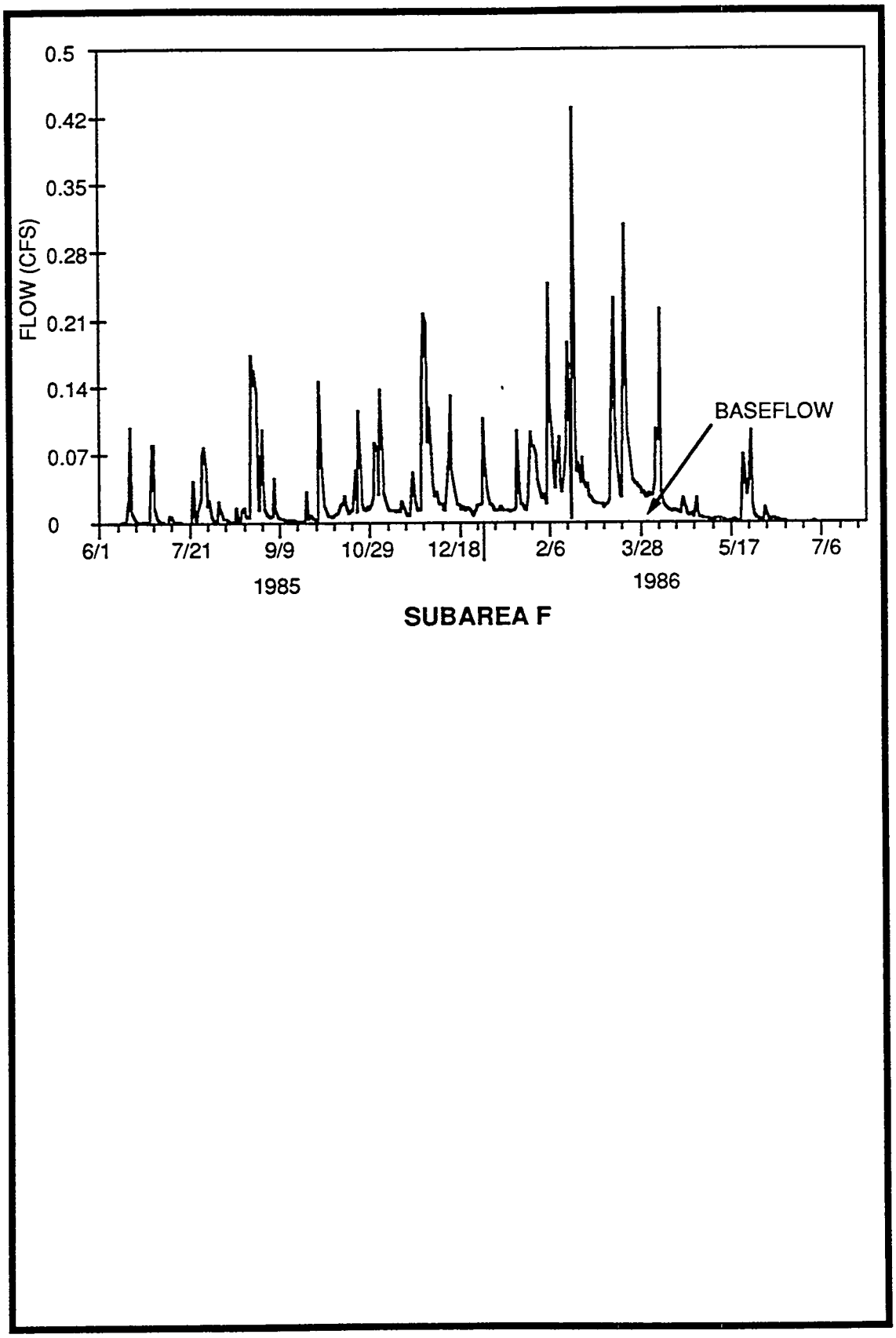
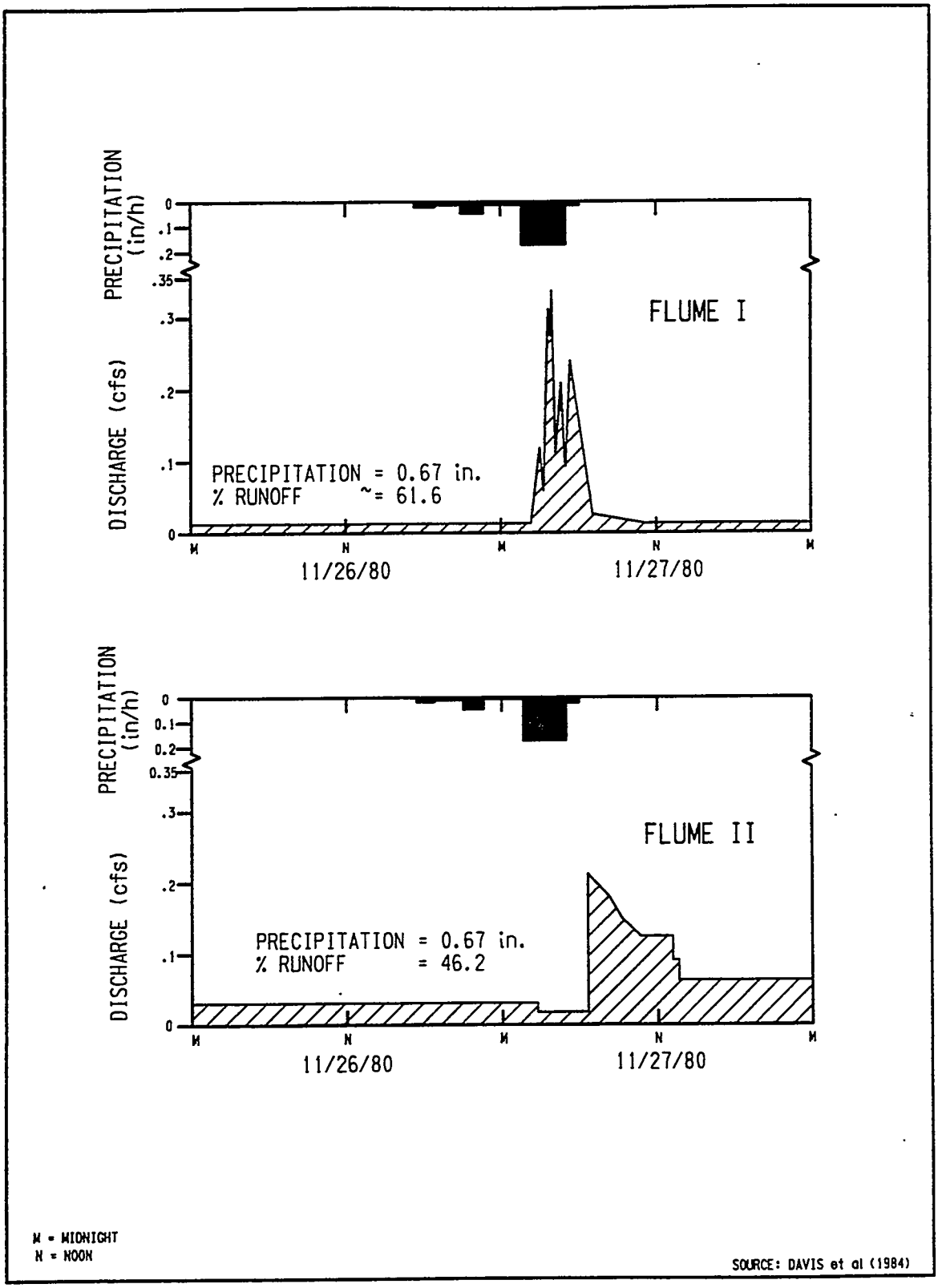
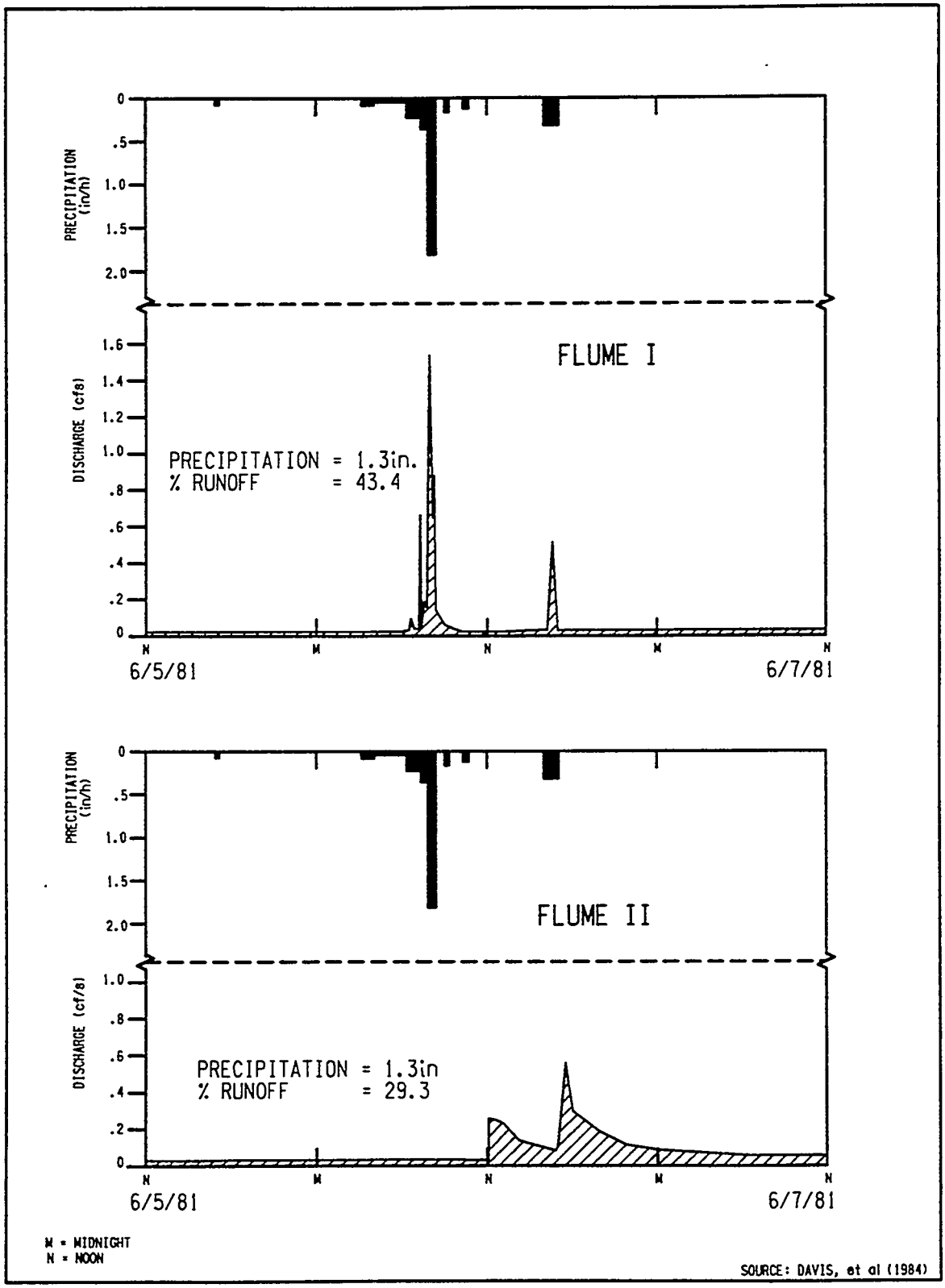



Fig. 3C.6b. Mean daily flow hydrograph, June 1985-July 1986, Subarea F (combined FA and FB)




WAG6 06F333.DGN

**Fig. 3C.7a. Storm hydrograph, ETF site, November 1980.**




WAG6 06F334.DGN

**Fig. 3C.7b. Storm hydrograph, ETF site, June 1981.**

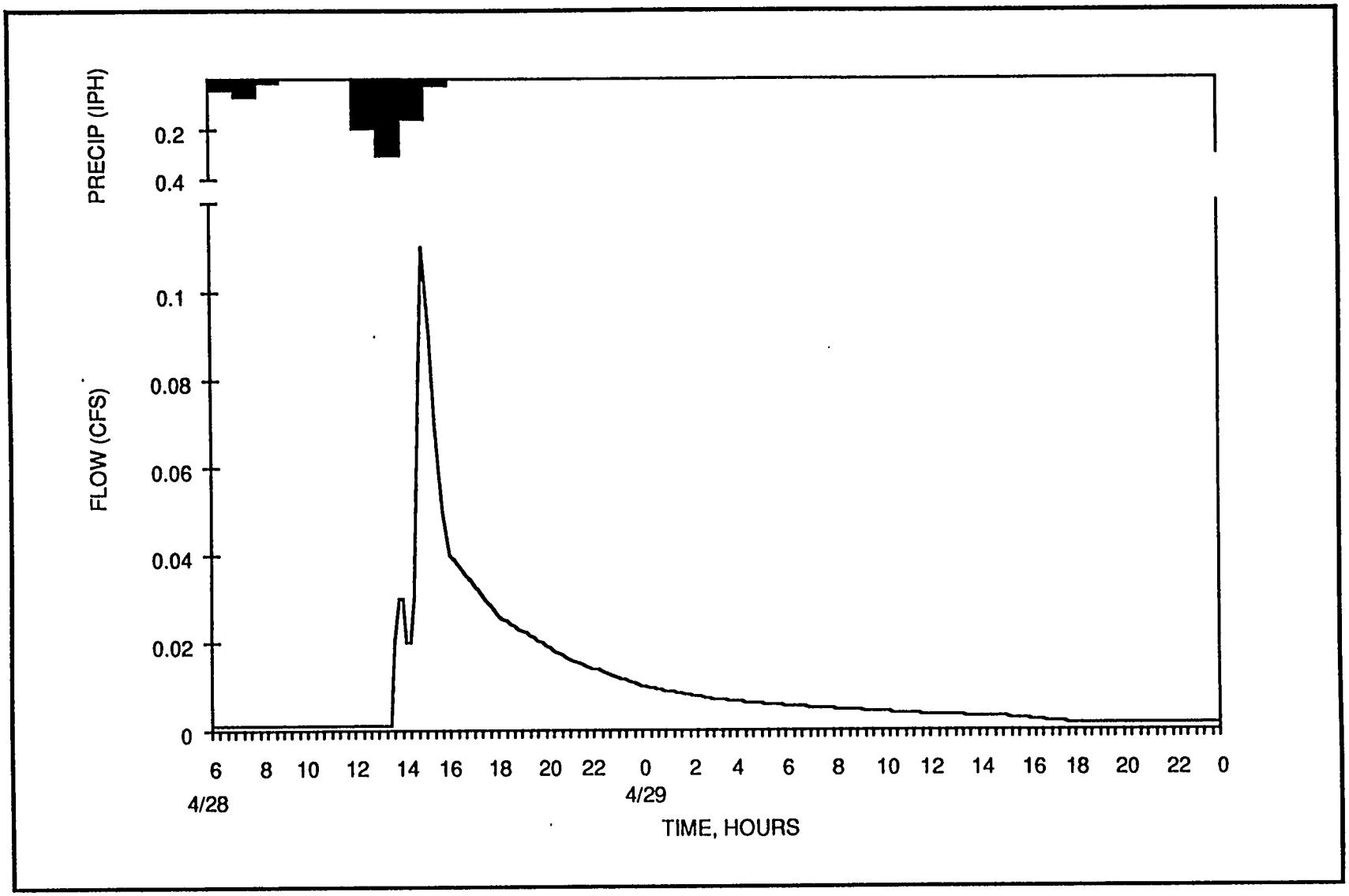



Fig. 3C.8a. Storm hydrograph, April 28, 1990, Subarea FA.

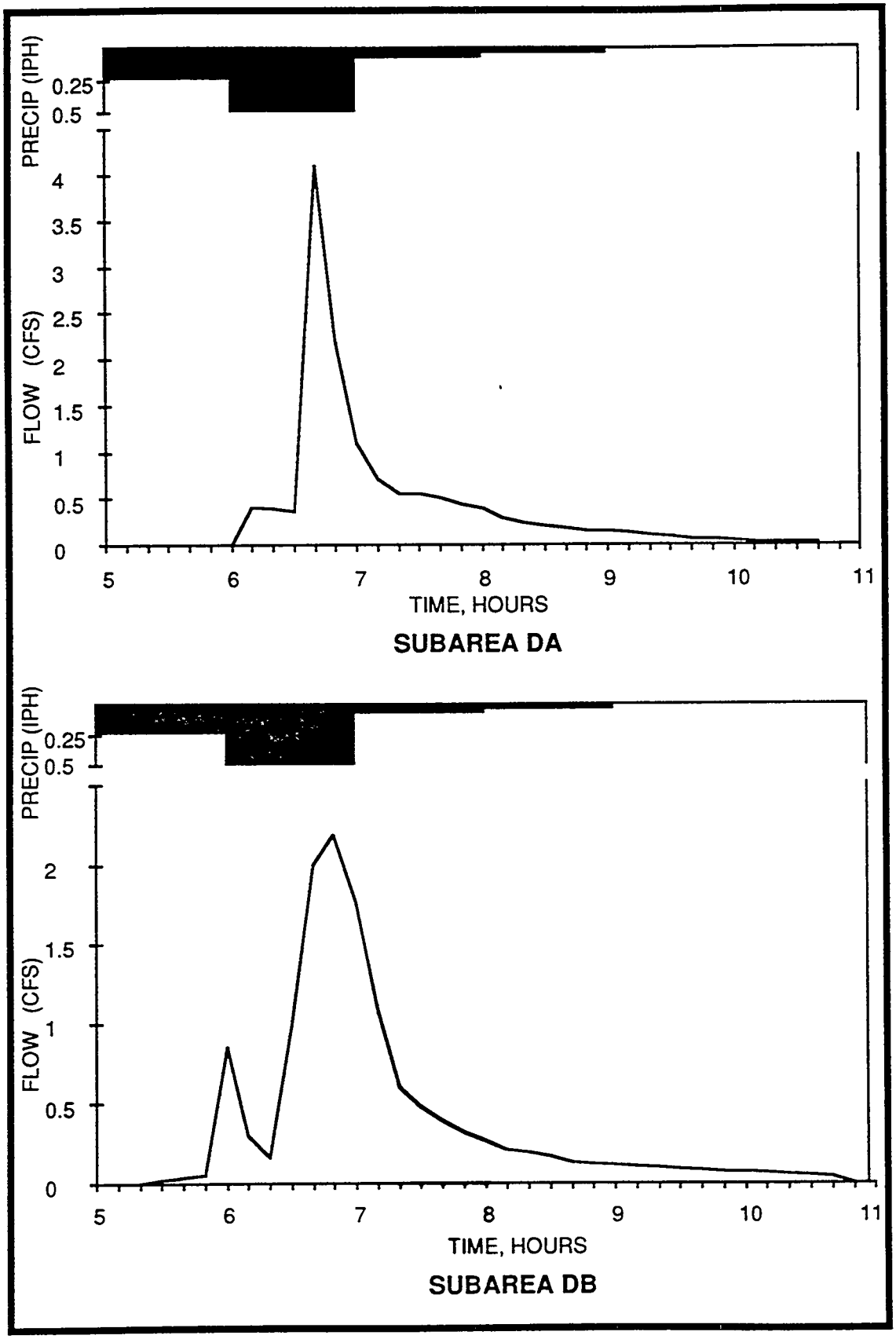



Fig. 3C.8b. Storm hydrograph, May 17, 1990, Subareas DA and DB.

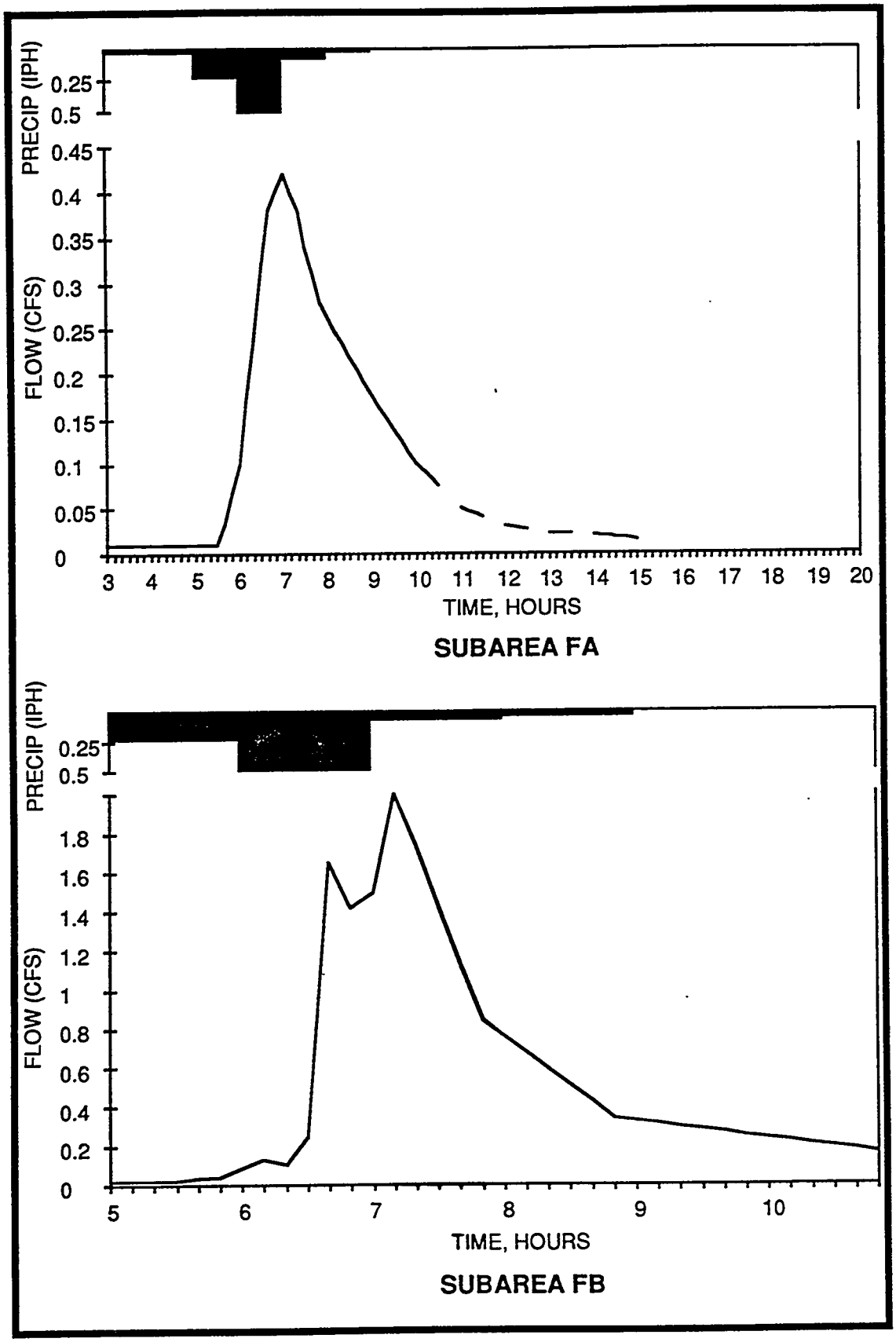



**Fig. 3C.8c. Storm hydrograph, May 17, 1990 (continued), Subareas FA and FB.**

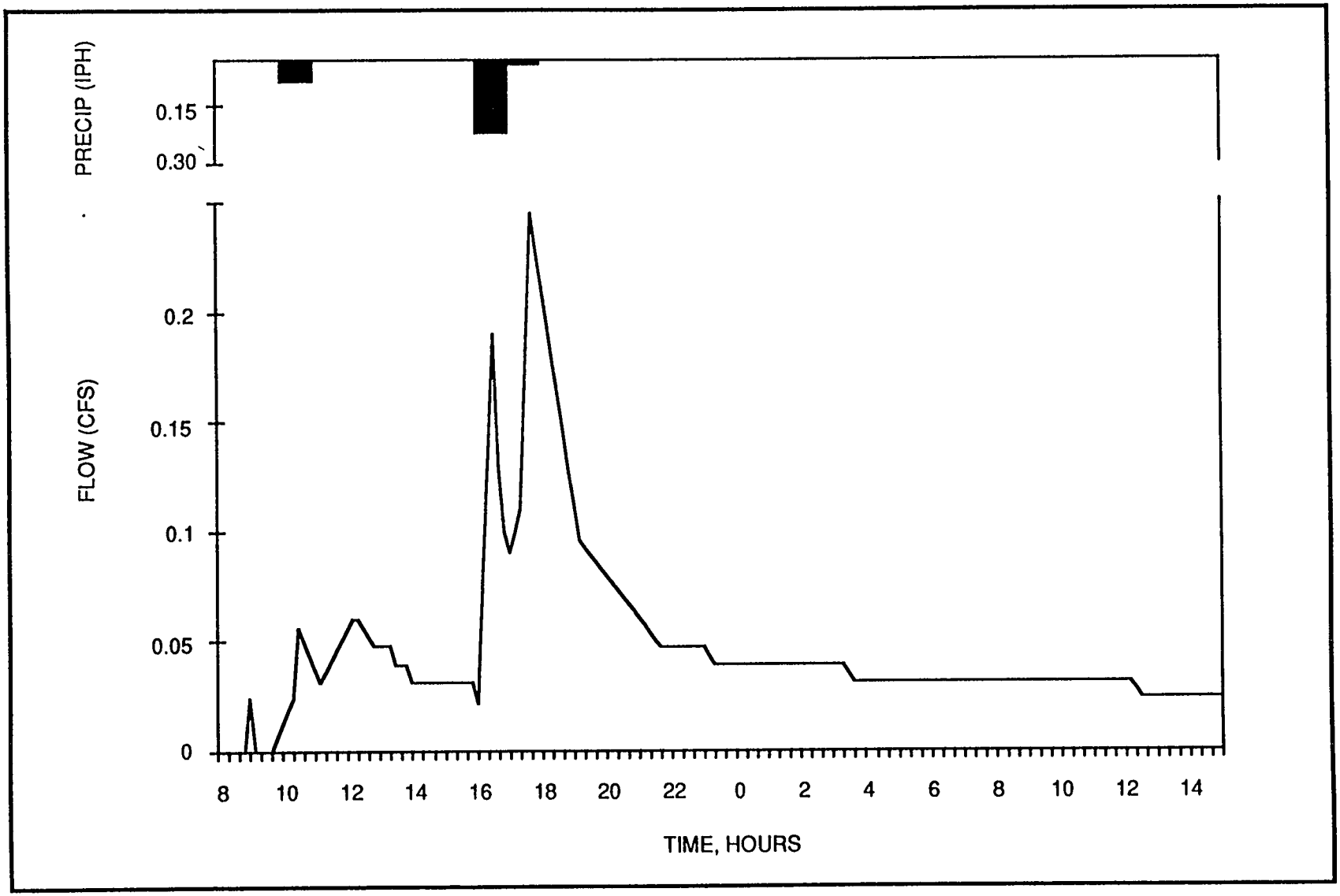



**Fig. 3C.8d. Storm hydrograph, May 20, 1990, Subarea FB.**

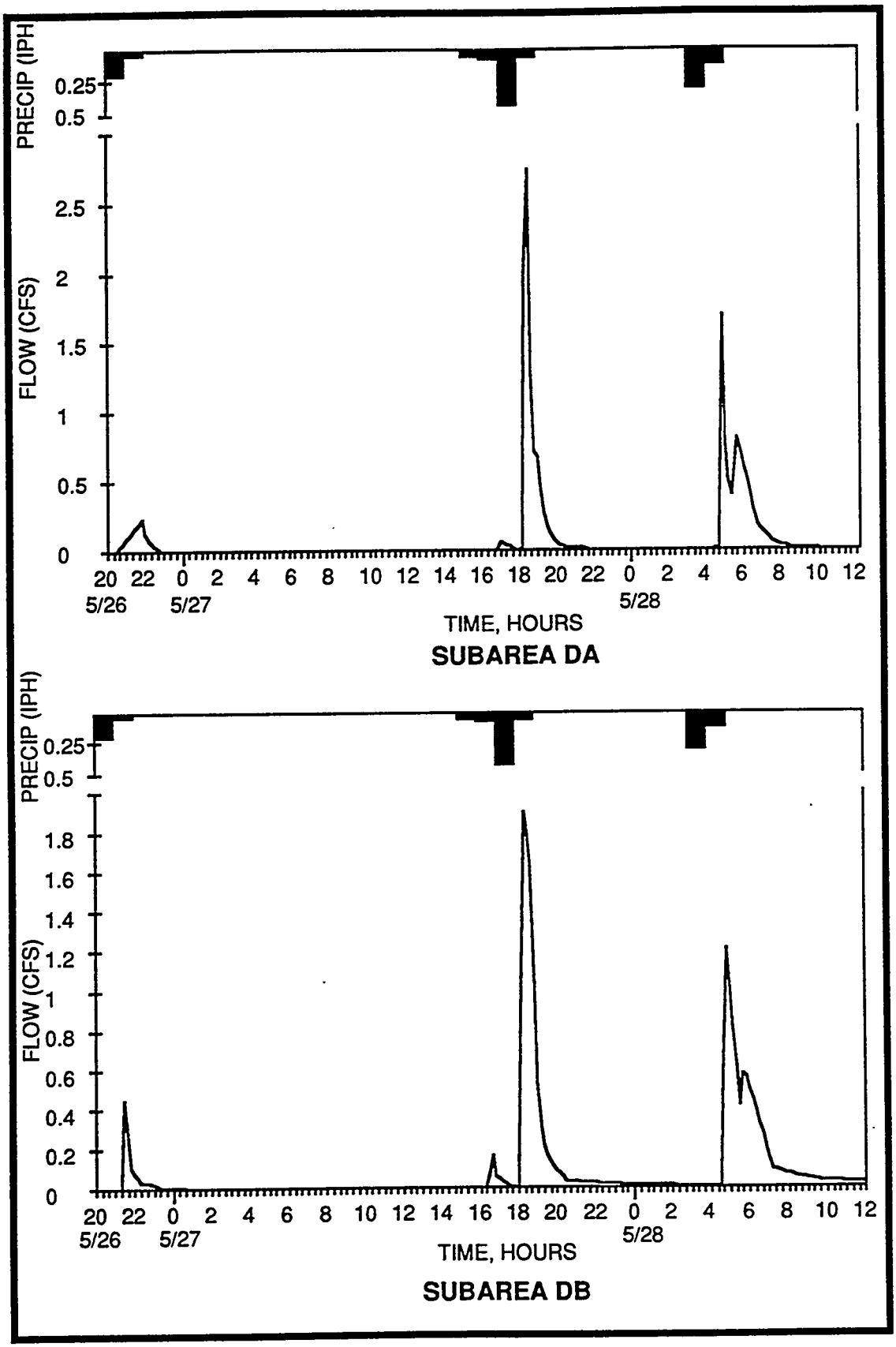



Fig. 3C.8e. Storm hydrograph, May 26-28, 1990, Subareas DA and DB.

5.18 4104.15

# APPENDIX 3D

# HYDROGEOLOGIC DATA

# Table 3D.1. WAG 6 hydrogeologic data

| WELL # | ORNL GRID NORTH | LOCATION EAST | GROUND ELEV. | TOP CASING | MEAS. POINT | TOTAL DEPTH | ELEV. TD | SCREEN INTERVAL DEPTH T/SCREEN | B/SCREEN | ELEV. T/SCREEN | B/SCREEN | WATER LEVEL DATA 8/25-30/89 DEPTH | ELEV. | 2/21-22/90 DEPTH | ELEV. | HYDRAULIC CONDUCTIVITY FT/DAY | CM/SEC | TEST TYPE | TOP OF BEDROCK DEPTH | ELEV. | MONITORED INTERVAL ZONE | FM | USE/ CLASS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1225 | 17754.77 | 24603.65 | 829.36 | 831.89 | 831.89 | 24.00 | 805.36 | 7.06 | 22.06 | 822.30 | 807.30 | 17.77 | 814.12 | 12.92 | 818.97 | | | | | <805.36 | OVERBURDEN | 2 | RFI-MW | |
| 1226 | 17043.45 | 23763.29 | 816.64 | 819.17 | 819.17 | 18.00 | 801.64 | 3.91 | 13.91 | 812.63 | 802.63 | DRY | <802.63 | DRY | <802.63 | | | | | <801.64 | OVERBURDEN | 2 | RFI-MW | Stormflow well |
| 1227 | 16569.39 | 23438.21 | 773.86 | 776.58 | 776.58 | 8.00 | 765.86 | 2.03 | 7.03 | 771.83 | 766.83 | 8.50 | 768.08 | 6.32 | 770.26 | | | | | <765.86 | OVERBURDEN | 5 | RFI-MW | |
| 1228 | 16334.67 | 23879.80 | 764.62 | 766.87 | 766.87 | 8.00 | 758.62 | 2.47 | 7.47 | 762.15 | 757.15 | 7.21 | 759.66 | 4.54 | 762.33 | | | | | <758.62 | OVERBURDEN | 5 | RFI-MW | |
| 1229 | 16453.32 | 24072.69 | 764.07 | 766.06 | 766.06 | 8.00 | 758.07 | 2.83 | 7.83 | 761.24 | 756.24 | 4.10 | 761.96 | 2.62 | 763.44 | | | | | <758.07 | OVERBURDEN | 5 | RFI-MW | |
| 1230 | 16204.70 | 24606.50 | 783.81 | 785.21 | 785.21 | 14.00 | 769.81 | 3.00 | 13.00 | 780.81 | 770.81 | 785.21 | <770.81 | 14.53 | 770.68 | | | | | <769.81 | OVERBURDEN | 5 | RFI-MW | Stormflow well |
| 1231 | 16403.79 | 24659.86 | 767.09 | 769.49 | 769.49 | 12.20 | 754.89 | 4.02 | 9.02 | 763.07 | 758.07 | 8.56 | 760.93 | 5.57 | 763.92 | | | | | <754.89 | OVERBURDEN | 5 | RFI-MW | |
| 1232 | 17020.14 | 24218.89 | 797.33 | 798.82 | 798.82 | 9.00 | 788.33 | 3.30 | 8.30 | 794.03 | 789.03 | 9.62 | 789.20 | 8.53 | 790.29 | | | | | <788.33 | OVERBURDEN | 2 | RFI-MW | Stormflow well |
| 1233 | 17005.25 | 24211.90 | 796.02 | 798.35 | 798.35 | 23.70 | 772.32 | 7.45 | 22.45 | 788.57 | 773.57 | 16.77 | 781.58 | 13.94 | 784.41 | | | | 14.00 | 782.02 | BOTH | 1 | RFI-MW | |
| 1234 | 16956.93 | 25249.05 | 772.32 | 774.56 | 774.56 | 147.00 | 626.32 | 126.00 | 146.00 | 648.56 | 628.56 | | | | | | | | 21.00 | 751.32 | D.BEDROCK | 1 | RFI-MW | fault @555.6' |
| 1235 | 16193.32 | 24618.54 | 786.45 | 788.73 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 777.41 | 762.41 | | | | | | | | 47.00 | 739.45 | OVERBURDEN | 5 | RFI-MW | |
| 1236 | 16195.25 | 23195.49 | 801.86 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | | | | | | | 50.50 | 751.05 | D.BEDROCK | 4 | RFI-MW | TD = 171.9, PBTD = 164 |
| 1237 | 17089.07 | 23868.74 | 826.47 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | | | | | | | 27.00 | 798.47 | SH.BEDROCK | 1 | RFI-MW | |
| 1238 | 17079.00 | 23862.43 | 824.86 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | | | | | | | 26.00 | 798.47 | D.BEDROCK | 1 | RFI-MW | TD = 170.5, PBTD = 161.5 |
| 1239 | 17013.86 | 22449.18 | 793.80 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 863.10 | 833.10 | | | | | | | | 24.30 | 769.23 | D.BEDROCK | 1 | RFI-MW | TD = 171, PBTD = 165 |
| 1240 | 16066.23 | 25183.90 | 797.73 | 800.34 | 800.34 | 26.57 | 774.18 | 7.57 | 22.57 | 792.77 | 777.77 | | | | | | | | 29.40 | 768.33 | SH.BEDROCK | 2 | RFI-MW | |
| 1241 | 17913.50 | 25097.59 | 805.70 | 808.24 | 808.24 | 36.18 | 769.52 | 15.18 | 35.18 | 793.06 | 773.06 | | | | | | | | 7.20 | 796.50 | OVERBURDEN | 1 | RFI-MW | |
| 1242 | 17367.94 | 25344.78 | 778.53 | 781.42 | 781.42 | 27.32 | 751.21 | 11.32 | 26.32 | 770.10 | 755.10 | | | | | | | | 16.30 | 762.23 | SH.BEDROCK | 1 | RFI-MW | |
| 1243 | 17065.60 | 25239.04 | 774.96 | 777.21 | 777.21 | 27.91 | 747.07 | 11.91 | 26.91 | 765.30 | 750.30 | | | | | | | | 10.20 | 764.78 | SH.BEDROCK | 1 | RFI-MW | |
| 1244 | 17155.45 | 25459.01 | 755.49 | 758.53 | 758.53 | 24.89 | 730.50 | 8.99 | 23.99 | 749.54 | 734.54 | | | | | | | | 7.00 | 748.49 | D.BEDROCK | 1 | RFI-MW | |
| 1245 | 16894.94 | 25429.95 | 753.03 | 755.70 | 755.70 | 58.06 | 694.97 | 37.06 | 57.06 | 718.64 | 698.64 | | | | | | | | 7.50 | 746.53 | D.BEDROCK | 1 | RFI-MW | |
| 1249 | 16969.58 | 25244.09 | 773.04 | 774.96 | 774.96 | 70.00 | 703.04 | 54.00 | 69.00 | 720.96 | 705.96 | | | | | | | | 21.00 | 752.04 | SH.BEDROCK | 1 | RFI-MW | Formerly #1234A |
| 745 | 16067.80 | 23808.30 | 764.18 | 766.99 | 766.99 | 60.20 | 693.98 | 35.00 | 60.20 | 719.18 | 693.98 | | | 3.01 | 763.98 | 5.81E-01 | 2.05E-04 | 1 | 3.00 | 761.18 | SH.BEDROCK | 4 | RCRA-WQMW | |
| 831 | 17387.40 | 24133.50 | 835.56 | 838.48 | 839.56 | 50.70 | 784.86 | 24.20 | 50.40 | 811.36 | 785.16 | | | 37.00 | 802.56 | | | | 20.00 | 815.56 | SH.BEDROCK | 1 | RCRA-WQMW | |
| 832 | 17385.60 | 24096.70 | 836.25 | 840.45 | 841.55 | 85.90 | 752.35 | 58.10 | 85.60 | 780.15 | 752.65 | | | 40.10 | 801.45 | 4.80E-02 | 1.70E-05 | 1 | 30.70 | 807.55 | SH.BEDROCK | 1 | RCRA-WQMW | |
| 833 | 16056.90 | 23842.40 | 762.74 | 765.05 | 766.34 | 31.00 | 721.74 | 9.50 | 30.70 | 743.24 | 722.04 | | | 4.00 | 762.34 | 4.42E-01 | 1.56E-04 | 1 | 4.20 | 748.54 | SH.BEDROCK | 4 | RCRA-WQMW | |
| 835 | 16787.70 | 23951.60 | 759.93 | 762.08 | 762.93 | 27.50 | 732.43 | 5.50 | 26.90 | 754.43 | 733.03 | | | 15.00 | 747.93 | 6.88E-01 | 2.43E-04 | 1 | | <732.43 | OVERBURDEN | 5 | RCRA-WQMW | |
| 836 | 16748.20 | 24138.80 | 763.32 | 766.26 | 767.32 | 28.50 | 734.82 | 7.00 | 28.20 | 756.32 | 735.12 | | | 18.90 | 748.42 | 7.45E-01 | 2.63E-04 | 1 | | <734.82 | OVERBURDEN | 5 | RCRA-WQMW | |
| 837 | 15845.60 | 24352.60 | 771.12 | 773.85 | 774.52 | 31.60 | 739.52 | 10.00 | 31.30 | 761.12 | 739.82 | | | 25.50 | 749.02 | | | | | <739.52 | OVERBURDEN | 5 | RCRA-WQMW | |
| 838 | 16308.70 | 24934.80 | 752.29 | 753.96 | 755.09 | 22.80 | 729.49 | 5.00 | 21.60 | 747.29 | 730.79 | | | 5.20 | 749.96 | 3.12E-01 | 1.10E-04 | 1 | 12.80 | 739.49 | BOTH | 6 | RCRA-WQMW | |
| 839 | 16308.80 | 24923.60 | 751.56 | 753.92 | 755.16 | 58.00 | 695.56 | 25.00 | 58.00 | 726.56 | 695.56 | | | 5.60 | 749.56 | 1.42E+00 | 5.01E-04 | 1 | 9.00 | 742.56 | SH.BEDROCK | 4 | RCRA-WQMW | |
| 840 | 16928.60 | 25251.70 | 766.94 | 769.03 | 770.94 | 26.90 | 740.04 | 11.00 | 26.60 | 755.94 | 740.34 | | | 20.80 | 750.14 | 1.35E+00 | 4.75E-04 | 1 | 2.50 | 764.44 | SH.BEDROCK | 1 | RCRA-WQMW | |

Revised 06-13-91

# Table 3D.1. (continued)

| WELL # | ORNL GRID LOCATION NORTH | EAST | GROUND ELEV. | TOP CASING | MEAS. POINT | TOTAL DEPTH | ELEV. TD | SCREEN INTERVAL DEPTH T/SCREEN | B/SCREEN | ELEV. T/SCREEN | B/SCREEN | WATER/ LEVEL DATA 8/25-30/89 DEPTH | ELEV. | 2/21-22/90 DEPTH | ELEV. | HYDRAULIC CONDUCTIVITY FT/DAY | CM/SEC | TEST TYPE | TOP OF BEDROCK DEPTH | ELEV. | MONITORED INTERVAL ZONE | FM | USE/ CLASS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 641 | 17206.30 | 26294.80 | 766.04 | 768.50 | 769.74 | 56.50 | 709.54 | 36.30 | 56.30 | 729.74 | 709.74 | | | 12.05 | 757.69 | 1.20E-02 | 4.40E-06 | 1 | 6.00 | 760.04 | SH.BEDROCK | 1 | RCRA-WQMW | |
| 642 | 17216.10 | 25296.40 | 767.25 | 769.56 | 770.05 | 26.80 | 740.45 | 8.00 | 23.20 | 759.25 | 744.05 | | | 9.80 | 760.25 | 2.49E-01 | 8.82E-05 | 1 | 3.00 | 764.25 | SH.BEDROCK | 1 | RCRA-WQMW | |
| 643 | 17597.10 | 26221.40 | 781.43 | 782.91 | 783.93 | 21.00 | 760.43 | 3.60 | 19.30 | 777.83 | 762.13 | | | 2.00 | 781.93 | 2.97E-01 | 1.05E-04 | 1 | 8.80 | 772.63 | BOTH | 3 | RCRA-WQMW | |
| 644 | 17602.60 | 26228.60 | 780.95 | 783.69 | 784.75 | 52.00 | 728.95 | 24.60 | 51.70 | 756.35 | 729.25 | | | 11.60 | 773.15 | 1.00E-02 | 3.68E-06 | 1 | 9.00 | 771.95 | SH.BEDROCK | 1 | RCRA-WQMW | |
| 645 | 17108.20 | 24968.30 | 807.33 | 810.30 | 811.23 | 41.00 | 766.33 | 19.20 | 39.90 | 788.13 | 767.43 | 25.45 | 785.78 | 22.40 | 788.83 | 9.69E-01 | 3.42E-04 | 1 | 25.00 | 782.33 | BOTH | 3 | RCRA-WQMW | |
| 646 | 18030.70 | 24803.50 | 861.03 | 863.93 | 865.03 | 81.00 | 780.03 | 55.00 | 81.00 | 806.03 | 780.03 | | | 39.15 | 825.88 | 7.00E-03 | 2.76E-06 | 1 | 19.10 | 841.93 | SH.BEDROCK | 1 | RCRA-WQMW | |
| 647 | 17769.90 | 24790.50 | 839.62 | 842.40 | 843.12 | 67.00 | 772.62 | 45.40 | 65.60 | 794.22 | 773.62 | | | 34.10 | 809.02 | | | | 26.00 | 813.62 | SH.BEDROCK | 1 | RCRA-WQMW | |
| 648 | 16942.40 | 24656.30 | 799.50 | 801.44 | 802.10 | 32.00 | 767.50 | 9.80 | 31.50 | 789.70 | 768.00 | 21.59 | 780.51 | 21.15 | 780.95 | | | | 15.00 | 784.50 | BOTH | 3 | RCRA-WQMW | |
| 649 | 16781.80 | 24215.20 | 787.68 | 791.18 | 791.48 | 32.90 | 754.78 | 10.50 | 32.60 | 777.18 | 755.08 | 15.02 | 776.46 | 11.70 | 779.78 | 6.21E-01 | 2.19E-04 | 1 | 16.80 | 770.88 | BOTH | 3 | RCRA-WQMW | |
| 650 | 16595.40 | 24793.50 | 769.96 | 771.36 | 772.06 | 22.70 | 747.26 | 6.00 | 21.70 | 763.96 | 748.26 | 5.65 | 766.43 | 4.80 | 767.28 | | | | 9.00 | 760.96 | BOTH | 3 | RCRA-WQMW | |
| 651 | 16485.00 | 24058.20 | 766.36 | 769.15 | 770.16 | 21.60 | 744.76 | 4.00 | 20.00 | 762.36 | 746.36 | 5.30 | 764.86 | 2.50 | 767.66 | 3.09E-01 | 1.09E-04 | 1 | 8.00 | 758.36 | BOTH | 6 | RCRA-WQMW | |
| 652 | 16346.90 | 23911.60 | 767.65 | 769.68 | 770.65 | 25.30 | 742.25 | 5.40 | 21.50 | 762.15 | 746.05 | 10.21 | 760.44 | 7.30 | 763.35 | 9.04E-01 | 3.19E-04 | 1 | 7.00 | 760.65 | BOTH | 6 | RCRA-WQMW | |
| 653 | 16695.10 | 24047.50 | 780.39 | 783.54 | 784.39 | 27.70 | 752.69 | 4.50 | 25.50 | 778.89 | 754.59 | 13.43 | 770.96 | 11.10 | 773.29 | 1.70E-01 | 6.03E-05 | 1 | 12.00 | 768.39 | BOTH | 3 | RCRA-WQMW | |
| 654 | 16711.90 | 23851.90 | 781.48 | 783.23 | 784.68 | 27.50 | 753.98 | 5.00 | 27.30 | 776.48 | 754.18 | 11.34 | 773.34 | 9.00 | 775.68 | 1.67E+00 | 5.80E-04 | 1 | 14.50 | 766.98 | BOTH | 3 | RCRA-WQMW | |
| 655 | 16755.30 | 23427.70 | 811.28 | 813.78 | 815.18 | 52.00 | 759.28 | 30.00 | 51.70 | 781.28 | 759.58 | | | 15.30 | 799.88 | 1.27E+00 | 4.48E-04 | 1 | 27.00 | 784.28 | SH.BEDROCK | 1 | RCRA-WQMW | |
| 656 | 16764.40 | 23432.90 | 810.17 | 812.63 | 813.67 | 82.00 | 728.17 | 55.00 | 81.20 | 755.17 | 728.97 | | | 13.20 | 800.47 | 5.40E-02 | 1.90E-05 | 1 | 26.00 | 784.17 | D.BEDROCK | 1 | RCRA-WQMW | |
| 657 | 16538.00 | 23106.30 | 847.18 | 848.74 | 849.58 | 70.00 | 777.18 | 49.70 | 69.60 | 797.48 | 777.58 | | | 51.00 | 796.58 | 8.67E-01 | 3.06E-04 | 1 | | <777.18 | OVERBURDEN | 5 | RCRA-WQMW | |
| 658 | 16542.10 | 23115.80 | 847.22 | 849.65 | 850.72 | 108.40 | 740.82 | 84.50 | 106.10 | 762.72 | 741.12 | | | 54.40 | 796.32 | 5.00E-03 | 2.00E-06 | 1 | 79.80 | 767.42 | SH.BEDROCK | 1 | RCRA-WQMW | |
| 659 | 16009.40 | 23246.20 | 777.90 | 780.28 | 781.01 | 26.50 | 751.40 | 5.40 | 26.20 | 772.50 | 751.70 | | | 9.95 | 771.06 | 1.65E+00 | 5.50E-04 | 1 | | <751.40 | OVERBURDEN | 5 | RCRA-WQMW | |
| 660 | 15996.60 | 23252.90 | 777.14 | 779.18 | 780.24 | 81.80 | 715.34 | 34.00 | 61.50 | 743.14 | 715.64 | | | 9.00 | 771.24 | 8.50E-01 | 3.02E-04 | 1 | 27.50 | 749.64 | SH.BEDROCK | 4 | RCRA-WQMW | |
| 1078 | 17406.94 | 25613.69 | 769.00 | 770.78 | 770.78 | 20.00 | 749.00 | 8.75 | 18.75 | 760.25 | 750.25 | | | 1.30 | 769.48 | | | | 6.90 | 762.10 | SH.BEDROCK | 1 | RCRA-WQMW | |
| 1079 | 17359.59 | 25612.66 | 768.40 | 770.28 | 770.28 | 70.00 | 698.40 | 55.00 | 70.00 | 713.40 | 698.40 | | | 9.00 | 761.28 | | | | 6.90 | 761.50 | D.BEDROCK | 1 | RCRA-WQMW | ADJACENT TO SEEP/SPRING |
| 636 | 17668.04 | 24326.17 | 833.03 | 834.71 | 834.71 | 54.00 | 779.03 | 39.00 | 54.00 | 794.03 | 779.03 | 30.08 | 804.63 | 27.90 | 806.81 | 6.20E-02 | 2.20E-05 | 1 | 26.00 | 807.03 | SH.BEDROCK | 1 | RAP-PZ | |
| 637 | 17715.14 | 24135.97 | 859.42 | 861.60 | 861.60 | 66.00 | 793.42 | 49.00 | 66.00 | 810.42 | 793.42 | | | 46.95 | 814.65 | 4.26E-03 | 1.51E-06 | 1 | 10.00 | 849.42 | SH.BEDROCK | 1 | RAP-PZ | |
| 638 | 17495.05 | 24119.35 | 848.36 | 849.87 | 849.87 | 70.00 | 778.36 | 55.00 | 70.00 | 793.36 | 778.36 | | | 39.34 | 810.53 | 1.44E-01 | 5.10E-05 | 1 | 8.00 | 840.36 | SH.BEDROCK | 1 | RAP-PZ | |
| 639 | 17305.38 | 24138.11 | 835.91 | 837.50 | 837.50 | 63.50 | 772.41 | 52.50 | 62.50 | 783.41 | 773.41 | | | 39.21 | 798.29 | 6.20E-01 | 2.20E-04 | 1 | 9.00 | 827.91 | SH.BEDROCK | 1 | RAP-PZ | |
| 640 | 17614.70 | 24719.55 | 835.84 | 835.79 | 835.79 | 60.00 | 775.84 | 45.00 | 60.00 | 790.84 | 775.84 | 33.79 | 802.00 | 31.62 | 804.17 | 2.36E-01 | 8.35E-05 | 1 | 5.00 | 830.84 | SH.BEDROCK | 1 | RAP-PZ | |
| 641 | 17383.49 | 23065.24 | 843.79 | 845.79 | 845.79 | 60.00 | 783.79 | 45.00 | 60.00 | 798.79 | 783.79 | | | 20.06 | 825.73 | 1.10E-01 | 3.94E-05 | 1 | 8.00 | 835.79 | SH.BEDROCK | 1 | RAP-PZ | |
| 642 | 16580.96 | 24035.55 | 773.03 | 776.96 | 776.96 | 30.00 | 743.03 | 15.00 | 30.00 | 758.03 | 743.03 | 5.79 | 771.17 | 3.48 | 773.48 | 7.80E-02 | 2.76E-05 | 1 | 12.50 | 760.53 | SH.BEDROCK | 4 | RAP-PZ | |
| 643 | 16344.38 | 24204.78 | 773.17 | 773.11 | 773.11 | 21.50 | 751.67 | 6.00 | 21.50 | 767.17 | 751.67 | | | | | | | | 15.50 | 757.67 | BOTH | 4 | RAP-PZ | DESTROYED |
| 644 | 16748.86 | 24846.36 | 776.30 | 776.21 | 776.21 | 17.00 | 759.30 | 7.00 | 17.00 | 769.30 | 759.30 | 6.52 | 769.69 | 4.37 | 771.84 | 5.60E-02 | 1.97E-05 | 1 | 5.00 | 771.30 | SH.BEDROCK | 1 | RAP-PZ | |
| 645 | 17173.65 | 25274.60 | 764.78 | 766.31 | 766.31 | 25.00 | 739.78 | 15.00 | 25.00 | 749.78 | 739.78 | 7.63 | 758.68 | 6.65 | 759.66 | 4.30E-01 | 1.50E-04 | 1 | 8.00 | 755.78 | SH.BEDROCK | 1 | RAP-PZ | |

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# Table 3D.1. (continued)

| WELL # | ORNL GRID LOCATION NORTH | EAST | GROUND ELEV. | TOP CASING | MEAS. POINT | TOTAL DEPTH | ELEV. TD | SCREEN INTERVAL DEPTH T/SCREEN | B/SCREEN | ELEV. T/SCREEN | B/SCREEN | WATER LEVEL DATA 8/25-30/89 DEPTH | ELEV. | 2/21-22/90 DEPTH | ELEV. | HYDRAULIC CONDUCTIVITY FT/DAY | CM/SEC | TEST TYPE | TOP OF BEDROCK DEPTH | ELEV. | MONITORED INTERVAL ZONE | FM | USE/ CLASS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 646 | 17550.78 | 25167.05 | 785.18 | 788.91 | 788.91 | 39.00 | 746.18 | 29.00 | 39.00 | 756.18 | 746.18 | 14.54 | 772.37 | 14.40 | 772.51 | 1.30E-02 | 4.76E-06 | 1 | 14.00 | 771.18 | SH.BEDROCK | 1 | RAP-PZ | |
| 647 | 17145.66 | 24749.00 | 816.67 | 820.35 | 820.35 | 36.00 | 780.67 | 26.00 | 36.00 | 790.67 | 780.67 | 32.51 | 787.84 | 9.64 | 810.71 | | | | 26.00 | 791.67 | SH.BEDROCK | 1 | RAP-PZ | |
| 648 | 17374.55 | 24524.24 | 823.42 | 824.73 | 824.73 | 45.00 | 778.42 | 35.00 | 45.00 | 788.42 | 778.42 | 24.67 | 800.06 | 22.90 | 801.83 | | | | 31.50 | 791.92 | SH.BEDROCK | 1 | RAP-PZ | |
| 649 | 17375.49 | 25075.50 | 821.47 | 821.40 | 821.40 | 37.00 | 784.47 | 22.00 | 37.00 | 799.47 | 784.47 | 26.73 | 794.67 | 27.45 | 793.95 | | | | 15.00 | 806.47 | SH.BEDROCK | 1 | RAP-PZ | |
| 650A | 17273.53 | 25150.16 | 817.07 | 820.13 | 820.13 | 38.00 | 779.07 | 21.75 | 29.75 | 795.32 | 787.32 | DRY | <787.32 | 32.48 | 787.65 | | | | 15.00 | 802.07 | SH.BEDROCK | 1 | RAP-PZ | |
| 650B | 17273.68 | 25150.56 | 817.07 | 820.13 | 820.13 | 60.00 | 757.07 | 52.00 | 60.00 | 765.07 | 757.07 | 39.18 | 780.95 | 38.50 | 781.63 | | | | 15.00 | 802.07 | SH.BEDROCK | 1 | RAP-PZ | |
| 651 | 16670.85 | 25190.67 | 796.32 | 799.53 | 799.53 | 110.41 | 685.91 | 90.00 | 95.00 | 706.32 | 701.32 | | | 29.60 | 768.93 | 3.60E-01 | 1.27E-04 | 1 | 16.50 | 779.82 | D.BEDROCK? | 1 | RAP-PZ | |
| 652 | 16159.68 | 24900.00 | 770.16 | 769.75 | 769.75 | 90.00 | 680.16 | 70.00 | 90.00 | 700.16 | 680.16 | | | 20.18 | 749.57 | 6.90E-02 | 2.44E-05 | 1 | 20.00 | 750.16 | D.BEDROCK? | 4 | RAP-PZ | |
| 653 | 15792.51 | 24070.40 | 763.54 | 766.63 | 766.63 | 63.00 | 700.54 | 50.00 | 60.00 | 713.54 | 703.54 | | | 18.83 | 747.80 | 6.90E-01 | 2.44E-04 | 1 | 12.00 | 751.54 | D.BEDROCK? | 4 | RAP-PZ | |
| 654 | 16618.16 | 24054.76 | 775.14 | 775.07 | 775.07 | 90.00 | 685.14 | 70.00 | 90.00 | 705.14 | 685.14 | 1.83 | 773.24 | 0.00 | 775.07 | 5.20E-01 | 1.86E-04 | 1 | 21.00 | 754.14 | D.BEDROCK? | 1 | RAP-PZ | |
| 655 | 17469.72 | 24815.30 | 838.29 | 839.64 | 839.64 | 125.00 | 713.29 | 100.00 | 125.00 | 738.29 | 713.29 | 41.48 | 798.18 | 37.72 | 801.92 | 9.50E-02 | 3.36E-05 | 1 | 16.00 | 822.29 | D.BEDROCK | 1 | RAP-PZ | |
| 656 | 17923.92 | 24692.96 | 847.59 | 847.79 | 847.79 | 120.00 | 727.59 | 100.00 | 120.00 | 747.59 | 727.59 | 39.08 | 808.71 | 33.82 | 813.97 | 1.38E-01 | 4.87E-05 | 1 | 18.00 | 829.59 | D.BEDROCK | 4 | RAP-PZ | |
| 739 | 15628.89 | 23604.03 | 759.86 | 761.18 | 761.18 | 33.00 | 726.86 | 23.00 | 33.00 | 736.86 | 726.86 | | | 13.43 | 747.75 | 4.90E-01 | 1.74E-04 | 1 | 24.50 | 735.36 | SH.BEDROCK | 4 | RAP-PZ | |
| 740 | 15778.95 | 23372.30 | 767.30 | 769.01 | 769.01 | 24.00 | 743.30 | 14.00 | 24.00 | 753.30 | 743.30 | | | 12.62 | 756.39 | 7.60E-02 | 2.67E-05 | 1 | 18.00 | 749.30 | BOTH | 6 | RAP-PZ | |
| 741 | 15596.74 | 23352.05 | 758.31 | 759.41 | 759.41 | 22.00 | 736.31 | 12.00 | 22.00 | 746.31 | 736.31 | | | 11.23 | 748.18 | 7.90E-01 | 2.78E-04 | 1 | 18.00 | 740.31 | BOTH | 6 | RAP-PZ | |
| 748 | 15891.10 | 25534.60 | 758.79 | 760.06 | 760.06 | 22.50 | 736.29 | 12.50 | 22.50 | 746.29 | 736.29 | | | 7.86 | 752.20 | 2.59E-01 | 9.10E-05 | 1 | 5.50 | 753.29 | SH.BEDROCK | 4 | RAP-PZ | |
| 749 | 16314.90 | 26038.60 | 758.88 | 760.31 | 760.31 | 22.50 | 736.38 | 12.50 | 22.50 | 746.38 | 736.38 | | | 4.53 | 755.78 | 3.05E-01 | 1.07E-04 | 1 | 22.00 | 736.88 | OVERBURDEN | 5 | RAP-PZ | |
| T-1 | 16398.76 | 23552.76 | 774.50 | 776.91 | 776.91 | 9.10 | 765.40 | 4.10 | 9.10 | 770.40 | 765.40 | | | 4.48 | 772.43 | 2.20E-01 | 7.76E-05 | 1 | 9.10 | 765.40 | OVERBURDEN | 5 | NMF-PZ | Plugged and abandoned 4/90 |
| T-5 | 16343.63 | 23695.86 | 767.50 | 768.85 | 768.85 | 4.70 | 762.80 | 0.00 | 4.70 | 767.50 | 762.80 | | | 2.27 | 766.58 | 4.40E-01 | 1.55E-04 | 1 | 5.00 | 762.50 | OVERBURDEN | 5 | NMF-PZ | Plugged and abandoned 4/90 |
| T-7 | 16299.72 | 23550.04 | 770.70 | 772.06 | 772.06 | 9.40 | 761.30 | 4.40 | 9.40 | 766.30 | 761.30 | 4.48 | 767.58 | 2.30 | 769.78 | 1.05E-01 | 3.68E-05 | 1 | | <761.30 | OVERBURDEN | 5 | NMF-PZ | Plugged and abandoned 4/90 |
| T-10 | 16250.96 | 23401.11 | 782.40 | 783.19 | 783.19 | 21.60 | 760.80 | 16.60 | 21.60 | 765.80 | 760.80 | | | 6.98 | 776.21 | 4.10E-01 | 1.45E-04 | 1 | | <760.80 | OVERBURDEN | 5 | NMF-PZ | Plugged and abandoned 4/90 |
| T-17 | 16199.86 | 23550.51 | 766.80 | 768.88 | 768.88 | 11.30 | 755.50 | 6.30 | 11.30 | 760.50 | 755.50 | 4.70 | 764.18 | 2.77 | 766.11 | 1.30E+00 | 4.58E-04 | 1 | | <755.50 | OVERBURDEN | 5 | NMF-PZ | Plugged and abandoned 4/90 |
| T-18 | 16201.27 | 23653.42 | 762.50 | 765.17 | 765.17 | 7.30 | 755.20 | 2.30 | 7.30 | 760.20 | 755.20 | | | 4.15 | 761.02 | 4.59E-01 | 1.61E-04 | 1 | 7.50 | 755.00 | OVERBURDEN | 5 | NMF-PZ | Plugged and abandoned 4/90 |
| T-20 | 16200.96 | 23750.45 | 761.10 | 763.26 | 763.26 | 10.80 | 750.30 | 5.80 | 10.80 | 755.30 | 750.30 | 5.10 | 758.18 | 3.40 | 759.88 | 4.07E-01 | 1.44E-04 | 1 | 10.80 | 750.30 | OVERBURDEN | 5 | NMF-PZ | Plugged and abandoned 4/90 |
| T-22 | 16137.52 | 23405.93 | 777.80 | 779.56 | 779.56 | 16.00 | 761.80 | 11.00 | 16.00 | 766.80 | 761.80 | | | 6.45 | 773.11 | 1.30E-01 | 4.59E-05 | 1 | 18.80 | 759.00 | OVERBURDEN | 5 | NMF-PZ | Plugged and abandoned 4/90 |
| T-27 | 16096.86 | 23253.89 | 785.40 | 787.69 | 787.69 | 19.30 | 766.10 | 14.30 | 19.30 | 771.10 | 766.10 | | | 14.15 | 773.54 | 2.80E-01 | 9.88E-05 | 1 | 20.00 | 765.40 | OVERBURDEN | 5 | NMF-PZ | Plugged and abandoned 4/90 |
| T-36 | 15996.81 | 23455.12 | 765.10 | 767.21 | 767.21 | 16.50 | 748.60 | 11.50 | 16.50 | 753.60 | 748.60 | | | 3.25 | 763.96 | 4.10E-01 | 1.45E-04 | 1 | 16.80 | 748.30 | OVERBURDEN | 5 | NMF-PZ | Plugged and abandoned 4/90 |
| HHMS-4A | 16144.55 | 24609.77 | 790.37 | 793.89 | 793.89 | 400.40 | 389.97 | 380.00 | 400.00 | 410.37 | 390.37 | | | 147.10 | 646.79 | 5.10E-06 | 1.80E-09 | 3 | | | DEEP Cnl | 1 | HHMS | |
| HHMS-4B | 16148.20 | 24688.37 | 787.78 | 791.05 | 792.06 | 215.30 | 572.48 | 174.28 | 215.28 | 613.50 | 572.50 | | | 35.45 | 756.63 | 9.63E-02 | 3.40E-05 | 2 | | | DEEP Cnl | 4 | HHMS | |
| HHMS-4C | 16170.59 | 24678.08 | 787.86 | 790.71 | 791.74 | 61.50 | 726.36 | 40.80 | 61.50 | 747.06 | 726.36 | | | 34.18 | 757.56 | 8.49E-01 | 3.00E-04 | 2 | | | SHALLOW Cnl | 4 | HHMS | |
| HHMS-5A | 15814.83 | 24525.34 | 767.48 | 770.30 | 770.30 | 400.40 | 367.08 | 380.00 | 400.00 | 387.48 | 367.48 | (223.3) | 547.00 | (199.5) | 570.80 | | | | | | DEEP Cnl | 1 | HHMS | |
| HHMS-5B | 15827.63 | 24596.29 | 766.43 | 769.26 | 769.96 | 219.50 | 546.93 | 196.08 | 219.48 | 570.35 | 546.95 | | | 17.48 | 752.48 | 1.33E-02 | 4.70E-06 | 2 | | | DEEP Cnl | 4 | HHMS | |

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# Table 3D.1. (continued)

| WELL # | ORIG. GRID NORTH | LOCATION EAST | GROUND ELEV. | TOP CASING | MEAS. POINT | TOTAL DEPTH | ELEV. TD | SCREEN INTERVAL DEPTH T/SCREEN | B/SCREEN | ELEV. T/SCREEN | B/SCREEN | WATER LEVEL DATA 8/25-30/89 DEPTH | ELEV. | 2/21-22/90 DEPTH | ELEV. | HYDRAULIC CONDUCTIVITY FT/DAY | CM/SEC | TEST TYPE | TOP OF BEDROCK DEPTH | ELEV. | MONITORED INTERVAL ZONE | FM | USE/ CLASS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HHMS-5C | 16833.48 | 24561.12 | 766.79 | 769.95 | 770.65 | 63.00 | 703.79 | 42.10 | 63.00 | 724.69 | 703.79 | | | 22.74 | 747.91 | 1.64E-01 | 5.80E-05 | 2 | | | SHALLOW Cnl | 4 | HHMS | |
| HHMS-6A | 16306.95 | 24764.04 | 762.09 | 763.88 | 763.88 | 402.50 | 359.59 | 380.00 | 400.00 | 382.09 | 362.09 | (57.96) | 705.90 | (33.49) | 730.39 | 1.19E-05 | 4.20E-09 | 3 | | | DEEP Cnl | 4 | HHMS | |
| HHMS-6B | 16269.25 | 24745.18 | 762.27 | 764.85 | 765.38 | 295.00 | 467.27 | 275.00 | 295.00 | 487.27 | 467.27 | | | 17.62 | 747.56 | 1.19E-02 | 4.20E-06 | 2 | | | DEEP Cnl | 4 | HHMS | |
| HHMS-6C | 16268.72 | 24732.51 | 762.47 | 764.91 | 765.93 | 178.00 | 584.47 | 158.00 | 178.00 | 604.47 | 584.47 | | | 11.26 | 754.65 | 1.87E-01 | 6.60E-05 | 2 | | | SHALLOW Cnl | 4 | HHMS | |
| HHMS-7A | 17540.65 | 24512.09 | 808.54 | 811.35 | 811.89 | 402.50 | 406.04 | 380.00 | 400.00 | 428.54 | 408.54 | | | 22.30 | 789.59 | 6.52E-05 | 2.30E-08 | 3 | | | DEEP Crg | 7 | HHMS | |
| HHMS-7B | 17518.90 | 24509.40 | 808.64 | 810.53 | 810.53 | 295.00 | 513.64 | 275.00 | 295.00 | 533.64 | 513.64 | | | 18.60 | 791.93 | 2.15E-03 | 7.60E-07 | 2 | | | DEEP Cmr | 1 | HHMS | |
| HHMS-7C | 17496.37 | 24506.56 | 808.78 | 810.69 | 810.69 | 178.00 | 630.78 | 158.00 | 178.00 | 650.78 | 630.78 | | | 9.72 | 800.97 | 2.07E-03 | 7.30E-07 | 2 | | | SHALLOW Cmr | 1 | HHMS | |
| HHMS-8A | 16862.02 | 24694.84 | 786.06 | 787.95 | 787.95 | 400.00 | 386.06 | 380.00 | 400.00 | 406.06 | 386.06 | | | 150.62 | 637.33 | 5.38E-06 | 1.90E-09 | 3 | | | DEEP Crg | 7 | HHMS | |
| HHMS-8B | 16810.70 | 24697.05 | 783.53 | 785.59 | 785.59 | 197.00 | 586.53 | 177.00 | 197.00 | 606.53 | 586.53 | | | 9.15 | 776.44 | 4.82E-05 | 1.70E-08 | 3 | | | DEEP Cmr | 1 | HHMS | |
| HHMS-8C | 16782.51 | 24668.21 | 786.09 | 788.62 | 788.62 | 79.00 | 707.09 | 59.00 | 79.00 | 727.09 | 707.09 | | | 9.74 | 778.88 | 1.59E-02 | 5.60E-06 | 2 | | | SHALLOW Cmr | 1 | HHMS | |
| TR-03 | 16762.00 | 24331.00 | 760.25 | 763.10 | 763.10 | 23.30 | 736.95 | 13.30 | 23.30 | 746.95 | 736.95 | | | 18.14 | 746.96 | | | | | <736.95 | OVERBURDEN | 5 | TRACETEST | |
| TR-04 | 16862.00 | 24409.00 | 773.70 | 774.24 | 774.24 | 33.00 | 740.70 | 22.50 | 32.50 | 751.20 | 741.20 | | | 24.58 | 749.66 | | | | | <740.70 | OVERBURDEN | 5 | TRACETEST | |
| TR-05 | 16867.00 | 24405.00 | 772.50 | 773.01 | 773.01 | 31.00 | 741.50 | 20.50 | 30.50 | 752.00 | 742.00 | | | 23.35 | 749.66 | | | | | <741.50 | OVERBURDEN | 5 | TRACETEST | |
| TR-07 | 16851.00 | 24378.00 | 772.00 | 772.47 | 772.47 | 31.00 | 741.00 | 20.70 | 30.70 | 751.30 | 741.30 | | | 22.75 | 749.72 | | | | | <741.00 | OVERBURDEN | 5 | TRACETEST | |
| TR-09 | 16867.00 | 24352.00 | 772.90 | 773.41 | 773.41 | 33.00 | 739.90 | 22.60 | 32.60 | 750.30 | 740.30 | | | 23.53 | 749.88 | | | | | <739.90 | OVERBURDEN | 5 | TRACETEST | |
| TARA-1 | 17806.99 | 25192.38 | 831.94 | 834.86 | 834.86 | 62.82 | 769.12 | 39.84 | 59.84 | 792.10 | 772.10 | 40.65 | 794.21 | 35.00 | 799.86 | | | | | (8057) | SH.BEDROCK? | 1 | TARA-PZ | |
| TARA-2 | 17816.12 | 25102.48 | 837.06 | 840.14 | 840.14 | 63.38 | 773.68 | 40.26 | 60.26 | 796.80 | 776.80 | 50.04 | 790.10 | 38.13 | 802.01 | | | | | | SH.BEDROCK? | 1 | TARA-PZ | |
| TARA-3 | 17752.28 | 25062.08 | 838.01 | 839.88 | 839.88 | 53.60 | 784.21 | 31.88 | 51.88 | 806.13 | 786.13 | 40.96 | 798.90 | 37.02 | 802.86 | | | | | (8157) | SH.BEDROCK? | 1 | TARA-PZ | |
| TARA-4 | 17654.24 | 25002.48 | 834.57 | 837.72 | 837.72 | 58.49 | 778.08 | 35.31 | 55.31 | 799.26 | 779.26 | 44.85 | 792.87 | 34.88 | 802.84 | | | | | (808.57) | SH.BEDROCK? | 1 | TARA-PZ | |
| TARA-5 | 17549.78 | 24928.23 | 836.18 | 838.74 | 838.74 | 63.22 | 772.96 | 40.61 | 60.61 | 795.57 | 775.57 | 43.25 | 795.49 | 37.12 | 801.62 | | | | | (807.57) | SH.BEDROCK? | 1 | TARA-PZ | |
| TARA-6 | 17606.96 | 25086.38 | 835.75 | 838.11 | 838.11 | 63.09 | 772.66 | 40.67 | 60.67 | 795.08 | 775.08 | 49.06 | 789.03 | 41.70 | 796.41 | | | | | (8057) | SH.BEDROCK? | 1 | TARA-PZ | |
| TARA-7 | 17689.47 | 25141.24 | 839.09 | 840.01 | 840.01 | 63.38 | 775.71 | 42.41 | 62.41 | 796.68 | 776.68 | 50.50 | 789.51 | 42.82 | 797.19 | | | | | | SH.BEDROCK? | 1 | TARA-PZ | |
| TARA-8 | 17814.50 | 24903.14 | 806.26 | 809.01 | 809.01 | 39.00 | 767.26 | 16.21 | 36.21 | 790.05 | 770.05 | 19.26 | 789.75 | 17.72 | 791.29 | | | | | | SH.BEDROCK? | 1 | TARA-PZ | |
| TARA-9 | 17879.49 | 25041.76 | 805.08 | 807.04 | 807.04 | 39.00 | 766.08 | 16.99 | 36.99 | 788.09 | 768.09 | 19.72 | 787.32 | 17.35 | 789.69 | | | | | | SH.BEDROCK? | 1 | TARA-PZ | |
| TARA-10 | 17697.16 | 24945.94 | 806.75 | 808.95 | 808.95 | 39.00 | 767.75 | 16.74 | 36.74 | 790.01 | 770.01 | 15.06 | 793.89 | 11.16 | 797.79 | | | | | (8107) | SH.BEDROCK? | 1 | TARA-PZ | |
| TARA-11 | 17709.84 | 25256.02 | 811.83 | 813.93 | 813.93 | 48.80 | 763.03 | 26.64 | 46.64 | 785.19 | 765.19 | 33.63 | 780.30 | 28.85 | 785.08 | | | | | (7907) | SH.BEDROCK? | 1 | TARA-PZ | |
| TARA-12 | 17645.69 | 25295.15 | 782.89 | 784.67 | 784.67 | 29.99 | 752.90 | 8.18 | 28.18 | 774.71 | 754.71 | 11.91 | 772.76 | 5.35 | 779.32 | | | | | (7827) | SH.BEDROCK? | 1 | TARA-PZ | |
| TARA-13 | 17695.08 | 25151.41 | 803.83 | 804.98 | 804.98 | 39.00 | 764.83 | 17.80 | 37.80 | 786.03 | 766.03 | 22.74 | 782.24 | 19.68 | 785.30 | | | | | (8157) | SH.BEDROCK? | 1 | TARA-PZ | |
| 1035 | 16417.57 | 24174.86 | 771.67 | 774.50 | 774.50 | 15.45 | 756.22 | 10.20 | 15.20 | 761.47 | 756.47 | | | | | | | | 14.75 | 756.92 | OVERBURDEN | 5 | TUMULUS-I | DESTROYED |
| 1036 | 16326.57 | 24231.08 | 767.98 | 771.90 | 771.90 | 26.70 | 741.28 | 13.00 | 23.00 | 754.98 | 744.98 | | | 7.40 | 764.50 | 1.05E-01 | 3.71E-03 | 1 | 26.41 | 741.57 | OVERBURDEN | 5 | TUMULUS-I | Fitted w/ Well Wizard |
| 1037 | 16228.14 | 24175.72 | 771.14 | 774.60 | 774.60 | 26.17 | 744.97 | 12.30 | 22.30 | 758.84 | 748.84 | | | 15.88 | 758.72 | 1.04E-01 | 3.67E-03 | 1 | 25.75 | 745.39 | OVERBURDEN | 5 | TUMULUS-I | Fitted w/ Well Wizard |
| 1038 | 16251.36 | 24096.88 | 765.60 | 768.68 | 768.68 | 15.92 | 749.68 | 8.60 | 13.60 | 757.00 | 752.00 | | | 9.10 | 759.58 | 7.90E-02 | 2.79E-03 | 1 | 15.58 | 750.02 | OVERBURDEN | 5 | TUMULUS-I | Fitted w/ Well Wizard |

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# Table 3D.1. (continued)

| WELL # | ORNL GRID NORTH | LOCATION EAST | GROUND ELEV. | TOP CASING | MEAS. POINT | TOTAL DEPTH | ELEV. TD | SCREEN INTERVAL DEPTH T/SCREEN | B/SCREEN | ELEV. T/SCREEN | B/SCREEN | WATER/ LEVEL DATA 8/25-30/89 DEPTH | ELEV. | 2/21-22/90 DEPTH | ELEV. | HYDRAULIC CONDUCTIVITY FT/DAY | CM/SEC | TEST TYPE | TOP OF BEDROCK DEPTH | ELEV. | MONITORED INTERVAL ZONE | FM | USE/ CLASS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1039 | 16313.32 | 24093.26 | 765.40 | 768.28 | 768.28 | 17.62 | 747.78 | 6.50 | 11.50 | 758.90 | 753.90 | | | 7.00 | 761.28 | 8.30E-02 | 2.93E-03 | 1 | 12.83 | 752.57 | OVERBURDEN | 5 | TUMULUS-I | Fitted w/ Well Wizard |
| 1040 | 16373.13 | 24103.13 | 766.88 | 769.78 | 769.78 | 17.42 | 749.46 | 9.40 | 14.40 | 757.48 | 752.48 | | | 8.43 | 761.35 | 7.30E-02 | 2.58E-03 | 1 | 17.00 | 749.88 | OVERBURDEN | 5 | TUMULUS-I | Fitted w/ Well Wizard |
| ETF-1 | 16756.00 | 23641.20 | 797.36 | 799.64 | 799.64 | 26.71 | 768.67 | 24.70 | 29.70 | 772.68 | 768.68 | | | 14.65 | 784.99 | 8.90E-01 | 3.13E-04 | 1 | 13.30 | 784.08 | SH.BEDROCK? | 1 | ETF-PZ | |
| ETF-2 | 16778.30 | 23665.20 | 797.48 | 799.90 | 799.90 | 31.80 | 765.68 | 27.90 | 31.80 | 769.68 | 765.68 | | | 12.56 | 784.34 | 6.60E-02 | 2.32E-05 | 1 | | | SH.BEDROCK? | 1 | ETF-PZ | |
| ETF-3 | 16764.90 | 23672.80 | 796.19 | 797.60 | 797.60 | 30.84 | 765.35 | 26.84 | 30.84 | 769.35 | 765.35 | | | 15.54 | 782.06 | 1.31E-01 | 4.60E-05 | 1 | 22.96 | 773.23 | SH.BEDROCK | 1 | ETF-PZ | |
| ETF-4 | 16749.10 | 23673.30 | 795.31 | 795.71 | 795.71 | 30.78 | 764.53 | 26.78 | 30.78 | 768.53 | 764.53 | | | 12.30 | 783.41 | 3.81E-01 | 1.26E-04 | 1 | 18.37 | 776.94 | SH.BEDROCK | 1 | ETF-PZ | |
| ETF-5 | 16732.50 | 23665.30 | 794.47 | 795.55 | 795.55 | 30.26 | 764.22 | 26.25 | 30.25 | 768.22 | 764.22 | | | 12.36 | 783.19 | 8.53E-01 | 3.02E-04 | 1 | 24.60 | 769.87 | SH.BEDROCK | 1 | ETF-PZ | |
| ETF-6 | 16724.10 | 23651.00 | 794.31 | 795.59 | 795.59 | 30.09 | 764.22 | 26.09 | 30.09 | 768.22 | 764.22 | | | 12.54 | 783.05 | 1.12E+00 | 3.94E-04 | 1 | 22.96 | 771.35 | SH.BEDROCK | 1 | ETF-PZ | |
| ETF-7 | 16723.20 | 23633.60 | 793.96 | 794.82 | 794.82 | 30.41 | 763.55 | 26.41 | 30.41 | 767.55 | 763.55 | | | 11.42 | 783.40 | 5.58E-01 | 1.97E-04 | 1 | | | SH.BEDROCK | 1 | ETF-PZ | |
| ETF-8 | 16729.20 | 23618.60 | 792.94 | 793.87 | 793.87 | 29.76 | 763.18 | 24.76 | 29.76 | 768.18 | 763.18 | | | 9.72 | 784.15 | 8.90E-01 | 3.13E-04 | 1 | | | SH.BEDROCK | 1 | ETF-PZ | |
| ETF-9 | 16745.30 | 23610.30 | 794.02 | 794.82 | 794.82 | 30.91 | 763.11 | 26.91 | 30.91 | 767.11 | 763.11 | | | 6.65 | 788.17 | 1.40E-01 | 4.90E-05 | 1 | 14.00 | 780.02 | SH.BEDROCK | 1 | ETF-PZ | |
| ETF-10 | 16763.50 | 23609.80 | 796.54 | 796.35 | 796.35 | 31.07 | 765.47 | 27.07 | 31.07 | 769.47 | 765.47 | | | 13.24 | 785.11 | | | | | | SH.BEDROCK | 1 | ETF-PZ | |
| ETF-11 | 16773.00 | 23702.60 | 791.59 | 793.11 | 793.11 | 49.58 | 742.01 | 41.58 | 49.58 | 750.01 | 742.01 | | | 12.54 | 780.57 | 6.89E-01 | 2.44E-04 | 1 | 19.02 | 772.57 | SH.BEDROCK | 1 | ETF-PZ | |
| ETF-12 | 16737.90 | 23584.40 | 790.15 | 792.74 | 792.74 | 50.10 | 740.05 | 42.10 | 50.10 | 748.05 | 740.05 | | | 7.67 | 785.07 | 1.14E+00 | 4.05E-04 | 1 | 15.09 | 776.06 | SH.BEDROCK | 1 | ETF-PZ | |
| ETF-13 | 16872.00 | 23596.30 | 809.22 | 812.29 | 812.29 | 250.73 | 558.49 | 240.73 | 250.73 | 568.49 | 558.49 | | | 19.18 | 793.11 | 4.90E-02 | 1.74E-05 | 1 | 21.90 | 787.42 | D.BEDROCK | 1 | ETF-PZ | |
| ETF-14 | 16849.20 | 23618.50 | 804.96 | 807.10 | 807.10 | 94.59 | 710.37 | 84.59 | 94.59 | 720.37 | 710.37 | | | 11.69 | 795.41 | 6.50E-02 | 2.31E-05 | 1 | 20.80 | 784.16 | SH.BEDROCK | 1 | ETF-PZ | |
| ETF-15 | 16841.40 | 23603.50 | 805.58 | 807.29 | 807.29 | 48.75 | 758.83 | 36.75 | 46.75 | 768.83 | 758.83 | | | 12.70 | 794.59 | 1.90E-02 | 6.60E-06 | 1 | 19.80 | 785.78 | SH.BEDROCK | 1 | ETF-PZ | |
| ETF-16 | 16841.40 | 23614.10 | 804.97 | 806.87 | 806.87 | 244.50 | 560.47 | 234.50 | 244.50 | 570.47 | 560.47 | | | 12.63 | 794.24 | 8.20E-02 | 2.89E-05 | 1 | 19.21 | 785.76 | D.BEDROCK | 1 | ETF-PZ | |
| ETF-17 | 16782.90 | 23606.40 | 799.18 | 799.52 | 799.52 | 18.73 | 780.45 | 12.73 | 18.73 | 786.45 | 780.45 | | | 9.93 | 789.59 | 2.70E-02 | 9.61E-06 | 1 | | <780.45 | OVERBURDEN | 2 | ETF-PZ | |
| ETF-18 | 16791.20 | 23624.80 | 800.24 | 801.12 | 801.12 | 19.49 | 780.75 | 13.49 | 19.49 | 786.75 | 780.75 | | | 11.49 | 789.63 | | | | 19.50 | 780.74 | OVERBURDEN | 2 | ETF-PZ | |
| ETF-20 | 16789.50 | 23606.70 | 796.78 | 796.93 | 796.93 | 21.82 | 774.94 | 15.82 | 21.82 | 780.94 | 774.94 | | | | | 6.50E-01 | 2.31E-04 | 1 | | | BOTH | 3 | ETF-PZ | |
| ETF-22 | 16788.00 | 23641.20 | 800.12 | 800.41 | 800.41 | 22.51 | 777.61 | 16.51 | 22.51 | 783.61 | 777.61 | | | 14.83 | 785.58 | 1.20E-01 | 4.24E-05 | 1 | | | BOTH? | 3 | ETF-PZ | |
| ETF-25 | 16773.90 | 23637.90 | 796.54 | 796.69 | 796.69 | 21.59 | 776.95 | 15.59 | 21.59 | 782.95 | 776.95 | | | 13.83 | 784.86 | 2.16E-01 | 7.62E-05 | 1 | 24.30 | 774.24 | OVERBURDEN | 2 | ETF-PZ | |
| ETF-27 | 16746.50 | 23616.40 | 794.84 | 795.30 | 795.30 | 20.41 | 774.43 | 14.41 | 20.41 | 780.43 | 774.43 | | | 10.55 | 784.75 | 6.20E-02 | 2.19E-05 | 1 | 14.00 | 780.84 | SH.BEDROCK | 1 | ETF-PZ | |
| ETF-29 | 16769.40 | 23651.40 | 797.99 | 797.37 | 797.37 | 20.74 | 777.26 | 14.74 | 20.74 | 783.26 | 777.26 | | | 13.43 | 783.94 | 6.20E-02 | 2.19E-05 | 1 | | | BOTH | 3 | ETF-PZ | |
| ETF-36 | 16749.10 | 23658.60 | 796.43 | 796.67 | 796.67 | 21.16 | 775.27 | 15.16 | 21.16 | 781.27 | 775.27 | | | 12.56 | 784.11 | 4.30E-02 | 1.52E-05 | 1 | | <775.27 | OVERBURDEN | 2 | ETF-PZ | |
| ETF-39 | 16735.80 | 23654.90 | 795.61 | 795.85 | 795.85 | 22.16 | 773.43 | 16.16 | 22.16 | 779.43 | 773.43 | | | 12.05 | 783.80 | 1.21E-01 | 4.27E-05 | 1 | 27.76 | 767.86 | OVERBURDEN | 2 | ETF-PZ | |
| ETF-40 | 16743.60 | 23671.40 | 795.04 | 795.34 | 795.34 | 20.67 | 774.37 | 14.67 | 20.67 | 780.37 | 774.37 | | | 12.03 | 783.31 | 1.57E-01 | 5.54E-05 | 1 | | <774.37 | OVERBURDEN | 2 | ETF-PZ | |
| 107 | 17044.53 | 24391.85 | 811.15 | 814.73 | 814.73 | 122.34 | 688.81 | | | | | 23.79 | 790.94 | 23.15 | 791.58 | | | | | (779?) | BEDROCK | 1 | PRERAP-PZ | SCREENED FROM JUST... |
| 108 | 17279.00 | 24584.00 | 827.91 | 832.66 | 832.66 | 126.27 | 701.64 | 40.27 | 126.27 | 787.64 | 701.64 | 29.50 | 803.16 | 27.25 | 805.41 | | | | | <790.57) | BEDROCK | 1 | PRERAP-PZ | ...BELOW BEDROCK... |
| 109 | 17330.00 | 24499.00 | 819.65 | 821.55 | 821.55 | 126.13 | 693.52 | 38.00 | 126.00 | 781.65 | 693.65 | 22.70 | 798.85 | 20.78 | 800.77 | | | | | (787?) | BEDROCK | 1 | PRERAP-PZ | * ...TO DEEPER BEDROCK |
| 266 | 15968.00 | 23327.00 | 773.19 | 774.17 | 774.17 | 16.59 | 756.60 | 0.00 | 16.59 | 773.19 | 756.60 | | | * | * | | | | | <756.60 | OVERBURDEN | 5 | PRERAP-PZ | * SUBMERGED |

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## Table 3D.1. (continued)

| WELL # | ORNL GRID NORTH | LOCATION EAST | GROUND ELEV. | TOP CASING | MEAS. POINT | TOTAL DEPTH | ELEV. TD | SCREEN INTERVAL DEPTH T/SCREEN | SCREEN INTERVAL DEPTH B/SCREEN | SCREEN INTERVAL ELEV. T/SCREEN | SCREEN INTERVAL ELEV. B/SCREEN | WATER/ LEVEL DATA 8/25-30/89 DEPTH | 8/25-30/89 ELEV. | 2/21-22/90 DEPTH | 2/21-22/90 ELEV. | HYDRAULIC CONDUCTIVITY FT/DAY | CM/SEC | TEST TYPE | TOP OF BEDROCK DEPTH | ELEV. | MONITORED INTERVAL ZONE | FM | USE/ CLASS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 267 | 16118.00 | 23221.00 | 789.56 | 790.62 | 790.62 | 17.23 | 772.33 | 0.00 | 17.00 | 789.56 | 772.56 | | | 8.09 | 782.53 | | | | | <772.33 | OVERBURDEN | 5 | PRERAP-PZ | |
| 269 | 16511.00 | 23104.00 | 846.59 | 847.36 | 847.36 | 20.00 | 826.59 | 0.00 | 20.00 | 846.59 | 826.59 | | | 10.10 | 837.26 | | | | | <826.59 | OVERBURDEN | 2 | PRERAP-PZ | |
| 270 | 16602.00 | 23303.00 | 837.43 | 837.83 | 837.83 | 21.00 | 816.43 | 0.00 | 21.00 | 837.43 | 816.43 | | | DRY | <816.77 | | | | | <816.77 | OVERBURDEN | 5 | PRERAP-PZ | |
| 274 | 16210.00 | 23347.00 | 787.01 | 787.83 | 787.83 | 19.00 | 766.01 | 0.00 | 19.00 | 787.01 | 768.01 | | | 11.56 | 776.27 | | | | | <766.01 | OVERBURDEN | 5 | PRERAP-PZ | |
| 278 | 16211.00 | 23896.00 | 758.53 | 759.33 | 759.33 | 6.00 | 752.53 | 0.00 | 6.00 | 758.53 | 752.53 | 1.25 | 758.08 | 0.96 | 758.35 | | | | | <752.53 | OVERBURDEN | 5 | PRERAP-PZ | |
| 279 | 16696.00 | 24205.00 | 779.27 | 781.35 | 781.35 | 10.00 | 769.27 | 0.00 | 10.00 | 779.27 | 769.27 | | | 4.59 | 776.76 | | | | | <769.27 | OVERBURDEN | 2 | PRERAP-PZ | |
| 284 | 16750.00 | 23963.00 | 785.67 | 788.29 | 788.29 | 17.00 | 768.67 | 0.00 | 17.00 | 785.67 | 768.67 | | | 9.63 | 778.66 | | | | | <768.67 | OVERBURDEN | 2 | PRERAP-PZ | |
| 295 | 16703.00 | 23992.00 | 792.90 | 794.57 | 794.57 | 15.00 | 767.90 | 0.00 | 12.00 | 792.90 | 770.90 | | | 6.92 | 777.65 | | | | | <767.90 | OVERBURDEN | 5 | PRERAP-PZ | |
| 305 | 16660.00 | 23914.00 | 781.41 | 783.76 | 783.76 | 14.00 | 767.41 | 0.00 | 14.00 | 781.41 | 767.41 | | | 4.41 | 779.35 | | | | | <767.41 | OVERBURDEN | 5 | PRERAP-PZ | |
| 310 | 16697.00 | 23936.00 | 783.24 | 783.99 | 783.99 | 12.00 | 771.24 | 0.00 | 12.00 | 783.24 | 771.24 | | | 7.16 | 776.84 | | | | | <771.24 | OVERBURDEN | 5 | PRERAP-PZ | |
| 317 | 16768.49 | 24323.60 | 792.32 | 794.74 | 794.74 | 14.00 | 778.32 | 0.00 | 14.00 | 792.32 | 778.32 | 12.57 | 782.17 | 8.55 | 786.19 | | | | | <778.32 | OVERBURDEN | 2 | PRERAP-PZ | |
| 318 | 17225.00 | 24323.00 | 799.34 | 800.06 | 800.06 | 15.00 | 784.34 | 0.00 | 15.00 | 799.34 | 784.34 | 10.71 | 789.35 | 11.13 | 788.93 | | | | | <784.34 | OVERBURDEN | 2 | PRERAP-PZ | |
| 343 | 16763.00 | 25010.00 | 788.92 | 789.60 | 789.60 | 24.00 | 764.92 | 0.00 | 24.00 | 788.92 | 764.92 | | | DRY | <764.92 | | | | | <764.92 | OVERBURDEN | 2 | PRERAP-PZ | |
| 348 | 16361.00 | 24881.00 | 756.59 | 757.26 | 757.26 | 11.00 | 745.59 | 0.00 | 11.00 | 756.59 | 745.59 | 3.33 | 753.93 | 3.32 | 753.94 | | | | | <745.59 | OVERBURDEN | 5 | PRERAP-PZ | |
| 351 | 16028.00 | 24661.00 | 777.63 | 778.82 | 778.82 | 24.00 | 753.63 | 0.00 | 24.00 | 777.63 | 753.63 | | | 13.35 | 765.47 | | | | | <753.63 | OVERBURDEN | 5 | PRERAP-PZ | |
| 356 | 16481.00 | 24451.00 | 772.02 | 772.75 | 772.75 | 9.00 | 763.02 | 0.00 | 9.00 | 772.02 | 763.02 | 10.00 | 762.75 | 10.13 | 762.62 | | | | | <763.02 | OVERBURDEN | 5 | PRERAP-PZ | |
| 362 | 16588.00 | 23718.00 | 776.54 | 778.28 | 778.28 | 9.00 | 767.54 | 0.00 | 8.00 | 776.54 | 767.54 | | | 7.94 | 770.34 | | | | | <767.54 | OVERBURDEN | 5 | PRERAP-PZ | |
| 363 | 16420.00 | 23748.00 | 763.97 | 766.58 | 766.58 | 4.00 | 759.97 | 0.00 | 4.00 | 763.97 | 759.97 | | | 3.44 | 763.14 | | | | | <759.97 | OVERBURDEN | 5 | PRERAP-PZ | |
| 365 | 16454.00 | 23681.00 | 767.72 | 769.87 | 769.87 | 6.00 | 761.72 | 0.00 | 6.00 | 767.72 | 761.72 | | | 2.86 | 767.01 | | | | | <761.72 | OVERBURDEN | 5 | PRERAP-PZ | |
| 367 | 17723.00 | 25091.00 | 841.70 | 844.20 | 844.20 | 69.00 | 772.70 | 59.00 | 69.00 | 782.70 | 772.70 | 57.15 | 787.05 | 51.28 | 792.92 | | | | | (8107) | SH.BEDROCK | 2 | PRERAP-PZ | |
| 368 | 17348.00 | 25155.00 | 819.50 | 819.50 | 819.50 | 39.00 | 780.50 | 29.00 | 39.00 | 790.50 | 780.50 | 24.87 | 794.63 | 28.73 | 790.77 | 5.26E+00 | 1.85E-03 | | | (790.57) | SH.BEDROCK | 1 | PRERAP-PZ | |
| 369 | 17476.00 | 24806.00 | 838.24 | 841.00 | 841.00 | 48.00 | 790.24 | 38.00 | 48.00 | 800.24 | 790.24 | | | 31.00 | 810.00 | | | | | (8167) | SH.BEDROCK | 1 | PRERAP-PZ | |
| 370 | 17145.00 | 24981.00 | 806.96 | 810.70 | 810.70 | 34.00 | 772.96 | 24.00 | 34.00 | 782.96 | 772.96 | | | 20.67 | 790.03 | | | | | (7847) | SH.BEDROCK | 1 | PRERAP-PZ | |
| 371 | 16393.00 | 25090.00 | 765.40 | 768.10 | 768.10 | 30.00 | 735.40 | 20.00 | 30.00 | 745.40 | 735.40 | 21.92 | 746.18 | 21.37 | 746.73 | 1.60E-01 | 5.65E-05 | | | (746.57) | SH.BEDROCK | 4 | PRERAP-PZ | |
| 374 | 17462.00 | 25346.00 | 781.28 | 783.50 | 783.50 | 31.00 | 750.28 | 21.00 | 31.00 | 760.28 | 750.28 | | | 15.65 | 767.85 | 2.79E-01 | 9.85E-05 | | | (7807) | SH.BEDROCK | 1 | PRERAP-PZ | |
| 375 | 16935.00 | 23531.00 | 813.63 | 816.20 | 816.20 | 26.00 | 787.63 | 16.00 | 26.00 | 797.63 | 787.63 | | | 18.43 | 797.77 | | | | | (787.63) | OVERBURDEN | 2 | PRERAP-PZ | |
| 376 | 16584.00 | 23479.00 | 806.46 | 809.50 | 809.50 | 35.00 | 771.46 | 25.00 | 35.00 | 781.46 | 771.46 | | | 21.56 | 787.94 | 2.19E+00 | 7.73E-04 | | | (372.57) | BOTH? | 6 | PRERAP-PZ | |
| 377 | 16610.00 | 23297.00 | 836.82 | 839.80 | 839.80 | 56.00 | 780.82 | 46.00 | 56.00 | 790.82 | 780.82 | | | 41.48 | 798.32 | | | | | <790.82 | OVERBURDEN | 5 | PRERAP-PZ | |
| 378 | 16474.00 | 23092.00 | 842.15 | 845.10 | 845.10 | 60.00 | 782.15 | 50.00 | 60.00 | 792.15 | 782.15 | | | 47.20 | 797.90 | | | | | <782.15 | OVERBURDEN | 5 | PRERAP-PZ | |
| 379 | 16156.00 | 23206.00 | 792.13 | 792.99 | 792.99 | 37.00 | 755.13 | 27.00 | 37.00 | 765.13 | 755.13 | | | 17.88 | 775.11 | 2.99E-01 | 1.06E-04 | | | (7557) | SH.BEDROCK | 4 | PRERAP-PZ | |
| 380 | 15977.00 | 23320.00 | 772.65 | 774.80 | 774.80 | 31.00 | 741.55 | 21.00 | 31.00 | 751.55 | 741.55 | | | 7.26 | 767.54 | 1.21E+00 | 4.27E-04 | | | (7527) | SH.BEDROCK | 4 | PRERAP-PZ | |
| 381 | 16248.00 | 24266.00 | 777.59 | 780.10 | 780.10 | 35.35 | 742.24 | 25.35 | 35.35 | 752.24 | 742.24 | | | 20.86 | 759.24 | 1.70E-01 | 6.00E-05 | | | (7457) | BOTH | 6 | PRERAP-PZ | |

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## Table 3D.1. (continued)

| WELL # | ORNL GRID NORTH | LOCATION EAST | GROUND ELEV. | TOP CASING | MEAS. POINT | TOTAL DEPTH | ELEV. TD | SCREEN INTERVAL DEPTH T/SCREEN | DEPTH B/SCREEN | ELEV. T/SCREEN | ELEV. B/SCREEN | WATER LEVEL DATA 8/25-30/90 DEPTH | ELEV. | 2/21-22/90 DEPTH | ELEV. | HYDRAULIC CONDUCTIVITY FT/DAY | CM/SEC | TEST TYPE | TOP OF BEDROCK DEPTH | ELEV. | MONITORED INTERVAL ZONE | FM | USE/ CLASS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 382 | 15814.00 | 24025.00 | 763.34 | 765.70 | 765.70 | 21.00 | 742.34 | 11.00 | 21.00 | 752.34 | 742.34 | | | 17.65 | 748.05 | 1.70E-01 | 6.00E-05 | | | (7457) | BOTH | 6 | PRERAP-PZ | |
| 383 | 16165.00 | 24895.00 | 769.38 | 771.50 | 771.50 | 33.00 | 736.38 | 23.00 | 33.00 | 746.38 | 736.38 | | | 23.72 | 747.78 | 2.20E-01 | 7.77E-05 | | | (7487) | SH.BEDROCK | 4 | PRERAP-PZ | |
| 385 | 17903.00 | 24669.00 | 841.27 | 843.90 | 843.90 | 45.00 | 796.27 | 35.00 | 45.00 | 806.27 | 796.27 | | | 24.11 | 819.69 | 5.60E-02 | 1.96E-05 | | | (827.67) | SH.BEDROCK | 1 | PRERAP-PZ | |
| 386 | 16892.00 | 24828.00 | 779.19 | 782.04 | 782.04 | 12.00 | 767.19 | 0.00 | 12.00 | 779.19 | 767.19 | 5.67 | 776.37 | 4.37 | 777.67 | | | | | (775) | SH.BEDROCK | 1 | PRERAP-PZ | |
| 389 | 16796.40 | 24203.49 | 786.34 | 788.57 | 788.57 | 14.93 | 771.41 | 9.93 | 14.93 | 776.41 | 771.41 | 13.46 | 775.11 | 9.13 | 779.44 | | | | | <771.41 | OVERBURDEN | 1 | 49TR-PZ | |
| 390 | 16841.59 | 24199.67 | 787.03 | 790.21 | 790.21 | 15.09 | 771.94 | 10.09 | 15.09 | 776.94 | 771.94 | 11.19 | 779.02 | 6.00 | 784.21 | | | | | <771.94 | OVERBURDEN | 1 | 49TR-PZ | |
| 391 | 16899.81 | 24192.39 | 790.61 | 790.61 | 790.61 | 9.97 | 780.64 | 4.97 | 9.97 | 785.64 | 780.64 | 7.62 | 782.99 | 5.08 | 785.53 | | | | | <780.61 | OVERBURDEN | 1 | 49TR-PZ | |
| 392 | 16974.25 | 24317.29 | | 803.83 | 803.83 | 20.37 | 783.51 | 15.37 | 20.37 | 788.51 | 783.51 | DRY | <783.51 | DRY | <783.51 | | | | | <783.51 | OVERBURDEN | 1 | 49TR-PZ | |
| 393 | 16963.14 | 24259.03 | | 800.58 | 800.58 | 24.26 | 776.35 | 19.26 | 24.26 | 781.35 | 776.35 | 14.27 | 786.31 | 12.63 | 787.95 | | | | | <776.35 | OVERBURDEN | 1 | 49TR-PZ | |
| 394 | 17010.56 | 24420.05 | | 808.95 | 808.95 | 27.62 | 781.38 | 22.62 | 27.62 | 786.38 | 781.38 | 21.56 | 787.39 | 20.86 | 788.09 | | | | | <781.38 | OVERBURDEN | 1 | 49TR-PZ | |
| 395 | 16896.17 | 24235.26 | | 795.89 | 795.89 | 23.52 | 772.40 | 18.52 | 23.52 | 777.40 | 772.40 | 11.61 | 784.28 | 7.91 | 787.98 | | | | | <772.40 | OVERBURDEN | 1 | 49TR-PZ | |
| 396 | 16894.54 | 24245.22 | | 796.50 | 796.50 | 22.80 | 773.72 | 17.80 | 22.80 | 778.72 | 773.72 | 9.68 | 786.82 | | | | | | | <773.72 | OVERBURDEN | 1 | 49TR-PZ | |
| 397 | 16925.31 | 24227.29 | | 797.14 | 797.14 | 20.83 | 776.37 | 15.83 | 20.83 | 781.37 | 776.37 | DRY | <776.37 | 8.37 | 788.77 | | | | | <776.37 | OVERBURDEN | 1 | 49TR-PZ | |
| 398 | 16939.44 | 24427.38 | | 803.76 | 803.76 | 26.11 | 775.70 | 23.11 | 26.11 | 780.70 | 775.70 | 17.56 | 786.20 | 11.48 | 792.28 | | | | | (781?) | SH.BEDROCK? | 1 | 49TR-PZ | |
| 399 | 16881.26 | 24349.51 | | 800.12 | 800.12 | 26.67 | 771.58 | 23.67 | 26.67 | 776.58 | 771.58 | 17.39 | 782.73 | 12.43 | 787.69 | | | | | (774.57) | BOTH? | 1 | 49TR-PZ | |
| 400 | 17065.08 | 24304.61 | | 807.01 | 807.01 | 23.78 | 783.26 | 18.78 | 23.78 | 788.26 | 783.26 | 18.77 | 788.24 | 16.30 | 790.71 | | | | | (778.57) | SH.BEDROCK? | 1 | 49TR-PZ | |
| 401 | 17022.31 | 24360.21 | | 808.52 | 808.52 | 29.87 | 779.71 | 23.87 | 29.87 | 784.71 | 779.71 | 18.93 | 789.59 | 19.75 | 788.77 | | | | | <779.71 | OVERBURDEN | 1 | 49TR-PZ | |
| 402 | 16816.65 | 24277.51 | | 793.46 | 793.46 | 18.41 | 775.10 | 13.41 | 18.41 | 780.10 | 775.10 | 8.40 | 785.06 | 5.74 | 787.72 | | | | | <775.10 | OVERBURDEN | 1 | 49TR-PZ | |
| 403 | 16777.67 | 24183.08 | | 774.93 | 774.93 | 12.72 | 762.25 | 7.72 | 12.72 | 767.25 | 762.25 | 3.38 | 771.55 | 2.65 | 772.28 | | | | | (769) | SH.BEDROCK? | 1 | 49TR-PZ | |
| 403A | 16789.60 | 24181.66 | | 780.17 | 780.17 | 5.80 | 774.37 | | | 779.37 | 774.37 | DRY | <774.37 | DRY | <782.61 | | | | | <774.37 | OVERBURDEN | 1 | 49TR-PZ | |
| 404 | 16786.33 | 24159.05 | | 774.70 | 774.70 | 10.07 | 764.67 | | | 769.67 | 764.67 | 3.38 | 771.32 | 2.96 | 771.74 | | | | | (770?) | SH.BEDROCK? | 1 | 49TR-PZ | |
| 404A | 16800.43 | 24180.46 | | 780.21 | 780.21 | 5.87 | 774.40 | | | 779.40 | 774.40 | DRY | <774.40 | DRY | <774.71 | | | | | <774.40 | OVERBURDEN | 1 | 49TR-PZ | |
| 405 | 16791.79 | 24167.96 | | 774.96 | 774.96 | 13.26 | 761.76 | | | 766.76 | 761.76 | 3.54 | 771.42 | 3.10 | 771.86 | | | | | (771?) | SH.BEDROCK? | 1 | 49TR-PZ | |
| 405A | 16810.86 | 24178.24 | | 780.90 | 780.90 | 8.85 | 772.11 | | | 777.11 | 772.11 | DRY | <772.10 | 6.70 | 774.20 | | | | | <772.11 | OVERBURDEN | 1 | 49TR-PZ | |
| EXP-4 | 17017.56 | 24424.29 | | 809.56 | 809.56 | | 784.26 | | | 789.26 | 784.26 | 23.07 | 786.49 | 22.57 | 786.99 | | | | | <784.26 | OVERBURDEN | 1 | 49TR-PZ | |
| EXP-5 | 16927.81 | 24432.54 | | 802.84 | 802.84 | | 775.77 | | | 780.77 | 775.77 | 24.02 | 778.82 | 22.93 | 779.91 | | | | | (780.17) | SH.BEDROCK? | 1 | 49TR-PZ | |
| 0+54 | 16527.25 | 24474.94 | 776.56 | 778.57 | 778.57 | 8.06 | 770.50 | 4.06 | 8.06 | 772.50 | 770.50 | | | 5.88 | 772.69 | | | | | <770.50 | IN DRAIN | | FRDRN-PZ | |
| 1+33 | 16608.03 | 24469.71 | 783.82 | 785.82 | 785.82 | 12.20 | 771.62 | 10.20 | 12.20 | 773.62 | 771.62 | | | DRY | <771.62 | | | | | <771.62 | IN DRAIN | | FRDRN-PZ | |
| 1+53 | 16625.30 | 24469.22 | 785.23 | 787.23 | 787.23 | 14.10 | 771.13 | 12.10 | 14.10 | 773.13 | 771.13 | | | 13.64 | 773.59 | | | | | <771.13 | IN DRAIN | | FRDRN-PZ | |
| 1+85 | 16656.08 | 24467.64 | 787.33 | 789.33 | 789.33 | 15.71 | 771.62 | 13.71 | 15.71 | 773.62 | 771.62 | | | 15.43 | 773.90 | | | | | <771.62 | IN DRAIN | | FRDRN-PZ | |
| 2+02 | 16674.21 | 24467.89 | 788.08 | 790.08 | 790.08 | 18.70 | 771.38 | 14.70 | 16.70 | 773.38 | 771.38 | | | 15.90 | 774.18 | | | | | <771.38 | IN DRAIN | | FRDRN-PZ | |
| 2+26 | 16695.99 | 24467.03 | 789.26 | 791.26 | 791.26 | 17.29 | 771.97 | 15.27 | 17.29 | 773.99 | 771.97 | | | 16.52 | 774.74 | | | | | <771.97 | IN DRAIN | | FRDRN-PZ | |

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# Table 3D.1. (continued)

| WELL # | ORNL GRID NORTH | LOCATION EAST | GROUND ELEV. | TOP CASING | MEAS. POINT | TOTAL DEPTH | ELEV. TD | SCREEN INTERVAL DEPTH T/SCREEN | B/SCREEN | ELEV. T/SCREEN | B/SCREEN | WATER / LEVEL DATA 8/25-30/89 DEPTH | ELEV. | 2/21-22/90 DEPTH | ELEV. | HYDRAULIC CONDUCTIVITY FT/DAY | CM/SEC | TEST TYPE | TOP OF BEDROCK DEPTH | ELEV. | MONITORED INTERVAL ZONE | FM | USE/ CLASS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2+51 | 16724.09 | 24464.48 | 790.54 | 792.54 | 792.54 | 18.70 | 771.84 | 16.70 | 18.70 | 773.84 | 771.84 | | | 16.60 | 776.94 | | | | 16.54 | 775.00 | IN DRAIN | | FRDRN-PZ | |
| 3+03 | 16773.11 | 24458.03 | 793.13 | 795.13 | 795.13 | 20.34 | 772.79 | 18.34 | 20.34 | 774.79 | 772.79 | | | 18.13 | 777.00 | | | | 16.13 | 777.00 | IN DRAIN | | FRDRN-PZ | |
| 3+52 | 16818.25 | 24452.43 | 795.13 | 797.14 | 797.14 | 23.85 | 771.29 | 21.85 | 23.85 | 773.29 | 771.29 | | | 20.10 | 777.04 | | | | 24.13 | 771.00 | IN DRAIN | | FRDRN-PZ | |
| 3+76 | 16840.88 | 24449.03 | 796.41 | 798.42 | 798.42 | 23.29 | 773.12 | 21.29 | 23.29 | 775.12 | 773.12 | | | 21.50 | 776.92 | | | | 26.41 | 768.00 | IN DRAIN | | FRDRN-PZ | |
| 4+01 | 16870.56 | 24445.99 | 797.69 | 799.70 | 799.70 | 26.11 | 771.58 | 24.11 | 26.11 | 773.58 | 771.58 | | | 22.70 | 777.00 | | | | 26.19 | 769.50 | IN DRAIN | | FRDRN-PZ | |
| 4+27 | 16890.80 | 24443.19 | 799.53 | 801.53 | 801.53 | 25.43 | 774.10 | 23.43 | 25.43 | 776.10 | 774.10 | | | 24.53 | 777.00 | | | | 26.53 | 771.00 | IN DRAIN | | FRDRN-PZ | |
| 4+58 | 16922.75 | 24440.75 | 801.57 | 803.57 | 803.57 | 28.14 | 773.43 | 26.14 | 28.14 | 775.43 | 773.43 | | | 26.57 | 777.00 | | | | 19.57 | 782.00 | IN DRAIN | | FRDRN-PZ | |
| 4+77 | 16943.31 | 24437.96 | 802.02 | 805.96 | 805.96 | 29.56 | 772.46 | 27.56 | 29.56 | 774.46 | 772.46 | | | 28.90 | 776.96 | | | | 19.02 | 783.00 | IN DRAIN | | FRDRN-PZ | |
| 5+04 | 16969.46 | 24435.04 | 806.42 | 808.42 | 808.42 | 28.72 | 780.70 | 23.75 | 25.75 | 782.67 | 780.67 | | | DRY | <780.70 | | | | 21.92 | 784.50 | IN DRAIN | | FRDRN-PZ | |
| 5+27 | 16991.24 | 24431.87 | 808.65 | 810.65 | 810.65 | 27.49 | 781.16 | 25.49 | 27.49 | 783.16 | 781.16 | | | 26.88 | 783.77 | | | | 23.65 | 785.00 | IN DRAIN | | FRDRN-PZ | |
| 5+50 | 17013.87 | 24428.96 | 810.29 | 812.29 | 812.29 | 27.06 | 783.23 | 25.06 | 27.06 | 785.23 | 783.23 | | | DRY | <783.29 | | | | 24.29 | 786.00 | IN DRAIN | | FRDRN-PZ | |
| 5+77 | 17041.00 | 24424.94 | 812.09 | 814.09 | 814.09 | 27.39 | 784.70 | 25.39 | 27.39 | 786.70 | 784.70 | | | DRY | <784.70 | | | | 25.59 | 786.50 | IN DRAIN | | FRDRN-PZ | |
| 6+16 | 17065.21 | 24411.92 | 813.31 | 815.31 | 815.31 | 27.16 | 788.15 | 25.16 | 27.16 | 789.15 | 788.15 | | | DRY | <788.15 | | | | 39.31 | 774.00 | IN DRAIN | | FRDRN-PZ | |
| 7+81 | 17121.29 | 24258.15 | 800.12 | 802.12 | 802.12 | 16.47 | 783.65 | 14.47 | 16.47 | 785.65 | 783.65 | | | DRY | <783.65 | | | | 21.12 | 779.00 | IN DRAIN | | FRDRN-PZ | |
| T33 | 17033.87 | 24266.94 | | 803.90 | 803.90 | | 788.21 | | | 793.21 | 788.21 | 13.52 | 790.29 | 12.66 | 791.14 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T35 | 17020.20 | 24279.83 | | 804.23 | 804.23 | | 791.89 | | | 796.89 | 791.89 | 11.68 | 792.55 | 10.95 | 793.29 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T40 | 17060.18 | 24306.44 | | 807.03 | 807.03 | | 792.14 | | | 797.14 | 792.14 | 11.35 | 795.68 | 11.31 | 795.72 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T42 | 16918.43 | 24254.86 | | 798.37 | 798.37 | | 785.34 | | | 790.34 | 785.34 | 7.22 | 791.15 | 5.08 | 793.29 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T125 | 17042.64 | 24339.40 | | 807.89 | 807.89 | | 793.55 | | | 798.55 | 793.55 | 12.78 | 795.13 | 12.46 | 795.43 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T133 | 17016.00 | 24351.17 | | 806.78 | 806.78 | | 792.77 | | | 797.77 | 792.77 | 1.28 | 805.50 | 0.32 | 806.46 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T145 | 16824.86 | 24232.70 | | 791.31 | 791.31 | | 779.00 | | | 784.00 | 779.00 | 10.66 | 780.65 | 5.91 | 785.40 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T147 | 16823.03 | 24253.99 | | 792.59 | 792.59 | | 777.56 | | | 782.56 | 777.56 | 10.01 | 782.58 | 6.56 | 786.03 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T150 | 16824.98 | 24269.70 | | 793.27 | 793.27 | | 781.43 | | | 786.43 | 781.43 | 7.94 | 785.33 | 4.10 | 789.17 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T152 | 16826.47 | 24285.14 | | 794.33 | 794.33 | | 781.17 | | | 786.17 | 781.17 | 8.20 | 786.13 | 5.64 | 788.69 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T156 | | | | 790.42 | 790.42 | | 782.51 | | | 787.51 | 782.51 | 7.68 | 782.56 | 2.68 | 787.74 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T161 | 16895.10 | 24343.43 | | 800.39 | 800.39 | | 785.07 | | | 790.07 | 785.07 | 12.31 | 788.09 | 10.76 | 789.63 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T163 | 16812.44 | 24319.61 | | 794.81 | 794.81 | | 779.65 | | | 784.65 | 779.65 | 7.15 | 787.66 | 6.94 | 788.87 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T168 | 16970.16 | 24378.73 | | 805.34 | 805.34 | | 790.31 | | | 795.31 | 790.31 | 9.02 | 796.32 | 7.81 | 797.53 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T171 | 16885.25 | 24356.03 | | 800.26 | 800.26 | | 784.47 | | | 789.47 | 784.47 | 13.06 | 787.22 | 10.37 | 789.91 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T185 | 16929.10 | 24403.03 | | 803.41 | 803.41 | | 791.80 | | | 796.80 | 791.80 | 9.12 | 794.29 | 8.92 | 794.49 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T191 | 16940.99 | 24417.58 | | 803.94 | 803.94 | | 789.44 | | | 794.44 | 789.44 | 10.24 | 793.70 | 9.35 | 794.59 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T193 | 16857.93 | 24405.83 | | 799.56 | 799.56 | | 787.68 | | | 792.68 | 787.68 | 9.29 | 790.27 | 8.53 | 791.03 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |

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## Table 3D.1. (continued)

| WELL # | ORNL GRID NORTH | LOCATION EAST | GROUND ELEV. | TOP CASING | MEAS. POINT | TOTAL DEPTH | ELEV. TD | SCREEN INTERVAL DEPTH T/SCREEN | B/SCREEN | ELEV. T/SCREEN | B/SCREEN | WATER LEVEL DATA 8/25-30/90 DEPTH | ELEV. | 2/21-22/90 DEPTH | ELEV. | HYDRAULIC CONDUCTIVITY FT/DAY | CM/SEC | TEST TYPE | TOP OF BEDROCK DEPTH | ELEV. | MONITORED INTERVAL ZONE | FM | USE/ CLASS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T196 | 16820.45 | 24401.66 | | 796.82 | 796.82 | | 784.45 | | | 789.45 | 784.45 | 10.99 | 785.83 | 8.78 | 788.06 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T198 | 16866.55 | 24427.03 | | 799.32 | 799.32 | | 788.99 | | | 793.99 | 788.99 | | | 8.69 | 790.63 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T201 | 16914.55 | 24399.91 | | 796.36 | 796.36 | | 781.10 | | | 786.10 | 781.10 | 13.12 | 783.24 | 11.08 | 785.28 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T203 | 16848.67 | 24439.96 | | 797.80 | 797.80 | | 782.71 | | | 787.71 | 782.71 | 14.37 | 783.43 | 12.76 | 785.04 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T206 | 16805.89 | 24436.67 | | 795.18 | 795.18 | | 779.69 | | | 784.69 | 779.69 | | | 14.43 | 780.75 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T207 | 16762.32 | 24442.42 | | 792.52 | 792.52 | | 783.49 | | | 788.49 | 783.49 | | 785.96 | 6.30 | 786.27 | | | | | | TRENCH | | 49TR-PZ | IN TRENCH |
| T8 | 17714.70 | 25067.70 | 841.22 | 843.02 | 843.02 | 15.90 | 825.32 | 10.90 | 15.90 | 830.32 | 825.32 | | | 12.18 | 830.84 | | | | | | TRENCH? | | CAP-PZ | IN TARA AREA |
| T260-2 | 16614.80 | 23908.80 | 779.92 | 781.65 | 781.65 | 9.50 | 770.42 | 4.50 | 9.50 | 775.42 | 770.42 | | | 3.88 | 777.77 | | | | | | TRENCH? | | CAP-PZ | |
| T260-3 | 16592.10 | 23908.70 | 779.77 | 782.18 | 782.18 | 7.00 | 772.77 | 2.00 | 7.00 | 777.77 | 772.77 | | | 4.47 | 777.71 | | | | | | TRENCH? | | CAP-PZ | |
| T-82 | 17702.00 | 24641.00 | 830.65 | 832.50 | 832.50 | 13.19 | 817.46 | 8.19 | 13.19 | 822.46 | 817.46 | | | | | | | | | | TRENCH | | CAP1-PZ | IN TRENCH |
| T103 | 17703.00 | 24663.00 | 834.38 | 836.24 | 836.24 | 18.99 | 817.39 | 11.99 | 16.99 | 822.39 | 817.39 | | | | | | | | | | TRENCH | | CAP1-PZ | IN TRENCH |
| T120 | 17650.00 | 24637.00 | 829.21 | 831.80 | 831.80 | 14.30 | 814.91 | 9.30 | 14.30 | 819.91 | 814.91 | | | | | | | | | | TRENCH | | CAP1-PZ | IN TRENCH |
| T370 | 17587.00 | 24683.00 | 832.66 | 834.25 | 834.25 | 13.75 | 818.91 | 8.75 | 13.75 | 823.91 | 818.91 | | | | | | | | | | TRENCH | | CAP1-PZ | IN TRENCH |
| T380 | 17642.00 | 24680.00 | 832.49 | 834.52 | 834.52 | 11.48 | 821.01 | 6.48 | 11.48 | 826.01 | 821.01 | | | | | | | | | | TRENCH | | CAP1-PZ | IN TRENCH |
| T444 | 17660.00 | 24715.00 | 835.05 | 837.47 | 837.47 | 13.29 | 821.77 | 8.30 | 13.29 | 826.76 | 821.76 | | | | | | | | | | TRENCH | | CAP1-PZ | IN TRENCH |
| S-11 | 17627.70 | 24820.80 | 827.76 | 829.21 | 829.21 | 45.30 | 782.46 | 30.30 | 45.30 | 797.46 | 782.46 | | | 24.75 | 804.46 | | | | | (9237) | SH.BEDROCK? | 1 | CAP1-PZ | OUTSIDE TRENCH |
| T69 | 16870.00 | 24565.00 | 796.64 | 798.26 | 798.26 | 10.37 | 786.17 | 5.37 | 10.37 | 791.17 | 786.17 | | | DRY | <782.46 | | | | | | TRENCH | | CAP2-PZ | IN TRENCH |
| T84 | 17057.00 | 24600.00 | 811.21 | 813.01 | 813.01 | 14.11 | 797.10 | 9.11 | 14.11 | 802.10 | 797.10 | | | DRY | | | | | | | TRENCH | | CAP2-PZ | IN TRENCH |
| T121 | 17106.00 | 24629.00 | 816.22 | 818.09 | 818.09 | 14.80 | 801.42 | 9.80 | 14.80 | 806.42 | 801.42 | | | DRY | | | | | | | TRENCH | | CAP2-PZ | IN TRENCH |
| T330 | 17044.00 | 24562.00 | 809.09 | 810.60 | 810.60 | 15.00 | 794.09 | 10.00 | 15.00 | 799.09 | 794.09 | | | DRY | | | | | | | TRENCH | | CAP2-PZ | IN TRENCH |
| T363 | 16969.00 | 24567.00 | 801.93 | 803.37 | 803.37 | 12.40 | 789.53 | 7.40 | 12.40 | 794.53 | 789.53 | | | DRY | <789.53 | | | | | | TRENCH | | CAP2-PZ | IN TRENCH |
| T397 | 17049.00 | 24508.00 | 812.52 | 815.64 | 815.64 | 14.47 | 796.05 | 9.47 | 14.47 | 803.05 | 796.05 | | | | | | | | | | TRENCH | | CAP2-PZ | IN TRENCH |
| T408 | 17169.00 | 24550.00 | 819.66 | 821.50 | 821.50 | 14.76 | 804.90 | 9.76 | 14.76 | 809.90 | 804.90 | | | DRY | <804.9 | | | | | | TRENCH | | CAP2-PZ | IN TRENCH |
| T417 | 17140.90 | 24529.30 | 818.28 | 821.11 | 821.11 | 12.76 | 805.52 | 7.70 | 12.70 | 810.58 | 805.58 | | | 15.62 | 805.49 | | | | | | TRENCH | | CAP2-PZ | WATER LEVEL = TD |
| T85 | 16638.00 | 24614.00 | 782.62 | 784.16 | 784.16 | 10.50 | 772.12 | 5.50 | 10.50 | 777.12 | 772.12 | | | 6.36 | 777.80 | | | | | | TRENCH | | CAP5-PZ | IN TRENCH |
| T92-1 | 16733.00 | 24613.00 | 787.42 | 792.17 | 792.17 | 11.58 | 775.84 | 6.58 | 11.58 | 780.84 | 775.84 | | | 12.79 | 779.38 | | | | | | TRENCH | | CAP5-PZ | IN TRENCH |
| T92-2 | 16728.00 | 24615.00 | 786.79 | 790.12 | 790.12 | 11.16 | 775.64 | 6.16 | 11.16 | 780.64 | 775.64 | | | 10.33 | 779.79 | | | | | | TRENCH | | CAP5-PZ | IN TRENCH |
| T105 | 16574.00 | 24642.00 | 779.36 | 780.99 | 780.99 | 10.10 | 769.26 | 5.10 | 10.10 | 774.26 | 769.26 | | | 8.10 | 772.89 | | | | | | TRENCH | | CAP5-PZ | IN TRENCH |
| T110 | 16684.00 | 24650.00 | 784.02 | 785.82 | 785.82 | 8.79 | 775.23 | 3.79 | 8.79 | 780.23 | 775.23 | | | DRY | <775.23 | | | | | | TRENCH | | CAP5-PZ | IN TRENCH |
| T112 | 16626.00 | 24651.00 | 782.05 | 783.39 | 783.39 | 10.43 | 771.62 | 5.43 | 10.43 | 776.62 | 771.62 | | | 8.20 | 775.19 | | | | | | TRENCH | | CAP5-PZ | IN TRENCH |
| T308 | 16757.00 | 24673.00 | 784.67 | 786.97 | 786.97 | 9.74 | 774.93 | 4.74 | 9.74 | 779.93 | 774.93 | | | 10.99 | 775.98 | | | | | | TRENCH | | CAP5-PZ | IN TRENCH |
| T318 | 16638.00 | 24719.00 | 778.38 | 779.44 | 779.44 | 9.80 | 768.58 | 4.80 | 9.80 | 773.58 | 768.58 | | | 7.41 | 772.03 | | | | | | TRENCH | | CAP5-PZ | IN TRENCH |

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# Table 3D.1. (continued)

| WELL # | ORNL GRID NORTH | LOCATION EAST | GROUND ELEV. | TOP CASING | MEAS. POINT | TOTAL DEPTH | ELEV. TD | SCREEN INTERVAL DEPTH T/SCREEN | B/SCREEN | ELEV. T/SCREEN | B/SCREEN | WATER/ LEVEL DATA 8/25-30/89 DEPTH | ELEV. | 2/21-22/90 DEPTH | ELEV. | HYDRAULIC CONDUCTIVITY FT/DAY | CM/SEC | TEST TYPE | TOP OF BEDROCK DEPTH | ELEV. | MONITORED INTERVAL ZONE | FM | USE/ CLASS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T101 | 16423.00 | 25037.00 | 762.79 | 763.90 | 763.90 | 10.93 | 751.86 | 5.93 | 10.93 | 756.86 | 751.86 | | | 11.12 | 752.78 | | | | | | TRENCH | | CAP6-PZ | IN TRENCH |
| T316 | 16575.00 | 24965.00 | 768.77 | 769.37 | 769.37 | 9.33 | 760.44 | 3.33 | 8.33 | 765.44 | 760.44 | | | DRY | <760.44 | | | | | | TRENCH | | CAP6-PZ | IN TRENCH |
| T329 | 16678.00 | 24922.00 | 774.89 | 777.64 | 777.64 | 9.90 | 764.99 | 4.90 | 9.90 | 769.99 | 764.99 | | | 9.64 | 767.90 | | | | | | TRENCH | | CAP6-PZ | IN TRENCH |
| T395 | 16718.00 | 24942.00 | 779.42 | 780.76 | 780.76 | 9.32 | 770.10 | 4.32 | 9.32 | 775.10 | 770.10 | | | 8.85 | 771.91 | | | | | | TRENCH | | CAP6-PZ | IN TRENCH |
| T413 | 16598.00 | 25006.00 | 775.39 | 776.93 | 776.93 | 9.68 | 765.71 | 4.68 | 9.68 | 770.71 | 765.71 | | | DRY | <765.71 | | | | | | TRENCH | | CAP6-PZ | IN TRENCH |
| T414 | 16650.00 | 24987.00 | 778.29 | 779.62 | 779.62 | 9.68 | 768.61 | 4.68 | 9.68 | 773.61 | 768.61 | | | DRY | <768.61 | | | | | | TRENCH | | CAP6-PZ | IN TRENCH |
| T428 | 16729.00 | 24962.00 | 783.13 | 784.82 | 784.82 | 10.43 | 772.70 | 5.43 | 10.43 | 777.70 | 772.70 | | | DRY | <772.70 | | | | | | TRENCH | | CAP6-PZ | IN TRENCH |
| T44 | 15809.00 | 23965.00 | 761.41 | 763.23 | 763.23 | 14.96 | 746.45 | 9.96 | 14.96 | 751.45 | 746.45 | | | 15.16 | 748.07 | | | | | | TRENCH | | CAP8-PZ | IN TRENCH |
| T57 | 15761.00 | 24032.00 | 763.79 | 764.48 | 764.48 | 14.83 | 749.96 | 9.83 | 14.83 | 753.96 | 749.96 | | | DRY | <749.96 | | | | | | TRENCH | | CAP8-PZ | IN TRENCH |
| T60 | 15700.00 | 24053.00 | 761.12 | 763.13 | 763.13 | 11.38 | 749.74 | 6.38 | 11.38 | 754.74 | 749.74 | | | DRY | <749.74 | | | | | | TRENCH | | CAP8-PZ | IN TRENCH |
| T63 | 15873.00 | 24026.00 | 761.95 | 763.88 | 763.88 | 14.60 | 747.35 | 9.60 | 14.60 | 752.35 | 747.35 | | | 15.68 | 748.20 | | | | | | TRENCH | | CAP8-PZ | IN TRENCH |
| T162 | 15768.00 | 24082.00 | 764.20 | 765.83 | 765.83 | 11.35 | 752.85 | 6.35 | 11.35 | 757.85 | 752.85 | | | DRY | <752.85 | | | | | | TRENCH | | CAP8-PZ | IN TRENCH |
| T180 | 15862.00 | 24076.00 | 762.95 | 765.44 | 765.44 | 14.30 | 748.65 | 9.30 | 14.30 | 753.65 | 748.65 | | | DRY | <748.65 | | | | | | TRENCH | | CAP8-PZ | IN TRENCH |
| T226 | 15949.00 | 24054.00 | 763.26 | 765.14 | 765.14 | 14.57 | 748.68 | 9.57 | 14.57 | 753.68 | 748.68 | | | | | | | | | | TRENCH | | CAP8-PZ | IN TRENCH |
| T237 | 15842.00 | 24113.00 | 763.82 | 764.89 | 764.89 | 14.67 | 749.26 | 9.67 | 14.67 | 754.26 | 749.26 | | | DRY | <749.26 | | | | | | TRENCH | | CAP8-PZ | IN TRENCH |
| T241 | 15793.00 | 24134.00 | 764.72 | 766.66 | 766.66 | 11.71 | 753.01 | 6.71 | 11.71 | 758.01 | 753.01 | | | DRY | <753.01 | | | | | | TRENCH | | CAP8-PZ | IN TRENCH |
| T352 | 15950.00 | 24111.00 | 767.63 | 769.32 | 769.32 | 13.45 | 754.18 | 8.45 | 13.45 | 759.18 | 754.18 | | | DRY | <754.18 | | | | | | TRENCH | | CAP8-PZ | IN TRENCH |
| T367 | 15896.00 | 24148.00 | 765.77 | 768.71 | 768.71 | 10.50 | 755.27 | 5.50 | 10.50 | 760.27 | 755.27 | | | DRY | <755.27 | | | | | | TRENCH | | CAP8-PZ | IN TRENCH |
| T373 | 15994.00 | 24126.00 | 772.25 | 774.49 | 774.49 | 12.53 | 759.72 | 7.53 | 12.53 | 764.72 | 759.72 | | | DRY | <759.72 | | | | | | TRENCH | | CAP8-PZ | IN TRENCH |
| T374 | 15806.00 | 24177.00 | 765.17 | 766.35 | 766.35 | 12.17 | 753.00 | 7.17 | 12.17 | 758.00 | 753.00 | | | DRY | <753.00 | | | | | | TRENCH | | CAP8-PZ | IN TRENCH |
| T422 | 15876.00 | 24189.00 | 766.75 | 768.15 | 768.15 | 9.21 | 757.54 | 4.21 | 9.21 | 762.54 | 757.54 | | | DRY | <757.54 | | | | | | TRENCH | | CAP8-PZ | IN TRENCH |
| T424 | 16038.00 | 24188.00 | 778.13 | 780.12 | 780.12 | 13.85 | 764.28 | 8.85 | 13.85 | 769.28 | 764.28 | | | DRY | <764.28 | | | | | | TRENCH | | CAP8-PZ | IN TRENCH |
| T453 | 15929.00 | 24220.00 | 771.31 | 773.60 | 773.60 | 8.73 | 762.58 | 3.73 | 8.73 | 767.58 | 762.58 | | | DRY | <762.58 | | | | | | TRENCH | | CAP8-PZ | IN TRENCH |
| SCA1 | 17922.00 | 24529.10 | 839.00 | | | 16.60 | 822.40 | | | | | | | | | | | | 16.60 | 822.40 | N/A | | RFI-SB | SOIL BORING |
| SCA2 | 17721.70 | 24793.70 | 838.70 | | | 15.40 | 823.30 | | | | | | | | | | | | 15.40 | 823.30 | N/A | | RFI-SB | SOIL BORING |
| SCA3 | 17574.10 | 24824.00 | 839.40 | | | 24.60 | 814.80 | | | | | | | | | | | | 24.60 | 814.80 | N/A | | RFI-SB | SOIL BORING |
| SCA4 | 17395.60 | 24835.70 | 834.10 | | | 36.40 | 797.70 | | | | | | | | | | | | 36.40 | 797.70 | N/A | | RFI-SB | SOIL BORING |
| SCA5 | 17021.10 | 24870.80 | 789.90 | | | 8.10 | 781.80 | | | | | | | | | | | | 8.10 | 781.80 | N/A | | RFI-SB | SOIL BORING |
| SCA6 | 16670.70 | 24789.10 | 770.60 | | | 11.80 | 758.80 | | | | | | | | | | | | 11.80 | 758.80 | N/A | | RFI-SB | SOIL BORING |
| SCA8 | 16568.40 | 24908.60 | 765.10 | | | 8.80 | 756.30 | | | | | | | | | | | | 8.80 | 756.30 | N/A | | RFI-SB | SOIL BORING |
| SCA9 | 16444.00 | 24965.30 | 758.50 | | | 9.90 | 748.60 | | | | | | | | | | | | 9.90 | 748.60 | N/A | | RFI-SB | SOIL BORING |
| SCA10 | 16460.00 | 24840.50 | 763.40 | | | 9.10 | 754.30 | | | | | | | | | | | | 9.10 | 754.30 | N/A | | RFI-SB | SOIL BORING |

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## Table 3D.1. (continued)

| WELL # | ORNL GRID NORTH | LOCATION EAST | GROUND ELEV. | TOP CASING | MEAS. POINT | TOTAL DEPTH | ELEV. TD | SCREEN INTERVAL DEPTH T/SCREEN | B/SCREEN | SCREEN INTERVAL ELEV. T/SCREEN | B/SCREEN | WATER LEVEL DATA 8/25-30/89 DEPTH | ELEV. | 2/21-22/90 DEPTH | ELEV. | HYDRAULIC CONDUCTIVITY FT/DAY | CM/SEC | TEST TYPE | TOP OF BEDROCK DEPTH | ELEV. | MONITORED INTERVAL ZONE | FM | USE/ CLASS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SCA11 | 16510.50 | 24581.30 | 774.40 | | | 16.80 | 757.60 | | | | | | | | | | | | 16.80 | 757.60 | N/A | | RFI-SS | SOIL BORING |
| SCA12 | 16634.10 | 24590.70 | 781.50 | | | 15.50 | 766.00 | | | | | | | | | | | | 15.50 | 766.00 | N/A | | RFI-SS | SOIL BORING |
| SCA13 | 16795.00 | 24570.00 | 791.00 | | | 17.00 | 774.00 | | | | | | | | | | | | 17.00 | 774.00 | N/A | | RFI-SS | SOIL BORING |
| SCA14 | 16781.10 | 24376.30 | 793.30 | | | 26.00 | 767.30 | | | | | | | | | | | | 26.00 | 767.30 | N/A | | RFI-SS | SOIL BORING |
| SCA15 | 16752.00 | 24230.60 | 788.10 | | | 23.40 | 764.70 | | | | | | | | | | | | 23.40 | 764.70 | N/A | | RFI-SS | SOIL BORING |
| SCA16 | 16658.10 | 24199.50 | 789.10 | | | 15.40 | 773.70 | | | | | | | | | | | | 15.40 | 773.70 | N/A | | RFI-SS | SOIL BORING |
| SCA17 | 17024.40 | 24248.90 | 801.50 | | | 24.10 | 777.40 | | | | | | | | | | | | 24.10 | 777.40 | N/A | | RFI-SS | SOIL BORING |
| SCA18 | 17247.00 | 24368.90 | 807.30 | | | 19.80 | 787.50 | | | | | | | | | | | | 19.80 | 787.50 | N/A | | RFI-SS | SOIL BORING |
| SCA19 | 17398.40 | 24514.60 | 819.20 | | | 24.30 | 794.90 | | | | | | | | | | | | 24.30 | 794.90 | N/A | | RFI-SS | SOIL BORING |
| SCB2 | 17643.60 | 25103.20 | 838.70 | | | 15.40 | 823.30 | | | | | | | | | | | | 15.40 | 823.30 | N/A | | RFI-SS | SOIL BORING |
| SCB3 | 17649.10 | 25000.80 | 836.20 | | | 33.70 | 802.50 | | | | | | | | | | | | 33.70 | 802.50 | N/A | | RFI-SS | SOIL BORING |
| SCC1 | 17482.70 | 25252.90 | 804.50 | | | 16.60 | 787.90 | | | | | | | | | | | | 16.60 | 787.90 | N/A | | RFI-SS | SOIL BORING |
| SCC2 | 17356.30 | 25233.60 | 816.30 | | | 25.80 | 790.50 | | | | | | | | | | | | 25.80 | 790.50 | N/A | | RFI-SS | SOIL BORING |
| SCC3 | 17277.60 | 25168.60 | 814.60 | | | 23.60 | 791.00 | | | | | | | | | | | | 23.60 | 791.00 | N/A | | RFI-SS | SOIL BORING |
| SCC4 | 17201.60 | 25086.10 | 814.70 | | | 32.00 | 782.70 | | | | | | | | | | | | 32.00 | 782.70 | N/A | | RFI-SS | SOIL BORING |
| SCC5 | 17031.70 | 25156.30 | 798.40 | | | 40.00 | 758.40 | | | | | | | | | | | | 40.00 | 758.40 | N/A | | RFI-SS | SOIL BORING |
| SCC6 | 16894.70 | 25135.20 | 793.00 | | | 28.00 | 765.00 | | | | | | | | | | | | 28.00 | 765.00 | N/A | | RFI-SS | SOIL BORING |
| SCC7 | 16701.70 | 25067.20 | 784.10 | | | 33.40 | 750.70 | | | | | | | | | | | | 33.40 | 750.70 | N/A | | RFI-SS | SOIL BORING |
| SCC8 | 16489.80 | 25132.90 | 766.40 | | | 22.70 | 743.70 | | | | | | | | | | | | 22.70 | 743.70 | N/A | | RFI-SS | SOIL BORING |
| SCC9 | 16831.60 | 24872.90 | 781.40 | | | 12.20 | 769.20 | | | | | | | | | | | | 12.20 | 769.20 | N/A | | RFI-SS | SOIL BORING |
| SCC10 | 17343.30 | 24996.50 | 823.50 | | | 21.80 | 801.70 | | | | | | | | | | | | 21.80 | 801.70 | N/A | | RFI-SS | SOIL BORING |
| SCC11 | 17440.10 | 25147.10 | 814.90 | | | 21 | 793.9 | | | | | | | | | | | | 21.00 | 793.90 | N/A | | RFI-SS | SOIL BORING |
| SCD1 | 16192.60 | 24294.30 | 784.10 | | | 37.3 | 746.8 | | | | | | | | | | | | 37.30 | 746.80 | N/A | | RFI-SS | SOIL BORING |
| SCD2 | 15985.00 | 24522.70 | 776.30 | | | 36.4 | 739.9 | | | | | | | | | | | | 36.40 | 739.90 | N/A | | RFI-SS | SOIL BORING |
| SCD3 | 15897.00 | 24475.20 | 771.70 | | | 38.6 | 733.1 | | | | | | | | | | | | 38.60 | 733.10 | N/A | | RFI-SS | SOIL BORING |
| SCD4 | 15776.50 | 24227.30 | 765.40 | | | 27.9 | 737.5 | | | | | | | | | | | | 27.90 | 737.50 | N/A | | RFI-SS | SOIL BORING |
| SCD5 | 15651.20 | 24076.50 | 756.70 | | | 25 | 731.7 | | | | | | | | | | | | 25.00 | 731.70 | N/A | | RFI-SS | SOIL BORING |
| SCD6 | 15722.80 | 23944.30 | 756.40 | | | 23.5 | 732.9 | | | | | | | | | | | | 23.50 | 732.90 | N/A | | RFI-SS | SOIL BORING |
| SCD7 | 15934.70 | 23901.70 | 753.50 | | | 12.9 | 740.6 | | | | | | | | | | | | 12.90 | 740.60 | N/A | | RFI-SS | SOIL BORING |
| SCD8 | 16002.40 | 23975.90 | 759.40 | | | 13 | 746.4 | | | | | | | | | | | | 13.00 | 746.40 | N/A | | RFI-SS | SOIL BORING |
| SCD9 | 16095.60 | 24083.20 | 768.80 | | | 22.4 | 746.4 | | | | | | | | | | | | 22.40 | 746.40 | N/A | | RFI-SS | SOIL BORING |
| SCE1 | 17096.30 | 23929.30 | 822.20 | | | 33.3 | 788.9 | | | | | | | | | | | | 33.30 | 788.90 | N/A | | RFI-SS | SOIL BORING |

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## Table 3D.1. (continued)

| WELL # | ORNL GRID LOCATION NORTH | EAST | GROUND ELEV. | TOP CASING | MEAS. POINT | TOTAL DEPTH | ELEV. TD | SCREEN INTERVAL DEPTH T/SCREEN | B/SCREEN | ELEV. T/SCREEN | B/SCREEN | WATER LEVEL DATA 8/25-30/88 DEPTH | ELEV. | 2/21-22/90 DEPTH | ELEV. | HYDRAULIC CONDUCTIVITY FT/DAY | CM/SEC | TEST TYPE | TOP OF BEDROCK DEPTH | ELEV. | MONITORED INTERVAL ZONE | FM | USE/ CLASS | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SCE2 | 16994.60 | 24014.50 | 803.80 | | | 30 | 773.8 | | | | | | | | | | | | 30.00 | 773.80 | N/A | | RFI-88 | SOIL BORING |
| SCE3 | 16825.70 | 24023.60 | 786.00 | | | 20.5 | 765.5 | | | | | | | | | | | | 20.50 | 765.50 | N/A | | RFI-88 | SOIL BORING |
| SCE4 | 16548.70 | 24051.10 | 771.90 | | | 13 | 758.9 | | | | | | | | | | | | 13.00 | 758.90 | N/A | | RFI-88 | SOIL BORING |
| SCE5 | 16457.50 | 24029.60 | 767.70 | | | 8.6 | 759.1 | | | | | | | | | | | | 8.60 | 759.10 | N/A | | RFI-88 | SOIL BORING |
| SCE6 | 16345.60 | 24022.80 | 760.30 | | | 5.4 | 754.9 | | | | | | | | | | | | 5.40 | 754.90 | N/A | | RFI-88 | SOIL BORING |
| SCE7 | 16347.50 | 23879.60 | 765.10 | | | 11.2 | 753.9 | | | | | | | | | | | | 11.20 | 753.90 | N/A | | RFI-88 | SOIL BORING |
| SCE8 | 16484.30 | 23867.20 | 773.50 | | | 11.9 | 761.6 | | | | | | | | | | | | 11.90 | 761.60 | N/A | | RFI-88 | SOIL BORING |
| SCE9 | 16590.60 | 23863.10 | 776.10 | | | 13.5 | 762.6 | | | | | | | | | | | | 13.50 | 762.60 | N/A | | RFI-88 | SOIL BORING |
| SCE10 | 16783.90 | 23837.00 | 784.30 | | | 16.9 | 767.4 | | | | | | | | | | | | 16.90 | 767.40 | N/A | | RFI-88 | SOIL BORING |
| SCE11 | 16946.50 | 23770.50 | 799.40 | | | 22.4 | 777 | | | | | | | | | | | | 22.40 | 777.00 | N/A | | RFI-88 | SOIL BORING |
| SDMS1 | 16360.40 | 23275.70 | 806.80 | | | 51.2 | 755.6 | | | | | | | | | | | | 51.20 | 755.60 | N/A | | RFI-88 | SOIL BORING |

DESCRIPTOR "TYPE" CODES (Describe aquifer test type and analytical solution)

1 SLUG TEST DATA, BOUWER & RICE SOLUTION
2 SLUG TEST DATA, HVORSLEV SOLUTION
3 SLOW RECOVERY DATA, MODIFIED HVORSLEV SOLUTION

"FM" CODES (Describes hydrogeologic unit monitored and/or tested)

1 MARYVILLE BEDROCK
2 MARYVILLE OVERBURDEN
3 INTERVAL STRADDLES BOTH MARYVILLE BEDROCK AND OVERBURDEN
4 NOLICHUCKY BEDROCK
5 NOLICHUCKY OVERBURDEN
6 INTERVAL STRADDLES BOTH NOLICHUCKY BEDROCK AND OVERBURDEN
7 ROGERSVILLE BEDROCK

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Table 3D.2. WAG 6 water table elevation fluctuation data

| WELL | ORNL GRID LOCATION NORTHING | EASTING | USE/CLASS | MAXIMUM FLUCTUATION (FT) | NOTE | DATA SOURCE |
|---|---|---|---|---|---|---|
| 403A | 16789.60 | 24181.66 | 49TR-PZ | 0.00 | | 1 |
| 392 | 16974.25 | 24317.28 | 49TR-PZ | 0.00 | | 1 |
| 1234 | 16956.93 | 25249.05 | RFI-MW | 0.16 | | 8 |
| 1234a | 16969.58 | 25244.09 | RFI-MW | 0.18 | | 8 |
| 1245 | 16900.21 | 25424.11 | RFI-MW | 0.30 | | 8 |
| 1244 | 17155.45 | 25495.01 | RFI-MW | 0.49 | | 8 |
| 1237 | 17089.07 | 23868.74 | RFI-MW | 0.50 | | 8 |
| 647 | 17145.66 | 24749.00 | RAP-PZ | 0.82 | | 2 |
| 1229 | 16453.32 | 24072.69 | RFI-MW | 1.30 | | 8 |
| 318 | 17225.00 | 24323.00 | PRERAP-PZ | 1.31 | | 2 |
| S-11 | 17627.70 | 24620.80 | CAP1-PZ | 1.38 | | 2 |
| 838 | 16308.70 | 24934.80 | RCRA-MW | 1.39 | | 7 |
| 839 | 16308.80 | 24923.60 | RCRA-MW | 1.40 | | 7 |
| 745 | 16067.80 | 23808.30 | RCRA-MW | 1.58 | | 7 |
| 833 | 16056.90 | 23842.40 | RCRA-MW | 1.69 | | 7 |
| 840 | 16928.60 | 25251.70 | RCRA-MW | 1.77 | | 7 |
| 739 | 15628.89 | 23604.03 | RAP-PZ | 2.30 | | 3 |
| 853 | 16695.10 | 24047.50 | RCRA-MW | 2.41 | | 7,8 |
| 841 | 17206.30 | 25294.80 | RCRA-MW | 2.49 | | 7 |
| 362 | 16588.00 | 23718.00 | PRERAP-PZ | 2.49 | | 4 |
| 645 | 17173.65 | 25274.60 | RAP-PZ | 2.60 | | 3 |
| EXP5 | 16927.81 | 24432.54 | 49TR-PZ | 2.66 | | 1 |
| 851 | 16485.00 | 24058.20 | RCRA-MW | 2.75 | | 7,8 |
| 368 | 17348.00 | 25155.00 | PRERAP-PZ | 2.77 | | 6 |
| 741 | 15596.74 | 23352.05 | RAP-PZ | 2.80 | | 3 |
| 643 | 16344.38 | 24204.78 | RAP-PZ | 2.93 | | 5 |
| 652 | 16159.68 | 24900.00 | RAP-PZ | 3.00 | | 3 |
| ETF-13 | 16872.00 | 23596.30 | ETF-PZ | 3.08 | | 4 |
| 850 | 16595.40 | 24793.50 | RCRA-MW | 3.13 | | 7,8 |
| 1233 | 17005.25 | 24211.90 | RFI-MW | 3.18 | | 8 |
| EXP4 | 17017.56 | 24424.29 | 49TR-PZ | 3.22 | | 1 |
| 852 | 16346.90 | 23911.60 | RCRA-MW | 3.22 | | 7,8 |
| ETF-14 | 16849.20 | 23618.50 | ETF-PZ | 3.25 | | 4 |
| 363 | 16420.00 | 23748.00 | PRERAP-PZ | 3.30 | | 6 |
| 1243 | 17085.60 | 25239.04 | RFI-MW | 3.37 | | 8 |
| 1242 | 18347.99 | 25104.36 | RFI-MW | 3.42 | | 8 |
| 383 | 16165.00 | 24895.00 | PRERAP-PZ | 3.48 | | 4 |
| 365 | 16454.00 | 23681.00 | PRERAP-PZ | 3.74 | | 4 |
| 836 | 15748.20 | 24138.80 | RCRA-MW | 3.76 | | 7 |
| 1236 | 16195.25 | 23195.49 | RFI-MW | 3.79 | | 8 |
| 1225 | 17754.77 | 24603.65 | RFI-MW | 3.93 | | 8 |
| 844 | 17602.50 | 25228.60 | RCRA-MW | 3.99 | | 7 |
| ETF-15 | 16841.40 | 23603.50 | ETF-PZ | 4.04 | | 4 |
| 370 | 17145.00 | 24981.00 | PRERAP-PZ | 4.07 | | 4 |

Table 3D.2. (continued)

| WELL | ORNL GRID LOCATION NORTHING | EASTING | USE/CLASS | MAXIMUM FLUCTUATION (FT) | NOTE | DATA SOURCE |
|---|---|---|---|---|---|---|
| 1238 | 17079.00 | 23862.43 | RFI-MW | 4.20 | | 8 |
| 1241 | 17913.59 | 25097.59 | RFI-MW | 4.20 | | 8 |
| 654 | 16618.16 | 24054.76 | RAP-PZ | 4.23 | | 5 |
| 845 | 17108.20 | 24988.30 | RCRA-MW | 4.42 | | 7,8 |
| 386 | 16892.00 | 24828.00 | PRERAP-PZ | 4.46 | | 4 |
| 376 | 16584.00 | 23497.00 | PRERAP-PZ | 4.51 | | 6 |
| 835 | 15767.70 | 23951.80 | RCRA-MW | 4.56 | | 7 |
| 849 | 16781.80 | 24215.20 | RCRA-MW | 4.65 | | 7,8 |
| 375 | 16935.00 | 23531.00 | PRERAP-PZ | 4.65 | | 6 |
| 394 | 17010.56 | 24420.05 | 49TR-PZ | 4.66 | | 1 |
| 1228 | 16334.67 | 23878.80 | RFI-MW | 4.72 | | 8 |
| 653 | 15792.51 | 24070.40 | RAP-PZ | 4.90 | | 3 |
| 740 | 15778.95 | 23372.39 | RAP-PZ | 4.90 | | 3 |
| 404A | 16800.43 | 24180.46 | 49TR-PZ | 5.35 | | 1 |
| 107 | 17044.53 | 24391.85 | PRERAP-PZ | 5.46 | | 6 |
| 345 | 16361.00 | 24881.00 | PRERAP-PZ | 5.63 | | 6 |
| 636 | 17668.04 | 24326.17 | RAP-PZ | 5.64 | | 4 |
| 371 | 16393.00 | 25090.00 | PRERAP-PZ | 5.74 | | 4 |
| 1240 | 18066.23 | 25183.89 | RFI-MW | 5.81 | | 8 |
| 646 | 17550.78 | 25167.05 | RAP-PZ | 5.90 | | 3 |
| 644 | 16748.86 | 24848.36 | RAP-PZ | 5.90 | | 3 |
| 842 | 17216.10 | 25298.40 | RCRA-MW | 5.97 | | 7 |
| 108 | 17279.00 | 24584.00 | PRERAP-PZ | 6.04 | | 1 |
| 843 | 17597.10 | 25221.40 | RCRA-MW | 6.15 | | 7 |
| 651 | 16870.85 | 25190.67 | RAP-PZ | 6.17 | | 4 |
| 382 | 15814.00 | 24025.00 | PRERAP-PZ | 6.20 | | 6 |
| 831 | 17387.40 | 24133.50 | RCRA-MW | 6.22 | | 7 |
| 847 | 17769.90 | 24790.50 | RCRA-MW | 6.24 | | 7 |
| 393 | 16953.14 | 24259.03 | 49TR-PZ | 6.30 | | 1 |
| 638 | 17495.05 | 24119.35 | RAP-PZ | 6.66 | | 4 |
| 832 | 17385.60 | 24096.70 | RCRA-MW | 6.77 | | 7 |
| 642 | 16580.96 | 24035.55 | RAP-PZ | 6.90 | | 3 |
| 848 | 16942.40 | 24656.30 | RCRA-MW | 6.90 | | 7 |
| 356 | 16481.00 | 24451.00 | PRERAP-PZ | 6.99 | | 6 |
| 639 | 17395.38 | 24138.11 | RAP-PZ | 7.00 | | 3 |
| 655 | 17469.72 | 24815.30 | RAP-PZ | 7.40 | | 3 |
| 377 | 16610.00 | 23297.00 | PRERAP-PZ | 7.41 | | 6 |
| 279 | 16696.00 | 24205.00 | PRERAP-PZ | 7.48 | | 4 |
| 276 | 16211.00 | 23895.00 | PRERAP-PZ | 7.58 | | 4 |
| 284 | 16750.00 | 23983.00 | PRERAP-PZ | 7.60 | | 6 |
| 374 | 17462.00 | 25346.00 | PRERAP-PZ | 7.91 | | 6 |
| 269 | 16511.00 | 23104.00 | PRERAP-PZ | 8.07 | | 6 |
| 295 | 16703.00 | 23992.00 | PRERAP-PZ | 8.16 | | 6 |
| 405A | 16810.86 | 24178.24 | 49TR-PZ | 8.17 | | 1 |
| 395 | 16896.17 | 24235.26 | 49TR-PZ | 8.33 | | 1 |

Table 3D.2. (continued)

| WELL | ORNL GRID LOCATION NORTHING | EASTING | USE/CLASS | MAXIMUM FLUCTUATION (FT) | NOTE | DATA SOURCE |
|---|---|---|---|---|---|---|
| 637 | 17715.14 | 24135.97 | RAP-PZ | 8.40 | | 3 |
| 385 | 17903.00 | 24669.00 | PRERAP-PZ | 8.63 | | 6 |
| 391 | 16899.81 | 24192.39 | 49TR-PZ | 8.89 | | 1 |
| 274 | 16210.00 | 23347.00 | PRERAP-PZ | 9.27 | * | 6 |
| 855 | 16755.30 | 23427.70 | RCRA-MW | 9.83 | | 7 |
| 856 | 16764.40 | 23432.90 | RCRA-MW | 9.95 | | 7 |
| 396 | 16894.54 | 24245.22 | 49TR-PZ | 10.33 | | 1 |
| 367 | 17723.00 | 25091.00 | PRERAP-PZ | 10.56 | | 4 |
| 379 | 16156.00 | 23206.00 | PRERAP-PZ | 10.86 | | 6 |
| 846 | 18030.70 | 24803.50 | RCRA-MW | 10.92 | | 7 |
| 381 | 16248.00 | 24266.00 | PRERAP-PZ | 11.37 | | 6 |
| 640 | 17614.70 | 24719.55 | RAP-PZ | 11.40 | | 3 |
| 380 | 15977.00 | 23320.00 | PRERAP-PZ | 11.75 | | 6 |
| 854 | 16711.90 | 23851.90 | RCRA-MW | 12.34 | | 7,8 |
| 351 | 16028.00 | 24661.00 | PRERAP-PZ | 12.63 | * | 6 |
| 369 | 17476.00 | 24805.00 | PRERAP-PZ | 12.83 | | 4 |
| 390 | 16841.59 | 24199.67 | 49TR-PZ | 13.19 | | 1 |
| 860 | 15996.60 | 23252.90 | RCRA-MW | 13.20 | | 7 |
| 317 | 16768.49 | 24323.60 | PRERAP-PZ | 13.32 | | 1 |
| 858 | 16542.10 | 23115.80 | RCRA-MW | 13.47 | | 7 |
| 378 | 16474.00 | 23092.00 | PRERAP-PZ | 13.54 | | 6 |
| 266 | 15968.00 | 23327.00 | PRERAP-PZ | 13.76 | | 6 |
| 389 | 16798.40 | 24203.49 | 49TR-PZ | 13.94 | | 1 |
| 267 | 16118.00 | 23221.00 | PRERAP-PZ | 14.02 | * | 6 |
| 656 | 17923.92 | 24692.96 | RAP-PZ | 15.50 | | 3 |
| 857 | 16538.00 | 23106.30 | RCRA-MW | 15.63 | | 7 |
| 397 | 16925.31 | 24227.29 | 49TR-PZ | 17.13 | | 1 |
| 343 | 16763.00 | 25010.00 | PRERAP-PZ | 19.91 | | 4 |
| 641 | 17383.49 | 23985.24 | RAP-PZ | 23.10 | * | 4 |
| 109 | 17330.00 | 24499.00 | PRERAP-PZ | 26.41 | * | 4 |
| 649 | 17375.49 | 25075.50 | RAP-PZ | 27.82 | * | 4 |

MEAN MAXIMUM FLUCTUATION (FT): 6.67

* = These fluctuations reflect maximum observed fluctuations, and are not consistent over various periods of observations.

Table 3D.2. (continued)

DATA SOURCE REFERENCES

(1) Raw data acquired from Della Marshal (ORNL) 3/90, covering period 01-20-88 through 02-20-90.

(2) Raw data (log book copy) acquired from Della Marshal (ORNL) 3/90, covering period 01-18-90 through 02-20-90.

(3) Piezometer data from Brian Smith (BNI, 1989).

(4) Davis et al., 1987.

(5) Webster, D.A., 1976.

(6) Moore, J.

(7) ORNL R L RAP Database, 1988-1990

(8) Data gathered as part of the WAG 6 RFI

# APPENDIX 3E

## Bird, Mammal, Reptile, and Amphibian Species Found on the Oak Ridge Reservation

Table 3E.1. Bird species found on the Oak Ridge Reservation

| Common name | Scientific name |
|---|---|
| Common loon | *Gavia immer* |
| Pied-billed grebe | *Podilymbus podiceps* |
| Great blue heron | *Ardea herodias* |
| Cattle egret | *Bubulcus ibis* |
| Green heron | *Butorides virescens* |
| Common egret | *Casmerodius albus* |
| Wood duck | *Aix sponsa* |
| Pintail | *Anas acuta* |
| Green-wing teal | *Anas carolinensis* |
| Blue-wing teal | *Anas discors* |
| Mallard | *Anas platyrhynchos* |
| Black duck | *Anas rubripes* |
| Gadwall | *Anas strepera* |
| Lesser scaup | *Aythya affinis* |
| Redhead | *Aythya americana* |
| Ring-necked duck | *Aythya collaris* |
| Canvasback | *Aythya valisineria* |
| Canada goose | *Branta canadensis* |
| Bufflehead | *Bucephala albeola* |
| Common goldeneye | *Bucephala clangula* |
| Hooded merganser | *Lophodytes cucullatus* |
| American widgeon | *Mareca americana* |
| Common merganser | *Mergus merganser* |
| Red-breasted merganser | *Mergus serrator* |
| Ruddy duck | *Oxyura jamaicensis* |
| Turkey vulture | *Cathartes aura* |
| Black vulture | *Coragyps atratus* |
| Cooper's hawk | *Accipiter cooperii* |
| Sharp-shinned hawk | *Accipiter striatus* |
| Red-tailed hawk | *Buteo jamaicensis* |
| Red-shouldered hawk | *Buteo lineatus* |
| Broad-winged hawk | *Buteo platypterus* |
| Marsh hawk | *Circus cyaneus* |
| Sparrow hawk | *Falco sparverius* |
| Bald eagle | *Haliaeetus leucocephalus* |
| Osprey | *Pandion haliaetus* |
| Ruffed grouse | *Bonasa umbellus* |
| Bobwhite | *Colinus virginianus* |
| Turkey | *Meleagris gallopavo* |
| American coot | *Fulica americana* |
| Common gallinule | *Gallinula chloropus* |
| Spotted sandpiper | *Actitus macularia* |

**Table 3E.1. (continued)**

| Common name | Scientific name |
|---|---|
| Common snipe | *Capella gallinago* |
| Killdeer | *Charadrius vociferus* |
| Black tern | *Chlidonias niger* |
| Herring gull | *Larus argentatus* |
| Ring-billed gull | *Larus delawarensis* |
| American woodcock | *Philohela minor* |
| Rock dove | *Columba livia* |
| Mourning dove | *Zenaidura macroura* |
| Yellow-billed cuckoo | *Coccyzus americanus* |
| Chuck-will's-widow | *Caprimulgus carolinensis* |
| Whippoorwill | *Caprimulgus vociferus* |
| Common nighthawk | *Chordeilis minor* |
| Great-horned owl | *Bubo virginianus* |
| Screech owl | *Otus asio* |
| Barred owl | *Strix varia* |
| Barn owl | *Tyto alba* |
| Ruby-throated hummingbird | *Archilochus colubris* |
| Red-bellied woodpecker | *Centurus carolinus* |
| Yellow-shafted flicker | *Colantes auratus* |
| Downy woodpecker | *Dendrocopus pubescens* |
| Hairy woodpecker | *Dendrocopus villosus* |
| Pileated woodpecker | *Dryocopus pileatus* |
| Red-headed woodpecker | *Melanerpes erythrocephalus* |
| Yellow-bellied sapsucker | *Sphyrapicus varius* |
| Belted kingfisher | *Megaceryle alcyon* |
| Red-winged blackbird | *Agelaius phoeniceus* |
| Bachman's sparrow | *Aimophila aestivalis* |
| Grasshopper sparrow | *Ammodramus savannarum* |
| Cedar waxwing | *Bombycilla cedrorum* |
| Purple finch | *Carpodacus purpureus* |
| Brown creeper | *Certhia familiaris* |
| Eastern woodpewee | *Contopus virens* |
| Common crow | *Corvus brachyrhynchos* |
| Blue jay | *Cyanocitta cristata* |
| Bay-breasted warbler | *Dendroica castanea* |
| Cerulean warbler | *Dendroica cerulea* |
| Myrtle warbler | *Dendroica coronata* |
| Prairie warbler | *Dendroica discolor* |
| Yellow-throated warbler | *Dendroica dominica* |
| Magnolia warbler | *Dendroica magnolia* |

Table 3E.1. (continued)

| Common name | Scientific name |
|---|---|
| Chestnut-sided warbler | *Dendroica pennsylvanica* |
| Yellow warbler | *Dendroica petechia* |
| Pine warbler | *Dendroica pinus* |
| Catbird | *Dumatella carolinensis* |
| Least flycatcher | *Empidonax minimus* |
| Acadian flycatcher | *Empidonax virescens* |
| Horned lark | *Eremophila alpestris* |
| Yellowthroat | *Geothlypis trichas* |
| Blue grosbeak | *Guiraca caerulea* |
| Worm-eating warbler | *Helmitheros vermivorus* |
| Evening grosbeak | *Hesperiphona vespertina* |
| Barn swallow | *Hirundo rustica* |
| Hermit thrush | *Hylocichla guttata* |
| Wood thrush | *Hylocichla mustelina* |
| Yellow-breasted chat | *Icteria virens* |
| Orchard oriole | *Icterus spurius* |
| Slate-colored junco | *Junco hyemalis* |
| Logger-head shrike | *Lanius ludovicianus* |
| Swainson's warbler | *Limnothlypis swainsonii* |
| Red crossbill | *Loxia curvirostra* |
| Song sparrow | *Melospiza melodia* |
| Mockingbird | *Mimus polyglottos* |
| Black-and-white warbler | *Mniotilta varia* |
| Brown-headed cowbird | *Molothrus ater* |
| Great-crested flycatcher | *Myiarchus crinitus* |
| Whistling swan | *Olor columbianus* |
| Kentucky warbler | *Oporornis formosus* |
| Parula warbler | *Parula americana* |
| Tufted titmouse | *Parus bicolor* |
| Carolina chickadee | *Parus carolinensis* |
| English sparrow | *Passer domesticus* |
| Henslow's sparrow | *Passerherbulus henslowii* |
| Indigo bunting | *Passerina cyanea* |
| Rose-breasted grosbeak | *Pheucticus ludovicianus* |
| Rufous-sided towhee | *Pipilo erythrophthalmus* |
| Scarlet tanager | *Piranga olivacea* |
| Summer tanager | *Piranga rubra* |
| Blue-gray gnatcatcher | *Polioptila caerulea* |
| Purple martin | *Progne subis* |
| Prothonotary warbler | *Protonotaria citrea* |

**Table 3E.1. (continued)**

| Common name | Scientific name |
|---|---|
| Common grackle | *Quiscalus quiscula* |
| Ruby-crowned kinglet | *Regulus calendula* |
| Golden-crowned kinglet | *Regulus satrapa* |
| Cardinal | *Richmondena cardinalis* |
| Bank swallow | *Riparia riparia* |
| Eastern phoebe | *Sayornis phoebe* |
| Louisiana water thrush | *Seiurus motacilla* |
| Ovenbird | *Seiurus aurocapillus* |
| American redstart | *Setophaga ruticilla* |
| Eastern bluebird | *Sialia sialis* |
| White-breasted nuthatch | *Sitta carolinensis* |
| Pine siskin | *Spinus pinus* |
| American goldfinch | *Spinus tristis* |
| Chipping sparrow | *Spizella passerina* |
| Field sparrow | *Spizella pusilla* |
| Rough-winged swallow | *Stelgidopteryx ruficollis* |
| Eastern meadowlark | *Sturnella magna* |
| Starling | *Sturnus vulgarus* |
| Bewick's wren | *Thryomanes bewickii* |
| Carolina wren | *Thryothorus ludovicianus* |
| Brown thrasher | *Toxostoma rufum* |
| House wren | *Troglodytes aedon* |
| Robin | *Turdus migratorius* |
| Eastern kingbird | *Tyrannus tyrannus* |
| Blue-winged warbler | *Vermivora pinus* |
| Yellow-throated vireo | *Vireo flavifrons* |
| White-eyed vireo | *Vireo griseus* |
| Red-eyed vireo | *Vireo olivaceus* |
| Hooded warbler | *Wilsonia citrina* |
| White-throated sparrow | *Zonotrichia albicollis* |

*Source*: Kitchings and Mann 1976.

**Table 3E.2 Mammal species found on the Oak Ridge Reservation**

| Common name | Scientific name |
|---|---|
| Opossum | *Didelphis marsupialis* |
| Shorttail shrew | *Blarina brevicauda* |
| Least shrew | *Cryptotis parva* |
| Eastern mole | *Scalopus aquaticus* |
| Southeastern shrew | *Sorex longirostris* |
| Big brown bat | *Eptesicus fuscus* |
| Silver-haired bat | *Lasionycteris noctivagans* |
| Red bat | *Lasiurus borealis* |
| Hoary bat | *Lasiurus cinereus* |
| Keen's myotis | *Myotis keeni* |
| Little brown bat | *Myotis lucifugus* |
| Indiana myotis | *Myotis sodalis* |
| Evening bat | *Nycticeius humeralis* |
| Eastern pipistrelle | *Pipistrellus subflavus* |
| Eastern cottontail | *Sylvilagus floridanus* |
| Beaver | *Castor canadensis* |
| Southern flying squirrel | *Glaucomys volans* |
| Woodchuck | *Marmota monax* |
| Pine vole | *Microtus pinetorum* |
| House mouse | *Mus musculus* |
| Golden mouse | *Peromyscus nuttalli* |
| Muskrat | *Ondatra zibethicus* |
| Marsh rice rat | *Oryzomys palustris* |
| White-footed mouse | *Peromyscus leucopus* |
| Norway rat | *Rattus norvegicus* |
| Eastern harvest mouse | *Reithrodontomys humulis* |
| Gray squirrel | *Sciurus carolinensis* |
| Hisped cotton rat | *Sigmodon hispidus* |
| Eastern chipmunk | *Tamias striatus* |
| Bobcat | *Lynx rufus* |
| Striped skunk | *Mephitis mephitis* |
| Longtail weasel | *Mustela frenata* |
| Mink | *Mustela vison* |
| Raccoon | *Procyon lotor* |
| Gray fox | *Urocyon cinereoargenteus* |
| Red fox | *Vulpes vulpes* |
| White-tailed deer | *Odocoileus virginianus* |

*Source*: Kitchings and Mann 1976.

**Table 3E.3. Reptile and amphibian species found on the Oak Ridge Reservation**

| Common Name | Scientific Name |
|---|---|
| Northern cricket frog | *Acris crepitans* |
| American toad | *Bufo americanus* |
| Fowler's toad | *Bufo woodhousei* |
| Eastern narrow-mouthed toad | *Gastrophryne carolinensis* |
| Spring peeper | *Hyla crucifer* |
| Gray tree frog | *Hyla versicolor* |
| Upland chorus frog | *Pseudacris triseriata* |
| Bullfrog | *Rana catesbeiana* |
| Bronze frog | *Rana clamitans* |
| Pickerel frog | *Rana palustris* |
| Leopard frog | *Rana pipiens* |
| Wood frog | *Rana sylvatica* |
| Eastern spadefoot | *Scaphiopus holbrookii* |
| Spotted salamander | *Ambystoma maculatum* |
| Hellbender | *Cryptobranchus alleganiensis* |
| Dusky salamander | *Desmognathus fuscus* |
| Red-spotted newt | *Notophthalmus v. viridescens* |
| Southern two-lined salamander | *Eurycea bislineata* |
| Three-lined salamander | *Eurycea longicauda* |
| Cave salamander | *Eurycea lucifuga* |
| Spring salamander | *Gyrinophilus porphyriticus* |
| Mudpuppy | *Necturus maculosus* |
| Red-backed salamander | *Plethodon cinereus* |
| Slimy salamander | *Plethodon glutinosus* |
| Northern red salamander | *Pseudotriton ruber* |
| Snapping turtle | *Chelydra serpentina* |
| Eastern painted turtle | *Chrysemys picta* |
| Map turtle | *Malaclemys geographica* |
| Ouachita map turtle | *Malaclemys p. ouachitensis* |
| River cooter | *Chrysemys concinna* |
| Yellow-bellied turtle | *Chrysemys s. scripta* |
| Striped-neck musk turtle | *Sternothaerus minor* |
| Stinkpot | *Sternothaerus odoratus* |
| Eastern box turtle | *Terrapene carolina* |
| Eastern spiny softshell turtle | *Trionyx s. spiniferus* |
| Northern copperhead | *Agkistrodon contortrix* |
| Green anole | *Anolis carolinensis* |
| Eastern worm snake | *Carphophis amoenus* |
| Scarlet snake | *Cemophora coccinea* |
| Six-line racerunner | *Cnemidophorus sexlineatus* |
| Northern black racer | *Coluber constrictor* |
| Timber rattlesnake | *Crotalus horridus* |

Table 3E.3. (continued)

| Common Name | Scientific Name |
|---|---|
| Northern ringneck snake | *Diadophis punctatus* |
| Corn snake | *Elaphe guttata* |
| Black rat snake | *Elaphe obsoleta* |
| Five-lined skink | *Eumeces fasciatus* |
| Broadhead skink | *Eumeces laticeps* |
| Eastern hognose snake | *Heterodon platyrhinos* |
| Mole snake | *Lampropeltis calligaster* |
| Eastern milk snake | *Lampropeltis triangulum* |
| Black king snake | *Lampropeltis getulus* |
| Ground skink | *Lygosoma laterale* |
| Queen snake | *Regina s. septemvittata* |
| Northern water snake | *Natrix s. sipedon* |
| Rough green snake | *Opheodrys aestivus* |
| Slender glass lizard | *Ophisaurus attenuatus* |
| Fence lizard | *Sceloporus undulatus* |
| Northern brown snake | *Storeria dekayi* |
| Northern red-bellied snake | *Storeria occipitomaculata* |
| Southeastern crown snake | *Tantilla coronata* |
| Eastern garter snake | *Thamnophis sirtalis* |

*Source*: Kitchings and Mann 1976.

## 4A.1 INTRODUCTION

Data collected during a site characterization activity are used to determine whether contaminants on or migrating from the site represent a significant human health or environmental hazard, and to provide a basis for the selection of remediation alternatives. The appropriate selection of sampling strategies and the quality or usability of the analytical data generated will determine how well a site has been characterized. Data quality is typically determined by the evaluation of precision, accuracy, representativeness, comparability, and completeness (PARCC). An evaluation of these data provides data users with a comprehensive summary of the data that are fully useable, and of the data that are either unusable or have potential for bias. The following sections present an assessment of both the quality and potential limitations of the sampling and analysis activities associated with the WAG 6 RFI.

## 4A.2 DATA SOURCES

Data collected during an RFI are generally collected in several stages, with initial data efforts usually limited to developing a general understanding of the site. As a basic understanding of site characteristics is achieved, subsequent data collection efforts focus on filling identified gaps in the understanding of site characteristics and gathering information necessary to evaluate remedial alternatives. In this way the overall investigation effort can be continually scoped to minimize the collection of unnecessary data and maximize data quality.

Scoping activities typically begin with the collection of existing site data, including data from previous or concurrent investigations. Thus, data from multiple sources must be evaluated. The primary source of sample analytical data for the WAG 6 RFI comes from samples collected in or near WAG 6 by Bechtel team personnel and analyzed by the analytical subcontractor or at the field operations facility (FOF) laboratory. Another significant source of sample analytical data consists of results from analysis of groundwater samples collected by ORNL from RCRA monitoring wells associated with WAG 6. In addition, there are many smaller sources of WAG 6 data associated with various studies performed during the time period 1978 to 1991. These smaller studies primarily produced data from analysis of samples for radiological parameters, and a lesser amount of data from analysis of samples for VOAs, BNAs, and metals. Finally, an inventory of materials which were disposed within the confines of WAG 6 during its use has been compiled. A more detailed description of these data sources has been given in Appendix 1B of this report. Each section of this report provides a list of data sources used in the evaluation detailed therein.

## 4A.3 DOCUMENTATION

In a study of this type, it is necessary to develop and maintain adequate documentation of tasks within the study to allow later verification that these tasks were indeed accomplished in an acceptable manner. This section addresses several types of documentation from this study which have been evaluated for the previously stated purpose.

### 4A.3.1 Chain-of-Custody

A randomly selected group of chain-of-custody (COC) forms were examined for Bechtel-collected samples and ORNL/RCRA monitoring well samples. Those COCs which were examined were field and laboratory COCs for Bechtel-collected samples, and laboratory COCs for ORNL/RCRA monitoring well samples. An audit of randomly selected BNI groundwater and surface water samples concluded that 100% of these samples were properly documented with the appropriate COC forms.

Quality Assurance / Quality Control Documents. For all Bechtel activities during the WAG 6 RFI, the QA/QC sections of the WAG 6 Field Sampling Plan (Section B.11) and Project Procedures Manual were followed, as was the Subcontract Laboratory QA Program. For all ORNL activities, the Chemical and Physical Analysis Quality Assurance Program, Organic Analysis Laboratory Quality Assurance Program, and Low Level Radiochemical Analysis Group Quality Assurance Program were followed.

### 4A.3.2 Standard Operating Procedures

For all Bechtel activities during the WAG 6 RFI, standard operating procedures (SOPs) contained in the ORNL RI/FS Project Procedures Manual, WAG 6 Work Plan, WAG 6 Field Sampling Plan (FSP), WAG 6 Quality Assurance Project Plan (QAPP), and Subcontract Laboratory SOPs were followed. For all ORNL activities, RCRA-WQ1 through RCRA-WQ7 SOPs were used for sampling activities, and Analytical Chemistry Division SOPs were used for sample analysis activities.

### 4A.3.3 Review of Logbook Records

Field logbooks were examined for Bechtel team activities; these included sampling logbooks and well-installation logbooks. The sample dates and locations were verified during this process. The contents of these logbooks were adequate for their intended purpose.

## 4A.4 Data Validation

Data validation is a quality assessment function. It is a review of data conducted to assess the level of useability and uncertainty associated with the data. Any uncertainty in the data may have an impact on the level of confidence with which the data can be used. Thus, the purpose of data validation is to determine if the data are of acceptable quality and how the data may be used. The following paragraphs describe in brief detail the scope of the validation effort, guidance documents utilized in the validation, and the use of reviewer qualifiers assigned to the data.

Data generated during the WAG 6 RFI field sampling activities were validated by the BNI team to ensure that data quality objectives (DQOs) were achieved. All Target Analyte List (TAL) metals, Target Compound List (TCL) volatile organic compounds (VOC), semi-volatile organic compounds (SVOC) and pesticide/polychlorinated biphenyl (PCB) data were validated using the Laboratory Data Validation Functional Guidelines For Evaluating Organic

Analysis and the Laboratory Data Validation Functional Guidelines For Evaluating Inorganic Analysis (EPA 1988b,c). Organophosphorus pesticides, herbicides, dioxins/furans and other miscellaneous parameters were also validated based on available quality control (QC) information, documented holding times, adherence to standard or lab-specific methodologies and professional judgement. Appendix IX compounds were also included in the validation. A limited validation was performed on BNAE and VOC tentatively identified compounds (TIC) using information on blank contamination, known aldol condensate products, and other compounds associated with GC column degradation. Only two blank types were assessed for the validation; trip blanks (VOC only) and laboratory method blanks. Radiological data were evaluated for the PARCC parameters but were not validated.

The Functional Data Validation Guidelines provide specific guidance concerning items to be addressed in the validation procedure. Established QC limits and performance levels are provided to assure comparability between validated data sets. A list of items which are addressed during data validation are as follows:

- Holding Times
- Instrument Performance
  - GC/MS tuning
  - Pesticide instrument performance (Pest/PCB)
- Calibration
  - Initial
  - Continuing
- Blanks
- Surrogate Recovery
- ICP Interference Check Sample (metals only)
- Laboratory Control Sample (metals only)
- Duplicate Sample Analysis
- Matrix Spike/Matrix Spike Duplicate Analysis
- Internal Standard Performance
- Furnace Atomic Absorption QC (metals only)
- ICP Serial Dilution (metals only)
- Compound Identification
  - TCL Compounds
  - TIC Compounds (SVOC, VOC)
  - TAL Compounds (metals only)
- Overall Assessment of Data For a Case
  - Data Assessment Summary Form
  - Case Narrative

Specific QC limits and performance levels are included in Tables 4A.1 through 4A.3.

Upon completion of the data validation any problems encountered in the sample analyses are presented in the data assessment summary form. This form provides an overall assessment of precision, accuracy and completeness for each analytical parameter. Justification or rationale for qualified data will be presented in the data assessment.

All validated data were assigned a validation code (ValCode). This code reflects whether the data were validated (VV), if the validation was limited (VL) due to incomplete data submittal, or if the data are unusable (VI). Reviewer qualifiers (RevQual) were assigned to indicate any problems or limitations associated with the validated data. Examples of problems addressed in the reviewer qualifier field include holding time violation, surrogate and matrix spike recoveries outside of established QC limits, and blank contaminants. Data which were deemed unusable (RevQual"R") were not used. Reviewer qualifiers were used in the assessment of chemical data. A list of validation codes, reviewer qualifiers and brief descriptions of each is presented in Table 4A.4.

QC levels, as specified in the analytical subcontract, were assigned for all samples (Table 4A.5). These levels defined the QC to be performed with each sample analysis and the amount of supporting documentation required for submittal with each sample data package. This ensures that adequate information concerning the sample analysis is available to the data validator. All samples identified as critical by risk assessment guidance were analyzed and reported as QC level III.

## 4A.5 DATA QUALITY INDICATORS FOR CHEMICAL DATA

### 4A.5.1 Precision

Precision is the quantitative term that expresses the agreement (reproducibility) among individual measurements of the same property performed under prescribed similar conditions. Measurements of all types, including quantitative chemical analyses, are characterized by error in the measurement process, which produces uncertainty in the measurement results. Statistical theory says that this measurement error can be broadly divided into two types: random error and systematic error.

Random error is described by discussing the precision of the measurements. Precision measures the reproducibility of measurements under a given set of conditions. Specifically, it is a quantitative measure of the variability of a group of measurements compared to their average value. Statistically this concept is referred to as dispersion and can be measured using the relative percent difference (RPD) of duplicate analyses.

The formula for computing relative percent difference (RPD) between duplicates is:

$$RPD = \frac{(R1-R2)}{(R1+R2)/2} \times 100$$

where R1 and R2 are the results from the first and second duplicate samples, respectively.

The overall precision of measurement data is a mixture of sampling and analytical factors. Analytical precision is much easier to control and quantify than sampling precision. There are more historical data related to individual method performance and the area is limited to the samples received in the laboratory. In contrast, sampling precision is unique to each site. Sampling precision may be determined by collecting and analyzing collocated

or field duplicate samples. The analytical results from the collocated or field duplicate samples provide data on overall measurement precision; analysis results from the laboratory replicates provide data on analytical precision.

Sampling precision was evaluated by calculating the RPD between field duplicate samples. This evaluation provides an estimate of both the sampling and analysis precision. Duplicate samples were reviewed only if contaminants were detected in the analyses. Not all matrices had duplicate data with detected compound of interest, which prevented a complete evaluation of sampling precision. Duplicate sets with low RPDs (within limits) indicate good sampling precision and relatively homogeneous matrices. Duplicate results with higher RPDs (out of limits) may not necessarily reflect negatively on sampling procedures, but could indicate a likelihood of matrix effects interfering with the extraction and analysis procedure or could be associated with the non-homogeneity of a soil matrix. Table 4A.6 summarizes the results of the evaluation of field duplicate samples by matrix and parameter type.

Matrix spike duplicate pairs (MS/MSD) are also used to evaluate the precision of the analysis by comparing the results of the two samples. This comparison is also expressed as the RPD. The acceptance criteria, or DQOs, for precision used in this sampling and analysis effort are the upper and lower control limits, delineating the range of acceptability for the RPDs calculated from the analyses of QC samples. These control limits are defined by the 95 percent confidence interval and are provided with the precision summary tables. Control limits for precision vary for each analyte and with each analytical method. A general guideline for acceptable precision in the measurement of an analyte in a water matrix is less than 20 percent RPD; for soils, a value of less than 35 percent. Soil matrices results are more difficult to measure for sampling and analytical precision because of possible sample inhomogeneity.

The result of the evaluation of the organics MS/MSDs show that the RPDs calculated are generally within the acceptance criteria, indicating acceptable analytical precision. As could be expected, RPDs for water matrices more frequently fall within acceptance criteria than those for soil. Tables 4A.7 and 4A.8 present summaries of the precision evaluations for organic analyses for water and soil matrices.

RPD limits for inorganics MS/MSD analyses are considered to be for advisory purposes only because of potential interferences. Traditionally, matrix spike sample analysis is more common to organics than inorganics analysis, but evaluation of MS/MSDs for inorganics provides an indication of system performance. Overall evaluation of the inorganics MS/MSDs show that the RPDs calculated are generally within acceptance criteria, indicating acceptable analytical precision. Tables 4A.9 and 4A.10 present summaries of the precision evaluations for inorganic analyses for water and soil matrices.

In conclusion, precision is a quantitative data quality characteristic. The evaluation of precision includes as much of the total measurement system (i.e., field as well as laboratory aspects) as possible in order to provide a more meaningful estimate of data quality. The overall evaluation of precision for WAG 6 data concludes that: RPDs calculated are generally

within the acceptance criteria, indicating acceptable precision; adequate procedures were used for calculating these data quality characteristics; and the reported estimates of data quality are appropriate to the analytical results.

### 4A.5.2 Accuracy

Accuracy is a quantitative data quality characteristic that expresses the degree of agreement or closeness of an individual measurement or an average of a number of measurements to a true or known value. If we refer to a single measurement result, the nearness of the result to the true value—or accuracy of the result—depends upon the magnitude of both random and systematic errors. In this context, accuracy has components of both bias and imprecision. If we refer to the nearness of an average value to the true value, we are talking primarily about the bias error component; by taking the average, we have averaged out the random errors. The total error in the average of repeated measurements depends less upon the magnitude of the random error component (imprecision) as the number of measurements increase. Accuracy used in this context takes on the meaning equivalent to that of the term bias.

Accuracy is controlled primarily by the analytical process. Analytical accuracy may be assessed through the use of known and unknown QC samples and matrix spikes. Sampling bias can be assessed by evaluating the results of field/trip blanks. Field blanks are evaluated to estimate the potential bias caused by contamination from sample collection, preparation, shipping, and/or storage. Results for the analysis of field blanks indicate whether contamination resulted in bias, but are not estimates of accuracy. Performance audits, in which a laboratory is evaluated based on the analysis of performance evaluations (PE) samples, are quantitative and also provide valuable quality assessment information. Blanks and PE samples are evaluated during the data evaluation/validation process.

Analytical accuracy is evaluated by calculating the recovery of an analyte spiked into a sample. These spiked samples are prepared by adding a known amount of one or more analytes to a sample, followed by analysis for those analytes. Two types of spike samples are prepared: matrix spike (MS) samples and surrogate spike samples. The analytes used to prepare MS samples are expected to be present in the unadulterated sample, while surrogate compounds are unlikely to be present in the unadulterated sample, yet are chemically similar to analytes of interest. After analysis, percent recovery is calculated by dividing the analytical result by the known amount of addition.

The formula for computing percent recovery is as follows:

$$\text{Percent Recovery} = \frac{\text{(Measured Amount - Amount in Unspiked Sample)}}{\text{Amount Spiked}} \times 100$$

The acceptance criteria, or DQOs, for accuracy used in this sampling and analysis effort are the upper and lower control limits, delineating the range of acceptability for the percent recoveries calculated from the analyses of QC samples. These control limits are defined by the 95 percent confidence interval.

Surrogate spikes are used only in organics analysis. As with matrix spikes, surrogate spikes can be similarly affected by matrix interferences. However, they differ from matrix spikes in that the compounds are different non-target compounds and are spiked into every sample. The results of the evaluation of the organic surrogate spikes show that recoveries are generally within acceptance criteria, indicating acceptable analytical accuracy. Tables 4A.11 and 4A.12 present summaries of the surrogate accuracy evolutions for organic analyses for water and soil matrices.

The evaluation of organics matrix spike samples show generally acceptable recoveries. As could be expected, percent recoveries for water matrices are more often within acceptance criteria than those for soil. Tables 4A.13 and 4A.14 present summaries of the matrix spike accuracy evaluations for organics analyses for water and soil matrices.

Evaluation of inorganics matrix spike samples show an acceptable recovery of the majority of the constituents. In some instances, a smaller data set prohibited complete evaluation of accuracy. Control limits for inorganics recoveries are for advisory purposes only, and may not always be attainable. Tables 4A.15 and 4A.16 present summaries of the matrix spike accuracy evaluations for inorganics analyses for waster and soil matrices.

Conclusion: To conclude, when spike recoveries are higher than control limits, false positive results are possible. When spike recoveries are lower than control limits, false negative results are possible. The data quality reviewer must take into consideration the potential for both false positive and false negative results for individual analyses as a result of bias, as indicated by percent recoveries outside of acceptance criteria. The overall evaluation of accuracy concludes that: percent recoveries are generally within the acceptance criteria indicating acceptable accuracy; adequate procedures were used for calculating accuracy; and the reported estimates of data quality are appropriate to the analytical results.

### 4A.5.3. Representativeness

#### 4A.5.3.1. Introduction

Representativeness is defined as the degree or extent to which the data obtained from a sample collection activity accurately reflect the contamination present at a site. Evaluating representativeness is often a subjective and qualitative process. The proper selection of analytical and sampling strategies will determine the degree of representativeness achieved. Limiting and/or identifying the number of false positives and false negatives that are introduced in the sampling and measurement process is a key element in gauging representativeness. A review of sampling and analytical representativeness for the WAG 6 RFI is presented in the following paragraphs.

#### 4A.5.3.2. Sampling representativeness

The WAG 6 RFI employed both judgmental and random sampling strategies. The judgmental sampling focused on three principle solid waste management units (SWMU) located in or near WAG 6. Selection of areas for judgmental sampling were made on the

basis of sample disposal records pertaining to WAG 6. Additional random locations in WAG 6 were selected for sampling to further determine the possible migration of radiological and chemical contaminants. The combination of judgmental and random sampling decreased the level of bias that is associated with the exclusive use of judgmental sampling. A presentation of the spatial distribution and frequency of sampling for all matrices sampled in the WAG 6 RFI is presented in Figs. 4A.1 through 4A.4.

Various measures were employed during the field sampling activities to ensure representativeness. These measures include compositing (soil sampling), the collection of field blanks and rinseates, and the inclusion of trip blanks in all sample sets. Compositing was performed for every 6 ft soil interval to increase the homogeneity of the samples and better define the distribution of chemical and radiological contaminants. Samples obtained for volatile analysis were taken from 2 ft intervals to ensure that chemical contaminants would not be diluted or volatilized in the compositing process. Field blanks and rinseates were collected to determine if site conditions, sample containers or preservatives, or inadequate sampling equipment decontamination could have introduced false positive results in the chemical and radiological analyses of the samples. Compounds detected in field blanks and rinseates that were also detected in the associated regular samples are presented in Table 4A.17. It should be noted that no field blanks or rinseates could be associated with soil matrices. This situation introduces the possibility of false positive detects for this matrix. Trip blanks, which were analyzed for volatile compounds only, are not presented for evaluation since they were used in the validation procedure to qualify all volatile data.

#### 4A.5.3.3. Analytical representativeness

Various measures were used to ensure that false negatives and false positives were not introduced during the analytical measurement process. Method blanks were analyzed and reported for each analytical parameter to determine if any laboratory contaminants were introduced in the sample analysis process. Compounds detected in the method blanks were evaluated in the validation procedure during qualification of all chemical data, thus reducing the possibility of false positive results. In order to evaluate the potential for false negative results, items such as sample preservation, holding times and the appropriate selection of analyses to be performed were evaluated. All liquid samples were preserved to ensure that biological or chemical degradation, resulting in the loss of chemical constituents, would be minimized. Instructions concerning the appropriate use of preservatives for all analytical parameters were incorporated in the FSP and subsequently evaluated in the validation process. A list of chemical analyses and methods of preservation is presented in Table 4A.18. Holding times for sample analyses were also evaluated during the data validation. Any uncertainties in the analytical measurement resulting from holding time violations, were reflected by the qualifiers assigned to the data.

Holding times were evaluated using the date of sample collection, in accordance with the CLP data validation guidelines and 40 CFR guidelines. A significant proportion of volatile analyses for liquid matrices exceeded established holding time criteria. In these instances non-detected and detected compounds were qualified as estimated. These results

for volatile compounds from samples with exceeded holding times could potentially represent an underestimate of the chemicals actually present on the site.

#### 4A.5.3.4 Conclusions

Representativeness is a qualitative term that expresses the extent by which data define an environmental condition. Assessing the level of representativeness achieved for a collection activity will, by the very nature of the term, be somewhat subjective. A qualitative evaluation of representativeness will ultimately be linked to the validity of the field sampling plan rationale and the amount of supporting QC information. The only factor which was felt to have potentially significant impact on representativeness were holding time violations for volatiles in water matrices, which would introduce an underestimate of sample concentrations. Assuming that the sampling rationale was valid and supporting QA/QC activities were adequate, the data for the WAG 6 RFI meet the qualitative criteria for representativeness.

### 4A.5.4 Comparability

Comparability is defined as the confidence with which one data set can be compared to another and the degree to which the data are found to be equivalent. For different data sets to be truly comparable, all aspects of the collection and measurement process should be identical. Some of the parameters that should be consistent include the following:

- Samples must be from the same source
- Samples must be collected in the same or similar manner
- Samples must be preserved in the same manner
- Samples must be prepared and analyzed by the same method
- Data must be reported in the same units
- Data from each set must be of comparable quality

Table 4A.19 includes a list of analytical methodology, detection limits, and reporting units for water samples, for both Bechtel's analytical subcontractor and the laboratory which analyzed the ORNL RCRA monitoring well samples. Although there are some discrepancies for detection limits, in general the predominance of standardized analytical methodology provides the basis for comparability between the data from samples analyzed by these two laboratories.

Sample splits for analysis by both laboratories were done for wells 855, 856, 841, and 842. These sample analysis results have been tabulated previously in Table 18 of Technical Memorandum 06-09A. The results for tritium for well 841 and for thorium-234 for well 842 were within 20% for the two laboratories. The remainder of the results for which there is an adequate contamination level for comparison usually agree within less than a factor of two.

Field QC protocols for the two data sources were equivalent. In particular, both groups included provision in their SOPs for collection of trip/field blanks, equipment blanks, and field replicate samples.

### 4A.5.5 Completeness

#### 4A.5.5.1. Introduction

Completeness is a measure of the amount of data obtained from a measurement process compared to the amount of data that was expected to be obtained under the conditions of the measurement. Completeness can be defined from two different points of view: the field (sampling) and the laboratory (analysis). Analytical completeness is defined as the percentage of valid data (useable data) derived from any given sample collection activity. Completeness, as related to field sampling, is defined as the number of samples planned to be collected versus the number actually collected for which valid data exists. Analytical and sampling completeness obtained during the WAG 6 RFI is expressed as a percentage as discussed in the following sections.

#### 4A.5.5.2 Analytical completeness

Completeness is defined as the amount of usable data generated from a data collection activity. All data, with the exception of radiological data, were examined for usability. Unusable data are defined as analytical data that received a reviewer qualifier (RevQual) of "R". The following percentages of useable analytical data points were obtained during the WAG 6 RFI:

| Matrix | Useable data (percent of total data) |
|---|---|
| Groundwater | 97% |
| Surface water | 99% |
| Soil | 99% |
| Sediment | 99% |

Analytical completeness for all matrices combined was ninety-eight percent. This means that ninety-eight percent of all the analytical data reviewed was found to be valid and usable. The majority of invalid data from the groundwater data were from SVOC analyses. Results from phenolic compounds, detected in SVOC analyses, were often found to be invalid. This could be attributed to problems associated with the analytical technique. Metals results accounted for nearly all of the invalid data found for soil and sediment matrices. This is most likely due to matrix interferences commonly encountered in the analysis of soil or sediment. Metals and volatiles results were found to be the most frequently invalid in the surface water data. Only three samples were invalid for an entire analytical analysis:

| Sample no. | Date | Location | Analysis | Matrix | Sample type |
|---|---|---|---|---|---|
| W49TSB | 26-SEP-89 | W49TS | VOC | SW | Field blank |

| | | | | | |
|---|---|---|---|---|---|
| 0532 | 15-MAY-90 | 1228 | BNAE | GW | Regular |
| 0531 | 14-MAY-90 | 1229 | BNAE | GW | Regular |

Ninety-eight percent completeness for all matrices exceeded the ninety-five percent completeness goal as stated in sections 1303 and 1304 of the project procedures manual. A detailed listing of all invalid data, including sample numbers and locations, is provided for all matrices in Tables 4A.20 through 4A.23.

### 4A.5.5.3. Sampling completeness

Sampling completeness was assessed by examining the number of samples planned to be obtained for analysis, compared to the actual number collected and analyzed. An extensive inventory of all samples analyzed was performed for all matrices (see Tables 4A.24 through 4A.27). These inventories were compared with the WAG 6 Field Sampling Plan (FSP) to determine if the projected number and type of samples had been collected during the WAG 6 RFI. Sampling completeness for all matrices is as follows:

| Matrix | Sample type | Percentage of completeness |
|---|---|---|
| Groundwater | Regular | 99% |
| Groundwater | QC | 99% |
| Surface water | Regular | 189% |
| Surface water | QC | 94% |
| Soil | Regular | 74% |
| Soil | QC | 20% |
| Sediment | Regular | 148% |
| Sediment | QC | 51% |

The amount of regular samples to be collected, as outlined in the FSP, was achieved or exceeded for all matrices with the exception of soil. The number of regular soil samples that were analyzed is seventy-four percent of the number of samples projected for collection and analysis in the FSP. Some areas of WAG 6 were projected to be sampled in the FSP, but were not actually sampled. Areas that were either not sampled, or were sampled and not submitted for analysis, include the EWB, the EDT, and various subsurface locations throughout WAG 6. Samples that were collected, but not sent for analysis, were eliminated on the basis of radiological and volatile screening results from the Close Support Laboratory (CSL). Sample screening was performed in order to eliminate unnecessary analytical analyses. Gross alpha and beta analyses were performed as a part of all radiological screening by the CSL. Volatile headspace analysis was also performed on all

soil samples using dual field instrumentation (OVA and hNU) or a gas chromatograph. The samples that were collected, screened and not sent for analysis represent a large portion of the twenty-six percent of samples that were projected for analysis in the FSP but not analyzed. The validity of screening results and the appropriate selection of soil samples for analysis will have the largest impact on representativeness for soil sampling activities. Soil samples were not collected for either the EWB or the EDT. It was projected that two samples would be obtained from the EWB and six samples would be taken from the EDT. During WAG 6 field sampling activities an unsuccessful effort was made to ascertain the location of the EDT. It was postulated that the EDT is located under the interim corrective measures (ICM) cap. Sampling at the EWB was limited to the collection of sediment and surface water samples only, no soil samples were collected. Factors such as limited site access and lost or broken samples did not play a significant role in reducing sampling completeness.

The number of quality control (QC) samples (duplicates, field blanks, rinseates and trip blanks) collected and analyzed for each matrix was found to be adequate with the exception of soil and sediment. Although the number of QC samples obtained for sediment sampling was less than the amount projected in the FSP, the total number of QC samples collected is fourteen percent of the total number of samples collected. Field QC Procedures (section B11.1 of the FSP) states that for a soil or sediment matrix, fifteen percent of the samples collected must be QC samples. Soil sampling activities produced an average of seven percent QC samples, eight percent below the number of QC samples projected. A reduced number of QC samples for soil could increase the uncertainty associated with the analytical results for soil matrices.

#### 4A.5.5.4 Conclusions

The overall completeness obtained for WAG 6 RFI data exceeded the goal of 95% completeness. Although data for individual matrices did not always reach the 95% objective (as discussed in Sections 4A.5.2 and 4A.5.3) the overall completeness obtained was 98% for analysis and 97% for sampling.

## 4A.6 DATA QUALITY OBJECTIVES FOR RADIOLOGICAL DATA

### 4A.6.1 INTRODUCTION

National guidelines for data review of radiological analyses have not been established. It is possible, however, to evaluate these data for most of the PARCC parameters. Radiological contaminants behave similar to inorganic contaminants in nature. Therefore the representativeness of the two data types are similar. Many radiological analyses use the same instruments and counting techniques for various nuclides, and comparability can be achieved. Spikes, duplicates, performance evaluation (PE) samples, and field QC samples for radiological analyses are measures of the precision, accuracy, and representativeness.

Most environmental media contain naturally occurring radioactive materials such as uranium, thorium, radium, and potassium-40. For certain analyses (e.g., gross radioactivity)

the presence of these natural emitters makes interpretation of data difficult. Also, radioactive decay is random in nature, therefore the measurement of radiations produced during decay have inherent errors associated with the randomness in the decay process. Consequently, numerical comparison of two or more absolute values is not valid. Instead, comparisons must be made using statistical techniques. These inherent errors are more pronounced at low concentrations due to the limitations of the measurement processes, and the randomness of decay.

Screening techniques are often used to determine elevated concentrations of radionuclides. The techniques usually applied are gross alpha and beta determinations, tritium analysis, and gamma spectroscopy. The gross alpha and beta analyses are non-isotopic specific measurements of any non-volatile nuclides that decay by alpha and/or beta emissions, with the exception of low energy beta emitters such as tritium. Tritium is analyzed by liquid scintillation counting following chemical separation. Gamma spectroscopy is a quantitative and qualitative technique that determines total nuclides emitting gamma photons (and some X-rays) that enter the sensitive area of the detector. These techniques allow the determination of measurable radiological contamination and requirement for further analyses.

## 4A.6.2 PRECISION

### 4A.6.2.1 Definition

Precision is a measurement of the reproducibility of measurements under a given set of conditions. Specifically, it is a quantitative measure of the variability of a group of measurements compared to their average value.

The precision of the radiological data was evaluated by examining the results of laboratory spikes and duplicates, and field duplicates. The information for the client laboratory was not included in the evaluation. The remainder of this discussion is concerned with the subcontract laboratory data only.

### 4A.6.2.2 Laboratory spikes

Laboratory spike data were evaluated by reviewing quarterly control charts supplied by the analytical subcontractor. Control charts were established for each parameter analyzed routinely. Control limits used by the laboratory were standard for the industry, i.e., values outside of 2 sigma were considered warnings, and values outside of 3 sigma were considered out of limits. The results of the control chart reviews including each routine analysis are shown in Tables 4A.28 through 4A.34.

**1989 results.** Several parameters did not have control charts for all of 1989. Control charts for cesium-137 were included for the second quarter; charts for iron-55, gross alpha, gross beta, and nickel-63 were for second through fourth quarters. Cesium-137 was the only parameter that did not have spike results for the third and fourth quarters.

During 1989, 2071 spikes were analyzed by the laboratory, resulting in 169 outliers form 27 different parameters. This resulted in 91.8% of the spikes being within control limits.

The only parameter exhibiting a bias during the 1989 period was calcium-45, which showed a slight low bias.

**1990 results.** The subcontract laboratory analyzed 1804 spikes during 1990. Of these, 285 were outside of control limits, which resulted in an acceptance value of 84.2%. An individual problem identified was radium-226 results for the first quarter, which had 23 out of 55 spikes out of control limits. No bias or trend was associated with these results, and the precision for radium-226 was not affected. All other results during this quarter had less than 21% outliers.

**Summary.** The results of laboratory spikes indicated good laboratory precision with 88% of the spikes within control limits.

### 4A.6.2.3 Laboratory duplicates

Control charts for laboratory duplicates were also maintained by the analytical subcontractor. Two and three sigma limits were again used for acceptance criteria. Each quarter was evaluated, and the results summarized in Tables 4A.28 through 4A.34.

**1989 results.** During 1989, 955 duplicate measurements were made on 27 analyses. There were 38 outliers as a result of these tests. The tests for radium-224 and thorium-234 had 58.3% and 33.3% outliers. Thorium-228 had 22.2% outliers, and the other 23 tests had less than 12% outliers.

The overall acceptable percentage of results was 96% for 1989.

**1990 results.** During 1990, 936 duplicates were analyzed by the laboratory. The results showed 38 outliers during 1990, which equates to an acceptable percentage of 95.9%. The analyses/parameters that indicated problems with laboratory precision were gross beta (first and fourth quarters), strontium-90 (second and third quarters), cobalt-60 (third quarter), and radium-226 (third quarter). The third quarter values for cobalt-60, strontium-90, and radium-226 had a potential high bias, but the bias was determined to be not significant.

**4A.6.2.3.4 Summary.** The evaluation of laboratory duplicate samples indicates an acceptable precision of 96%.

### 4A.6.2.4 Field duplicates

Field duplicates provide a measurement of the overall sampling and analytical precision. Field duplicates were evaluated by calculating the RPDs for all radionuclides/parameters that were detected in both the regular sample and the duplicate. The data validation protocols for evaluating inorganics were used. For parameters greater than five times the contract required

detection limit (CRDL),the RPD must be within ± 20% (35% for soils), and for results less than five times the CRDL, the RPD should be less than ± the CRDL (two times the CRDL for soils). For parameters that no CRDL was specified, the 20% value (35% for soils) was used. Parameters that were analyzed for but not detected were not included in this evaluation.

The results of this evaluation are shown in Tables 4A.35 through 4A.37, and summarized below.

**Groundwater.** One hundred and thirty four total radiological parameters were analyzed in 9 groundwater samples. Of these, 45 had positive results. Of the 45, 33 were within control limits (73%), and 12 were outside of control limits (27%). Of the 12 outside of control limits, 2 were greater than plus or minus the CRDL, but at very low levels, and were determined to be within a reasonable range for the analysis.

The precision for the groundwater sampling and analysis was less than expected for a water matrix, due in part to the limited population size of data under study and the limitations of the measurement processes.

**Surface water.** Sixty seven radiological determinations were made on 6 duplicate samples. Of these, 18 had positive results. Fifteen were within control limits (83%), and 3 outside of limits (17%). All three of the results outside of limits were at low levels and within reasonable ranges. Therefore, the precision of the surface water results was determined to be acceptable.

**Soil samples.** The largest amount of duplicate precision data was available for soils, due to the natural occurring radioisotopes that were detected during the analyses. One hundred and five total measurements were made on 7 samples. Positive results were detected in 76; 73 were within control limits (96%), and 3 were outside of limits (4%).

The precision of the soil radiological determinations was determined to be excellent based on these criteria, especially considering the difficulty usually associated with the analysis of solid matrices.

### 4A.6.2.5 Conclusion

The precision of the subcontract laboratory for radiological analyses was determined to be acceptable, based on the criteria evaluated.

## 4A.6.3 ACCURACY

### 4A.6.3.1 Definition

Accuracy is the difference between the mean of a series of measurements and the true value of the property measured. Accuracy of the radiological data was determined by evaluating data from field QC samples (field blanks and rinseates), performance evaluation (PE) samples, and spiked samples.

### 4A.6.3.2 Field blanks and rinseates

Field QC samples, field blanks and rinseates, for the ORNL data were not included in this evaluation. The remainder of this section deals with the subcontract laboratory generated data.

**Groundwater.** One rinseate and nine field blanks were collected and analyzed for radiological parameters. Radium-224 was detected in the rinseate by gamma spectroscopy, but was determined to be an erroneous value, as it was not confirmed by the gross alpha determination. A summary of field QC samples is shown in Table 4A.38, and indicates that the data were not adversely affected by sampling techniques. Several natural radioisotopes were detected at environmental levels in both the rinseate and field blanks. These low levels of radioisotopes would be expected in blanks due to random decay and the limitations of the measurement process. Tritium was detected in one field blank at an elevated level of 1980 $\pm$ 280 pCi/L. This level is four times the instrument detection level and could result from field and/or laboratory contamination, although this value is 10% of the allowable tritium content in drinking water. The tritium levels in the samples were significantly higher and not affected by the blank.

**Surface water.** Four rinseates and seven field blanks were collected during surface water sampling. The radioisotopes detected were similar to those detected during groundwater sampling, with the exception of one rinseate (sample number 0481) which contained plutonium-238 at 2.4 $\pm$ 1.1 pCi/L. All surface water samples collected with this sampling equipment during this sampling event are considered to be biased high for plutonium-238. A summary of the surface water field QC samples is shown in Table 4A.39.

**4A.6.3.2.3 Soil/Sediment.** Two rinseate samples were collected during background soil sampling. Both samples showed gross alpha content of 2 to 7 times the detection limit (1 pCi/L), and radium-224 was detected in one of the samples. The typical alpha background for soil can range from 10 to 30 pCi/g depending upon the content of uranium and thorium. If the density of the rinseate samples are considered to be 1g/cc, the conversion of these values to weight basis results in a gross alpha content of $<$1pCi/g, which is below the method detection level for solids. Therefore the gross alpha values associated with the background samples were not affected by these rinseates. A summary of background sampling field QC samples is shown in Table 4A.40.

### 4A.6.3.3 Performance Evaluation (PE) Samples

**ORNL Analytical Chemistry Division (ACD) Laboratory.** Performance evaluation (PE) sample results were reviewed for 1988, 1989, and 1990. The PE samples were prepared by the USEPA Environmental Measurements Laboratory - Las Vegas (EMSL-LV), and submitted to the laboratory quarterly. Typical PE sample media consisted of filters, water, and milk. All three matrices were used in the evaluation. Sample results were scored by the EPA and determined to be within pre-determined acceptable/unacceptable ranges.

Acceptable/unacceptable values were provided for 1989 and 1990, and the percentage of acceptable results calculated. The 1988 results did not have the EPA evaluation (acceptable/unacceptable) and RPDs were calculated. An acceptance criterion of 25 percent was used for the 1988 data.

The 1988 data had 7 analyses out of 34 (21%) outside of the control limits. Two of the out of control analyses were less than five times the method detection limit and determined to be within a reasonable range. Therefore, there were five results outside of control limits (85% within), which indicates good laboratory accuracy.

The 1989 results had 2 out of 53 analyses determined to be unacceptable by EPA criteria, and one analysis at the warning level. Assuming the warning value as unacceptable, the overall 1989 results were acceptable for 94% of the analyses performed.

For 1990 PE sample results, the ACD laboratory had 100% of the results determined to be acceptable (54 out of 54).

The overall accuracy of the ACD laboratory on PE samples was excellent, with 93% (131 out of 141) of the analyses within the acceptance criteria.

**Subcontract laboratory.** The subcontract laboratory also received and analyzed EMSL-LV PE samples during 1988, 1989, and 1990. Water, milk, and air filter samples were the matrices analyzed. The standard EPA protocols for acceptability were used for evaluation of the results.

The percentage of acceptable and unacceptable results was calculated by dividing the outliers and results within the acceptable range by the total number of results. Based on these criteria, 84.5% of the samples were found to be within limits, and 15.5% were outside the limits. The laboratory was consistent throughout the period, with scores of 83% for 1988, 83% for 1989, and 88% for 1990.

The subcontract laboratory accuracy for PE samples was therefore determined to be acceptable.

#### 4A.6.3.4 Interlaboratory spikes

Interlaboratory spikes were prepared by the client laboratory and sent to each laboratory providing data. Both a laboratory spike (deionized water) and a field spike, consisting of WAG 6 groundwater, were prepared. An additional spike set was prepared and sent to another laboratory. This laboratory was to be considered as a referee, and the results are not included. The spikes were prepared and analyzed for gross alpha, gross beta, gamma spectroscopy (cobalt-60 and cesium-137), and tritium.

Matrix spike acceptance criteria for the evaluation of inorganic analytes was used for review of the data. However, RPDs were calculated rather than spike recoveries, as unspiked analysis was not performed. The acceptable criteria for the spikes was attainment of an RPD of less than 25%.

The results of the spiking experiment are shown in Table 4A.41. Relative percent differences (RPD) for both the true spiked amount and the RPD between laboratories were calculated. Both laboratories had overall RPDs of less than 15%, with the highest single RPD for both laboratories being for gross alpha analysis on the field spike. This RPD was +46% for the subcontract laboratory, and -40% for the client laboratory. The gross alpha laboratory spike RPD for both laboratories was within 15%, and the referee laboratory reported a RPD on the field spike sample of within 5%. Therefore, both laboratories had apparent difficulty analyzing this groundwater sample for gross alpha, although if the two sigma measurement error is used, the values for both laboratories are within 35%. The overall RPDs for both laboratories were within these established limits, and the accuracy for radiological analyses is acceptable.

#### 4A.6.3.5 Conclusion

Evaluation of analytical accuracy was performed by reviewing field QC samples, performance evaluation samples, and spikes prepared by the project and submitted to the laboratories as unknowns.

Review of the radiological results from each data source has been shown to provide accurate results.

### 4A.6.4. REPRESENTATIVENESS

#### 4A.6.4.1 Definition

Representativeness is defined as the degree or extent to which the data obtained from a sample collection activity accurately reflects the contamination at the site. Analytical representativeness of the radiological data was determined by reviewing sample storage and preservation techniques and field blanks and other field QC samples. Representativeness is a qualitative measure that identifies potential false positives and negatives.

Sampling representativeness is discussed in Section 4A.5.3. The remainder of this discussion deals with the analytical representativeness of the radiological data.

#### 4A.6.4.2 Storage and preservation

All liquid samples for non-volatile radionuclides were acidified with nitric acid upon collection. Liquids for volatile nuclide analysis (Tritium and iodine isotopes) and solids were collected without preservation. Samples were stored and maintained under identical chain of custody procedures as for other analytes, although it was not necessary for storage at 4 degrees centigrade.

#### 4A.6.4.3 Field QC samples

Field QC sample results are detailed in Section 3.2. Results of the QC samples indicate the potential for a high bias for plutonium-238 in surface water samples. No other significant biases were found from the reviews of Field QC samples.

#### 4A.6.4.4 Conclusion

A review of field QC samples, storage and preservation techniques, and sampling protocols has determined that the sampling and analytical techniques by the project have met the criteria for representativeness.

### 4A.6.5. COMPLETENESS

#### 4A.6.5.1 Definition

Completeness is a measure of the amount of data obtained from a measurement process compared to the amount of data that was expected to be obtained under the conditions of the measurement. Completeness is expressed as a percentage, and is a way of evaluating whether a sufficient number of positive events have occurred in the sampling and analytical program to support the data.

#### 4A.6.5.2 Subcontract laboratory generated data

Completeness of radiological data is not determined by comparing invalid to valid data points as such in a formal data validation process, but instead by review and evaluation of holding times, COC, and adherence to standard methods. It is possible to identify problems with the laboratory such as backgrounds and/or contamination by reviewing the individual isotopic values and comparing these with the gross determinations. Alpha and beta emitting isotopes emit varying amounts of alpha and beta particles, all of which are detected in the gross measurements. If the sum of the isotopic values is not within the expected range for the gross determination, the isotopic value can be determined to be invalid. The gross measurements were determined by two laboratories (Close Support Laboratory and off-site analysis), and can easily be compared and determined to be within expected ranges. By using these methods, six thorium-234 results (13%) were determined to be invalid.

The subcontract support laboratory was instructed to perform isotopic determinations if the associated gross values were in excess of background. For alpha emitters, the laboratory was instructed to initially analyze for uranium isotopes, thorium isotopes, and radium-226/228. If these analyses do not account for all of the gross alpha activity, analysis for plutonium isotopes, americium-241, and curium isotopes should have occurred. For beta emitters strontium-90, technetium-99, and iodine-131 were to be analyzed.

The decision to proceed with further analysis was the responsibility of the subcontract laboratory so that the analytical process could be expedited. Therefore, the request for analysis forms could not specify exactly which radionuclides to analyze, and a ratio of analyses requested to analyses received is not applicable. In addition, gamma spectroscopy analysis reporting consisted of reporting only the isotopes detected. If no isotopes were detected, only the detection limit for cesium-137 was reported by the laboratory (although many isotopes were analyzed during the analysis). Therefore, there was no option determining if all analytes requested were performed.

In each media under study there were several samples where the subcontract laboratory did not continue the isotopic analyses until all gross alpha and beta activity had been accounted for. This was due to late reporting of data and communication difficulties. The gross alpha/beta values (and other analyses) do indicate the presence of radiological contamination at several areas, although not all radionuclides contributing to the contamination were determined. For example, the data used for Nature and Extent of Contamination in groundwater consisted of 66 measurements for gross alpha/beta and/or various isotopic determinations. In all samples the evaluation was performed in cases where the gross alpha content was over 15 pCi/L, and the gross beta over 50 pCi/L. Of the 66, 18 samples (27%) had higher gross alpha values than the sum of the isotopic analyses. For beta emitters, 7 samples (11%) had higher gross beta values than the sum of the isotopic determinations. Using this technique as a measure of completeness of the radiological data indicated that 81% of all groundwater data were complete.

For surface water data, 137 samples were used in the evaluation. Of these, 65 samples had gross alpha, beta, and various radionuclides analyzed. Of the 65, 2 samples had gross alpha values not accounted for by the isotopic analyses, and 2 samples had gross beta values not accounted for. Two additional samples had gross beta values higher than isotopics (strontium-90 was not analyzed) but further sampling and analysis from the same location confirmed that strontium-90 was the isotope contributing to the gross beta. This review resulted in 97% (4 out of 13) completeness for surface water.

Evaluation of soil and sediment consisted of using the average gross alpha and beta background results as levels above which the evaluation should be performed. The average sediment background was 21.2 pCi/g gross alpha and 26.5 pCi/g gross beta. For soil samples, the background was 17.6 pCi/g alpha and 24.7C/g beta. All samples above this level were evaluated for completeness, which resulted in a 86% completeness for soil and sediment matrices.

#### 4A.6.5.3 Client laboratory generated data

Samples submitted for analysis at the client laboratory were analyzed for the parameters listed on the requests for analysis. No protocols were established for accounting of radionuclide contamination, as site history was used for the selection of requested radionuclide analyses. The request for analysis forms were unavailable, therefore an evaluation of completeness was not performed.

#### 4A.6.5.4 Conclusion

Sampling completeness was discussed in Section 4A.5.5, and found to be acceptable. Analytical completeness as defined by normal methods (valid/invalid data points) is not applicable for this review. However, an examination of reported gross alpha/beta values and corresponding isotopic results concluded that for all matrices 88% of the samples had a sufficient number of isotopic analyses to support the gross alpha and beta measurements. Alpha emitting isotopic determinations accounted for the majority of the 14% of samples with incomplete isotopic analyses.

### 4A.6.6. COMPARABILITY

#### 4A.6.6.1 Definition

Comparability is a measure of the degree of confidence to which data from different sources can be considered to be equivalent. The indicated level of comparability implies the ability to combine analytical results acquired from different sources.

Comparability for the radiological data was determined by examining procedures and techniques utilized by the laboratories. Methods of sample preparation, analytical determinations, units of measure, QA/QC protocols, and counting techniques were reviewed.

An additional measurement of comparability is the analysis of interlaboratory spikes. These spikes were prepared and analyzed by both laboratories providing data. Analysis of spikes can also be used as an indicator of laboratory accuracy. The results are summarized in Section 4A.5.4.

#### 4A.6.6.2 Methods

Both laboratories involved have extensive experience in analyzing samples for radiological constituents. For the routine parameters of gross alpha/beta, tritium, and gamma spectroscopy, industry established methods (EPA 900 series or Standard Methods) were followed or referenced in laboratory modified and validated procedures. The client laboratory data utilized for the Risk Assessment were for groundwater samples only. Therefore, the comparison of the client and subcontract laboratories methods will be confined to those for liquid matrices.

Comparability for sampling of radiological parameters is similar to that for the inorganic parameters and is discussed in Section 4A.5.4.

### 4A.6.6.3 Sample preparation methods

**Liquid samples.** Sample preparation methods used by each laboratory for liquid matrices were as specified in the EPA 900 series methods and were the same for gross determinations, gamma spectroscopy, tritium and strontium-90. All samples with the exception of those requiring tritium analysis were acidified on collection with nitric acid. Tritium samples were not preserved to avoid interference with the analytical method. Non-volatile alpha and beta emitters were prepared by reducing an aliquot volume by heating on a hot plate, and subsequently transferring the residue to a counting planchet for counting. Gamma spectroscopy sample preparation consisted of measuring a known volume into a special counting container and placing this directly on the detector. Tritium samples had an oxidizing agent added ($KMnO_4$) and were distilled prior to counting. Alpha isotopic sample preparation (except radium-226/228) consisted of acidification, ion exchange, selective removal of the radionuclides from the resin, and electrodeposition onto counting planchets. Radium and non-volatile beta emitters preparation consisted of chemical separations of the isotope of interest from other radionuclides. Tracer radionuclides or non-radioactive elements that behave similarly to the selected radionuclide during preparation were added to measure the separation process for both alpha and beta emitters similar to the use of surrogates for chemical analysis.

**Solid samples.** Solid samples prepared for analysis by the subcontract laboratory were treated as follows: Non-volatile alpha and beta emitters were dried and ground to a homogeneous particle size. A measured weight of the sample was then placed into counting vessels (planchets for gross alpha/beta, petri dishes or other standard containers for gamma spectroscopy) and counted. Tritium samples were leached with deionized water, filtered and counted. Samples for isotopic analyses were either dissolved in acids or leached with acid solutions. Following acid dissolution and leaching, the samples were handled as liquids and prepared for counting as described in the preceding section.

### 4A.6.6.4 Analytical and counting methods

Both laboratories used the following methods and counting techniques for analysis after sample preparation:

- Gross alpha/Beta - Gas flow proportional detectors
- Gamma Spectroscopy - Intrinsic germanium detectors
- Tritium - Liquid scintillation detectors
- Alpha isotopics - Surface barrier detectors
- Beta isotopics (other than low energy emitters)- Gas flow proportional detectors
- Low energy beta emitters - Liquid scintillation detectors

### 4A.6.6.5 Quality assurance/quality control

Standard radiochemistry counting techniques were utilized by each laboratory. These consisted of daily or more frequent background determinations, appraisal of instrument performance using NIST traceable sources, and maintaining control charts for each instrument. Standard radiochemistry control charts are used to measure instrument performance by comparing daily values with expected values and plotting on control charts for each instrument. If the daily value is within $\pm$ 2 sigma (standard deviations) of the expected value, the instrument is determined to be acceptable for use. Values outside of $\pm$ 2 sigma, but within $\pm$ 3 sigma are considered to be in a warning zone. Values outside of $\pm$ 3 sigma are considered out of control, and the instrument is not to be used for sample analysis until it is recalibrated and/or repaired.

Laboratory control samples were used by each laboratory to monitor the entire process of sample preparation and analysis. These control samples were prepared, analyzed and handled like regular samples throughout the analytical process.

Use of control chart by the subcontract laboratory is discussed in section 6.0. Control charts from the client laboratory were not available for review.

Performance evaluation (PE) samples were also received from the Environmental Measurements Support Laboratory - Las Vegas (EMSL-LV) and analyzed by the laboratories involved. These PE samples were submitted independently to the laboratories and analyzed routinely. The results were reported to EMSL-LV and the laboratories performance scored. These scores are discussed in Section 5.3.

### 4A.6.6.6 Units of measure

Radioisotopes are measured by determining the particle emission rates. Therefore, they are normally expressed in terms of decay rate, i.e., the rate at which the isotopes are disintegrating. These are normally expressed in disintegrations per minute (dpm) or per second (dps). The dps, or becquerel, is the SI unit of activity, and was used by the client laboratory for all radiochemistry determinations.

The curie, a commonly used unit, was the unit of measure reported for all samples analyzed by the subcontract laboratory. A curie is the quantity of any radioactive isotope equivalent to $3.7 \times 10^{10}$ dps. Naturally occurring (environmental)levels of radioactivity are measured at the picocurie (E-12 curies) level, and the conversion factor for becquerels to picocuries is 27.0.

All radiological data used in this report have been reported in or converted to picocuries.

### 4A.6.6.7 Interlaboratory spikes

Spiked laboratory deionized water and groundwater samples were prepared and sent to both laboratories for analysis identified as regular samples. Spikes were prepared for gross alpha and beta, gamma spectroscopy (cobalt-60 and cesium-137), and tritium. The relative percent differences (RPD) obtained by each laboratory are shown in Table 4A.40. These RPDs indicate good comparability between laboratories, with an overall RPD of less than 25%.

### 4A.6.6.8 Conclusion

Based on the criteria listed above, the radiological data utilized in this report were determined to be comparable. This includes comparability between data sources and nationally recognized sources.

# Appendix 4A Tables

**Table 4A.1. Matrix spike/matrix spike duplicate recovery and relative percent difference limits**

| Compound | Water recovery limits | Water RPD limits | Soil recovery limits | Soil RPD limits |
|---|---|---|---|---|
| **VOCS** | | | | |
| 1,1-Dichoroethene | (61-145) | 14 | (59-172) | 22 |
| Trichloroethene | (71-120) | 14 | (62-137) | 24 |
| Benzene | (76-127) | 11 | (66-142) | 21 |
| Toluene | (76-125) | 13 | (59-139) | 21 |
| Chlorobenzene | (75-130) | 13 | (60-133) | 21 |
| **SVOC Compounds** | | | | |
| Phenol | (12-89) | 42 | (26-90) | 35 |
| 2-Chlorophenol | (27-123) | 40 | (25-102) | 50 |
| 1,4-Dichlorobenzene | (36-97) | 28 | (28-104) | 27 |
| N-Nitroso-di-n-propylamine | (41-116) | 38 | (41-126) | 38 |
| 1,2,4-Trichlorobenzene | (39-98) | 28 | (38-107) | 23 |
| 4-Chloro-3-methylphenol | (23-97) | 42 | (26-103) | 33 |
| Acenaphthene | (46-118) | 31 | (31-137) | 19 |
| 4-Nitrophenol | (10-80) | 50 | (11-114) | 50 |
| 2,4-Dinitrotoluene | (24-96) | 38 | (28-89) | 47 |
| Pentachlorophenol | (9-103) | 50 | (17-109) | 47 |
| Pyrene | (26-127) | 31 | (35-142) | 36 |
| **Pest/PCB Compounds** | | | | |
| gamma-BHC (Lindane) | (56-123) | 15 | (46-127) | 50 |
| Heptachlor | (40-131) | 20 | (35-130) | 31 |
| Aldrin | (40-120) | 22 | (34-132) | 43 |
| Dieldrin | (52-126) | 18 | (31-134) | 38 |
| Endrin | (56-121) | 21 | (42-139) | 45 |
| 4-4'-DDT | (38-127) | 27 | (23-134) | 50 |

**Table 4A.2. Surrogate recovery limits**

| Surrogate | Water QC Limits (%) | Soil QC Limits |
|---|---|---|
| **VOC** | | |
| S1 (TOL)=Toluene-d8 | (88-110) | (81-117) |
| S2 (BFB)=Bromofluorobenzene | (86-115) | (74-12-) |
| S3 (DCE) 1, 2-Dichloroethane-d4 | (76-114) | (70-121) |
| **SVOC** | | |
| S1 (NBZ)=Nitrobenzene-d5 | (35-114) | (23-120) |
| S2 (FBP)=2-Fluorobiphenyl | (43-116) | (30-115) |
| S3 (TPH)=Terphenyl-d14 | (33-141) | (18-137) |
| S4 (PHL)=Phenol-d6 | (10-94) | (24-113) |
| S5 (2FP)=2-Fluorophenol | (21-100) | (25-121) |
| S6 (TBP)=2, 4,6-Tribromophenol | (10-123) | (19-122) |
| **Pesticides/PCB** | | |
| S1 (DBC)=Dibutylchlorendate | (24-154) | (24-150) |

**Table 4A.3. Holding time requirements for organic and inorganic analysis[a]**

| | Water | Soil |
|---|---|---|
| **Organics** | | |
| VOC | (Unpreserved) 7 days<br>(Preserved) 14 days | 14 days |
| SVOC | Extraction within 7 days;<br>Extract analyzed within 40 days | Extraction within 7 days;<br>Extract analyzed within 40 days |
| Pest/PCB | Extracted within 7 days;<br>Extract analyzed within 40 days | Extracted within 7 days;<br>Extract analyzed within 40 days |
| Chlorinated Herbicides | Extracted within 7 days;<br>Extract analyzed within 40 days | Extracted within 7 days;<br>Extract analyzed within 40 days |
| Organophosphorus Pesticides | Extracted within 7 days;<br>Extract analyzed within 40 days | Extracted within 7 days;<br>Extract analyzed within 40 days |
| Dioxins/Furans | Extraction within 7 days;<br>Extract analyzed within 40 days | Extraction within 7 days;<br>Extract analyzed within 40 days |
| Phenols | Extraction within 7 days;<br>Extract analyzed within 70 days | Extraction within 7 days;<br>Extract analyzed within 40 days |
| **Inorganics** | | |
| Metals | 6 months | 6 months |
| Mercury | 28 days | 28 days |
| Cyanide | 14 days | 14 days |
| **Miscellaneous Parameters** | | |
| Sulfide | 7 days | 7 days |
| TKN/$NH_3$ | 28 days | 28 days |
| Nitrate | 48 hours | 48 hours |
| Sulfate | 28 days | 28 days |
| Total Phosphate Phosphorus | 48 hours | 48 hours |
| TOX | 7 days | 7 days |
| TOC | 28 days | 28 days |
| Bicarbonate, as $CaCO_3$ | 14 days | 14 days |
| Carbonate as $CaCO_3$ | 14 days | 14 days |
| Total Dissolved Solids | 7 days | 7 days |
| BOD | 48 hours | 48 hours |
| COD | 28 days | 28 days |
| Fecal Coliform | 6 hours | 6 hours |
| Iodide | 48 hours | 48 hours |
| Bromide | 28 days | 28 days |
| Fluoride | 28 days | 28 days |
| Chloride | 28 days | 28 days |

[a] All sample holding times are determined from date of collection.

**Table 4A.4. Validation codes**

| CODE | DESCRIPTION |
|---|---|
| UN | Unvalidated |
| VI | Verified/Invalid |
| VV | Verified/Valid |
| VL | Verified/Limited Use |

REVIEWER VALIDATION QUALIFIERS FOR INORGANIC AND ORGANIC CHEMICAL DATA

| | |
|---|---|
| U | The material was analyzed for, but not detected. The associated numerical value is the SQL. |
| J | The associated numerical value is an estimated quantity. |
| R | Quality control indicates that the data are unusable (compound may or may not be present). Re-sampling and/or re-analysis is necessary for verification. |
| NJ | Presumptive evidence of material (tentative identification) at an estimated quantity. |
| UJ | The material was analyzed for, but was not detected. The associated value is an estimate and may be inaccurate or imprecise. |

**Table 4A.5. Quality control levels**

| | |
|---|---|
| Level I - | QC protocols, including instrument calibration, are as defined as standard practice in the analytical subcontractor's quality assurance manual and the appropriate laboratory-specific attachments. A minimum of fifteen percent QC samples (blank/spike/duplicate) for every analytical batch is required. Documentation of results is the Certificate of Analysis. |
| Level II - | Specific QC protocols, including instrument calibration, are as defined by the method selected. As a minimum, this includes Fifteen percent QC samples (blank, duplicate, spike, or duplicate spike) for every analytical batch. The results of all QC samples are reported in a QC summary report. For TCL samples, or samples for which CLP protocols are specified, this includes the CLP QC summary forms. Raw data are not included. |
| Level III - | QC protocols, including instrument calibration, are as defined by the US EPA CLP for TCL samples and samples for which CLP protocols are specified. For non-TCL analyses, which are not covered by the CLP Statements of Work, the QC program employed must meet the intent of the CLP. As a minimum, 20 percent QC samples for each analytical batch is required. QC data, including raw data, are reported in a CLP, or "CLP-like," data package. |

**Table 4A.6. Field duplicate precision (RPD)**

| | LIMIT (%) | IN | OUT | % IN LIMITS |
|---|---|---|---|---|
| **Soil/Sediment** | | | | |
| VOCs | 35 | 5 | 6 | 45 |
| SVOCs | 35 | 0 | 2 | 0 |
| Metals | 35 | 93 | 25 | 79 |
| Misc Parameters | 35 | 13 | 0 | 100 |
| **Groundwater** | | | | |
| VOCs | 20 | 16 | 13 | 55 |
| SVOCs | 20 | 1 | 3 | 25 |
| Metals, filtered | 20 | 58 | 41 | 59 |
| Metals, unfiltered | 20 | 92 | 47 | 66 |
| Misc Parameters | 20 | 22 | 20 | 52 |
| **Surface water** | | | | |
| VOCs | 20 | 14 | 7 | 67 |
| SVOCs | 20 | NA | NA | NA |
| Metals, filtered | 20 | 41 | 21 | 66 |
| Metals, unfiltered | 20 | 44 | 12 | 79 |
| Misc Parameters | 20 | 10 | 1 | 91 |

NA - compounds not detected in analysis, RPDs not available

**Table 4A.7. Water matrix spike/matrix spike duplicate precision (RPD), organics**

| | LIMIT (%) | IN | OUT | % IN LIMITS |
|---|---|---|---|---|
| **VOCs** | | | | |
| 1,1-Dichloroethene | 14 | 14 | 0 | 100 |
| Trichloroethene | 14 | 14 | 0 | 100 |
| Benzene | 11 | 14 | 0 | 100 |
| Toluene | 13 | 14 | 0 | 100 |
| Chlorobenzene | 13 | 14 | 0 | 100 |
| **SVOCs** | | | | |
| Phenol | 42 | 10 | 0 | 100 |
| 2-Chlorophenol | 40 | 10 | 0 | 100 |
| 1,4-Dichlorobenzene | 28 | 9 | 1 | 90 |
| N-Nitroso-di-n-propylamine | 38 | 10 | 0 | 100 |
| 1,2,4-Trichlorobenzene | 28 | 10 | 0 | 100 |
| 4-Chloro-3-methylphenol | 42 | 10 | 0 | 100 |
| Acenaphthene | 31 | 10 | 0 | 100 |
| 4-Nitrophenol | 50 | 10 | 0 | 100 |
| 2,4-Dinitrotoluene | 38 | 10 | 0 | 100 |
| Pentachlorophenol | 50 | 8 | 2 | 80 |
| Pyrene | 31 | 10 | 0 | 100 |
| **PEST/PCB** | | | | |
| gamma-BHC (Lindane) | 15 | 7 | 0 | 100 |
| Heptachlor | 20 | 7 | 0 | 100 |
| Aldrin | 22 | 7 | 0 | 100 |
| Dieldrin | 18 | 7 | 0 | 100 |
| Endrin | 21 | 7 | 0 | 100 |
| 4-4'-DDT | 27 | 7 | 0 | 100 |
| Silvex | 20 | 1 | 0 | 100 |

**Table 4A.8. Soil matrix spike/matrix spike duplicate precision (RPD), organics**

| | LIMIT (%) | IN | OUT | % IN LIMITS |
|---|---|---|---|---|
| **VOCs** | | | | |
| 1,1-Dichloroethene | 22 | 12 | 0 | 100 |
| Trichloroethene | 24 | 12 | 0 | 100 |
| Benzene | 21 | 12 | 0 | 100 |
| Toluene | 21 | 12 | 0 | 100 |
| Chlorobenzene | 21 | 12 | 0 | 100 |
| **SVOCs** | | | | |
| Phenol | 35 | 12 | 1 | 92 |
| 2-Chlorophenol | 50 | 12 | 1 | 92 |
| 1,4-Dichlorobenzene | 27 | 12 | 1 | 92 |
| N-Nitroso-di-n-propylamine | 38 | 11 | 1 | 92 |
| 1,2,4-Trichlorobenzene | 23 | 10 | 3 | 77 |
| 4-Chloro-3-methylphenol | 33 | 11 | 2 | 85 |
| Acenaphthene | 19 | 10 | 3 | 77 |
| 4-Nitrophenol | 50 | 12 | 1 | 92 |
| 2,4-Dinitrotoluene | 47 | 12 | 1 | 92 |
| Pentachlorophenol | 47 | 12 | 1 | 92 |
| Pyrene | 36 | 12 | 1 | 92 |
| **PEST/PCB** | | | | |
| gamma-BHC (Lindane) | 50 | 20 | 1 | 95 |
| Heptachlor | 31 | 17 | 4 | 81 |
| Aldrin | 43 | 18 | 3 | 86 |
| Dieldrin | 38 | 18 | 3 | 86 |
| Endrin | 45 | 18 | 3 | 86 |
| 4-4'-DDT | 50 | 20 | 1 | 95 |

**Table 4A.9. Water matrix spike/matrix spike duplicate precision (RPD), inorganics**

| | Limit (%) | In | Out | % in limits |
|---|---|---|---|---|
| **METALS** | | | | |
| Aluminum | 20 | 18 | 9 | 67 |
| Antimony | 20 | 10 | 1 | 91 |
| Barium | 20 | 24 | 6 | 80 |
| Beryllium | 20 | 18 | 3 | 86 |
| Cadmium | 20 | 14 | 8 | 64 |
| Calcium | 20 | 19 | 3 | 86 |
| Chromium | 20 | 22 | 2 | 92 |
| Cobalt | 20 | 12 | 2 | 86 |
| Copper | 20 | 16 | 1 | 94 |
| Iron | 20 | 18 | 11 | 62 |
| Magnesium | 20 | 14 | 6 | 70 |
| Manganese | 20 | 19 | 9 | 68 |
| Nickel | 20 | 12 | 4 | 75 |
| Silver | 20 | 10 | 6 | 63 |
| Sodium | 20 | 19 | 2 | 90 |
| Vanadium | 20 | 15 | 4 | 79 |
| Zinc | 20 | 22 | 8 | 73 |
| Arsenic | 20 | 21 | 2 | 91 |
| Lead | 20 | 25 | 8 | 76 |
| Selenium | 20 | 17 | 8 | 68 |
| Thallium | 20 | 18 | 1 | 95 |
| Mercury | 20 | 9 | 3 | 75 |
| Potassium | 20 | 9 | 2 | 82 |
| Boron | 20 | 1 | 0 | 100 |
| Osmium | 20 | 1 | 0 | 100 |
| Tin | 20 | 0 | 1 | 0 |
| **OTHER** | | | | |
| IC Anions | 20 | 76 | 2 | 97 |
| Misc Parameters | 20 | 46 | 3 | 94 |

**Table 4A.10. Soil matrix spike/matrix spike duplicate precision (RPD), inorganics**

| | LIMIT (%) | IN | OUT | % IN LIMITS |
|---|---|---|---|---|
| **METALS** | | | | |
| Aluminum | 35 | 8 | 0 | 100 |
| Antimony | 35 | NA | NA | NA |
| Barium | 35 | 8 | 0 | 100 |
| Beryllium | 35 | 8 | 0 | 100 |
| Cadmium | 35 | 8 | 0 | 100 |
| Calcium | 35 | 8 | 0 | 100 |
| Chromium | 35 | 8 | 0 | 100 |
| Cobalt | 35 | 8 | 0 | 100 |
| Copper | 35 | 8 | 0 | 100 |
| Iron | 35 | 8 | 0 | 100 |
| Magnesium | 35 | 8 | 0 | 100 |
| Manganese | 35 | 7 | 1 | 88 |
| Nickel | 35 | 8 | 0 | 100 |
| Silver | 35 | 1 | 1 | 50 |
| Sodium | 35 | 6 | 2 | 75 |
| Vanadium | 35 | 8 | 0 | 100 |
| Zinc | 35 | 8 | 0 | 100 |
| Arsenic | 35 | 8 | 0 | 100 |
| Lead | 35 | 7 | 1 | 88 |
| Selenium | 35 | 1 | 1 | 50 |
| Thallium | 35 | 4 | 0 | 100 |
| Mercury | 35 | 4 | 1 | 80 |
| Potassium | 35 | 7 | 0 | 100 |
| Boron | 35 | NA | NA | NA |
| Osmium | 35 | NA | NA | NA |
| Tin | 35 | NA | NA | NA |
| **OTHER** | | | | |
| Misc Parameters | 35 | 4 | 0 | 100 |

NA - compounds not used in matrix spike, RPDs not available

**Table 4A.11. Water organic accuracy (surrogate recovery)**

| | LIMITS (%) | IN | OUT | % IN LIMITS |
|---|---|---|---|---|
| **VOCs** | | | | |
| S1=Toluene-d8 | 88-110 | 102 | 0 | 100 |
| S2= Bromofluorobenzene | 86-115 | 101 | 0 | 100 |
| S3=1,2-Dichloroethane-d4 | 76-114 | 101 | 0 | 100 |
| **SVOCs** | | | | |
| S1=Nitrobenzene-d5 | 35-114 | 57 | 1 | 98 |
| S2=2-Fluorobiphenyl | 43-116 | 57 | 1 | 98 |
| S3=Terphenyl-d14 | 33-141 | 54 | 4 | 93 |
| S4=Phenol-d6 | 10-123 | 50 | 8 | 86 |
| S5=2-Fluorophenol | 21-100 | 45 | 13 | 78 |
| S6=2,4,6-Tribromophenol | 10-123 | 50 | 8 | 86 |
| **PEST/PCBs** | | | | |
| S1=Dibutylchlorendate | 24-154 | 21 | 3 | 88 |

**Table 4A.12. Soil organic accuracy (surrogate recovery)**

| | LIMITS (%) | IN | OUT | % IN LIMITS |
|---|---|---|---|---|
| **VOCs** | | | | |
| S1=Toluene-d8 | 84-138 | 66 | 0 | 100 |
| S2= Bromofluorobenzene | 59-113 | 65 | 1 | 98 |
| S3=1,2-Dichloroethane-d4 | 70-121 | 57 | 1 | 98 |
| **SVOCs** | | | | |
| S1=Nitrobenzene-d5 | 23-120 | 54 | 1 | 98 |
| S2=2-Fluorobiphenyl | 30-115 | 54 | 1 | 98 |
| S3=Terphenyl-d14 | 18-137 | 52 | 3 | 95 |
| S4=Phenol-d6 | 24-113 | 54 | 1 | 98 |
| S5=2-Fluorophenol | 25-121 | 54 | 1 | 98 |
| S6=2,4,6-Tribromophenol | 19-122 | 54 | 1 | 98 |
| **PEST/PCBs** | | | | |
| S1=Dibutylchlorendate | 24-150 | 37 | 30 | 55 |

**Table 4A.13. Water organic accuracy (matrix spike recovery)**

| | LIMITS (%) | IN | OUT | % IN LIMITS |
|---|---|---|---|---|
| **VOCs** | | | | |
| 1,1-Dichloroethene | 61-145 | 26 | 2 | 93 |
| Trichloroethene | 71-120 | 28 | 0 | 100 |
| Benzene | 76-127 | 28 | 0 | 100 |
| Toluene | 76-125 | 28 | 0 | 100 |
| Chlorobenzene | 75-130 | 28 | 0 | 100 |
| **SVOCs** | | | | |
| Phenol | 12-110 | 20 | 0 | 100 |
| 2-Chlorophenol | 27-123 | 20 | 0 | 100 |
| 1,4-Dichlorobenzene | 36-97 | 18 | 2 | 90 |
| N-Nitroso-di-n-propylamine | 41-116 | 19 | 1 | 95 |
| 1,2,4-Trichlorobenzene | 39-98 | 19 | 1 | 95 |
| 4-Chloro-3-methylphenol | 23-97 | 20 | 1 | 95 |
| Acenaphthene | 46-118 | 19 | 1 | 95 |
| 4-Nitrophenol | 10-80 | 18 | 2 | 90 |
| 2,4-Dinitrotoluene | 24-96 | 20 | 0 | 100 |
| Pentachlorophenol | 9-103 | 17 | 3 | 85 |
| Pyrene | 26-127 | 16 | 4 | 80 |
| **PEST/PCB** | | | | |
| gamma-BHC (Lindane) | 56-123 | 14 | 0 | 100 |
| Heptachlor | 40-131 | 14 | 0 | 100 |
| Aldrin | 40-120 | 14 | 0 | 100 |
| Dieldrin | 52-126 | 14 | 0 | 100 |
| Endrin | 56-121 | 14 | 0 | 100 |
| 4-4'-DDT | 38-127 | 13 | 1 | 93 |
| Silvex | 75-125 | 2 | 0 | 100 |

**Table 4A.14. Soil organic accuracy (matrix spike recovery)**

| | LIMITS (%) | IN | OUT | % IN LIMITS |
|---|---|---|---|---|
| **VOCs** | | | | |
| 1,1-Dichloroethene | 59-172 | 22 | 2 | 92 |
| Trichloroethene | 62-137 | 24 | 0 | 100 |
| Benzene | 66-142 | 24 | 0 | 100 |
| Toluene | 59-139 | 24 | 0 | 100 |
| Chlorobenzene | 60-133 | 24 | 0 | 100 |
| **SVOCs** | | | | |
| Phenol | 26-90 | 25 | 1 | 96 |
| 2-Chlorophenol | 25-102 | 25 | 1 | 96 |
| 1,4-Dichlorobenzene | 28-104 | 23 | 3 | 88 |
| N-Nitroso-di-n-propylamine | 41-126 | 22 | 2 | 92 |
| 1,2,4-Trichlorobenzene | 38-107 | 21 | 5 | 81 |
| 4-Chloro-3-methylphenol | 26-103 | 25 | 1 | 96 |
| Acenaphthene | 31-137 | 25 | 1 | 96 |
| 4-Nitrophenol | 11-114 | 18 | 8 | 69 |
| 2,4-Dinitrotoluene | 28-89 | 21 | 5 | 81 |
| Pentachlorophenol | 17-109 | 15 | 11 | 58 |
| Pyrene | 35-142 | 22 | 4 | 85 |
| **PEST/PCB** | | | | |
| gamma-BHC (Lindane) | 46-127 | 35 | 7 | 83 |
| Heptachlor | 35-130 | 37 | 5 | 88 |
| Aldrin | 34-132 | 38 | 4 | 90 |
| Dieldrin | 31-134 | 40 | 2 | 95 |
| Endrin | 42-139 | 38 | 4 | 90 |
| 4-4'-DDT | 23-134 | 36 | 6 | 86 |

**Table 4A.15. Water inorganic accuracy (matrix spike recovery)**

| | LIMITS (%) | IN | OUT | % IN LIMITS |
|---|---|---|---|---|
| **METALS** | | | | |
| Aluminum | 75-125 | 32 | 7 | 82 |
| Antimony | 75-125 | 32 | 9 | 78 |
| Barium | 75-125 | 41 | 0 | 100 |
| Beryllium | 75-125 | 40 | 1 | 98 |
| Cadmium | 75-125 | 39 | 2 | 95 |
| Calcium | 75-125 | NA | NA | NA |
| Chromium | 75-125 | 39 | 2 | 95 |
| Cobalt | 75-125 | 40 | 1 | 98 |
| Copper | 75-125 | 38 | 3 | 93 |
| Iron | 75-125 | 30 | 9 | 77 |
| Magnesium | 75-125 | NA | NA | NA |
| Manganese | 75-125 | 34 | 5 | 87 |
| Nickel | 75-125 | 41 | 0 | 100 |
| Silver | 75-125 | 19 | 22 | 46 |
| Sodium | 75-125 | NA | NA | NA |
| Vanadium | 75-125 | 40 | 0 | 100 |
| Zinc | 75-125 | 34 | 1 | 97 |
| Arsenic | 75-125 | 52 | 5 | 91 |
| Lead | 75-125 | 44 | 10 | 81 |
| Selenium | 75-125 | 33 | 24 | 58 |
| Thallium | 75-125 | 50 | 7 | 88 |
| Mercury | 75-125 | 27 | 6 | 82 |
| Potassium | 75-125 | NA | NA | NA |
| Boron | 75-125 | 1 | 0 | 100 |
| Osmium | 75-125 | 1 | 1 | 50 |
| Tin | 75-125 | 2 | 0 | 100 |
| **OTHER** | | | | |
| IC Anions | 75-125 | 147 | 3 | 98 |
| Misc Parameters | 75-125 | 27 | 0 | 100 |

NA - matrix spike information for these compounds not available

**Table 4A.16. Soil inorganics accuracy (matrix spike recovery)**

| | Limits (%) | In | Out | % in limits |
|---|---|---|---|---|
| **METALS** | | | | |
| Aluminum | 75-125 | NA | NA | NA |
| Antimony | 75-125 | 1 | 3 | 25 |
| Barium | 75-125 | 8 | 0 | 100 |
| Beryllium | 75-125 | 8 | 0 | 100 |
| Cadmium | 75-125 | 6 | 2 | 75 |
| Calcium | 75-125 | NA | NA | NA |
| Chromium | 75-125 | 7 | 1 | 88 |
| Cobalt | 75-125 | 8 | 0 | 100 |
| Copper | 75-125 | 8 | 0 | 100 |
| Iron | 75-125 | NA | NA | NA |
| Magnesium | 75-125 | NA | NA | NA |
| Manganese | 75-125 | 3 | 5 | 38 |
| Nickel | 75-125 | 8 | 0 | 100 |
| Silver | 75-125 | 2 | 2 | 50 |
| Sodium | 75-125 | NA | NA | NA |
| Vanadium | 75-125 | 8 | 0 | 100 |
| Zinc | 75-125 | 8 | 0 | 100 |
| Arsenic | 75-125 | 4 | 4 | 50 |
| Lead | 75-125 | 3 | 5 | 38 |
| Selenium | 75-125 | 0 | 8 | 0 |
| Thallium | 75-125 | 6 | 2 | 75 |
| Mercury | 75-125 | 5 | 3 | 63 |
| Potassium | 75-125 | NA | NA | NA |
| Boron | 75-125 | NA | NA | NA |
| Osmium | 75-125 | NA | NA | NA |
| Tin | 75-125 | NA | NA | NA |
| **OTHER** | | | | |
| Misc Parameters | 75-125 | 12 | 2 | 86 |

NA - matrix spike information for these compounds not available

**Table 4A.17. Compounds detected in QC samples[a]**

| QC Sample No. | QC Sample Date | QC Sample Type | Compound Detected | QC Sample Result | Associated Regular Samples | Regular Sample Results |
|---|---|---|---|---|---|---|
| **Groundwater** | | | | | | |
| 12251 | 09-JUN-89 | Field Blank | 2-Butanone | 25J | 1229 | 2J |
| 12251 | 09-JUN-89 | Field Blank | Vinyl Chloride | 14 | 1233 | 79J |
| 12332 | 10-MAY-89 | Field Blank | Tetrachloroethene | 14J | 12331 | 4700J |
| | | | | | 1233 | 4900 |
| 12232 | 10-MAY-89 | Field Blank | Vinyl Chloride | 12 | 12331 | 56J |
| 853B | 29-AUG-89 | Field Blank | Vinyl Chloride | 6J | 849 | 22J |
| | | | | | 8492 | 17J |
| 8541 | 11-MAY-89 | Field Blank | Benzene | 2J | 849 | 3J |
| | | | | | 852 | 14J |
| 8541 | 11-MAY-89 | Field Blank | Vinyl Chloride | 6J | 849 | 31J |
| 8541 | 11-MAY-89 | Field Blank | Methylene Chloride | 21J | 852 | 13J |
| | | | | | 853 | 25J |
| 8541 | 11-MAY-89 | Field Blank | 1,1-Dichloroethene | 2J | 849 | 1J |
| 8541 | 11-MAY-89 | Field Blank | Trichloroethene | 2J | 849 | 1300J |
| **Surface Water** | | | | | | |
| BBAB | 09-JUN-89 | Field Blank | Vinyl Chloride | 10J | WFBB2[b] | 11 |
| | | | | | WSP1 | 1J |
| 9547 | 21-MAY-90 | Rinseates | 4-Methyl 2-Pentanone | 84 | 054908[c] | 1J |
| W51TS | 18-APR-89 | Field Blank | bis(2-Ethylhexyl)phthalate | 4J | W49TS[d] | 2J |

[a]Field blanks and rinseates only.
[b]Associated sample locations; WFBB2 and WSP1
[c]Associated sample locations; FB
[d]Associated sample location; W49TS

**Table 4A.18. Sample types, containers, and preservatives for water and soil samples**

| Sample Type | Analysis | Container | Filtered | Preservation |
|---|---|---|---|---|
| Water | Inorganic Chemicals<br>- Anions | Two 1-liter polyethylene bottles | No | Iced to 4°C |
| | • Nitrate | One 1-liter polyethylene bottle | No | Iced to 4°C |
| | • Sulfide | One 1-liter polyethylene bottle | No | Iced to 4°C - Zinc acetate plus sodium hydroxide to pH > 9 |
| | - TKN, TOC, Nitrate and Nitrite | One 1-liter polyethylene bottle | No | $H_2SO_4$ to pH < 2; Iced to 4°C |
| | - TDS | One 1-liter polyethylene bottle | No | Iced to 4°C |
| | Radiological | One 1-gallon polyethylene bottle | Yes | $HNO_3$ to pH < 2 |
| | Semi Volatiles | One 1-gallon amber glass jar | No | Iced to 4°C |
| | Volatiles | Two 40-ml teflon lined glass (VOA) vials | No | Iced to 4°C |
| | Dioxins | Two 1-liter amber glass jars | No | Iced to 4°C<br>0.008% $Na_2S_2O_3$ |
| | Metals | One 1-liter polyethylene bottle | No | $HNO_3$ to pH < 2<br>Iced to 4°C |
| | Cyanides | One 1-liter polyethylene bottle | No | NaOH to pH < 12<br>Iced to 4°C |
| | Pesticides/PCBs/Herbicides | One 1/2-gallon amber glass jar | No | Iced to 4°C |
| | Other<br>- COD | One 1-liter polyethylene bottle | No | $H_2SO_4$ to pH < 2<br>Iced to 4°C |
| | - BOD | One 2-liter polyethylene bottle | No | Iced to 4°C |
| | - Coliform | One 1-liter polyethylene bottle | No | Iced to 4°C |
| | - Fecal Streptococci | One 1-liter polyethylene bottle | No | Iced to 4°C |
| Soils | TCL Metals, Semi-Volatile Organics, Pesticides/PCBs/Herbicides; Cyanide | One 1-liter teflon lined wide-mouth glass jar | No | Iced to 4°C |
| | TCL Volatile Organics | One 40-ml teflon lined VOA vial | No | Iced to 4°C |
| | Radiological | One 1-liter teflon lined wide mouth glass jar | No | Iced to 4°C |

**Table 4A.19. Comparison of analytical methods, RDLs, and reporting units, WAG 6 groundwater samples**

| Analyte | Analytical Subcontractor | | | ORNL | | |
|---|---|---|---|---|---|---|
| | Method | RDL (μg/L) | Reporting Units | Method | RDL (μg/L) | Reporting Units |
| TOX | | | | 9020 | 5 | ug/L |
| TOC | | | | 9060 | 1000 | mg/L |
| Endrin | 8080 | 10 | ug/L | 8080 | 0.2 | ug/L |
| Lindane | 8080 | 0.05 | ug/L | 8080 | 2 | ug/L |
| Methoxychlor | 8080 | 2 | ug/L | 8080 | 8 | ug/L |
| Toxaphene | 8080 | 2 | ug/L | 8080 | 5 | ug/L |
| 2,4-D | 8015 | 10 | ug/L | 8150, 83XX | 10 | ug/L |
| 2,4,5-TP (Silvex) | 8015 | 2 | ug/L | 8150, 83XX | 10 | ug/L |
| Chloride | | | | 300.0, 325.1, 325.2 | 1000 | mg/L |
| Fluoride | | | | 300.1, 340.1, 340.2, 340.3 | 1000 | mg/L |
| Nitrate (as N) | | | | 300.0, 353.2 | 5000 | mg/L |
| Sulfate | | | | 300.0, 375.1, 375.2, 375.3 | 5000 | mg/L |
| Phenols | | | | 420.1 | Refer. | ug/L |
| Coliform | | | | 909c | 1 colony/ 100 mL | Colonies/ 100 mL |
| Turbidity | | | | 180.1 | 0.1 NTU | NTU |
| Gross Alpha | | | | 900.0 | 0.30 | Bq/L |
| Gross Beta | | | | 900.0 | 0.12 | Bq/L |
| Radium | | | | 903.3 | 0.05 | Bq/L |
| Gamma Scan | | | | 901.1 | "Refer. | Bq/L |
| Total Strontium | | | | 905.0 | 0.12 | Bq/L |
| Tritium | | | | 906.0 | 200 | Bq/L |
| Aldrin | 8080 | 0.05 | ug/L | 608 | 0.05 | ug/L |
| Alpha BHC | 8080 | 0.05 | ug/L | 608 | 0.05 | ug/L |
| Beta BHC | 8080 | 0.05 | ug/L | 608 | 0.05 | ug/L |
| Delta BHC | 8080 | 0.10 | ug/L | 608 | 0.05 | ug/L |
| Chlordane | 8080 | 0.10 | ug/L | 608 | 0.05 | ug/L |
| 4,4'-DDD | 8080 | 0.10 | ug/L | 608 | 0.10 | ug/L |
| 4,4'-DDE | 8080 | 0.005 | ug/L | 608 | 0.10 | ug/L |
| 4,4'-DDT | 8080 | 0.10 | ug/L | 608 | 0.10 | ug/L |
| Dieldrin | 8080 | 0.05 | ug/L | 608 | 0.10 | ug/L |
| Heptachlor | 8080 | 0.05 | ug/L | 608 | 0.05 | ug/L |
| Heptachlor Epoxide | 8080 | 1.0 | ug/L | 608 | 0.5 | ug/L |
| Endosulfan I | 8080 | 0.10 | ug/L | 608 | 0.5 | ug/L |
| Endosulfan II | 8080 | 0.05 | ug/L | 608 | 0.10 | ug/L |
| Endosulfan Sulfate | 8080 | 0.5 | ug/L | 608 | 0.10 | ug/L |

Table 4A.19. (continued)

| Analyte | Analytical Subcontractor | | | ORNL | | |
|---|---|---|---|---|---|---|
| | Method | RDL (μg/L) | Reporting Units | Method | RDL (μg/L) | Reporting Units |
| Endrin Ketone | 8080 | 0.20 | ug/L | 608 | 0.10 | ug/L |
| Aroclor-1016 | 8080 | 0.5 | ug/L | 608 | 0.5 | ug/L |
| Aroclor-1221 | 8080 | 0.5 | ug/L | 608 | 0.5 | ug/L |
| Aroclor-1232 | 8080 | 0.5 | ug/L | 608 | 0.5 | ug/L |
| Aroclor-1242 | 8080 | 0.5 | ug/L | 608 | 0.5 | ug/L |
| Aroclor-1248 | 8080 | 0.5 | ug/L | 608 | 0.5 | ug/L |
| Aroclor-1254 | 8080 | 1.0 | ug/L | 608 | 1.0 | ug/L |
| Aroclor-1260 | 8080 | 1.0 | ug/L | 608 | 1.0 | ug/L |
| Aluminum | | | | 200.7 | 200 | |
| Antimony | 6010 | 300 | mg/L | | | |
| Antimony | 7041 | 30 | mg/L | 200.7 | 150 | |
| Arsenic | 7060 | 10 | mg/L | 7060 | 10 | mg/L |
| Arsenic | 7061 | 20 | mg/L | 200.7 | 250 | |
| Barium | 6010 | 20 | mg/L | 7080 | 1000 | mg/L |
| Barium | 7080 | 1000 | mg/L | 200.7 | 200 | |
| Beryllium | 6010 | 3 | mg/L | 200.7 | 5 | |
| Cadmium | 6010 | 40 | mg/L | 7131 | 2 | mg/L |
| Cadmium | 7131 | 1 | mg/L | 200.7 | 20 | |
| Calcium | | | | 200.7 | 2000 | |
| Chromium | 6010 | 70 | mg/L | 7191 | 20 | mg/L |
| Chromium | 7191 | 10 | mg/L | 200.7 | 10 | |
| Cobalt | 6010 | 70 | mg/L | | | |
| Cobalt | 7201 | 10 | mg/L | 200.7 | 50 | |
| Copper | 6010 | 60 | mg/L | | | |
| Copper | 7210 | 200 | mg/L | 200.7 | 25 | |
| Iron | | | | 7381 | 50 | mg/L |
| Iron | | | | 200.7 | 100 | |
| Lead | 6010 | 40 | mg/L | 7421 | 20 | mg/L |
| Lead | 7421 | 1000 | mg/L | 200.7 | 100 | |
| Magnesium | | | | 200.7 | 5000 | |
| Manganese | | | | 7461 | 10 | mg/L |
| Manganese | | | | 200.7 | 15 | |
| Mercury | 7470 | 2 | mg/L | 7470 | 0.2 | mg/L |
| Mercury | | | | 200.7 | NR | |
| Nickel | 6010 | 50 | mg/L | 200.7 | 40 | |
| Nickel | 7520 | 400 | mg/L | | | |
| Potassium | | | | 200.7 | 5000 | |
| Selenium | 6010 | 750 | mg/L | 7741 | 5 | mg/L |
| Selenium | 7740 | 20 | mg/L | 200.7 | 400 | |
| Silver | 6010 | 70 | mg/L | 7761 | 5 | mg/L |
| Silver | 7760 | 100 | mg/L | 200.7 | 30 | |
| Sodium | | | | 7770 | 1000 | mg/L |

Table 4A.19. (continued)

| Analyte | Analytical Subcontractor | | | ORNL | | |
|---|---|---|---|---|---|---|
| | Method | RDL (μg/L) | Reporting Units | Method | RDL (μg/L) | Reporting Units |
| Sodium | | | | 200.7 | 5000 | |
| Thallium | 6010 | 400 | mg/L | 200.7 | 200 | |
| Thallium | 7841 | 10 | mg/L | | | |
| Vanadium | 6010 | 80 | mg/L | 200.7 | 50 | |
| Vanadium | 7910 | 2000 | mg/L | | | |
| Zinc | 6010 | 20 | mg/L | 200.7 | 20 | |
| Zinc | 7950 | 50 | mg/L | | | |
| | | | | | | |
| Chloromethane | 8240 | 10 | ug/L | 624 | 10 | ug/L |
| Bromomethane | 8240 | 10 | ug/L | 624 | 10 | ug/L |
| Vinyl Chloride | 8240 | 10 | ug/L | 624 | 10 | ug/L |
| Methylene Chloride | 8240 | 10 | ug/L | 624 | 5 | ug/L |
| 1,1-Dichloroethene | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| 1,1-Dichloroethane | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| 1,2-Dichloroethane | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| Chloroform | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| 1,2-Dichloroethene | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| 1,1,1-Trichloromethane | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| Carbon Tetrachloride | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| Bromodichloromethane | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| 1,2-Dichloropropane | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| Trans-1,3-Dichloropropene | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| Trichloroethene | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| Benzene | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| Dibromochloromethane | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| 1,1,2-Trichloromethane | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| Cis-1,3-Dichloropropene | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| Bromoform | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| 1,1,2,2-Tetrachloroethane | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| Toluene | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| Chlorobenzene | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| Ethylbenzene | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| Chloromethane | 8240 | 10 | ug/L | 624 | 10 | ug/L |
| Tetrachloroethene | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| Acetone | 8240 | 100 | ug/L | 624 | 10 | ug/L |
| 2-Butanone | 8240 | 100 | ug/L | 624 | 10 | ug/L |
| 2-Hexanone | 8240 | 50 | ug/L | 624 | 10 | ug/L |
| 4-methyl-2-pentanone | 8240 | 50 | ug/L | 624 | 10 | ug/L |
| Styrene | 8240 | 5 | ug/L | 624 | 5 | ug/L |
| Xylenes (total) | 8240 | 10 | ug/L | 624 | 5 | ug/L |
| | | | | | | |
| 2,6-Dinitrotoluene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Diethylphthalate | 8270 | 10 | ug/L | 625 | 10 | ug/L |

**Table 4A.19. (continued)**

| Analyte | Analytical Subcontractor | | | ORNL | | |
|---|---|---|---|---|---|---|
| | Method | RDL (μg/L) | Reporting Units | Method | RDL (μg/L) | Reporting Units |
| 4-Chlorophenyl Phenyl ether | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Fluorene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 4-Nitroaniline | 8270 | 50 | ug/L | 625 | 50 | ug/L |
| 4,6-Dinitro-2-methylphenol | 8270 | 50 | ug/L | 625 | 50 | ug/L |
| N-nitrosodiphenylamine | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 4-Bromophenyl Phenyl ether | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Hexachlorobenzene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Pentachlorophenol | 8270 | 50 | ug/L | 625 | 50 | ug/L |
| Phenanthrene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Anthracene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Di-n-butylphthalate | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Fluoranthene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Pyrene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Butyl Benzyl Phthalate | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 3,3-Dichlorobenzidine | 8270 | 20 | ug/L | 625 | 20 | ug/L |
| Benzo(a)anthracene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| bis(2-ethylhexyl)phthalate | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Chrysene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Di-n-octyl Phthalate | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Benzo(b)fluoranthene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Benzo(k)fluoranthene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Benzo(a)pyrene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Indeno(1,2,3-cd)pyrene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Dibenz(a,h)anthracene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Benzo(g,h,i)perylene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Phenol | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| bis(2-Chloroethyl)ether | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 2-Chlorophenol | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 1,3-Dichlorobenzene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 1,4-Dichlorobenzene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Benzyl Alcohol | 8270 | 20 | ug/L | 625 | 10 | ug/L |
| 1,2-Dichlorobenzene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 2-Methylphenol | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| bis(2-Chloroisopropyl)ether | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 4-Methylphenol | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| N-Nitroso-Dipropylamine | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Hexachloroethane | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Nitrobenzene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Isophorone | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 2-Nitrophenol | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 2,4-Dimethylphenol | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Benzoic Acid | 8270 | 50 | ug/L | 625 | 50 | ug/L |
| bis(2-Chloroethoxy)methane | 8270 | 10 | ug/L | 625 | 10 | ug/L |

Table 4A.19. (continued)

| Analyte | Analytical Subcontractor | | | ORNL | | |
|---|---|---|---|---|---|---|
| | Method | RDL (μg/L) | Reporting Units | Method | RDL (μg/L) | Reporting Units |
| 2,4-Dichlorophenol | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 1,2,4-Trichlorobenzene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Naphthalene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 4-Chloroaniline | 8270 | 20 | ug/L | 625 | 10 | ug/L |
| Hexachlorobutadiene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 4-Chloro-3-methylphenol | 8270 | 20 | ug/L | 625 | 10 | ug/L |
| 2-Methylnaphthalene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Hexachlorocyclopentadiene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 2,4,6-Trichlorophenol | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 2,4,5-Trichlorophenol | 8270 | 10 | ug/L | 625 | 50 | ug/L |
| 2-Chloronaphthalene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 2-Nitroaniline | 8270 | 50 | ug/L | 625 | 50 | ug/L |
| Dimethyl Phthalate | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| Acenaphthylene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 3-Nitroaniline | 8270 | 50 | ug/L | 625 | 50 | ug/L |
| Acenaphthene | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 2,4-Dinitrophenol | 8270 | 50 | ug/L | 625 | 50 | ug/L |
| 4-Nitrophenol | 8270 | 50 | ug/L | 625 | 10 | ug/L |
| Dibenzofuran | 8270 | 10 | ug/L | 625 | 10 | ug/L |
| 2,4-Dinitrotoluene | 8270 | 10 | ug/L | 625 | 10 | ug/L |

Table 4A.20. Invalid laboratory data WAG 6 sediment

| LOCATION | SAMPLE NUMBER | DATA TYPE | SAMPLE TYPE | CASNO | COMPOUND | RESULT | UNITS | LAB QUAL | REV QUAL | VA CO |
|---|---|---|---|---|---|---|---|---|---|---|
| EWB01 | 019102 | 2 | REGULAR | 7440-36-0 | Antimony | 6.3 | mG/kg | UN | R | VI |
| EWB02 | 019207 | 2 | REGULAR | 7440-36-0 | Antimony | 7.9 | mG/kg | UN | R | VI |
| EWB04 | 019404 | 2 | REGULAR | 7440-36-0 | Antimony | 6.3 | mG/kg | UN | R | VI |
| EWB05 | 019305 | 2 | REGULAR | 7440-36-0 | Antimony | 7.9 | mG/kg | UN | R | VI |
| EWB06 | 019003 | 2 | REGULAR | 7439-92-1 | Lead | 22.4 | mG/kg | N* | R | VI |
| EWB06 | 019003 | 2 | REGULAR | 7782-49-2 | Selenium | .48 | mG/kg | UN | R | VI |
| EWB06 | 019003 | 2 | REGULAR | 7440-36-0 | Antimony | 6 | mG/kg | UN | R | VI |
| EWB07 | 024205 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 12 | uG/kg | U | R | VI |
| EWB07 | 024204 | 2 | REGULAR | 7440-36-0 | Antimony | 3.7 | mG/kg | UN | R | VI |
| EWB08 | 024304 | 2 | REGULAR | 7440-36-0 | Antimony | 4 | mG/kg | UN | R | VV |
| EWB08 | 024305 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 13 | uG/kg | U | R | VI |
| EWB09 | 018803 | 2 | REGULAR | 7782-49-2 | Selenium | .48 | mG/kg | UN | R | VI |
| EWB09 | 018803 | 2 | REGULAR | 7440-36-0 | Antimony | 6 | mG/kg | UN | R | VI |
| EWB10 | 024105 | 2 | REGULAR | 7440-36-0 | Antimony | 4.2 | mG/kg | UN | R | VI |
| EWB10 | 024103 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 13 | uG/kg | U | R | VI |
| EWB14 | 021710 | 2 | REGULAR | 7440-36-0 | Antimony | 6.1 | mG/kg | UN | R | VI |
| EWB15 | 024004 | 2 | REGULAR | 7440-36-0 | Antimony | 4.6 | mG/kg | UN | R | VI |
| EWB15 | 024002 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 13 | uG/kg | U | R | VI |
| EWB16 | 018603 | 2 | REGULAR | 7440-36-0 | Antimony | 5.5 | mG/kg | UN | R | VI |
| EWB16 | 018603 | 2 | REGULAR | 7782-49-2 | Selenium | .37 | mG/kg | UN | R | VI |
| EWB17 | 018502 | 2 | REGULAR | 7440-36-0 | Antimony | 5.8 | mG/kg | UN | R | VI |
| EWB17 | 018502 | 2 | REGULAR | 7782-49-2 | Selenium | .44 | mG/kg | UWN | R | VI |
| EWB18 | 019603 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 12 | uG/kg | U | R | VI |
| EWB18 | 019606 | 2 | REGULAR | 7440-36-0 | Antimony | 3.5 | mG/kg | U | R | VI |
| EWB19 | 023904 | 2 | REGULAR | 7440-36-0 | Antimony | 3.7 | mG/kg | UN | R | VI |
| EWB19 | 023905 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 12 | uG/kg | U | R | VI |
| SWA1 | 021511 | 2 | FIELD DUP | 7440-36-0 | Antimony | 6.2 | mG/kg | UN | R | VI |
| SWA1 | 021412 | 2 | REGULAR | 7440-36-0 | Antimony | 7.2 | mG/kg | UN | R | VI |
| SWB1 | 018102 | 2 | REGULAR | 7440-36-0 | Antimony | 5.5 | mG/kg | UN | R | VI |
| SWB1 | 018002 | 2 | FIELD DUP | 7782-49-2 | Selenium | .46 | mG/kg | UWN | R | VI |
| SWB1 | 018102 | 2 | REGULAR | 7440-22-4 | Silver | 1.8 | mG/kg | UN* | R | VI |
| SWB1 | 018002 | 2 | FIELD DUP | 7440-36-0 | Antimony | 7.8 | mG/kg | UN | R | VI |
| SWB1 | 018002 | 2 | FIELD DUP | 7440-22-4 | Silver | 2.6 | mG/kg | UN* | R | VI |
| SWB1 | 018102 | 2 | REGULAR | 7782-49-2 | Selenium | .37 | mG/kg | UWN | R | VI |
| SWC1 | 018302 | 2 | REGULAR | 7782-49-2 | Selenium | .52 | mG/kg | UWN | R | VI |
| SWC1 | 018302 | 2 | REGULAR | 7440-22-4 | Silver | 2.3 | mG/kg | UN* | R | VI |
| SWC1 | 018302 | 2 | REGULAR | 7440-36-0 | Antimony | 6.8 | mG/kg | UN | R | VI |
| W49TN | 017803 | 2 | REGULAR | 7440-36-0 | Antimony | 6.6 | mG/kg | UN | R | VI |
| W49TN | 017803 | 2 | REGULAR | 7782-49-2 | Selenium | .43 | mG/kg | UWN | R | VI |
| W49TS | 017006 | 2 | REGULAR | 7782-49-2 | Selenium | .51 | mG/kg | UWN | R | VI |
| W49TS | 017006 | 2 | REGULAR | 7440-36-0 | Antimony | 7.6 | mG/kg | UN | R | VI |
| WBAA1 | 017302 | 2 | REGULAR | 7782-49-2 | Selenium | .54 | mG/kg | UWN | R | VI |
| WBAA1 | 017302 | 2 | REGULAR | 7440-36-0 | Antimony | 8.8 | mG/kg | UN | R | VI |
| WBAB1 | 017604 | 2 | REGULAR | 7440-36-0 | Antimony | 6.9 | mG/kg | UN | R | VI |
| WBAB1 | 017604 | 2 | REGULAR | 7782-49-2 | Selenium | .5 | mG/kg | UWN | R | VI |
| WBAB2 | 017703 | 2 | REGULAR | 7440-36-0 | Antimony | 7.4 | mG/kg | UN | R | VI |
| WBAB2 | 017703 | 2 | REGULAR | 7782-49-2 | Selenium | .42 | mG/kg | UWN | R | VI |

Table 4A.20. (continued)

| LOCATION | SAMPLE NUMBER | DATA TYPE | SAMPLE TYPE | CASNO | COMPOUND | RESULT | UNITS | LAB QUAL | REV QUAL | VA CO |
|---|---|---|---|---|---|---|---|---|---|---|
| WDA1 | 018202 | 2 | REGULAR | 7782-49-2 | Selenium | .51 | mG/kg | UWN | R | VI |
| WDA1 | 018202 | 2 | REGULAR | 7440-36-0 | Antimony | 7.5 | mG/kg | UN | R | VI |
| WDA1 | 018202 | 2 | REGULAR | 7440-22-4 | Silver | 2.5 | mG/kg | UN* | R | VI |
| WDB2 | 018412 | 2 | REGULAR | 7782-49-2 | Selenium | .51 | mG/kg | UWN | R | VI |
| WDB2 | 018412 | 2 | REGULAR | 7440-36-0 | Antimony | 8.4 | mG/kg | UN | R | VI |
| WDB2 | 018412 | 2 | REGULAR | 7440-22-4 | Silver | 2.8 | mG/kg | UN* | R | VI |
| WFBA1 | 017403 | 2 | REGULAR | 7782-49-2 | Selenium | .57 | mG/kg | UWN | R | VI |
| WFBA1 | 017403 | 2 | REGULAR | 7440-36-0 | Antimony | 7 | mG/kg | UN | R | VI |
| WFBB1 | 021609 | 2 | REGULAR | 7440-36-0 | Antimony | 8.1 | mG/kg | UN | R | VI |
| WFBB2 | 017902 | 2 | REGULAR | 7440-36-0 | Antimony | 7.3 | mG/kg | UN | R | VI |
| WFBB2 | 017902 | 2 | REGULAR | 7782-49-2 | Selenium | .47 | mG/kg | UWN | R | VI |
| WFBB3 | 017104 | 2 | REGULAR | 7782-49-2 | Selenium | .39 | mG/kg | UWN | R | VI |
| WFBB3 | 017104 | 2 | REGULAR | 7440-36-0 | Antimony | 6.5 | mG/kg | UN | R | VI |
| WSP1 | 017203 | 2 | REGULAR | 7782-49-2 | Selenium | .48 | mG/kg | UWN | R | VI |
| WSP1 | 017203 | 2 | REGULAR | 7440-36-0 | Antimony | 7.2 | mG/kg | UN | R | VI |

Table 4A.21. Invalid laboratory data WAG 6 surface water

| LOCATION | SAMPLE NUMBER | DATA TYPE | SAMPLE TYPE | CASNO | COMPOUND | RESULT | UNITS | LAB QUAL | REV QUAL | VA CO |
|---|---|---|---|---|---|---|---|---|---|---|
| DA-C | 051201 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UWN | R | VI |
| DA-C | 051001 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UWN | R | VI |
| DA-C | 051101 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UWN | R | VI |
| DA-D | 057401 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UN | R | VI |
| DA-D | 057501 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UWN | R | VI |
| DA-D | 051901 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UWN | R | VI |
| DB-C | 057701 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UN | R | VI |
| DB-C | 057601 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UN | R | VI |
| DB-D | 058301 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UWN | R | VI |
| DB-D | 058501 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UN | R | VI |
| DB-D | 058101 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UN | R | VI |
| DB-D | 038101 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UWN | R | VI |
| DB-D | 058201 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UN | R | VI |
| FA-A | 038703 | 2U | REGULAR | 7782-49-2 | Selenium | 8 | uG/Liter | UN | R | VI |
| FB | 049305 | 7 | FIELD DUP | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| FDA4C | 057001 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UWN | R | VI |
| FFA1A | 035001 | 2U | REGULAR | 7782-49-2 | Selenium | 4 | uG/Liter | UN | R | VI |
| FFA1B | 039204 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UWN | R | VI |
| FFB2 | 044102 | 2U | RINSEATE | 7439-92-1 | Lead | 2 | uG/Liter | UN | R | VI |
| FFB2 | 044401 | 2U | FIELD DUP | 7439-92-1 | Lead | 2 | uG/Liter | UWN | R | VI |
| FFB4D | 043602 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UWN | R | VI |
| FFB4D | 043702 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UWN | R | VI |
| FFB4D | 043502 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UWN | R | VI |
| SWA1 | SWA1 | 2U | REGULAR | 7440-22-4 | Silver | 5 | uG/Liter | U | R | VI |
| SWA1 | SWA1 | 2F | REGULAR | 7440-22-4 | Silver | 5 | uG/Liter | U | R | VI |
| SWB1 | SWB1 | 10 | REGULAR | 0-007 | Fecal Coliform | 0 | Col/100 mL | | R | VI |
| SWB1 | SWB1 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| SWDA1 | SWDA-1 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| SWDA1 | SWDA-1 | 9 | REGULAR | 99-09-2 | Benzenamine, 3-nitro | 50 | uG/Liter | U | R | VI |
| SWDA1 | SWDA-1 | 10 | REGULAR | 0-007 | Fecal Coliform | 13 | Col/100 mL | | R | VI |
| W49TS | W51TS | 10 | FIELD BLK | 0-007 | Fecal Coliform | 0 | Col/100 mL | | R | VI |
| W49TS | W52TS | 9 | FLD SPIKE | 65-85-0 | Benzoic acid | 250 | uG/Liter | U | R | VI |
| W49TS | W50TS | 10 | FIELD DUP | 0-007 | Fecal Coliform | 0 | Col/100 mL | | R | VI |
| W49TS | W51TS | 9 | FIELD BLK | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| W49TS | W51TS | 2U | FIELD BLK | 7440-22-4 | Silver | 5 | uG/Liter | UN | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 108-10-1 | Methylisobutylketone | 10 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 75-27-4 | Methane, bromodichloro | 1 | uG/Liter | J | R | VI |
| W49TS | W50TS | 2U | FIELD DUP | 7440-22-4 | Silver | 5 | uG/Liter | UN | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 79-01-6 | Trichloroethylene | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 78-93-3 | Methyl ethyl ketone | 20 | uG/Liter | B | R | VI |
| W49TS | W50TS | 7 | FIELD DUP | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 74-83-9 | Methyl bromide | 10 | uG/Liter | U | R | VI |
| W49TS | W49TS | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| W49TS | W49TD | 9 | FIELD DUP | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| W49TS | W49TD | 2U | FIELD DUP | 7440-41-7 | Beryllium | 1 | uG/Liter | U | R | VI |
| W49TS | W49TS | 2U | REGULAR | 7440-22-4 | Silver | 5 | uG/Liter | UN | R | VI |
| W49TS | W49TS | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| W49TS | W49TS | 10 | REGULAR | 0-007 | Fecal Coliform | 0 | Col/100 mL | | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 75-35-4 | 1,1-Dichloroethene | 5 | uG/Liter | U | R | VI |
| W49TS | W49TS | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| W49TS | W49TS | 2U | REGULAR | 7440-41-7 | Beryllium | 1 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 79-34-5 | Ethane, 1,1,2,2-tetrachloro | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 108-90-7 | Chlorobenzene | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 79-00-5 | Ethane, 1,1,2-trichloro | 5 | uG/Liter | U | R | VI |
| W49TS | W50TS | 9 | FIELD DUP | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 108-05-4 | Acetic acid, ethenyl ester | 10 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 10061-01-5 | 1-Propene, 1,3-dichloro-, (Z)- | 5 | uG/Liter | U | R | VI |

Table 4A.21. (continued)

| LOCATION | SAMPLE NUMBER | DATA TYPE | SAMPLE TYPE | CASNO | COMPOUND | RESULT | UNITS | LAB QUAL | REV QUAL | VA CO |
|---|---|---|---|---|---|---|---|---|---|---|
| W49TS | W49TSB | 7 | FIELD BLK | 108-88-3 | Benzene, methyl | 1 | uG/Liter | BJ | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 75-25-2 | Bromoform | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 78-87-5 | Propylene dichloride | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 100-41-4 | Benzene, ethyl | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 100-42-5 | Benzene, ethenyl- | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 56-23-5 | Carbon tetrachloride | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 75-01-4 | Ethene, chloro | 8 | uG/Liter | J | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 75-00-3 | Ethyl chloride | 10 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 10061-02-6 | 1-Propene, 1,3-dichloro-, (E)- | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 124-48-1 | Chlorodibromomethane | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 75-34-3 | 1,1-Dichloroethane | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 540-59-0 | 1,2-Dichloroethylene | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 75-09-2 | Dichloromethane | 4 | uG/Liter | BJ | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 71-43-2 | Benzene | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 67-64-1 | Acetone | 47 | uG/Liter | B | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 591-78-6 | 2-Hexanone | 10 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 75-15-0 | Carbon disulfide | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 127-18-4 | Tetrachloroethylene | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 74-87-3 | Methyl chloride | 10 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 67-66-3 | Trichloromethane | 17 | uG/Liter | | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 107-06-2 | Ethylene dichloride | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 1330-20-7 | Xylene (total) | 5 | uG/Liter | U | R | VI |
| W49TS | W49TSB | 7 | FIELD BLK | 71-55-6 | 1,1,1-trichloromethane | 5 | uG/Liter | U | R | VI |
| WBAA1 | WBAA1 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| WBAB1 | WBAB1 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| WBAB1 | WBAB1 | 2F | REGULAR | 7440-22-4 | Silver | 5 | uG/Liter | U | R | VI |
| WBAB1 | WBAB1 | 2U | REGULAR | 7440-22-4 | Silver | 5 | uG/Liter | U | R | VI |
| WBAB2 | WBAB2 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| WDA1 | WDA1 | 2U | REGULAR | 7440-22-4 | Silver | 5 | uG/Liter | U | R | VI |
| WDA1 | WDA1 | 2F | REGULAR | 7440-22-4 | Silver | 5 | uG/Liter | U | R | VI |
| WDB1 | WDB1 | 2F | REGULAR | 7440-22-4 | Silver | 5 | uG/Liter | U | R | VI |
| WDB1 | WDB1 | 2U | REGULAR | 7440-22-4 | Silver | 5 | uG/Liter | U | R | VI |
| WEWB | WEWB | 2U | REGULAR | 7440-22-4 | Silver | 5 | uG/Liter | U | R | VI |
| WEWB | WEWB | 2F | REGULAR | 7440-22-4 | Silver | 5 | uG/Liter | U | R | VI |
| WFBA1 | WFBA1 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| WFBA1 | WFBA1 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| WFBB1 | WFBB1 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| WFBB1 | WFBB1 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| WFBB1 | WFBB1 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| WFBB2 | WFBB2 | 2U | REGULAR | 7440-41-7 | Beryllium | 1 | uG/Liter | U | R | VI |
| WFBB2 | WFBB2 | 9 | REGULAR | 99-09-2 | Benzenamine, 3-nitro | 50 | uG/Liter | U | R | VI |
| WFBB2 | SWFBB2 | 2U | REGULAR | 7440-22-4 | Silver | 5 | uG/Liter | U | R | VI |
| WFBB2 | SWFBB2 | 2F | REGULAR | 7440-22-4 | Silver | 5 | uG/Liter | U | R | VI |
| WFBB2 | WFBB2 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| WFBB2 | WFBB2 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| WFBB2 | WFBB2 | 10 | REGULAR | 0-007 | Fecal Coliform | 0 | Col/100 mL | | R | VI |
| WFBB3 | SWFBB3 | 2F | REGULAR | 7440-22-4 | Silver | 5 | uG/Liter | U | R | VI |
| WFBB3 | SWFBB3 | 2U | REGULAR | 7440-22-4 | Silver | 5 | uG/Liter | U | R | VI |
| WSP1 | 055606 | 2U | REGULAR | 7439-97-6 | Mercury | .2 | uG/Liter | U | R | VI |
| WSP1 | 055703 | 2U | FIELD DUP | 7439-97-6 | Mercury | .2 | uG/Liter | U | R | VI |
| WSP1 | 030108 | 7 | RINSEATE | 75-69-4 | Trichlorofluoromethane | 5 | uG/Liter | U | R | VI |
| WSP1 | 030108 | 7 | RINSEATE | 123-91-1 | p-Dioxane | 5000 | uG/Liter | U | R | VI |
| WSP1 | 030108 | 7 | RINSEATE | 75-71-8 | Methane, dichlorodifluoro | 200 | uG/Liter | U | R | VI |
| WSP1 | 030108 | 7 | RINSEATE | 110-86-1 | Pyridine | 5000 | uG/Liter | U | R | VI |
| WSP1 | 030009 | 7 | REGULAR | 123-91-1 | p-Dioxane | 5000 | uG/Liter | U | R | VI |
| WSP1 | 030009 | 7 | REGULAR | 75-69-4 | Trichlorofluoromethane | 5 | uG/Liter | U | R | VI |
| WSP1 | 030009 | 7 | REGULAR | 110-86-1 | Pyridine | 5000 | uG/Liter | U | R | VI |
| WSP1 | 029909 | 7 | TRIP BLK | 75-69-4 | Trichlorofluoromethane | 5 | uG/Liter | U | R | VI |
| WSP1 | 029909 | 7 | TRIP BLK | 75-71-8 | Methane, dichlorodifluoro | 200 | uG/Liter | U | R | VI |
| WSP1 | 029909 | 7 | TRIP BLK | 110-86-1 | Pyridine | 5000 | uG/Liter | U | R | VI |

Table 4A.22. Invalid laboratory data WAG 6 soil

| LOCATION | SAMPLE NUMBER | DATA TYPE | SAMPLE TYPE | CASNO | COMPOUND | RESULT | UNITS | LAB QUAL | REV QUAL | VA CO |
|---|---|---|---|---|---|---|---|---|---|---|
| 1234 | 009914 | 2 | FIELD DUP | 7440-70-2 | Calcium | 2430 | mG/kg | | R | VI |
| 1234 | 010211 | 2 | REGULAR | 7440-70-2 | Calcium | 447 | mG/kg | B | R | VI |
| 1234 | 010304 | 2 | REGULAR | 7440-70-2 | Calcium | 2290 | mG/kg | | R | VI |
| 1234 | 010007 | 2 | REGULAR | 7440-70-2 | Calcium | 1350 | mG/kg | | R | VI |
| 1236 | 008910 | 2 | REGULAR | 7782-49-2 | Selenium | .45 | mG/kg | UWN | R | VI |
| 1236 | 008910 | 2 | REGULAR | 7440-36-0 | Antimony | 7.1 | mG/kg | UN | R | VI |
| 1237 | 009303 | 2 | REGULAR | 7440-36-0 | Antimony | 6 | mG/kg | UN | R | VI |
| 1240 | 026202 | 2 | REGULAR | 7782-49-2 | Selenium | .41 | mG/kg | UWN | R | VI |
| 1240 | 026202 | 2 | REGULAR | 7440-28-0 | Thallium | .41 | mG/kg | UN | R | VI |
| 1240 | 026202 | 2 | REGULAR | 7440-22-4 | Silver | 2.2 | mG/kg | UN | R | VI |
| 1241 | 027202 | 2 | REGULAR | 7440-36-0 | Antimony | 7.1 | mG/kg | UN | R | VI |
| 1242 | 026502 | 2 | REGULAR | 7440-38-2 | Arsenic | 4.4 | mG/kg | N | R | VI |
| 1242 | 026502 | 2 | REGULAR | 7440-28-0 | Thallium | .48 | mG/kg | UN | R | VI |
| 1242 | 026502 | 2 | REGULAR | 7440-22-4 | Silver | 2.1 | mG/kg | UN | R | VI |
| 1242 | 026502 | 2 | REGULAR | 7782-49-2 | Selenium | .48 | mG/kg | UWN | R | VI |
| 1243 | 026705 | 2 | REGULAR | 7440-28-0 | Thallium | .47 | mG/kg | UN | R | VI |
| 1243 | 026705 | 2 | REGULAR | 7440-38-2 | Arsenic | 1.6 | mG/kg | BN | R | VI |
| 1243 | 026705 | 2 | REGULAR | 7782-49-2 | Selenium | .47 | mG/kg | UWN | R | VI |
| 1243 | 026705 | 2 | REGULAR | 7440-22-4 | Silver | 2.1 | mG/kg | UN | R | VI |
| | | | | | hloro-,(1a | | | | | |
| SB07 | 027004 | 2 | REGULAR | 7782-49-2 | Selenium | .48 | mG/kg | UWN | R | VI |
| SB07 | 027004 | 2 | REGULAR | 7440-28-0 | Thallium | .48 | mG/kg | UN | R | VI |
| SCA01 | SCA01(10-1 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 11 | uG/kg | U | R | VI |
| SCA01 | SCA01(12-1 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | UWN | R | VI |
| SCA01 | SCA01(06-1 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | UWN | R | VI |
| SCA01 | SCA01(06-1 | 9 | REGULAR | 99-09-2 | Benzenamine, 3-nitro | 1700 | uG/kg | U | R | VI |
| SCA02 | SCA02(00-0 | 2 | REGULAR | 7782-49-2 | Selenium | 5 | mG/kg | UW | R | VI |
| SCA02 | SCA02(12-1 | 2 | REGULAR | 7782-49-2 | Selenium | 5 | mG/kg | UW | R | VI |
| SCA02 | SCA02(06-1 | 2 | REGULAR | 7440-36-0 | Antimony | .8 | mG/kg | B | R | VI |
| SCA04 | SCA04(06-1 | 2 | REGULAR | 7782-49-2 | Selenium | 3 | mG/kg | UW | R | VI |
| SCA06 | SCA06(00-0 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | UWN | R | VI |
| SCA06 | SCA06(06-1 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | UWN | R | VI |
| SCA08 | SCA08(06-0 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | UN | R | VI |
| SCA09 | SCA09(06-0 | 2 | REGULAR | 7782-49-2 | Selenium | .3 | mG/kg | UWN | R | VI |
| SCA12 | SCA12(06-1 | 2 | FIELD DUP | 7439-89-6 | Iron | 38300 | mG/kg | | R | VI |
| SCA12 | SCA12(06-1 | 2 | FIELD DUP | 7429-90-5 | Aluminum | 22300 | mG/kg | | R | VI |
| SCA12 | SCA12(06-1 | 2 | REGULAR | 7439-89-6 | Iron | 48800 | mG/kg | | R | VI |
| SCA12 | SCA12(00-0 | 2 | REGULAR | 7439-89-6 | Iron | 33500 | mG/kg | | R | VI |
| SCA12 | SCA12(00-0 | 2 | REGULAR | 7429-90-5 | Aluminum | 19700 | mG/kg | | R | VI |
| SCA12 | SCA12(06-1 | 2 | REGULAR | 7429-90-5 | Aluminum | 26400 | mG/kg | | R | VI |
| SCA16 | SCA16(12-1 | 2 | REGULAR | 7440-36-0 | Antimony | .6 | mG/kg | B | R | VI |
| SCA17 | SCA17(18-2 | 2 | REGULAR | 7440-36-0 | Antimony | .7 | mG/kg | B | R | VV |
| SCA18 | SCA18(12-1 | 2 | REGULAR | 7440-36-0 | Antimony | 1.4 | mG/kg | B | R | VI |
| SCB03 | SCB03(12-1 | 2 | FIELD DUP | 7782-49-2 | Selenium | 3 | mG/kg | UW | R | VI |
| SCB03 | SCB03(12-1 | 2 | REGULAR | 7782-49-2 | Selenium | 3 | mG/kg | UW | R | VI |
| SCC01 | SCC01(06-1 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | UN* | R | VI |
| SCC02 | SCC02(12-1 | 2 | REGULAR | 7782-49-2 | Selenium | 9 | mG/kg | UWN | R | VI |
| SCC02 | SCC02(24-2 | 2 | REGULAR | 7782-49-2 | Selenium | 4 | mG/kg | UWN | R | VI |
| SCC02 | SCC02(18-2 | 2 | REGULAR | 7782-49-2 | Selenium | 5 | mG/kg | UWN | R | VI |

Table 4A.22. (continued)

| LOCATION | SAMPLE NUMBER | DATA TYPE | SAMPLE TYPE | CASNO | COMPOUND | RESULT | UNITS | LAB QUAL | REV QUAL | VA CO |
|---|---|---|---|---|---|---|---|---|---|---|
| SCC03 | SCC03(18-2 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | U | R | VI |
| SCC03 | SCC03(18-2 | 2 | REGULAR | 7440-22-4 | Silver | .1 | mG/kg | U | R | VI |
| SCC03 | SCC03(12-1 | 2 | REGULAR | 7782-49-2 | Selenium | 1 | mG/kg | U | R | VI |
| SCC03 | SCC03(18-2 | 2 | REGULAR | 7782-49-2 | Selenium | 2 | mG/kg | U | R | VV |
| SCC04 | SCC04(12-1 | 2 | FIELD DUP | 7782-49-2 | Selenium | 2 | mG/kg | U | R | VI |
| SCC04 | SCC04(12-1 | 2 | FIELD DUP | 7440-22-4 | Silver | .1 | mG/kg | U | R | VI |
| SCC04 | SCC04(12-1 | 2 | FIELD DUP | 7440-36-0 | Antimony | .1 | mG/kg | U | R | VI |
| SCC04 | SCC04(12-1 | 2 | REGULAR | 7440-22-4 | Silver | .1 | mG/kg | U | R | VI |
| SCC04 | SCC04(12-1 | 2 | REGULAR | 7782-49-2 | Selenium | 2 | mG/kg | U | R | VI |
| SCC04 | SCC04(12-1 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | U | R | VI |
| SCC05 | SCC05(18-2 | 2 | REGULAR | 7439-89-6 | Iron | 31900 | mG/kg | | R | VI |
| SCC05 | SCC05(18-2 | 2 | REGULAR | 7429-90-5 | Aluminum | 18700 | mG/kg | | R | VI |
| SCC07 | SCC07(24-3 | 2 | REGULAR | 7429-90-5 | Aluminum | 12900 | mG/kg | | R | VI |
| SCC07 | SCC07(24-3 | 2 | REGULAR | 7439-89-6 | Iron | 26400 | mG/kg | | R | VI |
| SCC08 | SCC08(12-1 | 3 | REGULAR | 319-85-7 | beta-BHC | 133 | uG/kg | Y | R | VI |
| SCC08 | SCC08(12-1 | 2 | REGULAR | 7429-90-5 | Aluminum | 18000 | mG/kg | | R | VI |
| SCC08 | SCC08(12-1 | 3 | REGULAR | 319-84-6 | Cyclohexane, 1,2,3,4,5,6-hexac | 115 | uG/kg | Y | R | VI |
| SCC08 | SCC08(12-1 | 2 | REGULAR | 7439-89-6 | Iron | 33500 | mG/kg | | R | VI |
| SCC09 | SCC09(06-1 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | U | R | VI |
| SCC09 | SCC09(00-0 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | U | R | VI |
| SCC10 | SCC10(08-1 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | U | R | VI |
| SCC10 | SCC10(08-1 | 2 | REGULAR | 7440-22-4 | Silver | .1 | mG/kg | U | R | VI |
| SCC10 | SCC10(08-1 | 2 | REGULAR | 7782-49-2 | Selenium | .5 | mG/kg | U | R | VI |
| SCD02 | SCD02(30-3 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | UWN | R | VI |
| SCD03 | SCD03(30-3 | 2 | REGULAR | 7439-89-6 | Iron | 29100 | mG/kg | | R | VI |
| SCD03 | SCD03(30-3 | 2 | REGULAR | 7429-90-5 | Aluminum | 19300 | mG/kg | | R | VI |
| SCD03 | SCD03(12-1 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | U | R | VI |
| SCD04 | SCD04(24-3 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | UN | R | VI |
| SCD04 | SCD04(18-2 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | UN | R | VI |
| SCD05 | SCD05(00-0 | 2 | REGULAR | 7439-89-6 | Iron | 29000 | mG/kg | | R | VI |
| SCD05 | SCD05(12-1 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | UN | R | VI |
| SCD05 | SCD05(00-0 | 2 | REGULAR | 7429-90-5 | Aluminum | 18200 | mG/kg | | R | VI |
| SCD09 | SCD09(18-2 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | UWN | R | VI |
| SCD09 | SCD09(12-1 | 2 | REGULAR | 7782-49-2 | Selenium | 4 | mG/kg | UW | R | VI |
| SCE02 | SCE02(12-1 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | U | R | VI |
| SCE03 | SCE03(12-1 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | U | R | VI |
| SCE04 | SCE04(12-1 | 2 | REGULAR | 7429-90-5 | Aluminum | 12000 | mG/kg | | R | VI |
| SCE04 | SCE04(12-1 | 2 | REGULAR | 7439-89-6 | Iron | 31300 | mG/kg | | R | VI |
| SCE04 | SCE04(06-1 | 2 | REGULAR | 7439-89-6 | Iron | 31800 | mG/kg | | R | VI |
| SCE04 | SCE04(06-1 | 2 | REGULAR | 7429-90-5 | Aluminum | 15200 | mG/kg | | R | VI |
| SCE07 | SCE07(06-1 | 2 | REGULAR | 7439-89-6 | Iron | 33100 | mG/kg | | R | VI |
| SCE07 | SCE07(06-1 | 2 | REGULAR | 7429-90-5 | Aluminum | 19400 | mG/kg | | R | VI |
| SCE08 | SCE08(06-1 | 2 | REGULAR | 7429-90-5 | Aluminum | 24400 | mG/kg | | R | VI |
| SCE08 | SCE08(06-1 | 2 | REGULAR | 7439-89-6 | Iron | 37100 | mG/kg | | R | VI |
| SCE10 | SCE10(12-1 | 2 | REGULAR | 7440-36-0 | Antimony | .7 | mG/kg | B | R | VI |
| SCE11 | SCE11(12-1 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | U | R | VI |
| SCE11 | SCE11(18-2 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | U | R | VI |
| SDMS1 | SDMS1(48-5 | 2 | REGULAR | 7440-22-4 | Silver | .6 | mG/kg | U | R | VI |
| SDMS1 | SDMS1(18-2 | 2 | REGULAR | 7440-36-0 | Antimony | .1 | mG/kg | UWN | R | VI |
| SDMS1 | SDMS1(48-5 | 2 | REGULAR | 7782-49-2 | Selenium | 2 | mG/kg | UW | R | VI |

Table 4A.23. Invalid laboratory data WAG 6 groundwater

| Location | Sample number | Data Type | Sample Type | Cas no. | Compound | Result | Units | Lab Qual | Rev Qual | Va co |
|---|---|---|---|---|---|---|---|---|---|---|
| 838 | 066002 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UW | R | VI |
| 839 | 067402 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UW | R | VI |
| 841 | 054008 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 843 | 065402 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UW | R | VI |
| 845 | 845 | 2F | REGULAR | 7440-62-2 | Vanadium | 17.2 | uG/Liter | BN | R | VI |
| 845 | 845 | 2F | REGULAR | 7440-66-6 | Zinc | 16 | uG/Liter | BEN | R | VI |
| 845 | 845 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 845 | 845 | 10 | REGULAR | 0-007 | Fecal Coliform | 0 | Col/100 mL | | R | VI |
| 845 | 845 | 10 | REGULAR | 18496-25-8 | Sulfide | .5 | mG/Liter | U | R | VI |
| 845 | B421G, TB | 7 | TRIP BLK | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 848 | 848 | 10 | REGULAR | 18496-25-8 | Sulfide | .5 | uG/Liter | U | R | VI |
| 848 | 848 | 10 | REGULAR | 0-007 | Fecal Coliform | 0 | Col/100 mL | | R | VI |
| 848 | 848 | 7 | REGULAR | 1779-19-7 | 1,3,6-Trioxocane | 11 | uG/Liter | J | R | VI |
| 848 | 848 | 7 | REGULAR | 60-29-7 | Diethyl ether | 14 | uG/Liter | J | R | VI |
| 848 | 848 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 848 | 848 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 849 | 849 | 2U | REGULAR | 7440-22-4 | Silver | 10 | uG/Liter | UN* | R | VI |
| 849 | 849 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 849 | 849 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UN | R | VI |
| 849 | 849 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 849 | 849 | 10 | REGULAR | 0-007 | Fecal Coliform | 0 | Col/100 mL | | R | VI |
| 849 | 849 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 849 | 8491 | 10 | FIELD BLK | 0-007 | Fecal Coliform | 0 | Col/100 mL | | R | VI |
| 849 | 8491 | 7 | FIELD BLK | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 850 | 8500 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 850 | 8500 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 850 | 8500 | 9 | REGULAR | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 850 | 8500 | 9 | REGULAR | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 850 | 8500 | 9 | REGULAR | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 850 | 8500 | 9 | REGULAR | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 850 | 8500 | 9 | REGULAR | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 850 | 8500 | 9 | REGULAR | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 850 | 8500 | 9 | REGULAR | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |
| 850 | 8500 | 9 | REGULAR | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 850 | 8500 | 9 | REGULAR | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 850 | 8500 | 9 | REGULAR | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 850 | 8500 | 10 | REGULAR | 0-007 | Fecal Coliform | 0 | Col/100 mL | | R | VI |
| 850 | 8500 | 9 | REGULAR | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 850 | 8500 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 850 | 8500 | 9 | REGULAR | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |
| 850 | 8500 | 9 | REGULAR | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 850 | 8501 | 9 | FIELD DUP | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 850 | 8501 | 9 | FIELD DUP | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 850 | 8501 | 9 | FIELD DUP | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 850 | 8501 | 9 | FIELD DUP | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 850 | 8501 | 9 | FIELD DUP | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |
| 850 | 8501 | 7 | FIELD DUP | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 850 | 8501 | 9 | FIELD DUP | 105-67-9 | Phenol, 2,4-dimethyl- | 6 | uG/Liter | J | R | VI |

Table 4A.23. (continued)

| Location | Sample number | Data Type | Sample Type | Cas no. | Compound | Result | Units | Lab Qual | Rev Qual | Va co |
|---|---|---|---|---|---|---|---|---|---|---|
| 850 | 8501 | 9 | FIELD DUP | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 850 | 8501 | 9 | FIELD DUP | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 850 | 8501 | 9 | FIELD DUP | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 850 | 8501 | 9 | FIELD DUP | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 850 | 8501 | 9 | FIELD DUP | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 850 | 8501 | 9 | FIELD DUP | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 850 | 8501 | 9 | FIELD DUP | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 850 | 8501 | 9 | FIELD DUP | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |
| 850 | 8501 | 9 | FIELD DUP | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 850 | 8501 | 10 | FIELD DUP | 0-007 | Fecal Coliform | 0 | Col/100 mL | | R | VI |
| 850 | TB421, TB | 7 | TRIP BLK | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 851 | 851 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 851 | 851 | 10 | REGULAR | 18496-25-8 | Sulfide | .5 | uG/Liter | U | R | VI |
| 851 | 851 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 851 | 851 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UN | R | VI |
| 851 | 851 | 2U | REGULAR | 7440-22-4 | Silver | 10 | uG/Liter | UN* | R | VI |
| 851 | 851 | 10 | REGULAR | 0-007 | Fecal Coliform | 0 | Col/100 mL | | R | VI |
| 851 | 851 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 851 | 8511 | 9 | FIELD DUP | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 851 | 8511 | 2U | FIELD DUP | 7782-49-2 | Selenium | 2 | uG/Liter | UN | R | VI |
| 851 | 8511 | 9 | FIELD DUP | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 851 | 8511 | 2U | FIELD DUP | 7440-22-4 | Silver | 10 | uG/Liter | UN* | R | VI |
| 852 | 852 | 10 | REGULAR | 18496-25-8 | Sulfide | .5 | mG/Liter | U | R | VI |
| 852 | 852 | 2F | REGULAR | 7440-62-2 | Vanadium | 28.3 | uG/Liter | BN | R | VI |
| 852 | 852 | 9 | REGULAR | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 852 | 852 | 9 | REGULAR | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 852 | 852 | 2F | REGULAR | 7440-66-6 | Zinc | 7.2 | uG/Liter | BEN | R | VI |
| 852 | 852 | 9 | REGULAR | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 852 | 852 | 9 | REGULAR | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |
| 852 | 852 | 9 | REGULAR | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 852 | 852 | 2U | REGULAR | 7440-22-4 | Silver | 10 | uG/Liter | U | R | VI |
| 852 | 852 | 9 | REGULAR | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 852 | 852 | 10 | REGULAR | 0-007 | Fecal Coliform | 0 | Col/100 mL | | R | VI |
| 852 | 852 | 9 | REGULAR | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 852 | 852 | 9 | REGULAR | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 852 | 852 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 852 | 852 | 9 | REGULAR | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 852 | 852 | 9 | REGULAR | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 852 | 852 | 9 | REGULAR | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |
| 852 | 852 | 9 | REGULAR | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 852 | 852 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 852 | 852 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 852 | 852 | 9 | REGULAR | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |

Table 4A.23. (continued)

| Location | Sample number | Data Type | Sample Type | Cas no. | Compound | Result | Units | Lab Qual | Rev Qual | Va co |
|---|---|---|---|---|---|---|---|---|---|---|
| 853 | 853 | 9 | REGULAR | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 7 | REGULAR | 1779-19-7 | 1,3,6-Trioxocane | 7 | uG/Liter | J | R | VI |
| 853 | 853 | 9 | REGULAR | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 2U | REGULAR | 7440-22-4 | Silver | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 10 | REGULAR | 18496-25-8 | Sulfide | .5 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 853 | 853 | 9 | REGULAR | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |
| 853 | 853 | 10 | REGULAR | 0-007 | Fecal Coliform | 0 | Col/100 mL | | R | VI |
| 853 | 853B | 10 | FIELD BLK | 18496-25-8 | Sulfide | .5 | uG/Liter | U | R | VI |
| 854 | 854 | 2U | REGULAR | 7440-22-4 | Silver | 10 | uG/Liter | U | R | VI |
| 854 | 854 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 854 | 854 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 854 | 854 | 10 | REGULAR | 0-007 | Fecal Coliform | 0 | Col/100 mL | | R | VI |
| 854 | 854 | 2F | REGULAR | 7440-62-2 | Vanadium | 18.3 | uG/Liter | BN | R | VI |
| 854 | 854 | 2F | REGULAR | 7440-66-6 | Zinc | 17.1 | uG/Liter | BEN | R | VI |
| 854 | 854 | 10 | REGULAR | 18496-25-8 | Sulfide | .5 | mG/Liter | U | R | VI |
| 854 | 854 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 854 | 8541 | 2U | FIELD BLK | 7440-22-4 | Silver | 10 | uG/Liter | U | R | VI |
| 854 | 8541 | 9 | FIELD BLK | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 854 | 8541 | 9 | FIELD BLK | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |

Table 4A.23. (continued)

| Location | Sample number | Data Type | Sample Type | Cas no. | Compound | Result | Units | Lab Qual | Rev Qual | Va co |
|---|---|---|---|---|---|---|---|---|---|---|
| 855 | 053711 | 2U | REGULAR | 7439-92-1 | Lead | 40 | uG/Liter | U | R | VI |
| 856 | 053803 | 2U | REGULAR | 7439-92-1 | Lead | 40 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 111-44-4 | Dichloroethyl ether | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |

Table 4A.23. (continued)

| Location | Sample number | Data Type | Sample Type | Cas no. | Compound | Result | Units | Lab Qual | Rev Qual | Va co |
|---|---|---|---|---|---|---|---|---|---|---|
| 1225 | 1225 | 9 | REGULAR | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 1225 | 1225 | 9 | REGULAR | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 1225 | 1225D | 9 | FIELD DUP | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |
| 1225 | 1225D | 9 | FIELD DUP | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225D | 9 | FIELD DUP | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 1225 | 1225D | 9 | FIELD DUP | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225D | 9 | FIELD DUP | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 1225 | 1225D | 9 | FIELD DUP | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |
| 1225 | 1225D | 9 | FIELD DUP | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 1225 | 1225D | 9 | FIELD DUP | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 1225 | 1225D | 9 | FIELD DUP | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 1225 | 1225D | 9 | FIELD DUP | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 1225 | 1225D | 9 | FIELD DUP | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 1225 | 1225D | 9 | FIELD DUP | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 1225 | 1225D | 9 | FIELD DUP | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 1225 | 1225D | 9 | FIELD DUP | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 1225 | 1225D | 9 | FIELD DUP | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1226 | 9 | REGULAR | 65-85-0 | Benzoic acid | 52 | uG/Liter | U | R | VI |
| 1225 | 1226 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UN | R | VI |
| 1225 | 1226 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 1225 | 1226 | 9 | REGULAR | 51-28-5 | Phenol, 2,4-dinitro | 52 | uG/Liter | U | R | VI |
| 1225 | 1226 | 9 | REGULAR | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 1225 | 1226 | 9 | REGULAR | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 1225 | 1226 | 9 | REGULAR | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1226 | 9 | REGULAR | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1226 | 9 | REGULAR | 87-86-5 | Pentachlorophenol | 52 | uG/Liter | U | R | VI |
| 1225 | 1226 | 9 | REGULAR | 534-52-1 | Dinitrocresol | 52 | uG/Liter | U | R | VI |
| 1225 | 1226 | 9 | REGULAR | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 1225 | 1226 | 9 | REGULAR | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 1225 | 1226 | 9 | REGULAR | 95-95-4 | Phenol, 2,4,5-trichloro- | 52 | uG/Liter | U | R | VI |
| 1225 | 1226 | 9 | REGULAR | 100-02-7 | p-Nitrophenol | 52 | uG/Liter | U | R | VI |
| 1225 | 1226 | 9 | REGULAR | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 1225 | 1226 | 9 | REGULAR | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |
| 1226 | 065602 | 2U | FIELD DUP | 7782-49-2 | Selenium | 2 | uG/Liter | UW | R | VI |
| 1227 | 1227 | 2U | REGULAR | 7440-41-7 | Beryllium | 1 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |

Table 4A.23. (continued)

| Location | Sample number | Data Type | Sample Type | Cas no. | Compound | Result | Units | Lab Qual | Rev Qual | Va co |
|---|---|---|---|---|---|---|---|---|---|---|
| 1228 | 1228 | 9 | REGULAR | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 78-59-1 | 3,5,5-Trimethyl-2-cyclohexenone | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 1228 | 1228 | 9 | REGULAR | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |

Table 4A.23. (continued)

| Location | Sample number | Data Type | Sample Type | Cas no. | Compound | Result | Units | Lab Qual | Rev Qual | Va co |
|---|---|---|---|---|---|---|---|---|---|---|
| 1228 | 1228 | 9 | REGULAR | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 132-64-9 | Dibenzofuran | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 121-14-2 | Benzene, 1-methyl-2,4-dinitro | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 606-20-2 | Benzene, 2-methyl-1,3-dinitro- | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 99-09-2 | Benzenamine, 3-nitro | 50 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 83-32-9 | Acenaphthene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 208-96-8 | Acenaphthylene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 86-30-6 | Benzenamine, N-nitroso-N-phenyl | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 100-01-6 | Benzenamine, 4-nitro- | 50 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 86-73-7 | Fluorene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 7005-72-3 | Benzene, 1-chloro-4-phenoxy | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 84-66-2 | 1,2-Benzenedicarboxylic acid, diethyl ester | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 91-58-7 | Naphthalene, 2-chloro- | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 88-74-4 | Benzenamine, 2-nitro | 50 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 131-11-3 | Dimethyl phthalate | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 101-55-3 | 1-Bromo-4-phenoxybenzene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 108-60-1 | Propane, 2,2'-oxybis[1-chloro- | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 95-50-1 | 1,2-Dichlorobenzene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 100-51-6 | Benzyl alcohol | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 87-68-3 | 1,3-Butadiene, 1,1,2,3,4,4-hexachloro- | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 621-64-7 | N-Nitrosodi-n-propylamine | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 111-44-4 | Dichloroethyl ether | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 106-46-7 | p-Dichlorobenzene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 541-73-1 | m-Dichlorobenzene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 106-47-8 | p-Chloroaniline | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 91-20-3 | Naphthalene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 67-72-1 | Ethane, hexachloro | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 98-95-3 | Benzene, nitro- | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 85-01-8 | Phenanthrene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 78-59-1 | 3,5,5-Trimethyl-2-cyclohexenone | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 120-82-1 | Benzene, 1,2,4-trichloro- | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 111-91-1 | Ethane, 1,1'-[methylenebis(oxy)]bis[2-chloro- | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 111-91-1 | Ethane, 1,1'-[methylenebis(oxy)]bis[2-chloro- | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 129-00-0 | Pyrene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 91-57-6 | Naphthalene, 2-methyl | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 77-47-4 | Hexachlorocyclopentadiene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 91-94-1 | 1,1'-Biphenyl-4,4'-diamine, 3,3'-dichloro | 20 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 56-55-3 | Benz(a)anthracene | 10 | uG/Liter | U | R | VI |

Table 4A.23. (continued)

| Location | Sample number | Data Type | Sample Type | Cas no. | Compound | Result | Units | Lab Qual | Rev Qual | Va co |
|---|---|---|---|---|---|---|---|---|---|---|
| 1228 | 053201 | 9 | REGULAR | 85-68-7 | Butyl benzyl phthalate | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 218-01-9 | Chrysene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 117-81-7 | bis(2-Ethylhexyl) phthalate | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 206-44-0 | Fluoranthene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 120-12-7 | Anthracene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 84-74-2 | Di-n-butyl phthalate | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 53-70-3 | Dibenz(a,h)anthracene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 191-24-2 | Benzo(ghi)perylene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 193-39-5 | Indeno(1,2,3-cd)pyrene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 117-84-0 | Phthalic acid, dioctyl ester | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 205-99-2 | Benz(e)acephenanthrylene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 207-08-9 | Benzo(k)fluoranthene | 10 | uG/Liter | U | R | VI |
| 1228 | 053201 | 9 | REGULAR | 50-32-8 | Benzo(a)pyrene | 10 | uG/Liter | U | R | VI |
| 1228 | 053209 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 50 | uG/Liter | B | R | VI |
| 1228 | 063002 | 2U | REGULAR | 7782-49-2 | Selenium | 8 | uG/Liter | UEN | R | VI |
| 1229 | TB428 | 7 | TRIP BLK | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 1229 | 1229 | 2F | REGULAR | 7440-62-2 | Vanadium | 17.2 | uG/Liter | BN | R | VI |
| 1229 | 1229 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 1229 | 1229 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 1229 | 1229 | 2F | REGULAR | 7440-66-6 | Zinc | 40.4 | uG/Liter | EN | R | VI |
| 1229 | 1229 | 2U | REGULAR | 7440-22-4 | Silver | 10 | uG/Liter | U | R | VI |
| 1229 | 1229 | 10 | REGULAR | 18496-25-8 | Sulfide | .5 | mG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 51-28-5 | Phenol, 2,4-dinitro | 50 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 83-32-9 | Acenaphthene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 100-02-7 | p-Nitrophenol | 50 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 606-20-2 | Benzene, 2-methyl-1,3-dinitro- | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 99-09-2 | Benzenamine, 3-nitro | 50 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 208-96-8 | Acenaphthylene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 86-73-7 | Fluorene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 7005-72-3 | Benzene, 1-chloro-4-phenoxy | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 132-64-9 | Dibenzofuran | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 121-14-2 | Benzene, 1-methyl-2,4-dinitro | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 84-66-2 | 1,2-Benzenedicarboxylic acid, diethyl ester | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 100-01-6 | Benzenamine, 4-nitro- | 50 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 1X. | UNK C6H10 | 33 | uG/Liter | J | R | VI |
| 1229 | 053101 | 9 | REGULAR | 50-32-8 | Benzo(a)pyrene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 91-57-6 | Naphthalene, 2-methyl | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 53-70-3 | Dibenz(a,h)anthracene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 191-24-2 | Benzo(ghi)perylene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 131-11-3 | Dimethyl phthalate | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 91-58-7 | Naphthalene, 2-chloro- | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 95-95-4 | Phenol, 2,4,5-trichloro- | 50 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 77-47-4 | Hexachlorocyclopentadiene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 88-06-2 | Phenol, 2,4,6-trichloro- | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 193-39-5 | Indeno(1,2,3-cd)pyrene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 67-72-1 | Ethane, hexachloro | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 621-64-7 | N-Nitrosodi-n-propylamine | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 98-95-3 | Benzene, nitro- | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 101-55-3 | 1-Bromo-4-phenoxybenzene | 10 | uG/Liter | U | R | VI |

Table 4A.23. (continued)

| Location | Sample number | Data Type | Sample Type | Cas no. | Compound | Result | Units | Lab Qual | Rev Qual | Va co |
|---|---|---|---|---|---|---|---|---|---|---|
| 1229 | 053101 | 9 | REGULAR | 88-74-4 | Benzenamine, 2-nitro | 50 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 56-55-3 | Benz(a)anthracene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 105-67-9 | Phenol, 2,4-dimethyl- | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 78-59-1 | 3,5,5-Trimethyl-2-cyclohexenone | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 88-75-5 | Phenol, 2-nitro- | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 534-52-1 | Dinitrocresol | 50 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 85-01-8 | Phenanthrene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 87-86-5 | Pentachlorophenol | 50 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 120-12-7 | Anthracene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 86-30-6 | Benzenamine, N-nitroso-N-phenyl | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 118-74-1 | Hexachlorobenzene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 91-94-1 | 1,1'-Biphenyl-4,4'-diamine, 3,3'-dichloro | 20 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 85-68-7 | Butyl benzyl phthalate | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 129-00-0 | Pyrene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 84-74-2 | Di-n-butyl phthalate | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 206-44-0 | Fluoranthene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 111-91-1 | Ethane, 1,1'-[methylenebis(oxy)]bis[2-chloro- | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 108-60-1 | Propane, 2,2'-oxybis[1-chloro- | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 95-48-7 | 2-Methylphenol | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 95-50-1 | 1,2-Dichlorobenzene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 637-88-7 | 1,4-Cyclohexanedione | 13 | uG/Liter | J | R | VI |
| 1229 | 053101 | 9 | REGULAR | 453-20-3 | 3-Furanol, Tetrahydro- | 44 | uG/Liter | J | R | VI |
| 1229 | 053101 | 9 | REGULAR | 1X. | UNK C6H10 | 20 | uG/Liter | J | R | VI |
| 1229 | 053101 | 9 | REGULAR | 106-44-5 | 4-Methyl phenol | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 95-57-8 | Phenol, 2-chloro | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 111-44-4 | Dichloroethyl ether | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 207-08-9 | Benzo(k)fluoranthene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 120-83-2 | Phenol, 2,4-dichloro- | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 218-01-9 | Chrysene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 120-82-1 | Benzene, 1,2,4-trichloro- | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 91-20-3 | Naphthalene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 205-99-2 | Benz(e)acephenanthrylene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 117-81-7 | bis(2-Ethylhexyl) phthalate | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 117-84-0 | Phthalic acid, dioctyl ester | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 100-51-6 | Benzyl alcohol | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 59-50-7 | 4-Chloro-m-cresol | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 87-68-3 | 1,3-Butadiene, 1,1,2,3,4,4-hexachloro- | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 106-47-8 | p-Chloroaniline | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 106-46-7 | p-Dichlorobenzene | 10 | uG/Liter | U | R | VI |
| 1229 | 053101 | 9 | REGULAR | 541-73-1 | m-Dichlorobenzene | 10 | uG/Liter | U | R | VI |
| 1229 | 053108 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 2 | uG/Liter | J | R | VI |
| 1229 | 062902 | 2U | REGULAR | 7782-49-2 | Selenium | 8 | uG/Liter | UWN | R | VI |
| 1231 | 1231 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 1231 | 1231 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 1231 | 1231 | 2U | REGULAR | 7440-47-3 | Chromium | 17.9 | uG/Liter | | R | VI |
| 1231 | 1231 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 1231 | 1231 | 2U | REGULAR | 7440-22-4 | Silver | 10 | uG/Liter | U | R | VI |
| 1231 | 1231 | 9 | REGULAR | 65-85-0 | Benzoic acid | 54 | uG/Liter | U | R | VI |
| 1231 | 1231 | 9 | REGULAR | 108-95-2 | Carbolic Acid | 11 | uG/Liter | U | R | VI |

Table 4A.23. (continued)

| Location | Sample number | Data Type | Sample Type | Cas no. | Compound | Result | Units | Lab Qual | Rev Qual | Va co |
|---|---|---|---|---|---|---|---|---|---|---|
| 1231 | 1231D | 7 | FIELD DUP | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 1231 | 1231D | 7 | FIELD DUP | 74-87-3 | Methyl chloride | 10 | uG/Liter | U | R | VI |
| 1231 | 0831T | 7 | TRIP BLK | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 1233 | TB427 | 7 | TRIP BLK | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 1233 | 12332 | 2U | FIELD BLK | 7440-22-4 | Silver | 10 | uG/Liter | U | R | VI |
| 1233 | 12331 | 7 | FIELD DUP | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 1233 | 1233 | 2U | REGULAR | 7440-22-4 | Silver | 10 | uG/Liter | U | R | VI |
| 1233 | 1233 | 9 | REGULAR | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 1233 | 1233 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 1233 | 12331 | 9 | FIELD DUP | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 1233 | 12331 | 2U | FIELD DUP | 7440-22-4 | Silver | 10 | uG/Liter | U | R | VI |
| 1233 | 12331 | 9 | FIELD DUP | 108-95-2 | Carbolic Acid | 10 | uG/Liter | U | R | VI |
| 1233 | 12331 | 9 | FIELD DUP | 65-85-0 | Benzoic acid | 52 | uG/Liter | U | R | VI |
| 1233 | 12332 | 9 | FIELD BLK | 65-85-0 | Benzoic acid | 50 | uG/Liter | U | R | VI |
| 1234A | 055901 | 9 | REGULAR | 86-30-6 | Benzenamine, N-nitroso-N-phenyl | 21 | uG/Liter | | R | VI |
| 1234A | 055913 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 1234 | 056405 | 9 | REGULAR | 55-18-5 | Ethanamine, N-ethyl-N-nitroso- | 14 | uG/Liter | U | R | VI |
| 1236 | 065002 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UW | R | VI |
| 1239 | 056010 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 10 | uG/Liter | U | R | VI |
| 1239 | 065902 | 2U | REGULAR | 7782-49-2 | Selenium | 4 | uG/Liter | UW | R | VI |
| 1241 | 063502 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UWN | R | VI |
| 1242 | 062701 | 2U | REGULAR | 7782-49-2 | Selenium | 10 | uG/Liter | U | R | VI |
| 1243 | 063101 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UWN | R | VI |
| 1244 | 050008 | 7 | REGULAR | 78-93-3 | Methyl ethyl ketone | 68 | uG/Liter | B | R | VI |
| 1244 | 053002 | 7 | FIELD DUP | 78-93-3 | Methyl ethyl ketone | 6 | uG/Liter | BJ | R | VI |
| 1244 | 063201 | 2U | REGULAR | 7782-49-2 | Selenium | 2 | uG/Liter | UWN | R | VI |
| 1244 | 063601 | 2U | FIELD DUP | 7782-49-2 | Selenium | 2 | uG/Liter | UWN | R | VI |
| 1245 | 048602 | 9 | REGULAR | 55-18-5 | Ethanamine, N-ethyl-N-nitroso- | 10 | uG/Liter | U | R | VI |
| 1245 | 048602 | 9 | REGULAR | 86-30-6 | Benzenamine, N-nitroso-N-phenyl | 12 | uG/Liter | B | R | VI |

**Table 4A.24. Summary of groundwater analyses for WAG 6**

| | Number of Analyses Performed | | NUMBER OF ANALYS PROJECTED | |
|---|---|---|---|---|
| | Regular Samples | QC Samples[a] | Regular Samples | QC Sampl |
| RADIOLOGICAL LABORATORY ANALYSES CSL (Gross Alpha, Gross Beta and Tritium) | 115 | 18 | 90 | 18 |
| SUBCONTRACT LABORATORY (Gross Alpha, Gross Beta, Gamma Spec and Isotopic) | 68 | 18 | 45 | 9 |
| CHEMICAL LABORATORY ANALYSES | | | | |
| SVOC | 61 | 17 | 40 | 10 |
| VOC | 62 | 57 | 40 | 10 |
| Pest/PCB | 27 | 6 | 40 | 10 |
| Metal-F | 86 | 16 | 40 | 10 |
| Metal-U | 106 | 19 | 55 | 10 |
| Dioxins/Furans | 2 | 0 | 40 | 10 |
| Herbicides | 2 | 0 | 40 | 10 |
| Organophosphorus/Pesticides | 2 | 0 | 40 | 10 |
| MISCELLANEOUS PARAMETERS: | | | | |
| Anions | 90 | 12 | 85 | 18 |
| Bicarbonate | 90 | 12 | 85 | 18 |
| BOD | 23 | 6 | 90 | 22 |
| Carbonate | 89 | 12 | 85 | 18 |
| COD | 27 | 8 | 90 | 22 |
| Cyanide | 46 | 12 | 40 | 10 |
| Fecal Coliform | 21 | 5 | 90 | 22 |
| Sulfide | 29 | 7 | 85 | 18 |
| TDS | 27 | 7 | 85 | 18 |
| TKN | 27 | 8 | 85 | 18 |
| TOC | 14 | 4 | 85 | 18 |
| TOX | 14 | 4 | NA | NA |
| AVERAGE PERCENT COMPLETENESS | 99% | 99% | | |

[a]QC samples include duplicates, field blanks, rinsates and VOC trip blanks.
[b]Not addressed in field sampling plan.

Table 4A.25. Summary of soil analyses for WAG 6

| | Number of analyses performed | | Number of analyses projected | |
|---|---|---|---|---|
| | Regular samples | QC samples[a] | Regular samples | QC samples |
| RADIOLOGICAL LABORATORY ANALYSES | | | | |
| CSL (Gross Alpha, Gross Beta and Tritium) | 277 | 10 | 197 | 77 |
| SUBCONTRACT LABORATORY (Gross Alpha, Gross Beta, Gamma Spec and Isotopic) | 74 | 6 | 99 | 39 |
| CHEMICAL LABORATORY ANALYSES | | | | |
| SVOC | 76 | 5 | 157 | 61 |
| VOC | | 10 | 157 | 61 |
| Pest/PCB | 77 | 5 | 157 | 61 |
| Metal | 75 | 5 | 157 | 61 |
| | 74 | | | |
| MISCELLANEOUS PARAMETERS: Cyanide | 73 | 56 | 157 | 61 |
| AVERAGE PERCENT COMPLETENESS | 74% | 20% | | |

[a]QC samples include duplicates, field blanks, rinseates and VOC trip blanks.

Table 4A.26. Summary of sediment analyses for WAG 6

| | Number of Analyses Performed | | Number of Analyses Projected | |
|---|---|---|---|---|
| | Regular Samples | QC Samples[a] | Regular Samples | QC Sample |
| RADIOLOGICAL LABORATORY ANALYSES | | | | |
| CSL | | | | |
| (Gross Alpha, Gross Beta and Tritium) | 32 | 4 | 34 | 9 |
| SUBCONTRACT LABORATORY | | | | |
| (Gross Alpha, Gross Beta, Gamma Spec and Isotopic) | 32 | 4 | 16 | 4 |
| CHEMICAL LABORATORY ANALYSES | | | | |
| SVOC | 32 | 3 | 18 | 8 |
| VOC | 32 | 7 | 18 | 8 |
| Pest/PCB | 32 | 4 | 18 | 8 |
| Metal | 32 | 4 | 18 | 8 |
| Dioxins/Furans | 2 | 1 | NA[2] | NA |
| Herbicides | 3 | 1 | NA | NA |
| Organophosphorus/Pesticides | 3 | 1 | NA | NA |
| MISCELLANEOUS PARAMETERS: | | | | |
| Cyanide | 32 | 2 | 18 | 8 |
| Sulfide | 3 | 1 | NA | NA |
| AVERAGE PERCENT COMPLETENESS | 148% | 51% | | |

[a]QC samples include duplicates, field blanks, rinseates, and VOC trip blanks.
[b]Not addressed in field sampling plan.

Table 4A.27. Summary of surface water analyses

| | Number of Analyses Performed | | Number of Analyses Projected | |
|---|---|---|---|---|
| | Regular Samples | QC Samples[a] | Regular Samples | QC Samples |
| RADIOLOGICAL LABORATORY ANALYSES | | | | |
| CSL (Gross Alpha, Gross Beta and Tritium) | 381 | 27 | 105 | 52 |
| SUBCONTRACT LABORATORY (Gross Alpha, Gross Beta, Gamma Spec and Isotopic) | 118 | 21 | 53 | 26 |
| CHEMICAL LABORATORY ANALYSES | | | | |
| SVOC | 54 | 15 | 31 | 8 |
| VOC | 62 | 52 | 31 | 8 |
| Pest/PCB | 18 | 5 | 31 | 8 |
| Metal-F | 54 | 13 | 16 | 12 |
| Metal-U | 120 | 24 | 31 | 8 |
| Dioxins/Furans | 2 | 3 | NA[b] | NA |
| Herbicides | 2 | 3 | NA | NA |
| Organophosphorus/Pesticides | 2 | 3 | NA | NA |
| MISCELLANEOUS PARAMETERS: | | | | |
| Anions | 21 | 6 | 57 | 16 |
| Bicarbonate | 21 | 6 | 57 | 16 |
| BOD | 20 | 4 | 57 | 16 |
| Carbonate | 21 | 6 | 57 | 16 |
| COD | 21 | 6 | 57 | 16 |
| Cyanide | 34 | 11 | 31 | 8 |
| Fecal Coliform | 14 | 2 | 57 | 16 |
| Sulfide | 23 | 8 | 57 | 16 |
| TDS | 21 | 6 | 57 | 16 |
| TKN | 21 | 6 | 57 | 16 |
| TOC | 17 | 4 | 57 | 16 |
| TOX | 1 | 0 | NA | NA |
| AVERAGE PERCENT COMPLETENESS | 189% | .94% | | |

[a]QC samples include duplicates, field blanks, rinseates and VOC trip blanks.
[b]Not addressed in field sampling plan.

**Table 4A.28. Subcontract Laboratory First Quarter 1989 Control Chart Summary**

| Test | N | Number of Outliers | Dates | Percent In | Percent Out |
|---|---|---|---|---|---|
| $Am^{241}$ | 7 | 0 | 1/13-3/19 | 100 | 0 |
| $Co^{60}$ | 1 | 1 | 2/9 | 0 | 100[a] |
| $Cs^{137}$ | 2 | 1 | 2/9-2/9 | 50 | 50[a] |
| GALPH | 7 | 0 | 1/13-2/24 | 100 | 0 |
| GBETW | 7 | 0 | 1/12-2/24 | 100 | 0 |
| $K^{40}$ | 6 | 0 | 1/12-2/24 | 100 | 0 |
| $Pu^{238}$ | 7 | 0 | 1/11-3/9 | 100 | 0 |
| $Pu^{239/240}$ | 7 | 0 | 1/11-3/9 | 100 | 0 |
| $Ra^{224}$ | 6 | 1 | 1/11-2/24 | 83.3 | 16.7 |
| $Ra^{226}$ | 6 | 1 | 1/13-2/24 | 83.3 | 16.7 |
| $Ra^{228}$ | 6 | 1 | 1/13-2/24 | 83.3 | 16.7 |
| $Sr^{90}$ | 1 | 0 | 3/23 | 100 | 0 |
| $Th^{228}$ | 6 | 0 | 1/11-3/6 | 100 | 0 |
| $Th^{230}$ | 7 | 1 | 1/11-3/9 | 85.7 | 14.3 |
| $Th^{232}$ | 6 | 0 | 1/11-3/9 | 100 | 0 |
| $Th^{234}$ | 2 | 1 | 1/18-1/31 | 50 | 50[a] |
| $H^{3}$ | 1 | 0 | 2/24 | 100 | 0 |
| $U^{234}$ | 5 | 0 | 1/11-3/9 | 100 | 0 |
| $U^{235/236}$ | 7 | 0 | 1/11-3/9 | 100 | 0 |
| $U^{238}$ | 4 | 0 | 1/11-3/9 | 100 | 0 |

[a]Out of control values

The Type of Results for these Parameters are for Replicate Samples using the Normalized Range

**Table 4A.29. 1989 Subcontract laboratory control chart summary**

| Test | Type | N | Number of Outliers | Dates | Percent In | Percent Out | Q |
|---|---|---|---|---|---|---|---|
| $Am^{241}$ | Duplicate | 12 | 1 | 1/13-6/22 | 92.3 | 7.7 | 1 & 2 |
| $C^{14}$ | Duplicate | 5 | 0 | 3/8-12/22 | 100 | 0 | 1- |
| $Co^{60}$ | Duplicate | 5 | 1 | 2/9-10/11 | 80 | 20 | 1- |
| $Cs^{137}$ | Duplicate | 37 | 1 | 1/26-10/11 | 97.3 | 2.7 | 1- |
| $Fe^{55}$ | Duplicate | 5 | 0 | 3/17-12/6 | 100 | 0 | 1- |
| GALPH | Duplicate | 18 | 0 | 1/13-12/11 | 100 | 0 | 1- |
| GBET | Duplicate | 19 | 2 | 1/12-12/17 | 89.5 | 10.5 | 1- |
| $I^{129}$ | Duplicate | 11 | 0 | 2/2-12/14 | 100 | 0 | 1- |
| $K^{40}$ | Duplicate | 7 | 0 | 1/12-4/25 | 100 | 0 | 1- |
| $NP^{237}$ | Duplicate | 47 | 1 | 1/4-12/1 | 97.9 | 2.1 | 1- |
| $Pu^{238}$ | Duplicate | 10 | 0 | 1/10-5/10 | 100 | 0 | 1- |
| $Pu^{239}$ | Duplicate | 75 | 0 | 1/4-12/1 | 100 | 0 | 1- |
| $Pu^{240}$ | Duplicate | 5 | 0 | 1/12-3/9 | 100 | 0 | 1 |
| $Ra^{224}$ | Duplicate | 12 | 7 | 1/13-10/19 | 41.7 | 58.3 | 1- |
| $Ra^{226}$ | Duplicate | 70 | 6 | 1/9-12/21 | 91.4 | 8.6 | 1- |
| $Ra^{228}$ | Duplicate | 65 | 3 | 1/4-12/19 | 95.4 | 4.6 | 1- |
| $Sr^{90}$ | Duplicate | 80 | 9 | 1/4-12/27 | 88.7 | 11.3 | 1- |
| $Tc^{99}$ | Duplicate | 67 | 0 | 1/30-12/22 | 100 | 0 | 1- |
| $Th^{228}$ | Duplicate | 9 | 2 | 1/10-5/10 | 77.8 | 22.2 | 1- |
| $Th^{230}$ | Duplicate | 9 | 1 | 1/10-5/10 | 88.9 | 11.1 | 1- |
| $Th^{232}$ | Duplicate | 98 | 1 | 1/4-12/22 | 99 | 1.0 | 1- |
| $U^{238}$ | Duplicate | 112 | 1 | 1/3-12-21 | 99.1 | 0.9 | 1- |
| $U^{236}$ | Duplicate | 6 | 0 | 1/12-3/10 | 100 | 0 | 1 |
| $U^{235}$ | Duplicate | 10 | 0 | 1/3-5/10 | 100 | 0 | 1- |
| $U^{234}$ | Duplicate | 103 | 1 | 1/3-12/22 | 99 | 1.0 | 1- |
| $H^{3}$ | Duplicate | 67 | 0 | 1/16-12/27 | 100 | 0 | 1- |
| $Th^{234}$ | Duplicate | 3 | 1 | 1/13-1/31 | 66.7 | 33.3 | 1- |

**Table 4A.30. 1989 Subcontract laboratory control chart summary**

| Test | Type | N | Number of Outliers | Dates | Percent In | Percent Out | Quarter |
|---|---|---|---|---|---|---|---|
| $Cs^{137}$ | Spike | 5 | 0 | 3/14-6/22 | 85.7 | 14.3 | 2 |
| $Ca^{45}$ | Spike | 40 | 10 | 1/12-12/8 | 75 | 25 | 1-4 |
| $C^{14}$ | Spike | 21 | 0 | 1/24-12/26 | 100 | 0 | 1-4 |
| $Am^{241}$ | Spike | 49 | 11 | 1/12-12/28 | 77.6 | 22.4 | 1-4 |
| $Fe^{55}$ | Spike | 17 | 1 | 3/17-12/22 | 94.1 | 5.9 | 2-4 |
| GALPH | Spike | 36 | 5 | 3/30-11/2 | 87.8 | 12.2 | 2-4 |
| GBETW | Spike | 36 | 9 | 3/30-11/1 | 78 | 22 | 2-4 |
| $I^{125}$ | Spike | 50 | 2 | 1/6-11/15 | 96 | 4 | 1-4 |
| $I^{129}$ | Spike | 21 | 2 | 1/16-12/15 | 90.5 | 9.5 | 1-4 |
| $I^{131}$ | Spike | 59 | 3 | 1/7-11/20 | 94.9 | 5.1 | 1-4 |
| $N^{63}$ | Spike | 7 | 0 | 3/25-12/26 | 100 | 0 | 2-4 |
| $Np^{237}$ | Spike | 101 | 5 | 1/2-12/15 | 95 | 5 | 1-4 |
| $Pb^{210}$ | Spike | 19 | 4 | 1/2-12/6 | 96.2 | 21 | 1-4 |
| $Pu^{239}$ | Spike | 158 | 6 | 1/3-12/22 | 91.7 | 3.8 | 1-4 |
| $Pu^{239}$ | MS | 48 | 4 | 1/12-12/1 | 84 | 8.3 | 1-4 |
| $Ra^{226}$ | Spike | 162 | 26 | 1/9-12/26 | 88.2 | 16 | 1-4 |
| $Ra^{228}$ | Spike | 138 | 26 | 1/3-12/29 | 96.7 | 18.8 | 1-4 |
| $Sr^{90}$ | Spike | 195 | 23 | 1/7-12/29 | 97.8 | 11.8 | 1-4 |
| $Tc^{99}$ | Spike | 152 | 5 | 1/3-12/29 | 88 | 3.3 | 1-4 |
| $Th^{232}$ | Spike | 135 | 3 | 1/3-12/20 | 93.4 | 2.2 | 1-4 |
| $Th^{233}$ | Spike | 75 | 9 | 1/12-12/21 | 100 | 12 | 1-4 |
| $H^{3}$ | Spike | 12 | 0 | 1/23-11/8 | 96.9 | 0 | 1-4 |
| $H^{3}$ | MS | 76 | 5 | 1/5-12/27 | 99.4 | 6.6 | 1-4 |
| $U^{234}$ | Spike | 163 | 0 | 1/6-12/28 | 90.3 | 0 | 1-4 |
| $U^{234}$ | MS | 65 | 2 | 1/12-12/21 | | 3.1 | 1-4 |
| $U^{238}$ | Spike | 168 | 1 | 1/4-12/28 | | 0.6 | 1-4 |
| $U^{238}$ | MS | 62 | 6 | 1/12-12/21 | | 9.7 | 1-4 |

**Table 4A.31. Subcontract laboratory 1990 control chart summary**

**Fourth Quarter QA/QC Control Charts 1990**

| Test | Type | N | Number of Outliers | Dates | Percent In | Percent Out |
|---|---|---|---|---|---|---|
| $Sr^{90}$ | Spike | 4 | 1 | 12/7-12/12/90 | 75.0 | 25.0 |
| $Th^{232}$ | Spike | 3 | 0 | 10/9-12/18 | 100 | 0 |
| $U^{238}$ | Spike | 4 | 0 | 12/10-12/28 | 100 | 0 |
| $Sr^{90}$ | Spike | 3 | 0 | 11/21-12/17 | 100 | 0 |
| $H^3$ | Spike | 8 | 0 | 10/19-11/29 | 100 | 0 |
| $Cs^{137}$ | Duplicate | 3 | 0 | 11/30-12/19 | 100 | 0 |
| GALPH | Insufficient number of samples available | | | 10/11-11/25 | - | - |
| GBETW | Duplicate | 4 | 1 | 10/11-12/1 | 75.0 | 25.0 |
| $H^3$ | Duplicate | 5 | 1 | 10/7-11/10 | 80.0 | 20.0 |

**Table 4A.32. Subcontract laboratory 1990 control chart summary**

**Third Quarter Control Charts 1990**

| Test | Type | N | Number of Outliers | Date | Percent In | Percent Out |
|---|---|---|---|---|---|---|
| $Am^{241}$ | Spikes | 4 | 0 | 8/24-8/28 | 100 | 0 |
| $Np^{237}$ | Spikes | 5 | 0 | 8/3-8/11 | 100 | 0 |
| $Pu^{239}$ | Spikes | 12 | 1 | 8/3-8/28 | 91.7 | 8.3 |
| $Ra^{226}$ | Spikes | 15 | 6 | 8/5-8/22 | 60 | 40* |
| $Tc^{99}$ | Spikes | 3 | 1 | 8/7-8/29 | 67.7 | 33.3* |
| $Th^{232}$ | Spikes | 7 | 0 | 8/3-8/18 | 100 | 0 |
| $U^{238}$ | Spikes | 11 | 3 | 8/3-8/25 | 72.7 | 27.3* |
| $Ra^{228}$ | Spikes | 7 | 2 | 8/6-8/26 | 71.4 | 28.6* |
| $Ra^{228}$ | Spikes | 3 | 2 | 8/6-8/23 | 33.3 | 66.7* |
| $Am^{241}$ | Spikes | 3 | 0 | 9/1-9/2 | 100 | 0 |
| GALPH | Spikes | 9 | 3 | 9/4-9/28 | 67.7 | 33.3* |
| GBETW | Spikes | 8 | 4 | 9/4-9/26 | 50 | 50* |
| $Np^{237}$ | Spikes | 5 | 0 | 9/7-9/22 | 100 | 0 |
| $Pb^{210}$ | Spikes | 3 | 0 | 9/24-9/24 | 100 | 0 |
| $Pu^{239}$ | Spikes | 13 | 0 | 9/1-9/24 | 100 | 0 |
| $Ra^{228}$ | Spikes | 4 | 1 | 9/4-9/23 | 75 | 25 |
| $Sr^{89}$ | Spikes | 3 | 2 | 9/5-9/24 | 33.3 | 66.7* |
| $Sr^{90}$ | Spikes | 18 | 6 | 9/5-9/30 | 66.7 | 33.3* |
| $Tc^{99}$ | Spikes | 11 | 3 | 9/5-9/25 | 72.7 | 27.3* |
| $Th^{232}$ | Spikes | 24 | 1 | 9/2-9/28 | 95.8 | 4.2 |
| $H^{3}$ | Spikes | 11 | 6 | 9/7-9/25 | 45.5 | 54.5* |
| $U^{238}$ | Spikes | 25 | 4 | 9/2-9/28 | 84 | 16 |
| $Co^{60}$ | Duplicate | 4 | 2 | 9/12-9/28 | 50 | 50 |
| $Cs^{137}$ | Duplicate | 6 | 1 | 9/12-9/28 | 83.3 | 16.7 |
| GALPH | Duplicate | 5 | 1 | 9/4-9/25 | 80 | 20 |
| GBETW | Duplicate | 5 | 0 | 9/4-9/25 | 100 | 0 |
| $Ra^{226}$ | Duplicate | 6 | 2 | 9/17-9/23 | 67.7 | 33.3 |
| $Sr^{90}$ | Duplicate | 4 | 1 | 9/20-9/30 | 75 | 25 |
| $Tc^{99}$ | Duplicate | 8 | 0 | 9/6-9/25 | 100 | 0 |
| $Th^{232}$ | Duplicate | 7 | 1 | 9/2-9/25 | 85.7 | 14.3 |
| $H^{3}$ | Duplicate | 17 | 0 | 9/7-9/25 | 100 | 0 |
| $U^{238}$ | Duplicate | 5 | 1 | 9/12-9/25 | 80 | 20 |

**Table 4A.33. Subcontract laboratory 1990 control chart summary**

**Second Quarter QA/QC Control Charts 1990**

| Test | Type | N | Number of Outliers | Dates | Percent In | Percent Out |
|---|---|---|---|---|---|---|
| $Am^{241}$ | Spike | 23 | 5 | 1/5-6/20 | 78.3 | 21.7 |
| $Am^{241}$ | Duplicate | 5 | 0 | 3/18-6/13 | 100 | 0 |
| $C^{14}$ | Spike | 9 | 0 | 1/10-3/12 | 100 | 0 |
| $C^{14}$ | Duplicate | 4 | 0 | 1/10-3/12 | 100 | 0 |
| $Co^{60}$ | Duplicate | 13 | 1 | 1/31-5/5 | 92.3 | 7.6 |
| $Cs^{137}$ | Duplicate | 47 | 1 | 1/15-6/30 | 97.9 | 2.1 |
| *$Fe^{55}$ | | 3 | 1 | 1/2-3/2 | 66.7 | 33.3 |
| GALPH | Spike | 11 | 2 | 2/5-5/16 | 81.8 | 18.2 |
| GALPH | Duplicate | 13 | 1 | 3/5-5/16 | 92.3 | 7.6 |
| GBETW | Spike | 7 | 2 | 3/15-5/18 | 71.4 | 28.6 |
| GBETS | Duplicate | 6 | 0 | 3/5-4/17 | 100 | 0 |
| GBETW | Duplicate | 6 | 1 | 3/8-5/16 | 83.3 | 16.7 |
| $I^{129}$ | Spike | 4 | 0 | 1/22-3/3 | 100 | 0 |
| $N^{63}$ | Spike | 8 | 0 | 1/6-3/9 | 100 | 0 |
| $N^{63}$ | Duplicate | 3 | 0 | 1/6-3/9 | 100 | 0 |
| $Np^{237}$ | Spike | 55 | 5 | 1/2-6/24 | 90.9 | 9.1 |
| $Np^{237}$ | Duplicate | 14 | 0 | 1/2-6/24 | 100 | 0 |
| $Pu^{239}$ | Spike | 101 | 12 | 1/2-6/24 | 88.1 | 11.9 |
| $Pu^{239}$ | Duplicate | 27 | 1 | 1/2-6/24 | 96.3 | 3.7 |
| $Ra^{224}$ | Duplicate | 4 | 0 | 1/15-6/29 | 100 | 0 |
| $Ra^{226}$ | Spike | 62 | 0 | 1/12-6/26 | 100 | 0 |
| $Ra^{226}$ | Duplicate | 28 | 2 | 1/8-6/29 | 92.9 | 7.1 |
| $Ra^{228}$ | Spike | 58 | 16 | 1/2-6/28 | 72.4 | 27.6 |
| $Ra^{228}$ | Duplicate | 10 | 0 | 1/15-6/12 | 100 | 0 |
| $Sr^{89}$ | Duplicate | 8 | 0 | 1/25-3/26 | 100 | 0 |
| $Sr^{90}$ | Spike | 123 | 41 | 1/2-6/28 | 66.7 | 33.3 |
| $Sr^{90}$ | Duplicate | 29 | 5 | 1/25-6/14 | 82.8 | 17.24 |
| $Tc^{99}$ | Spike | 45 | 8 | 1/3-6/12 | 82.2 | 17.8 |
| $Tc^{99}$ | Duplicate | 38 | 2 | 1/3-5/7 | 94.7 | 5.3 |

Table 4A.33. (Continued)

| Test | Type | N | Number of Outliers | Dates | Percent In | Percent Out |
|---|---|---|---|---|---|---|
| $Th^{232}$ | Spike | 169 | 16 | 1/2-6/28 | 90.5 | 9.5 |
| $Th^{232}$ | Duplicate | 57 | 1 | 1/2-6/27 | 98.2 | 1.8 |
| $H^{3}$ | Spike | 71 | 3 | 1/4-6/21 | 95.8 | 4.2 |
| $H^{3}$ | Duplicate | 51 | 0 | 1/4-6/21 | 100 | 0 |
| $U^{234}$ | Spike | 48 | 4 | 1/2-4/9 | 91.7 | 8.3 |
| $U^{234}$ | Duplicate | 10 | 0 | 1/3-2/28 | 100 | 0 |
| $U^{238}$ | Spike | 139 | 9 | 1/2-6/24 | 93.5 | 6.5 |
| $U^{238}$ | Duplicate | 55 | 2 | 1/3-6/24 | 96.4 | 3.6 |

Table 4A.34. Subcontract laboratory 1990 control chart summary

First Quarter Control Charts 1990

| Test | Type | N | Number of Outliers | Dates | Percent In | Percent Out |
|---|---|---|---|---|---|---|
| $Am^{241}$ | Spike | 21 | 4 | 11/8/89-3/27/90 | 81 | 19.0 |
| $Am^{241}$ | Duplicate | 3 | 0 | 3/18/90-3/27/90 | 100 | 0 |
| $C^{14}$ | Spike | 16 | 0 | 12/14/89-3/12/90 | 100 | 0 |
| $C^{14}$ | Duplicate | 7 | 0 | 12/14/89-3/12/90 | 100 | 0 |
| $Co^{60}$ | Spike | 7 | 1 | 10/10/89-3/27/90 | 85.7 | 14.3 |
| $Cs^{137}$ | Duplicate | 16 | 1 | 10/10/89-3/27/90 | 93.7 | 6.3 |
| $Fe^{55}$ | Spike | 24 | 5 | 12/6/89-3/30/90 | 79.2 | 20.8 |
| $Fe^{55}$ | Duplicate | 5 | 1 | 12/6/89-3/2/90 | 80.0 | 20.0 |
| GALPH | Spike | 6 | 0 | 11/2/89-3/15/90 | 100 | 0 |
| GALPH | Duplicate | 9 | 0 | 12/11/89-3/26/90 | 100 | 0 |
| GBETW | Spike | 5 | 1 | 11/1/89-3/15/90 | 80.0 | 20.0 |
| GBETW | Duplicate | 9 | 2 | 11/1/89-3/26/90 | 77.8 | 22.2 |
| $I^{29}$ | Spike | 6 | 0 | 12/14/89-3/13/90 | 100 | 0 |
| $I^{29}$ | Duplicate | 3 | 0 | 12/14/89-3/3/90 | 100 | 0 |
| $Ni^{63}$ | Spike | 13 | 0 | 12/13/89-3/9/90 | 100 | 0 |
| $Ni^{63}$ | Duplicate | 3 | 0 | 1/6/90-3/9/90 | 100 | 0 |
| $Np^{237}$ | Spike | 40 | 5 | 10/6/89-3/30/90 | 87.5 | 12.5 |
| $Pu^{239}$ | Spike | 89 | 11 | 10/6/89-3/29-90 | 87.6 | 12.4 |
| $Pu^{239}$ | Duplicate | 16 | 0 | 10/18/89-3/30/90 | 100 | 0 |
| $Ra^{224}$ | Duplicate | 4 | 0 | 10/11/89-1/15/90 | 100 | 0 |
| $Ra^{226}$ | Spike | 55 | 23 | 10/2/89-3/30/90 | 58.2 | 41.8 |
| $Ra^{226}$ | Duplicate | 17 | 0 | 10/6/89-3/5/90 | 100 | 0 |
| $Ra^{228}$ | Spike | 48 | 8 | 10/6/89-3/29/90 | 83.3 | 16.7 |
| $Ra^{228}$ | Duplicate | 9 | 1 | 10/6/89-3/8/90 | 88.9 | 11.1 |
| $Sr^{89}$ | Duplicate | 8 | 0 | 1/25/90-3/26/90 | 100 | 0 |
| $Sr^{90}$ | Spike | 106 | 22 | 10-5/89-3/29/90 | 79.2 | 20.8 |
| $Sr^{90}$ | Duplicate | 24 | 5 | 11/30/89-3/29/90 | 79.2 | 20.8 |

**Table 4A.34. (continued)**

| Test | Type | N | Number of Outliers | Dates | Percent In | Percent Out |
|---|---|---|---|---|---|---|
| $Th^{232}$ | Spike | 172 | 17 | 10/9/89-3/30/90 | 90.1 | 9.9 |
| $Th^{232}$ | Duplicate | 62 | 1 | 10/17/89-3/30/90 | 98.4 | 1.6 |
| $H^{3}$ | Spike | 55 | 4 | 10/3/89-3/29/90 | 92.7 | 7.3 |
| $H^{3}$ | Duplicate | 41 | 0 | 10/5/89-3/29/90 | 100 | 0 |
| $U^{234}$ | Spike | 112 | 4 | 10/1/89-3/31/90 | 96.4 | 3.6 |
| $U^{234}$ | Duplicate | 36 | 0 | 10/17/89-2/28/90 | 100 | 0 |
| $U^{238}$ | Spike | 140 | 14 | 10/1/89-3/31/90 | 90 | 10 |
| $U^{238}$ | Duplicate | 54 | 1 | 10/17/89-3/31/90 | 98.1 | 1.9 |

Table 4A.35. Groundwater field duplicate evaluation

| Isotope | CRDL | 5X CRDL | Original sample pCi/L | Duplicate sample pCi/L | Lab qual | RPD | Control limits | No within limits | No. out limits |
|---|---|---|---|---|---|---|---|---|---|
| SAMPLE 1225D | | | | | | | | | |
| H-3 | 500 | 2500 | 879000 | 867000 | | 1.37 | 20% | 1 | |
| CS-137 | 20 | 100 | 20 | 20 | U | | | | |
| GROSS ALPHA | 1 | 5 | 24 | 30 | | 22.22 | 20% | | 1 |
| GROSS BETA | 4 | 20 | 8224 | 6456 | | 24.09 | 20% | | 1 |
| RA-226 | 1 | 5 | 16.2 | 13 | | 21.92 | 20% | | 1 |
| U-235/236 | 1 | 5 | 1 | 1 | U | | | | |
| SR-90 | 5 | 25 | 4410 | 4487 | | 1.73 | 20% | 1 | |
| CO-60 | NS | | 19.7 | 22.4 | | 12.83 | 20% | 1 | |
| U-234 | 1 | 5 | 1 | 1 | U | | | | |
| TH-230 | 1 | 5 | 1 | 1 | U | | | | |
| TH-228 | 1 | 5 | 1.39 | 1.34 | | 3.66 | +/-1 | 1 | |
| TH-232 | 1 | 5 | 1 | 1 | U | | | | |
| U-238 | 1 | 5 | 1 | 1 | U | | | | |
| | | | | | | | | AVE. RPD | 12.55 |
| SAMPLE 0546 | | | | | | | | | |
| 5/236 | 1 | 5 | 1 | 1 | U | | | | |
| GROSS ALPHA | 1 | 5 | 16.7 | 20.6 | | 20.91 | 20% | 1 | |
| GROSS BETA | 4 | 20 | 120 | 147 | | 20.22 | 20% | 1 | |
| RA-224 | NS | 22.1 | 147 | 42.86 | | | 20% | 1 | |
| RA-226 | 1 | 5 | 1.55 | 2.24 | | 36.41 | +/-1 | 1 | |
| RA-228 | 3 | 15 | 1.99 | 3 | U | | | | |
| PU-239/240 | 1 | 5 | 1 | 1 | U | | | | |
| U-234 | 1 | 5 | 1.09 | 1.22 | | 11.26 | +/-1 | 1 | |
| PU-238 | 1 | 5 | 1 | 1 | U | | | | |
| TH-230 | 1 | 5 | 1.39 | 1.04 | | 28.81 | +/-1 | 1 | |
| TH-228 | 1 | 5 | 1.99 | 1.23 | | 47.20 | +/-1 | 1 | |
| AM-241 | 1 | 5 | 1 | 1 | U | | | | |
| TH-232 | 1 | 5 | 1.19 | 1.07 | | 10.62 | +/-1 | 1 | |
| U-238 | 1 | 5 | 1 | 1 | U | | | | |
| H-3 | 500 | 2500 | 500 | 500 | U | | | | |
| CS-137 | 20 | 100 | 20 | 20 | U | | | | |
| SR-90 | 5 | 25 | 5 | 5 | U | | | | |
| | | | | | | | | AVE. RPD | 27.29 |
| SAMPLE 1231D | | | | | | | | | |
| U-235/236 | 1 | 5 | 1 | 1 | U | | | | |
| GROSS ALPHA | 1 | 5 | 24 | 7 | U | | | | |
| GROSS BETA | 4 | 20 | 21 | 19 | | 10.00 | +/-4 | 1 | |
| RA-226 | 1 | 5 | 2.1 | 1.6 | | 27.03 | +/-1 | 1 | |
| U-234 | 1 | 5 | 1 | 1 | U | | | | |

Table 4A.35. (continued)

| Isotope | CRDL | 5X CRDL | Original sample pCi/L | Duplicate sample pCi/L | Lab qual | RPD | Control limits | No within limits | No. out limits |
|---|---|---|---|---|---|---|---|---|---|
| TH-230 | 1 | 5 | 1 | 1 | U | | | | |
| TH-228 | 1 | 5 | 1.87 | 1 | U | 60.63 | +/-1 | 1 | |
| TH-232 | 1 | 5 | 1 | 1 | U | | | | |
| U-238 | 1 | 5 | 1 | 1 | U | | | | |
| H-3 | 500 | 2500 | 54000 | 54000 | | 0.00 | 20% | 1 | |
| CS-137 | 20 | 100 | 20 | 20 | U | | | | |
| SR-90 | 5 | 25 | 5 | 5 | U | | | | |
| RA-228 | 5 | 25 | 3.1 | 3 | U | | | | |
| | | | | | | | | AVE. RPD | 32.55 |
| SAMPLE 12331 APRIL 89 | | | | | | | | | |
| U-235/236 | 1 | 5 | 1 | 1 | U | | | | |
| GROSS ALPHA | 1 | 5 | 267 | 328 | | 20.50 | 20% | 1 | |
| GROSS BETA | 4 | 20 | 202 | 355 | | 54.94 | 20% | 1 | |
| RA-226 | 1 | 5 | 1 | 1.3 | | 26.09 | +/-1 | 1 | |
| RA-228 | 3 | 15 | 3 | 3 | U | | | | |
| PU-239/240 | 1 | 5 | 1 | 1 | U | | | | |
| U-234 | 1 | 5 | 1.84 | 2.03 | | 9.82 | +/-1 | 1 | |
| PU-238 | 1 | 5 | 1 | 1 | U | | | | |
| TH-230 | 1 | 5 | 2.96 | 1.83 | | 47.18 | +/-1 | 0 | 1 |
| TH-228 | 1 | 5 | 5.89 | 6.43 | | 8.77 | 20% | 1 | |
| AM-241 | 1 | 5 | 1.3 | 1 | U | | | | |
| TH-232 | 1 | 5 | 4.42 | 5.33 | | 18.67 | +/-1 | | |
| U-238 | 1 | 5 | 1.38 | 1.53 | | 10.31 | +/-1 | 1 | |
| H-3 | 500 | 2500 | 770000 | 820000 | | 6.29 | 20% | 1 | |
| CS-137 | 20 | 100 | 20 | 20 | U | | | | |
| Sr-90 | 5 | 25 | 5 | 5 | U | | | | |
| | | | | | | | | AVE. RPD | 22.51 |
| SAMPLE 12331 MAY 89 | | | | | | | | | |
| U-235/236 | 1 | 5 | 1 | 1 | U | | | | |
| GROSS ALPHA | 1 | 5 | 76 | 64 | | 17.14 | 20% | 1 | |
| GROSS BETA | 4 | 20 | 180 | 182 | | 1.10 | 20% | 1 | |
| K-40 | NS | 125 | 260 | 70.13 | | 20 | ±1 | | |
| PU-239/240 | 1 | 5 | 1 | 1 | U | | | | |
| U-234 | 1 | 5 | 1.6 | 1.5 | | 6.45 | +/-1 | 1 | |
| PU-238 | 1 | 5 | 1 | 1 | U | | | | |
| TH-230 | 1 | 5 | 1 | 1.6 | | 46.15 | +/-1 | 1 | |
| TH-228 | 1 | 5 | 1 | 3 | | 100.00 | +/-1 | 1 | |
| AM-241 | 1 | 5 | 1 | 1 | U | | | | |
| TH-232 | 1 | 5 | 1 | 1.7 | | 51.85 | +/-1 | 1 | |
| U-238 | 1 | 5 | 1.1 | 1.1 | | 0.00 | +/-1 | 1 | |

Table 4A.35. (continued)

| Isotope | CRDL | 5X CRDL | Original sample pCi/L | Duplicate sample pCi/L | Lab qual | RPD | Control limits | No within limits | No. out limits |
|---|---|---|---|---|---|---|---|---|---|
| H-3 | 500 | 2500 | 440000 | 630000 | | 35.51 | 20% | 1 | |
| CS-137 | 20 | 100 | 7.7 | 13.4 | U | | | | |
| SR-90 | 5 | 25 | 5 | 5 | U | | | | |
| | | | | | | | | AVE. RPD | 36.48 |
| SAMPLE 0530 | | | | | | | | | |
| U-235/236 | 1 | 5 | 1 | 1 | U | | | | |
| GROSS ALPHA | 1 | 5 | 24 | 25.7 | | 6.84 | 20% | 1 | |
| GROSS BETA | 4 | 20 | 1080 | 1110 | | 2.74 | 20% | 1 | |
| RA-224 | NS | 15.4 | 22.8 | | U | | | | |
| RA-226 | 1 | 5 | 1 | 1 | U | | | | |
| RA-228 | 3 | 15 | 3 | 3 | U | | | | |
| PU-239/240 | 1 | 5 | 1 | 1 | U | | | | |
| U-234 | 1 | 5 | 15.8 | 16.7 | | 5.54 | 20% | 1 | |
| PU-238 | 1 | 5 | 1 | 1 | U | | | | |
| TH-230 | 1 | 5 | 1.62 | 1 | U | | | | |
| TH-228 | 1 | 5 | 1 | 1 | U | | | | |
| 241 | 1 | 5 | 1 | 1 | U | | | | |
| TH-232 | 1 | 5 | 1 | 1 | U | | | | |
| U-238 | 1 | 5 | 1 | 1 | U | | | | |
| H-3 | 500 | 2500 | 51200 | 51000 | | 0.39 | 20% | 1 | |
| CS-137 | 20 | 100 | 20 | 20 | U | | | | |
| SR-90 | 5 | 25 | 5 | 5 | U | | | | |
| | | | | | | | | AVE. RPD | 3.88 |
| SAMPLE 8492 | | | | | | | | | |
| GROSS ALPHA | 1 | 5 | 8 | 6 | U | | | | |
| GROSS BETA | 4 | 20 | 13 | 9 | U | | | | |
| RA-226 | 1 | 5 | 1.2 | 1 | U | | | | |
| RA-228 | 3 | 15 | 3 | 3 | U | | | | |
| H-3 | 500 | 2500 | 2600000 | 2700000 | | 3.77 | 20% | 1 | |
| CS-137 | 20 | 100 | 20 | 20 | U | | | | |
| U-235/236 | 1 | 5 | 1 | 1 | U | | | | |
| SR-90 | 5 | 25 | 5 | 5 | U | | | | |
| U-234 | 1 | 5 | 1 | 1 | U | | | | |
| TH-230 | 1 | 5 | 1 | 1 | U | | | | |
| TH-228 | 1 | 5 | 3 | 3 | U | | | | |
| TH-232 | 1 | 5 | 1 | 1 | U | | | | |
| [illegible]8 | 1 | 5 | 1 | 1 | U | | | | |
| | | | | | | | | AVE. RPD | 3.77 |
| SAMPLE 8501 | | | | | | | | | |
| GROSS ALPHA | 1 | 5 | 9 | 8 | | 11.76 | 20% | 1 | |

Table 4A.35. (continued)

| Isotope | CRDL | 5X CRDL | Original sample pCi/L | Duplicate sample pCi/L | Lab qual | RPD | Control limits | No within limits | No. out limits |
|---|---|---|---|---|---|---|---|---|---|
| GROSS BETA | 4 | 20 | 9 | 9 | | 0.00 | +/-4 | 1 | |
| H-3 | 500 | 2500 | 30600 | 33200 | | 8.15 | 20% | 1 | |
| CS-137 | 20 | 100 | 20 | 20 | U | | | | |
| U-235/236 | 1 | 5 | 1 | 1 | U | | | | |
| SR-90 | 5 | 25 | 5 | 5 | U | | | | |
| U-234 | 1 | 5 | 1 | 1 | U | | | | |
| TH-230 | 1 | 5 | 1 | 1 | U | | | | |
| TH-228 | 1 | 5 | 1 | 1 | U | | | | |
| TH-232 | 1 | 5 | 1 | 1 | U | | | | |
| U-238 | 1 | 5 | 1 | 1 | U | | | | |
| RA-228 | 3 | 15 | 3 | 3 | U | | | | |
| AM-241 | 1 | 5 | 1 | 1 | U | | | | |
| RA-226 | 1 | 5 | 1 | 1 | U | | | | |
| PU-238 | 1 | 5 | 1 | 1 | U | | | | |
| PU-239/240 | 1 | 5 | 1 | 1 | U | | | | |
| | | | | | | | | AVE. RPD | 6 |
| SAMPLE 8511 | | | | | | | | | |
| GROSS ALPHA | 1 | 5 | 2 | 2 | U | | | | |
| GROSS BETA | 4 | 20 | 9 | 9 | U | | | | |
| H-3 | 500 | 2500 | 50000 | 50000 | | 0.00 | 20% | 1 | |
| CS-137 | 20 | 100 | 12 | 13.6 | U | | | | |
| U-235/236 | 1 | 5 | 1 | 1 | U | | | | |
| SR-90 | 5 | 25 | 5 | 5 | U | | | | |
| U-234 | 1 | 5 | 1 | 1 | U | | | | |
| TH-230 | 1 | 5 | 1 | 1 | U | | | | |
| TH-228 | 1 | 5 | 3 | 1 | U | | | | |
| TH-232 | 1 | 5 | 1 | 1 | U | | | | |
| U-238 | 1 | 5 | 1 | 1 | U | | | | |
| AM-241 | 1 | 5 | 1 | 1 | U | | | | |
| PU-238 | 1 | 5 | 1 | 1 | U | | | | |
| PU-239/240 | 1 | 5 | 1 | 1 | U | | | | |
| | | | | | | | | AVE. RPD | 0.00 |
| | | | | | TOTALS | 33 | 12 | | |

**Table 4A.36. Surface water field duplicate evaluation**

| Isotope | CRDL | 5X CRDL | Original sample pCi/L | Duplicate sample pCi/L | Lab Qual | RPD | Control limits | No. within limits | No. out of limits |
|---|---|---|---|---|---|---|---|---|---|
| **Sample DBAB2** | | | | | | | | | |
| H-3 | 500 | 2500 | 216000 | 221000 | | 2.29 | 20% | 1 | |
| CS-137 | 20 | 100 | 20 | 20 | U | | | | |
| GROSS ALPHA | 1 | 5 | 3 | 2 | U | | | | |
| GROSS BETA | 4 | 20 | 7 | 6 | | 15.38 | +/-4 | 1 | |
| SR-90 | 5 | 25 | 5 | 5 | U | | | | |
| | | | | AVE. RPD | | 8.84 | | | |
| **SAMPLE W49TD** | | | | | | | | | |
| U-235/236 | 1 | 5 | 1 | 1 | U | | | | |
| GROSS ALPHA | 1 | 5 | 2 | 1 | U | | | | |
| GROSS BETA | 4 | 20 | 23 | 2 | | 168.00 | +/-4 | 1 | |
| U-234 | 1 | 5 | 1 | 1 | U | | | | |
| TH-230 | 1 | 5 | 1 | 1 | U | | | | |
| TH-228 | 1 | 5 | 1 | 1 | U | | | | |
| TH-232 | 1 | 5 | 1 | 1 | U | | | | |
| H-[illegible] | 500 | 2500 | 5310000 | 5380000 | | 1.31 | 20% | 1 | |
| [illegible] | 1 | 5 | 1 | 1 | U | | | | |
| [illegible].37 | 20 | 100 | 12 | 12 | U | | | | |
| | | | | AVE. RPD | | 84.65 | | | |
| **SAMPLE 49TSD** | | | | | | | | | |
| U-235/236 | 1 | 5 | 1 | 1 | U | | | | |
| GROSS ALPHA | 1 | 5 | 4 | 2 | | 66.67 | +/-1 | | 1 |
| GROSS BETA | 4 | 20 | 12 | 10 | | 18.18 | +/-4 | 1 | |
| RA-226 | 1 | 5 | 1 | 1 | U | | | | |
| RA-228 | 3 | 15 | 1 | 3 | U | | | | |
| U-234 | 1 | 5 | 1 | 1 | U | | | | |
| TH-230 | 1 | 5 | 1 | 1 | U | | | | |
| TH-228 | 1 | 5 | 3 | 1 | U | | | | |
| TH-232 | 1 | 5 | 1 | 1 | U | | | | |
| U-238 | 1 | 5 | 1 | 1 | U | | | | |
| H-3 | 500 | 2500 | 14000000 | 15000000 | | 6.90 | 20% | 1 | |
| CS-137 | 20 | 100 | 20 | 20 | U | | | | |
| SR-90 | 5 | 25 | 5 | 5 | U | | | | |
| | | | | AVE. RPD | | | 30.58 | | |
| **SAMPLE W49TD** | | | | | | | | | |
| U-235/236 | 1 | 5 | 1 | 1 | U | | | | |
| GROSS ALPHA | 1 | 5 | 1 | 3 | U | | | | |
| GROSS BETA | 4 | 20 | 11 | 10 | | 9.52 | +/-4 | 1 | |
| PU-239/240 | 1 | 5 | 1 | 1 | U | | | | |
| U-234 | 1 | 5 | 1 | 1 | U | | | | |
| [illegible]8 | 1 | 5 | 1 | 1 | U | | | | |
| [illegible].30 | 1 | 5 | 1 | 1 | U | | | | |
| TH-228 | 1 | 5 | 1 | 1 | U | | | | |
| AM-241 | 1 | 5 | 1 | 1 | U | | | | |

**Table 4A.36. (continued)**

| Isotope | CRDL | 5X CRDL | Original sample pCi/L | Duplicate sample pCi/L | Lab Qual | RPD | Control limits | No. within limits | No. out of limits |
|---|---|---|---|---|---|---|---|---|---|
| TH-232 | 1 | 5 | 1 | 1 | U | | | | |
| U-238 | 1 | 5 | 1 | 2.3 | | 78.79 | ±/-1 | | 1 |
| H-3 | 500 | 2500 | 8500000 | 8700000 | | 2.33 | 20% | | 1 |
| CS-137 | 20 | 100 | 11 | 6.66 | U | | | | |
| SR-90 | 5 | 25 | 5 | 5 | U | | | | |
| | | | | AVE. RPD | | | 30.21 | | |
| **SAMPLE W49TSD** | | | | | | | | | |
| U-235/236 | 1 | 5 | 1 | 1 | U | | | | |
| GROSS ALPHA | 1 | 5 | 1 | 2 | | 66.67 | +/-1 | 1 | |
| GROSS BETA | 4 | 20 | 16 | 9 | | 56.00 | +/-4 | | 1 |
| RA-226 | 1 | 5 | 1 | 1 | U | | | | |
| RA-228 | 3 | 15 | 3 | 3 | U | | | | |
| U-234 | 1 | 5 | 1 | 1 | U | | | | |
| TH-230 | 1 | 5 | 1 | 1 | U | | | | |
| TH-228 | 1 | 5 | 1 | 1 | U | | | | |
| TH-232 | 1 | 5 | 1 | 3 | U | | | | |
| U-238 | 1 | 5 | 1 | 1 | U | | | | |
| H-3 | 500 | 2500 | 4270000 | 4280000 | | 0.23 | 20% | 1 | |
| CS-137 | 20 | 100 | 20 | 20 | U | | | | |
| SR-90 | 5 | 25 | 7.3 | 5 | U | | | | |
| | | | | AVE. RPD | | | 40.97 | | |
| **SAMPLE W50TS** | | | | | | | | | |
| GROSS ALPHA | 1 | 5 | 4 | 5 | | 22.22 | +/-1 | 1 | |
| GROSS BETA | 4 | 20 | 12 | 9 | | 28.57 | +/-4 | 1 | |
| H-3 | 500 | 2500 | 12000000 | 12000000 | | 0.00 | 20% | 1 | |
| CS-137 | 20 | 100 | 20 | 20 | U | | | | |
| U-235/236 | 1 | 5 | 1 | 1 | U | | | | |
| SR-90 | 5 | 25 | 5 | 5 | U | | | | |
| U-234 | 1 | 5 | 1 | 1 | U | | | | |
| TH-230 | 1 | 5 | 1 | 1 | U | | | | |
| TH-228 | 1 | 5 | 1 | 1 | U | | | | |
| TH-232 | 1 | 5 | 1 | 1 | U | | | | |
| U-238 | 1 | 5 | 1 | 1 | U | | | | |
| PU-239/240 | 1 | 5 | 1 | 1 | U | | | | |
| | | | | AVE RPD | 16.93 | | | | |
| | | | | | | | TOTALS | 13 | 3 |

**Table 4A.37. Soil field duplicate evaluation**

| Isotope | CRDL | 5x CRDL | Original sample pCi/g | Duplicate sample pCi/g | Lab qual | RPD | Control limits | No. within limits | No. out limits |
|---|---|---|---|---|---|---|---|---|---|
| Sample 0099 | | | | | | | | | |
| H-3 | 50 | 250 | 50 | 50 | U | | | | |
| Cs-137 | 0.2 | 1 | 0.2 | 0.2 | U | | | | |
| Gross alpha | 1 | 5 | 13.2 | 14.4 | | 8.70 | 35% | 1 | |
| Gross beta | 2 | 10 | 20.8 | 20.5 | | 1.45 | 35% | 1 | |
| Ra-224 | NS | | 1.52 | 1.28 | | 17.14 | 35% | 1 | |
| K-40 | NS | | 25.6 | 25.7 | | 0.39 | 35% | 1 | |
| Ra-226 | 0.3 | 1.5 | 0.8 | 0.71 | | 11.92 | ±0.6 | 1 | |
| Ra-228 | 0.5 | 2.5 | 1.52 | 1.51 | | 0.66 | ±1.0 | 1 | |
| | | | | | | AVE. RPD 6.71 | | | |
| SCA12 (06-12) | | | | | | | | | |
| 5/236 | 0.6 | 3 | 0.6 | 0.6 | U | | | | |
| ɔss alpha | 1 | 5 | 15 | 22 | | 37.84 | 35% | 1 | |
| Gross beta | 2 | 10 | 24 | 24 | | 0.00 | 35% | 1 | |
| Ra-224 | NS | | 1.43 | 1.83 | | 24.54 | 35% | 1 | |
| K-40 | NS | | 25.6 | 28.7 | | 11.42 | 35% | 1 | |
| Ra-226 | 0.3 | 1.5 | 0.82 | 0.83 | | 1.21 | ±0.6 | 1 | |
| Ra-228 | 0.5 | 2.5 | 1.4 | 1.65 | | 16.39 | ±1 | 1 | |
| Pu-239/240 | 0.6 | 3 | 0.6 | 0.6 | U | 0 | | | |
| U-234 | 0.6 | 3 | 0.67 | 0.62 | | 7.75 | ±1.2 | 1 | |
| Pu-238 | 0.6 | 3 | 0.6 | 0.6 | U | 0 | | | |
| Th-230 | 0.6 | 3 | 0.6 | 0.63 | | 4.88 | ±1.2 | 1 | |
| Th-228 | 0.6 | 3 | 0.66 | 1.03 | | 43.79 | ±1.2 | 1 | |
| Am-241 | 0.6 | 3 | 0.6 | 0.6 | U | 0 | | | |
| Th-232 | 0.6 | 3 | 0.9 | 0.7 | | 25.00 | ±1.2 | 1 | |
| U-238 | 0.6 | 3 | 0.6 | 0.77 | | 24.82 | ±1.2 | 1 | |
| | | | | | AVE. RPD 19.76 | | | | |
| SCA15(12-18) | | | | | | | | | |
| U-235/236 | 0.6 | 3 | 0.6U | 0.6 | U | 0 | | | |
| Gross alpha | 1 | 5 | 21 | 16 | | 27.03 | 35% | 1 | |
| Gross beta | 2 | 10 | 32 | 27 | | 16.95 | 35% | 1 | |
| ,24 | NS | | 1.42 | 1.41 | | 0.71 | 35% | 1 | |
| K-40 | NS | | 30 | 28.1 | | 6.54 | 35% | 1 | |
| Ra-226 | 0.3 | 1.5 | 0.64 | 0.68 | | 6.06 | ±0.6 | 1 | |
| PU-239/240 | 0.6 | 3 | 0.6 | 0.6 | U | 0 | | | |

**Table 4A.37. (continued)**

| Sample 0099 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Isotope | CRDL | 5x CRDL | Original sample pCi/g | Duplicate sample pCi/g | Lab qual | RPD | Control limits | No. within limits | No. out limits |
| U-234 | 0.6 | 3 | 0.75 | 0.77 | | 2.63 | ±1.2 | 1 | |
| Pu-238 | 0.6 | 3 | 0.6 | 0.6 | U | 0 | | | |
| Th-230 | 0.6 | 3 | 1.24 | 0.56 | | 75.56 | ±1.2 | 1 | |
| Th-228 | 0.6 | 3 | 1.04 | 1.53 | | 38.13 | ±1.2 | 1 | |
| Am-241 | 0.6 | 3 | 0.6 | 0.6 | U | 0 | | | |
| Th-234 | 0.6 | 3 | 0.84 | 1.1 | | 26.80 | ±1.2 | 1 | |
| Th-232 | 0.6 | 3 | 0.8 | 0.82 | | 2.47 | ±1.2 | 1 | |
| U-238 | 0.6 | 3 | 0.78 | 0.72 | | 8.00 | ±1.2 | 1 | |
| | | | | | AVE. RPD 19.17 | | | | |
| SCB03(12-18) | | | | | | | | | |
| U-235/236 | 0.6 | 3 | 0.6 | 0.6 | U | | | | |
| Gross alpha | 1 | 5 | 13 | 13 | | 0.00 | 35% | 1 | |
| Gross beta | 2 | 10 | 24 | 23 | | 4.26 | 35% | 1 | |
| RA-224 | NS | | 1.3 | 1.38 | | 5.97 | 35% | 1 | |
| K-40 | NS | | 28.1 | 31.4 | | 11.09 | 35% | 1 | |
| Ra-226 | 0.3 | 1.5 | 0.67 | 0.71 | | 5.80 | ±0.6 | 1 | |
| Ra-228 | 0.5 | 2.5 | 1.39 | 1.59 | | 13.42 | ±1.0 | 1 | |
| Pu-239/240 | 0.6 | 3 | 0.6 | 0.6 | U | | | | |
| U-234 | 0.6 | 3 | 0.6 | 0.6 | U | | | | |
| Pu-238 | 0.6 | 3 | 0.6 | 0.6 | U | | | | |
| Th-230 | 0.6 | 3 | 0.67 | 0.84 | | 22.52 | ±1.2 | 1 | |
| Th-228 | 0.6 | 3 | 0.67 | 0.96 | | 35.58 | ±1.2 | 1 | |
| Am-241 | 0.6 | 3 | 0.6 | 0.6 | U | | | | |
| Th-234 | 0.6 | 3 | 1.17 | 1 | | 15.67 | ±1.2 | 1 | |
| Th-232 | 0.6 | 3 | 0.73 | 0.66 | | 10.07 | ±1.2 | 1 | |
| U-238 | 0.6 | 3 | 0.6 | 0.65 | | 8.00 | ±1.2 | 1 | |
| | | | | | AVE. RPD 12.03 | | | | |
| SCC02(12-18) | | | | | | | | | |
| U-235/236 | 0.6 | 3 | 0.6 | 0.6 | U | | | | |
| Gross alpha | 1 | 5 | 18 | 18 | | 0.00 | 35% | 1 | |
| Gross beta | 2 | 10 | 24 | 30 | | 22.22 | 35% | 1 | |
| Ra-224 | NS | | 1.22 | 1.33 | | 8.63 | 35% | 1 | |
| K-40 | NS | | 31.5 | 34.2 | | 8.22 | 35% | 1 | |
| Ra-226 | 0.3 | 1.5 | 0.76 | 0.78 | | 2.60 | ±0.6 | 1 | |
| Ra-228 | 0.5 | 2.5 | 1.5 | 1.47 | | 2.02 | ±1.0 | 1 | |
| Pu-239/240 | 0.6 | 3 | 0.6 | 0.6 | U | | | | |
| U-234 | 0.6 | 3 | 0.65 | 0.89 | | 31.17 | ±1.2 | 1 | |

Table 4A.37. (continued)

| Sample 0099 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Isotope | CRDL | 5x CRDL | Original sample pCi/g | Duplicate sample pCi/g | Lab qual | RPD | Control limits | No. within limits | No. out limits |
| Pu-238 | 0.6 | 3 | 0.6 | 0.6 | U | | | | |
| Th-230 | 0.6 | 3 | 1.29 | 0.88 | | 37.79 | ±1.2 | 1 | |
| Th-228 | 0.6 | 3 | 1.56 | 1.33 | | 15.92 | ±1.2 | 1 | |
| Am-241 | 0.6 | 3 | 0.6 | 0.6 | U | | | | |
| Th-234 | 0.6 | 3 | 0.87 | 1.08 | | 21.54 | ±1.2 | 1 | |
| Th-232 | 0.6 | 3 | 1.22 | 0.93 | | 26.98 | ±1.2 | 1 | |
| U-238 | 0.6 | 3 | 0.97 | 0.811 | | 7.98 | ±1.2 | 1 | |
| | | | | | AVE. RPD 16.25 | | | | |
| U-235/236 | 0.6 | 3 | 0.6 | 0.6 | U | | | | |
| Gross alpha | 1 | 5 | 15.9 | 14.5 | | 9.21 | 35% | 1 | |
| Gross beta | 2 | 10 | 26.6 | 28 | | 5.13 | 35% | 1 | |
| Ra-224 | NS | | 13.1 | 12.5 | | 4.69 | 35% | 1 | |
| Ra-226 | 0.3 | 1.5 | 0.73 | 0.67 | | 8.57 | ±0.6 | 1 | |
| P- 228 | 0.5 | 2.5 | 1.36 | 1.31 | | 3.75 | ±1.0 | 1 | |
| 39/240 | 0.6 | 3 | 0.6 | 0.6 | U | | | | |
| U-234 | 0.6 | 3 | 0.89 | 0.84 | | 5.78 | ±1.2 | 1 | |
| Pu-238 | 0.6 | 3 | 0.6 | 0.6 | U | | | | |
| Th-230 | 0.6 | 3 | 1.09 | 1.08 | | 0.92 | ±1.2 | 1 | |
| Th-228 | 0.6 | 3 | 1.42 | 1.72 | | 19.11 | ±1.2 | 1 | |
| Am-241 | 0.6 | 3 | 0.77 | 0.71 | | 8.11 | ±1.2 | 1 | |
| Th-232 | 0.6 | 3 | 1.18 | 0.99 | | 17.51 | ±1.2 | 1 | |
| U-238 | 0.6 | 3 | 0.75 | 0.69 | | 8.33 | ±1.2 | 1 | |
| H-3 | 50 | 250 | 50 | 50 | U | | | | |
| Cs-137 | 0.2 | 1 | 0.894 | 0.42 | | 72.15 | ±0.4 | 1 | |
| Sr-90 | 0.5 | 2.5 | 0.79 | 1.22 | | 42.79 | ±1.0 | 1 | |
| Cm-244 | 0.6 | 3 | 0.6 | 0.6 | U | | | | |
| Ni-63 | 10 | 50 | 10 | 10 | U | | | | |
| Tc-99 | 0.9 | 4.5 | 0.9 | 0.9 | U | | | | |
| Sr-89 | 3 | 15 | 6 | 6 | U | | | | |
| Pm-147 | 5 | 25 | 5 | 5 | U | | | | |
| Fe-55 | 10 | 50 | 10 | 10 | U | | | | |
| C-14 | 10 | 50 | 10 | 10 | U | | | | |
| I-129 | 10 | 50 | 10 | 10 | U | | | | |
| Cm-242 | 0.6 | 3 | 0.6 | 0.6 | U | | | | |
| | | | | | AVE. RPD 15.85 | | | | |
| 0180 and 0181 | | | | | | | | | |
| Gross alpha | 1 | 5 | 20.9 | 15.7 | | 28.42 | 35% | 1 | |

**Table 4A.37. (continued)**

Sample 0099

| Isotope | CRDL | 5x CRDL | Original sample pCi/g | Duplicate sample pCi/g | Lab qual | RPD | Control limits | No. within limits | No. out limits |
|---|---|---|---|---|---|---|---|---|---|
| Gross beta | 2 | 10 | 21.8 | 19.6 | | 10.63 | 35% | 1 | |
| Ra-224 | NS | | 1.34 | 1.34 | | 0.00 | 35% | 1 | |
| K-40 | NS | | 23.6 | 24.6 | | 4.15 | 35% | 1 | |
| Ra-226 | 0.3 | 1.5 | 0.73 | 0.73 | | 0.00 | ±0.6 | 1 | |
| Ra-228 | 0.5 | 2.5 | 1.34 | 1.35 | | 0.74 | ±1.0 | 1 | |
| Th-234 | 0.6 | 3 | 1.06 | 1.35 | | 24.07 | ±1.2 | 1 | |
| H-3 | 50 | 250 | 153 | 166 | | 8.15 | ±1.0 | 1 | |
| Cs-137 | 0.2 | 1 | 0.97 | 0.56 | | 53.59 | ±0.4 | 1 | |
| | | | | | | | AVE. RPD 14.42 | | |
| | | | | | | | TOTALS703 | | |

**Table 4A.38. Groundwater field QC sample results**

| Sample no. | Sample type | Parameter | Activity, pCi/L | Comments |
|---|---|---|---|---|
| 0439 | Rinsak | Ra-224 | 11.5 ± 6.9 | Alpha emitter, not confirmed by gross analysis |
| 12251 | Field blank | none | --- | --- |
| 1227 | Field blank | H-3 | 1980 ± 280 | --- |
| 12271 | Field blank | Gross alpha | 1 ± 1 | Value at detection limit |
| | | Gross beta | 5 ± 1 | Value slightly above detection limit |
| 1227B | Field blank | Ra-226 | 2.9 ± 0.6 | Value below drinking water standards |
| 12282 | Field blank | Gross alpha | 1 ± 1 | Value at detection limit |
| | | K-40 | 257 ± 123 | Detected by gamma spectroscopy result not confirmed by gross beta |
| | | Ra-228 | 3.7 ± 0.8 | |
| 12332 | Field blank | none | -- | -- |
| 8491 | Field blank | Gross alpha | 2 ± 1 | --- |
| 853B | Field blank | None | --- | --- |
| 8541 | Field blank | Th-228 | 2.0 ± 0.4 | Detected by gamma spectroscopy |

Table 4A.39. Surface water field QC sample results.

| Sample no. | Sample type | Parameter | Activity, pCi/L | Comments |
|---|---|---|---|---|
| 0481 | Rinseate | Ra-228 | 13.2 ± 8.1 | Detected by gamma spectroscopy, approximately at detection level |
| | | K-40 | 232 ± 113 | Detected by gamma spectroscopy, above background levels |
| | | Pu-238 | 2.42 ± 1.14 | Detected by gamma spectroscopy, above background levels |
| 0547 | Rinseate | Ra-224 | 18.3 ± 8.3 | Detected by gamma spectroscopy, above background levels |
| 0438 | Rinseate | Ra-224 | 20.6 ± 9.2 | Detected by gamma spectroscopy, above background levels |
| 0441 | Rinseate | Ra-224 | 20.6 ± 8.7 | Detected by gamma spectroscopy, above background levels |
| | | K-40 | 193 ± 95 | Detected by gamma spectroscopy, above background levels |
| | | Th-234 | 244 ± 64 | Detected by gamma spectroscopy, above background levels |
| | | Th-230 | 1.1 ± 0.29 | Detected by gamma spectroscopy, above background levels |
| BBAB2 | Field blank | none | --- | --- |
| SWFB | Field blank | H-3 | 727 ± 223 | Detection limit 500 pCi/L |
| | Gross alpha | Gross beta | 14 ± 3 | |
| 49TSB | Field blank | none | --- | --- |
| W49FB | Field blank | none | --- | --- |
| W49TSB | Field blank | Th-228 | 1.17 ± 0.29 | Alpha emitters, not confirmed by gross analysis |
| W51TS | Field blank | none | --- | --- |
| W51TSD | Field blank | none | --- | --- |

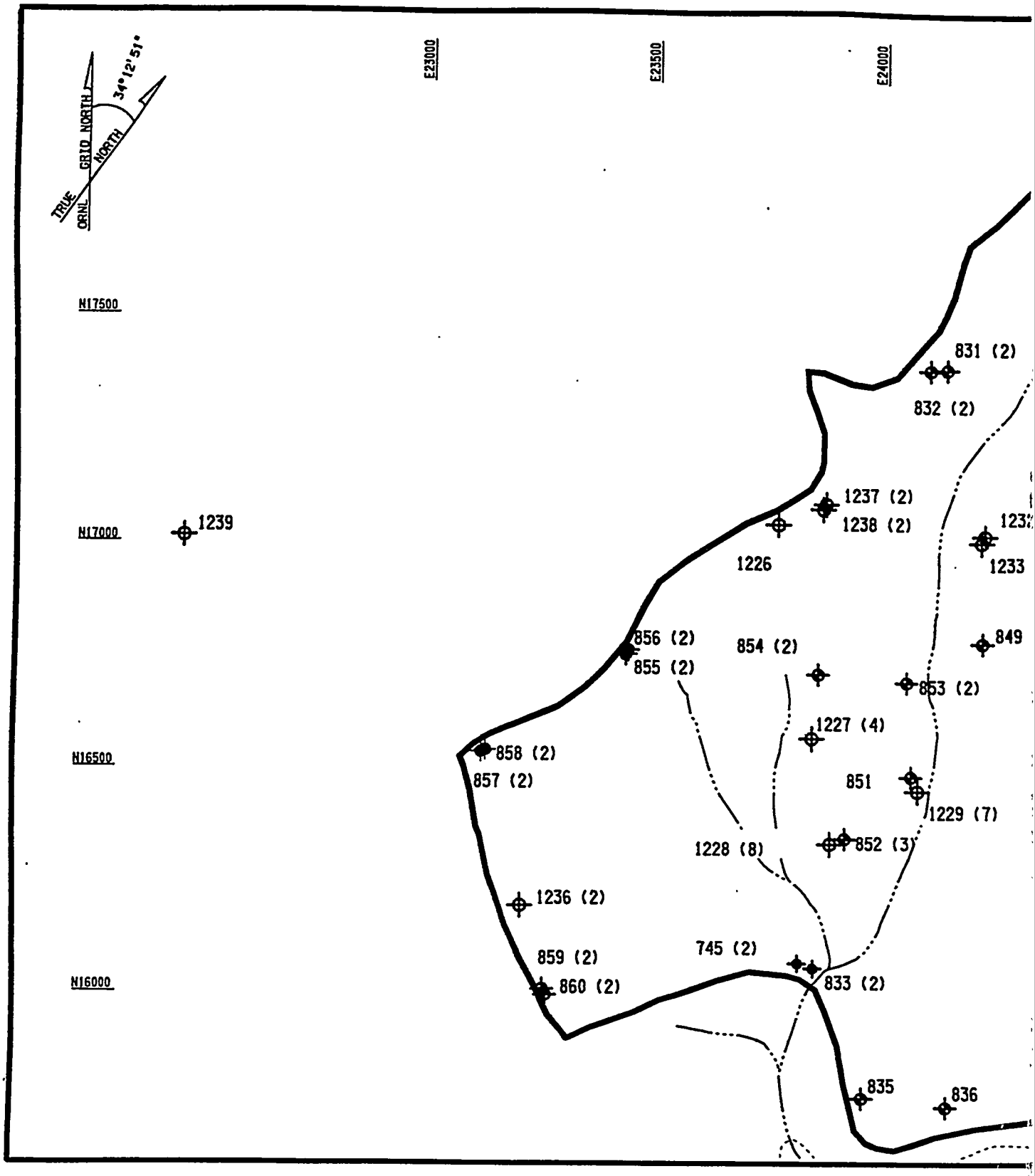
Table 4A.40. Background solid field QC sample results.

| Sample no. | Sample type | Parameter | Activity, pCi/L | Comments |
|---|---|---|---|---|
| 0187 | Rinseate | Gross alpha | 7 ± 2 | --- |
| | | Ra-224 | 8.0 ± 7.9 | Detected by gamma spectroscopy |
| 0197 | Rinseate | Gross alpha | 2 ± 1 | --- |

**Table 4A.41. Interlaboratory spike comparison**

| INTERLAB | RAD DATA | | | | | | |
|---|---|---|---|---|---|---|---|
| ANALYTE | SPIKE PCI/L | IT PCI/L | IT SPIKE RPD | ORNL PCI/L | ORNL SPIKE RPD | | ORN RPD |
| GROSS A | 215 | 218 | 1.39 | 189 | 12.87 | | 14.2 |
| GROSS B | 201 | 159 | 23.33 | 189 | 6.15 | | 17.2 |
| H-3 | 34865 | 33500 | 3.99 | 29700 | 16.00 | | 12.0 |
| C0-60 | 203 | 230 | 12.47 | 216 | 6.21 | | 6.28 |
| CS-137 | 267 | 293 | 9.29 | 297 | 10.64 | | 1.36 |
| AM-241 | 215 | NA | | 192 | 11.30 | | |
| | | AVE.RPD | 12.62 | AVE.RPD | 10.53 | AVE.RPD | 10.2 |
| | | | | | | | |
| ANALYTE | SPIKE PCI/L | IT PCI/L | IT RPD | ORNL PCI/L | ORNL RPD | | ORN RPD |
| GROSS A | 215 | 342 | 45.60 | 143 | 40.22 | | 82.0 |
| GROSS B | 201 | 200 | 0.50 | 189 | 6.15 | | 5.66 |
| H-3 | 34865 | 34600 | 0.76 | 29700 | 16.00 | | 15.2 |
| C0-60 | 203 | 231 | 12.90 | 205 | 0.98 | | 11.9 |
| CS-137 | 267 | 281 | 5.11 | 270 | 1.12 | | 3.99 |
| AM-241 | 215 | | | 200 | 7.23 | | |
| | | AVE RPD | 14.94 | AVE RPD | 11.95 | | |
| | | OVERALL RPD | 13.78 | OVERALL RPD | 11.24 | AVE.RPD | 23.7 |

# Appendix 4A Figures




WAG6 06f280.DGN

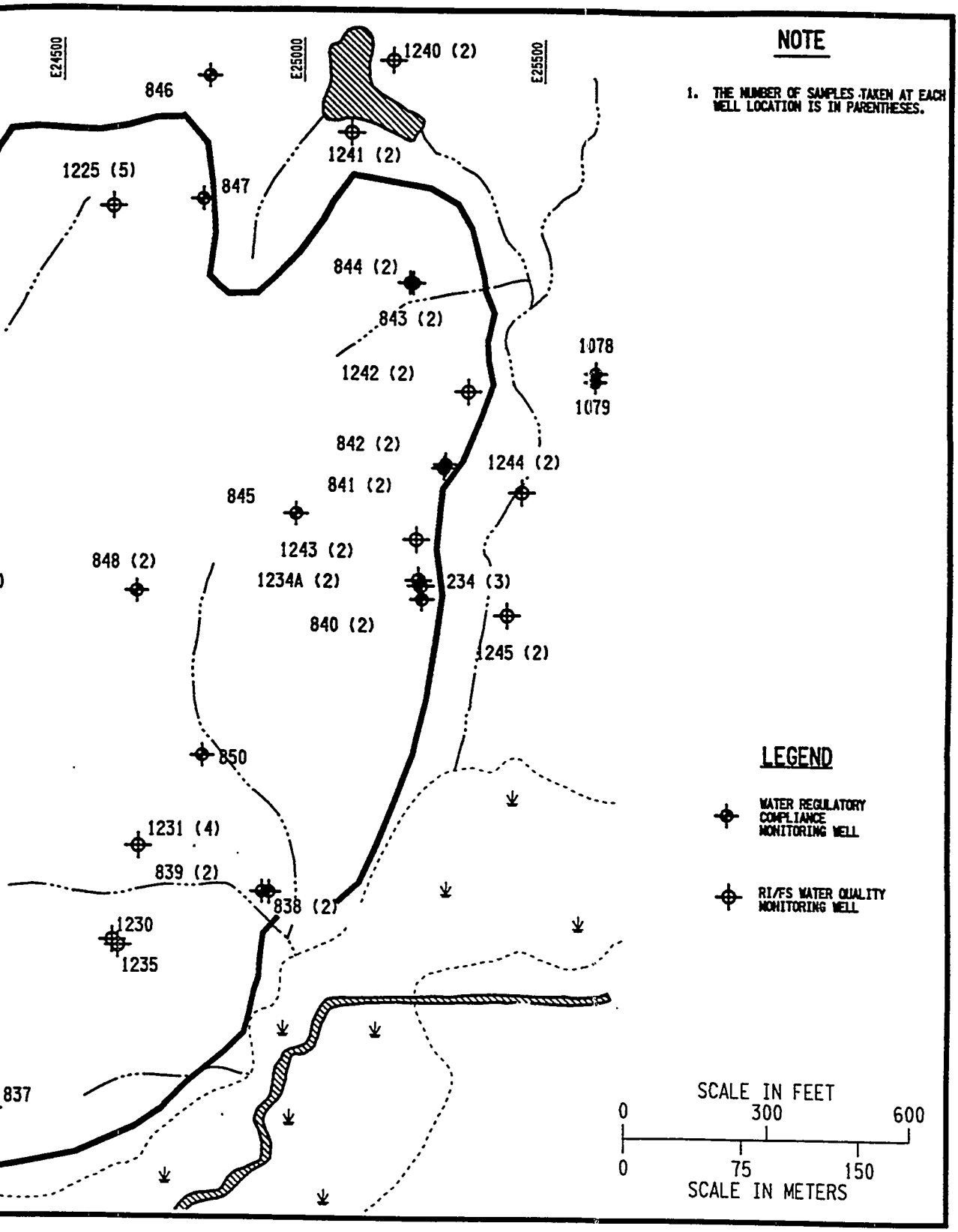
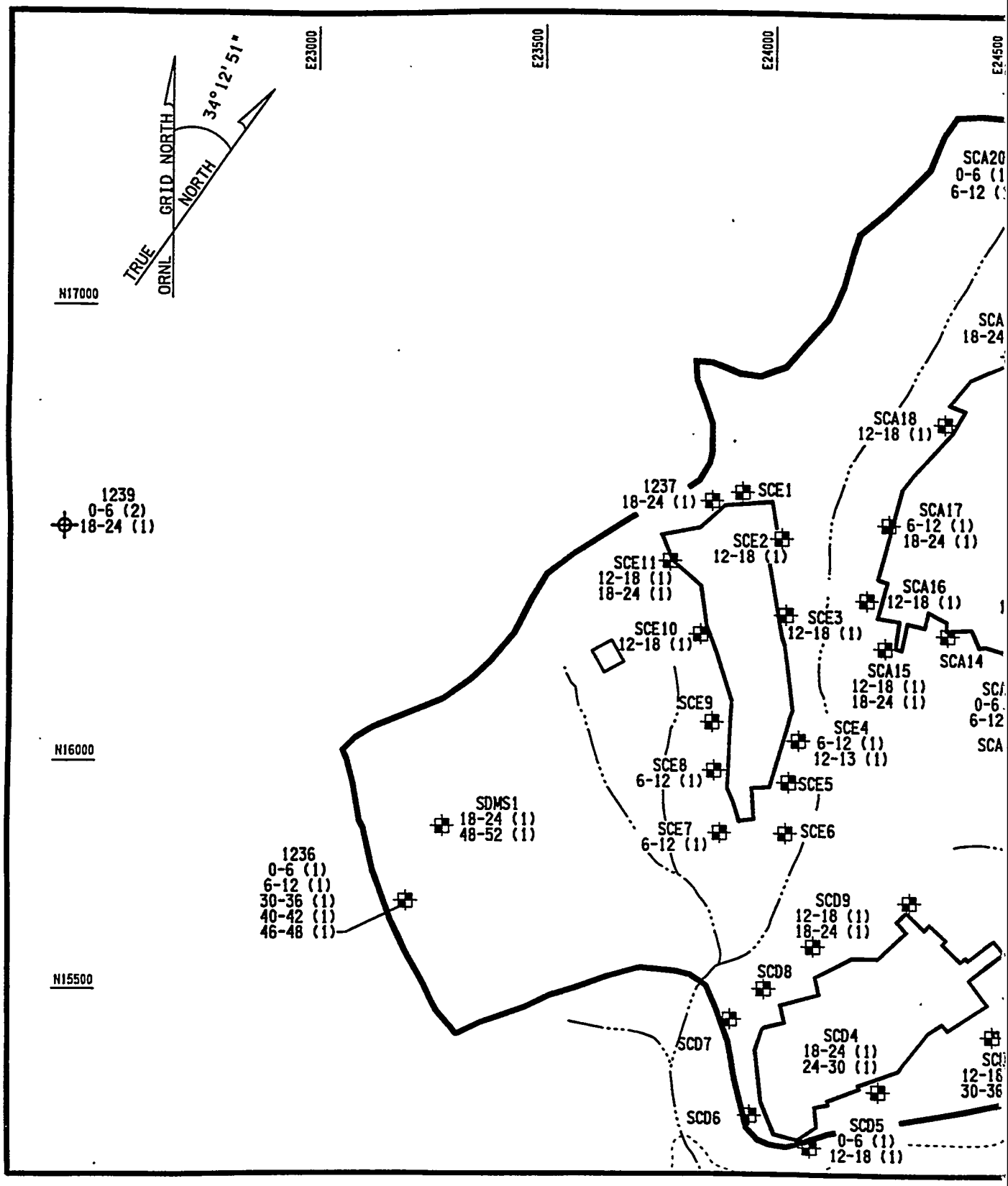



Fig. 4A.1. WAG 6 groundwater sampling locations.




WAG6 06F274.DGN

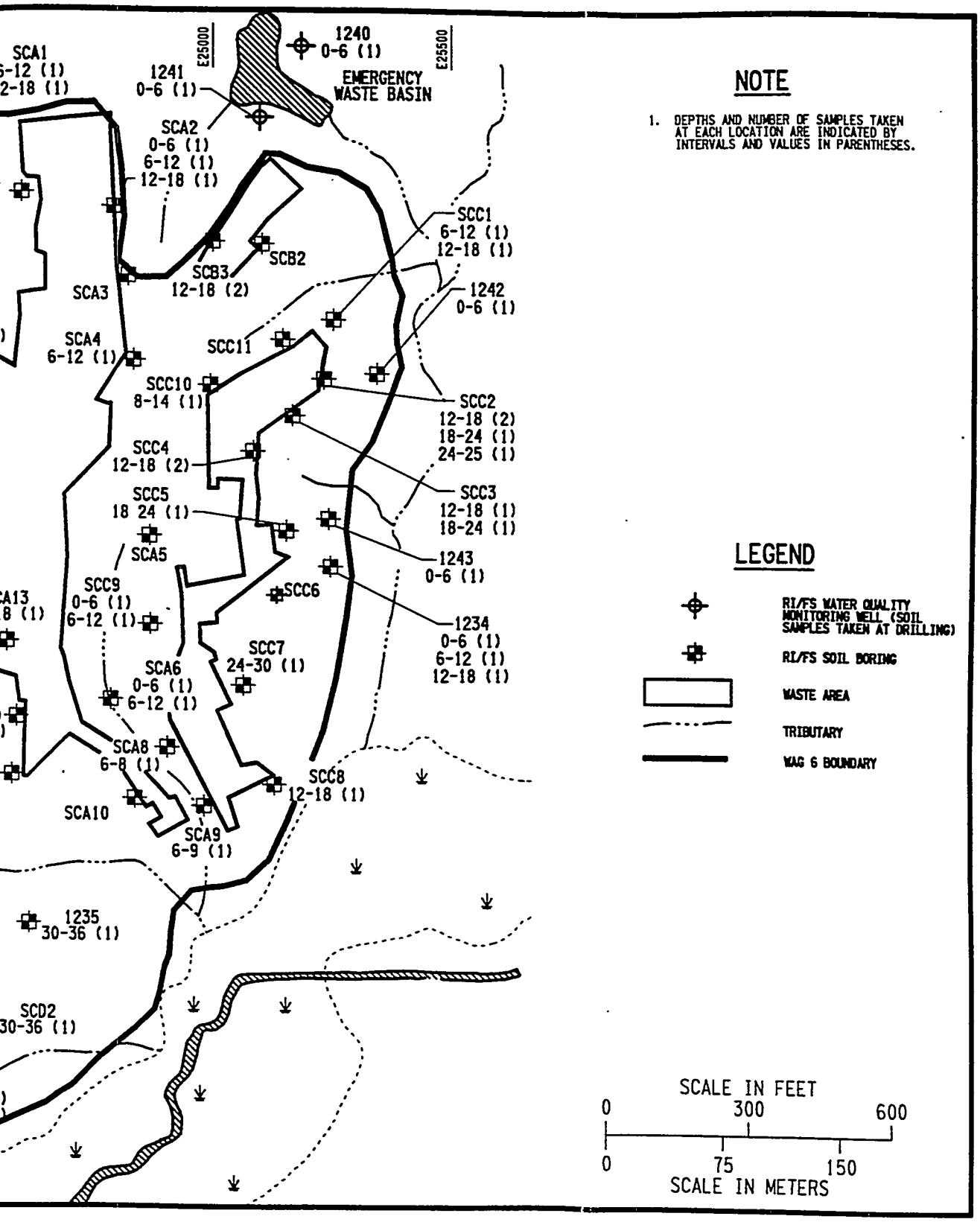
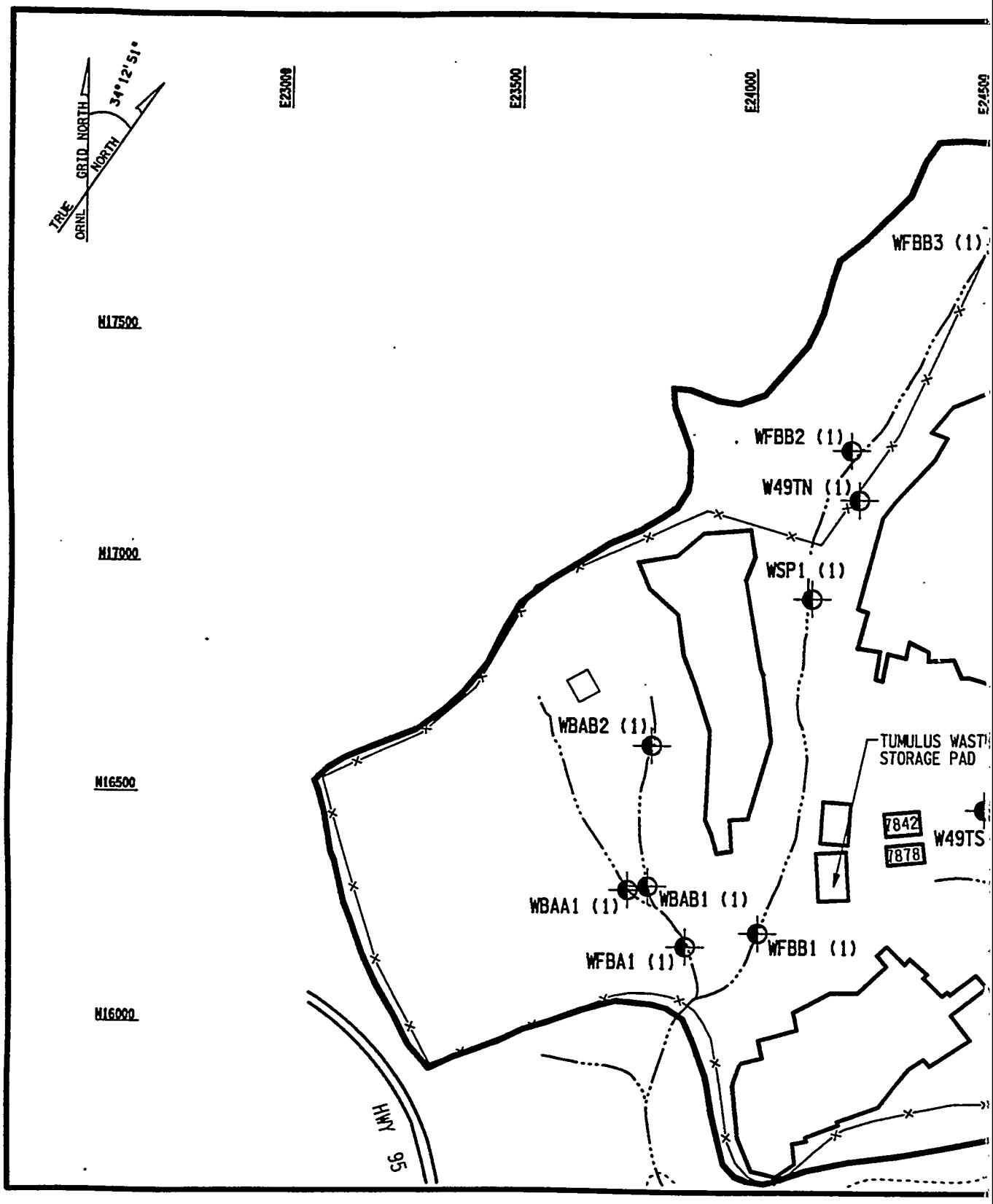



Fig. 4A.2. WAG 6 soil sampling locations.




WAG 6 06F262.DGN

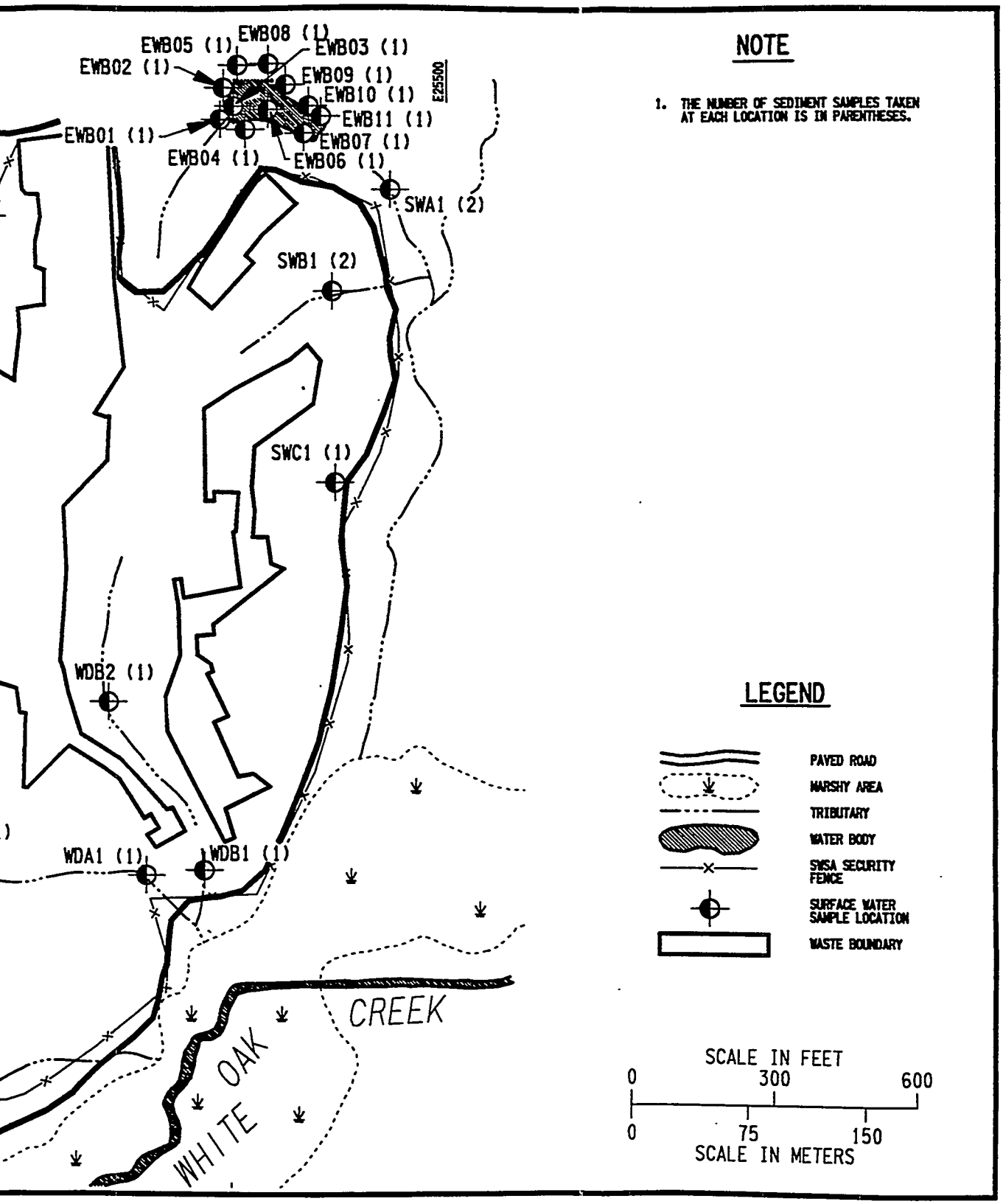
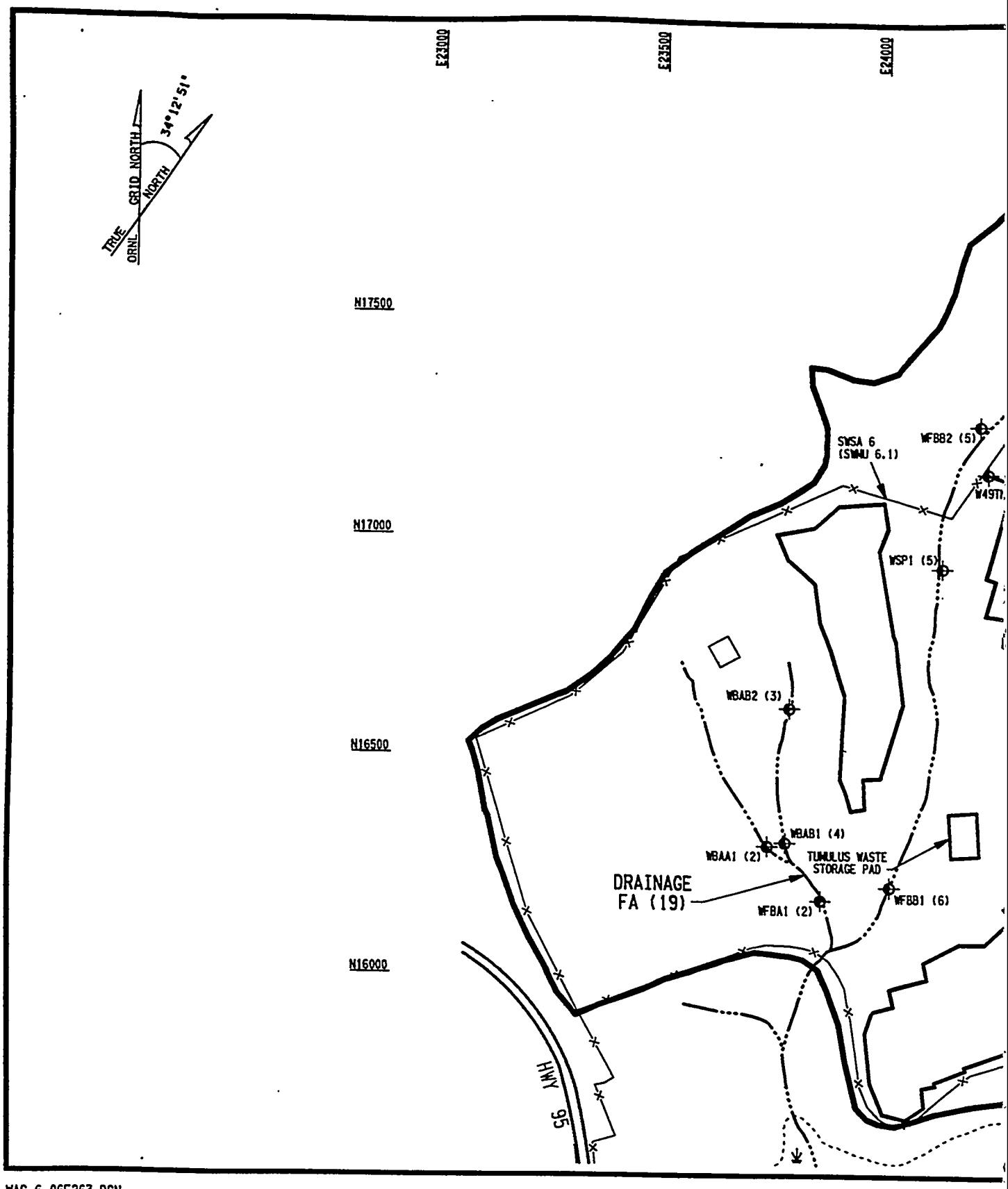



Fig. 4A.3. WAG 6 sediment sampling locations.




WAG 6 06F263.DGN

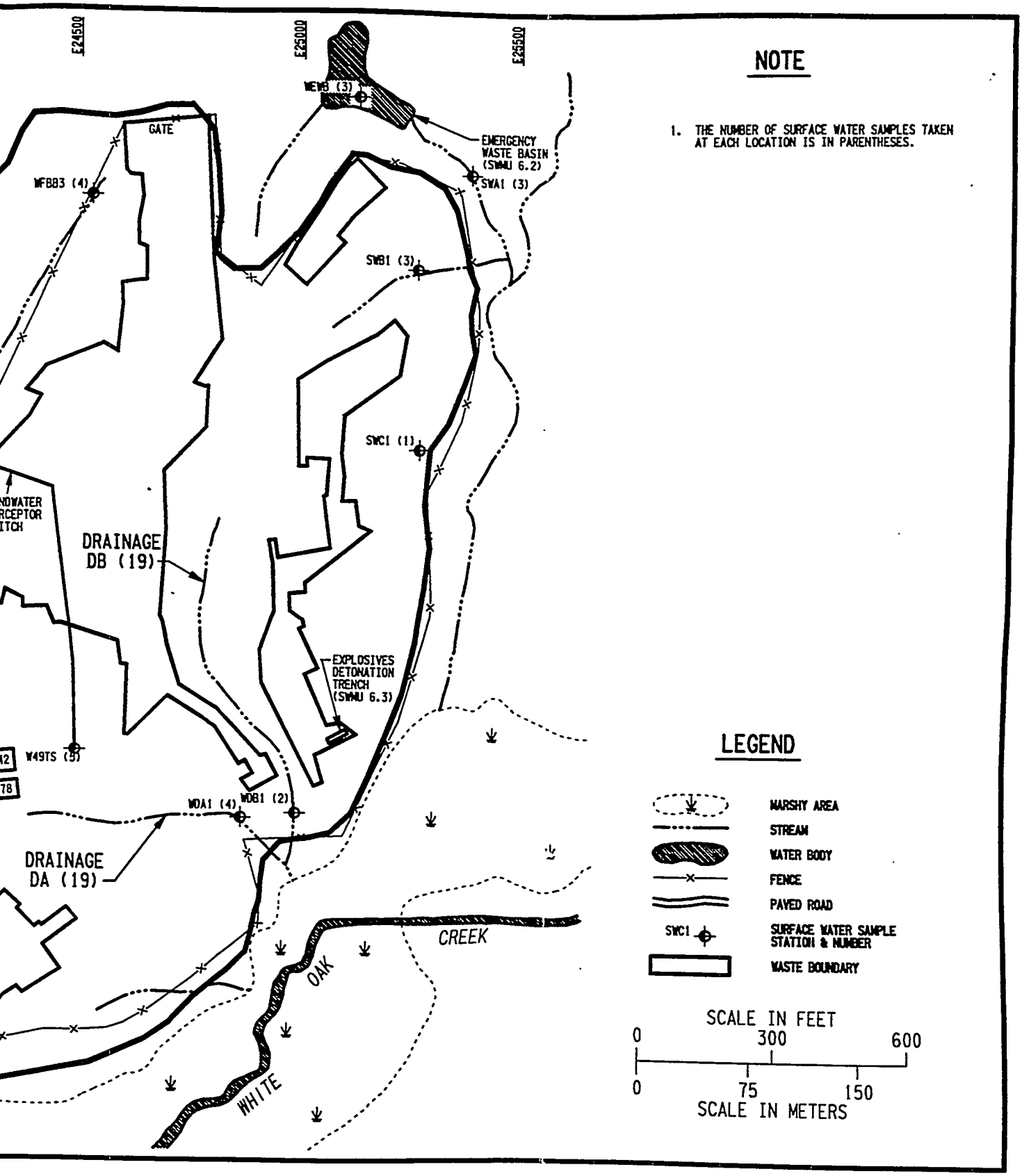



Fig. 4A.4. WAG 6 surface water sampling locations.

# APPENDIX 4B. STATISTICAL ANALYSIS

This appendix supplements Sect. 4.1.2 on the contaminants detected in the main report.

The chemicals detected in each of the four environmental media were evaluated to determine their distribution. Contaminants were generally found not to be normally distributed. The data evaluation also indicted the occurrence of volatile, semivolatile and organic compounds and herbicides at detected concentrations on WAG 6 are sporadic.

These results directed the selection of the statistical method used to test for differences between reference and WAG 6 chemical concentration levels. Chemicals which were found to have statistically significant differences between the site and reference chemical concentrations were included in the list of contaminants for evaluation for nature and extent and inclusion in the risk assessment. Statistical significant, it is assumed, indicates elevated concentrations on WAG 6. The level of significance (alpha) of the test used .05. This means that there is a 5 percent (1 in 20) chance that it will be concluded that concentrations of contaminants are higher than reference when they actually are not (a false positive result). Alpha is normally fixed at .05 per the Risk Assessment Guidance for Superfund (EPA 1989). The chemicals which were not found to be statistically significantly different were not automatically excluded from the list of contaminants for evaluation for nature and extend and inclusion in the risk assessment, but were in some cases subjected to a further detailed evaluation (see Sects. 4 and 6).

The Mann-Whitney test, a non-parametric statistical test, was used for comparison of WAG 6 against reference sample locations. Non-parametric statistical tests are useful in cases where data are not normally distributed. The Mann-Whitney test relies on the "rank" (or "order") of a concentration. Specifically the Mann-Whitney test compares the WAG 6 and reference data and determines if the ranks represented by one of the data sets is significantly higher than the ranks found in the other set. Specific sample locations used in the Mann-Whitney test are indicated on Table 4B.1 Tables 4B.2 through 4B.5 presents the Mann-Whitney test results from the comparisons of reference and WAG for groundwater, surface water, soil and sediment chemicals, respectively. The chemicals evaluated for nature and extent and included in the risk assessment from this list have an alpha of less than .05. These are summarized in Table 4B.5 in the main report.

# Appendix 4B Tables

**Table 4B.1. Risk assessment sample locations**

| Area | Sample locations |
|---|---|
| | **MATRIX** |
| | **GROUNDWATER** [N=41] |
| REFERENCE [N=7] | 831, 832, 846, 855, 856, 857, 858 |
| WAG6 [N=29] | 1225, 1227, 1228, 1229, 1231, 1233, 1237, 1241, 1249, 745, 833, 835, 836, 837, 838, 839, 840, 843, 844, 847, 848, 849, 850, 851, 852, 853, 854, 859, 860 |
| AUGER [N=5] | 1242, 1243, 841, 842, 845 |
| | **SURFACE WATER** [N=15] |
| REFERENCE [N=2] | MBBA, MBBG |
| WAG6 [N= 12] | SWA1, SWB1, SWC1, WBAB1, WBAB2, WDA1, WDB1, WFBA1, WFBB1, WFBB2, WFBB3, WSP1 |
| EMERGENCY WASTE BASIN WEWB [N=1] | |
| | **SOIL** [N=27] |
| REFERENCE [N=14] | CML1, CML2, CMR1, CMR2, MBBA1, MBBA2, MBBA3, MBBA4, MBBA5, MBBG1, MBBG2, MBBG3, MBBG4, MBBG5 |
| WAG6 [N=10] | 1236, 1239, 1240, 1241, SCA02, SCA06, SCA12, SCA20, SCC09, SCD05 |
| AUGER AREA [N=3] | 1234, 1242, 1243 |
| | **SEDIMENT** [N=18] |
| REFERENCE [N=4] | BG01, BG02, BG03, BG04 |
| EMERGENCY WASTE BASIN [N=14] | EWB01, EWB02, EWB04, EWB05, EWB06, EWB07 EWB08, EWB09, EWB14, EWB15, EWB16, EWB17, EWB18, EWB19 |

**Table 4B.2. Mann-Whitney comparisons: WAG 6 groundwater**

| PARAMETER: CAS. NO. | REFERENCE COUNT | SITE COUNT | PROBABILITY REFERENCE/WAG 6 |
|---|---|---|---|
| **METALS/INORGANICS** | | | |
| V: 7440-62-2 | 29 | 149 | 0.000 |
| MN: 7439-96-5 | 35 | 149 | 0.000 |
| CO: 7440-48-4 | 35 | 149 | 0.002 |
| NI: 7440-02-0 | 34 | 149 | 0.002 |
| NA: 7440-23-5 | 39 | 158 | 0.003 |
| CR: 7440-47-3 | 35 | 147 | 0.007 |
| FE: 7439-89-6 | 35 | 149 | 0.006 |
| MG: 7439-95-4 | 39 | 157 | 0.020 |
| SR: 7440-24-6 | 25 | 57 | 0.033 |
| CA: 7440-70-2 | 39 | 158 | 0.036 |
| HG: 7439-97-6 | 33 | 146 | 0.010 [TIES] |
| TL: 7440-28-0 | 27 | 80 | 0.010 [TIES] |
| CD: 7440-43-9 | 35 | 149 | 0.018 [TIES] |
| AG: 7440-22-4 | 35 | 141 | 0.020 [TIES] |
| TI: 7440-32-6 | 8 | 69 | 0.029 [TIES] |
| AL: 7429-90-5 | 35 | 149 | 0.065 |
| CU: 7440-50-8 | 35 | 149 | 0.080 |
| AS: 7440-38-2 | 35 | 149 | 0.138 |
| SI: 7440-21-3 | 27 | 80 | 0.192 |
| BA: 7440-39-3 | 35 | 148 | 0.413 |
| BE: 7440-41-7 | 35 | 148 | 0.237 |
| K: 7440-09-7 | 12 | 78 | 0.276 |
| PB: 7439-92-1 | 33 | 149 | 0.250 |
| ZN: 7440-66-6 | 35 | 149 | 0.636 |
| B: 7440-42-8 | 29 | 80 | 0.791 |
| TOTAL PHENOLS: 1*3 | 26 | 80 | 0.842 |
| SB: 7440-36-0 | 35 | 149 | 0.931 |
| **RADIOISOTOPES** | | | |
| TRIT: 10028-17-8 | 36 | 149 | 0.000 |
| BETA: 12587-47-2 | 29 | 134 | 0.005 |
| ALPHA: 12587-46-1 | 29 | 134 | 0.007 |
| CS137: 10045-97-3 | 29 | 135 | 0.005 [TIES] |
| CO60: 10198-40-0 | 27 | 86 | 0.224 |
| SR90: 10097-97-2 | 2 | 55 | 0.566 |
| TOTAL RADIUM: | 26 | 78 | 0.591 |
| TOTAL SR: | 26 | 78 | 0.632 |
| RA224: 13233-32-4 | 2 | 8 | 0.794 |

Table 4B.2. (continued)

| PARAMETER: CAS. NO. | REFERENCE COUNT | SITE COUNT | PROBABILITY REFERENCE/WAG6 |
|---|---|---|---|
| **RADIONUCLIDES** cont'd | | | |
| AM241: 14596-10-2 | 0 | | NA |
| CUR244:13981-15-2 | 0 | | NA |
| K40: 13966-00-2 | 0 | | NA |
| PU238: 13981-16-3 | 0 | | NA |
| PU239/240: 0-013 | 0 | | NA |
| RA226: 13982-63-3 | 0 | | NA |
| RA228: 15262-20-1 | 0 | | NA |
| TH228: 14274-82-9 | 0 | | NA |
| TH230: 14269-63-7 | 0 | | NA |
| TH232: 7440-29-1 | 0 | | NA |
| TH234: 15065-10-8 | 0 | | NA |
| U234: 13966-29-5 | 0 | | NA |
| U238: 7440-61-1 | 0 | | NA |
| **VOLATILE ORGANICS** | | | |
| ETBENZ: 100-41-4 | 36 | 147 | 0.003 |
| 12-DCy: 540-59-0 | 36 | 147 | 0.019 |
| 11DCEa: 75-34-3 | 36 | 147 | 0.073 |
| TCE: 79-01-6 | 36 | 146 | 0.071 |
| METCL: 75-09-2 | 36 | 147 | 0.231 |
| TOLUENE: 108-88-3 | 36 | 147 | 0.215 |
| ACETONE: 67-64-1 | 36 | 147 | 0.762 |
| 111TCE: 71-55-6 | 36 | 146 | 0.128 |
| VCL: 75-01-4 | 36 | 147 | 0.238 |
| PCE: 127-18-4 | 36 | 147 | 0.281 |
| CTET: 56-23-5 | 36 | 147 | 0.342 |
| 112TCEa:79-00-5 | 35 | 147 | 0.395 |
| TOTXYL: 1330-20-7 | 36 | 146 | 0.582 |
| CLMETH: 74-87-3 | 36 | 147 | 0.621 |
| CLETHa: 75-00-3 | 36 | 147 | 0.621 |
| 1122PCE:79-34-5 | 36 | 147 | 0.621 |
| C2SULF: 75-15-0 | 36 | 147 | 0.774 |
| 12DCEa: 107-06-2 | 36 | 146 | 0.720 |
| CLROFOR:67-66-3 | 36 | 147 | 0.823 |
| BUTANO: 78-93-3 | 36 | 130 | 0.841 |
| BENZEN: 71-43-2 | 36 | 147 | 0.913 |
| 11DCAe: 75-35-4 | 36 | 147 | 1.000 |

**Table 4B.2. (continued)**

| PARAMETER: CAS. NO. | REFERENCE COUNT | SITE COUNT | PROBABILITY REFERENCE/WAG6 |
|---|---|---|---|
| **SEMI-VOLATILE ORGANICS** | | | |
| 2ETHP: 84-66-2 | 21 | 119 | 0.096 |
| 2NBUTP: 84-74-2 | 118 | 118 | 0.098 |
| NAPHTH: 91-20-3 | 21 | 120 | 0.195 |
| 2MTPHE: 95-48-7 | 21 | 106 | 0.430 |
| bis2EHP:117-81-7 | 21 | 67 | 0.535 |
| HERBICIDES/PCBs | | | |
| ARO1254:11097-69-1 | 27 | 101 | 0.128 |
| 245TP: 93-72-1 | 26 | 80 | 0.247 |
| 245T: 93-76-5 | 13 | 42 | 0.578 |
| 24D: 94-75-7 | 26 | 80 | 0.600 |

Table 4B.3. Mann Whitney comparisons: WAG 6 surface water

| ANALYTICAL PARAMETER: | CAS # | REFERENCE COUNT | WAG6 COUNT | REFERENCE/WAG6 COMPARISON |
|---|---|---|---|---|
| **BASE NEUTRAL ORGANICS** | | | | |
| 206-44-0 | Fluoranthene | 2 | 14 | 0.008 [TIES] |
| 84-74-2 | Dinbutphthalate | 2 | 14 | 1.000 |
| **INORGANIC/METAL** | | | | |
| 7439-92-1 | Lead | 1 | 14 | 0.020 [TIES] |
| 7440-22-4 | Silver | 2 | 11 | 0.029 [TIES] |
| 7440-62-2 | Vanadium | 2 | 14 | 0.076 [TIES] |
| 7440-39-3 | Barium | 2 | 14 | 0.081 |
| 7440-43-9 | Cadmium | 2 | 14 | 0.096 |
| 7440-66-6 | Zinc | 2 | 14 | 0.057 [R > W] |
| 7429-90-5 | Aluminum | 1 | 14 | 0.105 |
| 7439-95-4 | Magnesium | 1 | 13 | 0.107 |
| 7440-09-7 | Potassium | 1 | 14 | 0.132 |
| 7440-70-2 | Calcium | 1 | 14 | 0.165 |
| 7440-41-7 | Beryllium | 2 | 14 | 0.220 |
| 7439-89-6 | Iron | 1 | 14 | 0.355 |
| 7440-23-5 | Sodium | 1 | 14 | 0.355 |
| 7440-02-0 | Nickel | 2 | 13 | 0.566 |
| 7439-96-5 | Manganese | 1 | 14 | 0.643 |
| 7440-50-8 | Copper | 2 | 14 | 0.927 |
| 7440-38-2 | Arsenic | 2 | 14 | 1.000 |
| 7439-97-6 | Mercury | 0 | 17 | NA |
| **RADIONUCLIDES** | | | | |
| 10028-17-8 | Tritium | 3 | 14 | 0.008 |
| 12587-47-2 | Gross Beta | 3 | 14 | 0.008 |
| 14269-63-7 | Th230 | 3 | 14 | 0.031 [TIES] |
| 10045-97-3 | Cs137 | 3 | 11 | 0.242 |
| 15262-20-1 | Ra228 | 3 | 8 | 0.364 |
| 12587-46-1 | Alpha | 3 | 14 | 0.611 |
| 13966-29-5 | U234 | 3 | 14 | 1.000 |
| 13982-63-3 | Ra226 | 3 | 10 | 1.000 |
| 14274-82-9 | Th228 | 3 | 14 | 1.000 |
| 7440-29-1 | Th232 | 3 | 14 | 1.000 |
| 0-012 | U235/236 | 3 | 14 | 1.000 |
| 7440-61-1 | U238 | 3 | 14 | 1.000 |
| 13966-29-5 | U234 | 2 | 17 | 1.000 |
| 13233-32-4 | RA224 | 3 | 0 | NA |

**Table 4B.3. (continued)**

| ANALYTICAL PARAMETER: | CAS # | REFERENCE COUNT | WAG6 COUNT | REFERENCE/WAG6 COMPARISON |
|---|---|---|---|---|
| 15065-10-8 | Th234 | 1 | 0 | NA |
| 13981-16-3 | Pu238 | 0 | 14 | NA |
| 0-013 | PU239/240 | 0 | 14 | NA |
| 10098-97-2 | SR90 | 0 | 8 | NA |
| 13981-15-2 | CU244 | 0 | 1 | NA |
| 14596-10-2 | AM241 | 0 | 14 | NA |
| 15262-20-1 | CU242 | 0 | 1 | NA |
| **VOLATILE ORGANICS** | | | | |
| 78-93-3 | MEK | 2 | 14 | 0.268 |
| 540-59-0 | 12DCE | 2 | 14 | 0.465 |
| 79-01-6 | TCE | 2 | 14 | 0.562 |
| 75-15-0 | Cdisulfide | 2 | 14 | 0.705 |
| 67-64-1 | Acetone | 2 | 14 | 1.000 |
| 127-18-4 | PCE | 2 | 14 | 1.000 |
| 591-78-6 | 2-Hexanone | 0 | 14 | NA |

Table 4B.4. Mann Whitney comparisons: WAG 6 soils

| ANALYTICAL PARAMETER: | CAS NUMBER | REFERENCE COUNT | WAG6 COUNT | REFERENCE/WAG6 COMPARISON |
|---|---|---|---|---|
| **BASE NEUTRAL** | | | | |
| PNPHENOL: | 100-02-7 | 14 | 15 | 0.000: REF >WAG6 |
| BENZALC: | 100-51-6 | 14 | 15 | 0.000: REF > WAG6 |
| CARBACID: | 108-95-2 | 14 | 15 | 0.000: REF > WAG6 |
| PYRENE: | 129-00-0 | 14 | 15 | 0.000: REF > WAG6 |
| BKF: | 207-08-9 | 14 | 15 | 0.000: REF > WAG6 |
| CHRYSENE: | 218-01-9 | 14 | 15 | 0.000: REF > WAG6 |
| BAA: | 56-55-3 | 14 | 15 | 0.000: REF > WAG6 |
| 4CLMCRES: | 59-50-7 | 14 | 15 | 0.000: REF > WAG6 |
| 12B2CARB: | 84-66-2 | 14 | 15 | 0.000: REF > WAG6 |
| PCP: | 87-86-5 | 14 | 15 | 0.000: REF > WAG6 |
| 2CLPHENOL: | 95-57-8 | 14 | 15 | 0.000: REF > WAG6 |
| BIS2EHPH: | 117-81-7 | 14 | 15 | 0.002: REF > WAG6 |
| BENZOIC: | 65-85-0 | 14 | 15 | 0.186 |
| NNNPBZAM: | 86-30-6 | 14 | 15 | 0.511 |
| NPBENZAM: | 122-39-4 | 14 | 0 | NA |
| **HERBICIDE** | | | | |
| 245TP: | 93-72-1 | 4 | 0 | NA |
| 245T: | 93-76-5 | 4 | 0 | NA |
| **INORGANICS/METALS** | | | | |
| SE: | 7782-49-2 | 13 | 11 | 0.004: WAG6 > REF |
| AL: | 7429-90-5 | 13 | 13 | 0.006: WAG6 > REF |
| CR: | 7440-47-3 | 13 | 15 | 0.006: WAG6 > REF |
| TL: | 7440-28-0 | 13 | 12 | 0.010: WAG6 > REF |
| V: | 7440-62-2 | 13 | 15 | 0.013: WAG6 > REF |
| FE: | 7439-89-6 | 13 | 13 | 0.020: WAG6 > REF |
| K: | 7440-09-7 | 13 | 15 | 0.036: WAG6 > REF |
| AS: | 7440-38-2 | 13 | 13 | 0.051 |
| PB: | 7439-92-1 | 13 | 15 | 0.080 |
| NA: | 7440-23-5 | 13 | 15 | 0.100 |
| CD: | 7440-43-9 | 13 | 15 | 0.111 |
| NI: | 7440-02-0 | 13 | 15 | 0.147 |
| CU: | 7440-50-8 | 13 | 15 | 0.182 |
| ZN: | 7440-66-6 | 13 | 15 | 0.222 |
| SB: | 7440-36-0 | 7 | 12 | 0.351 |
| MN: | 7439-96-5 | 13 | 15 | 0.381 |
| MG: | 7439-95-4 | 13 | 15 | 0.394 |
| BE: | 7440-41-7 | 13 | 15 | 0.472 |
| AG: | 7440-22-4 | 13 | 12 | 0.564 |
| CO: | 7440-48-4 | 13 | 15 | 0.730 |
| HG: | 7439-97-6 | 13 | 15 | 0.754 |
| A: | 7440-39-3 | 13 | 15 | 0.927 |
| CA: | 7440-70-2 | 13 | 13 | 0.980 |
| OS: | 7440-04-2 | 13 | 0 | NA |
| SN: | 7440-31-5 | 13 | 0 | NA |

**Table 4B.4. (continued)**

| ANALYTICAL PARAMETER: | CAS NUMBER | REFERENCE COUNT | WAG6 COUNT | REFERENCE/WAG6 COMPARISON |
|---|---|---|---|---|
| **RADIONUCLIDES** | | | | |
| SR89: | 14158-27-1 | 15 | 4 | 0.000: WAG6 > REF |
| SR90: | 10098-97-2 | 15 | 5 | 0.030: WAG6 > REF |
| RA226: | 13982-63-3 | 16 | 15 | 0.004: REF > WAG6 |
| CS137: | 10045-97-3 | 16 | 14 | 0.016: REF > WAG6 |
| TH232: | 7440-29-1 | 17 | 10 | 0.063: REF > WAG6 |
| TH234: | 15065-10-8 | 9 | 9 | 0.171 |
| U238: | 7440-61-1 | 16 | 10 | 0.254 |
| TH228: | 14274-82-9 | 16 | 10 | 0.356 |
| K40: | 13966-00-2 | 16 | 14 | 0.383 |
| U234: | 13966-29-5 | 16 | 10 | 0.428 |
| ALPHA: | 12587-46-1 | 16 | 15 | 0.464 |
| BETA: | 12587-47-2 | 16 | 15 | 0.593 |
| TH230: | 14269-63-7 | 16 | 10 | 0.615 |
| RA228: | 15262-20-1 | 16 | 15 | 0.737 |
| RA224: | 13233-32-4 | 16 | 15 | 0.859 |
| U235236: | 0-012 | 16 | 10 | 1.000 |
| H3: | 10028-17-8 | 15 | 8 | 1.000 |
| PU239240: | 0-013 | 0 | 6 | NA |
| CO60: | 10198-40-0 | 0 | 1 | NA |
| PU238: | 13981-16-3 | 0 | 6 | NA |
| NI63: | 13981-37-8 | 15 | 0 | NA |
| TC99: | 14133-76-7 | 15 | 0 | NA |
| PM147: | 14380-75-7 | 13 | 0 | NA |
| AM241: | 14596-10-2 | 0 | 6 | NA |
| FE55: | 14681-59-5 | 15 | 0 | NA |
| C14: | 14762-75-5 | 15 | 0 | NA |
| ACTINIUM: | 14952-40-0 | 0 | 1 | NA |
| I129: | 15046-84-1 | 15 | 0 | NA |
| **VOLATILE ORGANICS** | | | | |
| 12DCYLE: | 540-59-0 | 18 | 15 | 0.132 |
| CDISULF: | 75-15-0 | 18 | 15 | 0.132 |
| MEK: | 78-93-3 | 18 | 15 | 0.137 |
| ACETONE: | 67-64-1 | 18 | 15 | 0.145 |
| PCE: | 127-18-4 | 18 | 15 | 0.173 |
| ETHBENZ: | 100-41-4 | 18 | 15 | 0.278 |
| ETHEBENZ: | 100-42-5 | 18 | 15 | 0.278 |
| 13CLZPROP: | 10061-01-5 | 18 | 15 | 0.278 |
| 13CLEPROP: | 10061-02-6 | 18 | 15 | 0.278 |
| ETHYL2CL: | 107-06-2 | 18 | 15 | 0.278 |
| CLBENZ: | 108-90-7 | 18 | 15 | 0.278 |
| CL2BRMETH: | 124-48-1 | 18 | 15 | 0.278 |
| CTET: | 56-23-5 | 18 | 15 | 0.278 |
| BENZENE: | 71-43-2 | 18 | 15 | 0.278 |
| 111TCA: | 71-55-6 | 18 | 15 | 0.278 |

Table 4B.4. (continued)

| ANALYTICAL RAMETER: | CAS NUMBER | REFERENCE COUNT | WAG6 COUNT | REFERENCE/WAG6 COMPARISON |
|---|---|---|---|---|
| VOLATILE ORGANICS cont'd | | | | |
| BRFORM: | 75-25-2 | 18 | 15 | 0.2782 |
| CLMETH: | 75-27-4 | 18 | 15 | 0.278 |
| 11DCA: | 75-34-3 | 18 | 15 | 0.278 |
| 11DCE: | 75-35-4 | 18 | 15 | 0.278 |
| PROP2CL: | 78-87-5 | 18 | 15 | 0.278 |
| 112TCA: | 79-00-5 | 18 | 15 | 0.278 |
| 1122TCA: | 79-34-5 | 18 | 15 | 0.278 |
| METBENZ: | 108-88-3 | 18 | 15 | 0.289 |
| 2CLMETH: | 75-09-2 | 18 | 15 | 0.573 |
| TCE: | 79-01-6 | 18 | 15 | 0.645 |
| 3CLMETH: | 67-66-3 | 18 | 15 | 0.667 |
| TOTXYL: | 1330-20-7 | 18 | 15 | 0.789 |
| ACETIC: | 108-05-4 | 18 | 15 | 0.936 |
| MIBK: | 108-10-1 | 18 | 15 | 0.936 |
| 2HEX: | 591-78-6 | 18 | 15 | 0.936 |
| METHBR: | 74-83-9 | 18 | 15 | 0.936 |
| METHCL: | 74-87-3 | 18 | 15 | 0.936 |
| ETHCL: | 75-00-3 | 18 | 15 | 0.936 |
| CLETHE: | 75-01-4 | 18 | 15 | 0.936 |
| ETHYL2BR: | 106-93-4 | 18 | 0 | NA |
| ACROLEIN: | 107-02-8 | 15 | 0 | NA |
| LLYLCL: | 107-05-1 | 18 | 0 | NA |
| ROPNIT: | 107-12-0 | 18 | 0 | NA |
| ACRYLNIT: | 107-13-1 | 18 | 0 | NA |
| 14CL3BUT: | 110-57-6 | 18 | 0 | NA |
| PYRIDINE: | 110-86-1 | 14 | 0 | NA |
| PDIOXANE: | 123-91-1 | 13 | 0 | NA |
| METACRYLN: | 126-98-7 | 18 | 0 | NA |
| CLPRENE: | 126-99-8 | 18 | 0 | NA |
| 1112TCA: | 630-20-6 | 18 | 0 | NA |
| METHI: | 74-88-4 | 18 | 0 | NA |
| METHEBR: | 74-95-3 | 18 | 0 | NA |
| ACETONIT: | 75-05-8 | 16 | 0 | NA |
| 3CLFMETH: | 75-69-4 | 16 | 0 | NA |
| 2CL2FMETH: | 75-71-8 | 13 | 0 | NA |
| 1PROP2MET: | 78-83-1 | 18 | 0 | NA |
| METHMETAC: | 80-62-6 | 18 | 0 | NA |
| 2BRCLPROP: | 96-12-8 | 18 | 0 | NA |
| 123CLPROP: | 96-18-4 | 18 | 0 | NA |
| ETHMETHAC: | 97-63-2 | 18 | 0 | NA |

**Table 4B.5. Mann Whitney comparisons: WAG 6 Sediments**

| ANALYTICAL PARAMETER: | CAS # | REFERENCE COUNT | WAG 6 COUNT | REFERENCE/WAG6 COMPARISON |
|---|---|---|---|---|
| BASE NEUTRAL | | | | |
| BIS2EHPH: | 117-81-7 | 4 | 14 | 0.149 |
| DINBUTPH: | 84-74-2 | 4 | 14 | 0.180 |
| NPBENZAM: | 122-39-4 | 1 | 1 | 0.317 |
| NNNPBZAM: | 86-30-6 | 4 | 14 | 0.392 |
| 2MET2NIB: | 606-20-2 | 4 | 14 | 0.453 |
| CARBACID: | 108-95-2 | 4 | 14 | 0.591 |
| BENZOIC: | 65-85-0 | 4 | 14 | 0.826 |
| METALS/INORGANICS | | | | |
| AG: | 7440-22-4 | 4 | 14 | 0.008: WAG6 > REF |
| AS: | 7440-38-2 | 4 | 14 | 0.004: REF > WAG6 |
| NA: | 7440-23-5 | 4 | 14 | 0.013: REF > WAG6 |
| NI: | 7440-02-0 | 4 | 14 | 0.071 |
| BE: | 7440-41-7 | 4 | 14 | 0.134 |
| CD: | 7440-43-9 | 4 | 14 | 0.201 |
| K: | 7440-09-7 | 4 | 14 | 0.202 |
| MG: | 7439-95-4 | 4 | 14 | 0.203 |
| CR: | 7440-47-3 | 4 | 14 | 0.203 |
| CO: | 7440-48-4 | 4 | 14 | 0.288 |
| SN: | 7440-31-5 | 1 | 1 | 0.317 |
| MN: | 7439-96-5 | 4 | 14 | 0.396 |
| PB: | 7439-92-1 | 4 | 14 | 0.428 |
| FE: | 7439-89-6 | 4 | 14 | 0.524 |
| BA: | 7440-39-3 | 4 | 14 | 0.524 |
| ZN: | 7440-66-6 | 4 | 14 | 0.524 |
| AL: | 7429-90-5 | 4 | 14 | 0.595 |
| CU: | 7440-50-8 | 4 | 14 | 0.750 |
| V: | 7440-62-2 | 4 | 14 | 0.873 |
| CA: | 7440-70-2 | 4 | 14 | 0.915 |
| SE: | 7782-49-2 | 4 | 14 | 1.000 |
| HG: | 7439-97-6 | 0 | 13 | NA |
| OS: | 7440-04-2 | 0 | 1 | NA |
| RADIONUCLIDES | | | | |
| RA224: | 13233-32-4 | 4 | 14 | 0.089 |
| SR90: | 10098-97-2 | 4 | 1 | 0.147 |
| TH230: | 14269-63-7 | 4 | 1 | 0.157 |
| CS137: | 10045-97-3 | 4 | 14 | 0.279 |
| TH234: | 15065-10-8 | 2 | 7 | 0.380 |
| U234: | 13966-29-5 | 4 | 1 | 0.480 |
| TH228: | 14274-82-9 | 4 | 1 | 0.480 |
| TH232: | 7440-29-1 | 4 | 1 | 0.480 |
| U238: | 7440-61-1 | 4 | 1 | 0.480 |
| RA228: | 15262-20-1 | 4 | 14 | 0.489 |
| ALPHA: | 12587-46-1 | 4 | 14 | 0.595 |

Table 4B.5. (continued)

| ALYTICAL PARAMETER: | CAS # | REFERENCE COUNT | WAG6 COUNT | REFERENCE/WAG6 COMPARISON |
|---|---|---|---|---|
| **RADIONUCLIDES cont'd** | | | | |
| H3: | 10028-17-8 | 4 | 14 | 0.560 |
| RA226: | 13982-63-3 | 4 | 14 | 0.671 |
| BETA: | 12587-47-2 | 4 | 14 | 0.915 |
| K40: | 13966-00-2 | 4 | 12 | 0.952 |
| U235236: | 0-012 | 4 | 1 | 1.000 |
| SR89: | 14158-27-1 | 4 | 1 | 1.000 |
| PU239240: | 0-013 | 0 | 1 | NA |
| CO60: | 10198-40-0 | 0 | 1 | NA |
| CM244: | 13981-15-2 | 0 | 1 | NA |
| PU238: | 13981-16-3 | 0 | 1 | NA |
| NI63: | 13981-37-8 | 0 | 1 | NA |
| TC99: | 14133-76-7 | 0 | 1 | NA |
| PM147: | 14380-75-7 | 0 | 1 | NA |
| AM241: | 14596-10-2 | 0 | 1 | NA |
| FE55: | 14681-59-5 | 0 | 1 | NA |
| C14: | 14762-75-5 | 0 | 1 | NA |
| I129: | 15046-84-1 | 0 | 1 | NA |
| CM242: | 15510-73-3 | 0 | 1 | NA |
| **LATILE ORGANIC** | | | | |
| MEK: | 78-93-3 | 4 | 9 | 0.007: WAG6 > REF |
| 3CLMETH: | 67-66-3 | 4 | 14 | 0.031: WAG6 > REF |
| TCE: | 79-01-6 | 4 | 14 | 0.274 |
| METBENZ: | 108-88-3 | 4 | 14 | 0.303 |
| 3CLFMETH: | 75-69-4 | 1 | 1 | 0.317 |
| CLMETH: | 75-09-2 | 4 | 14 | 0.790 |
| ACETONE: | 67-64-1 | 4 | 14 | 0.956 |

# APPENDIX 4C. NATURE AND EXTENT OF ON-SITE CONTAMINATION BY MEDIA

## 4C.1 GROUNDWATER

### 4C.1.1 Previous Investigations

Between 1976 and the present, there have been numerous groundwater investigations at WAG 6. Table 4C.1 lists WAG 6 groundwater investigators, the wells that were involved, and the dates the investigations occurred. Table 4C.2 presents the constituents that were analyzed for during each of the studies. Appendix 1B summarizes the scope of previous groundwater studies and presents data collected during the investigations. In the following discussion on nature and extent of groundwater contamination at WAG 6, the previous studies are discussed where applicable.

### 4C.1.2 Radiological Contamination

Both man-made and naturally occurring radionuclides have been detected in groundwater samples from wells at WAG 6. Man-made radionuclides that have been detected include tritium, cobalt-60, strontium-90, cesium-137, and transuranics which include americium-241, curium-244, plutonium-238, and plutonium 239/240. Naturally occurring radionuclides detected in groundwater samples at WAG 6 include potassium-40, and radionuclides belonging to the uranium series (uranium-238, thorium-234, uranium-234, thorium-230, radium-226), and the thorium series (thorium-232, radium-228, thorium-228, radium-224).

Concentration standards for drinking water for types of radioactivity (alpha or beta radiation) as for several specific radionuclides have been established by the Safe Drinking Water Act (52 FR 25690 1987). MCLs have been established for gross alpha (15 pCi/L), tritium (20,000 pCi/L), strontium-90 (8 pCi/L), radium (5 pCi/L, includes sum of radium-226 and radium-228 concentrations), uranium-234 (30 pCi/L), uranium-238 (30 pCi/L), and man-made beta (4 millirems per year). For other man-made radionuclides, a 4 millirem per year MCL exists. Naturally occurring radionuclides that do not have MCLs promulgated must be compared to background concentrations to determine if detected concentrations are indicative of contamination. The MCL for radium is currently under review at EPA. Consideration is being given to raising the MCL to 40 pCi/L for the sum of radium-226 and radium-228 (20 pCi/L each).

#### 4C.1.2.1 Nature

**Gross alpha and gross beta.** Gross alpha and gross beta were detected in all wells that were analyzed. Both naturally occurring and man-made radionuclides, including transuranic radionuclides, contribute to either gross alpha and/or gross beta concentrations. Figures 4C.1 through 4C.4 show the variability in gross alpha and gross beta concentrations detected in WAG 6 RFI and ORNL RCRA compliance wells. For ease of display, ORNL RCRA results are presented separately from RFI results. This is the case for other radionuclides also.

Gross alpha concentrations analyzed for in groundwater samples from ORNL RCRA compliance wells did not exceed 15 pCi/L except in two wells (wells 832 and 857). In these two cases, the error terms associated with these measurements exceeded the measurement and for practical purposes can be considered non-detected measurements.

Although not pervasive, gross alpha concentrations exceeding 15 pCi/L were detected in groundwater samples collected during ORNL RCRA monitoring and the RFI. In some cases, naturally occurring radionuclides accounted for the gross concentrations exceeding 15 pCi/L. These are discussed more fully below (see Naturally Occurring Radionuclides).

**Man-made radionuclides.** Tritium was detected in a majority of groundwater samples collected at the site (Figures 4C.5 and 4C.6). Tritium concentrations exceeded the 20,000 pCi/L MCL in numerous wells at the site. Concentrations ranged from non-detectable levels to over 4,000,000 pCi/L.

Cesium-137, cobalt-60, and strontium-90 have been detected in groundwater samples at WAG 6. None of these radionuclides are widely distributed in groundwater at WAG 6.

The Safe Drinking Water Act MCL for strontium-90 in groundwater is 8 pCi/L. Other man-made beta-emitting radionuclides are limited in acceptable concentrations equal to a dose of four millirem per year. To determine if cobalt-60 or cesium-137 concentrations detected at the site exceed the 4 millirem per year dose level, a concentration expressed in pCi/L equal to a dose of 4 millirem per year was calculated assuming drinking 2 liters of water each day for one year (EPA 1989b). Concentrations in pCi/L which equal 4 millirem/year exposure for cobalt-60 and cesium-137 were calculated to be 203.3 pCi/L and 109.6 pCi/L, respectively. Maximum detected concentration for cesium-137 did not exceed the 4 millirem per year MCL. The maximum detected concentration for cobalt-60 did exceed the 4 millirem per year MCL in samples from only one, 842, and exceeded it consistently throughout its sampling history. The 8 pCi/L MCL for strontium-90, including total radioactive strontium, was exceeded in six wells at the site (Wells 846, 848, 850, 858, 1225, and 1237). However, in Wells 846, 850, and 858 only the first sampling event exhibited concentrations exceeding 8 pCi/L. Subsequent sampling events have been non-detects suggesting that previous analyses were anomalous.

The range in concentrations observed for cesium-137, cobalt-60, and total strontium (including strontium-90) in groundwater samples has been observed to vary over time. This variation is displayed in Figs. 4C.7 through 4C.13). While the range in variability is not as great for total strontium the apparent variability present in cobalt-60 and cesium-137 concentrations is due primarily to concentrations that also have large error determinations most of which were analyzed during the January/February 1989 sampling period. In most instances, the associated error terms for cobalt-60 and cesium-137 during that sampling period indicates overlapping concentration ranges with lower concentrations suggesting that the elevated concentrations may not be an accurate indication of conditions actually present in these groundwater samples.

**Transuranic radionuclides.** An analysis of the nature and extent of transuranic radionuclides in groundwater at WAG 6 is based on analyses conducted in RFI wells and those compliance wells that were sampled by the BNI team during this investigation only (see Sect. 2). Not all ORNL RCRA compliance wells were sampled for transuranic radionuclides; therefore, their extent at WAG 6 may be underestimated. The transuranics detected include americium-241, curium-244, plutonium-238, and plutonium-239/240.

**Naturally occurring radionuclides (gross alpha and radium).** Groundwater samples from ORNL RCRA compliance well sampling were not analyzed for naturally occurring radionuclides except for total radium concentrations which includes the sum of radium-224 and radium-226 concentrations. Total radium concentrations do not display large variations by well and among wells (Fig. 4C.13). Total radium (radium-224 and radium-226) concentrations reported in ORNL RCRA monitoring data, did not exceed the 5 pCi/L MCL; however, when radium-226 and radium-228 were analyzed for during RFI sampling the 5 pCi/L MCL was exceeded in some wells.

Naturally occurring radionuclides of the uranium and thorium series, which are primarily alpha emitters, were analyzed for to determine if gross alpha concentrations exceeding 15 pCi/L could be attributed to the presence of naturally occurring radionuclides. In some instances, the higher gross alpha concentrations could be attributed to radium-224 which was detected at concentrations approaching that of the gross alpha concentrations. In other instances in which gross alpha concentrations exceeded 15 pCi/L, radionuclides analyzed for were not detected in sufficient concentrations to account for the increased alpha activity. These occurrences are discussed below.

### 4C.1.2.2 Extent

**Naturally occurring radionuclides (gross alpha and radium).** Monitoring wells in which maximum detected gross alpha concentrations exceed 15 pCi/L are highlighted on Fig. 4C.14. The wells in which naturally occurring radionuclides account for concentrations exceeding 15 pCi/L are also highlighted and are not considered to be contaminated by site operations.

The wells in which gross alpha concentrations have not been accounted for by naturally occurring radionuclides are wells at the high activity trench area and low activity trench areas of the central waste disposal area, and wells adjacent to the biological trench area of the west waste disposal area (Fig. 4C.14). Except for two wells (Wells 1228 and 849), man-made transuranic radionuclides have been detected in groundwater samples from these wells. It is not known if additional man-made radionuclides are present or that naturally occurring radionuclides attribute to higher alpha concentrations.

Figure 4C.14 shows wells in which the sum of radium-226 and radium-228 exceeded 5 pCi/L. These wells are 1241 located south of the EWB, Well 1225 located west of the high activity trench area of the central waste disposal area, Well 1233 located west of the 49-Trench area, and Well 1229 located east of the biological trenches of the west waste disposal area. Except for radium-228, which was detected at 860 pCi/L in Well 1225, radium-226

concentrations in the other wells exceeded 5 pCi/L. Radium-228 was not detected or was very close to the detection limit (3 pCi/L) in the other wells. Highest radium-226 concentration was 113 pCi/L in Well 1129. Concentration levels in other wells were below 17.3 pCi/L.

**Man-made radionuclides—tritium.** Tritium has been analyzed for and detected in numerous groundwater samples during ORNL compliance monitoring, the RFI monitoring, and in numerous independent studies conducted by ORNL researchers such as Poreda, Cerling and Soloman 1988; Boegly 1984; Doyle and Taylor 1986; Davis et al. 1989; Solomon et al. 1988; Yager and Craig 1989; Ashwood 1989; Vaughan et al. 1982; Dreier and Toran 1989, and Morrissey 1990 just to name a few. It is the most widely distributed man-made radionuclide at the site.

The Safe Drinking Water Act maximum concentration level (MCL) for tritium is 20,000 pCi/L. Figure 4C.15 presents analytical results on tritium levels. The maximum concentration detected at any location is represented by a dot whose relative size is indicative of a concentration range (see figure legend). The smallest dot corresponds to non-detected levels or to detected levels below the 20,000 pCi/L MCL.

Tritium has been detected above the MCL in groundwater samples from wells adjacent to nearly all waste disposal areas at WAG 6. Groundwater samples from up-gradient wells on the northwest perimeter of the site and from wells located at the southwest section have not contained concentrations exceeding the MCL. There are also wells located in the interior of the WAG in which groundwater samples have not had elevated concentrations of tritium detected.

Highest concentrations of tritium appear to be associated with the high and low activity trench areas of the WAG while tritium levels exceeding the MCL have also been detected in groundwater samples adjacent to biological trenches. Maximum detected levels of tritium in groundwater samples from wells adjacent to biological trench areas have not exceeded 100,000 pCi/L. Tritium concentrations exceeding 100,000 pCi/L have been detected in groundwater samples in wells adjacent to the high-activity trench areas of the central waste disposal area, the 19-Trench area, the northern half of the east disposal area, the low activity trench area of the central waste disposal area, the low activity trench area of the west waste disposal area, and the Tumulus area (Fig 4C.15). Tritium concentration levels exceeding 1,000,000 pCi/L have been detected in groundwater samples from wells located at the northern-most trench areas and the low-level trenches of the central waste disposal area.

Tritium has been detected in groundwater samples from the TARA-series wells up to 7,290,000 pCi/L in the northeastern part of the WAG (Davis et al. 1989). This area also has the highest potential for migration of tritium off WAG boundaries. (Davis et al. 1989) sampled the TARA series wells at the 19-trench area and identified a tritium plume emanating from this area. ORNL RCRA compliance wells in the area confirm the elevated concentrations. Highest detected concentrations occur nearest to the trench area and to the southeast towards Drainage B. Concentrations generally decrease to the north and northwest

towards the EWB, although concentrations exceeding 100,000 pCi/L have been detected in surface water samples collected from the EWB.

The northeast auger hole area of the east waste disposal area also contains levels of tritium above the MCL. A tritium plume appears to be migrating easterly-southeasterly towards the unnamed tributary. Wells to the south of the auger hole area generally contain low levels of tritium. Tritium from the auger hole area could be reaching groundwater in Well 1244, located approximately 300 ft east and separated by the unnamed tributary. It may also be receiving tritium from adjacent WAG 7 located to the east of the well. Well 1244 has been sampled once and 51,200 pCi/L were detected.

Groundwater samples collected from some wells at the low activity trench areas located in the central part of the WAG also contain levels of tritium exceeding 100,000 pCi/L. Two wells (Wells 848 and 849) at the low level trenches of the central waste disposal area contain levels of tritium exceeding 1,000,000 pCi/L. The high levels observed at the 49-Trench area of the central waste disposal have not been detected in wells located to the west across Drainage FB, except for Well 854 which probably intercepts high levels of tritium from the low activity trenches of the west waste disposal area. Surface water samples collected adjacent to the 49-Trench area from Drainage FB have had tritium concentrations detected in excess of 400,000 pCi/L. Water collected from the outfall of the French Drain have contained the highest concentration detected on site (14,000,000 pCi/L) strongly suggesting that the 49-Trench area is a major source area of tritium.

Independent studies conducted by Yager and Craig (1989) and Ashwood (1989) at the Tumulus area have identified high levels of tritium associated with Well 1036 in the area (Fig. 18). Increasing concentrations of tritium have been detected in groundwater samples from Well 1036 which is located on the eastern side of the Tumulus area (Figure 4C.15). From 11 samples collected between June 1987 and May 1990, tritium concentrations have increased from a low of 486 pCi/L to a high of 226,800 pCi/L. Tritium has reportedly not been disposed of in this area. All the other wells, except for Well 1039, which is located to the west along strike to Well 1036 have had concentrations below 11,000 pCi/L with no discernible trends. Concentration levels have been increasing in well 1039 also, but to date have remained below the MCL. A possible source of the tritium could be the outfall from the French Drain area located to the northeast of the Tumulus area. Since none of the Tumulus wells located to the south of 1036 have displayed increasing trends in tritium concentration, it appears that along strike migration maybe a primary pathway.

Groundwater samples from wells located along the southeastern and southern boundary of WAG-6 have, on occasion, had tritium detected at concentrations exceeding 20,000 pCi/L. The monitoring network in this area presently suggests that this area is not releasing elevated levels of tritium off WAG boundaries.

**Man-made radionuclides—cesium-137, cobalt-60, and strontium-90.** Cesium-137 has been detected in groundwater samples from 4 wells at WAG 6. These wells are 846, 856, 836, and 860 (Figure 4C.16). Wells 846 and 856 are reference wells located up gradient from waste disposal sites. Well 836 is located at the southern waste disposal area, and

Well 860 is located in the southwest corner of WAG 6 to which the nearest waste disposal area is over 700 ft to the east. Except for Well 836, cesium-137 was detected in the first sampling event of these wells and subsequent sampling events have not detected cesium-137. Cesium-137 was detected in a third sampling event of Well 836 in which previous and subsequent sampling events indicated cesium-137 not to be present. Figure 4C.7 (ORNL RCRA monitoring results) and Fig. 4C.8 (RFI results) illustrate the range in variation of cesium-137 analyses. Cesium-137 was not detected in RFI monitoring wells.

Concentrations of cobalt-60 and strontium-90 detected in groundwater samples from a few wells were significantly above the level at which the majority of other sample concentrations were detected at (Figs. 4C.9 through 4C.12). The associated error terms for the higher concentrations indicate a high degree of certainty of the detection.

Occurrences of cobalt-60 and strontium-90, are limited to the north and northeast sections of WAG 6. In particular, the high-activity trench area and the eastern half of the central waste disposal area, the 19-Trench area, and the central part of the east waste disposal area, contain wells in which strontium-90 and cobalt-60 have been detected in groundwater samples (Fig. 4C.16).

Cobalt-60 distribution in groundwater is presently confined to the vicinity of the 19-Trench area and the central part of the east waste disposal area (Fig. 4C.16). Concentrations detected in Well 843, located to the east of the 19-Trench area, have been marginally elevated from what has typically been observed at the site overall. Data collected by Davis et al. (1989) from TARA wells located adjacent to the site indicate low levels of cobalt-60 below the magnitude of that detected in Well 843 (Fig. 4C.17). This may reflect a temporal difference for the TARA data were collected only once in 1987. Groundwater samples from adjacent Well 844, which monitors a zone deeper than Well 843, has not had cobalt-60 detected. Migration is most likely southerly and easterly towards discharge points along Drainage B and possibly off WAG boundaries through the groundwater system.

Cobalt-60 concentrations are highest along the eastern boundary of the WAG adjacent to the east waste disposal area (Fig. 4C.16). It is doubtful that the cobalt-60 detected in groundwater samples from this area originated from the 19-Trench area. Therefore, it appears that the auger hole area of the eastern waste disposal area is a separate source. Cobalt-60 occurrence is presently confined to the upper-part of the groundwater system, and was not detected in deeper Well 841 which is adjacent to 842. Cobalt-60 was not detected in wells located south of Well 1243 (Fig. 4C.18). Migration of cobalt-60 contaminated groundwater off WAG 6 to the east is likely.

Strontium-90 has been detected in groundwater samples from three wells (Wells 1225, 1237, and 848). Groundwater samples from Well 1225, located on the western boundary of the high activity trench area of the central waste disposal area (Fig. 4C.16), has had the highest concentrations of strontium detected at the site (up to 5400 pCi/L). Strontium-90 was not detected in Well 847, located to the east of the high activity trench area. Downgradient wells to the south are possibly too deep to detect any possible plume moving in that direction (Fig. 4C.19).

Well 848 is located south of the low activity trenches of the eastern part of the central waste disposal area. Strontium-90 has been detected in adjacent Drainage DB to the east. Figure 4C.20 illustrates strontium-90 occurrences with depth in this area.

Strontium-90 has also been detected in Well 1237, located upgradient to the west waste disposal area. This well has been sampled only once and wells paired with 1239 have not had strontium-90 detected in groundwater samples taken from them.

**Transuranic Radionuclides.** Transuranics, consisting of americium-241, curium-244, plutonium-238, and plutonium-239/240, were detected in groundwater samples from six wells located at the high activity trench area and the 49-Trench area of the central waste disposal area, the west waste disposal area (in both upgradient and downgradient wells at the low activity trenches, and the biological trench area), and the auger hole area of the east waste disposal area (Fig. 4C.21). Concentrations are generally low in most wells (below 3 pCi/L) but are higher in Well 1225, where americium-241 was detected at 23.9 pCi/L. Americium-241 occurrences in groundwater samples from Wells 1227, 1233, 1237, and 1242 are questionable. Previous analytical results from Wells 1227 and 1233 indicated americium-214 not present above the detection limit of 1 pCi/L. Wells 1237 and 1242 have been sampled only once. Well 1237 is also located upgradient to any waste disposal area. Plutonium-238 was detected in groundwater samples from Wells 1225 and 1229, and curium-244 was detected in Well 1225.

Relatively higher concentrations of transuranic radionuclides were detected in groundwater samples from Well 1225 located on the western perimeter of the high activity trench area (Fig. 4C.21). Strontium-90 and tritium exceeded MCL concentrations have also been detected in groundwater samples from this well. Americium-241, curium-244, plutonium-238, and plutonium-239/240 were detected. Gross alpha concentrations observed in groundwater samples from adjacent Well 847 located on the eastern side of the high activity trench area suggest that transuranics, if present, do not contribute significantly to alpha activity in the groundwater (maximum detected gross alpha in Well 847 was 10.8 pCi/L which is within background concentration ranges).

**Summary.** To summarize the nature and extent of radionuclide contamination at WAG 6, of the radionuclides detected, tritium is the most prevalent having been detected in wells adjacent to most waste disposal areas The potential exists for off-site migration of tritium in groundwater along the northern, eastern, and southern boundaries.

Transuranic radionuclides have been detected; however, their distribution is limited and concentration levels are relatively low. The greatest potential for off-site migration exists at the high activity trench area of the central waste disposal area.

The presence of any appreciable amounts of cesium-137 in groundwater is questionable due to large error terms associated with analytical results. Cobalt-60 and strontium-90 have been detected; however, like the transuranics, distribution is limited. Off-site migration of these radionuclides in groundwater is most likely to occur in the northern and northeastern

parts of WAG 6 at the high activity trench area, the 19-Trench area, and the northern part of the east waste disposal area.

Gross alpha concentrations have been detected in excess of 15 pCi/L in which contributing specified radionuclides have not been identified. It is possible that naturally occurring radionuclides are responsible.

### 4C.1.3 Chemical Contamination

#### 4C.1.3.1 Nature

This section is subdivided into a discussion of the inorganic and organic constituents analyzed in groundwater. These constituents include metals, VOCs, SVOCs, pesticides, polychlorinated biphenyls (PCBs), organophosphorus pesticides, dioxins, furans, and herbicides. Of the organic compounds detected, the VOCs comprise the largest group and consequently have much of the discussion devoted to them. Of the inorganic compounds, the only group discussed are the metals. Miscellaneous inorganic parameters, such as pH, conductivity, etc., are not addressed as they are indicators of natural groundwater geochemistry.

**Volatile organic compounds.** VOCs were detected in a majority of groundwater samples collected from ORNL RCRA compliance and RFI monitoring wells at WAG 6. Some occurrences have been attributed to laboratory (common laboratory contaminants) or field sampling induced contamination and have been eliminated from further consideration (see Sect. 4.1.1.3 in main report). Common laboratory compounds have been identified in disposal trench leachate samples at WAG 6 (Soloman 1989) and may have entered the groundwater system. Therefore, when these compounds have been detected and cannot be identified as induced contamination, their presence in the groundwater is possible.

The VOCs detected in groundwater samples collected from ORNL compliance and RFI monitoring wells included two tentatively identified compounds (TICs) which are components of scintillation fluids disposed of at the site. Numerous other TICs have been detected and have undergone data validation procedures; most have been identified as laboratory induced contamination (Appendix 4A) and are subsequently not discussed.

Table 4.2 in the main report lists the VOCs detected in groundwater at the site. The compounds most frequently occurring by well include tetrachloroethene (12 wells), 1,2-dichlorethene (10 wells), and trichloroethene (10 wells), chloroform (10 wells), methylene chloride (8 wells, and benzene (6 wells). All other compounds were detected in five wells or less.

Of the VOCs detected in groundwater samples from ORNL RCRA and RFI monitoring wells, MCLs exist for eight. Compounds detected which exceed MCLs (of which there were six) are listed as follows: (the first number in parenthesis following the VOC is the MCL for that compound, the second number is the maximum detected concentration in $\mu$g/L): trichloroethene (5/1300, trichloromethane (100/190), benzene 5/11, vinyl chloride (2/88),

1,2-dichloroethane (5/44), and carbon tetrachloride (5/96). Compounds which are detected for which MCLs have been established but will not be effective until January 30, 1992 include toluene, 1,2-dichloroethene, and tetrachloroethene. Concentrations of 1,2-dichloroethene and tetrachloroethene have exceeded the MCLs.

VOC concentrations ranged from a low of 0.4 μg/L 1,1,1-trichloroethane in Well 843 to a high of 6800 μg/L tetrachloroethene in Well 1233. The maximum detected concentrations for all compounds detected in any single well including results from all sampling events have been summed to present a "worst case" condition for that (Table 4C.3). Comparisons with other wells are made using this value because all wells were not sampled concurrently and in some instances data are available from five to six sampling events for a well, and no concentration trends are apparent in the data.

The wells with the greatest summed VOC concentrations (as presented in Fig. 4C.22) are Well 1233 (8307 μg/L) located just west of the central waste disposal area, Well 849 (1658 μg/L) located south of Well 1233 at the central waste disposal area, Well 850 (6755 μg/L) located east of the biological trench area of the east waste disposal area, Well 842 (798 μg/L) located east of the auger hole area of the east waste disposal area, and Well 648 (4545 μg/L) located south of the high activity trench area of the central waste disposal area. All other summed VOC concentrations did not exceed 300 μg/L.

**Semi-volatile organic compounds.** SVOCs were detected in groundwater samples from wells analyzed during detection/compliance monitoring and the RFI. Many of these compounds can be attributed to contamination through the sampling and/or analysis procedures (see Sect. 4.1.1.3 of the main report) and were detected in various blanks. Several SVOCs were detected that could not be directly attributable to the sampling or analysis procedures but which are common laboratory and environmental contaminants. These compounds are bis-2-ethylhexyl phthalate, di-n-butyl phthalate, and diethyl phthalate. Phthalates are plasticizers that have been identified as common laboratory contaminants (EPA 1990). The maximum detected concentration level for any of the previously mentioned phthalates was estimated at 7 μg/L. SVOCs present in groundwater at the site include 2-methyl phenol, dimethyl benzene, and naphthalene. Their frequency of occurrence is limited to Wells 852 and 1228 located at the biological trench area of the west waste disposal area and Well 852 located southwest of the biological trench area of the central waste disposal area. Maximum detected concentrations ranged from an estimated low of 1 μg/L for naphthalene in Well 852 to a high of 1000 μg/L for naphthalene in Well 850. Maximum summed SVOC concentrations ranged from an estimated low of 7 μg/L in Well 1228 to a high of 1022 μg/L in Well 850.

**Other chemical compounds.** The herbicides 2,4,5-TP (Silvex), 2,4,5-T, and 2,4-D have been detected in groundwater samples during ORNL RCRA compliance sampling. The introduction of herbicides to groundwater at WAG 6 has been attributed to the localized land applications prior to installation of caps on the wells (ORNL 1989).

Except for two occurrences of the PCB aroclor 1254, at levels estimated at 1 $\mu$g/L or lower, no other PCBs were detected at the site. Other compounds not detected at the site include dioxins, furans, and organophosphorus pesticides.

**Metals.** Metals occur naturally in the groundwater environment and were detected in every groundwater sample in which metals were analyzed. To determine if any metals were present in concentrations indicative of releases to the environment or in concentrations harmful to human health and the environment, comparisons were made to reference conditions at the site and to other criteria such as the Safe Drinking Water Act MCLs. For the purposes of this study, the only metals of concern are metals for which MCLs or RFI Guidance Health Based Criteria exist. After these comparisons were made, it was determined that three metals are present in groundwater at levels of concern. These metals are barium, cadmium, and lead. The maximum concentration detected for these metals are as follows (the first number in parenthesis represents the MCL reported in micrograms per liter, the second is maximum concentration): barium (1000/27100), cadmium (10/94.5), lead (50/100). Arsenic, mercury, antimony, and silver were also detected above their respective MCLs; however, occurrences were sporadic within wells in which they were detected and were localized. All other metals were detected at levels that did not significantly exceed background concentrations or did not exceed MCLs.

### 4C.1.3.2 Extent

The discussion on extent of chemical contamination in groundwater at WAG 6 is separated by parameter. First is a discussion of the organic chemicals of which the VOCs constitute the major group. The VOC discussion is followed by discussion of SVOCs, herbicides, and metals detected.

**Volatile organic compounds.** Groundwater monitoring wells in which VOCs were detected are presented in Fig. 4C.22. A graphical representation (rose diagram) of the various VOCs detected and their maximum concentration is also presented. Each segment of the rose diagram represents a distinct VOC, the distance radially represents the maximum concentration observed for that constituent for that well. The concentration scale is logarithmic. Specific VOCs plotted on the rose diagram are: 1,2-dichloroethene, trichloroethene, tetrachloroethene, chloroform, total xylenes, toluene, benzene, and acetone. An additional segment includes a sum of the remaining constituents detected in that well and is labeled as "others." The primary VOCs were chosen based on frequency of occurrence. These "other" compounds include the following: 1,1-dichloroethene, 1,1-dichloroethane, 1,2-dichloroethane, carbon tetrachloride, methylene chloride, 1,1,1-trichloroethane, vinyl chloride, ethyl benzene, dichloromethane, 2-butanone, trichloromethane, carbon disulfide, 1,1,2,2-tetrachloromethane, 1,1,2-trichloroethane, ethyl chloride, including ethyl ether, diethyl ether, and 1,4 dioxane which are TICs. The VOCs have been arranged to discern distribution patterns. Generally, chlorinated alkenes occupy the right side of the rose, aromatics occupy the left. The order of arrangement of VOCs is consistent from one to the other.

Releases of VOCs from some of the areas have VOC suites distinctly different from those of other areas. Scintillation fluids (commonly various aromatic hydrocarbons) have been disposed in biological trenches and typical components of these fluids have been detected in groundwater in the vicinity of the biological trenches located in the southern sections of the west waste disposal area and the central waste disposal area. On the other hand, the low and high activity trench areas and the auger hole areas contain a different suite of VOCs dominated by the chlorinated alkenes trichloroethene, tetrachloroethene, and 1,2-dichloroethene. Some aromatic compounds are present at auger hole areas.

The discussion on extent of VOC contamination is presented by proximity to drainage features generally from an upgradient to downgradient position at the site. The discussion starts with the northernmost waste disposal unit of the central waste disposal area (the high activity trench area) and proceeds southward along the FB drainage to the south waste disposal area. The discussion continues with the northeastern half of the WAG (the 19-Trench area) southward across Drainages B and C to the east waste disposal area (Fig. 4C.22).

- **Drainage FB - north high activity trench area.** The high activity trench area is the northernmost waste disposal area adjacent to drainage FB. Here, VOCs have been detected in monitoring wells located to the west (Well 1225) and to the south (Well 648) (Fig. 4C.22). Ten different VOCs were detected in Well 648, which is located downgradient from within a field of solvent auger holes. Concentrations ranged from 6 $\mu$g/L xylenes to 2323 $\mu$g/L trichloroethene (Soloman et al. 1988). MCLs for 1,1-dichloroethene, 1,2-dichloroethane, trichloroethene, and benzene were exceeded. Groundwater from Well 648 may be influenced by materials released from the high activity trench area in addition to the releases from the solvent auger holes. Only three VOCs (tetrachloroethene, 1,2-dichloroethene, and acetone) were detected in 1225. The highest concentration detected was 120 $\mu$g/L of acetone.

  Known vertical distribution of VOCs in this area is presented in Figs. 4C.23 and 4C.24. Although VOCs have not been detected to the east of the high activity trench area in Well 847, this is screened in the shallow bedrock approximately 15 ft below the base of Well 1225 and does not intersect the water table (Fig. 4C.23). The screen may be too deep to intercept VOCs migrating to the east. VOCs have also not been detected in upgradient Well 846.

  A cluster of three wells (HHMS-7A, HHMS-7B, and HHMS-7C) are south of the high activity trench area and down gradient but have not been sampled for VOCs (Fig. 4C.24). VOCs are known to occur at least as deep as well 648 extends which is 45 ft below the surface (778 ft above mean sea level). Based on the understanding of site hydrogeology (described in Sect. 3 of the main report), groundwater is expected to flow towards Drainage FA. Surface water samples collected southwest of the solvent auger hole area in Drainage FB have had 1,2 dichloroethene, tetrochloroethene, and trichloroethene detected (Sect. 4C.2.3).

- **Drainage FB - 49 Trench area.** VOCs have been detected in groundwater samples from wells located at the 49-Trench area of the central waste disposal area. Maximum concentration levels ranged from a low of 1 $\mu$g/L for chloroform, 1,1-dichloroethene, trichloromethane, and ethyl chloride to a high of 6800 $\mu$g/L tetrachloroethene. MCLs were exceeded for trichloroethene and vinyl chloride in Wells 849 and 1233. Well 1232 has been dry since installation.

  Lateral extent of VOCs detected in these wells to the west appears to be bounded by Drainage FB. Surface water samples collected adjacent to 1233 have had several VOCs detected. Wells on the western side of drainage FB, while having VOCs detected in groundwater samples from them, contain different suites of VOCs except for the occurrence of trichloroethene at very low levels.

  Eastern migration of VOCs from the 49-Trench area in groundwater is most likely intercepted by the French Drain. Water samples from the outfall of the French Drain have contained relatively high concentrations of similar VOCs detected in upgradient wells and surface water locations (Sect. 4C.3.3). Known vertical distribution of VOCs at the 49-Trench area is presented in Figs. 4C.25 and 4C.26.

- **Drainage FB - west waste disposal area.** The west waste disposal area can be divided into the northern half consisting of low activity trenches and the southern half consisting of biological trenches (Fig. 4C.22). Five ORNL RCRA compliance and RFI monitoring wells are adjacent to the low activity trenches. Wells 1226, 1237, and 1238 are located upgradient. Well 1226 has been dry since installation. Except for carbon disulfide, which was detected once at 22 $\mu$g/L in Well 1237, no other VOCs were detected in these wells. Downgradient to the low activity trenches, Wells 853 and 854 have had no other VOCs detected in groundwater samples, except for one occurrence of methylene chloride in each well at 25 and 20 $\mu$g/L, respectively.

  Analyses of groundwater samples collected from Wells 851, 852, 1228, and 1229 indicate that the biological trenches of the west waste disposal area have released components of scintillation fluids (benzene, toluene, xylenes, 1,4-dioxane, and diethyl ether) along with acetone, and minor amounts of 1,2-dichloroethene, tetrachloroethene, chloroform, methylene chloride, vinyl chloride, and possibly 2-butanone (Fig. 4C.22). Only benzene in Well 852 exceeded any primary MCL (detected at a maximum concentration of 110 $\mu$g/L). The greater concentrations were detected in Wells 852 (393 $\mu$g/L maximum summed VOC concentration) and 1228 (294 $\mu$g/L maximum summed VOC concentration) located at the southwestern tip of the biological trench area.

  Low concentrations of VOCs have been detected in groundwater samples from wells 851 and 1229 which are located in close proximity to each other. Well 851 contained the scintillation fluid components 1,4-dioxane (160 $\mu$g/L) and ethyl ether (8 $\mu$g/L), while 1229 contained tetrachloroethene and possibly 2-butanone each at 2 $\mu$g/L (which is below sample quantification limits for these compounds). Benzene was also detected in Well 1228 at a maximum concentration of 1 $\mu$g/L. Groundwater samples from

monitoring Wells 745 and 833, located approximately 300 ft south of Wells 1228 and 852, do not appear to be affected by VOC releases from the biological trench area. Except for a one-time detection of 1,1-dichloroethene in Well 833 at an estimated level of 1 $\mu$g/L (Fig. 4C.27), no other VOCs have been detected. These wells are completed in bedrock and not the saturated overburden, however. They are positioned on the west side of the FA drainage system possibly precluding them from intercepting any volatile organic plume migrating southward from the west waste disposal area. It is probable that VOCs are migrating towards the FB or FA drainage systems which surface water sampling results suggest.

- **South waste disposal area.** The south waste disposal area consists of biological trenches to the west and low level trenches to the east (Fig. 4C.22). This waste disposal area is located near the southern boundary of WAG 6 just north of White Oak Lake. Three compliance wells (835, 836, and 837) monitor groundwater conditions in the unconsolidated zone. Groundwater samples from Well 837 have not contained detectable VOCs. Groundwater samples from Well 835 have contained levels of trichloroethene and benzene below the MCL in addition to other components of scintillation fluids (1,4 dioxane and ethyl ether). Well 836 has contained low to moderate concentrations of chloroform and tetrachloroethene (Fig. 4C.28). Trench leachate analysis has indicated the presence of various VOCs, of which components of scintillation fluids were detected at highest concentrations (i.e. xylenes 3696 $\mu$g/L, toluene 2,500 $\mu$g/L). No primary MCLs have been exceeded. Considering the wells' proximity to the WAG boundary, it is probable that migration of VOCs off-site may be occurring.

- **Southwestern area of WAG 6.** VOCs have been detected sporadically and at low concentrations in Well 859 in the extreme southwest corner of WAG 6 (Fig. 4C.22). Well 859 is completed in the overburden and is paired with 860 which monitors the bedrock zone. Occurrences of ethyl benzene, toluene, and xylenes, the typical suite of VOCs associated with biological trench leachate, have been detected occasionally during January and May 1989. Occurrences of these volatiles were not repeated in a sampling event that occurred one year later during May of 1990.

- **19-Trench area.** The 19-Trench area is located in the northeastern part of WAG 6 on high ground between two small drainages, Drainage A to the northwest and Drainage B to the southeast (Fig. 4C.22). Relatively low levels of VOCs have been detected in groundwater samples from compliance wells 843 and 844 in this area. Between June 1988 and May 1990, ORNL sampled and analyzed groundwater from these wells five times. Maximum summed VOC concentration obtained for Well 843 was 20.9 $\mu$g/L and 14 $\mu$g/L for Well 844. No primary MCLs were exceeded in these wells.

  Low levels (4-11 $\mu$g/L) of 1,2-dichloroethene have been detected in shallow Well 843 for each sampling event except for the last sampling episode in May 1990 when it was not detected. In April 1989, four other VOCs were detected in Well 843, but at levels below the sample quantification limit. Results from the May 1990 sampling indicate a presence of low levels of chlorinated organics in deeper Well 844 for the first time. Volatile organic compounds have not been detected north of the 19-Trench area in

Well 1241. Since three sides of the 19-Trench area are bounded by streams, it is likely that contaminated groundwater from the area flows toward these drainages and then discharges to them from RFI monitoring Well 1242, located approximately 300 ft southwest of Wells 843 and 844 and across a drainage divide (Figure 4C.29).

- **East waste disposal area.** South of the 19-Trench area is the east waste disposal area Figure 4C.22. The east waste disposal area is located between Drainage B to the north, Drainage DB to the southwest, and the unnamed tributary to the east. This waste disposal area is divided into a northern section that consists primarily of high activity auger holes (including a group of solvent auger hole areas) and a southern section consisting of asbestos waste trenches. Separating the two major areas is a narrow zone of biological trenches and additional auger holes.

  VOCs at elevated concentrations have been detected in groundwater samples from several compliance monitoring wells located immediately downslope of the solvent auger hole area. (Fig. 4C.22). Summed maximum VOC concentration is greatest in shallow Well 842 (798 $\mu$g/L) compared with 53 $\mu$g/L in the deeper adjacent Well 841. Both of these wells are completed in bedrock. Primary MCLs for carbon tetrachloride, 1,2-dichloroethane, and trichloroethene have been exceeded in Well 842. Well 841 exhibits a subset of the suite of VOCs detected in Well 842 and generally in lesser concentrations (Fig. 4C.29). Well 845, located immediately southwest of the high activity auger hole area, has had low levels of 1,2-dichloroethene detected in groundwater samples. Wells to the south and to the east of the waste disposal area (1243, 1249, 1234, and 840), have not had VOCs detected in groundwater samples (Fig. 4C.29) except for 840 in which trichloroethene was detected once in five sampling events at a level of 1 $\mu$g/L and chloroform at 2 $\mu$g/L.

  It appears that the plume emanating from the solvent auger hole area is migrating southeastwardly towards WOC. Off-site migration to the east of Well 841 and 842 is likely considering the length of time VOCs have been detected in these wells (over 2 years) and the concentrations at which they have been detected. Wells 1244 and 1245 were installed east of the solvent auger hole area in the eastern side of the unnamed tributary (Fig. 4C.22) to aid in defining the extent of VOC contamination. With the exception of chloroform detected at an estimated 3 $\mu$g/L, no other VOCs have been detected. Discharge of VOC contaminated groundwater in this area is likely to occur to the unnamed tributary.

- **Central waste disposal area - eastern section.** Low to high levels of VOCs have been detected in compliance wells located at the eastern part of the central waste disposal area east of the 49-Trench area (Fig. 4C.22) This area consists primarily of low-level trenches with an area of biological trenches to the south followed by a thin zone of more low activity trenches. This area is bounded to the west by the French Drain, to the east by Drainage DB and to the south by Drainage DA. Near the northern low-level trenches, low concentrations of VOCs consisting of acetone, 1,1-dichloroethane, 1,2-dichloroethene, 1,1,1-trichloroethene and 1,4-dioxcane have been detected in Well 848 which monitors the bedrock/unconsolidated zone. Maximum summed VOC

concentration was 59.7 μg/L. It is possible that the VOC plume coming from these trenches could be discharging to Drainage DB to the east, the French Drain to the west, or may be attenuated by the time water from this reaches other monitoring wells. Figure 4C.30 illustrates the known vertical distribution of VOCs in the low-activity trench area.

Numerous VOCs detected at high concentrations have been detected in ORNL RCRA compliance Well 850 located southeast of the biological trenches of the central waste disposal area (Fig. 4.25). Groundwater samples collected from Well 850 contain typical components of scintillation fluids (toluene, xylenes, ethylbenzene, and benzene) with occurrences of chloroform, acetone, and trichloroethene. The second highest summed total VOC concentration for the site (6755 μg/L) was obtained in this well. Primary MCLs for benzene and trichloroethene were exceeded.

Well 850 monitors the bedrock/unconsolidated zone interface. Wells 1231, 838, and 839 are located downgradient to the biological trenches and the thin zone of low level trenches (Fig. 4C.22). VOCs have been detected in each of these wells. Well 1231 is located due south of the biological trenches. VOCs detected are trichloroethene and tetrachloroethene. The MCL for trichloroethene has been exceeded in groundwater samples from this well. The components of scintillation fluid detected in upgradient Well 850 have not be detected. It is possible that outfall from the French Drain located to the west is the source of VOC contamination in this Well. Wells 838 and 839 are located southeast of the biological trenches and south of the low-activity trenches. Relatively low concentration of VOCs (chloromethane and tetrachloroethene) have been detected (Figure 4C.31). If migration of VOCs in this region is primarily along strike, as may be indicated by the presence of VOCs in Well 850 and a different suite of VOCs in Well 1231, discharge of contaminated groundwater may be to Drainage DB. This creek is dry, however, for the most part of the year. In that case, discharge may be to WOC, which is off WAG 6 boundaries.

**Semivolatiles/organic compounds.** Semivolatile organic compounds contamination of the groundwater is not extensive at WAG 6. The occurrences of SVOCs have been associated with releases of VOCs and are apparently confined to the biological trench areas of the west waste disposal area and the central waste disposal area. Groundwater samples from Wells 1228 and 852, located at the biological trenches of the west waste disposal area, have contained low concentrations of dimethyl benzene and naphthalene. Concentration levels have been below detection limits and are therefore estimated values. Groundwater samples from Well 850, located east of the biological trenches of the central waste disposal area, contain higher concentrations of SVOCs. Naphthalene is the most prevalent, having been detected during several sampling events. The maximum detected concentration of naphthalene, for which there is no MCL, was 1000 μg/L. Other SVOCs detected include 2-methyl phenol and total recoverable phenolics, seen at levels below 30 μg/L. SVOCs, as a group, are generally less mobile than VOCs, and therefore probably have not migrated far from source areas.

**Herbicides.** Groundwater samples from 16 wells have contained detectable concentrations of herbicides (Table 4C.4). The herbicide 2,4-D was detected most frequently in these wells, maximum concentration did not exceed 12 $\mu$g/L. Concentrations ranged from 0.3 to 12 $\mu$g/L. The herbicides 2,4,5-T and 2,4,5-TP were detected in one and four wells, respectively. Concentrations did not exceed any MCLs for any of the herbicides detected.

**Metals.** Elevated concentrations of metals in groundwater at WAG 6 are not extensive and are confined to eight wells at the site which are adjacent to four waste disposal areas. These disposal areas are: (1) the high-activity trench area of the central waste disposal area, (2) the 49-Trench area of the central waste disposal area, (3) the biological trench area of the west waste disposal area, and (4) the biological trench area of the east disposal area (Fig. 4C.32). Barium is common to all sites except the high-activity trench area, and appears to be a common component of the biological trenches of the west and central waste disposal areas. Barium has not been detected in wells at the biological trenches of the south waste disposal area above 1000 $\mu$g/L (the detection limit during the analyses was 1000 $\mu$g/L which is equal to the MCL). Occurrences of lead and cadmium in concentrations greater than their respective MCLs are also common to all four waste disposal areas. The highest total concentration of lead was detected in Well 1231 at 100 $\mu$g/L. The highest occurrence of cadmium was detected in Well 1225 at 94.5 $\mu$g/L.

Mercury, antimony, and silver were detected above the MCL at only one location. Mercury was detected at 2.4 $\mu$g/L in Well 851 on May 11,1989; however, mercury levels were below the detection limit during the April 20, 1989 sampling. Antimony and silver both were detected above the MCL in Well 1225. Antimony was detected above the MCL during only one out of five sampling events while silver appeared above the MCL on two separate sampling events.

## 4C.2 SURFACE WATER

Approximately 70% of the surface area of WAG 6 lies within four main basin areas with associated intermittent streams (Fig. 4C.33). Three smaller, ephemeral drainages, named A, B, and C, drain the northeastern portion of the site. All of the surface water runoff eventually flows off WAG 6 to WOC and WOL (WAG 2).

As described in Sect. 2, surface water grab samples were collected during the WAG 6 RFI from all drainages in WAG 6 during six separate sampling events over an 8-month period in 1989. In addition, the outfall from the 49-Trench Area French Drain and the EWB were sampled. Table 4C.5 summarizes these sampling events. Samples were generally analyzed for radionuclides, volatile organics, semivolatile organics and metals.

Continuous surface water sampling was performed during two storm events in April - May 1990 at flumes constructed in Drainages DA, DB, FA, and FB (Fig. 4C.33). The purpose of this sampling was to characterize contaminant flux off-site and for calibration of the surface water and subsurface water contaminant transport model. This sampling effort and its results are discussed in greater detail in Appendix 5B.

### 4C.2.1 Previous Investigations

This section provides an overview of previous investigations conducted at WAG 6 which yielded surface water quality analytical data. The actual data and sampling locations are presented in Appendix 1B. Table 4C.6 lists WAG 6 surface water investigations, the locations sampled, the dates the investigations occurred, and the constituents that were analyzed for during each of the studies. As appropriate, specific data from these investigations are integrated into the discussion on the nature and extent of contamination.

Surface water samples were collected from Drainages BAA and BAB between October 1980 and March 1983 by Davis et al. (1984) as part of the performance assessment of selected site characterization techniques. Samples were analyzed for tritium, cobalt-60, strontium-90, and cesium-137.

Between February and April 1987, pre-Interim Corrective Measure (ICM), storm-flow surface water samples were collected by Davis, et al. (1987) from Drainages DA, DB, and F. These samples were analyzed for tritium.

During a performance assessment of the 49-Trench area French Drain, conducted by Davis and Marshall (1988), samples were collected from the southern outflow of the French Drain and from a seep adjacent to the 49-Trench Area, in Drainage FB. Samples were analyzed for tritium, cobalt-60, strontium-90, and cesium-137.

Miller, Black, and Craig (1989) performed an extensive surface water sampling effort for major drainages in WAG 6. Samples were collected from October 1988 to June 1989 and analyzed for tritium, cobalt-60, strontium-90, and cesium-137.

### 4C.2.2 Radiological Contamination

#### 4C.2.2.1 Nature of contamination

Table 4.6 in the main report lists the radionuclides detected in surface water samples WAG 6. Tritium and strontium-90 were detected more frequently and at higher levels than any other radionuclide. Tritium and strontium-90 appear above MCLs at 12 of 15 and 5 of 12 locations sampled, respectively. The highest level of tritium detected was 14,000,000 pCi/L occurring at the outfall of the 49-Trench area French Drain. All sampling locations in Drainage FB had strontium-90 levels over the MCL. The highest level of strontium-90 in WAG 6 surface water, 10,222 pCi/L occurred at the headwaters of FB drainage. The distribution of tritium, cobalt-60 and strontium-90 is shown in Fig. 4C.34. The transuranic radionuclides plutonium-239,240, curium-242, and curium-244 have also been detected.

#### 4C.2.2.2 Extent of contamination

**Drainages A and B.** Radionuclide concentrations in Drainages A and B are low in comparison to concentrations elsewhere at WAG 6. Tritium concentrations in these drainages

ranged from 2550 pCi/L to 30,000 pCi/L and are approximately 10 to 100 times less than most other surface water samples from WAG 6. The MCL for tritium (20,000 pCi/L) was exceed only in Drainage B. Strontium-90 was detected at 11.2 pCi/L in one sample from Drainage A. However, this was the only time strontium-90 or any other radionuclide, except tritium, was detected in either of the drainages.

**Emergency Waste Basin.** Tritium was detected in surface water samples in concentrations exceeding the MCL both times the EWB was sampled during the RFI. Concentrations were 190,000 pCi/L and 160,000 pCi/L. Strontium-90 was also detected (7.5 and 5.1 pCi/L); however, these concentrations are below the MCL of 8 pCi/L. Surface water sampled below the EWB in Drainage A indicated tritium concentrations below the MCL; strontium-90 was not detected.

**Drainage C.** Only one sample was collected from Drainage C. This sample was collected during a storm flow event when the water table was high. The drainage was dry during all other sampling events. Tritium was detected above the MCL at 190,000 pCi/L. Wells adjacent to Drainage C have also contained comparable levels of tritium exceeding the MCL (Figure 4C.15). No strontium-90 was detected in this sample; however, cobalt-60 was detected at 550 pCi/L. This represented the only time cobalt-60 was detected in any WAG 6 surface water sample. Cobalt-60 was also detected in Wells 842 (267-351 pCi/L) and 1243 (1880 pCi/L) located to the north and south, respectively, of Drainage C (Fig. 4C.16). The groundwater flow in this area is in a south/southeasterly direction; therefore, the most probable source of the cobalt-60 is the northeast auger hole area, which is known to contain cobalt-60.

**Drainage DA.** Surface water samples were collected at sampling point WDA1 in Drainage DA (Fig. 4C.35). Samples were also collected at the effluent point, W49TS, for the 49-Trench area French Drain that flows into Drainage DA. Tritium was detected at concentrations of 4,270,000 pCi/L to 12,000,000 pCi/L from samples collected from the 49-Trench Area French Drain which greatly exceed the MCL. Davis and Marshall (1988) also detected comparable concentrations of tritium from the French Drain samples collected at the outfall. Similar concentrations of tritium were detected at sampling station WDAL in Drainage DA. Well 1231, located east of the outfall of the French Drain (Fig. 4C.15), has had tritium concentrations exceeding the MCL (51,000-83,000 pCi/L). Comparable concentrations near WDA1 were also found by Davis, et al (1987) and Miller, Black, and Craig (1989). The tritium levels found during the RFI at the WDA1 location were approximately an order of magnitude below the levels found at the W49TS location.

Strontium-90 has been detected only once in four sampling events at both the French Drain outfall and in Drainage DB samples. Concentrations have not exceeded the MCL. Davis and Marshall (1988) have detected strontium-90 in French Drain outfall samples also.

It appears that the 49-Trench area French Drain is providing a direct conduit for the migration of contaminants leaching from the low activity trenches of the central waste disposal area to the DA drainage and White Oak Creek and Lake.

**Drainage DB.** This drainage is frequently dry; therefore, few samples have been collected during the RFI. Surface water samples collected during a high groundwater storm event contained tritium at a concentration of 73,000 pCi/L which exceeds the MCL (Fig. 4.38). Strontium-90, detected at 6 pCi/L, was below the MCL. Strontium-90 has also been detected in Well 848 located west of WDB2 adjacent to the central waste disposal area (Fig. 4C.16).

**Drainage FA.** Drainages BAA and BAB combine to form Drainage FA. Drainage BAA has only one sampling location, located near the conference of BAA and BAB. Drainage BAA has only had enough flow to sample during periods of high groundwater after storm events. Tritium was detected at 1,500 pCi/L which is well below the MCL. Plutonium-239/240 was detected in a surface water sample collected from WBAB2 at a concentration of 1.1 pCi/L.

Tritium concentrations in Drainage BAB are about two orders of magnitude higher than in BAA near the meeting point of the two drainages (WBAB1) (Figure 4C.34). Davis, et al (1984) also found the same relationship of tritium concentrations in these two drainages. Tritium levels near the head of Drainage BAB (WBAB2) are low and did not exceed 19.7 pCi/L. This fact indicates that BAB is gaining tritium-contaminated groundwater between WBAB2 and WBAB1. The source of the tritium contamination is most likely the west waste disposal area. This is supported by the fact that the wells directly downgradient of the west waste disposal area also have elevated levels of tritium (Figure 4C.15).

Samples collected beyond the point where Drainages BAA and BAB meet to form Drainage FA (WFBA1 sampling location), indicate concentrations of tritium that are slightly less than those seen upstream at WBAB1 (Figure 4C.34). However, the concentration levels still exceed the MCL.

**Drainage FB.** Samples from surface water sampling point WFBB3, located at the headwaters of Drainage FB and west of a high-activity trench area, have had concentrations of tritium and strontium-90 detected exceeding both MCLs. Tritium has been detected in concentrations up to 190,000 pCi/L. Strontium-90 concentrations have been as high as 10,222 pCi/L. This sample point lies west/south-west of the high-activity trench area. Well 1225 is located between WFBB3 and the high-activity trench area, and shows tritium and strontium-90 (Figure 4C.16) detected at similar concentrations. Curium-242 and curium-244 have been detected at WFBB3 at 7.88 and 134.7 pCi/g, respectively. These radionuclides have not been detected in any downstream sampling locations. Curium-244 has also been detected in well 1225 located to the west of WFBB3. It appears that radionuclides leaching from the high activity trench area are being discharged to Drainage FB in the vicinity of WFBB3.

Although the results from downstream sampling location WFBB2 show lower levels of tritium and strontium-90 than found at WFBB3, they still exceed the MCL.

Tritium levels, at this sampling point, increase generally by an order of magnitude from those detected in upstream location WFBB2—which implies a new source area. Groundwater

wells in the vicinity of WSPl, located east towards the 49-Trench area (Figure 4C.15) have been shown to contain tritium in concentrations up to 770,000 pCi/L. Strontium-90 concentrations at WSP1 are not as high as upstream concentrations suggesting possibly no additional source originating from the 49-Trench area. Drainage FB appears to be losing water from sampling point WFBB2 to downstream location WSP1. This loss is evident because surface water levels have not been adequate to collect samples at WSP1 during any of the base flow sampling events; however water levels were adequate to collect a sample at the WFBB2 point which lies approximately 350 ft upstream from WSP1.

Sampling point WFBB1 has consistently shown an order of magnitude higher concentrations of tritium (up to 3,910,000 pCi/L) levels over upstream samples while strontium-90 levels have remained fairly consistent with upstream levels. This difference in tritium concentrations appears to be due to a seep that has been identified in the area directly to the west of Well 849. Results of sampling of Well 849 have confirmed comparable levels of tritium in the groundwater. This area is underlain by the geologic contact between the Nolichucky Shale and Maryville Limestone, which may provide a conduit for east/west groundwater flow instead of the southerly flow which is expected. The most probable source of this contamination is the 49-Trench area. Sampling of a seep adjacent to the 49-Trench area was performed by Davis and Marshall (1988). Results of this sampling indicated tritium and strontium-90 entering Drainage FB from this seep. The Miller, Black, and Craig et al (1989) study confirmed tritium entering Drainage FB in this area.

### 4C.2.3 Chemical Contamination

#### 4C.2.3.1 Nature of contamination

VOCs were detected in surface water samples collected from WAG 6. Table 4.2 in the main report lists all of the VOCs detected in surface water samples. Trichloroethene, 1,2-dichloroethene, and tetrachloroethene represent 98% of the VOCs detected. The distribution of these VOCs is shown in Fig. 4C.35. Concentrations exceeding drinking water MCLs were exceeded by trichloroethene, 1,2-dichloroethene, tetrachloroethene (MCL effective 1/30/91), and vinyl chloride.

SVOCs were detected in very few surface water samples. Table 4.2 in the main report lists all the semivolatiles that were detected and the levels at which they were detected. Most of the semivolatiles detected were at extremely low levels and are either phthalates or phthalate derivatives, both of which are common laboratory contaminants.

Results from metals analysis were compared to the following water quality criteria: maximum contaminant levels found in the SDWA, RFI Guidance Health Based Criteria, and Tennessee Water Quality Control Board standards.

Results from only two samples exceeded water quality limits for metals. The barium MCL of 1000 $\mu$g/L was exceeded by a 2400 $\mu$g/L reading at WBAB1 in Drainage BAB. The cadmium MCL of 10 $\mu$g/L was exceeded by a factor of three from a sample collected at WBAA1 collected in the Drainage BAA. Concentrations of these metals did not exceed

MCL on any other sampling events at these locations. Therefore, these samples are believed to be outliers and do not accurately represent metal concentrations at these locations.

### 4C.2.3.2 Extent of contamination

**Drainages A, B, C, and DB.** No VOCs were detected in samples from Drainages A, B, C, and DB with the exception of 2 $\mu$g/L of trichloroethene that was detected in one sample from SWA1 in the A drainage. Therefore, it is concluded that none of these drainages currently represent a significant pathway for off-WAG migration of VOCs.

**Emergency Waste Basin.** VOCs were not detected in samples collected from the EWB except for 2-hexanone detected at an estimated 1 $\mu$g/L one time.

**Drainage DA.** Surface water samples collected at sampling point WDA1 in Drainage DA indicated virtually no VOCs. However, upstream samples collected at W49TS, the outfall of the 49-Trench area French Drain, showed highly elevated levels of VOCs. As pointed out in Sect. 4C.1.2.2, dilution of radionuclides appears to be occurring between W49TS and WDA1. A combination of dilution and air stripping would account for the volatile organics not appearing in the WDA1 samples.

Surface water samples collected from Drainage DA contained few VOCs (chloroform at 15 $\mu$g/L and 2-butanone at 2 $\mu$g/L) and one SVOC, bis (2-ethylhexyl) phthalate, detected at 3 $\mu$g/L. These concentrations are low and all three compounds are usually common laboratory contaminants.

In contrast to samples from Drainage DA, samples collected from the outfall of the 49-Trench area French Drain have contained various VOCs. VOCs detected which have exceeded MCLs include 1,2-dichloroethene, and trichloroethene. The MCL for tetrachloroethene (5 $\mu$g/L) will be effective January 30, 1992 and has been exceeded in samples from the outfall of the French Drain. Although 1,1-dichloroethane and 1,2-dichloroethane were detected, they were present in relatively lower concentrations.

**Drainage FA.** Tetrachloroethene, trichloroethene, and 1,2 dichloroethene have been detected at sampling point WBAA1 in the Drainage BAA. The MCL for trichloroethene was met in the one sampling event of Drainage BAA. The concentration at which tetrachloroethene was detected (70 $\mu$g/L) exceeds the MCL that will be effective in 1992. Except for tetrachloroethene, which was detected once at an estimated concentration of 1 g/L no VOCs have been detected in Drainage BAB.

Although VOCs were detected in Drainage FA, none have been detected in upstream samples in the BAA and BAB. The compounds are acetone, toluene, 2-butanone, methylisobutyl ketone, and 1,1,2,2-tetrachloroethane. All were estimated concentrations and except for 1,1,2,2-tetrachloroethane, the other compounds are common laboratory contaminants.

**Drainage FB.** Drainage FB exhibits the greatest diversity in VOCs of all drainages at WAG 6. The MCLs for trichloroethene and vinyl chloride have been exceeded. The MCLs for 1,2-dichloroethene and tetrachloroethene, which become effective January 30, 1992, were also exceeded at various sampling points along the drainage. The MCL for trichloroethene only was equaled at the most downstream sampling point in the drainage.

Uppermost sampling point, WFBB3, contained the characteristic VOCs trichloroethene and 1,2-dichloroethene in relatively low concentrations compared with elsewhere in the drainage. Downstream sampling locations WFBB2 and WSP1 each contained the characteristic VOCs trichloroethene, 1,2-dichloroethene, and tetrachloroethene (all in excess of their respective MCLs), and also vinyl chloride, chlorobenzine, toluene, benzine, 1,1-dichloroethene. The MCL for vinyl chloride was exceeded at sampling location WPBB2. Vinyl chloride was detected at a maximum concentration of 11 $\mu$g/L. Lowest sampling point WFBB1, except for one detect of 2-butanone, contains only trichloroethene, 1,2-dichlorothene, and tetrachloroethene.

Surface water sampling point WFBB2 is located in a position that may be intercepting water that flows through Well 648. This sampling point has indicated elevated levels of chlorinated hydrocarbons and radionuclides at several sampling events. When a comparison is made between the points WFBB2 and upstream location WFBB3 (Fig. 4C.36), it appears that there is a net loss of radionuclides from WFBB3 to WFBB2 and a net gain of chlorinated hydrocarbons. Since Well 1225 has a high concentration of radionuclides and a low concentration of organics and Well 648 displays the opposite concentrations of contaminants, one can assume that the surface water, as it moves away from its radionuclide source near WFBB3 and toward a primarily organic source near Well 648, should show lower values of radionuclides and higher values of organics as the contamination originating from one source is diluted and the contamination from the other source begins to contribute.

Once the VOCs enter Drainage FB between WFBB3 and WFBB2, concentrations downstream decrease. This indicates that there does not appear to be any other VOC sources contaminating Drainage FB.

### 4C.2.4 Conclusions

- High levels of tritium and strontium-90 at concentrations exceeding the MCL are being transported via Drainage FB, most likely from the 49-Trench area, off the WAG 6 boundary.

- The 49-Trench area French Drain is a point source of both radionuclide and VOC contamination.

- Contamination exiting the WAG in Drainage FA is virtually all tritium.

- Cobalt-60 appears to be migrating from the northeast auger hole area in a southeasterly direction. Cobalt-60 appears to be confined to groundwater except in times of high groundwater conditions coupled with high flow conditions.

## 4C.3 SEDIMENTS

Thirty sediment samples were collected from drainages in WAG 6 and the EWB area during the RFI. These sample locations are shown in Figs. 4C.37 and 4C.38. The WAG samples were collected in mid-February 1990 and the EWB samples were collected in mid-February through early-March 1990. These samples were analyzed for volatile and semivolatile organics, metals and radionuclides. From these analyses an assessment of the nature and extent of sediment contamination is presented below. These results are grouped by drainages from which the samples were collected.

### 4C.3.1 Previous Investigations

The following paragraphs provide an overview of previous investigations conducted at WAG 6 which yielded sediment analytical data. The actual data and sampling locations are presented in Appendix 1B.

Cerling and Spalding (1981) completed a comprehensive assessment of cobalt-60, strontium-90, and cesium-137 concentrations in streambed gravel from contaminated drainages to White Oak Creek. This study included sampling locations in Drainages DA, DB and FB drainages in WAG 6 as locations along the unnamed tributary along the east side of WAG 6.

A study performed by Cerling and Huff (198) measured the cobalt-60, strontium-90, and cesium-137 concentrations in streambed gravel for major tributaries to White Oak Creek. Samples were collected during July and August 1985 from Drainage F, downstream from where Drainages FA and FB combine; Drainage D, downstream from where the DA and DB drainages combine; and in the unnamed tributary along the east side of WAG 6.

Sediment samples were collected by Huff (1986) from Drainages DA, DB, and F in WAG 6, from the unnamed tributary to the east of WAG 6, and from the marshy area near where the unnamed tributary enters White Oak Creek. These samples were analyzed for cobalt-60, strontium-90, and cesium-137. The samples from the unnamed tributary were collected from a location due east of the northeast auger holes.

The most extensive sediment sampling of the WAG 6 drainages for cobalt-60, cesium-37, and strontium-90 was performed by Miller, Black, and Craig (1989). Sampling was conducted in Drainages DA, DB, F, FA, and FB from October 1988 to April 1989.

Table 4C.7 lists WAG 6 sediment investigators, the locations sampled, and the dates the investigations occurred. Table 4C.8 presents the constituents that were analyzed for during each of the studies.

## 4C.3.2 Radiological Contamination

### 4C.3.2.1 Nature of contamination

Both naturally occurring and man-made radionuclides have been detected in sediment samples collected at WAG 6 (Table 4.7 in the main report). Naturally occurring radionuclides include potassium-40, radionuclides belonging to uranium series (uranium-228, thorium-234, uranium-234, thorium-230, radium-226) and the thorium series (thorium-232, radium-238, thorium-228, radium-224. No transuranic radionuclides were detected. Naturally occurring radionuclides were within background ranges and were analyzed to account for gross radiation concentrations. These radionuclides are not addressed in extent.

Man-made radionuclides detected in sediment samples include: tritium, cobalt-60, strontium-90, and cesium-137. Tritium was detected in 13 of 30 sediment samples. The highest level of tritium detected was 840 pCi/g occurring in Drainage FB just before it combines with Drainage FA. Cesium-137 was the most frequently detected radionuclide in WAG 6 sediment samples. Cesium-137 was detected at 22 of 30 locations sampled. Concentrations of cesium-137 in sediments ranged from 0.244 to 2.14 pCi/g. Cobalt-60 and strontium-90 were detected at three locations each. Cobalt-60 was analyzed for at all 30 locations. Strontium-90 was only analyzed for three times.

### 4C.3.2.2 Extent of contamination

Analytical results for radionuclides detected in the WAG 6 drainages and EWB are presented in Figs. 4C.37 and 4C.38.

**Drainage A and the Emergency Waste Basin.** Tritium was detected only in sediment samples EWB02, EWB05, and EWB08 from the EWB. The EWB is both fed and drained by Drainage A. The first two of these three samples were upgradient to EWB while the third sample was collected below the point where Drainage A is intercepted by EWB, as seen in Fig. 4C.37. Tritium concentrations ranged from 197 pCi/g in the first sample to 518 pCi/g and 453 pCi/G in the other two samples. Tritium was not detected in sample SWA1 collected from Drainage A. Cesium-137 was detected in 11 of the 15 samples collected from the EWB and from the one sample in Drainage A. In these samples cesium-137 was detected at concentrations levels ranging from just above the detection limit (0.2 pCi/g) to 4.57 pCi/g in sample EWB18 from the northeast side of EWB. There was no readily apparent pattern to the distribution of cesium-137 contamination in the EWB. Cobalt-60 was detected once at 0.0775 pCi/g in sample EWB05. While strontium-90 was detected at EWB14 (1.49 pCi/g) and SWA1 (0.79 pCi/g).

**Drainage B.** Tritium and cesium-137 were the only man-made radionuclides detected in the Drainage B. The concentration of tritium detected was at 153 pCi/g. Tritium was also detected in surface water samples (2700 to 30,000 pCi/L).

**Drainage C.** Analysis of sediment sample SWC1 collected from Drainage C near the edge of WAG 6 detected tritium at 71 pCi/g, cesium-137 at 2.14 pCi/g, and cobalt-60 at

53.3 Ci/g. This is the highest concentration of cobalt-60 detected in sediment samples during the RFI. Tritium and cobalt-60 were also detected in the only surface water sample collected from Drainage C. As stated in Sect. 4.4.2.2, the most likely source for this contamination is the northeast auger hole area. Miller, Black, and Craig (1989) collected one sediment sample from the unnamed tributary just north of Drainage C. Cobalt-60 was detected in their analysis. Cerling and Spalding (1981) also found high levels of cobalt-60 in the same area.

**Drainage DA .** Cesium-137 was the only man-made radionuclide detected in the sediment sample W49TS, collected from the southern end of the 49-Trench area French Drain. It is unusual that no tritium was detected in this sample because the surface water samples collected from this location showed the highest tritium levels (up to 14,000,000 pCi/L) found on WAG 6. However, in sediment sample WDA1 collected near the flume on Drainage DA, downgradient from the 49-Trench area, tritium was detected at 414 pCi/g and cesium-137 was detected at 1.12 pCi/g. Miller, Black, and Craig (1989) detected cesium-137 and cobalt-60 near the WDA1 sampling location but did not analyze for tritium in sediment samples.

**Drainage DB.** The analysis of sediment sample WDB2 from Drainage DB detected tritium at 66.7 pCi/g and cesium-137 at 0.297 pCi/g, just above the detection limits. Surface water samples also indicated tritium levels in this drainage to be only slightly higher compared to other locations in WAG 6. Miller, Black, and Craig (1989) detected higher concentrations of strontium-0 and cesium-137 in this drainage than detected during the RFI and also detected cobalt-60.

**Drainage FA.** Four sediment samples were collected along Drainage FA including WBAB2, WBAB1, WBAA1, and WFBA1. These samples were collected in the order listed from the upper reach of Drainage FA to the point where Drainage FA combines with Drainage FB near the southern boundary of WAG 6.

Tritium was detected in sediment sample WBAB2, at 312 pCi/g and at 78.8 pCi/g in sample WFBA1. However, it was not detected in downstream samples WBAB1 and WBAA1. Cesium-137 was detected in samples WBAB1 and WBAA1 at 0.368 pCi/g and 0.748 pCi/g, respectively, but was not detected in upstream sample WBAB2 or downstream sample WFBA1. Cesium-137 was also detected near WFBA1 by Miller, Black, and Craig (1989). However, the highest level detected was low at 0.3 pCi/g.

**Drainage FB.** Four sediment samples were collected along Drainage FB. These samples, WFBB3, WFBB2, WSP1, and WFBB1, were collected in the order listed from the upper reach of Drainage FB, near the northern boundary of WAG 6, to the lower end of Drainage FB, near the southern boundary of WAG 6.

Tritium levels in upstream samples WFBB3 and WFBB2 were 70.6 pCi/g and below detection, respectively. However, in samples WSP1 and WFBB1 from the lower portion of drainage FB, tritium was detected at 551 pCi/g and 840 pCi/g, respectively. This trend of decreasing tritium levels from WFBB3 to WFBB2 and increasing levels from WFBB2 to WFBB3 is consistent with the same trend observed in surface water samples.

Cesium-137 was detected at 1.13 pCi/g in sample WFBB2, at 0.652 pCi/g in sample WSP1, and at 0.46 pCi/g in sample WFBB1, but was below detection in sample WFBB3 from the upper reach of Drainage FB.

Sample WFBB3 indicated a gross beta concentration of 508 pCi/g. The Field Operation Facility (FOF) confirmed a high gross beta count on this sample. Strontium-90 was not analyzed on this sample; however WFBB3 is located downgradient from the high-activity trench area which is believed to be leaching strontium-90. Relatively high levels of strontium-90 were detected in surface water samples collected at WFBB3. Miller, et al. (1989) detected high levels of strontium-90 entering Drainage FB in this area.

### 4C.3.3 Chemical Contamination

#### 4C.3.3.1 Nature of contamination

The most frequently detected VOCs in sediment samples collected from WAG 6 are trichloroethene, chloroform, and toluene. Table 4.3 in the main report lists VOCs detected in sediments. All other VOCs, except for the three previously mentioned, were detected in 20 or fewer samples. No occurrence exceeded any "action levels." The highest detected concentrations for trichloroethene, chloroform, and toluene were 17 $\mu$g/kg, 64 $\mu$g/kg, and 5 $\mu$g/kg, respectively.

Semivolatile organics from the target compound list were detected in very few sediment samples with the exception of bis(2-ethylhexyl) phthalate. This SVOC a common laboratory contaminant and is not believed to be associated with contaminants found at WAG 6. Table 4.3 in the main report lists the semivolatiles found in sediment samples. Due to the low number of semivolatiles found in sediment samples, it is apparent that they are not a problem and do not merit further discussion.

Reference samples for sediments and soils were combined to establish a statistically appropriate range for metals concentrations in sediment samples. When sediment sampling results were compared to this range, no sample indicated any metal concentrations significantly above reference levels.

#### 4C.3.3.2 Extent of contamination

Because of the lack of diversity in VOCs detected in WAG 6 sediments, the discussion of extent will not proceed by drainage systems as in previous sections Instead, a general WAG-wide overview will be presented. Figures 4C.39 and 4C.40 illustrate VOC occurrence in sediment at WAG 6.

In nearly all drainages, either trichloroethene, chloroform, or toluene were detected. Combinations of the three were also very common. Only in Drainage B, in the northeast section of the WAG 6, were no VOCs detected. Sediment samples from drainages on the eastern side of WAG 6 did not contain any other VOCs than trichloroethene, chloroform, or toluene, except for a single occurrence of xylenes (2 $\mu$g/kg) detected in Drainage DA.

Highest concentration for any VOC did not exceed 17 $\mu$g/kg which is approximately four orders of magnitude below any action limits.

Sediment samples from drainages on the west side of WAG 6 have had the same VOCs detected as the east side with the addition of tetrachloroethene, propylene dichloride, 1,2-dichloroethene, ethylbenzene, and methyl bromide. Except for methyl bromide, these additional VOCs have been detected in sediments adjacent to the 49-Trench area. Samples of other media (groundwater and surface water) from the same area have had VOCs detected, strongly implicating this region as a VOC source.

Sediment samples from the EWB have had toluene and chloroform detected; however, trichloroethene was detected in one sample only. Acetone was also detected in sediment samples in concentrations not exceeding 11 $\mu$g/kg. Although acetone was not detected in associated laboratory blanks with analyses of the sediment samples, acetone is a common laboratory contaminant and occurrence of low concentrations should be considered tenuous.

## 4C.4 SOIL

The objectives of the WAG 6 RFI soils investigation were: (1) to identify areas of gross soil contamination that might represent potential secondary source areas, (2) to aid in location of areas of contaminant release, and (3) to provide geological and soil engineering data to aid in understanding site physical characteristics. The scope of this investigation is described in greater detail in Sect. 2.7. Secondary source areas are characterized by areas having contaminants in sufficient quantity and concentration to act as a source reservoir for contaminant migration. The presence of a secondary source may require the extension of a cap or other remedial action targeted for the trenches.

Boring locations for collection of soil samples were chosen along the perimeter of disposal areas to define the extent of the secondary sources. As illustrated in Fig. 4C.41, soil borings were generally arranged around the perimeter of the major waste disposal areas, and were frequently within 10 to 15 ft of waste disposal trenches. These areas are the 19-Trench area and the EWB, the central waste disposal area, the western waste disposal area, the southwestern region of WAG 6, the southern waste disposal area, and the eastern waste disposal area as shown in Fig. 4C.41 and listed on Table 4C.9. The Tumulus area is presented as a separate area. No soil investigations were conducted under the RFI for the Tumulus area; however, previous investigations have characterized this site and are discussed below.

Soil samples were collected from 63 soil borings completed to auger refusal as part of the WAG 6 RFI effort between December 1988 and March 1990. The locations of the borings are shown on Fig. 4C.41. Borings were drilled to auger refusal (typically the top of bedrock) from which one to three samples were usually collected for analysis. Field screening in addition to RFI close support laboratory (CSL) screening resulted in some samples from some borings which required no further analysis due to a lack of identifiable contamination. Soil samples were also collected at off-site locations and analyzed to develop background data. The results of these analyses are presented in Technical Memorandum

06-15. The details of the methods and procedures for radionuclide analysis of soil samples and detailed soil boring logs are presented in WAG 6 RFI Technical Memorandum 06-12. The results of the investigation for radiological and chemical contamination are discussed below for each area and presented in Figs. 4C.41 through 4C.47.

### 4C.4.1 Previous Investigations

The following paragraphs provide an overview of previous investigations conducted at WAG 6 which yielded soil sample analytical data. Principal sources of analytical data from previous investigations are reported in Davis et al.(1989) and Yager and Craig (1989). Table 4C.10 summarizes the scope and timing of these soil investigations and the analytes of concern.

As part of the site characterization investigation of the TARA area in the extreme northeastern part of WAG 6, Davis et al. (1989) collected soil samples from 22 soil borings around the waste disposal trenches. Soil samples were collected from the soil borings every 18 in. to a total depth of 15 ft. Soil samples were also collected from the bottom of trenches at 15 locations. All soil samples were analyzed for radionuclides. Selected samples were also analyzed for volatile organic compounds.

Yager and Craig (1989) presented quarterly analytical data for soils collected as part of the environmental monitoring for the Tumulus Demonstration Project. Soil samples were collected from the uppermost 7 to 10 in. of soil at 11 sampling locations around the Tumulus pad between February 1987 and July 1988 and analyzed for radionuclides. These soil samples were collected and analyzed to evaluate the potential spread of contaminants as a result of the Tumulus project.

### 4C.4.2 Radiological Contamination

#### 4C.4.2.1 Nature

Table 4.7 in the main report lists the radionuclides that were detected during RFI sampling at WAG 6. Both naturally occurring and man-made radionuclides were detected. Naturally occurring radionuclides were detected within concentration ranges detected in reference samples and are therefore not discussed further. No transuranic radionuclides were detected. Man-made radionuclides that were detected include cobalt-60 and strontium-90. These occurrences are discussed below.

#### 4C.4.2.2 Extent

Because man-made radionuclides were detected in only a few soil samples, an area-by-area discussion, as presented for other media, will not be presented here. Instead, the discussion will focus directly on the occurrence of the specific man-made radionuclide.

**Strontium-90.** Strontium-90 was detected at concentrations exceeding background at the locations: (1) SB07 located north of the EWB (Fig. 4C.42); (2) SCA19 located west of

the solvent auger hole area of the central waste disposal area (Fig. 4C.43); and (3) location 1243 located east of the biological trenches of the eastern disposal area (Fig. 4C.46). Maximum detected concentration above backgrounds was 8.54 pCi/g at SB07.

A region of suspected radiological contamination was identified during a surface radiological investigation conducted in the vicinity of the EWB during December 1989 (Technical Memorandum No. 06-04A). Soil sample SB07 was collected and the 2 to 4 ft interval was analyzed. Only strontium-90 was detected at above reference concentrations. This concentration (8.54 pCi/g) is below Heast ingestion limits (Table 4.7 in the main report).

At location 1243 (Figure 4.49), strontium-90 was detected at 6.22 pCi/g is the 0 to 2 ft interval. Soil samples to the west and south (SCCO5 and 1234, respectively) did not have strontium-90 detected. Strontium-90 was also detected in the 20 to 22 ft interval from location SCA19 (Figure 4.46). The concentration of detection (1.10 pCi/g) is slightly higher than the maximum detected reference concentration of 0.8pCi/g.

**Cobalt-60.** Cobalt-60 has been detected in the soil borings: 1) SCA17 located west of the low-activity trenches of the central waste disposal area; 2) SCC4 located at the high-activity auger holes of the east disposal area; and 3) SCC9 located west of the low activity trenches of the east waste disposal area.

The concentration of cobalt-60 at SCA17, from the 6 to 12 ft interval, is low (0.06 pCi/g) and barely above detectable concentrations. Other media sampled in the area did not have cobalt-60 detected. In contrast, as a sample from the 12 to 18 ft interval of SCC4 at the east waste disposal area had cobalt-60 detected at 7.96 pCi/g. Cobalt-60 has been detected in both groundwater and surface water and sediments in the area. Soil sample location SCC9, located southwest of SCC4 also had cobalt-60 detected in a sample from the 0 to 6 ft interval. Cobalt-60 has not been detected in other media from this area; however, groundwater samples from Well 845 (Figure 4.29) contained strontium-90.

Yager and Craig (1989) report low levels of cesium-137 (up to 0.4 pCi/g), cobalt-60 (up to 0.08 pCi/g), gross alpha (up to 37 pCi/g), and gross beta (up to 46 pCi/g) in shallow soils (0 to 6 in.) in the vicinity of the Tumulus Pad. Yager and Craig further report that the concentration of radionuclides in shallow surficial soils in the Tumulus Pad area are comparable to other soils within SWSA 6. The results indicate no difference between pre-operational and operational periods for the Tumulus I facility; data show a great deal of random variation with no discernible trends or patterns in radionuclide concentration.

### 4C.4.3 Chemical Contamination

#### 4C.4.3.1 Nature of contamination

Analyses were performed on soil samples for VOCs, SVOCs, and metals. Table 4.3 in the main report lists the chemicals detected in soil samples.

**Volatile organic compounds.** VOCs detected include acetone, toluene, 2-butanone, and methylene chloride which are common laboratory contaminants. While acetone and toluene have been detected in trench leachate samples and in groundwater samples from wells adjacent to biological trenches, the nearly -ubiquitous detection of these two VOCs in soil samples is very suspect except where they have been detected in other media within the vicinity.

Methylene chloride and 2-butanone must also be considered suspect in WAG 6 soils primarily because they have been detected frequently and in no obvious correlation with releases detected in other media and because they are commonly induced contaminants.

Various SVOCs were also detected among which bis (2-ethyehexyl) phthalate is the most common. Its detection should also be considered suspect because it is widely distributed vertically and laterally in WAG 6 soils, and is a common laboratory contaminant.

**Metals.** Metals that have been detected in WAG 6 soils are listed in Table 4.5 in the main report. Concentrations vary, in some instances, by orders of magnitude for both on-site and reference soil samples. Variations both vertically and laterally must also be considered in evaluating metals due to different soil types developed in various strata at WAG 6. Taking into account both these considerations and also the analytical procedure used (which can produce anomalous results), the metals that have been detected at WAG 6 that are discussed in detail include arsenic, cobalt, lead, and mercury.

### 4C.4.3.2 Extent of contamination

**Emergency Waste Basin and 19-Trench area.** Relatively low levels of VOCS and SVOCs were detected in soil samples collected from the EWB and the 19-Trench area (Fig. 4C.42). Other media sampled in the area indicate comparable levels of organics. VOC concentrations did not exceed action levels. Lead was detected at an estimated concentration of 125 $\mu$g/kg at soil sample location 1241. This occurrence should be considered suspect due to laboratory quality control problems encountered during the analysis.

**Central waste disposal area - northern region.** This area includes the high-activity trench area and the solvent auger hole area to the south. VOCs and some SVOCs have been detected in soil samples at relatively higher concentrations than other waste areas. Soil samples collected from the east and west sides of the high-activity, low-activity trenches (SCA20 and SCA02) contained greater concentrations of VOCs and SVOCs than soil samples to the north and south. The relatively high levels of VOCs detected in boring location SCA20 is consistent with concentrations detected in groundwater in Well 1225 (Fig. 4C.22) which supports the contention that the high-activity trench area is source of organic contamination. Soil samples from boring location SCA02, located in the east side of the high-activity trenches and adjacent to low-activity trenches, contained a greater diversity of VOCs than boring location SCA20. Acetone, common to samples from both borings, was detected in SCA02 at concentrations generally an order of magnitude less than SCA20. Ethylbenzene, trichloroethene, and 1,2-dichloroethene were detected in SCA02 and not in SCA20, suggesting an additional source. Groundwater sampling in Well 847 (Figure 4C.22)

located near boring SCA02, resulted in no VOCs being detected. This well is screened in the bedrock, however, and not across the water table where VOCs are more likely to be detected if present.

Samples from other borings indicate lower levels of VOCs than detected in SCA20 and SCA02. Concentrations did not exceed action levels presented in proposed RCRA subpart S concentration criteria.

**Central disposal area - southern region.** Analysis of soil samples from borings in this area indicate VOCs present; however, concentrations are relatively low and do not exceed action levels presented in proposed RCRA subpart S concentration criteria.

Higher concentrations of VOCs in this region have been detected at the western boundary of the low-activity trenches (Figure 4C.44). VOCs were also detected in groundwater samples along the western boundary surface water samples from Drainage FB.

The highest concentration of arsenic was detected in a sample from location SCA17. Detected at 195 $\mu$g/kg, this concentration exceeds the next highest concentration by an order of magnitude and also exceeds the proposed RCRA subpart S (80 $\mu$g/kg) concentration criteria. In addition to arsenic, lead and cobalt were detected at the highest concentrations observed at WAG 6 (200 and 120 $\mu$g/kg, respectively) at soil sample location SCA12. Both of these concentrations are estimated and their presence at these levels. The sample should be considered suspect due to laboratory quality control problems encountered during their analysis.

**Western waste disposal area.** VOCs have been detected in soil samples from borings from the northern and southern sections of the west waste disposal area (Fig. 4C.45). Groundwater and surface water samples in the western waste disposal area have also had VOCs detected (Figs. 4C.22 and 4C.35, respectively). Ethylbenzene and acetone have been detected most frequently. Concentrations of other VOCs are frequently below the detection limit and estimated values. The SVOC, naphthalene, has also been detected in groundwater samples from wells located at the biological trenches.

VOCs and SVOCs detected in samples from borings SDMS1 and 1236, located in the southwestern part of WAG 6 (Figure 4C.45) are anomalous. No waste disposal activities have been conducted in the area of WAG 6. Trichloroethene, detected in samples throughout boring 1236 (down to 48 ft) suggests a localized problem possible associated with the sample collection. Trichloroethene has not been commonly detected in soil samples closer to known waste disposal areas although groundwater samples had trichloroethene detected. The VOC 1,1,1,-tetrachloroethane, detected in soil sample SDMS1 has not been detected elsewhere at the site in any other media. The occurrences of acetone, toluene, and xylenes are also anomalous because SDMS1 is located in an area not known to have received organic wastes.

**East waste disposal area.** Soil samples collected from borings adjacent to the east waste disposal area have had VOCs detected in them (Fig. 4C.46). Acetone is the most

widely distributed. Concentrations are below proposed RCRA subpart S concentration criteria for all detected compounds.

Soil samples from boring SCC03, located southeast of a solvent auger hole area in the northern section of the waste disposal area, has had a greater diversity of VOCs detected in it than other borings at this disposal area. Concentrations do not exceed 65 $\mu$g/L for any compound detected, however. Groundwater samples from wells located to the east (Fig. 4C.22) of the solvent auger hole area have also had VOCs detected.

**South waste disposal area.** Soil samples collected from borings adjacent to the south waste disposal area have had VOCs detected in relatively low concentrations and diversity compared with other borings at the site. Acetone is the most widely distributed VOC detected. Concentrations of all VOCs detected did not exceed proposed RCRA subpart S concentration criteria. Mercury was detected at the highest concentration on-site (200 $\mu$g/kg) at soil sample location 1235, located northeast of the south waste disposal area. The next highest concentration detected on-site was 0.7 $\mu$g/kg. The proposed RCRA subpart S concentration criteria for mercury (20 $\mu$g/kg) was exceeded by an order of magnitude. Laboratory quality control protocols appear to have been in order during the analysis. The occurrence of mercury at location 1235 is anomalous because of its distance from any identified disposal area.

### 4C.4.4 Summary

Contaminant concentrations vary considerably from one soil horizon to another and from one location to another. Results indicate that maximum concentrations typically occur at depths in the range of 12 to 20 ft. This is to be expected since the waste is buried to a similar depth.

The contaminant concentrations also indicate that secondary sources were not present at the sampled locations. This limits source areas to the trenches and soils immediately adjacent to the trenches bounded by the borings.

# Appendix 4C Tables

**Table 4C.1. Summary of WAG 6 groundwater sampling by previous investigations**

| Source | Wells | Dates sampled |
|---|---|---|
| Yager & Craig 1989 | 1035-1040 | 6/87, 8/87, 12/87, 3/88, 6/88, 9/88, 1/89 |
| Solomon 1988 | 741 | 5/88 |
| Poreda, Cerling, and Solomon 1988 | 108, 109, 345, 347, 370, 371, 373, 374, 382, 383, 386, | 9/86 |
| | 381, 388 | 3,86/9/86 |
| Sherwood & Borders 1987 | 739 | |
| Vaughan et. al. 1982 | ETF-1 through ETF-12 | 4/81, 8/81 |
| | T-1, T-5, T-7, T-17, T-18, T-20 | |
| Solomon et al. 1988 | 647 | 7/86 |
| | 648 | 1/87 |
| | 649, 650 | 3/87 |
| | 511 | 3/86 |
| Doyle and Taylor 1986 | 279, 382, 371, 272, 380, 305 | |
| Morrissey 1990 | T1, T7, T10, T17, T18, T20, T22, T36 | 10/89 |
| Boegly 1984 | 109, 284, 296, 356, 370, 372, 381 | 8/83 |
| | 313 | 8/83, 12/83 |
| | 318 | 3/82 |
| | 345, 388 | 8/83, 12/83, 6/84 |
| | 355 | 12/83, 3/84, 6/84 |
| | 376 | 6/84 |
| | 382 | 12/83, 6/84 |
| Ashwood and Spalding 1990 | 1036, 1039 | 6/87, 8/87, 12/87, 3,88, 6/88, 9,88 1/89, 3/89, 6,89/,9/89, 9/89, 12,89, 5/90 |
| Huff a & b 1988 | T-1, T-5, T-7, T-017, T-18, T-20 | 10/88 |
| Davis et al. 1989 | T-A-R-A-1 through TARA-13, 367, 646 | 4/87, 11/87, 6/88, 8/88 |
| Dreier & Toran 1989 | 27, 36, 41, 42, 123, 127, 129 135, 137, 139, 145, 150, 152, 153, 156, 160, 161, 163, 166, 168, 171, 173, 177, 177A, 279, 317 | Spring 1976 |
| Wickliff, Morrissey, and Ashwood 1990 | 4, 5, 6, 7, 8, 11, 12, 13 | 2/90 |
| Ashwood 1991 | 8, 11, 15, 19, 25, 27, 28, 30, 32, 35, 38, 40, 42, 43, C520, C595, FISI, FIS, AUG4 | 12/90 |
| Wickliff, Morrissey, and Ashwood 1991 | 4, 5, 6, 8, 9, 10, 11, 12, 15, 18, 19A, 198, 20, 22, 23, 24, 25, 26, 27 28, 30, 32, 36, 38, 39, 40, 41, 42 43, 44, 45, 46 | 2/91 |
| Davis et al. 1987 | 49-Trench Area French Drain | 9/83, 2/84, 4/84, 5/85, 10/85, 1/86, 3/86, 10/86 |

**Table 4C.2. Summary of WAG 6 groundwater analysis previous investigations**

| Source | Wells | Tritium | Gross Alpha | Gross Beta | Gross Gamma | Cs-137 | Sr-90 | Co-60 | C-14 | Tc-99 | Total Radium | VOC | BNA | Metals | Cations/ Anions | TOC/ TOX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yager & Craig 1989 | 1035-1040 | X | X | X | | X | | X | | | | X | X | X | X | XX |
| Solomon 1988 | 741 | X | | | | | | | | | | | | | | |
| Poreda et al. 1988 | 108, 109, 345, 347, 370, 371, 373, 374, 381, 382, 383, 386, 388 | X | | | | | | | | | | | | | | |
| Sherwood & Borders 1987 | 739 | X | X | X | | X | X | X | | | | | | X | X | |
| Vaughn et al. 1989 | ETF-1 through ETF-12 | X | X | | | X | X | X | | | | | | | | |
| Solomon et al. 1988 | 647-650, 511 | X | X | X | X | X | | X | X | X | X | X | X | | | |
| Taylor & Doyle 1986 | 279, 382, 371, 272, 380, 305 | X | | | | X | X | X | | | | | | | | |
| Morrisey 1990 | T1, T7, T10, T17, T18, T20, T22, T36 | X | X | X | | X | X | X | | | | | | | | |
| Boegly 1984 | 104, 284, 296, 313, 318, 345, 355, 356, 370, 372, 376, 381, 382, 388 | X | X | | | X | X | X | | | | | | X | | |
| | ETF-1 through ETF-12 | | | | | | | | | | | | | | | |
| Ashwood, et al. 1990 | 1036, 1039 | X | | | | | | | | | | | | | | |
| Huff a & b 1988 | T-1, T-5, T-7, T-17, T-18, T-20 | X | | | X | X | | | | | | | | | | |
| Davis et al. 1989 | TARA-1 through TARA-13 367, 646 | X | X | X | | | | | | | | | | | | |
| Drier and Toran 1989 | HHMS-4A, 4B, 4C, 5A, 5B, 5C, 6A, 6B, 6C, 7A, 7B, 7C, 8A, 8B, 8C | X | X | X | | X | X | X | | | | | | | | |

**Table 4C.2. (continued)**

| Source | Wells | Tritium | Gross Alpha | Gross Beta | Gross Gamma | Cs-137 | Sr-90 | Co-60 | C-14 | Tc-99 | Total Radium | VOC | BNA | Metals | Cations/ Anions | TOC/ TOX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tamura et al. 1980 | 27, 36, 41, 42, 123, 127, 129, 135, 137, 139, 145, 150, 152, 153, 156, 160, 161, 163, 166, 168, 171, 173, 177, 177A, 179, 317 | | | | | X | X | X | | | | | | | | |
| Wickliff et al. 1990 | 4, 5, 6, 7, 8, 11, 12, 13 | | X | X | | X | | X | | | | | | | | |
| Ashwood 1991 | 8, 11, 15, 19, 25, 27, 28, 30, 32, 35, 38, 40, 42, 43, C520, C595, FIS1, FIS2, AUG4 | | X | X | | X | | X | | | | | | | | |
| Wickliff 1991 | 4, 5, 6, 8, 9, 10, 11, 12, 15, 18, 19A, 19B, 20, 22, 23, 24, 25, 26, 27, 28, 30, 32, 36, 38, 39, 40, 41, 42, 43, 44, 45, 46 | | X | X | | X | X | | | | | | | | | |
| Davis et al. 1987 | 49-Trench Area French Drain | X | X | | | X | X | X | | | | | | | | |

Table 4C.3. Maximum summed VOC concentration (μg/L) in groundwater samples from WAG 6

| Well no. | Sum | Well no. | Sum |
|---|---|---|---|
| 745 | 0 | 856 | 4 |
| 831 | 3 | 857 | 0 |
| 832 | 0 | 858 | 0 |
| 833 | 1 | 859 | 18 |
| 835 | 167 | 860 | 0 |
| 836 | 11 | 1225 | 133 |
| 837 | 0 | 1226 | 0 (dry) |
| 838 | 15 | 1227 | 0 |
| 839 | 6 | 1228 | 294 |
| 840 | 3 | 1229 | 4 |
| 841 | 54 | 1230 | 0 (dry) |
| 842 | 808.5 | 1231 | 76 |
| 843 | 20.9 | 1232 | 0 (dry) |
| 844 | 14 | 1233 | 8326 |
| 845 | 10 | - | - |
| 846 | 2 | 1235 | 0 (dry) |
| 847 | 0 | 1236 | 0 |
| 848 | 59.7 | 1237 | 22 |
| 849 | 1661 | 1238 | 0 |
| 850 | 6778 | 1239 | 0 |
| 851 | 168 | 1240 | 0 |
| 852 | 393 | 1241 | 0 |
| 853 | 25 | 1242 | 0 |
| 854 | 20 | 1243 | 0 |
| 855 | 5 | 1244 | 3 |
| | | 1249 | 0 |

**Table 4C.4. Herbicides detected in groundwater at WAG 6**

| Well number | Herbicides (μg/L) 2,4,5-TP | 2,4,5-TP | 2,4-D |
|---|---|---|---|
| 745 | | | 2 |
| 831 | 2 | | 2 |
| 833 | | | 12 |
| 835 | 0.3 | | 0.8 |
| 836 | | | 0.6 |
| 838 | | | 2 |
| 839 | | 0.3 | 1 |
| 841 | 0.3 | | 0.8 |
| 842 | | | 1 |
| 843 | | | 0.4 |
| 844 | | | 4 |
| 855 | | | 0.3 |
| 856 | | | 2 |
| 857 | 0.2 | | 0.3 |
| 858 | | | 2 |
| 860 | | | 9 |

**Table 4C.5. Surface water sampling events**

| Date | Ground water table | Flow conditions | ICM cap status |
|---|---|---|---|
| 2/8-9/89 | High | Base | Under Construction |
| 4/18-21/89 | High | Base | Complete |
| 5/9/89 | High | Storm | Complete |
| 6/9/89 | High | Storm | Complete |
| 9/5-6/89 | Low | Base | Complete |
| 9/26-27/89 | Low | Storm | Complete |

**Table 4C.6. Summary of historical surface water analysis**

| Data source | Sample locations | Gross alpha | Gross beta | Cobalt-60 | Cesium-137 | Strontium-90 | Tritium |
|---|---|---|---|---|---|---|---|
| Davis et al. 1987 | MS-1, MS-2, MS-3, MS-4 | | | | | | X |
| Boegly 1984 | ETF Flume II | X | | X | X | X | X |
| Davis and Marshall 1988 | Stream FB SR-90 seep | X | | X | X | X | X |
| Miller et al. 1989 | 102, 103, 104, 201, 303, 305, 306, 301, 302, 308, 322, 304, 321 | X | X | X | X | X | X |

**Table 4C.7. Summary of WAG 6 sediment sampling by previous investigations**

| Source | Site/Sample | Dates Sampled |
|---|---|---|
| Cerling and Huff 1985 | 15, 16, 17 | 7/85, 8/85 |
| Cerling and Spalding 1981 | 234, 235, 236, 237, 238, 239, 240, 241, 242 | 10/78 |
| | 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361 | 11/78 |
| Huff 1986 | 6, 7, 34, 35, 36, 37 | 1978, 1985 |
| Miller, Black, and Craig 1989 | PRE-1-C-101, PRE-1-F-102, PRE-1-C-102, PRE-1-C-103, PRE-1-C-104, PRE-1-F-201, PRE-1-C-202, PRE-1-C-301, PRE-1-C-302, PRE-1-F-303, PRE-1-C-303, PRE-1-C-304, PRE-1-C-305, PRE-1-C-306, PRE-1-C-307, PRE-1-C-308, PRE-1-C-309, PRE-1-C-310, PRE-1-C-321, PRE-1-C-403 | 10/88 |
| | DUR-1-C-101, DUR-1-F-102, DUR-1-C-102, DUR-1-C-103, DUR-1-C-104, DUR-1-F-201, DUR-1-C-201, DUR-1-C-202, DUR-1-C-301, DUR-1-C-302, DUR-1-F-303, DUR-1-C-303, DUR-1-C-304, DUR-1-C-305, DUR-1-C-306, DUR-1-C-307, DUR-1-C-308, DUR-1-C-309, DUR-1-C-310, DUR-1-C-321 | 1/89 |
| | DUR-2-C-101, DUR-2-F-102, DUR-2-C-102, DUR-2-C-103, DUR-2-C-104, DUR-2-F-201, DUR-2-C-201, DUR-2-C-202, DUR-2-C-301, DUR-2-C-302, DUR-2-F-303, DUR-2-C-303, DUR-2-C-304, DUR-2-C-305, DUR-2-C-306, DUR-2-C-307, DUR-2-C-308, DUR-2-C-309, DUR-2-C-310, DUR-2-C-321 | 3/89 |
| | DUR-3-C-101, DUR-3-C-104, DUR-3-C-201, DUR-3-F-201, DUR-3-C-202, DUR-3-C-301, DUR-3-C-302, DUR-3-F-303, DUR-3-C-303, DUR-3-C-304, DUR-3-C-305, DUR-3-C-306, DUR-3-C-307, DUR-3-C-308, DUR-3-C-309, DUR-3-C-310 | 4/89 |
| | POS-1-C-101, POS-1-C-104, POS-1-F-201, POS-1-C-201, POS-1-C-202, POS-1-C-301, POS-1-C-302, POS-1-F-303, POS-1-C-303, POS-1-C-304, POS-1-C-305, POS-1-C-306, POS-1-C-307, POS-1-C-308, POS-1-C-309, POS-1-C-310, POS-1-C-321 | 6/89 |

**Table 4C.8. Summary of WAG 6 sediment sampling analyses by previous investigations**

| | Co-60 | Cs-137 | Sr-90 | Gross beta | Gross alpha | Zn |
|---|---|---|---|---|---|---|
| Cerling and Huff 1985 | X | X | X | | | X |
| Cerling and Spalding 1981 | X | X | X | | | |
| Huff 1986 | X | X | X | | | |
| Miller, Black, and Craig 1989 | X | X | X | X | X | X |

**Table 4C.9. WAG 6 soils investigation areas**

| Area | Soil borings included | Waste areas included |
|---|---|---|
| 1 | SCB-02 through SCB-07, SB-07, 1240, 1241 | Emergency Waste Basin, 19-Trench area |
| 2 | SCA-01 through SCA-06, SCA-08 through SCA-20 | Central Waste Disposal area, Low activity Silo area 1, 49-Trench area, High activity silo area, high activity trench area |
| 3 | SCE-01 through SCE-11, 1234, 1242, 1243 | East Waste Disposal area, Solvent Auger Hole area |
| 4 | SCD-01 through SCD-09, 1235 | South Waste Disposal area |
| 5 | SDMS-01, 1236 | Hillcut Slope Test Facility |
| 6 | SCE-01 through SCE-11, 1237, 1239 | West Waste Disposal area |
| 7 | Yager and Craig (1989) soil borings | Tumulus Pad area |

**Table 4C.10. Summary of WAG 6 soil sampling and analysis previous investigations**

| Source | Sample Location | Dates Sampled | Gross alpha | Gross beta | K-40 | Cs-137 | Co-60 | Sr-90 | VOC |
|---|---|---|---|---|---|---|---|---|---|
| Davis et al. 1989 | 1 through 22, 2A, 2B, 2C, 3A, 3B, 3C, 4A, 4B, 4C, 5A, 5B, 5C, 6A, 6B, 6C | 2/29/88 - 4/18/88 | | | | X | X | X | X |
| Yager and Craig 1989 | 3 | 2/87, 12/87, 3/88, 7/88, 9/88, 1/89 | X | X | X | X | X | X | X |
| | 4 | 2/87, 9/87, 12/87, 3/88, 7/88, 9/88, 1/89 | | | | | | | |
| | 5 | 9/87, 3/88, 7/88, 9/88, 1/89 | | | | | | | |
| | 6 | 9/87, 3/88, 7/88, 9/88, 1/89 | | | | | | | |
| | 7 | 1/89 | | | | | | | |
| | 9 | 9/87, 12/87, 3/88, 9/88, 1/89 | | | | | | | |
| | 12C | 2/87, 9/87, 12/87 | | | | | | | |
| | 56C | 2/87, 12/87 | | | | | | | |
| | 78C | 12/87, 3/88, 7/88, 9/88 | | | | | | | |
| | 1011C | 3/88, 7/88, 9/88, 1/89 | | | | | | | |

# Appendix 4C Figures

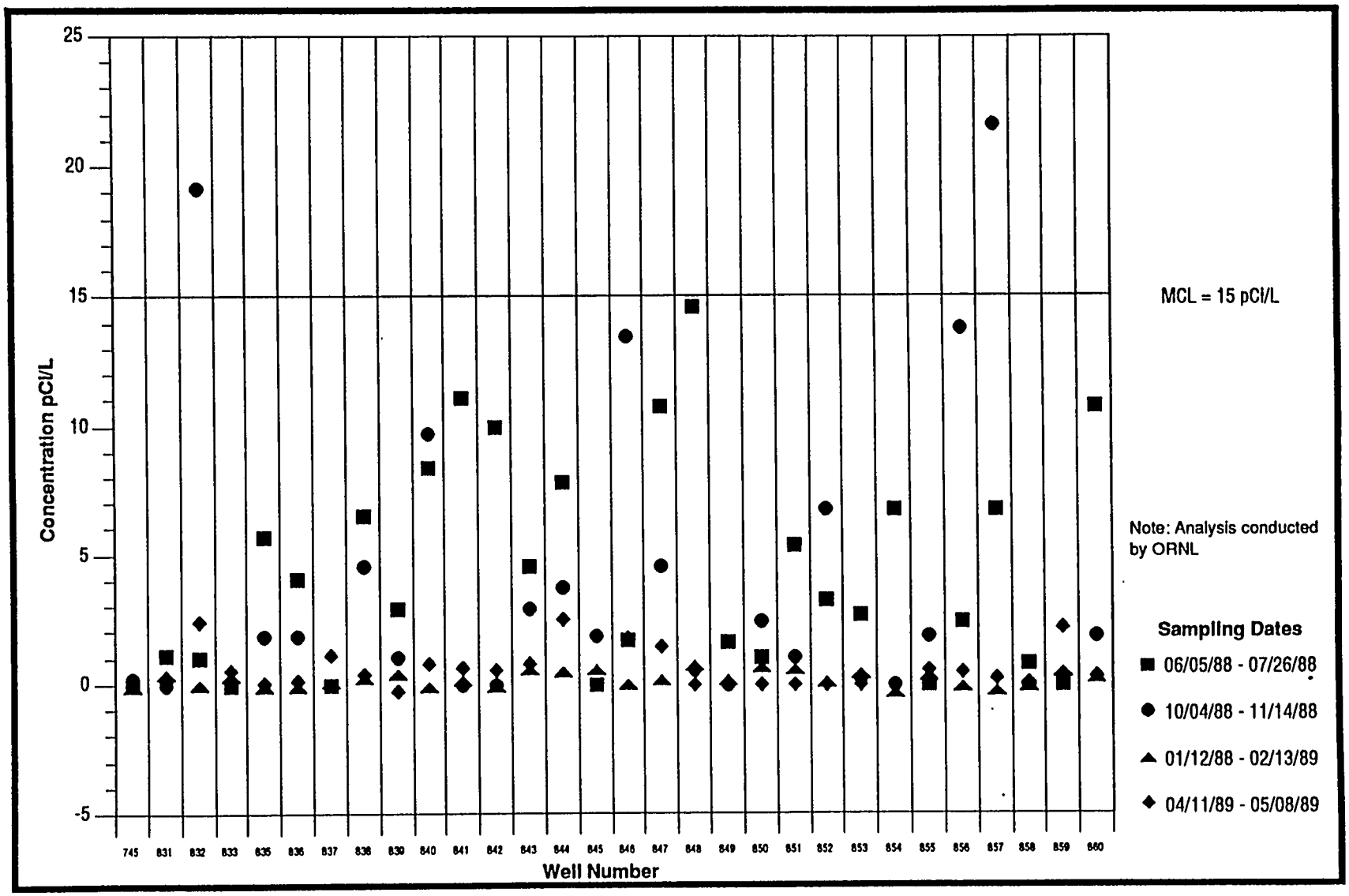
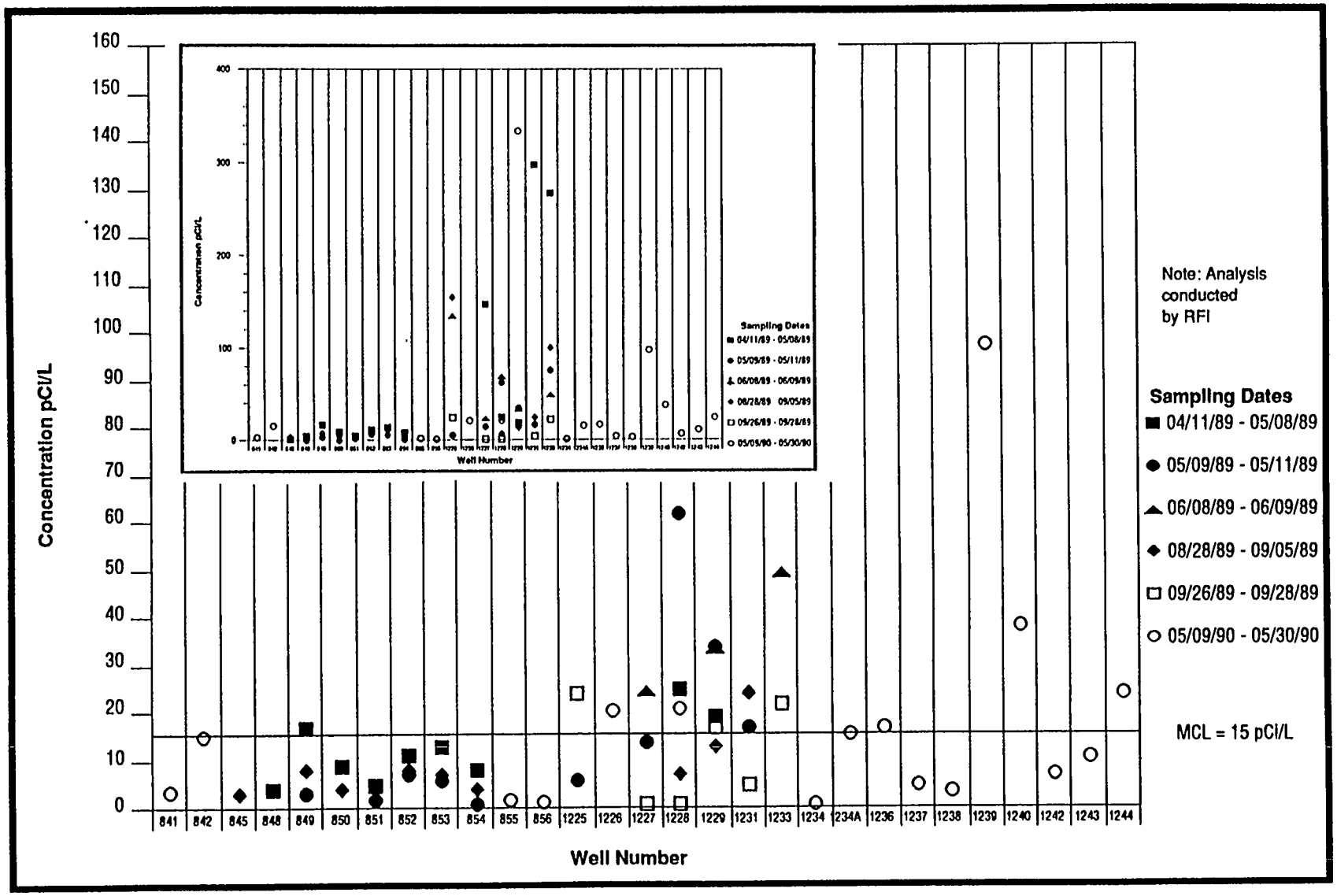



Fig. 4C.1. Gross alpha concentrations detected in groundwater samples from ORNL RCRA compliance wells at WAG 6.

5.18B 4104.81




4C.2. Gross alpha concentrations detected in groundwater samples from RFI wells and some ORNL RCRA compliance wells at WAG 6.

5.18B 4104.84

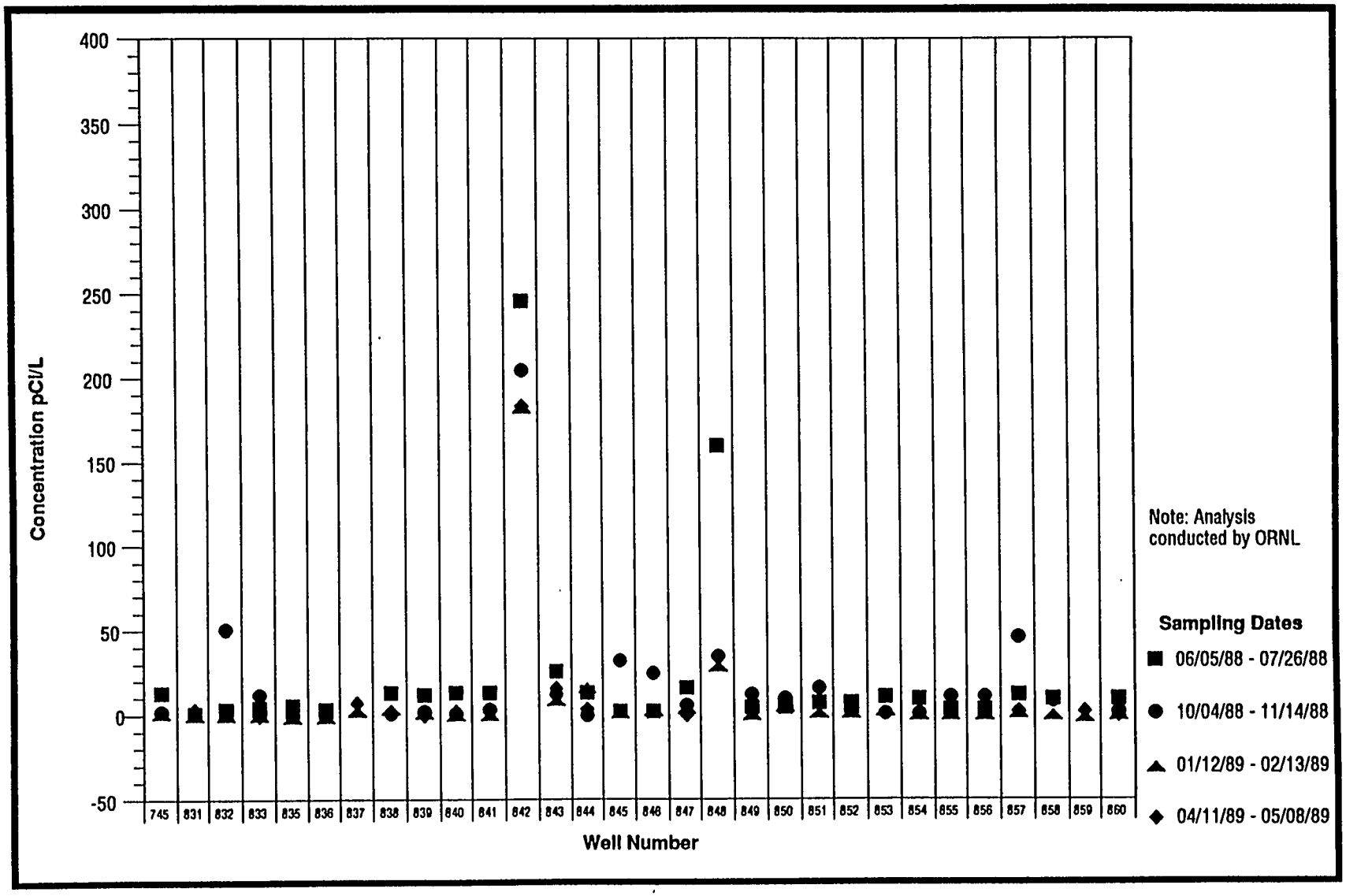



Fig. 4C.3. Gross beta concentrations detected in groundwater samples from ORNL RCRA compliance wells at WAG 6.

5.18B 4104.99

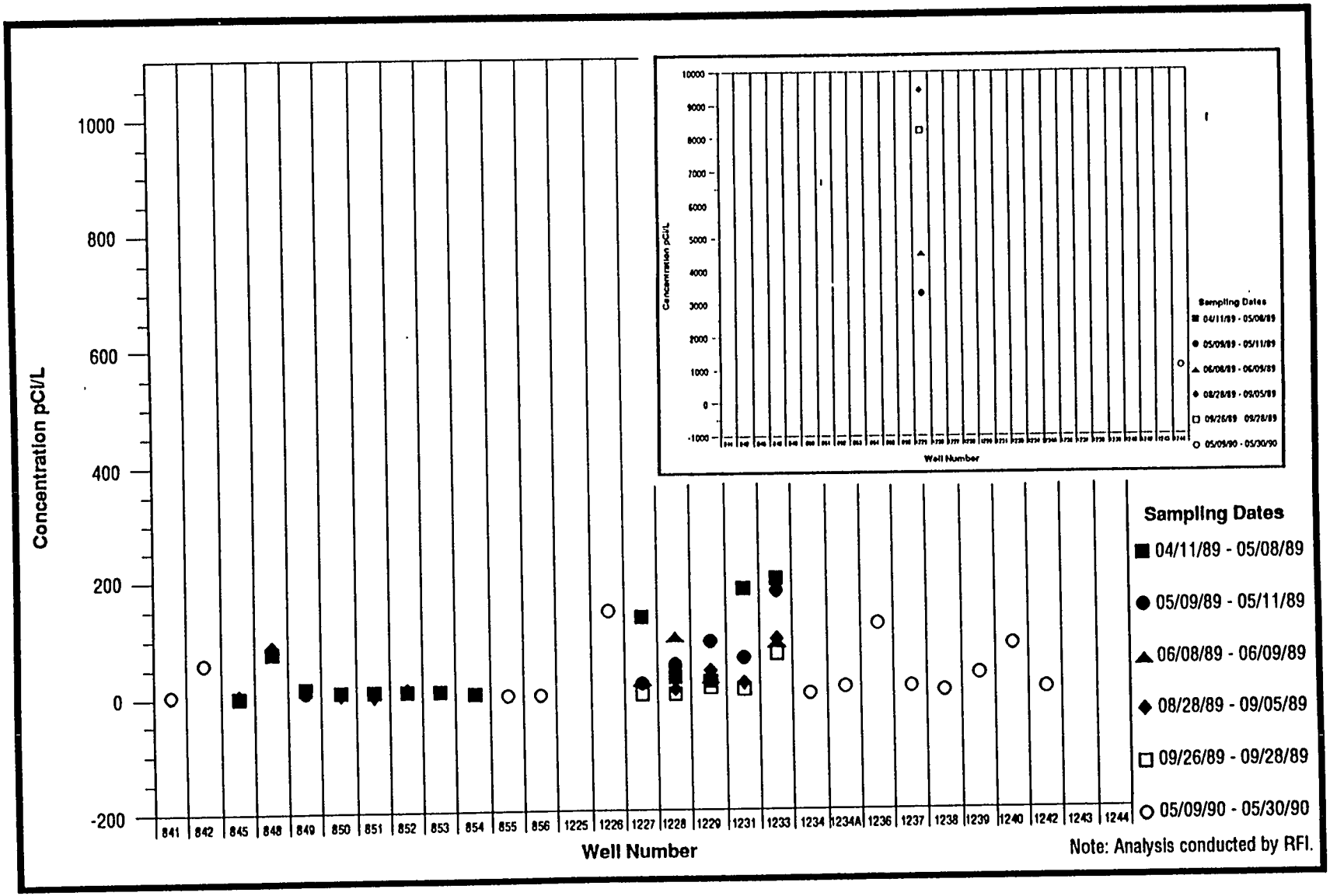



Fig. 4C.4. Gross beta concentrations detected in groundwater samples from RFI wells and some ORNL RCRA compliance wells at WAG 6.

5.18B 4104.102

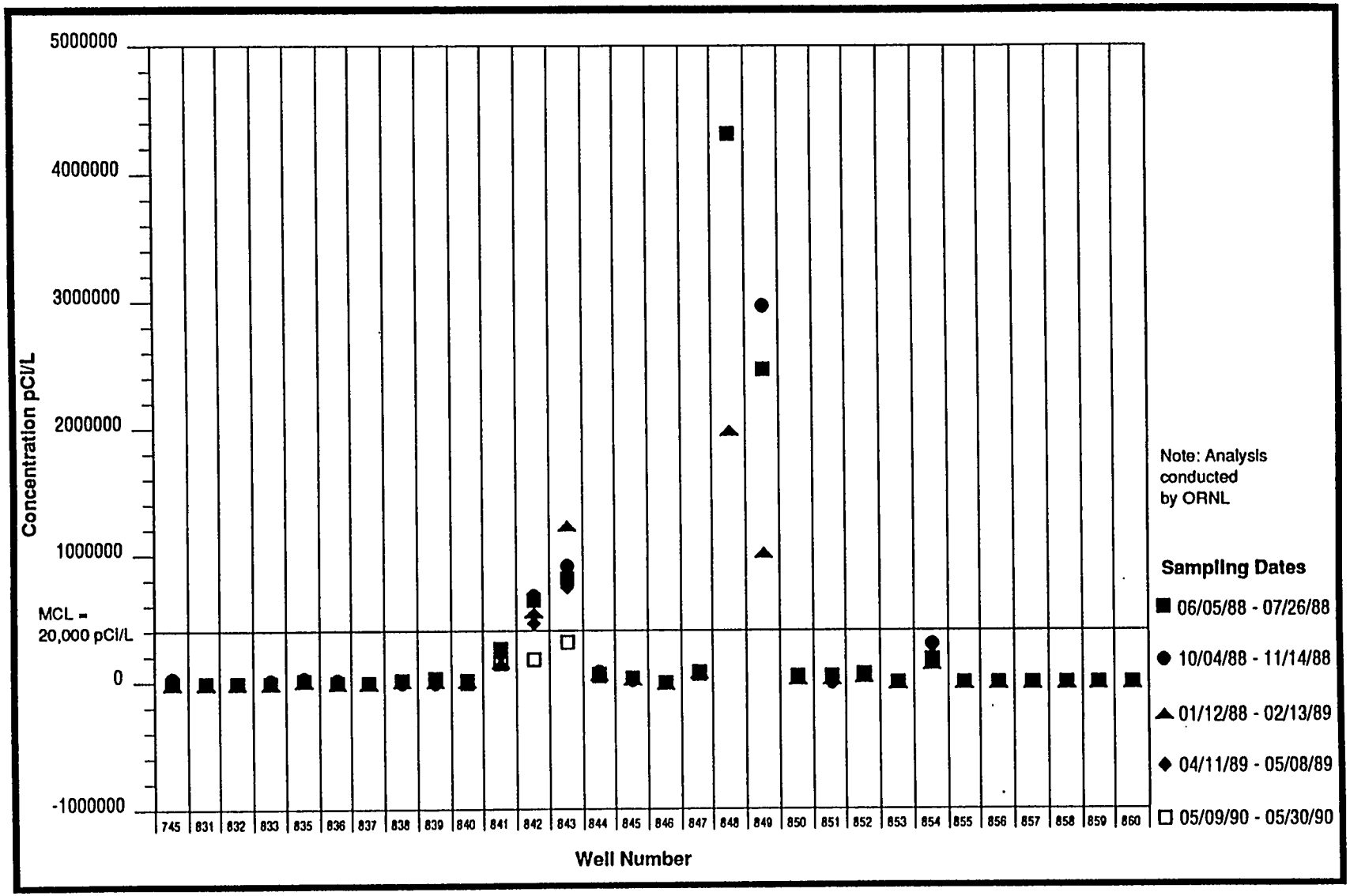



Fig. 4C.5. Tritium concentrations detected in groundwater samples from ORNL RCRA compliance wells at WAG 6.

5.18B 4104.89

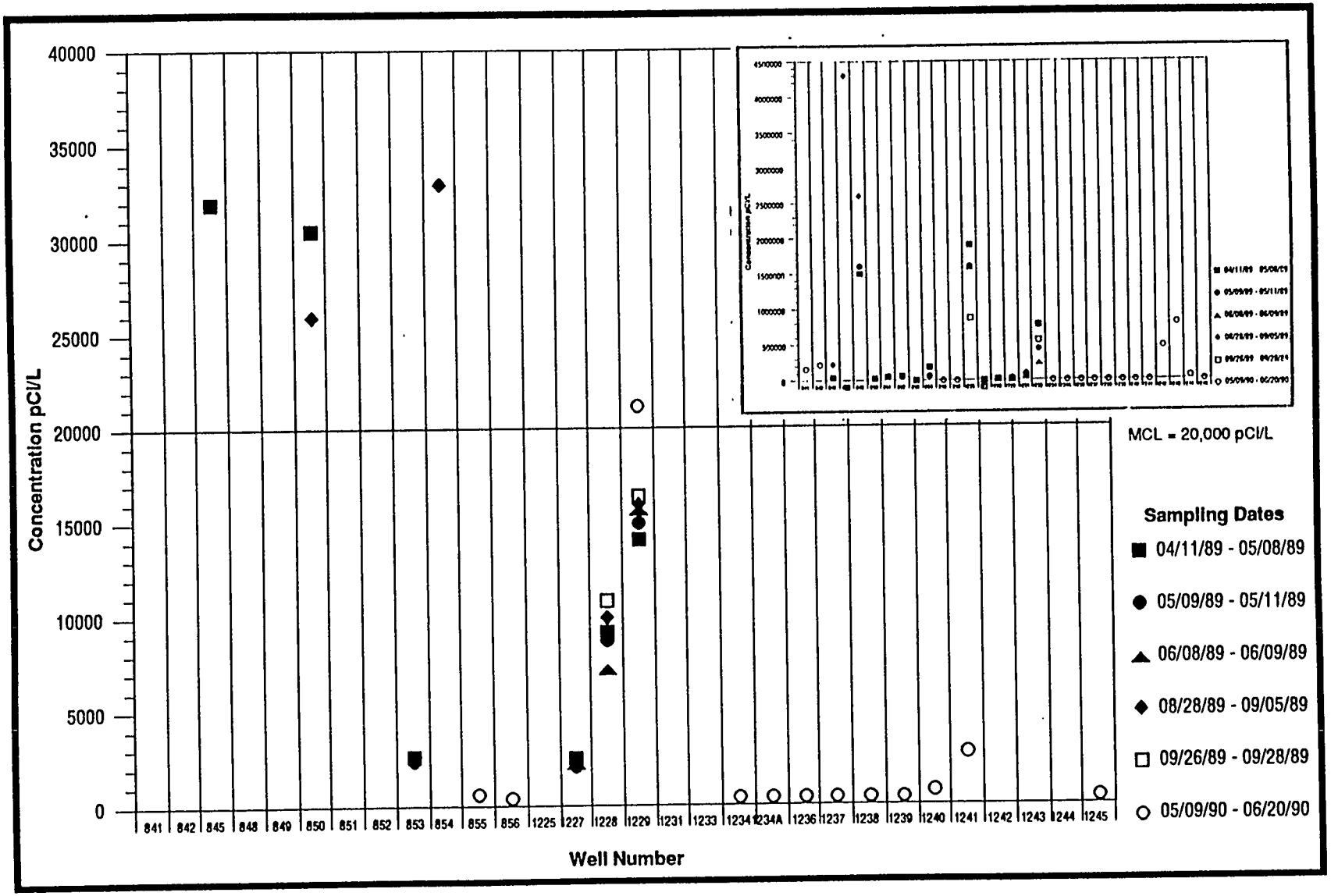



Fig. 4C.6. Tritium concentrations detected in groundwater samples from RFI wells and some ORNL RCRA compliance wells at WAG 6.

5.18B 4104.92

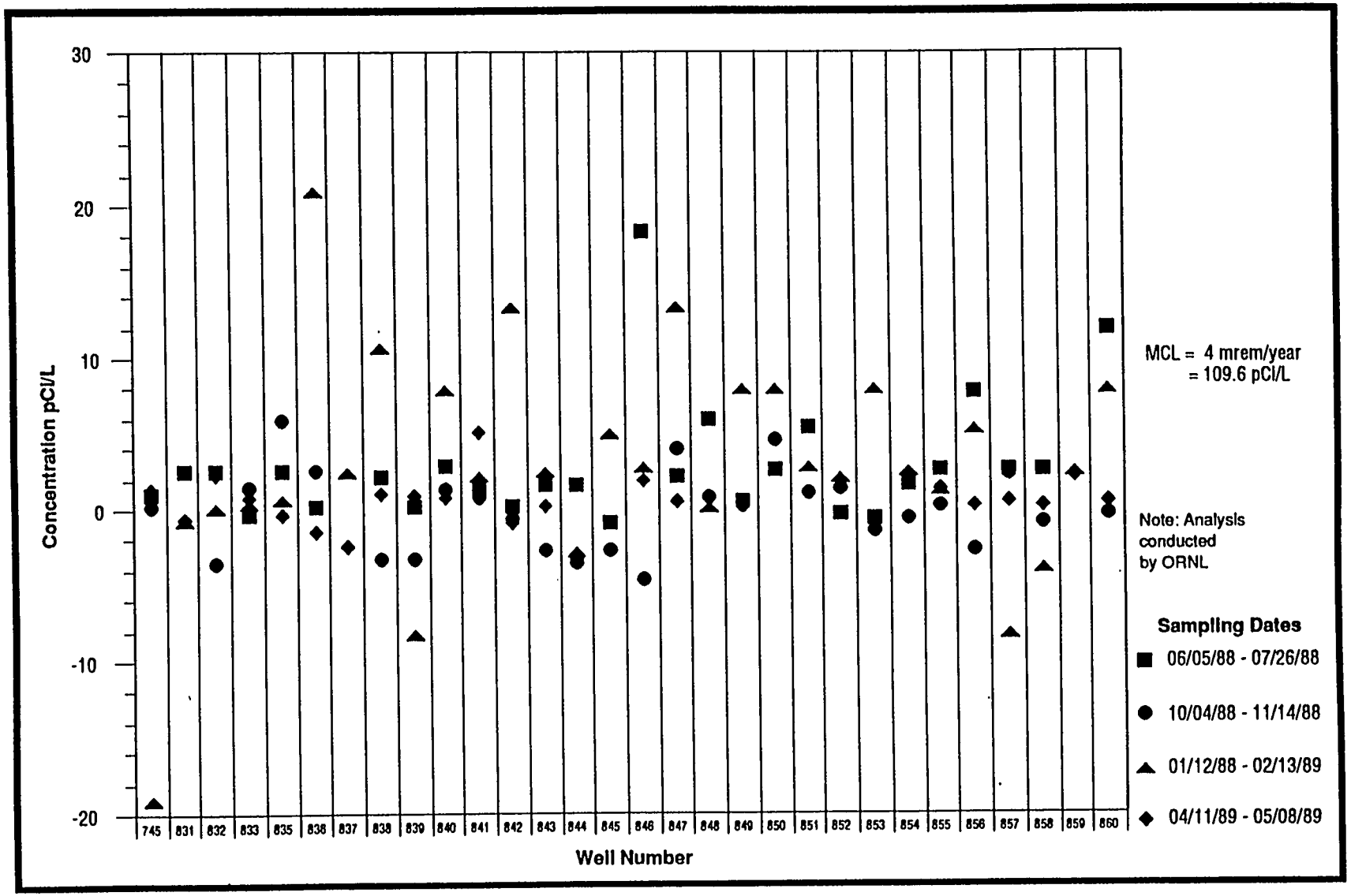



Fig. 4C.7. Cesium-137 concentrations detected in groundwater samples from ORNL RCRA compliance wells at WAG 6.

5.18B 4104.87

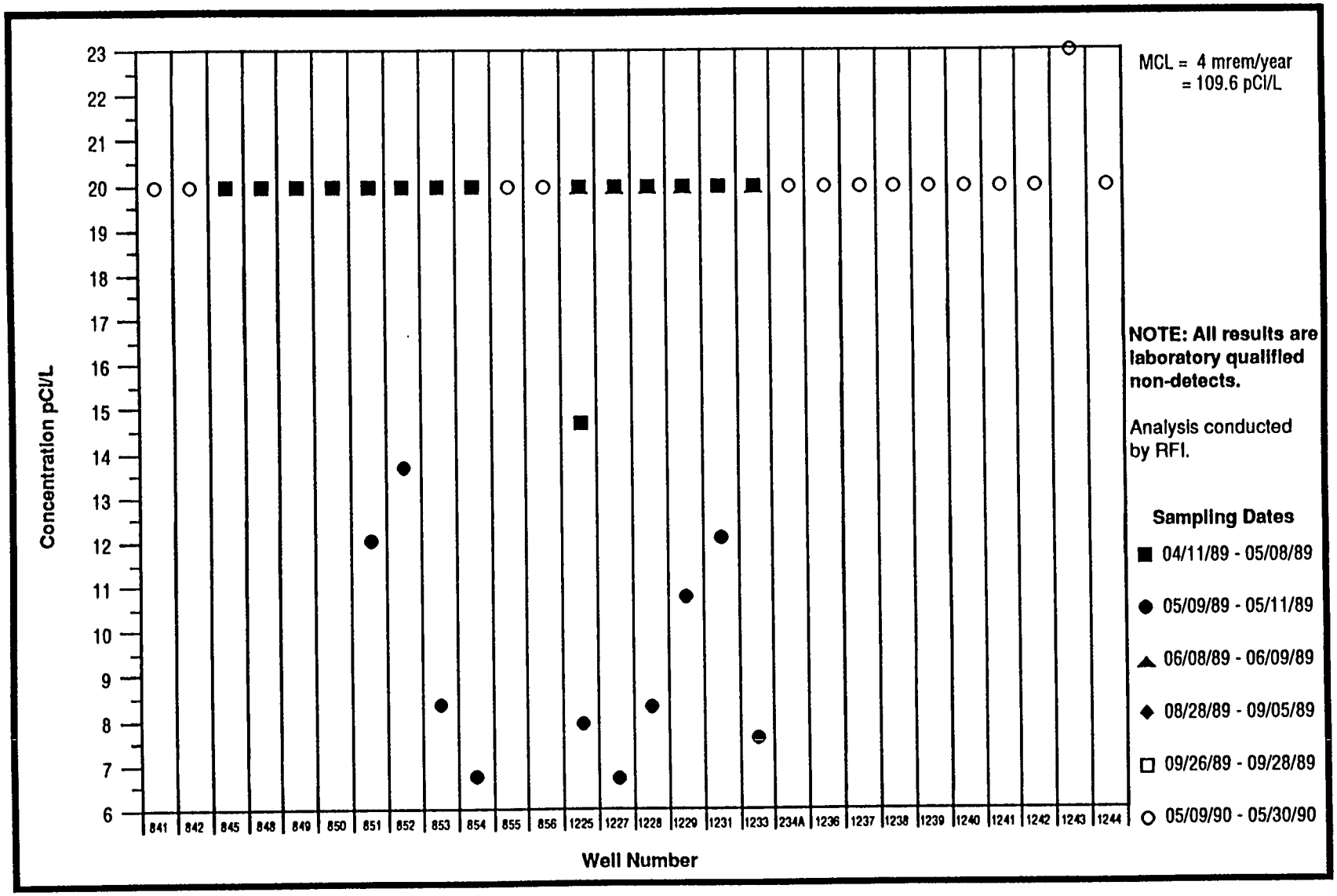



Fig. 4C.8. Levels of non-detection of Cesium-137 from groundwater samples from RFI wells and some ORNL RCRA compliance wells at WAG 6.

5.18B 4104.91

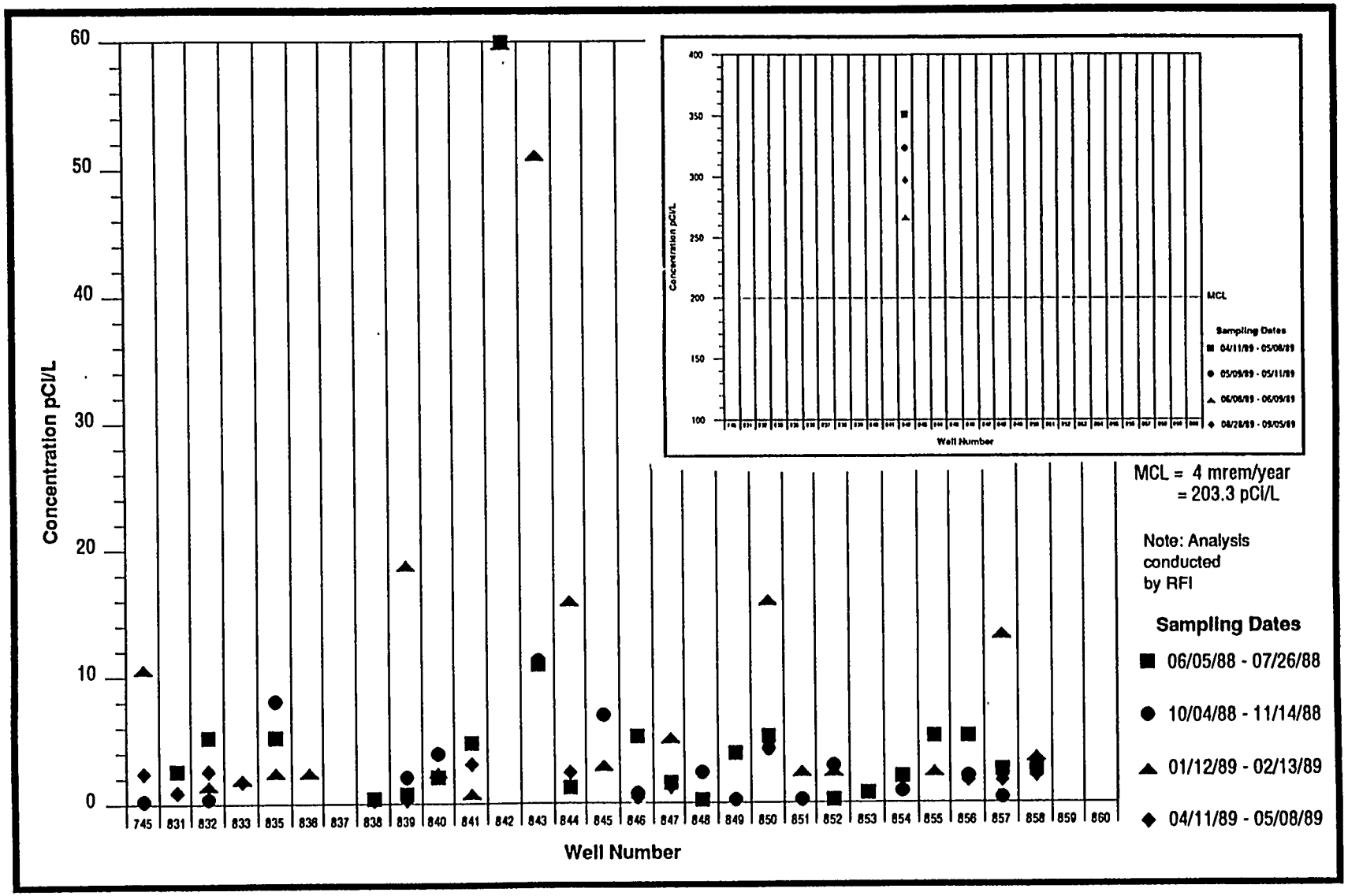



Fig. 4C.9. Cobalt-60 concentrations detected in groundwater samples from ORNL RCRA compliance wells at WAG 6.

5.18B 4104.97

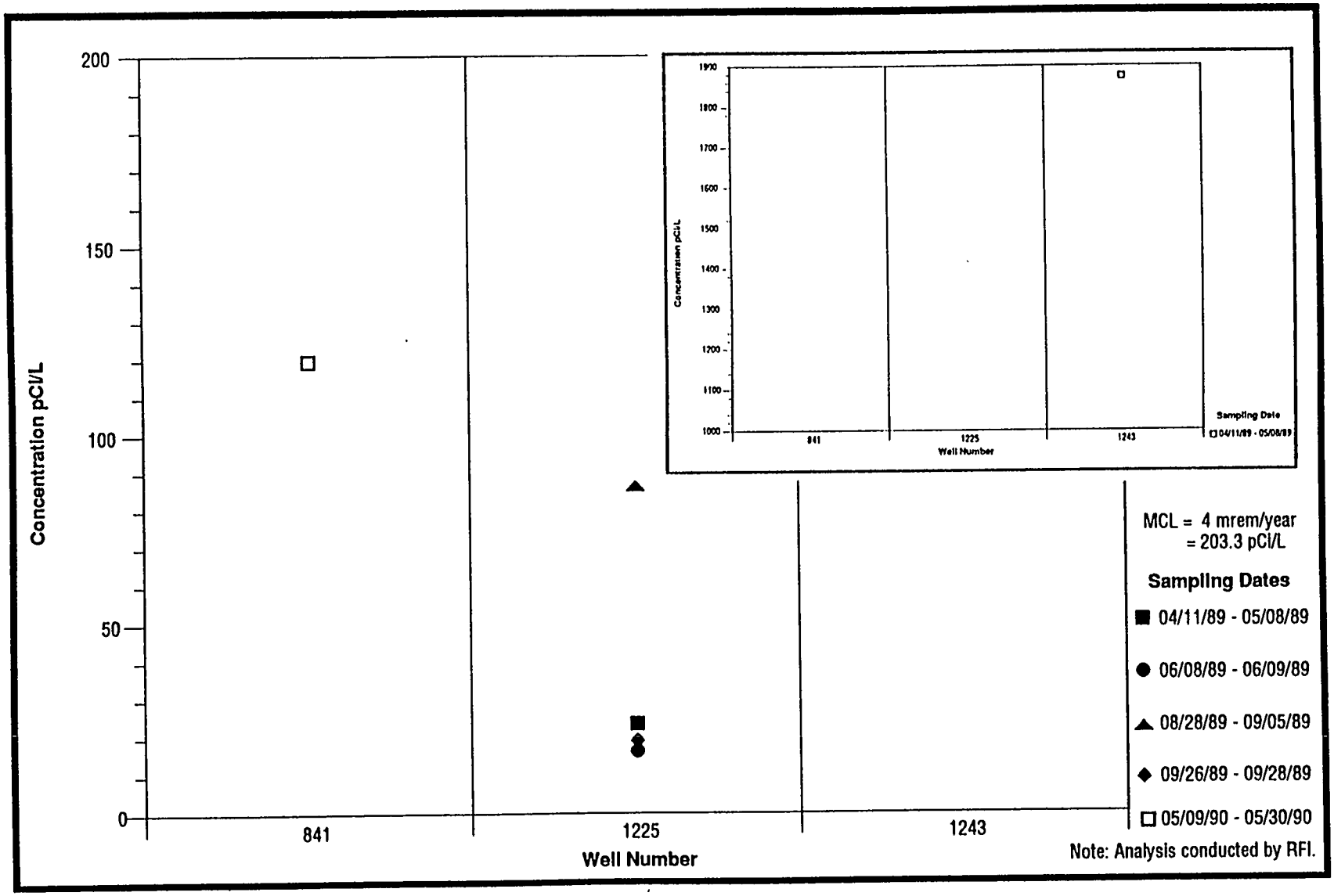



Fig. 4C.10. Cobalt-60 concentrations detected in groundwater samples from RFI wells and some ORNL RCRA compliance wells at WAG 6.

5.18B 4104.101

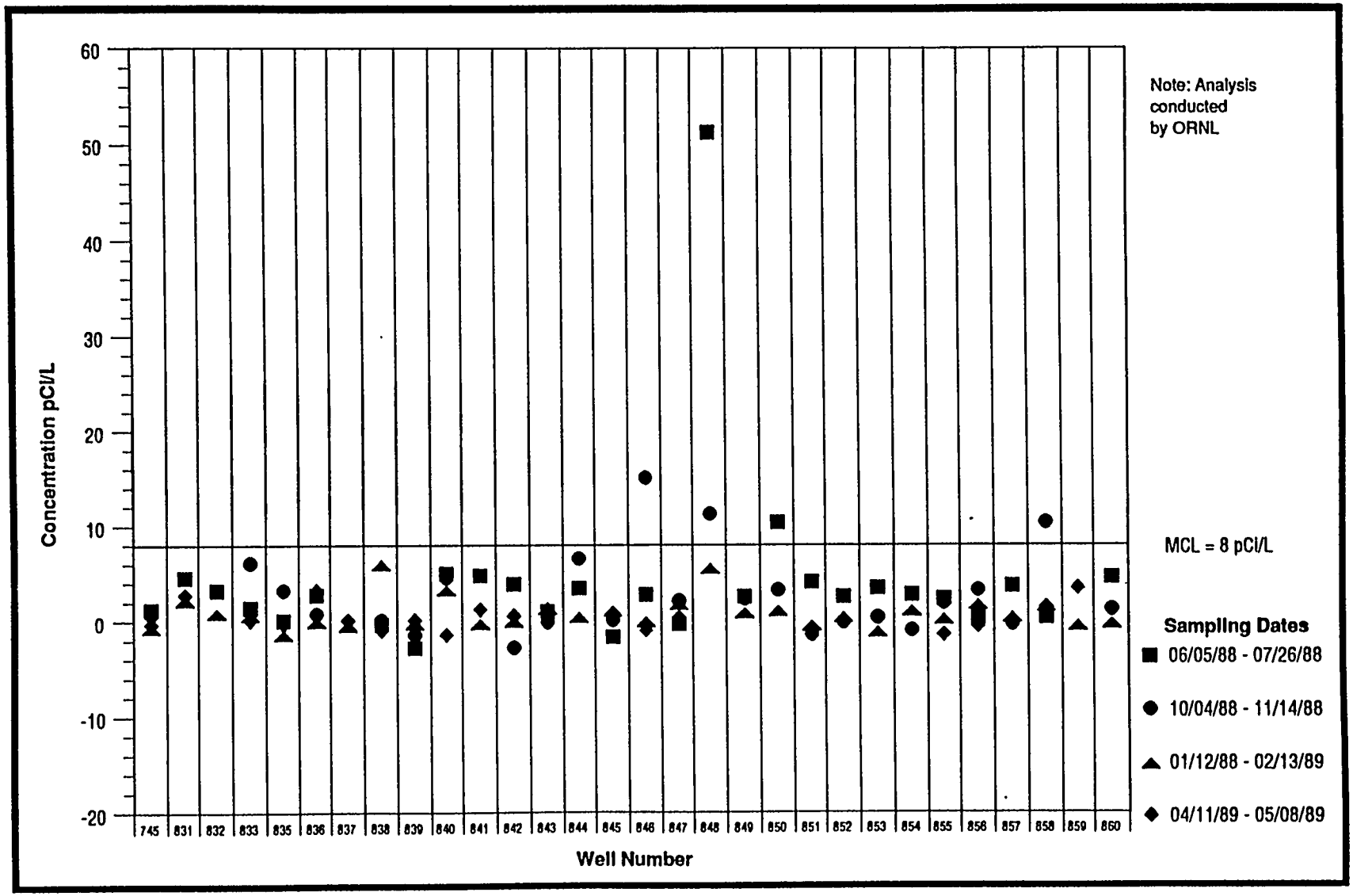



Fig. 4.C.11. Total strontium concentrations detected in groundwater samples from ORNL RCRA compliance wells at WAG 6.

5.18B 4104.86

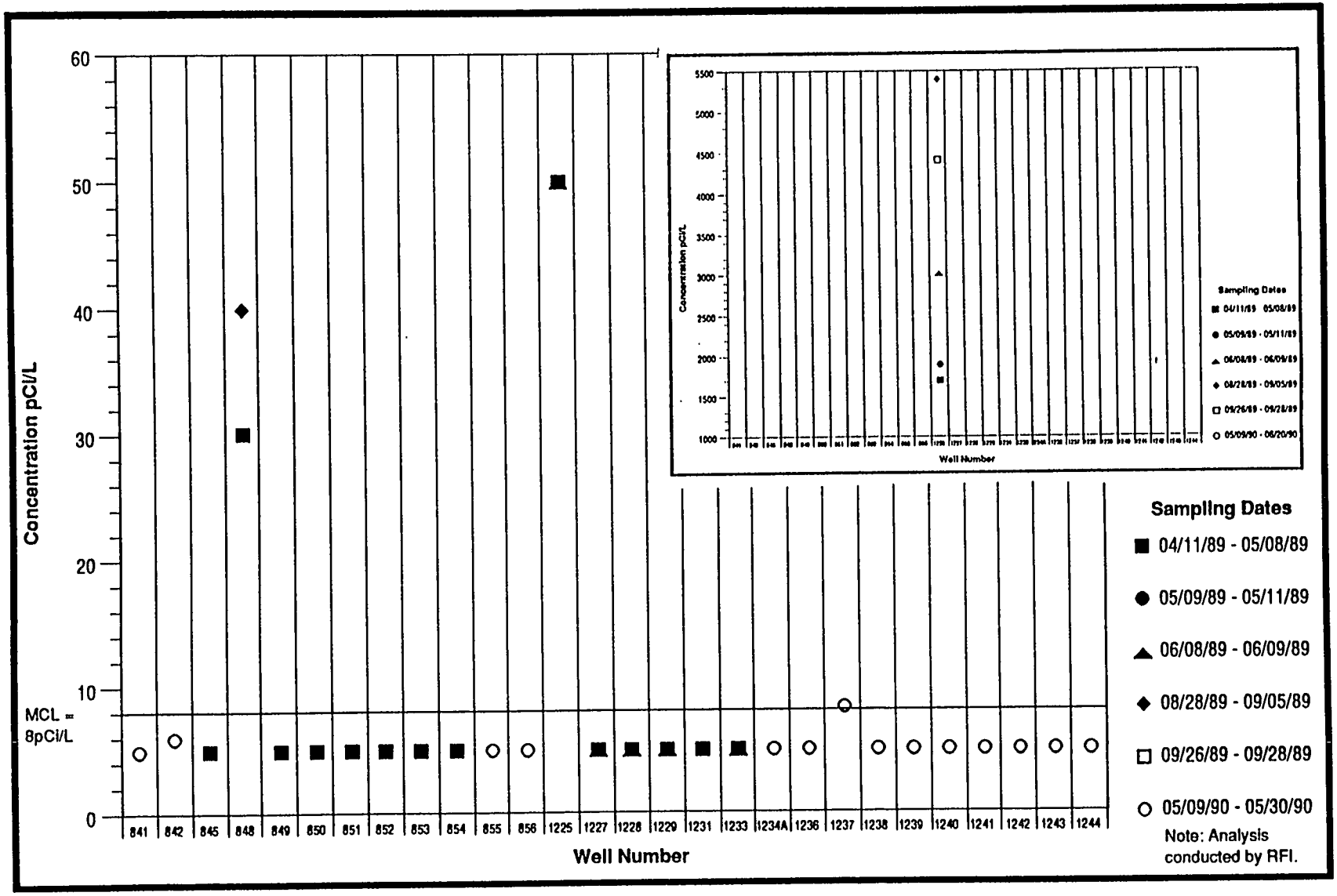



Fig. 4C.12. Strontium-90 concentrations detected in groundwater samples from RFI wells and some ORNL RCRA compliance wells at WAG 6.

5.18B 4104.95

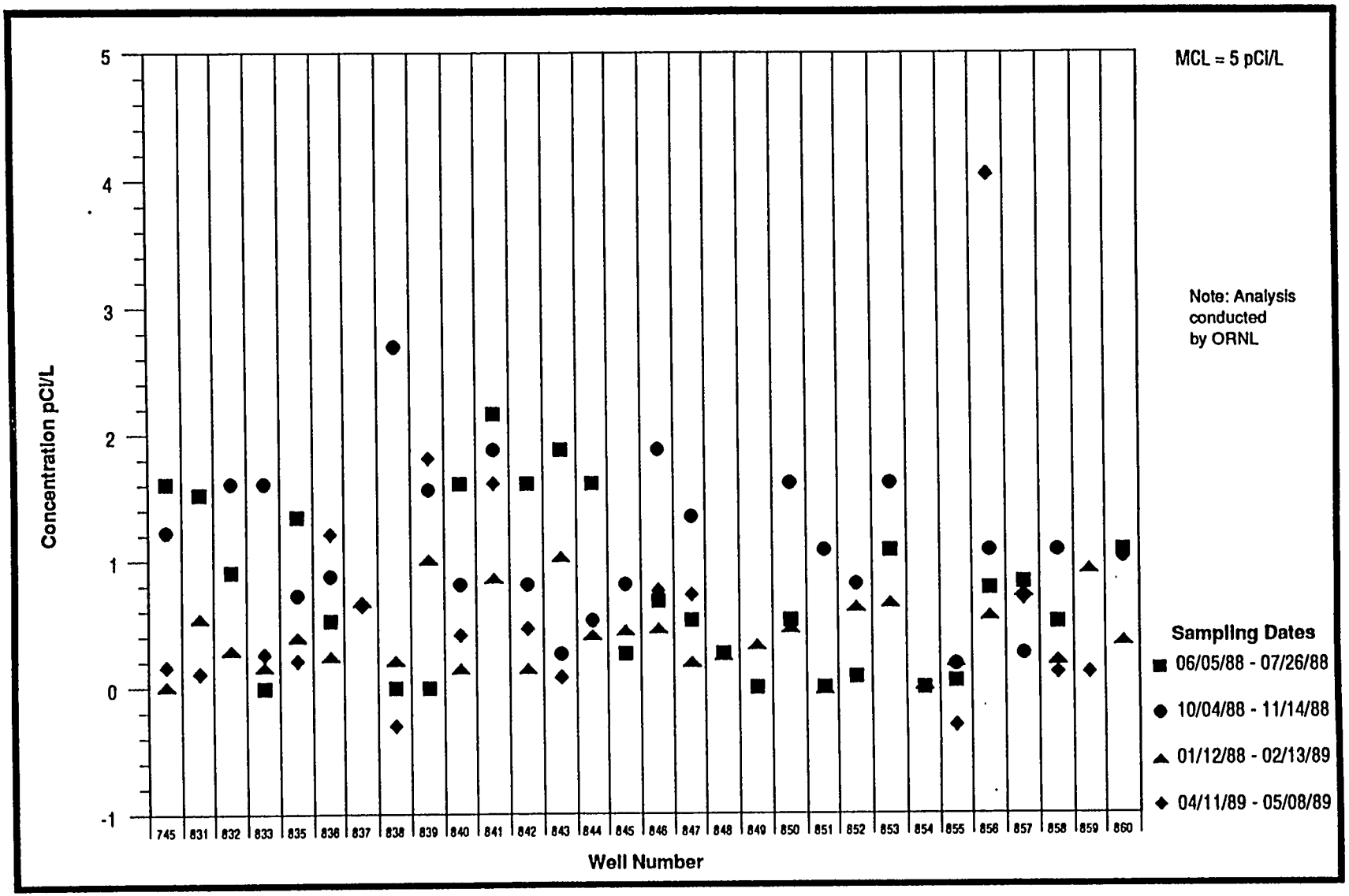
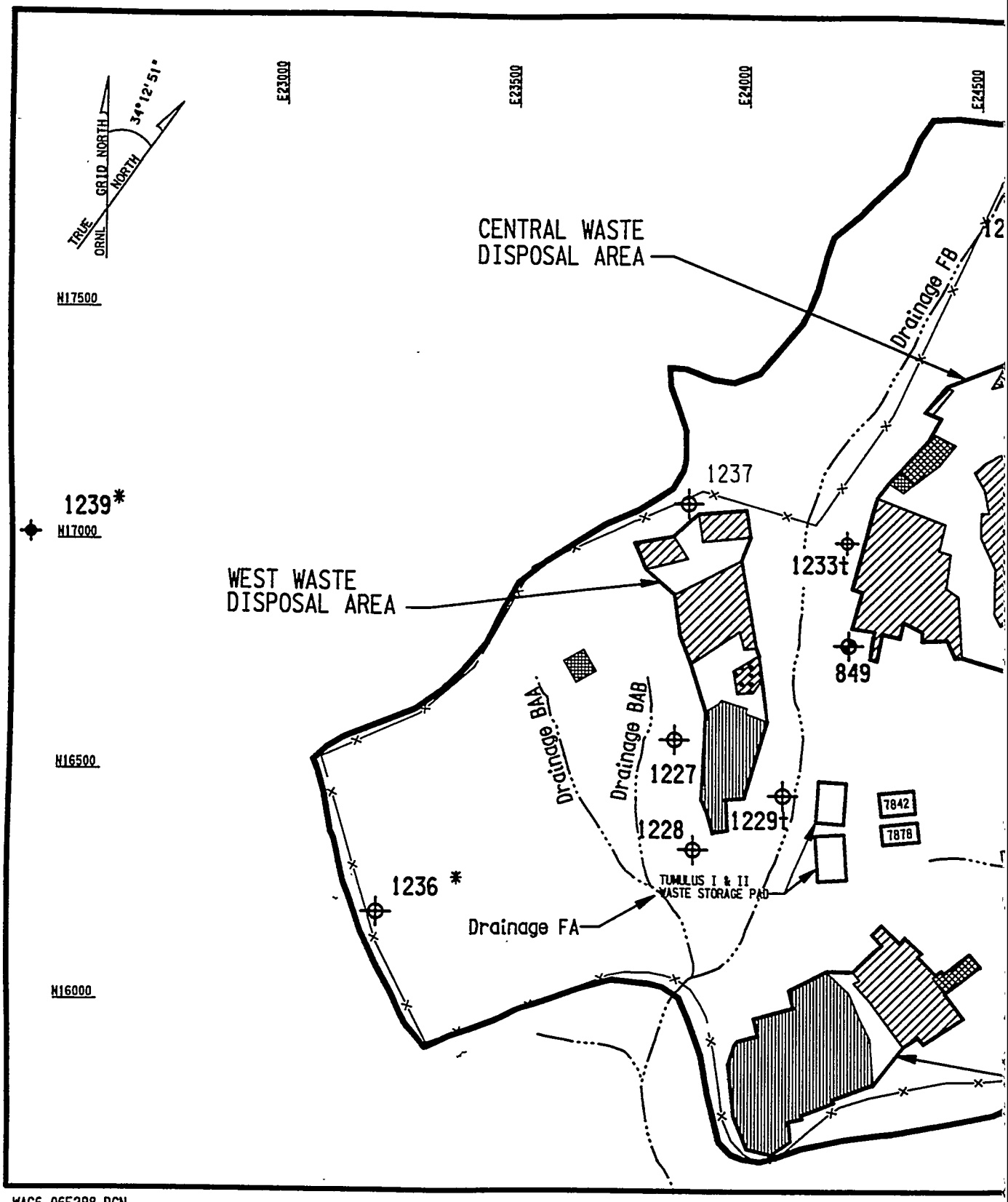



Fig. 4C.13. Total radium concentrations detected in groundwater samples from ORNL RCRA compliance wells at WAG 6.

5.18B 4104.82




WAG6 06F298.DGN

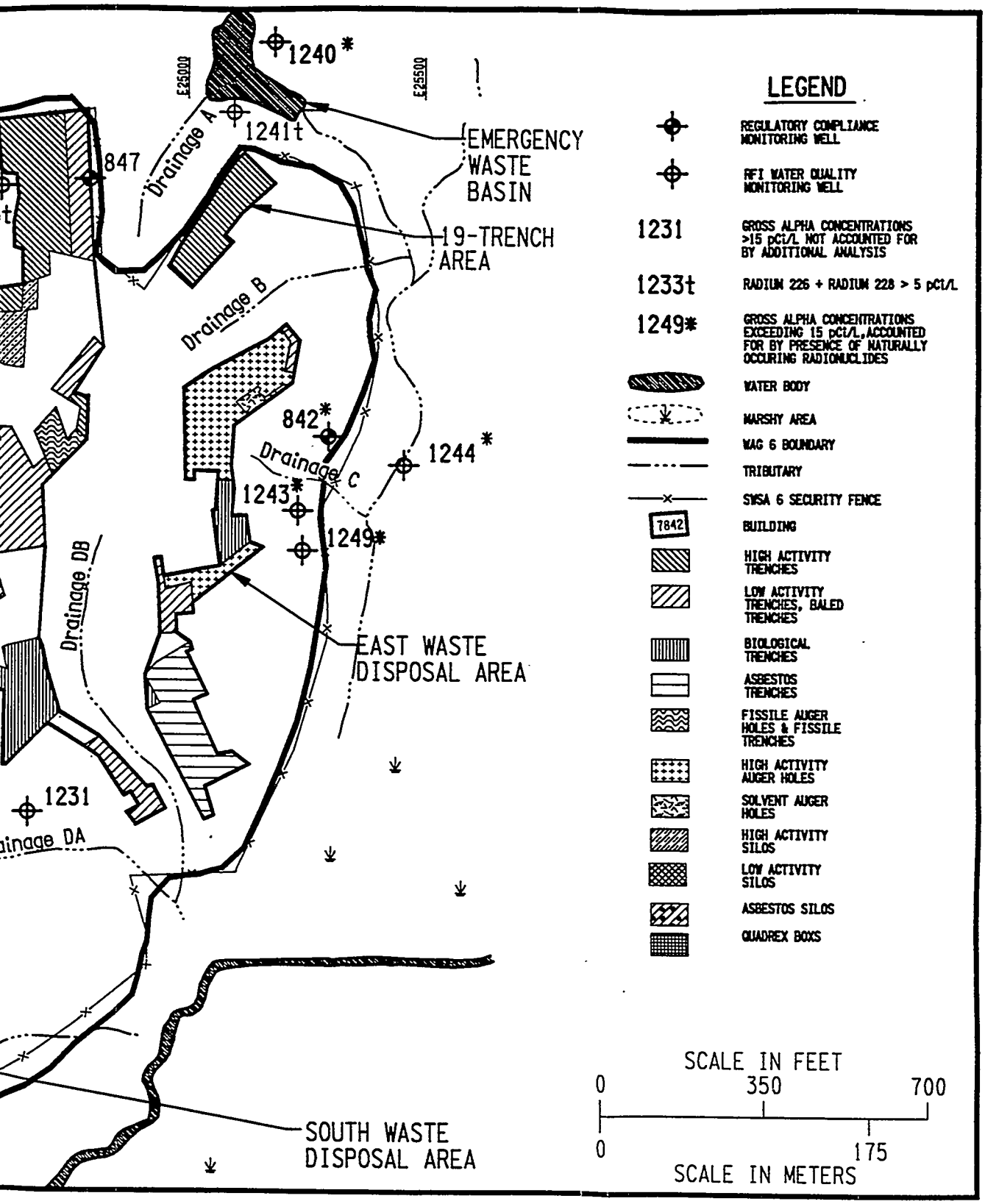
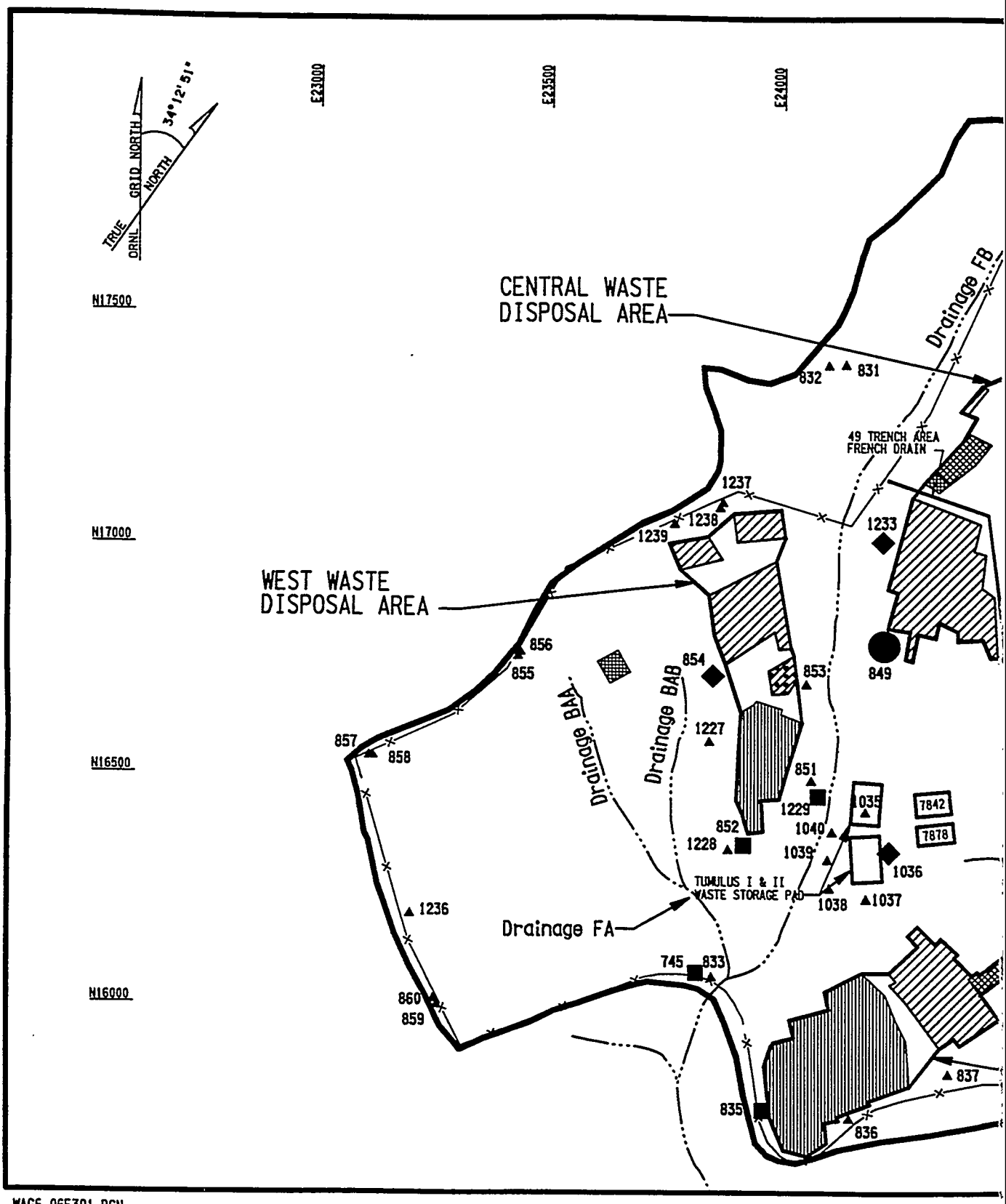



**Fig. 4C.14. Groundwater sampling locations where maximum gross alpha concentrations exceed 15 pCi/L and the sum of radium-226 and radium-228 exceeds 5 pCi/L.**




WAG6 06F301.DGN

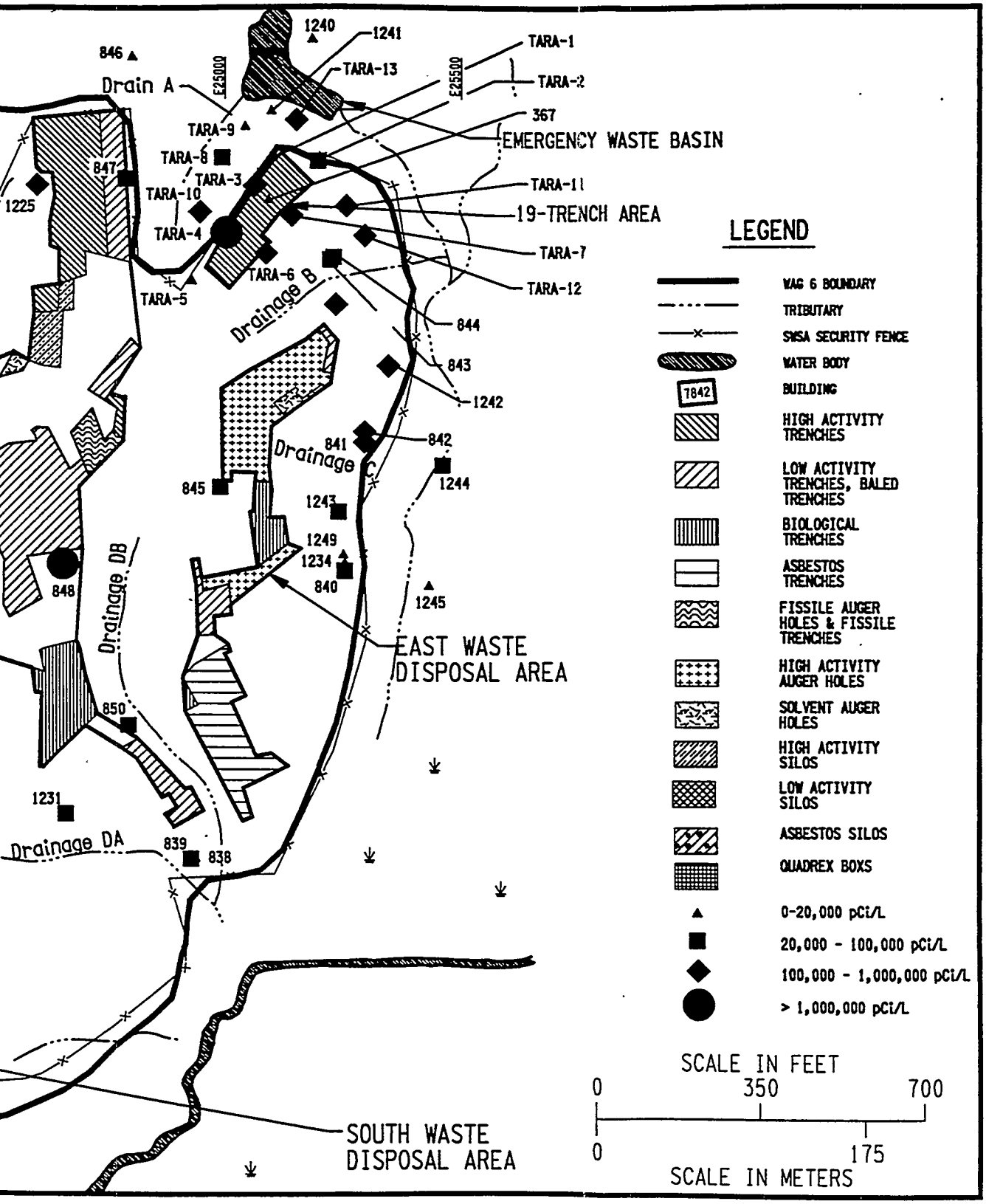
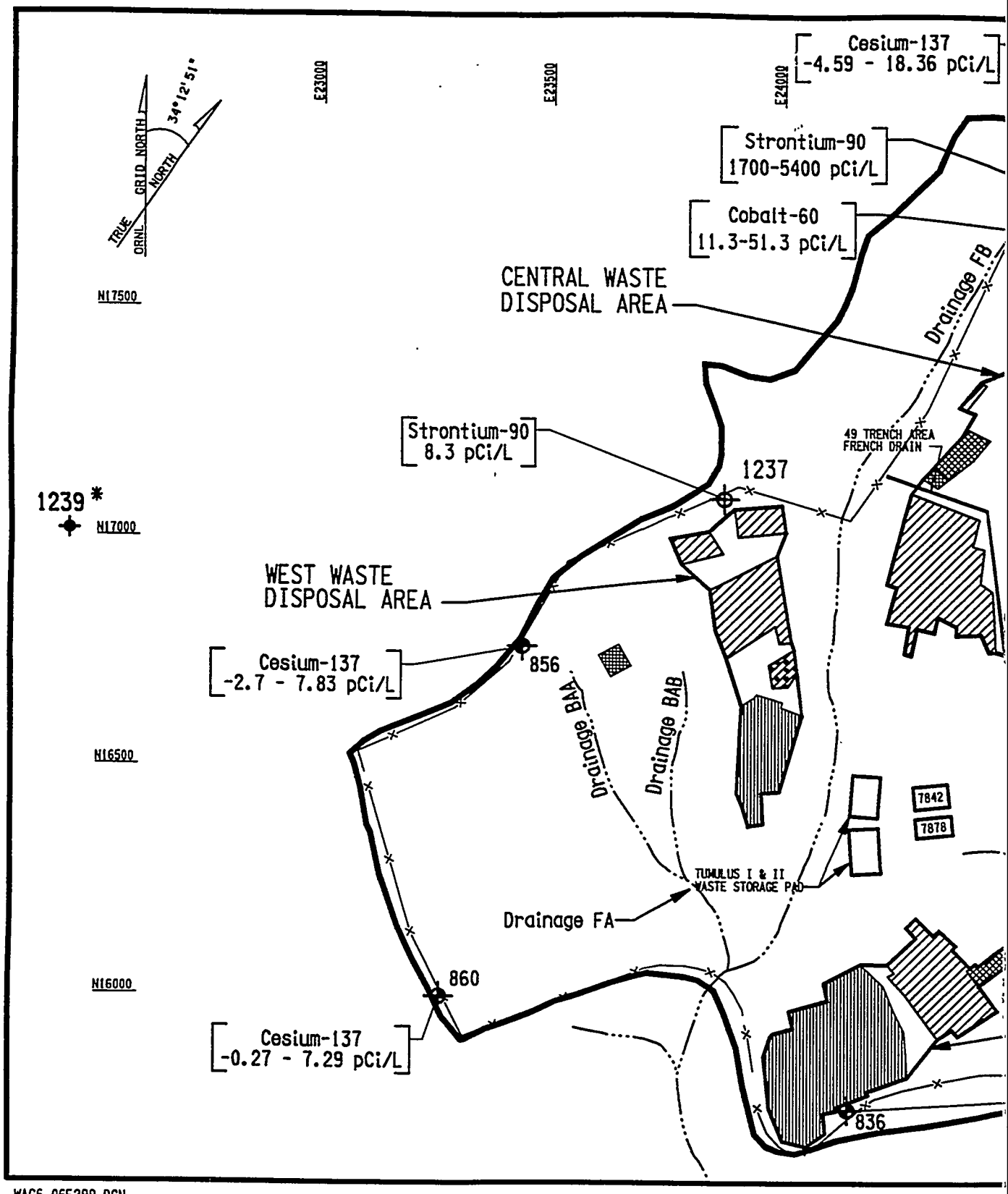



**Fig. 4C.15. Distribution of maximum detected tritium concentrations in groundwater at WAG 6.**

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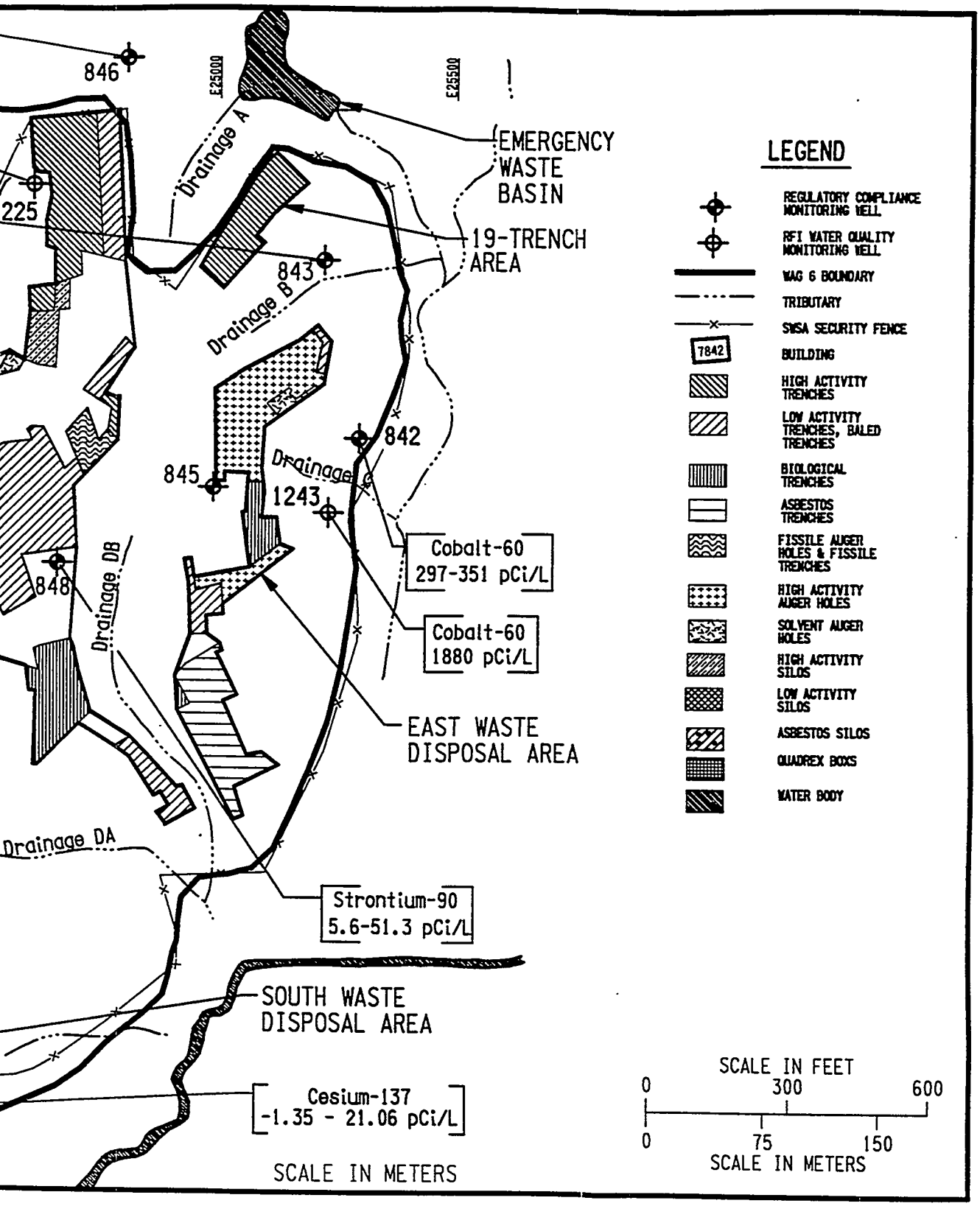
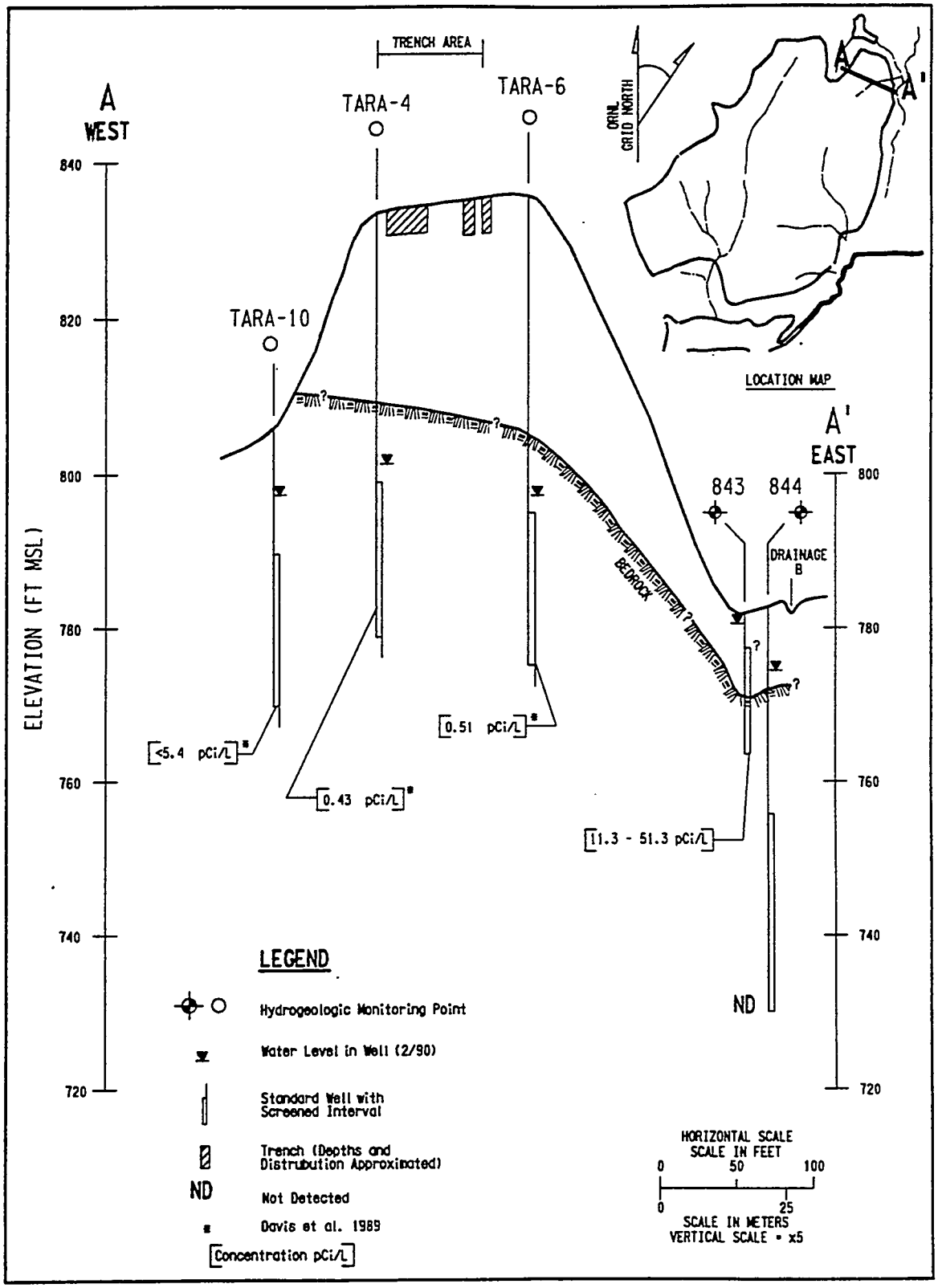
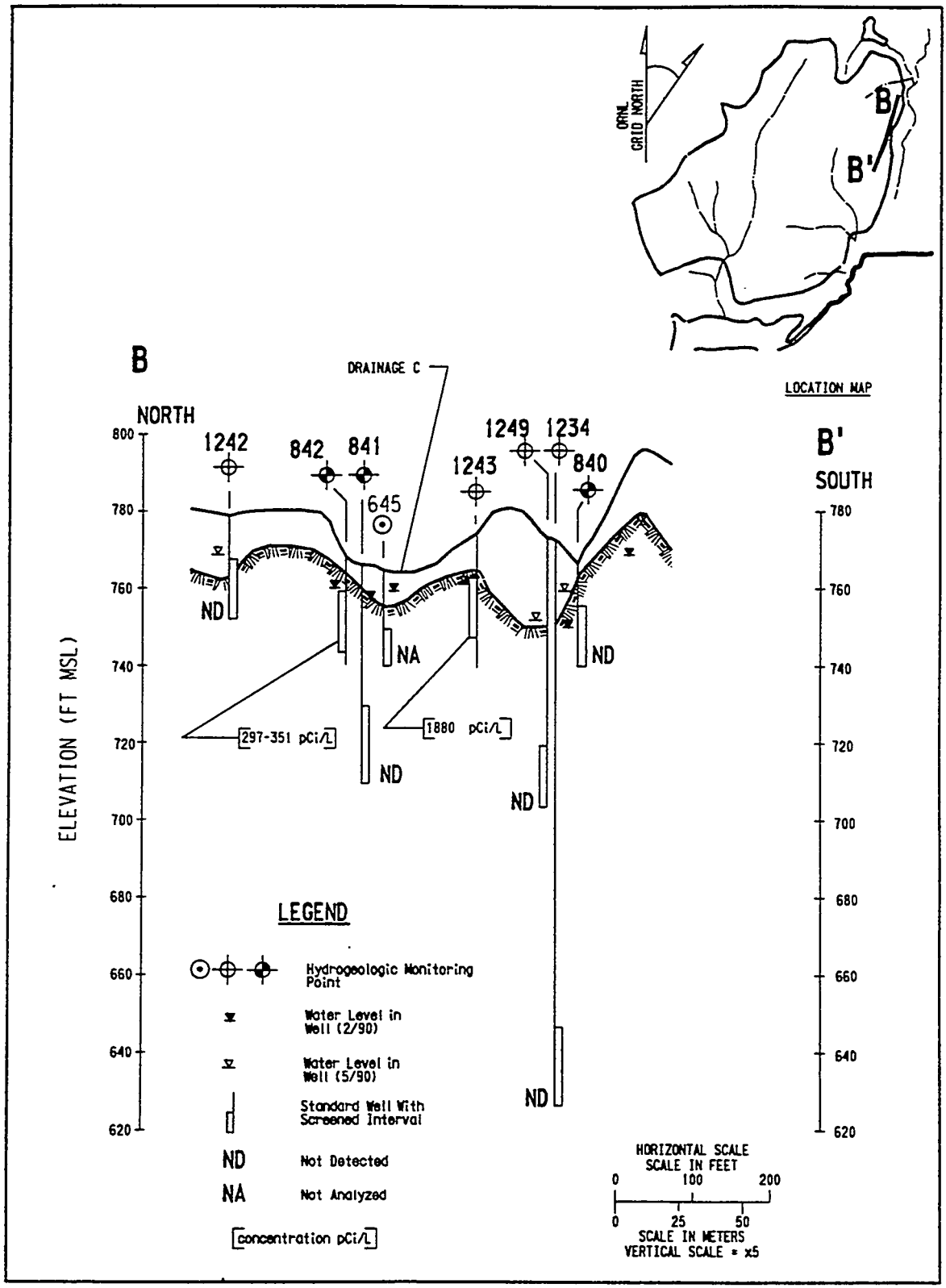



**Fig. 4C.16. Cesium -137, cobalt-60, and strontium-90 occurrences in groundwater at WAG 6.**



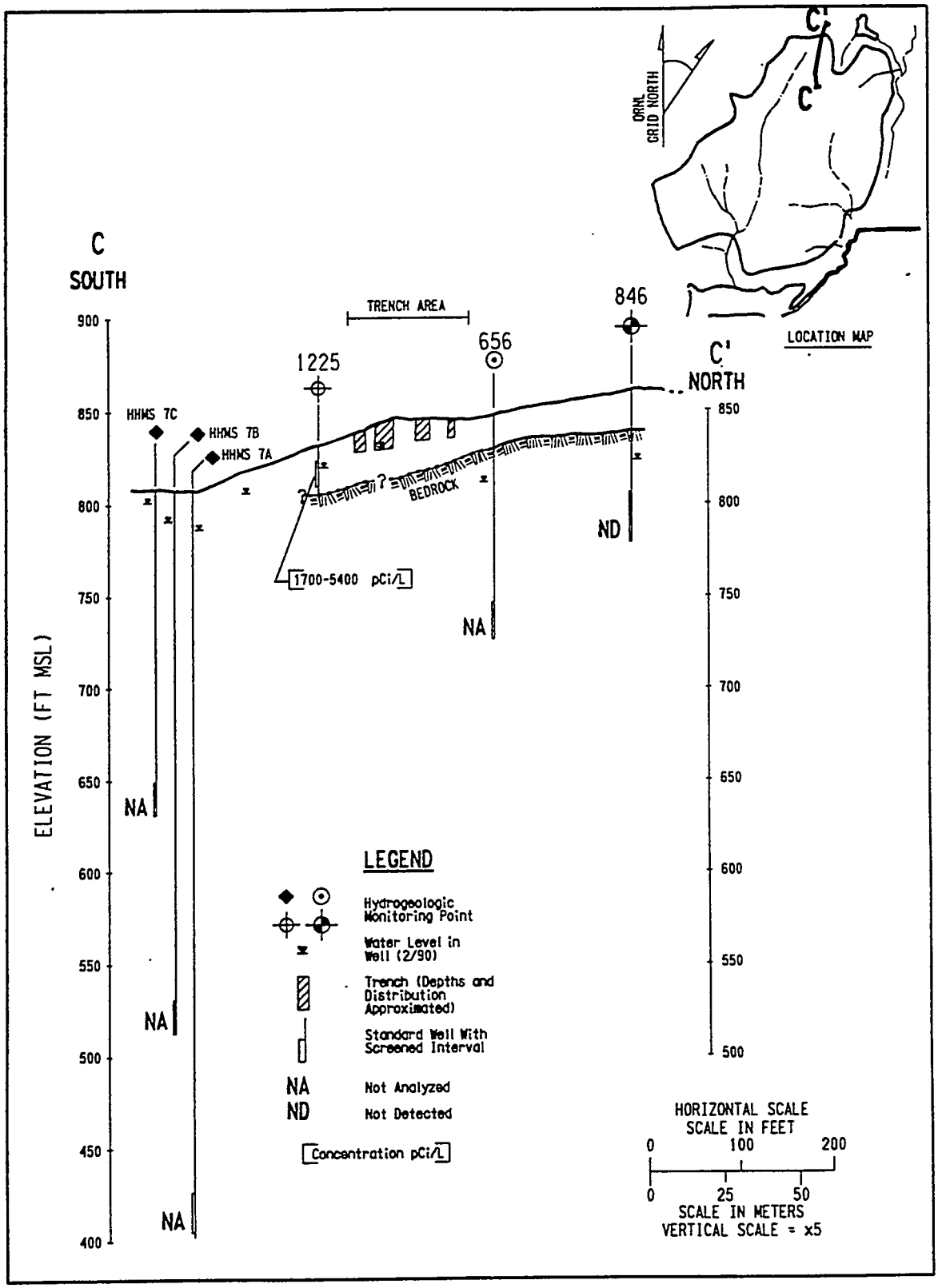

WAG6 06F296.DGN

**Fig. 4C.17. Occurrence of cobalt-60 in groundwater, cross section A-A'; 19-Trench area.**



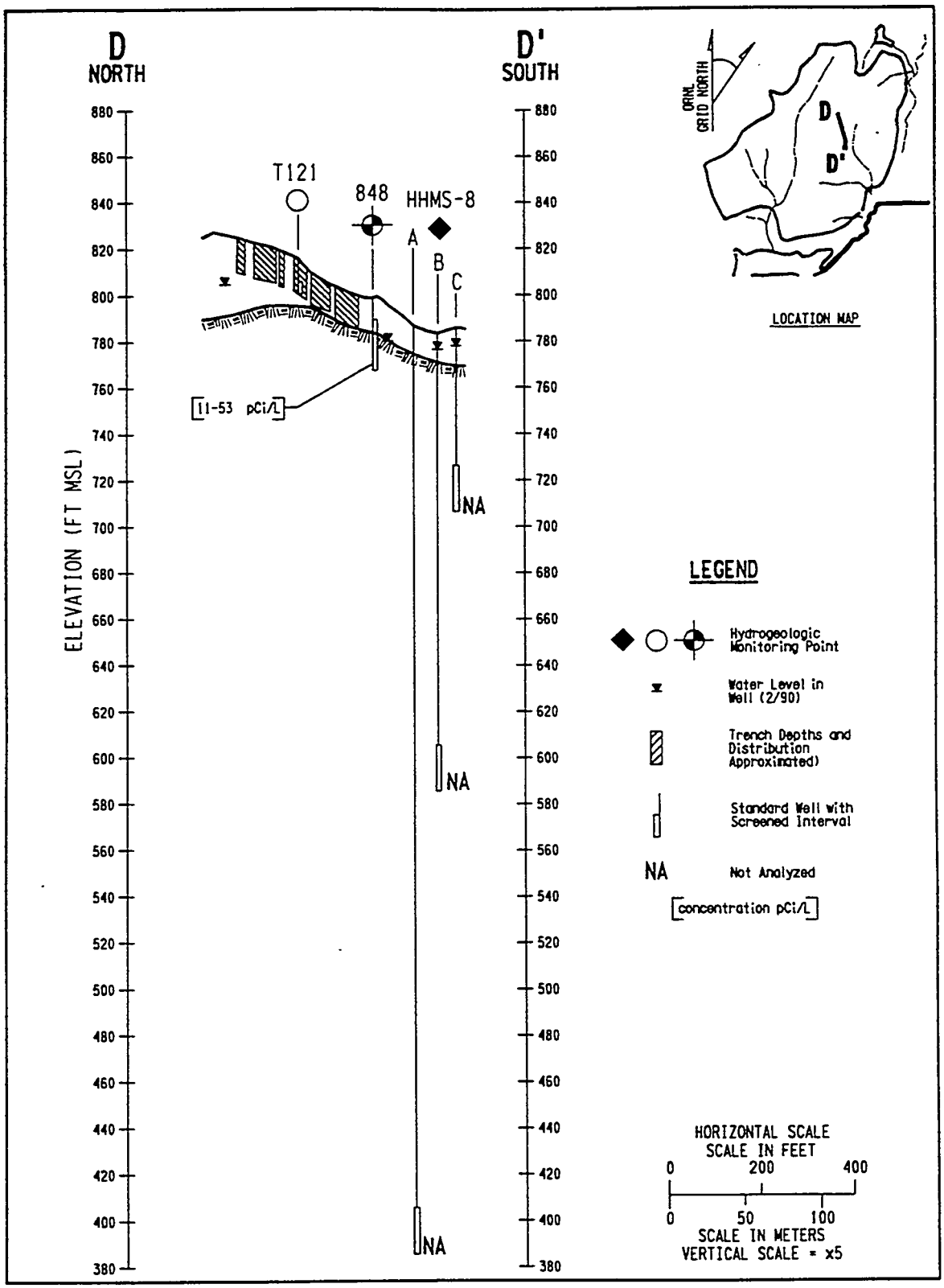

WAG6 06F295.DGN

**Fig. 4C.18. Occurrence of cobalt-60 in groundwater, cross section B-B'; east waste disposal area.**



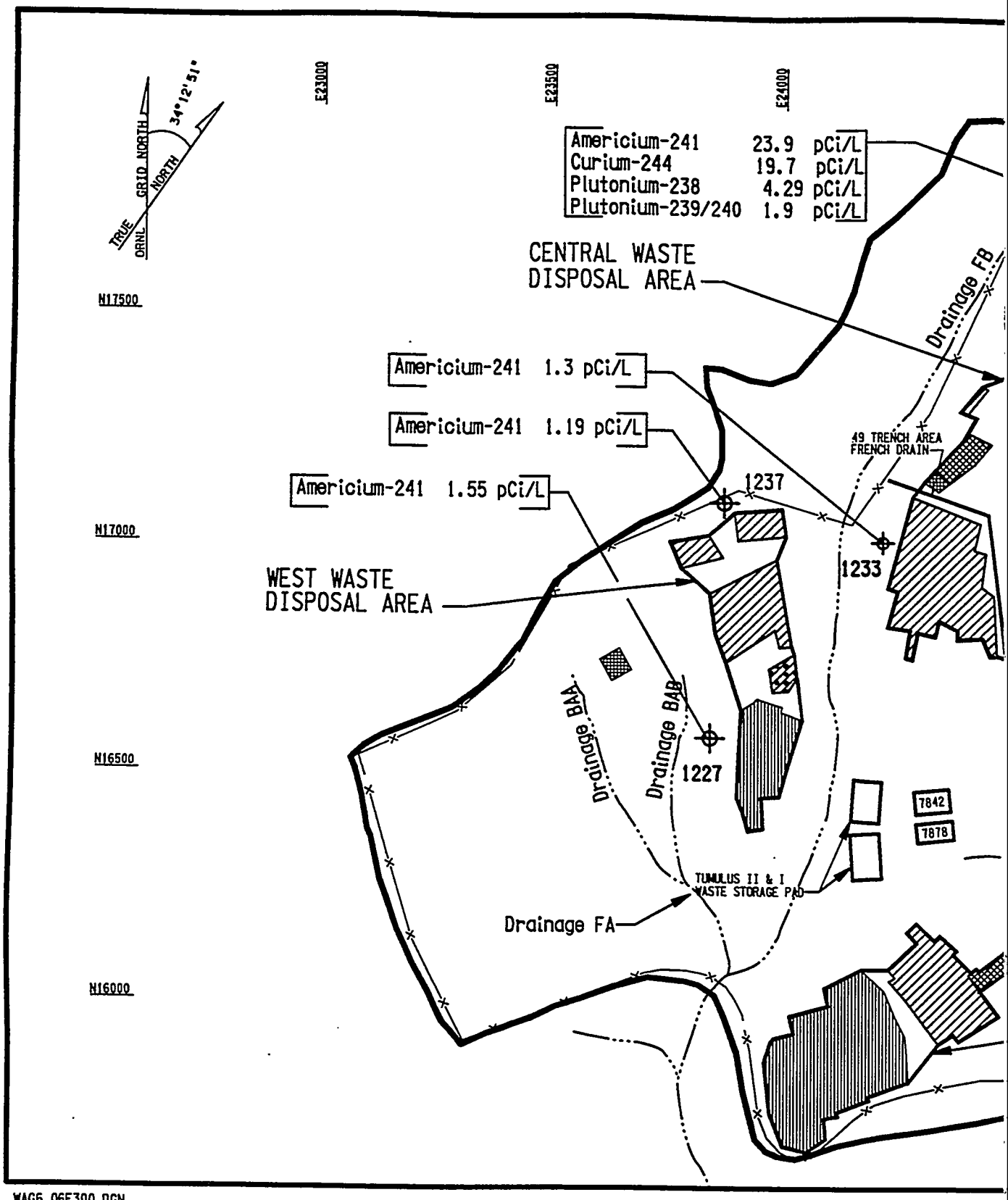

WAG6 06F293.DGN

**Fig. 4C.19. Occurrence of strontium-90 in groundwater, cross section C-C'; high-activity trench area of the central waste disposal area.**




WAG6 06F294.DGN

**Fig. 4C.20. Occurrence of strontium-90 in groundwater, cross section D-D'; eastern low-activity trench area of the central waste disposal area.**




WAG6 06F300.DGN

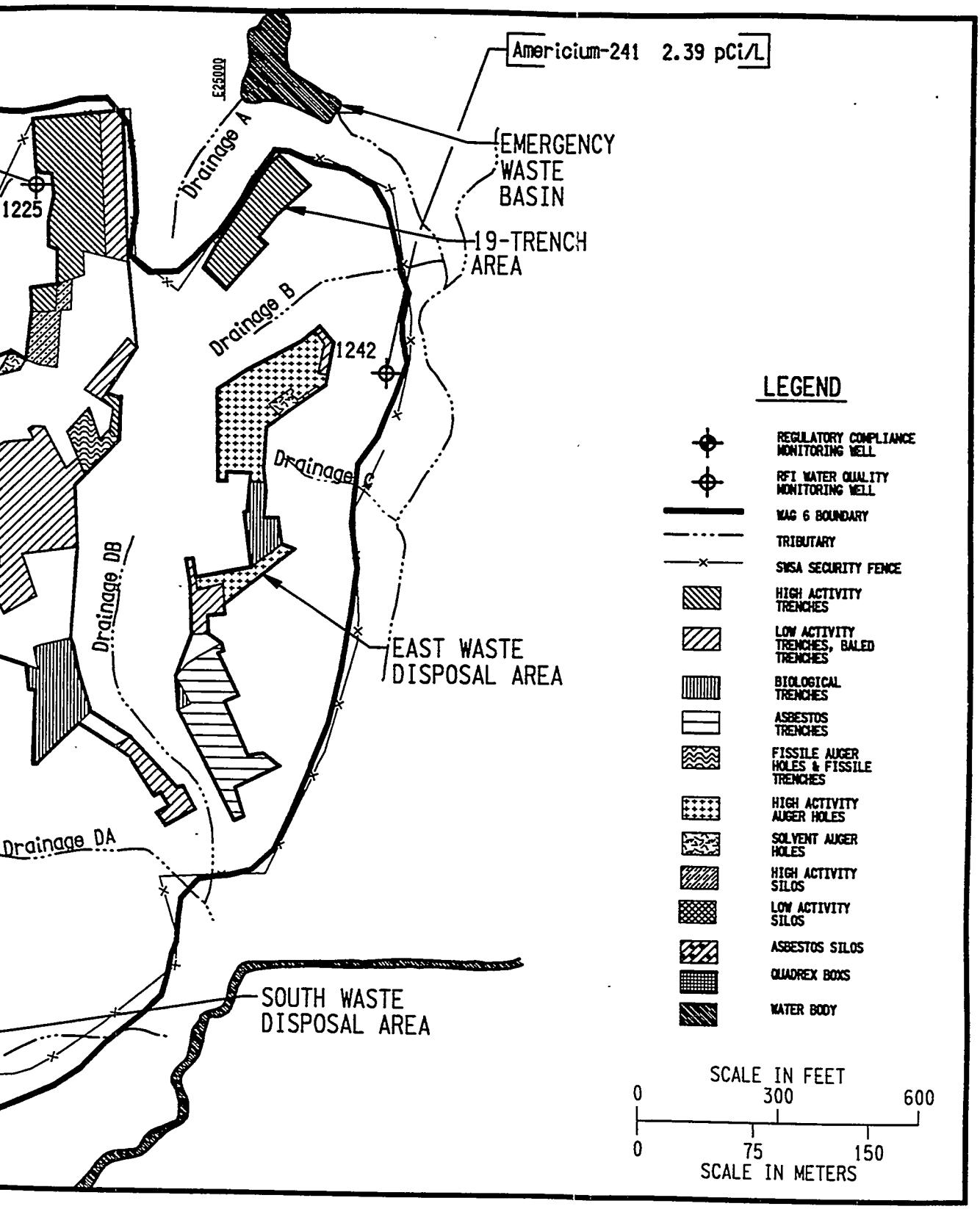
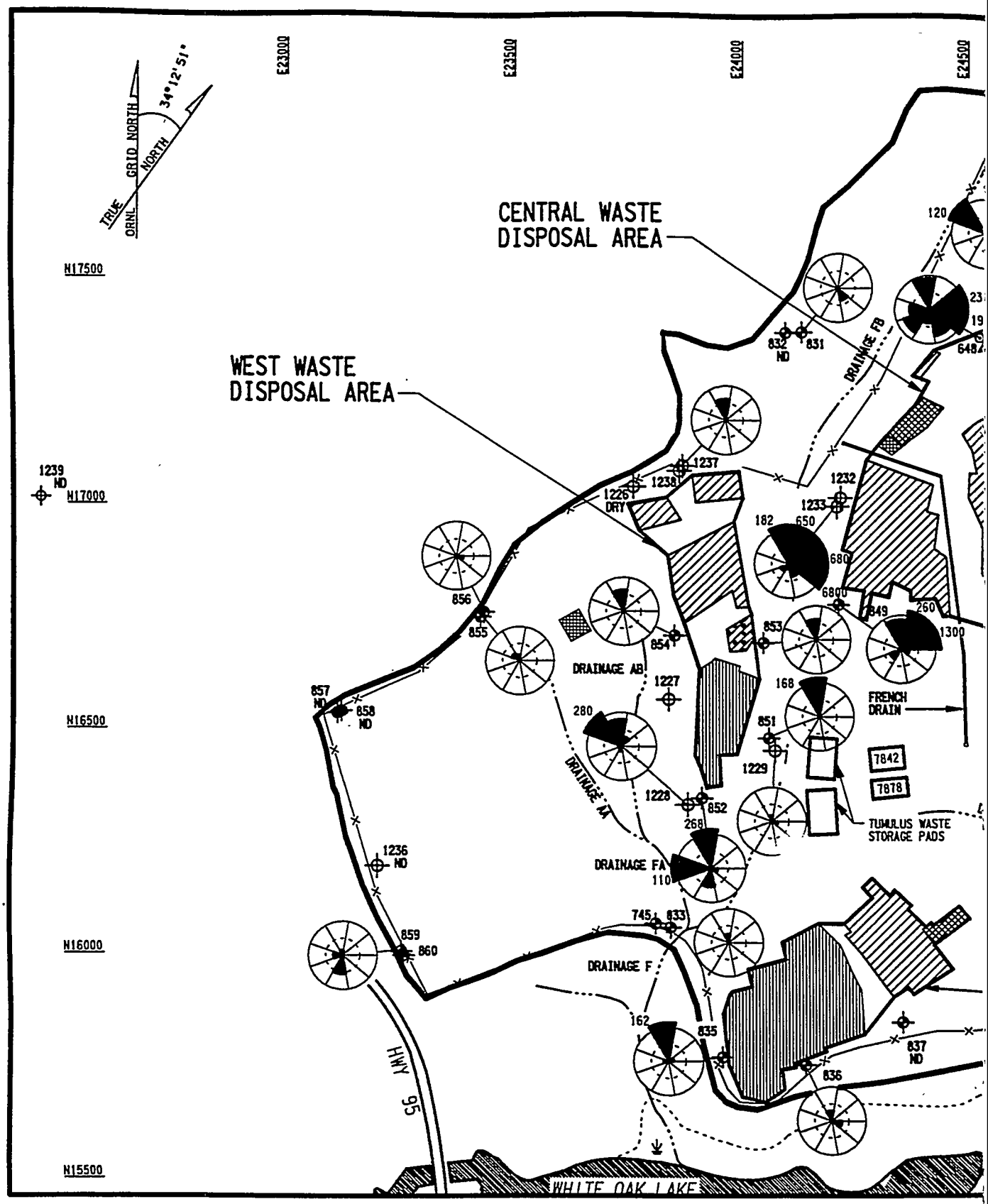



**Fig. 4C.21. Occurrence of transuranic radionuclides in groundwater samples at WAG 6.**




WAG6 06F286.DGN

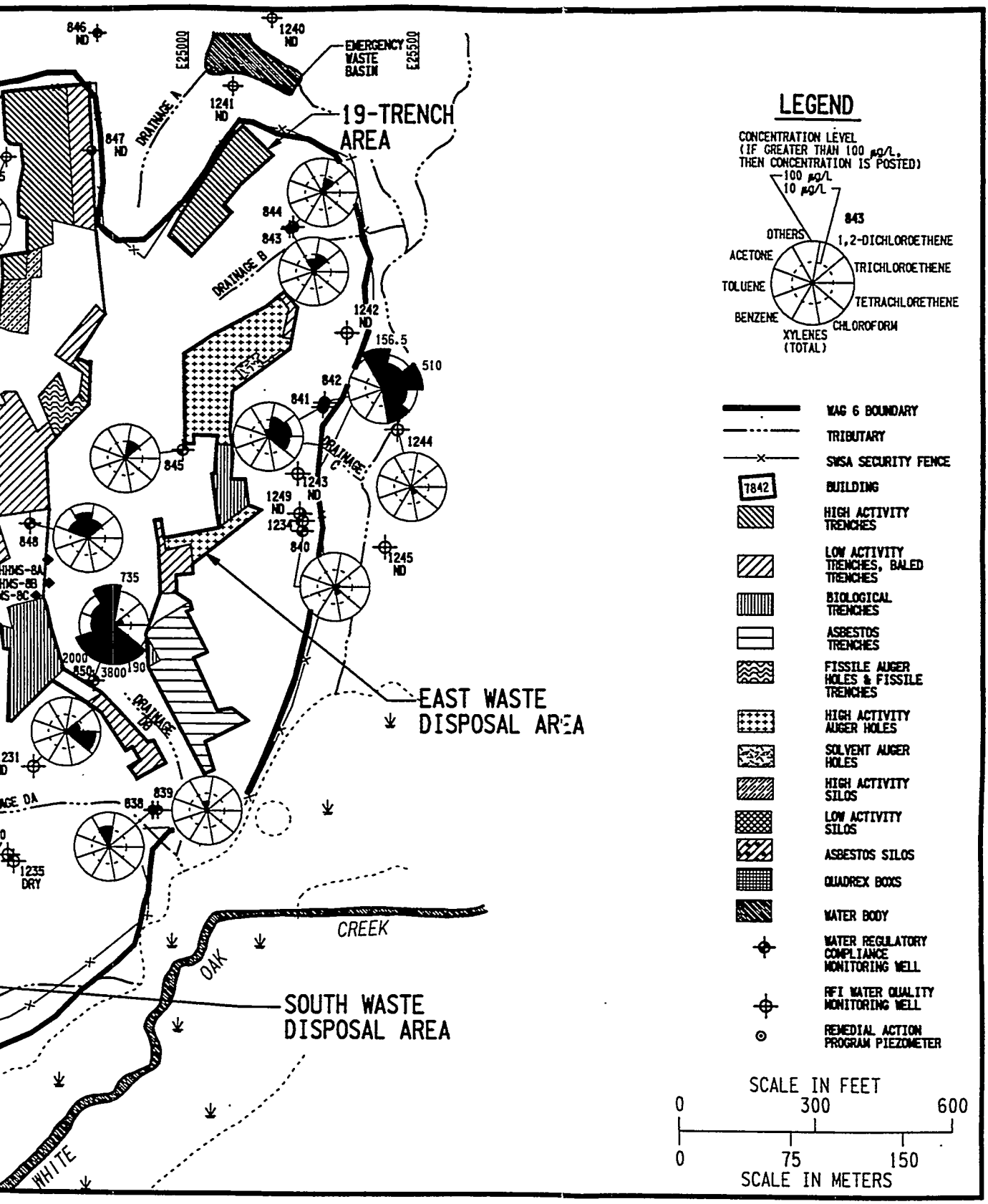
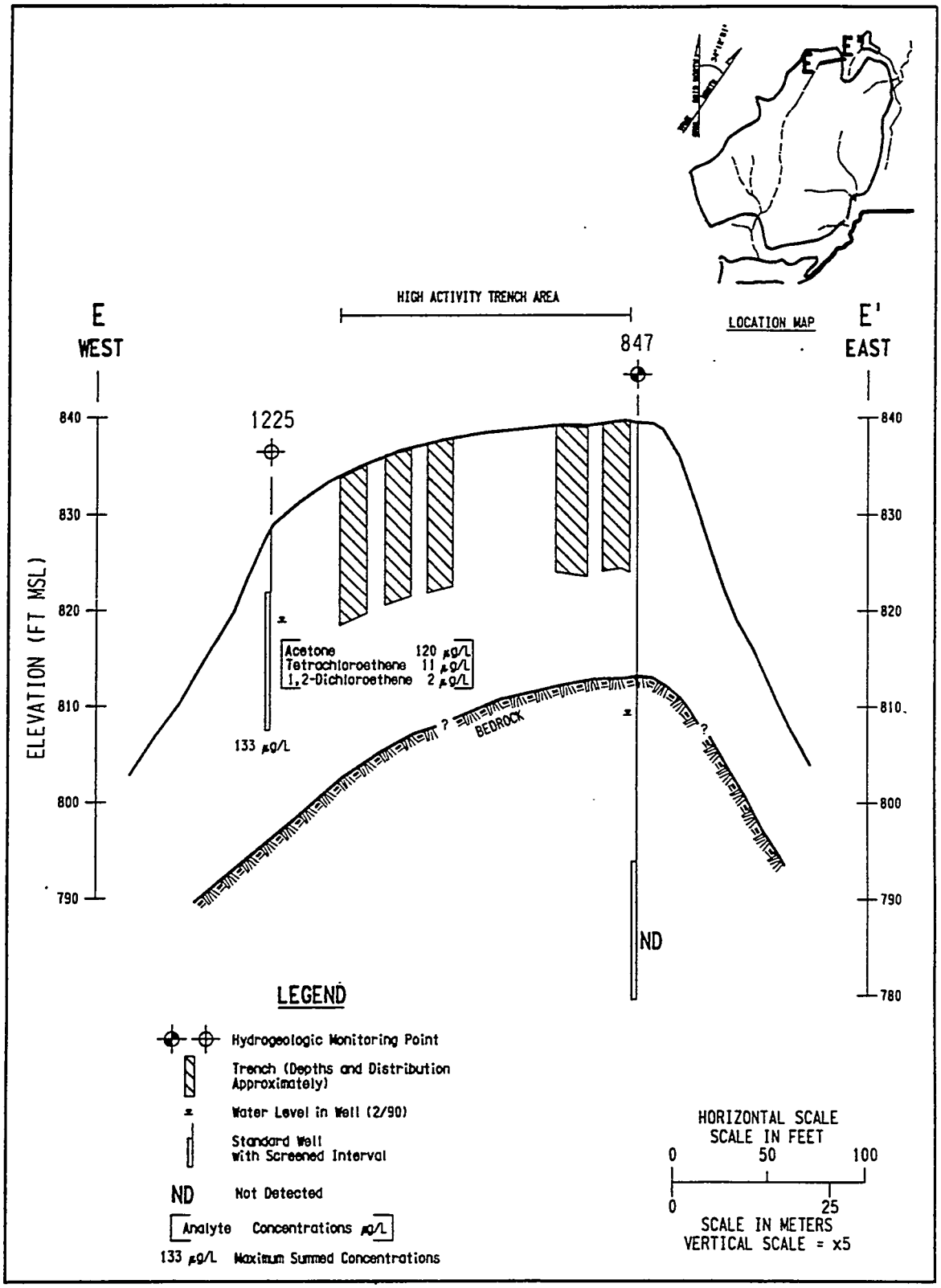
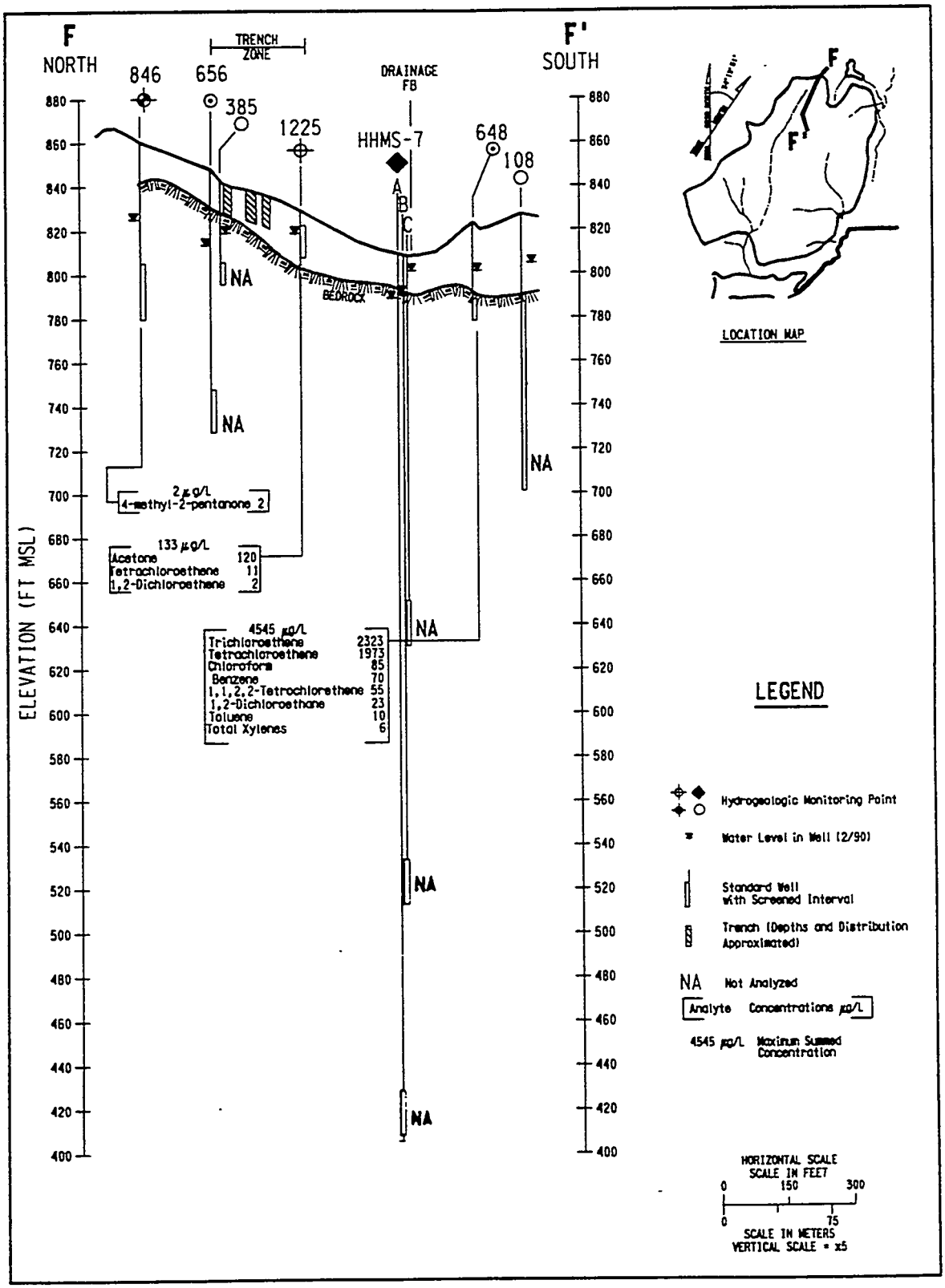



**Fig. 4C.22. Maximum volatile organic compound concentration distribution at WAG 6, June 1988 to June 1990.**



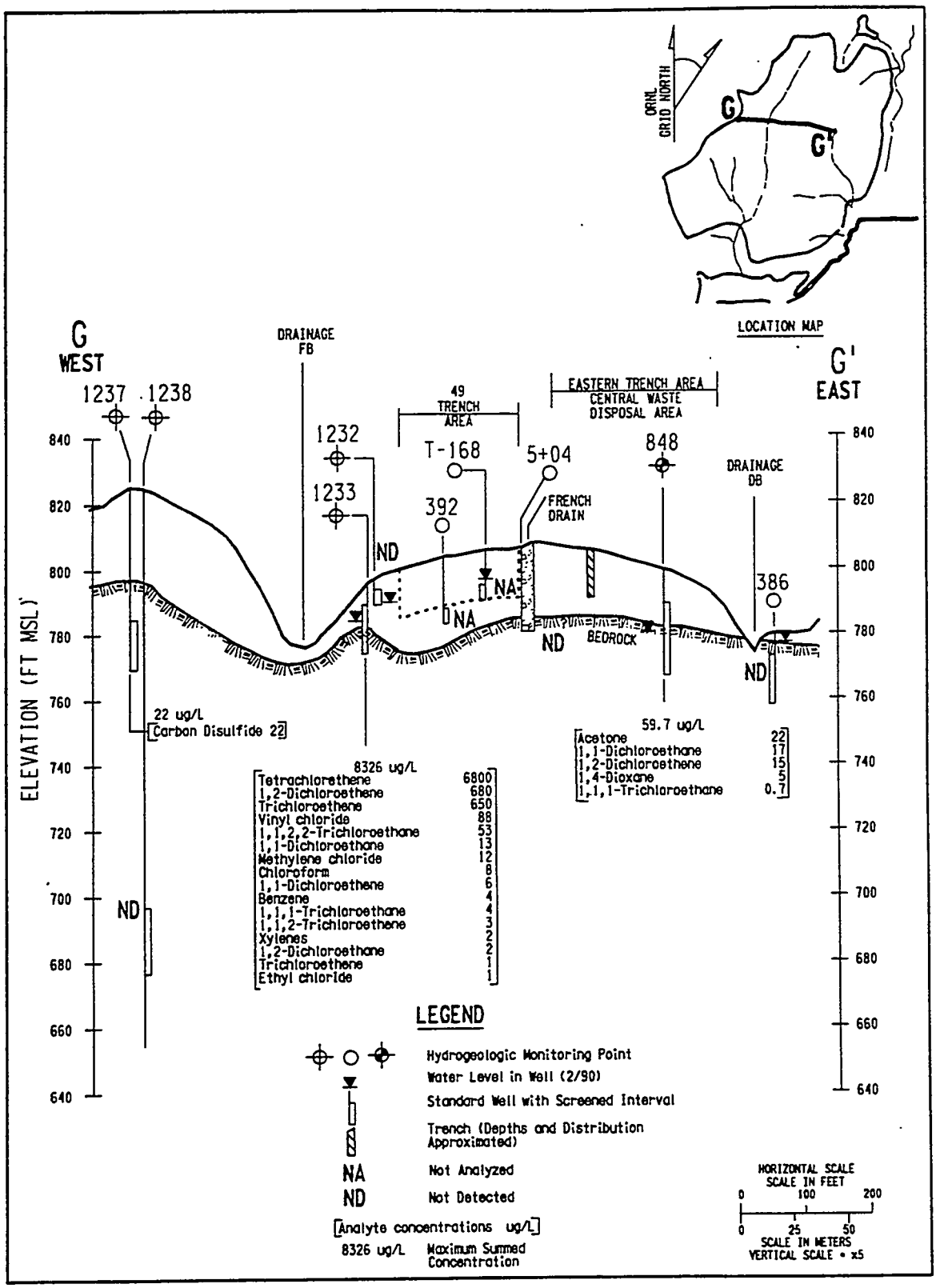

WAG6 06F226.DGN

**Fig. 4C.23. Maximum VOC concentrations in groundwater, cross section E-E'; high-activity trench area.**



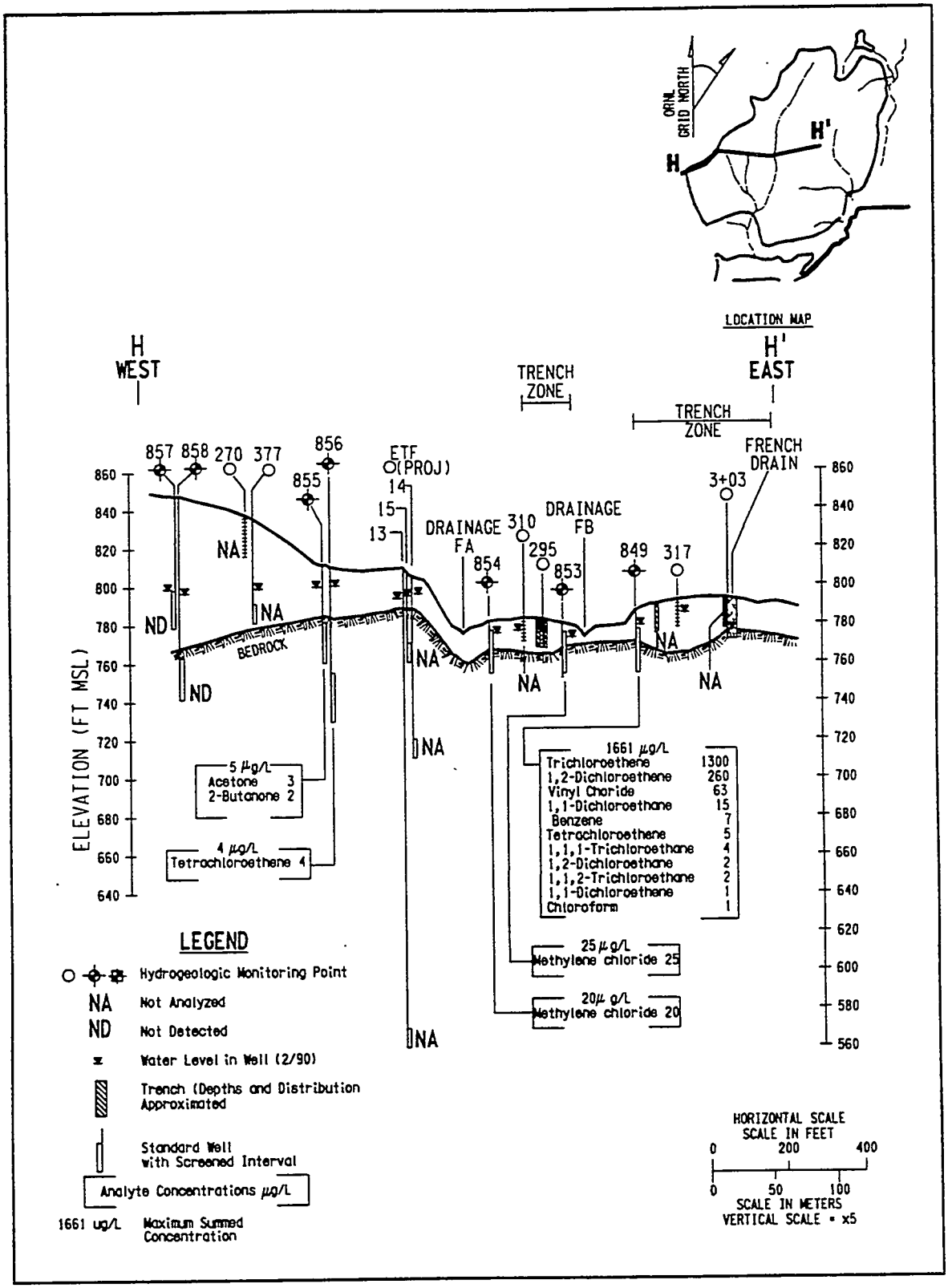

WAG6 06F297.DGN

**Fig. 4C.24. Maximum VOC concentrations in groundwater cross section F-F'; high-activity trench area.**



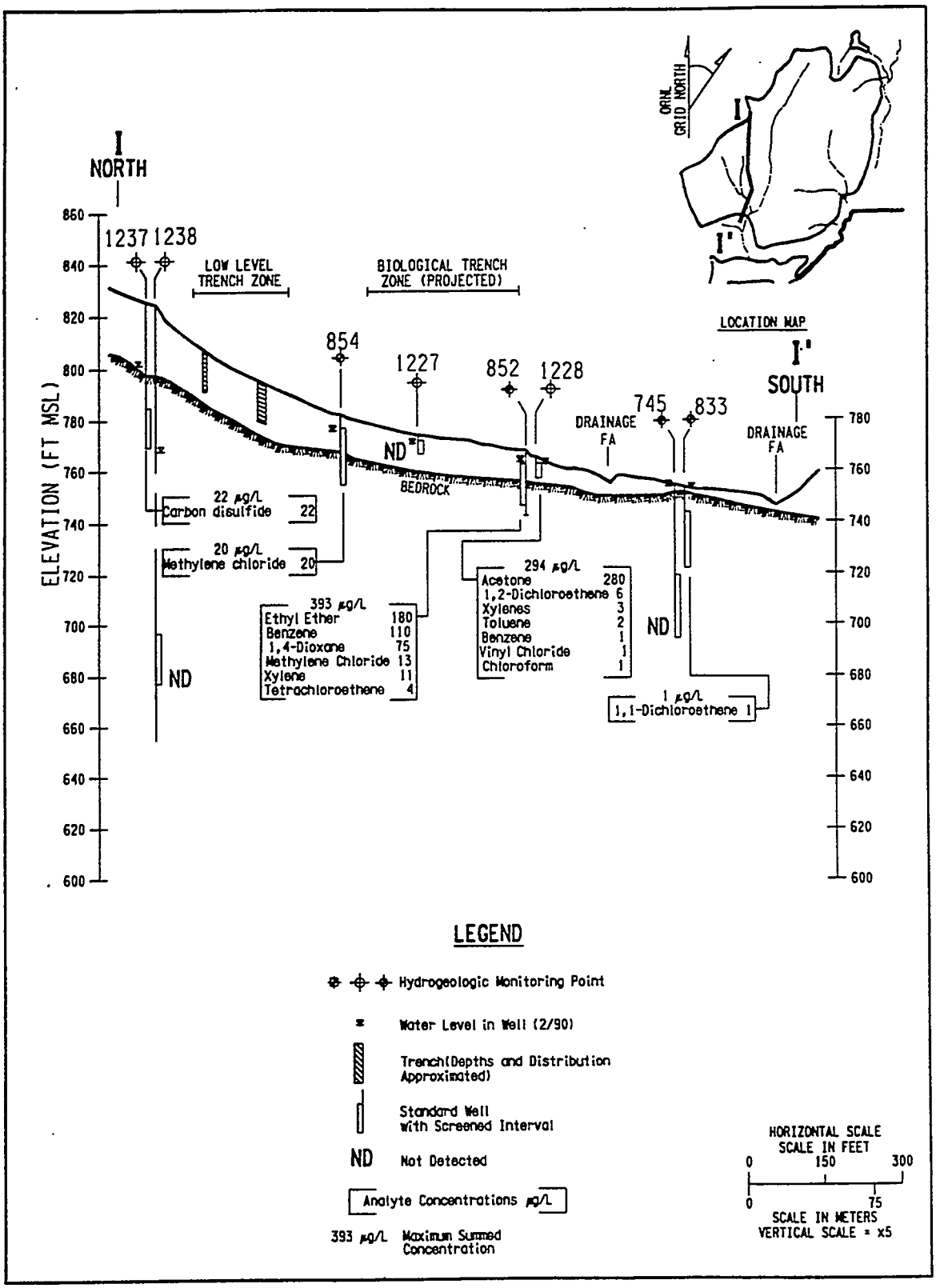

WAG6 06F180.DGN

**Fig. 4C.25. Maximum VOC concentrations in groundwater, cross section G-G'; central waste disposal area.**



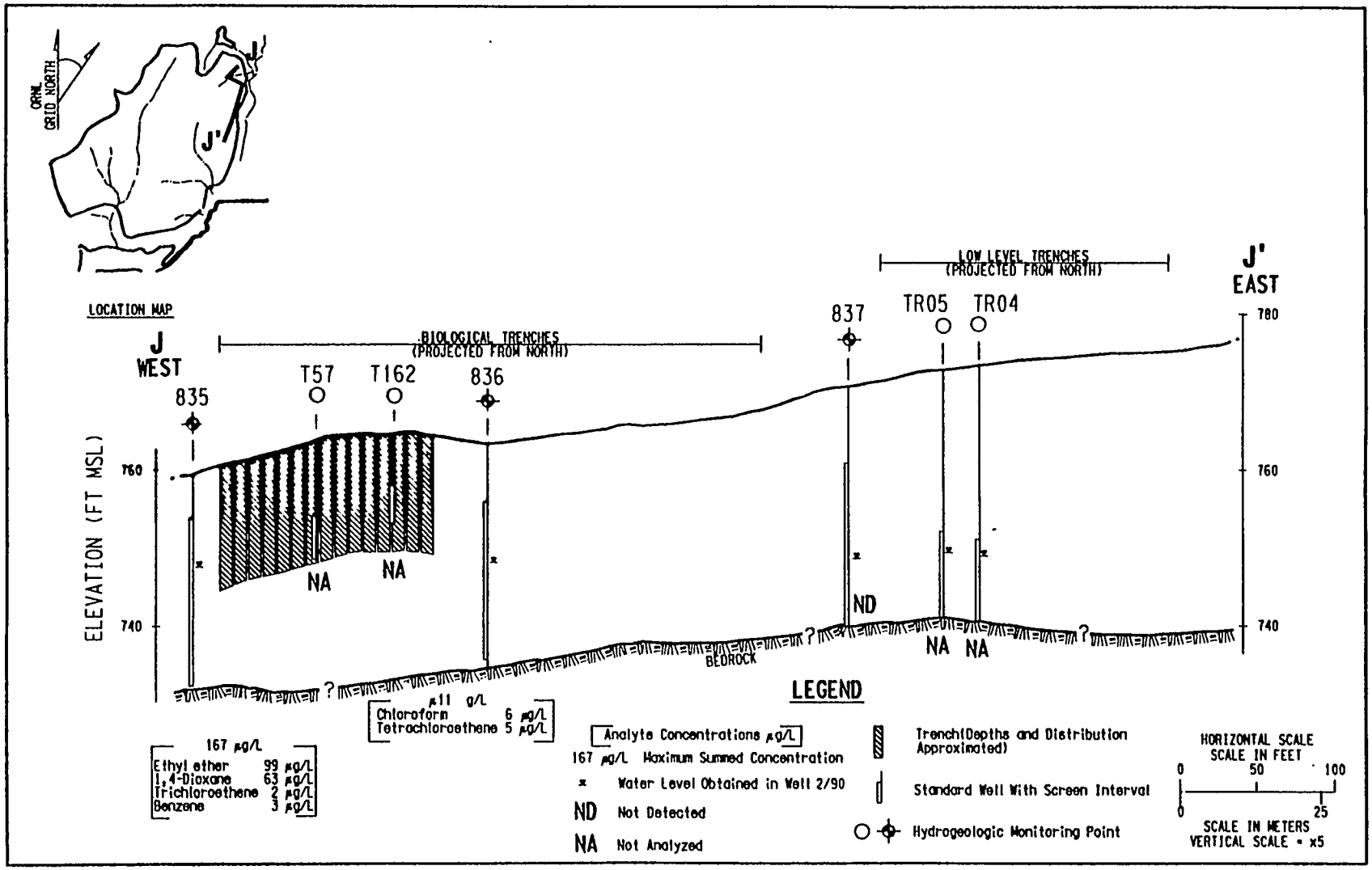

WAG6 06F282.DGN

**Fig. 4C.26. Maximum VOC concentrations in groundwater, cross section H-H'; west waste disposal area including the 49-Trench area.**



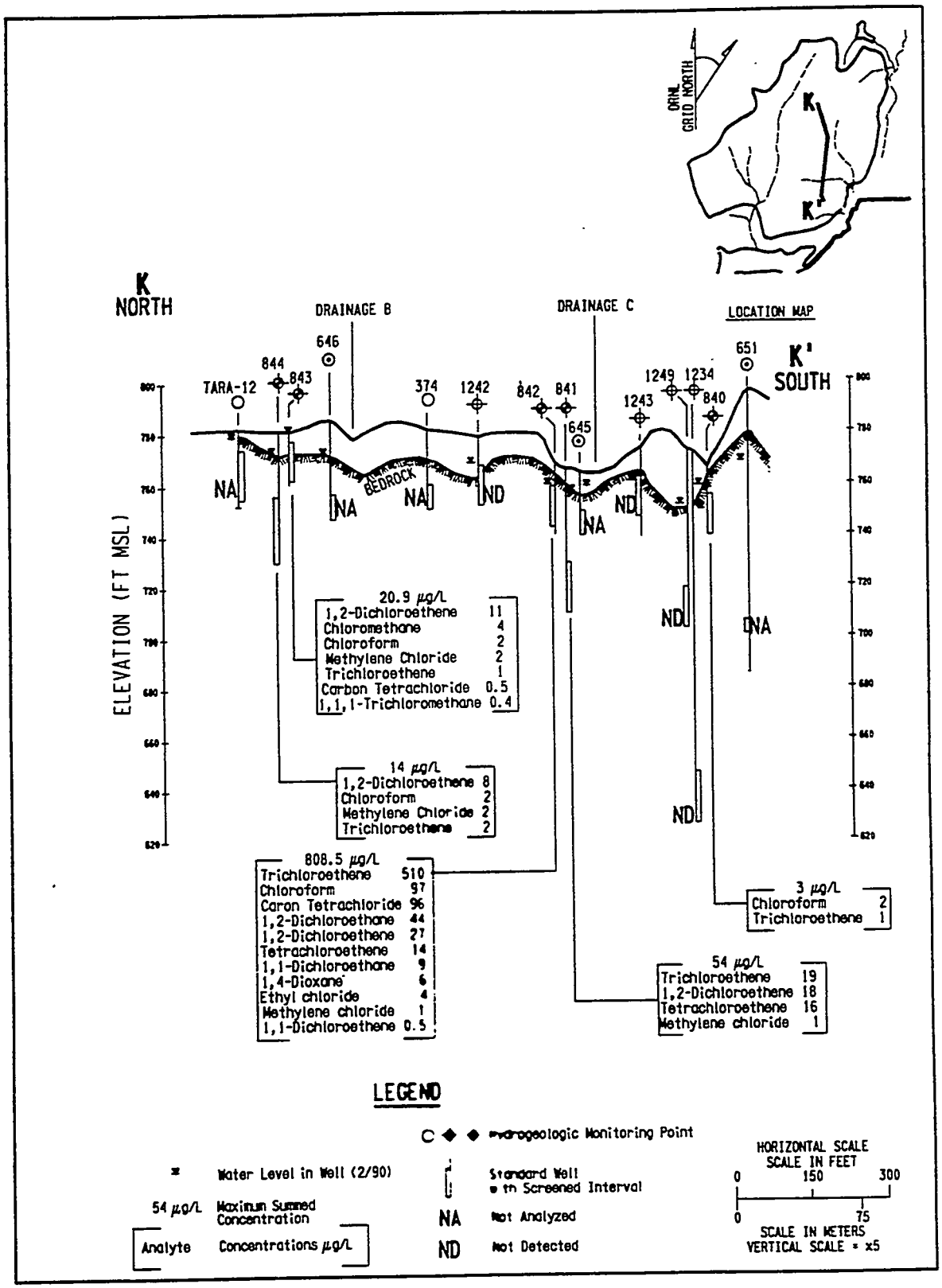

WAG6 06F283.DGN

**Fig. 4C.27. Maximum VOC concentrations in groundwater, cross section I-I'; west waste disposal area.**



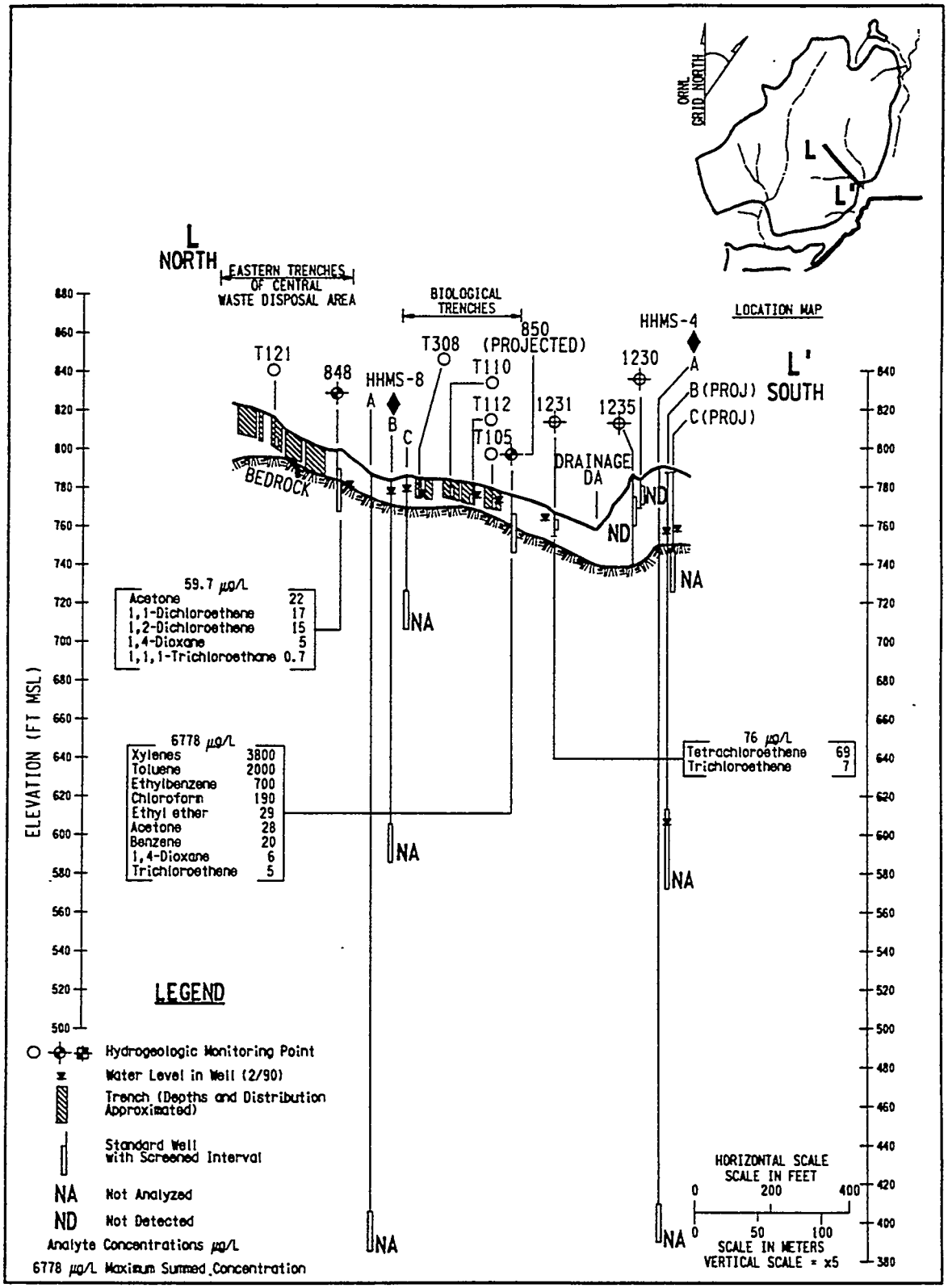

WAG6 06F290.DGN

**Fig. 4C.28. Maximum VOC concentrations in groundwater, cross section J-J'; southern waste disposal area.**



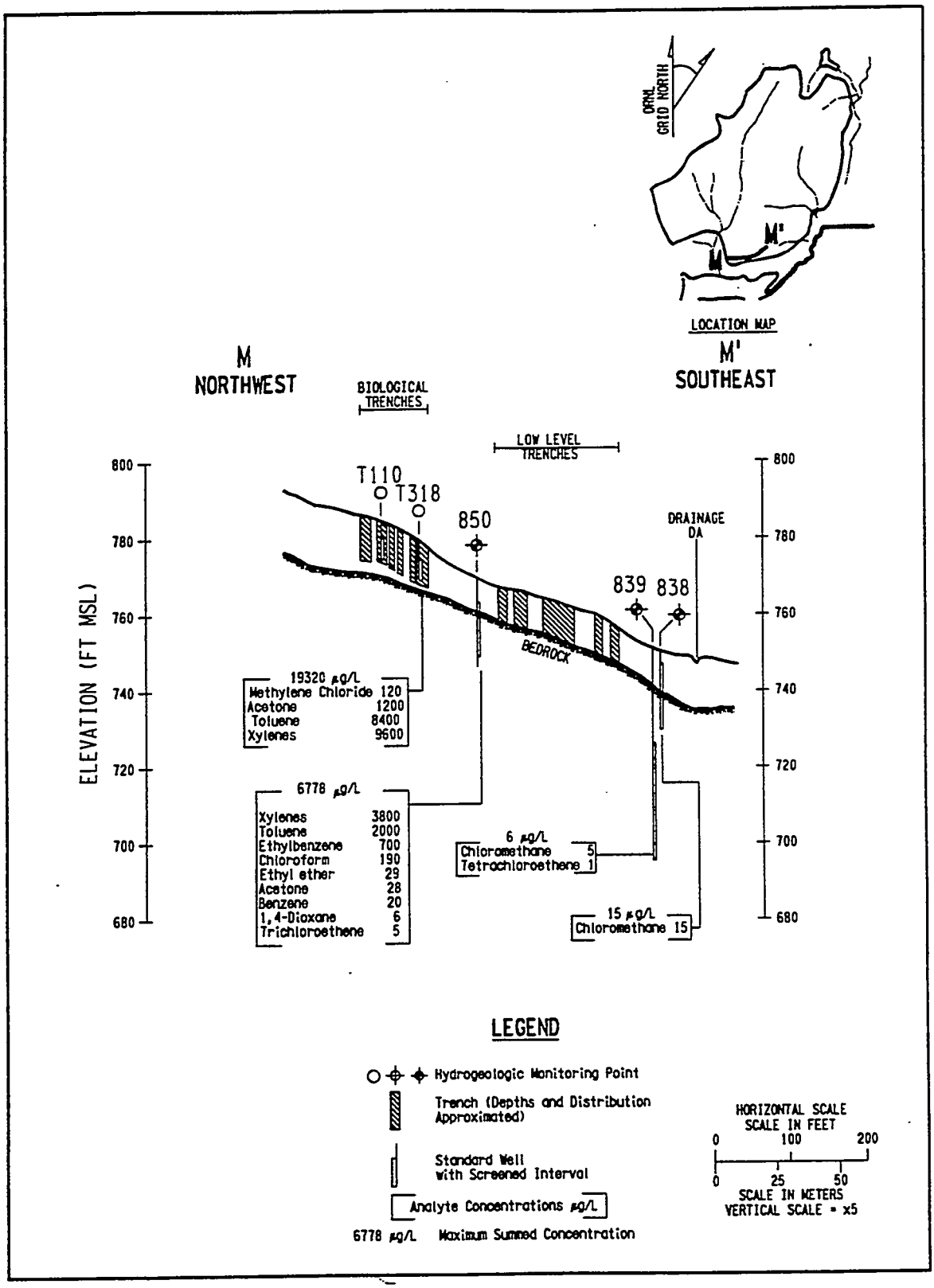

WAG6 06F284.DGN

**Fig. 4C.29. Maximum VOC concentrations in groundwater, cross section K-K'; 19-trench area and east waste disposal area.**



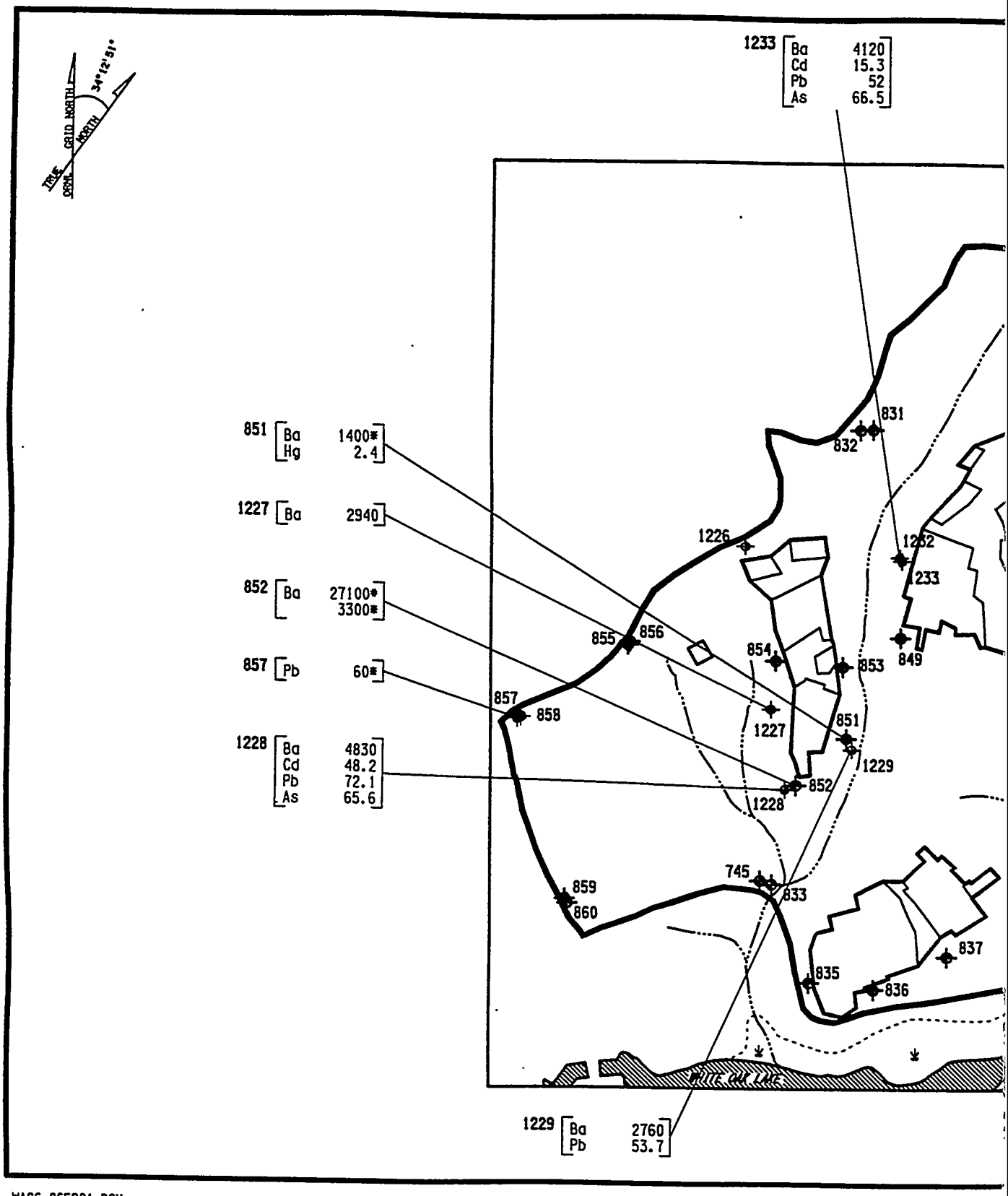

WAG6 06F285.DGN

**Fig. 4C.30. Maximum VOC concentrations in groundwater, cross section L-L'; eastern trenches of the central waste disposal area.**




WAG6 06F289.DGN

**Fig. 4C.31. Maximum VOC concentrations in groundwater, cross section M-M'; southeastern trenches of the central waste disposal area.**




WAG6 06F281.DGN

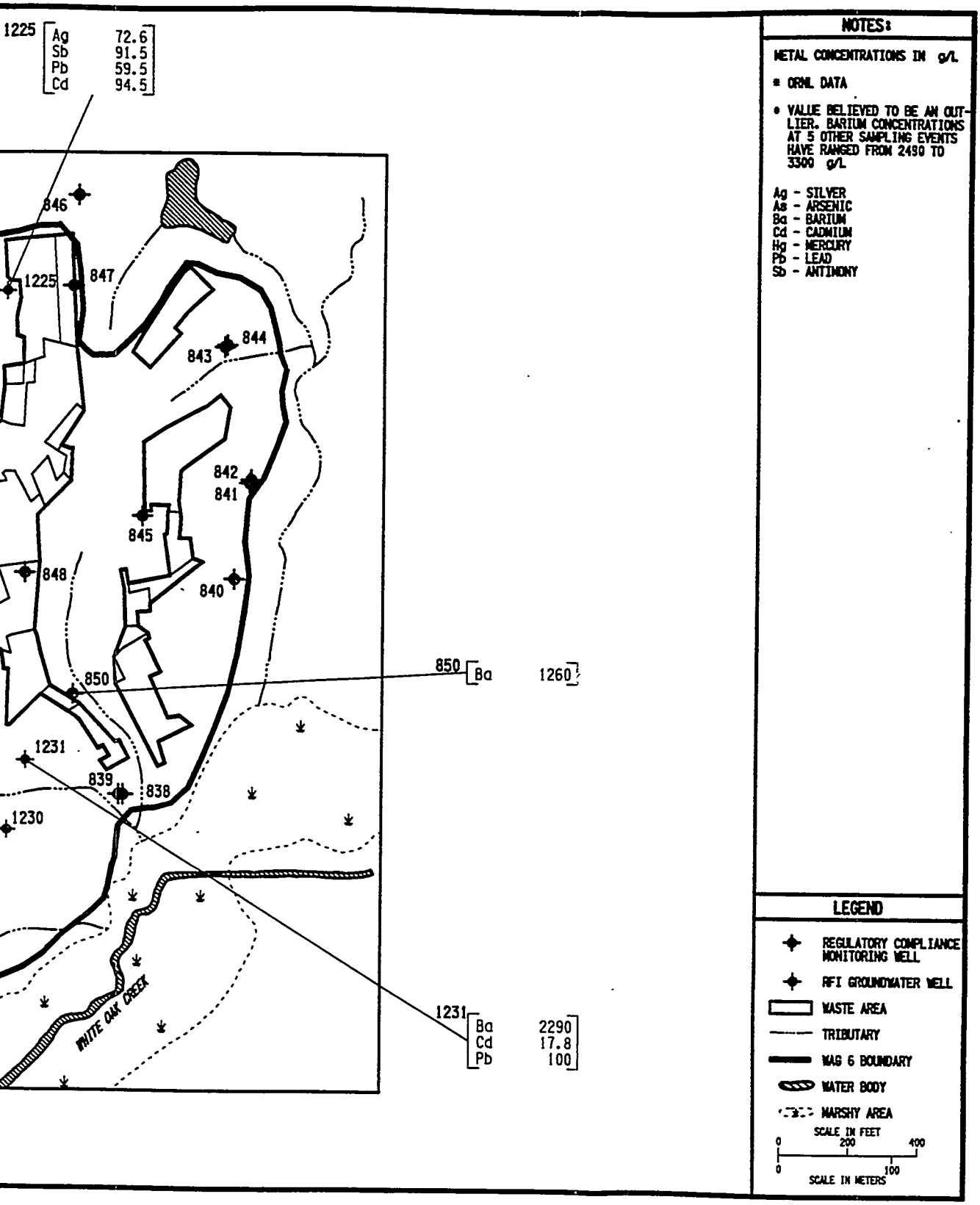
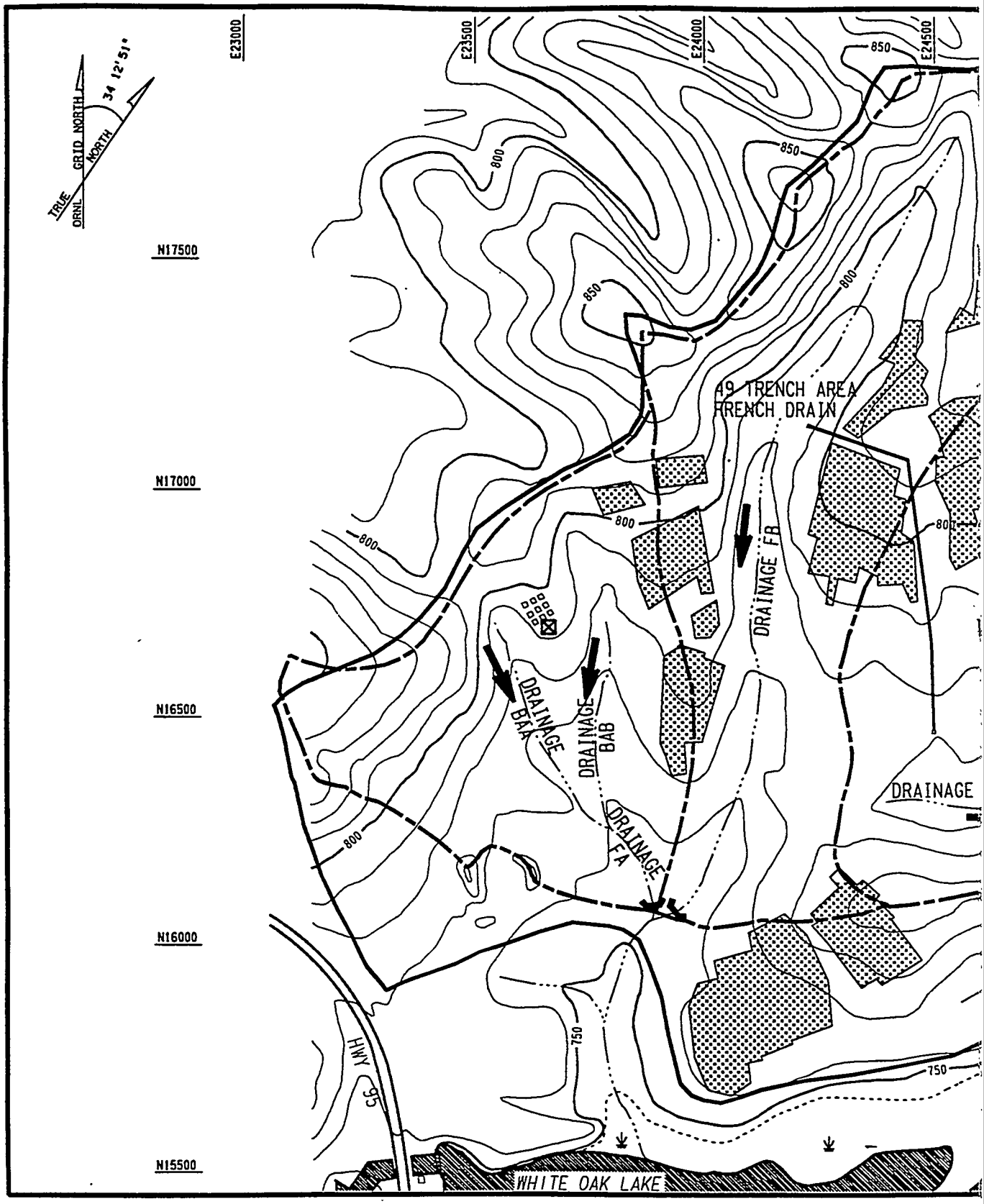



**Fig. 4C.32. Metals detected above MCLs in WAG 6 groundwater.**




WAG6 06F203.DGN

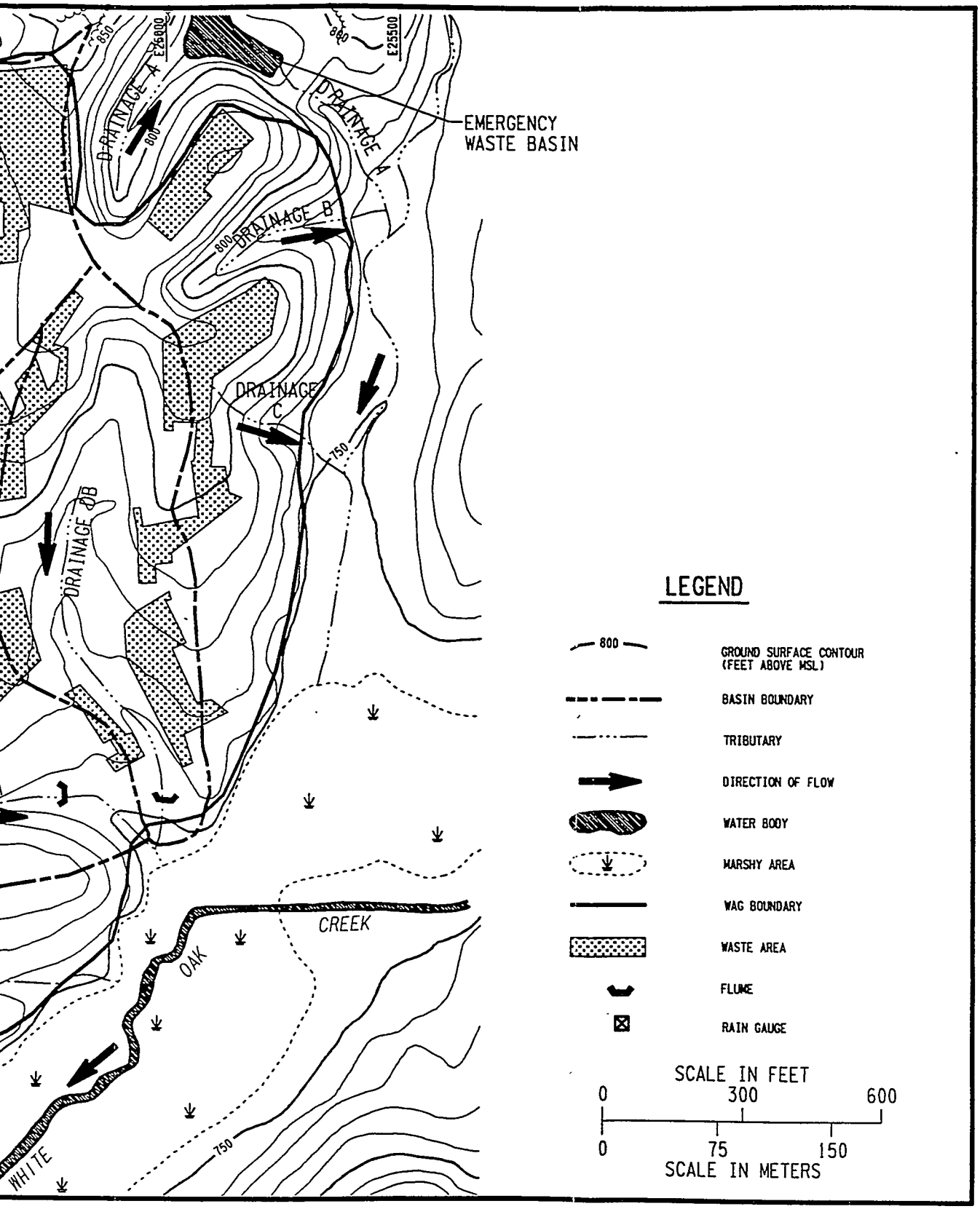
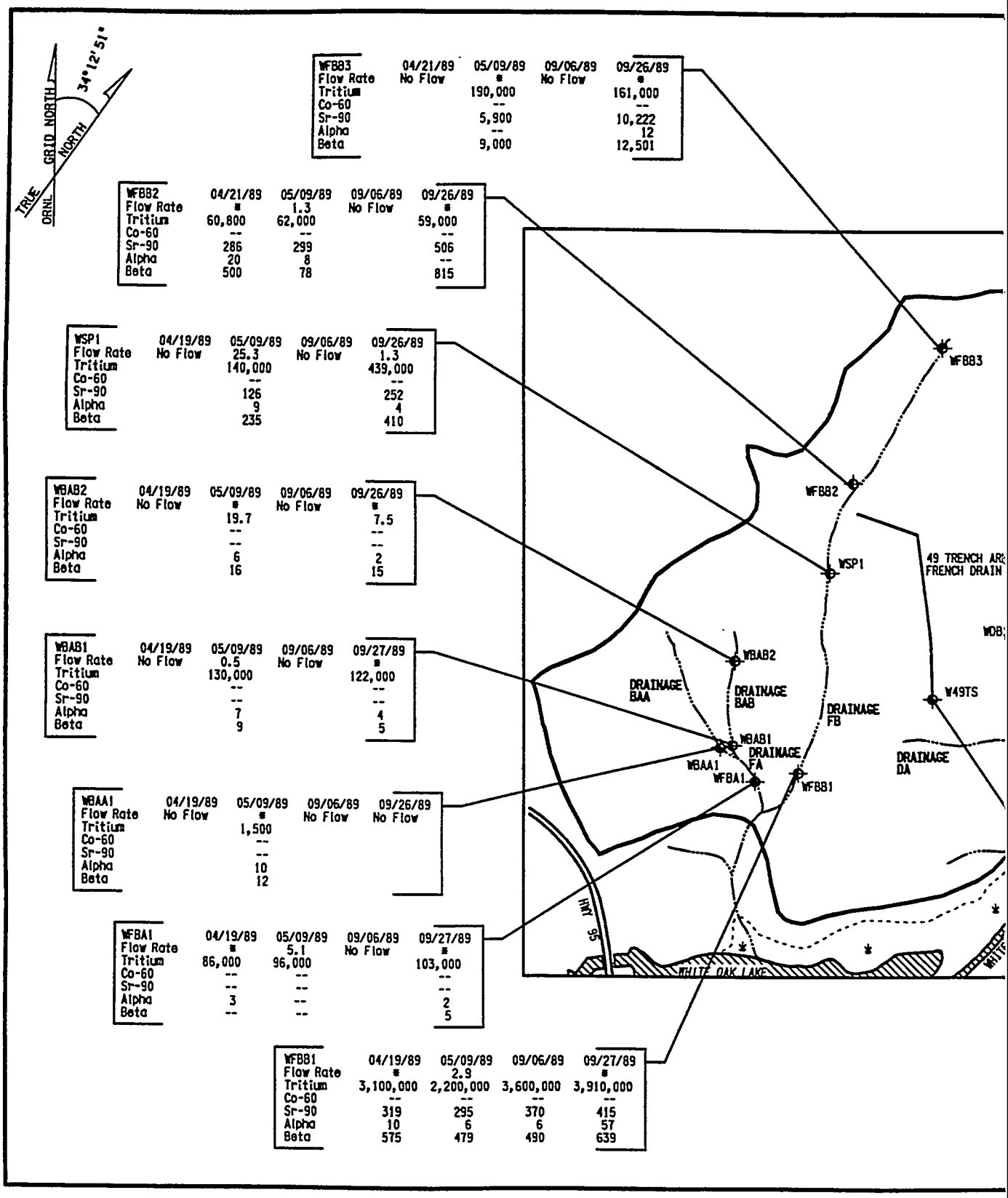



**Fig. 4C.33. Topography and drainage patterns at WAG 6 and adjacent areas.**




| WFB83 | 04/21/89 | 05/09/89 | 09/06/89 | 09/26/89 |
|---|---|---|---|---|
| Flow Rate | No Flow | * | No Flow | * |
| Tritium | | 190,000 | | 161,000 |
| Co-60 | | -- | | -- |
| Sr-90 | | 5,900 | | 10,222 |
| Alpha | | -- | | 12 |
| Beta | | 9,000 | | 12,501 |

| WFB82 | 04/21/89 | 05/09/89 | 09/06/89 | 09/26/89 |
|---|---|---|---|---|
| Flow Rate | * | 1.3 | No Flow | * |
| Tritium | 60,800 | 62,000 | | 59,000 |
| Co-60 | -- | -- | | -- |
| Sr-90 | 286 | 299 | | 506 |
| Alpha | 20 | 8 | | -- |
| Beta | 500 | 78 | | 815 |

| WSP1 | 04/19/89 | 05/09/89 | 09/06/89 | 09/26/89 |
|---|---|---|---|---|
| Flow Rate | No Flow | 25.3 | No Flow | 1.3 |
| Tritium | | 140,000 | | 439,000 |
| Co-60 | | -- | | -- |
| Sr-90 | | 126 | | 252 |
| Alpha | | 9 | | 4 |
| Beta | | 235 | | 410 |

| WBAB2 | 04/19/89 | 05/09/89 | 09/06/89 | 09/26/89 |
|---|---|---|---|---|
| Flow Rate | No Flow | * | No Flow | * |
| Tritium | | 19.7 | | 7.5 |
| Co-60 | | -- | | -- |
| Sr-90 | | -- | | -- |
| Alpha | | 6 | | 2 |
| Beta | | 16 | | 15 |

| WBAB1 | 04/19/89 | 05/09/89 | 09/06/89 | 09/27/89 |
|---|---|---|---|---|
| Flow Rate | No Flow | 0.5 | No Flow | * |
| Tritium | | 130,000 | | 122,000 |
| Co-60 | | -- | | -- |
| Sr-90 | | -- | | -- |
| Alpha | | 7 | | 4 |
| Beta | | 9 | | 5 |

| WBAA1 | 04/19/89 | 05/09/89 | 09/06/89 | 09/26/89 |
|---|---|---|---|---|
| Flow Rate | No Flow | * | No Flow | No Flow |
| Tritium | | 1,500 | | |
| Co-60 | | -- | | |
| Sr-90 | | -- | | |
| Alpha | | 10 | | |
| Beta | | 12 | | |

| WFBA1 | 04/19/89 | 05/09/89 | 09/06/89 | 09/27/89 |
|---|---|---|---|---|
| Flow Rate | * | 5.1 | No Flow | * |
| Tritium | 86,000 | 96,000 | | 103,000 |
| Co-60 | -- | -- | | -- |
| Sr-90 | -- | -- | | -- |
| Alpha | 3 | -- | | 2 |
| Beta | -- | -- | | 5 |

| WFB81 | 04/19/89 | 05/09/89 | 09/06/89 | 09/27/89 |
|---|---|---|---|---|
| Flow Rate | * | 2.9 | | * |
| Tritium | 3,100,000 | 2,200,000 | 3,600,000 | 3,910,000 |
| Co-60 | -- | -- | -- | -- |
| Sr-90 | 319 | 295 | 370 | 415 |
| Alpha | 10 | 6 | 6 | 57 |
| Beta | 575 | 479 | 490 | 639 |

WAG6 06F236.DGN

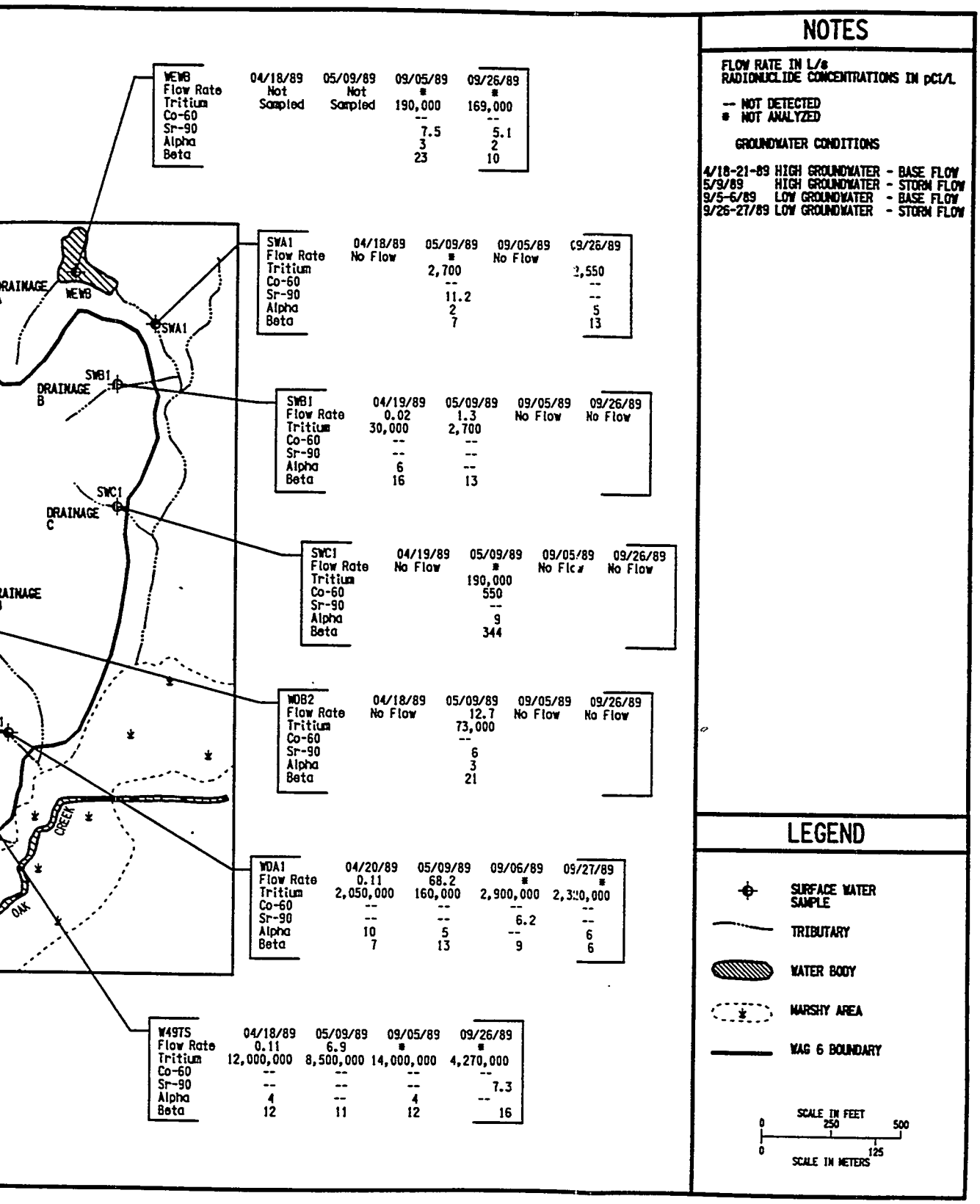
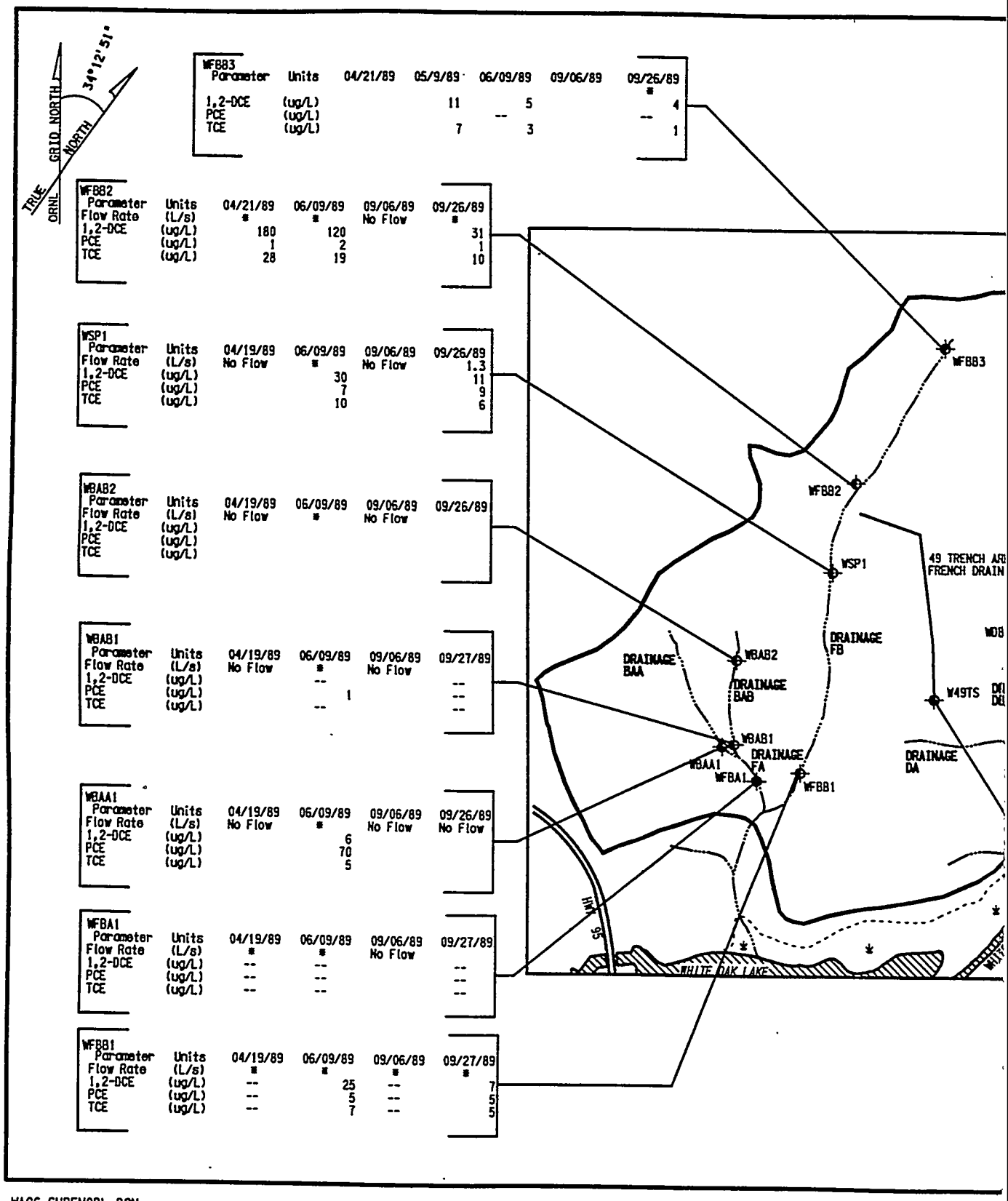



**Fig. 4C.34. Radionuclides detected in WAG 6 surface water.**




| WFB83 Parameter | Units | 04/21/89 | 05/9/89 | 06/09/89 | 09/06/89 | 09/26/89 |
|---|---|---|---|---|---|---|
| | | | | | | * |
| 1,2-DCE | (ug/L) | | 11 | 5 | | 4 |
| PCE | (ug/L) | | | -- | | -- |
| TCE | (ug/L) | | 7 | 3 | | 1 |

| WFB82 Parameter | Units | 04/21/89 | 06/09/89 | 09/06/89 | 09/26/89 |
|---|---|---|---|---|---|
| Flow Rate | (L/s) | * | * | No Flow | * |
| 1,2-DCE | (ug/L) | 180 | 120 | | 31 |
| PCE | (ug/L) | 1 | 2 | | 1 |
| TCE | (ug/L) | 28 | 19 | | 10 |

| WSP1 Parameter | Units | 04/19/89 | 06/09/89 | 09/06/89 | 09/26/89 |
|---|---|---|---|---|---|
| Flow Rate | (L/s) | No Flow | * | No Flow | 1.3 |
| 1,2-DCE | (ug/L) | | 30 | | 11 |
| PCE | (ug/L) | | 7 | | 9 |
| TCE | (ug/L) | | 10 | | 6 |

| WBAB2 Parameter | Units | 04/19/89 | 06/09/89 | 09/06/89 | 09/26/89 |
|---|---|---|---|---|---|
| Flow Rate | (L/s) | No Flow | * | No Flow | |
| 1,2-DCE | (ug/L) | | | | |
| PCE | (ug/L) | | | | |
| TCE | (ug/L) | | | | |

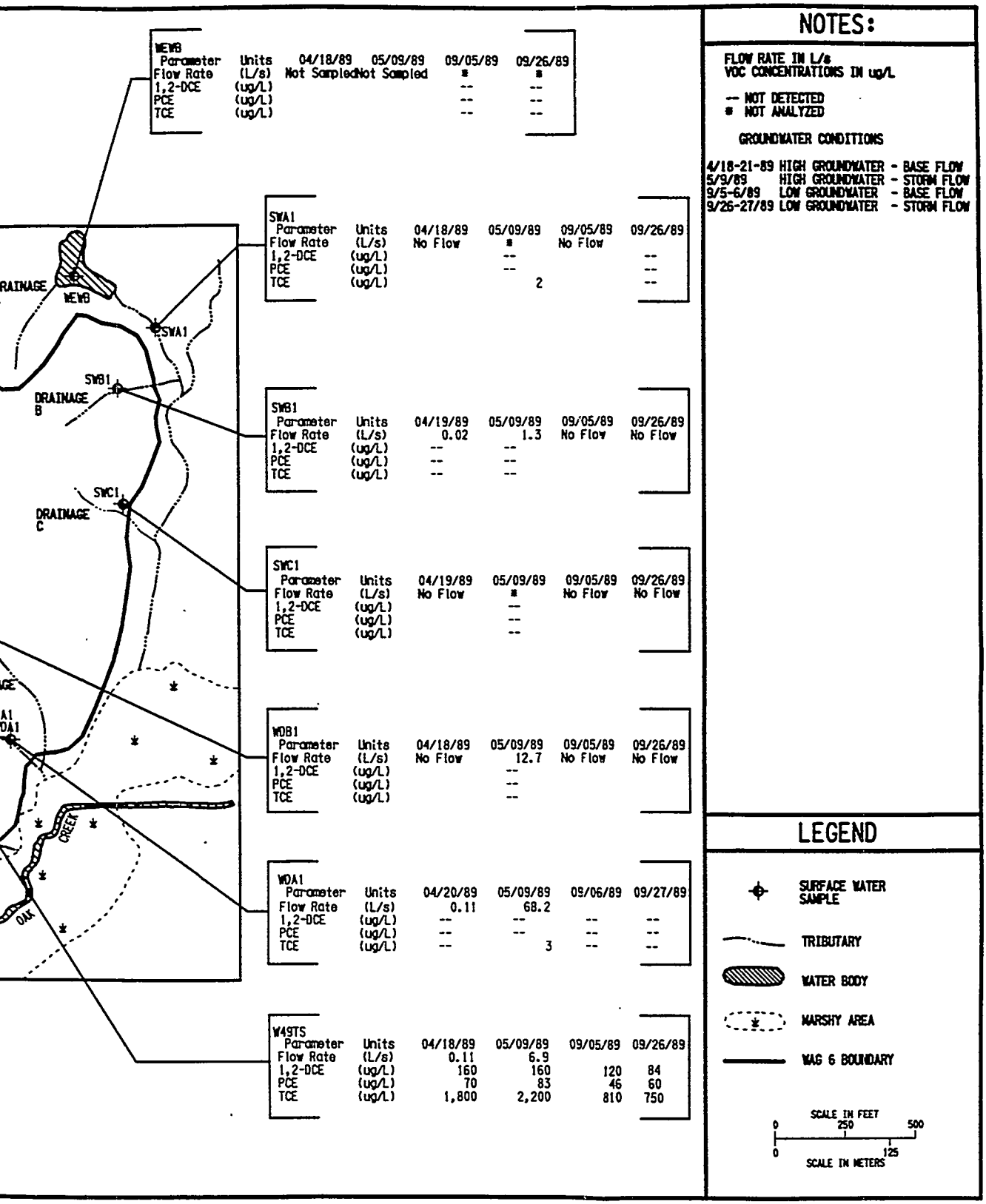
| WBAB1 Parameter | Units | 04/19/89 | 06/09/89 | 09/06/89 | 09/27/89 |
|---|---|---|---|---|---|
| Flow Rate | (L/s) | No Flow | * | No Flow | |
| 1,2-DCE | (ug/L) | | -- | | -- |
| PCE | (ug/L) | | 1 | | -- |
| TCE | (ug/L) | | -- | | -- |

| WBAA1 Parameter | Units | 04/19/89 | 06/09/89 | 09/06/89 | 09/26/89 |
|---|---|---|---|---|---|
| Flow Rate | (L/s) | No Flow | * | No Flow | No Flow |
| 1,2-DCE | (ug/L) | | 6 | | |
| PCE | (ug/L) | | 70 | | |
| TCE | (ug/L) | | 5 | | |

| WFBA1 Parameter | Units | 04/19/89 | 06/09/89 | 09/06/89 | 09/27/89 |
|---|---|---|---|---|---|
| Flow Rate | (L/s) | * | * | No Flow | |
| 1,2-DCE | (ug/L) | -- | -- | | -- |
| PCE | (ug/L) | -- | -- | | -- |
| TCE | (ug/L) | -- | -- | | -- |

| WFB81 Parameter | Units | 04/19/89 | 06/09/89 | 09/06/89 | 09/27/89 |
|---|---|---|---|---|---|
| Flow Rate | (L/s) | * | * | * | * |
| 1,2-DCE | (ug/L) | -- | 25 | -- | 7 |
| PCE | (ug/L) | -- | 5 | -- | 5 |
| TCE | (ug/L) | -- | 7 | -- | 5 |

WAG6 SURFMODL.DGN




WEW8

| Parameter | Units | 04/18/89 | 05/09/89 | 09/05/89 | 09/26/89 |
|---|---|---|---|---|---|
| Flow Rate | (L/s) | Not Sampled | Not Sampled | * | * |
| 1,2-DCE | (ug/L) | | | -- | -- |
| PCE | (ug/L) | | | -- | -- |
| TCE | (ug/L) | | | -- | -- |

SWA1

| Parameter | Units | 04/18/89 | 05/09/89 | 09/05/89 | 09/26/89 |
|---|---|---|---|---|---|
| Flow Rate | (L/s) | No Flow | * | No Flow | |
| 1,2-DCE | (ug/L) | | -- | | -- |
| PCE | (ug/L) | | -- | | -- |
| TCE | (ug/L) | | 2 | | -- |

SWB1

| Parameter | Units | 04/19/89 | 05/09/89 | 09/05/89 | 09/26/89 |
|---|---|---|---|---|---|
| Flow Rate | (L/s) | 0.02 | 1.3 | No Flow | No Flow |
| 1,2-DCE | (ug/L) | -- | -- | | |
| PCE | (ug/L) | -- | -- | | |
| TCE | (ug/L) | -- | -- | | |

SWC1

| Parameter | Units | 04/19/89 | 05/09/89 | 09/05/89 | 09/26/89 |
|---|---|---|---|---|---|
| Flow Rate | (L/s) | No Flow | * | No Flow | No Flow |
| 1,2-DCE | (ug/L) | | -- | | |
| PCE | (ug/L) | | -- | | |
| TCE | (ug/L) | | -- | | |

WOB1

| Parameter | Units | 04/18/89 | 05/09/89 | 09/05/89 | 09/26/89 |
|---|---|---|---|---|---|
| Flow Rate | (L/s) | No Flow | 12.7 | No Flow | No Flow |
| 1,2-DCE | (ug/L) | | -- | | |
| PCE | (ug/L) | | -- | | |
| TCE | (ug/L) | | -- | | |

WOA1

| Parameter | Units | 04/20/89 | 05/09/89 | 09/06/89 | 09/27/89 |
|---|---|---|---|---|---|
| Flow Rate | (L/s) | 0.11 | 68.2 | | |
| 1,2-DCE | (ug/L) | -- | -- | -- | -- |
| PCE | (ug/L) | -- | -- | -- | -- |
| TCE | (ug/L) | -- | 3 | -- | -- |

W49TS

| Parameter | Units | 04/18/89 | 05/09/89 | 09/05/89 | 09/26/89 |
|---|---|---|---|---|---|
| Flow Rate | (L/s) | 0.11 | 6.9 | | |
| 1,2-DCE | (ug/L) | 160 | 160 | 120 | 84 |
| PCE | (ug/L) | 70 | 83 | 46 | 60 |
| TCE | (ug/L) | 1,800 | 2,200 | 810 | 750 |

**Fig. 4C.35. VOCs detected in WAG 6 surface water on selected dates.**

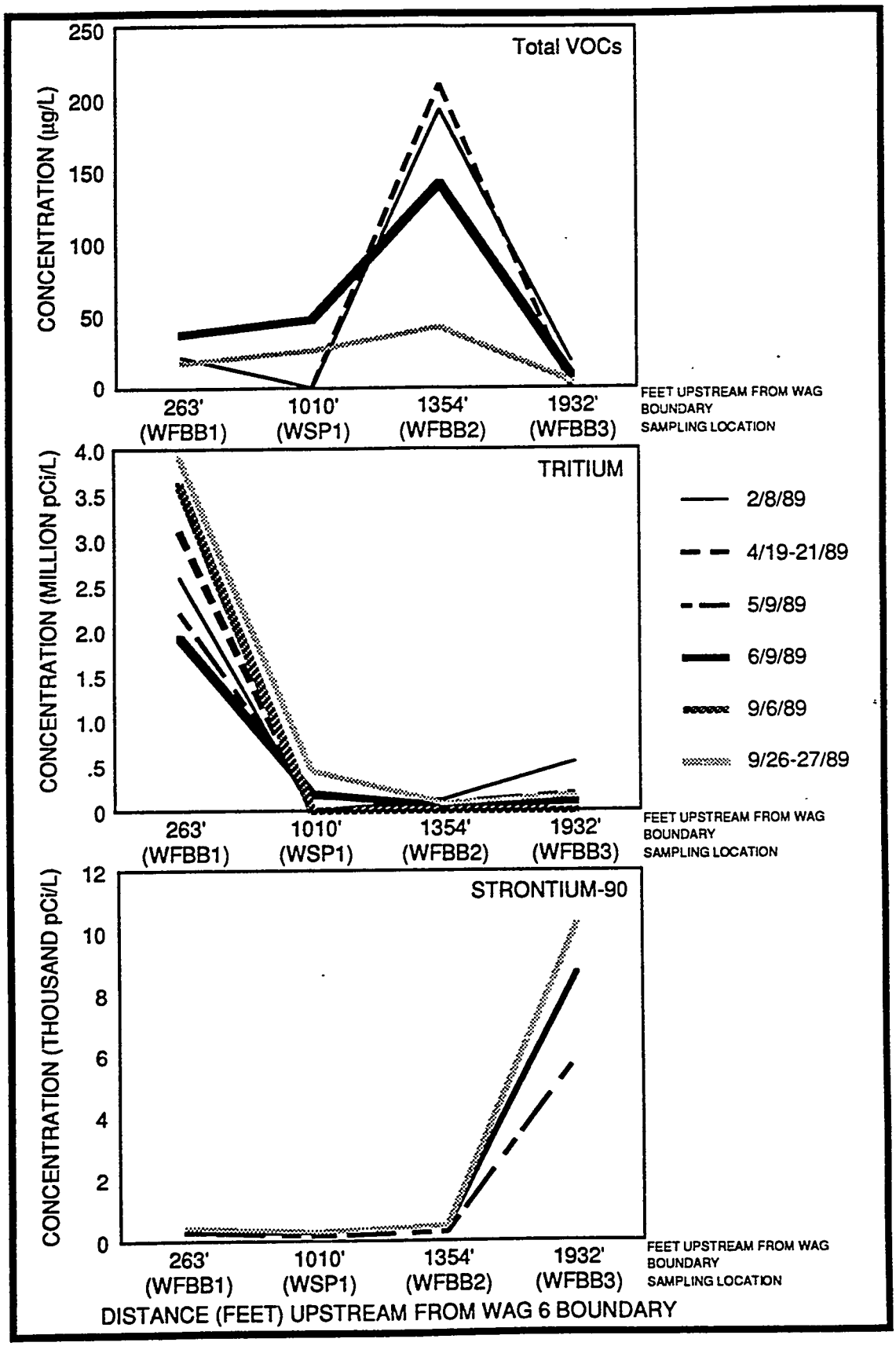
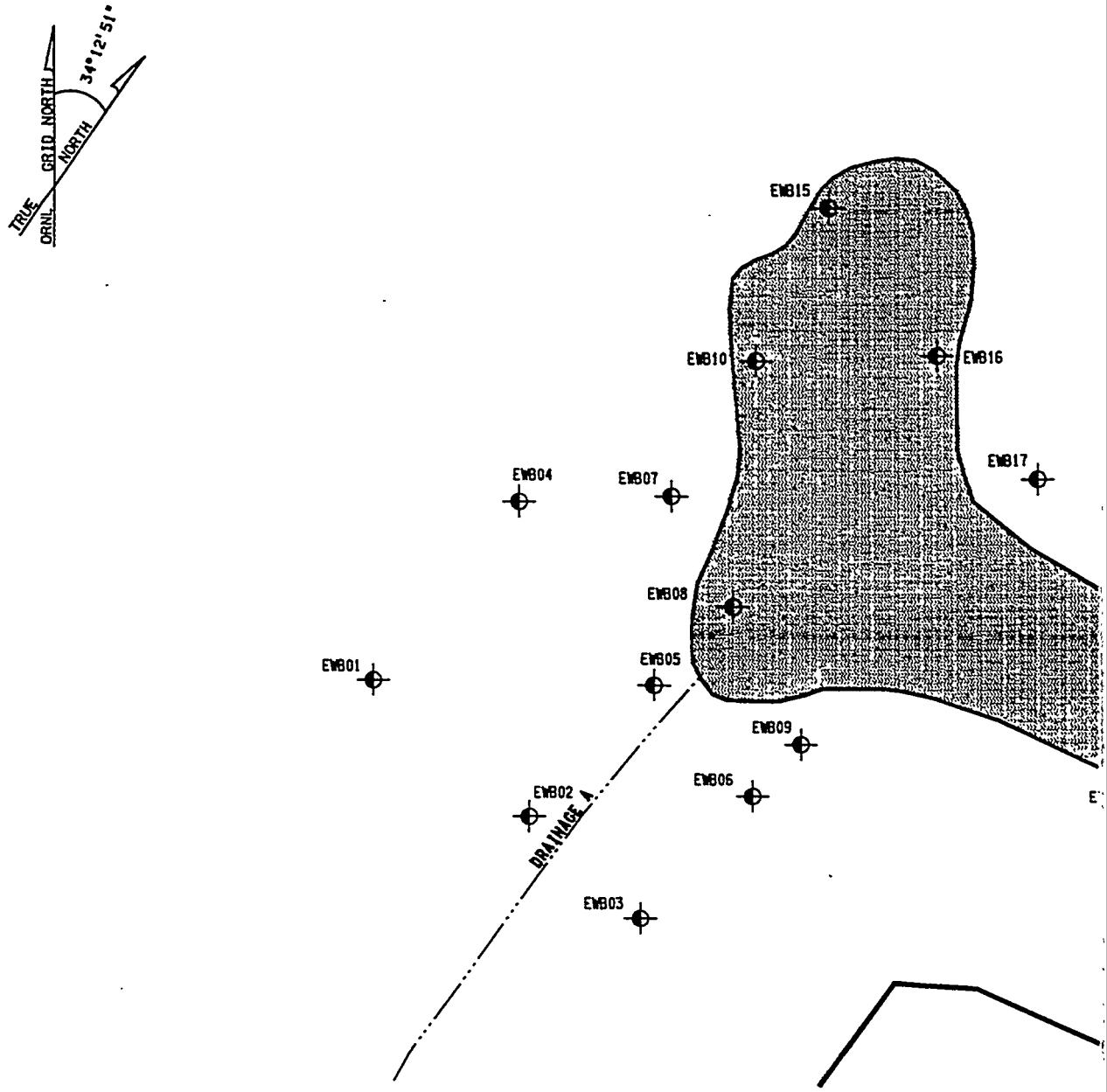


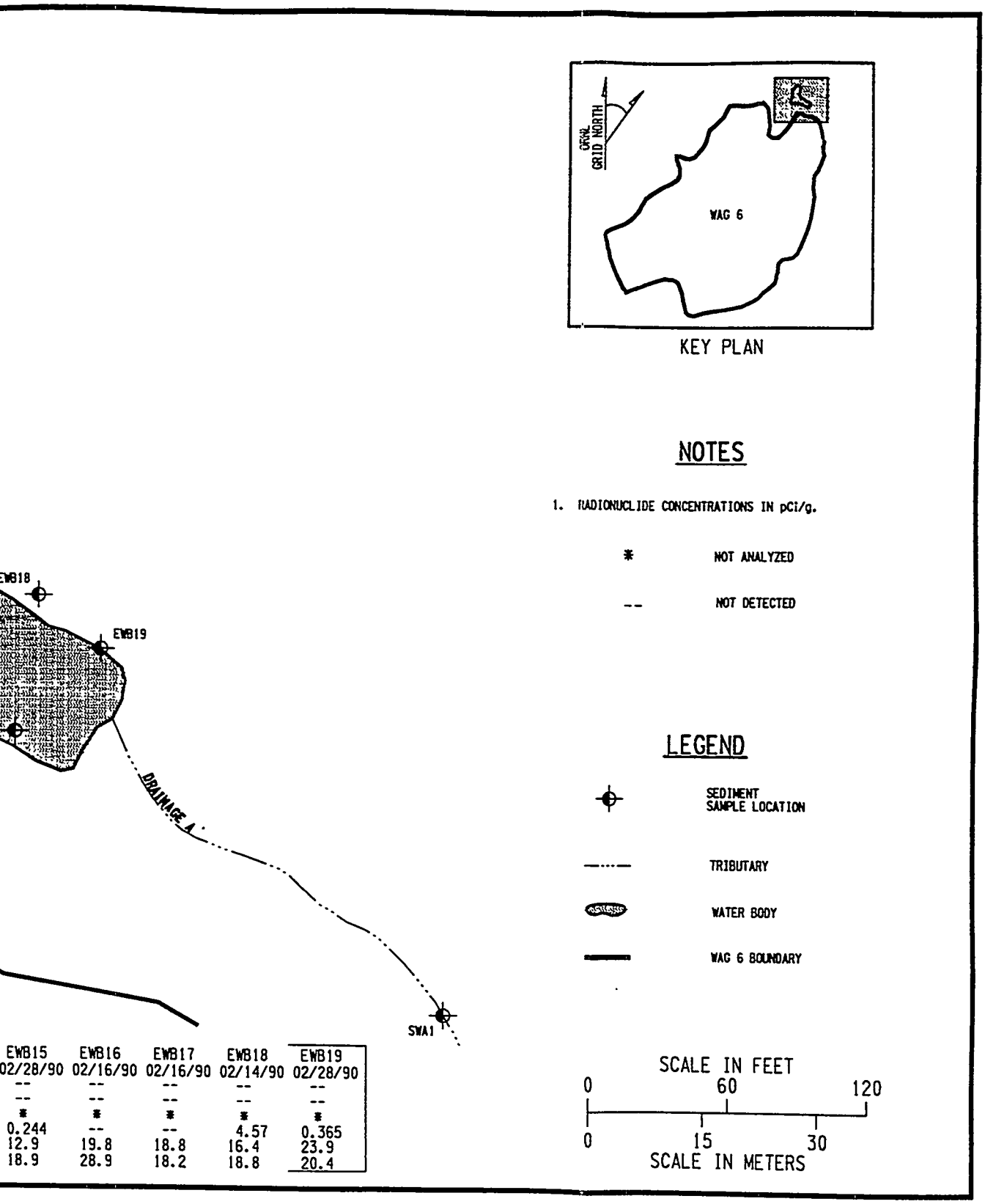

**Fig. 4C.36. Concentrations of total VOCs, tritium, and strontium-90 in FB drainage.**




Emergency Waste Basin Sediment Samples

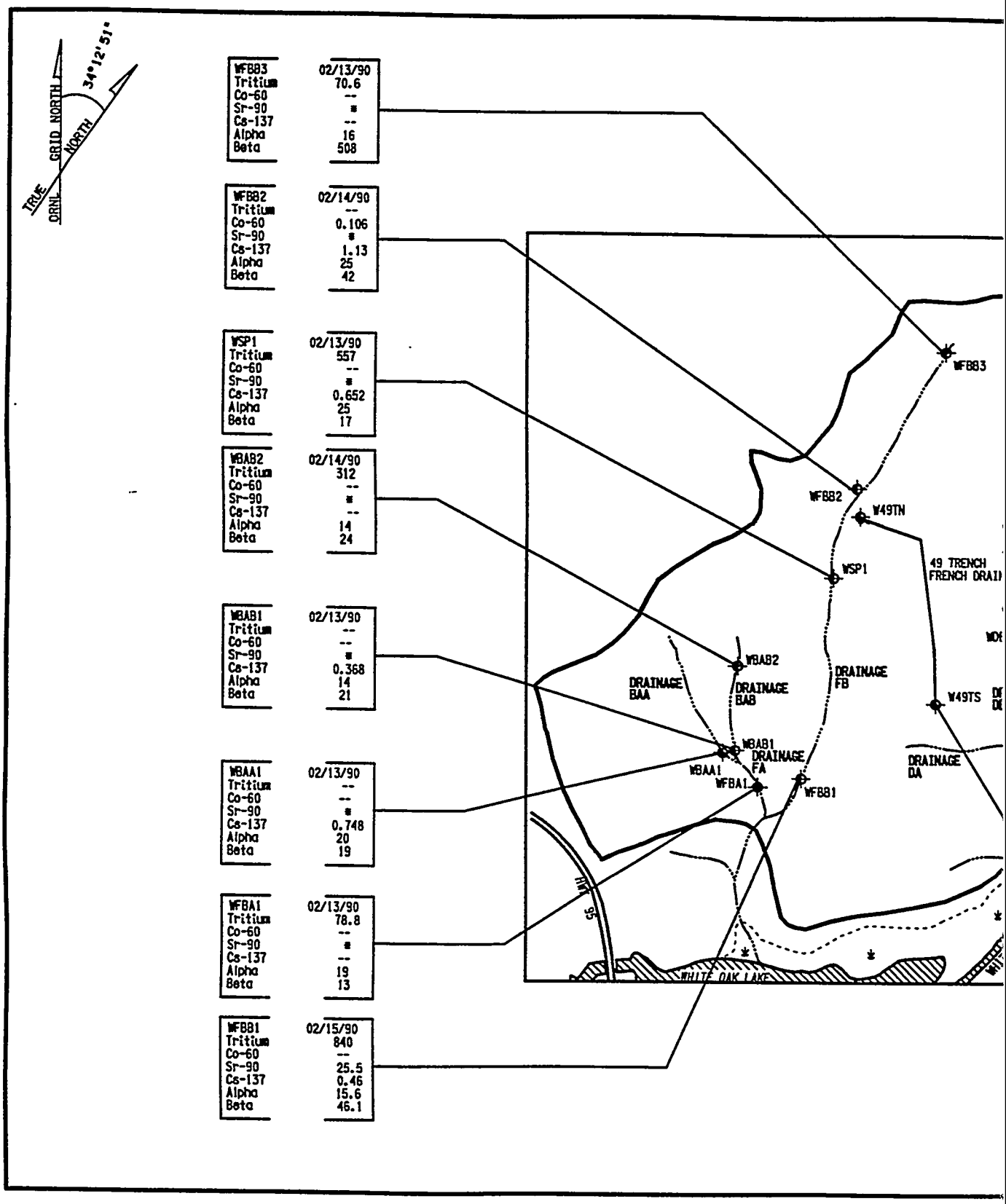
| Location | EWB01 | EWB02 | EWB04 | EWB05 | EWB06 | EWB07 | EWB08 | EWB09 | EWB10 | EWB14 |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | 02/20/90 | 02/20/90 | 02/20/90 | 02/20/90 | 02/20/90 | 03/01/90 | 03/02/90 | 02/20/90 | 03/01/90 | 02/15/9 |
| Tritium | -- | 197 | -- | 518 | -- | -- | 453 | -- | -- | -- |
| Co-60 | -- | -- | -- | 0.0775 | -- | -- | -- | -- | -- | -- |
| Sr-90 | * | * | * | * | * | * | * | * | * | 1.49 |
| Cs-137 | -- | 0.493 | 0.316 | 2.03 | 0.906 | 0.315 | 1.76 | -- | 0.944 | 1.96 |
| Alpha | 22.9 | 24.3 | 15.7 | 16 | 11.7 | 10.7 | 24.3 | 14.9 | 23.8 | 16 |
| Beta | 24 | 20.7 | 22.2 | 21.6 | 23.3 | 22.2 | 21.6 | 32.8 | 22.6 | 24.9 |

WAG6 06F249.DGN




| EWB15 | EWB16 | EWB17 | EWB18 | EWB19 |
|---|---|---|---|---|
| 02/28/90 | 02/16/90 | 02/16/90 | 02/14/90 | 02/28/90 |
| -- | -- | -- | -- | -- |
| -- | -- | -- | -- | -- |
| * | * | * | * | * |
| 0.244 | -- | -- | 4.57 | 0.365 |
| 12.9 | 19.8 | 18.8 | 16.4 | 23.9 |
| 18.9 | 28.9 | 18.2 | 18.8 | 20.4 |

**Fig. 4C.37. Radionuclide concentrations in Emergency Waste Basin sediment samples.**




WAG6 06F248.DGN

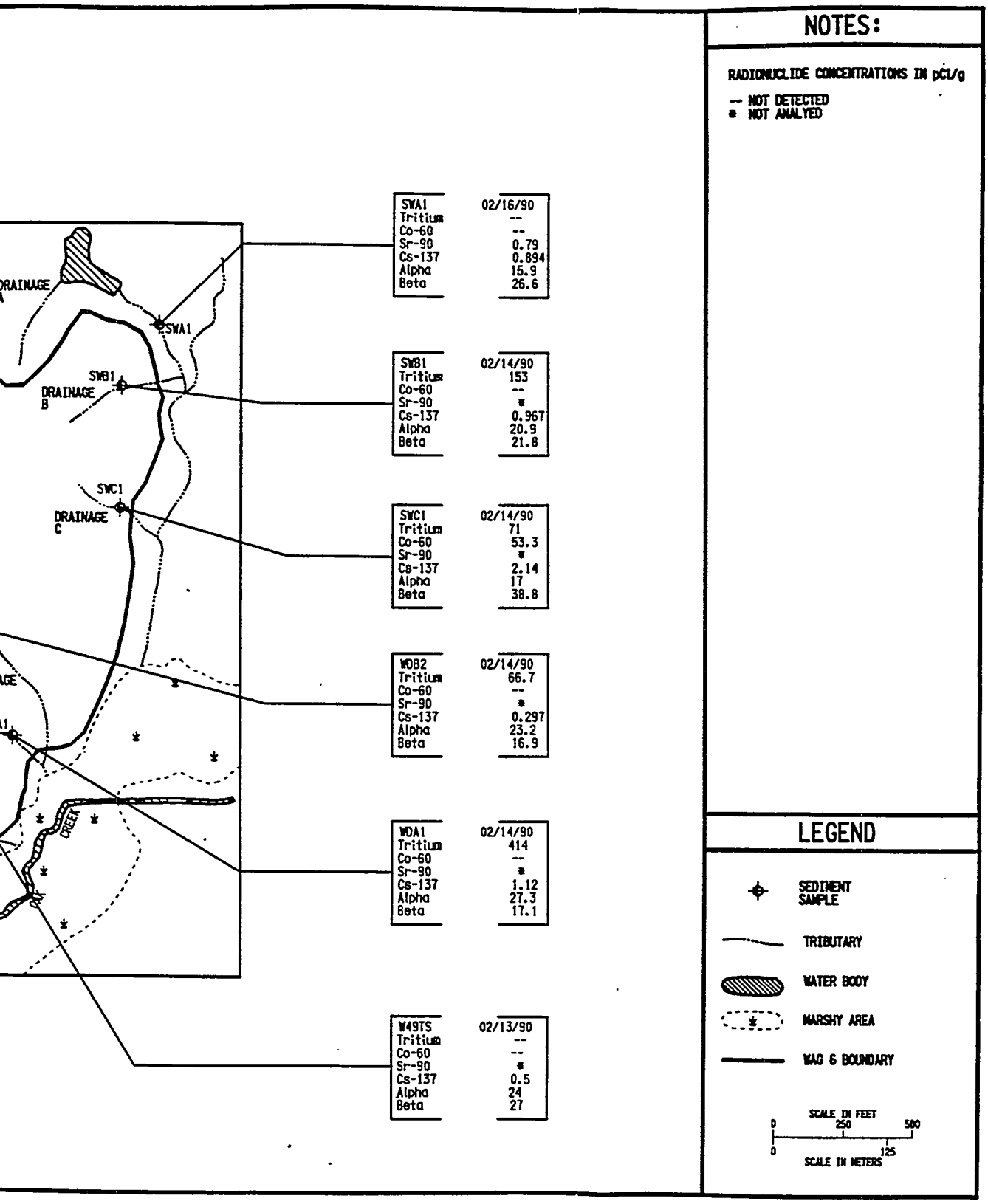
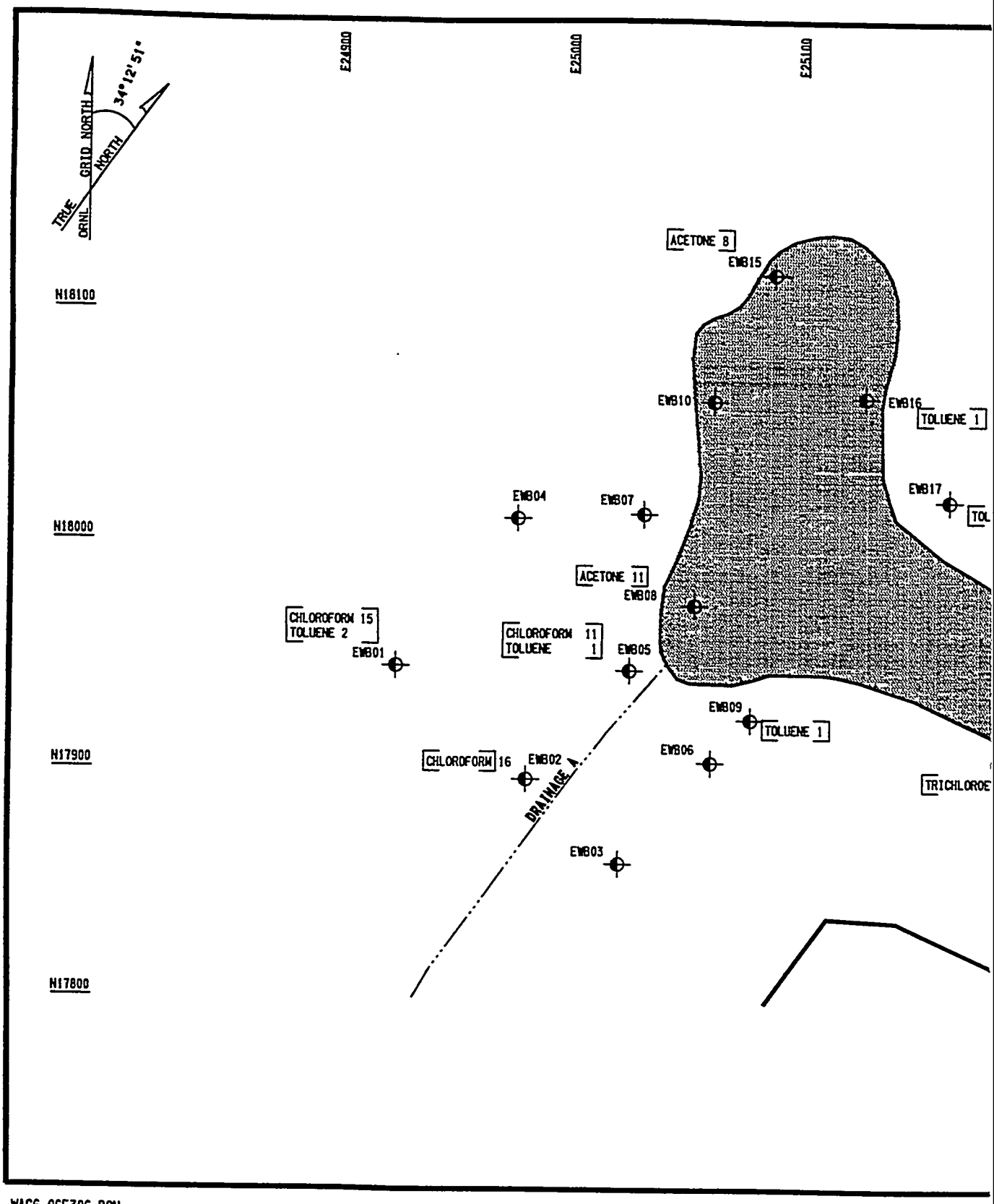



**Fig. 4C.38. Radionuclides detected in WAG 6 sediment samples.**




WAG6 06F306.DGN

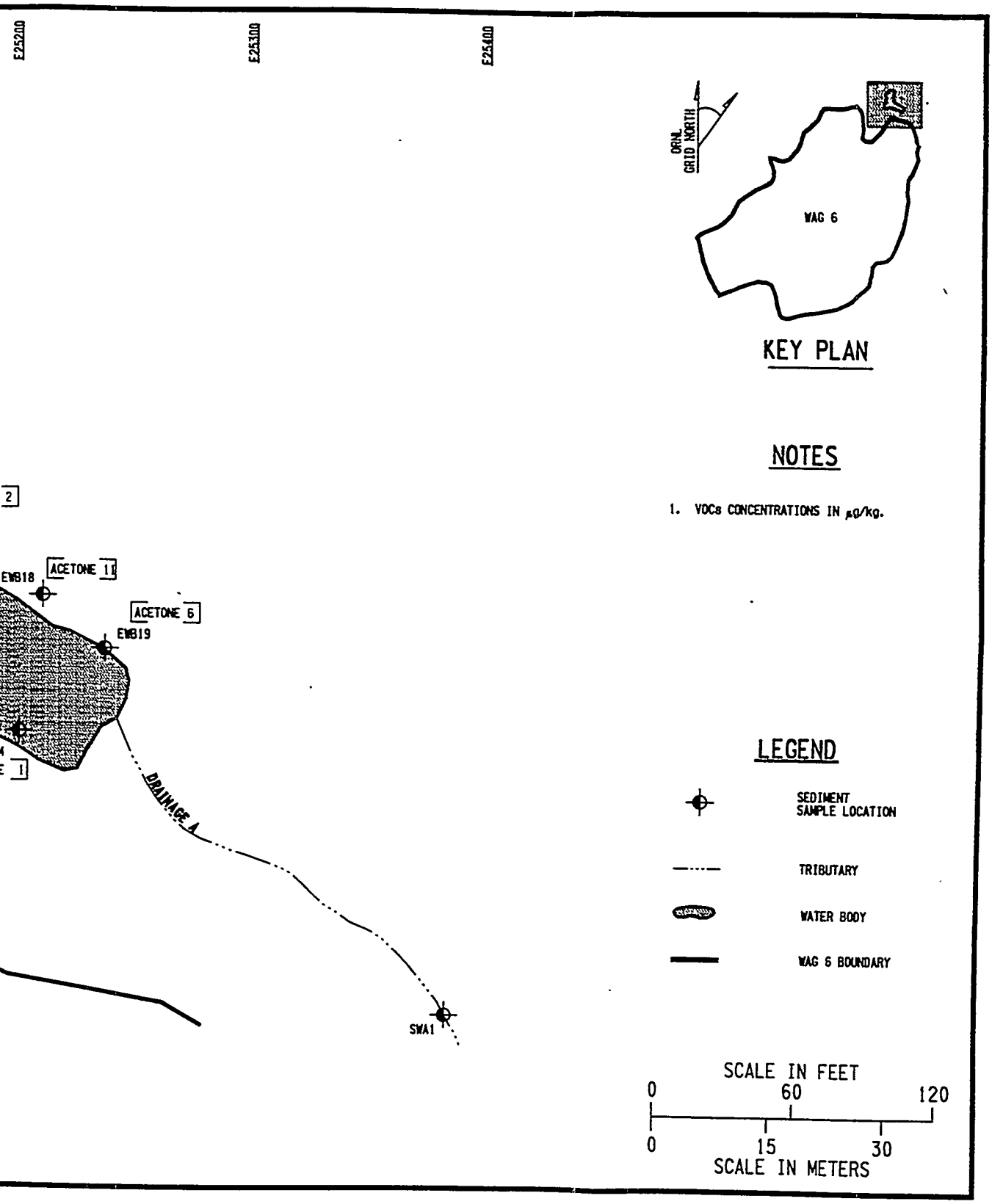
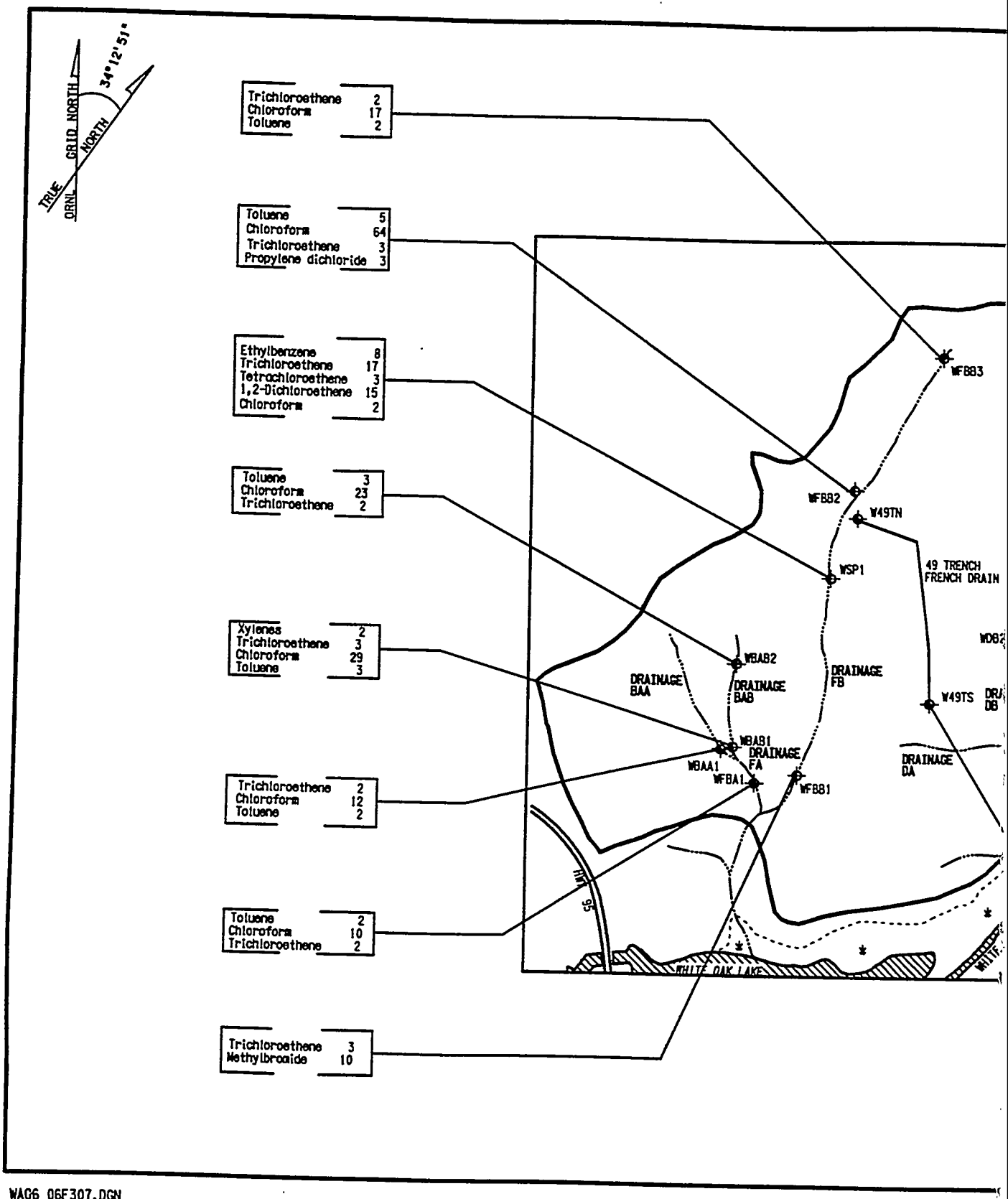



**Fig. 4C.39. VOCs detected in Emergency Waste Basin sediment samples.**

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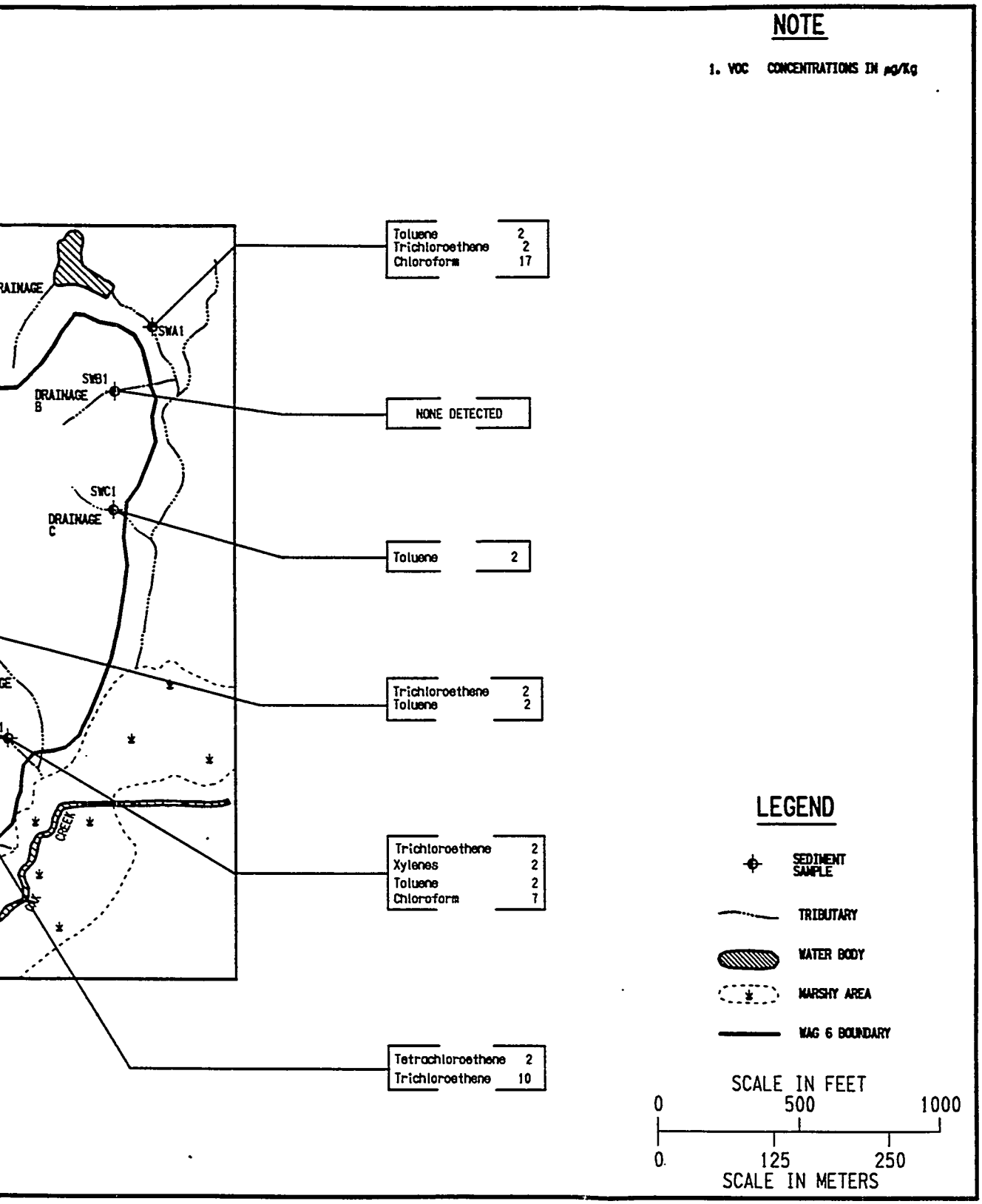
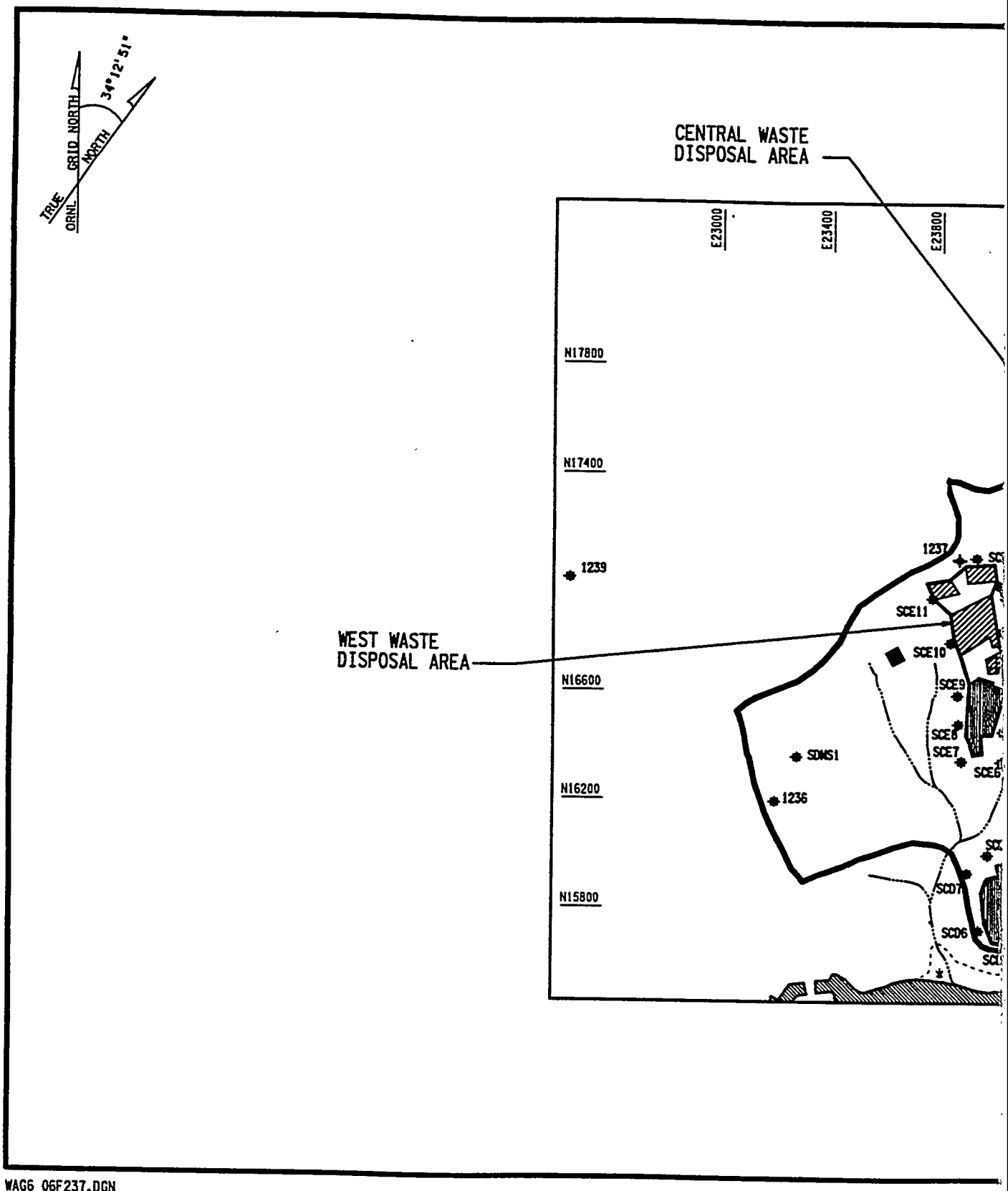



**Fig. 4C.40. VOCs detected in WAG 6 sediment samples.**

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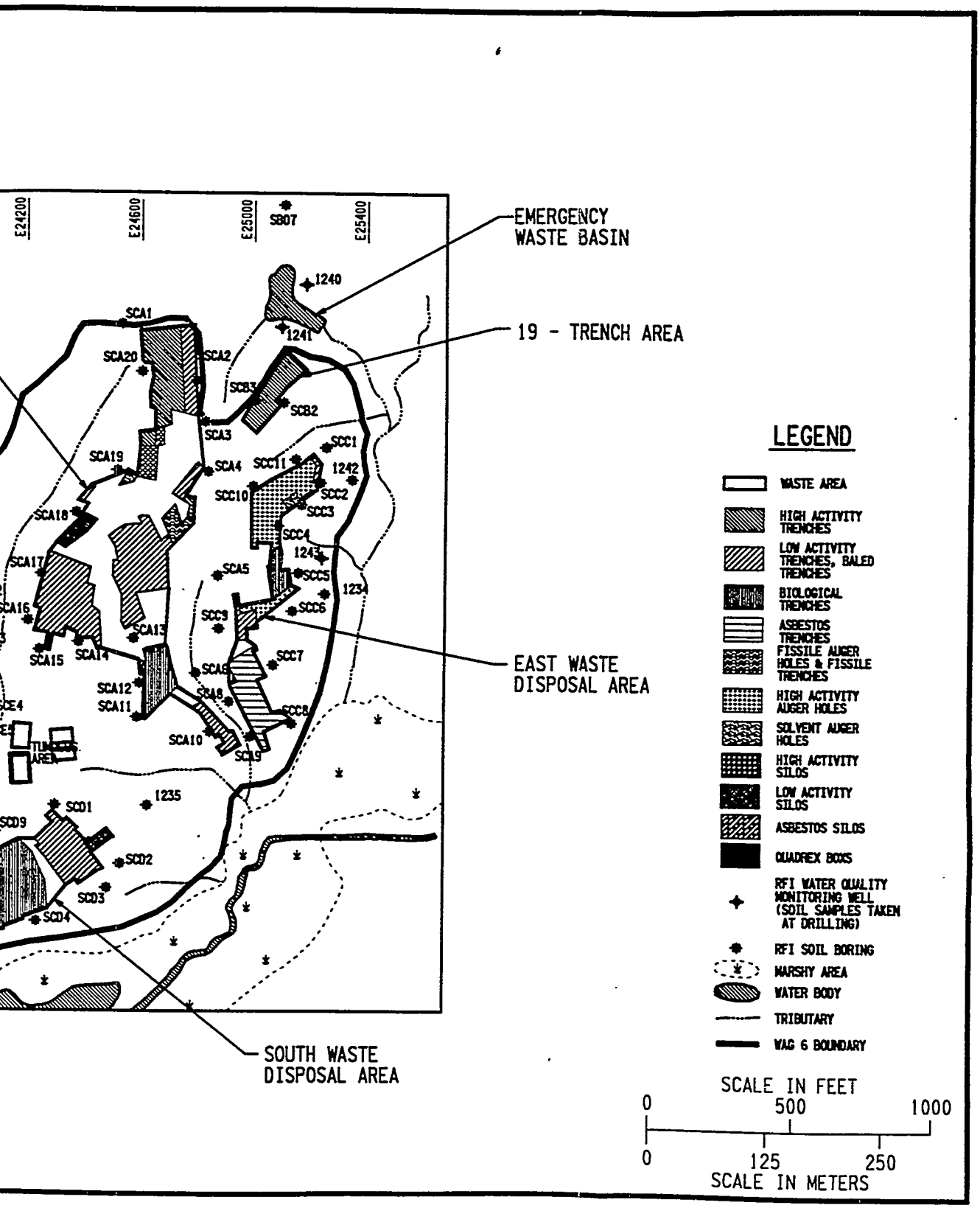
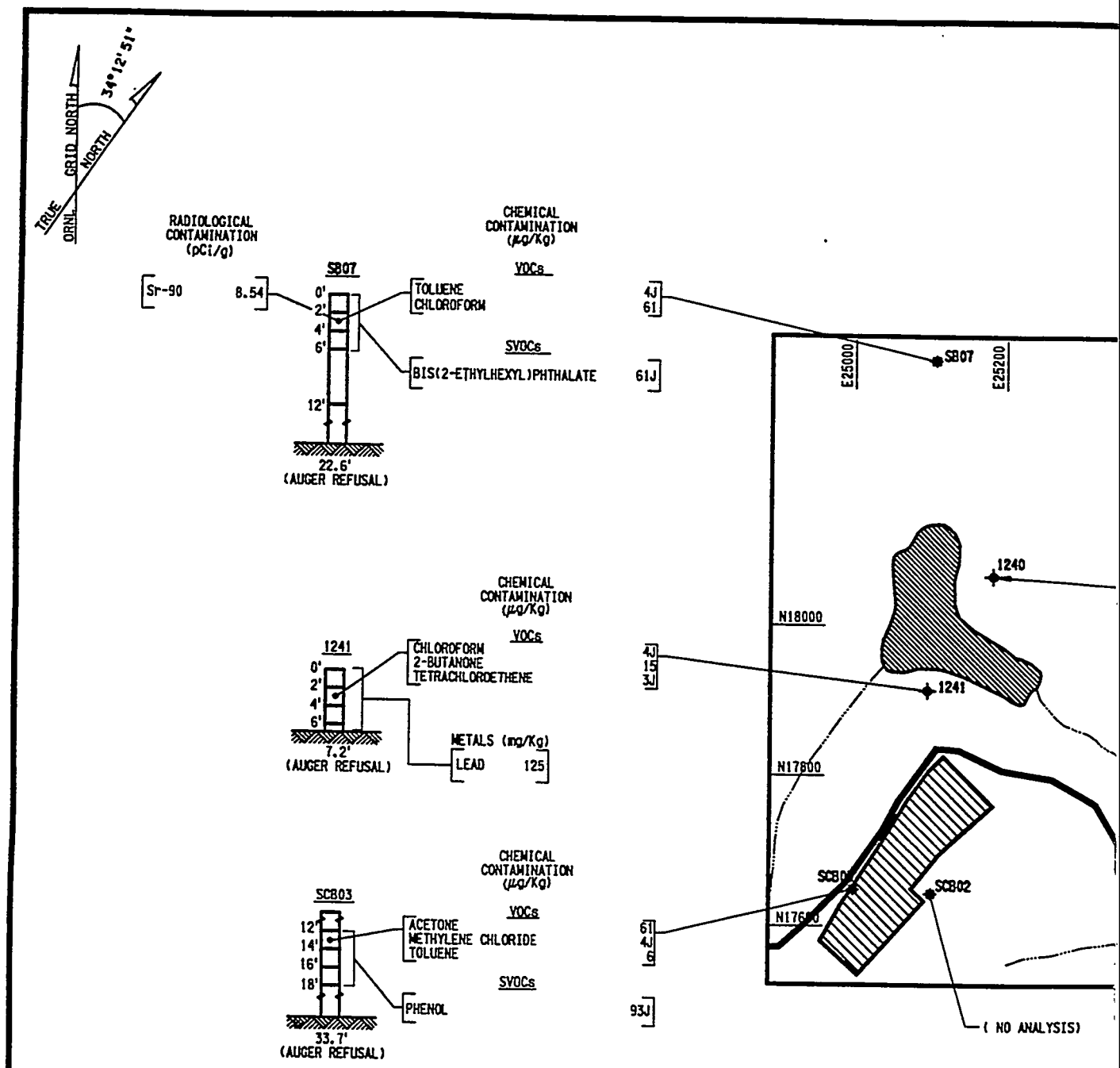



**Fig. 4C.41. Soil boring locations in WAG 6.**

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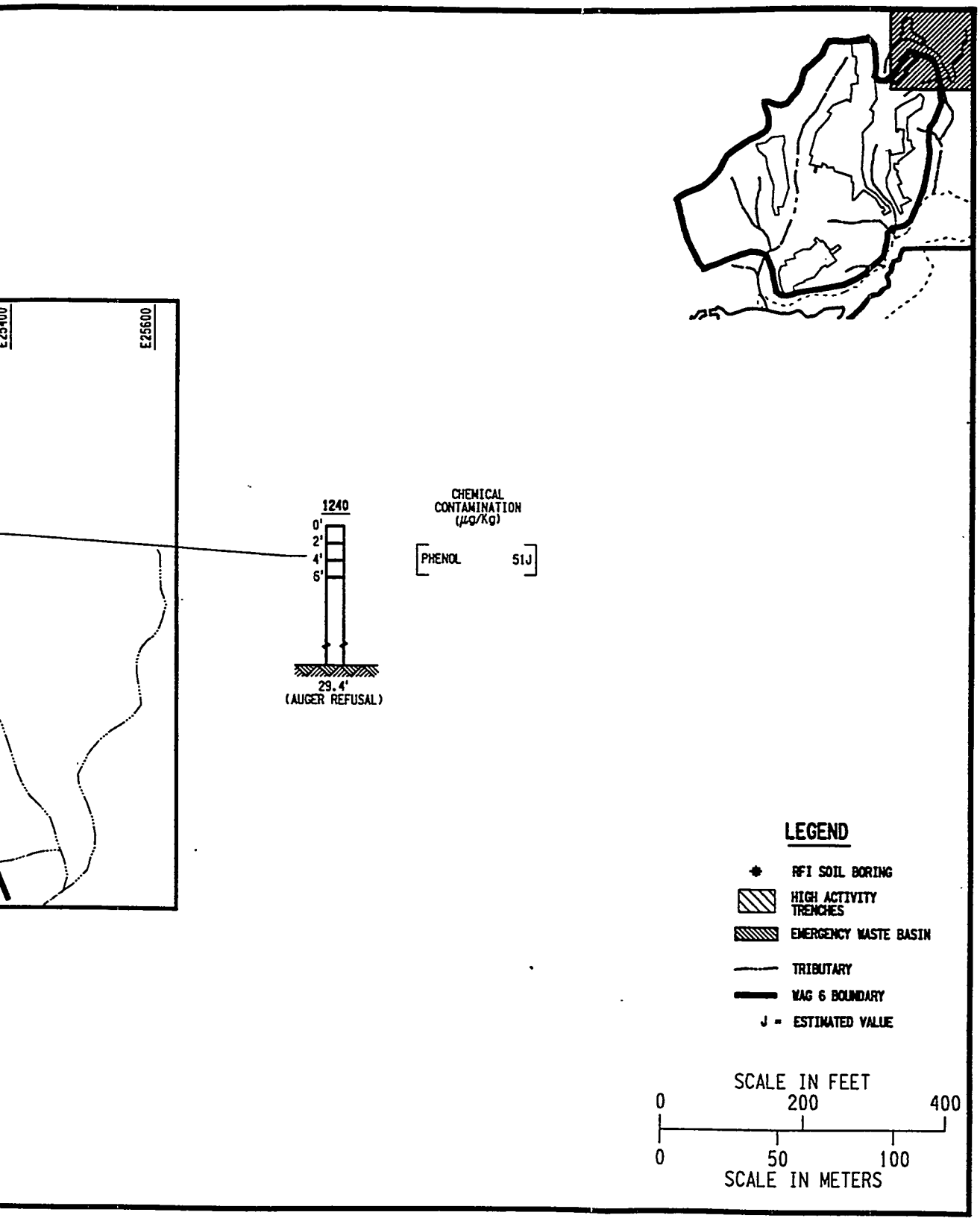
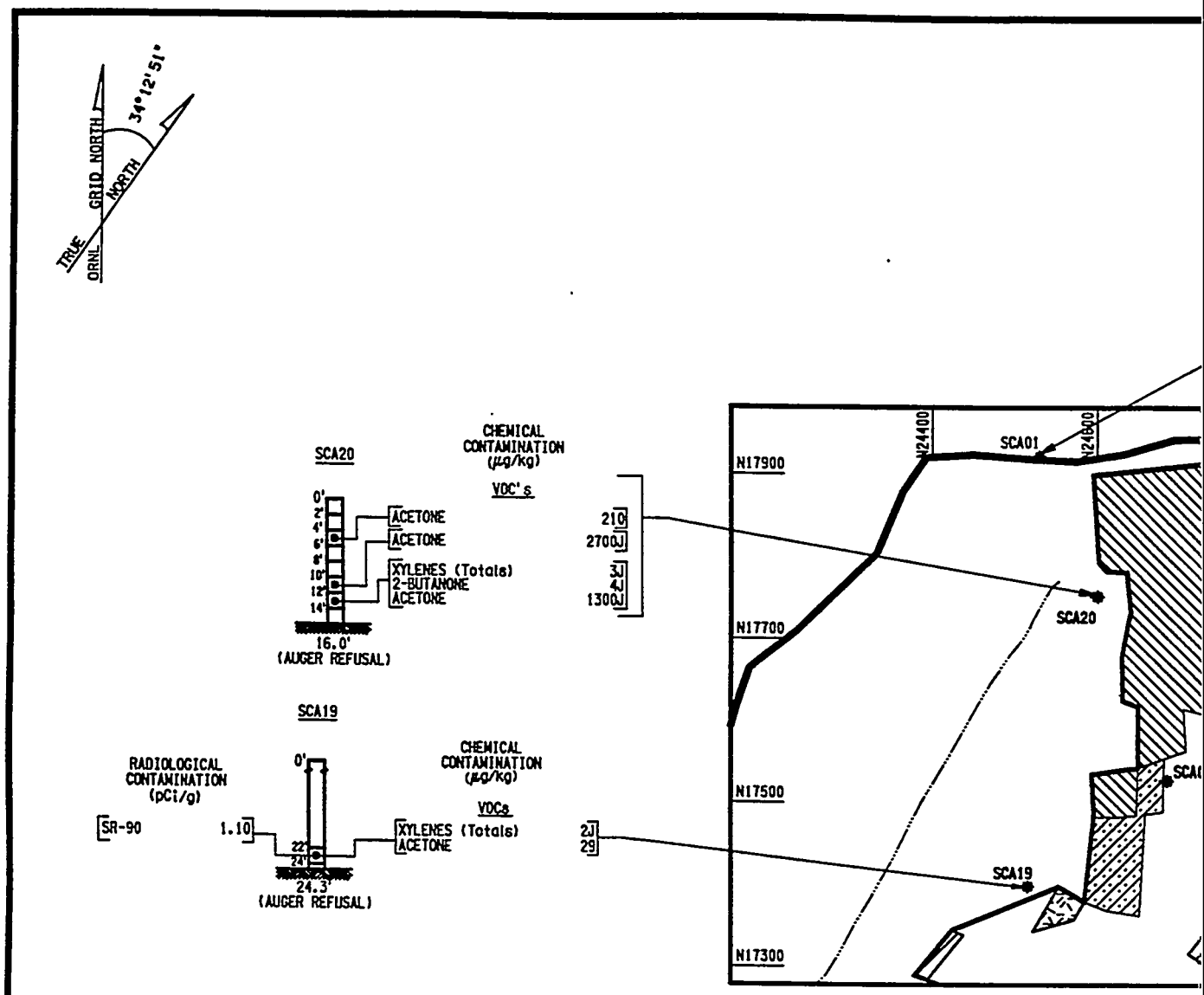



**Fig. 4C.42. Soil sample results from the 19-trench area and the Emergency Waste Basin.**




WAG6 06F240A.DGN

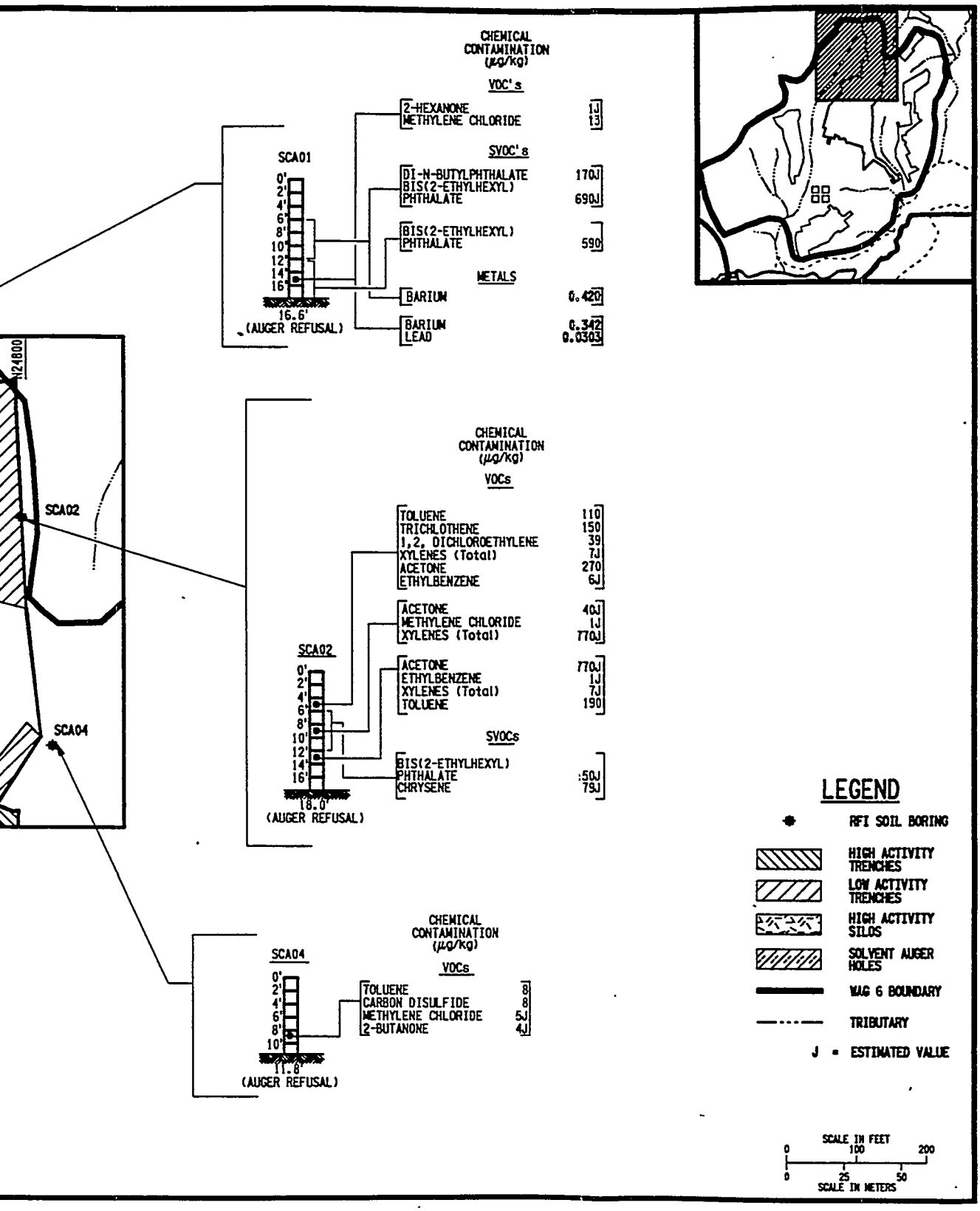
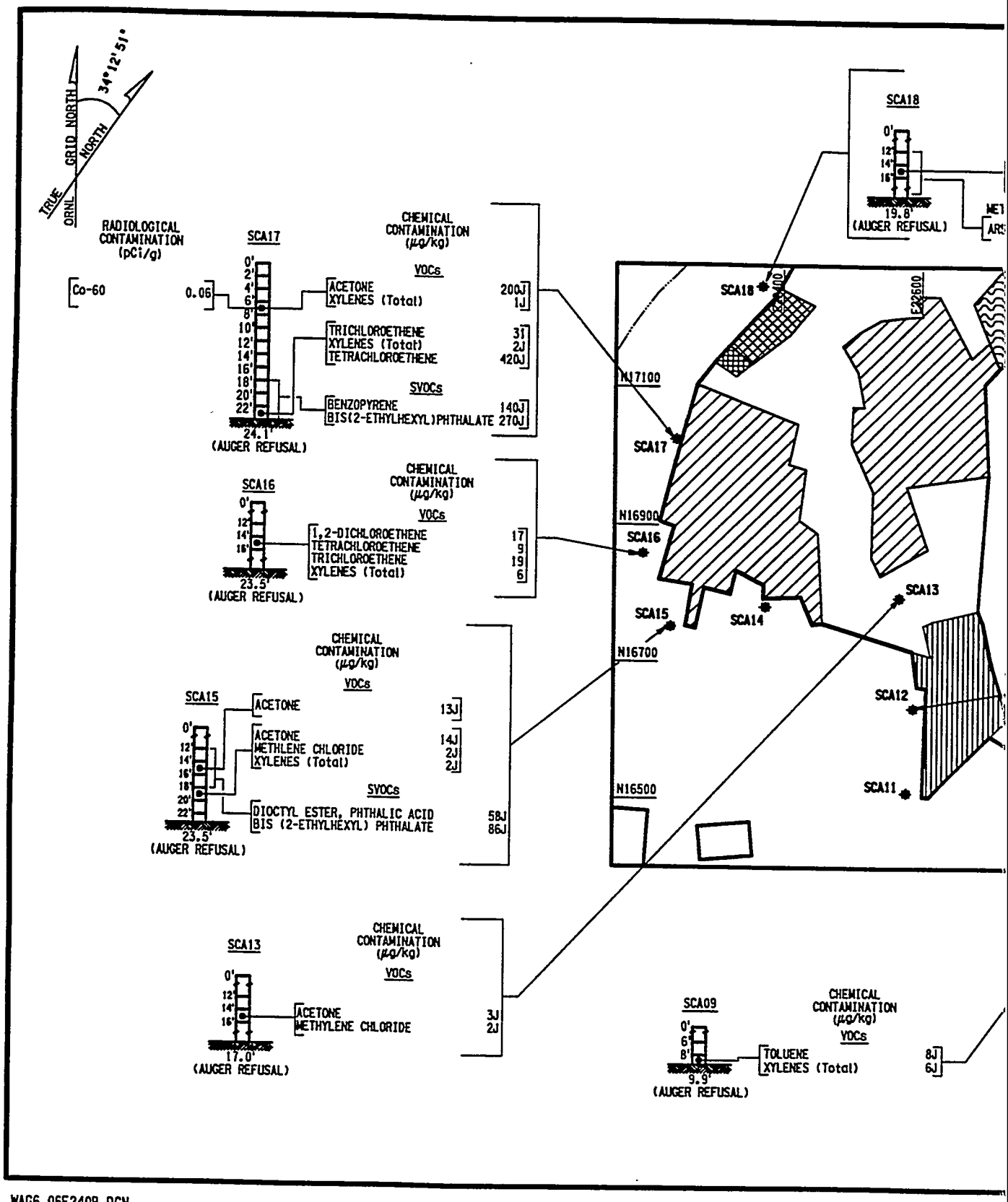



**Fig. 4C.43. Soil sample results from northern region of the central waste disposal area of WAG 6.**




WAG6 06F240B.DGN

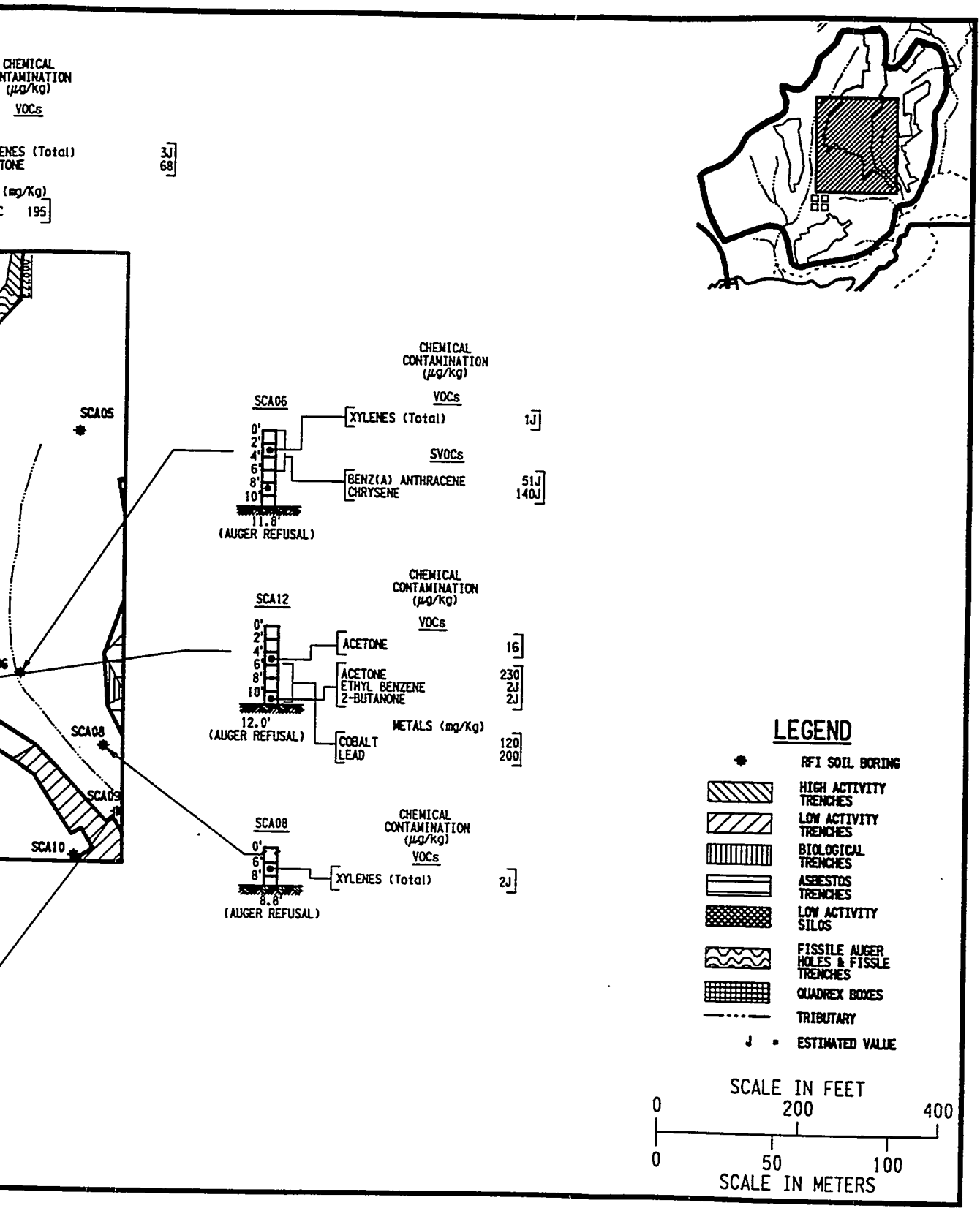
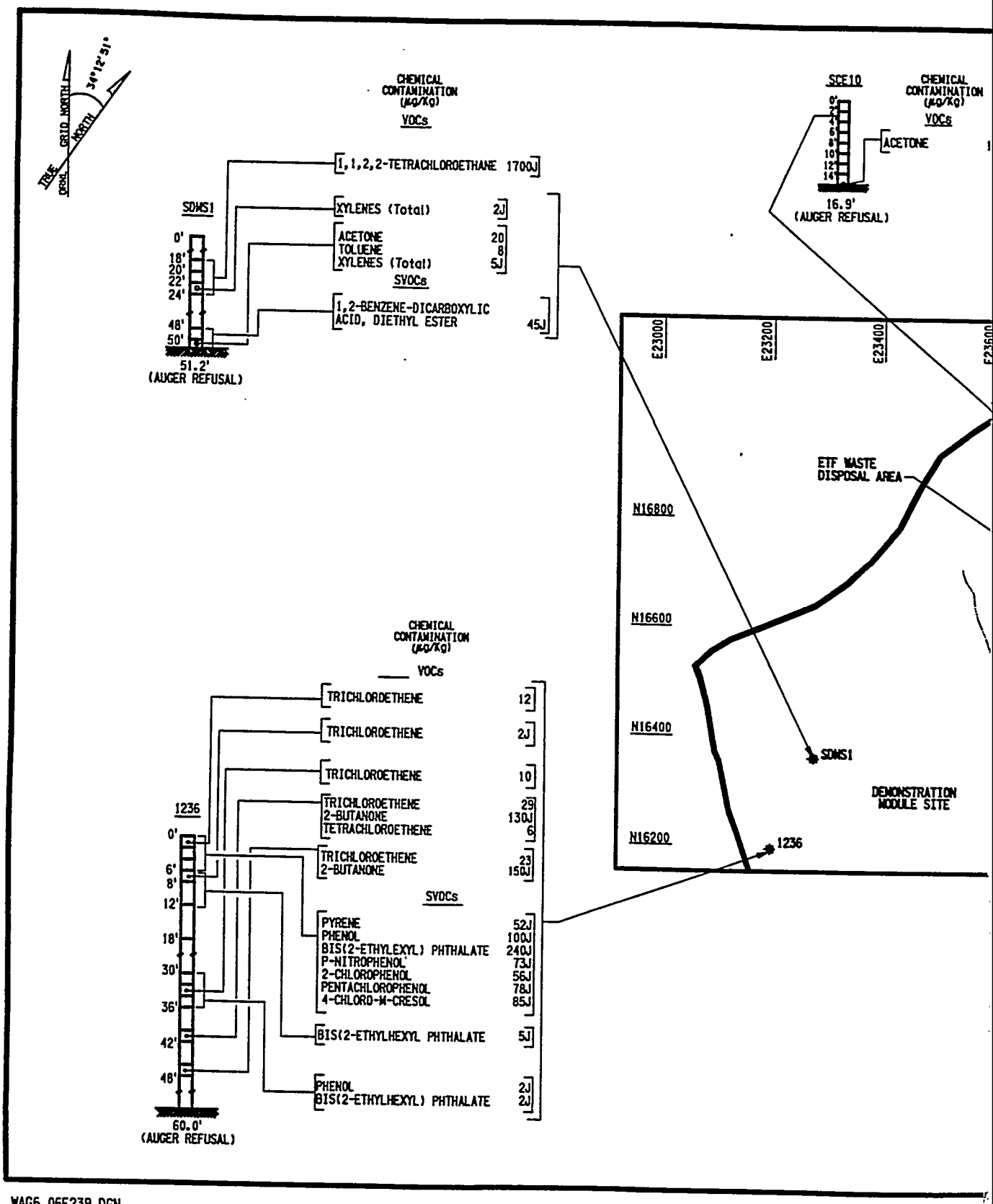



**Fig. 4C.44. Soil sample results from the southern region of the central waste disposal area.**




WAG6 06F239.DGN

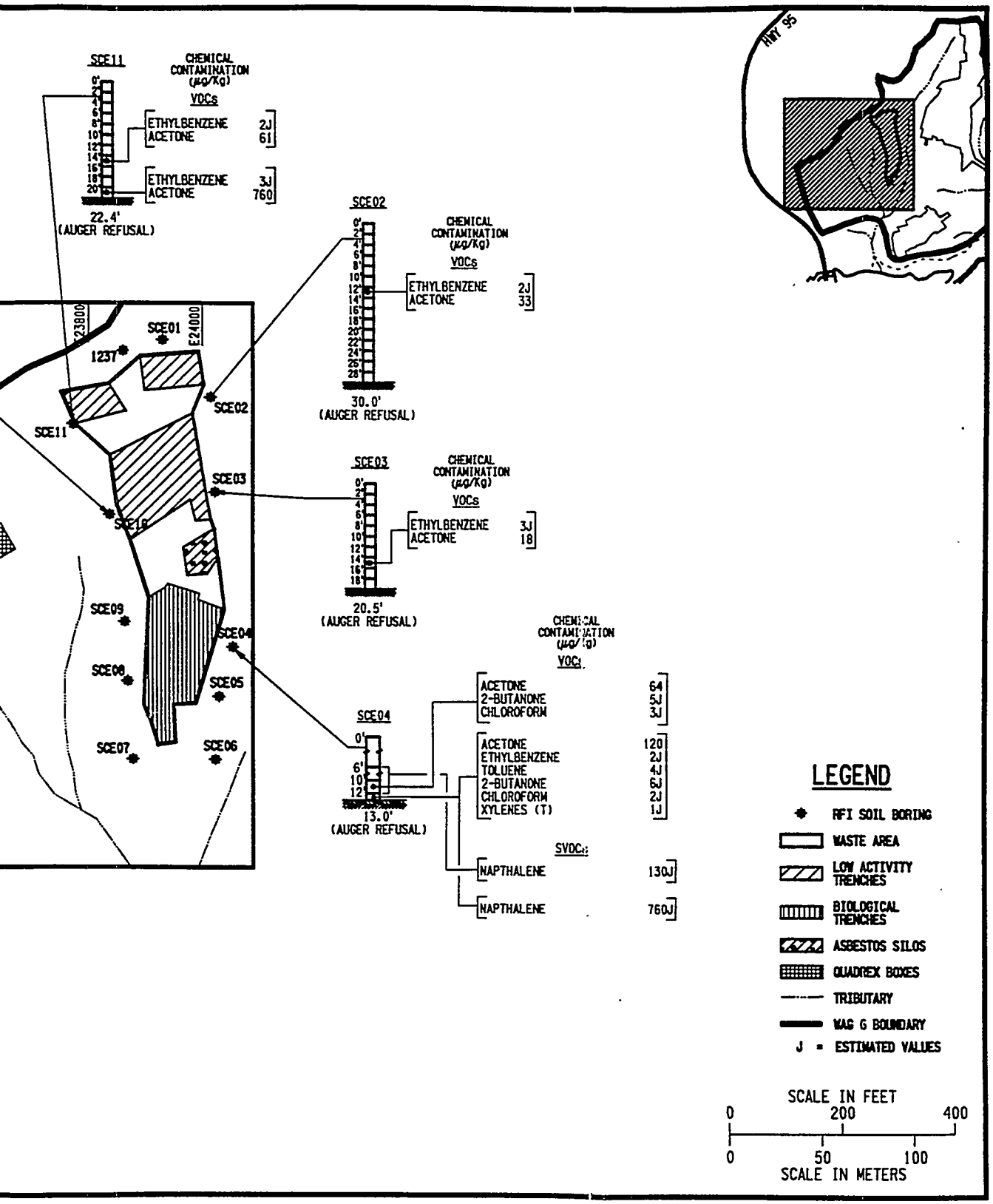
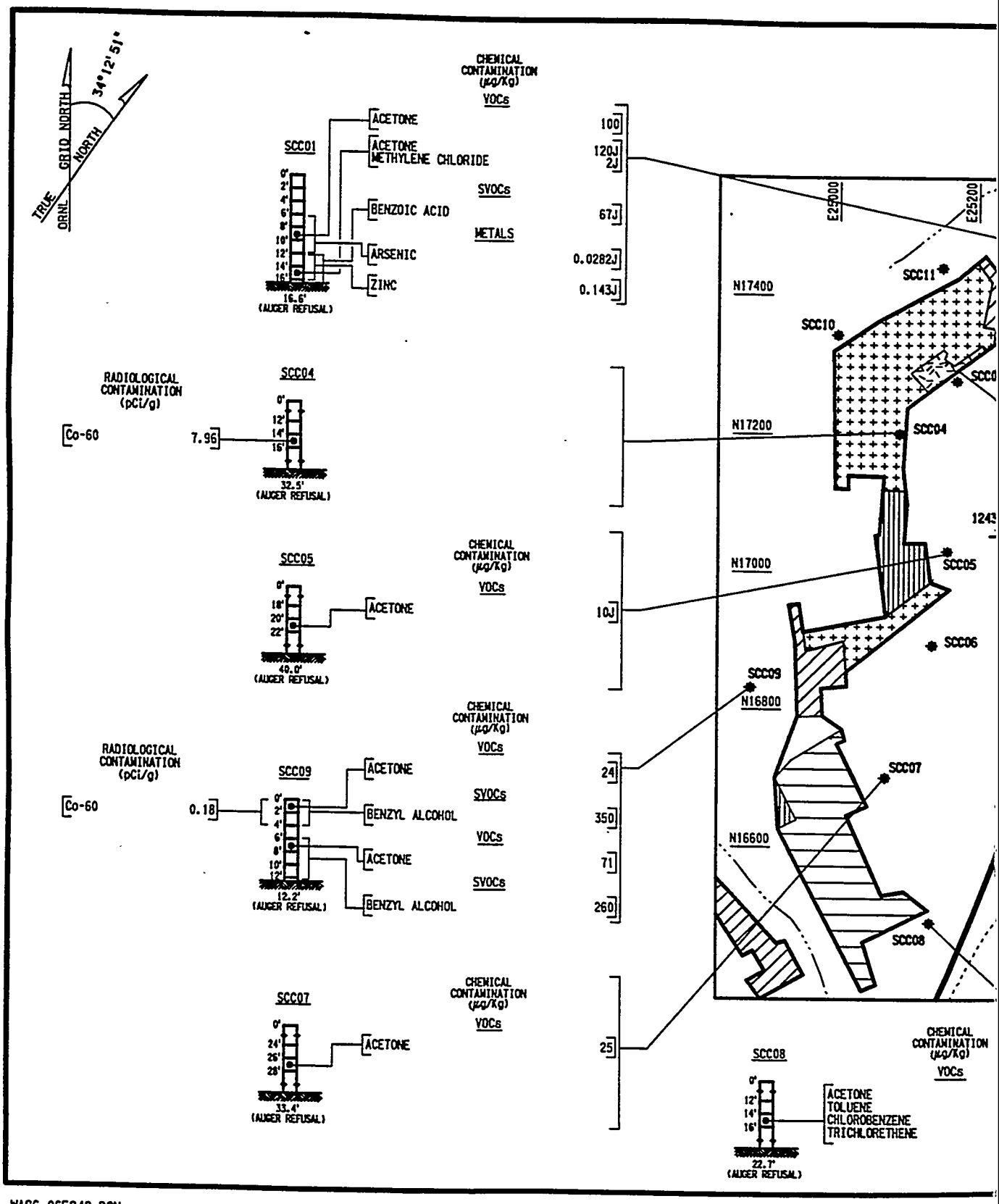



**Fig. 4C.45. Soil sample results from the western waste disposal area and the southwestern region of WAG 6.**

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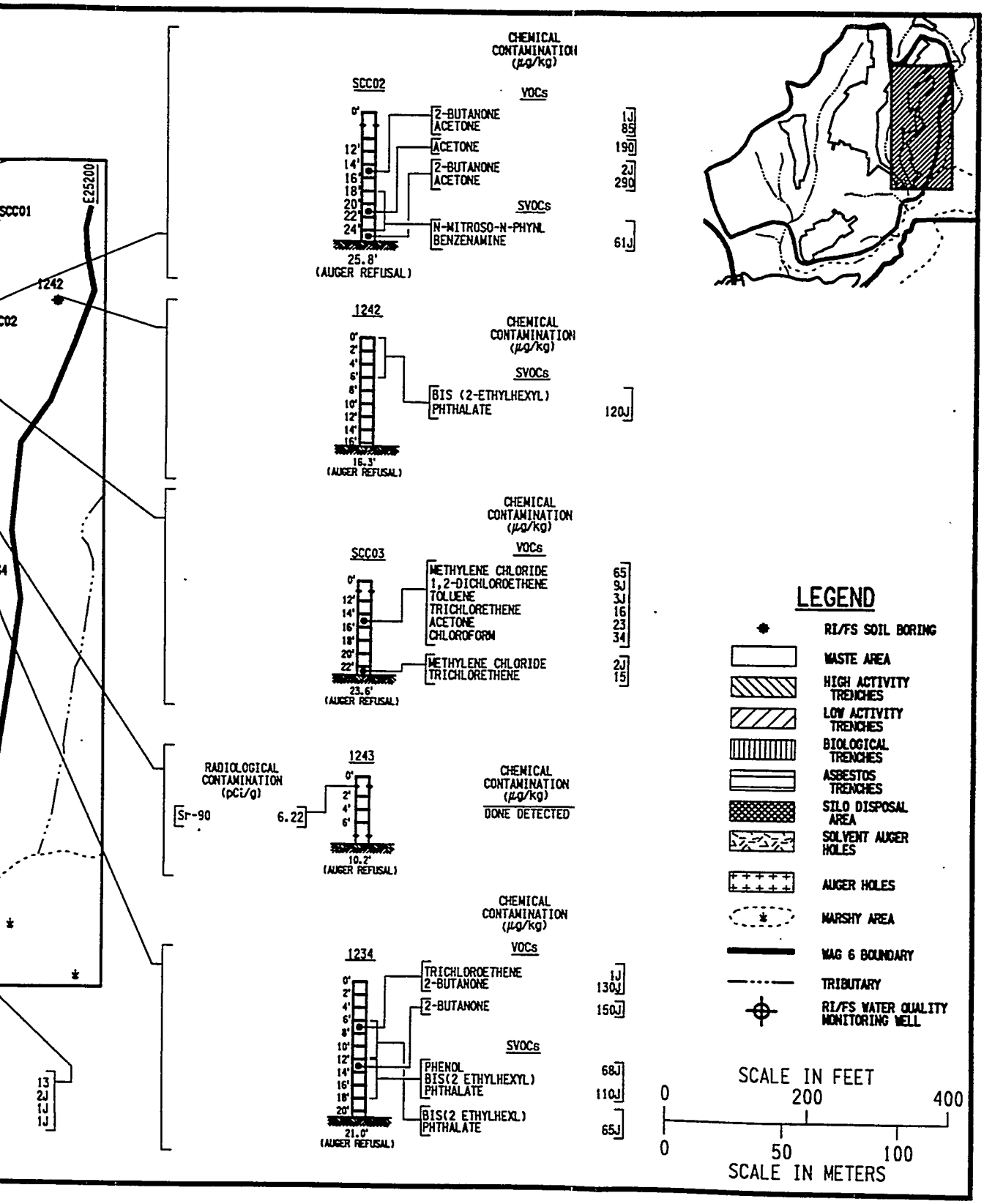
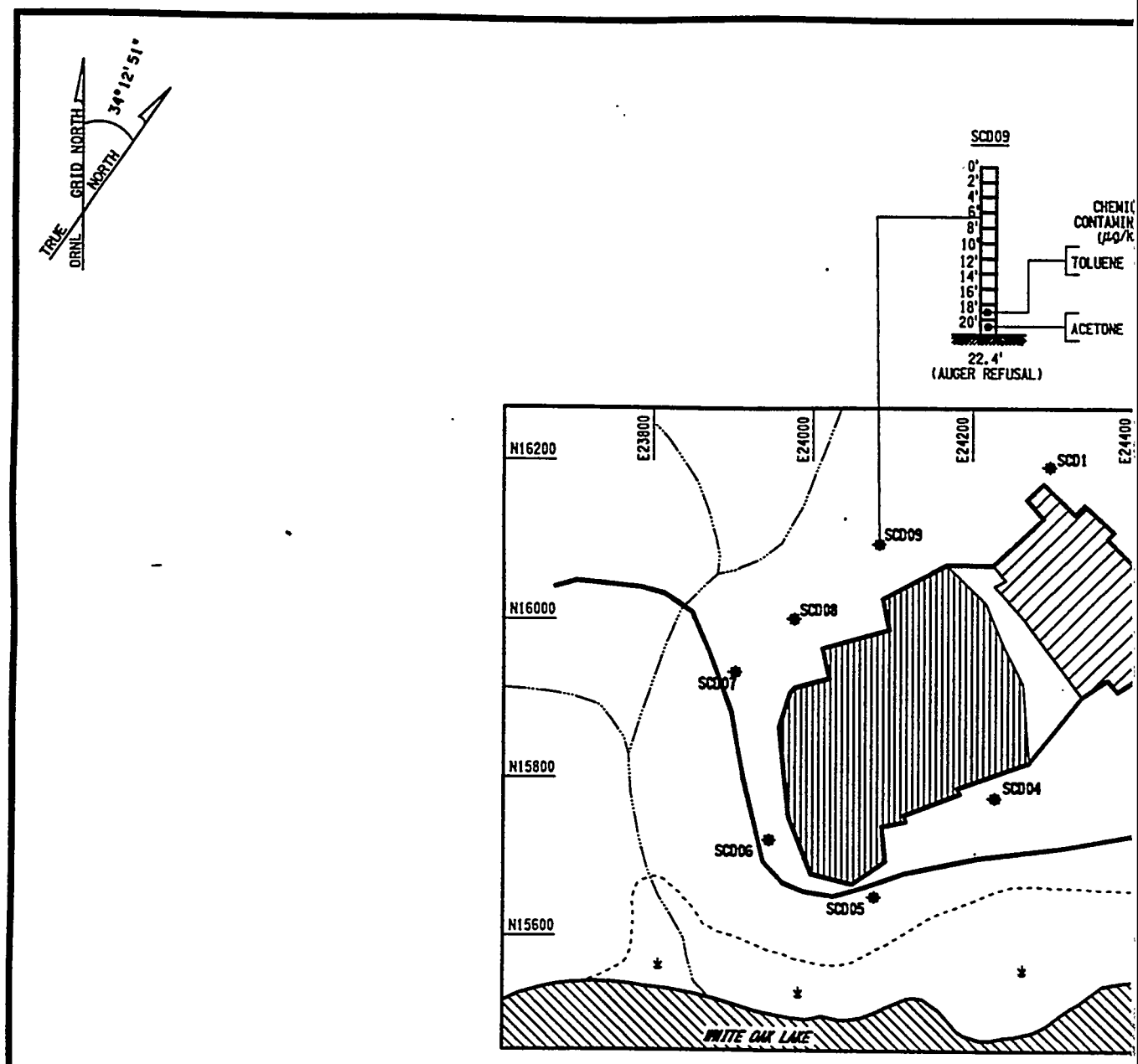



**Fig. 4C.46. Soil sample results from the eastern waste disposal area.**

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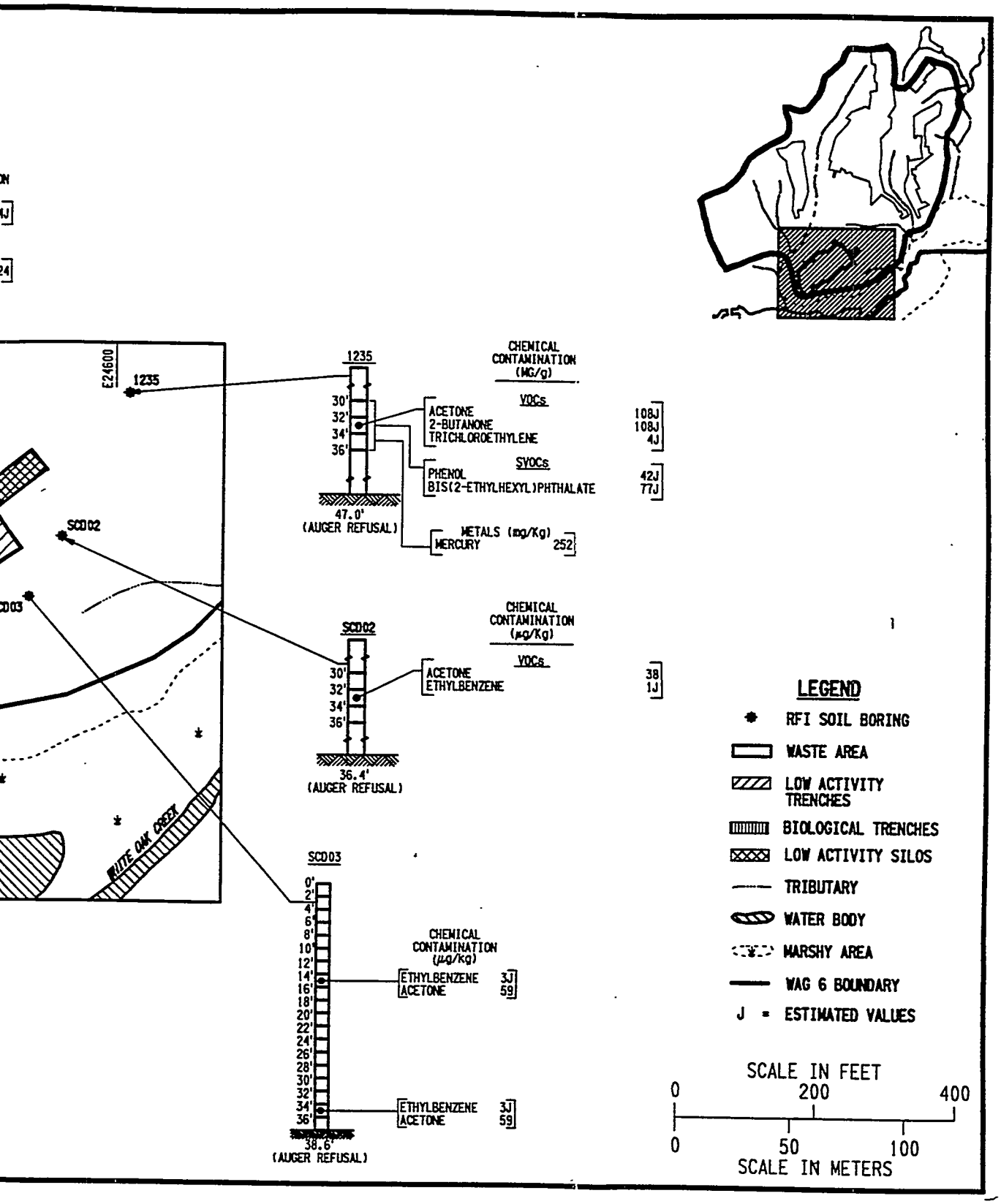


**Fig. 4C.47. Soil sample results from the southern waste disposal area WAG 6.**

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ORNL/ER/Sub-87/99053/33 & V3

# ORNL WAG 6 RFI REPORT

## VOLUME III: APPENDIXES (5A through 8C)

DRAFT

OAK RIDGE NATIONAL LABORATORY
REMEDIAL INVESTIGATION/FEASIBILITY STUDY

ENVIRONMENTAL RESTORATION DIVISION
DOCUMENT MANAGEMENT CENTER
BLDG 1210 MS 7256

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# APPENDIX 5A. SURFACE WATER MODELING

## 5A.1 INTRODUCTION

Surface runoff modeling was performed to support the data needs of fate and transport modeling. The CREAMS model, "A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems," was used to generate storm runoff volumes and recharge for an average climatic year for WAG 6. CREAMS was developed by the U.S. Department of Agriculture; it is a well-tested, field-verified, and well-documented model (Knisel 1980). The description of the model, its application to WAG 6, and the results are summarized in the following sections.

## 5A.2 DESCRIPTION OF THE CREAMS MODEL

The runoff component of CREAMS is a water-balance model requiring daily precipitation, mean monthly temperature, and solar radiation as input. The model continuously simulates hydrologic processes based on physical parameters of the basin being simulated. It requires little or no calibration. A general flow chart of the runoff portion of CREAMS is shown in Fig. 5A.1.

CREAMS uses the Soil Conservation Service curve number approach in partitioning the precipitation falling on land surface into surface runoff and infiltration. The infiltrated water is added to soil moisture storage where evapotranspiration and deep percolation take place. The curve number is adjusted daily by the soil moisture level.

CREAMS computes potential evaporation from input temperature and solar radiation. The actual evapotranspiration (the sum of the soil evaporation and the plant evaporation, which are computed separately) is limited by the available moisture supply and is less than the potential evaporation demand. Soil and plant evaporation are highly dependent on a leaf area index, defined as the area of plant leaves relative to the soil surface area. Evaporation and plant growth stop when soil moisture falls below wilting point (15-bar soil-moisture tension).

Deep percolation is computed using a soil storage routing. Deep percolation occurs when the field capacity of the soil is exceeded, the rate of percolation being a function of soil moisture storage and the saturated conductivity of the soil. Evapotranspiration loss from soil storage is computed as a function of root depth and the surface evapotranspiration.

## 5A.3 HYDROMETEOROLOGIC DATA

### 5A.3.1 Precipitation

Daily precipitation data for the 1981-1990 period at the ETF gauge, which is shown in Fig. 5A.2, was used to represent the WAG 6 precipitation. The annual precipitation amounts are shown in Table 5A.1, together with 43-year (1948-1990) annual precipitation data at the Oak Ridge gauge. The annual values at the ETF and Oak Ridge gauges were compared to estimate the long-term average precipitation at ETF and to assess the representativeness of the 1981-1990 period.

The 43-year mean annual precipitation at Oak Ridge, calculated from the data shown in Fig. 5A.3, was 54 in. with a standard deviation of 9.5 in. The coefficient of skew was 0.18, and 0.05 for the log-transformed data. A three-parameter log-normal distribution was fitted to the annual precipitation data, as shown in Fig. 5A.4. The data are random, based on run test, at the 5 percent significance level.

Spearman tests for independence and trend indicated that the data were independent and exhibited no trend. A Mann-Whitney split sample test for homogeneity was used to test the difference between two periods, 1948-1980 and 1981-1990. Although the mean value for the 1981-1990 period was 50.7 in. (3.3 in. less than the 43-year mean), the difference between the two periods is not statistically significant at the 5 percent significance level.

A linear regression relationship was developed using the ETF and Oak Ridge annual precipitation data for the 1981-1990 period. The correlation coefficient was 0.91. Using the regression relationship, the 43-year mean at ETF was estimated to be 51.2 in. Lower and upper 95 percentile confidence limits on the mean are 45 and 57.5 in., respectively.

The 10-year mean annual precipitation for the 1981-1990 period at ETF was 48.2 in., which was less than the long-term mean. The 1981-1990 period included three consecutive dry years (1985 through 1986) as well as wet and wetter-than-average years. The year 1984, which had precipitation close to average, was chosen as a representative year for the transport modeling.

### 5A.3.2 Evapotranspiration

The CREAMS model computes potential evapotranspiration based on mean monthly temperature and solar radiation. The data shown in Table 5A.2 are used as input to the CREAMS model. As a check on the generated potential evaporation, estimates of the annual pan evaporation and pan coefficient for the Oak Ridge area were estimated from two sources: NOAA Technical Report NWS 34, "Mean Monthly, Seasonal and Annual Pan Evaporation for the United States," and NOAA Technical Report NWS 33, "Evaporation Atlas for the Contiguous 48 United States" (Farnsworth and Thompson 1982: Farnsworth, Thompson, and Peck 1982). An average annual pan evaporation of 50.6 in. and a pan coefficient of 0.77 were estimated. A potential evapotranspiration demand of 39 in. was computed by multiplying the pan evaporation value with the pan coefficient. Further, in the publication, "Tennessee's Water Resources" (State of Tennessee 1961), a potential evapotranspiration estimate of about 33 in. was given for the Knoxville-Oak Ridge area. The monthly potential evapotranspiration amounts are shown in Fig. 5A.5.

### 5A.3.3 Streamflow

The streamflow records for the June 1985-July 1987 period at three gauging sites located at the outlet of drainages DA, DB, and F (shown in Fig. 5A.2) were used in the model calibration. DA, DB, and F have drainage areas of 10.23, 9.04, and 33.26 acres, respectively. The mean daily flows were available for the June 1985-July 1986 period and are shown in Figs. 5A.6a and 5A.6b for the three sites. The monthly flow data are given in Table 5A.3. The data were judged to be of fair to poor quality, as indicated in the surface water hydrology section of the report.

## 5A.4 LAND SEGMENTS AND INPUT PARAMETERS

The CREAMS model simulates the response of a unit land segment that is assumed to have homogeneous physical characteristics. A basin can be modeled as a composite of different homogeneous segments. Each of the basins (DA, DB, and F) was therefore assumed to be represented by three different land segments including a grassy area, a wooded area, and an impervious area segment. Although more segments would be necessary to adequately represent the areal variation in soils, land

cover, and topography, a three-segment representation of the rainfall-runoff response of WAG 6 basins is appropriate and sufficient because data for further refinement were not available.

Wooded areas were assumed to have higher infiltration rates and thicker soils. The impervious area segment was assumed to represent the surfaces of the streams and their saturated banks, road surfaces, and other impervious surfaces.

Model input parameters for the grass and wooded area segments are shown in Table 5A.4.

## 5A.5 MODEL CALIBRATION AND RESULTS

Although initial model parameters for CREAMS were determined based on site-specific data, final values of the parameters were determined through a trial-and-error calibration process in which parameters were adjusted until the simulated runoff matched the observed runoff. Observed surface runoff values for the June 1985-July 1986 period for DA, DB, and F basins were obtained from the daily hydrographs shown in Figs. 5A.6 through 5A.8 by subtracting the base flow component. The shaded area in these figures represent the volume of the base flow.

The monthly simulated and observed surface runoff values are listed in Table 5A.3 and plotted as a function of time for comparison in Figs. 5A.7a and 5A.7b. Except for August 1985 when the flow gauges had malfunctions, the fit of the simulated and observed values was quite satisfactory. Since the recorded data were of fair to poor quality, no further refinement in calibration was necessary. Summary statistics of rainfall and runoff for this period, excluding August 1985, were as follows:

| | Drainage | | |
|---|---|---|---|
| | DA | DB | F |
| Rainfall, in. | 36.8 | 36.8 | 36.8 |
| Total runoff, in. | 6.9 | 6.1 | 7.4 |
| Surface runoff, in. | 4.3 | 4.4 | 4.7 |
| Base-flow, in. | 2.6 | 1.7 | 2.7 |
| Base-flow as percent of rainfall | 7.1 | 4.6 | 7.3 |
| Base-flow as percent of total runoff | 37.7 | 27.9 | 36.5 |

The annual water balance values for the 1981 through 1990 period were obtained for the entire WAG 6 area and are shown in Table 5A.5. Disregarding the results for 1981 because of the effect of the initial conditions, the total runoff (surface runoff plus deep percolation) and the ET values for other years were reasonable. The simulated runoff and ET for 1982 and 1984, which have precipitation values close to long-term average precipitation for the ORNL area, were in agreement with previous estimates derived from local flow gauges (Moore 1988).

The daily surface runoff values for 1984 were used as input to the fate and transport model. These data are shown in Table 5A.6. The groundwater recharge and discharge for the fate and transport model were assumed to be equal to the percolation for 1984, or 7.6 in., 3.6 in. of which is assumed to be base flow (groundwater discharge into the stream); the remainder is assumed to be direct groundwater discharge to WOL. The base flow value, expressed as a percentage of rainfall for 1984, was derived from the observed flows for the period June 1985 through July 1986.

## 5A.6 SENSITIVITY ANALYSIS

A sensitivity analysis was performed to assess the impact of variation in the value of parameters such as runoff, evapotranspiration, and percolation on model output. Fourteen sensitivity runs were executed; in each run, only the value of the parameter whose sensitivity being investigated was changed. The parameters investigated include FUL (fraction of storage filled at field capacity), LAI (leaf area index), CN2 (average curve number), SIA (initial abstraction coefficient), RD (rooting depth), and RC (saturated hydraulic conductivity). The results of the 1981-1990 period simulation for the wooded and grass area segments are shown in Tables 5A.7a and 5A.7b.

The sensitivity analysis indicated that evapotranspiration did not change significantly with change in most parameters. The only significant variation occurred with a change in the leaf area index and the rooting depth. Even over a wide range of variation in these parameters, evapotranspiration varied 10% or less from the base values.

Surface runoff and percolation may vary as much as $\pm 100\%$ with changes in the parameters considered in the sensitivity analysis. Since the changes in evapotranspiration were insignificant, any change in surface runoff caused an opposite response in percolation. All of the parameters considered in the sensitivity analysis significantly influenced both surface runoff and percolation. The parameters FUL, LAI, RD, and RC were used within the model to calculate the water content in the soil. If the water content were high, a larger amount of the precipitation would become surface runoff. The parameters CN and SIA were empirical relationships that determined the amount of infiltration according to surface conditions such as land use. Figures 5A.8 through 5A.12 show the functional relationship between the value of each parameter and the volumes of surface runoff and percolation.

# Appendix 5A Tables

**Table 5A.1. Annual precipitation at Oak Ridge and ETF gauges**

| Year | Oak Ridge (in.) | ETF (in.) |
|---|---|---|
| 1948 | 58.1 | |
| 1949 | 52.5 | |
| 1950 | 61.6 | |
| 1951 | 60.2 | |
| 1952 | 39.4 | |
| 1953 | 46.3 | |
| 1954 | 56.7 | |
| 1955 | 56.1 | |
| 1956 | 67.1 | |
| 1957 | 67.9 | |
| 1958 | 37.4 | |
| 1959 | 50.5 | |
| 1960 | 54.3 | |
| 1961 | 60.9 | |
| 1962 | 61.1 | |
| 1963 | 44.7 | |
| 1964 | 49.9 | |
| 1965 | 47.8 | |
| 1966 | 47.2 | |
| 1967 | 68.8 | |
| 1968 | 39.6 | |
| 1969 | 49.6 | |
| 1970 | 52.2 | |
| 1971 | 53.3 | |
| 1972 | 64.9 | |
| 1973 | 76.3 | |
| 1974 | 57.6 | |
| 1975 | 60.7 | |
| 1976 | 53.3 | |
| 1977 | 62.8 | |
| 1978 | 48.4 | |
| 1979 | 67.3 | |
| 1980 | 40.1 | |
| 1981 | 42.6 | 40.7 |
| 1982 | 60.1 | 52.6 |
| 1983 | 47.7 | 41.6 |
| 1984 | 56.5 | 50.9 |
| 1985 | 46.5 | 39.8 |
| 1986 | 38.8 | 38.5 |
| 1987 | 40.3 | 45.3 |
| 1988 | 48.9 | 45.1 |
| 1989 | 66.0 | 64.5 |
| 1990 | 59.8 | 63.5 |
| mean | 54.0 | 48.2 |
| standard deviation | 9.8 | 9.7 |

**Table 5A.2. Mean monthly temperature and solar radiation**

| Month | Temperature[a] °F | Solar radiation langleys/day |
|---|---|---|
| January | 37.2 | 161.0 |
| February | 40.3 | 239.0 |
| March | 47.8 | 331.0 |
| April | 58.5 | 450.0 |
| May | 66.2 | 518.0 |
| June | 73.2 | 551.0 |
| July | 76.6 | 526.0 |
| August | 75.7 | 478.0 |
| September | 70.0 | 416.0 |
| October | 58.5 | 318.0 |
| November | 47.2 | 213.0 |
| December | 39.6 | 163.0 |

[a]Source, City of Oak Ridge (1959-1989)

Table 5A.3. Monthly simulated and recorded runoff, June 1985—July 1986, WAG 6

| | Segment runoff | | | Simulated runoff | | Recorded runoff drainage | | |
|---|---|---|---|---|---|---|---|---|
| Month | Impervious area | Wooded segment | Grass segment | F | DA or DB | DB | DA | F |
| JUN | 5.2 | 0.2 | 0.4 | 0.4 | 0.4 | 0.2 | 0.3 | 0.2 |
| JUL | 4.0 | 0.1 | 0.2 | 0.2 | 0.2 | 0.1 | 0.4 | 0.3 |
| AUG | 9.1 | 1.8 | 3.5 | 2.9 | 2.9 | 0.4 | 0.6 | 0.6 |
| SEP | 1.7 | 0.0 | 0.03 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 |
| OCT | 3.0 | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.4 |
| NOV | 4.0 | 0.3 | 1.0 | 0.9 | 0.8 | 0.7 | 0.7 | 0.7 |
| DEC | 2.1 | 0.0 | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.4 |
| JAN | 1.3 | 0.0 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.4 |
| FEB | 4.1 | 0.8 | 1.6 | 1.3 | 1.3 | 2.0 | 1.6 | 1.0 |
| MAR | 2.8 | 0.4 | 0.8 | 0.7 | 0.6 | 0.7 | 0.5 | 0.8 |
| APR | 2.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 |
| MAY | 3.0 | 0.1 | 0.2 | 0.2 | 0.2 | 0.1 | 0.0 | 0.2 |
| JUN | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| JUL | 2.7 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 |
| TOTAL: | | | | 4.7 | 4.4 | 4.4 | 4.4 | 4.7 |

Note: All values in in. Value for August is not included in the total as explained in the text.

**Table 5A.4. Input parameters**

| Parameters | Value: Grass | Value: Woods | Description |
|---|---|---|---|
| RC | 0.02 | 0.05 | effective saturated conductivity of the soil (in./hr) |
| FUL | 0.77 | 0.59 | fraction of pore space filled at field capacity (obtained from CREAMS User's Guide, Table A-3) |
| BST | 0.5 | 0.5 | fraction of plant-available water storage filled when simulation starts |
| CONA | 3.5 | 4.0 | soil evaporation parameter (User's Guide, Table A-3, Soil Porosity, Users Guide, Table A-3) |
| POROS | 0.43 | 0.47 | soil porosity, User's Guide, Table A-3 |
| BR15 | 0.30 | 0.2 | wilting point, at 15 bars tension, immobile soil water content, User's Guide Table A-3 |
| SIA | 0.1 | 0.1 | initial abstraction coefficient for SCS CN method |
| CN2 | 84 | 80 | SCS Curve number for antecedent soil moisture condition II - (User's Guide, Table A-4) |
| CHS | 0.05 | 0.05 | channel slope |
| WLW | 2.76 | 2.76 | watershed length/width ratio |
| RD | 24.0 | 40.0 | maximum rooting depth in in. |
| UL (1-7) | | | plant-available soil water storage for 7 layers of the root zone computed as: |
| | 0.03 | 0.1 | UL(1) = (porosity - wilting point) × RD × 1/36 |
| | 0.43 | 1.5 | UL(2) = (porosity - wilting point) × RD × 5/36 |
| | 0.52 | 1.8 | UL(3) - UL(7) = (porosity - wilting point) × RD × 1/6 |
| TEMP (1-12) | | a | average monthly temperature |
| RAD1 (1-12) | | a | average monthly solar radiation values, langleys/day |
| GR | | | winter crap factor (bare ground = 1.0) (ground = 0.5) |
| LDATE, | 200 | 200 | LDATE = Julian Day |
| AREA[b] | 0.65 | 0.65 | AREA = Leaf area index for the year |
| | | | Values are selected form CREAMS manual, Table II-08. CREAMS user's manual should be consulted for further details. |

[a]See Table A.2
[b]value shown is the maximum

**Table 5A.5. Simulated yearly water balance for WAG 6**

| Year | Precipitation (in.) | Surface runoff (in.) | ET (in.) | Deep percolation (in.) | Surface runoff plus deep percolation (in.) |
|---|---|---|---|---|---|
| 1982 | 52.6 | 11.7 | 30.3 | 10.9 | 22.7 |
| 1983 | 41.6 | 8.8 | 26.3 | 6.4 | 15.2 |
| 1984 | 50.9 | 14.3 | 29.3 | 7.5 | 21.8 |
| 1985 | 39.8 | 6.6 | 29.5 | 3.4 | 10.0 |
| 1986 | 38.5 | 7.2 | 26.7 | 5.1 | 12.3 |
| 1987 | 45.3 | 9.9 | 28.3 | 7.1 | 17.0 |
| 1988 | 45.1 | 10.8 | 28.5 | 4.8 | 15.6 |
| 1989 | 64.5 | 17.3 | 32.7 | 14.6 | 31.9 |
| 1990 | 63.5 | 19.2 | 32.4 | 11.6 | 30.8 |

**Table 5A.6. Simulated storm runoff values in inches**

| Date | Drainage DB | Drainage DA | Drainage F |
|---|---|---|---|
| 84010 | 0.039 | 0.039 | 0.043 |
| 84018 | 0.237 | 0.237 | 0.245 |
| 84024 | 0.135 | 0.135 | 0.140 |
| 84044 | 0.403 | 0.403 | 0.412 |
| 84054 | 0.016 | 0.016 | 0.019 |
| 84058 | 0.383 | 0.383 | 0.393 |
| 84075 | 0.016 | 0.016 | 0.019 |
| 84079 | 0.464 | 0.464 | 0.474 |
| 84080 | 0.050 | 0.050 | 0.052 |
| 84087 | 0.657 | 0.657 | 0.669 |
| 84094 | 0.355 | 0.355 | 0.364 |
| 84112 | 0.048 | 0.048 | 0.055 |
| 84117 | 0.031 | 0.031 | 0.037 |
| 84118 | 0.008 | 0.008 | 0.010 |
| 84119 | 0.027 | 0.027 | 0.030 |
| 84122 | 0.589 | 0.589 | 0.600 |
| 84123 | 0.699 | 0.699 | 0.707 |
| 84124 | 0.048 | 0.048 | 0.051 |
| 84126 | 0.642 | 0.642 | 0.652 |
| 84127 | 2.718 | 2.718 | 2.729 |
| 84128 | 0.318 | 0.318 | 0.322 |
| 84133 | 0.037 | 0.037 | 0.042 |
| 84148 | 0.389 | 0.389 | 0.402 |
| 84180 | 0.245 | 0.245 | 0.258 |
| 84181 | 0.330 | 0.330 | 0.338 |
| 84185 | 0.058 | 0.058 | 0.063 |
| 84186 | 0.133 | 0.133 | 0.139 |

**Table 5A.6. (continued)**

| Date | Drainage DB | Drainage DA | Drainage F |
|---|---|---|---|
| 84187 | 0.008 | 0.008 | 0.009 |
| 84188 | 0.415 | 0.415 | 0.423 |
| 84192 | 0.068 | 0.068 | 0.074 |
| 84198 | 0.173 | 0.173 | 0.181 |
| 84199 | 0.256 | 0.256 | 0.262 |
| 84208 | 0.359 | 0.359 | 0.369 |
| 84222 | 0.200 | 0.200 | 0.210 |
| 84281 | 0.035 | 0.035 | 0.043 |
| 84293 | 0.100 | 0.100 | 0.110 |
| 84295 | 0.994 | 0.994 | 1.009 |
| 84296 | 0.981 | 0.981 | 0.990 |
| 84308 | 0.009 | 0.009 | 0.011 |
| 84314 | 0.636 | 0.636 | 0.648 |
| 84319 | 0.071 | 0.071 | 0.076 |
| 84322 | 0.034 | 0.034 | 0.037 |
| 84332 | 0.166 | 0.166 | 0.174 |
| 84334 | 0.021 | 0.021 | 0.023 |
| 84339 | 0.015 | 0.015 | 0.018 |
| 84353 | 0.079 | 0.079 | 0.084 |
| 84354 | 0.075 | 0.075 | 0.078 |
| 84357 | 0.015 | 0.015 | 0.017 |
| 84358 | 0.020 | 0.020 | 0.022 |

Table 5A.7a. CREAMS sensitivity analysis - wooded segment

| | Parameter | | Surface runoff | | ET | | Percolation | |
|---|---|---|---|---|---|---|---|---|
| | Value | Percent change | Value | Percent change | Value | Percent change | Value | Percent change |
| Base | | | 6.2 | 0.0 | 32.0 | 0.0 | 9.7 | 0.00 |
| 1 | FUL = 0.45 | -23.7 | 4.3 | -30.0 | 31.6 | -1.4 | 12.2 | 25.42 |
| 2 | FUL = 0.75 | 27.1 | 9.7 | 57.5 | 32.1 | 0.2 | 5.9 | -38.72 |
| 3 | LAI = PASTURE | - | 4.8 | -21.8 | 34.4 | 7.4 | 8.8 | -9.63 |
| 4 | CN = 70 | -12.5 | 3.2 | -47.8 | 32.1 | 0.9 | 12.6 | 29.52 |
| 5 | CN = 84 | 5.0 | 8.0 | 29.8 | 31.9 | -0.3 | 8.0 | -17.94 |
| 6 | CN = 90 | 12.5 | 12.1 | 95.6 | 31.4 | -1.9 | 4.5 | -53.90 |
| 7 | SIA = 0.2 | 100.0 | 4.4 | -28.8 | 32.1 | 0.2 | 11.4 | 17.57 |
| 8 | SIA = 0.3 | 200.0 | 3.4 | -44.9 | 32.1 | 0.2 | 12.4 | 27.64 |
| 9 | RD = 12 | -70.0 | 4.3 | -29.7 | 28.8 | -10.1 | 15.1 | 55.61 |
| 10 | RD = 24 | -40.0 | 5.6 | -9.3 | 30.8 | -3.9 | 11.7 | 20.83 |
| 11 | RD = 70 | 75.0 | 6.8 | 10.4 | 32.1 | 0.3 | 8.7 | -10.71 |
| 12 | RC = 0.02 | 150.0 | 8.4 | 35.6 | 32.1 | 0.2 | 7.3 | -25.15 |
| 13 | RC = 0.10 | -50.0 | 5.3 | -14.3 | 32.9 | 2.9 | 10.8 | 11.78 |
| 14 | RC = 0.15 | 200.0 | 5.0 | -19.3 | 31.8 | -0.6 | 11.3 | 16.82 |

Note: Average annual values in in., based on 1981—1990 period.

**Table 5A.7b. CREAMS sensitivity analysis - grass segment**

| | Parameter | | Surface runoff | | ET | | Percolation | |
|---|---|---|---|---|---|---|---|---|
| Case | Value | Percent change | Value | Percent change | Value | Percent change | Value | Percent change |
| Base | | | 13.0 | 0.0 | 28.7 | 0.0 | 6.4 | 0.0 |
| 1 | FUL = 0.50 | -35.1 | 7.8 | -39.9 | 28.2 | -1.8 | 12.1 | 90.9 |
| 2 | FUL = 0.90 | 16.9 | 16.7 | 28.0 | 28.7 | 0.1 | 2.7 | -58.0 |
| 3 | LAI = PASTURE | - | 11.4 | -12.8 | 29.3 | 2.2 | 7.4 | 16.7 |
| 4 | CN = 70 | -16.4 | 8.2 | -37.4 | 29.2 | 1.6 | 10.8 | 69.4 |
| 5 | CN = 80 | -4.8 | 11.3 | -13.1 | 28.9 | 0.8 | 7.8 | 23.1 |
| 6 | CN = 90 | 7.1 | 16.5 | 26.9 | 27.8 | -3.2 | 3.8 | -40.0 |
| 7 | SIA = 0.2 | 100.0 | 11.8 | -9.8 | 29.0 | 0.9 | 7.4 | 15.9 |
| 8 | SIA = 0.3 | 200.0 | 10.9 | -16.2 | 29.0 | 1.3 | 8.1 | 27.3 |
| 9 | RD = 12 | -50.0 | 9.1 | -30.0 | 26.9 | -6.2 | 12.2 | 91.3 |
| 10 | RD = 40 | 66.7 | 13.4 | 2.6 | 29.8 | 3.9 | 4.5 | -28.8 |
| 11 | RD = 70 | 191.7 | 14.4 | 10.7 | 30.7 | 6.8 | 2.8 | -56.6 |
| 12 | RC = 0.05 | 150.0 | 9.4 | -28.0 | 28.6 | -0.3 | 10.2 | 60.1 |
| 13 | RC = 0.10 | 400.0 | 9.4 | -28.0 | 28.6 | -0.3 | 10.2 | 60.1 |
| 14 | RC = 0.15 | 650.0 | 9.4 | -28.0 | 28.6 | -0.3 | 10.2 | 60.1 |

Note: Average annual values in in., based on 1981—1990 period.

# Appendix 5A Figures

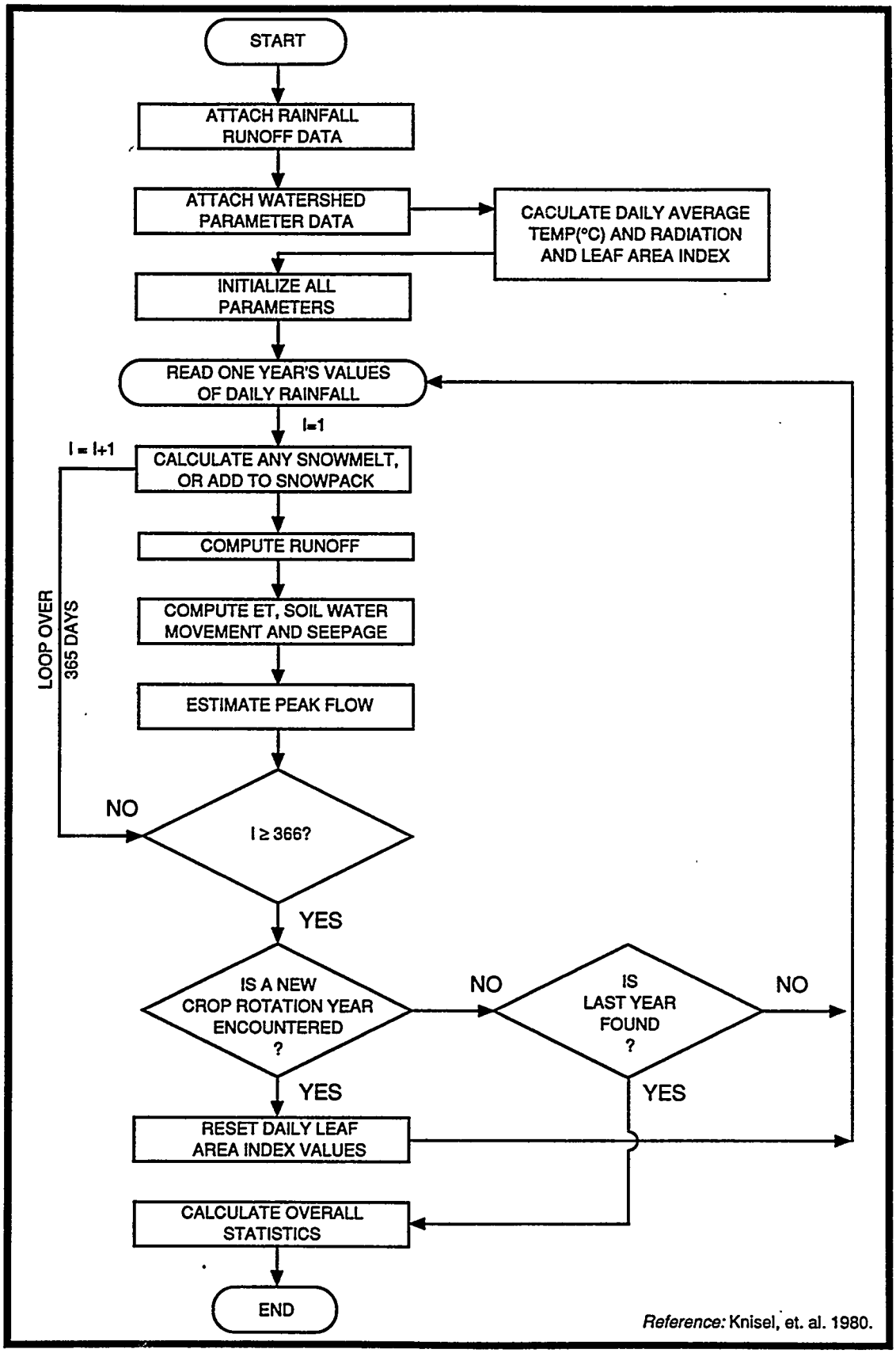
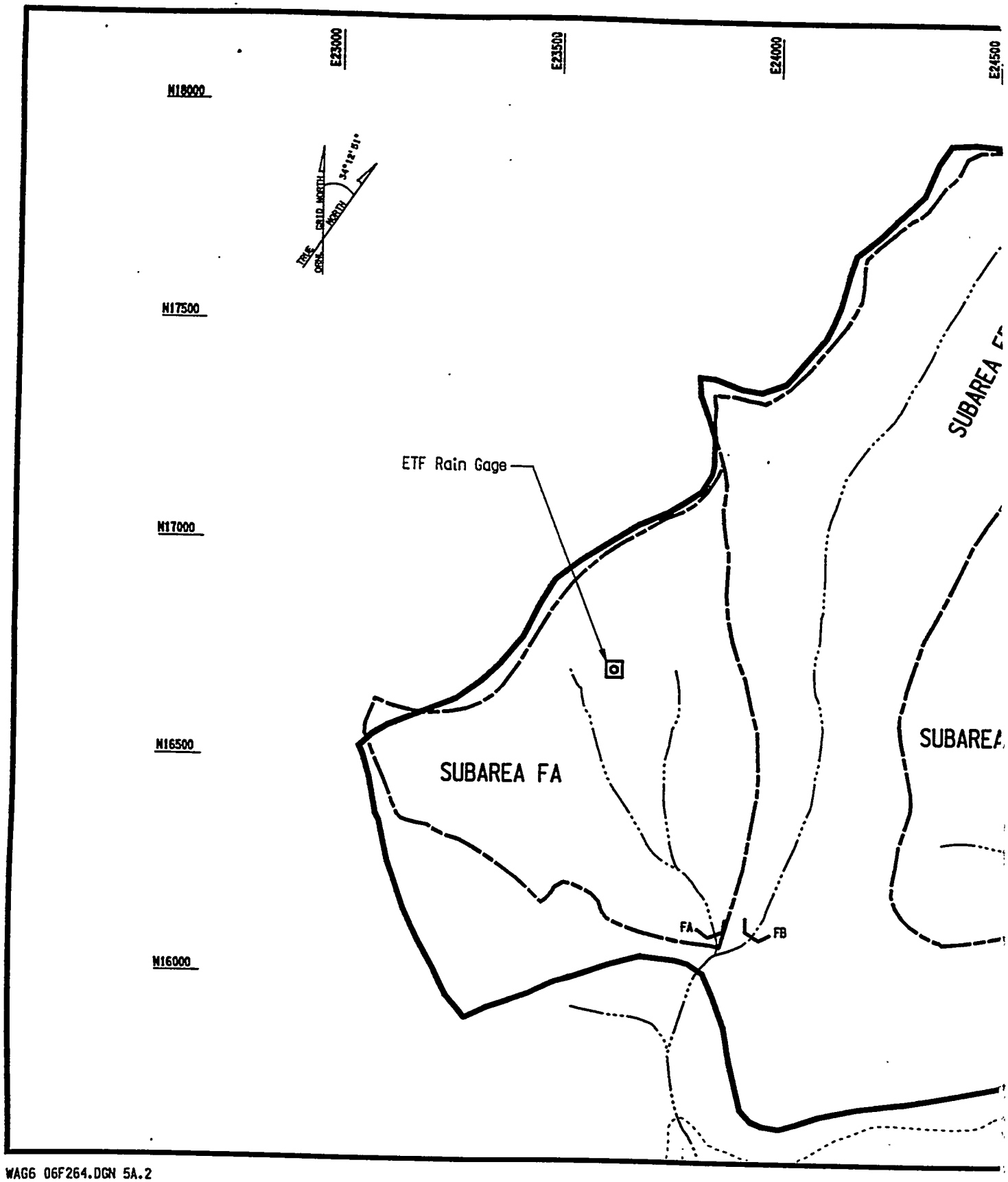



**Fig. 5A.1. Generalized flow chart for the runoff component of CREAMS.**




WAG6 06F264.DGN 5A.2

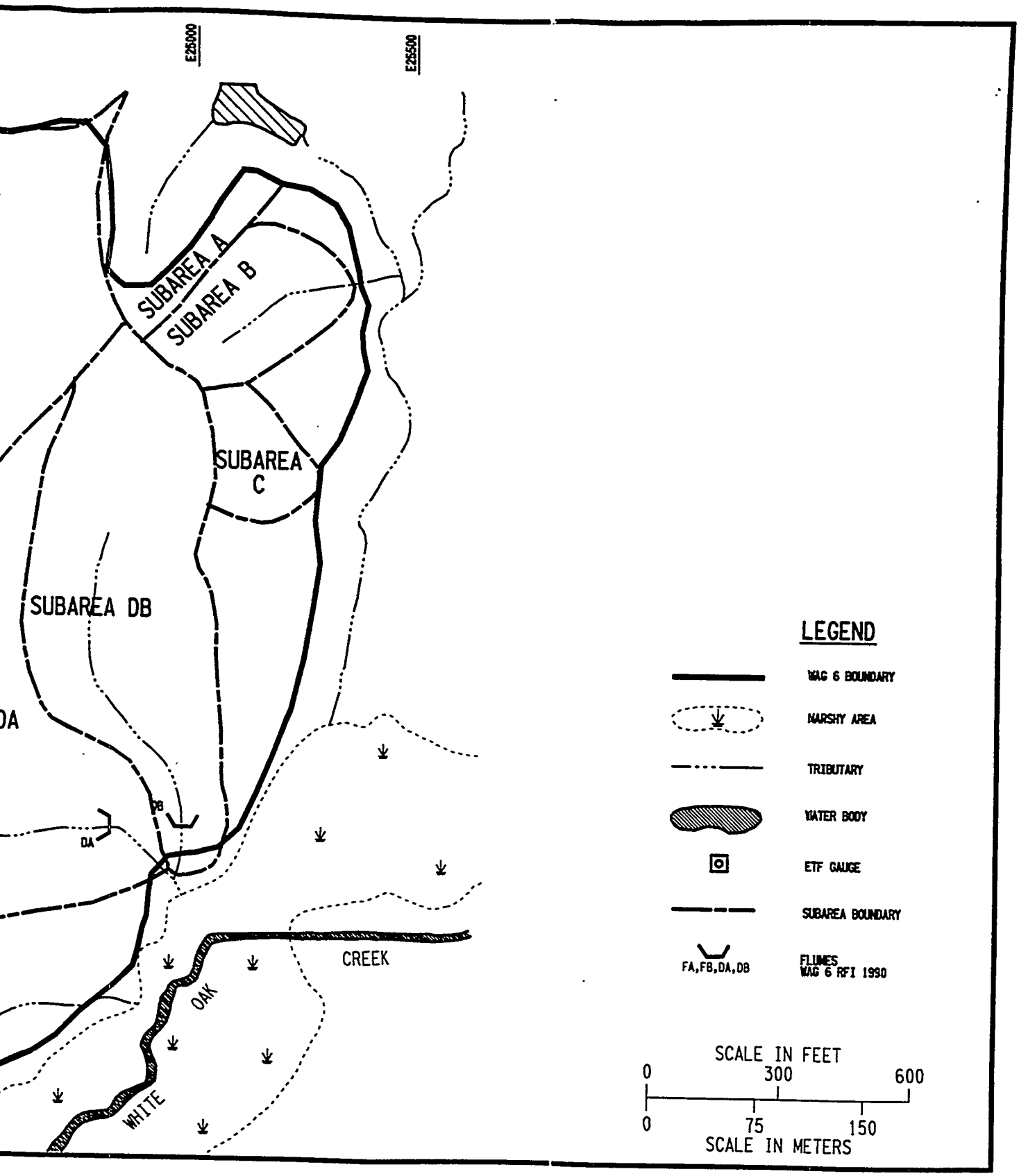



**Fig. 5A.2. WAG 6 storm flow/monitoring stations.**

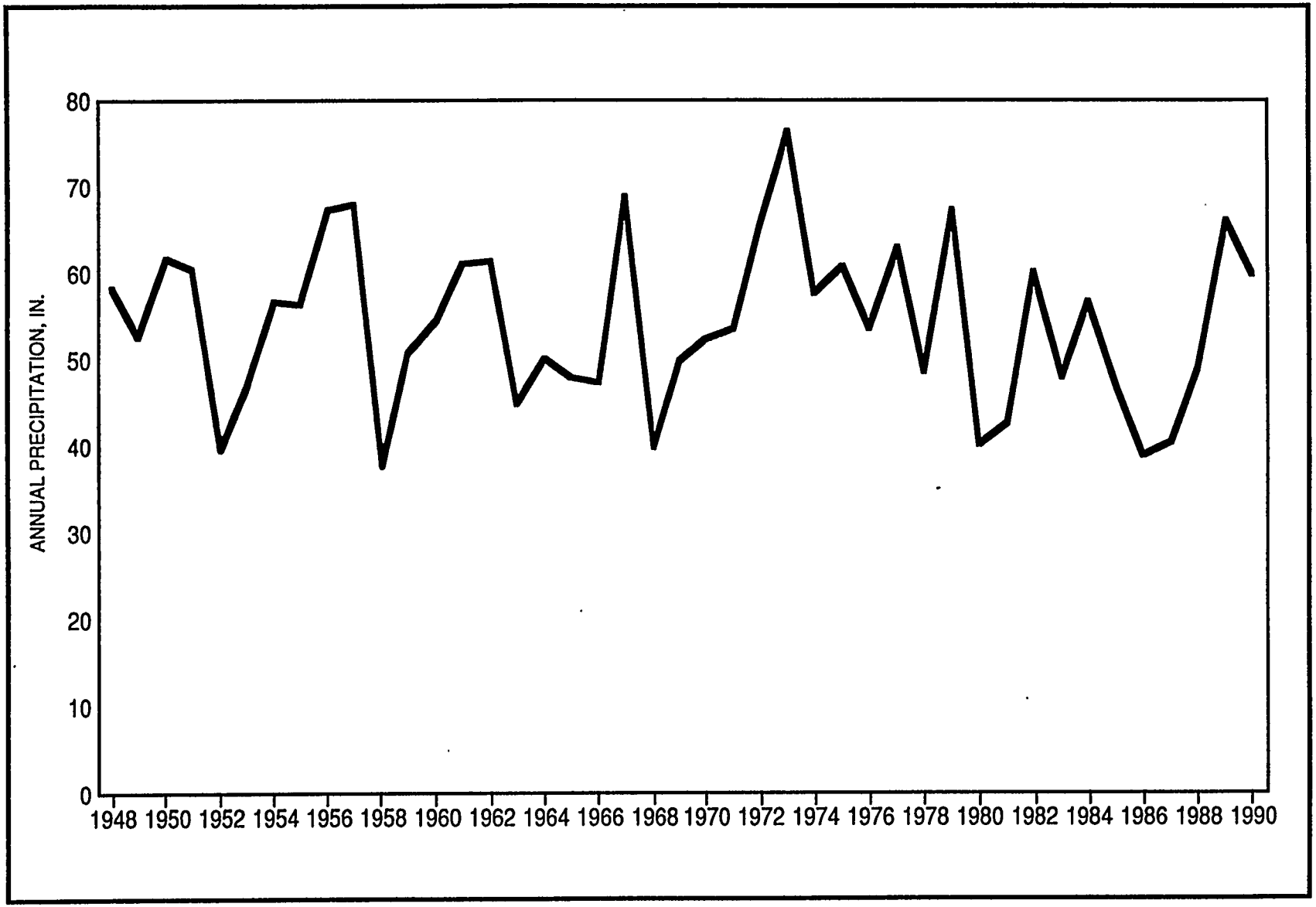



**Fig. 5A.3. Annual precipitation, Oak Ridge.**

5.18 4104.31

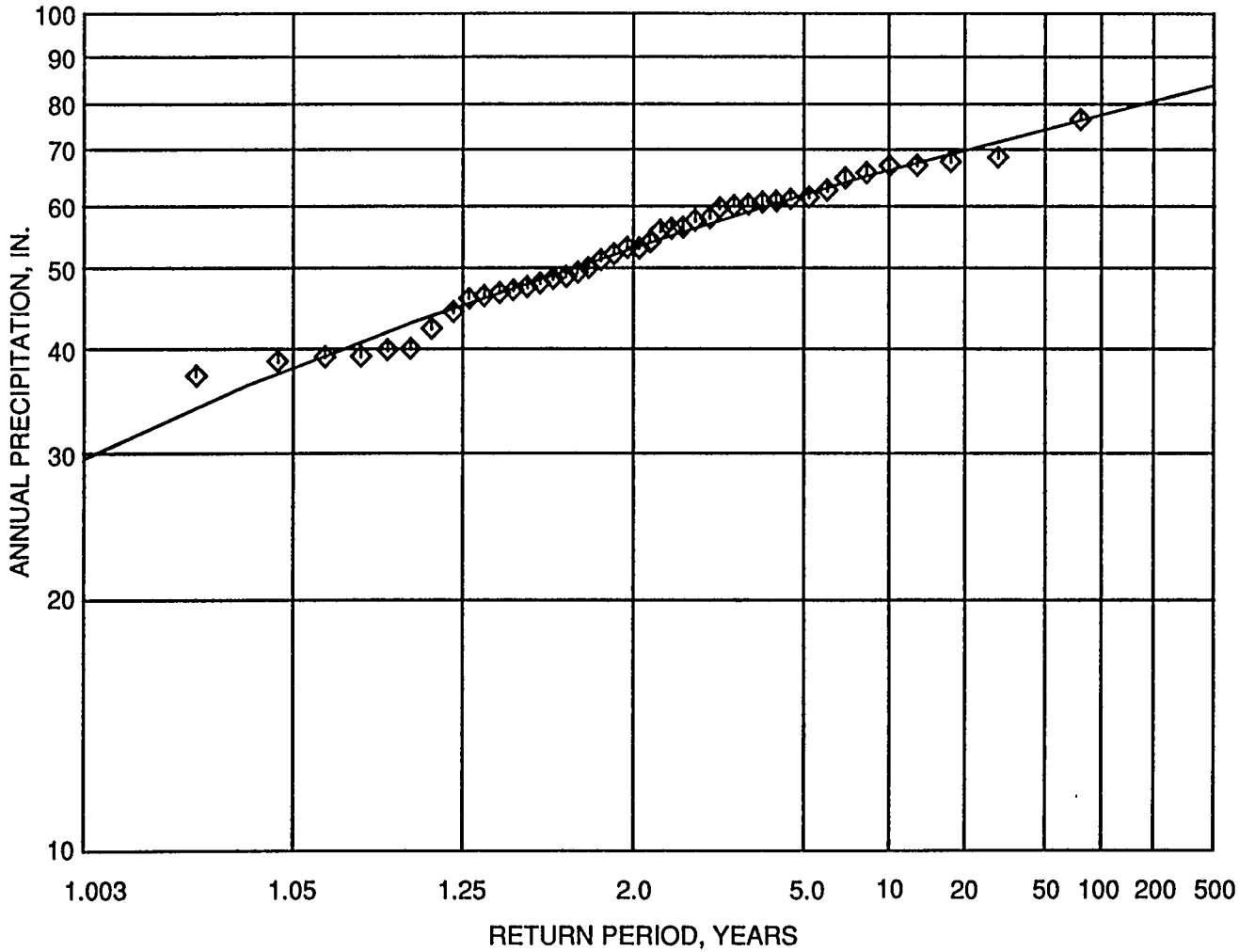



**Fig. 5A.4. Annual precipitation – frequency relationship, Oak Ridge.**

5.18 4104.32

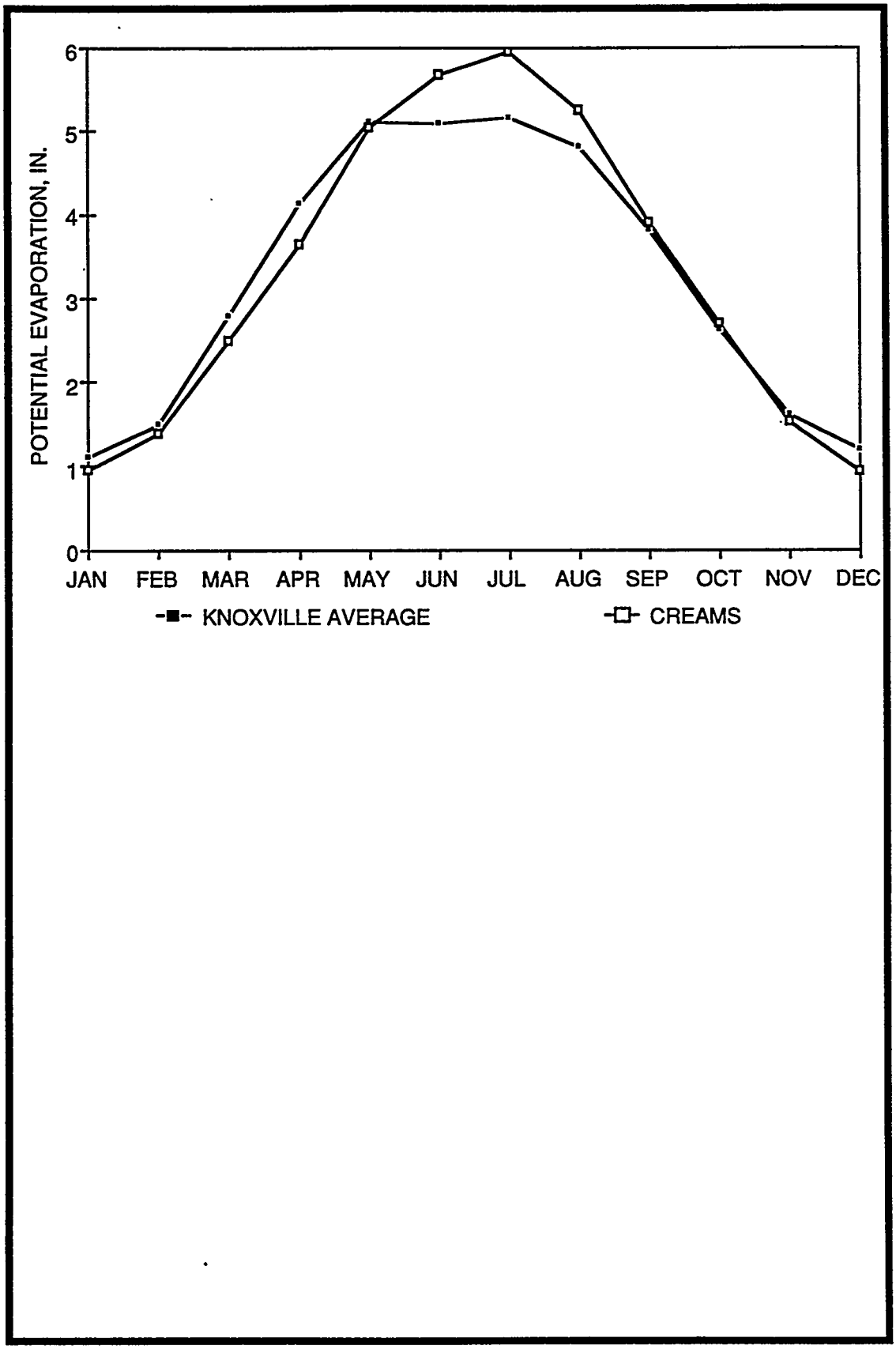



**Fig. 5A.5. Mean monthly potential evaporation, WAG 6.**

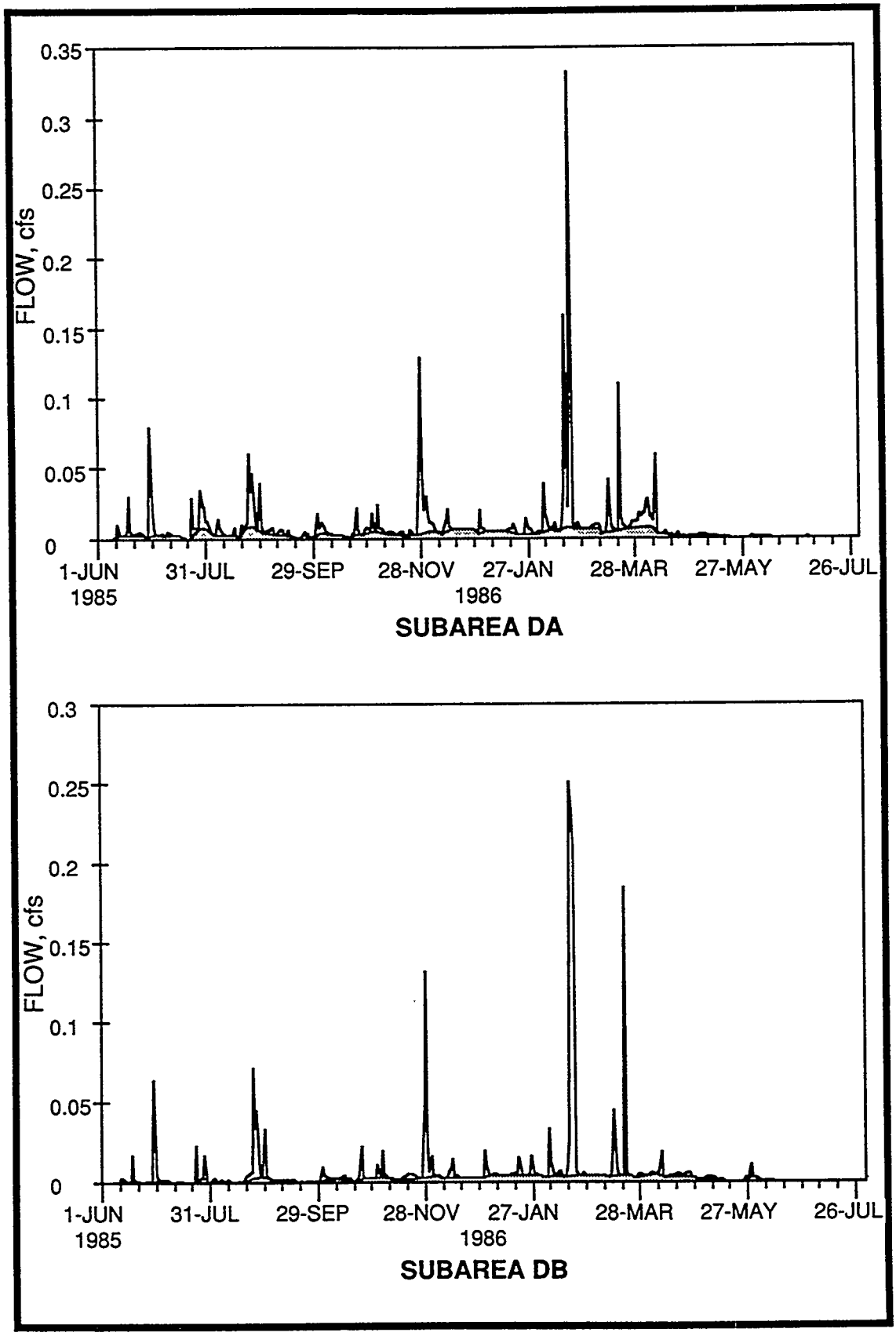



**Fig. 5A.6a. Mean daily flow hydrographs, June 1985-July 1986, (Subareas DA and DB).**

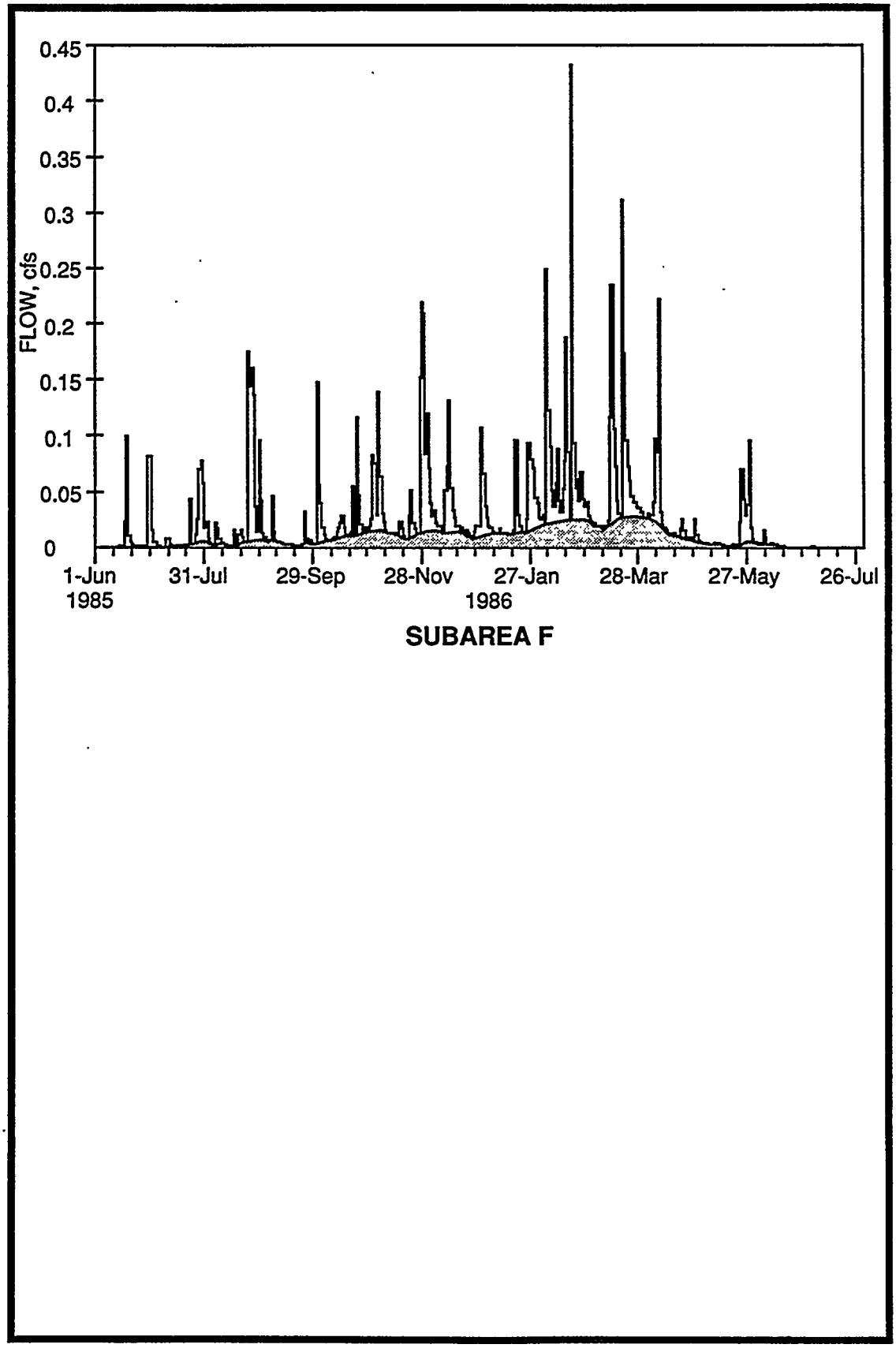



**Fig. 5A.6b. Mean daily flow hydrographs, June 1985 – July 1986 (Subarea F).**

5.18 4104.25

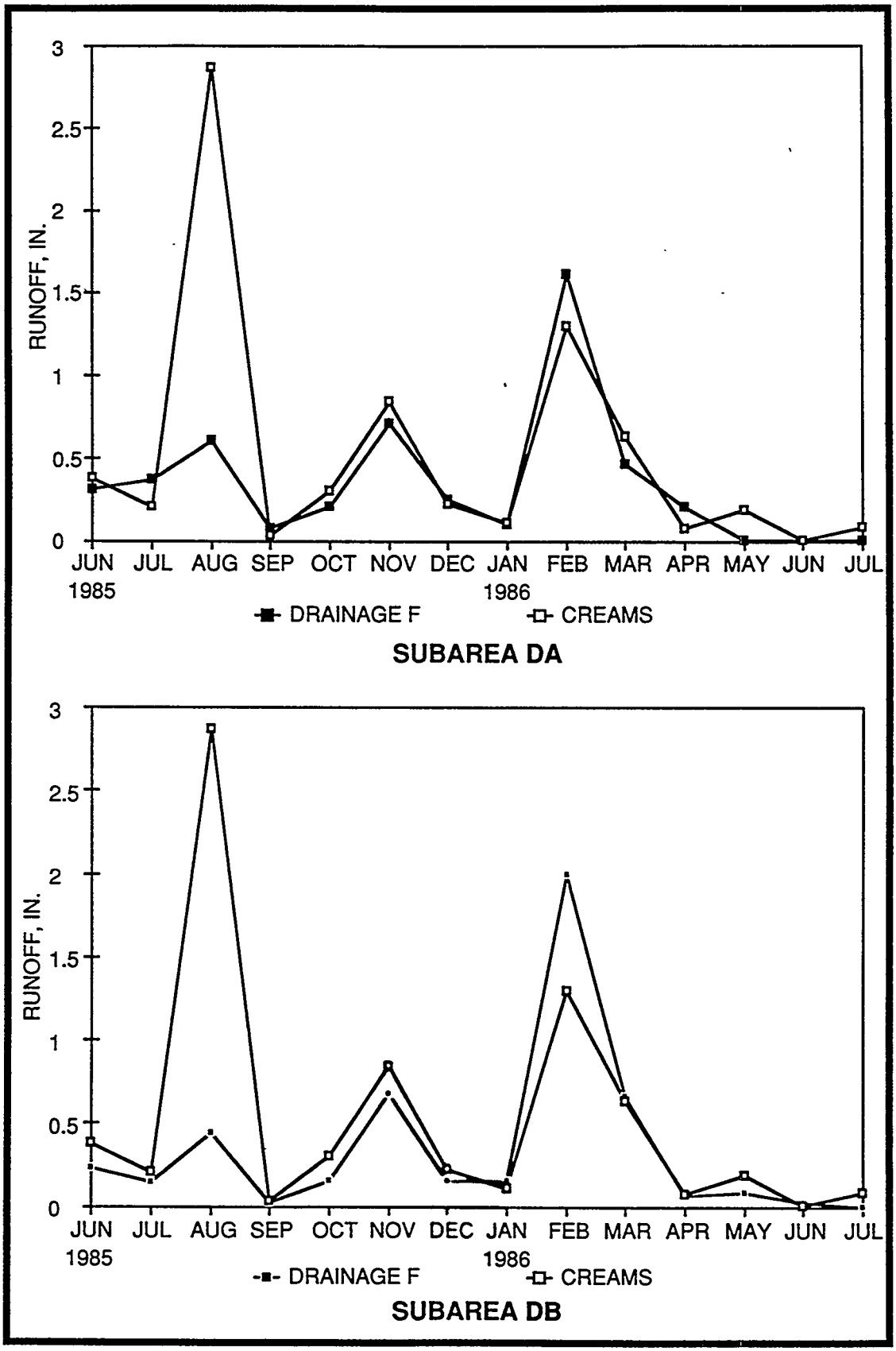



**Fig. 5A.7a. Simulated and recorded drainage flows (Subareas DA and DB).**

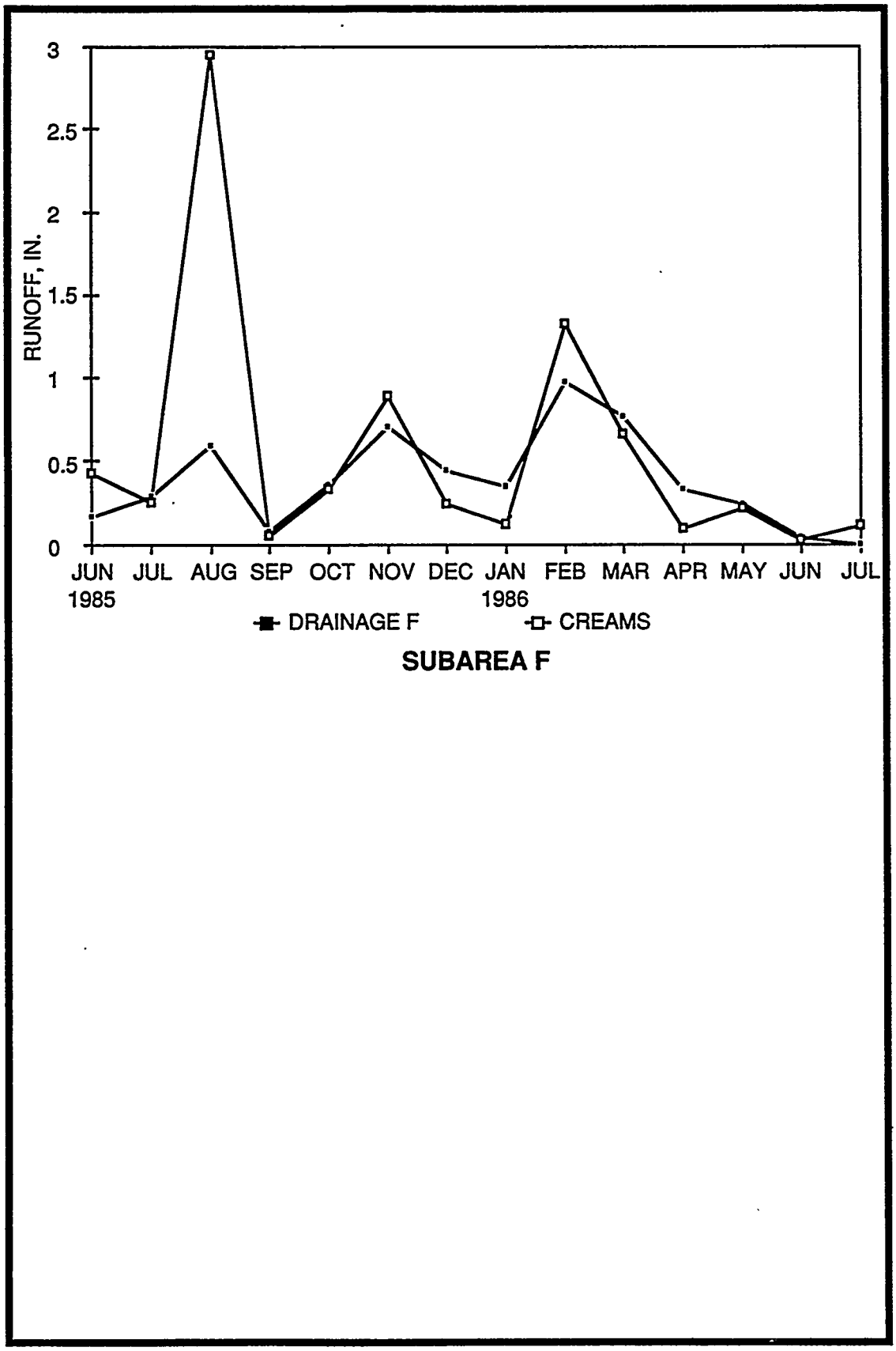



**Fig. 5A.7b. Simulated and recorded drainage flows (Subarea F).**

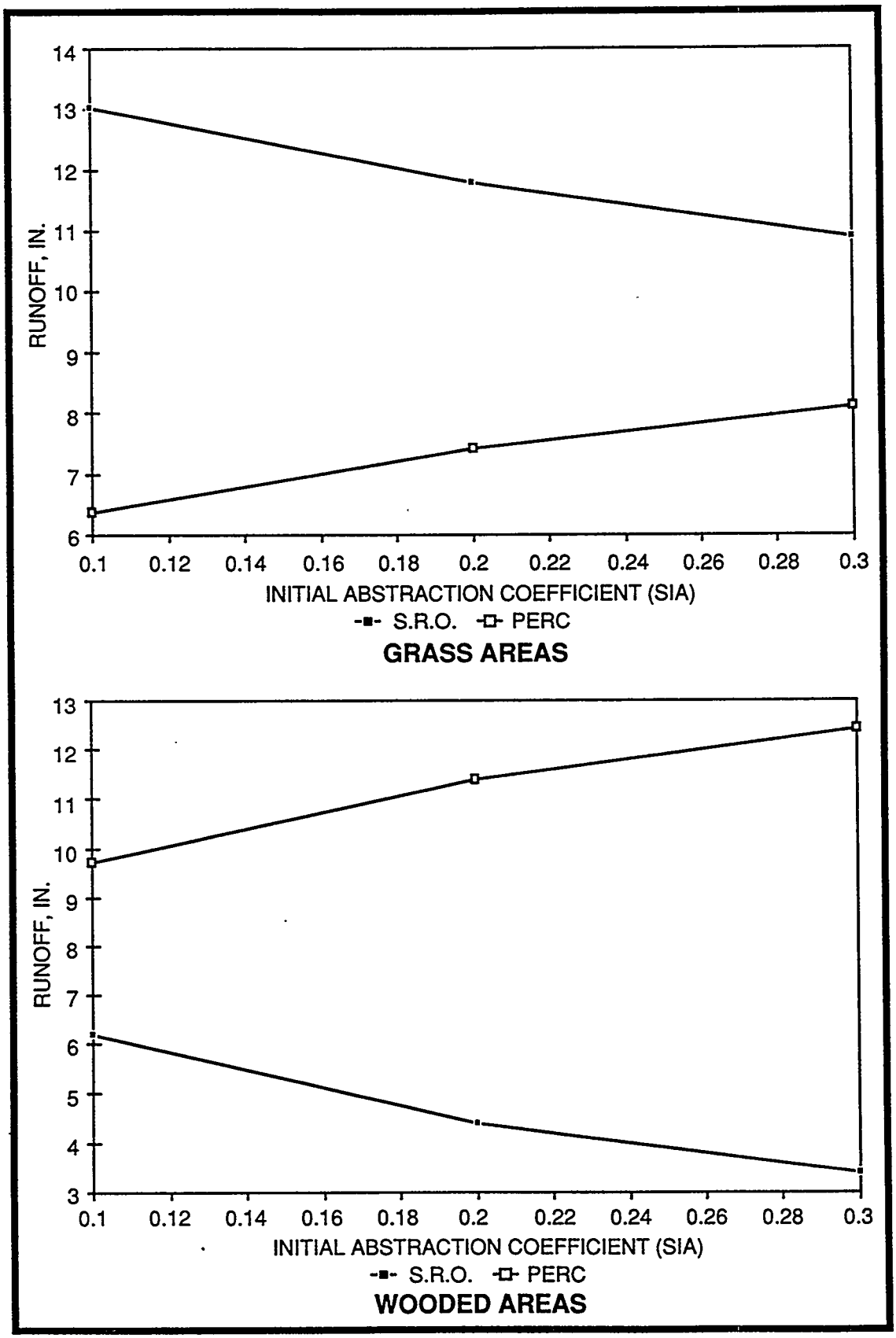



**Fig. 5A.8. CREAMS sensitivity analysis – initial abstraction coefficient.**

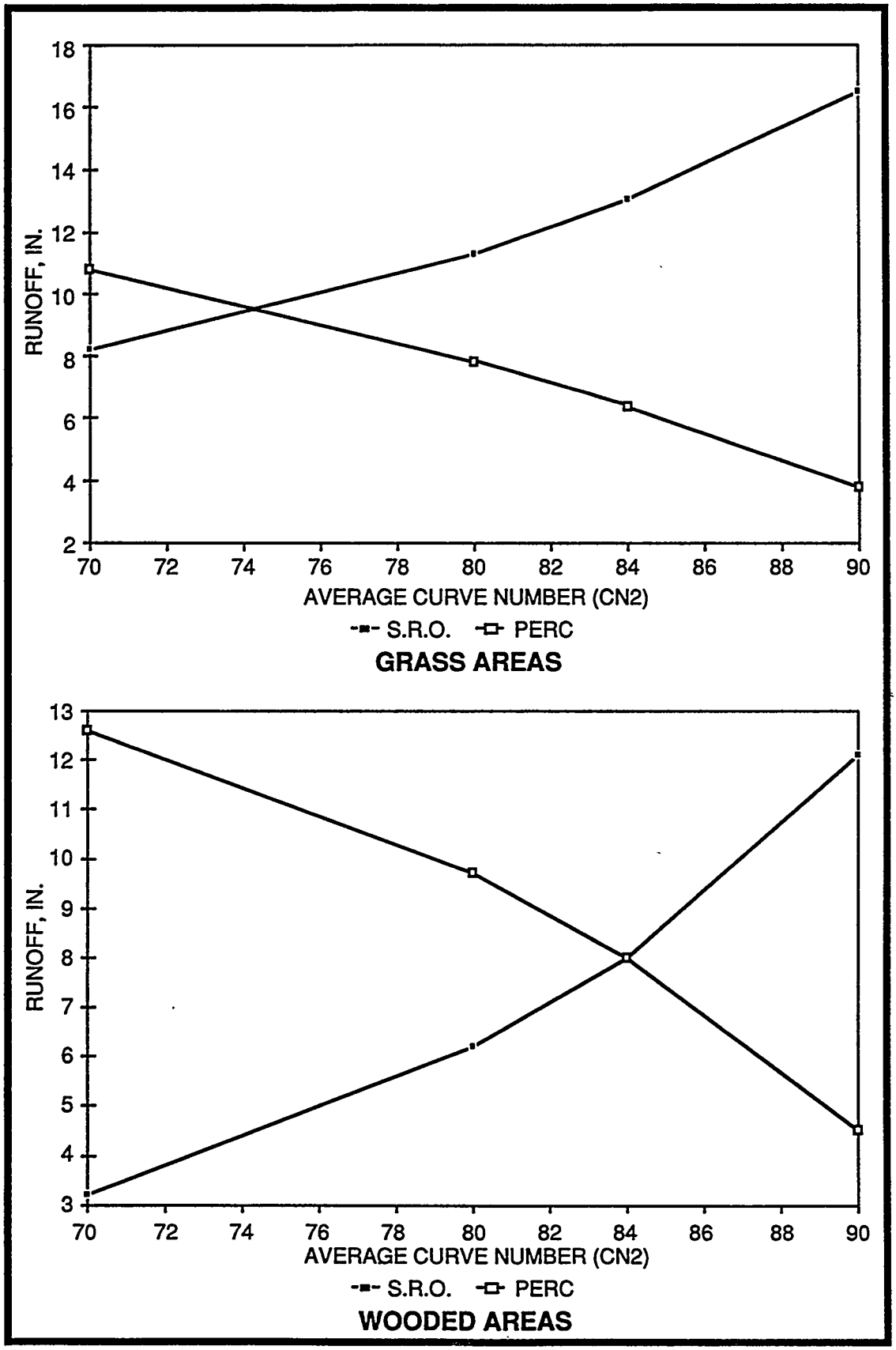



**Fig. 5A.9. CREAMS sensitivity analysis – average curve number.**

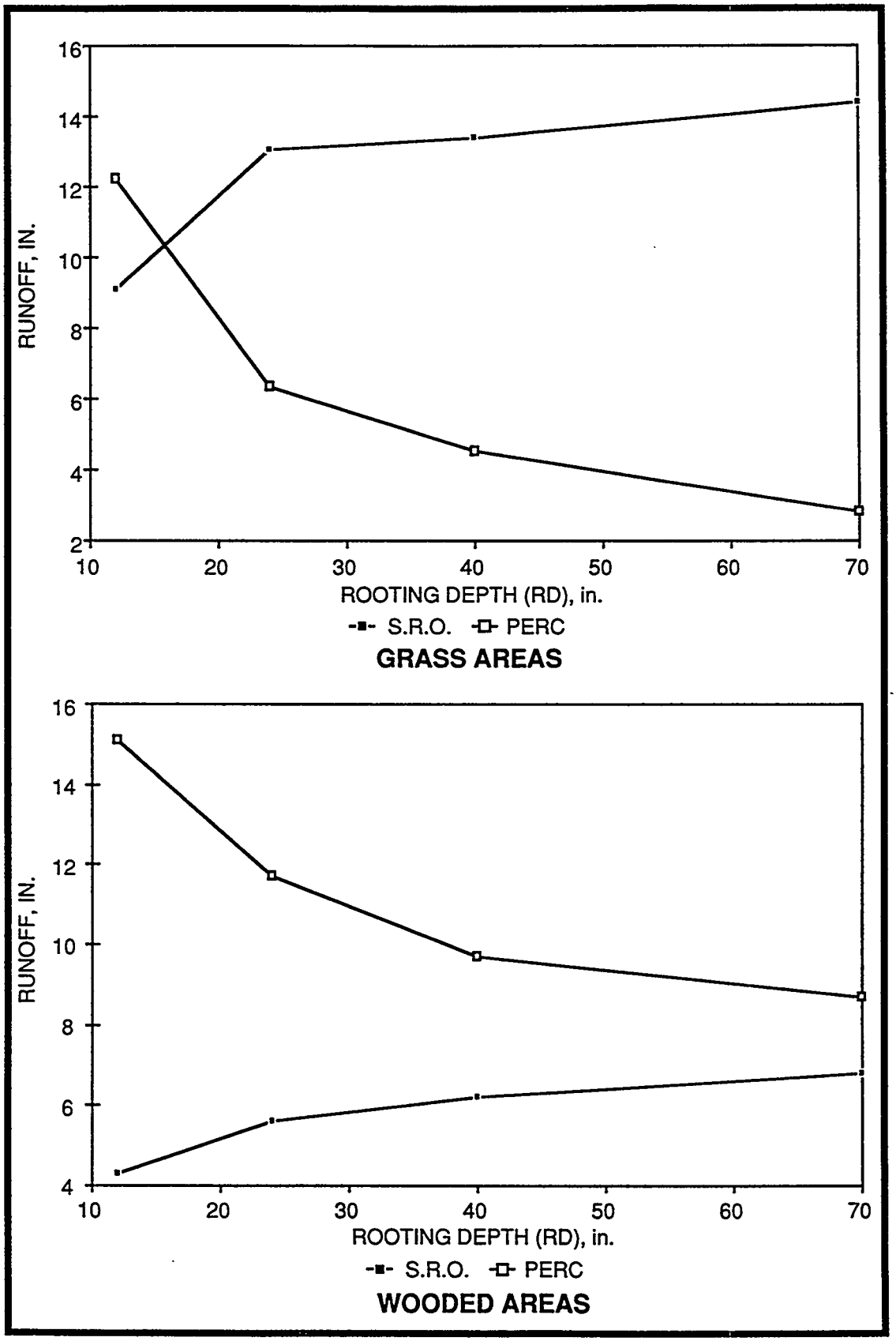



**Fig. 5A.10. CREAMS sensivity analysis – rooting depth.**

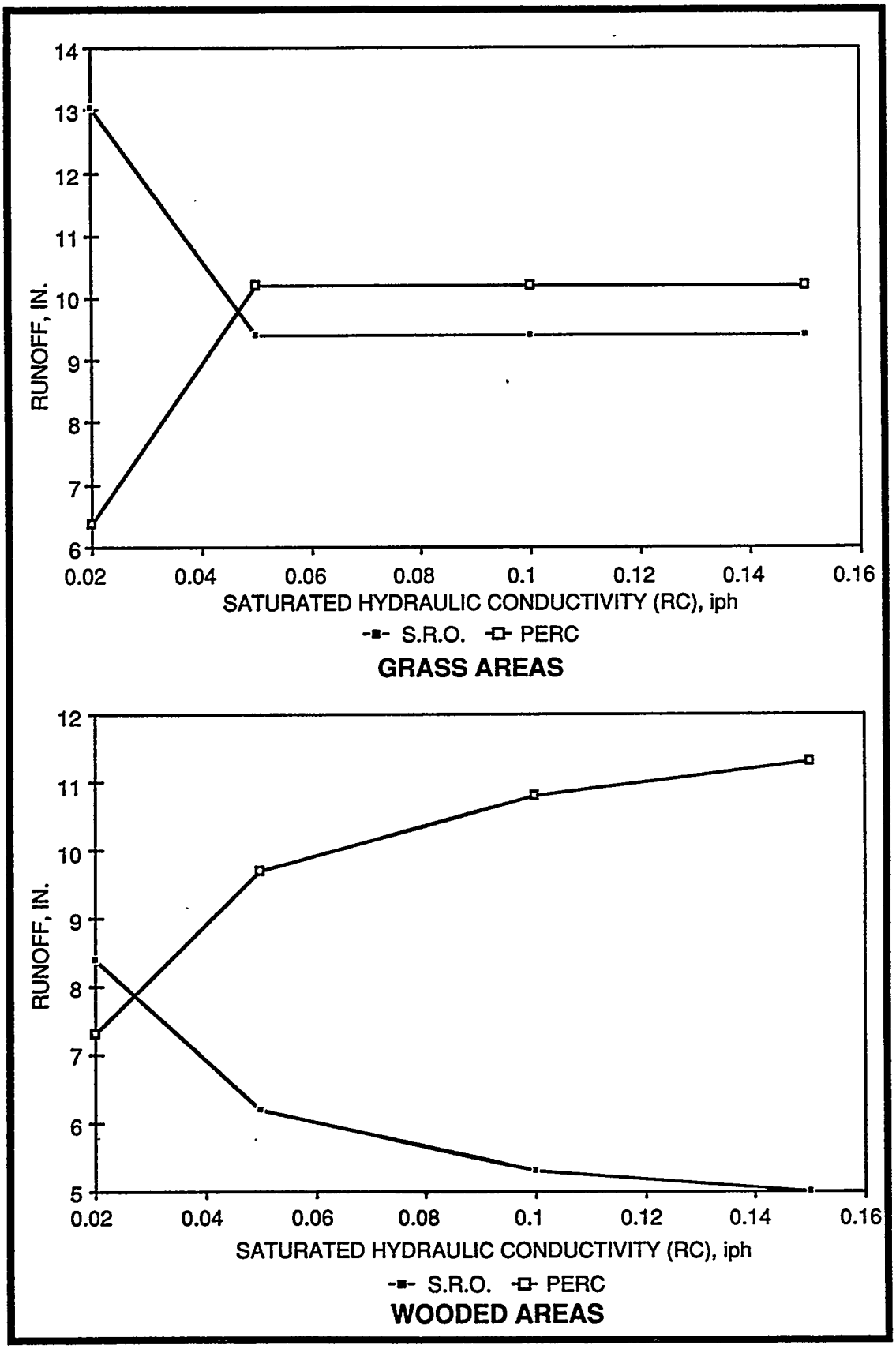



**Fig. 5A.11. CREAMS sensitivity analysis – saturated hydraulic conductivity.**

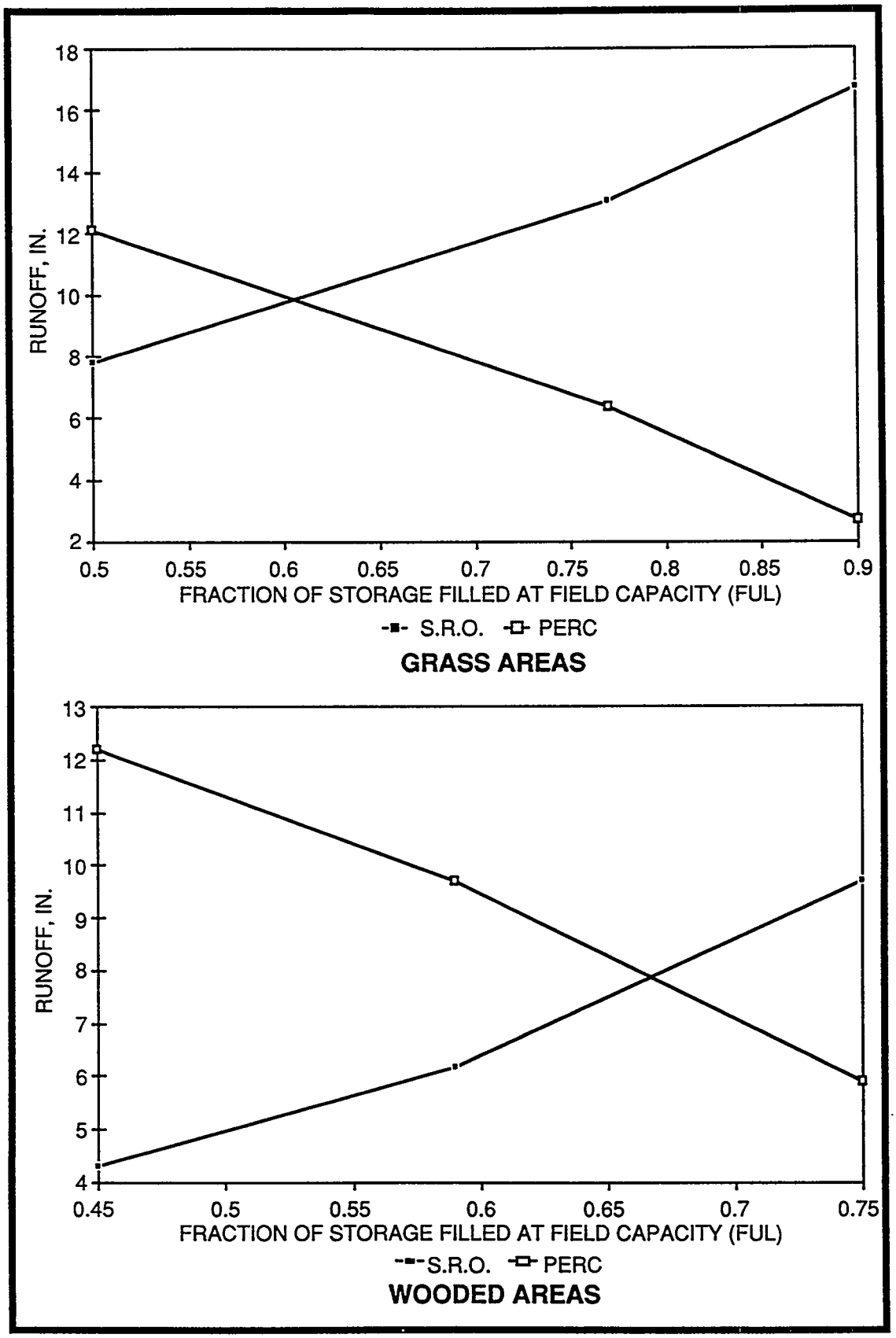



**Fig. 5A.12. CREAMS sensitivity analysis – fraction of storage filled at field capacity.**

# APPENDIX 5B. ANALYSIS AND RESULTS OF APRIL—MAY 1990 STORM SAMPLING

To calibrate the surface flux in the fate and contaminant transport model, the model used average contaminant concentrations in storm runoff and the volume of the storm runoff as input. These values were determined from field measurements.

During the months of April and May 1990, the four main streams (FA, FB, DA, and DB) draining WAG 6 were sampled during storm events. The sampling locations are shown in Fig. 5B.1. A series of samples were collected at 10-minute intervals during the course of a storm. Eight samples from each storm event were selected for analyses. The sample concentrations were at discrete points on the runoff hydrograph. Each of the four streams was sampled during two storms. A complete description of the sampling effort and the sample results is provided in TM 06-05A.

The pollutographs of the modeled constituents are shown in Figs. 5B.2 through 5B.9. The corresponding runoff hydrographs for each of the four streams are also shown in these figures.

To determine the average concentration for each storm, the runoff volume was first calculated from the time the sample was taken, by integrating under the runoff hydrograph. Base flow was not taken into consideration since little or no flow was in the streams prior to the storm. During that same time period, the total amount of contamination leaving the site was calculated by integrating under the pollutograph. The trapezoidal method is used for the integration. The average storm concentration is then determined by dividing the storm volume by the total contaminant flux.

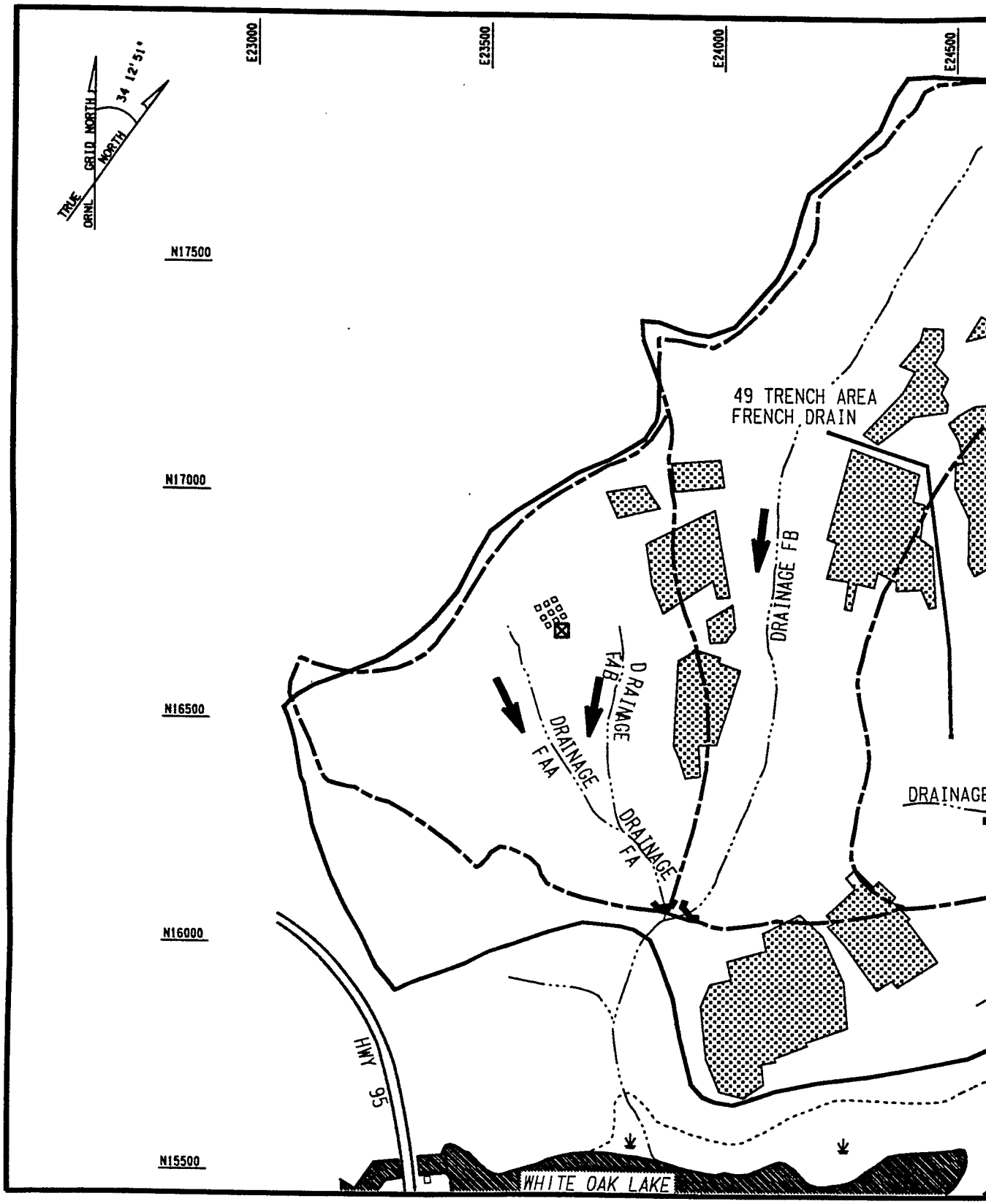
Of the modeled constituents, only tritium and strontium-90 were detected in more than one sample at a site. Drainage FA was not analyzed for tritium. The average storm concentrations used in the modeling are shown in Table 5B.1.

# Appendix 5B Tables

**Table 5B.1. Average concentrations of April-May storm samples used in the fate and contaminant transport model**

| Drainage area | Contaminant | Storm date | Storm runoff (in.) | Average concentration (pCi/L) |
|---|---|---|---|---|
| DA | Tritium | 5/17/90 | 0.26 | 1,009,410 |
| DA | Tritium | 5/27/90 | 0.17 | 78,000 |
| DB | Tritium | 5/17/90 | 0.23 | 598,000 |
| DB | Tritium | 5/27/90 | 0.53 | 63,800 |
| FB | Tritium | 5/17/90 | 0.17 | 738,000 |
| FB | Tritium | 5/20/90 | 0.04 | 1,623,000 |
| FB | Strontium-90 | 5/17/90 | 0.17 | 139 |
| FB | Strontium-90 | 5/20/90 | 0.04 | 225 |

# Appendix 5B Figures




WAG6 06F308.DGN

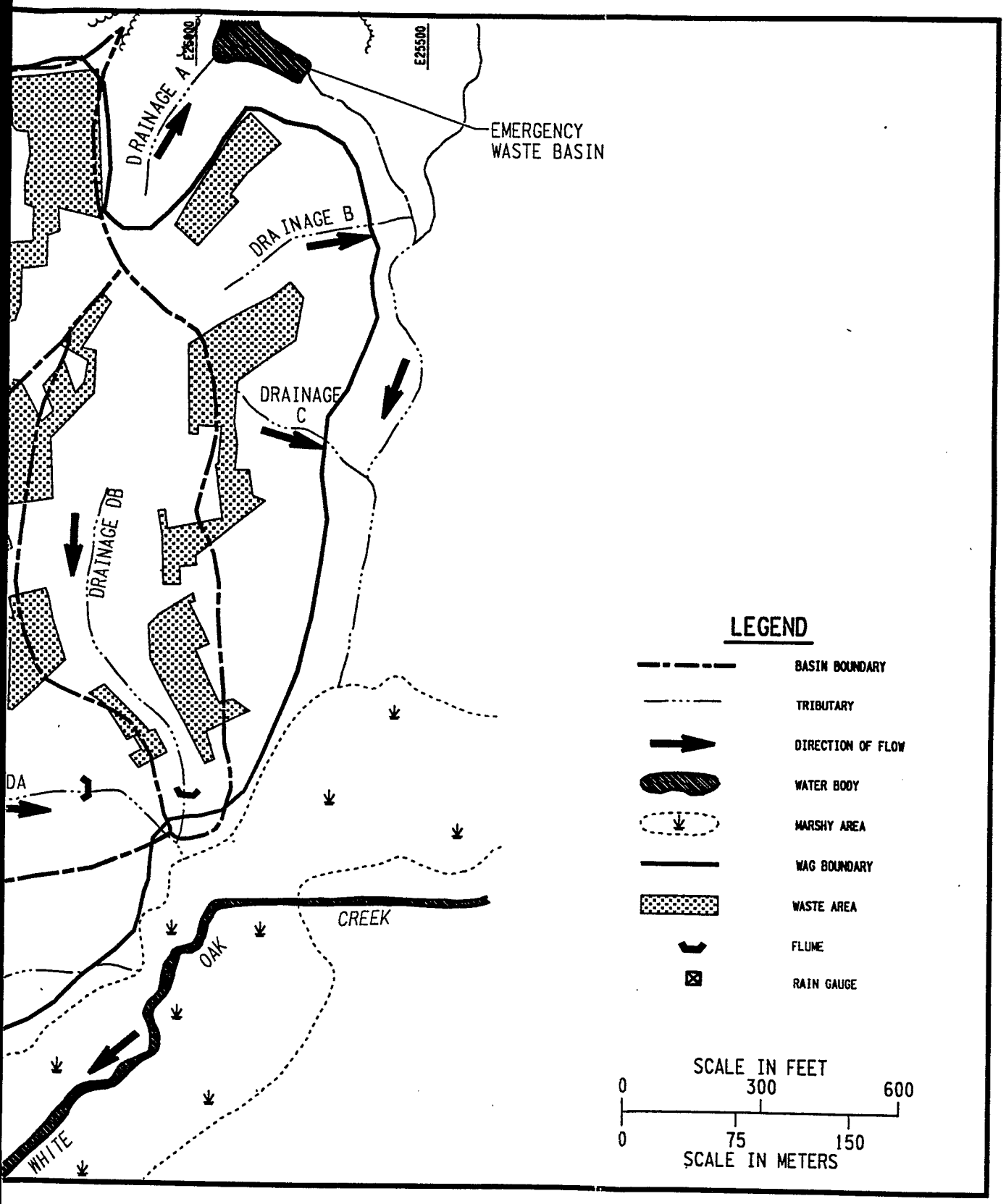



**Fig. 5E.2. Drainage patterns at WAG 6 and adjacent areas.**

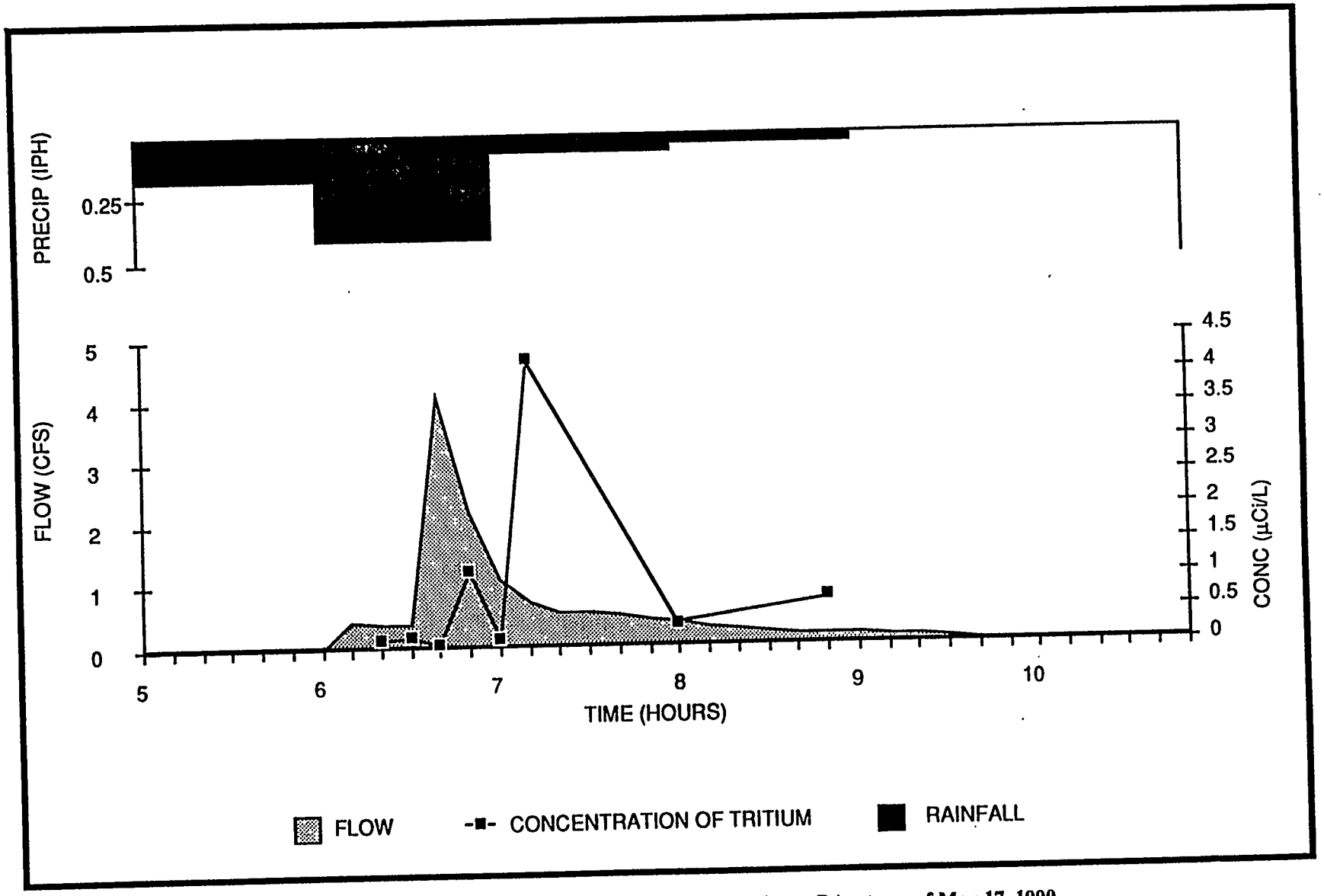



Fig. 5B.2. Tritium concentration in surface runoff; drainage DA; storm of May 17, 1990.

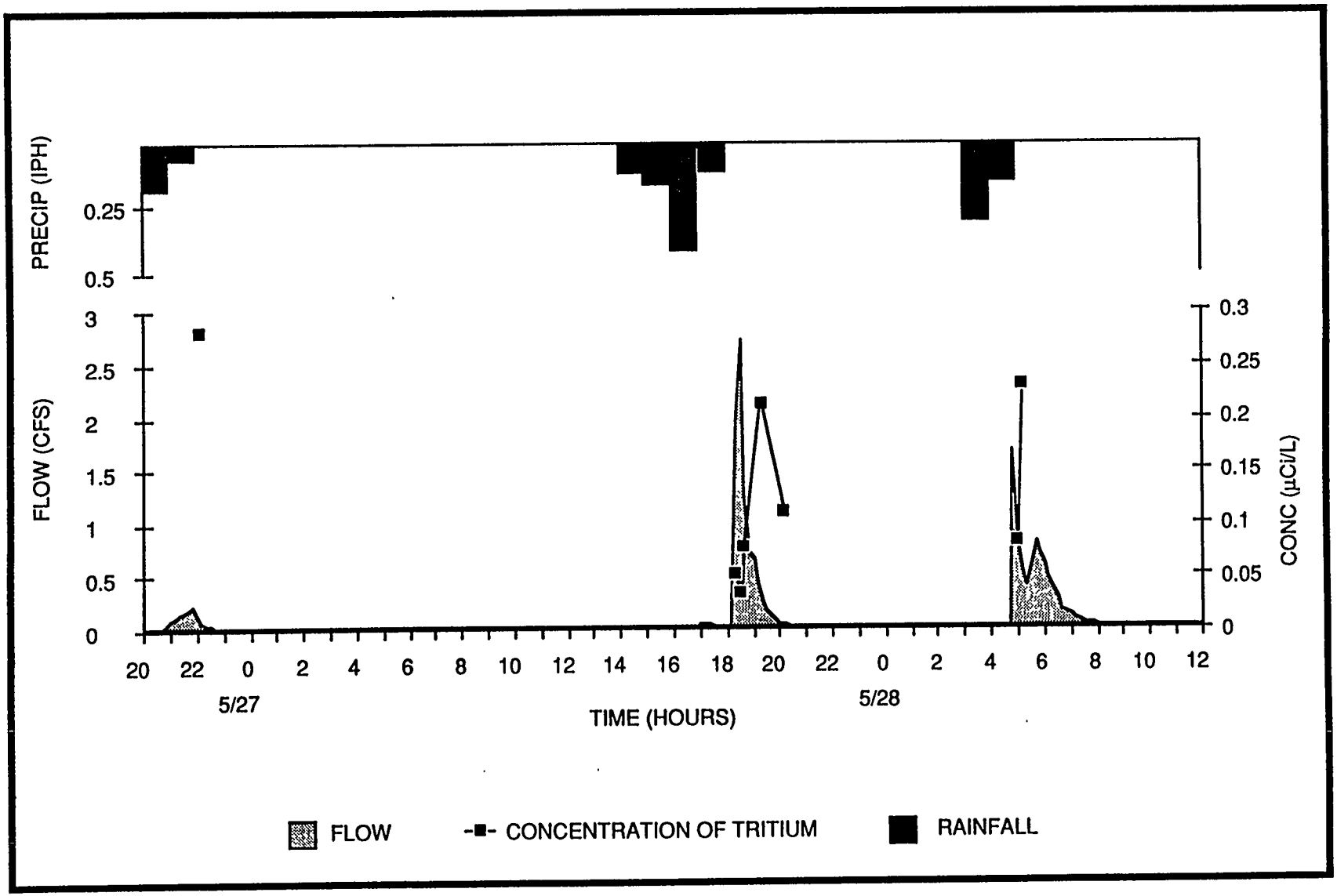



**Fig. 5B.3. Tritium concentration in surface runoff; drainage DA; storm of May 27, 1990.**

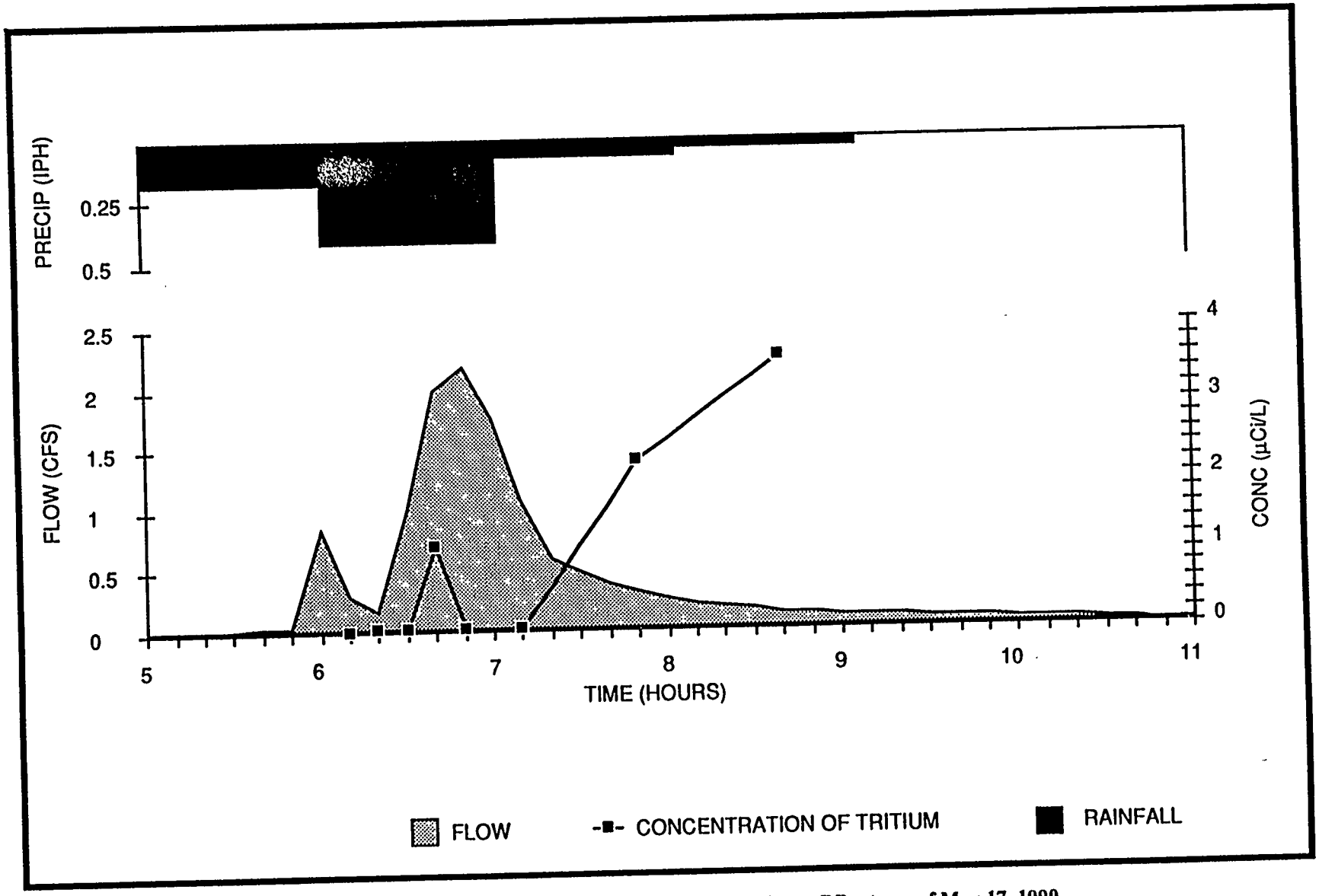



Fig. 5B.4. Tritium concentration in surface runoff; drainage DB; storm of May 17, 1990.

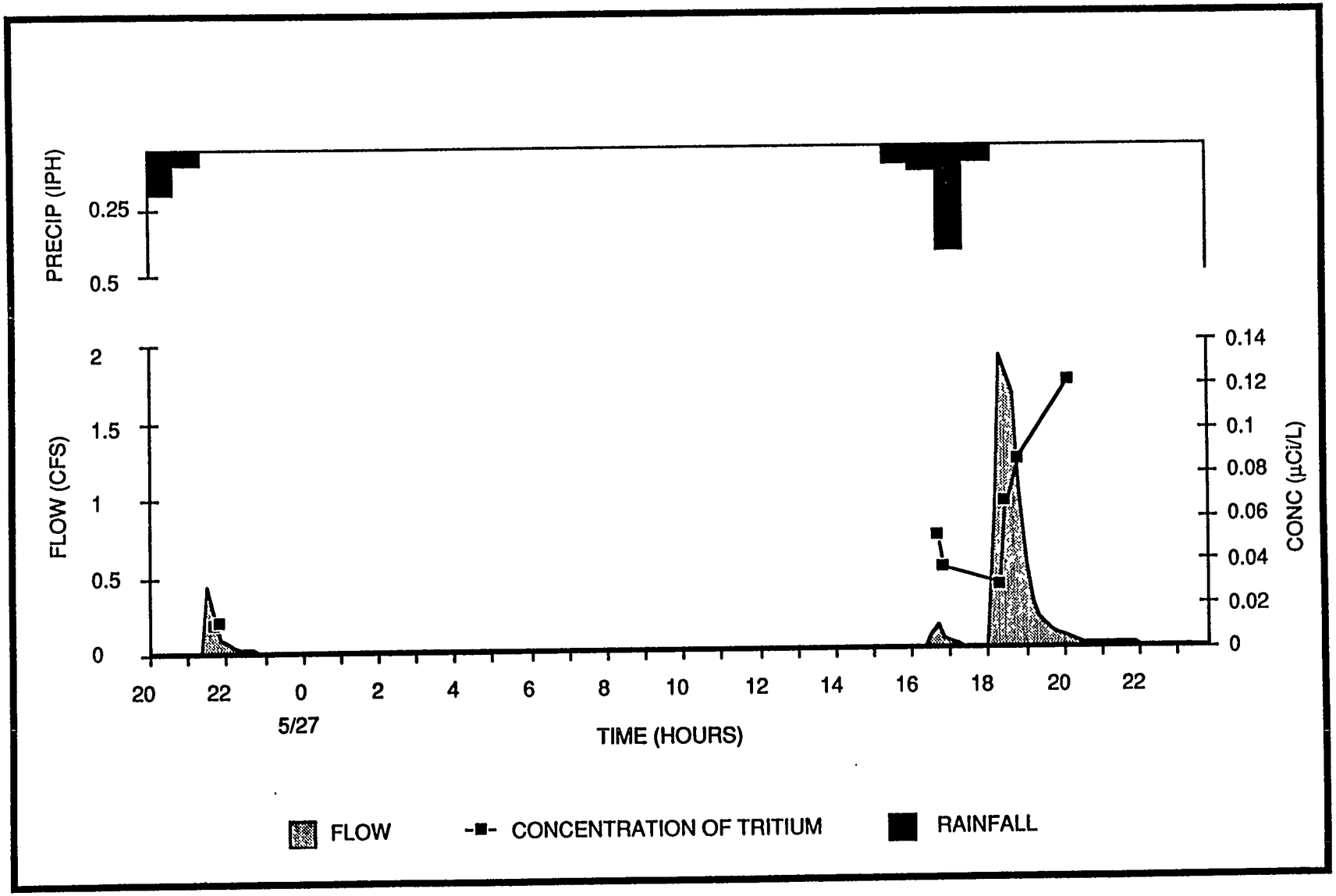



**Fig. 5B.5. Tritium concentration in surface runoff; drainage DB; storm of May 27, 1990.**

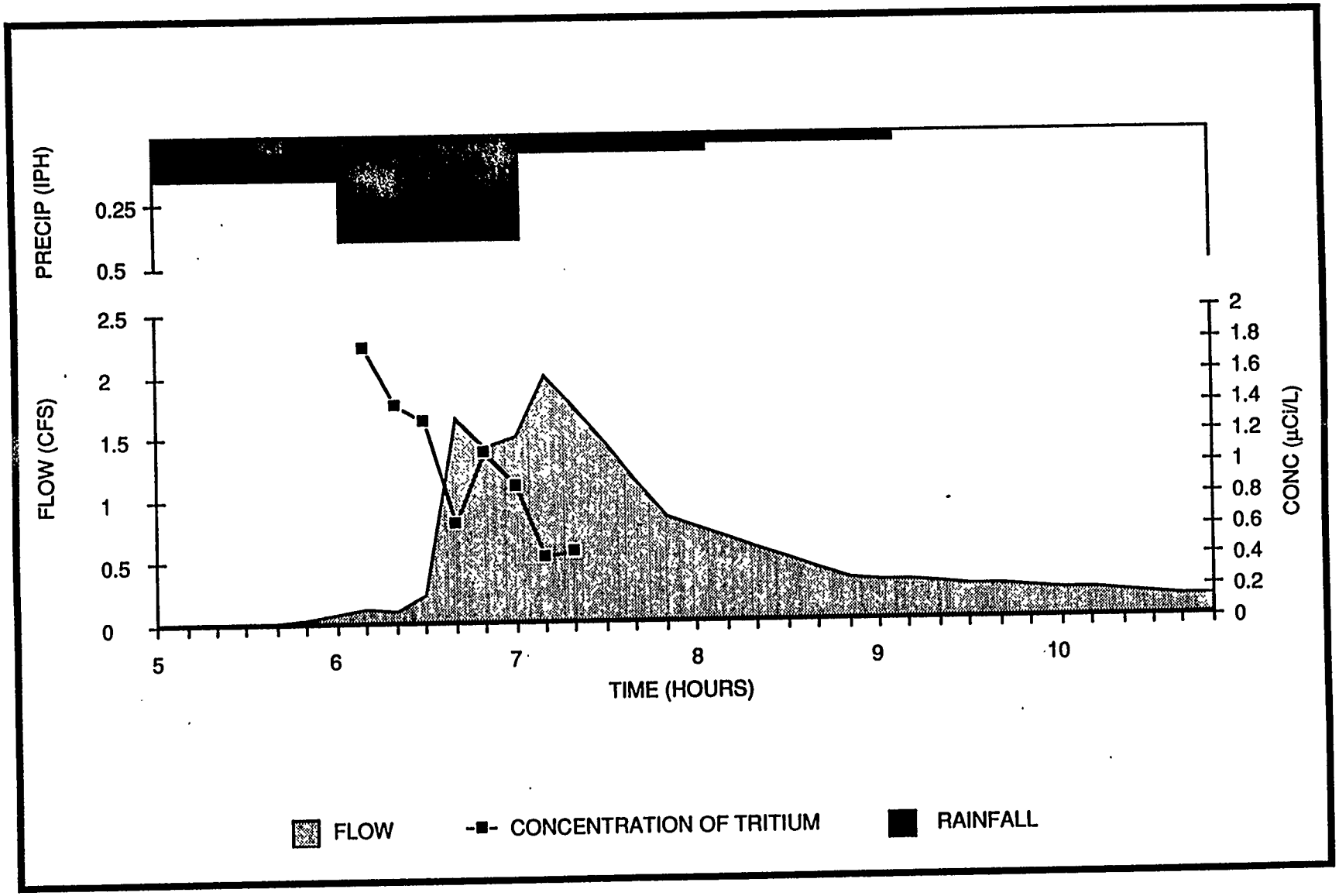



**Fig. 5B.6. Tritium concentration in surface runoff; drainage FB; storm of May 17, 1990.**

5.12 3092.16

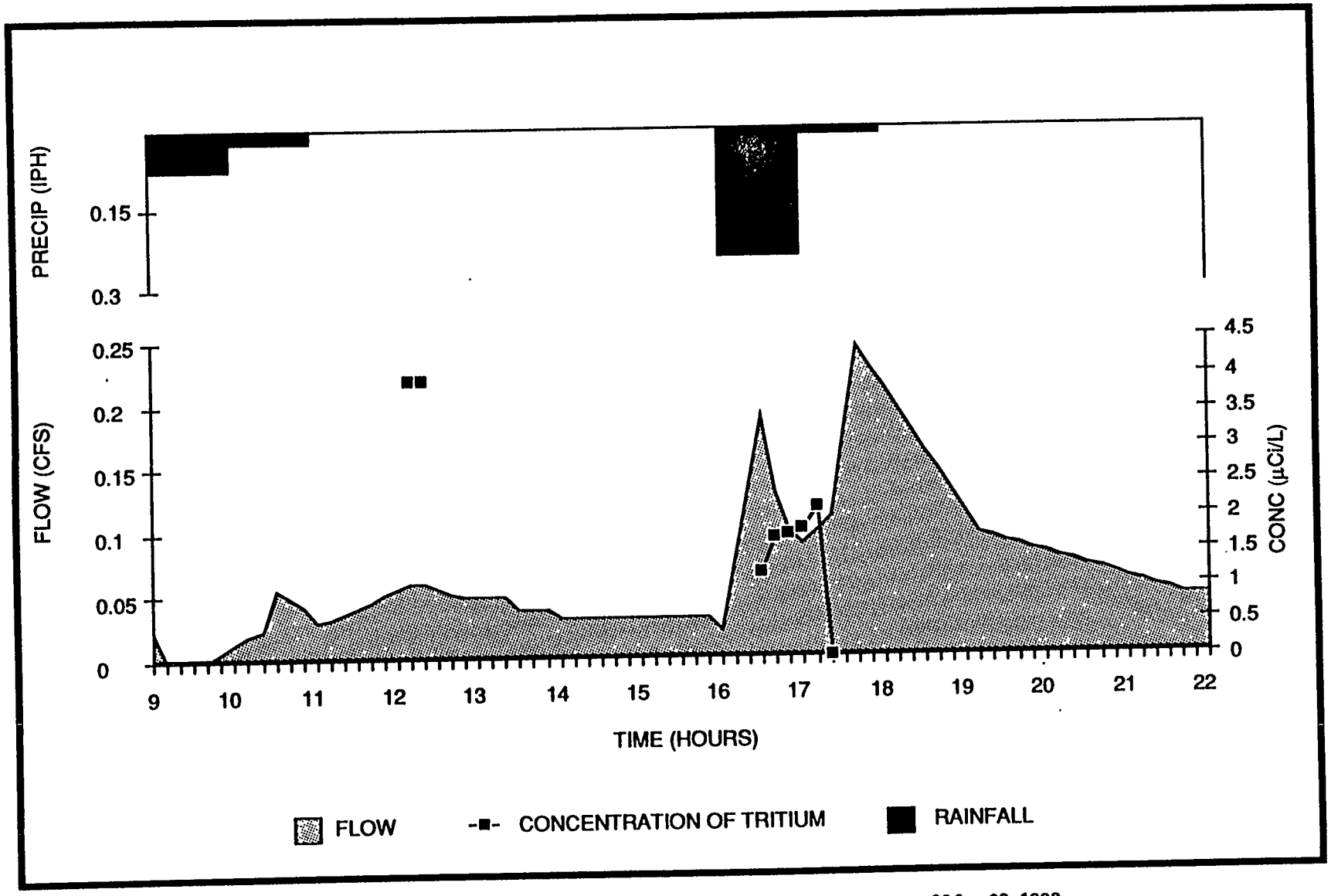



**Fig. 5B.7. Tritium concentration in surface runoff; drainage FB; storm of May 20, 1990.**

5.12 3092.18

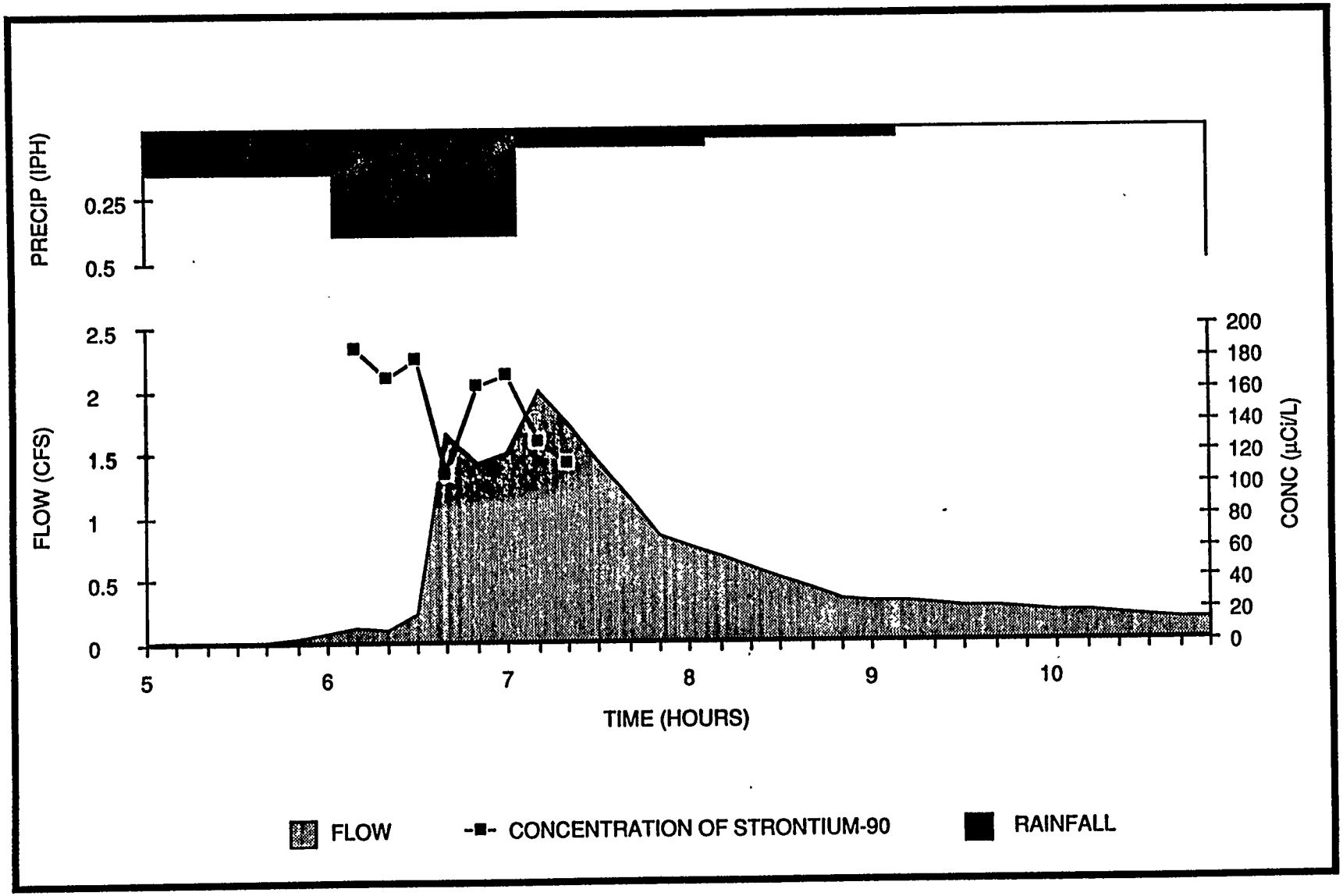



**Fig. 5B.8. Strontium-90 concentration in surface runoff; drainage FB; storm of May 17, 1990.**

5.12 3092.15

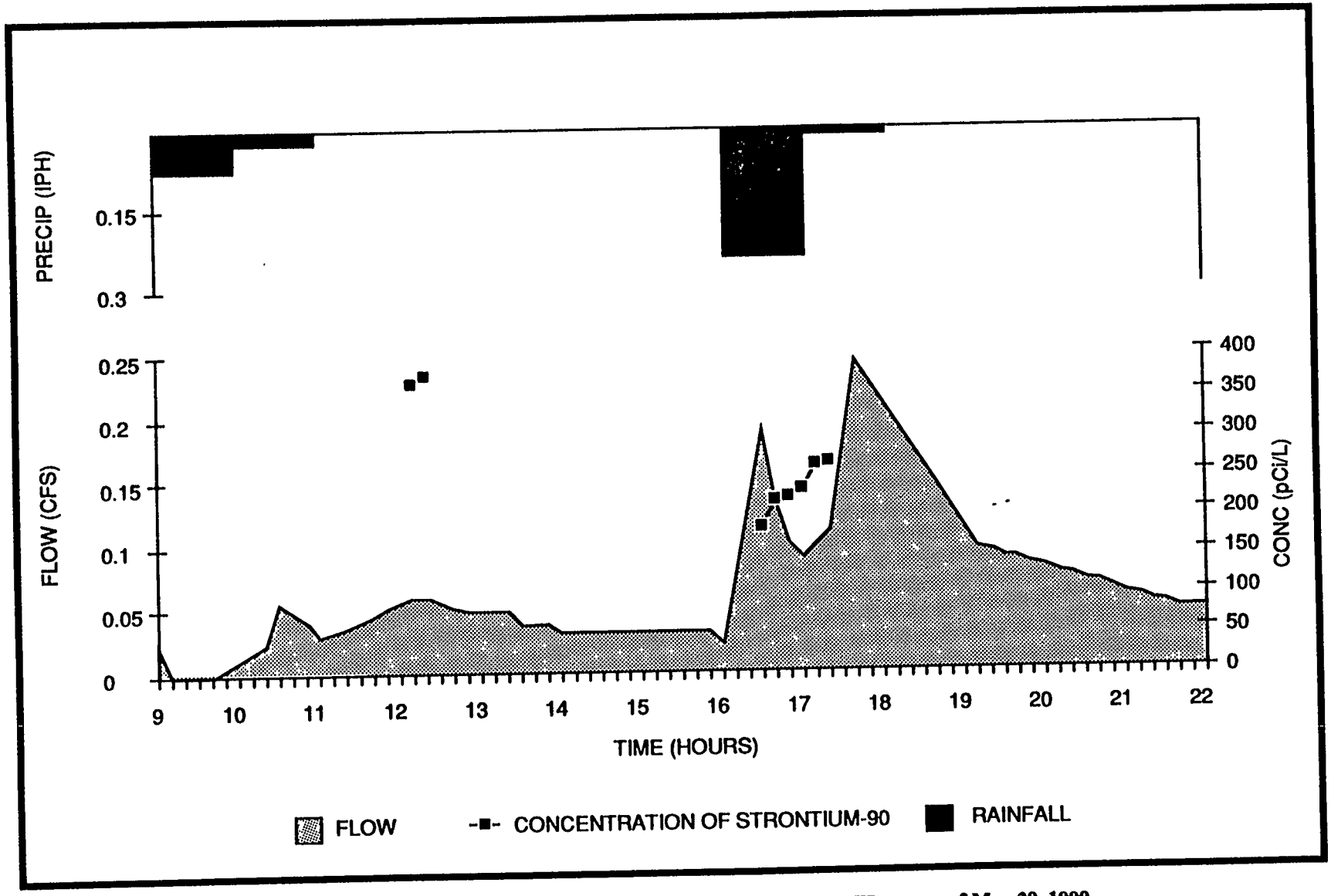



**Fig. 5B.9. Strontium-90 concentration in surface runoff; drainage FB; storm of May 20, 1990.**

5.12 3092.19

# APPENDIX 5C. SURFACE/SUBSURFACE WATER CONTAMINANT FATE AND TRANSPORT MODEL

## 5C.1 INTRODUCTION

An integrated surface/subsurface water contaminant fate and transport model was developed for WAG 6. The model's level of complexity is appropriate for generating future estimates of annual average contaminant concentrations in surface waters and groundwater for a baseline risk assessment, especially in an area where detailed definitions of contaminant release rates and the physical characteristics of the environmental media is not possible on a local scale. To directly incorporate the uncertainty into the analysis, a Monte Carlo simulation approach was chosen. The model included empirical and analytical algorithms for determining contaminant releases from a source area (i.e., a group of trenches and auger holes) into environmental media and contaminant transport to downgradient receptor points.

Using field-monitored stream and well concentration data, the model's built-in calibration feature determined site-specific and contaminant-specific values of the model parameters.

The modeling approach and the model algorithms are discussed in Sect. 5C.2, the computer program is described in Sect. 5C.3, and the input and output features of the model appear in Sect. 5C.4.

## 5C.2 MODELING APPROACH AND THEORETICAL BASIS

### 5C.2.1 General Modeling Assumptions

- The source area consisted of a group of waste trenches or auger holes located in the unsaturated soil zone
- Storm runoff volumes were available for a typical year. A steady-state approach was taken so that the same storms are assumed to occur for each year of the simulation period.
- Release rates were empirically determined
- Steady-state groundwater flow conditions were assumed, with known recharge, discharge, flow velocity, and water table elevation
- Since site streams drain small areas, less than 40 acres, no in-stream transport processes were simulated. Instead, an empirical approach was developed which linked source term to observed storm contaminant in streams
- A one-dimensional analytical model was used to simulate contaminant fate and transport in the vadose zone and in the saturated zone
- Field-monitored storm concentrations and well concentrations were available

### 5C.2.2 Monte Carlo Simulation

Fate and transport modeling was carried out within a Monte Carlo simulation framework; the uncertainty of the model parameters was directly incorporated into the modeling process. The Monte Carlo process is depicted in Fig. 5C.1. In each model application, 100 fate and transport simulation trials were performed. For each of the simulation trials, the values of the model input parameters were randomly generated from the input probability distributions of these parameters. The output of each of the 100 trials constituted an equally likely time-series of future concentrations or fluxes. A probability distribution of the output values was then generated for each year of the simulation. For the purpose of exposure assessment, the annual mean value and its 95th percentile upper limit were computed.

### 5C.2.3 Fate and Transport Model

An empirical/analytical approach was formulated to perform fate and transport analysis. The model had three components: a source component, a surface runoff component, and a groundwater component. A schematic diagram illustrating key geometric parameters is shown in Fig. 5C.2.

#### 5C.2.3.1 Source inventory and depletion

The contaminants were assumed to be located in the unsaturated soil above the water table in lined or unlined trenches and auger holes. The contaminant inventory and its date of placement were assumed to be known. Within the source volume, which is defined by the dimensions of the trenches, wastes of similar form and packaging were assumed to be placed in similar containers distributed uniformly.

Initially, only a fraction of the waste was assumed to be in contact with soil moisture within the source volume. The time before onset of accelerated failure of the containers to inhibit soil moisture contact was specified. Once the containers start disintegrating at an accelerated rate, the fraction of waste in contact with water was assumed to increase linearly to a specified maximum.

Assuming that the contaminants were distributed in equilibrium between the solid and liquid phases, the contaminant concentration in the soil water at any time could then be expressed as:

$$C_w = f_1 * M / [V_t * (K_d * \rho_b + \alpha * \Theta)], \qquad (1)$$

where

$C_w$ = contaminant concentration in the soil water ($g/m^3$ or $Ci/m^3$),

$M$ = inventory of the contaminant in any year (g or Ci),

$f_1$ = leaching fraction ($0 < f_1 < 1$),

$V_t$ = volume of the source ($m^3$),

$K_d$ = distribution coefficient in the source ($m^3/kg$),

$\rho_b$ = dry bulk density of source matrix ($kg/m^3$),

$\Theta$ = porosity of source matrix,

$\alpha$ = degree of saturation.

The water that infiltrated into the source volume was the major medium for the release of the contaminant leachate from the source area. The pathways of release included percolation into the groundwater, and surface runoff. Contaminants in the source volume would be depleted by releases into surface runoff and groundwater, as well as by decay due to physical, chemical, and biological processes.

The yearly source inventory can therefore be expressed as:

$$M_{t+1} = M_t * \exp(-\lambda) - R_{sw} - R_{gw}, \qquad (2)$$

where

$M_{t+1}$ = inventory in year t + 1,
$M_t$ = inventory in year t,
$\lambda$ = composite decay rate (1/year),
$R_{sw}$ = amount released to surface runoff (g/year or Ci/year),
$R_{gw}$ = amount released to groundwater (g/year or Ci/year).

### 5C.2.3.2 Surface water pathway

The amount of contaminant transferred to the stream by surface runoff during a storm is assumed to be a fraction ($f_2$) of the total leachate in the source volume, expressed as:

$$S = f_2 * V_t * \alpha * \Theta * C_w, \qquad (3)$$

where

S = surface runoff contaminant flux, (g) or (Ci),
$f_2$ = surface runoff leaching fraction, the ratio of fraction of surface flux per storm to the exposed trench inventory,
all other terms were as previously defined.

Substituting the value of $C_w$ from equation (1) into equation (3) gives:

$$S = f_1 * f_2 * M/[1 + (K_d * \rho_d)/(\alpha * \Theta)] \qquad (4)$$

The annual amount of contaminant loading in surface runoff would be the sum of the amounts generated by all the storms that occurred within the year. Therefore, annual average contaminant concentration in surface runoff can be computed as:

$$\overline{C}_{sf} = \sum_{1}^{n} S \,/\, \sum_{1}^{n} V_r, \qquad (5)$$

where

$C_s$ = annual average contaminant concentration in surface runoff ($g/m^3$ or $Ci/m^3$),
$V_r$ = storm runoff volume ($m^3$),
n = number of storms per year.

The annual average contaminant concentration of streamflow in a stream that receives base flow (groundwater discharge) is expressed as:

$$\overline{C}_{sf} = (\sum_{1}^{n} S + Q_b * C_g) \,/\, (\sum_{1}^{n} V_r + Q_b), \qquad (6)$$

where

$C_{sf}$ = annual average contaminant concentration in streamflow ($g/m^3$ or $Ci/m^3$),
$Q_b$ = base flow ($m^3$/year),
$C_g$ = contaminant concentration in base flow ($g/m^3$ or $Ci/m^3$).

**Determination of $f_2$.** Equation (4) suggests that an empirical relationship between $f_2$ and contaminant flux in storm runoff can be developed, assuming that all other terms of the equation are known. Developing this relationship would involve monitoring and sampling a few storms and determining the storm runoff volume and the corresponding contaminant flux. Continuous sampling would provide the storm hydrograph and the contaminant pollutograph from which contaminant flux and storm volume can be computed by integration.

If storm sampling were done in a stream that also carried base flow, the flux due to base flow must be separated from the total storm flux before the $f_2$ and surface runoff flux relationship is established. In this case, concurrent sampling of groundwater contaminant concentrations was necessary for computation of the flux from the base flow. The volume of the base flow was also isolated from the storm hydrograph by a storm hydrograph separation technique.

### 5C.2.3.3 Groundwater pathway

Leachate from the bottom of a source area traveled with the percolating water vertically through the vadose zone into groundwater and moves with groundwater horizontally toward a well or discharge point, subject to retardation. Transport was assumed to be one-dimensional in both zones.

The vertical water velocity and the retardation factor were computed as follows:

$$V_v = I/(\alpha * \Theta)$$
$$R_v = 1 + (\rho_b * K_{dv}) / (\alpha * \Theta), \qquad (7)$$

where

$K_{dv}$ = $K_d$ in vadose zone, $m^3/kg$
$V_v$ = vertical velocity (m/year),
$R_v$ = vertical retardation factor.

The horizontal velocity was input to the model, and the horizontal retardation factor was computed as

$$R_h = 1 + \rho_b * K_{dh}/(\Theta) \qquad (8)$$

where

$K_{dn}$ = $K_d$ in saturated zone, $m^3/kg$

Furthermore, the second term of the right side of equations (7) and (8) was replaced by $f_3$ as follows:

$$R_v = 1 + f_3$$
$$R_h = 1 + f_3$$

($f_3$ was a lumped calibration parameter that was assumed to be the same for both vertical and horizontal transport).

The vertical and horizontal travel times, $t_v$ and $t_h$, were then computed as follows:

$$t_v = D_v * R_v/V_v,$$

where

$D_v$ = vertical distance from the bottom of source to water table (m) and other terms were as previously defined;

$$t_h = D_h * R_h/V_h,$$

where

$D_h$ = horizontal distance to well (m) and other terms were as previously defined.

The sum of the horizontal and vertical travel times equaled the average breakthrough time for a contaminant from the source area to show up in an observation well.

The inflow of contaminants to the vadose zone at the bottom of the source was calculated as follows:

$$Q_0 = I * C_W * A, \qquad (10)$$

where

$Q_0$ = the rate of contaminant recharge to the vadose zone (Ci/year),
$I$ = the water percolation rate in the vadose zone (m/year),
$C_W$ = concentration of the contaminant in the percolating water at the bottom of the source (Ci/m$^3$),
$A$ = effective cross-sectional area of the source (m$^2$).

The transport of radionuclides through the vadose and saturated zones was evaluated using Hung's groundwater transport model (Hung 1986). The assumptions of the model were as follows:

- Transport was one-dimensional; flow was vertical in the vadose zone and downgradient in the saturated zone.
- Longitudinal dispersion was accounted for by use of a dispersion parameter Z.
- No transverse dispersion occurred in the vadose zone. The transverse dispersion in the saturated zone was described by an angle of dispersion.
- Vertical dispersion in the saturated zone was accounted for by the effective saturated zone thickness at the receptor. The thickness represented the depth of the plume at the exposure point.
- The contaminant concentration was assumed to be uniform across the cross-sectional area of the plume at the exposure point (described by the depth of the plume and the transverse width).

The basic equations of the model were as follows:

$$Q = Q_o * Z * \exp(-\lambda * t) \qquad (11)$$

and

$$Z = \exp[P/2-(P/2) * \sqrt{1+4*R*L*\lambda/(P * V)}]/\exp(-R * L * \lambda/V), \qquad (12)$$

where

$Z$ = a correction factor to compensate for the dispersion effect,
$R$ = retardation factor $R_v$ or $R_h$,
$P$ = Peclet number, $V_V D_V/d$ or $V_h D_h/d$,
$L$ = length, $D_V$ or $D_H$ (m),
$V$ = water flow velocity, $V_v$ or $V_h$ (m/year),
$t$ = transit time, $t_v$ or $t_h$,
$d$ = dispersion coefficient ($m^2$/year),
$Q$ = rate of contaminant transport at distance L form the source (Ci/year),
$Q_0$= rate of contaminant transport at the source (Ci/year), evaluated at time = (T-R * L/V),
$T$ = time of simulation (year),
$\lambda$ = decay constant ($year^{-1}$).

and other terms were as previously defined.

To calculate the radionuclide concentration at the receptor, the rate of groundwater flow in the plume of contamination at the receptor point was calculated as follows:

$$W_a = V_h * P_a * D_a [\sqrt{A} + 2 * \tan(a/2) * D_h], \qquad (13)$$

where

$W_a$ = the rate of contaminated water available for removal at the receptor point ($m^3$/year),
$V_h$ = groundwater velocity (m/year),
$P_a$ = porosity of the shallow saturated zone,
$D_a$ = effective thickness of the flow domain in the shallow saturated zone (m),
$a$ = angle of spread of the contaminant plume in the shallow saturated zone (radians),
$A$ = projected cross-sectional area of trench ($m^2$),
$D_h$ = distance to the receptor (m).

The contaminant concentration in the groundwater at the exposure point was calculated by

$$C_g = Q/W_a, \qquad (14)$$

where $C_g$ is expressed in $kg/m^3$ or $Ci/m^3$.

### 5C.2.4 Model Calibration

The model calibration consisted of an iterative procedure in which the initial values of certain key parameters are adjusted to match the time of travel and the observed contaminant concentration in groundwater. These parameters were the surface water and groundwater release fractions, ($f_2$ and $f_1$, respectively) and $f_3$, which was calibrated first; the value of $f_1$ was determined before that of $f_2$ because the formulation of $f_2$ included the $f_1$ term. An iterative procedure was necessary since the surface water and groundwater transport equations were coupled.

The calibration of $f_3$ was based on comparison of the simulated breakthrough time for both vadose and saturated zones with the observed time from waste emplacement well sampling. The

initial value of $f_3$ was calculated using assumed or known values of $K_d$, $\Theta$, $\rho$, and $\alpha$. If the simulated breakthrough time exceeded the time when the sample was taken, the $f_3$ values were decreased so that the breakthrough time matched the observed time. If the simulated breakthrough time was less than the observed time of the sample, no adjustments were made to the $f_3$ values, assuming that the plume already extended beyond the downgradient well. The next adjustment was initiated by comparing the observed and simulated well concentration. The $f_1$ fraction was simply scaled so that the simulated well concentration matched the observed concentration. An assumed coefficient of variation was introduced to derive the distribution of the calibrated $f_1$ and $f_3$.

Values for $f_2$ were recomputed for each change in the value of $f_1$ since the formulation of $f_2$ includes $f_1$ as an independent variable.

## 5C.3 DESCRIPTION OF THE COMPUTER PROGRAM

The model was written in FORTRAN 77 language and was debugged and compiled using Lahey Fortran compiler and editor. A Compaq 386/25e microcomputer was used in developing and running the model. The model is composed of several subroutines structured around a main program. The flowchart shown in Fig. 5C.3 presents the general structure of the model.

### 5C.3.1 Description of Subroutines

**Main Program.** The data input and output and the statistical analysis of the output data are performed in the main program. Calls to subroutines RNGEN, PARACORR, and SURTRAN are made from the main program.

**RNGEN.** Values of the specified number of Monte Carlo simulation parameters are generated in RNGEN. For the input distribution parameters (i.e., mean and standard deviation) and the specified probability distribution, RNGEN generates a random variable. The probability distributions presently supported are normal, log normal, and uniform distributions. RNGEN calls for the random number generator RANDOM before the selected probability distribution subroutine is called.

**SURTRAN.** This is the main computational subroutine where surface water and groundwater fate and transport analysis is carried out. A flowchart of SURTRAN is shown in Fig. 5C.4. Routines are provided for calibration and no calibration options. The subroutines CALF2 and HUNGVH are called form SURTRAN.

**DISTRIBUTE.** The distribution of the output values, the mean, and the 95th percentile upper limit of the mean are determined in this subroutine.

**AVEVAR.** This subroutine computes the mean and standard deviation of the output values.

**CALF2.** This subroutine determines the $f_2$ parameters for a number of storms in a year. Input to the subroutine includes storm volumes and average contaminant concentrations for the storms.

**FIT.** This subroutine fits a function to the calibration storm values and the corresponding average contaminant concentrations.

**HUNGVH.** The transport in the vadose and saturated zones is performed in this subroutine. Travel times and contaminant concentration at the receptor point in the groundwater are computed.

**HUNG FUNCTION.** The dispersion correction factor Z is computed by this function, which is called by the HUNGVH subroutine.

**RANDOM.** This subroutine generates a random number between 0 and 1. A seed number (i.e., 19118) is input to initiate the random number generator.

**UNIFORM.** This subroutine generates a uniformly distributed random number for a given set of minimum and maximum values.

**NORMAL.** This subroutine generates a normally distributed random number using the input mean and standard deviation.

**LOGNORMAL.** This subroutine generates a log normally distributed variate.

## 5C.4 MODEL INPUT PARAMETERS AND OUTPUT

The model input parameters are listed in Table 5C.1 in the order of their appearance in the computer input file. A list of the Monte Carlo Parameters is given in Table 5C.2. The model output consisted of an echo of the input parameters and the time-series of contaminant inventory and surface runoff and groundwater fluxes and/or concentrations. The time-series values are given in terms of annual mean and 95th percentile of the mean.

# Appendix 5C Tables

Table 5C.1 Model input parameters

TITLE 1

| | |
|---|---|
| TITLE 1: | Job title |

TITLE 2

| | |
|---|---|
| TITLE 2: | Job title |

TITLE 3

| | |
|---|---|
| TITLE 3: | Job title |

NIND, NPAR, MITER, ICLB, IDO

| | |
|---|---|
| NIND: | Number of Monte Carlo Variables |
| NPAR: | Number of distribution parameters |
| MITER: | Number of Monte Carlo Simulations |
| ICLB: | Maximum number of iterations for calibration |
| IDO: | Number of transects where well data are generated |

IXO

| | |
|---|---|
| IXO: | Seed number for the random number generator |

NYRS

| | |
|---|---|
| NYRS: | Years of simulation |

IFIT

| | |
|---|---|
| IFIT: | calibration option, yes = 1, no = 0 |

NNCLD

| | |
|---|---|
| NNCLD: | Constituent simulated |

TAREA,H

| | |
|---|---|
| TAREA: | Trench area in $m^2$ |
| H: | Trench depth in m |

FINT, FFIN, TINT, TFIN

| | |
|---|---|
| FINT: | Initial value of fl |
| FFIN: | Final value of fl |
| TINT: | Initial time of fl |
| TFIN: | Final time of fl |

ATREN, IYRC, SCONC

| | |
|---|---|
| ARTEN: | Trench inventory in curies |
| IYRC: | Age of source inventory in years |
| SCONC: | Calibration value of sample well concentration, pCi/L |

**Table 5C.1. (continued)**

DECAY, XKDV, XKDH, XKDT

| | |
|---|---|
| DECAY: | Decay rate (1/year) |
| XKDV: | $K_d$ in vadose zone, $m^3/kg$ |
| XKDH: | $K_d$ in saturated zone, $m^3/kg$ |
| XKDT: | $K_d$ in trench/auger hole, $m^3/kg$ |

RPERC, DVERT, DHORZ, DHOREX, EPORV, EPORA, PORT

| | |
|---|---|
| RPERC: | Recharge rate, m/year |
| DVERT: | Vadose zone depth, m |
| DHORZ: | Distance to receptor, m |
| DHOREX: | Horizontal distance between transects |
| EPORV: | Effective porosity, vadose zone |
| EPORA: | Effective porosity, saturated zone |
| PORT: | Total porosity, trench |

PORV, SSAT, BDENS, DISP, AQTHK, PORA, GWV, ADISP

| | |
|---|---|
| PORV: | Total porosity, vadose zone |
| SSAT: | Degree of saturation, vadose zone |
| BDENS: | Bulk density, $kg/m^3$ |
| DISP: | Dispersion length, m |
| AQTHK: | Saturated zone thickness, m |
| PORA: | Saturated zone porosity |
| GWV: | Groundwater velocity, m/year |
| ADISP: | Dispersion angle in radians |

BAREA, WAREA

| | |
|---|---|
| BAREA: | Basin area, $m^2$ |
| WAREA: | Tributary watershed area, $m^2$ |

NSR

| | |
|---|---|
| NSR: | Number of storms per year |

VR(I), I, NSR

| | |
|---|---|
| VR: | Storm volumes in inches (from 1st to NSR storm) |

NCSR, WTRI, ICAL

| | |
|---|---|
| NCSR: | Number of sampled storms |
| WTRI: | Watershed inventory, Ci (watershed at sampling site) |
| ICAL: | Runoff curve fitting parameter |

VRC(i), I=1, NCSR

| | |
|---|---|
| VCR: | Calibration storm volumes in inches |

CBAR(I), I=1, NCSR

| | |
|---|---|
| CBAR: | Calibration storm concentrations |

Table 5C.1. (continued)

**TTR, TXKDV, TXKDH, CRMN, CRMX**

| | |
|---|---|
| TTR: | Ratio of travel time to age of inventory |
| TXKDV: | Minimum value of vadose zone $K_d$ |
| TXKDH: | Minimum value of standard zone $K_d$ |
| CRMN: | Lower limit, ratio of simulated and recorded well concentrations |
| CRMX: | Upper limit, ratio of simulated and recorded well concentrations |

**NEW**

| | |
|---|---|
| NEW: | Flag to end input for one contaminant, (1=next contaminant simulation starts) |

**S1, S2, S3**

| | |
|---|---|
| S1: | Standard deviation for calibrated vadose zone $K_d$ |
| S2: | Standard deviation for calibrated vadose zone $K_d$ |
| S3: | Standard deviation for calibrated f1 |

**Monte Carlo Parameters: repeat following group of parameters for NIND times**

**IPARM**

| | |
|---|---|
| IPARM: | Parameter number (see the list of Monte Carlo Parameters) |

**DISTRIB**

| | |
|---|---|
| DISTRIB: | Name of the distribution: supported names: NORMAL, LOGNORMAL, UNIFORM, LOGUNIFORM |

**SINF**

| | |
|---|---|
| SINF: | 1st and 2nd parameters of the selected distribution |

**Table 5C.2. List of Monte Carlo Parameters**

| Parameter number | Description of parameters | |
|---|---|---|
| 1 | TAREA: | Trench area in $m^2$ |
| 2 | H: | Trench depth in m |
| 3 | FINT: | Initial value of f1 |
| 4 | FFIN: | Final value of f1 |
| 5 | ATREN: | Initial trench inventory, Ci |
| 6 | DECAY: | Decay rate, 1/year |
| 7 | XKDV: | $K_d$ in vadose zone, $m^3/kg$ |
| 8 | XKDH: | $K_d$ in saturated zone, $m^3/kg$ |
| 9 | XKDT: | $K_d$ in trench/auger hole, $m^3/kg$ |
| 10 | RPERC: | Recharge rate, m/year |
| 11 | DVERT: | Vadose zone depth, m |
| 12 | DHORZ: | Distance to receptor, m |
| 13 | EPORV: | Effective porosity, vadose zone |
| 14 | EPORA: | Effective porosity, saturated zone |
| 15 | PORT: | Total porosity, trench |
| 16 | PORV: | Total porosity, vadose zone |
| 17 | SSAT: | Degree of saturation, vadose zone |
| 18 | BDENS: | Bulk density, $kg/m^3$ |
| 19 | DISP: | Dispersion length, m |
| 20 | AQTHK: | Saturated zone thickness, m |
| 21 | PORA: | Saturated zone porosity |
| 22 | GWV: | Groundwater velocity, m/year |
| 23 | ADISP: | Dispersion angle in radians |
| 24 | BAREA: | Basin area in $m^2$ |
| 25 | QBASE: | Baseflow in $m^3$/year |
| 26 | IYRC: | Age of source inventory |
| 27 | SCONC: | Calibration value of well concentration, pCi/liter |
| 28 | WTRI: | Watershed inventory, Ci |

# Appendix 5C Figures

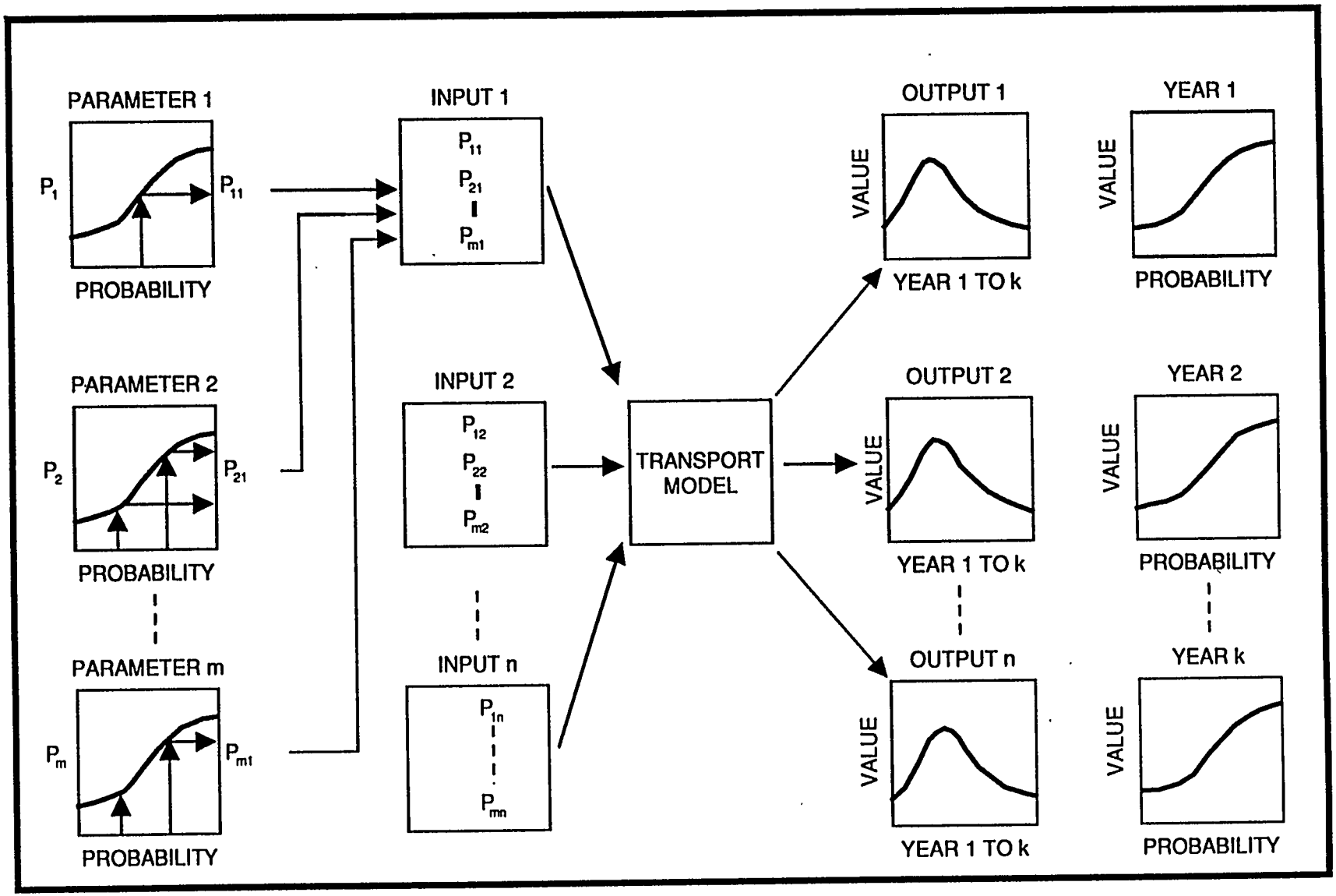



Fig. 5C.1. Monte Carlo simulation.

5.18A 4104.36

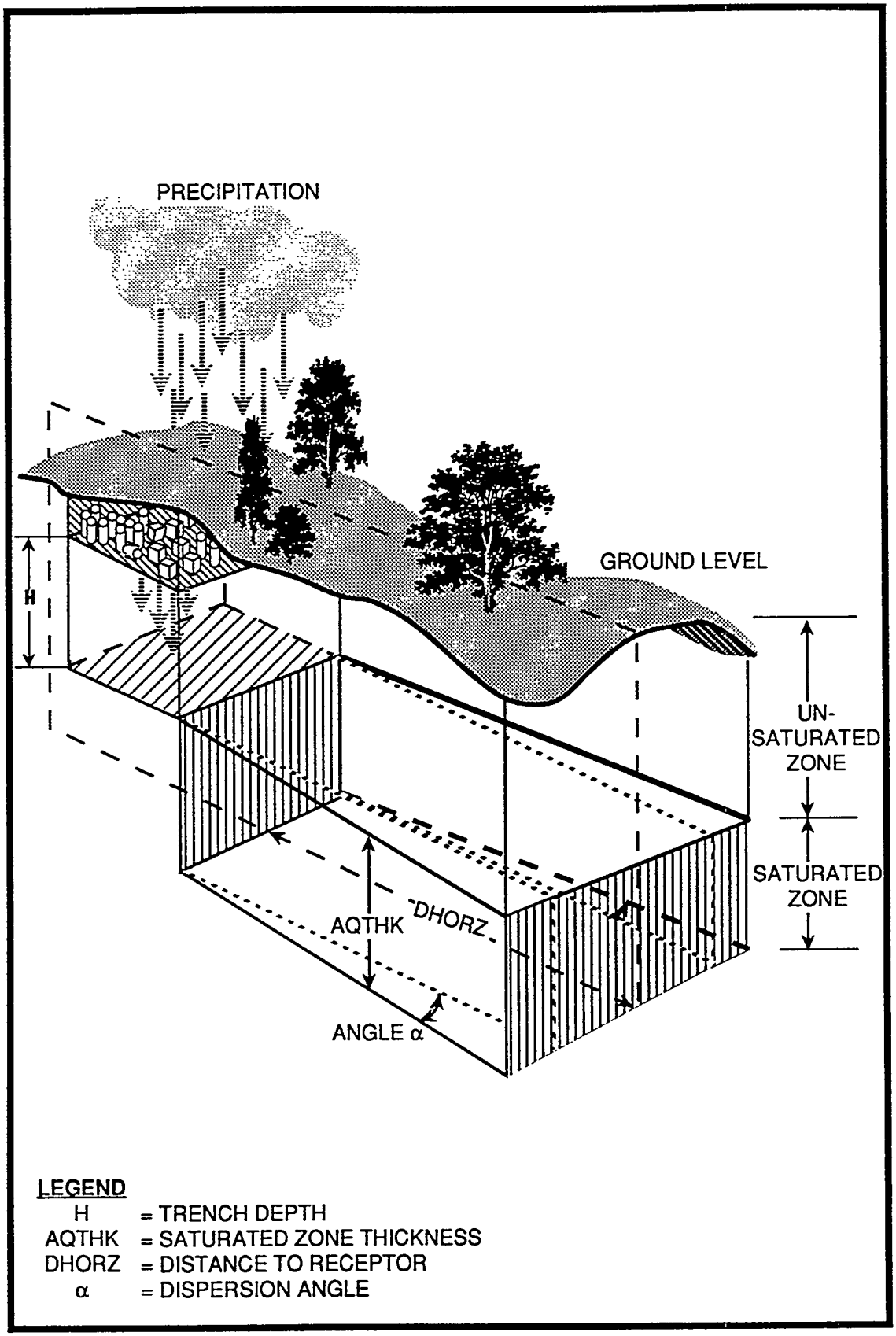



**Fig. 5C.2. Schematic diagram of the transport model.**

5.18A 4104.33

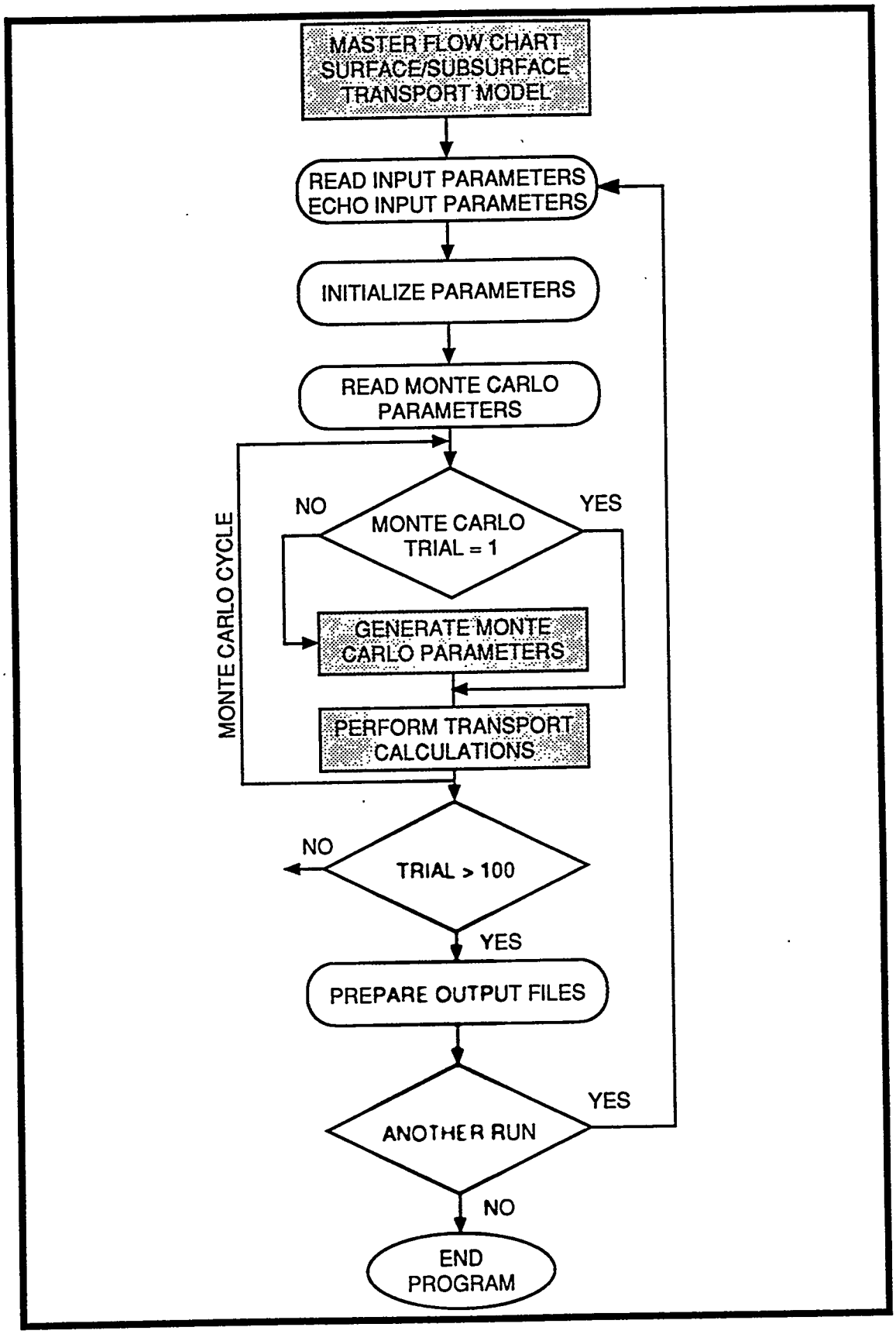



**Fig. 5C.3. General structure of the model.**

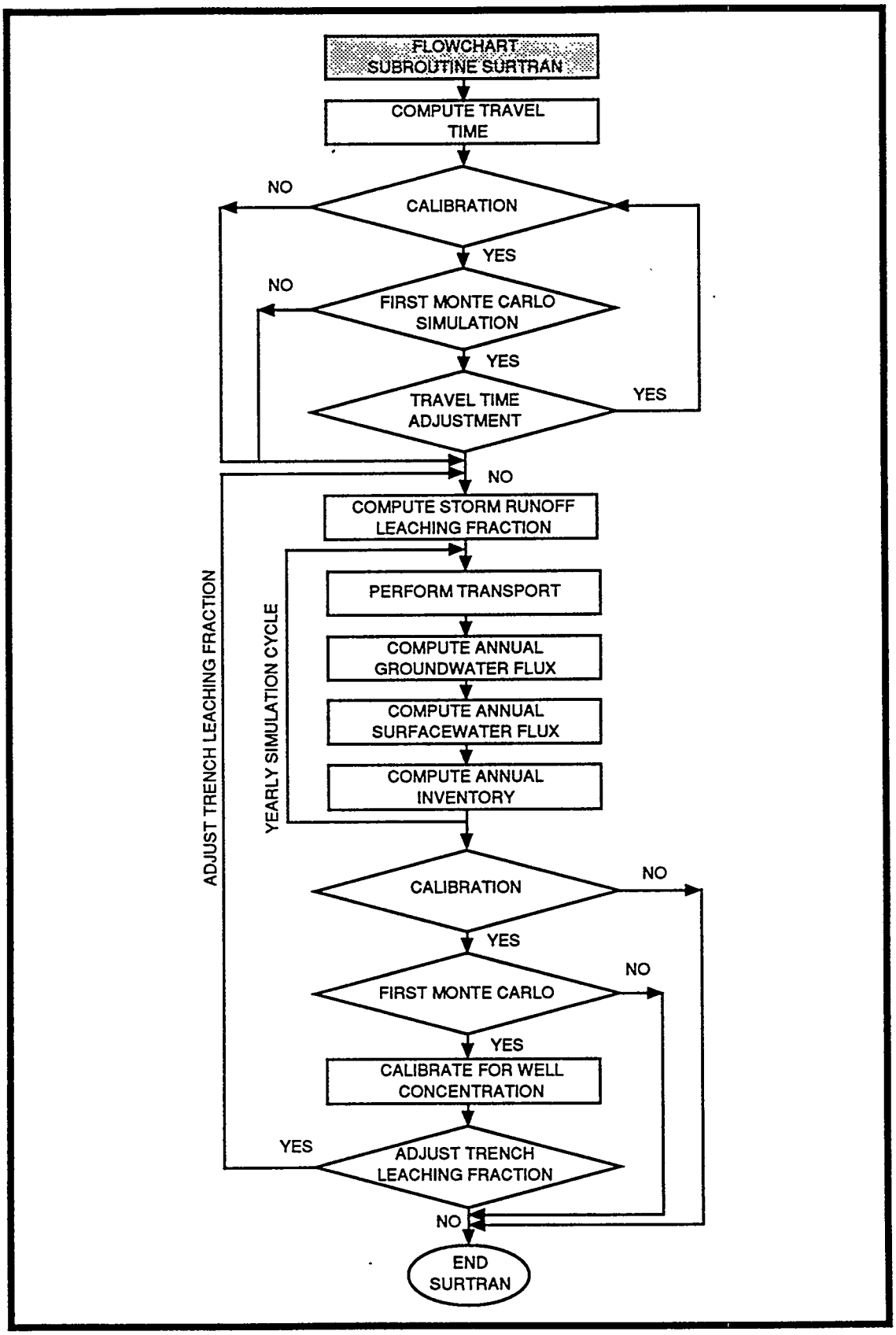



Fig. 5C.4. Flow chart of the SURTRAN subroutine.

5.18A 4104.35

# APPENDIX 5D. SURFACE/SUBSURFACE WATER FATE AND TRANSPORT MODELING IN WAG 6

## 5D.1 INTRODUCTION

The surface/subsurface water fate and transport model presented in Appendix 5C was used to perform fate and transport analysis for radionuclides. For modeling purposes, the waste areas in WAG 6 (i.e., trenches/auger holes) were divided into 26 source areas. These areas (A to Z) are shown in Fig. 5D.1. Modeling was also performed for one above-ground unit, Tumulus I.

The radionuclides modeled include tritium, cobalt-60, strontium-90, cesium-137, europium-152, europium-154, uranium-233, uranium-238, and thorium-232. The model was calibrated when possible, for each source area and for each radionuclide using the concentration data from surface water and groundwater sampling and the radionuclide inventory for the source area. For each area, the model output consists of 160 years of remaining radionuclide source inventory, surface water flux, and groundwater flux and concentration at calibration wells and points downgradient of wells within the WAG 6 boundary.

Radionuclide flux in streams was computed by combining the flux of surface runoff of the tributary areas (the output of the transport model) with the flux of groundwater discharging into streams. The radionuclide concentration in streams was then computed by dividing the stream radionuclide flux by the streamflow rate. The radionuclide plumes from source areas were superimposed to compute groundwater radionuclide flux and concentrations at the WAG 6 boundary.

Modeling input data and parameters are described in Sect. 5D.2. Section 5D.3 describes the calibration of the model and presents results, analysis, and conclusions. The approaches used in sensitivity and uncertainty analysis are presented in Sect. 5D.4.

## 5D.2 INPUT DATA AND PARAMETERS

### 5D.2.1 Storm Runoff

The model input data included the storm runoff volumes for 1984 and the storm runoff volumes and associated average radionuclide concentrations for the storms sampled in WAG 6 during April/May 1990. The 1984 storm runoff data are given in Appendix 5A. The storm runoff and radionuclide concentration data from 1990 sampling are given in Appendix 5B.

### 5D.2.2 Waste Inventory and Groundwater Data

The inventory of radionuclides for each of the 26 modeling areas is shown in Table 5D.1. Time-averaged contaminant concentrations in the wells were used as input to the transport model. Groundwater sampling at various wells was conducted between 1988 and 1990 by ORNL and BNI. Initially, the 800 series wells were sampled quarterly; later, some wells were sampled only semi-annually. The 1200 series wells were sampled by BNI. Sampling dates and concentration data are

presented in Table 5D.2, where data columns with headings 1 through 5 are the ORNL four quarterly and one semi-annual data.

### 5D.2.3 Model Input Parameters

Model input parameters are listed in Tables 5D.3 and 5D.4. The determination of the average values and distribution of the model input parameters, given in Appendix 5C, for each of the modeling areas is described below.

**TAREA.** TAREA was the cross-sectional area of a waste source. Since each of the subareas in WAG 6 (A through Z) was a cluster of trenches/auger holes representing one source, TAREA was the effective area encompassing any such cluster of trenches/auger holes.

**H.** The average trench depth (H) was assumed to be 15 ft (4.6m). Trenches were backfilled to above the water table wherever necessary; therefore, the depth of these trenches was less than 15 ft. The nominal depth of the auger holes is 20 ft. However, after backfilling, the actual depth ranged from 15 to 20 ft (Boegly 1984).

**FINT.** FINT was the initial value of the fraction ($f_1$) of the buried waste that was exposed to percolating water in the trench. For areas that included sampling wells, FINT was a calibration parameter. These values of FINT were used for other areas where no calibration wells existed, based on the similarity of trench or auger hole characteristics. FINT was assumed to be constant for a period of 30 years from the date of emplacement of the waste; thereafter, the integrity of the container was assured to be breached.

Uncertainty was introduced by predicting the future corrosion rates of the containers and using estimated values of FINT for areas with no sampling wells. The sensitivity of the model to the value of FINT was also high; therefore, FINT was an important model parameter.

**FFIN.** FFIN was the final value of $f_1$ (the leaching fraction). The value of $f_1$ was assumed to increase linearly to FFIN at year 160. The value of FFIN is 0.1. The uncertainty in FFIN and its variation in time were important because the leaching fraction was a sensitive parameter; however, the effect of variation in FFIN was reduced significantly when the inventory was rapidly depleted by a high rate of decay.

**ATREN.** ATREN was the total inventory for individual radionuclides or chemicals in each waste area. The accuracy of inventory records prior to 1986 was quite poor. In some cases, radioactive decay prior to actual waste disposal had not been accounted for. Many curies of unidentified inventory had been logged. Some of the records could have been in error by as much as an order of magnitude.

Inventory records included no contaminant entry for several trenches and auger holes. In such cases, an average value was determined from the inventory of similar trenches (high-level or low-level) or auger holes in other areas and was assigned to areas that lacked disposal records. Since

1986, waste disposal records have been well maintained. The radionuclide inventories (as recorded), for the modeling areas are given in Table 5D.1.

**DECAY.** Natural radioactive decay is a constant for each radioactive isotope, a function of its half-life. Half lives for the radionuclides modeled are listed in Table 5D.5.

**XKDV, XKDH.** Parameters XKDV and XKDH were the effective distribution coefficients for the contaminants in the unsaturated and saturated zones, respectively and their calibrated values were equal. These parameters represented cationic retardation of the radioactive isotopes in the aquifer and were referred to collectively as the calibration parameter $f_3$.

Several values for retardation coefficients for radionuclides are available in the literature. These values differ widely based on soil chemistry and soil type. The distribution coefficients ($K_d$) in the ETF studies documented by Davis et al. (1984) were determined from laboratory batch studies. Because these values are too large to explain the actual contaminant travel times in the field, estimation of this parameter in situ was necessary. The calibrated value of $f_3$, which is much lower, thus represents an effective $K_d$. The values are listed in Tables 5D.6 through 5D.14.

There are several reasons why distribution coefficients reported from laboratory studies (Davis et al. 1984) were higher than the actual site-specific effective $K_d$ values determined here. First, organics and solvents present in the field can complex with metals such as cobalt, strontium, and uranium, resulting in their mobilization. Second, the laboratory batch experiments provide suitable conditions for equilibrium to occur (e.g., mixing), while equilibrium may not be achieved in the field. Third, the rocks used for the batch studies were pulverized, thus increasing the level of intermedia contact. Finally, the large number of fractures allows contaminants to escape adsorption/retardation. For areas with no sampling wells, a representative value was selected from the calibrated distribution coefficients.

**XKDT.** XKDT was the distribution coefficient for contaminants in the trenches. A nominal value was chosen from the ETF studies or other reports in the literature. This parameter affected the leaching fraction via the source, and was effectively incorporated in the parameter FINT. Since FINT was calibrated using actual data, the precise value of XKDT was not critical for modeling purposes.

**RPERC.** RPERC was the annual groundwater recharge through the trench bottom, for which no estimates are available. A recharge value of 1.22 in./yr = .031 m was previously estimated for ORNL basins (Moore 1989a). In the water balance study performed in Appendix 5A using the CREAMS model, a value of 0.19 m/year was determined for WAG 6.

**DVERT.** DVERT was the vertical distance from the bottom of the trench or auger hole to the water table. This constituted the unsaturated zone or the vadose zone. In areas where the trenches were submerged, the vertical distance was assumed to be zero. Due to variation of trench depths and seasonal fluctuations in the water table, there was some uncertainty in the value of DVERT. Table 5D.4 lists the estimated values of DVERT for all areas.

**DHORZ.** DHORZ was the horizontal distance between the centroid of a waste area and a receptor point (usually a well). This distance was considered to be the average distance to the receptor point. The difference in horizontal distance between the nearest and farthest trenches is 20 to 40 m.

**EPORA, EPORV.** The parameters EPORA and EPORV were the effective porosities in the saturated aquifer and the vadose zone above the water table, respectively. EPORV had an estimated average value of 0.0042, with a range of 0.0025 to 0.006 (Moore 1989). EPORA values in the aquifer (up to 30 m) ranged from 0.001 to 0.002. ETF studies (Davis et al. 1984) showed an effective aquifer porosity of 0.03. An average value of 0.02 and a range of 0.004 to 0.04 were used for modeling purposes for both EPORV and EPORA.

**PORT.** PORT was the total porosity of the trench soil. It is assumed to be 0.5, which was representative of a silty clay soil.

**PORV, PORA.** PORV was the porosity in the vadose zone below the trench bottom, while PORA was the porosity of the saturated aquifer. The porosity varied based on rock material. Moore (1989) estimated a porosity of 0.1 to 0.15 for regolith, $10^{-3}$ to 0.1 for saprolite, and $10^{-5}$ to $10^{-3}$ for bedrock. A mean value of 0.1 was chosen for both PORV and PORA.

**SSAT.** SSAT was the degree of saturation of the vadose zone. The degree of saturation was calculated using the following equation (Clapp and Hornberger 1978):

$$\frac{\theta}{\theta_s} = \frac{q^{1/(2b+3)}}{K_s}$$

$\theta$ = volumetric water content in the unsaturated zone,

$\theta_s$ = volumetric water content of soil under saturated conditions,

q = percolation rate, m/day,

$K_s$ = saturated hydraulic conductivity, m/day,

b = soil-specific exponential parameter

The values for b obtained from the EPA *Superfund Exposure Assessment Manual*, (EPA 1989d), for silt clay was 10.4. Using a $K_s$ of .0216 m/day (Rawls 1986) and a percolation rate of 0.19m/year, $\theta/\theta_s$ was computed to be 0.855.

The value of SSAT would actually have been lower below the soil zone at the trench bottom where the contaminant transport was being modeled. The lower limit of SSAT, was taken as the

field capacity for silty clay soil, which is prevalent in WAG 6, was estimated to be 0.39 (Rawls 1986). An average representative value of 0.5 was chosen for SSAT.

**BDENS.** BDENS was the bulk density of the soil matrix and the aquifer material. The ETF studies (Davis et al. 1984) gave an average value of 1.32 $kg/m^3$ in the 0- to 2-m depth. In Sect. 3 of this report, the bulk density of the saprolite is given as 1.59 $kg/m^3$, and that of the bedrock is given as 2.63 $kg/m^3$. Because most of the flow (and, therefore, most of the transport) occurred through the weathered zone or fractured bedrock layers, a value of 1.3 $kg/m^3$ for BDENS was considered reasonable for the transport modeling.

**AQTHK.** AQTHK was the thickness of the shallow aquifer. In the Rome, Conasauga, and Chickamauga Groups, the shallow aquifer thickness was about 30 m (Moore 1989a). Groundwater flow at WAG 6 is local and occurred predominantly in the shallow aquifer to a depth of about 30 m. However, the water-bearing interval through which most of the flow occurs was about 15 ft. Also, because the extent of vertical dispersion of the contaminants were much less than the depth of the aquifer, a lower value for AQTHK (ranging from 4.6 to 6.9 m) was chosen for modeling purposes, as shown in Table 5D.3.

For the purpose of modeling, appropriate velocities for subareas were obtained, depending on whether the effective flow was in the regolith or bedrock aquifer, from the velocities given in Sect. 3 of this report. Since the velocities in Sect. 3 were calculated for high water table conditions, they represented the upper end of the range of velocities predicted for WAG 6. A lower value, 50 percent of these velocities, was used in transport modeling.

**ADISP.** ADISP was the effective angle of dispersion, assumed to be 0.3.

**IYRC.** IYRC was the age of the inventory to year 1989, when the groundwater samples were taken. Most waste areas were active for 3 to 6 years. The midpoint between the beginning and ending of waste deposition in an area was used as a representative year for all the waste deposition.

**SCONC.** This was a measured concentration at the well/reception point. Average values of the concentrations from sampling events were used for calibration of the model parameters.

**BAREA, WAREA.** BAREA was the area of the basin which contained the waste area. WAREA was the area of the watershed which contains BAREA, and where storm runoff was sampled.

**TINT.** The start year for container degradation was assumed to be 30 years from the date of emplacement of the waste.

**TFIN.** The final year for which the model is run was 160 years.

## 5D.3 MODEL CALIBRATION, RESULTS, AND ANALYSIS

### 5D.3.1 Model Calibration

As described in Appendix 5C, the model parameters $f_1$, $f_2$, and $f_3$ were calibrated using sampling data for groundwater concentration, travel time, and surface runoff concentration. Since the transport equations governing the surface and groundwater contaminant fluxes were coupled, an iterative approach was undertaken to calibrate these three parameters.

The parameter $f_1$ (leaching fraction) was the fraction of the waste in the disposal unit that was exposed to soil moisture. This leaching fraction directly influenced the groundwater concentration. $f_1$ was assumed to be constant for the first 30 years, after which the integrity of the container would be lost. $f_1$ was calibrated by matching the concentration predicted by the model with the actual measured data. After the first 30-year period, the factor $f_1$ increased at a steady rate to 0.1 at the end of 160 years. By this time, most of the contaminant would have been depleted in the disposal units. This predicted temporal variation of leaching (degradation rate) was impossible to verify and it therefore introduced a measure of uncertainty.

The parameter $f_2$ actually depended on the functional form of the relation

$$f_2 = f(V_r),$$

where

$f_2$ = the ratio of the fraction of surface flux per storm to the exposed trench inventory,
$V_r$ = the runoff in inches.

First, the functional form of the data for runoff concentration versus $V_r$ was empirically determined. The model allowed three options for the type of curve used to empirically fit the concentration vs $V_r$ data. The first option assumed a constant value of $f_2$ for all runoff values. The second option assumed a linear relationship, with concentration increasing linearly with runoff. The third option assumed an exponential relationship between $f_2$ and $V_r$.

In most cases, either an exponential or a uniform functional relationship was found reasonable. The former was based upon the rationale that the greater the runoff, the greater the amount of immobile particulate contaminants flushed out. However, in many cases the data were quite random and an average uniform concentration, regardless of runoff value, was appropriate.

The value of $f_3$ represented an effective $K_d$ (distribution coefficient). It was, therefore, a measure of contaminant retardation in groundwater transport. The factor $f_3$ was related to the distribution coefficient. However, it differed greatly in magnitude from the values of $K_d$ measured in the laboratory. The calibrated value of $f_3$ was used in the model, and resulted in conservative estimates of retardation.

The calibration of $f_3$ was based on the contaminant travel time. It was assumed that a contaminant first reached the sampling well when it was observed. However, the contaminant breakthrough at the well most likely occurred before the first sampling activity was implemented. Thus, considerable uncertainty may be involved and the effective $K_d$ may be much lower.

### 5D.3.2 Results

The calibrated model was used to predict concentrations of radionuclides in the groundwater and surface runoff for each modeled area. The model output for each of the 26 areas included: (1) predicted time-series of concentrations in the calibration well or at a downgradient receptor point; (2) predicted time-series of radionuclide inventory remaining in the source area; and (3) predicted time-series of radionuclide flux in surface runoff from the area. To illustrate typical results, the time-series plots for cobalt-60, cesium-137, europium-152, tritium, and strontium-90 for Areas A, B, C, D, and Y are shown in Figs. 5D.2 through 5D.26. All model output values presented correspond to the 95th percentile upper limit of the mean.

The predicted well concentrations in the first year radionuclide is seen in the well (breakthrough year) and the predicted peak value and its year of occurrence (e.g., a well) are summarized in Tables 5D.6 through 5D.14 for all the areas. The tables also show the initial inventory of the radionuclides in each area. Table 5D.14 is a summary of the predicted inventories in the year 2020 and 2120 and the time to complete depletion.

### 5D.3.3 Analyses of Results

The following is the analysis of the modeling results for groundwater contaminant concentrations for each of the waste areas. All concentrations reported are as the upper 95 percentile limit of the mean.

**Area A.** The wastes were stored in a mixture of lined and unlined auger holes between 1974 to 1981. Table 5D.1 gives the inventory of important radionuclides. There are large quantities of europium-152 (4176 Ci), europium-154 (1558 Ci), cobalt-60 (3357 Ci) and cesium-137 (1646 Ci).

The downgradient sampling well for Area A was 1242. The contaminant plume extended southeastward, not quite reaching Well 1242. Concentrations in this well were, therefore, much lower than those seen in Well 842, which monitors a similar area (Area B). The well was screened in the depth range of 12 to 25 ft and straddled the water table. Groundwater concentrations are given in Tables 5D.6 to 5D.12. The value was highest for tritium (31,600 pCi/L), and europium was not projected to show up until the year 1998. Peak concentrations of europium-152 (32.4 pCi/L) and europium-154 (2.2 pCi/L) were predicted for around the year 2030 because the aluminum cladding would prevent leaching of europium for the first 10 to 20 years. Europium has relatively reduced mobility because it does not complex with the organic solvents.

**Area B.** This area, adjacent to Area A, contained high-level auger holes and solvent wastes. The waste inventory included low levels of tritium (32.8 Ci) and high levels of cobalt-60 (1305 Ci), strontium-90 (284 Ci) and cesium-137 (771 Ci). Area B was active from 1973 to 1983.

Well 842 monitors the shallow aquifer downgradient from Area B. The concentration in groundwater of tritium (656,000 pCi/L) at the well was rather high. There were also high concentrations of cobalt-60 (1030 pCi/L), moderate levels of cesium-137 (12.4 pCi/L), and low levels of strontium-90 (4.3 pCi/L).

The high cobalt-60 concentrations may indicate that the distribution coefficient for cobalt-60 was lowered by complexation with organic solvents. The relatively low value for cesium-137 was due to its high retardation. The concentration of strontium-90 was predicted to reach a peak value of 418 pCi/L in 2052.

**Area C.** This area is located at the northern end of WAG 6. The wastes stored in Area C included large amounts of tritium (1071 Ci) and strontium-90 (105 Ci) and moderate quantities of cobalt-60 (15.2 Ci) and cesium-137 (34.1 Ci). There was also a small amount of uranium-233 (4.8 Ci). Waste was deposited in Area C from 1976 to 1978.

The general direction of the plume was southwest. The sampling Well 1225 was near (35 m from) the center of the area and monitored the plume. Significant quantities of all radionuclides were observed at the well. High levels of tritium (2.8 MCi/L) in the well were due to the large inventory of tritium. Extremely high levels of strontium-90 (5640 pCi/L) were also seen.

**Area D.** This area is adjacent to Area C. Waste was deposited in trenches in this area from 1978 to 1985. The initial inventory of cobalt-60 was high (3521 Ci). Moderate quantities of strontium-90 (68 Ci) and cesium-137 (53.3 Ci) were placed. The inventory of tritium was low (13.3 Ci). In addition, a small quantity of uranium-233 (2.8 Ci) was placed in Area D trenches. This area was open for waste deposition between 1978 and 1985.

The plume traveled southwestward toward the FB stream. There were no sampling wells downgradient of this area. The groundwater receptor point 50 m from the area showed low levels of cobalt-60, strontium-90, cesium-137 and uranium-233 because of low groundwater velocities. Cobalt-60, strontium-90, and cesium-137 did not reach the receptor point until the year 2024, 2055, 2126, respectively. However, large concentrations of tritium (1.04 $\mu$Ci/L) were found.

**Area E.** Area E is located close to the northern boundary of WAG 6. The water table was about 4.6 m below the trench bottom. The area had relatively low quantities of radionuclides. The inventory of major radionuclides included 16.2 Ci of cobalt-60, 50.4 Ci of tritium, 3.2 Ci of strontium-90, 12.5 Ci of cesium-137, 4.6 Ci of uranium-233, and 7.7 Ci of uranium-238. Area E was active between 1972 and 1973.

The groundwater contaminant plume moved in an eastward direction toward the Emergency Waste Basin. Well 867, located within 9m of this area, contained low levels of cobalt-60 (9.6

pCi/L), strontium-90 (4.3 pCi/L) and cesium-137 (5.2 pCi/L). The strontium-90 concentration was predicted to peak at 17.2 pCi/L in the year 2049. Uranium-233 (7.3 pCi/L) and uranium-238 (19 pCi/L) were predicted to reach the well in the year 2038. Peak concentrations of 149 pCi/L for uranium-233 and 400 pCi/L for uranium-238 were predicted for the year 2197.

**Area F.** Area F, located at the northern end of WAG 6, close to the Emergency Waste Basin, exhibited relatively small amounts of cobalt-60 and uranium-233 and moderate amounts of tritium, strontium-90, and cesium-137. The inventory of the major radionuclides consisted of 14.5 Ci of cobalt-60, 45.5 Ci of tritium, 93.3 Ci of strontium-90, 47.1 Ci of cesium-137, and 4.1 Ci of uranium-233. This area was active from 1972 to 1976.

Well 1241 is 65 m from the area. The contaminant plume migrated north toward the Emergency Waste Basin. Groundwater concentrations at Well 1241 included low levels of cobalt-60 (7.4 pCi/L), strontium-90 (8.02 pCi/L), and cesium-137 (20 pCi/L). The concentration of tritium was also relatively low (4700 pCi/L). The peak concentration of tritium (35,000 pCi/L) were predicted to occur in the year 2009, with strontium-90 peaking at 268 pCi/L in the year 2032. Uranium-233 were projected to reach the well in the year 2217 (2.5 pCi/L). The uranium-233 concentration was predicted to increase to 60.6 pCi/L in the year 2376, the final year of simulation.

**Area G.** Area G, adjacent to Area F, contained a few high-level trenches. The waste inventory consisted of moderate quantities of tritium (13 Ci), cobalt-60 (4.13 Ci), strontium-90 (26.7 Ci), cesium-137 (13.5 Ci), and uranium-233 (1.2 Ci). Area G was active for the year 1975.

Sampling Well 843 is about 55m east of the area. The direction of the hydraulic gradient of the underlying aquifer was toward the east. Groundwater well concentrations at Well 843 included high levels of cobalt-60 (105 pCi/L) and tritium (1.39 $\mu$Ci/L). The trenches in Area G were relatively old, with breached containers. Also, retardation of cobalt-60 was high, possibly because of organic complexation. Only small amounts of strontium-90 and cesium-137 were present. The peak concentration of strontium-90 (496 pCi/L) was predicted to reach the well in the year 2053; uranium-233 was not expected to reach the well for a long time.

**Area H.** Area H, situated in the north central part of WAG 6, contained auger holes and high-level silos. It had high inventories of cobalt-60 (82.2 Ci), strontium-90 (45 Ci), and cesium-137 (106 Ci). The quantity of tritium stored was relatively low (10 Ci). The waste was deposited between 1986 and 1990.

The plume traveled west toward Stream FB There was no sampling well to monitor the groundwater system. The results of modeling showed that most of the radionuclides had not reached the groundwater 50 m from the source. Only tritium was transported to that point and was present at a concentration of 843,000 pCi/L. Cobalt-60 and strontium-90 were predicted to reach a receptor point 50 m from the source in the year 1998. Cesium-137 was expected to reach the receptor point even later, in the year 2080, and was present at a very low concentration. Because this area was relatively new, cobalt-60 and most other radionuclides had not yet reached the well.

**Area I.** Area I is situated in the upper central region of WAG 6. The inventory included very small quantities of cobalt-60 and tritium, as well as strontium-90 (20.4 Ci) and cesium-137 (10.4 Ci). The area was active from 1986 to 1990.

There was no sampling well hydraulically downgradient of this area. The direction of the plume was southwest toward Stream FB. The concentration of tritium in the groundwater was predicted to be high (542,000 pCi/L) at a receptor point 50 m from the area in the year 1990 although very little tritium was deposited in the source area. This was because the trenches were relatively new, and the tritium source had undergone little depletion. Low levels of cobalt-60 were expected to reach the receptor point in the year 1999. Strontium-90 was predicted to reach the receptor point in the year 2013 at a concentration of 561 pCi/L. Low levels of cesium-137 were predicted to reach the receptor point in the year 2359.

**Area J.** Area J, situated in the north central region of WAG 6, contained a large number of fissile waste auger holes and a few solvent waste auger holes. This area was active from 1986 to 1988 and had a large inventory of cobalt-60 (250 Ci) and cesium-137 (702 Ci), a moderate amount of strontium-90 (43.7), and a small amount of tritium (5 Ci).

There was no sampling well to collect groundwater concentration data. The contaminant plume moved southeast toward Stream DB. Groundwater concentrations were modeled at a receptor point 50 m from the area. Cobalt-60 and strontium-90 were both predicted to reach this point in the year 1990 with concentrations of 96.6 pCi/L and 53.6 pCi/L, respectively. Strontium-90 was expected to reach a peak in the year 2049 at 130 pCi/L. Concentrations of cesium-137, low because of retardation, was predicted to reach this point in the year 2016. Tritium also showed low concentrations in the groundwater.

**Area K.** Area K, situated in the north central region of WAG 6, had only a few auger holes. The area was active in the year 1981 and received a large deposition of europium-152 (26,801 Ci) and europium-154 (48701 Ci). The radionuclide inventory also included cobalt-60 (20.9 Ci), strontium-90 (6.8 Ci), and cesium-137 (18.8 Ci). The quantity of tritium was very low. There was no downgradient sampling well to monitor groundwater concentrations.

The contaminant plume moved south toward Stream DB. The modeling results for a receptor point 50 m from that source showed the presence of cobalt-60 at a concentration of 7.56 pCi/L, strontium-90 at a concentration of 13.7 pCi/L, and very low levels of tritium and cesium-137. Europium-152 and europium-154 was predicted to reach the receptor point in the year 2010, 1996 at concentrations of 0.17 pCi/L and 48.8 pCi/L, respectively. Europium has a higher retardation because it does not complex with organic solvents.

**Area L.** Area L, situated in the central region of WAG 6, had a radionuclide inventory that included cobalt-60 (7.2 Ci), tritium (2488 Ci), strontium-90 (38 Ci), cesium-137 (159 Ci), uranium-233 (101 Ci), and uranium-238 (1.72 Ci). This area was active from 1979 to 1984. Sampling Well 848 is 44 m downgradient from this area.

The contaminant plume moved southwest to the French drain. A portion of the plume moved southeast to Stream DB. The concentration of strontium in the well was 59 pCi/L. Concentrations of cobalt-60 and cesium-137 were low because cobalt-60 had low inventory and cesium-137 has high retardation. High levels of tritium were present (7 $\mu$Ci/L). Uranium-233 and uranium-238 were predicted to reach the well in the year 2025. The concentration of uranium-233 was 19.7 pCi/L; very little uranium-238 was present.

**Area M.** Area M, located in the central region of WAG 6, was active between 1973 and 1976. The inventory of major radionuclides comprised 198 Ci of cobalt-60, 617 Ci of tritium, 39 Ci of strontium-90, 152 Ci of cesium-137, and 56 Ci of uranium-233. A small amount of thorium-232 (1.13 Ci) was also present.

Sampling Well 849, located about 58m from the centroid of the area, monitored the contaminant plume from Area M. The contaminant plume migrated predominantly southwest toward Stream FB. A portion of the plume was intercepted by the French Drain. The observed concentration of cesium-137 was 11.5 pCi/L. The tritium level was quite high (3.4 $\mu$Ci/L). Cobalt-60 and strontium-90 were present at low levels, and the concentration of thorium-232 was very low. Uranium-233 was predicted to reach the well in the year 2150 with a concentration of 27 pCi/L. The level of uranium-233 was predicted to increase over the years as the leaching rate increases with negligible decay.

**Area N.** Area N, situated in the western region of WAG 6, included low-level and asbestos trenches. The waste inventory consisted of large amounts of tritium (452 Ci) and cobalt-60 (645 Ci) and lesser amounts of strontium-90 (25 Ci), cesium-137 (35.4 Ci), uranium-233 (25 Ci), and uranium-238 (16.3 Ci). This area was active between 1976 and 1979.

Sampling Well 853, about 56 m south of the centroid of Area N, missed the thickest portion of the contaminant plume that migrated southeast to drainage FB. Therefore, concentrations of all radionuclides present at the well were low. Uranium-233 and uranium-238 were predicted to reach the well in the year 2057. The concentration of uranium was expected to increase due to the increasing leaching rate and the lack of significant decay.

**Area O.** Area O, is situated in the western region of WAG 6, was open between 1977 and 1978 and included low-level trenches. The inventory contained significant amounts of tritium (284, Ci), cobalt-60 (391 Ci), strontium-90 (19.1 Ci), cesium-137 (115 Ci), and small quantities of thorium-232 (1 Ci) and uranium-238 (1.12 Ci). Sampling Well 854, about 54 m from the center of Area O, had low concentrations of radionuclides other than tritium (292,000 pCi/L). The well missed most of the plume because of its location near the groundwater divide at the southern tip of Area 0.

**Area P.** Area P, in the eastern region of WAG 6, was active from 1986 to 1990 and included high-level auger holes. The inventory contained large amounts of cobalt-60 (21,064 Ci), tritium (2700 Ci), strontium-90 (129 Ci), cesium-137 (5822 Ci), europium-152 (250,865 Ci), europium-154 (187,368 Ci), and thorium-232 (6003 Ci). The area was monitored by two sampling wells, Well 845

(southwest) and Well 1243 (east). Since the predominant direction of groundwater flow was to the east, Well 1243 was more representative. High levels of cobalt-60 (8210 pCi/L), tritium (1.8 $\mu$Ci/L) and cesium-137 (37 pCi/L) were present in groundwater samples from Well 1243. These concentrations reflected the high activity in the auger holes. Organic solvents were present in the solvent auger holes, and formation of complexes with organics increased the mobility of cobalt-60. Because most of the high-activity auger holes were lined, leaching was initially reduced, preventing the groundwater concentrations from reaching even higher levels.

Europium was predicted to reach the well in 2005, with the europium-152 concentration at 163 pCi/L and the europium-154 concentration at 321 pCi/L. Europium-152 was predicted to achieve a peak concentration of 850 pCi/L in 2040, and europium-154 a peak concentration of 584 pCi/L in 2036. Thorium-232 was not expected to reach the well for a long time because of its relatively high distribution coefficient and consequent high retardation.

**Area Q.** Area Q, situated in the eastern region of WAG 6, just south of Area P, was capped and comprised trenches and a few auger holes. The inventory consisted of small amounts of tritium (6.2 Ci), but large quantities of cobalt-60 (377 Ci), strontium-90 (50 Ci), and cesium-137 (265 Ci). Area Q was active between 1973 and 1974. The contaminant plume migrated east and sampling Well 840 to the east of the area and intercepted the contaminant plume.

The well concentration for tritium was 123,000 pCi/L. Other radionuclides present included cobalt-60 (34.6 pCi/L), strontium-90 (9.3 pCi/L), and cesium-137 (2.3 pCi/L).

**Area R.** Area R, located in the eastern region of WAG 6 near Area Q, included a few trenches and auger holes. The waste inventory included large quantities of cobalt-60 (1001 Ci) and smaller quantities of tritium (19 Ci), strontium-90 (21 Ci) and cesium-137 (41 Ci). Area R was active from 1979 to 1986. There was no sampling well monitoring the contaminant plume from Area R.

The contaminant plume flowed southeast. Radionuclides present at a receptor point 50 m downgradient from the area included cobalt-60 (82 pCi/L), tritium (49,500 pCi/L), and strontium-90 (22.8 pCi/L). The concentration breakthrough curve for cesium-137 showed it reaching the receptor point in the year 2025.

**Area S.** Area S, located in the western region of WAG 6, also included biological trenches. The inventory showed very low levels of radionuclides. Only tritium was deposited in a significant amount (30 Ci). Area S was open to waste deposition from 1989 to 1990. Sampling Well 851, located about 36 m southeast of Area S, showed relatively low levels of tritium (38,000 pCi/L) and insignificant concentrations of other radionuclides due to the small quantities of their sources in the trenches. The contaminant plume migrated southeast, and the groundwater velocity was low.

**Area T.** Area T, located in the western region of WAG 6 adjacent to Area S, included animal trenches. It had an inventory of 34.5 Ci of tritium and very low quantities of other radionuclides. Area T was open to waste deposition between 1977 and 1979. Sampling Well 852, located 50 m

south of this area, was in the contaminant flow path. The contaminant plume migrated south-southwest, and the groundwater velocity was low.

The concentration of tritium in the well was 97,000 pCi/L. Other radionuclides were not present at significant levels.

**Area U.** Area U, located in the central region of WAG 6, included mostly biological trenches. The inventory consisted of small amounts of radionuclides, with only tritium (61.6 Ci) present in significant amounts. This area was open between 1979 and 1981. Sampling Well 850, located about 48 m south of the area, monitored the contaminant plume extending from southeast (toward Stream DB) to south (toward Stream DA).

The concentration of tritium in the well was 33,000 pCi/L. The concentrations of other radionuclides were close to background levels and may have represented contributions of the Area L plume, which was directly upgradient.

**Area V.** Area V, located near the southeastern boundary of WAG 6, was a small area that included low-level trenches. The inventory for tritium was 50.4 Ci. There were small quantities of cobalt-60 (16.2 Ci), strontium-90 (3.2 Ci), cesium-137 (12.5 Ci), uranium-233 (4.6 Ci), and uranium-238 (7.7 Ci). This area was an active storage site from 1978 to 1979. The contaminant plume traveled southeast to Stream DB. Well 838, 55 m from Area V, was a sampling well for this area.

Well 838 was on a groundwater divide and did not intercept the main portion of the plume. The concentration of tritium in the well was 17,900 pCi/L. Low levels of other radionuclides were also present. Both uranium isotopes were predicted to reach the well in the year 2064.

**Area W.** Area W, situated near the southeastern boundary of WAG 6, contained asbestos trenches. The area was active between 1979 and 1985. The inventory of radionuclides was very small. There was no sampling well monitoring the plume concentration.

The contaminant plume extended from southeast (traveling toward the WAG boundary) to south (traveling toward Stream FB). Modeling results for a receptor point 50 m from the source area showed a low concentration of tritium (169,000 pCi/L) due to its low retardation and high leaching rate.

**Area X.** Area X, at the southern end of WAG 6, included animal trenches and was active from 1972 to 1988. There was a significant inventory of cobalt-60 (25.7 Ci) and tritium (177 Ci). The other radionuclides were present in small quantities. The contaminant plume traveled toward WOL, and was monitored by Well 835.

The concentration of most radionuclides was low. Strontium-90 was predicted to exhibit a peak concentration of 41 pCi/L in the year 2049, and tritium was shown to be present at a concentration of 45,000 pCi/L.

**Area Y.** Area Y, near the southern boundary of WAG 6, comprised low-level trenches and was active from 1984 to 1986. The trench inventory included large quantities of tritium (805 Ci) and cobalt-60 (6436 Ci). Moderate quantities of strontium-90 (34.4 Ci), cesium-137 (40.6 Ci), uranium-233 (124.7 Ci), and uranium-238 (209 Ci) are also present. The contaminant plume traveled toward WOL. Sampling Well 837, 58 m south of the area, monitored the contaminant plume.

The concentrations of all radionuclides in the well were relatively low. The concentration of cobalt-60 was predicted to peak at 60 pCi/L in the year 2024. The trenches in Area Y were, on the average, 3.0 m above the water table. The groundwater aquifer may possibly have been influenced by intrusion of water from WOL, thereby diluting the contaminant plume and also increasing adsorption (retardation) of radionuclides.

Uranium isotopes were predicted to reach the well in the year 2091. The concentration of uranium-233 was 28.9 pCi/L, and that of uranium-238 was 84 pCi/L. The uranium concentrations were expected to continue increasing with time due to their very long half-lives.

**Area Z.** Area Z, located in the southern region of WAG 6, just east of Area Y, contained low-level trenches and was active between 1986 and 1990. The inventory of radionuclide waste consisted of tritium (9.5 Ci), strontium-90 (10.6 Ci), cesium-137 (20.2 Ci), and small amounts of other radionuclides. There were no sampling wells downgradient from this area.

At a receptor point 50 m away, the concentration of tritium was 477,000 pCi/L, and that of strontium-90 was 62 pCi/L. The other radionuclides were present at low levels.

**Tumulus I.** Tumulus I was the only above-ground unit simulated. This disposal unit, located in the southcentral region of WAG 6, received waste stored in casks from 1986 to 1990. Small quantities of radionuclides were stored in the tumulus. Only cobalt-60 (10.4 Ci), tritium (2.7 Ci), strontium-90 (12.0 Ci), and cesium-137 (14.3 Ci) were present in significant quantities. The groundwater moved in a predominantly southwesterly direction toward Stream FB. There were 6 monitoring wells around Tumulus I.

Model calculations were made to determine the concentration at a receptor well 50 m downstream from the disposal unit. Since the unit's concrete lining was assumed to hold for 100 years, no significant concentrations were predicted to be observed at the receptor point for some time. Only small amounts of tritium were expected to reach the groundwater via diffusion through the concrete. Strontium-90, which has a longer half-life and higher retardation factor than tritium was predicted to peak at 13.1 pCi/L in 2125 at the receptor point. Most of the other radionuclides were not expected to be present at significant concentrations at any time.

### 5D.3.4 Stream Flow Radionuclide Concentrations and Boundary Flux

Radionuclide concentrations in the streams and the flux of each of the isotopes across the WAG 6 boundary were required for the off-WAG 6 risk assessment. The contaminants can leave

the site in either surface water or groundwater. The flux in surface water could leave the site either in the streams draining the site or in overland flow. The groundwater flux could be intercepted by either the stream on the east side of WAG 6 or WOL.

The flux in the surface water came through two different pathways. The first pathway was surface runoff, which consisted of overland flow, saturated overland flow, and subsurface storm flow. The fluxes in the surface runoff are shown in the model output. The second pathway was base flow, which results from the groundwater discharge.

The surface runoff fluxes were routed down to the stream. The flux due to base flow was determined by finding the flux in the groundwater at a point at which it would intercept the stream. Not all of the groundwater will enter the stream as base flow; therefore, the groundwater flux was proportioned by the ratio of base flow to total percolation to derive the flux in the base flow. The rest of the flux will be transported in groundwater.

The radionuclide concentrations along the streams are listed in Tables 5D.16 through 5D.24. Plots of the time-series of radionuclide fluxes in surface water across the WAG boundary are shown in Figs. 5D.27 through 5D.35. Nine radionuclides were included: cobalt-60, cesium-137, tritium, strontium-90, europium-152, europium-154, thorium-232, uranium-233, and uranium-238. The time-series of the fluxes in surface water discharged into the Emergency Waste Basin are shown in Figs. 5D.36 through 5D.41.

### 5D.3.5 Boundary Fluxes in Groundwater

To satisfy the data requirements of the baseline risk assessment, the total contaminant flux exiting the WAG 6 boundary was determined, as well as the contaminant flux into the Emergency Waste Basin. The contaminant flux in groundwater at the boundary was calculated by the model for each of the plumes. Only the portion of the flux not discharged into the streams was considered to contribute to the total groundwater flux from WAG 6. A time-series plot of the contaminant flux across the WAG 6 boundary for each of the modeled constituents in groundwater is shown in Figs. 5D.42 through 5D.50. The fluxes in groundwater into the Emergency Waste Basin are shown in Figs. 5D.51 through 5D.56.

### 5D.3.6 Conclusions

High levels of cobalt-60 and tritium were present in the groundwater around auger hole areas (A, B, and P) in the east and the solvent auger hole areas (J and H). Groundwater fluxes of tritium and cobalt-60 entered the stream on the east of WAG 6 and eventually discharged to WOL. The cobalt-60 and tritium concentrations in the groundwater depleted monotonically due to decreasing leachate flux and radioactive decay. No significant peaks were predicted in the future.

The concentration of strontium-90 in groundwater was high in the north central region of WAG 6 (Areas C, D, E, H) around Stream FB. Also the plumes from Areas Z and L showed significant strontium-90 concentrations in the groundwater. Strontium-90 complexes with organics

less strongly than does cobalt-60 and therefore has relatively high retardation. Strontium-90 behaves as a calcium analog in competing for cationic adsorption sites in clays and minerals.

Strontium-90 has a longer half-life than cobalt-60 or tritium. Thus, in several areas with high strontium-90 inventory (e.g., Areas A, B, F, G, H, and P), the groundwater concentration was predicted to show a large peak in the future after the containers are breached. Due to plumes from Areas C, D, and H, there was a significant strontium-90 flux in groundwater discharging to Stream FB.

The cesium-137 concentration in the groundwater was very low in most areas. The concentration of cesium-137 is high in the contaminant plume downgradient of Areas A, B, C, N, O, and P. Area P had the highest groundwater concentration of cesium-137 (37 pCi/L). Due to its high retardation, the cesium-137 plume did not spread much and was not likely to pose widespread groundwater exposure concern.

The concentration of cesium-137 showed decrease with time in most areas. Very low peaks were seen at a later time. Only in the plume from Area P was a significant peak cesium-137 concentration (92 pCi/L) predicted in the year 2051.

Europium-152 and europium-154 were not present in most of the groundwater plumes. Most europium was placed in lined auger holes with control plates composed of a europium oxide-aluminum cermet clad with aluminum. Due to the lining in the auger holes and the aluminum cladding, the source leaching has been both delayed and reduced. There were high inventories of europium-152 in Areas B and P and of europium-154 in Areas B, K, and P. Significant concentrations of europium-152 were predicted to be present in the reception wells downgradient of Areas B and P around the year 2000. Around the same period, contaminant plumes from Areas B, K, and P were predicted to show elevated levels of europium-154. Europium concentration peaks were projected to occur between 2030 and 2040, after the aluminum claddings are breached.

There was a large inventory of uranium-233 in Areas L, M, N, and Y. Uranium-238 was present in large quantities in Areas E, N, V, and Y. The groundwater plume moved toward downgradient wells/receptor points slowly due to retardation. Therefore, the present concentrations of uranium in wells were almost negligible. The concentration in the plume was predicted to increase steadily with time. In the source area (Area L), the sampling well (Well 848) was predicted to have a uranium-233 concentration of 19.7 pCi/L in the year 2025. In Area Y, the sampling well (Well 837) was predicted to have a uranium-233 concentration of 28.9 pCi/L and a uranium-238 concentration of 84 pCi/L in year 2091. Due to their very long half-lives, uranium-233 and uranium-238 behaved as conservative substances for the period of study and were predicted to increase to concentrations greater than 500 pCi/L in future.

Thorium-232 inventory was high in Areas P (6003 Ci) and N (16.2 Ci). Thorium-232 has a very long half-life; therefore, thorium-232 concentrations, like those of uranium, increase for a long time. However, because thorium has a high retardation (almost an order of magnitude higher than

that of the other radionuclides analyzed), it was expected to reach the wells or receptor points only after a long time, and its concentrations were found to be negligible.

The source inventories of cesium-137, strontium-90, tritium, cobalt-60, europium-152, and europium-152 should deplete exponentially in relatively short periods of time; their half-lives are tens of years. In 30 years (i.e., in the year 2020), only Areas A. B, D, P, R, and Y (see Table 5D.15) were predicted to have significant cobalt-60 levels. Source Areas A, C, L, M, N, O, U, and Y were expected to have significant tritium levels at year 2020. Cobalt-60 and tritium were predicted to decrease to less than 1 Ci by 2050 in each area except in Area P, matched by cobalt-60 in the year 2063. Strontium-90 has a longer half-life and strontium-90 sources deplete slowly. By 2120, only Areas A, B, C, F, L, and P were predicted to have significant strontium-90 activity. Europium-152 and europium-154 were present in Areas A, B, K, and P. Europium-152 has a longer half-life (13.6 years) and was expected to be present at significant levels in all source areas in the year 2120, while europium-154 (half-life = 8.8 years) would likely be depleted except in Area P.

Uranium and thorium were present at significant levels in a few areas (see Table 5D.1). Relatively high levels of uranium-233 were present in Areas L, M, N, and Y, and high levels of uranium-238 were present in Areas M, N and Y. High activity of thorium-232 (6003 Ci) existed only in Area P. The groundwater leachate and surface runoff fluxes were small and were therefore not significant removal mechanisms. Uranium-233, uranium-238, and thorium-232 activities were predicted to remain almost steady in the source until the year 2100 and persist for a long time.

## 5D.4 SENSITIVITY AND UNCERTAINTY ANALYSIS

### 5D.4.1 Sensitivity Analysis

The sensitivity of a model output to a selected input parameter is the degree to which the modeling result is affected by changes in that parameter. A sensitivity analysis is conducted to identify sensitive input parameters, which should be given attention and defined with accuracy. Sensitivity analysis can range in complexity from a simple high-low screening approach to a complete factorial design using all combinations of levels of input parameter values.

The approach implemented in this study included an initial qualitative screening followed by a quantitative analysis. In a qualitative approach, the influence of the input parameters is ascertained by inspecting the model's equations. This qualitative appraisal identifies potentially sensitive as well as nonsensitive parameters and minimizes the number of parameters to be considered for a quantitative analysis. The sensitivity of the model can be appraised quantitatively by plotting the output parameter as a function of a single input parameter, holding the others constant. However, sensitivity to an input parameter may vary markedly under different sets of conditions (e.g., transient states).

### 5D.4.1.1 Qualitative screening

Surface water samples and preliminary modeling results showed low levels of radionuclides in the surface waters, except for tritium. The future groundwater concentration and the residual inventory in the trenches were the most important model output parameters considered for sensitivity analysis. Figures 5D.57 through 5D.75 illustrate the sensitivity of model output to changes in various parameters.

Source inventories are depleted by radioactive decay and leaching to groundwater. Since radioactive elements decay exponentially at a constant, unalterable rate, only the parameters that affect the leaching required investigation. Leaching to groundwater (see Appendix 5C) was expressed as:

$$AL = (RPERC \cdot ATREN \cdot f_1)/[H \cdot (PORT \cdot SSAT + XKDT \cdot BDENS)]$$

where

| | | |
|---|---|---|
| AL | = | leachate flux, Ci |
| RPERC | = | percolation, m/year |
| ATREN | = | present day trench inventory, Ci |
| F | = | leaching fraction |
| H | = | depth of trench, in. |
| PORT | = | porosity of trench |
| SSAT | = | degree of saturation in trench |
| XKDT | = | partition coefficient in trench, $m^3/kg$ |
| BDENS | = | bulk density, $kg/m^3$ |

The trench depth (H) was documented to be more or less constant (15 ft). The bulk density (BDENS) usually had low variability. XKDT manifested large variations that would likely influence model output. The term PORT × SSAT was usually much smaller than the term XKDT × BDENS, so its effect on the model output is less significant. The terms RPERC, ATREN, and $f_1$ directly affected the leaching flux AL. The parameter ATREN was directly related to the initial source inventory ATRENI.

The groundwater concentration at any cross-section of the plume was determined primarily by the leachate flux AL, the water flux WA at that point, and the travel time TRTH.

| | | |
|---|---|---|
| GWC | = | AL/WA × exp(-DECAY × TRTH) |
| WA | = | GWV × EPORA × AQTHK × AN |
| AN | = | AN (ADISP, TAREA, DHORZ) |
| TRTH | = | TRTH (GWV, DHORZ, PORA, BDENS, XKDH) |

where

| | | |
|---|---|---|
| GWC | = | groundwater concentration, $Ci/m^3$ |
| WA | = | water flux, $m^3$/year |
| GWV | = | groundwater velocity, m/year |
| EPORA | = | effective porosity in saturated zone |
| AQTHK | = | aquifer thickness, m |
| AN | = | cross-sectional area of plume, $m^2$ |
| ADISP | = | angle of dispersion, radians |
| TAREA | = | area of the waste source area, $m^2$ |
| DHORZ | = | horizontal distance to well, m |
| TRTH | = | travel time, year |
| XKDH | = | distribution coefficient in the aquifer, $kg/m^3$ |

As explained earlier, the variation in PORA and BDENS was not expected to cause much variation in the output parameter. Therefore, the likely sensitive parameters were GWV, EPORA, AQTHK, ADISP, RPERC, ATRENI, F, TAREA, DHORZ, and XKDH.

### 5D.4.1.2 Quantitative analysis

Sensitivity analysis done for tritium and cobalt-60, were representative of mobile and slow-moving isotopes, respectively. The sensitivity of the model output to change in the value of an input parameter was determined by the ratio of percent change in the output parameter to percent change in the input parameter. Table 5D.25 lists ratios calculated using nominal values of input parameters for cobalt-60. Table 5D.26 lists the corresponding values for tritium.

**Inventory.** In the analysis for trench inventory, both isotopes showed similar trends in changes in inventory with change in any input variable. However, inventory for cobalt-60 was less sensitive than the tritium inventory because radioactive decay is the predominant mechanism for loss of cobalt-60 from the trenches. Cobalt-60 inventory is insensitive to all parameters except ATREN (initial trench inventory).

Tritium is only moderately sensitive to RPERC and FINT (see Table 5D.26) and quite insensitive to other parameters. Figures 5D.57 and 5D.58 show the variation of inventory after 30 years of emplacement with variation in FINT and RPERC respectively.

**Groundwater concentrations.** The groundwater concentrations of both cobalt-60 and tritium are very sensitive to several input parameters, including ATREN, GWV, EPORA, RPERC, FINT, and AQTHK (Tables 5D.25 and 5D.26). Cobalt-60 is also very sensitive to IYRC and XKDT and moderately sensitive to DHORZ, XKDH, and ADISP. Tritium is moderately sensitive to DHORZ, IYRC, TAREA, and ADISP and very slightly sensitive to FFIN.

### 5D.4.2 Uncertainty Analysis

Uncertainty in fate and transport modeling can be related to (a) uncertainty in the input variables and (b) the accuracy with which environmental processes are represented. Uncertainty can be described quantitatively, semiquantitatively, or qualitatively. A quantitative approach requires that the probability distribution of the input parameters be known. Model results are highly dependent on the accuracy of the input variables used. The distribution of output will depend on the distribution of input variables. The wider the spread of the distribution, the larger the uncertainty.

For a semiquantitative treatment, only the range of parameter values is needed. Sensitivity analysis plots are used to determine the critical parameter and develop the bounds of the output parameter. In the qualitative treatment, the influence of individual parameter uncertainty and its sensitivity is analyzed. In this analysis, a quantitative and a qualitative treatment were considered.

#### 5D.4.2.1 Quantitative analysis

Uncertainty in the parameter value can be propagated through analytic or numerical (e.g., Monte Carlo simulation) methods. Except for simple formulations with few parameters, the analytical method is difficult to implement. Because of the large number of input parameters and the complex formulations in the model, a Monte Carlo simulation approach was used. The model equations were solved for a combination of different realizations of input parameter set. The mean of 100 simulation results with 95 percent upper limits were given in the computer printouts.

#### 5D.4.2.2 Qualitative analysis

Often, the most practical approach to characterizing parameter uncertainty is to develop a qualitative description of each parameter, indicating its influence on output result.

The contaminant release rate was represented by a leaching fraction ($f_1$) that is empirically calibrated. The actual breach mechanism was not modeled. Similarly, contaminant transport was modeled with a parameter ($f_3$) that represents a measure of retardation resulting from several inadequately understood transport processes due to fractures, solvent mobilization, and heterogeneity of media. However, because the model was calibrated with measured data for the leaching fraction ($f_1$) and the effective $K_d$ ($f_3$), the description of the actual mechanism is not critical.

The nominal value, the range of values and a qualitative classification of the uncertainty of the parameter set are given in Table 5D.27. Many of the parameters identified as uncertain are also identified as sensitive (see Table 5D.26).

# Appendix 5D Tables

**Table 5D.1. WAG 6 inventory of modeled radionuclides (Ci)**

| Waste area | H-3 | Co-60 | Sr-90 | Cs-137 | Eu-152 | Eu-154 | Th-232 | U-233U-238 |
|---|---|---|---|---|---|---|---|---|
| A | 91.6 | 3357 | 416 | 1646 | 4175 | 1558 | 0.001 | 00.015 |
| B | 32.8 | 1305 | 284 | 771 | 16,270 | 22,305 | 0 | 00.001 |
| C | 1071 | 15.2 | 105 | 34.1 | 0.154 | 0.003 | 0 | 4.80 |
| D | 13.3 | 3521 | 68 | 53.3 | 0.146 | 0.014 | 0 | 2.80 |
| E | 50.4 | 16.2 | 3.2 | 12.5 | 0.153 | 0.020 | 0.093 | 4.67.7 |
| F | 45.5 | 14.5 | 93.3 | 47.1 | 0.431 | 0.009 | 0 | 4.10 |
| G | 13.0 | 4.13 | 26.7 | 13.5 | 0.123 | 0.003 | 0 | 1.20 |
| H | 10.0 | 82.2 | 45.0 | 106 | 6.7 | 2.4 | 0 | 0.0040.010 |
| I | 4.9 | 1.9 | 20.4 | 10.4 | 4.1 | 2.1 | 0.008 | 0.3540.014 |
| J | 5.0 | 250 | 43.7 | 702 | 0 | 0 | 0.001 | 00.017 |
| K | 0.35 | 20.9 | 6.8 | 18.8 | 26,801 | 48,701 | 0 | 00 |
| L | 2488 | 7.2 | 38.0 | 159 | 2.0 | 0 | 0.849 | 1011.72 |
| M | 618 | 198 | 39 | 152 | 1.9 | 0.250 | 1.14 | 56.10.04 |
| N | 452 | 645 | 25.0 | 35.4 | 2.9 | 0.756 | 16.2 | 25.016.3 |
| O | 284 | 391 | 19.1 | 115 | 0 | 0.030 | 1.0 | 0.0221.12 |
| P | 2700 | 21064 | 129 | 5822 | 250,865 | 187,368 | 6003 | 00.024 |
| Q | 6.2 | 377 | 50.0 | 265 | 26.4 | 10.9 | 0 | 00.003 |
| R | 19.0 | 1001 | 21.0 | 41.0 | 0 | 0 | 0.100 | 0.0040.510 |
| S | 30 | 0.005 | 0.001 | 0.011 | 0 | 0 | 0 | 00 |
| T | 34.5 | 0.001 | 0.005 | 0.001 | 0.001 | 0 | 0 | 00.126 |
| U | 61.6 | 0.004 | 0.012 | 0.002 | 0 | 0 | 0 | 00 |
| V | 50.4 | 16.2 | 3.2 | 12.5 | 0.153 | 0.020 | 0.093 | 4.67.7 |
| W | 3.5 | 0.173 | 0.021 | 0.021 | 0 | 0 | 0 | 00.016 |
| X | 177 | 25.7 | 11.1 | 16.6 | 0.022 | 0.003 | 0 | 00.046 |
| Y | 805 | 6436 | 34.4 | 40.6 | 2.4 | 0.730 | 0.593 | 124.7209 |
| Z | 9.5 | 0.855 | 10.6 | 20.2 | 4.2 | 4.0 | 0.101 | 0.0030 |

Table 5D.2 WAG 6 calibration well data for radionuclides

Cobalt-60 (pCi/L)

| Well | 1 | | 2 | | 3 | | 4 | | 5 | | Apr-89 | Jun-89 | 5-Sep-89 | 27-Sep-89 | May-90 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 745 | 2.703 | U | 0.2703 | | 10.812 | | 2.4327 | | -- | | -- | -- | -- | -- | -- |
| 831 | 2.703 | U | -- | | 2.703 | U | 1.0812 | | 2.703 | U | -- | -- | -- | -- | -- |
| 832 | 2.703 | U | 0.5406 | | 1.6218 | | 2.703 | | 2.703 | U | -- | -- | -- | -- | -- |
| 833 | 2.703 | U | 2.703 | U | 2.1624 | | 1.8921 | | 2.703 | U | -- | -- | -- | -- | -- |
| 835 | 2.703 | U | 8.109 | | 2.703 | | 2.703 | U | 2.703 | U | -- | -- | -- | -- | -- |
| 836 | 2.703 | U | 2.703 | U | 2.703 | | 2.703 | U | 2.703 | U | -- | -- | -- | -- | -- |
| 837 | -- | | -- | | 2.703 | U | 2.703 | U | 2.703 | U | -- | -- | -- | -- | -- |
| 838 | 0.5406 | | 2.703 | U | 2.703 | U | 0.2703 | | 2.703 | U | -- | -- | -- | -- | -- |
| 839 | 0.8109 | | 2.1624 | | 18.921 | | 0.2703 | | 2.703 | U | -- | -- | -- | -- | -- |
| 840 | 2.1624 | | 4.0545 | | 2.703 | | 2.703 | U | 2.703 | U | -- | -- | -- | -- | -- |
| 841 | 4.8654 | | 2.703 | U | 1.0812 | | 3.2436 | | 2.703 | U | -- | -- | -- | -- | 120 |
| 842 | 351.39 | | 324.36 | | 267.597 | | 297.33 | | 2.703 | U | -- | -- | -- | -- | -- |
| 843 | 11.0823 | | 11.3526 | | 51.357 | | 11.3526 | | 17.2992 | | -- | -- | -- | -- | -- |
| 844 | 1.3515 | | 1.3515 | | 16.218 | | 2.4327 | | 2.703 | U | -- | -- | -- | -- | -- |
| 845 | 2.703 | U | 7.0278 | | 3.2436 | | -- | | -- | | -- | -- | -- | -- | -- |
| 846 | 2.703 | U | 0.8109 | | 2.703 | U | 0.5406 | | -- | | -- | -- | -- | -- | -- |
| 847 | 1.6218 | | 2.703 | U | 5.406 | | 1.3515 | | 2.703 | U | -- | -- | -- | -- | -- |
| 848 | 0.2703 | | 2.4327 | | 2.703 | U | -- | | -- | | -- | -- | -- | -- | -- |
| 849 | 4.0545 | | 0.2703 | | 2.703 | U | -- | | -- | | -- | -- | -- | -- | -- |
| 850 | 2.703 | U | 4.3248 | | 16.218 | | -- | | -- | | -- | -- | -- | -- | -- |
| 851 | 2.703 | U | 0.2703 | | 2.703 | | -- | | -- | | -- | -- | -- | -- | -- |
| 852 | 0.2703 | | 2.9733 | | 2.703 | | -- | | -- | | -- | -- | -- | -- | -- |
| 853 | 0.8109 | | 2.703 | U | 2.703 | U | -- | | -- | | -- | -- | -- | -- | -- |
| 854 | 2.1624 | | 1.0812 | | 2.703 | U | -- | | -- | | -- | -- | -- | -- | -- |
| 855 | 2.703 | U | 2.703 | U | 2.703 | | 2.703 | U | 4.5951 | | -- | -- | -- | -- | -- |
| 856 | 2.703 | U | 2.1624 | | 2.703 | U | 1.8921 | | 2.703 | U | -- | -- | -- | -- | -- |
| 857 | 2.703 | U | 0.5406 | | 13.515 | | 1.8921 | | 2.703 | U | -- | -- | -- | -- | -- |
| 858 | 2.703 | U | 2.703 | U | 3.7842 | | 2.1624 | | 2.703 | U | -- | -- | -- | -- | -- |
| 859 | -- | | -- | | 35.139 | | 2.703 | U | 2.703 | U | -- | -- | -- | -- | -- |
| 860 | 2.703 | U | 2.703 | U | 29.733 | | 2.703 | U | 2.703 | U | -- | -- | -- | -- | -- |
| 1225 | -- | | -- | | -- | | -- | | -- | | 24 | 16.4 | 87.4 | 19.7 | -- |
| 1227 | -- | | -- | | -- | | -- | | -- | | -- | -- | -- | -- | -- |
| 1228 | -- | | -- | | -- | | -- | | -- | | -- | -- | -- | -- | -- |
| 1229 | -- | | -- | | -- | | -- | | -- | | -- | -- | -- | -- | -- |
| 1231 | -- | | -- | | -- | | -- | | -- | | -- | -- | -- | -- | -- |
| 1233 | -- | | -- | | -- | | -- | | -- | | -- | -- | -- | -- | -- |
| 1234 | -- | | -- | | -- | | -- | | -- | | -- | -- | -- | -- | -- |
| 1234A | -- | | -- | | -- | | -- | | -- | | -- | -- | -- | -- | -- |
| 1236 | -- | | -- | | -- | | -- | | -- | | -- | -- | -- | -- | -- |
| 1237 | -- | | -- | | -- | | -- | | -- | | -- | -- | -- | -- | -- |
| 1238 | -- | | -- | | -- | | -- | | -- | | -- | -- | -- | -- | -- |
| 1239 | -- | | -- | | -- | | -- | | -- | | -- | -- | -- | -- | -- |
| 1240 | -- | | -- | | -- | | -- | | -- | | -- | -- | -- | -- | -- |
| 1241 | -- | | -- | | -- | | -- | | -- | | -- | -- | -- | -- | -- |
| 1242 | -- | | -- | | -- | | -- | | -- | | -- | -- | -- | -- | -- |
| 1243 | -- | | -- | | -- | | -- | | -- | | -- | -- | -- | -- | 1880 |
| 1244 | -- | | -- | | -- | | -- | | -- | | -- | -- | -- | -- | -- |

Table 5D.2 (continued)

Cesium-137 (pCi/L)

| Well | 1 | | 2 | | 3 | | 4 | | 5 | | Apr-89 | | May-89 | | Jun-89 | | Aug-89 | | 5-Sep-89 | | 27-Sep-89 | | May-90 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 745 | 1.0812 | | 0.2703 | | 2.703 | U | 1.3515 | | – | | – | | – | | – | | – | | – | | – | | – |
| 831 | 2.703 | U | – | | 2.703 | U | 2.703 | U | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 832 | 2.703 | U | 2.703 | U | 0.2703 | | 2.4327 | | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 833 | 2.703 | U | 1.72992 | | 0.5406 | | 0.8109 | | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 835 | 2.703 | U | 5.9466 | | 0.8109 | | 2.703 | U | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 836 | 0.2703 | | 2.703 | | 21.0834 | | 2.703 | U | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 837 | – | | – | | 2.703 | | 2.703 | U | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 838 | 2.1624 | | 2.703 | U | 10.812 | | 1.0812 | | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 839 | 0.2703 | | 2.703 | U | 2.703 | U | 0.97308 | | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 840 | 2.9733 | | 1.3515 | | 8.109 | | 0.8109 | | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 841 | 1.3515 | | 0.8109 | | 2.4327 | | 5.1357 | | 2.703 | U | – | | – | | – | | – | | – | | – | | 20U |
| 842 | 0.2703 | | 2.703 | U | 13.515 | | 2.703 | U | 2.703 | U | – | | – | | – | | – | | – | | – | | 20U |
| 843 | 1.6218 | | 2.703 | U | 2.703 | | 0.2703 | | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 844 | 1.6218 | | 2.703 | U | 2.703 | U | 2.703 | U | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 845 | 2.703 | U | 2.703 | U | 5.1357 | | – | | – | | 20 | U | – | | – | | 20 | U | – | | – | | – |
| 846 | 18.3804 | | 2.703 | U | 2.9733 | | 1.8921 | | – | | – | | – | | – | | – | | – | | – | | – |
| 847 | 2.1624 | | 4.0545 | | 13.515 | | 0.5406 | | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 848 | 5.9466 | | 0.8109 | | 0.2703 | | – | | – | | 20 | U | – | | – | | 20 | U | – | | – | | – |
| 849 | 0.5406 | | 0.2703 | | 8.109 | | – | | – | | 20 | U | – | | – | | 20 | U | – | | – | | – |
| 850 | 2.703 | U | 4.5951 | | 8.109 | | – | | – | | 20 | U | – | | – | | 20 | U | – | | – | | – |
| 851 | 5.406 | | 1.6218 | | 2.9733 | | – | | – | | 20 | U | 20 | U | – | | 20 | U | – | | – | | – |
| 852 | 2.703 | U | 1.3515 | | 2.1624 | | – | | – | | 20 | U | 20 | U | – | | 20 | U | – | | – | | – |
| 853 | 2.703 | U | 2.703 | U | 0.8109 | | – | | – | | 20 | U | 20 | U | – | | 20 | U | – | | – | | – |
| 854 | 3.7842 | | 2.703 | U | 2.703 | | – | | – | | 20 | U | 20 | U | – | | 20 | U | – | | – | | – |
| 855 | 2.703 | U | 2.703 | | 1.3515 | | 1.3515 | | 2.703 | U | – | | – | | – | | – | | – | | – | | 20U |
| 856 | 7.8387 | | 2.703 | U | 5.406 | | 0.2703 | | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 857 | 2.703 | U | 2.4327 | | 2.703 | U | 0.5406 | | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 858 | 3.7842 | | 2.703 | U | 2.703 | U | 0.2703 | | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 859 | – | | – | | 2.703 | | 2.1624 | | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 860 | 11.8932 | | 2.703 | U | 8.109 | | 0.5406 | | 2.703 | U | – | | – | | – | | – | | – | | – | | – |
| 1225 | – | | – | | – | | – | | – | | 20 | U | 20 | U | 20 | U | – | | 20 | U | 20 | U | – |
| 1227 | – | | – | | – | | – | | – | | 20 | U | 20 | U | 20 | U | – | | – | | – | | – |
| 1228 | – | | – | | – | | – | | – | | 20 | U | 20 | U | 20 | U | 20 | U | – | | 20 | U | 20U |
| 1229 | – | | – | | – | | – | | – | | 20 | U | 20 | U | 20 | U | – | | – | | – | | 20U |
| 1231 | – | | – | | – | | – | | – | | 20 | U | 20 | U | – | | 20 | U | – | | 20 | U | – |
| 1233 | – | | – | | – | | – | | – | | 20 | U | 20 | U | 20 | U | – | | 20 | U | 20 | U | – |
| 1234 | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | – |
| 1234A | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | 20U |
| 1236 | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | 20U |
| 1237 | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | 20U |
| 1239 | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | 20U |
| 1240 | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | 20U |
| 1241 | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | 20U |
| 1242 | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | 20U |
| 1243 | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | 20U |
| 1244 | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | – | | 20U |

Table 5D.2 (continued)

Tritium (pCi/L)

| Well | 1 | 2 | 3 | 4 | 5 | Apr-89 | May-89 | Jun-89 | Aug-89 | 5-Sep-89 | 27-Sep-89 | May-90 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 745 | 1270.41 U | 35139 | 1270.41 U | 1270.41 U | -- | -- | -- | -- | -- | -- | -- | -- |
| 831 | 594.66 | -- | 1270.41 U | 1270.41 U | 864.96 | -- | -- | -- | -- | -- | -- | -- |
| 832 | 108.12 | 973.08 | 1270.41 U | 351.39 | 1270.41 U | -- | -- | -- | -- | -- | -- | -- |
| 833 | 1270.41 U | 18650.7 | 1270.41 U | 513.57 | 1270.41 U | -- | -- | -- | -- | -- | -- | -- |
| 835 | 24867.6 | 32436 | 20272.5 | 26219.1 | 18650.7 | -- | -- | -- | -- | -- | -- | -- |
| 836 | 3513.9 | 13244.7 | 837.93 | 2243.49 | 1648.83 | -- | -- | -- | -- | -- | -- | -- |
| 837 | -- | -- | 1892.1 | 1486.65 | 2432.7 | -- | -- | -- | -- | -- | -- | -- |
| 838 | 14325.9 | 1270.41 U | 11352.6 | 7027.8 | 24867.6 | -- | -- | -- | -- | -- | -- | -- |
| 839 | 29733 | 8109 | 23786.4 | 26489.4 | 17839.8 | -- | -- | -- | -- | -- | -- | -- |
| 840 | 21624 | 21353.7 | 11352.6 | 3243.6 | 4054.5 | -- | -- | -- | -- | -- | -- | -- |
| 841 | 270300 | 243270 | 172992 | 216240 | 143259 | -- | -- | -- | -- | -- | -- | 163000 |
| 842 | 648720 | 675750 | 567630 | 459510 | 183804 | -- | -- | -- | -- | -- | -- | 219000 |
| 843 | 810900 | 919020 | 1243380 | 756840 | 324360 | -- | -- | -- | -- | -- | -- | -- |
| 844 | 72981 | 75684 | 59466 | 64872 | 54060 | -- | -- | -- | -- | -- | -- | -- |
| 845 | 26489.4 | 17569.5 | 40545 | -- | -- | 32000 | -- | -- | 230000 | -- | -- | -- |
| 846 | 270.3 | 108.12 | 1270.41 U | 1946.16 | -- | -- | -- | -- | -- | -- | -- | -- |
| 847 | 20002.2 | 89199 | 83793 | 81090 | 72981 | -- | -- | -- | -- | -- | -- | -- |
| 848 | 4324800 | 4324800 | 2000220 | -- | -- | -- | -- | -- | 4300000 | -- | -- | -- |
| 849 | 2459730 | 2973300 | 1027140 | -- | -- | 1500000 | 1600000 | -- | 2600000 | -- | -- | -- |
| 850 | 43248 | 37842 | 29733 | -- | -- | 30600 | -- | -- | 26000 | -- | -- | -- |
| 851 | 43248 | 3784.2 | 40545 | -- | -- | 43900 | 50000 | -- | 49000 | -- | -- | -- |
| 852 | 59466 | 59466 | 51357 | -- | -- | 56900 | 44000 | -- | 57000 | -- | -- | -- |
| 853 | 3243.6 | 1270.41 U | 1270.41 U | -- | -- | 2660 | 2400 | -- | 2600 | -- | -- | -- |
| 854 | 183804 | 297330 | 151368 | -- | -- | 185000 | 58000 | -- | 33000 | -- | -- | -- |
| 855 | 1162.29 | 54.06 | 1270.41 U | 378.42 | 864.96 | -- | -- | -- | -- | -- | -- | 500U |
| 856 | 324.36 | 1270.41 U | 81.09 | 432.48 | 1270.41 U | -- | -- | -- | -- | -- | -- | -- |
| 857 | 810.9 | 432.48 | 243.27 | 108.12 | 1270.41 U | -- | -- | -- | -- | -- | -- | -- |
| 858 | 270.3 | 135.15 | 1270.41 U | 1270.41 U | 1270.41 U | -- | -- | -- | -- | -- | -- | -- |
| 859 | -- | -- | 405.45 | 946.05 | 1243.38 | -- | -- | -- | -- | -- | -- | -- |
| 860 | 1270.41 U | 1270.41 U | 29.73 | 1270.41 U | 1270.41 U | -- | -- | -- | -- | -- | -- | -- |
| 1225 | -- | -- | -- | -- | -- | 1900000 | 1600000 | 1590000 | -- | 1600000 | 879000 | -- |
| 1227 | -- | -- | -- | -- | -- | 2600 | 2100 | 2360 | -- | -- | -- | -- |
| 1228 | -- | -- | -- | -- | -- | 9261 | 8800 | 7300 | 10000 | -- | 10900 | -- |
| 1229 | -- | -- | -- | -- | -- | 14100 | 15000 | 15800 | 16000 | -- | 16400 | 21200 |
| 1231 | -- | -- | -- | -- | -- | 51000 | 83000 | -- | 54000 | -- | 65200 | -- |
| 1233 | -- | -- | -- | -- | -- | 770000 | 440000 | 246000 | -- | 760000 | 561000 | -- |
| 1234 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 500U |
| 1234A | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 500U |
| 1236 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 500U |
| 1237 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 500U |
| 1238 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 500U |
| 1239 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 500U |
| 1240 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 801 |
| 1241 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2800 |
| 1242 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 472000 |
| 1243 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 794000 |
| 1244 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 51200 |
| 1245 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 500U |

Table 5 (continued)

Strontium-40 (pCi/L)

| Well | 1 | 2 | 3 | 4 | 5 | Apr-89 | May-89 | Jun-89 | Aug-89 | 5-Sep-89 | 27-Sep-89 | May-90 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 745 | 1.3515 | 0.8109 | 4.0545 U | 4.0545 U | – | – | – | – | – | – | – | – |
| 831 | 4.5951 | – | 2.35161 | 2.9733 | 5.1357 | – | – | – | – | – | – | – |
| 832 | 3.2436 | 3.2436 | 1.18932 | 4.0545 U | 4.0545 U | – | – | – | – | – | – | – |
| 833 | 1.6218 | 6.2169 | 0.83793 | 0.2703 | 4.0545 U | – | – | – | – | – | – | – |
| 835 | 0.2703 | 3.2436 | 4.0545 U | 4.0545 U | 4.0545 U | – | – | – | – | – | – | – |
| 836 | 2.9733 | 0.8109 | 0.29733 | 3.2436 | 4.0545 U | – | – | – | – | – | – | – |
| 837 | – | – | 4.0545 U | 0.2703 | 4.0545 U | – | – | – | – | – | – | – |
| 838 | 4.0545 U | 0.2703 | 6.2169 | 4.0545 U | 4.0545 U | – | – | – | – | – | – | – |
| 839 | 4.0545 U | 4.0545 U | 0.02703 | 0.2703 | 4.0545 U | – | – | – | – | – | – | – |
| 840 | 5.1357 | 4.5951 | 3.5139 | 4.0545 U | 4.0545 U | – | – | – | – | – | – | – |
| 841 | 4.8654 | 4.8654 | 0.02703 | 1.3515 | 4.0545 U | – | – | – | – | – | – | 5U |
| 842 | 4.0545 | 4.0545 U | 0.24327 | 0.72981 | 4.0545 U | – | – | – | – | – | – | 5.98 |
| 843 | 1.0812 | 4.0545 U | 1.64883 | 2.64894 | 4.0545 U | – | – | – | – | – | – | – |
| 844 | 3.5139 | 6.7575 | 0.56763 | 4.0545 U | 4.0545 U | – | – | – | – | – | – | – |
| 845 | 4.0545 U | 0.2703 | 1.40556 | – | – | 5 U | – | – | 5 U | – | – | – |
| 846 | 2.9733 | 15.1368 | 0.13515 | 4.0545 U | – | – | – | – | – | – | – | – |
| 847 | 4.0545 U | 2.1624 | 1.94616 | 0.5406 | 4.0545 U | – | – | – | – | – | – | – |
| 848 | 51.357 | 11.3526 | 5.6763 | – | – | 30.2 | – | – | 40 | – | – | – |
| 849 | 2.703 | 2.4327 | 1.02714 | – | – | 5 U | 5 | U – | 5 U | – | – | – |
| 850 | 10.5417 | 3.2436 | 1.43259 | – | – | 5 U | – | – | 5 U | – | – | – |
| 851 | 4.3248 | 4.0545 U | 4.0545 U | – | – | 5 U | 5 | U – | 5 U | – | – | – |
| 852 | 2.703 | 4.0545 U | 0.59466 | – | – | 5 U | 5 | U – | 5 U | – | – | – |
| 853 | 3.5139 | 0.5406 | 4.0545 U | – | – | 5 U | 5 | U – | 5 U | – | – | – |
| 854 | 3.5139 | 0.5406 | 4.0545 U | – | – | 5 U | 5 | U – | 5 U | – | – | – |
| 855 | 2.51379 | 1.8921 | 0.40545 | 4.0545 U | 4.0545 U | – | – | – | – | – | – | 5U |
| 856 | 0.43248 | 3.2436 | 1.8921 | 4.0545 U | 4.0545 U | – | – | – | – | – | – | – |
| 857 | 3.7842 | 3.5139 U | 0.67575 | 0.18921 | 4.0545 U | – | – | – | – | – | – | – |
| 858 | 0.45951 | 10.5417 | 1.70289 | 1.6218 | 4.0545 U | – | – | – | – | – | – | – |
| 859 | – | – | 4.0545 U | 8.109 | 4.0545 U | – | – | – | – | – | – | – |
| 860 | 4.5951 | 1.3515 | 4.0545 U | 4.0545 U | 4.0545 U | – | – | – | – | – | – | – |
| 1225 | – | – | – | – | – | 1700 | 1900 | 3031 | – | 5400 | 4410 | – |
| 1227 | – | – | – | – | – | 5 U | 5 | U 5 | U – | – | – | – |
| 1228 | – | – | – | – | – | 5 U | 5 | U 5 | U 5 | U – | 5 | U 5U |
| 1229 | – | – | – | – | – | 5 U | 5 | U 5 | U 5 | U – | 5 | U 5U |
| 1231 | – | – | – | – | – | 5 U | 5 | U – | 5 | U – | 5 | U – |
| 1233 | – | – | – | – | – | 5 U | 5 | U 5 | U – | 5 | U 5 | U – |
| 1234 | – | – | – | – | – | – | – | – | – | – | – | – |
| 1234A | – | – | – | – | – | – | – | – | – | – | – | 5U |
| 1236 | – | – | – | – | – | – | – | – | – | – | – | 5U |
| 1237 | – | – | – | – | – | – | – | – | – | – | – | 8.3 |
| 1238 | – | – | – | – | – | – | – | – | – | – | – | 5U |
| 1239 | – | – | – | – | – | – | – | – | – | – | – | 5U |
| 1240 | – | – | – | – | – | – | – | – | – | – | – | 5U |
| 1241 | – | – | – | – | – | – | – | – | – | – | – | 5U |
| 1242 | – | – | – | – | – | – | – | – | – | – | – | 5U |
| 1243 | – | – | – | – | – | – | – | – | – | – | – | 5U |
| 1244 | – | – | – | – | – | – | – | – | – | – | – | 5U |

Table 5D.2 (continued)

Thorium-232 (pCi/L)

| Well | Apr-89 | May-89 | Jun-89 | Aug-89 | 5-Sep-89 | 27-Sep-89 | May-90 |
|---|---|---|---|---|---|---|---|
| 845 | 1 U | – | – | 1 U | – | – | – |
| 848 | 1 U | – | – | 1 U | – | – | – |
| 849 | – | 1 U | – | 1 U | – | – | – |
| 850 | 1 U | – | – | 1 U | – | – | – |
| 851 | 1 U | 1 U | – | – | – | – | – |
| 852 | 1 U | 1 U | – | 1 U | – | – | – |
| 853 | 1 U | 1 U | – | 1 U | – | – | – |
| 854 | 1 U | 1 U | – | 1 U | – | – | – |
| 1225 | – | 1 U | 2.26 | – | 3.01 | 1 U | – |
| 1227 | 1.8 | 1 U | 1 U | – | – | – | – |
| 1228 | 1 U | 1.5 | 2.04 | 1 | U – | 1 | U – |
| 1229 | 1 U | 1.2 | 1.55 | 1 | U – | 1 | U 5.42 |
| 1231 | 6 | 1 U | – | 1 U | – | 1 U | – |
| 1233 | 4.42 | 1 U | 2.39 | – | 2.2 | 1 U | – |
| 1234 | – | – | – | – | – | – | 1.5 |
| 1234A | – | – | – | – | – | – | 1 U |
| 1236 | – | – | – | – | – | – | 1.19 |
| 1237 | – | – | – | – | – | – | 1 U |
| 1238 | – | – | – | – | – | – | 1 U |
| 1239 | – | – | – | – | – | – | 6.47 |
| 1240 | – | – | – | – | – | – | 1.83 |
| 1241 | – | – | – | – | – | – | 9.13 |
| 1242 | – | – | – | – | – | – | 1 U |
| 1243 | – | – | – | – | – | – | 1 U |
| 1244 | – | – | – | – | – | – | 1 U |

Table 5 (continued)

Uranium-238 (pCi/L)

| Well | Apr-89 | May-89 | Jun-89 | Aug-89 | 5-Sep-89 | 27-Sep-89 | May-90 |
|---|---|---|---|---|---|---|---|
| 845 | 1 U | – | – | 1 U | – | – | – |
| 848 | 1 U | – | – | 1 U | – | – | – |
| 849 | – | 1 U | – | 1 U | – | – | – |
| 850 | 1 U | – | – | 1 U | – | – | – |
| 851 | 1 U | 1 U | – | – | – | – | – |
| 852 | 1 U | 1 U | – | 1 U | – | – | – |
| 853 | 1 U | 1 U | – | 1 U | – | – | – |
| 854 | 1 U | 1 U | – | 1 U | – | – | – |
| 1225 | 1 U | 1 U | 1 U | – | 1 U | 1 U | – |
| 1227 | 1 U | 1 U | 1 U | – | – | – | – |
| 1228 | 1 U | 1 | 1 U | 1 U | – | 1 U | – |
| 1229 | 1.16 | 1.2 | 1 | U 1 | U – | 1 | U 1.91 |
| 1231 | 1.97 | 1 U | – | 1 U | – | 1 U | – |
| 1233 | 1.38 | 1.1 | 1.13 | – | 1 | U 1 | U – |
| 1234A | – | – | – | – | – | – | 1 U |
| 1236 | – | – | – | – | – | – | 1 U |
| 1237 | – | – | – | – | – | – | 1.24 |
| 1238 | – | – | – | – | – | – | 1 U |
| 1239 | – | – | – | – | – | – | 5 |
| 1240 | – | – | – | – | – | – | 1 U |
| 1241 | – | – | – | – | – | – | 7.83 |
| 1242 | – | – | – | – | – | – | 1.58 |
| 1243 | – | – | – | – | – | – | 1 U |
| 1244 | – | – | – | – | – | – | 1 U |

**Table 5D.3. List of parameters**

| Parameter | Nominal value |
|---|---|
| H | 4.6 m |
| RPERC | 0.19 m/year |
| EPROV | 0.02 |
| EPORA | 0.02 |
| PORT | 0.5 |
| PORV | 0.1 |
| SSAT | 0.5 |
| BDENS | 1300 $kg/m^3$ |
| DISP | 5 m |
| AQTHK | 4.6 m |
| PORA | 0.1 |
| GWV | Varies |
| ADISP | 0.3 radians |

Table 5D.4. Physical parameters TAREA, DHORZ, DVERT, and GWV

| Areas | Well no. | TAREA $m^2$ | DHORZ m | DVERT m | GWV m/year |
|---|---|---|---|---|---|
| A | 1242 | 1481 | 53 | 3.0 | 75 |
| B | 842 | 717 | 58.6 | 3.0 | 75 |
| C | 1225 | 1292 | 35 | 0 | 20 |
| D | -- | 2084 | 50 | 3.0 | 10 |
| E | 847 | 1868 | 9 | 4.6 | 20 |
| F | 1241 | 2093 | 65 | 6.1 | 27 |
| G | 843 | 557 | 55 | 6.1 | 7 |
| H | -- | 1430 | 50 | 0 | 29 |
| I | -- | 757 | 50 | 1.5 | 29 |
| J | -- | 2424 | 50 | 0 | 90 |
| K | -- | 441 | 50 | 0 | 90 |
| L | 848 | 5377 | 44 | 0 | 57 |
| M | 849 | 5731 | 58 | 0 | 29 |
| N | 853 | 3047 | 56 | 0 | 62 |
| O | 854 | 2363 | 54 | 0 | 62 |
| P | 1243 | 1791 | 63 | 1.5 | 62 |
| Q | 840 | 1438 | 52 | 1.5 | 76 |
| R | -- | 1397 | 50 | 0 | 62 |
| S | 851 | 1315 | 34 | 0 | 44 |
| T | 852 | 1468 | 50 | 0 | 44 |
| U | 850 | 2784 | 48 | 0 | 34 |
| V | 838 | 1357 | 55 | 0 | 29 |
| W | -- | 3702 | 50 | 0 | 22 |
| X | 835 | 8417 | 57 | 0 | 18 |
| Y | 837 | 3580 | 58 | 3.0 | 56 |
| Z | -- | 688 | 50 | 3.5 | 56 |

**Table 5D.5. Radionuclide half-lives**

| Isotope | Half-life (years) |
|---|---|
| Co-60 | 5.3 |
| Cs-137 | 30.2 |
| Eu-152 | 13.6 |
| Eu-154 | 8.8 |
| H-3 | 12.3 |
| Sr-90 | 28.6 |
| Th-232 | 1.4e5 |
| U-233 | 1.6e5 |
| U-238 | 4.4e9 |

**Table 5D.6. Summary model results-cobalt-60**

| | | | | Inventory | | Breakthrough concentration | | Peak concentration | |
|---|---|---|---|---|---|---|---|---|---|
| Area | Well no. | $f_1$ | $f_3$ | Ci | Year | pCi/L | Year[a] | pCi/L | Year[b] |
| A | 1242 | 1.0E-5 | 1.0E-3 | 3357 | 1978 | 7.6 | | 17.6 | 2024 |
| B | 842 | 4.0E-4 | 7.0E-4 | 1305 | 1978 | 1030 | | | |
| C | 1225 | 1.5E-2 | 7.0E-4 | 15.2 | 1977 | 37.3 | | | |
| D | -- | 1.0E-3 | 1.0E-3 | 3521 | 1982 | 590 | | | |
| E | 867 | 1.0E-3 | 1.5E-3 | 16.2 | 1973 | 9.6 | | | |
| F | 1241 | 3.5E-3 | 3.0E-4 | 14.5 | 1974 | 7.4 | | | |
| G | 843 | 1.2E-2 | 1.0E-4 | 4.13 | 1975 | 105 | | | |
| H | -- | 3.0E-3 | 4.0E-4 | 82.2 | 1988 | 57.6 | 1998 | | |
| I | -- | 3.0E-2 | 4.0E-4 | 1.9 | 1988 | 8.6 | 1999 | | |
| J | -- | 3.0E-3 | 4.0E-4 | 250 | 1987 | 96.6 | 2024 | | |
| K | -- | 3.0E-3 | 4.0E-4 | 20.9 | 1981 | 7.56 | | | |
| L | 848 | 5.0E-3 | 5.0E-4 | 7.2 | 1982 | 2.0 | | | |
| M | 849 | 2.6E-4 | 5.0E-4 | 198 | 1975 | 2.7 | | | |
| N | 853 | 1.0E-4 | 5.0E-4 | 645 | 1978 | 3.3 | 2024 | 3.3 | 2024 |
| O | 854 | 1.0E-4 | 5.0E-4 | 391 | 1978 | 3.2 | | | |
| P | 1243 | 1.5E-3 | 2.0E-4 | 21064 | 1985 | 8210 | | | |
| Q | 840 | 3.6E-3 | 5.0E-4 | 377 | 1974 | 34.6 | | | |
| R | -- | 1.0E-3 | 4.0E-4 | 1001 | 1983 | 82 | | | |
| S | 851 | -- | -- | .005 | 1979 | -- | | | |
| T | 852 | -- | -- | .001 | 1978 | -- | | | |
| U | 850 | -- | -- | .004 | | -- | | | |
| V | 838 | 1.0E-3 | 4.0E-4 | 16.2 | 1979 | 1.7 | | | |
| W | -- | -- | -- | .17 | 1982 | -- | | | |
| X | 835 | 1.7E-3 | 2.0E-4 | 25.7 | 1979 | 3.4 | | | |
| Y | 837 | 1.0E-5 | 1.5E-4 | 6436 | 1985 | 8.8 | | 60 | 2024 |
| Z | -- | -- | -- | .855 | 1988 | -- | | | |

[a] Unless indicated breakthrough year is 1989.
[b] Unless indicated peak occurred at breakthrough year

**Table 5D.7. Summary model results—tritium**

| Area | Well no. | $f_1$ | Inventory Ci | Inventory Year | Breakthrough concentration pCi/L | Breakthrough concentration Year[a] | Peak concentration pCi/L | Peak concentration Year[a] |
|---|---|---|---|---|---|---|---|---|
| A | 1242 | 8.0E-3 | 92 | 1978 | 31600 | | | |
| B | 842 | 4.0E-2 | 32 | 1978 | 656000 | | | |
| C | 1225 | 1.0E-3 | 1071 | 1977 | 2.8E+6 | | | |
| D | -- | 3.0E-2 | 13.2 | 1982 | 1.04E+6 | | | |
| E | 867 | 1.5E-3 | 50.4 | 1973 | 114000 | | | |
| F | 1241 | 1.0E-3 | 45.5 | 1974 | 4700 | | 35000 | 2009 |
| G | 843 | 1.6E-2 | 13 | 1975 | 1.39E+6 | | | |
| H | -- | 3.0E-2 | 10 | 1988 | 84300 | | | |
| I | -- | 3.0E-2 | 4.9 | 1988 | 54200 | | | |
| J | -- | 3.0E-2 | 5 | 1987 | 116000 | | | |
| K | -- | 3.0E-2 | 0.35 | 1981 | 10000 | | | |
| L | 848 | 5.0E-3 | 2488 | 1982 | 7.0E+6 | | | |
| M | 849 | 1.0E-2 | 617 | 1975 | 3.4E+6 | | | |
| N | 853 | 2.0E-5 | 456 | 1978 | 4000 | | 154000 | 2011 |
| O | 854 | 2.0E-3 | 283 | 1978 | 292000 | | 228000 | 2026 |
| P | 1243 | 1.0E-3 | 2700 | 1985 | 1.8E+6 | | 1.05E+6 | 2020 |
| Q | 840 | 1.0E-2 | 6.2 | 1974 | 20000 | | 1.6E+6 | 2024 |
| R | -- | 3.0E-3 | 19 | 1983 | 49500 | | | |
| S | 851 | 3.0E-3 | 30 | 1979 | 58200 | | | |
| T | 852 | 3.0E-3 | 34.5 | 1978 | 97000 | | | |
| U | 850 | 1.0E-3 | 61.6 | 1980 | 63800 | | | |
| V | 838 | 3.0E-4 | 50.4 | 1979 | 17900 | | 52600 | 2014 |
| W | -- | 3.0E-2 | 3.5 | 1982 | 169000 | | | |
| X | 835 | 2.0E-4 | 177 | 1979 | 45000 | | | |
| Y | 837 | 1.0E-4 | 804 | 1985 | 26300 | | | |
| Z | -- | 3.0E-2 | 9.5 | 1988 | 477000 | | | |

[a]See Table 5D.6

**Table 5D.8. Summary model results—strontium-90**

| Area | Well no. | $f_1$ | $f_3$ | Inventory Ci | Inventory Year | Breakthrough concentration pCi/L | Breakthrough concentration Year[a] | Peak concentration pCi/L | Peak concentration Year[a] |
|---|---|---|---|---|---|---|---|---|---|
| A | 1242 | 5.0E-5 | 1.0E-03 | 416 | 1978 | 4.6 | | 718 | 2052 |
| B | 842 | 5.0E-5 | 7.0E-6 | 284 | 1978 | 4.3 | | 418 | 2052 |
| C | 1225 | 4.0E-2 | 7.0E-4 | 105 | 1977 | 5640 | | | |
| D | -- | 2.0E-3 | 1.0E-3 | 68 | 1982 | 41 | 2055 | 117 | 2116 |
| E | 867 | 1.0E-3 | 1.5E-3 | 3.2 | 1973 | 4.3 | | 17.2 | 2049 |
| F | 1241 | 1.5E-4 | 3.0E-4 | 93.3 | 1974 | 8.0 | | 268 | 2032 |
| G | 843 | 4.0E-5 | 1.0E-4 | 26.7 | 1975 | 4.5 | | 496 | 2053 |
| H | -- | 3.0E-3 | 4.0E-4 | 45 | 1988 | 163 | 1998 | 419 | 2058 |
| I | -- | 3.0E-2 | 4.-E-4 | 20.4 | 1988 | 561 | 2013 | | |
| J | -- | 3.0E-3 | 4.0E-4 | 43.7 | 1987 | 53.6 | 1990 | 130 | 2049 |
| K | -- | 3.0E-3 | 4.0E-4 | 6.8 | 1981 | 13.7 | | | |
| L | 848 | 4.5E-3 | 5.0E-4 | 38 | 1982 | 59 | | 75 | 2045 |
| M | 849 | 4.0E-4 | 5.0E-4 | 39 | 1975 | 7.3 | | 100 | 2051 |
| N | 853 | 1.0E-3 | 5.0E-4 | 25 | 1978 | 8.5 | | 46.2 | 2050 |
| O | 854 | 1.0E-3 | 5.0E-4 | 19.1 | 1978 | 8.6 | | 39.4 | 2050 |
| P | 1243 | 3.0E-4 | 2.0E-4 | 129 | 1985 | 12.0 | | 201 | 2048 |
| Q | 840 | 5.0E-4 | 5.0E-4 | 50 | 1974 | 9.3 | | 79.2 | 2051 |
| R | -- | 3.0E-3 | 4.0E-3 | 21 | 1983 | 22.8 | | | |
| S | 851 | -- | -- | .001 | 1979 | -- | | | |
| T | 852 | -- | -- | .005 | 1978 | -- | | | |
| U | 850 | -- | -- | .012 | 1980 | -- | | | |
| V | 838 | 2.5E-3 | 4.0E-4 | 3.2 | 1979 | 7.5 | | 15.8 | 2045 |
| W | -- | -- | -- | .02 | 1982 | -- | | | |
| X | 835 | 8.0E-4 | 2.0E-4 | 11 | 1979 | 6.2 | | 41 | 2049 |
| Y | 837 | 4.0E-4 | 1.5E-4 | 34 | 1985 | 4.6 | | 48.3 | 2049 |
| Z | -- | 3.0E-2 | 4.0E-3 | 10.5 | 1988 | 62 | 2049 | | |

[a]See Fig. 5D.6

**Table 5D.9. Summary model results—cesium-137**

| Area | Well no. | $f_1$ | $f_3$ | Inventory Ci | Inventory Year | Breakthrough concentration pCi/L | Breakthrough concentration Year[a] | Peak concentration pCi/L | Peak concentration Year[b] |
|---|---|---|---|---|---|---|---|---|---|
| A | 1242 | 7.0E-4 | 1.0E-3 | 1646 | 1978 | 12.2 | | | |
| B | 842 | 5.0E-4 | 7.0E-4 | 771 | 1978 | 12.4 | | 12.5 | 2045 |
| C | 1225 | 1.0E-1 | 7.0E-4 | 34.1 | 1977 | 23.7 | | | |
| D | -- | 2.0E-3 | 4.0E-3 | 53 | 1982 | 0.62 | 2126 | 1.4 | 2187 |
| E | 867 | 6.6E-2 | 1.5E-3 | 12.5 | 1973 | 5.2 | | | |
| F | 1241 | 1.5E-1 | 3.0E-4 | 47.1 | 1974 | 20 | | | |
| G | 843 | 1.0E-2 | 1.0E-6 | 13.5 | 1975 | 2.9 | | | |
| H | -- | 3.0E-3 | 4.0E-3 | 106 | 1988 | 0.7 | 2080 | 1.1 | 2140 |
| I | -- | 3.0E-2 | 4.0E-3 | 10.4 | 1988 | .03 | 2359 | | |
| J | -- | 3.0E-3 | 4.0E-3 | 702 | 1987 | 16.6 | 2016 | 7.5 | 2077 |
| K | -- | 3.0E-3 | 4.0E-3 | 18.8 | 1981 | .17 | 2010 | .36 | 2072 |
| L | 848 | 5.0E-2 | 5.0E-4 | 159 | 1982 | 11.5 | | | |
| M | 849 | 3.0E-2 | 5.0E-4 | 152 | 1975 | 11 | | | |
| N | 853 | 2.5E-1 | 5.0E-4 | 35 | 1978 | 12.7 | | | |
| O | 854 | 7.0E-2 | 5.0E-4 | 115 | 1978 | 13.3 | | | |
| P | 1243 | 3.5E-3 | 2.0E-4 | 5822 | 1985 | 37 | | 92 | 2051 |
| Q | 840 | 1.0E-3 | 5.0E-4 | 265 | 1974 | 3.4 | | | |
| R | -- | 3.0E-3 | 4.0E-3 | 41 | 1983 | .1 | 2025 | .24 | 2086 |
| S | 851 | -- | -- | .011 | 1979 | -- | | | |
| T | 852 | -- | -- | .001 | 1978 | -- | | | |
| U | 850 | -- | -- | .002 | 1980 | -- | | | |
| V | 838 | 9.0E-2 | 4.0E-4 | 12.5 | 1979 | 4.4 | | | |
| W | -- | -- | -- | .021 | 1982 | -- | | | |
| X | 835 | 2.7E-1 | 2.0E-4 | 16.6 | 1979 | 3.6 | | | |
| Y | 837 | 4.4E-2 | 1.5E-4 | 40.5 | 1985 | 2.8 | | | |
| Z | -- | 3.0E-2 | 4.0E-3 | 20.2 | 1988 | .12 | 2597 | | |

[a]See Table 5D.6.

**Table 5D.10. Summary model results—europium-152**

| | | | | Inventory | | Breakthrough concentration | | Peak concentration | |
|---|---|---|---|---|---|---|---|---|---|
| Area | Well no. | $f_1$ | $f_3$ | Ci | Year | pCi/L | Year | pCi/L | Year |
| A | 1242 | 3.0E-5 | 1.0E-3 | 4175 | 1978 | 7.7 | 1998 | 32.4 | 2033 |
| B | 842 | 3.0E-5 | 1.0E-3 | 16270 | 1978 | 15.8 | 2000 | 85.2 | 2036 |
| K | -- | 3.0E-3 | 4.0E-3 | 26801 | 1981 | .17 | 2010 | .36 | 2072 |
| P | 1243 | 3.0E-5 | 1.0E-3 | 250865 | 1985 | 163 | 2005 | 850 | 2040 |

**Table 5D.11. Summary model results—europium-154**

| Area | Well no. | $f_1$ | $f_3$ | Inventory Ci | Inventory Year | Breakthrough concentration pCi/L | Breakthrough concentration Year | Peak concentration pCi/L | Peak concentration Year |
|---|---|---|---|---|---|---|---|---|---|
| A | 1242 | 3.0E-5 | 1.0E-3 | 1558 | 1978 | 0.85 | 1998 | 2.2 | 2028 |
| B | 842 | 3.0E-5 | 1.0E-3 | 22300 | 1978 | 47.7 | 2000 | 85.4 | 2029 |
| K | -- | 3.0E-5 | 1.0E-3 | 48700 | 1981 | 48.8 | 1996 | 23.5 | 2021 |
| P | 1243 | 3.0E-5 | 1.0E-3 | 187368 | 1985 | 321 | 2005 | 584 | 2036 |

**Table 5D.12. Summary model results—uranium-233**

| | | | | Inventory | | Breakthrough concentration | | Peak concentration | |
|---|---|---|---|---|---|---|---|---|---|
| Area | Well no. | $f_1$ | $f_3$ | Ci | Year | pCi/L | 1989 | pCi/L | Year |
| C | 1225 | 3.0E-3 | 4.0E-3 | 4.8 | 1977 | 7.6 | 2131 | 201 | 2290 |
| D | - | 3.0E-3 | 4.0E-3 | 2.8 | 1982 | 2.5 | 2219 | 61.4 | 2378 |
| E | 847 | 3.0E-3 | 4.0E-3 | 4.6 | 1973 | 7.3 | 2038 | 149 | 2197 |
| F | 1241 | 3.0E-3 | 4.0E-3 | 4.1 | 1974 | 2.5 | 2217 | 60.6 | 2376 |
| G | 843 | 3.0E-3 | 4.0E-3 | 1.2 | 1975 | 4.1 | 2671 | 100 | 2830 |
| L | 848 | 3.0E-3 | 4.0E-3 | 100 | 1982 | 19.7 | 2025 | 524 | 2184 |
| M | 849 | 3.0E-3 | 4.0E-3 | 56 | 1975 | 27 | 2150 | 780 | 2309 |
| N | 853 | 3.0E-3 | 4.0E-3 | 25 | 1978 | 8.3 | 2057 | 221 | 2216 |
| V | 838 | 3.0E-3 | 4.0E-3 | 4.6 | 1979 | 2.24 | 2064 | 59 | 2223 |
| Y | 837 | 3.0E-3 | 4.0E-3 | 124.7 | 1985 | 28.9 | 2091 | 695 | 2250 |

**Table 5D.13. Summary model calibration results—uranium-238**

| | | | | Inventory | | Breakthrough concentration | | Peak concentration | |
|---|---|---|---|---|---|---|---|---|---|
| Area | Well no. | $f_1$ | $f_3$ | Ci | Year | pCi/L | Year | pCi/L | Year |
| E | 847 | 3.0E-3 | 4.0E-3 | 7.7 | 1973 | 19 | 2038 | 400 | 2197 |
| L | 848 | 3.0E-3 | 4.0E-3 | 1.72 | 1982 | 0.3 | 2025 | 8.7 | 2184 |
| N | 853 | 3.0E-3 | 4.0E-3 | 16.3 | 1978 | 4.9 | 2057 | 144 | 2216 |
| O | 854 | 3.0E-3 | 4.0E-3 | 1.12 | 1978 | 0.4 | 2055 | 8.2 | 2215 |
| V | 838 | 3.0E-3 | 4.0E-3 | 7.7 | 1979 | 3.5 | 2064 | 100 | 2223 |
| Y | 837 | 3.0E-3 | 4.0E-3 | 209 | 1985 | 84 | 2091 | 1240 | 2250 |

**Table 5D.14. Summary model results—thorium-232**

| | | | | Inventory | | Breakthrough concentration | | Peak concentration | |
|---|---|---|---|---|---|---|---|---|---|
| Area | Well no. | $f_1$ | $f_3$ | Ci | Year | pCi/L | Year | pCi/L | Year |
| M | 849 | 2.0E-4 | 4.0E-2 | 1.1 | 1975 | 0.4 | 1989 | 0.83 | 2148 |
| N | 853 | 3.0E-3 | 4.0E-3 | 16.2 | 1978 | 4.9 | 2057 | 144 | 2216 |
| O | 854 | 4.0E-2 | 1.0E-3 | 1.0 | 1978 | 0.0 | - | 0.0 | - |
| P | 1243 | 3.0E-3 | 4.0E-2 | 6000 | 1985 | 57.8 | 2948 | 1080 | 3107 |

**Table 5D.15. Predicted radionuclide inventories (Ci) in source areas**

**Area A**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | Eu-152 | Eu-154 |
|---|---|---|---|---|---|---|
| 2020 | 16.6 | 6.8 | 168 | 768 | 581 | 65.6 |
| 2120 | -- | -- | 14.6 | 76.2 | 3.2 | -- |
| Year of depletion | 2042 | 2044 | >2138 | >2138 | >2138 | 2074 |

**Area B**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | Eu-152 | Eu-154 |
|---|---|---|---|---|---|---|
| 2020 | 6.44 | 2.0 | 128 | 343 | 1960 | 894 |
| 2120 | -- | -- | 11.1 | 34.1 | 10.8 | 0.3 |
| Year of depletion | 2035 | 2030 | >2138 | >2138 | >2138 | 2106 |

**Area C**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 |
|---|---|---|---|---|---|
| 2020 | -- | 35.9 | 46.1 | 14.4 | 5.56 |
| 2120 | -- | -- | 4.04 | 1.43 | 5.53 |
| Year of depletion | 1999 | 2042 | 2137 | 2136 | >2137 |

**Area D**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 |
|---|---|---|---|---|---|
| 2020 | 29.4 | 1.04 | 32.8 | 26.0 | 3.28 |
| 2120 | -- | -- | 2.8 | 2.6 | 3.27 |
| Year of depletion | 2046 | 2021 | >2142 | >2142 | >2142 |

**Area E**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 | U-238 |
|---|---|---|---|---|---|---|
| 2020 | -- | 1.0 | 1.24 | 4.76 | 5.54 | 9.59 |
| 2120 | -- | -- | -- | 0.5 | 5.52 | 9.59 |

Table 5D.15. (continued)

| | | | | | | |
|---|---|---|---|---|---|---|
| Year of depletion | 1996 | 2021 | 2029 | 2088 | >2133 | >2133 |

Area F

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 |
|---|---|---|---|---|---|
| 2020 | -- | .5 | 39 | 18.2 | 4.79 |
| 2120 | -- | -- | 3.4 | 1.8 | 4.77 |
| Year of depletion | 1996 | 2017 | >2134 | >2134 | >2134 |

Area G

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 |
|---|---|---|---|---|---|
| 2020 | -- | 0.65 | 11 | 5.4 | 1.37 |
| 2120 | -- | -- | 0.95 | 0.5 | 1.36 |
| Year of depletion | 1988 | 2015 | 2118 | 2093 | >2135 |

Area H

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | 1.25 | 1.29 | 23.6 | 57.8 |
| 2120 | -- | -- | 2.0 | 5.7 |
| Year of depletion | 2022 | 2024 | >2148 | >2148 |

Area I

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | -- | 0.6 | 11.5 | 5.66 |
| 2120 | -- | -- | 1.00 | 0.56 |
| Year of depletion | 1994 | 2013 | 2121 | 2096 |

Area J

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|

**Table 5D.15. (continued)**

| | | | | |
|---|---|---|---|---|
| 2020 | 3.33 | 0.68 | 22.4 | 375 |
| 2120 | -- | -- | 1.97 | 37.2 |
| Year of depletion | 2030 | 2014 | >2147 | >2147 |

**Area K**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | Eu-152 | Eu-154 |
|---|---|---|---|---|---|---|
| 2020 | .14 | -- | 3.0 | 8.7 | 4100 | 2860 |
| 2120 | -- | -- | 0.26 | 0.87 | 22.6 | 1.08 |
| Year of depletion | 2005 | -- | 2066 | 2114 | >2141 | 2122 |

**Area L**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-238 | U-238 |
|---|---|---|---|---|---|---|
| 2020 | -- | 249 | 25.7 | 16.2 | 11.7 | 2.18 |
| 2120 | -- | -- | -- | 1.36 | 11.6 | 2.18 |
| Year of depletion | 1998 | 2087 | 2056 | 2133 | >2142 | >2142 |

**Area M**

| Year | Co-60 | H-3 | Sr-90 | C-137 | U-233 | U-238 |
|---|---|---|---|---|---|---|
| 2020 | 0.63 | 25.7 | 16.2 | 61.4 | 71.1 | 103 |
| 2120 | -- | -- | 1.36 | 6.1 | 70.8 | 103 |
| Year of depletion | 2017 | 2056 | 2133 | 2135 | >2135 | >2135 |

**Area N**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 | U-238 |
|---|---|---|---|---|---|---|
| 2020 | 3.05 | 3.93 | 11.2 | 15.3 | 29.0 | 20.7 |
| 2120 | -- | -- | 0.95 | 1.5 | 28.9 | 20.7 |
| Year of depletion | 2029 | 2024 | 2118 | 2138 | >2138 | >2138 |

Table 5D.15. (continued)

Area O

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 | Th-232 |
|---|---|---|---|---|---|---|
| 2020 | 1.85 | 22.1 | 8.55 | 49.7 | 1.41 | 1.01 |
| 2120-- | -- | -- | 0.71 | 4.93 | 1.41 | 1.01 |
| Year of depletion | 2025 | 2055 | 2107 | 2138 | >2138 | >2138 |

Area P

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | Eu-152 | Eu-154 |
|---|---|---|---|---|---|---|
| 2020 | 261 | 283 | 67.3 | 2930 | 47700 | 15000 |
| 2120 | -- | -- | 5.88 | 290 | 263 | 5.66 |
| Year of depletion | 2063 | 2047 | >2145 | >2145 | >2145 | 2143 |

Area Q

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | 1.1 | 0.26 | 20 | 104 |
| 2120 | -- | -- | 1.75 | 10.3 |
| Year of depletion | 2021 | 2004 | >2137 | >2137 |

Area R

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | 9.1 | 2.4 | 10.7 | 20.1 |
| 2120 | -- | -- | 0.94 | 2.0 |
| Year of depletion | 2037 | 2033 | 2118 | >2143 |

Area S

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|

**Table 5D.15. (continued)**

| | | | | |
|---|---|---|---|---|
| 2020 | -- | 0.37 | -- | -- |
| 2120 | -- | -- | -- | -- |
| Year of depletion | -- | 2017 | -- | -- |

**Area T**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | -- | 2.1 | -- | -- |
| 2120 | -- | -- | -- | -- |
| Year of depletion | -- | 2035 | -- | -- |

**Area U**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 | U-238 |
|---|---|---|---|---|---|---|
| 2020 | -- | 4.1 | -- | -- | 5.31 | 9.79 |
| 2120 | -- | -- | -- | -- | 5.29 | 9.79 |
| Year of depletion | -- | 2032 | -- | -- | >2139 | >2139 |

**Area V**

| Year | Co-60 | H-3 | Sr-90 | CS-137 |
|---|---|---|---|---|
| 2020 | -- | 2.0 | 1.44 | 5.5 |
| 2120 | -- | -- | -- | 0.5 |
| Year of depletion | 2002 | 2024 | 2035 | 2094 |

**Area W**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | -- | 0.3 | -- | -- |
| 2120 | -- | -- | -- | -- |
| Year of depletion | -- | 2004 | -- | -- |

Table 5D.15. (continued)

**Area X**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | 0.14 | 3.7 | 5.05 | 1.65 |
| 2120 | -- | -- | 0.4 | -- |
| Year of depletion | 2005 | 2025 | 2086 | 2046 |

**Area Y**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 | U-233 | U-238 |
|---|---|---|---|---|---|---|
| 2020 | 80.5 | 61.3 | 18.3 | 20.4 | 14.6 | 2.55 |
| 2120 | -- | -- | 1.54 | 2.0 | 14.6 | 255 |
| Year of depletion | 2054 | 2035 | 2138 | >2145 | >2145 | >2145 |

**Area Z**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | -- | 1.28 | 5.86 | 10.9 |
| 2120 | - | -- | 0.5 | 1.08 |
| Year of depletion | -- | 2024 | 2093 | 2173 |

**Tumulus I**

| Year | Co-60 | H-3 | Sr-90 | Cs-137 |
|---|---|---|---|---|
| 2020 | 157 | .44 | 5.63 | 7.01 |
| 2120 | -- | -- | 0.049 | 0.7 |
| Year of depletion | 2006 | 2006 | 2092 | 2105 |

**Table 5D.16. Cobalt-60 concentrations in surface water (pCi/L)**

| Distance upstream (m)[a] | Time Period Year 1990-2019 | 1990-2059 | 2100-2129 |
|---|---|---|---|
| **Drainage DA** | | | |
| 209 | 4.21 | 2.37 | 0.00 |
| 140 | 3.55 | 1.98 | 0.00 |
| 110 | 2.29 | 1.28 | 0.00 |
| 98 | 1.45 | 0.81 | 0.00 |
| 17 | 1.25 | 0.70 | 0.00 |
| 0 | 1.29 | 0.72 | 0.00 |
| French Drain outlet | 0.66 | 0.42 | 0.00 |
| **Drainage DB** | | | |
| 261 | 67.03 | 146.78 | 0.04 |
| 180 | 46.99 | 101.79 | 0.03 |
| 123 | 35.76 | 70.91 | 0.02 |
| 110 | 31.38 | 62.12 | 0.02 |
| 0 | 23.18 | 45.50 | 0.01 |
| **Drainage FA** | | | |
| 184 | 34.83 | 26.22 | 0.00 |
| 87 | 12.93 | 9.74 | 0.00 |
| 67 | 9.36 | 7.01 | 0.00 |
| 17 | 4.69 | 3.51 | 0.00 |
| **Drainage FB** | | | |
| 512 | 8.23 | 3.98 | 0.07 |
| 461 | 23.51 | 10.99 | 0.05 |
| 397 | 17.87 | 8.32 | 0.04 |
| 343 | 9.94 | 4.63 | 0.02 |
| 196 | 11.93 | 7.03 | 0.01 |
| 95 | 10.67 | 6.28 | 0.01 |
| 17 | 11.83 | 10.97 | 0.01 |
| **Emergency Waste Basin** | | | |
| | 0.23 | 0.11 | 0.00 |

[a]Measured from the WAG 6 boundary

**Table 5D.17. Cesium-137 concentration in surface water (pCi/L)**

| Distance upstream (m)[a] | Time Period Year 1990-2019 | 1990-2059 | 2100-2129 |
|---|---|---|---|
| **Drainage DA** | | | |
| 209 | 42.96 | 32.05 | 6.00 |
| 140 | 35.99 | 26.83 | 5.00 |
| 110 | 24.27 | 18.10 | 3.38 |
| 98 | 15.93 | 11.88 | 2.22 |
| 17 | 13.81 | 10.29 | 1.92 |
| 0 | 12.73 | 9.44 | 1.72 |
| French Drain outlet | 9.55 | 7.26 | 1.50 |
| **Drainage DB** | | | |
| 261 | 16.44 | 51.85 | 44.63 |
| 180 | 25.46 | 46.21 | 32.71 |
| 123 | 17.26 | 31.37 | 22.22 |
| 110 | 15.21 | 27.53 | 19.46 |
| 0 | 12.27 | 20.91 | 14.31 |
| **Drainage FA** | | | |
| 184 | 222.29 | 155.49 | 20.66 |
| 87 | 82.55 | 57.74 | 7.67 |
| 67 | 60.05 | 41.79 | 5.49 |
| 17 | 30.11 | 20.95 | 2.75 |
| **Drainage FB** | | | |
| 512 | 32.97 | 25.54 | 5.44 |
| 461 | 27.33 | 24.51 | 8.52 |
| 397 | 21.38 | 18.96 | 6.44 |
| 343 | 11.90 | 10.55 | 3.58 |
| 196 | 23.58 | 17.78 | 3.62 |
| 95 | 21.08 | 15.89 | 3.24 |
| 17 | 19.45 | 14.62 | 2.93 |
| **Emergency Waste Basin** | 3.40 | 2.32 | 0.26 |

[a]Measured From the WAG 6 Boundary

**Table 5D.18. Europium-152 concentration in surface water (pCi/L)**

| Distance upstream (m)[a] | Time Period Year 1990-2019 | 1990-2059 | 2100-2129 |
|---|---|---|---|
| **Drainage DA** | | | |
| 209 | 0.00 | 0.00 | 0.00 |
| 140 | 0.00 | 0.00 | 0.00 |
| 110 | 0.00 | 0.00 | 0.00 |
| 98 | 0.00 | 0.00 | 0.00 |
| 17 | 0.00 | 0.00 | 0.00 |
| 0 | 0.00 | 0.00 | 0.00 |
| French Drain outlet | 0.00 | 0.00 | 0.00 |
| **Drainage DB** | | | |
| 261 | 31.39 | 42.37 | 3.09 |
| 180 | 21.70 | 29.29 | 2.14 |
| 123 | 14.63 | 19.74 | 1.44 |
| 110 | 12.81 | 17.29 | 1.26 |
| 0 | 9.35 | 12.62 | 0.92 |
| **Drainage FA** | | | |
| 184 | 0.00 | 0.00 | 0.00 |
| 87 | 0.00 | 0.00 | 0.00 |
| 67 | 0.00 | 0.00 | 0.00 |
| 17 | 0.00 | 0.00 | 0.00 |
| **Drainage FB** | | | |
| 512 | 0.00 | 0.00 | 0.00 |
| 461 | 0.00 | 0.00 | 0.00 |
| 397 | 0.00 | 0.00 | 0.00 |
| 343 | 0.00 | 0.00 | 0.00 |
| 196 | 0.00 | 0.00 | 0.00 |
| 95 | 0.00 | 0.00 | 0.00 |
| 17 | 0.00 | 0.00 | 0.00 |
| **Emergency Waste Basin** | | | |
| | 0.00 | 0.00 | 0.00 |

[a]Measured from the WAG 6 boundary

**Table 5D.19 Europium-152 concentration in surface water (pCi/L)**

| Distance upstream (m)[a] | Time Period Year 1990-2019 | 1990-2059 | 2100-2129 |
|---|---|---|---|
| **Drainage DA** | | | |
| 209 | 0.00 | 0.00 | 0.00 |
| 140 | 0.00 | 0.00 | 0.00 |
| 110 | 0.00 | 0.00 | 0.00 |
| 98 | 0.00 | 0.00 | 0.00 |
| 17 | 0.00 | 0.00 | 0.00 |
| 0 | 0.00 | 0.00 | 0.00 |
| French Drain outlet | 0.00 | 0.00 | 0.00 |
| **Drainage DB** | | | |
| 261 | 17.39 | 24.22 | 0.29 |
| 180 | 12.02 | 16.75 | 0.20 |
| 123 | 8.10 | 11.29 | 0.13 |
| 110 | 7.09 | 9.88 | 0.12 |
| 0 | 5.18 | 7.22 | 0.09 |
| **Drainage FA** | | | |
| 184 | 0.00 | 0.00 | 0.00 |
| 87 | 0.00 | 0.00 | 0.00 |
| 67 | 0.00 | 0.00 | 0.00 |
| 17 | 0.00 | 0.00 | 0.00 |
| **Drainage FB** | | | |
| 512 | 0.00 | 0.00 | 0.00 |
| 461 | 0.00 | 0.00 | 0.00 |
| 397 | 0.00 | 0.00 | 0.00 |
| 343 | 0.00 | 0.00 | 0.00 |
| 196 | 0.00 | 0.00 | 0.00 |
| 95 | 0.00 | 0.00 | 0.00 |
| 17 | 0.00 | 0.00 | 0.00 |
| **Emergency Waste Basin** | 0.00 | 0.00 | 0.00 |

[a]Measured from the WAG 6 boundary

**Table 5D.20. Tritium concentration in surface water (pCi/L)**

| Distance upstream (m)[a] | Time Period Year 1990-2019 | 1990-2059 | 2100-2129 |
|---|---|---|---|
| **Drainage DA** | | | |
| 209 | 456,080 | 259,748 | 228 |
| 140 | 421,554 | 240,522 | 206 |
| 110 | 328,190 | 187,252 | 160 |
| 98 | 241,952 | 138,048 | 118 |
| 17 | 216,492 | 123,522 | 106 |
| 0 | 194,531 | 110,923 | 93 |
| French Drain outlet | 2,669,856 | 1,531,075 | 1,378 |
| **Drainage DB** | | | |
| 261 | 731,451 | 699,760 | 2 |
| 180 | 809,609 | 659,545 | 170 |
| 123 | 548,035 | 446,332 | 119 |
| 110 | 489,081 | 396,451 | 104 |
| 0 | 363,693 | 293,111 | 77 |
| **Drainage FA** | | | |
| 184 | 192,805 | 119,013 | 57 |
| 87 | 71,603 | 44,199 | 21 |
| 67 | 56,440 | 34,740 | 19 |
| 17 | 28,295 | 17,416 | 10 |
| **Drainage FB** | | | |
| 512 | 796,833 | 405,032 | 3 |
| 461 | 583,725 | 296,755 | 5 |
| 397 | 416,667 | 211,806 | 4 |
| 343 | 231,832 | 117,848 | 2 |
| 196 | 254,589 | 125,395 | 5 |
| 95 | 227,605 | 112,104 | 4 |
| 17 | 215,221 | 109,530 | 4 |
| Emergency Waste Basin | 15,158 | 7,020 | 0 |

[a]Measured from the WAG 6 boundary

**Table 5D.21. Strontium-90 concentrations in surface water (pCi/L)**

| Distance upstream (m)[a] | Time Period Year 1990-2019 | 1990-2059 | 2100-2129 |
|---|---|---|---|
| **Drainage DA** | | | |
| 209 | 107.22 | 198.12 | 109.28 |
| 140 | 89.85 | 165.37 | 91.06 |
| 110 | 60.60 | 111.54 | 61.42 |
| 98 | 39.77 | 73.20 | 40.30 |
| 17 | 34.46 | 63.44 | 34.93 |
| 0 | 30.61 | 56.54 | 31.19 |
| French Drain outlet | 29.49 | 57.09 | 33.79 |
| **Drainage DB** | | | |
| 261 | 20.60 | 114.57 | 98.26 |
| 180 | 47.17 | 130.34 | 95.56 |
| 123 | 34.66 | 93.42 | 67.97 |
| 110 | 30.62 | 81.97 | 59.53 |
| 0 | 23.88 | 62.88 | 45.20 |
| **Drainage FA** | | | |
| 184 | 214.90 | 534.60 | 314.25 |
| 87 | 79.81 | 198.54 | 116.70 |
| 67 | 60.33 | 143.78 | 83.48 |
| 17 | 30.25 | 72.08 | 41.85 |
| **Drainage FB** | | | |
| 512 | 264.00 | 479.14 | 270.13 |
| 461 | 234.11 | 432.23 | 258.40 |
| 397 | 181.32 | 333.65 | 201.60 |
| 343 | 100.88 | 185.64 | 112.17 |
| 196 | 92.44 | 189.51 | 113.44 |
| 95 | 82.64 | 169.42 | 101.42 |
| 17 | 73.95 | 156.43 | 95.33 |
| **Emergency Waste Basin** | 43.12 | 106.28 | 60.48 |

[a]Measured from the WAG 6 boundary

Table 5D.22. Thorium-232 concentrations in surface water (pCi/L)

| Distance upstream (m)[a] | Time Period Year 1990-2019 | 1990-2059 | 2100-2129 |
|---|---|---|---|
| **Drainage DA** | | | |
| 209 | 0.19 | 0.23 | 0.37 |
| 140 | 0.16 | 0.19 | 0.30 |
| 110 | 0.10 | 0.13 | 0.21 |
| 98 | 0.07 | 0.08 | 0.13 |
| 17 | 0.06 | 0.07 | 0.12 |
| 0 | 0.05 | 0.06 | 0.10 |
| French Drain outlet | 0.09 | 0.10 | 0.16 |
| **Drainage DB** | | | |
| 261 | 11.08 | 104.60 | 523.61 |
| 180 | 7.66 | 72.32 | 362.04 |
| 123 | 5.16 | 48.74 | 244.00 |
| 110 | 4.52 | 42.68 | 213.65 |
| 0 | 3.30 | 31.16 | 155.96 |
| **Drainage FA** | | | |
| 184 | 2.57 | 2.29 | 1.22 |
| 87 | 0.95 | 0.85 | 0.45 |
| 67 | 0.68 | 0.61 | 0.32 |
| 17 | 0.34 | 0.30 | 0.16 |
| **Drainage FB** | | | |
| 512 | 0.00 | 0.00 | 0.00 |
| 461 | 0.00 | 0.00 | 0.00 |
| 397 | 0.00 | 0.00 | 0.00 |
| 343 | 0.00 | 0.00 | 0.00 |
| 196 | 0.31 | 0.28 | 0.15 |
| 95 | 0.28 | 0.25 | 0.14 |
| 17 | 0.24 | 0.22 | 0.12 |
| **Emergency Waste Basin** | 0.00 | 0.00 | 0.00 |

[a]Measured from the WAG 6 boundary

Table 5D.23. Uranium-233 concentrations in surface water (pCi/L)

| Distance upstream (m)[a] | Time Period Year 1990-2019 | 1990-2059 | 2100-2129 |
|---|---|---|---|
| **Drainage DA** | | | |
| 209 | 5.96 | 27.33 | 118.04 |
| 140 | 4.97 | 22.77 | 98.33 |
| 110 | 3.35 | 15.36 | 66.32 |
| 98 | 2.20 | 10.08 | 43.52 |
| 17 | 1.91 | 8.73 | 37.72 |
| 0 | 1.70 | 7.74 | 33.31 |
| French Drain outlet | 3.53 | 16.09 | 153.62 |
| **Drainage DB** | | | |
| 261 | 0.00 | 0.00 | 0.00 |
| 180 | 2.11 | 10.24 | 44.10 |
| 123 | 1.42 | 6.90 | 29.72 |
| 110 | 1.24 | 6.05 | 26.02 |
| 0 | 1.00 | 4.78 | 20.45 |
| **Drainage FA** | | | |
| 184 | 0.00 | 0.00 | 0.00 |
| 87 | 0.00 | 0.00 | 0.00 |
| 67 | 0.00 | 0.00 | 0.00 |
| 17 | 0.00 | 0.00 | 0.00 |
| **Drainage FB** | | | |
| 512 | 0.78 | 2.88 | 10.69 |
| 461 | 0.57 | 2.09 | 7.77 |
| 397 | 0.40 | 1.49 | 5.52 |
| 343 | 0.23 | 0.83 | 3.07 |
| 196 | 0.89 | 3.26 | 11.98 |
| 95 | 0.79 | 2.91 | 10.71 |
| 17 | 0.84 | 3.23 | 12.47 |
| Emergency Waste Basin | 0.19 | 0.61 | 2.09 |

[a]Measured from the WAG 6 boundary

**Table 5D.24. Uranium-238 concentrations in surface water (pCi/L)**

| Distance upstream (m)[a] | Time Period Year 1990-2019 | 1990-2059 | 2100-2129 |
|---|---|---|---|
| **Drainage DA** | | | |
| 209 | 10.28 | 45.58 | 190.75 |
| 140 | 8.56 | 41.30 | 158.91 |
| 110 | 5.78 | 27.86 | 107.18 |
| 98 | 3.79 | 18.28 | 70.33 |
| 17 | 3.29 | 15.84 | 60.96 |
| 0 | 2.79 | 13.48 | 51.85 |
| French Drain outlet | 3.87 | 26.68 | 115.08 |
| **Drainage DB** | | | |
| 261 | 0.00 | 0.00 | 0.00 |
| 180 | 0.08 | 0.38 | 1.60 |
| 123 | 0.06 | 0.25 | 1.08 |
| 110 | 0.05 | 0.22 | 0.94 |
| 0 | 0.37 | 1.49 | 5.89 |
| **Drainage FA** | | | |
| 184 | 2.86 | 10.53 | 39.46 |
| 87 | 1.06 | 3.91 | 14.66 |
| 67 | 0.76 | 2.80 | 10.48 |
| 17 | 0.38 | 1.40 | 5.25 |
| **Drainage FB** | | | |
| 512 | 0.27 | 0.86 | 2.91 |
| 461 | 0.20 | 0.62 | 2.11 |
| 397 | 0.14 | 0.44 | 1.50 |
| 343 | 0.08 | 0.25 | 0.83 |
| 196 | 3.95 | 18.66 | 71.59 |
| 95 | 3.53 | 16.68 | 64.00 |
| 17 | 3.26 | 15.63 | 60.85 |
| **Emergency Waste Basin** | 0.07 | 0.23 | 0.84 |

[a]Measured from the WAG 6 boundary

Table 5D.25. Sensitivity analysis for cobalt-60

| Output parameter (year) | Input parameter | Nominal value | Ratio of % change in output to % change in input | Sensitivity[a] |
|---|---|---|---|---|
| GW Conc (1)[b] | DHORZ | 53m | -0.37 | Medium |
| GW Conc (1) | ATREN | 3357 Ci | 1 | High |
| GW Conc (1) | IYRC | 11 years | -0.96 | High |
| GW Conc (1) | GWV | 21.5m/year | -1.22 | High |
| GW Conc (1) | GWV | 46 m/year | -1.27 | High |
| GW Conc (1) | GWV | 60.4 m/year | -0.776 | Medium |
| GW Conc (1) | XKDH | .00055 $m^3$/kg | -0.24 | Medium |
| GW Conc (1) | EPORA | .014 | -0.81 | High |
| GW Conc (1) | EPORA | .03 | -0.96 | High |
| GW Conc (1) | FFIN | 0.1 | 0 | - |
| GW Conc (31) | FFIN | 0.1 | .985 | High |
| GW Conc (1) | RPERC | 0.19 m/year | 1 | High |
| GW Conc (1) | RPERC | 0.399 m/year | 1.07 | High |
| GW Conc (1) | FINT | .000026 | 1 | High |
| GW Conc (1) | AQTHK | 4.6m | -0.85 | High |
| GW Conc (1) | ADISP | 0.3 | -0.28 | Medium |
| GW Conc (1) | TAREA | 1481 $m^2$ | -0.36 | Medium |
| GW Conc (1) | XKDT | .782 $m^3$/kg | 1.001 | High |
| Inventory (31) | RPERC | .19 | 0 | Low |
| Inventory (31) | FINT | .000026 | 0 | Low |

[a]Criteria for low, medium, and high sensitivity based on ratio of percent change of parameters: low (0-.1), medium (.1-.8) and high (> .8)
[b] GW Conc (1) = groundwater concentration, year 1

**Table 5D.26. Sensitivity analysis for tritium**

| Output parameter (year) | Input parameter | Nominal value | Ratio of % change in output to % change in input | Sensitivity[a] |
|---|---|---|---|---|
| GW Conc (1)[b] | DHORZ | 53 m | -0.35 | Medium |
| GW Conc (1) | ATREN | 91.6 Ci | 1.00 | High |
| GW Conc (1) | IYRC | 11 years | -0.5 | Medium |
| GW Conc (1) | GWV | 25.7 m/year | -1.07 | High |
| GW Conc (1) | GWV | 46 m/year | -1.025 | High |
| GW Conc (1) | EPORA | .0129 | -1.59 | High |
| GW Conc (1) | EPORA | .03 | -1.4 | High |
| GW Conc (1) | EPORA | .0497 | -.917 | High |
| GW Conc (31) | FFIN | .1 | 0.088 | Low |
| GW Conc (1) | RPERC | .19 m/year | 0.955 | High |
| GW Conc (1) | FINT | .021 | 1.0 | High |
| GW Conc (1) | AQTHK | 4.6 | -0.97 | High |
| GW Conc (1) | ADISP | 0.3 | -0.28 | Medium |
| GW Conc (1) | TAREA | 1481 | -0.356 | Medium |
| Inventory (31) | RPERC | 0.19 | -0.1 | Low |
| Inventory (31) | FINT | 0.021 | -0.105 | Low |

[a]Criteria for low, medium, and high sensitivity based on ratio of percent change of parameters: low (0-.1), medium (.1-.8) and high (> .8)

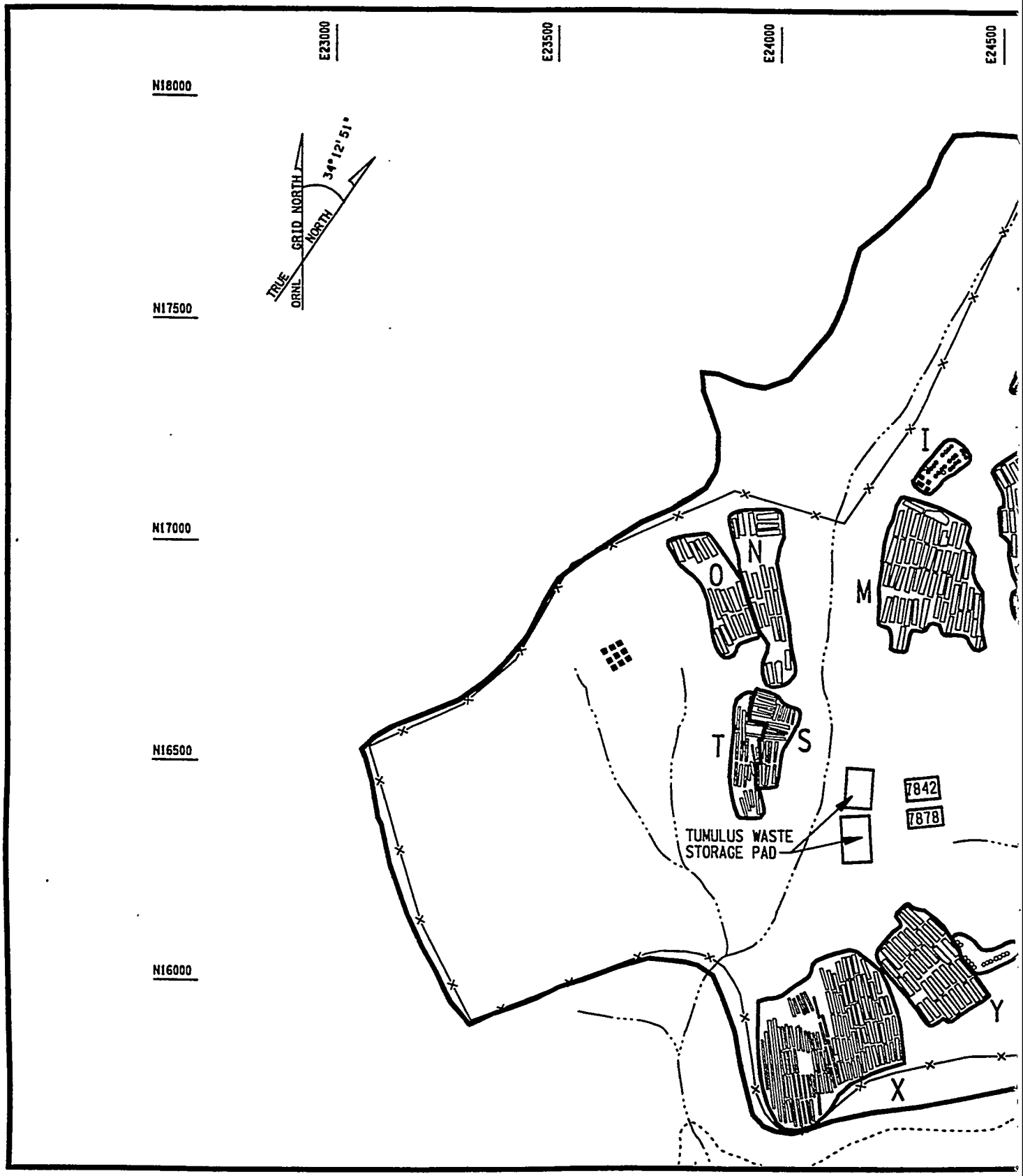
[b] GW Conc (1) = groundwater concentration, year 1

**Table 5D.27. Parameter range and uncertainty**

| Parameter | Nominal value | Distribution | Range | Uncertainty |
|---|---|---|---|---|
| TAREA | Varies | Normal | Cov[a] = 0.1 | Low |
| H | 4.6 m | Normal | Cov = 0.2 | Low |
| FINT | Varies | Normal | Cov = 1.0 | High |
| FFIN | 0.1 | Normal | Cov = 0.5 | High |
| ATREN | Varies | Normal | Cov = 0.5 | High |
| DECAY | Varies | --- | --- | Low |
| XKDV | Varies | Normal | Cov = 1.0 | High |
| XKDH | Varies | Normal | Cov = 1.0 | High |
| XKDT | Varies | Normal | Cov = 0.5 | High |
| RPERC | 0.19 m/yr | Normal | Cov = 1.0 | High |
| DVERT | Varies | Normal | Cov = 0.2 | Medium |
| DHORZ | Varies | Normal | Cov = 0.1 - 1.0 | Low |
| EPORV | 0.02 | Uniform | .004-.04 | High |
| EPORA | 0.02 | Uniform | .004-.04 | High |
| PORT | 0.5 | Normal | Cov = 0.5 | Low |
| PORV | 0.1 | Normal | Cov = 0.5 | Low |
| SSAT | 0.5 | Normal | Cov = 0.5 | Medium |
| BDENS | 1300 kg/m$^3$ | Normal | Cov = 0.25 | Low |
| DISP | 5m | Normal | Cov = 0.2 | Medium |
| AQTHK | 4.6m | Uniform | 4.6-6.4 | High |
| PORA | 0.1 | Normal | Cov = 0.5 | Medium |
| GWV | Varies | Normal | Cov = 0.5 | Medium |
| ADISP | 0.3 radians | Normal | Cov = 0.2 | Medium |
| IYRC | Varies | Normal | Cov = 0.2-0.5 | Low |
| WTRI | Varies | Normal | Cov = 0.5 | Medium |

[a]COV: coefficient of variation

# Appendix 5D Figures




WAG6 06F270.DGN 5D.1

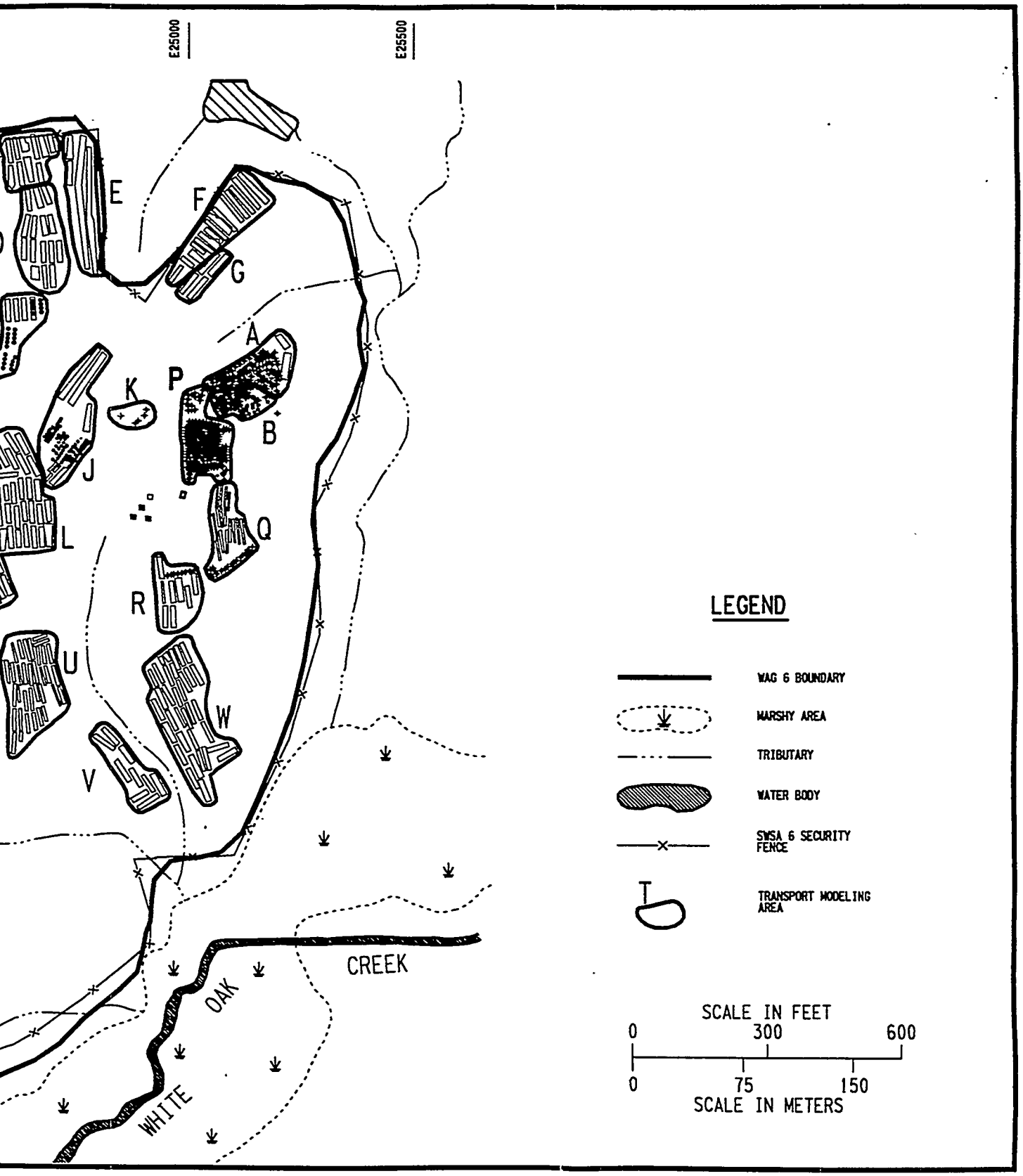



**Fig. 5D.1. WAG 6 transport modeling areas.**

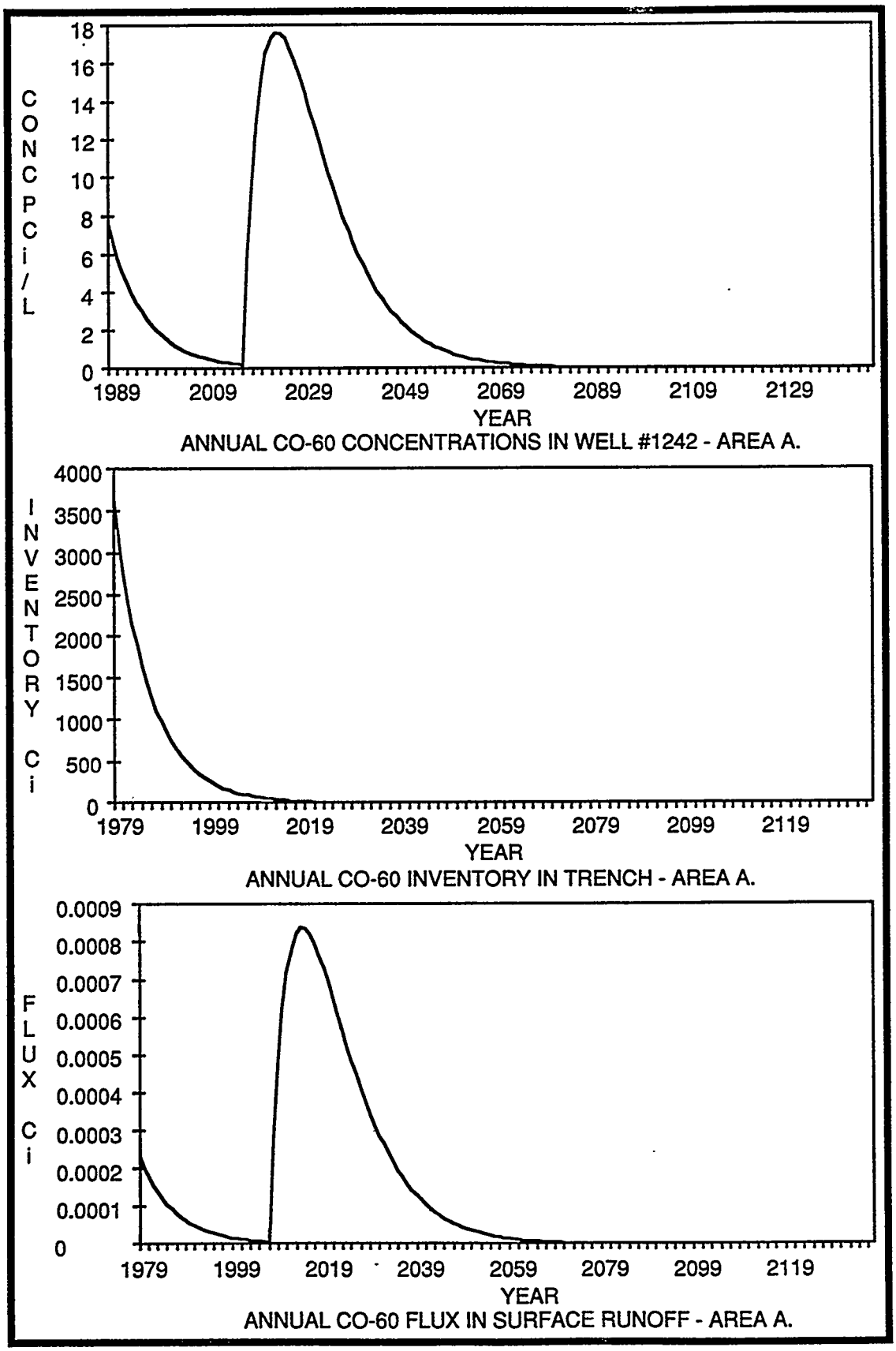



**Fig. 5D.2. Modeling output for cobalt-60, Area A.**

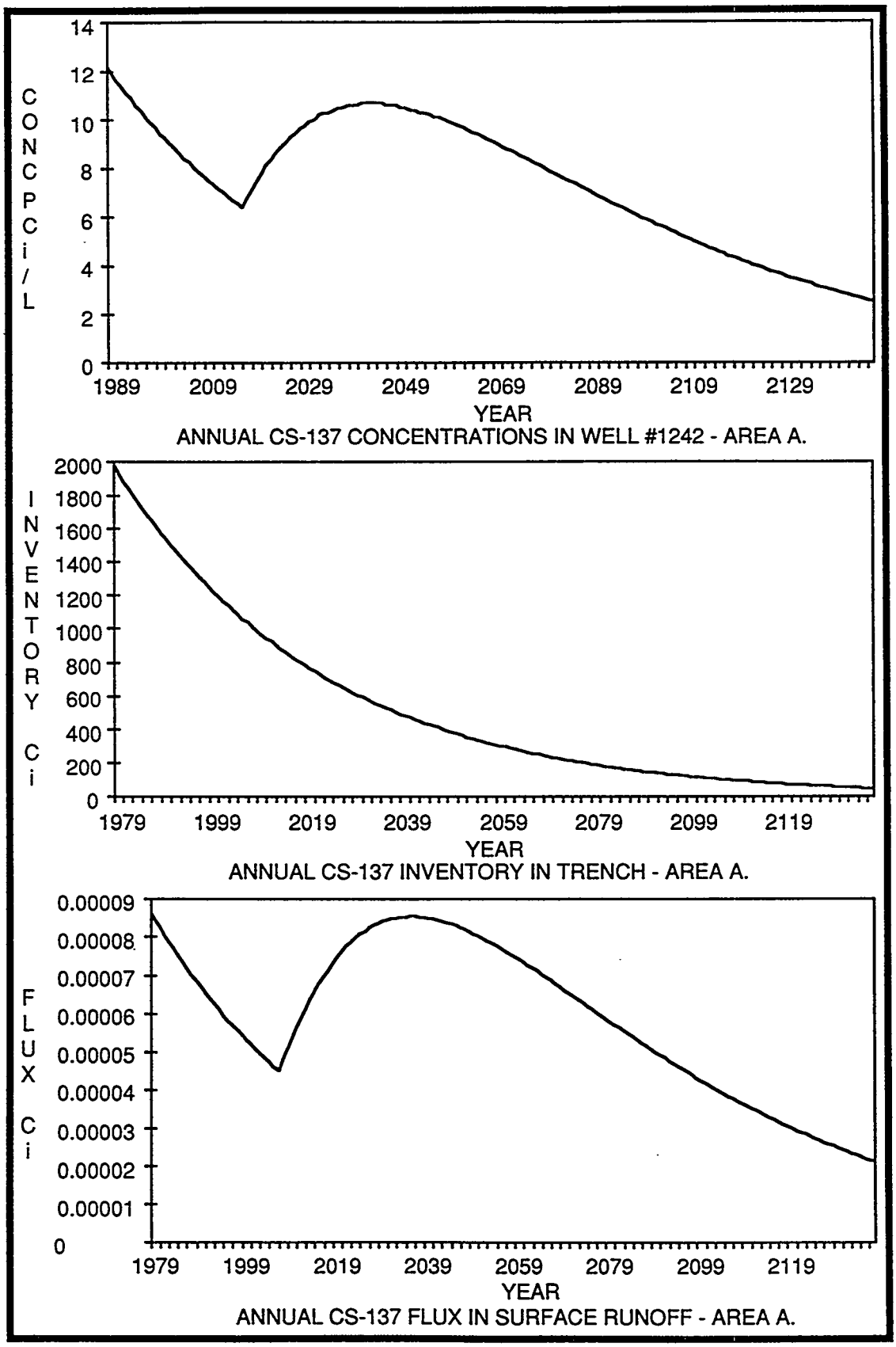



**Fig. 5D.3. Modeling output for cesium-137, Area A.**

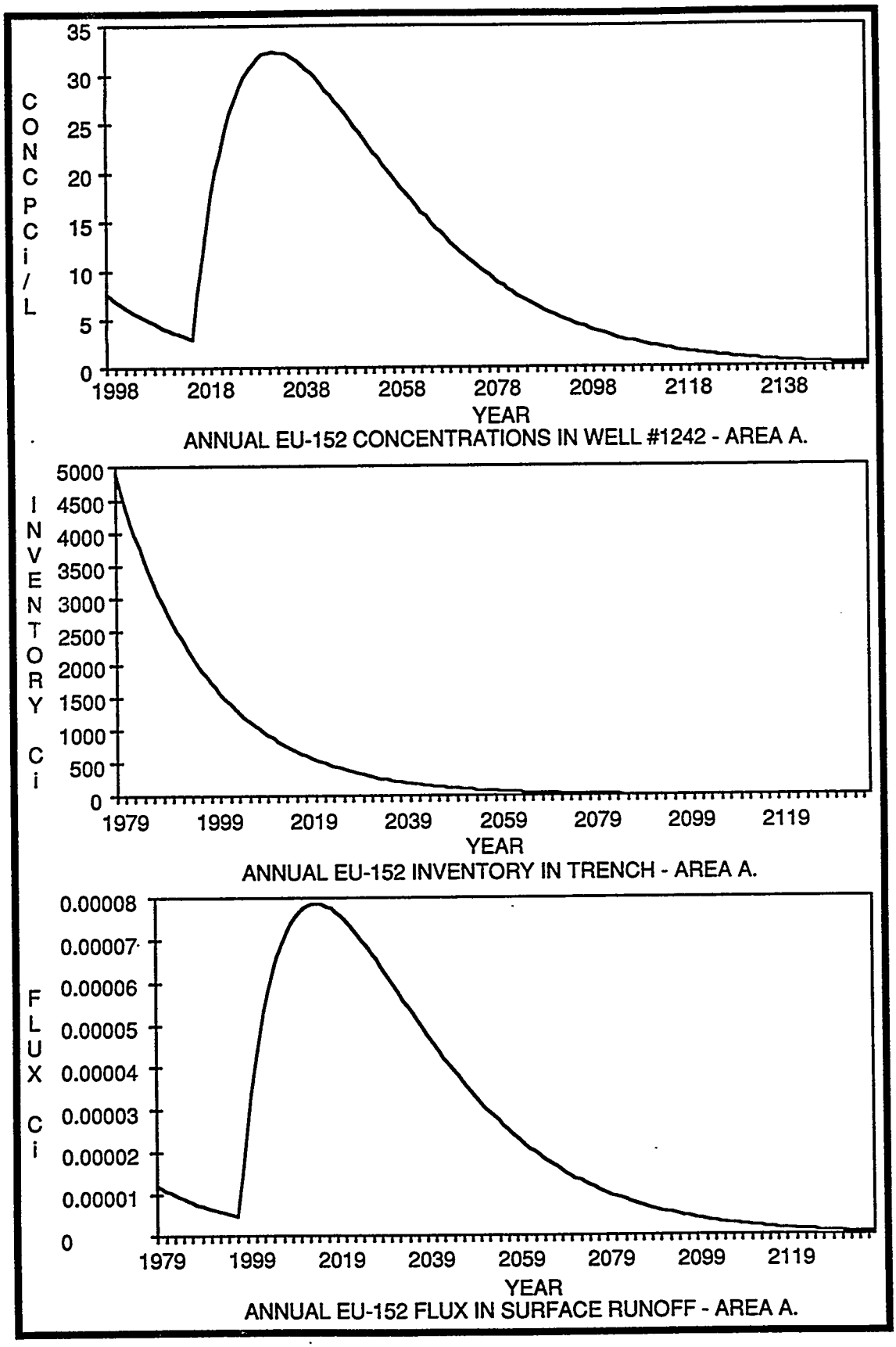



**Fig. 5D.4. Modeling output for europium-152, Area A.**

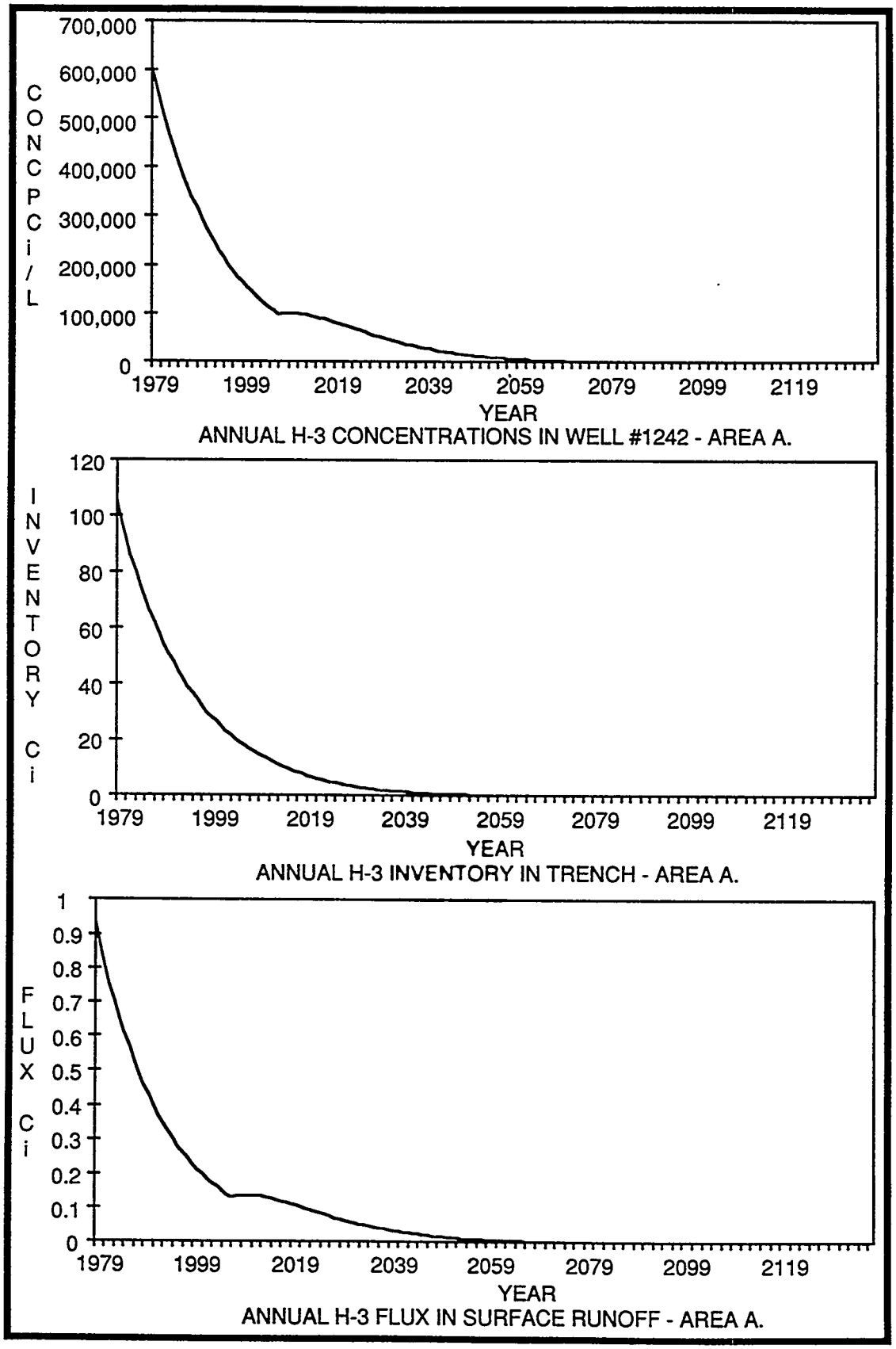



**Fig. 5D.5. Modeling output for tritium, Area A.**

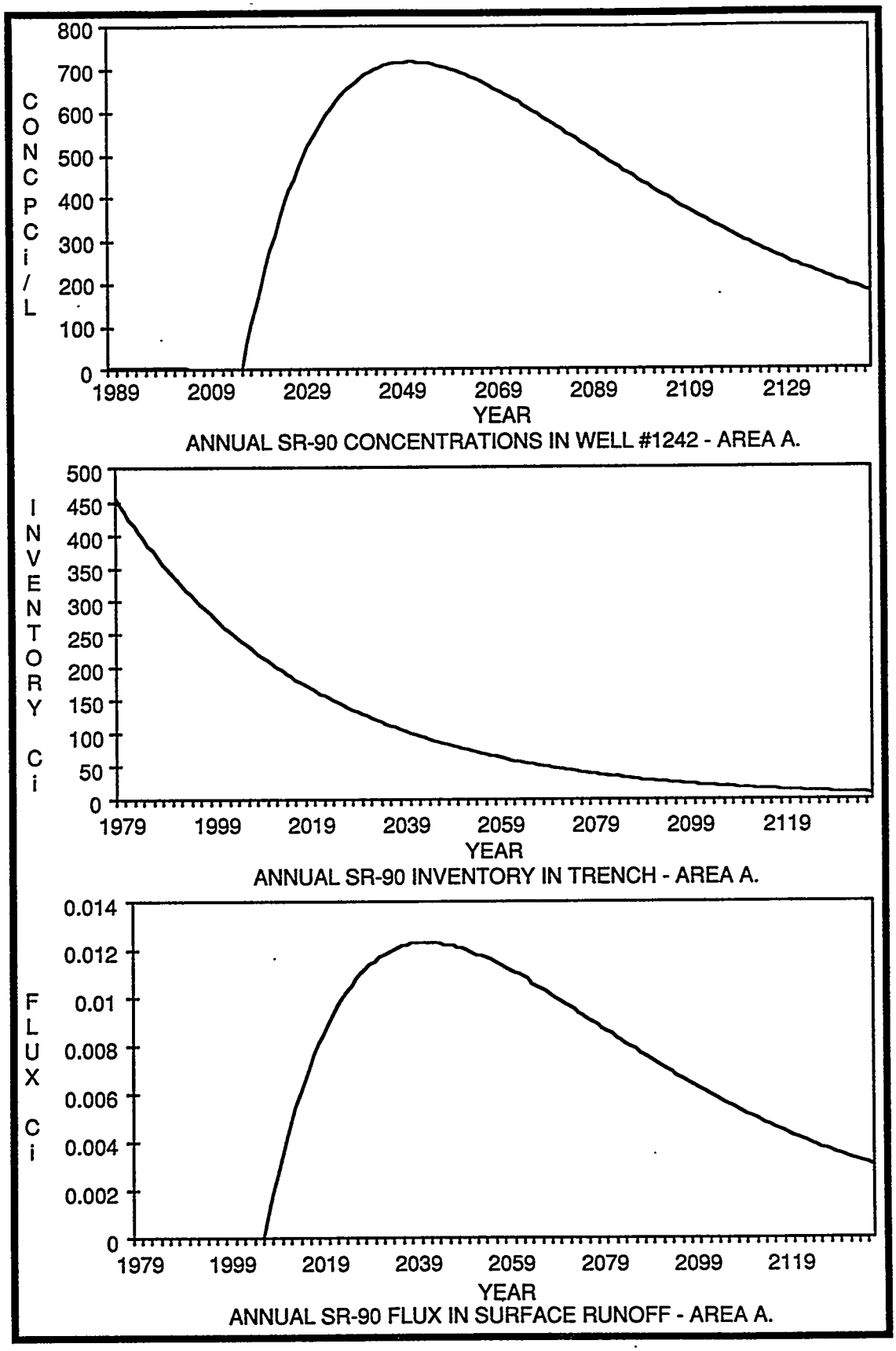



**Fig. 5D.6. Modeling output for strontium-90, Area A.**

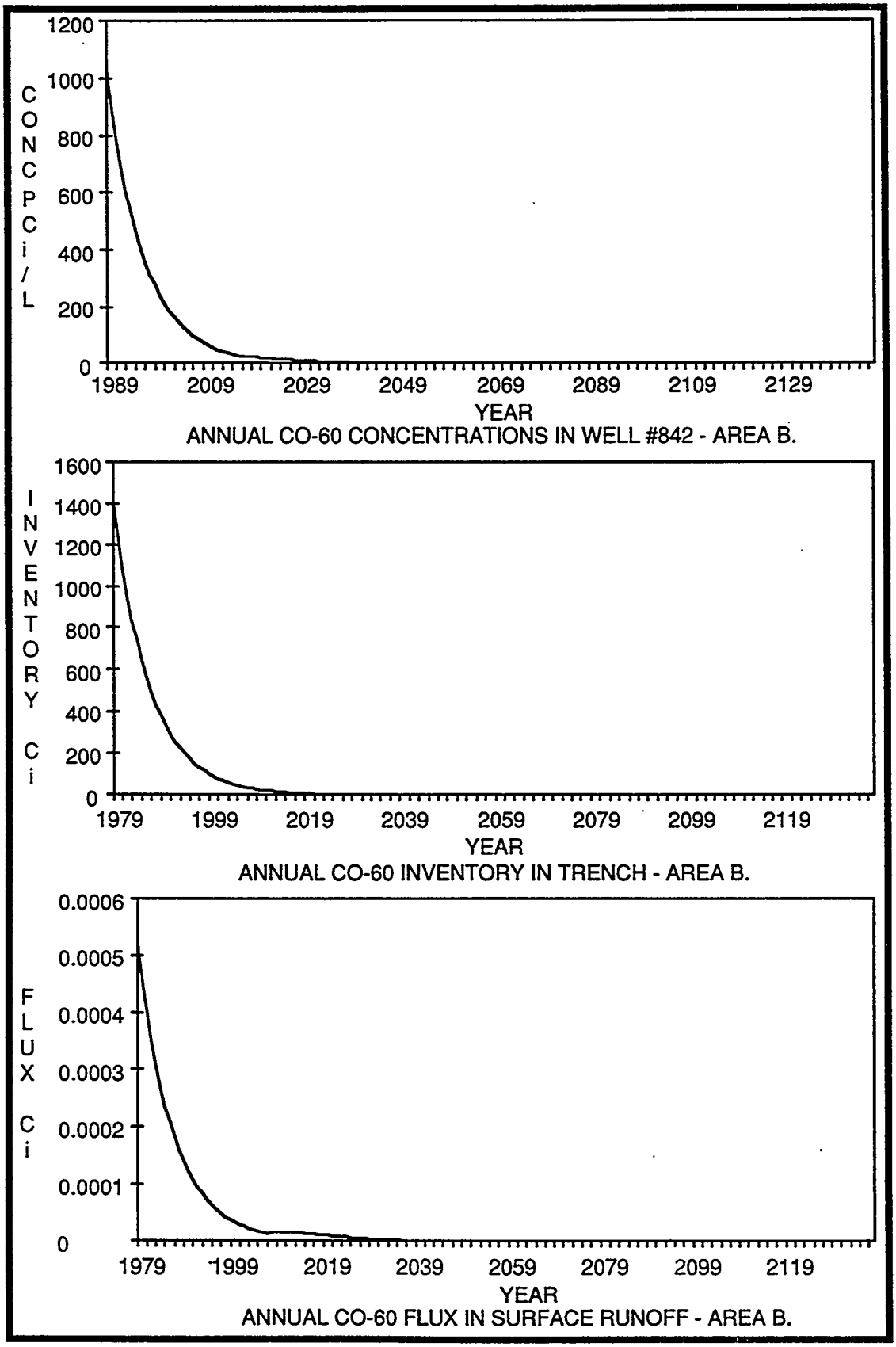



**Fig. 5D.7. Modeling output for cobalt-60, Area B.**

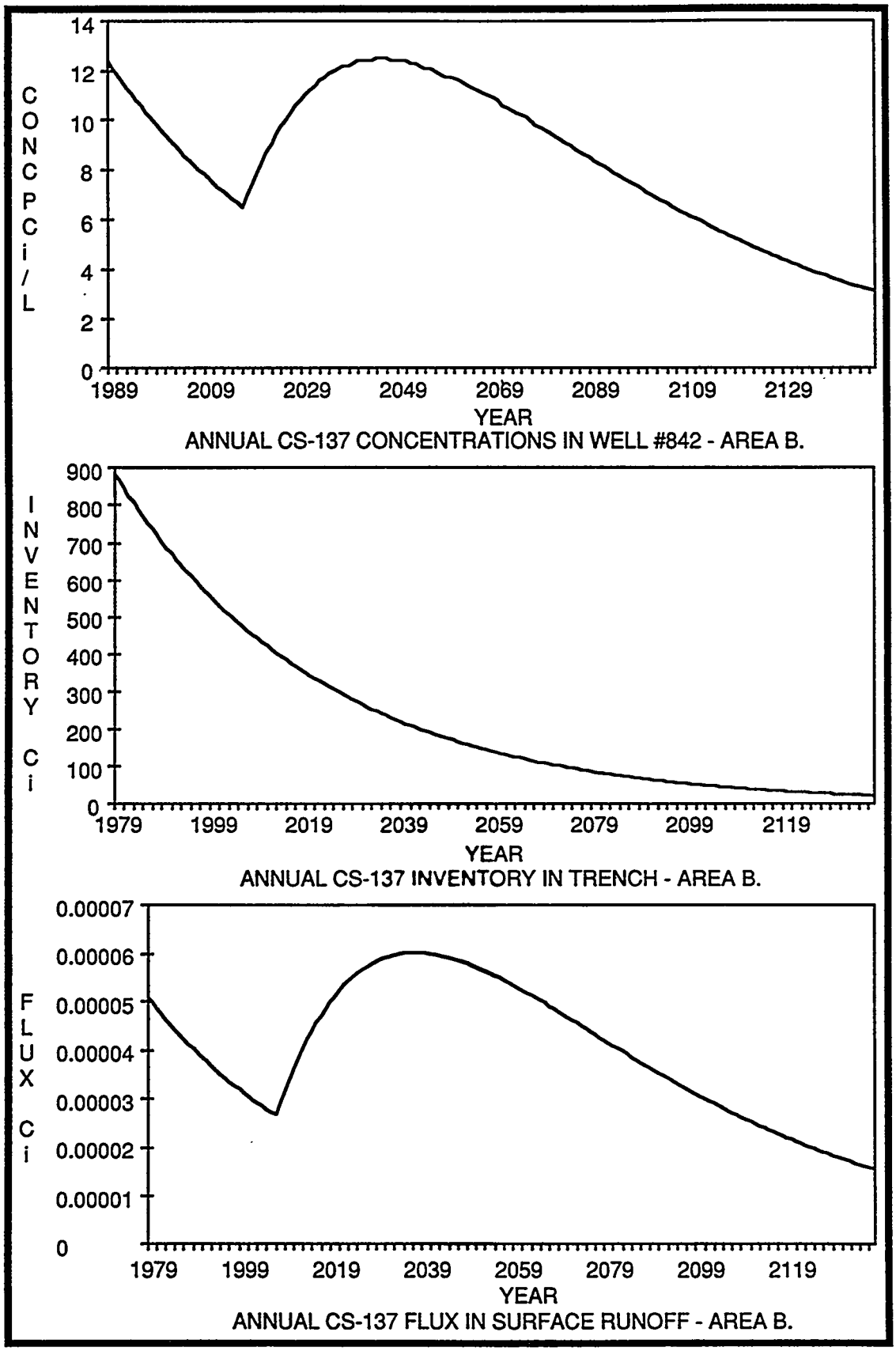



**Fig. 5D.8. Modeling output for cesium-137, Area B.**

5.18A 4104.43

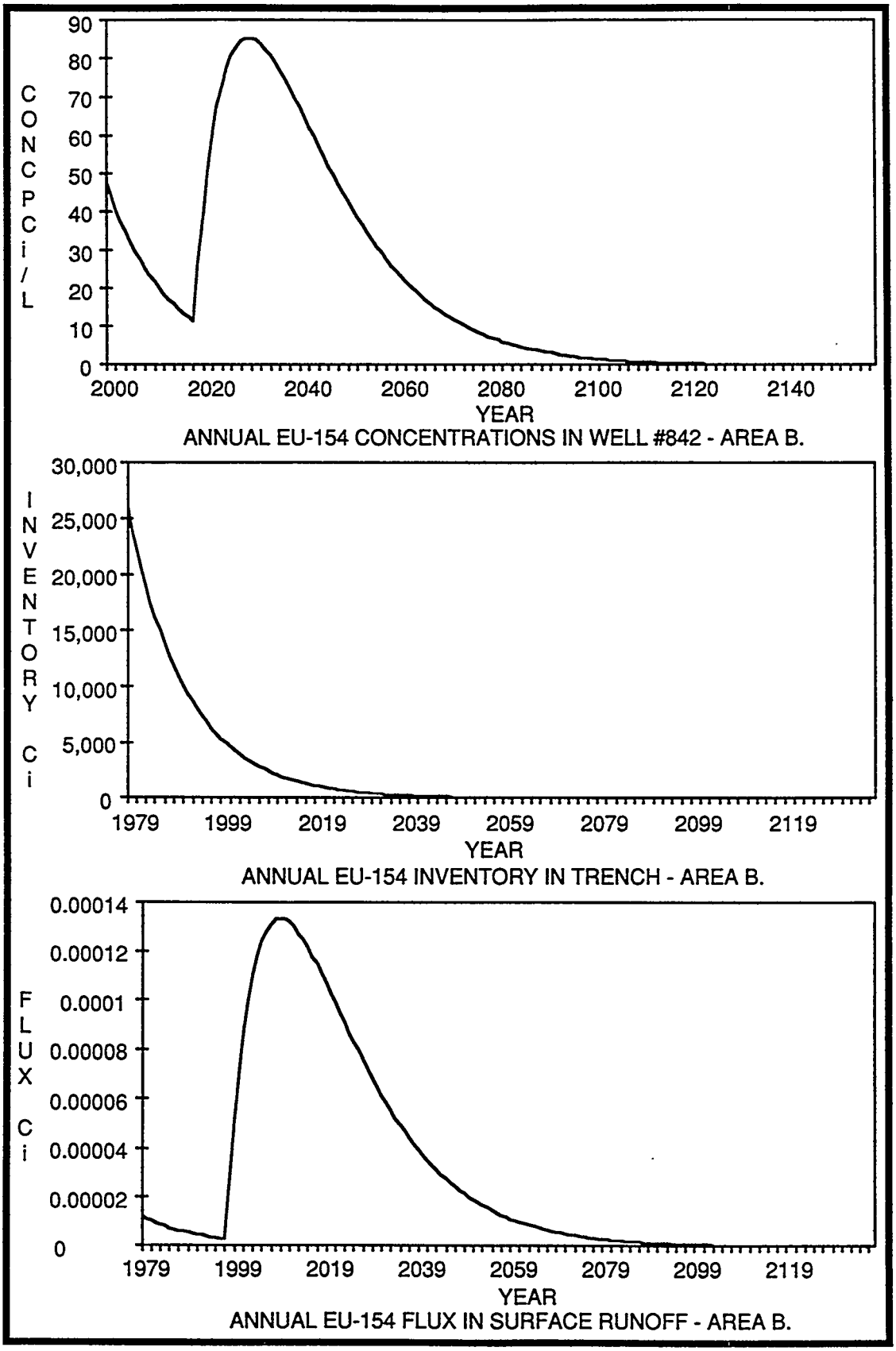



**Fig. 5D.9. Modeling output for europium-154, Area B.**

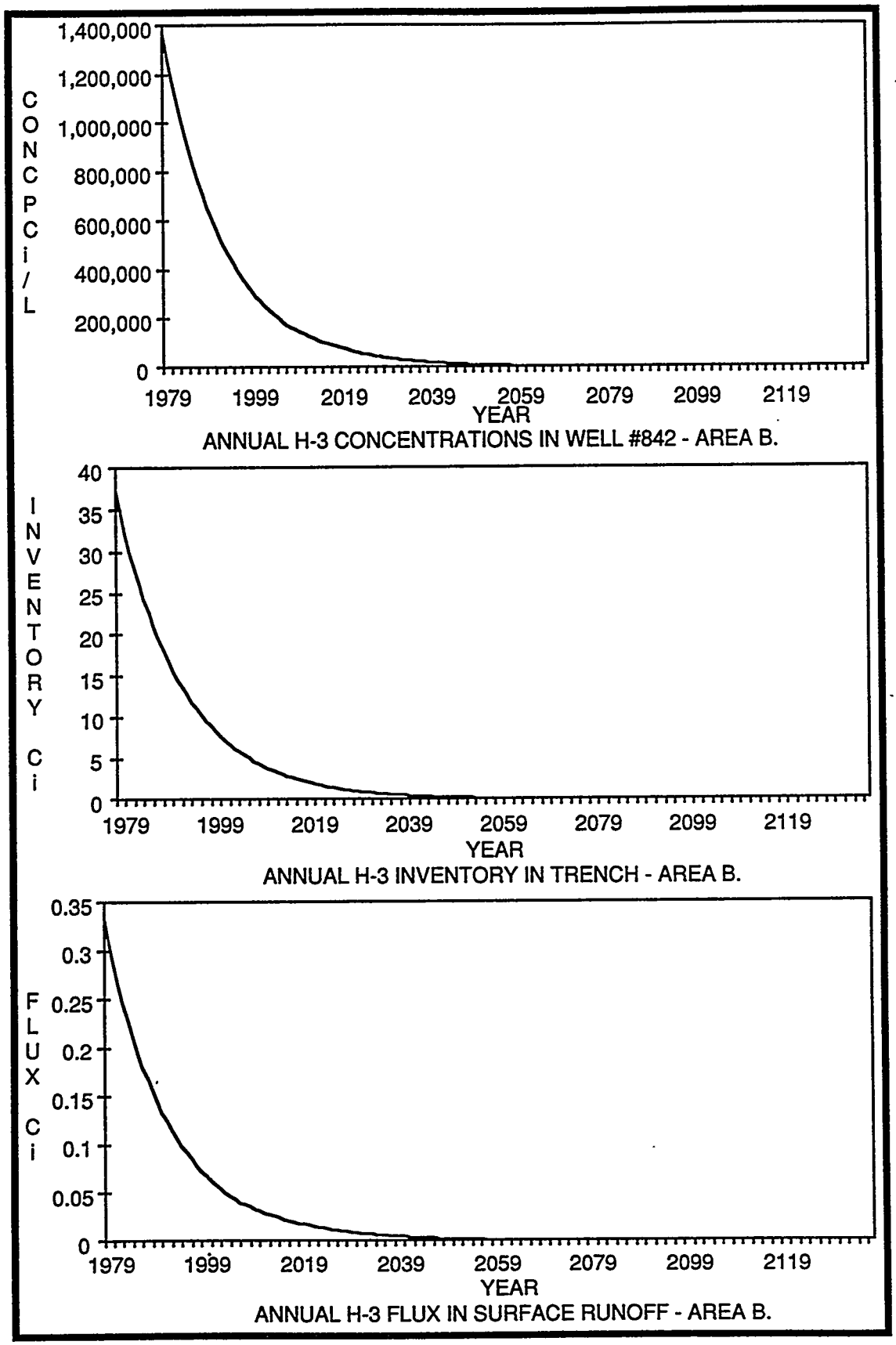



**Fig. 5D.10. Modeling output for tritium, Area B.**

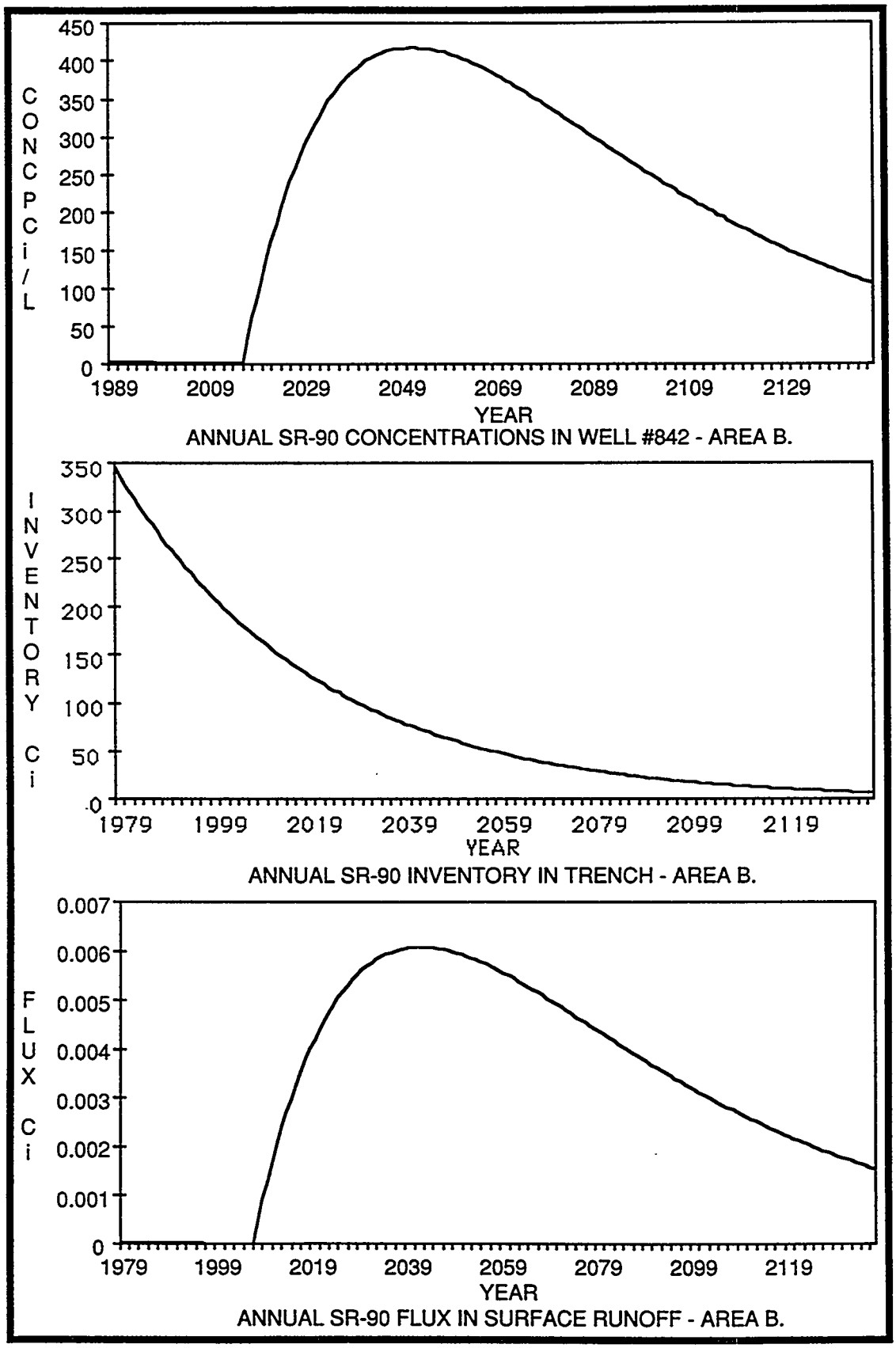



**Fig. 5D.11. Modeling output for strontium-90, Area B.**

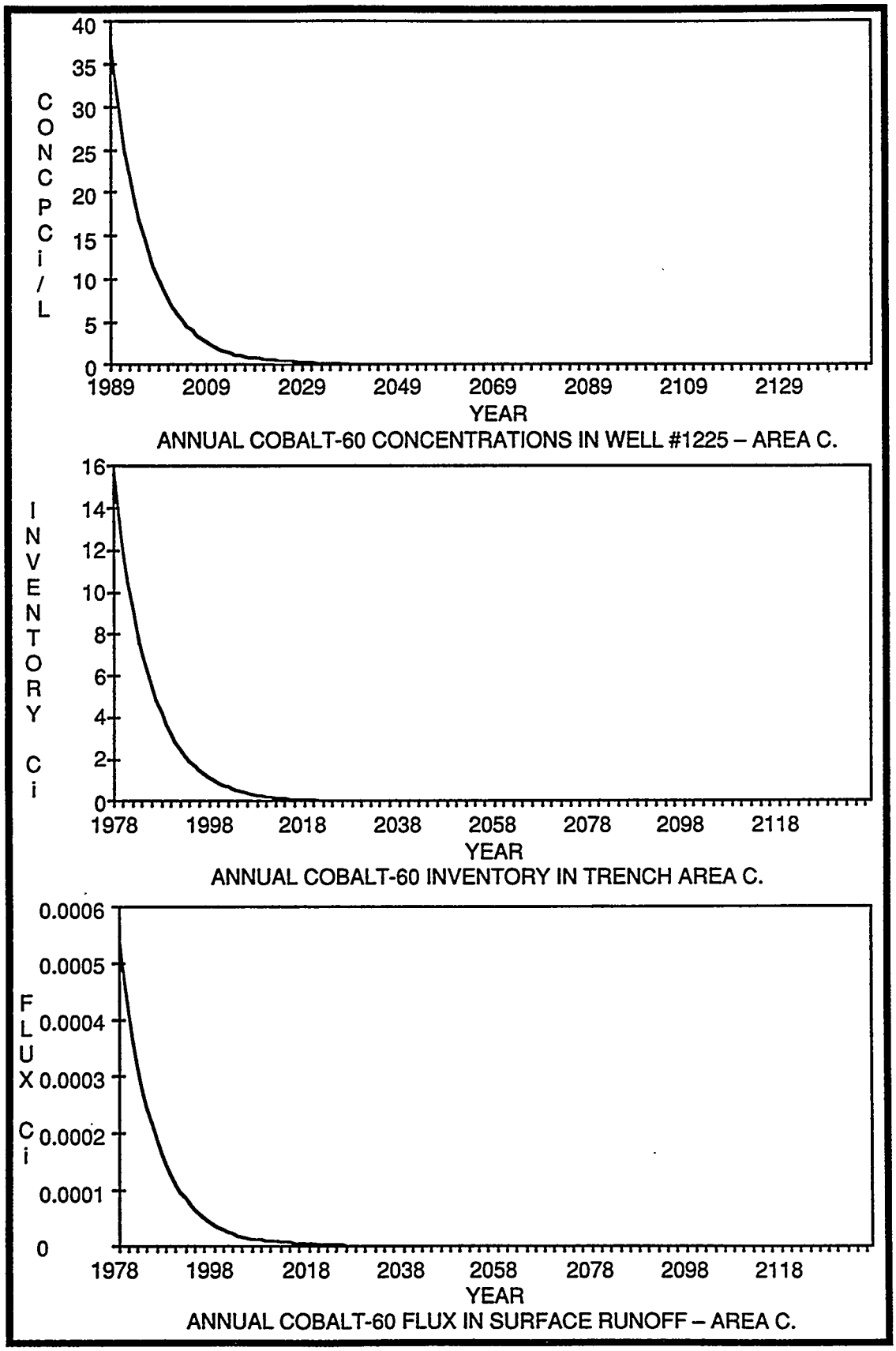



**Fig. 5D.12. Modeling output for cobalt-60, Area C.**

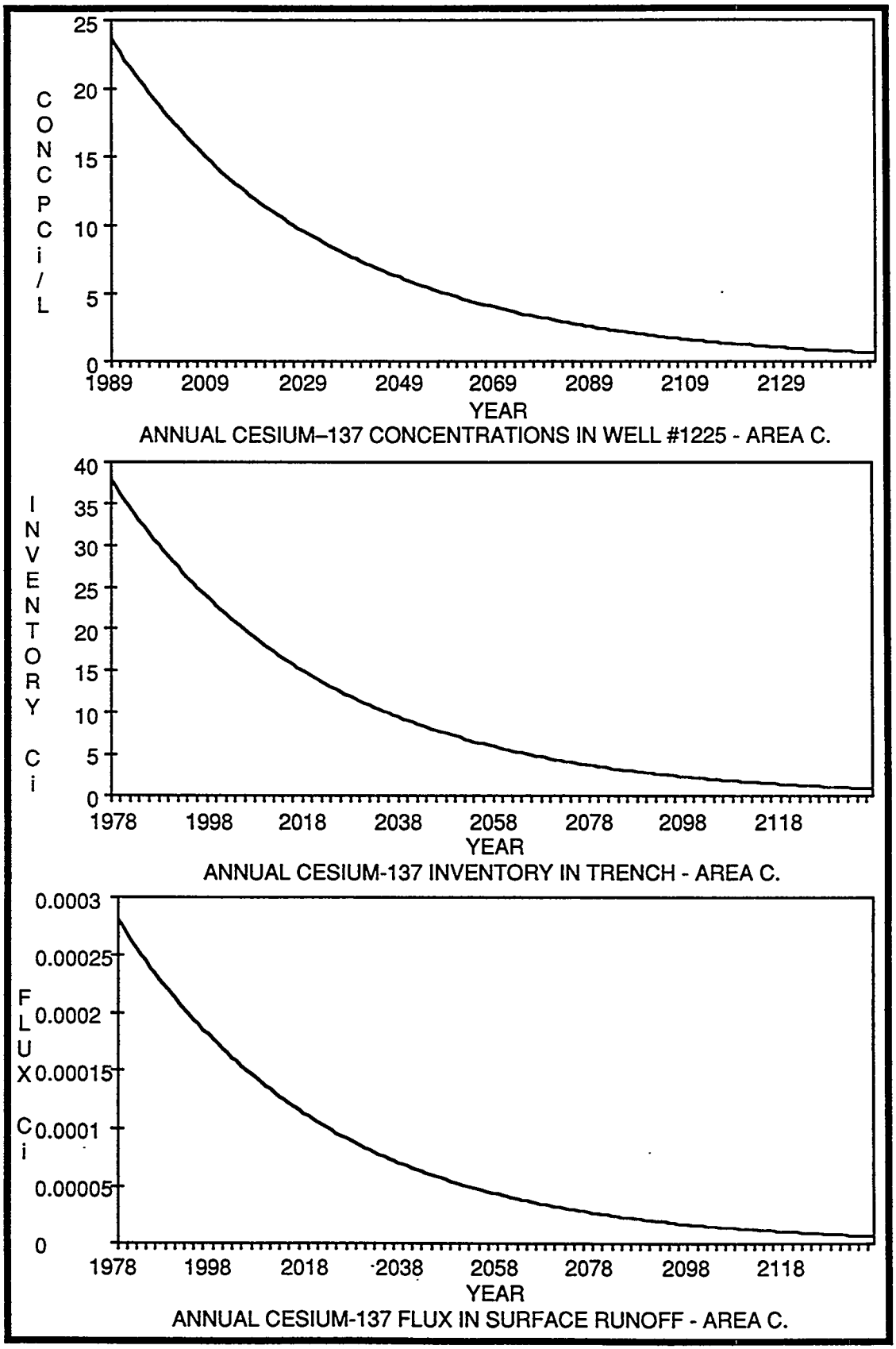



**Fig. 5D.13. Modeling output for cesium-137, Area C.**

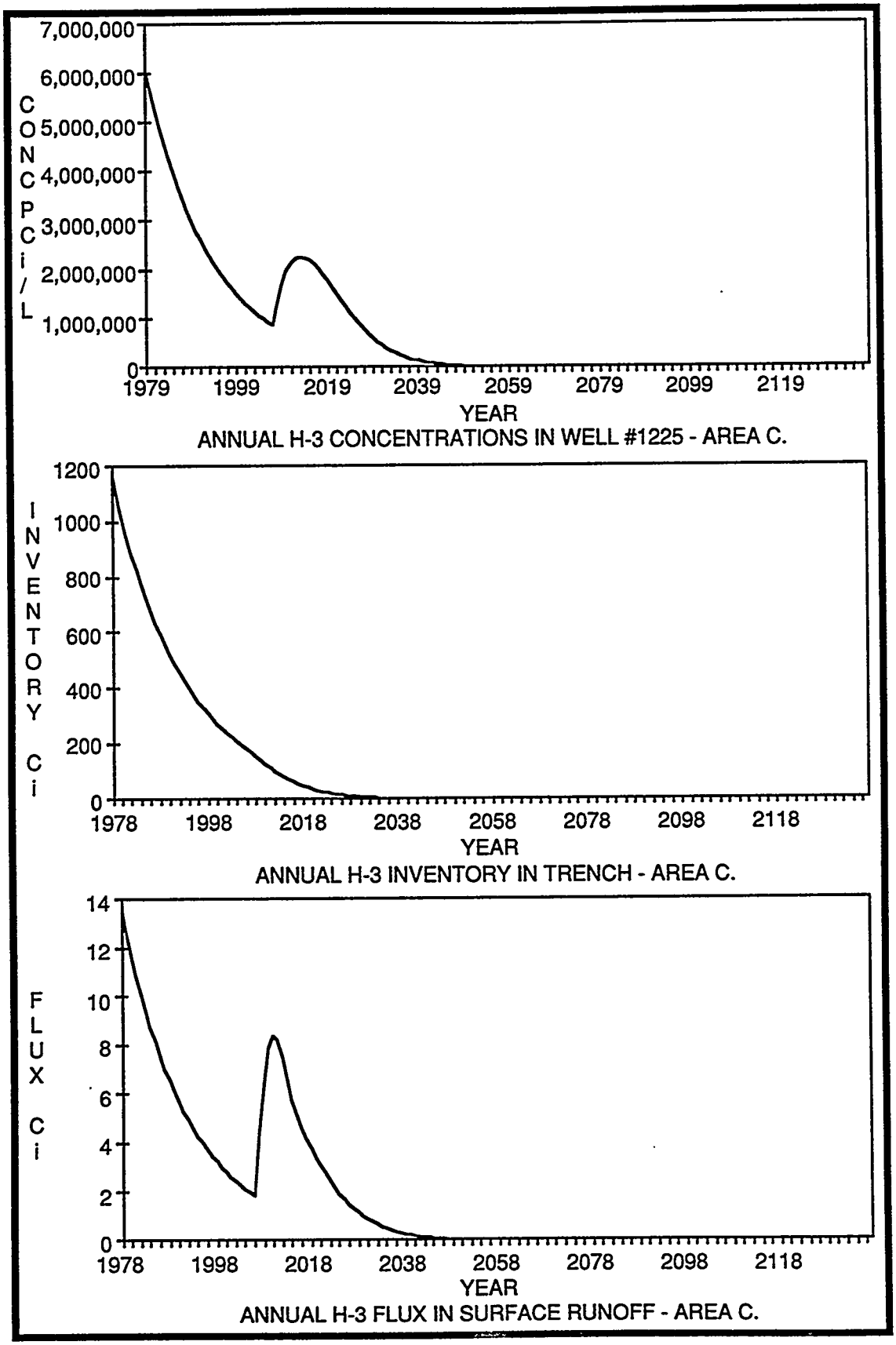



**Fig. 5D.14. Modeling output for tritium, Area C.**

5.18A 4104.49

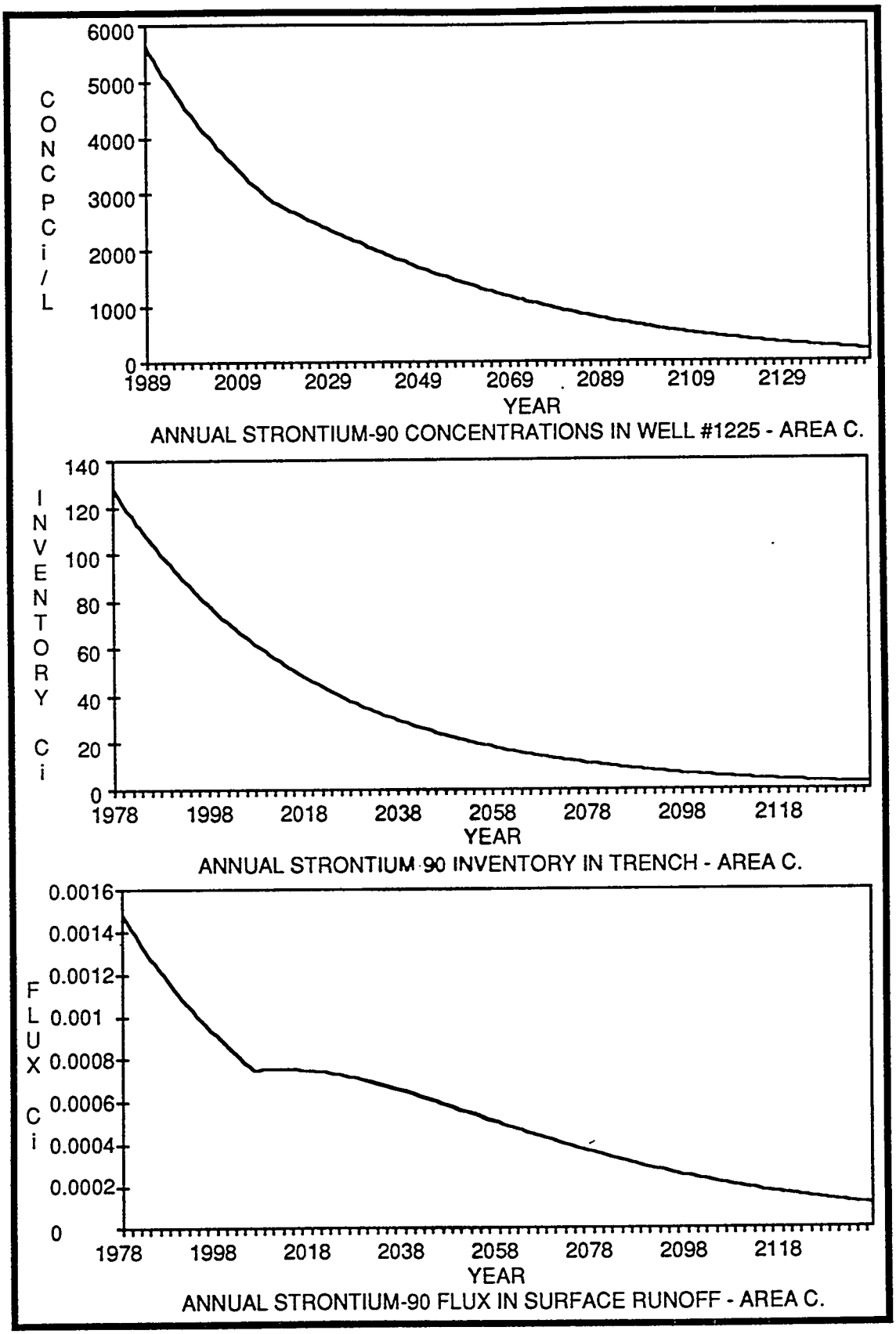



**Fig. 5D.15. Modeling output for strontium-90, Area C.**

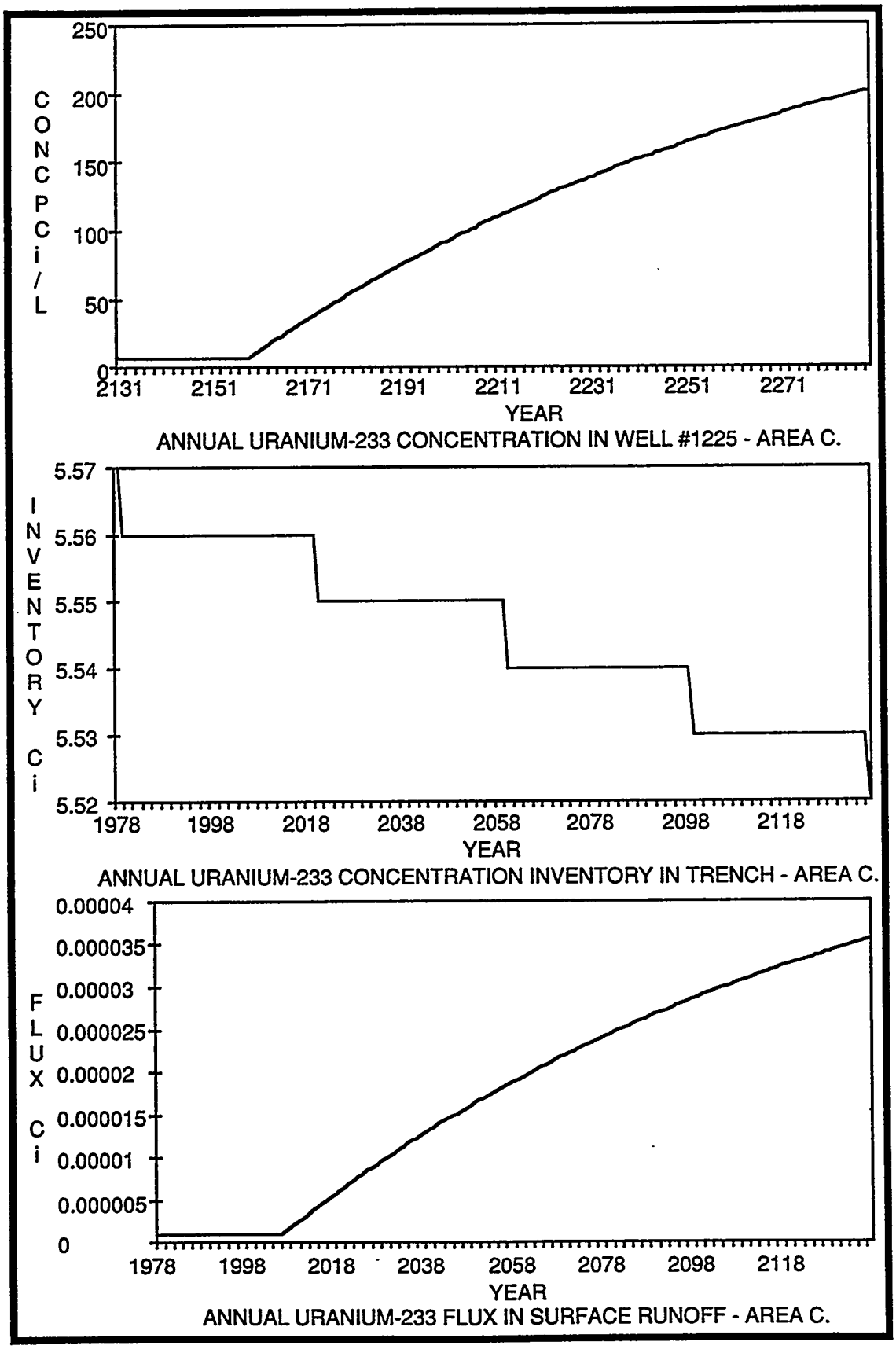



**Fig. 5D.16. Modeling output for uranium-233, Area C.**

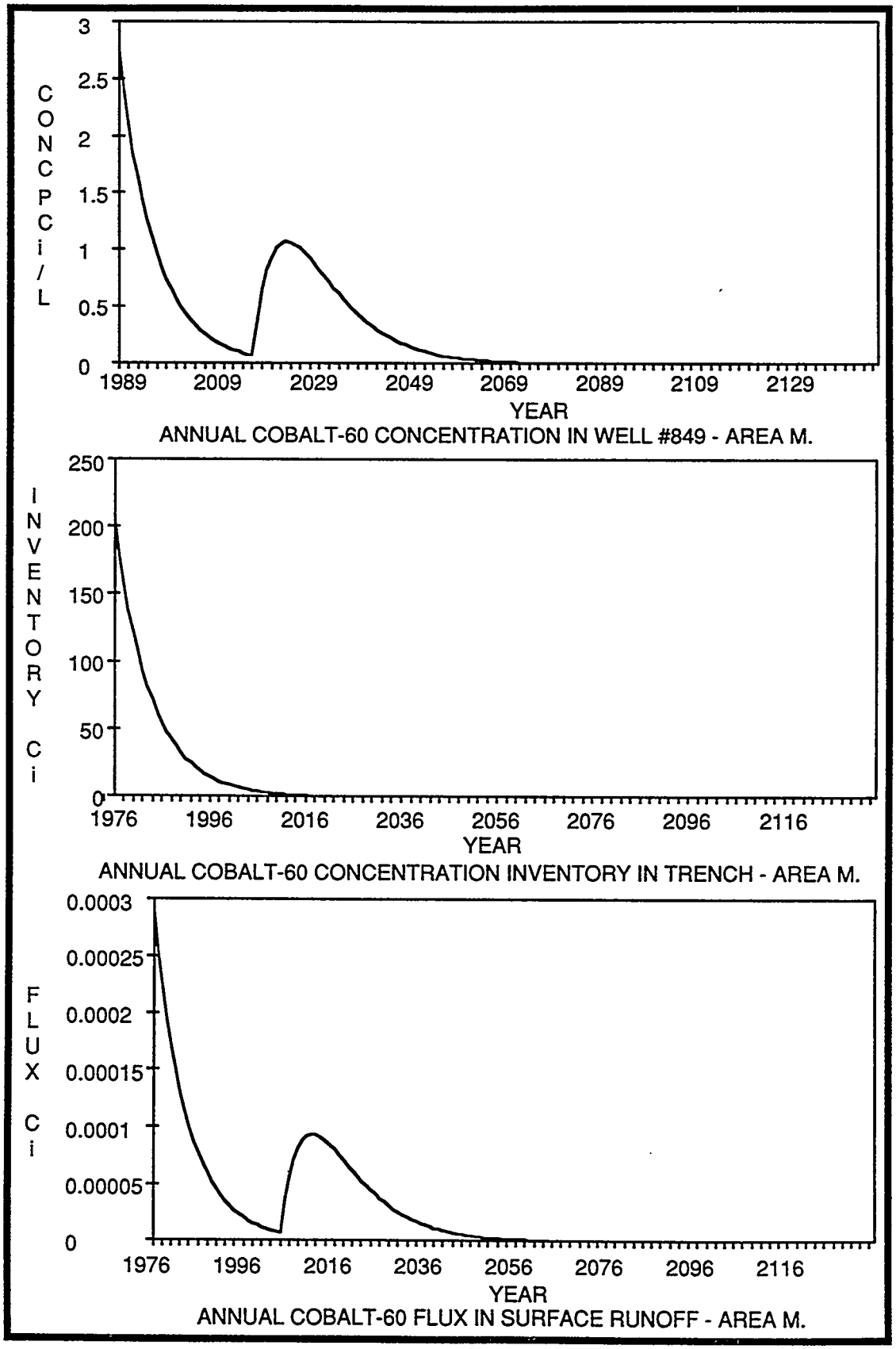



**Fig. 5D.17. Modeling output for cobalt-60, Area M.**

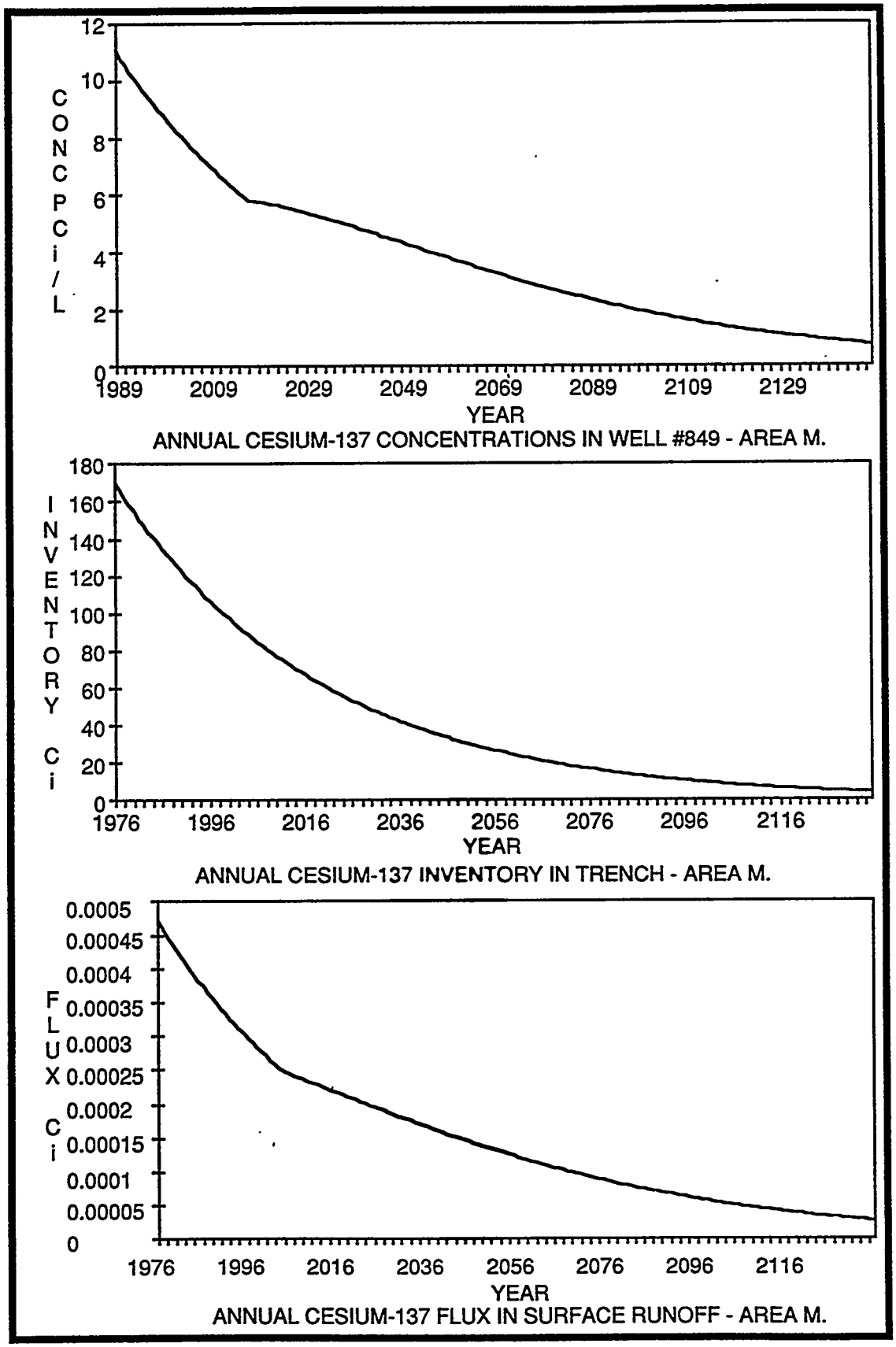



**Fig. 5D.18. Modeling output for cesium-137, Area M.**

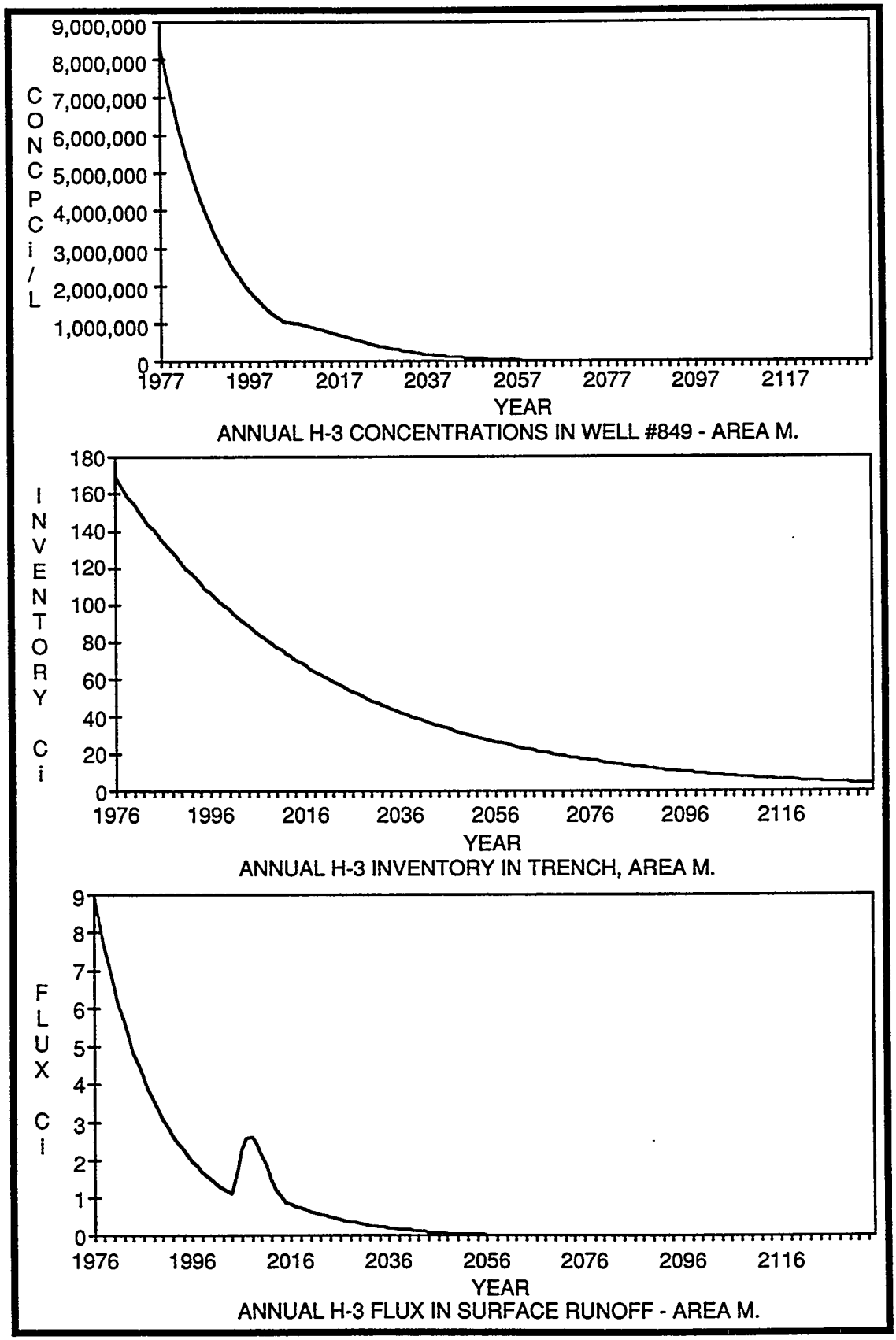



**Fig. 5D.19. Modeling output for tritium, Area M.**

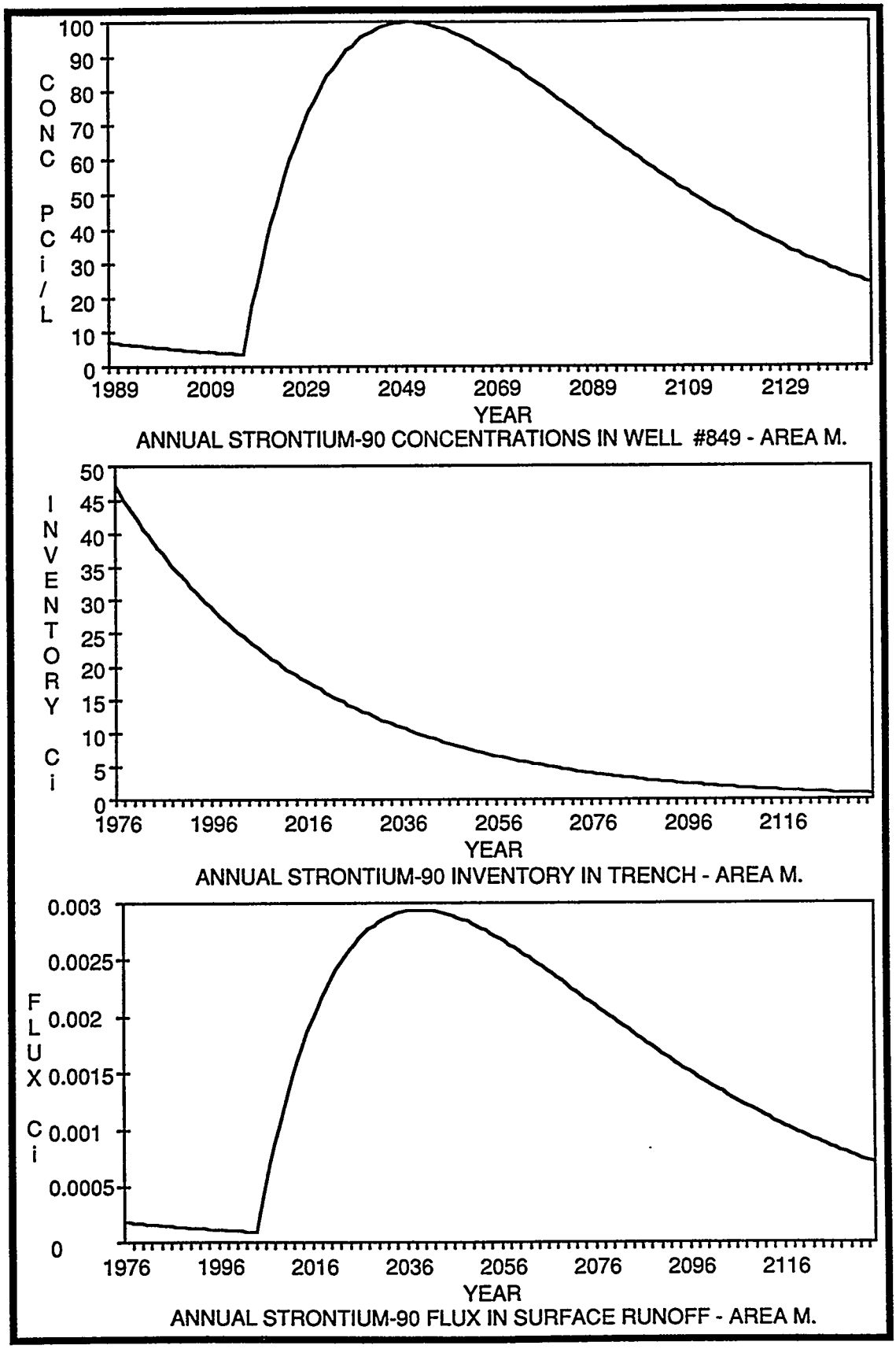



**Fig. 5D.20. Modeling output for strontium-90, Area M.**

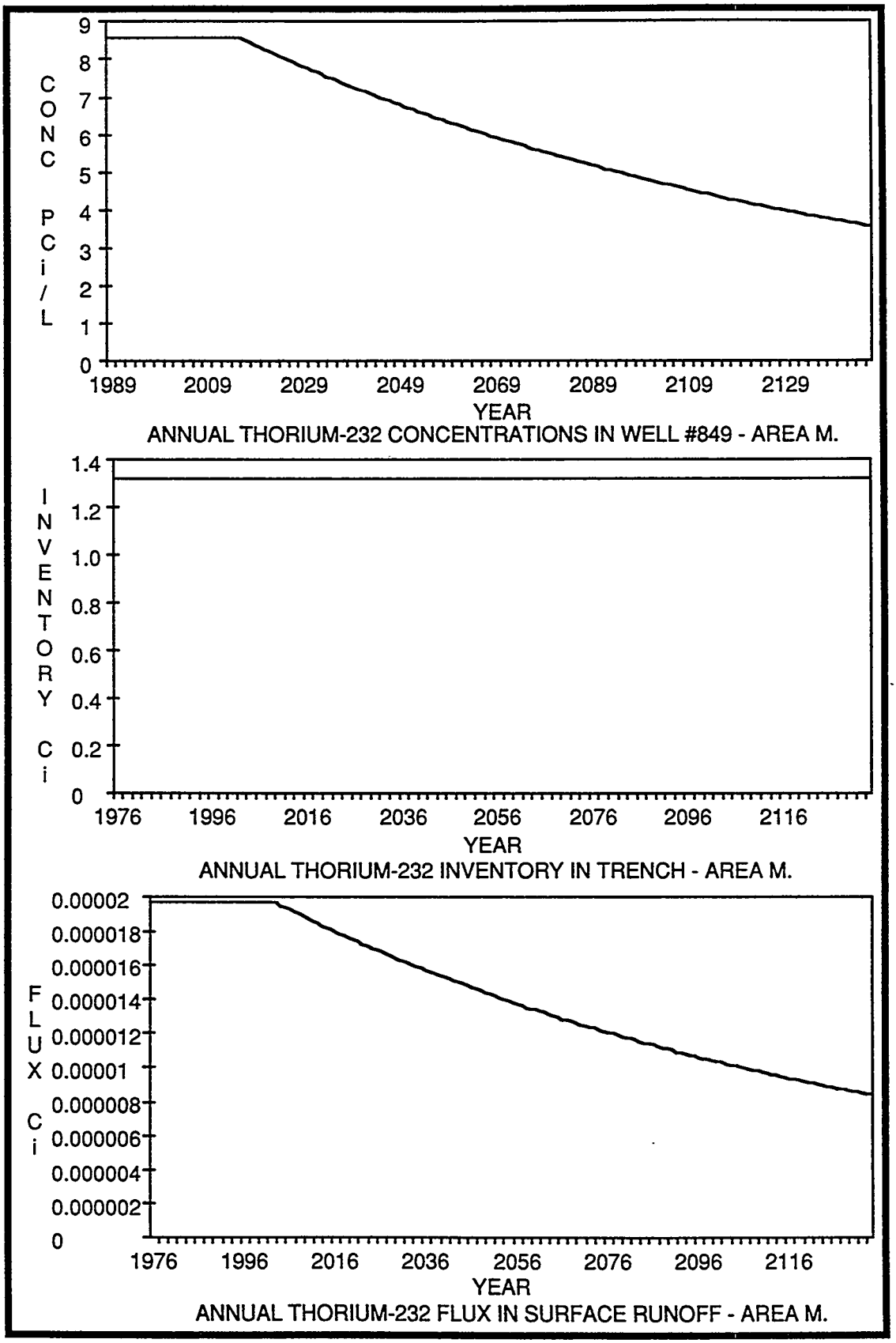



**Fig. 5D.21. Modeling output for thorium-232, Area M.**

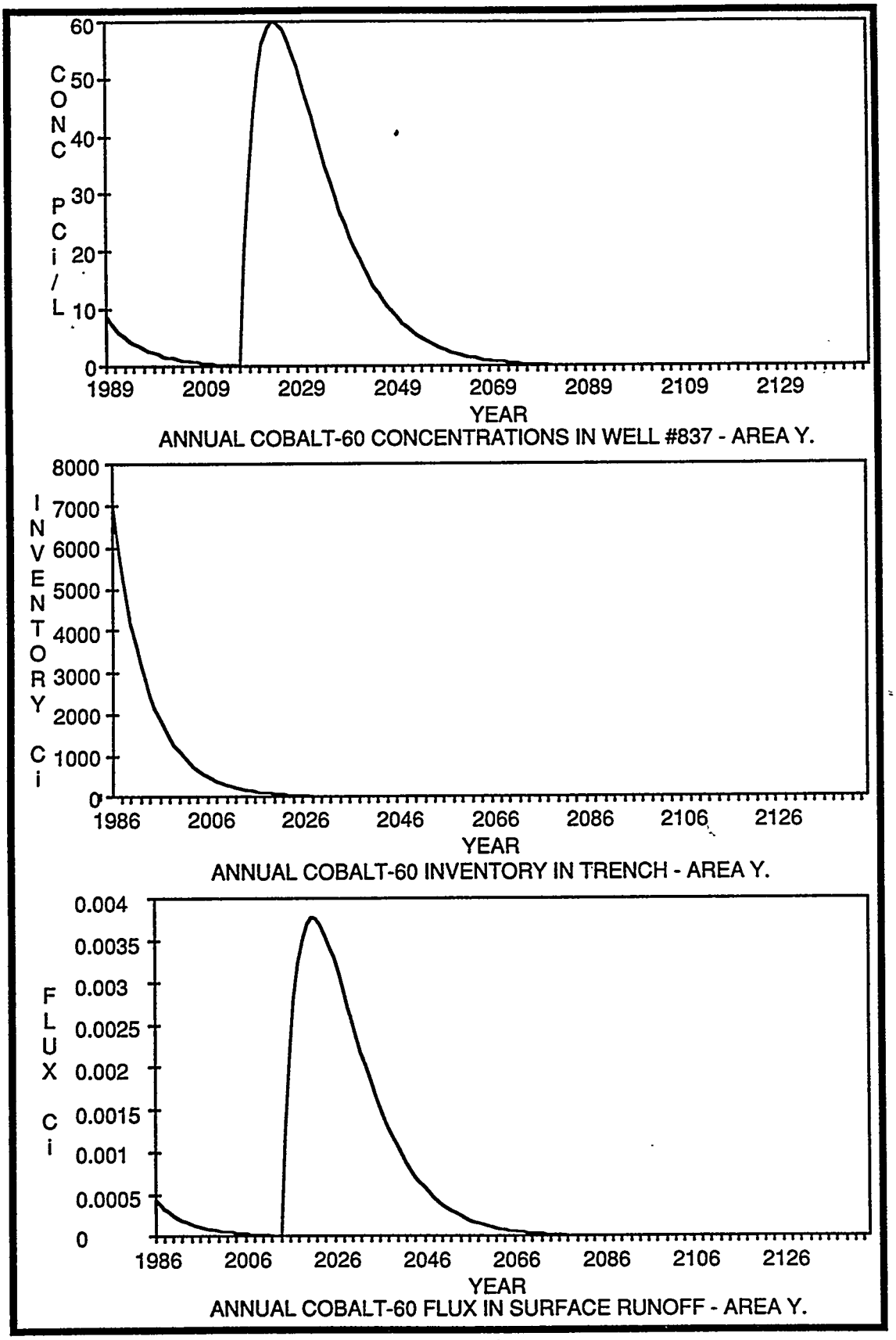



**Fig. 5D.22. Modeling output for cobalt-60, Area Y.**

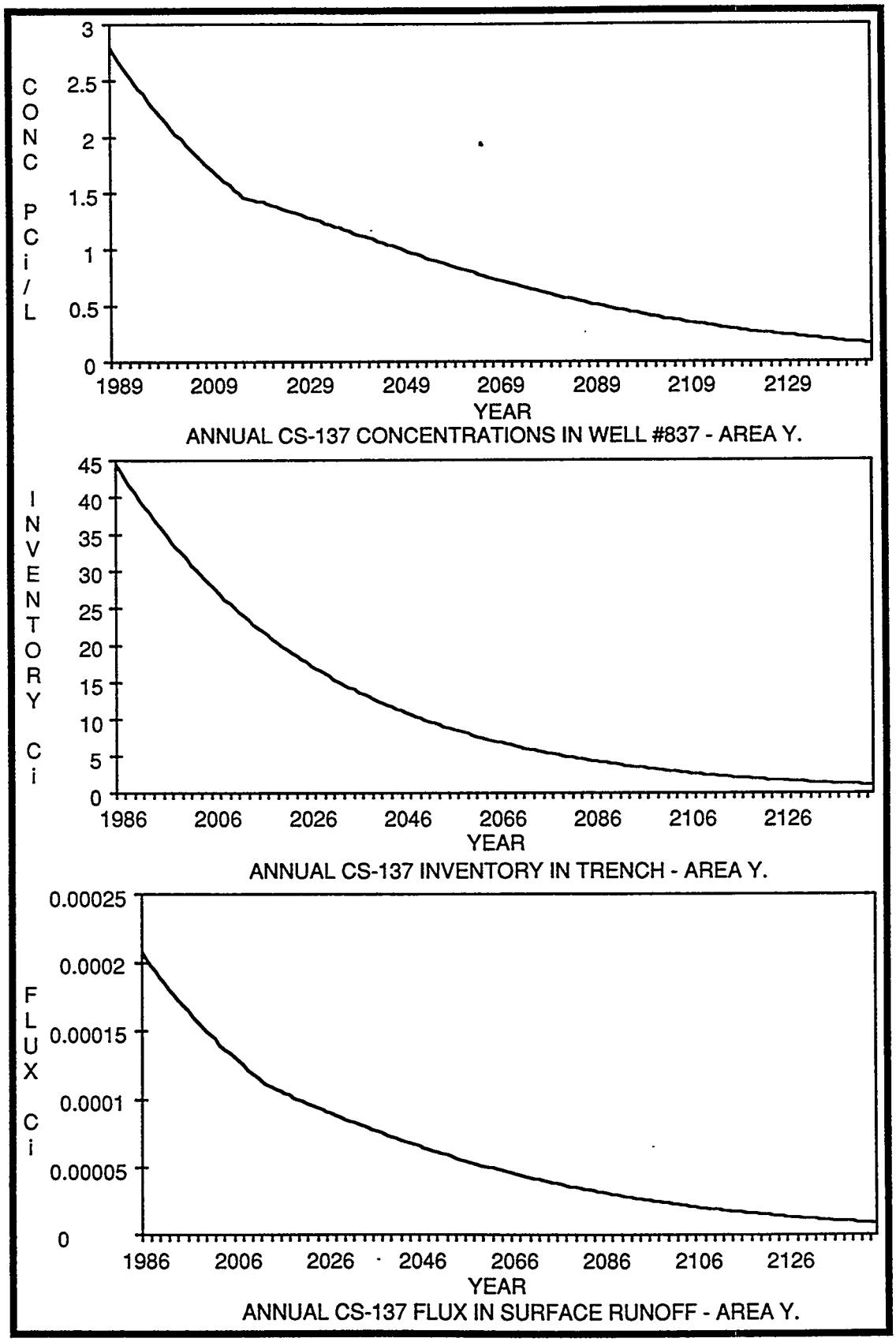



**Fig. 5D.23. Modeling output for cesium-137, Area Y.**

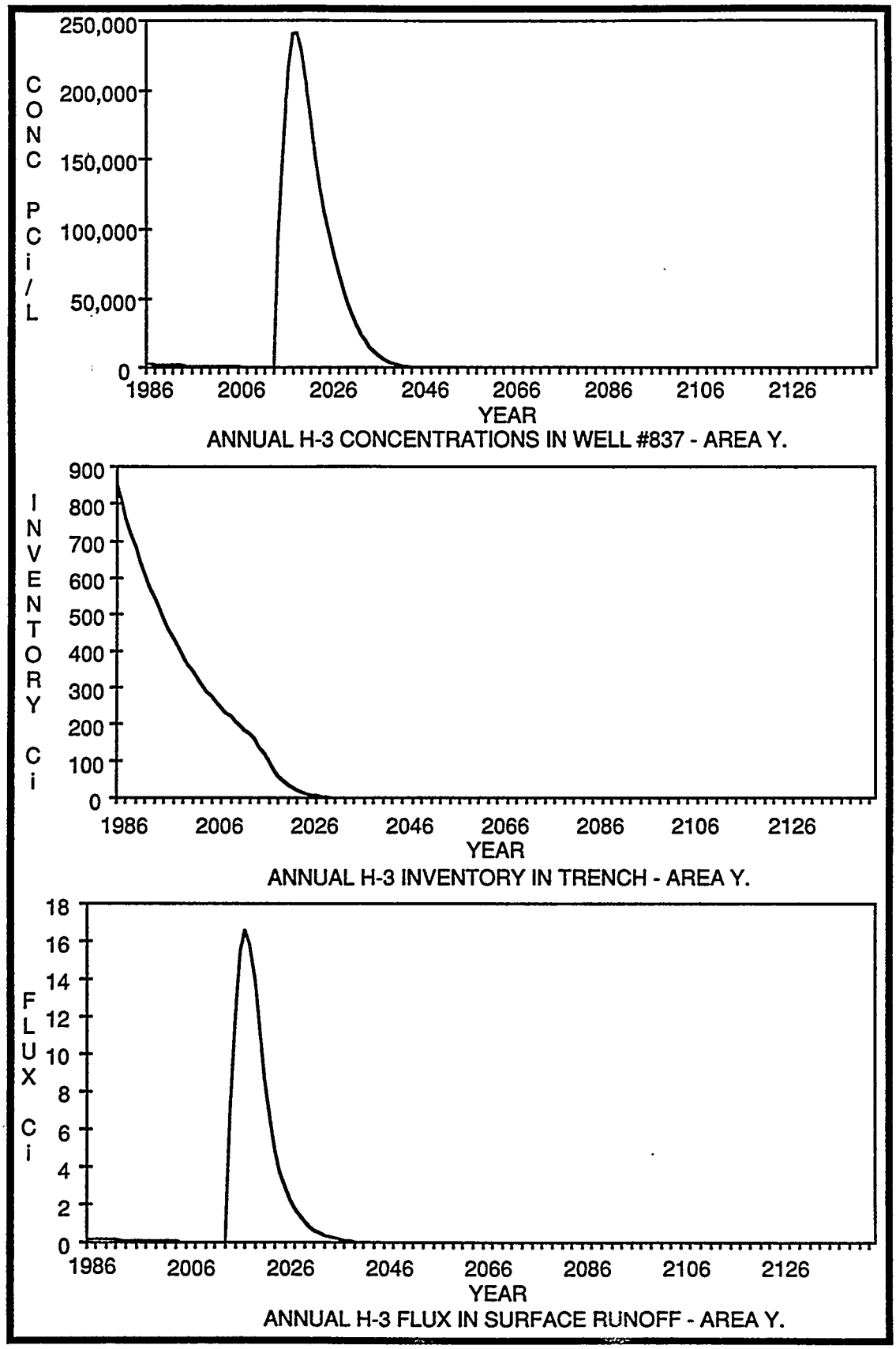



**Fig. 5D.24. Modeling output for tritium, Area Y.**

5.18A 4104.59

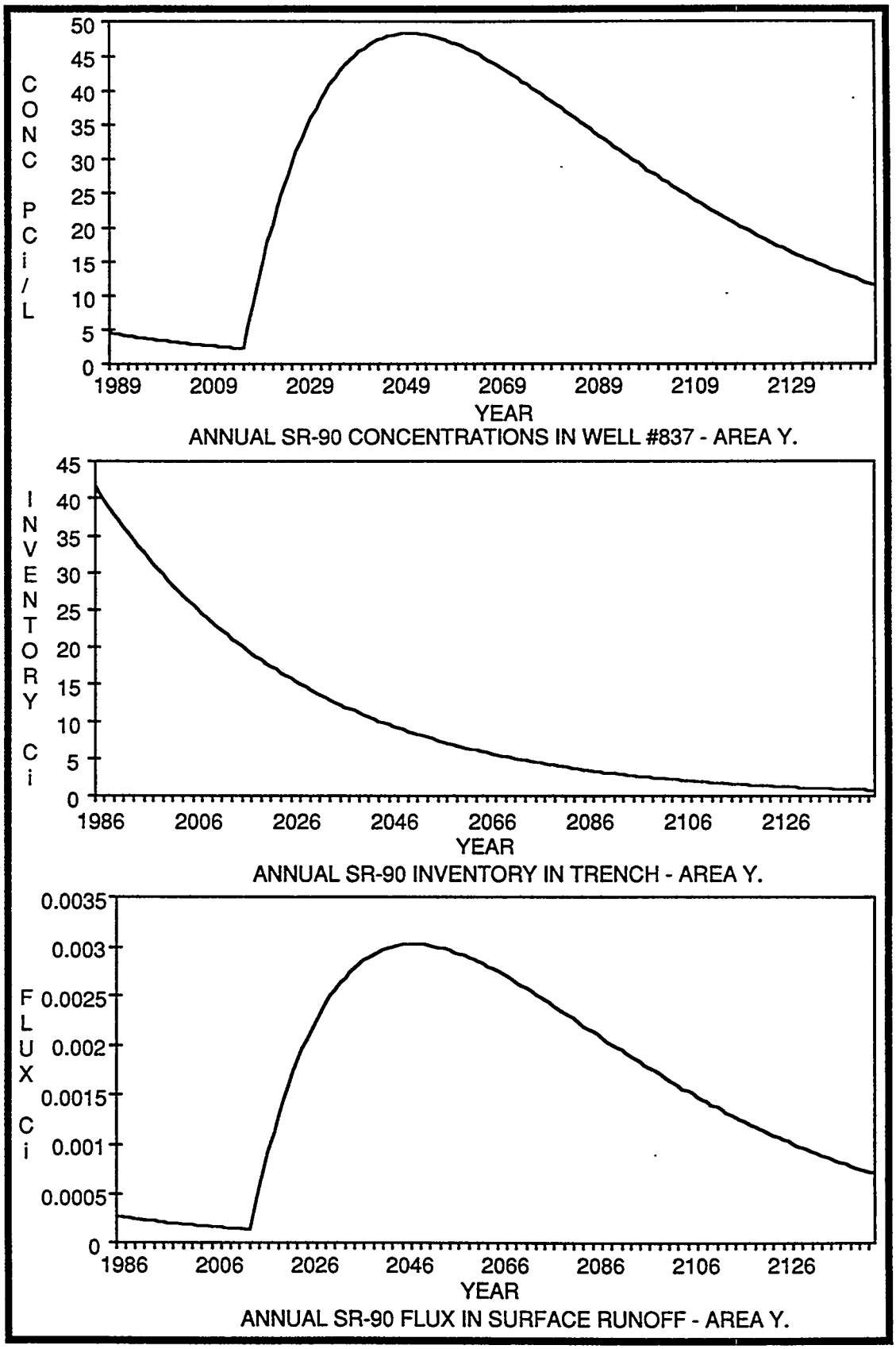



**Fig. 5D.25. Modeling output for strontium-90, Area Y.**

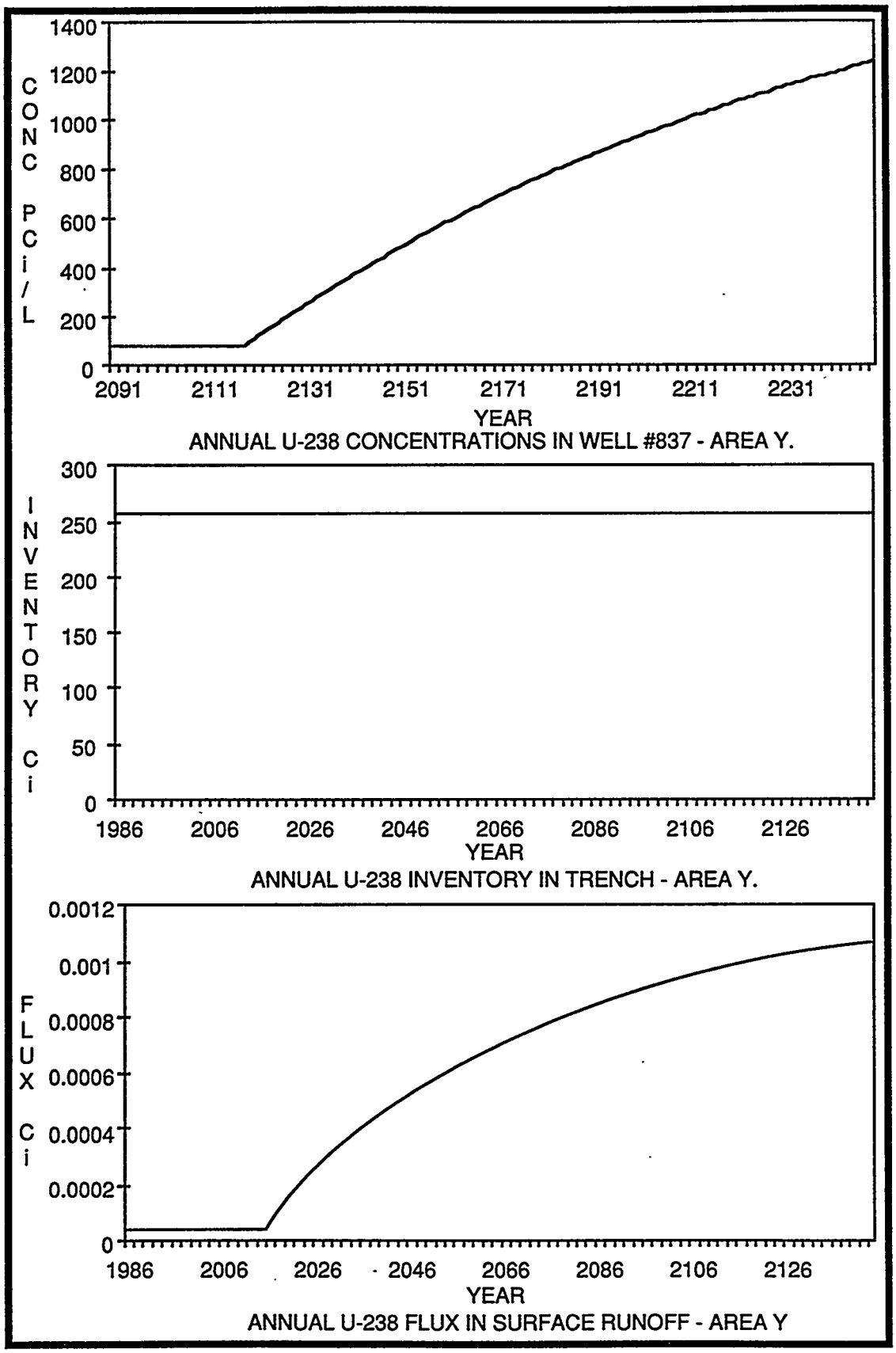



**Fig. 5D.26. Modeling output for uranium-238, Area Y.**

5.18A 4104.61

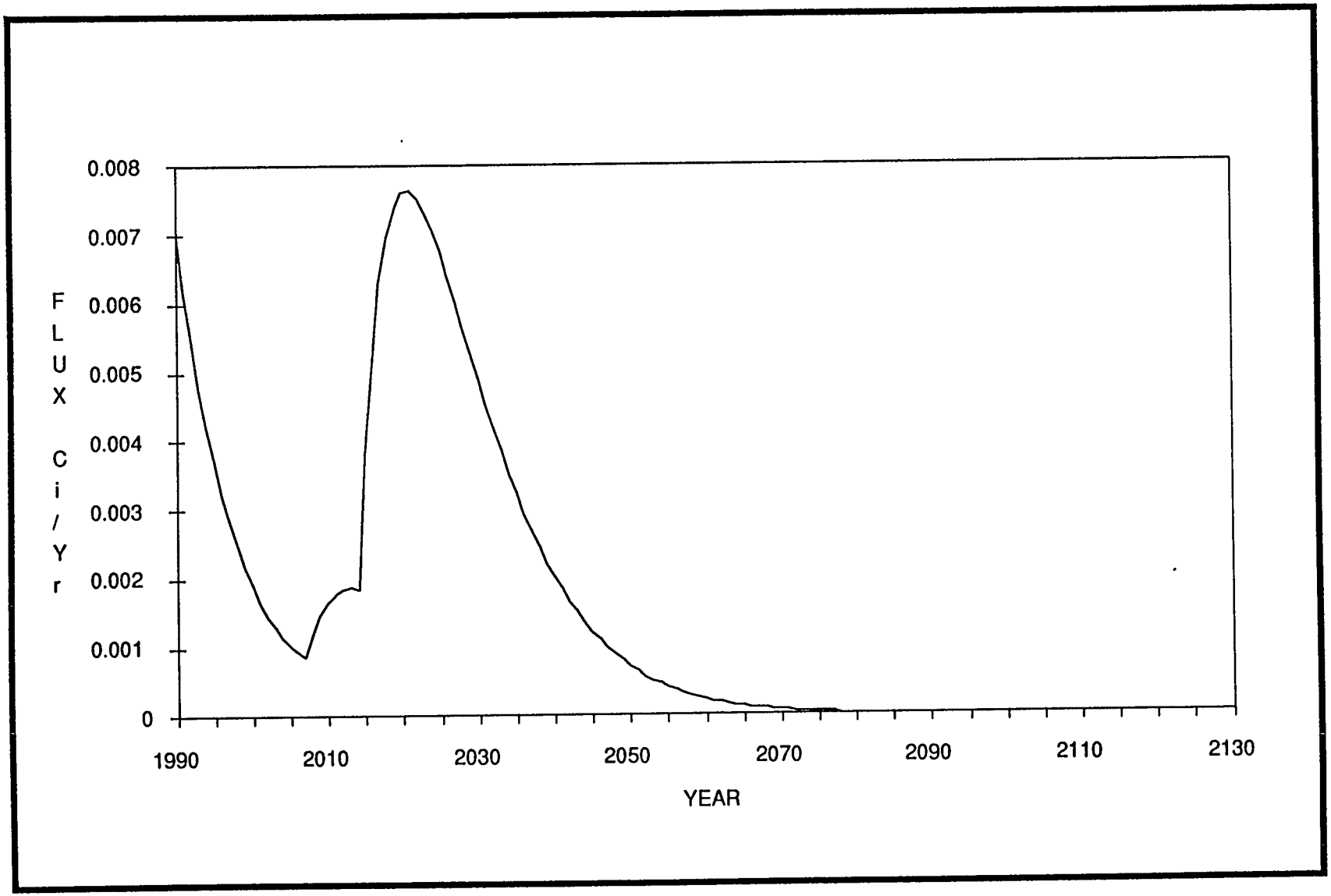



**Fig. 5D.27. Total Co-60 flux in surface water across the WAG 6 boundary.**

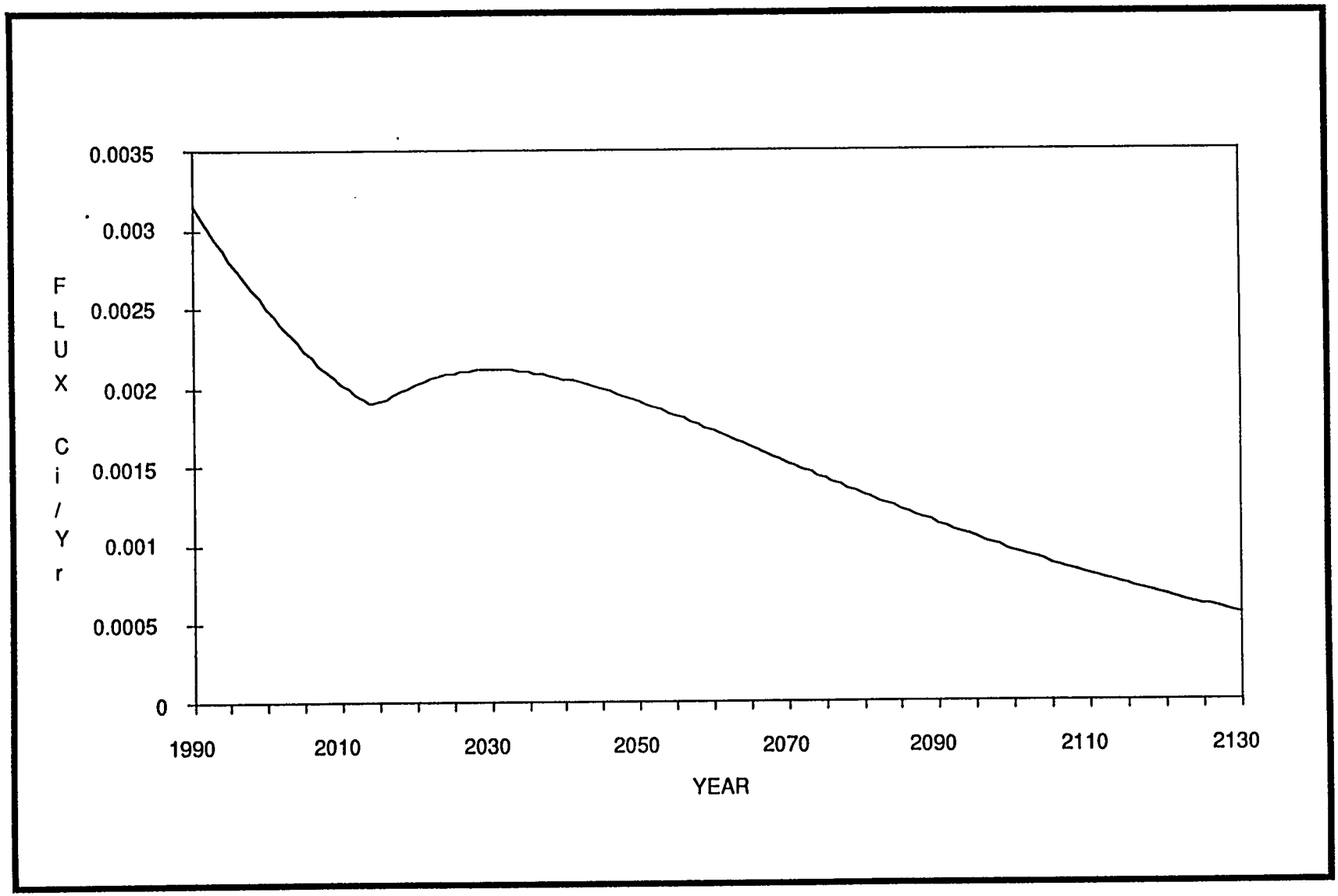



Fig. 5D.28. Total Cs-137 flux in surface water across the WAG 6 boundary.

5.18D 4104.107

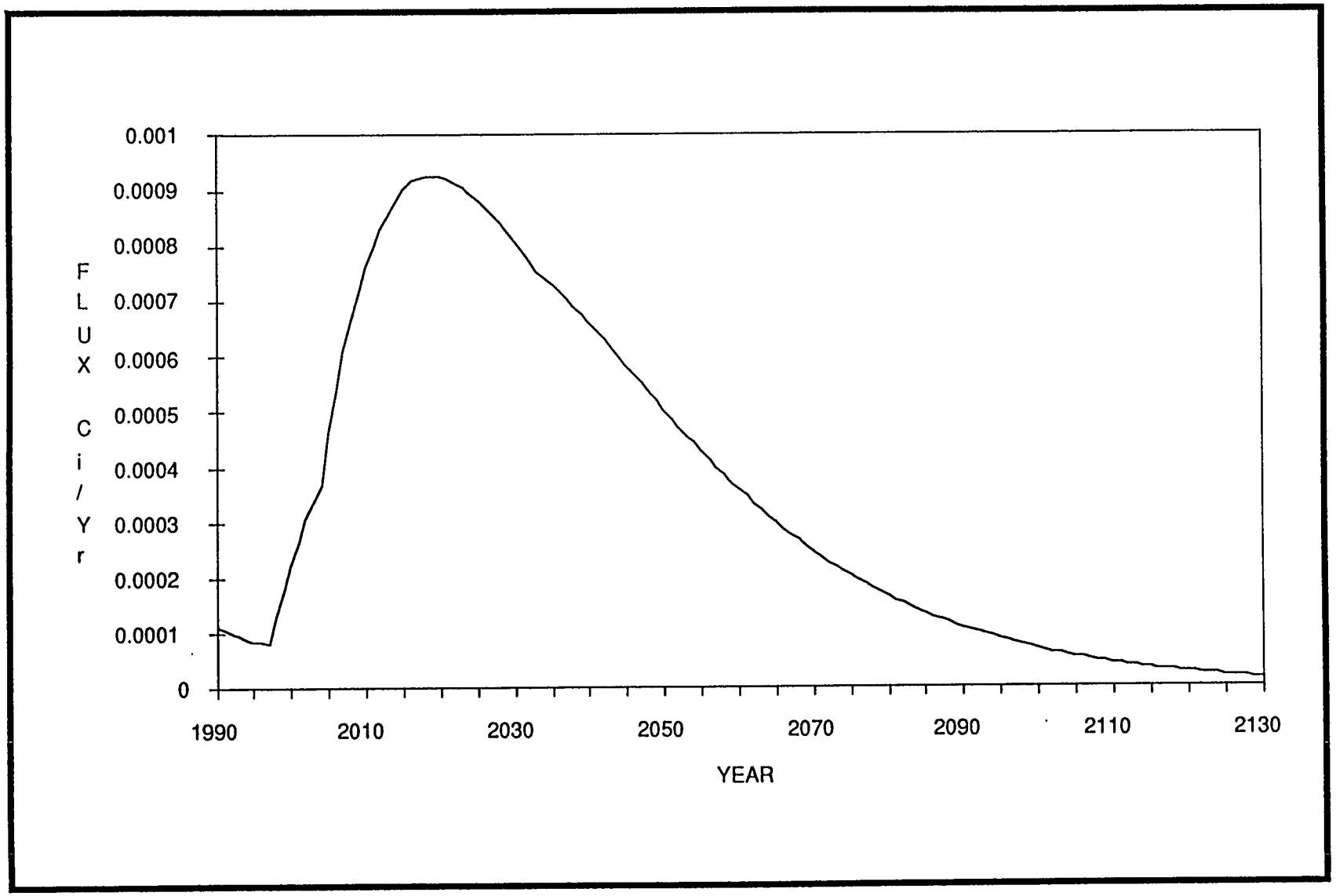



**Fig. 5D.29. Total Eu-152 flux in surface water across the WAG 6 boundary.**

5.18D 4104.108

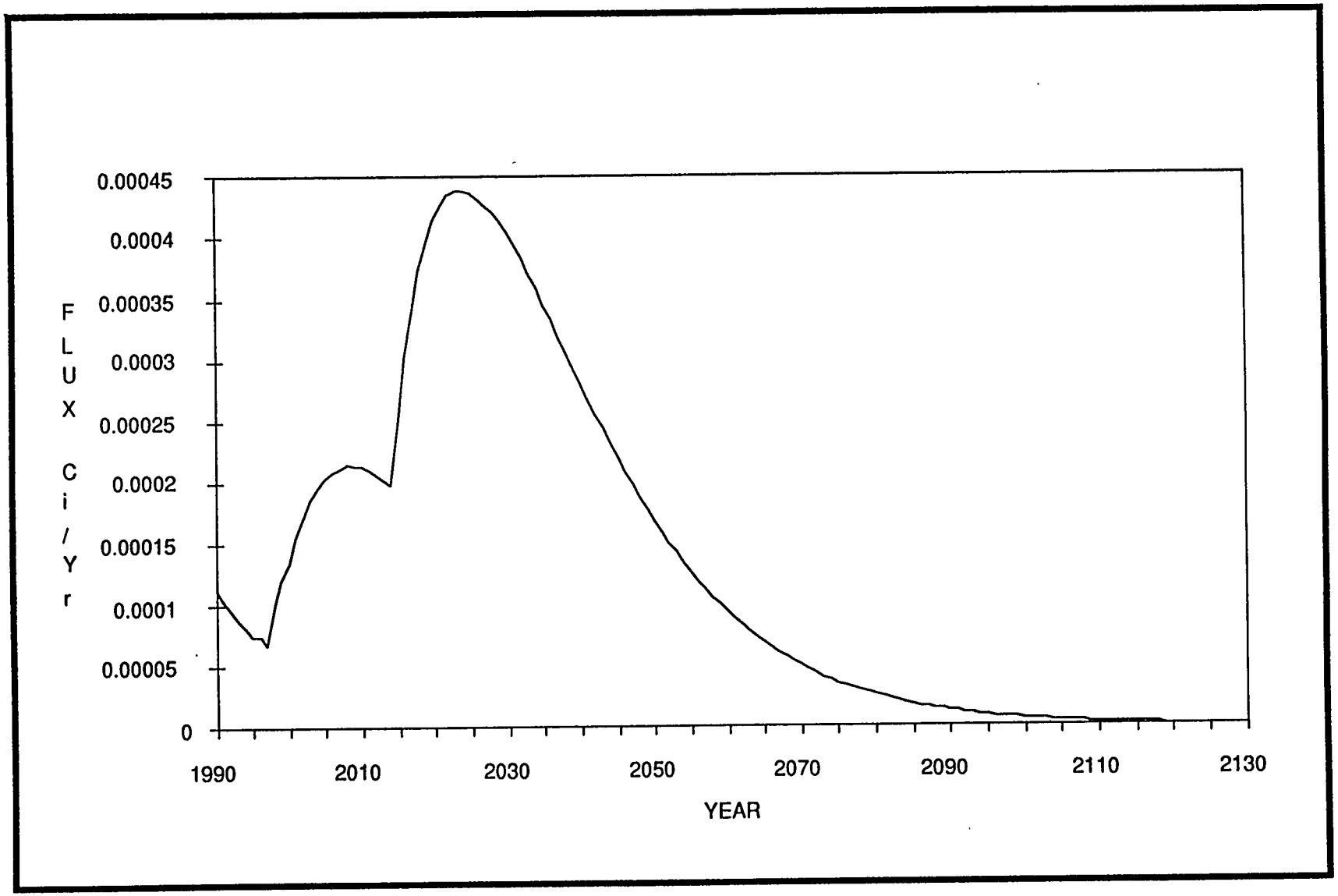



**Fig. 5D.30. Total Eu-154 flux in surface water across the WAG 6 boundary.**

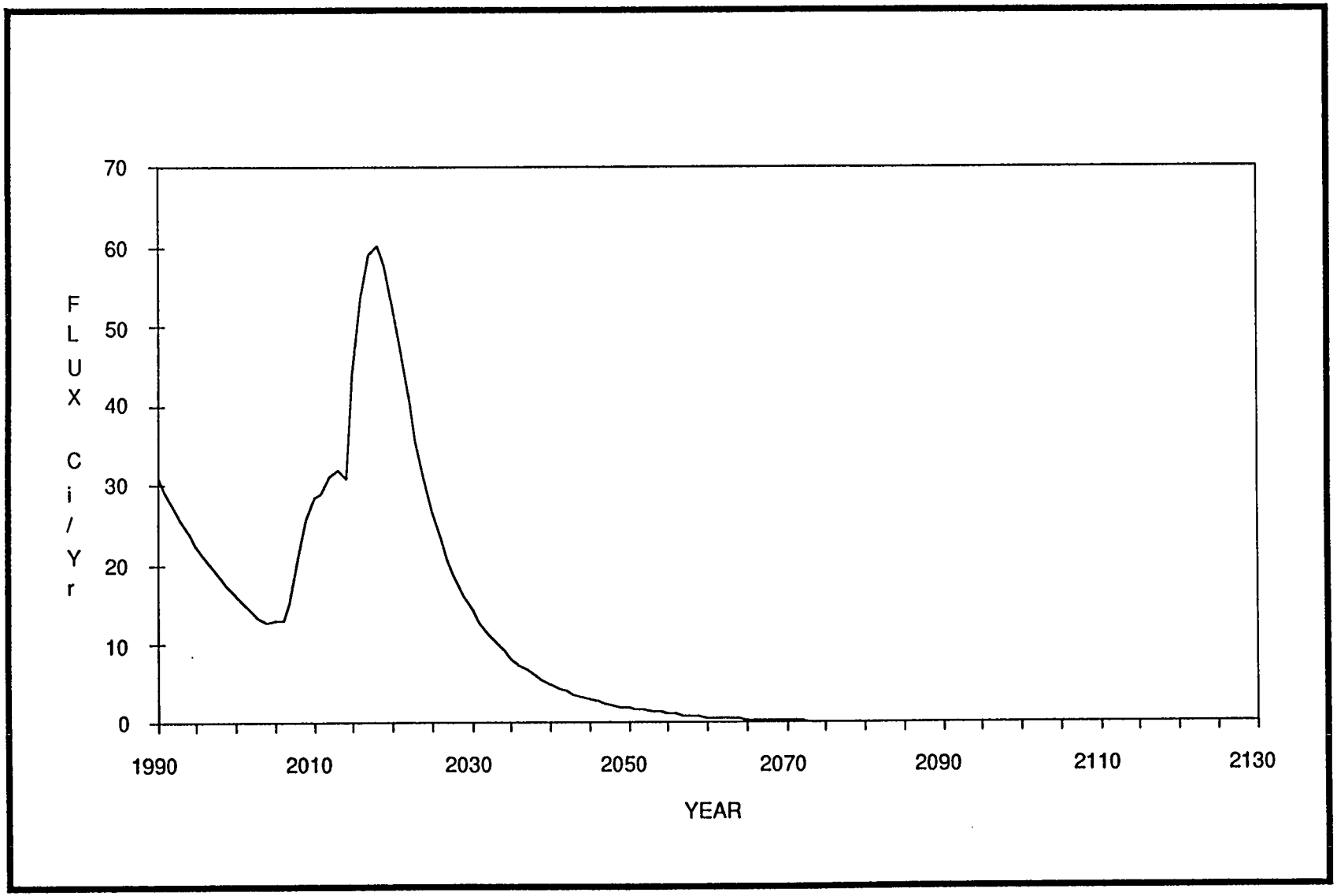



**Fig. 5D.31. Total H-3 flux in surface water across the WAG 6 boundary.**

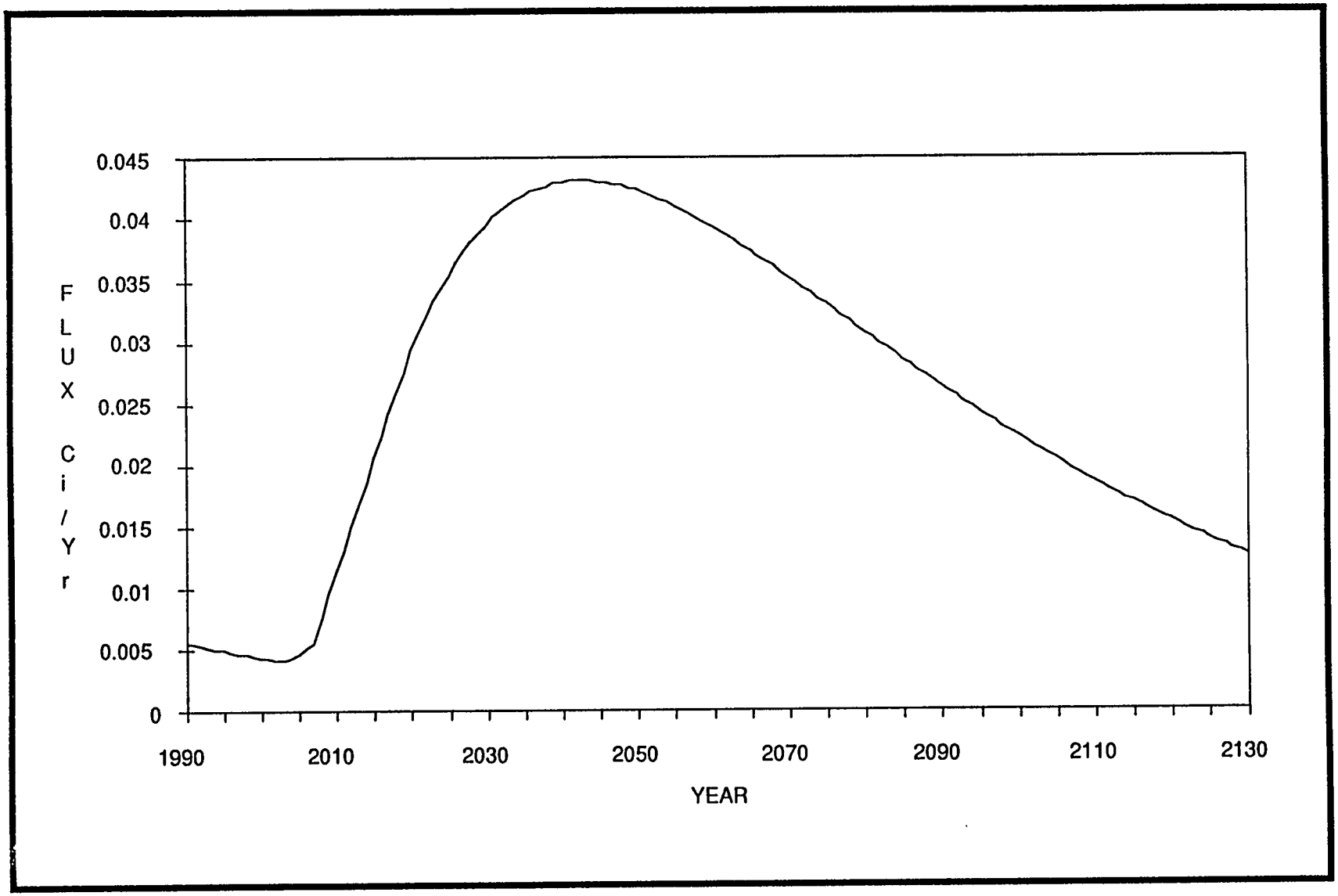



**Fig. 5D.32. Total Sr-90 flux in surface water across the WAG 6 boundary.**

5.18D 4104.111

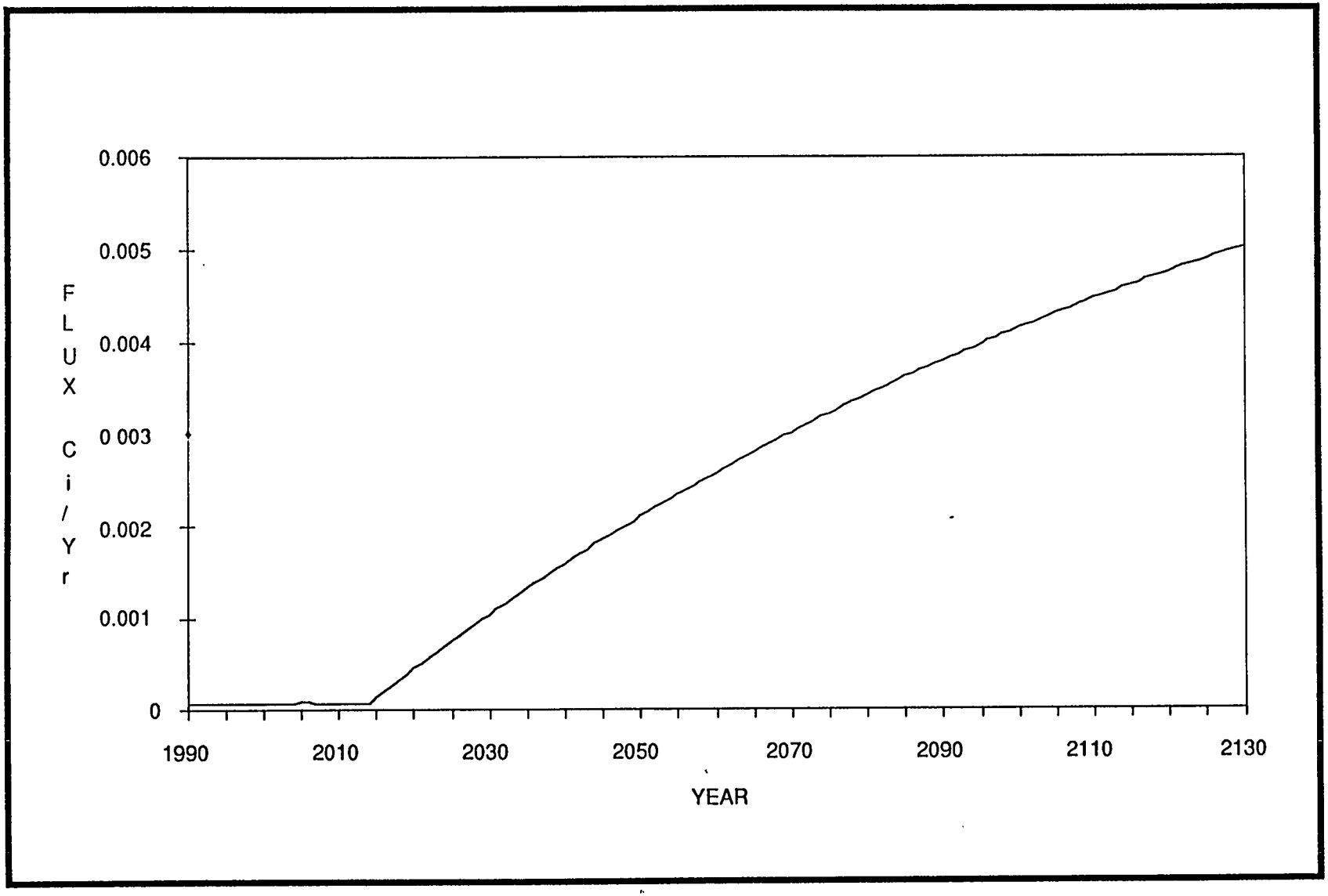



**Fig. 5D.33. Total Th-232 flux in surface water across the WAG 6 boundary.**

5.18D 4104.112

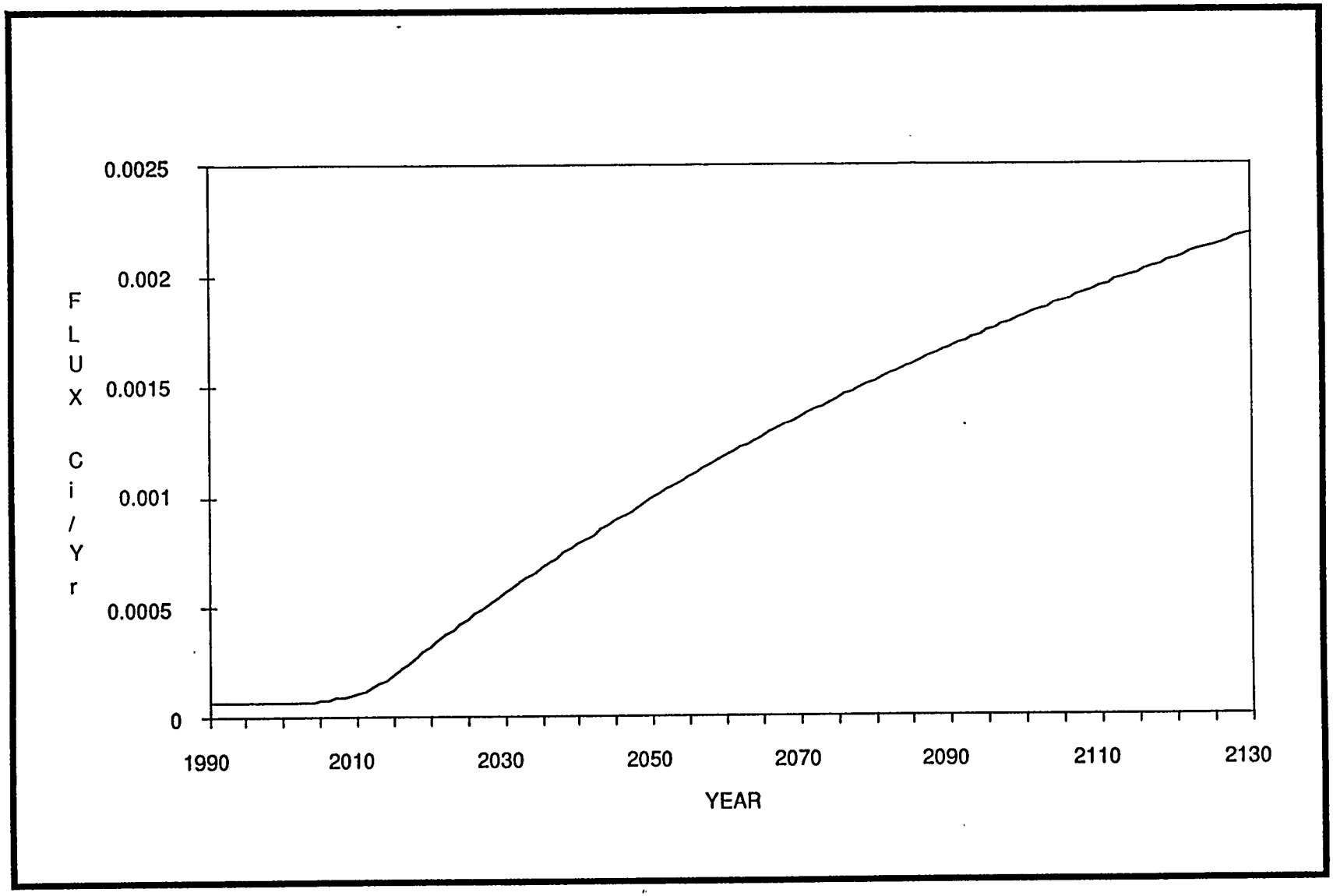



**Fig. 5D.34. Total U-233 flux in surface water across the WAG 6 boundary.**

5.18D 4104.113

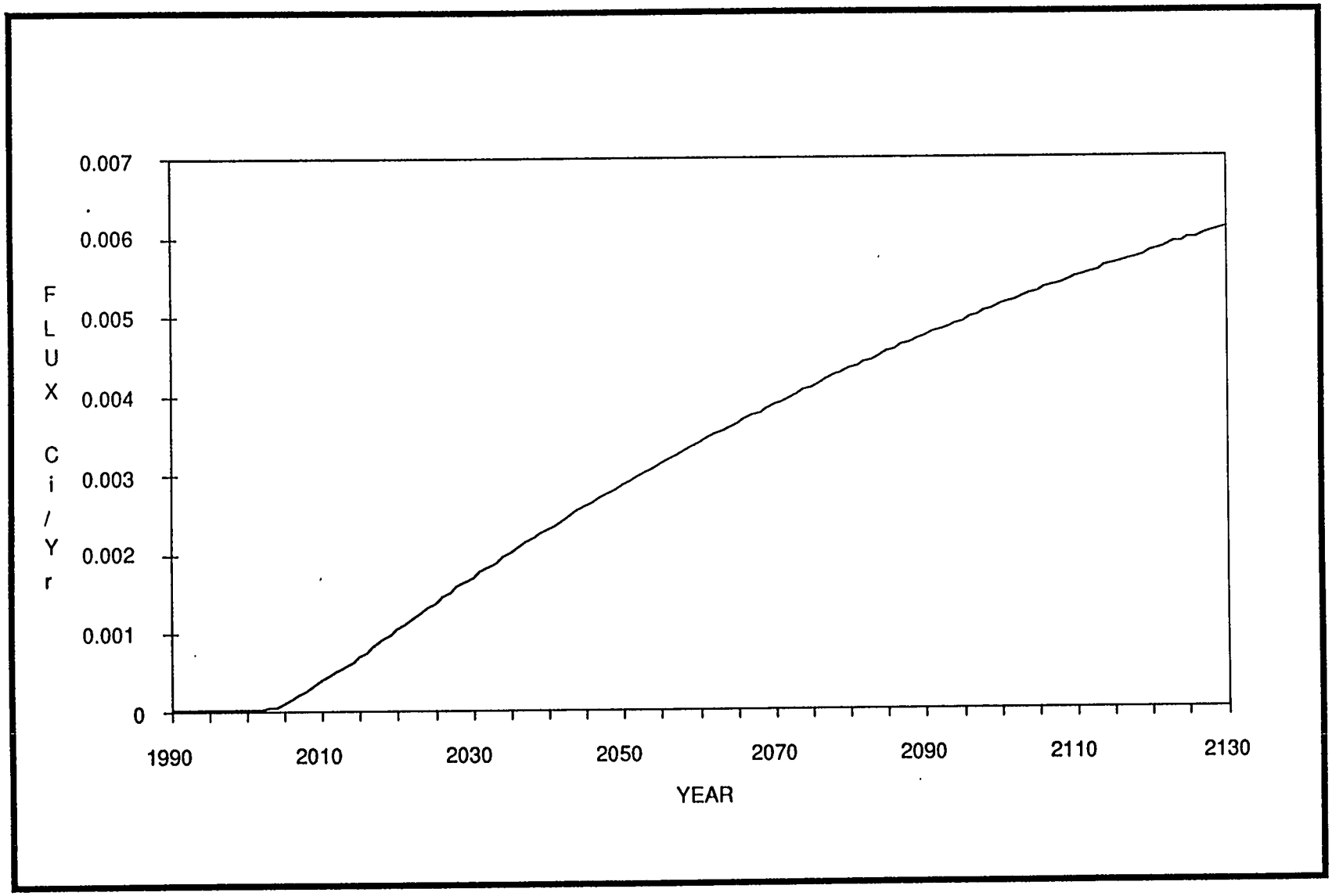



**Fig. 5D.35. Total U-238 flux in surface water across the WAG 6 boundary.**

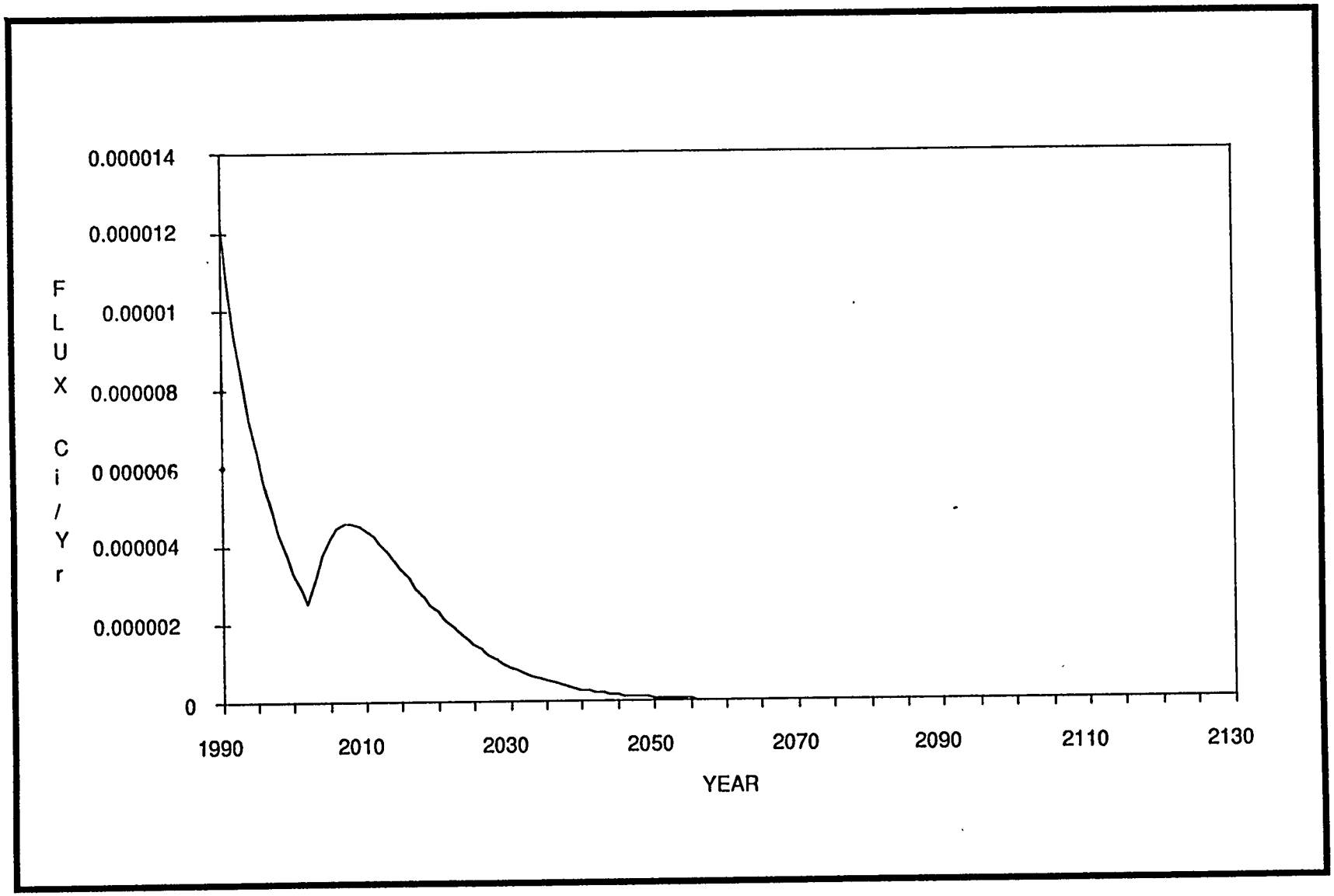



**Fig. 5D.36. Total Co-60 flux in surface water into the emergency waste basin.**

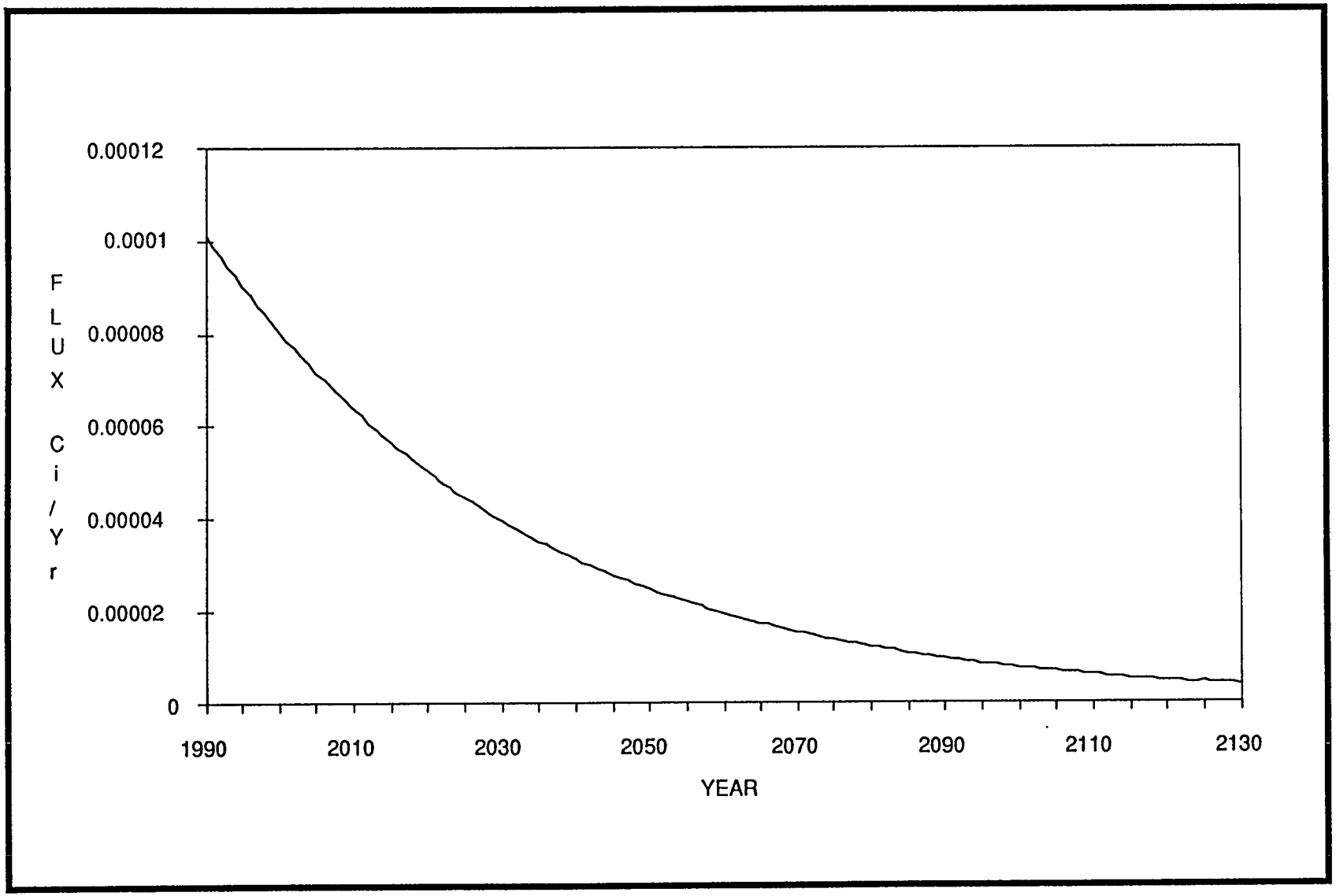



**Fig. 5D.37. Total Cs-137 flux in surface water into the emergency waste basin.**

5.18D 4104.116

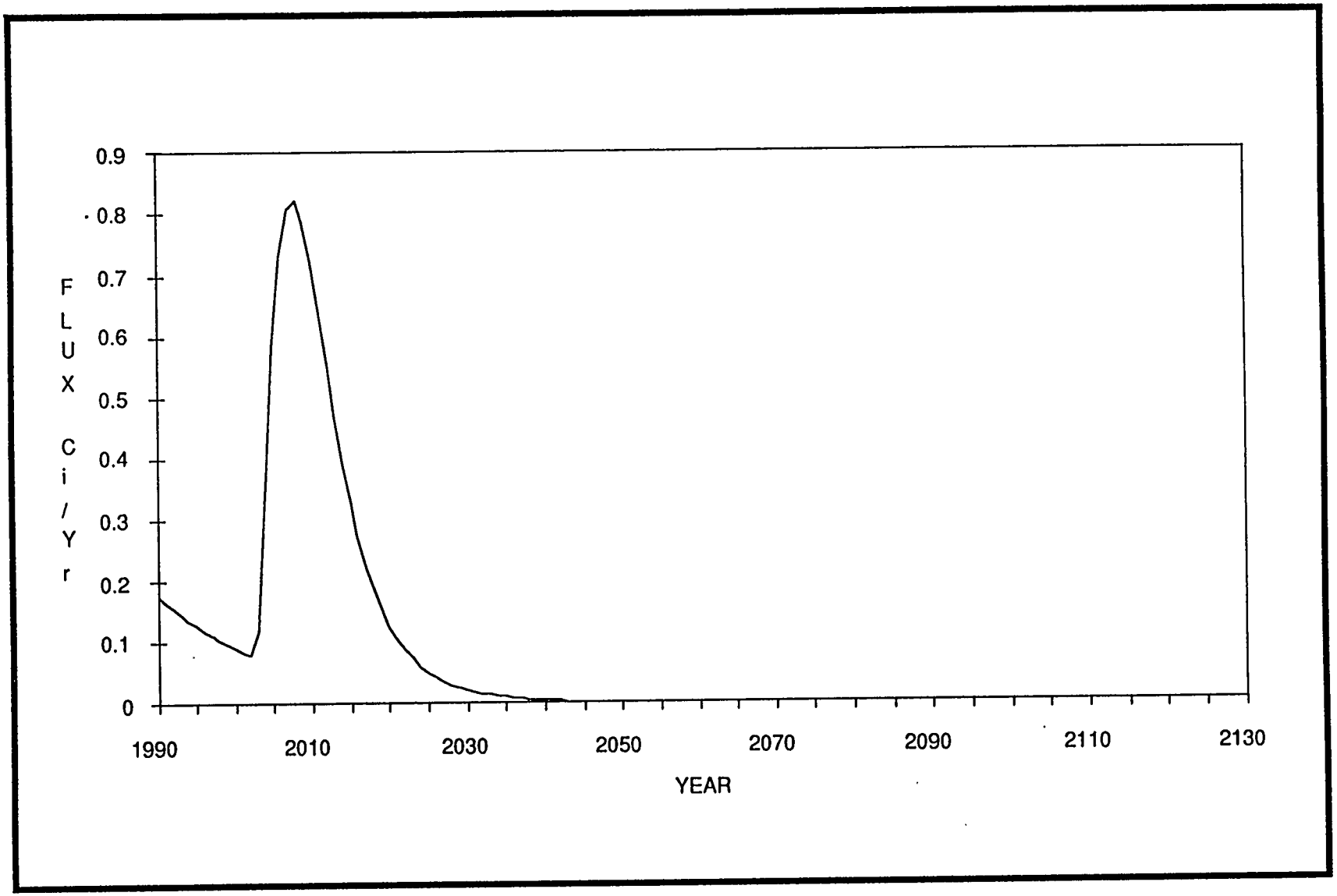



**Fig. 5D.38. Total H-3 flux in surface water into the emergency waste basin.**

5.18D 4104.117

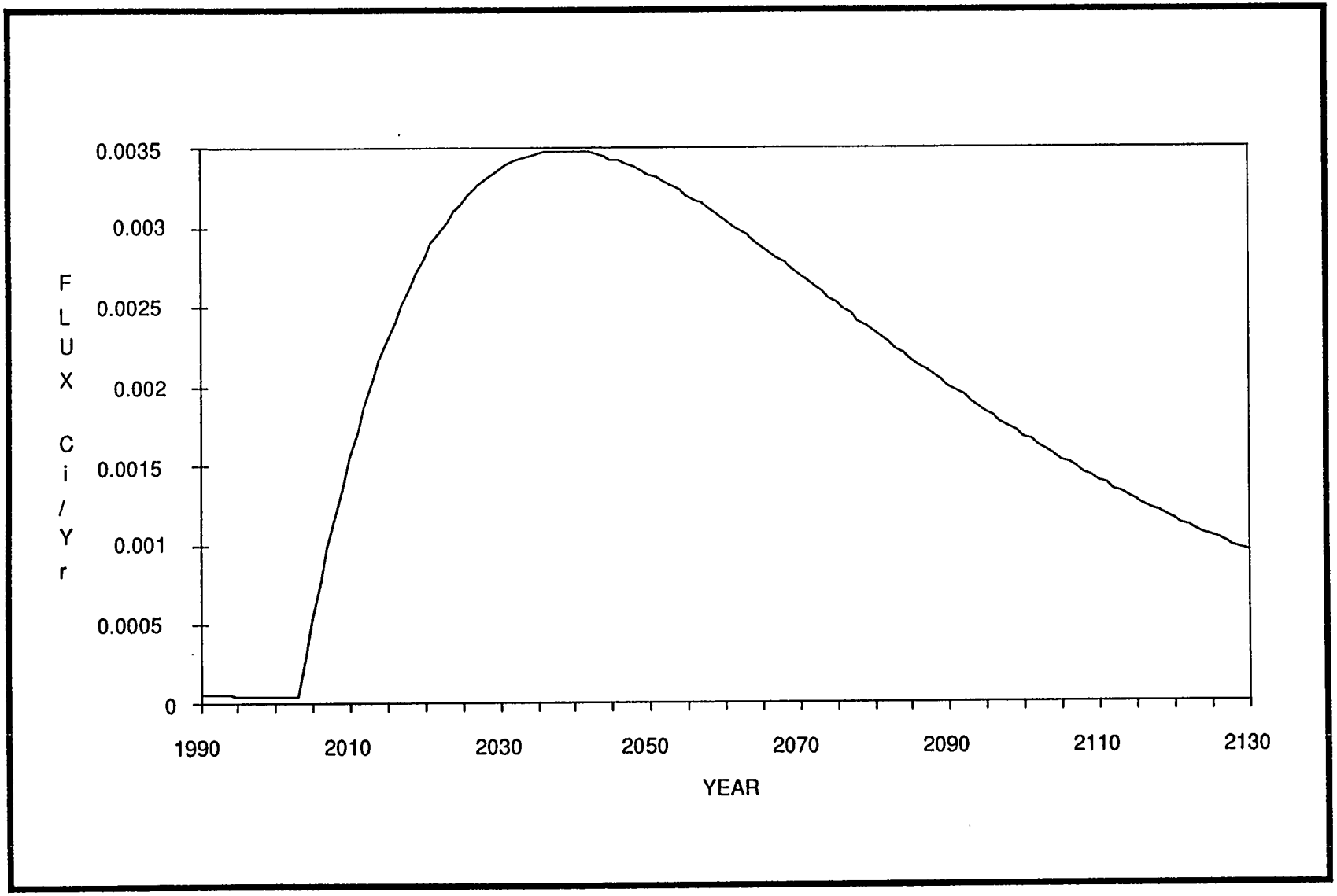



**Fig. 5D.39. Total Sr-90 flux in surface water into the emergency waste basin.**

5.18D 4104.118

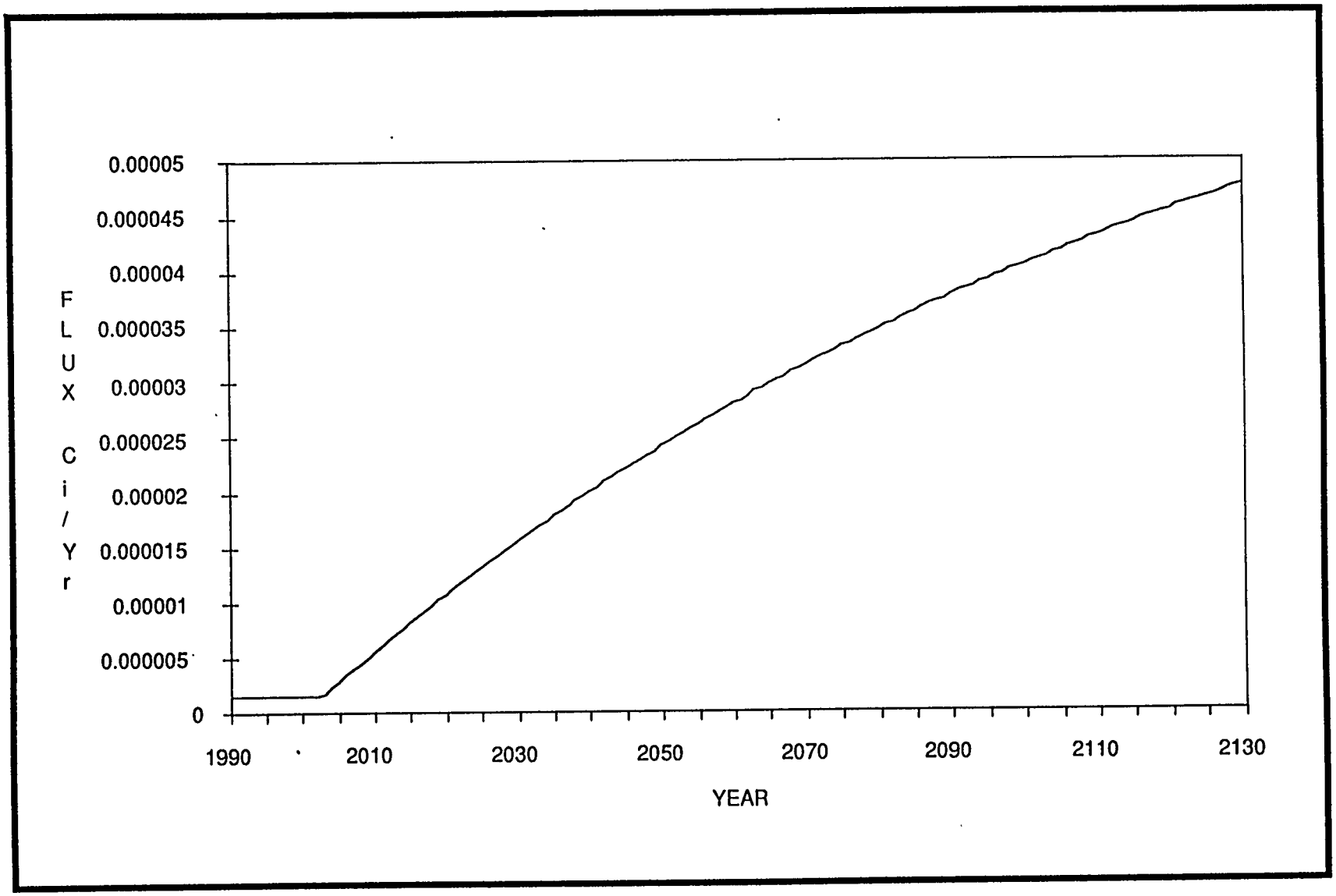



**Fig. 5D.40. Total U-233 flux in surface water into the emergency waste basin.**

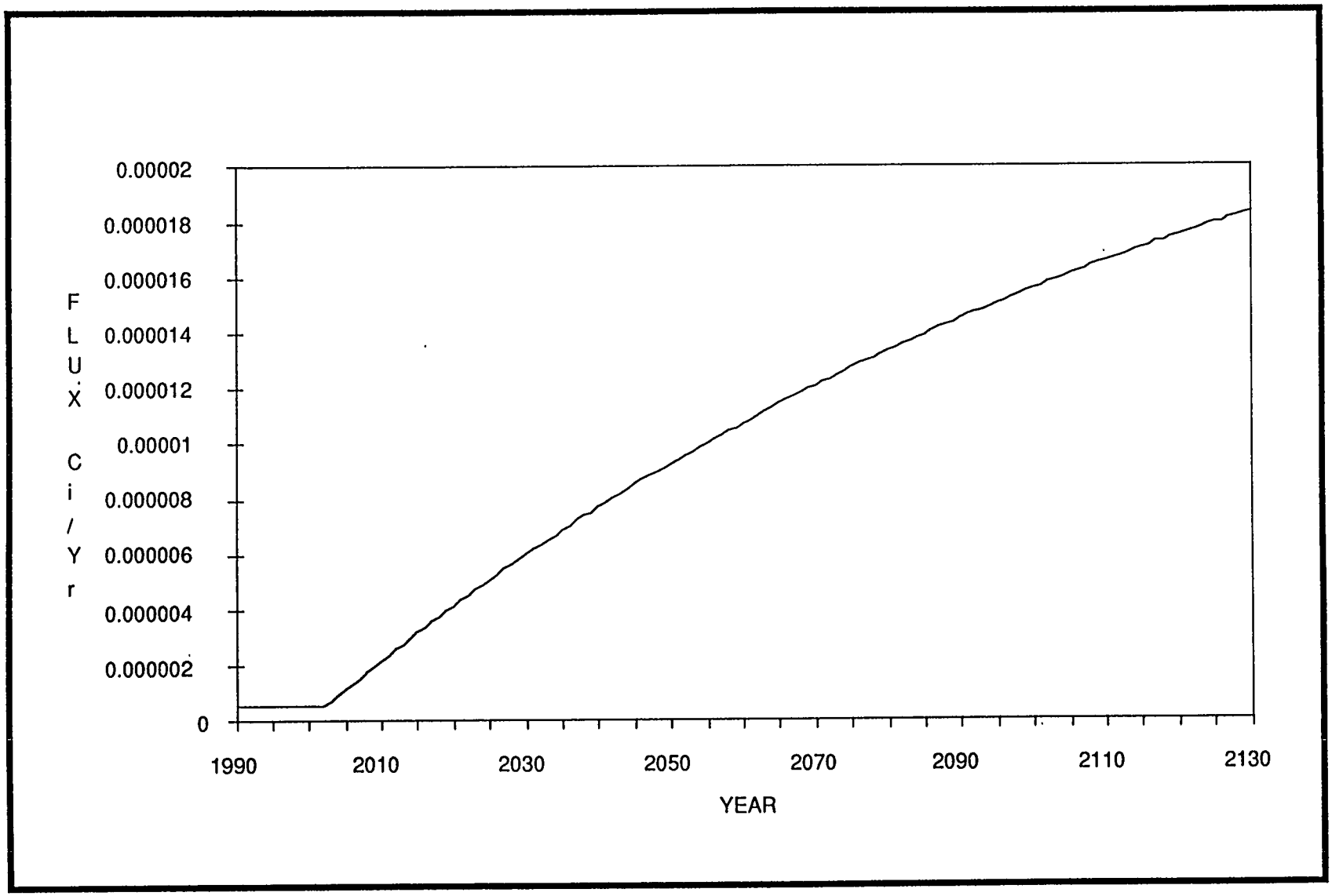



**Fig. 5D.41. Total U-238 flux in surface water into the emergency waste basin.**

5.18D 4104.120

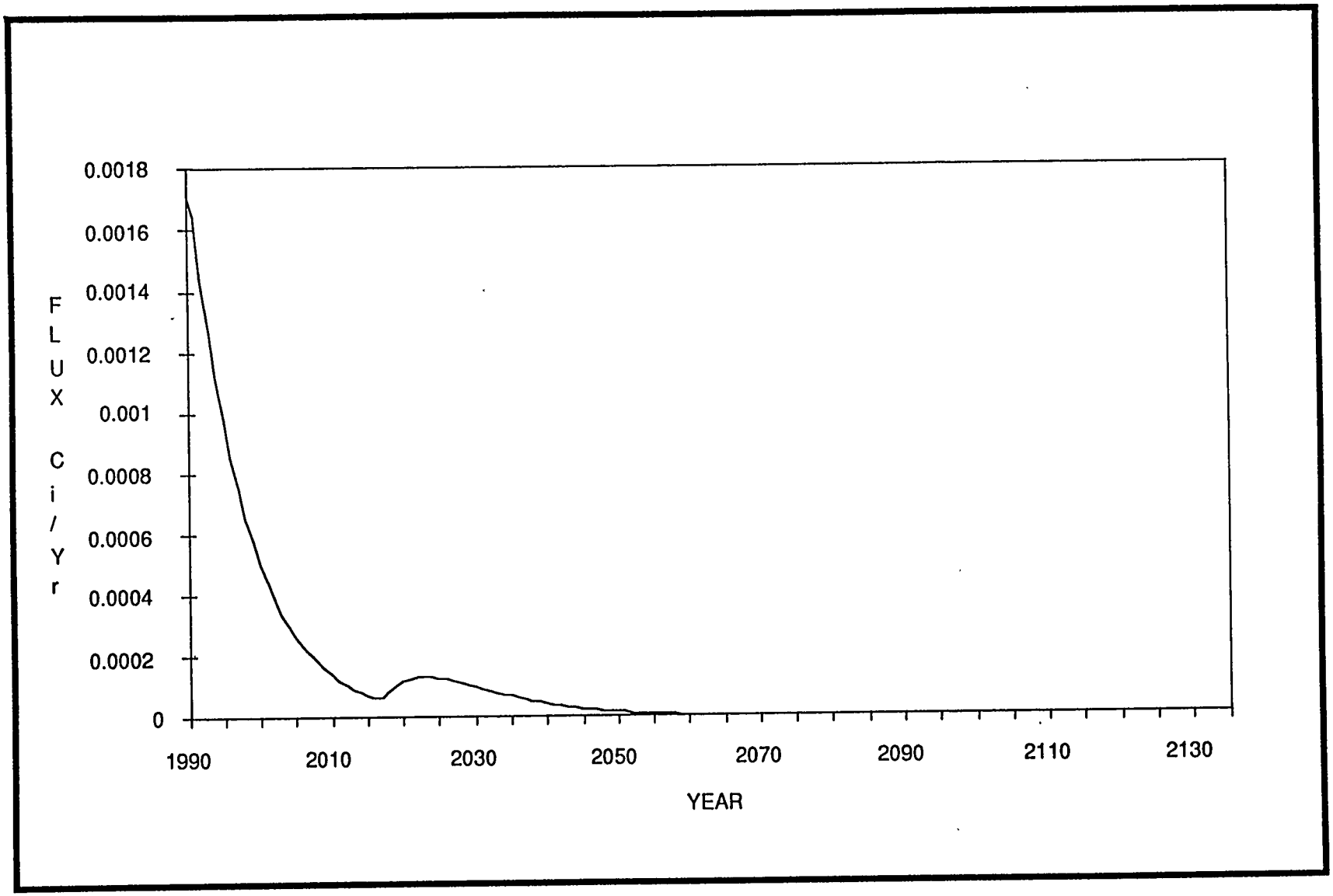



**Fig. 5D.42. Co-60 flux in groundwater across the WAG 6 boundary.**

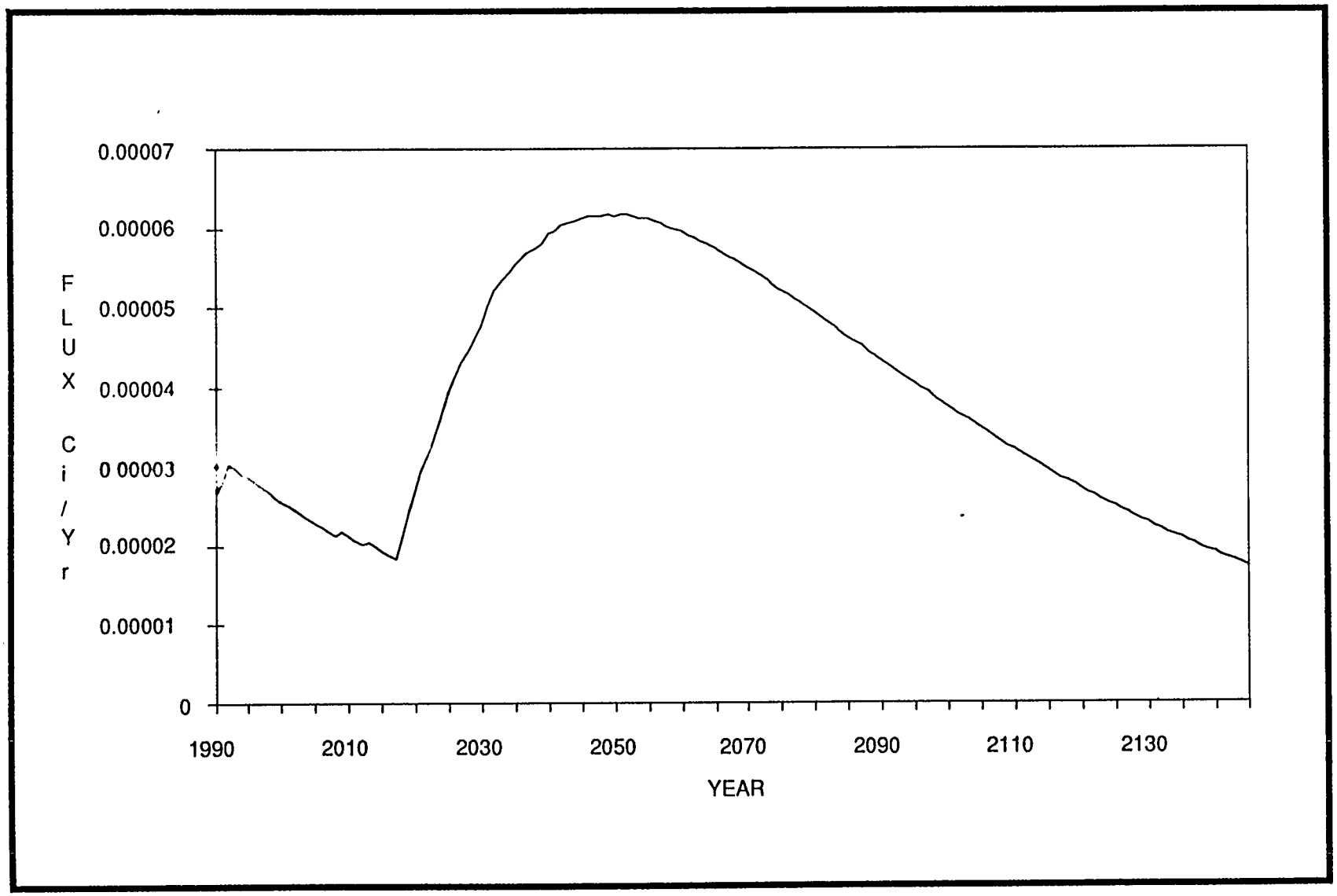



**Fig. 5D.43. Cs-137 flux in groundwater across the WAG 6 boundary.**

5.18D 4104.122

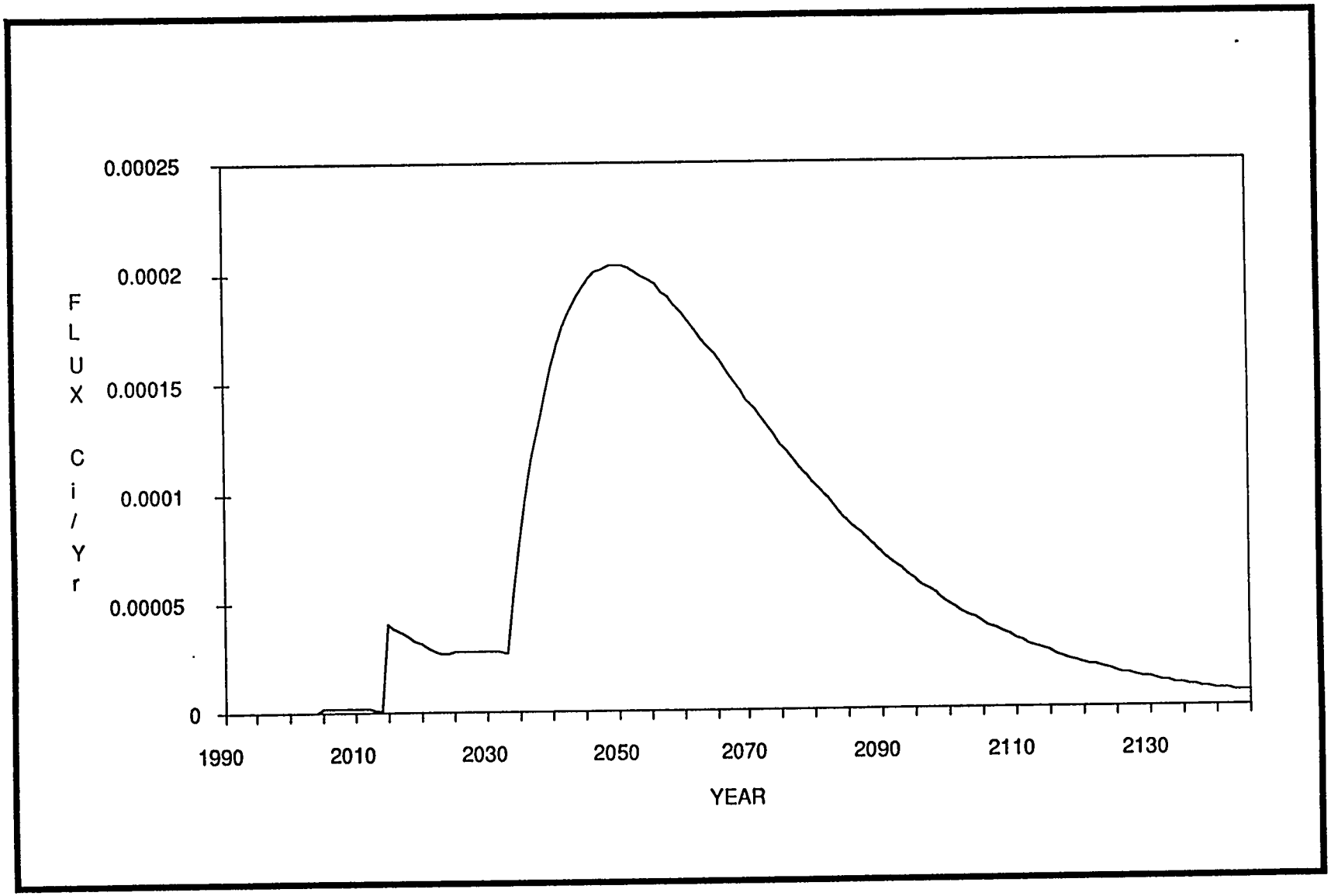



Fig. 5D.44. Eu-152 flux in groundwater across the WAG 6 boundary.

5.18D 4104.123

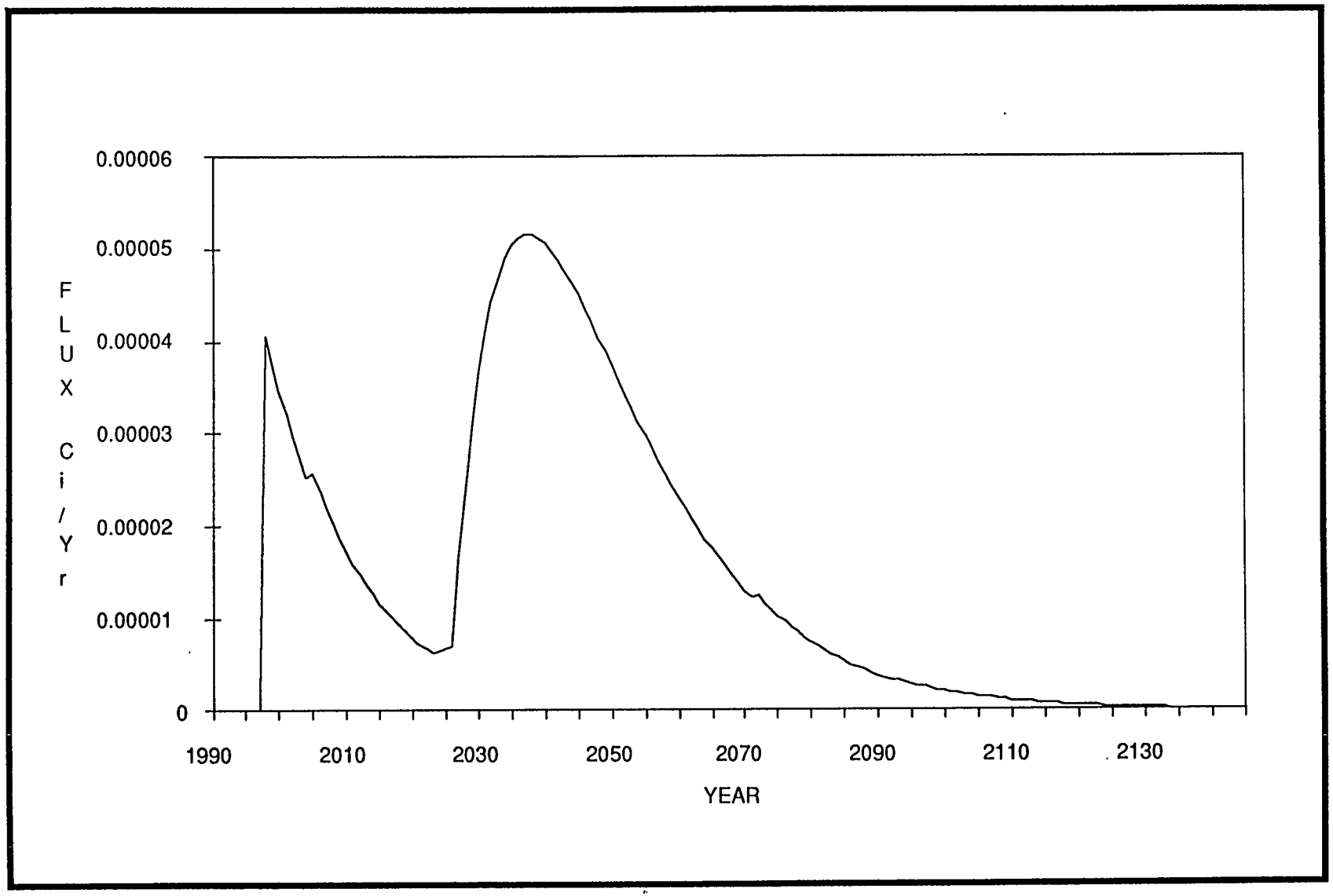



**Fig. 5D.45. Eu-154 flux in groundwater across the WAG 6 boundary.**

5.18D 4104.124

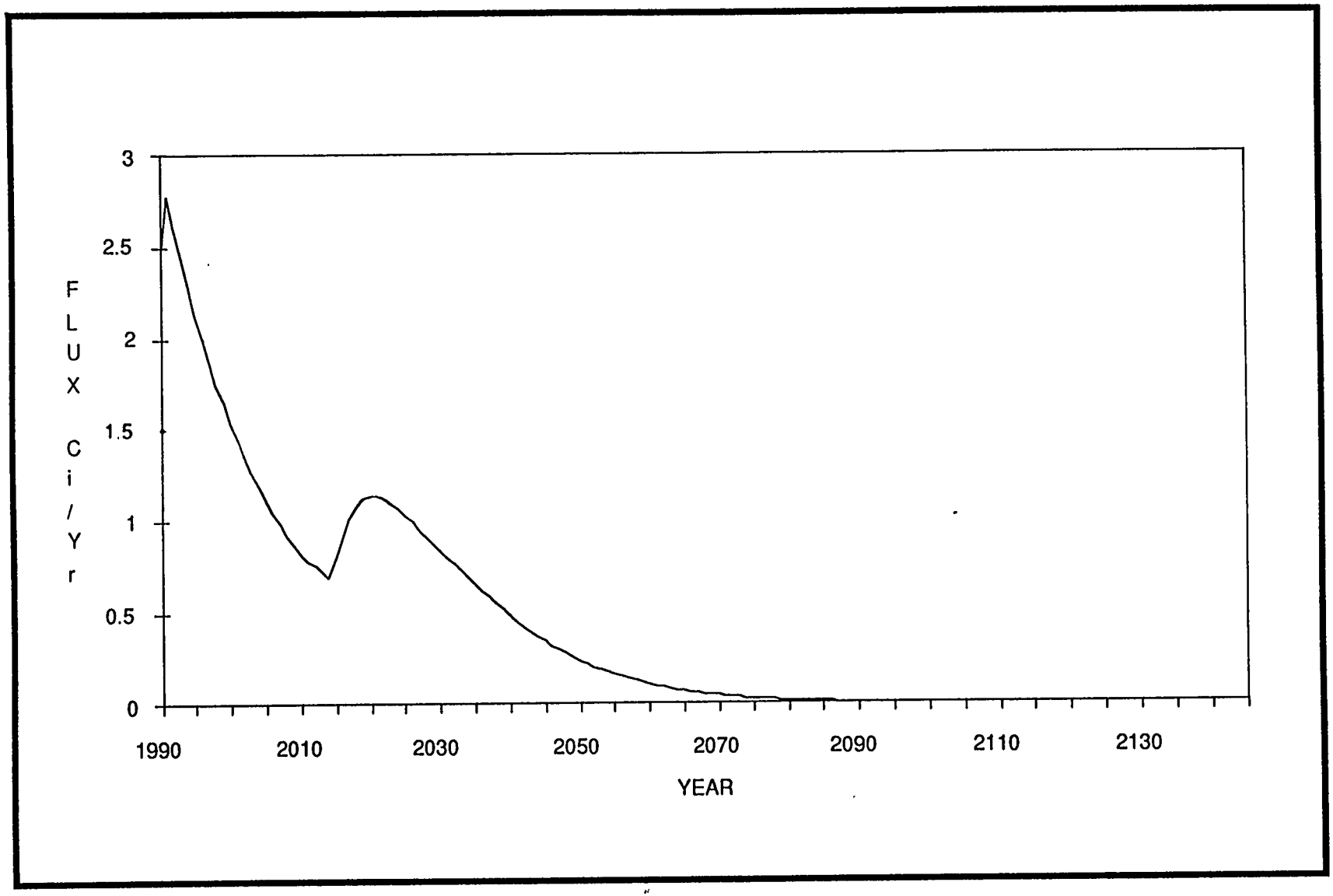



**Fig. 5D.46. H-3 flux in groundwater across the WAG 6 boundary.**

5.18D 4104.125

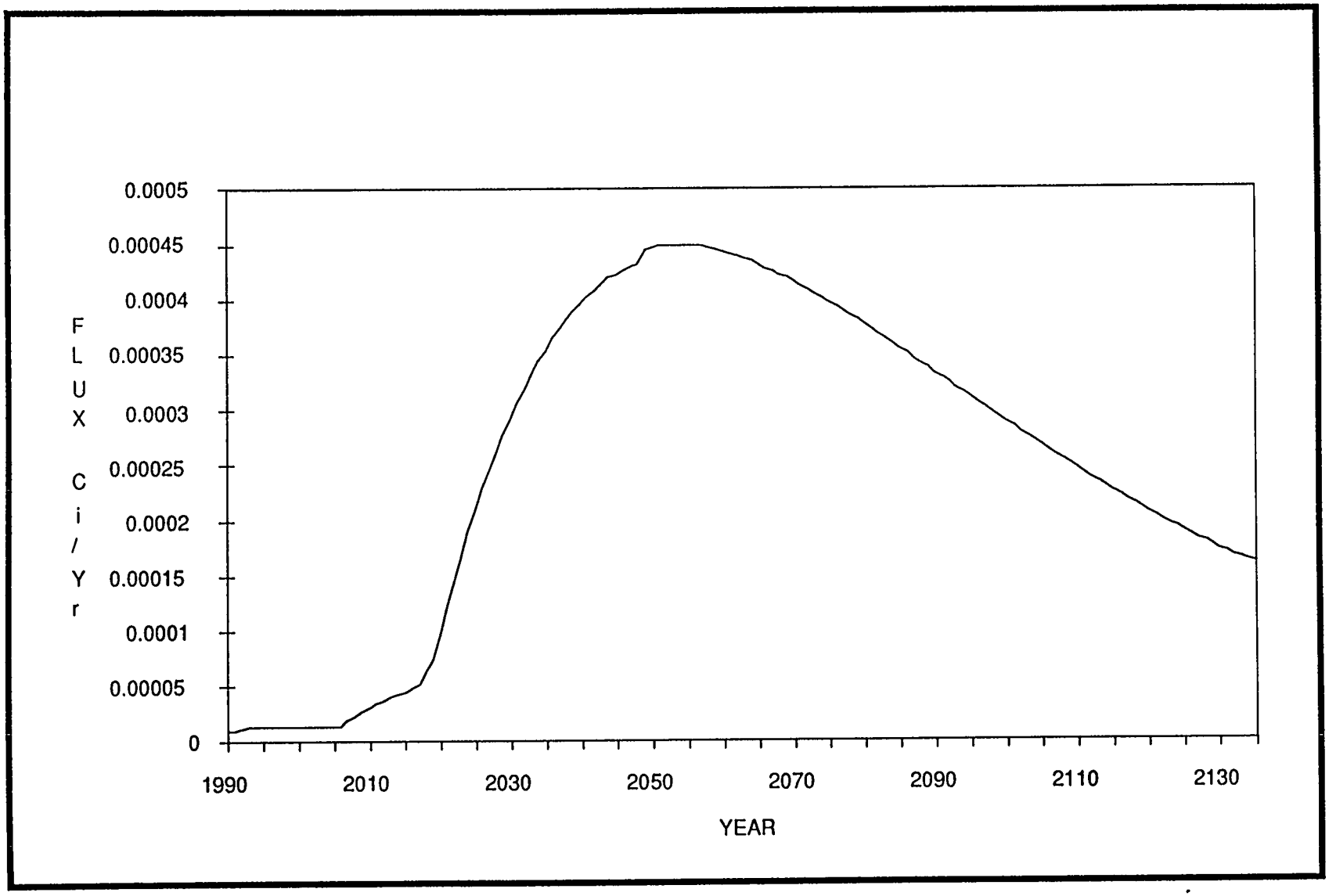



**Fig. 5D.47. Sr-90 flux in groundwater across the WAG 6 boundary.**

5.18D 4104.126

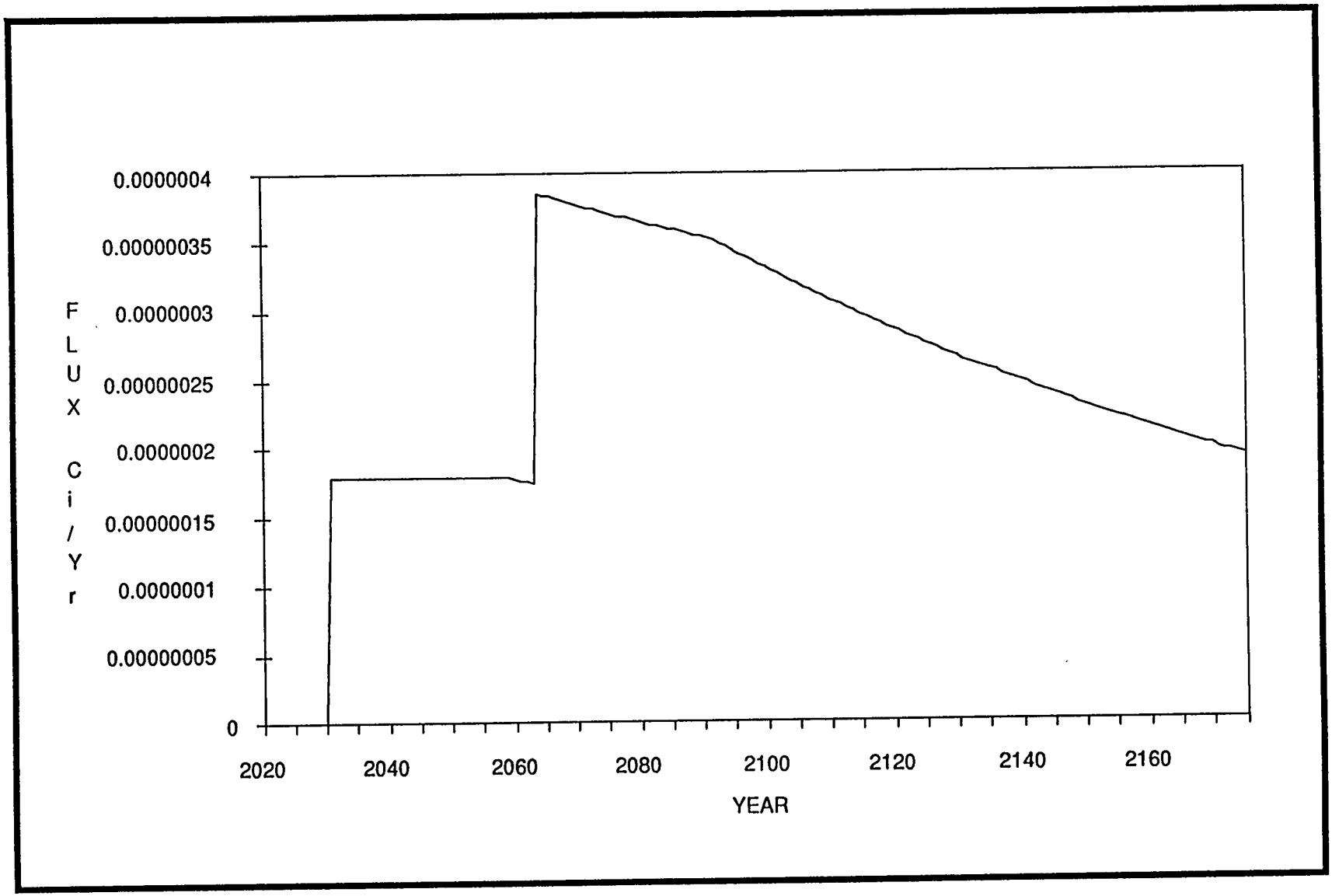



**Fig. 5D.48. Th-232 flux in groundwater across the WAG 6 boundary.**

5.18D 4104.127

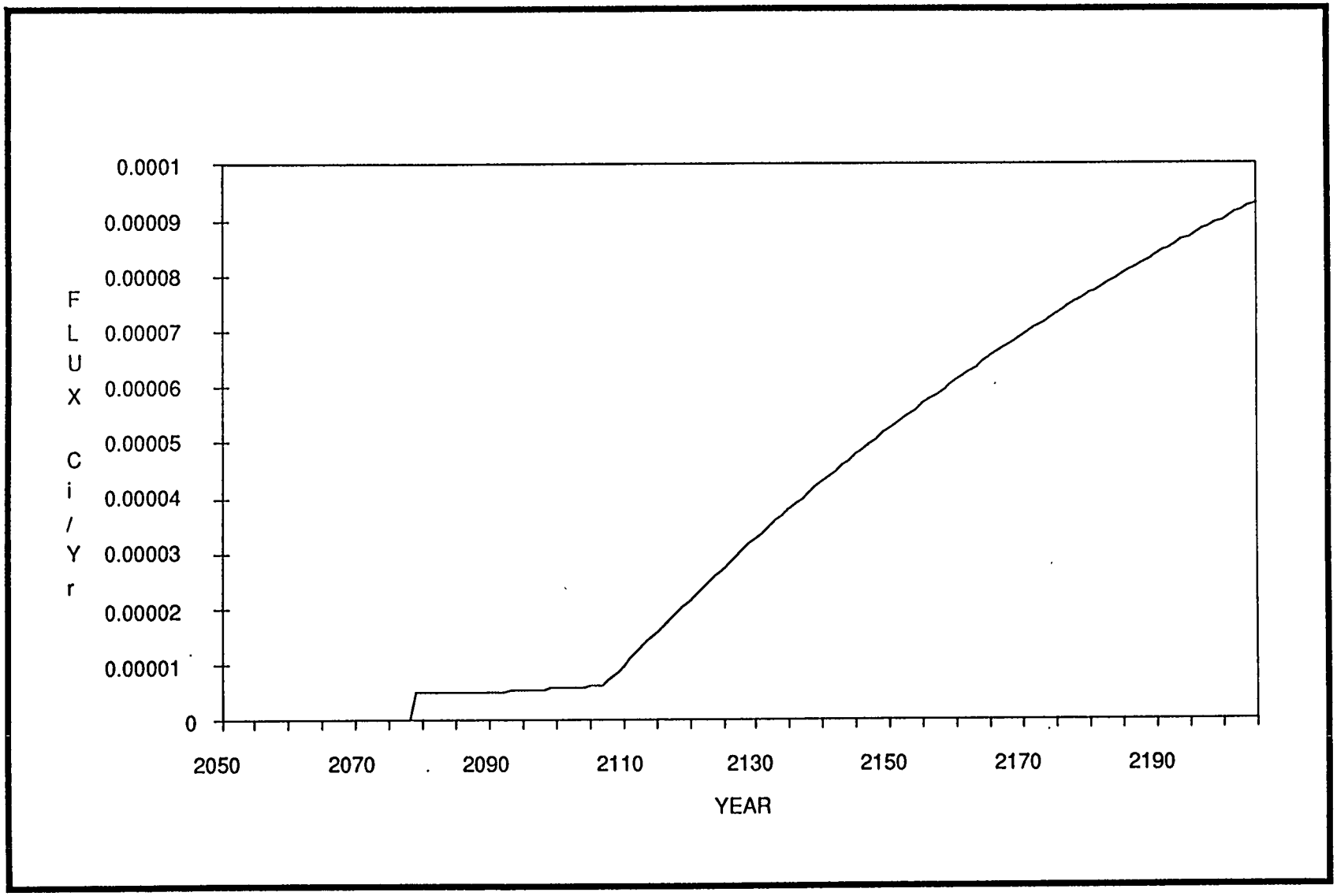



**Fig. 5D.49. U-233 flux in groundwater across the WAG 6 boundary.**

5.18D 4104.128

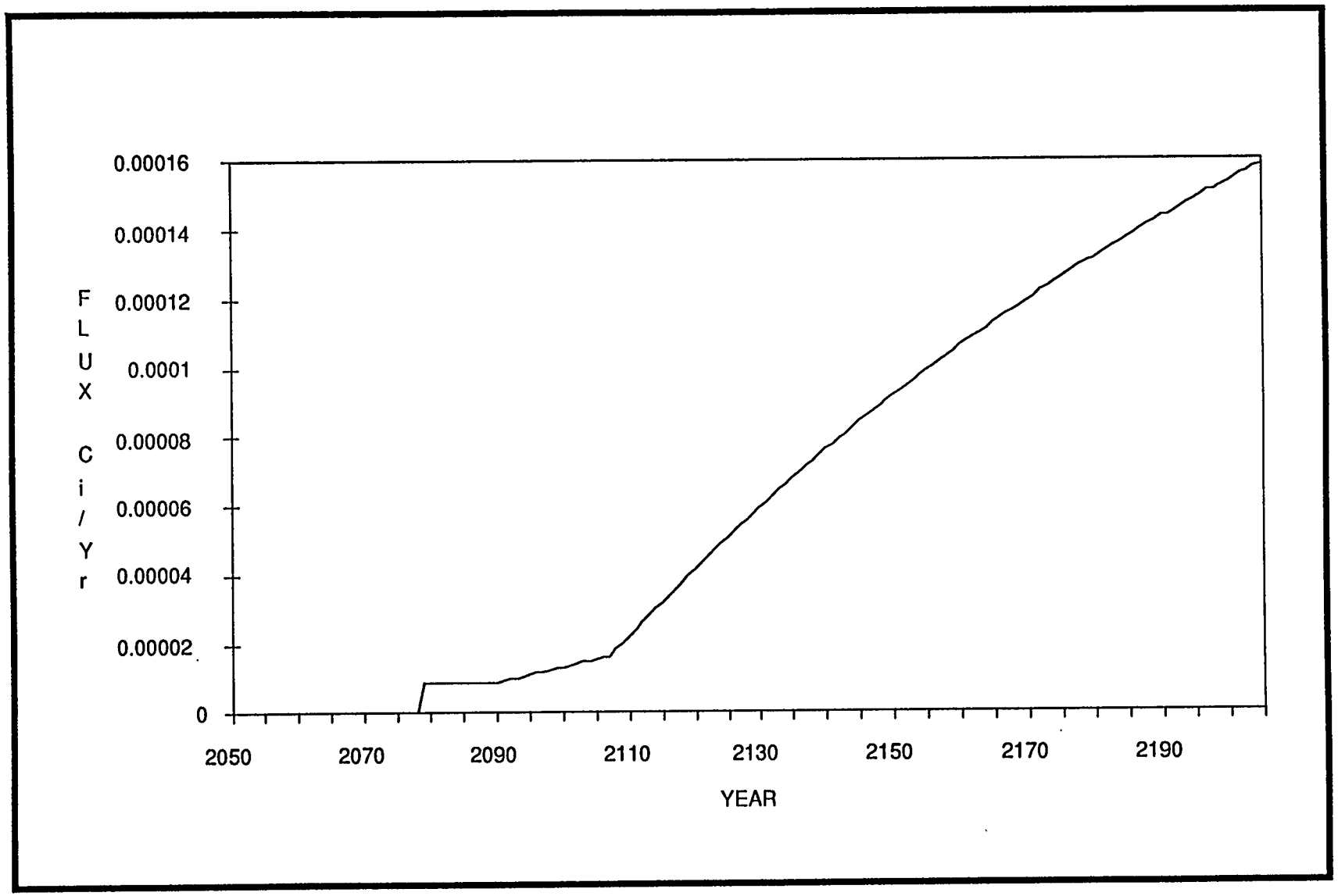



**Fig. 5D.50. U-238 flux in groundwater across the WAG 6 boundary.**

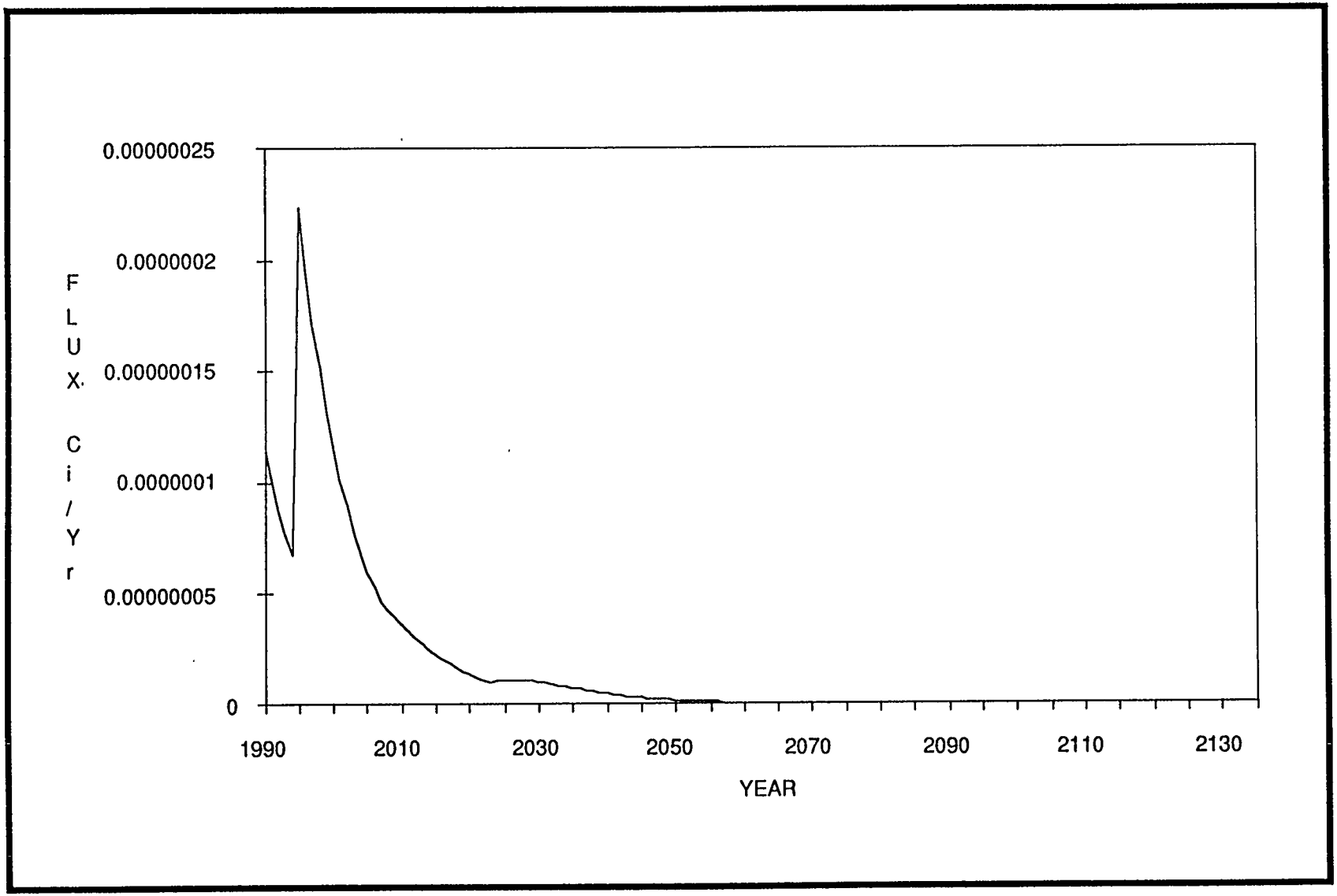



**Fig. 5D.51. Co-60 flux in groundwater into the emergency waste basin.**

5.18D 4104.130

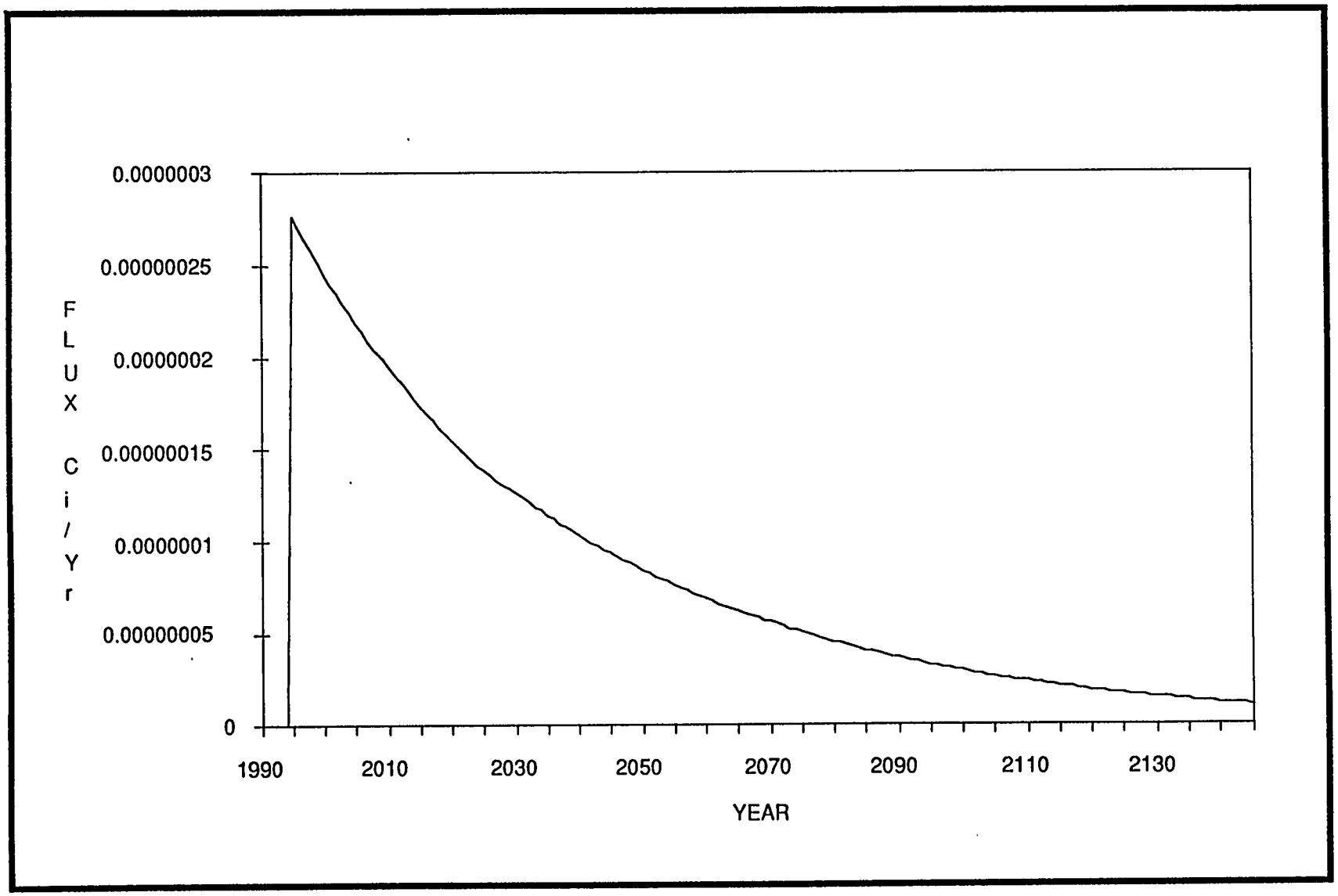



**Fig. 5D.52. Cs-137 flux in groundwater into the emergency waste basin.**

5.18D 4104.131

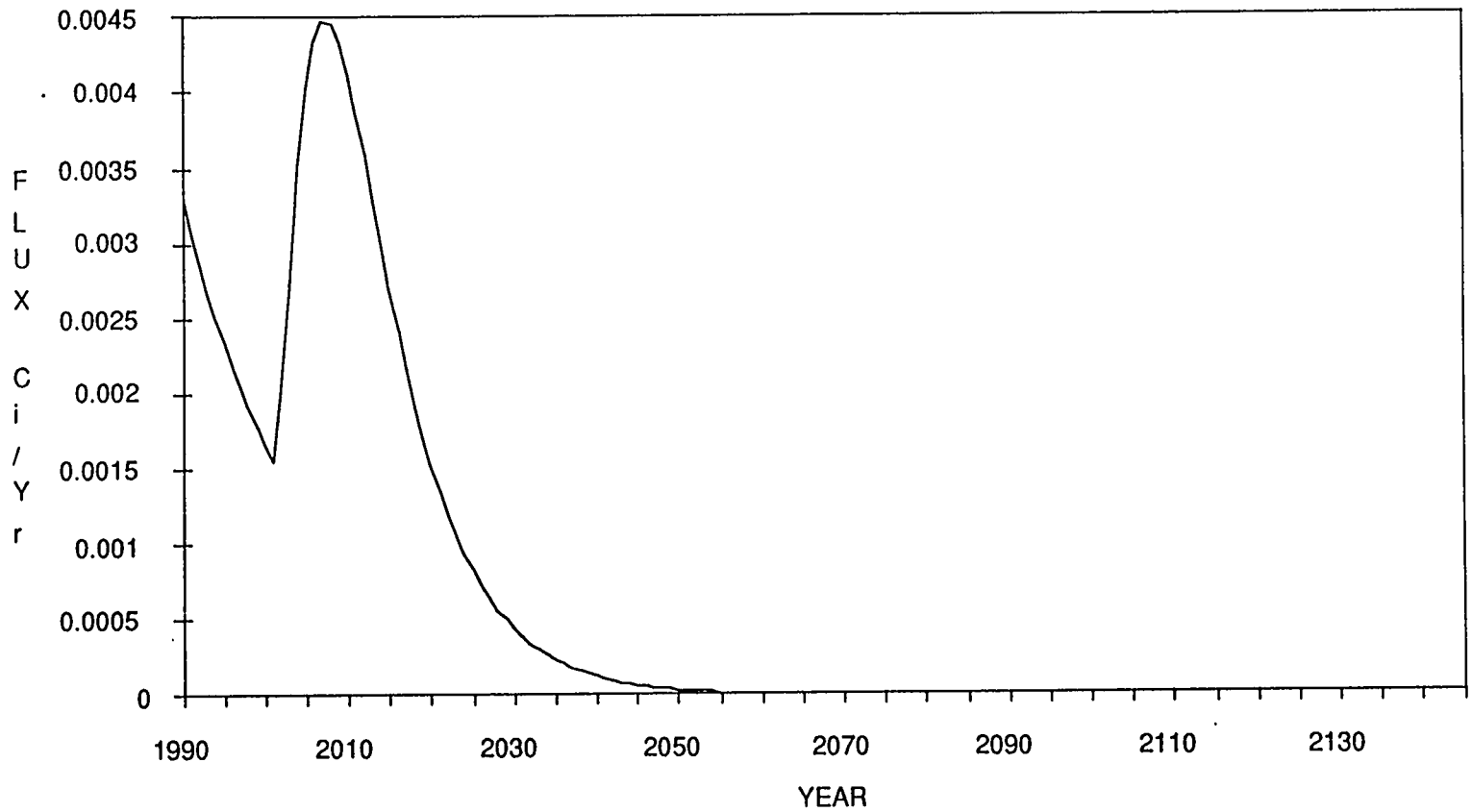



**Fig. 5D.53. H-3 flux in groundwater into the emergency waste basin.**

5.18D 4104.132

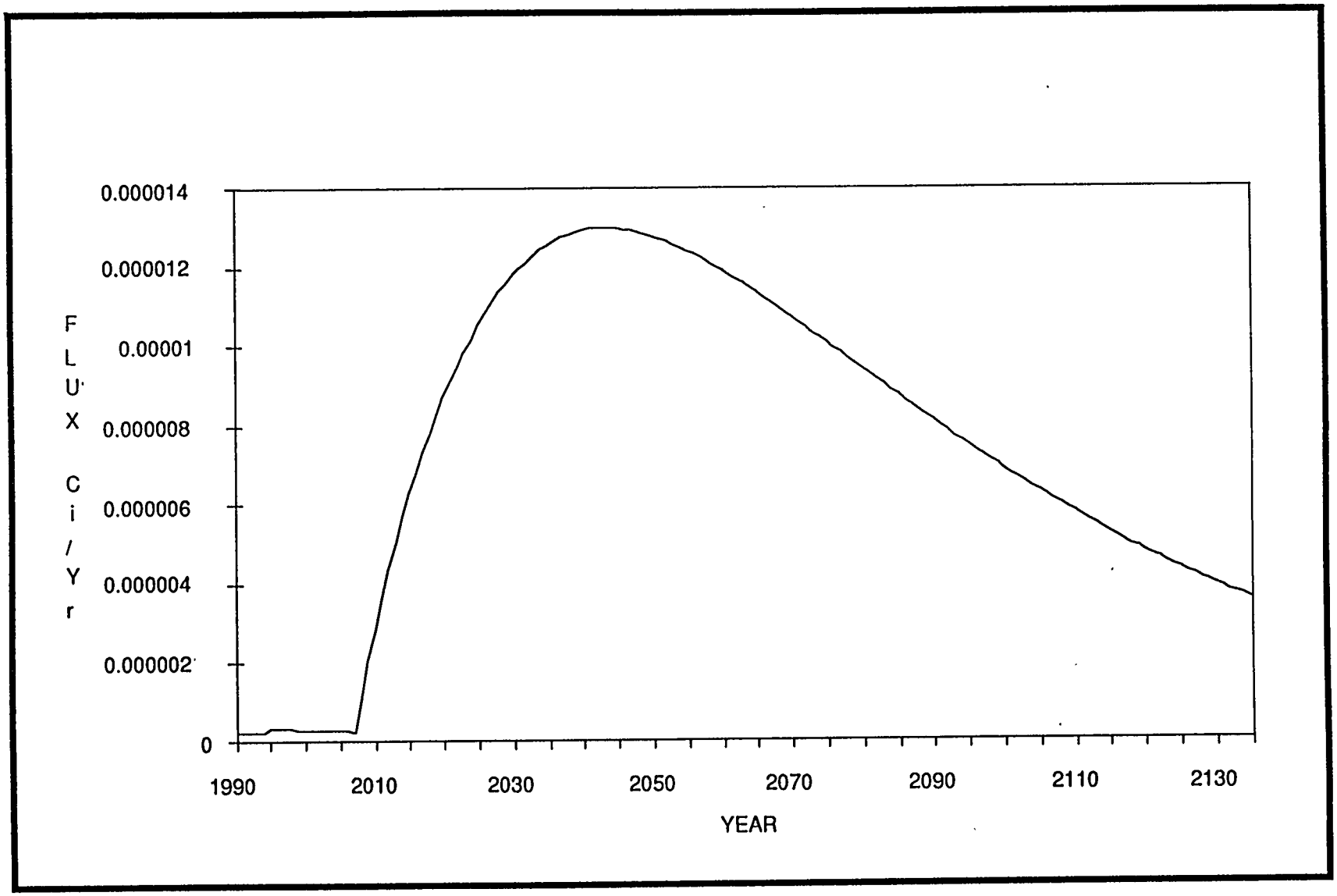



**Fig. 5D.54. Sr-90 flux in groundwater into the emergency waste basin.**

5.18D 4104.133

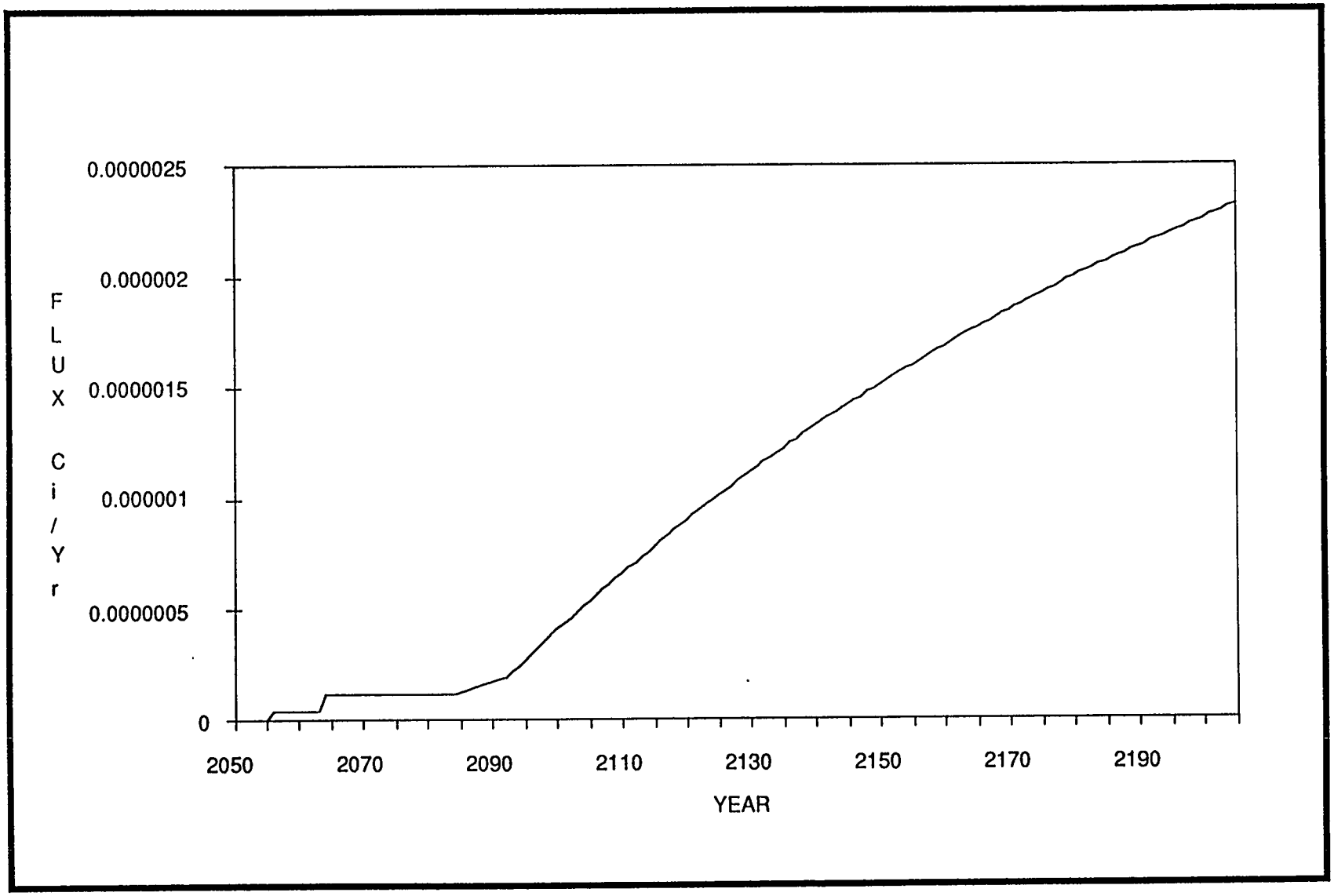



**Fig. 5D.55. U-233 flux in groundwater into the emergency waste basin.**

5.18D 4104.134

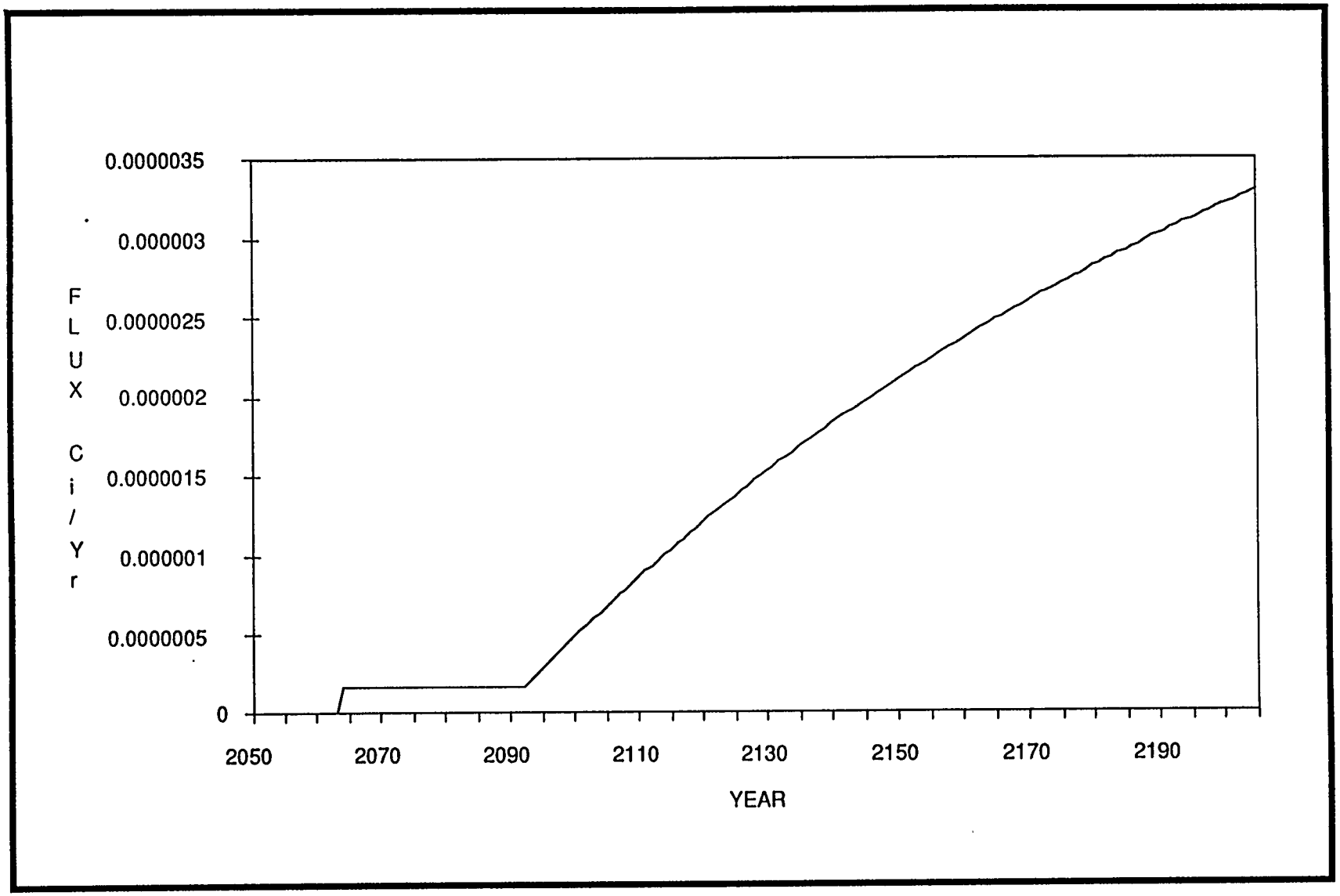



**Fig. 5D.56. U-238 flux in groundwater into the emergency waste basin.**

5.18D 4104.135

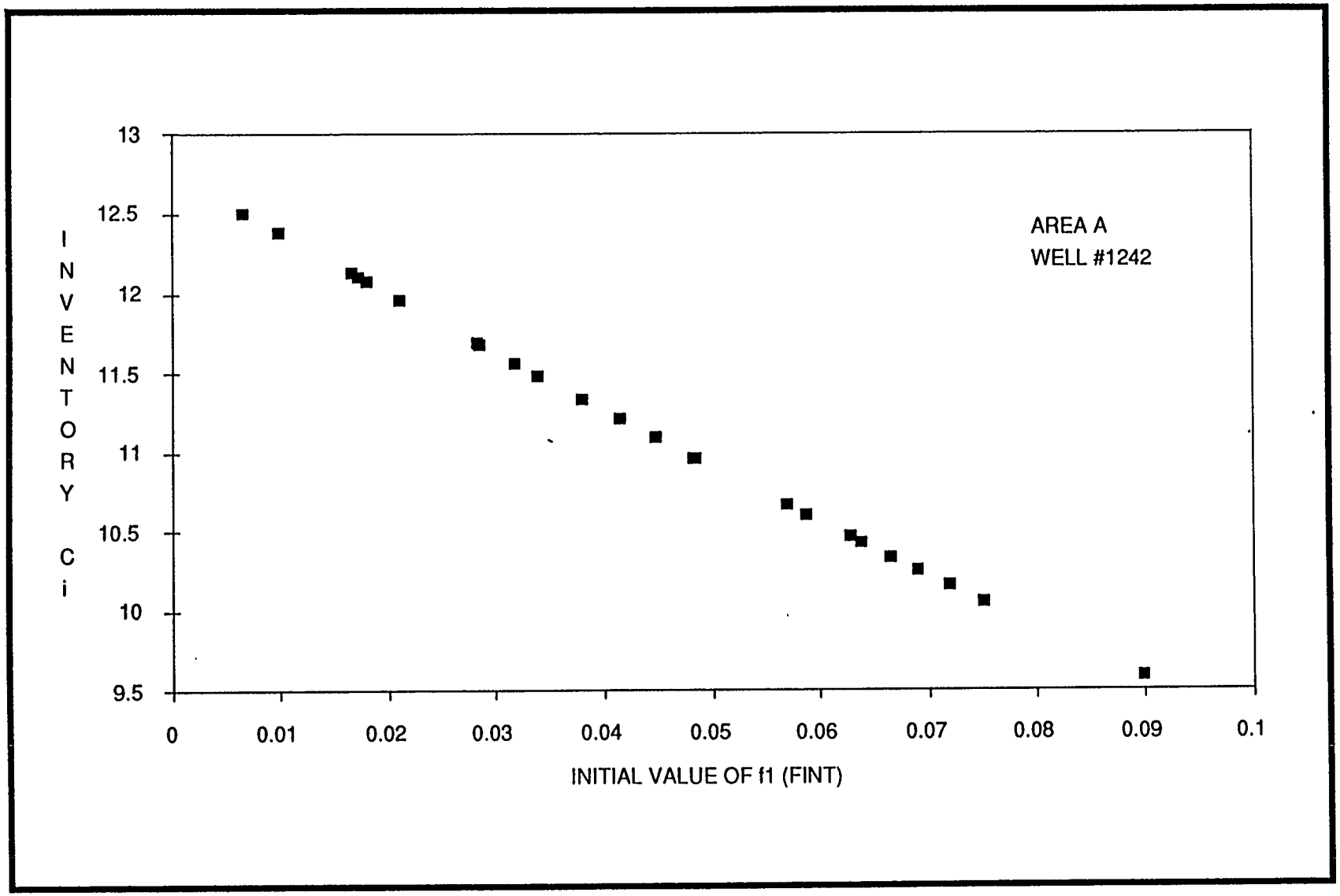



**Fig. 5D.57. Sensitivity analysis of WAG 6 contaminant transport model H-3 inventory — year 30.**

5.18F 4104.148

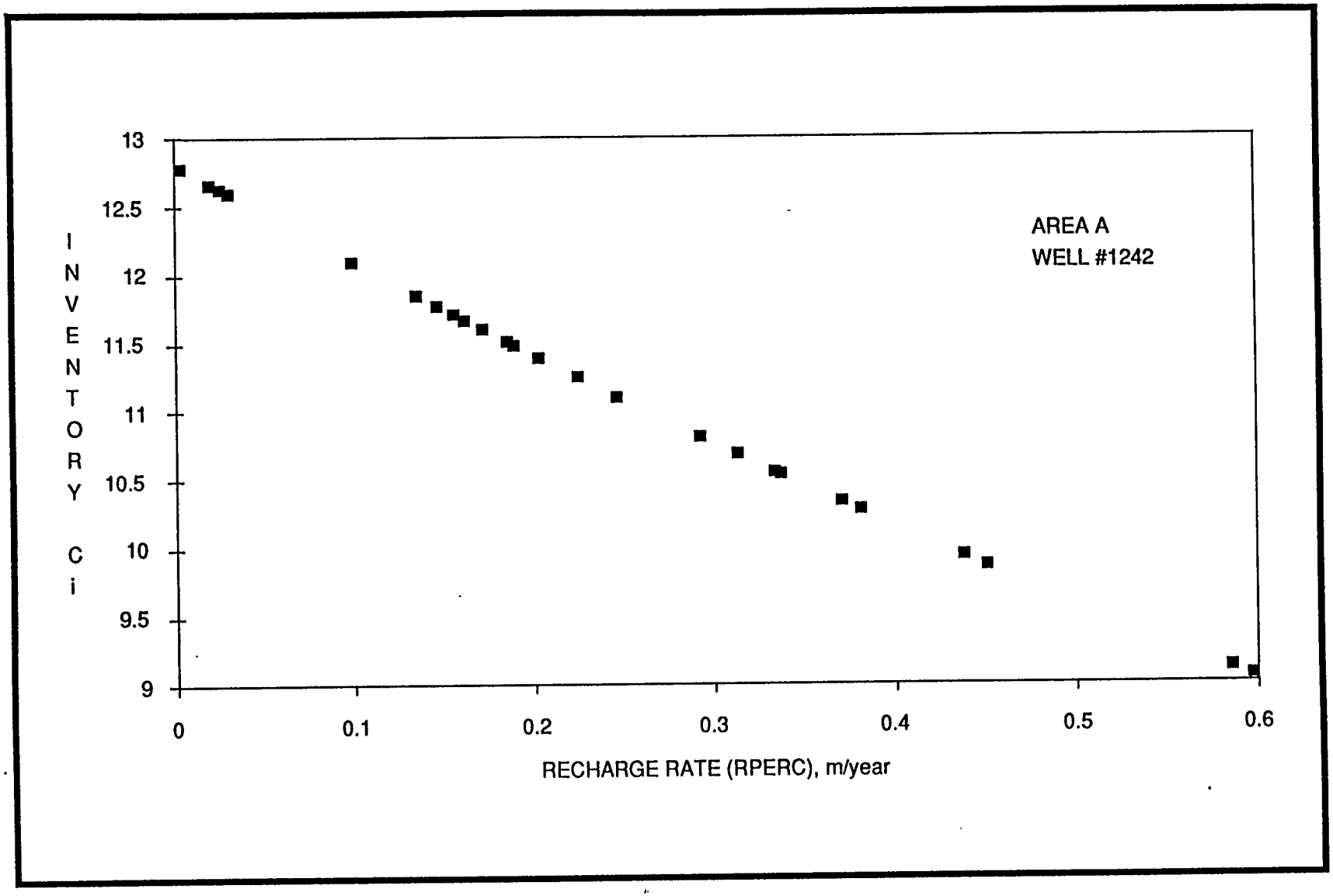



Fig. 5D.58. Sensitivity analysis of WAG 6 contaminant transport model H-3 inventory — year 30.

5.18F 4104.149

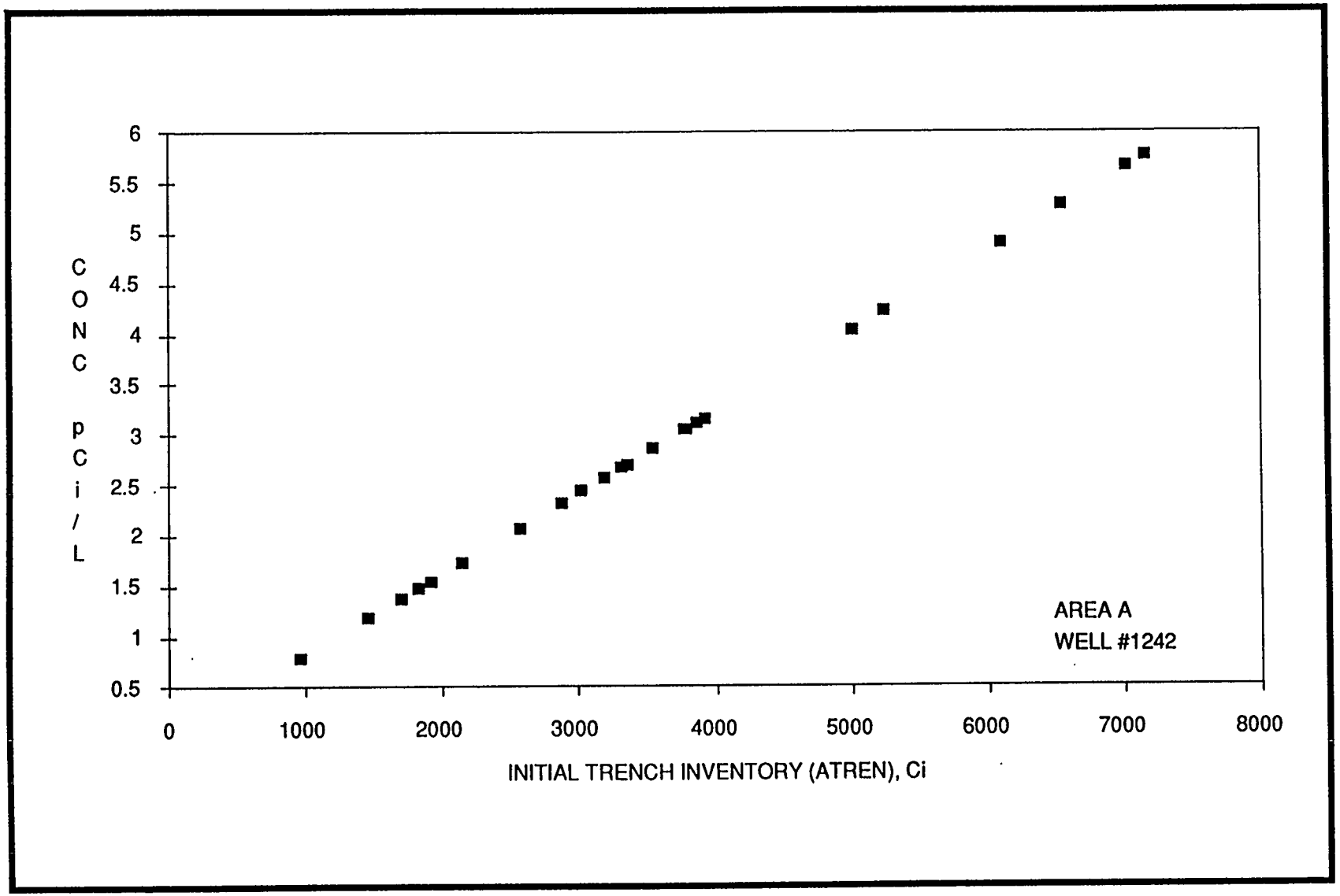



**Fig. 5D.59. Sensitivity analysis of WAG 6 contaminant transport model Co-60 concentration — year 1.**

5.18F 4104.150

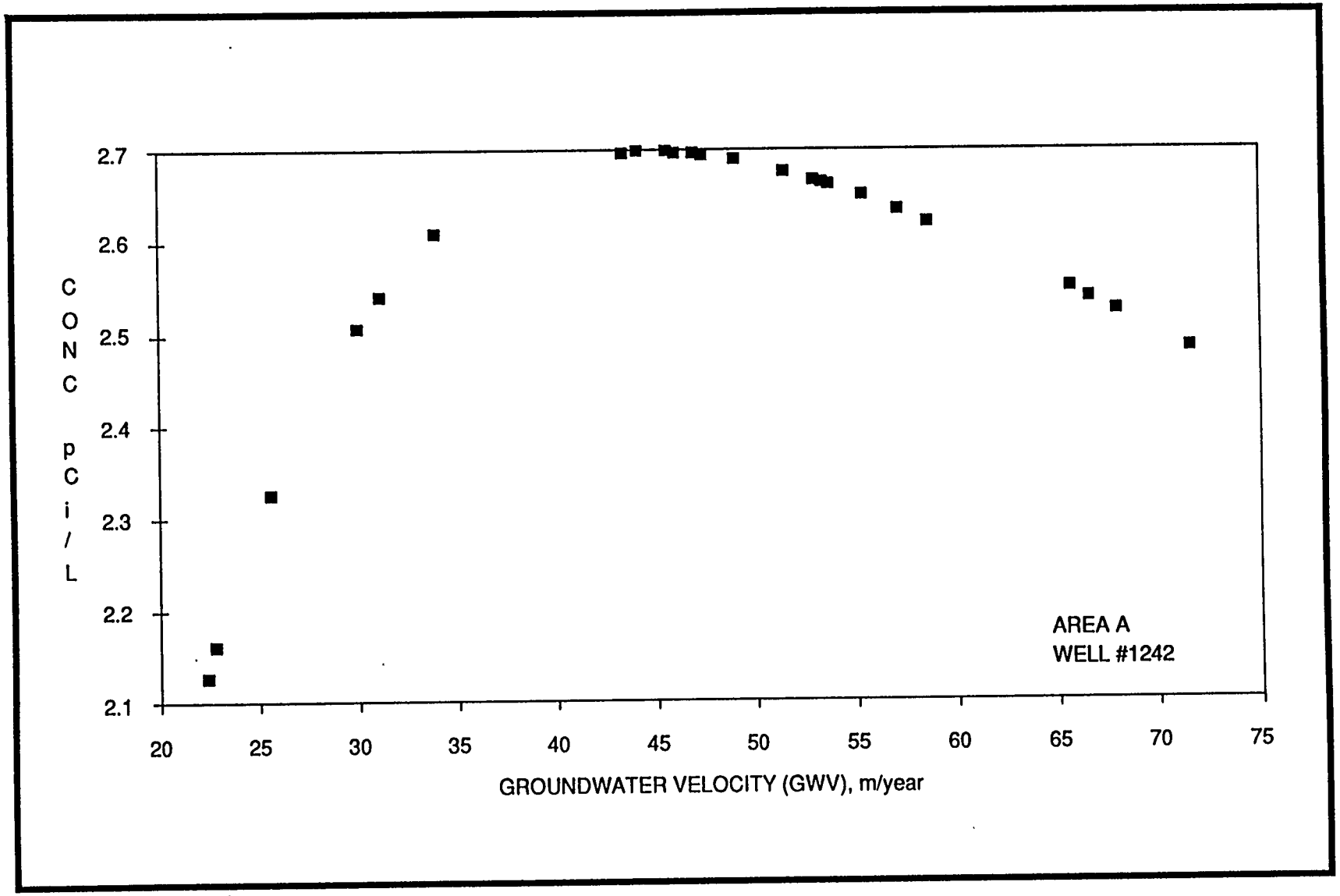



Fig. 5D.60. Sensitivity analysis of WAG 6 contaminant transport model Co-60 concentration — year 1.

5.18F 4104.151

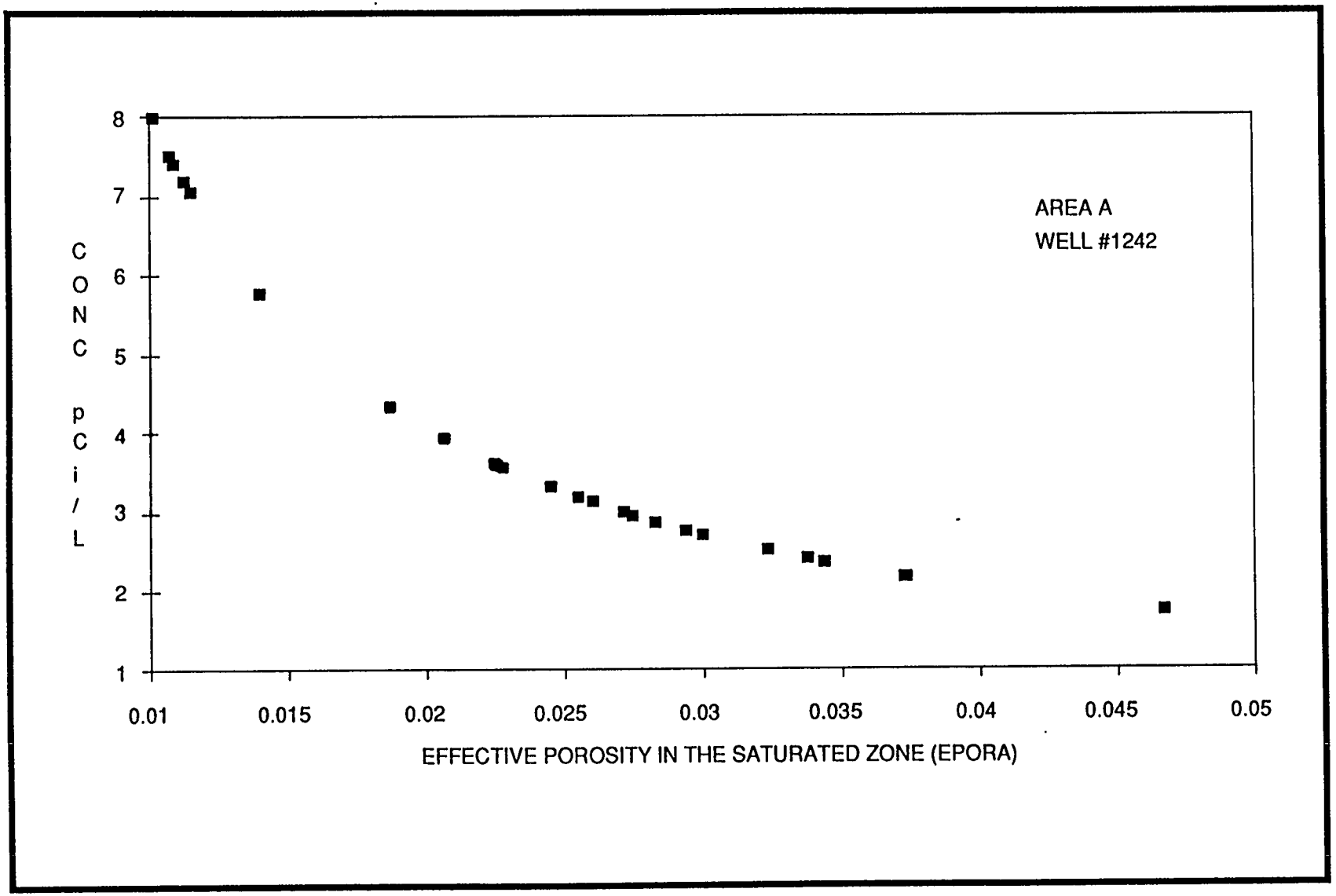



**Fig. 5D.61. Sensitivity analysis of WAG 6 contaminant transport model Co-60 concentration — year 1.**

5.18F 4104.152

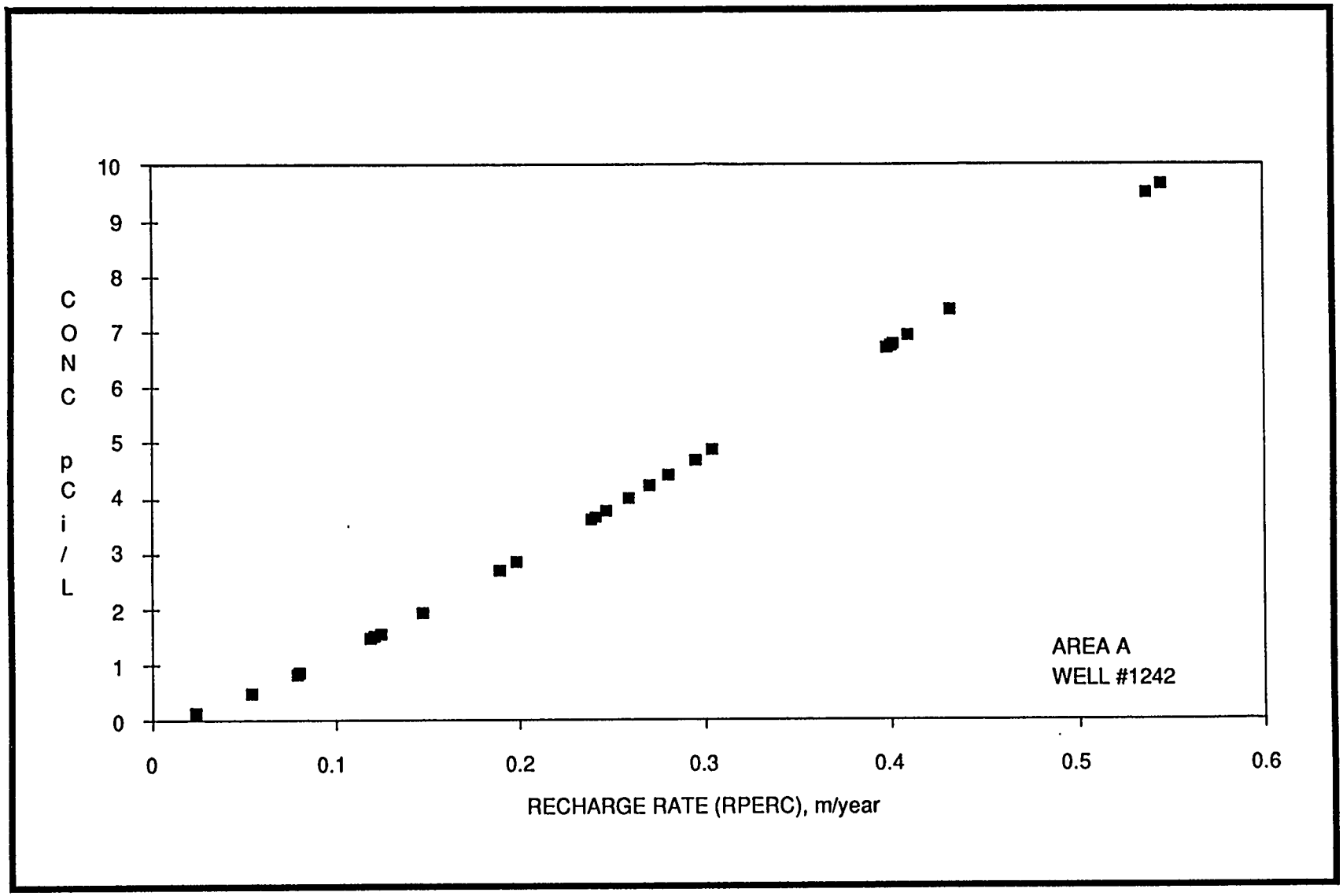



**Fig. 5D.62. Sensitivity analysis of WAG 6 contaminant transport model Co-60 concentration — year 1.**

5.18F 4104.153

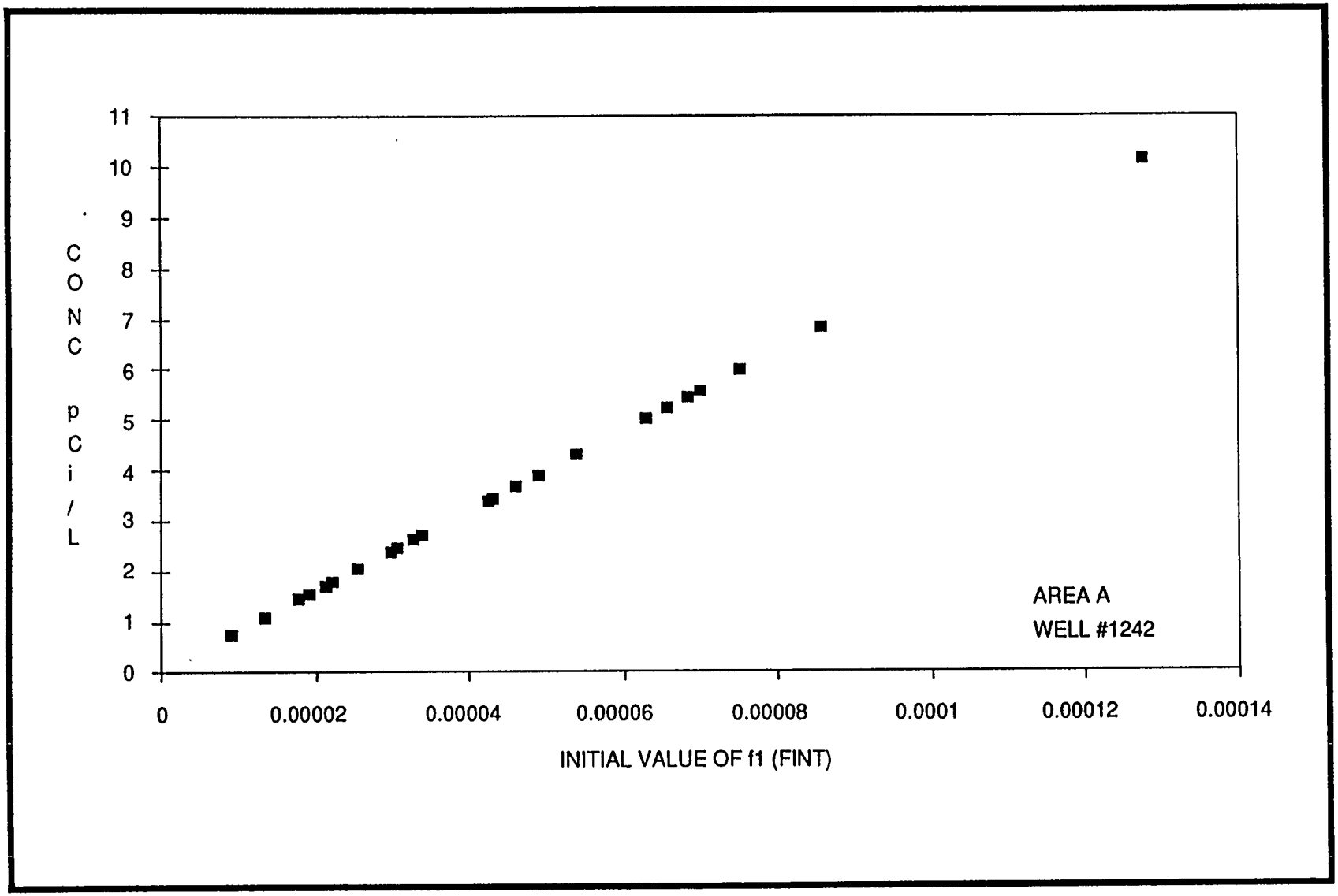



**Fig. 5D.63. Sensitivity analysis of WAG 6 contaminant transport model Co-60 concentration — year 1.**

5.18F 4104.154

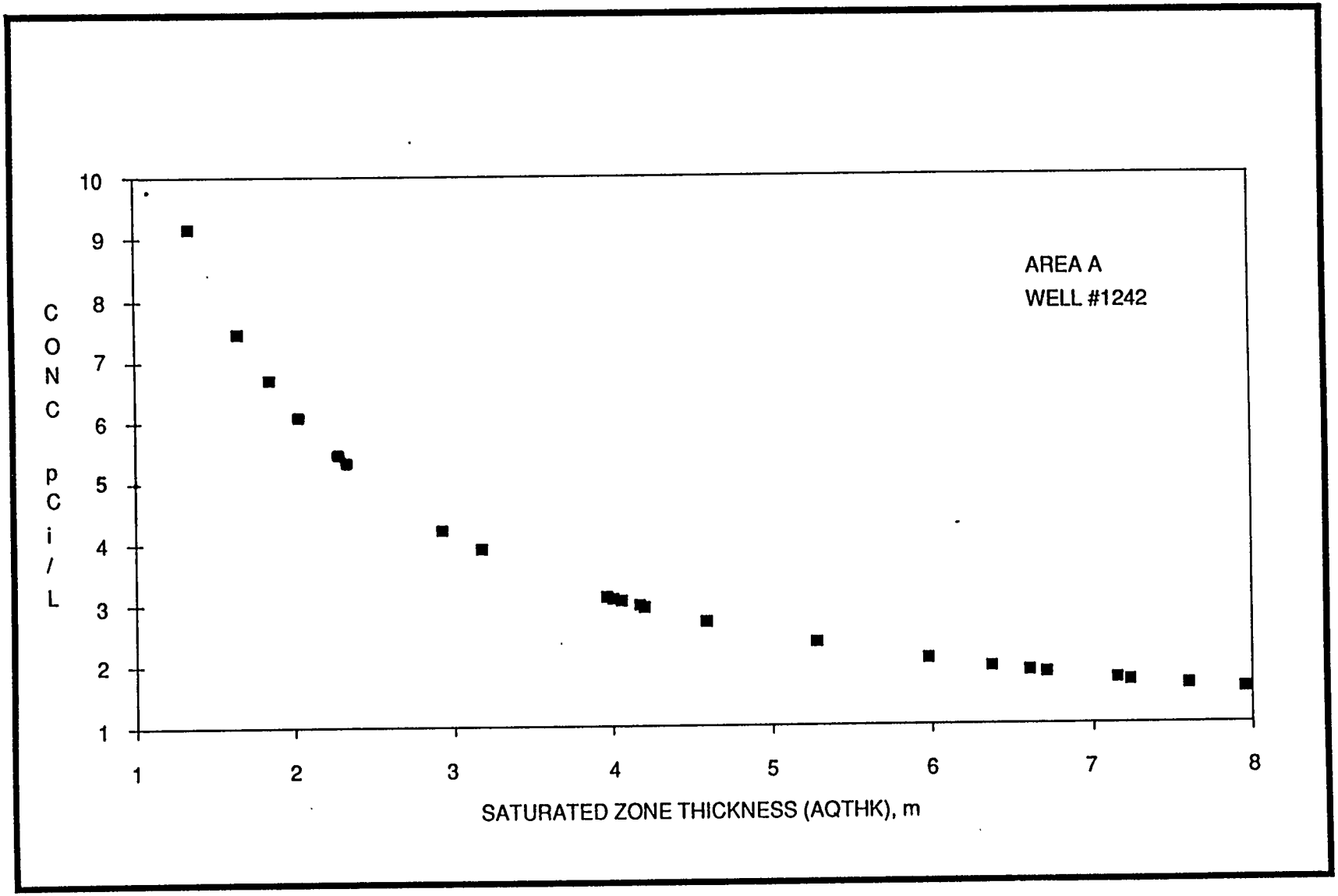



Fig. 5D.64. Sensitivity analysis of WAG 6 contaminant transport model Co-60 concentration — year 1.

5.18F 4104.155

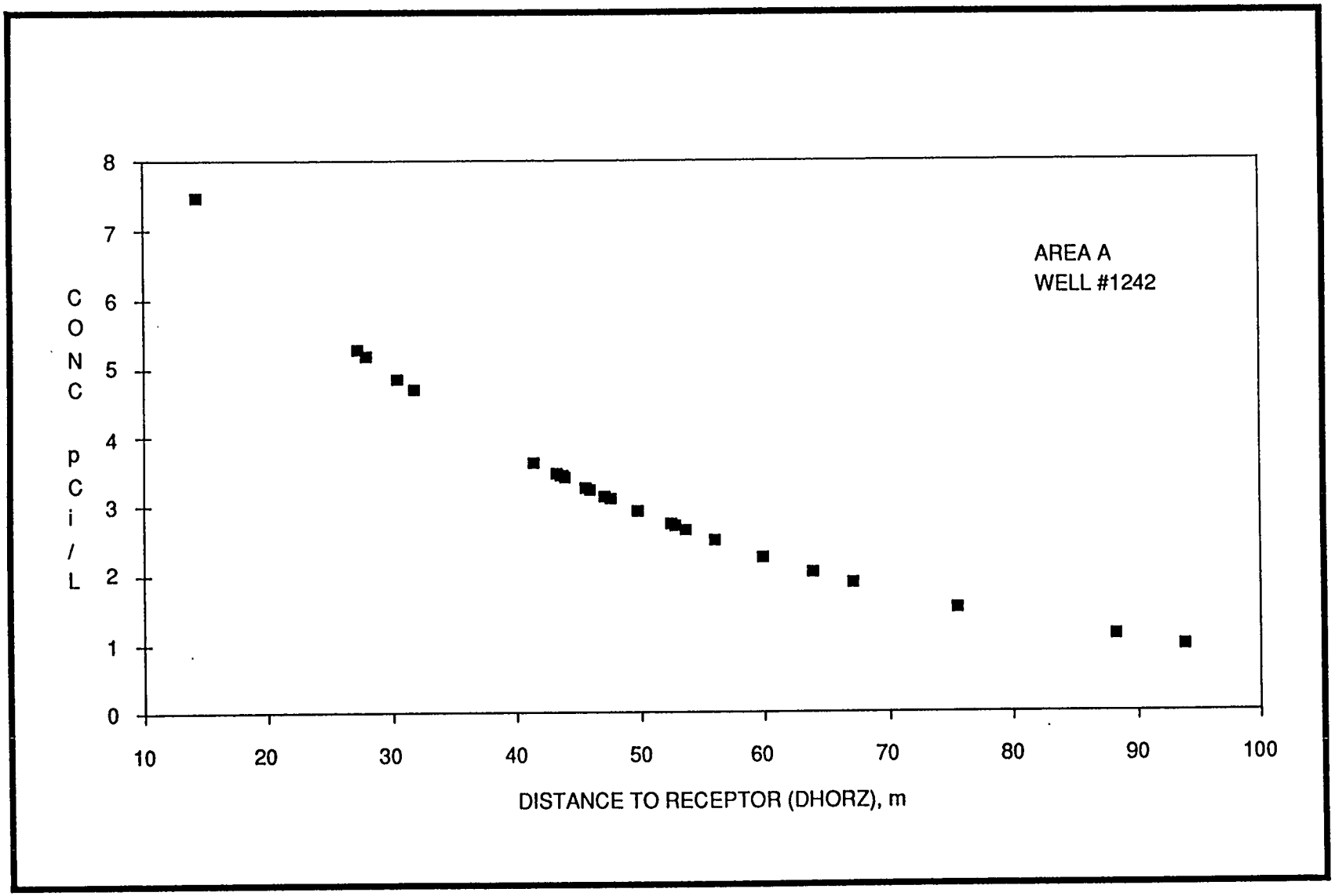



**Fig. 5D.65. Sensitivity analysis of WAG 6 contaminant transport model Co-60 concentration — year 1.**

5.18F 4104.156

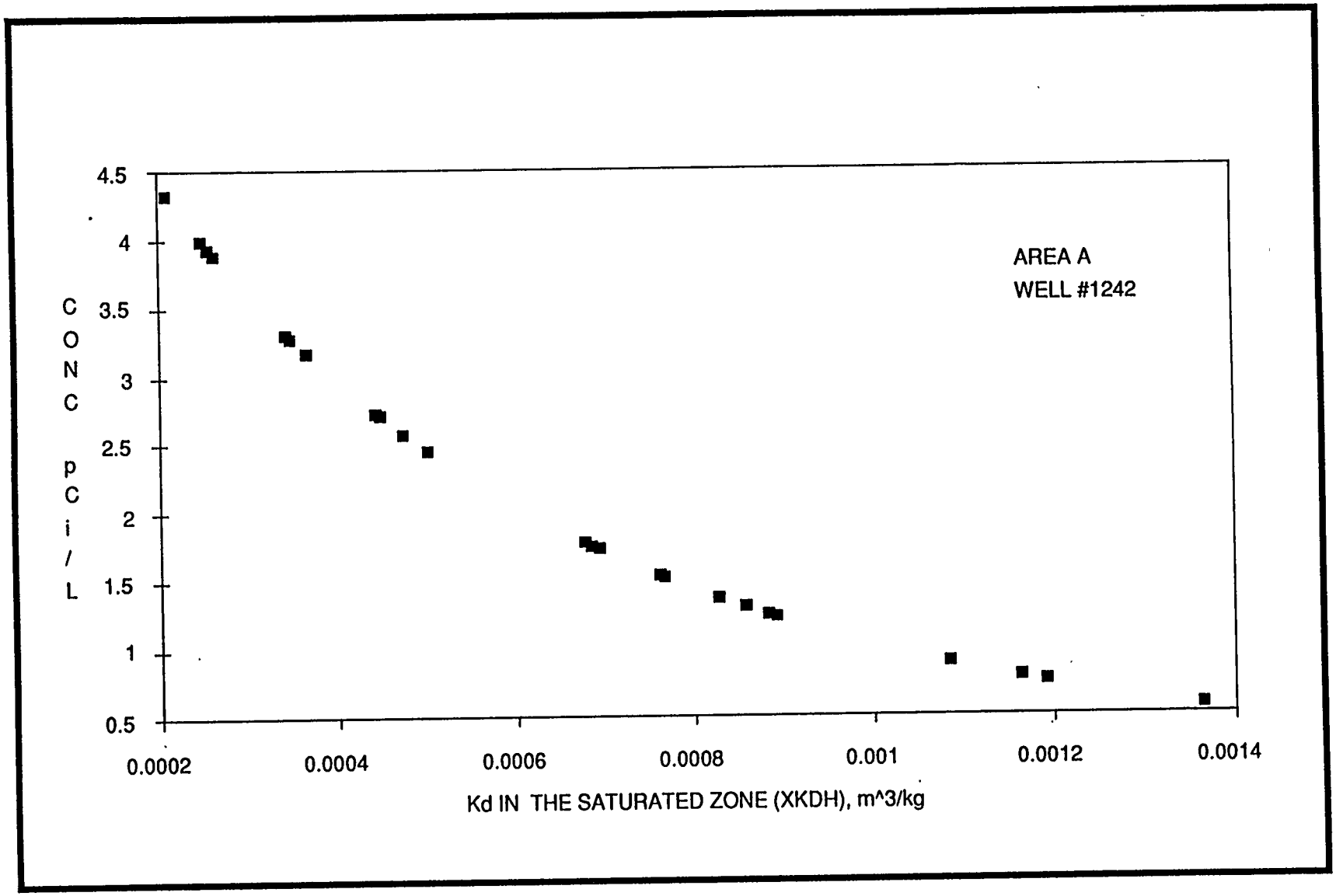



**Fig. 5D.66. Sensitivity analysis of WAG 6 contaminant transport model Co-60 concentration — year 1.**

5.18F 4104.157

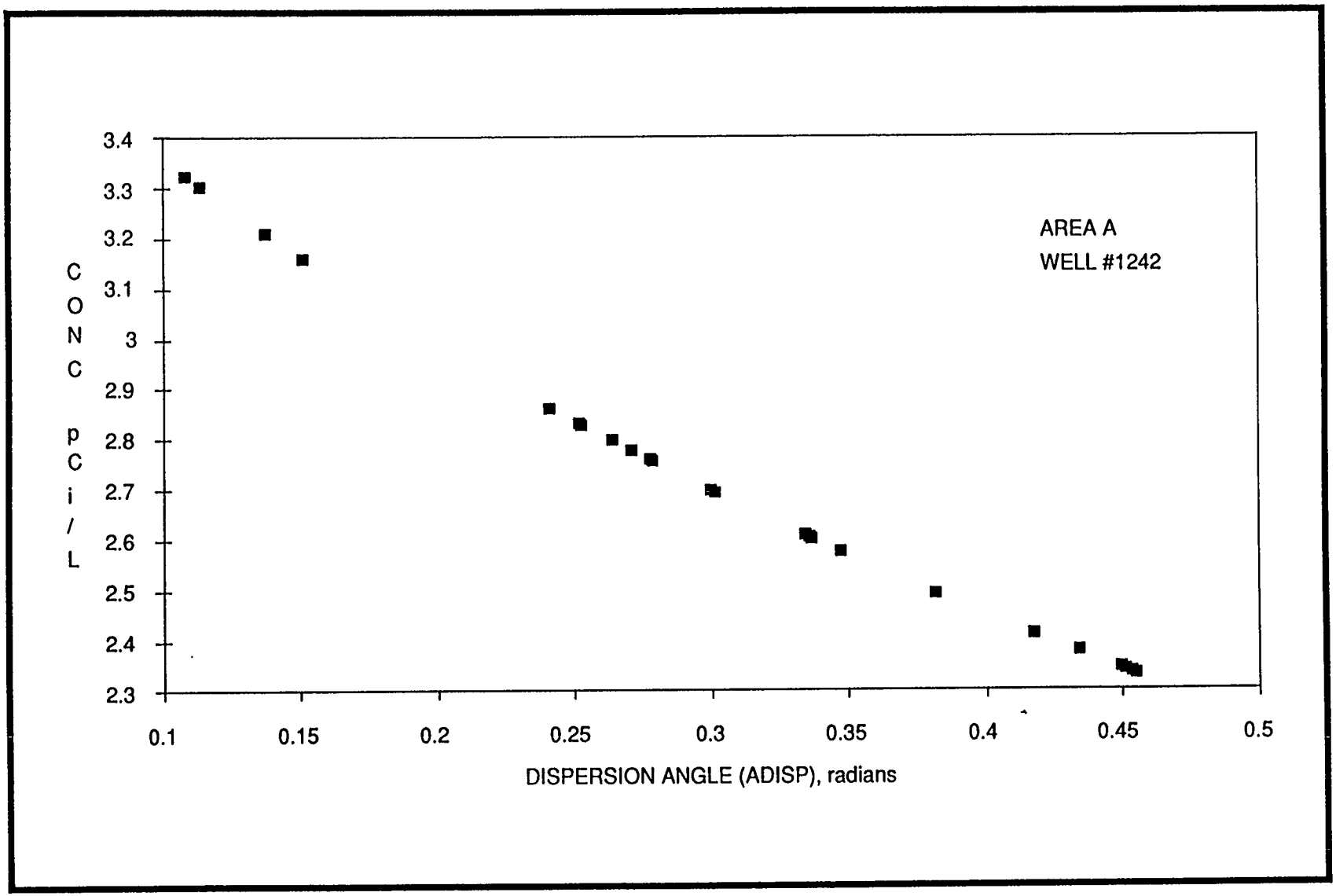



**Fig. 5D.67. Sensitivity analysis of WAG 6 contaminant transport model Co-60 concentration — year 1.**

5.18F 4104.158

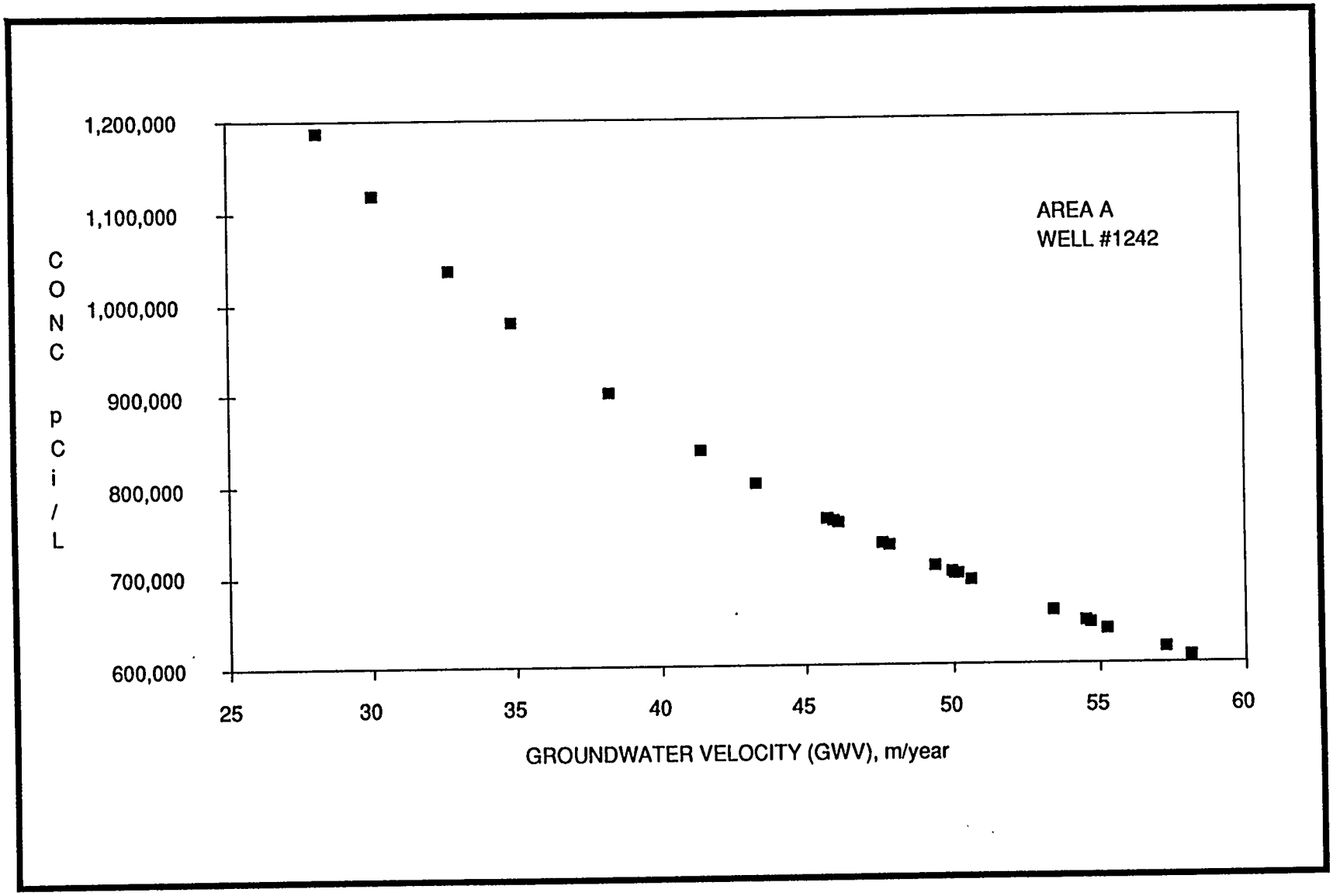



**Fig. 5D.68. Sensitivity analysis of WAG 6 contaminant transport model H-3 concentration — year 1.**

5.18F 4104.159

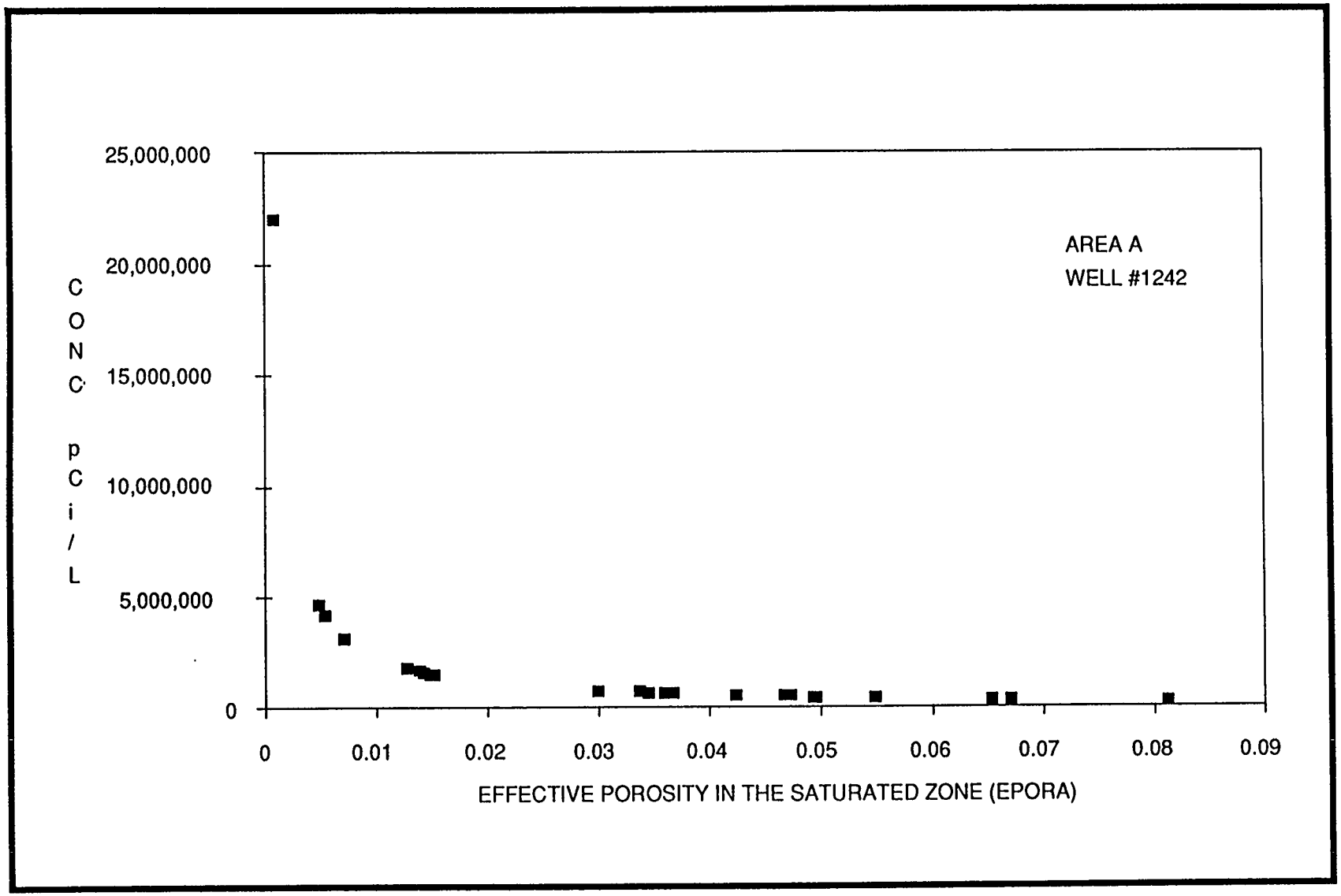



**Fig. 5D.69. Sensitivity analysis of WAG 6 contaminant transport model H-3 concentration — year 1.**

5.18F 4104.160

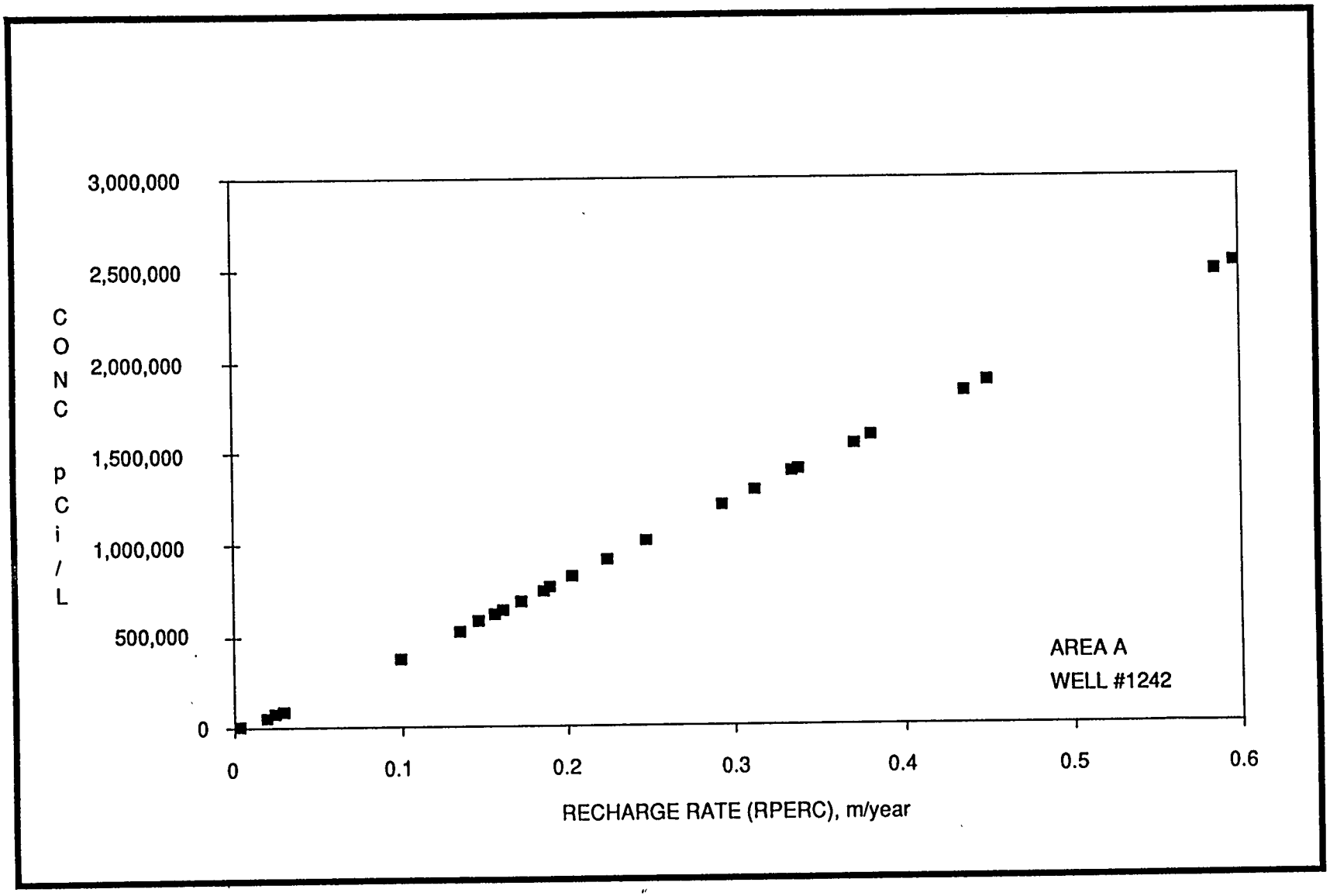



Fig. 5D.70. Sensitivity analysis of WAG 6 contaminant transport model H-3 concentration — year 1.

5.18F 4104.161

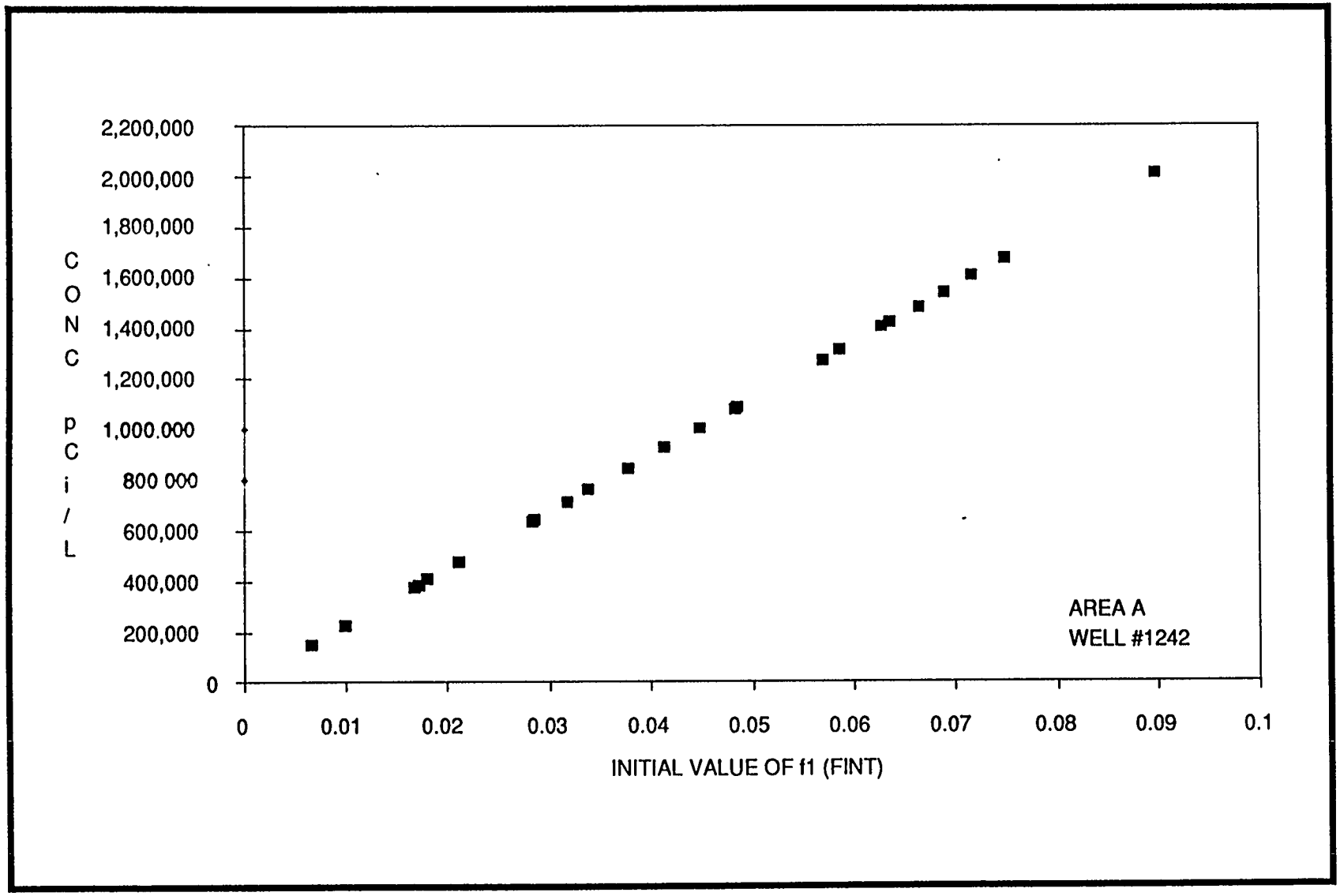



**Fig. 5D.71. Sensitivity analysis of WAG 6 contaminant transport model H-3 concentration — year 1.**

5.18F 4104.162

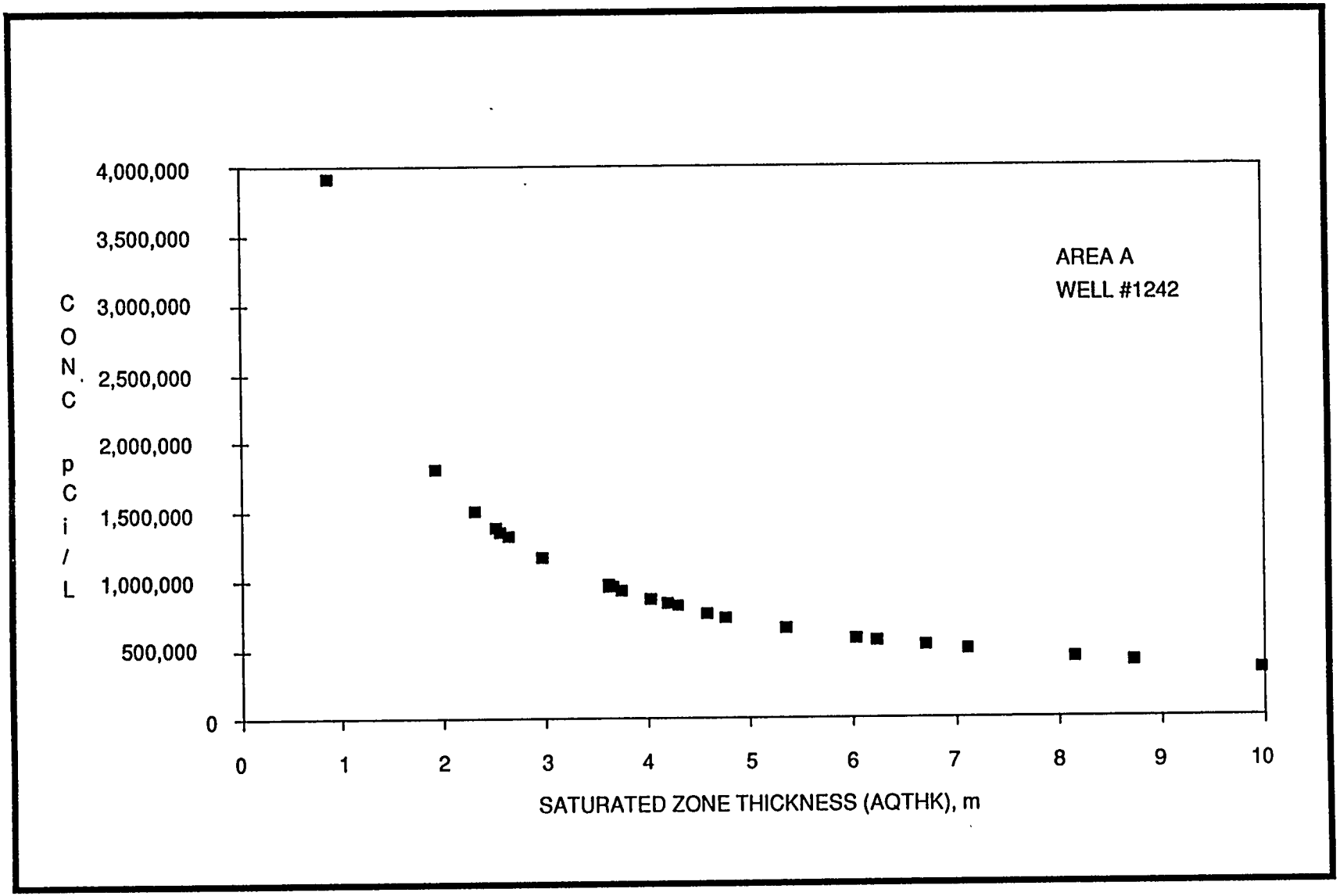



**Fig. 5D.72. Sensitivity analysis of WAG 6 contaminant transport model H-3 concentration — year 1.**

5.18F 4104.163

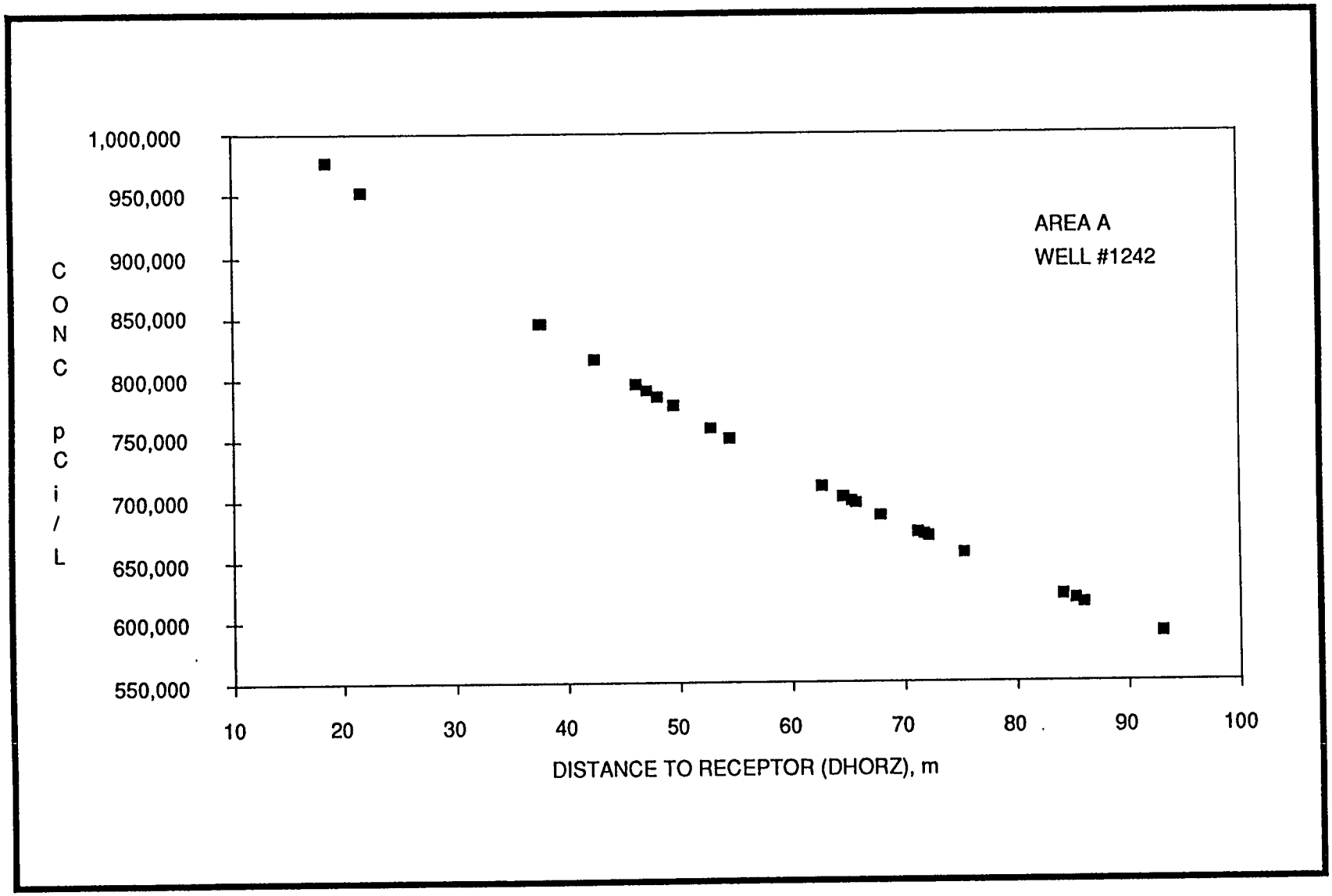



**Fig. 5D.73. Sensitivity analysis of WAG 6 contaminant transport model H-3 concentration — year 1.**

5.18F 4104.164

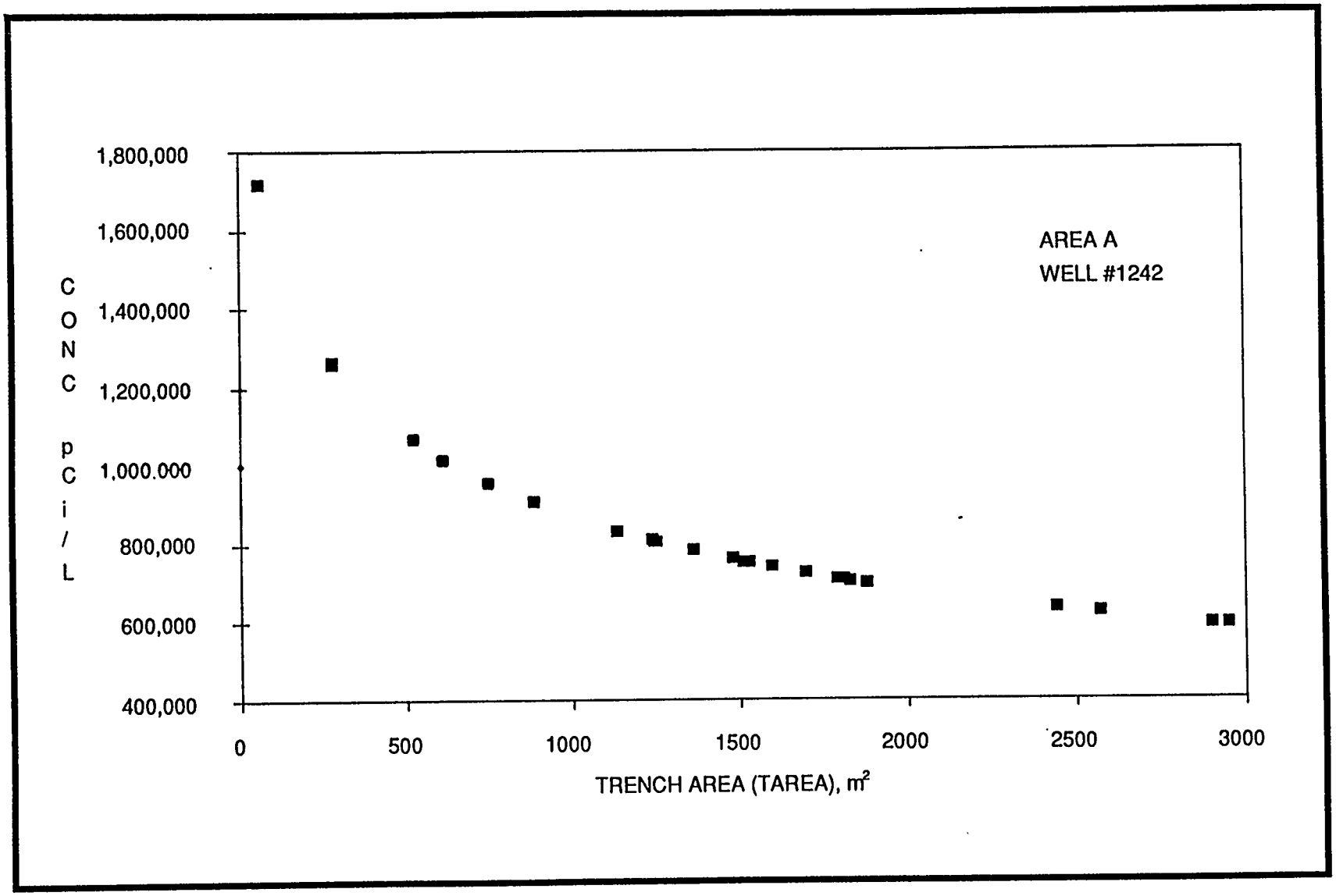



Fig. 5D.74. Sensitivity analysis of WAG 6 contaminant transport model H-3 concentration — year 1.

5.18F 4104.165

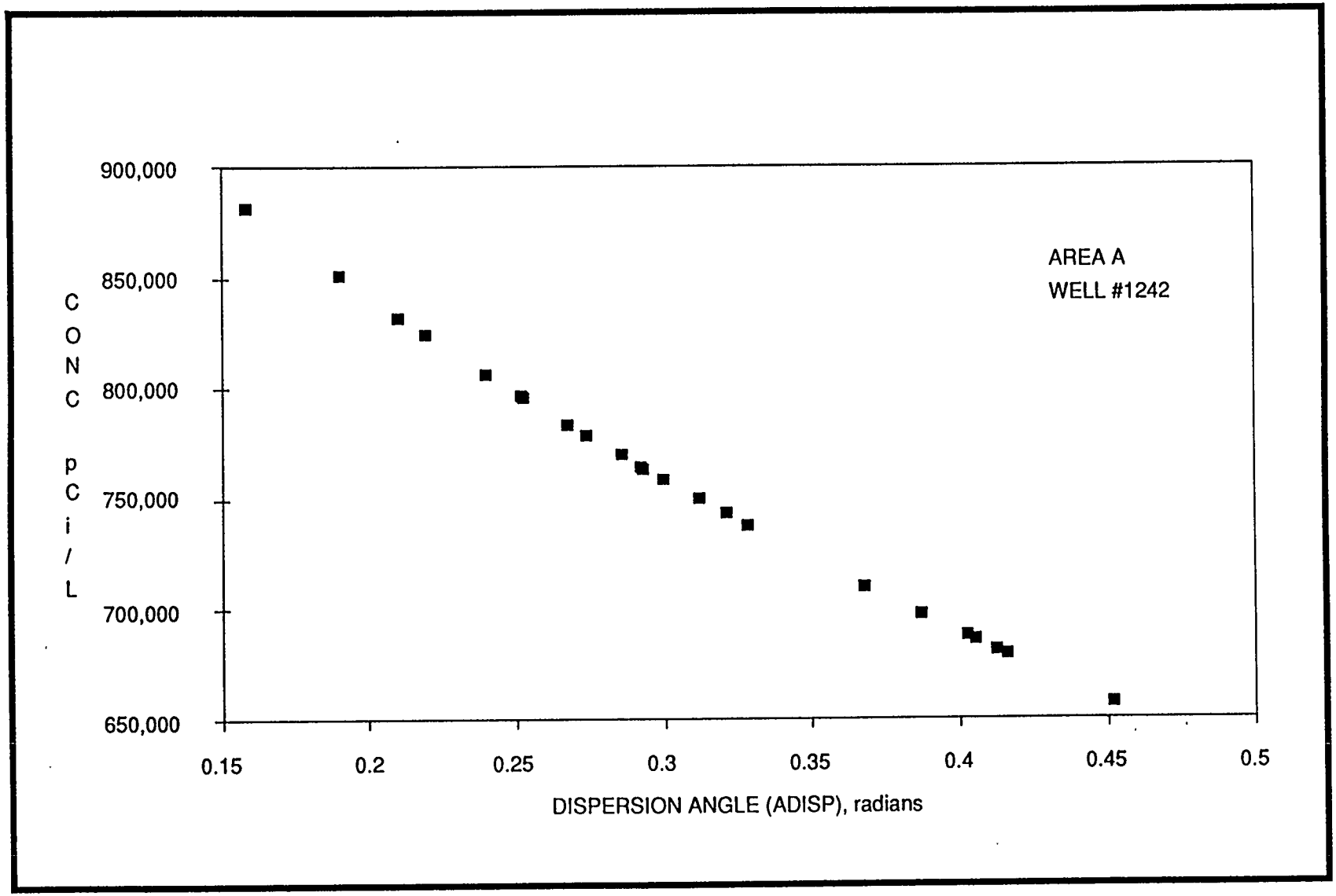



**Fig. 5D.75. Sensitivity analysis of WAG 6 contaminant transport model H-3 concentration — year 1.**

5.18F 4104.166

# APPENDIX 5E. AIR MODELING—MODELS USED, APPLICATION, AND RESULTS

## 5E.1 INTRODUCTION

Air modeling was performed to determine average annual airborne contaminant concentrations over the WAG 6 area for several periods corresponding to hypothetical receptor scenarios defined by the baseline risk assessment (Sect. 6). The modeling consisted of a screening level analysis of emissions and of atmospheric dispersion of the contaminants of concern including tritium and selected VOCs. Tritium was found in surface waters of WAG 6 and was assumed to be emitted to the atmosphere as water evaporates. VOCs were emitted from waste burial grounds in WAG 6.

Air emissions were estimated by EPA's landfill emissions estimation model CHEMDAT7 (EPA 1989). Dispersion modeling was performed using EPA's Industrial Source Complex Long Term (ISCLT) atmospheric dispersion model (EPA 1987b). The data used in modeling included sampling data for tritium and VOCs, and meteorological data for the 5-year period (1986-1990) at ORNL's Station TA, located near WAG 6.

This appendix includes the description of the data and the models used in the analysis, the application of the models to the site, and the modeling results.

## 5E.2 ENVIRONMENTAL CHARACTERIZATION

### 5E.2.1 Meteorological Data

The meteorological data required included wind speed and direction frequencies sorted by atmospheric stability classification for a representative period of record. A search of existing meteorological data sets available for the WAG 6 area identified two ORNL stations (TA and TB) near the WAG 6 site. These two data sets were evaluated for suitability, and the TA station was chosen as the most representative for WAG 6 because it was closer to the site. The location of the TA station is shown in Fig. 5E.1.

The data for the TA station was for a 5-year period (1986 to 1990). The data were obtained in raw form from ORNL and converted to model input form using several computer programs. While most of this conversion process involved reformatting and unit conversion, atmospheric stability classifications had to be extracted from the data using a typical classification scheme as shown in Table 5E-1 (EPA 1986b). These data were then summarized to produce a "joint frequency" of wind speed class versus wind direction class divided into their respective stability classifications. The choice of both the number of classes and the class limits was dependent on the requirements of the model used in this analysis. The resultant joint frequency analysis is presented in Table 5E-2.

Included in Table 5E.2 were both the joint frequencies for each stability class and the total wind frequency for the 5 years of data. The wind speed and direction were taken from a 10-m tower. Additionally, the listed wind speed value represented the approximate mid-point value of the specific wind speed class. The exceptions were the lowest wind speed class (1.5 m/s), which began at 1-m/s (below this value the wind speed sensor measurements tended to be unreliable), and the highest class

(>11 m/s), which summed all frequencies above this value. The wind directions indicated in the table represented the midpoint of a sector from which the wind was blowing to the station. The table includes summary statistics for the data processed. Calms were counted as valid data values below the 1-m/s wind sensor threshold. Missed observations included bad data points not processed into the joint frequency analysis.

Table 5E.2 shows that the winds experienced by TA station were about 43% calm during the 5-year period (1986 to 1990). The wind direction pattern was bimodal and indicative of a valley type flow along a west-southwest to east-northeast axis.

### 5E.2.2 Terrain

Terrain at and near the WAG 6 site generally consisted of rolling hills, ranging from 750 ft to 860 ft above sea level. However, for the purpose of screening level modeling, the terrain was assumed to be flat. Emissions, at ambient temperature, would not be buoyant and pollutant plumes should remain near the surface, where terrain should not be a factor.

## 5E.3 SOURCE CHARACTERIZATION

### 5E.3.1 Source Areas

Figure 5E.2 shows the features of WAG 6 relevant for air modeling, including the surface waters and the waste areas.

#### 5E.3.1.1 Tritium

Tritium emissions at the WAG 6 site were assumed to originate primarily from surface water. Major sources consisted of the outfall of the 49-Trench area French Drain, the Emergency Waste Basin (EWB), and streams. The French drain collected groundwater in the central waste disposal area. This water flowed underground and was discharged to the surface where it flooded the ground. Except for stream FB, all streams were assumed to contain water only during and immediately (approximately 2 days) following rain events. Therefore, tritium was not continually emitted from these intermittent sources. Assumed perennial sources, including the EWB, French drain, and stream FB, were assumed to have a constant emission rate throughout the year.

For modeling purposes, all sources were estimated as area sources. Because area sources for the programs used are, by definition, are square in shape, source geometry requires each source to be approximated by a series of area sources.

The rectangular shapes of the EWB and French Drain outlet were easily characterized by square area sources. The outlet of the French Drain was modeled as a 50-ft by 50-ft area source. The waste basin, with an approximate surface area of 22,500 $ft^2$, was modeled by three adjacent area sources. The widths of these areas were 100 ft, 100 ft, and 50 ft for a total area of 25,000 $ft^2$. Overestimation of the EWB area resulted in slightly conservative predicted tritium concentrations.

Streams were more difficult to model because they are several hundred feet long and only a few feet wide and were not easily represented by a single area source. Several adjoining 100-ft by 100-ft area sources represented each stream. Streams were segmented such that each area source contained one segment. Emissions were calculated based on the characteristics of the stream segment. This approximation maintained the spatial variability of stream emissions.

#### 5E.3.1.2 VOCs

VOC emissions at the WAG 6 site were assumed to originate primarily from the shallow land burial (SLB) waste areas. SLB waste areas were considered as 12 separate areas. One area of migratory soil contamination was also considered. The caps on the landfills were modeled as area sources of 100 ft by 100 ft. VOCs considered are listed in Sect. 5E.3.2.2.

### 5E.3.2 Emissions

#### 5E.3.2.1 Tritium

Emission rates were developed for four periods which were specified by the risk assessment. The first was based on surface water sampling data taken in 1989. The other three were based on time average emission rates for the periods 1990 to 2019, 1990 to 2059, and 2100 to 2129.

Air emissions for 1989 were estimated from sampled tritium concentrations in surface water. Samples were available at each of the twelve sampling points. Figure 5E.3 shows the sampling point locations. Sampling events were identified as:

- High water table
- Base flow -- low water table
- Storm flow I -- high water table
- Storm flow II -- low water table

Table 5E.3 contains tritium sampling data. The highest sampled concentrations were used in the analysis for conservatism.

Air emissions were estimated assuming that the dissolved tritium evaporated at the same rate as water. Assuming that one gram of tritium emitted 9600 Ci of radiation, the mass of tritium emitted to the atmosphere was obtained by multiplying the water concentration (pCi/L), the evaporated water volume ($m^3$), and the conversion rate of 9600 Ci/g (Jacobs 1968).

The volume of evaporated water from each stream was equal to the product of the source surface area and the annual evaporation rate. Evaporation rates for perennial sources were calculated

assuming conservatively that 39 in. of water evaporated per year. Intermittent source evaporation rates were based on the number of days that the stream contained water. Assuming that streams flowed for 2 days after a rainfall and assuming an average of 128 days of rain per year, the evaporation rate was assumed to be 28 in. per year.

Stream surface areas, tritium concentrations, and emission rates are summarized below. Table 5E.4 gives the predicted emission rates in 1989 and the parameters used for calculating these emissions for 51 source areas. The source areas are shown in Fig. 5E.4.

Tritium concentrations were similarly calculated for the other three time periods. However, surface water concentration data for these periods were obtained from the modeling presented in Appendix 5D. Modeling results gave tritium concentrations at one or several locations in each stream. Table 5E.5 lists the surface water modeling data, stream lengths, and area sources used in the air modeling. Table 5E.6 lists the tritium emissions for each source during each time period.

### 5E.3.2.2 VOCs

Air emissions for VOCs were estimated using the landfill emissions estimation model CHEMDAT7.

**Description of CHEMDAT7 model.** The CHEMDAT7 model (EPA 1989a) was developed by EPA's Office of Air Quality Planning and Standards as part of an effort to develop an air emissions model for hazardous waste treatment, storage, and disposal facilities (TSDF). The model primarily considers emissions of VOCs which escape into the atmospheric environment from typical TSDF sources such as surface impoundments, land treatment facilities, landfills, wastepiles, and wastewater treatment plant effluents. VOC emissions can be simulated in the model for a variety of mechanisms including volatilization, biological decomposition, adsorption, photochemical reaction, and hydrolysis.

The model includes an extensive chemical data base of more than 200 compounds and their associated chemical properties. The CHEMDAT7 model is implemented as a Lotus (TM) 1-2-3 spreadsheet allowing great user flexibility including many default values and the ability to utilize actual field data. The principal strength of the model lies in its ability to estimate emission levels comparable to actual field measurements from a limited amount of information. Additionally, estimated emissions can be adjusted for the age of the source months or years into the future.

**CHEMDAT7 model parameters.** The CHEMDAT7 model as applied in this analysis was confined to the "closed landfill" model. This section of the model is designed to estimate emissions from dilute aqueous sources contained in a closed (no longer active) landfill generally including an earthen layer or cap covering the landfill. CHEMDAT7 provides the ability to estimate emissions from the cap covering the landfill.

Ideally, CHEMDAT7 is designed to use as much information as is known about the potential source. For this detailed screening analysis, little source-specific information was available. Known or assumed data values used in the model included the following:

- Surface area of each landfill
- Thickness of the covering or cap, assumed to be 1 ft (30.48 cm) and to be uniform for all landfills analyzed in each case
- Cap air and total porosity values (0.1 and 0.5, respectively)
- The air porosity fraction of fixed waste (0.5 for all cases)
- Air and landfill temperatures and pressures (using default values of 15° C for temperature and 1013 mb for pressure both within and outside the landfill)
- Weight fractions of oil, water, and VOCs (assumed to be 0.0, 0.9999, and 0.0001, respectively). The VOCs were assumed to be equal to 0.0001; and per model instructions, the water plus VOC values should equal one
- Waste depth. Uniformly, all waste depths were assumed to be 15 ft (457 cm), which represents a reasonable approximation of the average depth of waste known to be present at the WAG 6 site

As stated above, site-specific data detailing amounts and varieties of emissions for each landfill site were unavailable for this analysis. However, a list of chemical constituents of concern for the air pathways analysis was generated based on results from the field sampling programs. This list includes the following VOCs:

- Ethylbenzene
- Carbon disulfide
- Chloroform
- 1,2-Dichloroethane
- Methyl ethyl ketone
- Tetrachloroethene (listed as tetrachloroethylene in CHEMDAT7 data base)
- Toluene
- Trichloroethene (listed as trichloroethylene in CHEMDAT7 data base)
- Xylene (including o-, m-, and p-xylenes)
- Chloromethane (listed as methyl chloride in CHEMDAT7 data base)

Since the quantities of these constituents in each landfill were unknown, it was assumed that all were present in equal amounts in each landfill simulated for emissions.

**CHEMDAT7 emissions.** Baseline emissions were calculated by using the baseline parameters for CHEMDAT7. The emission rates for the capped landfills were divided by the number of 10,000-$ft^2$ areas in each landfill. Table 5E.7 lists the 89 sources as input to ISCLT and their emissions. These sources as modeled with ISCLT are shown in Fig.5E.4 for the baseline emission sources.

## 5E.4 DISPERSION MODELING

### 5E.4.1 Description of ISCLT Model

The ISCLT model developed by EPA is a Gaussian dispersion model designed to calculate average concentration or total deposition for contaminants produced by emissions from multiple stack, volume, and area sources. The concentration or total deposition values can be calculated on

a seasonal or annual basis for an unlimited number of sources. The program is capable of producing the seasonal and/or annual results for each individual source input as well as the combined results from multiple groups of selected sources. Program calculations are performed for an input set of receptor coordinates defining a fixed receptor grid system and/or for discrete (arbitrarily placed) receptor points. All points are relative to a user-defined grid origin (usually X=0, Y=0) in either a Cartesian or a polar coordinate system.

### 5E.4.2 ISCLT Model Parameters

Input data for the ISCLT model consist of four categories: meteorological data, source data, receptor data, and program control parameters.

Meteorological data required for ISCLT consist of an annual joint frequency table, mixing height data, and temperature data. A joint frequency table is a matrix containing the frequencies of occurrence of 6 wind speed classes, 16 wind direction sectors, and 6 atmospheric stability categories. Mixing height data are required for each wind speed, stability category, and season. Temperature data are required for each stability category and season.

The program accepts three types of sources: point, area, and volume. Source data inputs include the location (in relation to a user-defined origin), elevation, and emission rate. For area sources, the area side length and effective emission height above ground level are also required.

ISCLT receptor data consist of grid and discrete receptors. Grid receptors, spaced along a 25-m, Cartesian coordinate grid, are used to determine on-site concentrations. Discrete receptors are placed along the site boundary to determine concentrations at the site fenceline.

Program control parameters and options allow the user to choose one or more of the model options. These options define the types of sources, receptors, and output to be used in each run; they also allow the user to change model default values.

### 5E.4.3 Predicted Annual Concentrations

Annual concentrations of tritium and VOCs were calculated for both fenceline and on-site receptors. The fenceline was delineated by receptors beginning at the southwest site border (177 m, 9 m) and continuing clockwise, approximately 25 m apart, to the northern border (347 m, 920 m). Receptors were not placed along the southern and eastern boundaries because these areas border other WAGs. On-site receptors were placed at 25-m intervals on a 25 by 40 grid ranging from coordinate (0 m, 0 m) at the southwest corner to coordinate (600 m, 975 m) at the northeast corner.

#### 5E.4.3.1 Tritium results

Annual tritium air pathway concentrations are shown in Figs. 5E.6 through 5E.9 for the periods 1989 (present), 1990 to 2019, 1990 to 2059, and 2100 to 2159, respectively. In each case, the maximum concentrations occurred near the French Drain. All other sources, with the exception of the EWB, had minimal impact on ambient concentrations. The predominant winds in the area caused concentrations to follow a southwest-northeast direction. Table 5E.8 lists the maximum

concentrations for both fenceline and on-site receptors for all four time periods. Emissions based on 1989 sampling data resulted in the highest concentrations with a maximum of 64,670 pg/m$^3$ occurring a few meters east of the French Drain. Due to the radioactive decay of tritium, concentrations decreased for the later time periods.

#### 5E.4.3.2 VOC results

Annual average total VOC concentrations are shown in Fig. 5E.10. The figure shows that the predominant winds for the WAG 6 area caused concentrations to generally elongate along a southwest-northeast axis. Table 5E.8 lists the maximum concentration values for both fenceline and on-site receptors. The maximum concentration of 166.5 pg/m$^3$ occurred in the 49-trench area.

## 5E.5 SUMMARY AND CONCLUSIONS

### 5E.5.1 Emission Rates

#### 5E.5.1.1 Tritium

Tritium emission rates were calculated using conservative assumptions. These calculations resulted in a conservative estimation of air emissions.

Tritium emission rates derived from 1989 water sampling data were taken from 12 surface water sampling points located throughout the site. Each point was sampled up to five times. The sampling events are listed in Sect. 5E.3.2.1. Table 5E.3 lists the concentrations at each sampling location and identifies the samples used in this analysis.

Air emissions for the intermittent streams were calculated using the highest storm event measurement. This value was chosen to represent these streams because normally they have flow only during wet weather periods. Perennial stream (FB) emission calculations considered each of the four samples. As a conservative estimate, the highest of the four measurements was used to characterize each stream.

Each stream was sampled in only one or two locations. For streams sampled in only one location the emission rates were assumed constant throughout the length of the stream. Streams sampled at two locations, such as FB and FAB, were characterized as homogeneous upstream and downstream of the sampling points and heterogeneous in between. Upstream emissions were derived from measurements taken at the upstream sampling point, and downstream emissions were derived from measurements taken at the downstream sampling point. The section of stream between the sampling points was characterized by a concentration gradient with emissions ranging between the two measurements. Actual stream emissions were unlikely to be either homogeneous or gradational. Instead, the streams probably exhibited a more patchy distribution of tritium, depending on the location of underground tritium sources. However, the surface water measurements were the only tritium data available; therefore, the above generalizations were necessary to characterize the streams.

Tritium emissions for the periods 1990 to 2019, 1990 to 2059, and 2100 to 2129 were based on surface water modeling results; therefore, further uncertainty was introduced into the emission calculation.

### 5E.5.1.2 VOCs

Since there was a lack of site-specific data, various conservative assumptions were made in the application of the CHEMDAT7 model to simulate emissions from the WAG 6 site. Therefore, the methodology that was used overpredicts emissions and was thus conservative.

### 5E.5.2 Transport

Area sources were used in both tritium and VOC modeling. Area sources were easily modeled by ISCLT, but line sources were not. To permit simulation of line sources with ISCLT, they were approximated as area sources. Although the total emissions released to the atmosphere were identical for both actual and simulated cases, the areas from which they were emitted were different. By using an area source to represent the streams or landfills (narrow or irregularly shaped source), emissions were spread over a comparatively large area. These approximations should not ordinarily cause noticeable differences in downwind concentrations far from the source, but some differences are likely at short distances. However, in this analysis, emissions from stream sources were practically negligible when compared to those from the French Drain and waste basin; therefore, the modeling results were not expected to be affected by using area sources in approximating the emissions from streams.

Uncertainty existed with respect to the predicted receptor concentrations. The manual for the ISCLT model indicates that concentrations predicted at receptor distances less than 1.5 area source side lengths from an area source should be used with caution. Many of the receptors used in the on-site grid analysis posed this source-receptor distance concern for some of the sources. Specifically, the ISCLT model will calculate a zero concentration for a source if the source is located within 1.5 side lengths of the receptor. However, concentrations for other sources at greater distances from the receptor will still be calculated. For receptors located near this source-receptor distance limit yet beyond the limit, the model may overpredict concentrations.

# Appendix 5E Tables

**Table 5E-1. Classification of atmospheric stability**

| Stability classification | Pasquill categories | Degrees |
|---|---|---|
| Extremely Unstable | A (1) | $\sigma\Theta \geq 22.5$ |
| Moderately Unstable | B (2) | $22.5 > \sigma\Theta > 17.5$ |
| Slightly Unstable | C (3) | $17.5 > \sigma\Theta > 12.5$ |
| Neutral | D (4) | $12.5 > \sigma\Theta > 7.5$ |
| Slightly Stable | E (5) | $7.5 > \sigma\Theta > 3.8$ |
| Moderately Stable | F (6) | $3.8 > \sigma\Theta > 0.0$ |

Nighttime Modified Sigma Theta Scheme

| If Stability is | and Wind Speed is | Then Stability Class is |
|---|---|---|
| A | WS < 2.9 | F (6) |
| | 2.9 ≤ WS < 3.6 | E (5) |
| | 3.6 ≤ WS | DN (7) |
| B | WS < 2.4 | F (6) |
| | 2.4 ≤ WS < 3.0 | E (5) |
| | 3.0 ≤ WS | DN (7) |
| C | WS < 2.4 | E (6) |
| | 2.4 ≤ WS | DN (7) |
| D | N/A | D |
| E | N/A | E |
| F | N/A | F |

Note: DN = D stability for nighttime regime. This is counted as stability class D in the joint frequency analysis.

**Table 5E.2. Frequency of wind speed and direction for atmospheric stability categories at ORNL Tower TA, 1986-1990**

| | Speed (m/s) | | | | | | |
|---|---|---|---|---|---|---|---|
| Direction | 1.5 | 2.5 | 4.5 | 7.0 | 9.5 | >11 | Total |
| N | .0541 | .0313 | .0000 | .0000 | .0000 | .0000 | .0855 |
| NNE | .0855 | .0313 | .0000 | .0000 | .0000 | .0000 | .1168 |
| NE | .1282 | .0798 | .0057 | .0000 | .0000 | .0000 | .2137 |
| ENE | .1567 | .1083 | .0000 | .0000 | .0000 | .0028 | .2679 |
| E | .2223 | .0513 | .0000 | .0000 | .0000 | .0000 | .2736 |
| ESE | .1282 | .0342 | .0000 | .0000 | .0000 | .0000 | .1624 |
| SE | .0855 | .0256 | .0000 | .0000 | .0000 | .0000 | .1111 |
| SSE | .1054 | .0199 | .0000 | .0000 | .0000 | .0000 | .1254 |
| S | .1852 | .0427 | .0028 | .0000 | .0000 | .0000 | .2308 |
| SSW | .2736 | .2166 | .0313 | .0000 | .0000 | .0000 | .5215 |
| SW | .4217 | .2650 | .0171 | .0000 | .0000 | .0000 | .7038 |
| WSW | .3790 | .1653 | .0028 | .0000 | .0000 | .0000 | .5471 |
| W | .1995 | .2052 | .0057 | .0000 | .0000 | .0000 | .4103 |
| WNW | .1140 | .1624 | .0085 | .0000 | .0000 | .0000 | .2850 |
| NW | .0541 | .0855 | .0057 | .0000 | .0000 | .0000 | .1453 |
| NNW | .0484 | .0513 | .0000 | .0000 | .0000 | .0000 | .0997 |
| Total | 2.6416 | 1.5758 | .0798 | .0000 | .0000 | .0028 | |

Calms = 320. Total Class Observations = 4.30%

Frequency (%) of Wind Speed & Direction for Stability Class B

| | Speed (m/s) | | | | | | |
|---|---|---|---|---|---|---|---|
| Direction | 1.5 | 2.5 | 4.5 | 7.0 | 9.5 | >11 | Total |
| N | .0912 | .0541 | .0000 | .0000 | .0000 | .0000 | .1453 |
| NNE | .1368 | .0484 | .0000 | .0000 | .0000 | .0000 | .1852 |
| NE | .2679 | .1368 | .0000 | .0000 | .0000 | .0000 | .4046 |
| ENE | .5614 | .2365 | .0028 | .0000 | .0000 | .0000 | .8007 |
| E | .4901 | .2166 | .0000 | .0000 | .0000 | .0000 | .7067 |
| ESE | .3419 | .0769 | .0000 | .0000 | .0000 | .0000 | .4189 |
| SE | .2080 | .0513 | .0000 | .0000 | .0000 | .0000 | .2593 |
| SSE | .2451 | .0313 | .0000 | .0000 | .0000 | .0000 | .2764 |
| S | .2622 | .0513 | .0000 | .0000 | .0000 | .0000 | .3135 |
| SSW | .6611 | .3277 | .0484 | .0114 | .0000 | .0000 | 1.0486 |
| SW | 1.3535 | .5044 | .0256 | .0028 | .0000 | .0000 | 1.8864 |
| WSW | .9261 | .3704 | .0114 | .0028 | .0000 | .0000 | 1.3108 |
| W | .5984 | .4445 | .0399 | .0000 | .0000 | .0000 | 1.0828 |
| WNW | .2793 | .2622 | .0285 | .0000 | .0000 | .0000 | .5699 |
| NW | .1881 | .0969 | .0028 | .0000 | .0000 | .0000 | .2878 |
| NNW | .1539 | .0769 | .0057 | .0000 | .0000 | .0000 | .2365 |
| Total | 6.7649 | 2.9864 | .1653 | .0171 | .0000 | .0000 | |

Calms = 852. Total Class Observations = 9.93%

Table 5E.2. (continued)

Surface Station No. TA Time Period: ANNUAL

| Direction | Speed (m/s) 1.5 | 2.5 | 4.5 | 7.0 | 9.5 | >11 | Total |
|---|---|---|---|---|---|---|---|
| N | .1311 | .0228 | .0000 | .0000 | .0000 | .0000 | .1539 |
| NNE | .1852 | .0655 | .0000 | .0000 | .0000 | .0000 | .2508 |
| NE | .5414 | .3306 | .0142 | .0000 | .0000 | .0000 | .8862 |
| ENE | .9774 | .5813 | .0057 | .0000 | .0000 | .0000 | 1.5644 |
| E | .6782 | .2451 | .0028 | .0000 | .0000 | .0000 | .9261 |
| ESE | .2964 | .0627 | .0000 | .0000 | .0000 | .0000 | .3590 |
| SE | .1738 | .0256 | .0028 | .0000 | .0000 | .0000 | .2023 |
| SSE | .1311 | .0171 | .0000 | .0000 | .0000 | .0000 | .1482 |
| S | .1824 | .0228 | .0000 | .0000 | .0000 | .0000 | .2052 |
| SSW | .7152 | .3704 | .0456 | .0057 | .0000 | .0000 | 1.1370 |
| SW | 1.6243 | .7494 | .0883 | .0028 | .0000 | .0000 | 2.4649 |
| WSW | 1.1199 | .4075 | .0199 | .0000 | .0000 | .0000 | 1.5473 |
| W | .5984 | .4331 | .0456 | .0000 | .0000 | .0000 | 1.0771 |
| WNW | .1795 | .1197 | .0114 | .0000 | .0000 | .0000 | .3106 |
| NW | .0912 | .0256 | .0000 | .0000 | .0000 | .0000 | .1168 |
| NNW | .0769 | .0114 | .0028 | .0000 | .0000 | .0000 | .0912 |
| Total | 7.7024 | 3.4907 | .2394 | .0085 | .0000 | .0000 | |

Calms = 1429. Total Class Observations = 11.44%

Frequency (%) of Wind Speed & Direction for Stability Class D

| Direction | Speed (m/s) 1.5 | 2.5 | 4.5 | 7.0 | 9.5 | >11 | Total |
|---|---|---|---|---|---|---|---|
| N | .0826 | .0114 | .0000 | .0000 | .0000 | .0000 | .0940 |
| NNE | .2622 | .0684 | .0028 | .0000 | .0000 | .0000 | .3334 |
| NE | 1.2681 | .9432 | .0199 | .0000 | .0000 | .0000 | 2.2312 |
| ENE | 1.9406 | .7751 | .0114 | .0000 | .0000 | .0000 | 2.7270 |
| E | .6583 | .1140 | .0028 | .0000 | .0000 | .0000 | .7751 |
| ESE | .1653 | .0142 | .0000 | .0000 | .0000 | .0000 | .1795 |
| SE | .1225 | .0085 | .0000 | .0000 | .0000 | .0000 | .1311 |
| SSE | .1225 | .0057 | .0000 | .0000 | .0000 | .0000 | .1282 |
| S | .1596 | .0114 | .0028 | .0000 | .0000 | .0000 | .1738 |
| SSW | .6981 | .4445 | .0456 | .0000 | .0000 | .0000 | 1.1883 |
| SW | 1.5302 | .4901 | .0342 | .0000 | .0000 | .0000 | 2.0545 |
| WSW | 2.1885 | .4417 | .0114 | .0000 | .0000 | .0000 | 2.6416 |
| W | .7466 | .4217 | .0114 | .0000 | .0000 | .0000 | 1.1797 |
| WNW | .1539 | .0228 | .0028 | .0000 | .0000 | .0000 | .1795 |
| NW | .0598 | .0028 | .0000 | .0000 | .0000 | .0000 | .0627 |
| NNW | .0513 | .0000 | .0000 | .0000 | .0000 | .0000 | .0513 |
| Total | 10.2100 | 3.7757 | .1453 | .0000 | .0000 | .0000 | |

Calms = 4682. Total Class Observations = 14.13%

Table E.2. (continued)

Frequency (%) of Wind Speed & Direction for Stability Class E

Surface Station No. TA Time Period: ANNUAL

| Direction | Speed (m/s) 1.5 | 2.5 | 4.5 | 7.0 | 9.5 | >11 | Total |
|---|---|---|---|---|---|---|---|
| N | .1282 | .0114 | .0000 | .0000 | .0000 | .0000 | .1396 |
| NNE | .2308 | .0484 | .0000 | .0000 | .0000 | .0000 | .2793 |
| NE | 1.0230 | .1881 | .0028 | .0000 | .0000 | .0000 | 1.2139 |
| ENE | 1.7325 | .2878 | .0000 | .0000 | .0000 | .0000 | 2.0203 |
| E | .4759 | .0256 | .0000 | .0000 | .0000 | .0000 | .5015 |
| ESE | .0712 | .0114 | .0000 | .0000 | .0000 | .0000 | .0826 |
| SE | .0513 | .0085 | .0000 | .0000 | .0000 | .0000 | .0598 |
| SSE | .0826 | .0057 | .0000 | .0000 | .0000 | .0000 | .0883 |
| S | .0769 | .0171 | .0000 | .0000 | .0000 | .0000 | .0940 |
| SSW | .1767 | .1140 | .0000 | .0000 | .0000 | .0000 | .2907 |
| SW | 1.0771 | .2422 | .0000 | .0000 | .0000 | .0000 | 1.3194 |
| WSW | 2.0175 | .2337 | .0000 | .0000 | .0000 | .0000 | 2.2512 |
| W | .8520 | .4189 | .0028 | .0000 | .0000 | .0000 | 1.2738 |
| WNW | .1852 | .0741 | .0000 | .0000 | .0000 | .0000 | .2593 |
| NW | .0598 | .0199 | .0000 | .0000 | .0000 | .0000 | .0798 |
| NNW | .1054 | .0171 | .0000 | .0000 | .0000 | .0000 | .1225 |
| Total | 8.3464 | 1.7240 | .0057 | .0000 | .0000 | .0000 | |

Calms= 5181. Total Class Observations = 10.08%

Frequency (%) of Wind Speed & Direction for Stability Class F

| Direction | Speed (m/s) 1.5 | 2.5 | 4.5 | 7.0 | 9.5 | >11 | Total |
|---|---|---|---|---|---|---|---|
| N | .1026 | .0171 | .0000 | .0000 | .0000 | .0000 | .1197 |
| NNE | .0798 | .0399 | .0000 | .0000 | .0000 | .0000 | .1197 |
| NE | .7494 | .0741 | .0000 | .0000 | .0000 | .0000 | .8235 |
| ENE | 1.7553 | .0798 | .0000 | .0000 | .0000 | .0028 | 1.8380 |
| E | .2992 | .0028 | .0057 | .0000 | .0000 | .0028 | .3106 |
| ESE | .0142 | .0000 | .0000 | .0000 | .0000 | .0000 | .0142 |
| SE | .0342 | .0057 | .0000 | .0000 | .0000 | .0000 | .0399 |
| SSE | .0228 | .0028 | .0000 | .0000 | .0000 | .0000 | .0256 |
| S | .0541 | .0171 | .0057 | .0000 | .0000 | .0000 | .0769 |
| SSW | .0598 | .0798 | .0427 | .0000 | .0000 | .0000 | .1824 |
| SW | .3106 | .1681 | .0370 | .0000 | .0000 | .0028 | .5186 |
| WSW | 1.1541 | .1282 | .0085 | .0000 | .0000 | .0000 | 1.2909 |
| W | .4645 | .2992 | .0285 | .0000 | .0000 | .0000 | .7922 |
| WNW | .1311 | .1539 | .0142 | .0000 | .0000 | .0000 | .2992 |
| NW | .1254 | .0541 | .0000 | .0000 | .0000 | .0000 | .1795 |
| NNW | .0855 | .0228 | .0000 | .0000 | .0000 | .0000 | .1083 |
| Total | 5.4427 | 1.1455 | .1425 | .0000 | .0000 | .0085 | |

Calms = 2759. Total Class Observations = 6.74%

Table E.2. (continued)

OAK RIDGE NATIONAL LABS TA-TOWER DATA YEARS 1986 to 1990

Frequency (%) of Wind Speed & Direction for All Stability Classes

Surface Station No. TA Time Period: ANNUAL

| Direction | Speed (m/s) 1.5 | 2.5 | 4.5 | 7.0 | 9.5 | >11 | Total |
|---|---|---|---|---|---|---|---|
| N | .5899 | .1482 | .0000 | .0000 | .0000 | .0000 | .7380 |
| NNE | .9803 | .3021 | .0028 | .0000 | .0000 | .0000 | 1.2852 |
| NE | 3.9780 | 1.7525 | .0427 | .0000 | .0000 | .0000 | 5.7732 |
| ENE | 7.1239 | 2.0688 | .0199 | .0000 | .0000 | .0057 | 9.2184 |
| E | 2.8239 | .6554 | .0114 | .0000 | .0000 | .0028 | 3.4936 |
| ESE | 1.0173 | .1995 | .0000 | .0000 | .0000 | .0000 | 1.2168 |
| SE | .6753 | .1254 | .0028 | .0000 | .0000 | .0000 | .8036 |
| SSE | .7095 | .0826 | .0000 | .0000 | .0000 | .0000 | .7922 |
| S | .9204 | .1624 | .0114 | .0000 | .0000 | .0000 | 1.0942 |
| SSW | 2.5846 | 1.5530 | .2137 | .0171 | .0000 | .0000 | 4.3684 |
| SW | 6.3175 | 2.4193 | .2023 | .0057 | .0000 | .0028 | 8.9477 |
| WSW | 7.7850 | 1.7468 | .0541 | .0028 | .0000 | .0000 | 9.5888 |
| W | 3.4594 | 2.2227 | .1339 | .0000 | .0000 | .0000 | 5.8160 |
| WNW | 1.0429 | .7950 | .0655 | .0000 | .0000 | .0000 | 1.9035 |
| NW | .5785 | .2850 | .0085 | .0000 | .0000 | .0000 | .8720 |
| NNW | .5215 | .1795 | .0085 | .0000 | .0000 | .0000 | .7095 |
| Total | 41.1079 | 14.6981 | .7779 | .0256 | .0000 | .0114 | |

Calms = 15223. hours
Missed Obs = 8083. hours Total Obs = 35093. hours
Total No. of Days Counted = 1799
Notes: 1. Total observation includes calms.
2. The total days counted are for the entire data set.
3. NCDC Wind speed ranges (m/s): 1.5 (0-1.8); 2.5 (1.8-3.3); 4.5 (3.3-5.4); 7.0 (5.4-8.5); 9.5 (8.5-11)

Date of run: 3/28/91

**Table 5E.3. WAG 6 surface water sampling results—tritium**

| Source | Sampling point | High water table | Sampling Period: Storm event I | Sampling Period: Baseflow | Sampling Period: Storm event II |
|---|---|---|---|---|---|
| Stream FB | WFBB1 | 3,100,000 | 2,200,000 | 3,600,000 | **3,910,000** |
| | WFBB3 | NS | **190,000** | NS | 161,000 |
| Stream FA | WFBA1 | 86,000 | 96,000 | NS | **103,000** |
| Stream FAA | WBAA1 | NS | **1500** | NS | NS |
| Stream FAB | WBAB1 | NS | **130,000** | NS | 122,000 |
| | WBAB2 | NS | 390,000 | NS | **393,000** |
| French Drain | W49TS | 12,000,000 | 8,500,000 | **14,000,000** | 4,270,000 |
| Stream DA | WDA1 | 2,050,000 | 160,000 | 2,900,000 | **2,320,000** |
| Stream DB | WDB1 | NS | **73,000** | NS | NS |
| Stream B | SWB1 | 30,000 | **2700** | NS | NS |
| Stream A2 | SWA1 | NS | **2700** | NS | 225[illegible] |
| Waste Basin | WEWB | NS | NS | **190,000** | 169,000 |

Concentrations are in pCi/L.

NS: not sampled.

Bolded numbers are those which were used to calculate present day emissions.

Table 5E.4. Tritium source data—1989

| Source | Source area | Length (ft) | Width (ft) | Area ($ft^2$) | Evaporation ($m^3$/year) | Tritium concentration (pCi/L) | Area source side length (ft) | Emission rate ($g/m^2/s$) |
|---|---|---|---|---|---|---|---|---|
| FA | | 285 | 2 | 570 | 44 | | | |
| | FA1 | 143 | 2 | 285 | 22 | 103000 | 100 | 6.95e-18 |
| | FA2 | 143 | 2 | 285 | 22 | 103000 | 100 | 6.95e-18 |
| FAA | | 530 | 1 | 530 | 41 | | | |
| | FAA1 | 133 | 1 | 133 | 10 | 1500 | 100 | 4.71e-20 |
| | FAA2 | 133 | 1 | 133 | 10 | 1500 | 100 | 4.71e-20 |
| | FAA3 | 133 | 1 | 133 | 10 | 1500 | 100 | 4.71e-20 |
| | FAA4 | 133 | 1 | 133 | 10 | 1500 | 100 | 4.71e-20 |
| FAB[a] | | 320 | 1 | 320 | 25 | | | |
| | FAB1 | 80 | 1 | 80 | 6 | 393000 | 100 | 7.44e-18 |
| | FAB2 | 80 | 1 | 80 | 6 | 305333 | 100 | 5.78e-18 |
| | FAB3 | 80 | 1 | 80 | 6 | 217667 | 100 | 4.12e-18 |
| | FAB4 | 80 | 1 | 80 | 6 | 130000 | 100 | 2.46e-18 |
| FB[b] | | 2356 | .75-2.25 | 3764 | 416 | | | |
| | FB1 | 70 | 1 | 70 | 8 | 62000 | 100 | 4.49e-18 |
| | FB2[c] | 70 | 1 | 50 | 6 | 62000 | 100 | 3.21e-18 |
| | FB3 | 140 | 0.75 | 105 | 12 | 62000 | 100 | 6.73e-18 |
| | FB4 | 159 | 1.5 | 238 | 26 | 62000 | 100 | 1.53e-17 |
| | FB5 | 159 | 1.5 | 238 | 26 | 62000 | 100 | 1.53e-17 |
| | FB6 | 159 | 1.5 | 238 | 26 | 62000 | 100 | 1.53e-17 |
| | FB7 | 159 | 1.5 | 238 | 26 | 411818 | 100 | 4.25e-17 |
| | FB8 | 159 | 1.5 | 238 | 26 | 761636 | 100 | 6.97e-17 |
| | FB9 | 159 | 1.5 | 238 | 26 | 1111455 | 100 | 9.69e-17 |
| | FB10 | 159 | 1.5 | 238 | 26 | 1461273 | 100 | 1.24e-16 |
| | FB11 | 159 | 1.5 | 238 | 26 | 1811091 | 100 | 1.51e-16 |
| | FB12[d] | 165 | 1.5 | 274 | 30 | 2160909 | 100 | 2.06e-16 |
| | FB13 | 83 | 2 | 165 | 18 | 2510727 | 100 | 1.42e-16 |
| | FB14 | 83 | 2 | 165 | 18 | 2860545 | 100 | 1.61e-16 |
| | FB15 | 83 | 2 | 165 | 18 | 3210364 | 100 | 1.80e-16 |
| | FB16 | 83 | 2 | 165 | 18 | 3560182 | 100 | 1.99e-16 |
| | FB17 | 103 | 2.25 | 232 | 26 | 3910000 | 100 | 3.07e-16 |
| | FB18 | 103 | 2.25 | 232 | 26 | 3910000 | 100 | 3.07e-16 |
| | FB19 | 103 | 2.25 | 232 | 26 | 3910000 | 100 | 3.07e-16 |
| French Drain | | 50 | 50 | 2500 | 276 | | | |
| | FD1 | 50 | 50 | 2500 | 276 | 14000000 | 50 | 4.73e-14 |
| DA | | 300 | 1.5 | 450 | 35 | | | |

**Table 5E.4. (continued)**

| Source | Source area | Length (ft) | Width (ft) | Area ($ft^2$) | Evaporation ($m^3$/year) | Tritium concentration (pCi/L) | Area source side length (ft) | Emission rate ($g/m^2/s$) |
|---|---|---|---|---|---|---|---|---|
| | DA1 | 100 | 1.5 | 150 | 12 | 2320000 | 100 | 8.24e-17 |
| | DA2 | 100 | 1.5 | 150 | 12 | 2320000 | 100 | 8.24e-17 |
| | DA3 | 100 | 1.5 | 150 | 12 | 2320000 | 100 | 8.24e-17 |
| DB | | 860 | 2 | 1720 | 133 | | | |
| | DB1 | 123 | 2 | 246 | 19 | 73000 | 100 | 4.25e-18 |
| | DB2 | 123 | 2 | 246 | 19 | 73000 | 100 | 4.25e-18 |
| | DB3 | 123 | 2 | 246 | 19 | 73000 | 100 | 4.25e-18 |
| | DB4 | 123 | 2 | 246 | 19 | 73000 | 100 | 4.25e-18 |
| | DB5 | 123 | 2 | 246 | 19 | 73000 | 100 | 4.25e-18 |
| | DB6 | 123 | 2 | 246 | 19 | 73000 | 100 | 4.25e-18 |
| | DB7 | 123 | 2 | 246 | 19 | 73000 | 100 | 4.25e-18 |
| B | | 480 | 1 | 480 | 37 | | | |
| | B1 | 120 | 1 | 120 | 9 | 2700 | 100 | 7.67e-20 |
| | B2 | 120 | 1 | 120 | 9 | 2700 | 100 | 7.67e-20 |
| | B3 | 120 | 1 | 120 | 9 | 2700 | 100 | 7.67e-20 |
| | B4 | 120 | 1 | 120 | 9 | 2700 | 100 | 7.67e-20 |
| A2 | | 450 | 2 | 900 | 70 | | | |
| | A21 | 113 | 2 | 225 | 17 | 2700 | 100 | 1.44e-19 |
| | A22 | 113 | 2 | 225 | 17 | 2700 | 100 | 1.44e-19 |
| | A23 | 113 | 2 | 225 | 17 | 2700 | 100 | 1.44e-19 |
| | A24 | 113 | 2 | 225 | 17 | 2700 | 100 | 1.44e-19 |
| Waste Basin[e] | | 150 | 150 | 22500 | 2487 | | | |
| | WB1 | 50 | 50 | 2500 | 276 | 190000 | 50 | 6.41e-16 |
| | WB2 | 100 | 100 | 10000 | 1106 | 190000 | 100 | 6.41e-16 |
| | WB3 | 100 | 100 | 10000 | 1106 | 190000 | 100 | 6.41e-16 |

[a] FAB1 is based on WBAB2 concentration; FAB2 and FAB3 are based on the concentration gradient between WBAB1 and WBAB2; FAB4 is based on WBAB1 concentration.

[b] FB1 through FB6 are based on WFBB3 concentration; FB7 through FB16 are based on the concentration gradient between WFBB2 and WFBB1; FB17 through FB19 are based on WFBB1 concentration.

[c] Length includes a 20 ft section of stream flowing underground; area does not account for this section.

[d] Includes a 6 ft by 6 ft pool in stream.

[e] Surface area is 22,467 $ft^2$.

Table 5E.5. Surface water modeling results—tritium

| Stream | Stream length | | Downstream distance | | Surface water modeling concentrations | | | Area sources[a] |
|---|---|---|---|---|---|---|---|---|
| | Surface water modeling (ft) | Air modeling (ft) | Surface water modeling (ft) | Air modeling[b] (ft) | 1990-2019 (pCi/L) | 1990-2059 (pCi/L) | 2100-2129 (pCi/L) | (Used in air modeling) |
| DA[c] | 686 | 300 | 0 | 0 | 194531 | 110923 | 93 | |
| | | | 56 | 24 | 216492 | 123522 | 106 | DA3 |
| | | | 322 | 141 | 241952 | 138048 | 118 | |
| | | | 361 | 158 | 328190 | 187252 | 160 | DA2 |
| | | | 459 | 201 | 421554 | 240522 | 206 | DA1 |
| | | | 686 | 300 | 456080 | 259748 | 228 | |
| DB | 856 | 860 | 0 | 0 | 363693 | 293111 | 77 | DB7 |
| | | | 361 | 363 | 489081 | 396451 | 104 | DB5, DB6 |
| | | | 404 | 406 | 548035 | 446332 | 119 | DB4 |
| | | | 591 | 594 | 809609 | 659545 | 170 | DB2, DB3 |
| | | | 856 | 860 | 731451 | 699760 | 2 | DB1 |
| FA/FAB | 604 | 605 | 56 | 56 | 28295 | 17416 | 10 | FA2 |
| | | | 220 | 220 | 56440 | 34740 | 19 | FA1 |
| | | | 285 | 285 | 71603 | 44199 | 21 | FAB3, FAB4 |
| | | | 604 | 605 | 192805 | 119013 | 57 | FAB1, FAB2 |
| FB | 1680 | 2356 | 56 | 79 | 215221 | 109530 | 4 | FB17 - FB19 |
| | | | 312 | 438 | 227605 | 112104 | 4 | FB13 - FB16 |
| | | | 643 | 902 | 254589 | 125395 | 5 | FB9 - FB12 |
| | | | 1125 | 1578 | 231832 | 117848 | 2 | FB6 - FB8 |
| | | | 1302 | 1826 | 416667 | 211806 | 4 | FB4, FB5 |
| | | | 1512 | 2120 | 583725 | 296755 | 5 | FB3 |
| | | | 1680 | 2356 | 796833 | 405032 | 3 | FB1, FB2 |
| French Drain | none | none | none | none | 2669856 | 1531075 | 1378 | FD1 |
| Waste Basin | none | none | none | none | 15158 | 7020 | 0 | WB1 - WB3 |

[a] Area sources correspond to the nearest modeled downstream concentration (using air modeling distance).

[b] Calculation: (AIR STREAM LENGTH / SURFACE WATER STREAM LENGTH) * SURFACE WATER DOWNSTREAM DISTANCE.

[c] Surface water modeling assumed stream DA was wet for entire length. Observations indicate that uppermost section of the stream is a dry channel.

Table 5E.6. Predicted surface water tritium emissions (g/m$^2$-sec)

| Source | Period 1989 | Period 1990 - 2019 | Period 1990 - 2059 | Period 2100 - 2129 |
|---|---|---|---|---|
| FA1 | 6.95E-18 | 3.81E-18 | 2.34E-18 | 1.28E-21 |
| FA2 | 6.95E-18 | 1.91E-18 | 1.18E-18 | 6.75E-22 |
| FAA1 | 4.71E-20 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| FAA2 | 4.71E-20 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| FAA3 | 4.71E-20 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| FAA4 | 4.71E-20 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| FAB1 | 7.44E-18 | 3.65E-18 | 2.25E-18 | 1.08E-21 |
| FAB2 | 5.78E-18 | 3.65E-18 | 2.25E-18 | 1.08E-21 |
| FAB3 | 4.12E-18 | 1.36E-18 | 8.37E-19 | 3.98E-22 |
| FAB4 | 2.46E-18 | 1.36E-18 | 8.37E-19 | 3.98E-22 |
| FB1 | 4.49E-18 | 1.88E-17 | 9.57E-18 | 7.09E-23 |
| FB2 | 3.21E-18 | 1.34E-17 | 6.84E-18 | 5.06E-23 |
| FB3 | 6.73E-18 | 2.07E-17 | 1.05E-17 | 1.77E-22 |
| FB4 | 1.53E-17 | 3.35E-17 | 1.70E-17 | 3.22E-22 |
| FB5 | 1.53E-17 | 3.35E-17 | 1.70E-17 | 3.22E-22 |
| FB6 | 1.53E-17 | 1.87E-17 | 9.48E-18 | 1.61E-22 |
| FB7 | 4.25E-17 | 1.87E-17 | 9.48E-18 | 1.61E-22 |
| FB8 | 6.97E-17 | 1.87E-17 | 9.48E-18 | 1.61E-22 |
| FB9 | 9.69E-17 | 2.05E-17 | 1.01E-17 | 4.02E-22 |
| FB10 | 1.24E-16 | 2.05E-17 | 1.01E-17 | 4.02E-22 |
| FB11 | 1.51E-16 | 2.05E-17 | 1.01E-17 | 4.02E-22 |
| FB12 | 2.06E-16 | 2.36E-17 | 1.16E-17 | 4.63E-22 |
| FB13 | 1.42E-16 | 1.27E-17 | 6.24E-18 | 2.23E-22 |
| FB14 | 1.61E-16 | 1.27E-17 | 6.24E-18 | 2.23E-22 |
| FB15 | 1.80E-16 | 1.27E-17 | 6.24E-18 | 2.23E-22 |
| FB16 | 1.99E-16 | 1.27E-17 | 6.24E-18 | 2.23E-22 |
| FB17 | 3.07E-16 | 1.69E-17 | 8.60E-18 | 3.14E-22 |
| FB18 | 3.07E-16 | 1.69E-17 | 8.60E-18 | 3.14E-22 |
| FB19 | 3.07E-16 | 1.69E-17 | 8.60E-18 | 3.14E-22 |
| FD1 | 4.73E-14 | 9.01E-15 | 5.17E-15 | 4.65E-18 |
| DA1 | 8.24E-17 | 1.50E-17 | 8.54E-18 | 7.32E-21 |
| DA2 | 8.24E-17 | 1.17E-17 | 6.65E-18 | 5.68E-21 |
| DA3 | 8.24E-17 | 7.69E-18 | 4.39E-18 | 3.76E-21 |
| DB1 | 4.25E-18 | 4.26E-17 | 4.07E-17 | 1.16E-22 |
| DB2 | 4.25E-18 | 4.71E-17 | 3.84E-17 | 9.89E-21 |
| DB3 | 4.25E-18 | 4.71E-17 | 3.84E-17 | 9.89E-21 |
| DB4 | 4.25E-18 | 3.19E-17 | 2.60E-17 | 6.92E-21 |
| DB5 | 4.25E-18 | 2.85E-17 | 2.31E-17 | 6.05E-21 |
| DB6 | 4.25E-18 | 2.85E-17 | 2.31E-17 | 6.05E-21 |
| DB7 | 4.25E-18 | 2.12E-17 | 1.71E-17 | 4.48E-21 |
| B1 | 7.67E-20 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| B2 | 7.67E-20 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| B3 | 7.67E-20 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| B4 | 7.67E-20 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| A21 | 1.44E-19 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| A22 | 1.44E-19 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| A23 | 1.44E-19 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| A24 | 1.44E-19 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| WB1 | 6.41E-16 | 5.12E-17 | 2.37E-17 | 0.00E+00 |
| WB2 | 6.41E-16 | 5.12E-17 | 2.37E-17 | 0.00E+00 |
| WB3 | 6.41E-16 | 5.12E-17 | 2.37E-17 | 0.00E+00 |

**Table 5E.7. Baseline CHEMDAT7 sources and emissions**

| Area[a] | Total area ($cm^2$) | No. of sources | Receptor no. | X (m) | Y (m) | Emissions rate ($g/m^2$-s) |
|---|---|---|---|---|---|---|
| 49-Trench | 69,675,000 | | | | | 1.18E-10 |
| | | 10 | 1 | 244 | 366 | 1.18E-11 |
| | | | 2 | 274 | 366 | 1.18E-11 |
| | | | 3 | 244 | 396 | 1.18E-11 |
| | | | 4 | 274 | 396 | 1.18E-11 |
| | | | 5 | 305 | 396 | 1.18E-11 |
| | | | 6 | 244 | 427 | 1.18E-11 |
| | | | 7 | 274 | 427 | 1.18E-11 |
| | | | 8 | 305 | 427 | 1.18E-11 |
| | | | 9 | 244 | 46 | 1.18E-11 |
| | | | 10 | 274 | 46 | 1.18E-11 |
| West Disposal Area | 92,900,000 | 14 | | | | 1.58E-10 |
| | | | 11 | 244 | 244 | 1.13E-11 |
| | | | 12 | 213 | 27 | 1.13E-11 |
| | | | 13 | 244 | 274 | 1.13E-11 |
| | | | 14 | 183 | 305 | 1.13E-11 |
| | | | 15 | 213 | 305 | 1.13E-11 |
| | | | 16 | 244 | 305 | 1.13E-11 |
| | | | 17 | 122 | 335 | 1.13E-11 |
| | | | 18 | 152 | 335 | 1.13E-11 |
| | | | 19 | 183 | 335 | 1.13E-11 |
| | | | 20 | 213 | 366 | 1.13E-11 |
| | | | 21 | 122 | 366 | 1.13E-11 |
| | | | 22 | 152 | 366 | 1.13E-11 |
| | | | 23 | 183 | 366 | 1.13E-11 |
| | | | 24 | 152 | 396 | 1.13E-11 |
| Central Disposal Area | 11,612,500 | 3 | | | | 1.97E-11 |
| | | | 25 | 427 | 396 | 6.57E-12 |
| | | | 26 | 457 | 396 | 6.57E-12 |
| | | | 27 | 488 | 396 | 6.57E-12 |
| North-East Disposal Area | 18,580,000 | 4 | | | | 3.16E-11 |
| | | | 28 | 427 | 549 | 7.90E-12 |
| | | | 29 | 457 | 549 | 7.90E-12 |
| | | | 30 | 396 | 579 | 7.90E-12 |
| | | | 31 | 427 | 579 | 7.90E-12 |
| 17-Trench | 20,902,500 | 3 | | | | 3.55E-11 |
| | | | 32 | 305 | 701 | 1.18E-11 |
| | | | 33 | 305 | 732 | 1.18E-11 |

Table 5E.7. (continued)

| Area[a] | Total area ($cm^2$) | No. of sources | Receptor no. | X (m) | Y (m) | Emissions rate ($g/m^2$-s) |
|---|---|---|---|---|---|---|
| | | | 34 | 305 | 762 | 1.18E-11 |
| HATA | 20,902,500 | 3 | | | | 3.55E-11 |
| | | | 35 | 183 | 671 | 1.18E-11 |
| | | | 36 | 183 | 701 | 1.18E-11 |
| | | | 37 | 213 | 701 | 1.18E-11 |
| Groundwater | 27,870,000 | 4 | | | | 4.74E-11 |
| | | | 38 | 427 | 671 | 1.19E-11 |
| | | | 39 | 427 | 701 | 1.19E-11 |
| | | | 40 | 46 | 701 | 1.19E-11 |
| | | | 41 | 427 | 732 | 1.19E-11 |
| South Disposal Area | 137,027,500 | 18 | | | | 2.33E-10 |
| | | | 42 | 335 | 122 | 1.29E-11 |
| | | | 43 | 335 | 152 | 1.29E-11 |
| | | | 44 | 366 | 61 | 1.29E-11 |
| | | | 45 | 366 | 91 | 1.29E-11 |
| | | | 46 | 366 | 122 | 1.29E-11 |
| | | | 47 | 366 | 152 | 1.29E-11 |
| | | | 48 | 366 | 183 | 1.29E-11 |
| | | | 49 | 366 | 213 | 1.29E-11 |
| | | | 50 | 396 | 61 | 1.29E-11 |
| | | | 51 | 396 | 61 | 1.29E-11 |
| | | | 52 | 396 | 122 | 1.29E-11 |
| | | | 53 | 396 | 152 | 1.29E-11 |
| | | | 54 | 396 | 183 | 1.29E-11 |
| | | | 55 | 396 | 213 | 1.29E-11 |
| | | | 56 | 427 | 122 | 1.29E-11 |
| | | | 57 | 427 | 152 | 1.29E-11 |
| | | | 58 | 427 | 183 | 1.29E-11 |
| | | | 59 | 427 | 213 | 1.29E-11 |
| South-Central Disposal Area | 41,805,000 | 5 | | | | 7.10E-11 |
| | | | 60 | 366 | 396 | 1.42E-11 |
| | | | 61 | 366 | 427 | 1.42E-11 |
| | | | 62 | 396 | 366 | 1.42E-11 |
| | | | 63 | 396 | 396 | 1.42E-11 |
| | | | 64 | 396 | 427 | 1.42E-11 |

Table 5E.7. (continued)

| Area[a] | Total area ($cm^2$) | No. of sources | Receptor no. | X (m) | Y (m) | Emissions rate ($g/m^2$-s) |
|---|---|---|---|---|---|---|
| Middle Central Disposal Area | 74,320,000 | 9 | | | | 1.26E-10 |
| | | | 65 | 274 | 488 | 1.40E-11 |
| | | | 66 | 274 | 518 | 1.40E-11 |
| | | | 67 | 305 | 457 | 1.40E-11 |
| | | | 68 | 305 | 488 | 1.40E-11 |
| | | | 69 | 305 | 518 | 1.40E-11 |
| | | | 70 | 305 | 549 | 1.40E-11 |
| | | | 71 | 335 | 427 | 1.40E-11 |
| | | | 72 | 335 | 457 | 1.40E-11 |
| | | | 73 | 335 | 488 | 1.40E-11 |
| North-Central Disposal Area | 23,225,000 | 2 | | | | 3.95E-11 |
| | | | 74 | 213 | 640 | 1.98E-11 |
| | | | 75 | 244 | 640 | 1.98E-11 |
| South-East Disposal Area | 71,997,500 | 8 | | | | 1.22E-10 |
| | | | 76 | 427 | 488 | 1.53E-11 |
| | | | 77 | 427 | 518 | 1.53E-11 |
| | | | 78 | 457 | 457 | 1.53E-11 |
| | | | 79 | 457 | 488 | 1.53E-11 |
| | | | 80 | 488 | 427 | 1.53E-11 |
| | | | 81 | 488 | 457 | 1.53E-11 |
| | | | 82 | 518 | 396 | 1.53E-11 |
| | | | 83 | 518 | 427 | 1.53E-11 |
| North-West Auger Hole Area | 55,740,000 | 6 | | | | 9.47E-11 |
| | | | 84 | 366 | 610 | 1.58E-11 |
| | | | 85 | 366 | 640 | 1.58E-11 |
| | | | 86 | 366 | 671 | 1.58E-11 |
| | | | 87 | 396 | 610 | 1.58E-11 |
| | | | 88 | 396 | 640 | 1.58E-11 |
| | | | 89 | 396 | 671 | 1.58E-11 |

[a]Locations are shown in Fig. 5E.5, Appendix 5E.

## Table 5E.8. Predicted maximum concentraitons of tritium and VOCs

| Tritium | | | | |
|---|---|---|---|---|
| | Maximum fenceline receptor | | Maximum on-site receptor | |
| | Concentration | | Concentration | |
| Period | (picograms/m$^3$) | (picocuries/m$^3$) | (picograms/m$^3$) | (picocuries/m$^3$) |
| 1989 (present) | 620 | 5,952,000 | 64,670 | 620,832,000 |
| 1990-2019 | 109 | 1,046,400 | 12,326 | 118,329,600 |
| 1990-2059 | 64 | 614,400 | 7,077 | 67,939,200 |
| 2100-2129 | 0.05 | 480 | 6 | 57,600 |

| VOCs | | |
|---|---|---|
| | Maximum fenceline receptor | Maximum on-site receptor |
| Case | Concentration (picograms/m$^3$) | Concentration (picograms/m$^3$) |
| Baseline | 64 | 166.5 |

# Appendix 5E Figures

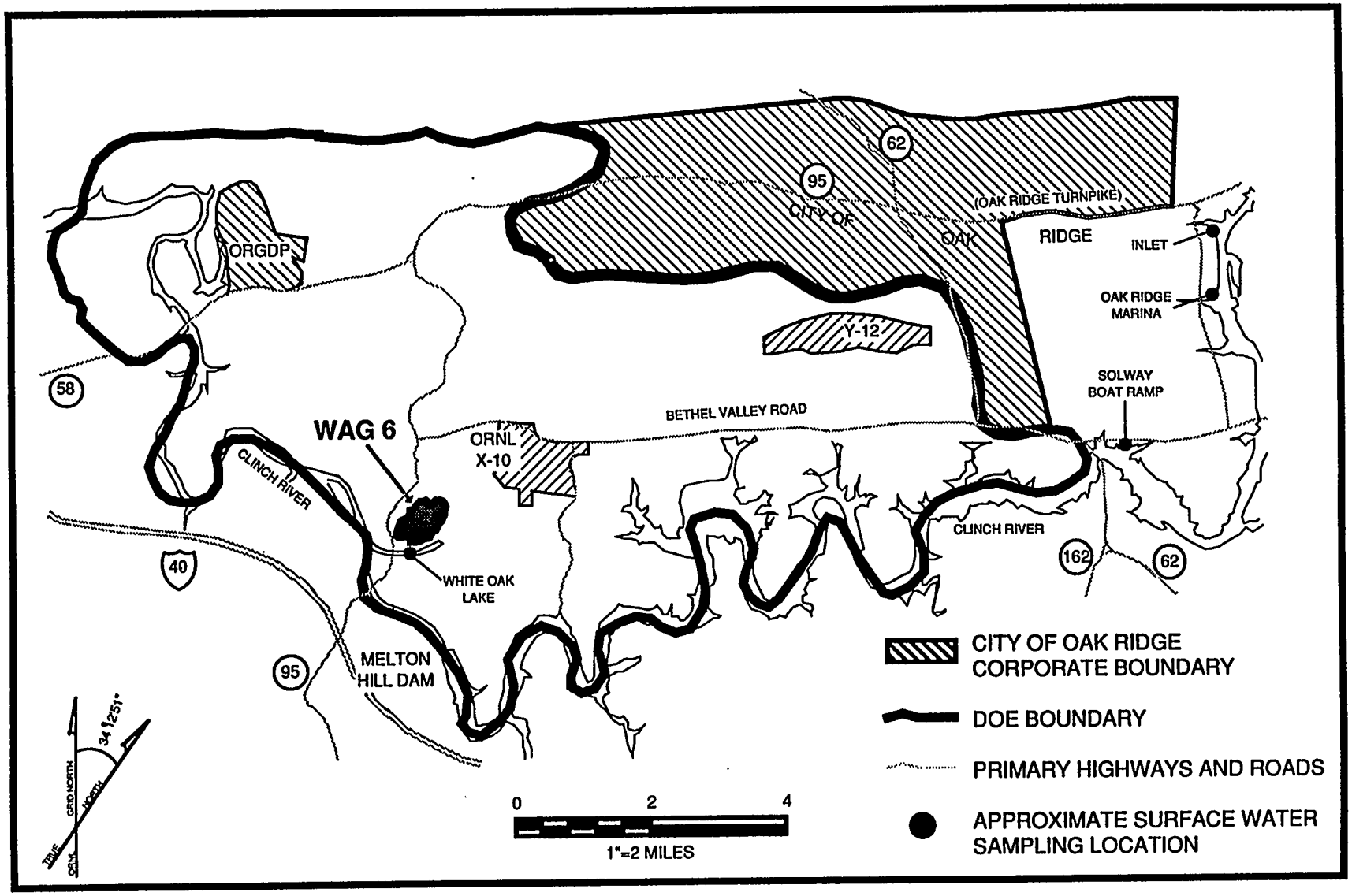
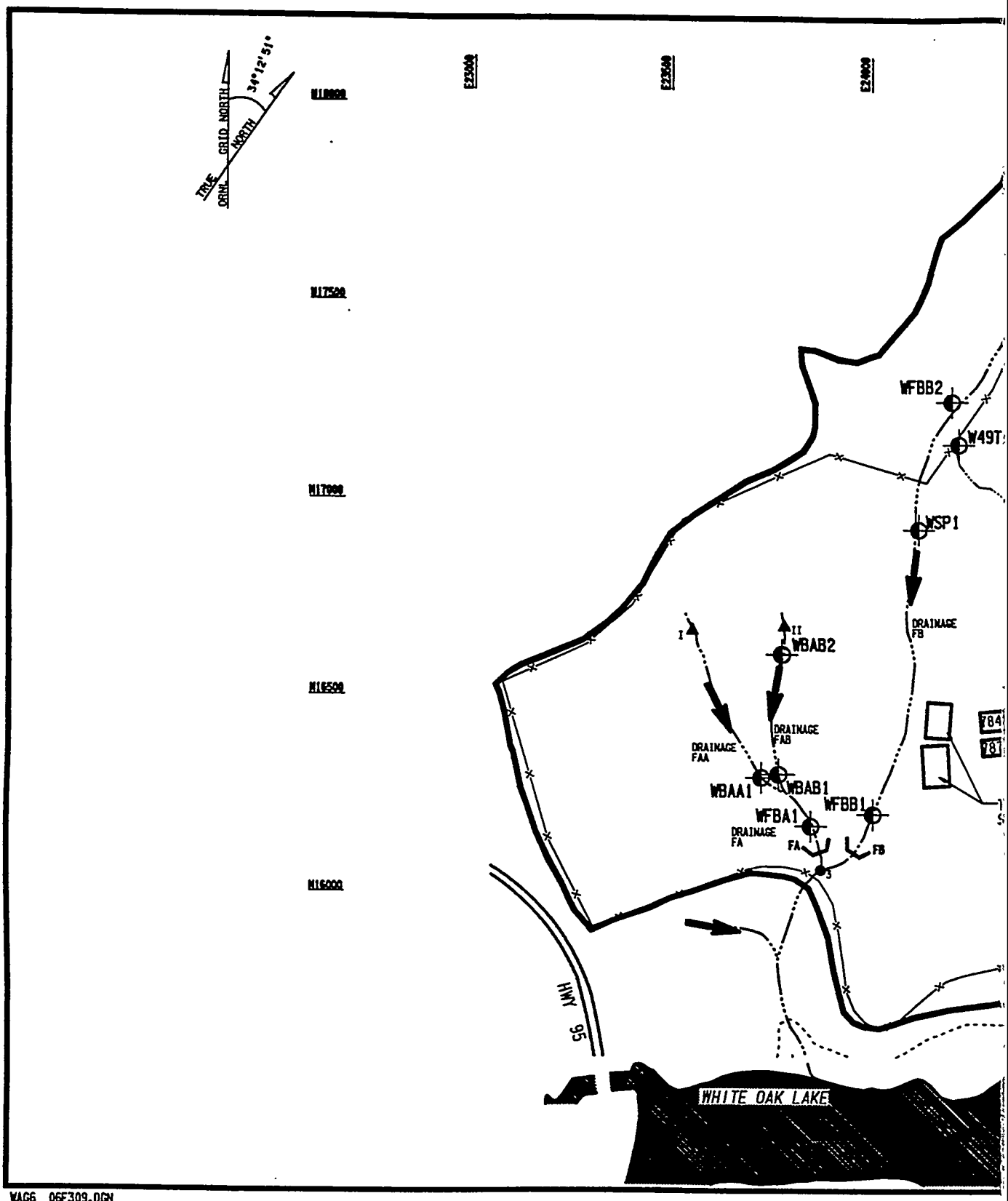



**Fig. 5E.1. Approximate microbiological surface water sampling locations, Activity 2.**

5.18F 4104.177




WAG6 06F309.DGN

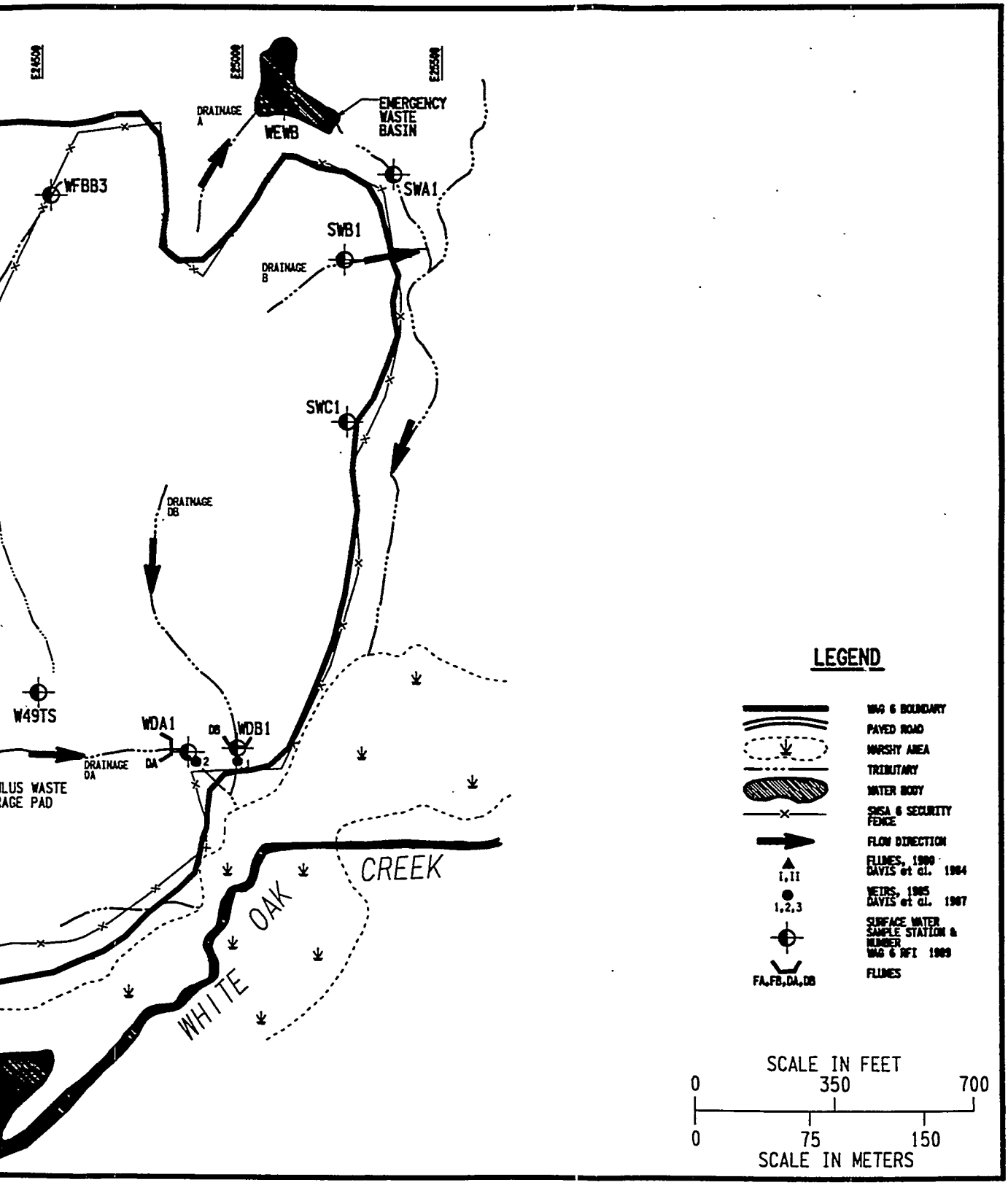
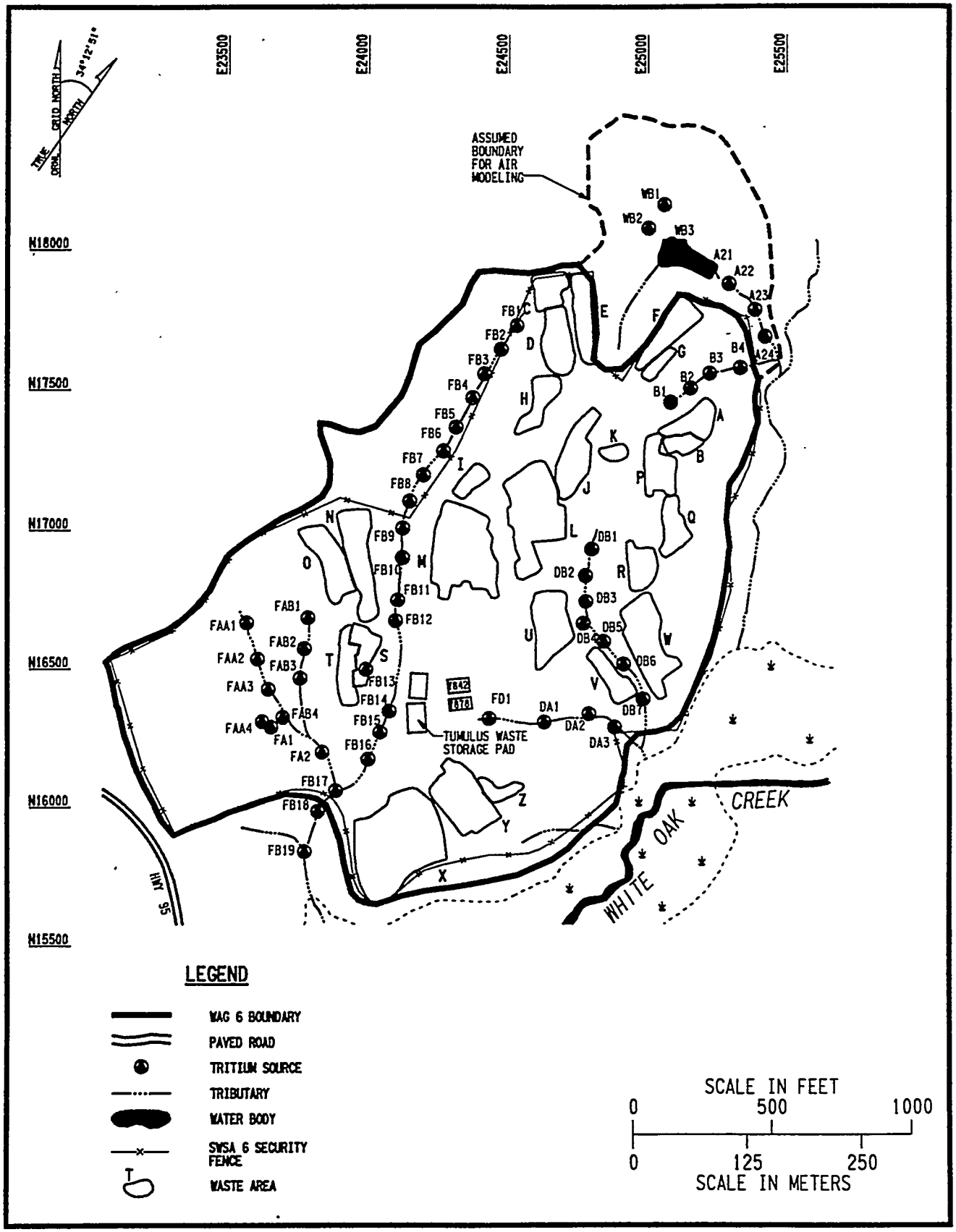
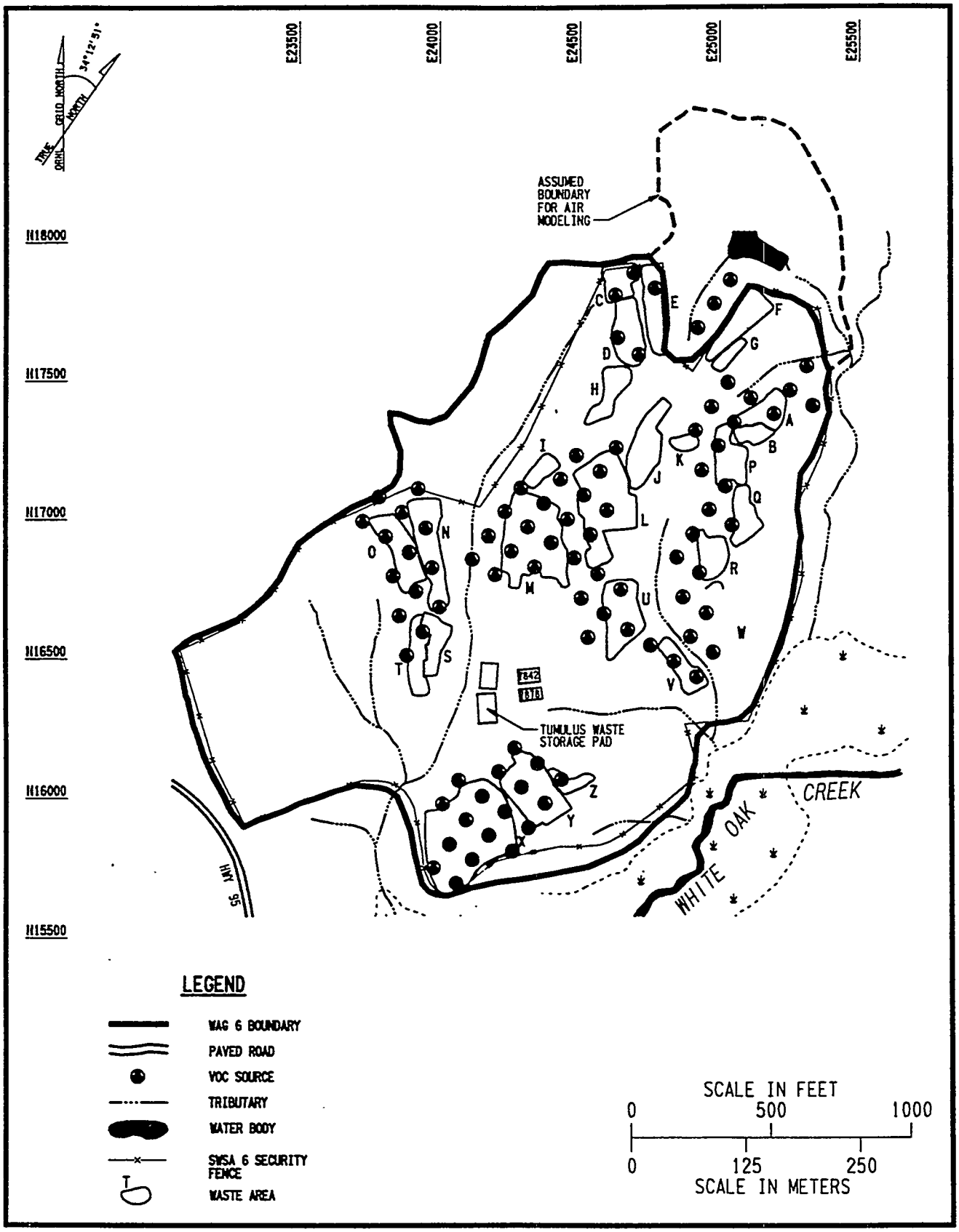



Fig. 5E.3. WAG 6 surface water flow stations and sampling sites.



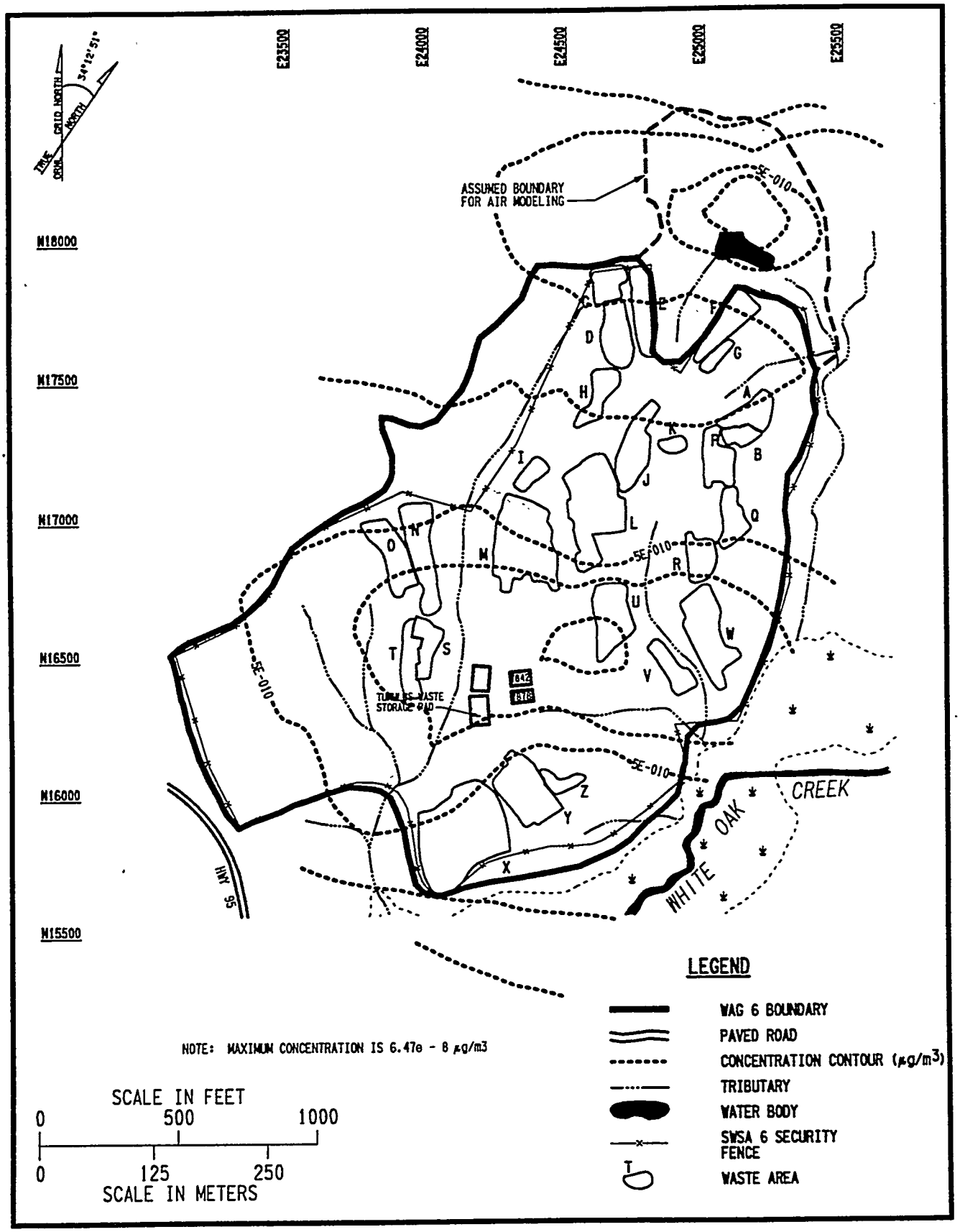

WAG6 ORSRC.DGN

**Fig. 5E.4. ISCLT model source areas, 51 tritium sources.**



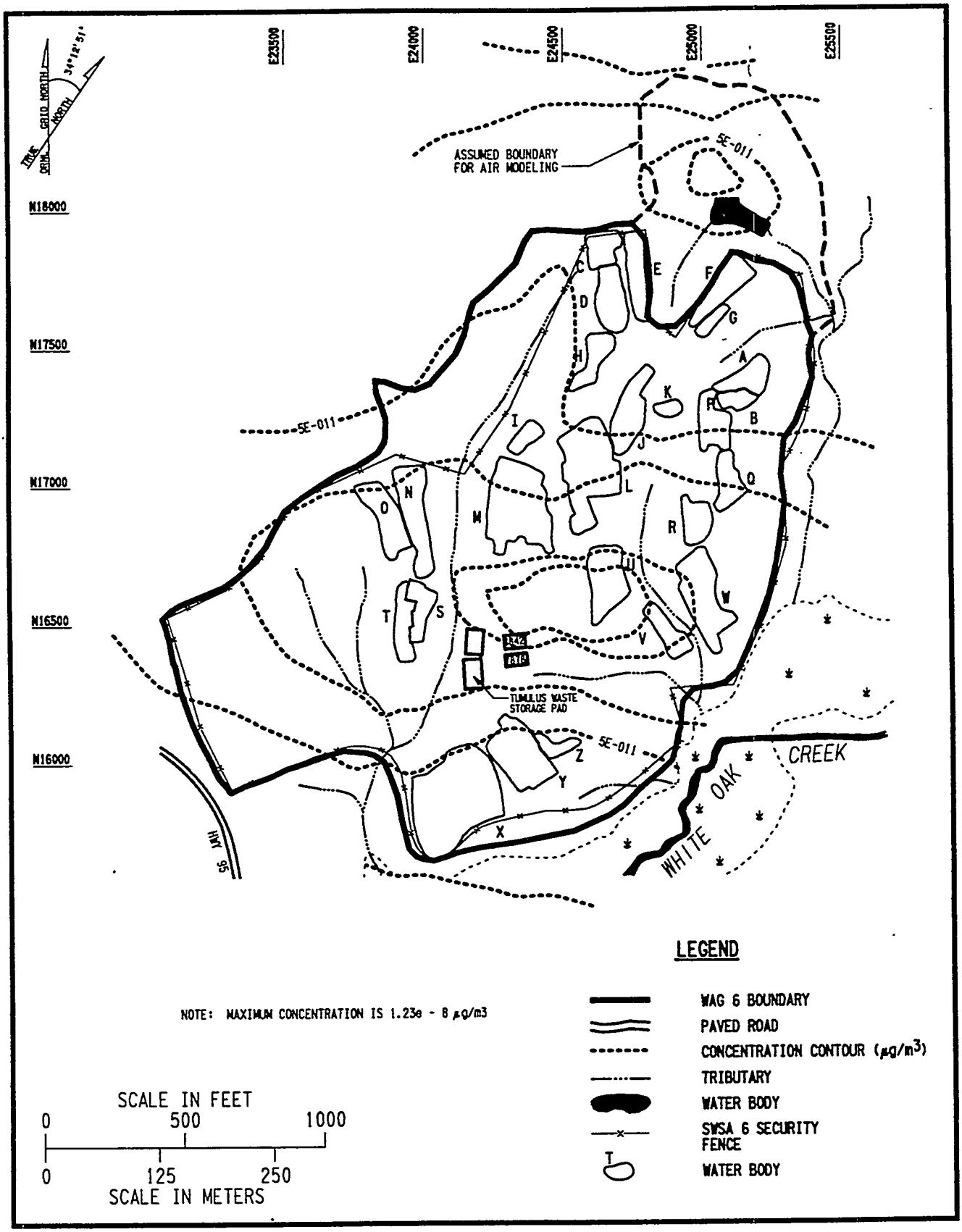

WAG6 ORSRCVOC.DGN

**Fig. 5E.5. ISCLT model source areas, 89 VOC sources.**



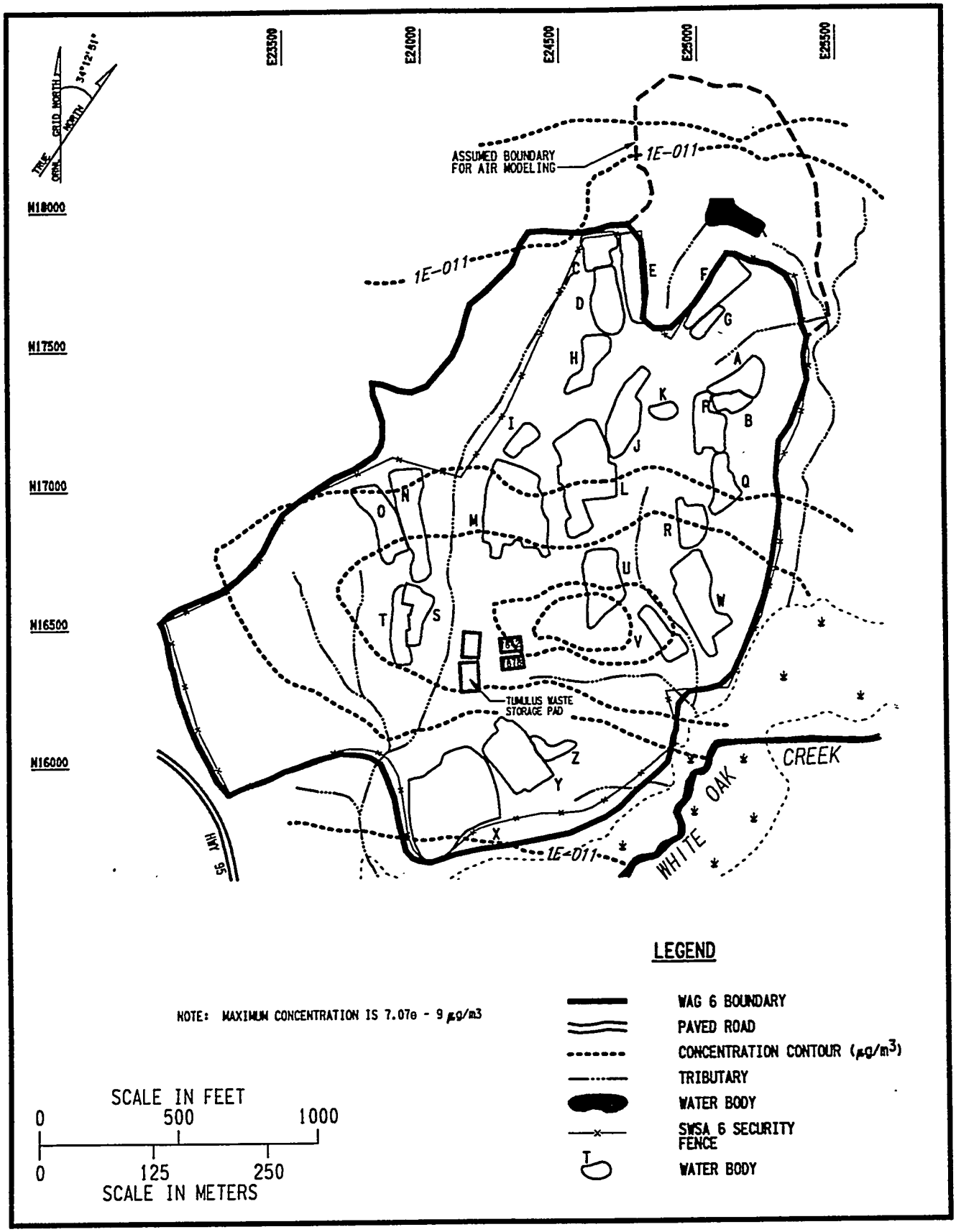

WAG6 06F275.DGN

**Fig. 5E.6. Tritium concentrations at present.**



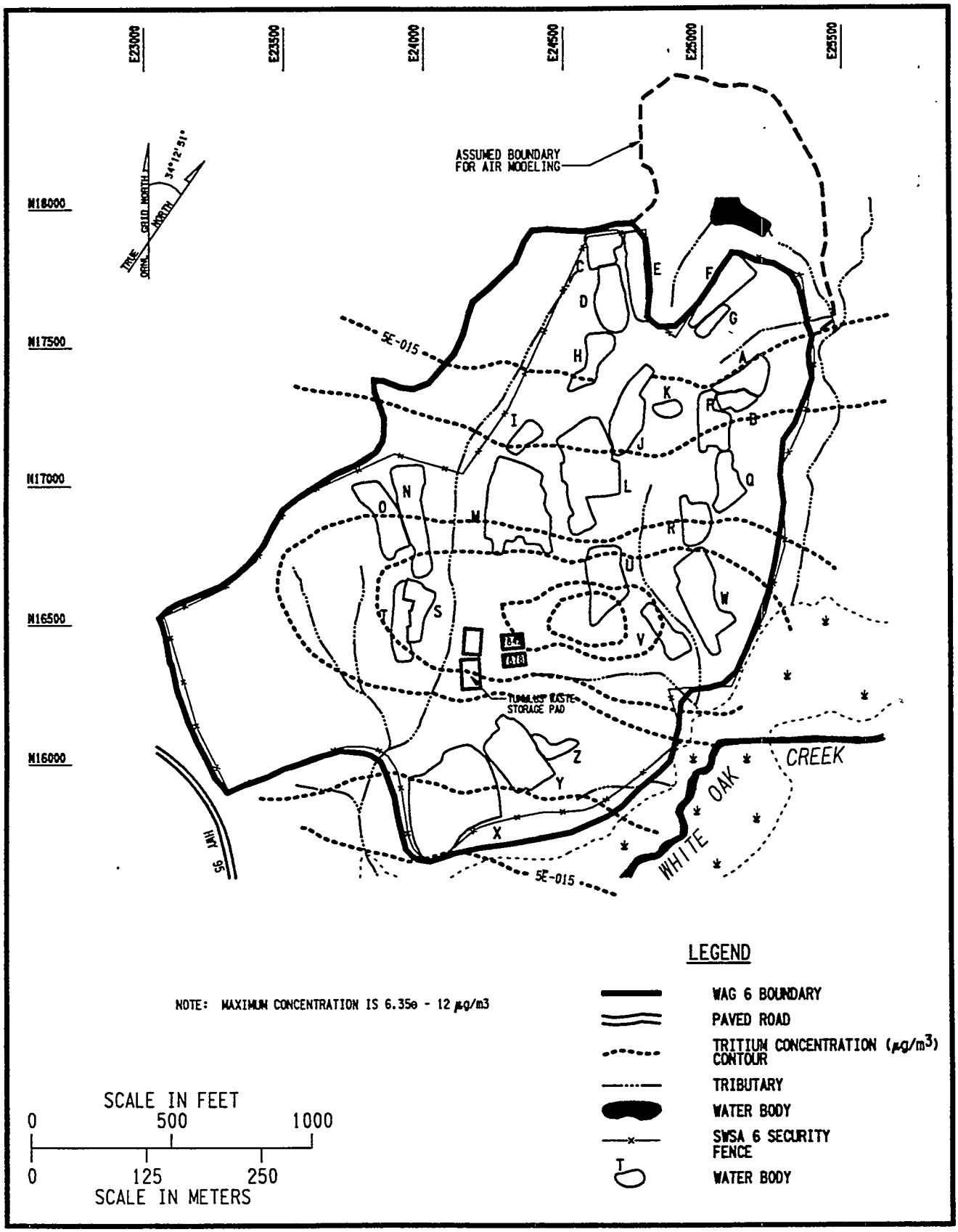

WAG6 06F276.DGN

**Fig. 5E.7. Predicted tritium concentrations 1990 to 2019.**



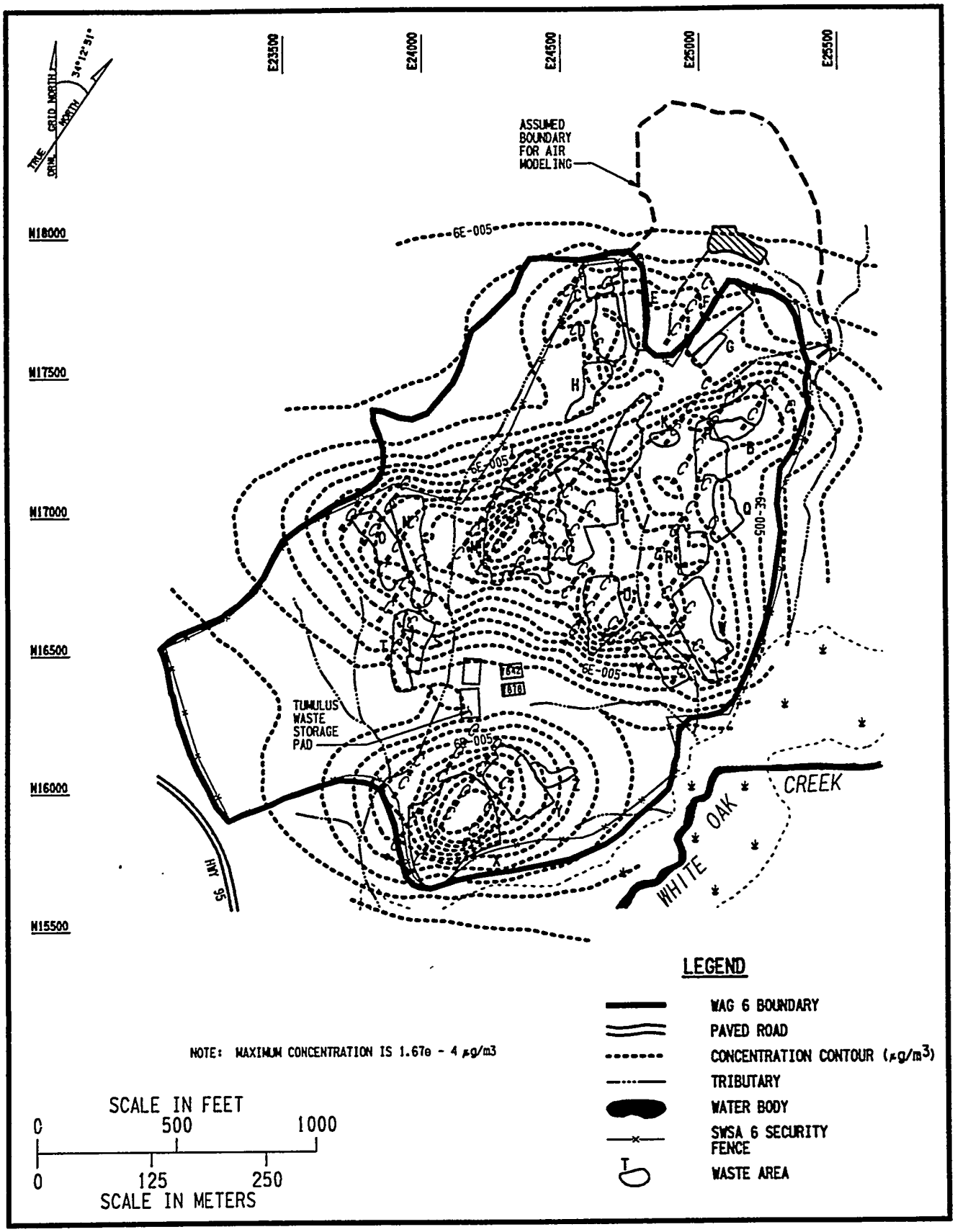

WAG6 06F277.DGN

**Fig. 5E.8. Predicted tritium concentrations 1990 to 2059.**




WAG6 06F278.DGN

**Fig. 5E.9. Predicted tritium concentrations 2100 to 2129.**




WAG6 ORGA.DGN

**Fig. 5E.10. Annual average baseline VOC concentrations.**

# APPENDIX 6A. RATIONALE FOR SELECTION OF INVENTORY INFORMATION

This appendix supplements Sect. 6.2.1 in the main report. It identifies the radionuclides in the wastes disposed of below-ground at WAG 6 and outlines the rationale for not using the aboveground and future radionuclide inventory in the baseline human health evaluation.

Wastes containing 82 radionuclides and 69 daughters with a total activity (decayed to January 1991) of 571,710 curies are buried at WAG 6 (Table 6A.1). Wastes in the aboveground disposal units contain 61 radionuclides with activity totaling 143 curies, approximately 0.025 percent of the below-ground unit curie content. This below-ground inventory includes all radionuclides present in wastes stored aboveground. Additional above- and below-ground storage units are planned. Using the conservative assumption that wastes will be stored in these units at the same rate as in the past, their inventory was estimated to comprise 37 radionuclides with an activity of 6,600 total curies, or 1.1 percent of the below-ground inventory. Table 6A.2 summarizes the above information. The field sampling data, summarized in Sect. 4 of the main report, contain radionuclides which are a subset of the below-ground inventory information.

Only the below-ground inventory was used in the baseline human health evaluation. Preliminary results (see Technical Bulletin 06-003) already indicated an unacceptable risk to selected receptors (the on-WAG homesteader) from this source alone; the aboveground and future inventories were comparatively insignificant. Moreover, the future inventory will in fact, be significantly less than the estimate cited above since the disposal rate is projected to decrease over time. In addition, the future units will be constructed in concrete and consequently migration will be effectively eliminated for hundreds of years (NRC 1989), barring catastrophic events.

# Appendix 6A Tables

**Table 6A.1 WAG 6 radionuclide inventory (decayed to 1 January 1991)**

| Radionuclide | Curies |
|---|---|
| Ac-225 | 1.48E-1 |
| Ac-227 | 9.08E-6 |
| Ac-228 | 1.75E+0 |
| Ag-109m | 1.15E-3 |
| Ag-110 | 1.70E-4 |
| Ag-110m | 1.13E-2 |
| Ag-111 | 2.69E-37 |
| Am-241 | 3.69E+0 |
| Am-243 | 2.08E-2 |
| Am-245 | 3.09E-9 |
| Ar-39 | 1.29E-3 |
| At-217 | 1.48E-1 |
| Ba-137m | 3.80E+4 |
| Be-10 | 7.12E+2 |
| Bi-207 | 9.49E-1 |
| Bi-210 | 1.04E-2 |
| Bi-211 | 8.79E-6 |
| Bi-212 | 1.39E+0 |
| Bi-213 | 1.48E-1 |
| Bi-214 | 1.04E-2 |
| Bk-249 | 3.09E-6 |
| Bk-250 | 9.80E-6 |
| C-14 | 2.69E+2 |
| Cd-109 | 1.15E-3 |
| Cd-113 | 4.00E+0 |
| Ce-141 | 1.05E-14 |
| Cf-249 | 1.29E-2 |
| Cf-250 | 1.07E-5 |
| Cf-252 | 2.49E-2 |
| Cl-36 | 3.06E-1 |
| Cm-242 | 3.34E-15 |
| Cm-243 | 9.60E-6 |
| Cm-244 | 2.24E+1 |
| Cm-245 | 3.47E-6 |
| Cm-248 | 2.40E-4 |
| Co-57 | 1.86E-3 |
| Co-58 | 4.47E-1 |
| Co-60 | 2.10E+4 |
| Cr-51 | 7.49E-10 |
| Cs-134 | 4.95E+0 |

**Table 6A.1 (continued)**

| Radionuclide | Curies |
|---|---|
| Cs-137 | 4.01E+4 |
| Es-253 | 2.90E-31 |
| Es-254 | 9.80E-6 |
| Eu-152 | 2.39E+5 |
| Eu-154 | 1.71E+5 |
| Eu-155 | 4.23E+4 |
| Eu-156 | 2.27E-25 |
| Fe-55 | 7.79E+1 |
| Fe-59 | 2.41E-2 |
| Fr-221 | 1.48E-1 |
| Fr-223 | 1.27E-7 |
| Ga-68 | 1.19E-2 |
| Gd-152 | 2.19E-9 |
| Gd-153 | 9.60E+1 |
| Ge-68 | 1.19E-2 |
| H-3 | 4.92E+3 |
| Hg-203 | 4.08E-11 |
| I-125 | 5.14E-5 |
| I-131 | 1.45E-14 |
| Ir-191m | 1.00E-7 |
| Ir-192 | 8.43E-1 |
| K-40 | 4.68E-3 |
| Kr-85 | 1.52E+0 |
| Mn-54 | 1.21E+1 |
| Na-22 | 2.70E-2 |
| Nb-93m | 9.56E+0 |
| Nb-95 | 9.11E-8 |
| Nb-95m | 3.95E-10 |
| Ni-63 | 1.95E+0 |
| Np-237 | 9.07E-3 |
| Np-239 | 2.08E-2 |
| Np-240 | 7.05E-15 |
| Np-240m | 7.05E-12 |
| Os-191 | 1.00E-7 |
| P-32 | 5.35E-11 |
| Pa-231 | 8.61E-5 |
| Pa-233 | 9.07E-3 |
| Pa-234 | 2.05E-1 |
| Pa-234m | 2.05E+2 |
| Pb-207m | 7.88E-1 |

**Table 6A.1 (continued)**

| Radionuclide | Curies |
|---|---|
| Pb-209 | 1.48E-1 |
| Pb-210 | 1.04E-2 |
| Pb-211 | 8.79E-6 |
| Pb-212 | 1.39E+0 |
| Pb-214 | 1.04E-2 |
| Pd-103 | 6.88E-5 |
| Pd-107 | 1.30E-1 |
| Pm-147 | 4.07E+1 |
| Po-210 | 1.03E-2 |
| Po-211 | 2.64E-8 |
| Po-212 | 8.89E-1 |
| Po-213 | 1.45E-1 |
| Po-214 | 1.04E-2 |
| Po-215 | 8.79E-6 |
| Po-216 | 1.39E+0 |
| Po-218 | 1.04E-2 |
| Pu-238 | 3.24E-2 |
| Pu-239 | 6.04E-1 |
| Pu-240 | 2.33E-2 |
| Pu-241 | 2.67E-7 |
| Pu-244 | 7.06E-12 |
| Ra-223 | 8.79E-6 |
| Ra-224 | 1.39E+0 |
| Ra-225 | 1.49E-1 |
| Ra-226 | 1.04E-2 |
| Ra-228 | 1.75E+0 |
| Re-188 | 1.82E-6 |
| Rh-103m | 6.89E-5 |
| Rh-106 | 3.10E+1 |
| Rn-219 | 8.79E-6 |
| Rn-220 | 1.39E+0 |
| Rn-222 | 1.04E-2 |
| Ru-106 | 3.10E+1 |
| S-35 | 2.05E-6 |
| Sm-147 | 4.79E-9 |
| Sm-151 | 1.37E+2 |
| Sn-119m | 5.23E-3 |
| Sn-121m | 7.16E+1 |
| Sn-123 | 5.44E-10 |
| Sr-85 | 1.97E-6 |

**Table 6A.1 (continued)**

| Radionuclide | Curies |
|---|---|
| Sr-89 | 5.07E+0 |
| Sr-90 | 6.55E+3 |
| Ta-179 | 1.08E-1 |
| Tc-95 | 2.06E-10 |
| Tc-95m | 5.22E-9 |
| Tc-99 | 3.83E+1 |
| Th-227 | 8.77E-6 |
| Th-228 | 1.39E+0 |
| Th-229 | 1.50E-1 |
| Th-230 | 6.10E-3 |
| Th-231 | 5.92E-1 |
| Th-232 | 2.66E+0 |
| Th-234 | 2.05E+2 |
| Tl-204 | 3.54E-2 |
| Tl-207 | 8.77E-6 |
| Tl-208 | 5.00E-1 |
| Tl-209 | 3.25E-3 |
| U-232 | 2.08E-2 |
| U-233 | 2.28E+2 |
| U-234 | 3.73E-3 |
| U-235 | 5.92E-1 |
| U-235m | 6.04E-1 |
| U-236 | 7.00E-5 |
| U-238 | 2.05E+2 |
| U-240 | 7.05E-12 |
| W-188 | 1.80E-6 |
| Xe-131m | 6.66E-13 |
| Y-90 | 6.55E+3 |
| Zn-65 | 1.11E+0 |
| Zr-93 | 2.26E+1 |
| Zr-95 | 4.14E-8 |
| Total Activity | 5.72E+5 |

Table 6A.2 Summary of WAG 6 waste disposal details

| Unit type | Unit Description; Disposal Dates | Total Curies | Percentage of Belowground Units |
|---|---|---|---|
| Below ground | Auger holes, silos, silo wells, trenches; January, 1962 - December 1990 | 571,710[a] | 100 |
| Aboveground | Tumulus I and II, Hill Cut Disposal Test Facility; 1981-December 1990 | 143 | 0.025 |
| Future | Tumulus II, silos, silo-wells; December 1990-September 1992 | ~6,600[b] | 1.1 |

[a]Decayed to 1 January 1991.
[b]Assuming that the same radioactive waste is disposed of in the future and at the same rate as in the past.

# APPENDIX 6B. SELECTION OF RADIONUCLIDES OF POTENTIAL CONCERN AT WAG 6

This appendix supplements Sect. 6.2.1 in the main report on the selection of radionuclides of potential concern, providing detail regarding the screening process employed to select radionuclides used in the quantification of risk (those considered to be of potential concern to human health) and the subsequent fate and transport modeling of these radionuclides.

The potential relative dose of each radionuclide in the WAG 6 inventory was calculated as the first step in the screening process.

$$RD_{ik} = \frac{A_i \times DCF_{ik}}{\sum_{j=1}^{n} \sum_{k=1}^{3} A_j \times DCF_{jk}}$$

where

| | | |
|---|---|---|
| $RD_{ik}$ | = | relative dose for the i'th radionuclide and k'th exposure route |
| $A_i$ | = | activity of the i'th radionuclide |
| $DCF_{ik}$ | = | dose conversion factor for the i'th radionuclide and k'th exposure route |
| $A_j$ | = | activity of the j'th radionuclide |
| $DCF_{jk}$ | = | dose conversion factor for the j'th radionuclide and k'th exposure route |

This equation does not include intake variables (e.g., exposure duration, ingestion rate), described in Sect. 6.3, and Appendix 6G. These variables are constant for a specific exposure pathway. Since relative dose is calculated on a pathway-specific basis, changes in intake variables do not change the results.

The potential relative dose was calculated for 1990 and 2100 using the WAG 6 radionuclide inventory decayed to these dates. This decay included the generation of radioactive decay products.

As the next step in the screening process, the radionuclides were ranked according to their potential relative doses. Those contributing the least (2.5% or less) were eliminated from further analyses. The remaining radionuclides, responsible for at least 97.5% of the potential dose, were considered to be preliminary contaminants of potential concern. These were cobalt-60, americium-241, barium-137m, curium-244, cesium-137, europium-152, europium-154, europium-155, radium-225, strontium-90, thorium-229, thorium-232, uranium-233, uranium-238, and yttrium-90.

All of the preliminary radionuclides of potential concern were selected for fate and transport modeling except barium-137m and yttrium-90, which are daughters of those selected and have a short half-life (assumed to be in secular equilibrium with the parent). These daughters were quantitatively evaluated in conjunction with the parent after the latter had been modeled for concentration at the point of ingestion, inhalation or external exposure. Protactinium-234m, thorium-234, and protactinium-234 were daughters that were similarly evaluated in conjunction with parents even though they themselves were not among the radionuclides originally selected through the screening process.

Additionally these radionuclides were compared to those detected in groundwater and surface water on the WAG. This comparison led to the identification of H-3 (tritium) as an additional radionuclide of potential concern. This is due to the elevated concentrations of tritium that have been detected and its high mobility in the environment.

Modeling was completed for all selected radionuclides except for radium-225 and thorium-229. The model could not adequately deal with the production of these two decay products of uranium-233 outside of the waste disposal areas.

The radionuclides of potential concern that were evaluated in the baseline human health evaluation are listed in Table 6.1 of the main report.

## APPENDIX 6C. SAMPLES USED TO IDENTIFY CHEMICALS OF POTENTIAL CONCERN

This Appendix supplements Sect. 6.2.2 in the main report and identifies the specific groups of samples analyzed to determine chemical contaminants of potential concern.

Groundwater, surface water, soil, and sediment were sampled for chemicals; those detected in each of these media are listed in Tables 4.2 through 4.7 (main report), respectively. Field sampling was performed for several purposes (e.g., to determine the nature and extent of contamination present, to yield data for modeling and risk assessment). Not all samples collected in the remedial investigation were used for the baseline human health evaluation. Those used directly in the evaluation are included in Appendix 4B.

Groundwater samples used were those from all sampling events at all of the RCRA compliance wells and RFI wells on WAG 6, except the deep wells (well numbers 1234, 1236, 1238, and 1239). Samples from the latter were not used because, as described in Sect. 3 of the main report, active groundwater flow is limited to depths up to 65 ft in bedrock; a preponderance of evidence (e.g., aquifer geochemistry, age-dating, and actual sampling results from the deep wells) suggests that the deeper groundwater is not being affected by operational activities associated with waste disposal at the WAG.

Surface water samples used were those from the baseflow sampling events of February 1989, April 1989, and September 1989. Soil samples used were from the 0-6 ft depth interval or some smaller portion thereof. Soils from this interval were assumed to be best suited for evaluating exposures to contaminants that might result from direct contact with, or ingestion of, surface soil. The sediment samples used were taken from the EWB, where it is assumed that sediment becomes suspended in the surface water when it is disturbed by swimmers.

## APPENDIX 6D. EVALUATION OF TENTATIVELY IDENTIFIED COMPOUNDS

This appendix supplements Section 6.2.2 in the main report. It addresses the evaluation of tentatively identified compounds (TICs) performed as part of the identification of chemical contaminants of potential concern.

In accordance with "Risk Assessment Guidance for Superfund: Human Health Evaluation Manual, Part A," (EPA 1989b) "Laboratory Data Validation - Functional Guidelines for Evaluation Organics Analyses," (EPA 1988b) and "Guidance for Data Useability in Risk Assessment," (EPA 1990a) samples used in the baseline human health evaluation (see Appendix 4B, Table 4B.1) were analyzed for TICs.

TICs identified in analytical data packages received from laboratories were eliminated from further evaluation if comparable concentrations thereof were found in associated blank samples, if the presence of the compound could be attributed to common lab artifacts or contaminants, or if the compound was a product of aldol condensation (i.e., a method artifact). TICs evaluated further were those listed in Tables 6D.1 through 6D.5. The concentrations shown are highly uncertain and could be higher or lower than the actual concentrations. TICs in the different QC levels were evaluated as follows. QC Level II samples, reconstructed ion chromatograms (RICs), necessary to further evaluate TICs were not available in the packages of analytical results and the assumption was therefore made that the tentative identifications were correct. For QC Level III samples, the RICs were evaluated to verify the given tentative identifications. All TICs listed as "unknown," or any TIC that could not be assigned a chemical class, was eliminated from the list. All remaining TICs were assigned to a chemical class to facilitate risk assessment. All concentration values were accepted as given in the analytical data packages.

One hundred and nineteen TICs were identified, encompassing 18 chemical classes as shown below.

| Chemical Class | Number of Occurrences |
|---|---|
| Alcohol | 5 |
| Alkane | 5 |
| Alkane, cyclic | 3 |
| Alkane, halogenated | 2 |
| Alkane, nitrogen-containing | 1 |
| Aliphatic heterocycle | 24 |
| Amide | 2 |
| Aromatic | 1 |
| Aromatic amine | 1 |
| Benzene derivative | 27 |
| Carboxylic acid | 10 |

| | |
|---|---|
| Cholesterol derivative | 1 |
| Ester | 5 |
| Hydrogen peroxide derivative | 1 |
| Ketone | 6 |
| PAH | 6 |
| Phenol derivative | 7 |
| Triterpenes | 3 |

Only seven TICs were present in concentrations of parts per million: two (benzene derivatives) in groundwater samples from the RCRA compliance wells and five (three esters and two ketones) in soil samples. Only two TICs were found (in concentrations of parts per billion) in more than one medium: 1,3,6-trioxocane was found in seven groundwater and two surface water samples; 1,2-benzenedicarboxylic acid was found in six surface water samples and one soil sample.

Because of the small number of TICs present at concentrations in the ppm range compared to the large number of chemicals of potential concern (44) and because no recognized toxicity values exist for TICs, it was decided not to include these compounds as contaminants of concern in the human health evaluation.

# Appendix 6D Tables

Table 6D.1. Results of the TIC evaluation for all media[a]

| CAS Number[b] | Compound | Frequency | Conc range (ppb) | Avg conc (ppb) | Chemical class |
|---|---|---|---|---|---|
| 40710-42-7 | 1-Hentetracontanol | 1/119 | 160 | | Alcohol |
| 2117-11-5 | 4-Pentyn-2-ol | 2/119 | 36-39 | 37.5 | Alcohol |
| 624-51-1 | 3-Nonanol | 1/119 | 11 | | Alcohol |
| 625-25-2 | 2-Methyl-2-Heptanol | 1/119 | 12 | | Alcohol |
| 10042-59-8 | 1-Heptanol, 2-Propyl- | 1/119 | 10 | | Alcohol |
| 2425-33-4 | 2-Bromo-,Tran Cyclohexanol | 3/119 | 12-30 | 19.3 | Alcohol |
| | 2-Bromocyclohexanol | 1/119 | 20 | | Alcohol |
| 54446-78-5 | Ethanol,1-(2-Butoxyethoxy) | 1/119 | 24 | | Alcohol |
| 57-15-8 | Chlorobutanol | 3/119 | 400-810 | 563.3 | Alcohol |
| 630-07-9 | Pentatriacontane | 1/119 | 180 | | Alkane |
| 96-14-0 | Pentane, 3-Methyl- | 2/119 | 14-36 | 25.0 | Alkane |
| | Unknown (Saturated Hydrocarbon) | 1/119 | 340 | | Alkane |
| 2216-34-4 | Octane,4-Methyl | 1/119 | 11 | | Alkane |
| 68998-21-0 | Cyclopropane, 1,1-Dimethyl-2 | 1/119 | 9 | | Alkane, cyclic |
| 1678-91-7 | Ethylcyclohexane | 2/119 | 9.4-15 | 12.2 | Alkane, cyclic |
| 3386-33-2 | Octadecane, 1-Chloro- | 1/119 | 200 | | Alkane, halogenated |
| 75-43-4 | Methane, Dichlorofluoro- | 1/119 | 12 | | Alkane, halogenated |
| 1741-01-1 | Trimethyl Hydrazine | 1/119 | 14 | | Alkane, nitrogen containing |
| 18172-67-3 | beta-Pinene | 1/119 | 7.7 | | Aliphatic heterocycle |
| 766-52-9 | 1-Ethyl-2-Methyl Piperidine | 3/119 | 10-14 | 11.3 | Aliphatic heterocycle |
| 1779-19-7 | 1,3,6-Trioxocane | 9/119 | 8-93 | 32.4 | Aliphatic heterocycle |
| 123-91-1 | 1,4-Dioxane | 11/119 | 3-160 | 48.2 | Aliphatic heterocycle |
| 301-02-0 | 9-Octadecenamide, (Z)- | 1/119 | 270 | | Amide |
| 75-12-7 | Formamide | 1/119 | 8.3 | | Amide |
| 28231-03-0 | 1H-3A,7-Methanoazulen-5-Ol, | 1/119 | 240 | | Aromatic |
| 42786-06-1 | 4H-1,2,4-Triazol-3-Amine, 4- | 1/119 | 14 | | Aromatic amine |
| 36875-10-2 | Benzene, 1-(Chloromethyl)-4- | 1/119 | 570 | | Benzene derivative |
| 89-16-7 | 1,2-Benzenedicarboxylic Acid | 7/119 | 22-690 | 173.4 | Benzene derivative |
| | 1-Methylethyl Benzene | 1/119 | 8.8 | | Benzene derivative |
| | 1-Ethylmethyl Benzene | 1/119 | 77 | | Benzene derivative |
| | Trimethyl Benzene | 1/119 | 51 | | Benzene derivative |
| 74672-05-2 | 1-(1,3-Diethyl-3-Benzene) | 1/119 | 38 | | Benzene derivative |
| | Benzene Derivative | 14/119 | 25-4100 | 572.2 | Benzene derivative |
| 4337-65-9 | Hexanedioic Acid, Mono(2-Eth | 1/119 | 230 | | Carboxylic acid |
| 74381-40-1 | Propanoic Acid, 2-Methyl-,1 | 1/119 | 380 | | Carboxylic acid |
| 57-11-4 | Stearic acid | 3/119 | 290-520 | 386.7 | Carboxylic acid |
| 1070-83-3 | 3,3-Dimethyl-Butanoic Acid | 1/119 | 34 | | Carboxylic acid |
| 97-61-0 | 2-Methyl-Pentanoic Acid | 1/119 | 17 | | Carboxylic acid |
| 116-53-0 | 2-Methyl-Butanoic Acid | 1/119 | 10 | | Carboxylic acid |

Table 6D.1 (continued)

| CAS Number[b] | Compound | Frequency | Conc range (ppb) | Avg conc (ppb) | Chemical class |
|---|---|---|---|---|---|
| 57-10-3 | Palmitic Acid | 1/119 | 12 | | Carboxylic acid |
| 1116-98-9 | 1,1-Dim,Cyano Acetic Acid | 1/119 | 16 | | Carboxylic acid |
| 303-43-5 | Cholest-5-En-3-Ol (.Beta.)- | 1/119 | | | Cholesterol derivative |
| 123-79-5 | Dioctyl adipate | 3/119 | 3100-34000 | 13866.7 | Ester |
| 126-73-8 | Tributyl Phosphate | 2/119 | 20-36 | 28.0 | Ester |
| 75-91-2 | 1,1-Dimethylethylhydroperoxide | 1/119 | 18 | | Hydrogen peroxide derivative |
| 563-80-4 | 2-Butanone, 3-Methyl- | 1/119 | 6 | | Ketone |
| 110-13-4 | 2,5-Hexanedione | 1/119 | 210 | | Ketone |
| | Hexen-2-one, 5-Methyl- | 1/119 | 800 | | Ketone |
| | Unk Hydroxy Pentanone | 1/119 | 1500 | | Ketone |
| 110-12-3 | 2 Hexanone, 5-Methyl- | 1/119 | 1500 | | Ketone |
| 3240-09-3 | 5-Hexen-2-One, 5-Methyl- | 1/119 | 220 | | Ketone |
| 511-15-9 | 2-Phenanthrenol, 4B,5,6,7,8 | 5/119 | 160-950 | 452.0 | PAH |
| 24035-50-5 | 1-Phenanthrenecarboxaldehyde | 1/119 | 740 | | PAH |
| 54932-78-4 | Phenol,4-(2,2,3,3-Tetrameth) | 2/119 | 100-100 | 100.0 | Phenol derivative |
| | 4-(Tetramethylbutyl)-Phenol | 2/119 | 48-70 | 59.0 | Phenol derivative |
| 84-16-2 | 4,4-(1,2-Diethyl-1,Phenol) | 1/119 | 21 | | Phenol derivative |
| 104-40-5 | p-Nonylphenol | 1/119 | 74 | | Phenol derivative |
| 25154-52-3 | Nonylphenol | 1/119 | 24 | | Phenol derivative |
| 14021-23-9 | D-Friedoolean-14-Ene, 3-Meth | 1/119 | 170 | | Triterpene |
| 18671-57-3 | D:A-Friedooleanan-7-Ol, | 1/119 | 190 | | Triterpene |
| 559-74-0 | Friedelin | 1/119 | 300 | | Triterpene |

[a]Evaluation performed for samples used in the baseline human health evaluation.
[b]No CAS number for indistinguishable isomer.

Table 6D.2. Results of the TIC evaluation for groundwater samples from RFI wells[a]

| CAS Number[b] | Compound | Frequency | Conc range (ug/L) | Avg conc (ug/L) | Chemical class |
|---|---|---|---|---|---|
| 2117-11-5 | 4-Pentyn-2-ol | 2/43 | 36-39 | 37.5 | Alcohol |
| 624-51-1 | 3-Nonanol | 1/43 | 11 | | Alcohol |
| 625-25-2 | 2-Methyl-2-Heptanol | 1/43 | 12 | | Alcohol |
| 10042-59-8 | 1-Heptanol, 2-Propyl- | 1/43 | 10 | | Alcohol |
| 2425-33-4 | 2-Bromo-,Tran Cyclohexanol | 3/43 | 12-30 | 19.3 | Alcohol |
| | 2-Bromocyclohexanol | 1/43 | 20 | | Alcohol |
| 54446-78-5 | Ethanol,1-(2-Butoxyethoxy) | 1/43 | 24 | | Alcohol |
| 766-52-9 | 1-Ethyl-2-Methyl Piperidine | 3/43 | 10-14 | 11.3 | Aliphatic heterocycle |
| 1779-19-7 | 1,3,6-Trioxocane | 7/43 | 8-93 | 33.7 | Aliphatic heterocycle |
| 2216-34-4 | Octane,4-Methyl | 1/43 | 11 | | Alkane |
| 1678-91-7 | Ethylcyclohexane | 2/43 | 9.4-15 | 12.2 | Alkane, cyclic |
| 1741-01-1 | Trimethyl Hydrazine | 1/43 | 14 | | Alkane, nitrogen containing |
| | 1-Methylethyl Benzene | 1/43 | 8.8 | | Benzene derivative |
| | 1-Ethylmethyl Benzene | 1/43 | 77 | | Benzene derivative |
| | Trimethyl Benzene | 1/43 | 51 | | Benzene derivative |
| 74672-05-2 | 1-(1,3-Diethyl-3-Benzene) | 1/43 | 38 | | Benzene derivative |
| 1070-83-3 | 3,3-Dimethyl-Butanoic Acid | 1/43 | 34 | | Carboxylic acid |
| 97-61-0 | 2-Methyl-Pentanoic Acid | 1/43 | 17 | | Carboxylic acid |
| 116-53-0 | 2-Methyl-Butanoic Acid | 1/43 | 10 | | Carboxylic acid |
| 57-10-3 | Palmitic Acid | 1/43 | 12 | | Carboxylic acid |
| 1116-98-9 | 1,1-Dim,Cyano Acetic Acid | 1/43 | 16 | | Carboxylic acid |
| 126-73-8 | Tributyl Phosphate | 2/43 | 20-36 | 28.0 | Ester |
| 75-91-2 | 1,1-Dimethylethylhydroperoxide | 1/43 | 18 | | Hydrogen peroxide derivative |
| 54932-78-4 | Phenol,4-(2,2,3,3-Tetrameth) | 2/43 | 100-100 | 100.0 | Phenol derivative |
| | 4-(Tetramethylbutyl)-Phenol | 2/43 | 48-70 | 59.0 | Phenol derivative |
| 84-16-2 | 4,4-(1,2-Diethyl-1,Phenol) | 1/43 | 21 | | Phenol derivative |
| 104-40-5 | p-Nonylphenol | 1/43 | 74 | | Phenol derivative |
| 25154-52-3 | Nonylphenol | 1/43 | 24 | | Phenol derivative |

[a]Evaluation performed for samples used in the baseline human health evaluation.

[b]No CAS number for indistinguishable isomer.

Table 6D.3. Results of the TIC evaluation for groundwater samples from ORNL RCRA compliance wells [a]

| CAS Number[b] | Compound | Frequency | Conc range (ug/L) | Average conc (ug/L) | Chemical class |
|---|---|---|---|---|---|
| 23-91-1 | 1,4-Dioxane | 11/26 | 3-160 | 48.2 | Aliphatic heterocycle |
| 75-43-4 | Methane, Dichlorofluoro- | 1/26 | 12 | | Alkane, halogenated |
| | Benzene Derivative | 14/26 | 25-4100 | 572.2 | Benzene derivative |

[a]Evaluation performed for samples used in the baseline human health evaluation.
[b]No CAS number for indistinguishable isomer.

Table 6D.4. Results of the TIC evaluation for surface water samples[a]

| CAS Number[b] | Compound | Frequency | Conc range (ug/L) | Average conc. (ug/L) | Chemical class |
|---|---|---|---|---|---|
| 1779-19-7 | 1,3,6-Trioxocane | 2/9 | 14-42 | 28.0 | Aliphatic heterocycle |
| 42786-06-1 | 4H-1,2,4-Triazol-3-Amine, 4- | 1/9 | 14 | | Aromatic amine |
| 89-16-7 | 1,2-Benzenedicarboxylic Acid | 6/9 | 22-230 | 87.3 | Benzene derivative |

[a]Evaluation performed for samples used in the baseline human health evaluation.
[b]No CAS number for indistinguishable isomer.

Table 6D.5. Results of the TIC evaluation for soil samples[a]

| CAS Number[b] | Compound | Frequency | Conc range (ug/kg) | Average conc (ug/kg) | Chemical class |
|---|---|---|---|---|---|
| 40710-42-7 | 1-Hentetracontanol | 1/40 | 160 | | Alcohol |
| 57-15-8 | Chlorobutanol | 3/40 | 400-810 | 563.3 | Alcohol |
| 630-07-9 | Pentatriacontane | 1/40 | 180 | | Alkane |
| 96-14-0 | Pentane, 3-Methyl- | 2/40 | 14-36 | 25.0 | Alkane |
| | Unknown (Saturated Hydrocarbon) | 1/40 | 340 | | Alkane |
| 68998-21-0 | Cyclopropane, 1,1-Dimethyl-2 | 1/40 | 9 | | Alkane, cyclic |
| 3386-33-2 | Octadecane, 1-Chloro- | 1/40 | 200 | | Alkane, halogenated |
| 18172-67-3 | beta-Pinene | 1/40 | 7.7 | | Aliphatic heterocycle |
| 301-02-0 | 9-Octadecenamide, (Z)- | 1/40 | 270 | | Amide |
| 75-12-7 | Formamide | 1/40 | 8.3 | | Amide |
| 28231-03-0 | 1H-3A,7-Methanoazulen-5-Ol, | 1/40 | 240 | | Aromatic |
| 36875-10-2 | Benzene, 1-(Chloromethyl)-4- | 1/40 | 570 | | Benzene, subst. |
| 4376-20-9 | 1,2-Benzenedicarboxylic Acid | 1/40 | 690 | | Benzene, subst |
| 4337-65-9 | Hexanedioic Acid, Mono(2-Eth | 1/40 | 230 | | Carboxylic acid |
| 74381-40-1 | Propanoic Acid, 2-Methyl-,1 | 1/40 | 380 | | Carboxylic acid |
| 57-11-4 | Stearic acid | 3/40 | 290-520 | 386.7 | Carboxylic acid |
| 303-43-5 | Cholest-5-En-3-Ol (.Beta.)- | 1/40 | | | Cholesterol derivative |
| 123-79-5 | Dioctyl adipate | 3/40 | 3100-34000 | 13866.7 | Ester |
| 563-80-4 | 2-Butanone, 3-Methyl- | 1/40 | 6 | | Ketone |
| 110-13-4 | 2,5-Hexanedione | 1/40 | 210 | | Ketone |
| | Hexen-2-one, 5-Methyl- | 1/40 | 800 | | Ketone |
| | Unk Hydroxy Pentanone | 1/40 | 1500 | | Ketone |
| 110-12-3 | 2 Hexanone, 5-Methyl- | 1/40 | 1500 | | Ketone |
| 3240-09-3 | 5-Hexen-2-One, 5-Methyl- | 1/40 | 220 | | Ketone |
| 511-15-9 | 2-Phenanthrenol, 4B,5,6,7,8 | 5/40 | 160-950 | 452.0 | PAH |
| 24035-50-5 | 1-Phenanthrenecarboxaldehyde | 1/40 | 740 | | PAH |
| 14021-23-9 | D-Friedoolean-14-Ene, 3-Meth | 1/40 | 170 | | Triterpene |
| 18671-57-3 | D:A-Friedooleanan-7-Ol, | 1/40 | 190 | | Triterpene |
| 559-74-0 | Friedelin | 1/40 | 300 | | Triterpene |

[a]Evaluation performed for samples used in the baseline human health evaluation.
[b]No CAS number for indistinguishable isomer.

# APPENDIX 6E. CONSIDERATIONS AND ANALYSES AFFECTING DESIGNATION OF SPECIFIC CHEMICALS AS CONTAMINANTS OF POTENTIAL CONCERN

This appendix supplements Sect. 6.2.2 in the main report. It elaborates on the exclusion of certain chemicals that are essential human nutrients from the list of contaminants of potential concern; it also addresses the rationale for including or excluding volatile and semi-volatile organics.

## 6E.1 EVALUATION OF ESSENTIAL HUMAN NUTRIENTS

Copper, iron, magnesium, zinc, calcium, potassium, and sodium were among the chemicals detected in WAG 6 field samples. Each is a trace element essential in human nutrition; relatively high concentrations are required to produce toxic effects. These elements occur naturally in widely varying concentrations. Table 6E.1 presents a comparison between the recommended dietary allowance of these nutrients and intakes calculated from concentrations detected in groundwater and soil on WAG 6. In each case the intake was far below the recommended dietary allowance and therefore these elements were not considered chemicals of potential concern.

## 6E.2 EVALUATION OF VOLATILE AND SEMI-VOLATILE ORGANIC CHEMICALS

As discussed in Sect. 6.2 of the main report, all volatile organic chemicals were considered as being of potential concern (with the exception of 2-hexanone) because concentrations thereof in samples may degrade significantly with time. The volatile organic chemical 2-hexanone was not considered of potential concern because it was detected only once on all media sampled and at a concentration of 1 ppb. Statistically and analytically, therefore, this compound was not considered to be of potential concern.

All semi-volatile chemicals detected in samples of environmental media were statistically evaluated to determine which exhibited significant differences between concentrations present at the WAG and reference concentrations (Appendix 4B). Statistically significantly different chemicals were designated as being of potential concern; the remainder underwent further analyses. Since these chemicals are generally man-made, they were included as being of potential concern if any of the following held true:

- A field sampling concentration was detected in excess of the CRDL
- The chemical was statistically significant in other media
- The chemical was a known WAG 6 contaminant (Teasley 1990)
- A field sampling concentration was detected in excess of a health-based criterion (identified in Sect. 4.1.2)

# Appendix 6E Tables

**Table 6E.1. Intakes of essential nutrients from media at WAG 6 compared with recommended dietary allowances**

| Element | Recommended dietary allowance (mg/day)[b] | Intake calculated from WAG 6 sampling results[a] | |
|---|---|---|---|
| | | Groundwater (mg/day)[b] | Soil (mg/day) |
| Calcium | 400-1200 | 200 | |
| Magnesium | 40-400 | 30 | |
| Iron | 6-30 | 17 | 4.0 |
| Sodium | 120-500 | 18 | |
| Potassium | 500-2000 | -- | 0.2 |

[a] Intakes calculated using average nutrient concentration detected and assuming consumption of 2 L water per day and 100 mg of soil per day.

[b] Includes adult males and females and sensitive individuals (i.e., children, infants, pregnant and lactating females).

*Source:* NRC 1989b.

**Table 6E.2. Results of further analysis of statistically nonsignificant semivolatile organics**

| Chemical[a,b] | CAS number | Concentration exceeded CRDL | Chemical statistically significant in other media | Concentration exceeded health-based criterion | Chemical known WAG contaminant |
|---|---|---|---|---|---|
| **Groundwater** | | | | | |
| Diethylphthalate | 84-66-2 | X | | | |
| Di-N-Butylphthalate | 84-74-2 | X | | | |
| Napthalene | 91-20-3 | X | | X | X |
| 2,4,5-TP | 93-72-1 | X | | | |
| 2,4,5-T | 93-76-5 | X | | | |
| 2,4-D | 94-75-7 | X | | | |
| 2-Methlyphenol | 95-48-7 | X | | | |
| Bis (2-Ethylhexyl) phthalate | 117-81-7 | | | X | |
| Arochlor | 11097-69-1 | X | | | |
| **Soil** | | | | | |
| Benzyl alcohol | 100-51-6 | X | | | |
| **Sediments** | | | | | |
| **Organics** | | | | | |
| Benzoic acid | 65-80-0 | | | | |
| Benzenamine, N-nitroso-N | 86-30-6 | | | | |
| Phenol | 108-95-2 | | | | |
| Bis (2-ethylhexyl) Phthalate | 117-81-7 | | | | |
| Benzene, 2-methyl-1, 3-din | 606-20-2 | | | | |
| **Surface water** | | | | | |
| Di-N-Butylphthalate | 84-74-2 | | | | |
| **Soils** | | | | | |
| Benz(a)anthracene | 56-55-3 | | | | |
| 4-Chloro-m-cresol | 59-50-7 | | | | |
| Pentachlorophenol | 87-86-5 | | | | |
| Phenol, 2-chloro | 95-57-8 | | | | |
| p-Nitrophenol | 100-02-7 | | | | |

**Table 6E.2 (continued)**

| Chemical[a,b] | CAS number | Concentration exceeded CRDL | Chemical statistically significant in other media | Concentration exceeded health-based criterion | Chemical known WAG contaminant |
|---|---|---|---|---|---|
| **Groundwater** | | | | | |
| Benzyl alcohol | 100-51-7 | X | | | |
| Phenol | 108-95-2 | | | | |
| Bis (2-Ethylhexyl) | 117-81-7 | | | | |
| phthalate | | | | | |
| Pyrene | | | | | |
| Benzo(k)fluoranthese | 207-08-9 | | | | |
| Chrysens | 218-01-9 | | | | |

[a] None in surface water or sediment met any of the four selection criteria shown in this table.
[b] Includes some pesticides and herbicides.

**Table 6E.3. Rationale for designation of individual chemicals as contaminants of concern**

| Chemical | CAS number | Medium | | | |
|---|---|---|---|---|---|
| | | Soil | Groundwater | Sediment | Surface water |
| **Organics** | | | | | |
| Carbon Tetrachloride | 56-23-5 | | V | | |
| Acetone | 67-64-1 | V | V | V | V |
| Chloroform | 67-66-3 | | V | SS | V |
| Benzene | 71-43-2 | | V | | |
| 1,1,1-Trichloroethane | 71-55-6 | | V | | |
| Ethyl Chloride | 75-00-3 | | V | | |
| Vinyl Chloride | 75-01-4 | | V | | |
| Methylene Chloride | 75-09-2 | V | V | V | |
| Carbon Disulfide | 75-15-0 | | V | | V |
| 1,1-Dichloroethane | 75-34-3 | | V | | |
| 1,1-Dichloroethene | 75-35-4 | | V | | |
| Trichlorofluoromethane | 75-69-4 | | | V | |
| 2-Butanone | 78-93-3 | | V | SS | |
| 1,1,2-Trichloroethane | 79-00-5 | | V | | |
| Trichloroethylene | 79-01-6 | V | V | V | V |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | | V | | |
| Diethylphthalate | 84-66-2 | | O | | |
| Di-N-Butylphthalate | 84-74-2 | | O | | |
| Napthalene | 91-20-3 | | O | | |
| 2,4,5-TP | 93-72-1 | | O | | |
| 2,4,5-T | 93-76-5 | | O | | |
| 2,4-D | 94-75-7 | | O | | |
| 2-Methlyphenol | 95-48-7 | | O | | |
| Ethylbenzene | 100-41-4 | V | SS | | |
| Benzyl Alcohol | 100-51-6 | O | | | |
| 1,2-Dichloroethane | 107-06-2 | | V | | |
| Toluene | 108-88-3 | V | V | V | |
| Bis (2-Ethylhexyl) phthalate | 117-81-7 | | O | | |
| Tetrachloroethylene | 127-18-4 | | V | | V |
| 1,2- Dichloroethylene | 540-59-0 | V | SS | | V |
| Xylene (total) | 1330-20-7 | V | V | | |
| Arochlor 1254 | 11097-69-1 | | O | | |

**Table 6E.3. (continued)**

| Chemical | CAS number | Medium | | | |
|---|---|---|---|---|---|
| | | Soil | Groundwater | Sediment | Surface water |
| **Inorganics** | | | | | |
| Aluminum | 7429-90-5 | SS | | | |
| Manganese | 7439-96-5 | | SS | | |
| Mercury | 7439-97-6 | | SS | | |
| Nickel | 7440-02-0 | | SS | | |
| Silver | 7440-22-4 | | SS | SS | SS |
| Strontium | 7440-24-6 | | SS | | |
| Thallium | 7440-28-0 | SS | | | |
| Titanium | 7440-32-6 | | SS | | |
| Cadmium | 7440-43-9 | | SS | | |
| Chromium | 7440-47-3 | SS | SS | | |
| Cobalt | 7440-48-4 | | SS | | |
| Vanadium | 7440-62-2 | SS | SS | | |

SS = statistically significant
V = volatile
O = other (in excess of CRDL; statistically significant in other media; in excess of health-based criterion; known WAG contaminant)

# APPENDIX 6F. CALCULATION OF UPPER CONFIDENCE LIMITS - CHEMICALS

This appendix supplements Sect. 6.3.4.1 in the main report. It describes the method for and results of calculating upper confidence limits for concentrations of chemical contaminants in environmental media, which values were then used in calculating intakes to hypothetical receptors.

Potential concentrations to which receptors could be exposed (contact concentrations) were calculated at the upper 95 percentile confidence interval on the median concentration for both the WAG-wide and auger hole study areas. The median (a nonparametric estimate of central tendency) was selected based on the non-normal distribution of the parameters detected. The 95 percentile upper confidence limit on the median was the concentration associated with the rank approximated in statistical tables (for sample sizes less than 20) or with the rank calculated (for sample sizes greater than 20) as described in Appendix 4B. Table 6F.1 summarizes the upper 95 percentile confidence limit on the median concentration for all chemicals of potential concern listed in Table 6.2 in main report.

# Appendix 6F Tables

**Table 6F.1. Upper 95 percentile confidence limit on median concentrations in groundwater, surface water, soil, and sediment**

| Parameter | CAS number | Auger hole area | WAG-wide |
|---|---|---|---|
| **Groundwater** | | | |
| **Metals/inorganics (mg/L)** | | | |
| Silver | 7440-22-4 | - | 0.005 |
| Cadmium | 7440-43-9 | 0.005 | 0.002 |
| Cobalt | 7440-48-4 | - | 0.010 |
| Chromium | 7440-47-3 | 0.020 | 0.020 |
| Manganese | 7439-96-5 | 0.063 | 0.090 |
| Nickel | 7440-02-0 | 0.020 | 0.020 |
| Strontium | 7440-24-6 | 0.346 | 0.300 |
| Vanadium | 7440-62-2 | 0.011 | 0.011 |
| Mercury | 7439-97-6 | - | 0.0002 |
| Titanium | 7440-32-6 | 0.025 | 0.020 |
| **Volatile organics (mg/L)** | | | |
| 1,1,1-Trichloroethane | 71-55-6 | - | 0.005 |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | - | 0.005 |
| 1,1,2-Trichloroethane | 79-00-5 | - | 0.005 |
| 1,1-Dichloroethene | 75-35-4 | - | 0.005 |
| 1,1-Dichloroethane | 75-34-3 | 0.005 | 0.005 |
| 1,2-Dichlorethane | 107-06-02 | 0.019 | 0.005 |
| 1,2-Dichloroethylene | 540-59-0 | 0.010 | 0.005 |
| 2-Butanone | 78-93-3 | - | 0.010 |
| Acetone | 67-64-1 | - | 0.010 |
| Benzene | 71-43-2 | - | 0.005 |
| Carbon tetrachloride | 56-23-5 | 0.052 | 0.005 |
| Carbon disulfide | 75-15-0 | - | 0.005 |
| Ethyl chloride | 75-00-3 | - | 0.010 |
| Chloroform | 67-66-3 | 0.061 | 0.005 |
| Ethyl benzene | 100-41-4 | - | 0.005 |
| Methylene chloride | 75-09-2 | 0.005 | 0.005 |
| Tetrachloroethene | 127-18-4 | 0.005 | 0.005 |
| Trichloroethene | 79-01-6 | 0.320 | 0.005 |
| Toluene | 108-88-3 | - | 0.005 |

Table 6F.1. (continued)

| Parameter | CAS Number | EWB | WAG-wide |
|---|---|---|---|
| Total xylene | 1330-20-7 | - | 0.005 |
| Vinyl chloride | 75-01-4 | - | 0.010 |
| **Semivolatile organics (mg/L)** | | | |
| 2-(Methylphenol) | 95-48-7 | - | 0.011 |
| Bis(2-ethylhexyl) phthalate | 117-81-7 | 0.011 | 0.011 |
| Diethylphthalate | 84-66-2 | 0.011 | 0.011 |
| Di-N-butylphthalate | 84-74-2 | 0.011 | 0.010 |
| Napthalane | 91-20-3 | - | 0.011 |
| **Herbicides/PCBs (mg/L)** | | | |
| 2,4,5-Trichlorophenoxyacetic acid | 93-76-5 | - | 0.0001 |
| 2-(2,4,5-Trichlorophenoxy) propionic acid | 93-72-1 | 0.0001 | 0.0001 |
| 2,4-Dichlorophenoxy acetic acid | 94-75-7 | 0.0002 | 0.0002 |
| Aroclor 1254 | 11097-69-1 | - | 0.0011 |
| **Soil** | | | |
| **Inorganics/metals (mg/kg)** | 12587-46-1 | 7 | 5 |
| Aluminum | 7429-90-5 | 21700 | 21700 |
| Chromium | 7440-47-3 | 43 | 39 |
| Thallium | 7440-28-0 | | 0.5 |
| Vanadium | 7440-62-2 | 23 | 22 |
| **Organics (mg/kg)** | | | |
| Methylene chloride | 75-09-2 | - | 0.033 |
| Acetone | 67-64-1 | - | 0.015 |
| Ethylbenzene | 100-41-4 | - | 0.006 |
| Toluene | 108-88-3 | - | 0.006 |
| Xylene (total) | 1330-20-7 | - | 0.006 |
| 1,2-Dichloroethylene | 540-59-0 | - | 0.006 |
| Trichloroethene | 79-01-6 | - | 0.006 |
| Benzyl alcohol | 100-51-6 | 0.460 | - |

Table 6F.1. (continued)

| Parameter | CAS Number | EWB | WAG-wide |
|---|---|---|---|
| **Surface water** | | | |
| Volatile organics (mg/L) | | | |
| 1,2-Dichloroethylene | 540-59-0 | - | 0.005 |
| Chloroform | 67-66-3 | - | 0.005 |
| Acetone | 67-64-1 | - | 0.010 |
| Tetrachloroethene | 127-18-4 | - | 0.005 |
| Trichloroethene | 79-01-6 | - | 0.005 |
| Carbon disfulide | 75-15-0 | - | 0.005 |
| Metals | | | |
| Silver | 7440-22-4 | - | 0.027 |
| **Sediment** | | | |
| Volatile organics (mg/kg) | | | |
| 2-Butanone | 78-93-3 | 0.140 | - |
| Chloroform | 67-66-3 | 0.013 | - |
| Trichlorofluoromethane | 75-69-4 | 0.072 | - |
| Methylene chloride | 75-09-2 | 0.031 | 0.062 |
| Acetone | 67-64-1 | 0.013 | - |
| Toluene | 108-88-3 | 0.006 | - |
| Trichloroethene | 79-01-6 | 0.006 | - |
| Inorganics/metals (mg/kg) | | | |
| Silver | 7440-22-4 | 02.5 J | |

-means undetected values for a chemical at a specific area.

# APPENDIX 6G. RADIOLOGICAL RISK ASSESSMENT METHODOLOGY AND RESULTS

## 6G.1 INTRODUCTION

A radiological risk and dose assessment model was developed using the radionuclide transport concepts and equations contained in DOE/CH/8901, "A Manual for Implementing Residual Radioactivity Guidelines," (DOE 1989). The model evaluates the risk and dose to a receptor from the following pathways:

- External radiation from soil contamination
- Inhalation
- Ingestion of fruits and vegetables
- Ingestion of meat
- Ingestion of milk
- Ingestion of fish
- Ingestion of drinking water
- Incidental ingestion of soil

The following assumptions are fundamental to the risk/dose model:

- Radionuclide concentrations in environmental media (soil, ground water and surface water) are the average concentration during the exposure period. The average concentration is used to keep the model consistent with the slope factors, which are "age-averaged lifetime" factors. This assumption also serves to simplify the model because radioactive decay, radioactive daughter ingrowth and environmental transport are accounted for in the average.

- The use of average radionuclide concentrations requires that radioactive decay and environmental transport be treated external to the model.

- Radionuclide transport performed by the model is from environmental media to the receptor.

- Decay products that have short half lives are not transported by the model. These radionuclides are assumed to exist in secular equilibrium with their parent in the pathway at the point of ingestion. They are explicitly included in the risk and dose calculations.

The model equations and additional assumptions for each pathway are described in the following sections. The equations for calculation of the radionuclide concentrations are presented first. The model calculations are illustrated using the exposure of the off-WAG Clinch River homesteader to Co-60.

## 6G.2 CONCENTRATIONS

Radionuclide concentrations in environmental media were estimated for WAG 6 by environmental fate and transport modeling. The fate and transport modelling used the available radionuclide inventory information and characterization data to predict contamination in the disposal areas, ground water, surface water, and air (volatile). Section 5, Contaminant Fate and Transport, contains the detailed discussion of the modeling methodology and results.

### 6G.2.1 External Radiation

For the purposes of this model, external radiation is exposure to radiation which is produced by the decay of radionuclides which are located outside the exposed individuals body. Gamma radiation is the dominant radiation for this pathway.

Since the main objective of this model is to predict the risk of cancer resulting from exposure to radionuclides in soil, many of the assumptions for this pathway are driven by the available slope factors (EPA 1990b). The slope factor for radionuclides is an estimate of the age-averaged lifetime total excess cancer incidence risk per unit exposure. The dosimetric model (EPA 1989f) used to calculate the slope factors treat the source as a uniform radionuclide concentration on an infinite plane. The slope factors are expressed as risk per year per pCi/m$^2$.

The activity per unit mass (pCi/g) in soil, which is the starting point for the model, must be converted to an effective surface concentration (in compatible units) using the soil density and a depth of contamination. The effective surface concentration does not increase linearly with depth due to the attenuation of the radiation by the soil. The "depth factor" used by DOE/CH/8901 takes this attenuation into account, but it was not used here because data was not available for all of the radionuclides of interest. A maximum depth of 10 cm (EPA 1990b), was used as a reasonable depth for calculating the effective surface concentration.

$$C_1 = 10^4 \times C_s \times \rho_b^{(cz)} \times T_e \times FA_1 \qquad (1)$$

where

$C_1$ = effective surface density of the contamination, in pCi/m$^2$

$C_s$ = radionuclide concentration in soil, in pCi/g (site specific value)

$\rho_b^{(cz)}$ = the bulk density of soil in the contaminated zone, in g/cm$^3$ (site specific value)

$T_e$ = effective depth of the contamination, in cm

= T  if: $T \leq 10$
= 10  if: $T > 10$

T = thickness of the contaminated zone, in cm (site specific value)

$FA_1$ = area factor, dimensionless. Values are obtained by interpolating between the values listed in Table 6G.1

A = Area of the contaminated soil, in $m^2$ (site specific value)

**Table 6G.1. Area Factor**

| Contaminated Area A ($m^2$) | Area Factor $FA_1$ |
|---|---|
| 1 | 0.016 |
| 25 | 0.4 |
| 100 | 0.55 |
| 500 | 0.8 |
| 1200 | 1.0 |

*Source*: DOE 1989

The effective Co-60 surface soil concentration is calculated below for the off-WAG Clinch River homesteader.

$C_s$ = 0.0615 pCi/g

$\rho_b^{(cz)}$ = 1.5 g/cm$^3$

T = 15 cm

$T_e$ = 10 cm

A = 2240 m$^2$

$FA_1$ = 1

$$C_1 = 10^4 \times C_s \times \rho_b^{(cz)} \times T_e \times FA_1$$

$$= 10^4 \times 0.0615 \times 1.5 \times 10 \times 1$$

$$= 9230 \text{ pCi/m}^2$$

### 6G.2.2 Inhalation

Mass loading is used to predict the radionuclide concentration (particulates) in air. Mass loading is the average mass of the airborne dust per unit volume of air. The dust is assumed to have originated from on-site contaminated surface soil. Transport of the contaminated dust off-site and clean dust on-site are not considered.

Tritium vapor concentrations are taken from the fate and transport modelling and is based on the surface water concentrations in the EWB and on-WAG ephemeral streams. Tritium vapor was considered only for the on-WAG receptors.

The radionuclide concentration in air particulates from contaminated soil is calculated as follows.

$$C_2 = C_s \text{ x } ASR_2 \times FO_2 \qquad (2)$$

where,

$C_2$ = radionuclide concentration in air, in pCi/m$^3$

$C_s$ = radionuclide concentration in soil, in pCi/g (site specific value)

$ASR_2$ = mass loading factor, in g/m$^3$

= 0.0002 g/m$^3$ (DOE 1989)

$FO_2$ = occupancy factor, dimensionless The occupancy factor should take into consideration the time spent outdoors versus the time spent and dust concentration indoors, versus time spent in uncontaminated areas. (site specific value)

The airborne Co-60 concentration due to resuspended soil is calculated below for the off-WAG Clinch River homesteader.

$C_s$ = 0.0615 pCi/g

$FO_2$ = 1

$$C_2 = C_s \times ASR_2 \times FO_2$$

$$= 0.0615 \times 0.0002 \times 1$$

$$= 1.23 \times 10^{-5}\ pCi/m^3$$

### 6G.2.3 Ingestion of Fruits and Vegetables

Radionuclide concentrations in biota (fruits and vegetables, beef, deer, milk, and fish) are calculated using the assumption that the radionuclide concentration in food is in equilibrium with the radionuclide concentration in soil and/or water. The ratio of the concentration in food to that in soil and/or water is typically referred to as a biotransfer or bioaccumulation factor. The biotransfer factors used for the biota pathways are presented in Table 6G.2.

**Table 6G.2. Biotransfer Factors**

| Element | Fruit & Vegetable $B_{iv}$ | Meat $FQR_4$ | Milk $FQR_5$ | Fish $FWR_{61}$ |
|---|---|---|---|---|
| Am | 2.5E-04 | 5.0E-03 | 2.5E-06 | 2.5E-02 |
| Cm | 2.5E-03 | 5.0E-03 | 2.5E-06 | 2.5E-02 |
| Co | 9.4E-03 | 1.0E-03 | 5.0E-04 | 5.0E-02 |
| Cs | 2.0E-03 | 3.0E-02 | 5.0E-03 | 2.0E+00 |
| Eu | 2.5E-03 | 5.0E-03 | 2.5E-06 | 2.5E-02 |
| H | 0.0 | 0.0 | 0.0 | 9.0E-04 |
| Sr | 2.0E-01 | 3.0E-04 | 1.5E-03 | 3.0E-02 |
| Th | 4.2E-03 | 5.0E-03 | 2.5E-06 | 3.0E-02 |
| U | 2.5E-03 | 5.0E-03 | 6.0E-04 | 2.0E-03 |

*Source*: DOE 1989

where

$B_{iv}$ = soil to fruit and vegetable transfer factor, dimensionless

$FQR_4$ = livestock water to meat transfer factor, in d/L

$FQR_5$ = livestock water to milk transfer factor, in d/L

$FWR_{61}$ = water to fish transfer factor, in L/g

The fruit and vegetable pathway is divided into three subpathways:

- root uptake from contaminated soil
- foliar uptake from contaminated dust on the foliage
- overhead irrigation (root uptake and foliar uptake)

This pathway is further divided into two plant groups:

- fruits and nonleafy vegetables
- leafy vegetables

The differences between these plant groups is related to their transfer coefficients for foliar deposited radionuclides (dust and irrigation water).

### 6G.2.3.1 Root uptake

The radionuclide concentration in fruits and vegetables due to root uptake from contaminated soil is calculated as follows.

$$C_{31} = C_s \times B_{iv} \times FCD_3 \qquad (3)$$

where

$C_{31}$ = radionuclide concentration in vegetables, in pCi/g

$C_s$ = radionuclide concentration in soil, in pCi/g (site specific value)

$B_{iv}$ = soil to fruit and vegetable transfer factor, dimensionless (Table 6G.2)

$FCD_3$ = cover and depth factor for root uptake, dimensionless

$= T/d_r$, if: $[C_d + T] < d_r$
$= 1 - C_d/d_r$, if: $C_d < d_r$, or $[C_d + T] \geq d_r$
$= 0$, if: $C_d \geq d_r$

$d_r$ = depth of root zone, in m

= 0.9 m (DOE 1989)

$T$ = thickness of the contaminated zone, in m (site specific value)

$C_d$ = the cover depth, in m (site specific value)

The Co-60 concentration in fruits and vegetables due to root uptake is calculated below for the off-WAG Clinch River homesteader.

$$C_s = 0.0615 \text{ pCi/g}$$

$$T = 0.15 \text{ m}$$

$$C_d = 0 \text{ m}$$

$$FCD_3 = T/d_r$$

$$= 0.15 / 0.9$$

$$= 0.1667$$

$$C_{31} = C_s \times B_{iv} \times FCD_3$$

$$= 0.0615 \times 0.0094 \times 0.1667$$

$$= 9.64 \times 10^{-5} \text{ pCi/g}$$

### 6G.2.3.2 Foliar deposition

The radionuclide concentration in fruits and vegetables due to foliar deposition of particulates from contaminated soil is calculated as follows:

$$C_{32} = C_s \times ASR_3 \times FAR_{32} \tag{4}$$

where

$C_{32}$ = radionuclide concentration in fruit and vegetables, in pCi/g

$C_s$ = radionuclide concentration in soil, in pCi/g (site specific value)

$ASR_3$ = air to soil concentration ratio, specified as the average mass loading of airborne contaminated soil in a garden during a growing season, in $g/m^3$

= $0.0001 \text{ g/m}^3$ (DOE 1989)

$FAR_{32}$ = the plant to air concentration ratio for foliar deposition, in $m^3/g$

$$= 3.16 \times 10^4 \frac{V_d \times f_r \times T_{iv} \times [\,1 - \exp(-\lambda_w \times t_e)\,]}{Y_v \times \lambda_w} \tag{4a}$$

$V_d$ = deposition velocity for contaminated dust, in m/s

= 0 m/s for H, C, Ar, Kr and Xe
= 0.01 m/s for F, Br, I, and Cl
= 0.001 m/s for all other elements
(DOE 1989)

$f_r$ = the fraction of deposited radionuclides retained on foliage, dimensionless

= 0.25 (DOE 1989)

$T_{iv}$ = foliage to food transfer coefficient, dimensionless

= 0.1 for fruit and nonleafy vegetables
= 1.0 for leafy vegetables
(DOE 1989)

$\lambda_w$ = the weathering constant for vegetation, in $y^{-1}$

= 20 $y^{-1}$ (DOE 1989)

$t_e$ = time of exposure to contamination during the growing season, in y

= 0.17 y for fruit and nonleafy vegetables
= 0.25 y for leafy vegetables
(DOE 1989)

$Y_v$ = wet-weight crop yield, in $kg/m^2$

= 0.7 $kg/m^2$ for fruit and nonleafy vegetables
= 1.5 $kg/m^2$ for leafy vegetables
(DOE 1989)

The Co-60 concentration in fruit and nonleafy vegetables due to foliar deposition is calculated below for the off-WAG Clinch River homesteader.

$V_d$ = 0.001 m/s

$T_{iv}$ = 0.1

$t_e$ = 0.17 y

$Y_v$ = 0.7 $kg/m^2$

$$FAR_{32} = 3.16 \times 10^4 \frac{V_d \times f_r \times T_{iv} \times [\,1 - \exp(-\lambda_w \times t_e)\,]}{Y_v \times \lambda_w}$$

$$= 3.16 \times 10^4 \frac{0.001 \times 0.25 \times 0.1 \times [1-\exp(-20 \times 0.17)]}{0.7 \times 20}$$

$$= 0.0546\ m^3/g$$

$$C_s = 0.0615\ pCi/g$$

$$C_{32} = C_s \times ASR_3 \times FAR_{32}$$

$$= 0.0615 \times 0.0001 \times 0.0546$$

$$= 3.35 \times 10^{-7}\ pCi/g$$

The Co-60 concentration in leafy vegetables due to foliar deposition is calculated below for the off-WAG Clinch River homesteader.

$$V_d = 0.001\ m/s$$

$$T_{iv} = 1$$

$$t_e = 0.25\ y$$

$$Y_v = 1.5\ kg/m^2$$

$$FAR_{32} = 3.16 \times 10^4 \frac{V_d \times f_r \times T_{iv} \times [\,1 - \exp(-\lambda_w \times t_e)\,]}{Y_v \times \lambda_w}$$

$$= 3.16 \times 10^4 \frac{0.001 \times 0.25 \times 1 \times [1-\exp(-20 \times 0.25)]}{1.5 \times 20}$$

$$= 0.262\ m^3/g$$

$$C_s = 0.0615\ pCi/g$$

$$C_{32} = C_s \times ASR_3 \times FAR_{32}$$

$$= 0.0615 \times 0.0001 \times 0.262$$

$$= 1.61 \times 10^{-6}\ pCi/g$$

### 6G.2.3.3 Overhead irrigation

The radionuclide concentration in fruits and vegetables due to overhead irrigation with contaminated water is calculated as follows:

$$C_{34} = C_w \times FWR_{34} \tag{5}$$

where

$C_{34}$ = radionuclide concentration in vegetables due to overhead irrigation, in pCi/g

$C_w$ = radionuclide concentration in irrigation water, in pCi/L (site specific value)

$FWR_{34}$ = fruit and vegetable to water concentration ratio for foliar uptake from irrigation water, in L/g

$$= \frac{I_{rr} \times f_r \times T_{iv} \times [\,1 - \exp(-\lambda_w \times t_e)\,]}{Y_v \times \lambda_w} + FWR_{33} \tag{5a}$$

$I_{rr}$ = irrigation rate, in m/y (site specific value)

$f_r$ = the fraction of deposited radionuclides retained on foliage, dimensionless (value defined for foliar deposition)

$T_{iv}$ = foliage to food transfer coefficient for nonleafy vegetables, dimensionless (values defined for foliar deposition)

$\lambda_w$ = the weathering constant for vegetation, in $y^{-1}$ (value defined for foliar deposition)

$t_e$ = time of exposure of nonleafy vegetables to contamination during the growing season, in y (value defined for foliar deposition)

$Y_v$ = wet-weight crop yield for nonleafy vegetables, in $g/m^2$ (value defined for foliar deposition)

$FWR_{33}$ = fruit and vegetable to water concentration ratio for root uptake from irrigation water, in L/g

$$= \frac{I_{rr} \times B_{iv} \times [\,1 - \exp(-L_i \times t_e)\,]}{Y_v \times L_i} \tag{5b}$$

$B_{iv}$ = vegetable/soil transfer factors for root uptake, dimensionless (Table 6G.1)

$L_i$ = leach rate constant, in $y^{-1}$

$$= \frac{I}{\theta^{(cz)} \times T \times R_d^{(cz)}} \quad (5c)$$

T = thickness of the contaminated zone, in m (site specific value)

I = infiltration rate, in m/y (site specific value)

$$= (1 - C_r) \times P_r + I_{rr} - E_t \quad (5d)$$

$C_r$ = runoff coefficient, dimensionless (site specific value)

$P_r$ = precipitation rate, in m/y (site specific value)

$I_{rr}$ = irrigation rate, in m/y (site specific value)

$E_t$ = evapotranspiration coefficient, dimensionless (site specific value)

$\theta^{(cz)}$ = volumetric water content of the contaminated zone, dimensionless (site specific value)

$$= P_t^{(cz)} \times (I/K_{sat}^{(cz)})^{1/[(2 \times b) + 3]} \quad (5e)$$

$P_t^{(cz)}$ = the total porosity of the contaminated zone, dimensionless (site specific value)

I = infiltration rate, in m/y (site specific value)

$K_{sat}^{(cz)}$ = saturated hydraulic conductivity of the contaminated zone, in m/y (site specific value)

b = soil-specific exponential parameter of the contaminated zone, dimensionless (site specific value), (DOE 1989)

$R_d^{(cz)}$ = retardation factor in the contaminated zone, dimensionless

$$= 1 + \frac{\rho_b^{(cz)} \times K_d^{(cz)}}{\theta^{(cz)}} \quad (5f)$$

$\rho_b^{(cz)}$ = the bulk density of soil in the contaminated zone, in $g/cm^3$ (site specific value)

$K_d^{(cz)}$ = radionuclide distribution coefficient for the contaminated zone, in $cm^3/g$. (site specific value)

The Co-60 concentration in fruits and nonleafy vegetables due to overhead irrigation are calculated below for the off-WAG Clinch River homesteader.

$$C_r = 0.4$$

$$P_r = 1.325 \text{ m/y}$$

$$I_{rr} = 0.354 \text{ m/y}$$

$$E_t = 0.762$$

$$I = (1 - C_r) \times P_r + I_{rr} - E_t$$

$$= (1 - 0.4) \times 1.325 + 0.354 - 0.762$$

$$= 0.387 \text{ m/y}$$

$$P_t^{(cz)} = 0.5$$

$$K_{sat}^{(cz)} = 45 \text{ m/y}$$

$$b = 10.4 \text{ (DOE, 1989)}$$

$$\theta^{(cz)} = P_t^{(cz)} \times (I/K_{sat}^{(cz)})^{1/[(2 \times b) + 3]}$$

$$= 0.5 \times (0.387/45)^{1/[(2 \times 10.4) + 3]}$$

$$= 0.409$$

$$\rho_b^{(cz)} = 1.5 \text{ g/cm}^3$$

$$K_d^{(cz)} = 1000 \text{ cm}^3\text{/g (DOE, 1989)}$$

$$R_d^{(cz)} = 1 + \frac{\rho_b^{(cz)} \times K_d^{(cz)}}{\theta^{(cz)}}$$

$$= 1 + \frac{1.5 \times 1000}{0.409}$$

$$= 3660$$

$$T = 0.15 \text{ m}$$

$$L_i = \frac{I}{\theta^{(cz)} \times T \times R_d^{(cz)}}$$

$$= \frac{0.387}{0.409 \times 0.15 \times 3660}$$

$$= 0.00172 \text{ y}^{-1}$$

$$B_{iv} = 0.0094$$

$$t_e = 0.17 \text{ y}$$

$$Y_v = 0.7 \text{ kg/m}^2$$

$$FWR_{33} = \frac{I_{rr} \times B_{iv} \times [\,1 - \exp(-L_i \times t_e)\,]}{Y_v \times L_i}$$

$$= \frac{0.354 \times 0.0094 \times [\,1 - \exp(-0.00172 \times 0.17)\,]}{0.7 \times 0.00172}$$

$$= 0.000809 \text{ L/g}$$

$$f_r = 0.25$$

$$T_{iv} = 0.1$$

$$\lambda_w = 20 \text{ y}^{-1}$$

$$FWR_{34} = \frac{I_{rr} \times f_r \times T_{iv} \times [\,1 - \exp(-\lambda_w \times t_e)\,]}{Y_v \times \lambda_w} + FWR_{33}$$

$$= \frac{0.354 \times 0.25 \times 0.1 \times [\,1 - \exp(-20 \times 0.17)\,]}{0.7 \times 20} + 0.000809$$

$$= 0.00142 \text{ L/g}$$

$$C_w = 0.216 \text{ pCi/L}$$

$$C_{34} = C_w \times FWR_{34}$$

$$= 0.216 \times 0.00142$$

$$= 0.000307 \text{ pCi/g}$$

The Co-60 concentration in leafy vegetables due to overhead irrigation are calculated below for the off-WAG Clinch River homesteader. Parameter values not listed are the same as for fruits and nonleafy vegetables above.

$$t_e = 0.25 \text{ y}$$

$$Y_v = 1.5 \text{ kg/m}^2$$

$$FWR_{33} = \frac{I_{rr} \times B_{iv} \times [\,1 - \exp(-L_i \times t_e)\,]}{Y_v \times L_i}$$

$$= \frac{0.354 \times 0.0094 \times [\,1 - \exp(-0.00172 \times 0.25)\,]}{1.5 \times 0.00172}$$

$$= 0.000555 \text{ L/g}$$

$$T_{iv} = 1$$

$$FWR_{34} = \frac{I_{rr} \times f_r \times T_{iv} \times [\,1 - \exp(-\lambda_w \times t_e)\,]}{Y_v \times \lambda_w} + FWR_{33}$$

$$= \frac{0.354 \times 0.25 \times 1 \times [\,1 - \exp(-20 \times 0.25)\,]}{1.5 \times 20} + 0.000555$$

$$= 0.00349 \text{ L/g}$$

$$C_w = 0.216 \text{ pCi/L}$$

$$C_{34} = C_w \times FWR_{34}$$

$$= 0.216 \times 0.00349$$

$$= 0.000753 \text{ pCi/g}$$

### 6G.2.4 Ingestion of Meat

The radionuclide concentration in meat due to contaminated livestock water is calculated as follows:

$$C_{42} = C_w \times FQR_4 \times QI_{42} \times 10^{-3} \quad (6)$$

where

$C_w$ = radionuclide concentration in livestock water, in pCi/L

$FQR_4$ = livestock water to meat transfer factor, in d/L (Table 6G.2)

$QI_{42}$ = livestock water intake rate, in L/d

The Co-60 concentration in meat due to livestock ingestion of water are calculated below for the off-WAG Clinch River homesteader.

$C_w$ = 0.216 pCi/L

$FQR_4$ = 0.001 d/L

$QI_{42}$ = 40 L/d

$$C_{42} = C_w \times FQR_4 \times QI_{42} \times 10^{-3}$$

$$= 0.216 \times 0.001 \times 40 \times 10^{-3}$$

$$= 8.64 \times 10^{-6} \text{ pCi/g}$$

### 6G.2.5 Ingestion of Milk

The radionuclide concentration in milk due to contaminated livestock water is calculated as follows:

$$C_{52} = C_w \times FQR_5 \times QI_{52} \times 10^{-3} \quad (7)$$

where

$C_w$ = radionuclide concentration in livestock water, in pCi/L

$FQR_5$ = livestock water to meat transfer factor, in d/L (Table 6G.2)

$QI_{52}$ = livestock water intake rate, in L/d

The Co-60 concentration in milk due to livestock ingestion of water are calculated below for the off-WAG Clinch River homesteader.

$$C_w = 0.216 \text{ pCi/L}$$

$$FQR_5 = 0.0005 \text{ d/L}$$

$$QI_{52} = 80 \text{ L/d}$$

$$C_{52} = C_w \times FQR_5 \times QI_{52} \times 10^{-3}$$

$$= 0.216 \times 0.0005 \times 80 \times 10^{-3}$$

$$= 8.64 \times 10^{-6} \text{ pCi/g}$$

### 6G.2.6 Ingestion of Fish

The radionuclide concentration in freshwater fish is calculated as follows:

$$C_{61} = C_w \times FWR_{61} \qquad (8)$$

where

$C_{61}$ = radionuclide concentration in fish, in pCi/g

$C_w$ = radionuclide concentration in surface water, in pCi/L (site specific values)

$FWR_{61}$ = water to fish transfer factor, in L/g (Table 6G.2)

The Co-60 concentration in fish due to surface water are calculated below for the off-WAG Clinch River homesteader.

$$C_w = 0.216 \text{ pCi/L}$$

$$FWR_{61} = 0.05 \text{ L/g}$$

$$C_{61} = C_w \times FWR_{61}$$

$$= 0.216 \times 0.05$$

$$= 0.0108 \text{ pCi/g}$$

### 6G.2.7 Drinking Water

The concentration of drinking water is taken to be the concentration of the source of the drinking water. For the on-WAG homesteader, well water (ground water) is used for drinking water. For the Off-WAG Clinch River homesteader, river water (surface water) is used for drinking water.

### 6G.2.8 Incidental Ingestion of Soil

The concentration of the soil ingested is taken to be the concentration of the surface soil in the contaminated zone.

### 6G.2.9 Decay Products

Table 6G.3 presents the decay products that are expected to be in secular equilibrium with their parents at the point of intake.

**Table 6G.3. Decay products assumed to be in secular equilibrium**

| Nuclide | Parent | Progeny to Parent Ratio |
|---|---|---|
| Y-90 | Sr-90 | 1.0 |
| Ba-137m | Cs-137 | 0.946 |
| Th-234 | U-238 | 1.0 |
| Pa-234m | U-238 | 1.0 |
| Pa-234 | U-238 | 0.0013 |

## 6G.3 INTAKE AND EXPOSURE

A summary of the annual intakes and exposure factors for all of the WAG 6 receptors is presented in Table 6G.4. The exposure duration for all receptors is 30 years, except the boundary receptor who is exposed for 70 years. Detailed discussion and the sources of these values is presented in Appendix 6I, which discusses the chemical risk assessment methodology. Because of differences in the chemical and radiological methodology, the fruit and vegetable intakes are treated differently. The chemical methodology treats fruits and vegetables separately while the radiological methodology only distinguishes between leafy and nonleafy vegetables (fruits are included with nonleafy vegetables). For the radiological methodology, ten percent of the total fruits and vegetables (from Appendix 6I) are assumed to be leafy vegetables and the remaining being fruits and nonleafy vegetables.

Table 6G.4. Annual Radionuclide Intakes and Exposure Factors

| Receptor / Pathway | annual radionuclide intake/exposure |
|---|---|
| on-WAG homesteader | |
| External exposure | 100 % |
| Inhalation | 10950 $m^3$ |
| Fruits and nonleafy vegetables | 40.1 kg |
| Leafy vegetables | 4.5 kg |
| Meat | 27.4 kg |
| Milk | 109.5 L |
| Drinking Water | 730 L |
| Incidental Soil | 36.5 g |
| off-WAG homesteader | |
| External Exposure | 100 % |
| Inhalation | 10950 $m^3$ |
| Fruits and nonleafy vegetables | 40.1 kg |
| Leafy vegetables | 4.5 kg |
| Meat | 27.4 kg |
| Milk | 109.5 L |
| Fish | 19.7 kg |
| Drinking Water | 730 L |
| Soil | 36.5 g |
| off-WAG hunter | |
| Deer | 15 kg |
| WAG boundary receptor | |
| External exposure | 100 % |
| Inhalation | 10950 $m^3$ |
| on-WAG ORNL employee | |
| External exposure | 14.2 % |
| Inhalation | 1560 $m^3$ |

## 6G.4 DOSE AND RISK

### 6G.4.1 Risk

Risk to a receptor due to a pathway is calculated from the previously determined radionuclide concentrations using the following equation:

$$R = C \times FI \times SF \tag{9}$$

where

R = risk

C = radionuclide concentration

FI = intake or exposure factor over the exposure period. Table 6G.4 lists the annual exposure factors for WAG 6 receptors.

SF = slope factor (Table 6G.5)

The slope factors used for the evaluation of WAG 6 receptors are presented in Table 6G.5. These slope factors were taken from EPA (EPA 1990b) except for Eu-155. The slope factor for Eu-155 was provided by Keith Eckerman, ORNL.

Whenever the total risk (sum across pathways) computed with Equation 9 is greater than 0.01 the one-hit risk should be computed and used. The one-hit risk is computed as follows:

$$R_1 = 1 - \exp( - C \times FI \times SF ) \tag{10}$$

where

$R_1$ = one-hit risk

C = radionuclide concentration

FI = intake or exposure factor over the exposure period. Table 6G.4 lists the annual exposure factors for WAG 6 receptors.

SF = slope factor (Table 6G.5)

Table 6G.5. Slope Factors

| Nuclide | External $(y^{-1})/(pCi/m^2)$ | Inhalation $(pCi^{-1})$ | Ingestion $(pCi^{-1})$ |
|---|---|---|---|
| H-3 | 0.0 | 7.8E-14 | 5.5E-14 |
| Co-60 | 1.3E-10 | 1.6E-10 | 1.5E-11 |
| Sr-90 | 0.0 | 5.6E-11 | 3.3E-11 |
| Cs-137 | 0.0 | 1.9E-11 | 2.8E-11 |
| Eu-152 | 6.3E-11 | 1.2E-08 | 2.1E-12 |
| Eu-154 | 6.8E-11 | 1.4E-10 | 3.0E-12 |
| Eu-155 | 5.2E-12 | 3.0E-09 | 5.2E-13 |
| Th-232 | 4.6E-14 | 3.1E-08 | 2.2E-11 |
| U-233 | 3.3E-14 | 2.7E-08 | 1.4E-10 |
| U-238 | 4.6E-14 | 2.4E-08 | 1.3E-10 |
| Am-241 | 1.6E-12 | 4.0E-08 | 3.1E-10 |
| Cm-244 | 5.8E-14 | 2.7E-08 | 2.0E-10 |
| Y-90 | 0.0 | 5.5E-12 | 3.2E-12 |
| Ba-137m | 3.4E-11 | 6.0E-16 | 2.4E-15 |
| Th-234 | 5.6E-13 | 3.2E-11 | 4.0E-12 |
| Pa-234m | 6.4E-13 | 1.6E-15 | 5.8E-15 |
| Pa-234 | 1.1E-10 | 5.4E-13 | 6.8E-13 |

*Source*: EPA, 1990

Risk to off-WAG Clinch River homesteader calculated due to Co-60 is presented in Table 6G.6. This calculation uses the Co-60 concentrations calculated in previous sections, the annual intake/exposure rom Table 6G.4, slope factors from Table 6G.6, and an exposure duration of 30 years.

Table 6G.6. Risk to off-WAG Clinch River homesteader due to Co-60

| Pathway | Co-60 Concentration C | Intake/ Exposure FI | Slope Factor SF | Risk R |
|---|---|---|---|---|
| External Exposure | 9.22E+03 $pCi/m^2$ | 3.00E+01 y | 1.30E-10 $(1/y)/(pCi/m^2)$ | 3.60E-05 |
| Inhalation | 1.23E-05 $pCi/m^3$ | 3.29E+05 $m^3$ | 1.60E-10 1/pCi | 6.46E-10 |
| Fruits & nonleafy vegetables | 4.03E-04 pCi/g | 1.20E+06 g | 1.50E-11 1/pCi | 7.28E-09 |
| Leafy vegetables | 8.51E-04 pCi/g | 1.34E+05 g | 1.50E-11 1/pCi | 1.71E-09 |
| Meat | 8.64E-06 pCi/g | 8.21E+05 g | 1.50E-11 1/pCi | 1.06E-10 |
| Milk | 8.64E-06 pCi/g | 3.29E+06 g | 1.50E-11 1/pCi | 4.26E-10 |
| Aquatic food | 1.08E-02 pCi/g | 5.91E+05 g | 1.50E-11 1/pCi | 9.57E-08 |
| Drinking water | 2.16E-01 pCi/L | 2.19E+04 L | 1.50E-11 1/pCi | 7.10E-08 |
| Incidental soil | 6.15E-02 pCi/g | 1.10E+03 g | 1.50E-11 1/pCi | 1.01E-09 |
| Total Risk | | | | 3.61E-05 |

## 6G.4.2 Dose

Similarly, dose to a receptor due to a pathway is calculated using the following equation:

$$D = C \times FI \times DCF \quad (10)$$

where

D = dose

C = radionuclide concentration

FI = intake or exposure factor over the exposure period. Table 6G.4 lists the annual exposure factors for WAG 6 receptors.

DCF = dose conversion factor (Table 6G.7)

The dose conversion factors used for the evaluation of WAG 6 receptors are presented in Table 6G.6. The inhalation and ingestion dose conversion factors were taken from EPA, 1988. The external dose conversion factors were taken from DOE, 1988.

**Table 6G.7. Dose Conversion Factors**

| Nuclide | External (mrem/y)/(pCi/m$^2$) | Inhalation (mrem/pCi) | Ingestion (mrem/pCi) |
|---|---|---|---|
| H-3 | 0.00 | 6.40E-08 | 6.40E-08 |
| Co-60 | 2.27E-04 | 2.19E-04 | 2.69E-05 |
| Sr-90 | 0.00 | 1.30E-03 | 1.42E-04 |
| Cs-137 | 0.00 | 3.19E-05 | 5.00E-05 |
| Eu-152 | 1.11E-04 | 2.21E-04 | 6.48E-06 |
| Eu-154 | 1.21E-04 | 2.86E-04 | 9.55E-06 |
| Eu-155 | 7.15E-06 | 4.14E-05 | 1.53E-06 |
| Th-232 | 6.66E-08 | 1.64E+00 | 2.73E-03 |
| U-233 | 5.00E-08 | 1.35E-01 | 2.89E-04 |
| U-238 | 6.46E-08 | 1.18E-01 | 2.55E-04 |
| Am-241 | 2.99E-06 | 4.44E-01 | 3.64E-03 |
| Cm-244 | 8.29E-08 | 2.48E-01 | 2.02E-03 |
| Y-90 | 0.00 | 8.44E-06 | 1.08E-05 |
| Ba-137m | 6.11E-05 | 0.00 | 0.00 |
| Th-234 | 1.01E-06 | 3.50E-05 | 1.37E-05 |
| Pa-234m | 1.13E-06 | 0.00 | 0.00 |
| Pa-234 | 1.96E-04 | 8.14E-07 | 2.16E-06 |

*Source*: DOE 1988 and EPA 1988

Dose to off-WAG Clinch River homesteader calculated due to Co-60 is presented in Table 6G.8. This calculation uses the Co-60 concentrations calculated in previous

sections, the annual intake/exposure rom Table 6G.4, dose conversion factors from Table 6G.7, and an exposure duration of 30 years.

Table 6G.8. Dose to off-WAG Clinch River homesteader due to Co-60

| | Co-60 Concentration C | Intake/ Exposure FI | Dose Conversion Factor DCF | Dose (rem) D |
|---|---|---|---|---|
| External Exposure | 9.22E+03 pCi/m$^2$ | 3.00E+01 y | 2.27E-04 (mrem/y)/(pCi/m$^2$) | 6.28E-02 |
| Inhalation | 1.23E-05 pCi/m$^3$ | 3.29E+05 m$^3$ | 2.19E-04 mrem/pCi | 8.84E-07 |
| Fruits & nonleafy vegetables | 4.03E-04 pCi/g | 1.20E+06 g | 2.69E-05 mrem/pCi | 1.31E-05 |
| Leafy vegetables | 8.51E-04 pCi/g | 1.34E+05 g | 2.69E-05 mrem/pCi | 3.06E-06 |
| Meat | 8.64E-06 pCi/g | 8.21E+05 g | 2.69E-05 mrem/pCi | 1.91E-07 |
| Milk | 8.64E-06 pCi/g | 3.29E+06 g | 2.69E-05 mrem/pCi | 7.65E-07 |
| Aquatic food | 1.08E-02 pCi/g | 5.91E+05 g | 2.69E-05 mrem/pCi | 1.72E-04 |
| Drinking water | 2.16E-01 pCi/L | 2.19E+04 L | 2.69E-05 mrem/pCi | 1.27E-04 |
| Incidental soil | 6.15E-02 pCi/g | 1.10E+03 g | 2.69E-05 mrem/pCi | 1.81E-06 |
| Total Dose (rem) | | | | 6.31E-02 |

### 6G.4.3 Dose to Risk

Slope factors are not available for receptors exposed to buried radionuclides. The dose to these receptors was calculated using a shielding model. In order to convert this dose to risk, a dose to risk conversion factor was derived using the dose conversion factors in Table 6G.7 and the slope factors in Table 6G.5 for the gamma emitting nuclides which comprise the bulk of the buried radionuclide inventory. This factor is the average shown in Table 6G.9.

Table 6G.9. External dose to risk factor

| Nuclide | DCF (mrem/y) / (pCi/m$^2$) | SF (1/y) / (pCi/m$^2$) | risk/rem |
|---|---|---|---|
| Co-60 | 2.270E-04 | 1.300E-10 | 5.73E-04 |
| Ba-137m | 6.110E-05 | 3.400E-11 | 5.56E-04 |
| Eu-152 | 1.110E-04 | 6.300E-11 | 5.68E-04 |
| Eu-154 | 1.210E-04 | 6.800E-11 | 5.62E-04 |
| Eu-155 | 7.150E-06 | 5.200E-12 | 7.27E-04 |
| Average | | | 5.97E-04 |

## 6G.5 RESULTS

The summary of results of the risk analyses for all of the WAG 6 receptors is presented in Table 6G.10. Because of the magnitude of the risk computed for two of the receptors the one-hit risk was also computed for theses receptors.

**Table 6G.10. Summary of WAG 6 Radiological Risk Analysis**

| Receptor | Dose (rem) | Risk | Risk (one hit) |
|---|---|---|---|
| Boundary Receptor | 9.46E-06 | 1.15E-08 | |
| on-WAG Worker | 1.86E+00 | 1.11E-03 | |
| off-WAG Hunter | 2.61E-05 | 8.24E-09 | |
| Clinch River Homesteader | 1.26E-01 | 6.87E-05 | |
| Current on-WAG Homesteader | 2.20E+05 | 1.23E+02 | 1.00 |
| Future on-WAG Homesteader | 3.52E+03 | 4.14E-01 | 3.39E-01 |

The following tables present additional detail about the WAG 6 radiological risk analysis. Tables are included for each receptor which presents the radionuclide concentrations in each pathway at the exposure point, the dose received during the exposure period and the corresponding risk.

Table 6G.15 presents a summary of the risk and dose for the current on-WAG homesteader (1990-2019) which shows the total risk and dose at the each of the 26 modelling sub areas and the risk and dose for each radionuclide averaged across all of the subareas.

Table 6G.16 presents a summary of the risk and dose for the future on-WAG homesteader (2100-2029) which shows the total risk and dose at the each of the 26 modelling sub areas and the risk and dose for each radionuclide averaged across all of the subareas.

Tables 6G.17 through 6G.42 present the risk and dose for each of the modelling subareas for the current on-WAG homesteader. Tables 6G.43 through 6G.68 present the risk and dose for each of the modelling subareas for the current on-WAG homesteader.

Table 6G.11. Radionuclide Concentrations, Dose, and Risk for the Boundary Receptor

| Pathway | Dose Rate (rem/hr) | Air (pCi/m$^3$) | Dose (rem) | Risk |
|---|---|---|---|---|
| External | 1.23E-17 | | 7.54E-12 | 4.50E-15 |
| H-3 vapor | | 1.93E-01 | 9.46E-06 | 1.15E-08 |
| Totals | | | 9.46E-06 | 1.15E-08 |

Table 6G.12. Radionuclide Concentrations, Dose, and Risk for the on-WAG Worker

| Pathway | Dose Rate (rem/hr) | Air (pCi/m$^3$) | Dose (rem) | Risk |
|---|---|---|---|---|
| External | 4.98E-05 | | 1.86E+00 | 1.11E-03 |
| H-3 vapor | | 1.78E+00 | 5.33E-06 | 6.50E-09 |
| Totals | | | 1.86E+00 | 1.11E-03 |

Table 6G.13. Radionuclide Concentrations, Dose, and Risk for the off-WAG Hunter

| Nuclide | Surface Water (pCi/L) | Meat (pCi/g) | Dose (rem) | Risk |
|---|---|---|---|---|
| H-3 | 9.96E+04 | 0.00 | 0.00 | 0.00 |
| Co-60 | 3.84E+00 | 1.15E-05 | 1.53E-07 | 8.51E-11 |
| Sr-90 | 2.35E+01 | 2.11E-05 | 1.48E-06 | 3.43E-10 |
| Y-90 | 2.35E+01 | 2.11E-05 | 1.12E-07 | 3.33E-11 |
| Cs-137 | 5.29E+00 | 4.76E-04 | 1.17E-05 | 6.55E-09 |
| Ba-137m | 5.00E+00 | 4.50E-04 | 0.00 | 5.31E-13 |
| Eu-152 | 1.43E+00 | 2.14E-05 | 6.83E-08 | 2.22E-11 |
| Eu-154 | 7.92E-01 | 1.19E-05 | 5.58E-08 | 1.75E-11 |
| Th-232 | 5.14E-01 | 7.70E-06 | 1.03E-05 | 8.34E-11 |
| U-233 | 5.13E-01 | 7.70E-06 | 1.09E-06 | 5.31E-10 |
| U-238 | 5.75E-01 | 8.63E-06 | 1.08E-06 | 5.52E-10 |
| Th-234 | 5.75E-01 | 8.63E-06 | 5.80E-08 | 1.70E-11 |
| Pa-234m | 5.75E-01 | 8.63E-06 | 0.00 | 2.46E-14 |
| Pa-234 | 7.48E-04 | 1.12E-08 | 1.19E-11 | 3.75E-15 |
| Totals | | | 2.61E-05 | 8.24E-09 |

Table 6G.14. Radionuclide Concentrations, Dose, and Risk for the 1990 Clinch River Homesteader

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegetables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) | Fish (pCi/g) |
|---|---|---|---|---|---|---|---|---|---|
| H-3 | 1.20E-03 | 0.00 | 1.85E+03 | 2.40E-07 | 1.13E+00 | 5.42E+00 | 0.00 | 0.00 | 1.66E+00 |
| Co-60 | 6.15E-02 | 0.00 | 2.16E-01 | 1.23E-05 | 4.03E-04 | 8.51E-04 | 8.64E-06 | 8.64E-06 | 1.08E-02 |
| Sr-90 | 2.32E-01 | 0.00 | 6.94E-01 | 4.63E-05 | 2.00E-02 | 1.79E-02 | 8.33E-06 | 8.33E-05 | 2.08E-02 |
| Y-90 | 2.32E-01 | 0.00 | 6.94E-01 | 4.63E-05 | 2.00E-02 | 1.79E-02 | 8.33E-06 | 8.33E-05 | 2.08E-02 |
| Cs-137 | 1.31E-01 | 0.00 | 1.63E-01 | 2.61E-05 | 1.72E-04 | 5.45E-04 | 1.96E-04 | 6.52E-05 | 3.26E-01 |
| Ba-137m | 1.24E-01 | 0.00 | 1.54E-01 | 2.47E-05 | 1.63E-04 | 5.15E-04 | 1.85E-04 | 6.17E-05 | 3.09E-01 |
| Eu-152 | 8.88E-03 | 0.00 | 3.28E-02 | 1.78E-06 | 3.09E-05 | 1.05E-04 | 6.57E-06 | 6.57E-09 | 8.21E-04 |
| Eu-154 | 3.60E-03 | 0.00 | 1.25E-02 | 7.20E-07 | 1.18E-05 | 4.00E-05 | 2.49E-06 | 2.49E-09 | 3.12E-04 |
| Th-232 | 4.99E-03 | 0.00 | 8.38E-03 | 9.98E-07 | 1.17E-05 | 3.23E-05 | 1.68E-06 | 1.68E-09 | 2.51E-04 |
| U-233 | 4.10E-03 | 0.00 | 7.91E-03 | 8.20E-07 | 8.27E-06 | 2.62E-05 | 1.58E-06 | 3.80E-07 | 1.58E-05 |
| U-238 | 5.96E-03 | 0.00 | 2.02E-02 | 1.19E-06 | 1.92E-05 | 6.48E-05 | 4.04E-06 | 9.69E-07 | 4.04E-05 |
| Th-234 | 5.96E-03 | 0.00 | 2.02E-02 | 1.19E-06 | 1.92E-05 | 6.48E-05 | 4.04E-06 | 9.69E-07 | 4.04E-05 |
| Pa-234m | 5.96E-03 | 0.00 | 2.02E-02 | 1.19E-06 | 1.92E-05 | 6.48E-05 | 4.04E-06 | 9.69E-07 | 4.04E-05 |
| Pa-234 | 7.75E-06 | 0.00 | 2.62E-05 | 1.55E-09 | 2.49E-08 | 8.42E-08 | 5.25E-09 | 1.26E-09 | 5.25E-08 |

**Dose (mrem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 | 0.00 | 5.05E-12 | 1.33E-04 | 0.00 | 0.00 | 6.29E-05 | 2.59E-03 | 8.41E-11 | 2.79E-03 |
| Co-60 | 6.28E-02 | 8.84E-07 | 1.61E-05 | 1.91E-07 | 7.65E-07 | 1.72E-04 | 1.27E-04 | 1.81E-06 | 6.31E-02 |
| Sr-90 | 0.00 | 1.98E-05 | 3.77E-03 | 9.75E-07 | 3.90E-05 | 1.75E-03 | 2.17E-03 | 3.61E-05 | 7.79E-03 |
| Y-90 | 0.00 | 1.28E-07 | 2.85E-04 | 7.37E-08 | 2.95E-06 | 1.33E-04 | 1.64E-04 | 2.73E-06 | 5.87E-04 |
| Cs-137 | 0.00 | 2.74E-07 | 1.40E-05 | 8.03E-06 | 1.07E-05 | 9.63E-03 | 1.78E-04 | 7.14E-06 | 9.85E-03 |
| Ba-137m | 3.40E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.40E-02 |
| Eu-152 | 4.44E-03 | 1.29E-07 | 3.32E-07 | 3.49E-08 | 1.40E-10 | 3.14E-06 | 4.66E-06 | 6.30E-08 | 4.44E-03 |
| Eu-154 | 1.96E-03 | 6.77E-08 | 1.87E-07 | 1.96E-08 | 7.82E-11 | 1.76E-06 | 2.61E-06 | 3.77E-08 | 1.97E-03 |
| Th-232 | 1.50E-06 | 5.37E-04 | 5.01E-05 | 3.76E-06 | 1.50E-08 | 4.06E-04 | 5.01E-04 | 1.49E-05 | 1.51E-03 |
| U-233 | 9.22E-07 | 3.65E-05 | 3.88E-06 | 3.76E-07 | 3.61E-07 | 2.70E-06 | 5.01E-05 | 1.30E-06 | 9.61E-05 |
| U-238 | 1.73E-06 | 4.64E-05 | 8.08E-06 | 8.44E-07 | 8.10E-07 | 6.07E-06 | 1.13E-04 | 1.66E-06 | 1.78E-04 |
| Th-234 | 2.71E-05 | 1.37E-08 | 4.33E-07 | 4.53E-08 | 4.34E-08 | 3.26E-07 | 6.03E-06 | 8.91E-08 | 3.41E-05 |
| Pa-234m | 3.03E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.03E-05 |
| Pa-234 | 6.84E-06 | 4.15E-13 | 8.91E-11 | 9.31E-12 | 8.94E-12 | 6.70E-11 | 1.24E-09 | 1.83E-11 | 6.84E-06 |
| Total | 1.03E-01 | 6.41E-04 | 4.28E-03 | 1.43E-05 | 5.46E-05 | 1.22E-02 | 5.90E-03 | 6.59E-05 | 1.26E-01 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 | 0.00 | 6.15E-15 | 1.15E-07 | 0.00 | 0.00 | 5.41E-08 | 2.23E-06 | 7.23E-14 | 2.39E-06 |
| Co-60 | 3.60E-05 | 6.46E-10 | 8.98E-09 | 1.06E-10 | 4.26E-10 | 9.57E-08 | 7.10E-08 | 1.01E-09 | 3.62E-05 |
| Sr-90 | 0.00 | 8.52E-10 | 8.74E-07 | 2.26E-10 | 9.03E-09 | 4.06E-07 | 5.02E-07 | 8.37E-09 | 1.80E-06 |
| Y-90 | 0.00 | 8.37E-11 | 8.47E-08 | 2.19E-11 | 8.76E-10 | 3.94E-08 | 4.87E-08 | 8.11E-10 | 1.75E-07 |
| Cs-137 | 0.00 | 1.63E-10 | 7.83E-09 | 4.50E-09 | 6.00E-09 | 5.40E-06 | 1.00E-07 | 4.00E-09 | 5.52E-06 |
| Ba-137m | 1.89E-05 | 4.87E-15 | 6.35E-13 | 3.65E-13 | 4.87E-13 | 4.38E-10 | 8.11E-12 | 3.25E-13 | 1.89E-05 |
| Eu-152 | 2.52E-06 | 7.00E-09 | 1.08E-10 | 1.13E-11 | 4.53E-14 | 1.02E-09 | 1.51E-09 | 2.04E-11 | 2.53E-06 |
| Eu-154 | 1.10E-06 | 3.31E-11 | 5.87E-11 | 6.15E-12 | 2.46E-14 | 5.53E-10 | 8.20E-10 | 1.18E-11 | 1.10E-06 |
| Th-232 | 1.03E-09 | 1.02E-08 | 4.04E-10 | 3.03E-11 | 1.21E-13 | 3.27E-09 | 4.04E-09 | 1.20E-10 | 1.91E-08 |
| U-233 | 6.09E-10 | 7.27E-09 | 1.88E-09 | 1.82E-10 | 1.75E-10 | 1.31E-09 | 2.43E-08 | 6.28E-10 | 3.63E-08 |
| U-238 | 1.23E-09 | 9.40E-09 | 4.12E-09 | 4.31E-10 | 4.14E-10 | 3.10E-09 | 5.75E-08 | 8.49E-10 | 7.70E-08 |
| Th-234 | 1.50E-08 | 1.25E-11 | 1.27E-10 | 1.33E-11 | 1.27E-11 | 9.54E-11 | 1.77E-09 | 2.61E-11 | 1.71E-08 |
| Pa-234m | 1.72E-08 | 6.27E-16 | 1.84E-13 | 1.92E-14 | 1.85E-14 | 1.38E-13 | 2.56E-12 | 3.79E-14 | 1.72E-08 |
| Pa-234 | 3.84E-09 | 2.75E-16 | 2.80E-14 | 2.93E-15 | 2.81E-15 | 2.11E-14 | 3.91E-13 | 5.77E-15 | 3.84E-09 |
| Total | 5.85E-05 | 3.56E-08 | 1.10E-06 | 5.53E-09 | 1.69E-08 | 6.00E-06 | 3.04E-06 | 1.58E-08 | 6.87E-05 |

Table 6G.15. Summary of Dose and Risk for 1990 on-WAG Homesteader

Dose (mrem) - totals across nuclide

| Sub-area | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| Area A | 5.88E+04 | 5.92E+00 | 4.95E+01 | 4.50E-04 | 1.09E-03 | 0.00 | 2.44E-01 | 1.37E+01 | 5.89E+04 |
| Area B | 4.11E+05 | 3.70E+01 | 7.88E+01 | 6.75E-04 | 1.80E-03 | 0.00 | 5.36E-01 | 3.13E+01 | 4.12E+05 |
| Area C | 4.12E+02 | 3.42E+01 | 2.04E+01 | 6.82E-03 | 2.40E-01 | 0.00 | 1.58E+01 | 5.83E+00 | 4.88E+02 |
| Area D | 1.69E+04 | 4.75E+00 | 9.55E+00 | 0.00 | 0.00 | 0.00 | 5.65E-01 | 2.52E+00 | 1.69E+04 |
| Area E | 1.11E+02 | 1.45E+01 | 4.52E-01 | 1.88E-04 | 4.38E-04 | 0.00 | 1.28E-01 | 6.18E-01 | 1.27E+02 |
| Area F | 2.95E+02 | 4.98E+00 | 1.05E+01 | 1.29E-05 | 4.63E-04 | 0.00 | 4.54E-02 | 1.33E+00 | 3.12E+02 |
| Area G | 3.34E+02 | 5.33E+00 | 1.11E+01 | 1.34E-04 | 6.33E-04 | 0.00 | 8.36E-01 | 1.41E+00 | 3.52E+02 |
| Area H | 2.03E+03 | 1.11E+00 | 8.35E+00 | 1.55E-04 | 5.72E-03 | 0.00 | 8.09E-01 | 1.58E+00 | 2.04E+03 |
| Area I | 2.13E+02 | 3.24E-01 | 6.45E+00 | 1.86E-04 | 7.36E-03 | 0.00 | 7.34E-01 | 7.24E-01 | 2.21E+02 |
| Area J | 5.73E+03 | 3.72E-01 | 4.91E+00 | 1.05E-04 | 2.47E-03 | 0.00 | 2.15E-01 | 2.93E+00 | 5.74E+03 |
| Area K | 1.66E+06 | 1.41E+02 | 1.28E+01 | 9.19E-05 | 7.21E-04 | 0.00 | 5.59E-02 | 7.55E+01 | 1.66E+06 |
| Area L | 4.57E+02 | 4.31E+01 | 2.22E+00 | 4.69E-04 | 3.06E-03 | 0.00 | 4.70E+00 | 1.97E+00 | 5.09E+02 |
| Area M | 4.84E+02 | 6.03E+01 | 1.92E+00 | 7.91E-04 | 1.08E-03 | 0.00 | 2.07E+00 | 2.52E+00 | 5.51E+02 |
| Area N | 1.33E+03 | 3.02E+01 | 2.28E+00 | 4.55E-04 | 9.80E-04 | 0.00 | 8.85E-02 | 1.47E+00 | 1.37E+03 |
| Area O | 1.58E+03 | 1.18E+01 | 2.20E+00 | 3.10E-03 | 1.01E-03 | 0.00 | 7.38E-01 | 1.03E+00 | 1.60E+03 |
| Area P | 3.44E+06 | 7.26E+04 | 4.81E+02 | 3.37E-03 | 9.17E-03 | 0.00 | 2.54E+00 | 2.18E+03 | 3.51E+06 |
| Area Q | 2.80E+03 | 4.15E-01 | 7.08E+00 | 1.38E-04 | 6.16E-04 | 0.00 | 4.42E-02 | 1.84E+00 | 2.80E+03 |
| Area R | 7.14E+03 | 4.47E-01 | 4.10E+00 | 4.94E-05 | 1.43E-03 | 0.00 | 1.21E-01 | 1.10E+00 | 7.15E+03 |
| Area S | 1.35E-01 | 7.14E-05 | 9.33E-05 | 4.81E-04 | 8.89E-04 | 0.00 | 5.11E-02 | 1.23E-04 | 1.88E-01 |
| Area T | 5.37E-03 | 1.00E-04 | 6.75E-04 | 2.41E-04 | 5.85E-04 | 0.00 | 9.62E-02 | 1.64E-04 | 1.03E-01 |
| Area U | 1.93E-02 | 2.65E-04 | 1.13E-03 | 4.61E-04 | 1.03E-03 | 0.00 | 9.27E-02 | 2.12E-04 | 1.15E-01 |
| Area V | 2.11E+02 | 1.99E+01 | 7.05E-01 | 1.64E-04 | 5.32E-04 | 0.00 | 5.28E-02 | 8.69E-01 | 2.32E+02 |
| Area W | 5.10E-01 | 1.94E-04 | 1.53E-03 | 4.51E-07 | 1.81E-05 | 0.00 | 8.92E-02 | 2.28E-04 | 6.01E-01 |
| Area X | 2.54E+01 | 1.77E-02 | 3.40E-01 | 1.34E-04 | 4.52E-04 | 0.00 | 8.61E-02 | 3.78E-02 | 2.59E+01 |
| Area Y | 2.65E+04 | 2.15E+02 | 5.06E+00 | 1.07E-04 | 3.61E-04 | 0.00 | 6.29E-02 | 1.15E+01 | 2.67E+04 |
| Area Z | 5.27E+02 | 2.50E-01 | 4.85E+00 | 0.00 | 0.00 | 0.00 | 2.69E-01 | 7.45E-01 | 5.33E+02 |
| Average | 2.17E+05 | 2.82E+03 | 2.79E+01 | 7.22E-04 | 1.09E-02 | 0.00 | 1.19E+00 | 9.00E+01 | 2.20E+05 |
| Minimum | 5.37E-03 | 7.14E-05 | 9.33E-05 | 0.00 | 0.00 | 0.00 | 4.42E-02 | 1.23E-04 | 1.03E-01 |
| Maximum | 3.44E+06 | 7.26E+04 | 4.81E+02 | 6.82E-03 | 2.40E-01 | 0.00 | 1.58E+01 | 2.18E+03 | 3.51E+06 |

Risk - totals across nuclide

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| Area A | 3.33E+01 | 1.28E-01 | 1.21E-02 | 2.47E-07 | 4.47E-07 | 0.00 | 1.89E-04 | 5.79E-03 | 3.34E+01 |
| Area B | 2.33E+02 | 9.05E-01 | 1.91E-02 | 3.71E-07 | 8.87E-07 | 0.00 | 4.01E-04 | 1.10E-02 | 2.34E+02 |
| Area C | 2.30E-01 | 4.13E-03 | 4.81E-03 | 1.88E-06 | 5.71E-05 | 0.00 | 5.26E-03 | 1.02E-03 | 2.45E-01 |
| Area D | 9.65E+00 | 1.15E-03 | 2.46E-03 | 0.00 | 0.00 | 0.00 | 4.86E-04 | 1.08E-03 | 9.65E+00 |
| Area E | 6.24E-02 | 2.93E-03 | 1.27E-04 | 1.04E-07 | 1.85E-07 | 0.00 | 1.02E-04 | 2.99E-04 | 6.58E-02 |
| Area F | 1.65E-01 | 9.16E-04 | 2.49E-03 | 3.55E-09 | 1.11E-07 | 0.00 | 2.29E-05 | 4.02E-04 | 1.69E-01 |
| Area G | 1.86E-01 | 9.83E-04 | 2.63E-03 | 7.19E-08 | 2.21E-07 | 0.00 | 6.99E-04 | 4.31E-04 | 1.91E-01 |
| Area H | 1.14E+00 | 1.28E-04 | 2.00E-03 | 4.07E-08 | 1.37E-06 | 0.00 | 4.96E-04 | 5.84E-04 | 1.15E+00 |
| Area I | 1.19E-01 | 1.82E-05 | 1.53E-03 | 4.45E-08 | 1.74E-06 | 0.00 | 3.76E-04 | 2.04E-04 | 1.21E-01 |
| Area J | 3.21E+00 | 1.03E-04 | 1.26E-03 | 3.95E-08 | 6.22E-07 | 0.00 | 9.89E-05 | 1.50E-03 | 3.21E+00 |
| Area K | 9.40E+02 | 3.14E+00 | 3.84E-03 | 2.89E-08 | 1.74E-07 | 0.00 | 1.81E-05 | 2.41E-02 | 9.43E+02 |
| Area L | 2.55E-01 | 8.59E-03 | 5.82E-04 | 2.42E-07 | 9.00E-07 | 0.00 | 3.95E-03 | 9.28E-04 | 2.69E-01 |
| Area M | 2.72E-01 | 1.11E-02 | 5.21E-04 | 3.30E-07 | 4.79E-07 | 0.00 | 1.73E-03 | 1.14E-03 | 2.86E-01 |
| Area N | 7.61E-01 | 6.08E-03 | 5.93E-04 | 2.52E-07 | 4.25E-07 | 0.00 | 5.96E-05 | 6.84E-04 | 7.68E-01 |
| Area O | 8.94E-01 | 4.99E-04 | 5.28E-04 | 3.49E-07 | 4.40E-07 | 0.00 | 3.29E-04 | 3.21E-04 | 8.96E-01 |
| Area P | 1.95E+03 | 1.01E+01 | 1.70E-02 | 1.80E-06 | 4.92E-06 | 0.00 | 1.79E-03 | 7.83E-02 | 1.96E+03 |
| Area Q | 1.57E+00 | 6.27E-05 | 1.72E-03 | 7.38E-08 | 2.07E-07 | 0.00 | 2.10E-05 | 8.13E-04 | 1.57E+00 |
| Area R | 4.08E+00 | 1.96E-04 | 1.06E-03 | 1.65E-08 | 3.57E-07 | 0.00 | 5.37E-05 | 4.96E-04 | 4.08E+00 |
| Area S | 7.54E-05 | 8.01E-08 | 2.44E-08 | 2.68E-07 | 4.16E-07 | 0.00 | 3.18E-05 | 8.13E-08 | 1.08E-04 |
| Area T | 3.02E-06 | 8.28E-08 | 1.60E-07 | 1.33E-07 | 2.40E-07 | 0.00 | 7.16E-05 | 9.96E-08 | 7.53E-05 |
| Area U | 1.09E-05 | 2.57E-07 | 2.67E-07 | 2.55E-07 | 4.38E-07 | 0.00 | 6.18E-05 | 1.13E-07 | 7.40E-05 |
| Area V | 1.19E-01 | 4.01E-03 | 1.95E-04 | 8.94E-08 | 1.93E-07 | 0.00 | 3.31E-05 | 4.20E-04 | 1.23E-01 |
| Area W | 2.91E-04 | 1.40E-07 | 3.68E-07 | 1.07E-10 | 4.27E-09 | 0.00 | 7.60E-05 | 8.16E-08 | 3.67E-04 |
| Area X | 1.45E-02 | 1.40E-06 | 8.07E-05 | 7.30E-08 | 1.62E-07 | 0.00 | 6.33E-05 | 1.06E-05 | 1.46E-02 |
| Area Y | 1.52E+01 | 4.25E-02 | 1.73E-03 | 5.82E-08 | 1.32E-07 | 0.00 | 4.52E-05 | 5.06E-03 | 1.52E+01 |
| Area Z | 2.94E-01 | 1.83E-05 | 1.16E-03 | 0.00 | 0.00 | 0.00 | 2.31E-04 | 2.66E-04 | 2.95E-01 |
| Average | 1.23E+02 | 5.52E-01 | 2.98E-03 | 2.61E-07 | 2.78E-06 | 0.00 | 6.42E-04 | 5.19E-03 | 1.23E+02 |
| Minimum | 3.02E-06 | 8.01E-08 | 2.44E-08 | 0.00 | 0.00 | 0.00 | 1.81E-05 | 8.13E-08 | 7.40E-05 |
| Maximum | 1.95E+03 | 1.01E+01 | 1.91E-02 | 1.88E-06 | 5.71E-05 | 0.00 | 5.26E-03 | 7.83E-02 | 1.96E+03 |

Table 6G.15. (continued)

Dose (mrem) - averages across subareas

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 3.74E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.74E-05 |
| H-3 | 0.00 | 3.75E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 5.53E-01 | 6.25E-04 | 5.53E-01 |
| Co-60 | 7.71E+03 | 2.85E-01 | 2.85E-01 | 7.74E-05 | 3.10E-04 | 0.00 | 5.16E-02 | 5.85E-01 | 7.71E+03 |
| Sr-90 | 0.00 | 4.54E-01 | 8.58E+00 | 2.37E-04 | 9.48E-03 | 0.00 | 5.26E-01 | 8.31E-01 | 1.04E+01 |
| Y-90 | 0.00 | 2.95E-03 | 6.49E-01 | 1.79E-05 | 7.16E-04 | 0.00 | 3.98E-02 | 6.28E-02 | 7.55E-01 |
| Cs-137 | 0.00 | 6.09E-02 | 1.68E-01 | 2.59E-04 | 3.45E-04 | 0.00 | 5.75E-03 | 1.59E+00 | 1.82E+00 |
| Ba-137m | 2.87E+03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.87E+03 |
| Eu-152 | 1.16E+05 | 8.85E+00 | 5.68E-01 | 3.58E-06 | 1.43E-08 | 0.00 | 4.78E-04 | 4.32E+00 | 1.16E+05 |
| Eu-154 | 8.95E+04 | 8.11E+00 | 5.93E-01 | 1.18E-05 | 4.70E-08 | 0.00 | 1.57E-03 | 4.51E+00 | 8.95E+04 |
| Eu-155 | 7.28E+02 | 1.62E-01 | 1.31E-02 | 1.13E-07 | 4.51E-10 | 0.00 | 1.50E-05 | 9.93E-02 | 7.28E+02 |
| Th-232 | 2.95E+00 | 2.78E+03 | 1.69E+01 | 8.04E-05 | 3.21E-07 | 0.00 | 1.07E-02 | 7.72E+01 | 2.88E+03 |
| U-233 | 7.35E-02 | 7.63E+00 | 3.57E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 2.71E-01 | 8.01E+00 |
| U-238 | 1.02E-01 | 7.15E+00 | 3.37E-02 | 7.92E-06 | 7.60E-06 | 0.00 | 1.06E-03 | 2.56E-01 | 7.55E+00 |
| Th-234 | 1.59E+00 | 2.12E-03 | 1.81E-03 | 4.25E-07 | 4.08E-07 | 0.00 | 5.66E-05 | 1.37E-02 | 1.61E+00 |
| Pa-234m | 1.78E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.78E+00 |
| Pa-234 | 4.02E-01 | 6.39E-08 | 3.72E-07 | 8.74E-11 | 8.39E-11 | 0.00 | 1.17E-08 | 2.83E-06 | 4.02E-01 |
| Am-241 | 1.05E-01 | 5.97E-01 | 1.24E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 8.16E-02 | 7.85E-01 |
| Cm-244 | 8.04E-03 | 9.22E-01 | 1.64E-02 | 2.74E-05 | 1.09E-07 | 0.00 | 3.65E-03 | 1.25E-01 | 1.07E+00 |
| Total | 2.17E+05 | 2.82E+03 | 2.79E+01 | 7.22E-04 | 1.09E-02 | 0.00 | 1.19E+00 | 9.00E+01 | 2.20E+05 |

Risk - averages across subareas

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 4.56E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.56E-08 |
| H-3 | 0.00 | 4.57E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 4.75E-04 | 5.37E-07 | 4.75E-04 |
| Co-60 | 4.42E+00 | 2.08E-04 | 1.59E-04 | 4.31E-08 | 1.72E-07 | 0.00 | 2.87E-05 | 3.25E-04 | 4.42E+00 |
| Sr-90 | 0.00 | 1.96E-05 | 1.99E-03 | 5.49E-08 | 2.20E-06 | 0.00 | 1.22E-04 | 1.92E-04 | 2.32E-03 |
| Y-90 | 0.00 | 1.92E-06 | 1.93E-04 | 5.32E-09 | 2.13E-07 | 0.00 | 1.18E-05 | 1.87E-05 | 2.25E-04 |
| Cs-137 | 0.00 | 3.62E-05 | 9.39E-05 | 1.45E-07 | 1.93E-07 | 0.00 | 3.22E-06 | 8.89E-04 | 1.02E-03 |
| Ba-137m | 1.60E+00 | 1.08E-09 | 7.62E-09 | 1.18E-11 | 1.57E-11 | 0.00 | 2.61E-10 | 7.21E-08 | 1.60E+00 |
| Eu-152 | 6.59E+01 | 4.81E-01 | 1.84E-04 | 1.16E-09 | 4.65E-12 | 0.00 | 1.55E-07 | 1.40E-03 | 6.63E+01 |
| Eu-154 | 5.03E+01 | 3.97E-03 | 1.86E-04 | 3.70E-09 | 1.48E-11 | 0.00 | 4.93E-07 | 1.42E-03 | 5.03E+01 |
| Eu-155 | 5.29E-01 | 1.17E-02 | 4.44E-06 | 3.83E-11 | 1.53E-13 | 0.00 | 5.11E-09 | 3.38E-05 | 5.41E-01 |
| Th-232 | 2.04E-03 | 5.26E-02 | 1.36E-04 | 6.47E-10 | 2.59E-12 | 0.00 | 8.63E-08 | 6.22E-04 | 5.54E-02 |
| U-233 | 4.85E-05 | 1.52E-03 | 1.73E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 1.32E-04 | 1.72E-03 |
| U-238 | 7.25E-05 | 1.45E-03 | 1.72E-05 | 4.04E-09 | 3.88E-09 | 0.00 | 5.39E-07 | 1.31E-04 | 1.67E-03 |
| Th-234 | 8.83E-04 | 1.93E-06 | 5.30E-07 | 1.24E-10 | 1.19E-10 | 0.00 | 1.66E-08 | 4.03E-06 | 8.90E-04 |
| Pa-234m | 1.01E-03 | 9.67E-11 | 7.68E-10 | 1.80E-13 | 1.73E-13 | 0.00 | 2.41E-11 | 5.84E-09 | 1.01E-03 |
| Pa-234 | 2.25E-04 | 4.24E-11 | 1.17E-10 | 2.75E-14 | 2.64E-14 | 0.00 | 3.67E-12 | 8.90E-10 | 2.25E-04 |
| Am-241 | 5.62E-05 | 5.38E-05 | 1.06E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 6.95E-06 | 1.17E-04 |
| Cm-244 | 5.63E-06 | 1.00E-04 | 1.63E-06 | 2.71E-09 | 1.09E-11 | 0.00 | 3.62E-07 | 1.24E-05 | 1.20E-04 |
| Total | 1.23E+02 | 5.52E-01 | 2.98E-03 | 2.61E-07 | 2.78E-06 | 0.00 | 6.42E-04 | 5.19E-03 | 1.23E+02 |

Table 6G.15. (continued)

Dose (rem) - totals across pathways

| Sub-area | H-3 vapor | H-3 | Co-60 | Sr-90 | Y-90 | Cs-137 | Ba-137m | Eu-152 | Eu-154 |
|---|---|---|---|---|---|---|---|---|---|
| Area A | 1.01E-05 | 2.04E-01 | 9.79E+03 | 5.16E+01 | 3.73E+00 | 7.78E+00 | 1.23E+04 | 3.03E+04 | 6.38E+03 |
| Area B | 1.01E-05 | 3.62E-01 | 7.86E+03 | 8.08E+01 | 5.85E+00 | 7.18E+00 | 1.13E+04 | 2.11E+05 | 1.80E+05 |
| Area C | 1.01E-05 | 2.45E+00 | 5.69E+01 | 3.41E+01 | 2.51E+00 | 2.43E-01 | 3.52E+02 | 0.00 | 0.00 |
| Area D | 1.01E-05 | 5.65E-01 | 1.65E+04 | 9.51E+00 | 6.88E-01 | 2.49E-01 | 3.94E+02 | 0.00 | 0.00 |
| Area E | 1.01E-05 | 1.12E-01 | 2.59E+01 | 4.11E-01 | 2.98E-02 | 5.54E-02 | 8.06E+01 | 0.00 | 0.00 |
| Area F | 1.01E-05 | 1.91E-02 | 2.09E+01 | 1.12E+01 | 8.12E-01 | 1.73E-01 | 2.75E+02 | 0.00 | 0.00 |
| Area G | 1.01E-05 | 7.97E-01 | 2.87E+01 | 1.18E+01 | 8.57E-01 | 1.95E-01 | 3.05E+02 | 0.00 | 0.00 |
| Area H | 1.01E-05 | 4.86E-01 | 8.98E+02 | 9.11E+00 | 6.60E-01 | 7.12E-01 | 1.13E+03 | 0.00 | 0.00 |
| Area I | 1.62E-05 | 3.25E-01 | 3.51E+01 | 7.27E+00 | 5.27E-01 | 1.12E-01 | 1.77E+02 | 0.00 | 0.00 |
| Area J | 1.01E-05 | 6.91E-02 | 1.41E+03 | 5.05E+00 | 3.66E-01 | 2.72E+00 | 4.31E+03 | 0.00 | 0.00 |
| Area K | 1.01E-05 | 5.96E-03 | 2.51E+02 | 3.13E+00 | 2.27E-01 | 2.97E-01 | 4.70E+02 | 7.18E+05 | 9.36E+05 |
| Area L | 2.03E-05 | 4.55E+00 | 1.25E+01 | 2.26E+00 | 1.64E-01 | 2.90E-01 | 4.44E+02 | 0.00 | 0.00 |
| Area M | 4.05E-05 | 1.99E+00 | 1.29E+02 | 1.72E+00 | 1.25E-01 | 2.23E-01 | 3.39E+02 | 0.00 | 0.00 |
| Area N | 6.08E-05 | 5.74E-02 | 1.17E+03 | 2.25E+00 | 1.63E-01 | 1.11E-01 | 1.58E+02 | 0.00 | 0.00 |
| Area O | 4.05E-05 | 3.57E-01 | 9.14E+02 | 2.21E+00 | 1.60E-01 | 4.32E-01 | 6.65E+02 | 0.00 | 0.00 |
| Area P | 2.03E-05 | 1.32E+00 | 1.28E+05 | 1.71E+01 | 1.24E+00 | 2.45E+01 | 3.88E+04 | 2.06E+06 | 1.21E+06 |
| Area Q | 2.03E-05 | 1.30E-02 | 7.87E+02 | 7.43E+00 | 5.38E-01 | 1.27E+00 | 2.01E+03 | 0.00 | 0.00 |
| Area R | 6.08E-05 | 3.51E-02 | 6.74E+03 | 4.17E+00 | 3.02E-01 | 2.54E-01 | 4.02E+02 | 0.00 | 0.00 |
| Area S | 6.08E-05 | 2.59E-02 | 2.39E-02 | 1.34E-02 | 1.01E-03 | 1.17E-02 | 1.12E-01 | 0.00 | 0.00 |
| Area T | 6.08E-05 | 7.56E-02 | 2.33E-03 | 1.50E-02 | 1.13E-03 | 5.74E-03 | 3.44E-03 | 0.00 | 0.00 |
| Area U | 2.03E-04 | 5.85E-02 | 1.05E-02 | 2.33E-02 | 1.76E-03 | 1.10E-02 | 9.73E-03 | 0.00 | 0.00 |
| Area V | 1.42E-04 | 3.13E-02 | 7.51E+01 | 6.56E-01 | 4.75E-02 | 8.53E-02 | 1.29E+02 | 0.00 | 0.00 |
| Area W | 1.01E-04 | 8.82E-02 | 4.29E-01 | 2.56E-03 | 1.89E-04 | 5.11E-05 | 8.09E-02 | 0.00 | 0.00 |
| Area X | 6.08E-06 | 6.73E-02 | 1.92E+01 | 3.77E-01 | 2.74E-02 | 7.02E-03 | 6.20E+00 | 0.00 | 0.00 |
| Area Y | 8.11E-06 | 4.79E-02 | 2.63E+04 | 3.09E+00 | 2.24E-01 | 1.16E-01 | 1.80E+02 | 0.00 | 0.00 |
| Area Z | 1.01E-05 | 2.69E-01 | 2.66E+01 | 5.15E+00 | 3.73E-01 | 3.16E-01 | 5.00E+02 | 0.00 | 0.00 |
| Average | 3.74E-05 | 5.53E-01 | 7.71E+03 | 1.04E+01 | 7.55E-01 | 1.82E+00 | 2.87E+03 | 1.16E+05 | 8.95E+04 |
| Minimum | 6.08E-06 | 5.96E-03 | 2.33E-03 | 2.56E-03 | 1.89E-04 | 5.11E-05 | 3.44E-03 | 0.00 | 0.00 |
| Maximum | 2.03E-04 | 4.55E+00 | 1.28E+05 | 8.08E+01 | 5.85E+00 | 2.45E+01 | 3.88E+04 | 2.06E+06 | 1.21E+06 |

Dose (rem) - totals across pathways (continued)

| Sub-area | Eu-155 | Th-232 | U-233 | U-238 | Th-234 | Pa-234m | Pa-234 | Am-241 | Cm-244 |
|---|---|---|---|---|---|---|---|---|---|
| Area A | 1.26E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area B | 1.39E+03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area C | 0.00 | 0.00 | 8.79E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.04E+01 | 1.08E+01 |
| Area D | 0.00 | 0.00 | 3.22E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.18E-01 |
| Area E | 0.00 | 0.00 | 6.07E+00 | 9.21E+00 | 1.97E+00 | 2.18E+00 | 4.91E-01 | 0.00 | 0.00 |
| Area F | 0.00 | 0.00 | 4.68E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area G | 0.00 | 0.00 | 5.02E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area H | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.50E-01 |
| Area I | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area J | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area K | 7.90E+03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area L | 0.00 | 0.00 | 4.45E+01 | 7.28E-01 | 1.55E-01 | 1.72E-01 | 3.87E-02 | 0.00 | 0.00 |
| Area M | 0.00 | 5.64E+00 | 2.54E+01 | 3.23E+01 | 6.88E+00 | 7.62E+00 | 1.72E+00 | 0.00 | 0.00 |
| Area N | 0.00 | 0.00 | 1.94E+01 | 1.22E+01 | 2.60E+00 | 2.88E+00 | 6.49E-01 | 0.00 | 0.00 |
| Area O | 0.00 | 1.07E+01 | 0.00 | 1.07E+00 | 2.29E-01 | 2.53E-01 | 5.70E-02 | 0.00 | 7.85E-01 |
| Area P | 9.50E+03 | 7.48E+04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area Q | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area R | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area S | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area T | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area U | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area V | 0.00 | 0.00 | 8.00E+00 | 1.29E+01 | 2.76E+00 | 3.06E+00 | 6.89E-01 | 0.00 | 0.00 |
| Area W | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area X | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area Y | 0.00 | 0.00 | 8.33E+01 | 1.28E+02 | 2.73E+01 | 3.02E+01 | 6.80E+00 | 0.00 | 1.49E+01 |
| Area Z | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Average | 7.28E+02 | 2.88E+03 | 8.01E+00 | 7.55E+00 | 1.61E+00 | 1.78E+00 | 4.02E-01 | 7.85E-01 | 1.07E+00 |
| Minimum | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Maximum | 9.50E+03 | 7.48E+04 | 8.33E+01 | 1.28E+02 | 2.73E+01 | 3.02E+01 | 6.80E+00 | 2.04E+01 | 1.49E+01 |

Table 6G.15. (continued)

Risk - totals across pathways

| Sub-area | H-3 vapor | H-3 | Co-60 | Sr-90 | Y-90 | Cs-137 | Ba-137m | Eu-152 | Eu-154 |
|---|---|---|---|---|---|---|---|---|---|
| Area A | 1.24E-08 | 1.76E-04 | 5.61E+00 | 1.15E-02 | 1.11E-03 | 4.37E-03 | 6.85E+00 | 1.73E+01 | 3.59E+00 |
| Area B | 1.24E-08 | 3.11E-04 | 4.50E+00 | 1.80E-02 | 1.75E-03 | 4.03E-03 | 6.32E+00 | 1.21E+02 | 1.01E+02 |
| Area C | 1.24E-08 | 2.11E-03 | 3.26E-02 | 7.72E-03 | 7.48E-04 | 1.36E-04 | 1.96E-01 | 0.00 | 0.00 |
| Area D | 1.24E-08 | 4.86E-04 | 9.43E+00 | 2.12E-03 | 2.06E-04 | 1.40E-04 | 2.19E-01 | 0.00 | 0.00 |
| Area E | 1.24E-08 | 9.62E-05 | 1.48E-02 | 9.18E-05 | 8.90E-06 | 3.11E-05 | 4.49E-02 | 0.00 | 0.00 |
| Area F | 1.24E-08 | 1.64E-05 | 1.19E-02 | 2.50E-03 | 2.43E-04 | 9.74E-05 | 1.53E-01 | 0.00 | 0.00 |
| Area G | 1.24E-08 | 6.85E-04 | 1.65E-02 | 2.64E-03 | 2.56E-04 | 1.10E-04 | 1.70E-01 | 0.00 | 0.00 |
| Area H | 1.24E-08 | 4.17E-04 | 5.14E-01 | 2.03E-03 | 1.97E-04 | 4.00E-04 | 6.28E-01 | 0.00 | 0.00 |
| Area I | 1.98E-08 | 2.79E-04 | 2.01E-02 | 1.62E-03 | 1.57E-04 | 6.29E-05 | 9.87E-02 | 0.00 | 0.00 |
| Area J | 1.24E-08 | 5.94E-05 | 8.10E-01 | 1.13E-03 | 1.09E-04 | 1.53E-03 | 2.40E+00 | 0.00 | 0.00 |
| Area K | 1.24E-08 | 5.12E-06 | 1.44E-01 | 6.99E-04 | 6.78E-05 | 1.67E-04 | 2.62E-01 | 4.10E+02 | 5.26E+02 |
| Area L | 2.47E-08 | 3.91E-03 | 7.16E-03 | 5.05E-04 | 4.90E-05 | 1.63E-04 | 2.47E-01 | 0.00 | 0.00 |
| Area M | 4.94E-08 | 1.71E-03 | 7.36E-02 | 3.84E-04 | 3.73E-05 | 1.26E-04 | 1.89E-01 | 0.00 | 0.00 |
| Area N | 7.41E-08 | 4.93E-05 | 6.69E-01 | 5.02E-04 | 4.87E-05 | 6.23E-05 | 8.82E-02 | 0.00 | 0.00 |
| Area O | 4.94E-08 | 3.07E-04 | 5.24E-01 | 4.92E-04 | 4.78E-05 | 2.42E-04 | 3.70E-01 | 0.00 | 0.00 |
| Area P | 2.47E-08 | 1.13E-03 | 7.31E+01 | 3.81E-03 | 3.69E-04 | 1.38E-02 | 2.16E+01 | 1.18E+03 | 6.77E+02 |
| Area Q | 2.47E-08 | 1.12E-05 | 4.51E-01 | 1.66E-03 | 1.61E-04 | 7.14E-04 | 1.12E+00 | 0.00 | 0.00 |
| Area R | 7.41E-08 | 3.02E-05 | 3.86E+00 | 9.30E-04 | 9.02E-05 | 1.42E-04 | 2.24E-01 | 0.00 | 0.00 |
| Area S | 7.41E-08 | 2.23E-05 | 1.37E-05 | 3.11E-06 | 3.01E-07 | 6.57E-06 | 6.21E-05 | 0.00 | 0.00 |
| Area T | 7.41E-08 | 6.50E-05 | 1.33E-06 | 3.47E-06 | 3.37E-07 | 3.22E-06 | 1.91E-06 | 0.00 | 0.00 |
| Area U | 2.47E-07 | 5.02E-05 | 5.98E-06 | 5.39E-06 | 5.23E-07 | 6.19E-06 | 5.41E-06 | 0.00 | 0.00 |
| Area V | 1.73E-07 | 2.69E-05 | 4.30E-02 | 1.46E-04 | 1.42E-05 | 4.79E-05 | 7.18E-02 | 0.00 | 0.00 |
| Area W | 1.24E-07 | 7.58E-05 | 2.46E-04 | 5.80E-07 | 5.62E-08 | 2.87E-08 | 4.50E-05 | 0.00 | 0.00 |
| Area X | 7.41E-09 | 5.78E-05 | 1.10E-02 | 8.43E-05 | 8.17E-06 | 3.94E-06 | 3.45E-03 | 0.00 | 0.00 |
| Area Y | 9.88E-09 | 4.12E-05 | 1.50E+01 | 6.90E-04 | 6.69E-05 | 6.51E-05 | 1.00E-01 | 0.00 | 0.00 |
| Area Z | 1.24E-08 | 2.31E-04 | 1.52E-02 | 1.15E-03 | 1.11E-04 | 1.78E-04 | 2.79E-01 | 0.00 | 0.00 |
| Average | 4.56E-08 | 4.75E-04 | 4.42E+00 | 2.32E-03 | 2.25E-04 | 1.02E-03 | 1.60E+00 | 6.63E+01 | 5.03E+01 |
| Minimum | 7.41E-09 | 5.12E-06 | 1.33E-06 | 5.80E-07 | 5.62E-08 | 2.87E-08 | 1.91E-06 | 0.00 | 0.00 |
| Maximum | 2.47E-07 | 3.91E-03 | 7.31E+01 | 1.80E-02 | 1.75E-03 | 1.38E-02 | 2.16E+01 | 1.18E+03 | 6.77E+02 |

Risk - totals across pathways (continued)

| Sub-area | Eu-155 | Th-232 | U-233 | U-238 | Th-234 | Pa-234m | Pa-234 | Am-241 | Cm-244 |
|---|---|---|---|---|---|---|---|---|---|
| Area A | 9.38E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area B | 1.04E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area C | 0.00 | 0.00 | 1.89E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 3.04E-03 | 1.20E-03 |
| Area D | 0.00 | 0.00 | 6.92E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.05E-05 |
| Area E | 0.00 | 0.00 | 1.30E-03 | 2.04E-03 | 1.09E-03 | 1.23E-03 | 2.75E-04 | 0.00 | 0.00 |
| Area F | 0.00 | 0.00 | 1.00E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area G | 0.00 | 0.00 | 1.08E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area H | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.41E-05 |
| Area I | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area J | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area K | 5.87E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area L | 0.00 | 0.00 | 9.54E-03 | 1.61E-04 | 8.58E-05 | 9.73E-05 | 2.17E-05 | 0.00 | 0.00 |
| Area M | 0.00 | 1.08E-04 | 5.44E-03 | 7.16E-03 | 3.80E-03 | 4.31E-03 | 9.64E-04 | 0.00 | 0.00 |
| Area N | 0.00 | 0.00 | 4.17E-03 | 2.70E-03 | 1.44E-03 | 1.63E-03 | 3.64E-04 | 0.00 | 0.00 |
| Area O | 0.00 | 2.03E-04 | 0.00 | 2.37E-04 | 1.26E-04 | 1.43E-04 | 3.20E-05 | 0.00 | 8.68E-05 |
| Area P | 7.06E+00 | 1.44E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area Q | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area R | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area S | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area T | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area U | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area V | 0.00 | 0.00 | 1.72E-03 | 2.87E-03 | 1.53E-03 | 1.73E-03 | 3.87E-04 | 0.00 | 0.00 |
| Area W | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area X | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area Y | 0.00 | 0.00 | 1.79E-02 | 2.83E-02 | 1.51E-02 | 1.71E-02 | 3.82E-03 | 0.00 | 1.67E-03 |
| Area Z | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Average | 5.41E-01 | 5.54E-02 | 1.72E-03 | 1.67E-03 | 8.90E-04 | 1.01E-03 | 2.25E-04 | 1.17E-04 | 1.20E-04 |
| Minimum | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Maximum | 7.06E+00 | 1.44E+00 | 1.79E-02 | 2.83E-02 | 1.51E-02 | 1.71E-02 | 3.82E-03 | 3.04E-03 | 1.67E-03 |

Table 6G.16. Summary of Dose and Risk for 2100 on-WAG Homesteader

Dose (mrem) - totals across nuclide

| Sub-area | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| Area A | 1.07E+03 | 1.90E-01 | 3.33E+00 | 7.62E-04 | 2.14E-02 | 0.00 | 1.18E+00 | 8.55E-01 | 1.07E+03 |
| Area B | 1.62E+03 | 3.30E-01 | 5.21E+00 | 5.97E-04 | 1.27E-02 | 0.00 | 6.91E-01 | 1.02E+00 | 1.62E+03 |
| Area C | 2.83E+01 | 1.12E+01 | 1.43E+00 | 7.71E-04 | 2.80E-02 | 0.00 | 1.55E+00 | 8.27E-01 | 4.33E+01 |
| Area D | 3.11E+01 | 3.09E+00 | 6.17E-01 | 1.78E-04 | 6.84E-03 | 0.00 | 3.82E-01 | 1.85E-01 | 3.54E+01 |
| Area E | 1.11E+01 | 1.45E+01 | 9.56E-02 | 1.27E-02 | 1.27E-02 | 0.00 | 1.71E+00 | 5.40E-01 | 2.80E+01 |
| Area F | 2.17E+01 | 4.47E+00 | 7.40E-01 | 1.97E-04 | 7.90E-03 | 0.00 | 4.39E-01 | 2.39E-01 | 2.76E+01 |
| Area G | 2.41E+01 | 4.78E+00 | 7.77E-01 | 4.20E-04 | 1.47E-02 | 0.00 | 8.12E-01 | 2.55E-01 | 3.07E+01 |
| Area H | 8.89E+01 | 3.92E-02 | 5.67E-01 | 3.78E-04 | 1.38E-02 | 0.00 | 7.65E-01 | 1.05E-01 | 9.04E+01 |
| Area I | 1.40E+01 | 2.21E-02 | 4.41E-01 | 1.63E-04 | 5.63E-03 | 0.00 | 3.12E-01 | 5.03E-02 | 1.48E+01 |
| Area J | 3.40E+02 | 2.29E-02 | 3.37E-01 | 3.67E-04 | 4.09E-03 | 0.00 | 2.13E-01 | 2.18E-01 | 3.41E+02 |
| Area K | 2.55E+03 | 2.05E-01 | 2.14E-01 | 4.04E-05 | 1.01E-03 | 0.00 | 5.60E-02 | 1.36E-01 | 2.55E+03 |
| Area L | 3.57E+01 | 4.27E+01 | 3.36E-01 | 1.55E-02 | 1.68E-02 | 0.00 | 2.16E+00 | 1.55E+00 | 8.25E+01 |
| Area M | 4.35E+01 | 6.01E+01 | 4.04E-01 | 3.08E-02 | 3.21E-02 | 0.00 | 4.25E+00 | 2.19E+00 | 1.10E+02 |
| Area N | 1.89E+01 | 3.00E+01 | 2.83E-01 | 5.81E-03 | 6.86E-03 | 0.00 | 8.40E-01 | 1.11E+00 | 5.12E+01 |
| Area O | 5.29E+01 | 1.11E+01 | 2.04E-01 | 1.15E-03 | 1.29E-03 | 0.00 | 2.05E-01 | 3.61E-01 | 6.48E+01 |
| Area P | 1.01E+04 | 7.23E+04 | 4.42E+02 | 2.55E-03 | 8.99E-03 | 0.00 | 3.99E-01 | 2.01E+03 | 8.48E+04 |
| Area Q | 1.58E+02 | 2.69E-02 | 4.85E-01 | 1.30E-04 | 2.41E-03 | 0.00 | 1.30E-01 | 1.33E-01 | 1.59E+02 |
| Area R | 3.17E+01 | 1.37E-02 | 2.65E-01 | 5.00E-05 | 1.61E-03 | 0.00 | 8.92E-02 | 4.30E-02 | 3.21E+01 |
| Area S | 7.65E-03 | 4.08E-05 | 1.54E-06 | 1.50E-05 | 2.03E-05 | 0.00 | 3.52E-04 | 4.33E-06 | 8.08E-03 |
| Area T | 4.10E-05 | 4.18E-05 | 2.51E-05 | 6.70E-07 | 3.69E-06 | 0.00 | 2.77E-04 | 2.47E-06 | 3.92E-04 |
| Area U | 6.43E-04 | 1.05E-04 | 7.38E-05 | 1.37E-05 | 3.15E-05 | 0.00 | 1.06E-03 | 7.49E-06 | 1.93E-03 |
| Area V | 1.69E+01 | 1.98E+01 | 1.37E-01 | 2.00E-03 | 2.35E-03 | 0.00 | 2.88E-01 | 7.42E-01 | 3.79E+01 |
| Area W | 6.37E-03 | 6.61E-05 | 1.04E-04 | 1.13E-07 | 3.61E-06 | 0.00 | 2.77E-04 | 1.36E-05 | 6.84E-03 |
| Area X | 4.88E-01 | 1.13E-03 | 2.26E-02 | 3.60E-05 | 1.17E-03 | 0.00 | 6.45E-02 | 2.45E-03 | 5.80E-01 |
| Area Y | 8.06E+01 | 2.01E+02 | 1.17E+00 | 6.88E-03 | 7.94E-03 | 0.00 | 9.87E-01 | 7.45E+00 | 2.91E+02 |
| Area Z | 3.94E+01 | 1.71E-02 | 3.30E-01 | 3.04E-05 | 1.22E-03 | 0.00 | 6.77E-02 | 5.34E-02 | 3.99E+01 |
| Average | 6.29E+02 | 2.80E+03 | 1.77E+01 | 3.13E-03 | 8.13E-03 | 0.00 | 6.77E-01 | 7.80E+01 | 3.52E+03 |
| Minimum | 4.10E-05 | 4.08E-05 | 1.54E-06 | 1.13E-07 | 3.61E-06 | 0.00 | 2.77E-04 | 2.47E-06 | 3.92E-04 |
| Maximum | 1.01E+04 | 7.23E+04 | 4.42E+02 | 3.08E-02 | 3.21E-02 | 0.00 | 4.25E+00 | 2.01E+03 | 8.48E+04 |

Risk - totals across nuclide

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| Area A | 5.96E-01 | 4.31E-04 | 8.05E-04 | 2.56E-07 | 5.15E-06 | 0.00 | 2.80E-04 | 3.76E-04 | 5.98E-01 |
| Area B | 9.08E-01 | 2.89E-03 | 1.25E-03 | 2.33E-07 | 3.12E-06 | 0.00 | 1.66E-04 | 4.04E-04 | 9.13E-01 |
| Area C | 1.57E-02 | 1.92E-03 | 3.48E-04 | 2.06E-07 | 6.65E-06 | 0.00 | 3.67E-04 | 2.16E-04 | 1.86E-02 |
| Area D | 1.73E-02 | 6.12E-04 | 1.50E-04 | 4.47E-08 | 1.62E-06 | 0.00 | 9.12E-05 | 7.61E-05 | 1.82E-02 |
| Area E | 6.24E-03 | 2.92E-03 | 4.08E-05 | 6.28E-06 | 6.15E-06 | 0.00 | 8.42E-04 | 2.66E-04 | 1.03E-02 |
| Area F | 1.21E-02 | 8.86E-04 | 1.80E-04 | 4.66E-08 | 1.87E-06 | 0.00 | 1.04E-04 | 9.95E-05 | 1.33E-02 |
| Area G | 1.34E-02 | 9.48E-04 | 1.90E-04 | 1.17E-07 | 3.49E-06 | 0.00 | 1.92E-04 | 1.06E-04 | 1.48E-02 |
| Area H | 4.94E-02 | 3.46E-06 | 1.36E-04 | 1.01E-07 | 3.27E-06 | 0.00 | 1.81E-04 | 4.05E-05 | 4.98E-02 |
| Area I | 7.78E-03 | 1.20E-06 | 1.04E-04 | 4.57E-08 | 1.34E-06 | 0.00 | 7.40E-05 | 1.44E-05 | 7.97E-03 |
| Area J | 1.89E-01 | 5.02E-06 | 8.60E-05 | 1.75E-07 | 1.08E-06 | 0.00 | 5.24E-05 | 1.12E-04 | 1.89E-01 |
| Area K | 1.45E+00 | 9.76E-03 | 5.24E-05 | 1.38E-08 | 2.44E-07 | 0.00 | 1.34E-05 | 4.70E-05 | 1.46E+00 |
| Area L | 1.99E-02 | 8.51E-03 | 1.30E-04 | 7.49E-06 | 7.66E-06 | 0.00 | 1.02E-03 | 7.50E-04 | 3.04E-02 |
| Area M | 2.44E-02 | 1.11E-02 | 1.56E-04 | 1.52E-05 | 1.53E-05 | 0.00 | 2.06E-03 | 1.00E-03 | 3.87E-02 |
| Area N | 1.06E-02 | 6.02E-03 | 1.04E-04 | 2.84E-06 | 3.03E-06 | 0.00 | 3.94E-04 | 5.43E-04 | 1.77E-02 |
| Area O | 2.95E-02 | 3.98E-04 | 3.65E-05 | 1.09E-07 | 3.60E-07 | 0.00 | 2.53E-05 | 4.08E-05 | 3.00E-02 |
| Area P | 5.70E+00 | 1.40E+00 | 3.92E-03 | 1.35E-06 | 3.11E-06 | 0.00 | 1.14E-04 | 1.72E-02 | 7.11E+00 |
| Area Q | 8.81E-02 | 3.10E-06 | 1.18E-04 | 5.42E-08 | 6.02E-07 | 0.00 | 3.13E-05 | 5.99E-05 | 8.83E-02 |
| Area R | 1.76E-02 | 1.01E-06 | 6.33E-05 | 1.51E-08 | 3.85E-07 | 0.00 | 2.12E-05 | 1.58E-05 | 1.77E-02 |
| Area S | 4.26E-06 | 1.48E-10 | 5.09E-10 | 8.39E-09 | 1.13E-08 | 0.00 | 1.91E-07 | 2.39E-09 | 4.47E-06 |
| Area T | 2.28E-08 | 1.10E-10 | 5.93E-09 | 3.52E-10 | 1.13E-09 | 0.00 | 1.34E-07 | 6.01E-10 | 1.65E-07 |
| Area U | 3.58E-07 | 3.04E-10 | 1.74E-08 | 7.58E-09 | 1.32E-08 | 0.00 | 3.46E-07 | 1.89E-09 | 7.45E-07 |
| Area V | 9.46E-03 | 4.00E-03 | 5.74E-05 | 9.87E-07 | 1.05E-06 | 0.00 | 1.36E-04 | 3.66E-04 | 1.40E-02 |
| Area W | 3.55E-06 | 3.97E-10 | 2.47E-08 | 3.47E-11 | 8.74E-10 | 0.00 | 1.13E-07 | 4.35E-09 | 3.69E-06 |
| Area X | 2.71E-04 | 5.87E-08 | 5.34E-06 | 1.08E-08 | 2.79E-07 | 0.00 | 1.53E-05 | 6.67E-07 | 2.93E-04 |
| Area Y | 4.55E-02 | 4.04E-02 | 5.26E-04 | 3.40E-06 | 3.58E-06 | 0.00 | 4.69E-04 | 3.66E-03 | 9.06E-02 |
| Area Z | 2.19E-02 | 1.26E-06 | 7.86E-05 | 7.18E-09 | 2.87E-07 | 0.00 | 1.61E-05 | 1.97E-05 | 2.20E-02 |
| Average | 3.55E-01 | 5.72E-02 | 3.28E-04 | 1.50E-06 | 2.68E-06 | 0.00 | 2.56E-04 | 9.79E-04 | 4.14E-01 |
| Minimum | 2.28E-08 | 1.10E-10 | 5.09E-10 | 3.47E-11 | 8.74E-10 | 0.00 | 1.13E-07 | 6.01E-10 | 1.65E-07 |
| Maximum | 5.70E+00 | 1.40E+00 | 3.92E-03 | 1.52E-05 | 1.53E-05 | 0.00 | 2.06E-03 | 1.72E-02 | 7.11E+00 |

Table 6G.16. (continued)

Dose (mrem) - averages across subareas

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.65E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.65E-05 |
| H-3 | 0.00 | 2.46E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 3.17E-04 | 4.10E-08 | 3.17E-04 |
| Co-60 | 4.01E-03 | 1.48E-07 | 1.48E-07 | 1.58E-07 | 6.32E-07 | 0.00 | 1.05E-04 | 3.04E-07 | 4.12E-03 |
| Sr-90 | 0.00 | 3.10E-02 | 5.85E-01 | 1.22E-04 | 4.88E-03 | 0.00 | 2.71E-01 | 5.66E-02 | 9.49E-01 |
| Y-90 | 0.00 | 2.01E-04 | 4.42E-02 | 9.22E-06 | 3.69E-04 | 0.00 | 2.05E-02 | 4.28E-03 | 6.96E-02 |
| Cs-137 | 0.00 | 4.79E-03 | 1.32E-02 | 1.41E-04 | 1.88E-04 | 0.00 | 3.13E-03 | 1.25E-01 | 1.46E-01 |
| Ba-137m | 2.26E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.26E+02 |
| Eu-152 | 3.80E+02 | 2.90E-02 | 1.86E-03 | 4.43E-06 | 1.77E-08 | 0.00 | 5.91E-04 | 1.42E-02 | 3.81E+02 |
| Eu-154 | 1.54E+01 | 1.40E-03 | 1.02E-04 | 4.33E-07 | 1.73E-09 | 0.00 | 5.77E-05 | 7.76E-04 | 1.54E+01 |
| Eu-155 | 1.49E-04 | 3.31E-08 | 2.68E-09 | 1.26E-11 | 5.04E-14 | 0.00 | 1.68E-09 | 2.04E-08 | 1.49E-04 |
| Th-232 | 2.95E+00 | 2.78E+03 | 1.69E+01 | 4.88E-05 | 1.95E-07 | 0.00 | 6.51E-03 | 7.72E+01 | 2.88E+03 |
| U-233 | 7.33E-02 | 7.60E+00 | 3.55E-02 | 9.70E-04 | 9.31E-04 | 0.00 | 1.29E-01 | 2.70E-01 | 8.11E+00 |
| U-238 | 1.02E-01 | 7.15E+00 | 3.37E-02 | 1.75E-03 | 1.68E-03 | 0.00 | 2.33E-01 | 2.56E-01 | 7.78E+00 |
| Th-234 | 1.59E+00 | 2.12E-03 | 1.81E-03 | 9.36E-05 | 8.99E-05 | 0.00 | 1.25E-02 | 1.37E-02 | 1.62E+00 |
| Pa-234m | 1.78E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.78E+00 |
| Pa-234 | 4.02E-01 | 6.39E-08 | 3.72E-07 | 1.93E-08 | 1.85E-08 | 0.00 | 2.57E-06 | 2.83E-06 | 4.02E-01 |
| Am-241 | 1.80E-02 | 1.02E-01 | 2.13E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 1.40E-02 | 1.34E-01 |
| Cm-244 | 1.19E-04 | 1.36E-02 | 2.43E-04 | 2.04E-07 | 8.15E-10 | 0.00 | 2.72E-05 | 1.85E-03 | 1.58E-02 |
| Total | 6.29E+02 | 2.80E+03 | 1.77E+01 | 3.13E-03 | 8.13E-03 | 0.00 | 6.77E-01 | 7.80E+01 | 3.52E+03 |

Risk - averages across subareas

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 2.01E-11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.01E-11 |
| H-3 | 0.00 | 3.00E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 2.73E-07 | 3.52E-11 | 2.73E-07 |
| Co-60 | 2.30E-06 | 1.08E-10 | 8.26E-11 | 8.79E-11 | 3.52E-10 | 0.00 | 5.86E-08 | 1.69E-10 | 2.36E-06 |
| Sr-90 | 0.00 | 1.34E-06 | 1.36E-04 | 2.82E-08 | 1.13E-06 | 0.00 | 6.28E-05 | 1.31E-05 | 2.14E-04 |
| Y-90 | 0.00 | 1.31E-07 | 1.31E-05 | 2.74E-09 | 1.10E-07 | 0.00 | 6.09E-06 | 1.27E-06 | 2.07E-05 |
| Cs-137 | 0.00 | 2.85E-06 | 7.40E-06 | 7.89E-08 | 1.05E-07 | 0.00 | 1.75E-06 | 7.01E-05 | 8.23E-05 |
| Ba-137m | 1.26E-01 | 8.52E-11 | 6.00E-10 | 6.40E-12 | 8.53E-12 | 0.00 | 1.42E-10 | 5.68E-09 | 1.26E-01 |
| Eu-152 | 2.16E-01 | 1.58E-03 | 6.04E-07 | 1.44E-09 | 5.75E-12 | 0.00 | 1.92E-07 | 4.60E-06 | 2.18E-01 |
| Eu-154 | 8.66E-03 | 6.83E-07 | 3.21E-08 | 1.36E-10 | 5.44E-13 | 0.00 | 1.81E-08 | 2.44E-07 | 8.66E-03 |
| Eu-155 | 1.09E-07 | 2.40E-09 | 9.11E-13 | 4.29E-15 | 1.71E-17 | 0.00 | 5.72E-13 | 6.93E-12 | 1.11E-07 |
| Th-232 | 2.04E-03 | 5.26E-02 | 1.36E-04 | 3.93E-10 | 1.57E-12 | 0.00 | 5.24E-08 | 6.22E-04 | 5.54E-02 |
| U-233 | 4.83E-05 | 1.52E-03 | 1.72E-05 | 4.70E-07 | 4.51E-07 | 0.00 | 6.26E-05 | 1.31E-04 | 1.78E-03 |
| U-238 | 7.25E-05 | 1.45E-03 | 1.72E-05 | 8.92E-07 | 8.56E-07 | 0.00 | 1.19E-04 | 1.31E-04 | 1.79E-03 |
| Th-234 | 8.83E-04 | 1.93E-06 | 5.29E-07 | 2.74E-08 | 2.63E-08 | 0.00 | 3.66E-06 | 4.03E-06 | 8.93E-04 |
| Pa-234m | 1.01E-03 | 9.67E-11 | 7.68E-10 | 3.98E-11 | 3.82E-11 | 0.00 | 5.30E-09 | 5.84E-09 | 1.01E-03 |
| Pa-234 | 2.25E-04 | 4.24E-11 | 1.17E-10 | 6.06E-12 | 5.82E-12 | 0.00 | 8.08E-10 | 8.90E-10 | 2.25E-04 |
| Am-241 | 9.61E-06 | 9.21E-06 | 1.81E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 1.19E-06 | 2.00E-05 |
| Cm-244 | 8.31E-08 | 1.48E-06 | 2.41E-08 | 2.02E-11 | 8.08E-14 | 0.00 | 2.69E-09 | 1.83E-07 | 1.78E-06 |
| Total | 3.55E-01 | 5.72E-02 | 3.28E-04 | 1.50E-06 | 2.68E-06 | 0.00 | 2.56E-04 | 9.79E-04 | 4.14E-01 |

**Table 6G.16. (continued)**

**Dose (rem) - totals across pathways**

| Sub-area | H-3 vapor | H-3 | Co-60 | Sr-90 | Y-90 | Cs-137 | Ba-137m | Eu-152 | Eu-154 |
|---|---|---|---|---|---|---|---|---|---|
| Area A | 1.42E-06 | 1.03E-04 | 5.05E-03 | 4.61E+00 | 3.37E-01 | 6.17E-01 | 9.69E+02 | 9.93E+01 | 1.10E+00 |
| Area B | 1.82E-06 | 1.21E-04 | 4.11E-03 | 6.16E+00 | 4.48E-01 | 5.72E-01 | 8.94E+02 | 6.92E+02 | 3.09E+01 |
| Area C | 1.01E-06 | 4.40E-09 | 2.83E-05 | 2.95E+00 | 2.18E-01 | 1.93E-02 | 2.77E+01 | 0.00 | 0.00 |
| Area D | 1.01E-06 | 1.75E-04 | 1.13E-02 | 1.00E+00 | 7.36E-02 | 1.97E-02 | 3.11E+01 | 0.00 | 0.00 |
| Area E | 1.01E-06 | 8.30E-08 | 1.24E-05 | 5.22E-02 | 3.86E-03 | 4.58E-03 | 6.35E+00 | 0.00 | 0.00 |
| Area F | 1.01E-06 | 0.00 | 1.01E-05 | 1.18E+00 | 8.70E-02 | 1.37E-02 | 2.16E+01 | 0.00 | 0.00 |
| Area G | 1.01E-06 | 3.29E-04 | 1.15E-05 | 1.57E+00 | 1.16E-01 | 1.65E-02 | 2.40E+01 | 0.00 | 0.00 |
| Area H | 1.01E-06 | 2.94E-04 | 4.65E-04 | 1.32E+00 | 9.81E-02 | 5.70E-02 | 8.89E+01 | 0.00 | 0.00 |
| Area I | 2.03E-06 | 1.55E-04 | 1.65E-05 | 7.65E-01 | 5.64E-02 | 9.38E-03 | 1.40E+01 | 0.00 | 0.00 |
| Area J | 1.62E-06 | 7.18E-05 | 7.38E-04 | 5.35E-01 | 3.94E-02 | 2.21E-01 | 3.40E+02 | 0.00 | 0.00 |
| Area K | 1.42E-06 | 5.55E-06 | 1.30E-04 | 2.65E-01 | 1.94E-02 | 2.37E-02 | 3.70E+01 | 2.35E+03 | 1.61E+02 |
| Area L | 6.08E-06 | 3.17E-03 | 6.17E-06 | 2.47E-01 | 1.82E-02 | 2.35E-02 | 3.49E+01 | 0.00 | 0.00 |
| Area M | 8.11E-06 | 2.89E-04 | 6.56E-05 | 2.63E-01 | 1.95E-02 | 1.86E-02 | 2.67E+01 | 0.00 | 0.00 |
| Area N | 1.01E-05 | 0.00 | 5.97E-04 | 2.17E-01 | 1.59E-02 | 8.50E-03 | 1.25E+01 | 0.00 | 0.00 |
| Area O | 1.01E-05 | 3.43E-04 | 4.64E-04 | 2.01E-01 | 1.48E-02 | 3.43E-02 | 5.24E+01 | 0.00 | 0.00 |
| Area P | 2.03E-06 | 2.79E-03 | 6.66E-02 | 1.48E+00 | 1.08E-01 | 1.98E+00 | 3.05E+03 | 6.75E+03 | 2.07E+02 |
| Area Q | 8.11E-06 | 4.32E-06 | 4.10E-04 | 6.31E-01 | 4.60E-02 | 1.02E-01 | 1.58E+02 | 0.00 | 0.00 |
| Area R | 1.01E-05 | 9.83E-05 | 3.52E-03 | 3.66E-01 | 2.68E-02 | 2.02E-02 | 3.17E+01 | 0.00 | 0.00 |
| Area S | 4.05E-05 | 0.00 | 0.00 | 1.95E-05 | 1.47E-06 | 3.72E-04 | 7.65E-03 | 0.00 | 0.00 |
| Area T | 4.05E-05 | 1.03E-04 | 0.00 | 1.79E-04 | 1.34E-05 | 1.47E-05 | 4.10E-05 | 0.00 | 0.00 |
| Area U | 1.01E-04 | 4.10E-09 | 0.00 | 7.99E-04 | 6.02E-05 | 3.29E-04 | 6.43E-04 | 0.00 | 0.00 |
| Area V | 1.01E-04 | 0.00 | 3.77E-05 | 6.60E-02 | 4.85E-03 | 6.79E-03 | 1.02E+01 | 0.00 | 0.00 |
| Area W | 6.08E-05 | 7.21E-05 | 7.63E-06 | 2.98E-04 | 2.22E-05 | 4.35E-06 | 6.37E-03 | 0.00 | 0.00 |
| Area X | 2.03E-06 | 0.00 | 9.83E-06 | 8.50E-02 | 6.35E-03 | 4.81E-04 | 4.88E-01 | 0.00 | 0.00 |
| Area Y | 6.08E-06 | 0.00 | 1.34E-02 | 2.76E-01 | 2.02E-02 | 9.33E-03 | 1.42E+01 | 0.00 | 0.00 |
| Area Z | 6.08E-06 | 1.32E-04 | 1.13E-05 | 4.14E-01 | 3.02E-02 | 2.49E-02 | 3.94E+01 | 0.00 | 0.00 |
| Average | 1.65E-05 | 3.17E-04 | 4.12E-03 | 9.49E-01 | 6.96E-02 | 1.46E-01 | 2.26E+02 | 3.81E+02 | 1.54E+01 |
| Minimum | 1.01E-06 | 0.00 | 0.00 | 1.95E-05 | 1.47E-06 | 4.35E-06 | 4.10E-05 | 0.00 | 0.00 |
| Maximum | 1.01E-04 | 3.17E-03 | 6.66E-02 | 6.16E+00 | 4.48E-01 | 1.98E+00 | 3.05E+03 | 6.75E+03 | 2.07E+02 |

**Dose (rem) - totals across pathways (continued)**

| Sub-area | Eu-155 | Th-232 | U-233 | U-238 | Th-234 | Pa-234m | Pa-234 | Am-241 | Cm-244 |
|---|---|---|---|---|---|---|---|---|---|
| Area A | 2.58E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area B | 2.85E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area C | 0.00 | 0.00 | 8.74E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.49E+00 | 1.59E-01 |
| Area D | 0.00 | 0.00 | 3.21E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.06E-02 |
| Area E | 0.00 | 0.00 | 6.53E+00 | 1.04E+01 | 2.03E+00 | 2.18E+00 | 4.91E-01 | 0.00 | 0.00 |
| Area F | 0.00 | 0.00 | 4.65E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area G | 0.00 | 0.00 | 4.98E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area H | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.11E-02 |
| Area I | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area J | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area K | 1.62E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area L | 0.00 | 0.00 | 4.61E+01 | 7.57E-01 | [illegible] | 1.72E-01 | 3.87E-02 | 0.00 | 0.00 |
| Area M | 0.00 | 5.66E+00 | 2.52E+01 | 3.61E+01 | [illegible] | [illegible]2E+00 | 1.72E+00 | 0.00 | 0.00 |
| Area N | 0.00 | 0.00 | 1.99E+01 | 1.25E+01 | [illegible] | [illegible]8E+00 | 6.49E-01 | 0.00 | 0.00 |
| Area O | 0.00 | 1.05E+01 | 0.00 | 1.09E+00 | [illegible] | [illegible]3E-01 | 5.69E-02 | 0.00 | 1.09E-02 |
| Area P | 1.95E-03 | 7.48E+04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area Q | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area R | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area S | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area T | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area U | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area V | 0.00 | 0.00 | 8.06E+00 | 1.31E+01 | [illegible] | [illegible]5E+00 | 6.88E-01 | 0.00 | 0.00 |
| Area W | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area X | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area Y | 0.00 | 0.00 | 8.35E+01 | 1.28E+02 | 2.73E+01 | 3.02E+01 | 6.80E+00 | 0.00 | 2.21E-01 |
| Area Z | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Average | 1.49E-04 | 2.88E+03 | 8.11E+00 | 7.78E+00 | 1.62E+00 | 1.78E+00 | 4.02E-01 | 1.34E-01 | 1.58E-02 |
| Minimum | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Maximum | 1.95E-03 | 7.48E+04 | 8.35E+01 | 1.28E+02 | 2.73E+01 | 3.02E+01 | 6.80E+00 | 3.49E+00 | 2.21E-01 |

Table 6G.16. (continued)

Risk - totals across pathways

| Sub-area | H-3 vapor | H-3 | Co-60 | Sr-90 | Y-90 | Cs-137 | Ba-137m | Eu-152 | Eu-154 |
|---|---|---|---|---|---|---|---|---|---|
| Area A | 1.73E-12 | 8.87E-08 | 2.89E-06 | 1.04E-03 | 1.01E-04 | 3.47E-04 | 5.39E-01 | 5.68E-02 | 6.17E-04 |
| Area B | 2.22E-12 | 1.04E-07 | 2.35E-06 | 1.38E-03 | 1.34E-04 | 3.21E-04 | 4.98E-01 | 3.96E-01 | 1.74E-02 |
| Area C | 1.24E-12 | 3.78E-12 | 1.62E-08 | 6.70E-04 | 6.50E-05 | 1.08E-05 | 1.54E-02 | 0.00 | 0.00 |
| Area D | 1.24E-12 | 1.50E-07 | 6.45E-06 | 2.26E-04 | 2.19E-05 | 1.11E-05 | 1.73E-02 | 0.00 | 0.00 |
| Area E | 1.24E-12 | 7.13E-11 | 7.09E-09 | 1.19E-05 | 1.15E-06 | 2.57E-06 | 3.53E-03 | 0.00 | 0.00 |
| Area F | 1.24E-12 | 0.00 | 5.79E-09 | 2.67E-04 | 2.59E-05 | 7.67E-06 | 1.20E-02 | 0.00 | 0.00 |
| Area G | 1.24E-12 | 2.83E-07 | 6.57E-09 | 3.57E-04 | 3.47E-05 | 9.29E-06 | 1.34E-02 | 0.00 | 0.00 |
| Area H | 1.24E-12 | 2.52E-07 | 2.66E-07 | 3.01E-04 | 2.92E-05 | 3.20E-05 | 4.94E-02 | 0.00 | 0.00 |
| Area I | 2.47E-12 | 1.33E-07 | 9.44E-09 | 1.73E-04 | 1.68E-05 | 5.27E-06 | 7.78E-03 | 0.00 | 0.00 |
| Area J | 1.98E-12 | 6.17E-08 | 4.22E-07 | 1.21E-04 | 1.17E-05 | 1.24E-04 | 1.89E-01 | 0.00 | 0.00 |
| Area K | 1.73E-12 | 4.77E-09 | 7.44E-08 | 5.96E-05 | 5.78E-06 | 1.33E-05 | 2.06E-02 | 1.35E+00 | 9.05E-02 |
| Area L | 7.41E-12 | 2.72E-06 | 3.54E-09 | 5.61E-05 | 5.44E-06 | 1.32E-05 | 1.94E-02 | 0.00 | 0.00 |
| Area M | 9.88E-12 | 2.49E-07 | 3.76E-08 | 5.99E-05 | 5.81E-06 | 1.05E-05 | 1.49E-02 | 0.00 | 0.00 |
| Area N | 1.24E-11 | 0.00 | 3.42E-07 | 4.89E-05 | 4.74E-06 | 4.77E-06 | 6.94E-03 | 0.00 | 0.00 |
| Area O | 1.24E-11 | 2.95E-07 | 2.66E-07 | 4.54E-05 | 4.40E-06 | 1.93E-05 | 2.92E-02 | 0.00 | 0.00 |
| Area P | 2.47E-12 | 2.40E-06 | 3.81E-05 | 3.33E-04 | 3.23E-05 | 1.11E-03 | 1.70E+00 | 3.86E+00 | 1.17E-01 |
| Area Q | 9.88E-12 | 3.71E-09 | 2.35E-07 | 1.42E-04 | 1.37E-05 | 5.71E-05 | 8.81E-02 | 0.00 | 0.00 |
| Area R | 1.24E-11 | 8.45E-08 | 2.01E-06 | 8.23E-05 | 7.98E-06 | 1.14E-05 | 1.76E-02 | 0.00 | 0.00 |
| Area S | 4.94E-11 | 0.00 | 0.00 | 4.50E-09 | 4.37E-10 | 2.09E-07 | 4.26E-06 | 0.00 | 0.00 |
| Area T | 4.94E-11 | 8.87E-08 | 0.00 | 4.12E-08 | 4.00E-09 | 8.24E-09 | 2.28E-08 | 0.00 | 0.00 |
| Area U | 1.24E-10 | 3.52E-12 | 0.00 | 1.84E-07 | 1.79E-08 | 1.84E-07 | 3.58E-07 | 0.00 | 0.00 |
| Area V | 1.24E-10 | 0.00 | 2.16E-08 | 1.49E-05 | 1.45E-06 | 3.82E-06 | 5.66E-03 | 0.00 | 0.00 |
| Area W | 7.41E-11 | 6.19E-08 | 4.25E-09 | 6.80E-08 | 6.60E-09 | 2.44E-09 | 3.55E-06 | 0.00 | 0.00 |
| Area X | 2.47E-12 | 0.00 | 5.63E-09 | 1.95E-05 | 1.89E-06 | 2.70E-07 | 2.71E-04 | 0.00 | 0.00 |
| Area Y | 7.41E-12 | 0.00 | 7.68E-06 | 6.22E-05 | 6.04E-06 | 5.24E-06 | 7.88E-03 | 0.00 | 0.00 |
| Area Z | 7.41E-12 | 1.13E-07 | 6.45E-09 | 9.28E-05 | 9.00E-06 | 1.40E-05 | 2.19E-02 | 0.00 | 0.00 |
| Average | 2.01E-11 | 2.73E-07 | 2.36E-06 | 2.14E-04 | 2.07E-05 | 8.23E-05 | 1.26E-01 | 2.18E-01 | 8.66E-03 |
| Minimum | 1.24E-12 | 0.00 | 0.00 | 4.50E-09 | 4.37E-10 | 2.44E-09 | 2.28E-08 | 0.00 | 0.00 |
| Maximum | 1.24E-10 | 2.72E-06 | 3.81E-05 | 1.38E-03 | 1.34E-04 | 1.11E-03 | 1.70E+00 | 3.86E+00 | 1.17E-01 |

Risk - totals across pathways (continued)

| Sub-area | Eu-155 | Th-232 | U-233 | U-238 | Th-234 | Pa-234m | Pa-234 | Am-241 | Cm-244 |
|---|---|---|---|---|---|---|---|---|---|
| Area A | 1.92E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area B | 2.12E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area C | 0.00 | 0.00 | 1.88E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 5.21E-04 | 1.78E-05 |
| Area D | 0.00 | 0.00 | 6.88E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.19E-06 |
| Area E | 0.00 | 0.00 | 1.53E-03 | 2.63E-03 | 1.10E-03 | 1.23E-03 | 2.75E-04 | 0.00 | 0.00 |
| Area F | 0.00 | 0.00 | 9.99E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area G | 0.00 | 0.00 | 1.07E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area H | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-06 |
| Area I | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area J | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area K | 1.20E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area L | 0.00 | 0.00 | 1.04E-02 | 1.76E-04 | 8.62E-05 | 9.73E-05 | 2.17E-05 | 0.00 | 0.00 |
| Area M | 0.00 | 1.08E-04 | 5.42E-03 | 9.13E-03 | 3.86E-03 | 4.31E-03 | 9.64E-04 | 0.00 | 0.00 |
| Area N | 0.00 | 0.00 | 4.39E-03 | 2.84E-03 | 1.44E-03 | 1.63E-03 | 3.64E-04 | 0.00 | 0.00 |
| Area O | 0.00 | 2.02E-04 | 0.00 | 2.46E-04 | 1.26E-04 | 1.43E-04 | 3.20E-05 | 0.00 | 1.21E-06 |
| Area P | 1.45E-06 | 1.44E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area Q | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area R | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area S | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area T | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area U | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area V | 0.00 | 0.00 | 1.76E-03 | 2.94E-03 | 1.53E-03 | 1.73E-03 | 3.86E-04 | 0.00 | 0.00 |
| Area W | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area X | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Area Y | 0.00 | 0.00 | 1.80E-02 | 2.86E-02 | 1.51E-02 | 1.71E-02 | 3.82E-03 | 0.00 | 2.47E-05 |
| Area Z | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Average | 1.11E-07 | 5.54E-02 | 1.78E-03 | 1.79E-03 | 8.93E-04 | 1.01E-03 | 2.25E-04 | 2.00E-05 | 1.78E-06 |
| Minimum | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Maximum | 1.45E-06 | 1.44E+00 | 1.80E-02 | 2.86E-02 | 1.51E-02 | 1.71E-02 | 3.82E-03 | 5.21E-04 | 2.47E-05 |

Table 6G.17. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area A

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegetables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 2.55E+03 | 1.46E+05 | 1.52E+04 | 5.10E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 2.51E+04 | 2.29E+00 | 2.27E-01 | 5.03E+00 | 1.00E+01 | 1.02E+01 | 9.17E-05 | 9.17E-05 |
| Sr-90 | 2.78E+04 | 8.45E+00 | 4.31E+01 | 5.56E+00 | 2.35E+02 | 2.36E+02 | 1.01E-04 | 1.01E-03 |
| Y-90 | 2.78E+04 | 8.45E+00 | 4.31E+01 | 5.56E+00 | 2.35E+02 | 2.36E+02 | 1.01E-04 | 1.01E-03 |
| Cs-137 | 1.24E+05 | 8.74E+00 | 3.40E+00 | 2.48E+01 | 1.07E+01 | 1.13E+01 | 1.05E-02 | 3.50E-03 |
| Ba-137m | 1.17E+05 | 8.27E+00 | 3.21E+00 | 2.35E+01 | 1.01E+01 | 1.07E+01 | 9.92E-03 | 3.31E-03 |
| Eu-152 | 1.59E+05 | 4.27E+00 | 0.00 | 3.18E+01 | 1.70E+01 | 1.79E+01 | 8.55E-04 | 8.55E-07 |
| Eu-154 | 3.08E+04 | 3.88E-01 | 0.00 | 6.15E+00 | 3.30E+00 | 3.46E+00 | 7.76E-05 | 7.76E-08 |
| Eu-155 | 1.03E+04 | 8.70E-01 | 0.00 | 2.06E+00 | 1.10E+00 | 1.16E+00 | 1.74E-04 | 1.74E-07 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 1.94E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-05 |
| H-3 | 0.00 | 1.07E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 2.04E-01 | 1.79E-04 | 2.04E-01 |
| Co-60 | 9.79E+03 | 3.61E-01 | 3.62E-01 | 2.03E-06 | 8.12E-06 | 0.00 | 1.35E-03 | 7.42E-01 | 9.79E+03 |
| Sr-90 | 0.00 | 2.37E+00 | 4.48E+01 | 1.19E-05 | 4.74E-04 | 0.00 | 2.64E-02 | 4.34E+00 | 5.16E+01 |
| Y-90 | 0.00 | 1.54E-02 | 3.39E+00 | 8.97E-07 | 3.59E-05 | 0.00 | 1.99E-03 | 3.28E-01 | 3.73E+00 |
| Cs-137 | 0.00 | 2.60E-01 | 7.17E-01 | 4.30E-04 | 5.74E-04 | 0.00 | 9.56E-03 | 6.79E+00 | 7.78E+00 |
| Ba-137m | 1.23E+04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.23E+04 |
| Eu-152 | 3.02E+04 | 2.31E+00 | 1.48E-01 | 4.54E-06 | 1.82E-08 | 0.00 | 6.06E-04 | 1.13E+00 | 3.03E+04 |
| Eu-154 | 6.38E+03 | 5.78E-01 | 4.23E-02 | 6.08E-07 | 2.43E-09 | 0.00 | 8.11E-05 | 3.22E-01 | 6.38E+03 |
| Eu-155 | 1.26E+02 | 2.80E-02 | 2.26E-03 | 2.18E-07 | 8.73E-10 | 0.00 | 2.91E-05 | 1.72E-02 | 1.26E+02 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 5.88E+04 | 5.92E+00 | 4.95E+01 | 4.50E-04 | 1.09E-03 | 0.00 | 2.44E-01 | 1.37E+01 | 5.89E+04 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-08 |
| H-3 | 0.00 | 1.31E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 1.75E-04 | 1.54E-07 | 1.76E-04 |
| Co-60 | 5.61E+00 | 2.64E-04 | 2.02E-04 | 1.13E-09 | 4.52E-09 | 0.00 | 7.53E-07 | 4.13E-04 | 5.61E+00 |
| Sr-90 | 0.00 | 1.02E-04 | 1.04E-02 | 2.75E-09 | 1.10E-07 | 0.00 | 6.11E-06 | 1.00E-03 | 1.15E-02 |
| Y-90 | 0.00 | 1.00E-05 | 1.01E-03 | 2.66E-10 | 1.07E-08 | 0.00 | 5.92E-07 | 9.74E-05 | 1.11E-03 |
| Cs-137 | 0.00 | 1.55E-04 | 4.02E-04 | 2.41E-07 | 3.22E-07 | 0.00 | 5.36E-06 | 3.81E-03 | 4.37E-03 |
| Ba-137m | 6.85E+00 | 4.63E-09 | 3.26E-08 | 1.96E-11 | 2.61E-11 | 0.00 | 4.35E-10 | 3.09E-07 | 6.85E+00 |
| Eu-152 | 1.72E+01 | 1.25E-01 | 4.80E-05 | 1.47E-09 | 5.89E-12 | 0.00 | 1.96E-07 | 3.66E-04 | 1.73E+01 |
| Eu-154 | 3.59E+00 | 2.83E-04 | 1.33E-05 | 1.91E-10 | 7.65E-13 | 0.00 | 2.55E-08 | 1.01E-04 | 3.59E+00 |
| Eu-155 | 9.17E-02 | 2.03E-03 | 7.70E-07 | 7.43E-11 | 2.97E-13 | 0.00 | 9.90E-09 | 5.86E-06 | 9.38E-02 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 3.33E+01 | 1.28E-01 | 1.21E-02 | 2.47E-07 | 4.47E-07 | 0.00 | 1.89E-04 | 5.79E-03 | 3.34E+01 |

Table 6G.18. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area B

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 1.65E+03 | 2.58E+05 | 1.52E+04 | 3.31E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 2.02E+04 | 2.40E+02 | 2.27E-01 | 4.04E+00 | 8.06E+00 | 8.17E+00 | 9.58E-03 | 9.58E-03 |
| Sr-90 | 4.36E+04 | 6.08E+00 | 4.31E+01 | 8.72E+00 | 3.69E+02 | 3.69E+02 | 7.30E-05 | 7.30E-04 |
| Y-90 | 4.36E+04 | 6.08E+00 | 4.31E+01 | 8.72E+00 | 3.69E+02 | 3.69E+02 | 7.30E-05 | 7.30E-04 |
| Cs-137 | 1.15E+05 | 8.92E+00 | 3.40E+00 | 2.29E+01 | 9.85E+00 | 1.05E+01 | 1.07E-02 | 3.57E-03 |
| Ba-137m | 1.08E+05 | 8.44E+00 | 3.21E+00 | 2.17E+01 | 9.32E+00 | 9.89E+00 | 1.01E-02 | 3.37E-03 |
| Eu-152 | 1.11E+06 | 6.28E+00 | 0.00 | 2.22E+02 | 1.19E+02 | 1.25E+02 | 1.26E-03 | 1.26E-06 |
| Eu-154 | 8.67E+05 | 4.92E+00 | 0.00 | 1.73E+02 | 9.30E+01 | 9.75E+01 | 9.83E-04 | 9.83E-07 |
| Eu-155 | 1.14E+05 | 2.85E+00 | 0.00 | 2.27E+01 | 1.22E+01 | 1.28E+01 | 5.70E-04 | 5.70E-07 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 1.94E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-05 |
| H-3 | 0.00 | 6.95E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 3.62E-01 | 1.16E-04 | 3.62E-01 |
| Co-60 | 7.86E+03 | 2.90E-01 | 2.91E-01 | 2.12E-04 | 8.48E-04 | 0.00 | 1.41E-01 | 5.96E-01 | 7.86E+03 |
| Sr-90 | 0.00 | 3.72E+00 | 7.03E+01 | 8.54E-06 | 3.41E-04 | 0.00 | 1.90E-02 | 6.80E+00 | 8.08E+01 |
| Y-90 | 0.00 | 2.42E-02 | 5.31E+00 | 6.45E-07 | 2.58E-05 | 0.00 | 1.43E-03 | 5.14E-01 | 5.85E+00 |
| Cs-137 | 0.00 | 2.40E-01 | 6.62E-01 | 4.39E-04 | 5.85E-04 | 0.00 | 9.75E-03 | 6.26E+00 | 7.18E+00 |
| Ba-137m | 1.13E+04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.13E+04 |
| Eu-152 | 2.11E+05 | 1.61E+01 | 1.03E+00 | 6.68E-06 | 2.67E-08 | 0.00 | 8.90E-04 | 7.86E+00 | 2.11E+05 |
| Eu-154 | 1.80E+05 | 1.63E+01 | 1.19E+00 | 7.71E-06 | 3.08E-08 | 0.00 | 1.03E-03 | 9.06E+00 | 1.80E+05 |
| Eu-155 | 1.39E+03 | 3.09E-01 | 2.50E-02 | 7.16E-07 | 2.86E-09 | 0.00 | 9.54E-05 | 1.90E-01 | 1.39E+03 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 4.11E+05 | 3.70E+01 | 7.88E+01 | 6.75E-04 | 1.80E-03 | 0.00 | 5.36E-01 | 3.13E+01 | 4.12E+05 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-08 |
| H-3 | 0.00 | 8.47E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 3.11E-04 | 9.96E-08 | 3.11E-04 |
| Co-60 | 4.50E+00 | 2.12E-04 | 1.62E-04 | 1.18E-07 | 4.72E-07 | 0.00 | 7.87E-05 | 3.32E-04 | 4.50E+00 |
| Sr-90 | 0.00 | 1.60E-04 | 1.63E-02 | 1.98E-09 | 7.91E-08 | 0.00 | 4.39E-06 | 1.58E-03 | 1.80E-02 |
| Y-90 | 0.00 | 1.58E-05 | 1.58E-03 | 1.92E-10 | 7.67E-09 | 0.00 | 4.26E-07 | 1.53E-04 | 1.75E-03 |
| Cs-137 | 0.00 | 1.43E-04 | 3.71E-04 | 2.46E-07 | 3.28E-07 | 0.00 | 5.47E-06 | 3.51E-03 | 4.03E-03 |
| Ba-137m | 6.32E+00 | 4.27E-09 | 3.01E-08 | 2.00E-11 | 2.66E-11 | 0.00 | 4.43E-10 | 2.85E-07 | 6.32E+00 |
| Eu-152 | 1.20E+02 | 8.74E-01 | 3.35E-04 | 2.17E-09 | 8.66E-12 | 0.00 | 2.89E-07 | 2.55E-03 | 1.21E+02 |
| Eu-154 | 1.01E+02 | 7.97E-03 | 3.74E-04 | 2.42E-09 | 9.69E-12 | 0.00 | 3.23E-07 | 2.85E-03 | 1.01E+02 |
| Eu-155 | 1.01E+00 | 2.24E-02 | 8.50E-06 | 2.43E-10 | 9.74E-13 | 0.00 | 3.25E-08 | 6.47E-05 | 1.04E+00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.33E+02 | 9.05E-01 | 1.91E-02 | 3.71E-07 | 8.87E-07 | 0.00 | 4.01E-04 | 1.10E-02 | 2.34E+02 |

Table 6G.19. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area C

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 3.79E+04 | 1.75E+06 | 1.52E+04 | 7.59E+00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 1.46E+02 | 8.68E+00 | 2.27E-01 | 2.92E-02 | 5.84E-02 | 5.91E-02 | 3.47E-04 | 3.47E-04 |
| Sr-90 | 1.16E+04 | 3.96E+03 | 4.31E+01 | 2.32E+00 | 9.84E+01 | 9.85E+01 | 4.75E-02 | 4.75E-01 |
| Y-90 | 1.16E+04 | 3.96E+03 | 4.31E+01 | 2.32E+00 | 9.84E+01 | 9.85E+01 | 4.75E-02 | 4.75E-01 |
| Cs-137 | 3.55E+03 | 1.69E+01 | 3.40E+00 | 7.10E-01 | 3.06E-01 | 3.24E-01 | 2.03E-02 | 6.77E-03 |
| Ba-137m | 3.36E+03 | 1.60E+01 | 3.21E+00 | 6.72E-01 | 2.89E-01 | 3.07E-01 | 1.92E-02 | 6.40E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 9.41E+02 | 0.00 | 1.94E-01 | 1.88E-01 | 1.01E-01 | 1.06E-01 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 5.32E+02 | 0.00 | 0.00 | 1.06E-01 | 6.37E-03 | 9.17E-03 | 0.00 | 0.00 |
| Cm-244 | 5.68E+02 | 0.00 | 0.00 | 1.14E-01 | 6.09E-02 | 6.39E-02 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-05 |
| H-3 | 0.00 | 1.60E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 2.45E+00 | 2.66E-03 | 2.45E+00 |
| Co-60 | 5.69E+01 | 2.10E-03 | 2.10E-03 | 7.68E-06 | 3.07E-05 | 0.00 | 5.12E-03 | 4.31E-03 | 5.69E+01 |
| Sr-90 | 0.00 | 9.92E-01 | 1.87E+01 | 5.56E-03 | 2.22E-01 | 0.00 | 1.24E+01 | 1.81E+00 | 3.41E+01 |
| Y-90 | 0.00 | 6.44E-03 | 1.42E+00 | 4.20E-04 | 1.68E-02 | 0.00 | 9.34E-01 | 1.37E-01 | 2.51E+00 |
| Cs-137 | 0.00 | 7.45E-03 | 2.05E-02 | 8.33E-04 | 1.11E-03 | 0.00 | 1.85E-02 | 1.94E-01 | 2.43E-01 |
| Ba-137m | 3.52E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.52E+02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 8.07E-02 | 8.37E+00 | 3.91E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 2.98E-01 | 8.79E+00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 2.73E+00 | 1.55E+01 | 3.24E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 2.12E+00 | 2.04E+01 |
| Cm-244 | 8.07E-02 | 9.25E+00 | 1.65E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 1.25E+00 | 1.08E+01 |
| Total | 4.12E+02 | 3.42E+01 | 2.04E+01 | 6.82E-03 | 2.40E-01 | 0.00 | 1.58E+01 | 5.83E+00 | 4.88E+02 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-08 |
| H-3 | 0.00 | 1.94E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 2.11E-03 | 2.29E-06 | 2.11E-03 |
| Co-60 | 3.26E-02 | 1.54E-06 | 1.17E-06 | 4.28E-09 | 1.71E-08 | 0.00 | 2.85E-06 | 2.40E-06 | 3.26E-02 |
| Sr-90 | 0.00 | 4.28E-05 | 4.34E-03 | 1.29E-06 | 5.15E-05 | 0.00 | 2.86E-03 | 4.20E-04 | 7.72E-03 |
| Y-90 | 0.00 | 4.20E-06 | 4.21E-04 | 1.25E-07 | 5.00E-06 | 0.00 | 2.78E-04 | 4.07E-05 | 7.48E-04 |
| Cs-137 | 0.00 | 4.43E-06 | 1.15E-05 | 4.67E-07 | 6.23E-07 | 0.00 | 1.04E-05 | 1.09E-04 | 1.36E-04 |
| Ba-137m | 1.96E-01 | 1.32E-10 | 9.33E-10 | 3.79E-11 | 5.05E-11 | 0.00 | 8.41E-10 | 8.83E-09 | 1.96E-01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 5.32E-05 | 1.67E-03 | 1.90E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 1.44E-04 | 1.89E-03 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 1.46E-03 | 1.40E-03 | 2.76E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 1.81E-04 | 3.04E-03 |
| Cm-244 | 5.65E-05 | 1.01E-03 | 1.64E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-04 | 1.20E-03 |
| Total | 2.30E-01 | 4.13E-03 | 4.81E-03 | 1.88E-06 | 5.71E-05 | 0.00 | 5.26E-03 | 1.02E-03 | 2.45E-01 |

Table 6G.20. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area D

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 3.92E+02 | 4.03E+05 | 1.52E+04 | 7.84E-02 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 4.23E+04 | 0.00 | 2.27E-01 | 8.46E+00 | 1.69E+01 | 1.71E+01 | 0.00 | 0.00 |
| Sr-90 | 5.13E+03 | 0.00 | 4.31E+01 | 1.03E+00 | 4.35E+01 | 4.35E+01 | 0.00 | 0.00 |
| Y-90 | 5.13E+03 | 0.00 | 4.31E+01 | 1.03E+00 | 4.35E+01 | 4.35E+01 | 0.00 | 0.00 |
| Cs-137 | 3.98E+03 | 0.00 | 3.40E+00 | 7.96E-01 | 3.42E-01 | 3.63E-01 | 0.00 | 0.00 |
| Ba-137m | 3.76E+03 | 0.00 | 3.21E+00 | 7.53E-01 | 3.24E-01 | 3.44E-01 | 0.00 | 0.00 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 3.45E+02 | 0.00 | 1.94E-01 | 6.90E-02 | 3.70E-02 | 3.88E-02 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 3.79E+01 | 0.00 | 0.00 | 7.59E-03 | 4.07E-03 | 4.27E-03 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-05 |
| H-3 | 0.00 | 1.65E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 5.65E-01 | 2.75E-05 | 5.65E-01 |
| Co-60 | 1.65E+04 | 6.08E-01 | 6.09E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 1.25E+00 | 1.65E+04 |
| Sr-90 | 0.00 | 4.38E-01 | 8.27E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.00E-01 | 9.51E+00 |
| Y-90 | 0.00 | 2.84E-03 | 6.25E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 6.05E-02 | 6.88E-01 |
| Cs-137 | 0.00 | 8.35E-03 | 2.30E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 2.18E-01 | 2.49E-01 |
| Ba-137m | 3.94E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.94E+02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 2.96E-02 | 3.07E+00 | 1.44E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 1.09E-01 | 3.22E+00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 5.39E-03 | 6.18E-01 | 1.10E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 8.38E-02 | 7.18E-01 |
| Total | 1.69E+04 | 4.75E+00 | 9.55E+00 | 0.00 | 0.00 | 0.00 | 5.65E-01 | 2.52E+00 | 1.69E+04 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-08 |
| H-3 | 0.00 | 2.01E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 4.86E-04 | 2.36E-08 | 4.86E-04 |
| Co-60 | 9.43E+00 | 4.45E-04 | 3.39E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 6.95E-04 | 9.43E+00 |
| Sr-90 | 0.00 | 1.89E-05 | 1.92E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 1.85E-04 | 2.12E-03 |
| Y-90 | 0.00 | 1.85E-06 | 1.86E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 1.80E-05 | 2.06E-04 |
| Cs-137 | 0.00 | 4.97E-06 | 1.29E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 1.22E-04 | 1.40E-04 |
| Ba-137m | 2.19E-01 | 1.48E-10 | 1.04E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 9.89E-09 | 2.19E-01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 1.95E-05 | 6.12E-04 | 6.96E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 5.29E-05 | 6.92E-04 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 3.77E-06 | 6.73E-05 | 1.09E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 8.31E-06 | 8.05E-05 |
| Total | 9.65E+00 | 1.15E-03 | 2.46E-03 | 0.00 | 0.00 | 0.00 | 4.86E-04 | 1.08E-03 | 9.65E+00 |

Table 6G.21. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area E

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 8.70E+02 | 7.98E+04 | 1.52E+04 | 1.74E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 6.65E+01 | 2.23E+00 | 2.27E-01 | 1.33E-02 | 2.66E-02 | 2.69E-02 | 8.94E-05 | 8.94E-05 |
| Sr-90 | 2.17E+02 | 3.12E+00 | 4.31E+01 | 4.33E-02 | 1.83E+00 | 1.84E+00 | 3.75E-05 | 3.75E-04 |
| Y-90 | 2.17E+02 | 3.12E+00 | 4.31E+01 | 4.33E-02 | 1.83E+00 | 1.84E+00 | 3.75E-05 | 3.75E-04 |
| Cs-137 | 8.14E+02 | 3.69E+00 | 3.40E+00 | 1.63E-01 | 7.00E-02 | 7.43E-02 | 4.42E-03 | 1.47E-03 |
| Ba-137m | 7.70E+02 | 3.49E+00 | 3.21E+00 | 1.54E-01 | 6.62E-02 | 7.03E-02 | 4.19E-03 | 1.40E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 6.50E+02 | 0.00 | 1.94E-01 | 1.30E-01 | 6.96E-02 | 7.31E-02 | 0.00 | 0.00 |
| U-238 | 1.12E+03 | 0.00 | 7.43E-02 | 2.25E-01 | 1.20E-01 | 1.26E-01 | 0.00 | 0.00 |
| Th-234 | 1.12E+03 | 0.00 | 7.43E-02 | 2.25E-01 | 1.20E-01 | 1.26E-01 | 0.00 | 0.00 |
| Pa-234m | 1.12E+03 | 0.00 | 7.43E-02 | 2.25E-01 | 1.20E-01 | 1.26E-01 | 0.00 | 0.00 |
| Pa-234 | 1.46E+00 | 0.00 | 9.66E-05 | 2.92E-04 | 1.57E-04 | 1.64E-04 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-05 |
| H-3 | 0.00 | 3.66E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 1.12E-01 | 6.10E-05 | 1.12E-01 |
| Co-60 | 2.59E+01 | 9.55E-04 | 9.57E-04 | 1.98E-06 | 7.91E-06 | 0.00 | 1.32E-03 | 1.96E-03 | 2.59E+01 |
| Sr-90 | 0.00 | 1.85E-02 | 3.49E-01 | 4.38E-06 | 1.75E-04 | 0.00 | 9.74E-03 | 3.38E-02 | 4.11E-01 |
| Y-90 | 0.00 | 1.20E-04 | 2.64E-02 | 3.31E-07 | 1.33E-05 | 0.00 | 7.36E-04 | 2.55E-03 | 2.98E-02 |
| Cs-137 | 0.00 | 1.71E-03 | 4.70E-03 | 1.81E-04 | 2.42E-04 | 0.00 | 4.03E-03 | 4.45E-02 | 5.54E-02 |
| Ba-137m | 8.06E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.06E+01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 5.57E-02 | 5.78E+00 | 2.70E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 2.06E-01 | 6.07E+00 |
| U-238 | 1.24E-01 | 8.74E+00 | 4.11E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 3.13E-01 | 9.21E+00 |
| Th-234 | 1.94E+00 | 2.59E-03 | 2.21E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 1.68E-02 | 1.97E+00 |
| Pa-234m | 2.18E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.18E+00 |
| Pa-234 | 4.91E-01 | 7.81E-08 | 4.54E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 3.45E-06 | 4.91E-01 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.11E+02 | 1.45E+01 | 4.52E-01 | 1.88E-04 | 4.38E-04 | 0.00 | 1.28E-01 | 6.18E-01 | 1.27E+02 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-08 |
| H-3 | 0.00 | 4.46E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 9.62E-05 | 5.24E-08 | 9.62E-05 |
| Co-60 | 1.48E-02 | 6.99E-07 | 5.33E-07 | 1.10E-09 | 4.41E-09 | 0.00 | 7.34E-07 | 1.09E-06 | 1.48E-02 |
| Sr-90 | 0.00 | 7.97E-07 | 8.09E-05 | 1.02E-09 | 4.06E-08 | 0.00 | 2.26E-06 | 7.83E-06 | 9.18E-05 |
| Y-90 | 0.00 | 7.83E-08 | 7.84E-06 | 9.85E-11 | 3.94E-09 | 0.00 | 2.19E-07 | 7.59E-07 | 8.90E-06 |
| Cs-137 | 0.00 | 1.02E-06 | 2.63E-06 | 1.02E-07 | 1.36E-07 | 0.00 | 2.26E-06 | 2.49E-05 | 3.11E-05 |
| Ba-137m | 4.49E-02 | 3.03E-11 | 2.14E-10 | 8.25E-12 | 1.10E-11 | 0.00 | 1.83E-10 | 2.02E-09 | 4.49E-02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 3.68E-05 | 1.15E-03 | 1.31E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 9.96E-05 | 1.30E-03 |
| U-238 | 8.86E-05 | 1.77E-03 | 2.10E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 1.60E-04 | 2.04E-03 |
| Th-234 | 1.08E-03 | 2.36E-06 | 6.47E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 4.92E-06 | 1.09E-03 |
| Pa-234m | 1.23E-03 | 1.18E-10 | 9.37E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 7.13E-09 | 1.23E-03 |
| Pa-234 | 2.75E-04 | 5.18E-11 | 1.43E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 1.09E-09 | 2.75E-04 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 6.24E-02 | 2.93E-03 | 1.27E-04 | 1.04E-07 | 1.85E-07 | 0.00 | 1.02E-04 | 2.99E-04 | 6.58E-02 |

Table 6G.22. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area F

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 9.58E+02 | 1.36E+04 | 1.52E+04 | 1.92E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 5.36E+01 | 1.72E+00 | 2.27E-01 | 1.07E-02 | 2.14E-02 | 2.17E-02 | 6.89E-05 | 6.89E-05 |
| Sr-90 | 6.04E+03 | 7.56E+00 | 4.31E+01 | 1.21E+00 | 5.12E+01 | 5.12E+01 | 9.07E-05 | 9.07E-04 |
| Y-90 | 6.04E+03 | 7.56E+00 | 4.31E+01 | 1.21E+00 | 5.12E+01 | 5.12E+01 | 9.07E-05 | 9.07E-04 |
| Cs-137 | 2.77E+03 | 0.00 | 3.40E+00 | 5.54E-01 | 2.38E-01 | 2.53E-01 | 0.00 | 0.00 |
| Ba-137m | 2.62E+03 | 0.00 | 3.21E+00 | 5.24E-01 | 2.26E-01 | 2.39E-01 | 0.00 | 0.00 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 5.01E+02 | 0.00 | 1.94E-01 | 1.00E-01 | 5.37E-02 | 5.63E-02 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-05 |
| H-3 | 0.00 | 4.03E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 1.91E-02 | 6.71E-05 | 1.91E-02 |
| Co-60 | 2.09E+01 | 7.70E-04 | 7.71E-04 | 1.52E-06 | 6.10E-06 | 0.00 | 1.02E-03 | 1.58E-03 | 2.09E+01 |
| Sr-90 | 0.00 | 5.16E-01 | 9.74E+00 | 1.06E-05 | 4.25E-04 | 0.00 | 2.36E-02 | 9.43E-01 | 1.12E+01 |
| Y-90 | 0.00 | 3.35E-03 | 7.36E-01 | 8.02E-07 | 3.21E-05 | 0.00 | 1.78E-03 | 7.12E-02 | 8.12E-01 |
| Cs-137 | 0.00 | 5.81E-03 | 1.60E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 1.52E-01 | 1.73E-01 |
| Ba-137m | 2.75E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.75E+02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 4.29E-02 | 4.45E+00 | 2.08E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 1.58E-01 | 4.68E+00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.95E+02 | 4.98E+00 | 1.05E+01 | 1.29E-05 | 4.63E-04 | 0.00 | 4.54E-02 | 1.33E+00 | 3.12E+02 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-08 |
| H-3 | 0.00 | 4.91E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 1.64E-05 | 5.77E-08 | 1.64E-05 |
| Co-60 | 1.19E-02 | 5.63E-07 | 4.29E-07 | 8.49E-10 | 3.40E-09 | 0.00 | 5.66E-07 | 8.80E-07 | 1.19E-02 |
| Sr-90 | 0.00 | 2.22E-05 | 2.26E-03 | 2.46E-09 | 9.83E-08 | 0.00 | 5.46E-06 | 2.18E-04 | 2.50E-03 |
| Y-90 | 0.00 | 2.18E-06 | 2.19E-04 | 2.38E-10 | 9.54E-09 | 0.00 | 5.30E-07 | 2.12E-05 | 2.43E-04 |
| Cs-137 | 0.00 | 3.46E-06 | 8.97E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 8.50E-05 | 9.74E-05 |
| Ba-137m | 1.53E-01 | 1.03E-10 | 7.28E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 6.89E-09 | 1.53E-01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 2.83E-05 | 8.88E-04 | 1.01E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 7.67E-05 | 1.00E-03 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.65E-01 | 9.16E-04 | 2.49E-03 | 3.55E-09 | 1.11E-07 | 0.00 | 2.29E-05 | 4.02E-04 | 1.69E-01 |

Table 6G.23. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area G

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 9.24E+02 | 5.68E+05 | 1.52E+04 | 1.85E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 7.38E+01 | 2.44E+01 | 2.27E-01 | 1.48E-02 | 2.95E-02 | 2.99E-02 | 9.76E-04 | 9.76E-04 |
| Sr-90 | 6.37E+03 | 6.78E+00 | 4.31E+01 | 1.27E+00 | 5.40E+01 | 5.40E+01 | 8.14E-05 | 8.14E-04 |
| Y-90 | 6.37E+03 | 6.78E+00 | 4.31E+01 | 1.27E+00 | 5.40E+01 | 5.40E+01 | 8.14E-05 | 8.14E-04 |
| Cs-137 | 3.08E+03 | 2.08E+00 | 3.40E+00 | 6.16E-01 | 2.65E-01 | 2.81E-01 | 2.50E-03 | 8.32E-04 |
| Ba-137m | 2.91E+03 | 1.97E+00 | 3.21E+00 | 5.82E-01 | 2.51E-01 | 2.66E-01 | 2.36E-03 | 7.87E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 5.37E+02 | 0.00 | 1.94E-01 | 1.07E-01 | 5.76E-02 | 6.04E-02 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-05 |
| H-3 | 0.00 | 3.88E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 7.97E-01 | 6.47E-05 | 7.97E-01 |
| Co-60 | 2.87E+01 | 1.06E-03 | 1.06E-03 | 2.16E-05 | 8.64E-05 | 0.00 | 1.44E-02 | 2.18E-03 | 2.87E+01 |
| Sr-90 | 0.00 | 5.44E-01 | 1.03E+01 | 9.52E-06 | 3.81E-04 | 0.00 | 2.12E-02 | 9.94E-01 | 1.18E+01 |
| Y-90 | 0.00 | 3.53E-03 | 7.77E-01 | 7.20E-07 | 2.88E-05 | 0.00 | 1.60E-03 | 7.52E-02 | 8.57E-01 |
| Cs-137 | 0.00 | 6.46E-03 | 1.78E-02 | 1.02E-04 | 1.37E-04 | 0.00 | 2.28E-03 | 1.68E-01 | 1.95E-01 |
| Ba-137m | 3.05E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.05E+02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 4.60E-02 | 4.78E+00 | 2.23E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 1.70E-01 | 5.02E+00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 3.34E+02 | 5.33E+00 | 1.11E+01 | 1.34E-04 | 6.33E-04 | 0.00 | 8.36E-01 | 1.41E+00 | 3.52E+02 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-08 |
| H-3 | 0.00 | 4.73E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 6.85E-04 | 5.56E-08 | 6.85E-04 |
| Co-60 | 1.65E-02 | 7.76E-07 | 5.91E-07 | 1.20E-08 | 4.81E-08 | 0.00 | 8.01E-06 | 1.21E-06 | 1.65E-02 |
| Sr-90 | 0.00 | 2.35E-05 | 2.38E-03 | 2.21E-09 | 8.83E-08 | 0.00 | 4.90E-06 | 2.30E-04 | 2.64E-03 |
| Y-90 | 0.00 | 2.30E-06 | 2.31E-04 | 2.14E-10 | 8.56E-09 | 0.00 | 4.75E-07 | 2.23E-05 | 2.56E-04 |
| Cs-137 | 0.00 | 3.84E-06 | 9.97E-06 | 5.74E-08 | 7.66E-08 | 0.00 | 1.28E-06 | 9.44E-05 | 1.10E-04 |
| Ba-137m | 1.70E-01 | 1.15E-10 | 8.08E-10 | 4.66E-12 | 6.21E-12 | 0.00 | 1.03E-10 | 7.65E-09 | 1.70E-01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 3.04E-05 | 9.52E-04 | 1.08E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 8.23E-05 | 1.08E-03 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.86E-01 | 9.83E-04 | 2.63E-03 | 7.19E-08 | 2.21E-07 | 0.00 | 6.99E-04 | 4.31E-04 | 1.91E-01 |

Table 6G.24. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area H

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 5.79E+02 | 3.46E+05 | 1.52E+04 | 1.16E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 2.31E+03 | 1.47E+01 | 2.27E-01 | 4.61E-01 | 9.21E-01 | 9.33E-01 | 5.89E-04 | 5.89E-04 |
| Sr-90 | 4.76E+03 | 9.38E+01 | 4.31E+01 | 9.51E-01 | 4.03E+01 | 4.03E+01 | 1.13E-03 | 1.13E-02 |
| Y-90 | 4.76E+03 | 9.38E+01 | 4.31E+01 | 9.51E-01 | 4.03E+01 | 4.03E+01 | 1.13E-03 | 1.13E-02 |
| Cs-137 | 1.14E+04 | 0.00 | 3.40E+00 | 2.28E+00 | 9.80E-01 | 1.04E+00 | 0.00 | 0.00 |
| Ba-137m | 1.08E+04 | 0.00 | 3.21E+00 | 2.15E+00 | 9.27E-01 | 9.83E-01 | 0.00 | 0.00 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 1.94E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 3.96E+01 | 0.00 | 0.00 | 7.93E-03 | 4.25E-03 | 4.46E-03 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-05 |
| H-3 | 0.00 | 2.44E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 4.86E-01 | 4.06E-05 | 4.86E-01 |
| Co-60 | 8.98E+02 | 3.31E-02 | 3.32E-02 | 1.30E-05 | 5.21E-05 | 0.00 | 8.68E-03 | 6.80E-02 | 8.98E+02 |
| Sr-90 | 0.00 | 4.06E-01 | 7.66E+00 | 1.32E-04 | 5.27E-03 | 0.00 | 2.93E-01 | 7.42E-01 | 9.11E+00 |
| Y-90 | 0.00 | 2.64E-03 | 5.79E-01 | 9.95E-06 | 3.98E-04 | 0.00 | 2.21E-02 | 5.61E-02 | 6.60E-01 |
| Cs-137 | 0.00 | 2.39E-02 | 6.58E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 6.23E-01 | 7.12E-01 |
| Ba-137m | 1.13E+03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.13E+03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 5.63E-03 | 6.46E-01 | 1.15E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 8.75E-02 | 7.50E-01 |
| Total | 2.03E+03 | 1.11E+00 | 8.35E+00 | 1.55E-04 | 5.72E-03 | 0.00 | 8.09E-01 | 1.58E+00 | 2.04E+03 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-08 |
| H-3 | 0.00 | 2.97E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 4.17E-04 | 3.49E-08 | 4.17E-04 |
| Co-60 | 5.14E-01 | 2.42E-05 | 1.85E-05 | 7.25E-09 | 2.90E-08 | 0.00 | 4.83E-06 | 3.79E-05 | 5.14E-01 |
| Sr-90 | 0.00 | 1.75E-05 | 1.78E-03 | 3.05E-08 | 1.22E-06 | 0.00 | 6.78E-05 | 1.72E-04 | 2.03E-03 |
| Y-90 | 0.00 | 1.72E-06 | 1.72E-04 | 2.96E-09 | 1.18E-07 | 0.00 | 6.57E-06 | 1.67E-05 | 1.97E-04 |
| Cs-137 | 0.00 | 1.42E-05 | 3.69E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 3.49E-04 | 4.00E-04 |
| Ba-137m | 6.28E-01 | 4.25E-10 | 2.99E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 2.83E-08 | 6.28E-01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 3.94E-06 | 7.03E-05 | 1.14E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 8.68E-06 | 8.41E-05 |
| Total | 1.14E+00 | 1.28E-04 | 2.00E-03 | 4.07E-08 | 1.37E-06 | 0.00 | 4.96E-04 | 5.84E-04 | 1.15E+00 |

Table 6G.25. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area I

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 7.71E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 4.55E+02 | 2.32E+05 | 1.52E+04 | 9.10E-02 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 9.02E+01 | 2.18E+00 | 2.27E-01 | 1.80E-02 | 3.60E-02 | 3.65E-02 | 8.71E-05 | 8.71E-05 |
| Sr-90 | 3.71E+03 | 1.22E+02 | 4.31E+01 | 7.43E-01 | 3.14E+01 | 3.15E+01 | 1.46E-03 | 1.46E-02 |
| Y-90 | 3.71E+03 | 1.22E+02 | 4.31E+01 | 7.43E-01 | 3.14E+01 | 3.15E+01 | 1.46E-03 | 1.46E-02 |
| Cs-137 | 1.79E+03 | 0.00 | 3.40E+00 | 3.58E-01 | 1.54E-01 | 1.63E-01 | 0.00 | 0.00 |
| Ba-137m | 1.69E+03 | 0.00 | 3.21E+00 | 3.39E-01 | 1.46E-01 | 1.55E-01 | 0.00 | 0.00 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 1.94E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.62E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.62E-05 |
| H-3 | 0.00 | 1.91E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 3.25E-01 | 3.19E-05 | 3.25E-01 |
| Co-60 | 3.51E+01 | 1.30E-03 | 1.30E-03 | 1.93E-06 | 7.71E-06 | 0.00 | 1.28E-03 | 2.66E-03 | 3.51E+01 |
| Sr-90 | 0.00 | 3.17E-01 | 5.98E+00 | 1.71E-04 | 6.84E-03 | 0.00 | 3.80E-01 | 5.79E-01 | 7.27E+00 |
| Y-90 | 0.00 | 2.06E-03 | 4.52E-01 | 1.29E-05 | 5.17E-04 | 0.00 | 2.87E-02 | 4.38E-02 | 5.27E-01 |
| Cs-137 | 0.00 | 3.76E-03 | 1.03E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 9.79E-02 | 1.12E-01 |
| Ba-137m | 1.77E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.77E+02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.13E+02 | 3.24E-01 | 6.45E+00 | 1.86E-04 | 7.36E-03 | 0.00 | 7.34E-01 | 7.24E-01 | 2.21E+02 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.98E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.98E-08 |
| H-3 | 0.00 | 2.33E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 2.79E-04 | 2.74E-08 | 2.79E-04 |
| Co-60 | 2.01E-02 | 9.48E-07 | 7.23E-07 | 1.07E-09 | 4.29E-09 | 0.00 | 7.16E-07 | 1.48E-06 | 2.01E-02 |
| Sr-90 | 0.00 | 1.37E-05 | 1.39E-03 | 3.96E-08 | 1.58E-06 | 0.00 | 8.80E-05 | 1.34E-04 | 1.62E-03 |
| Y-90 | 0.00 | 1.34E-06 | 1.34E-04 | 3.84E-09 | 1.54E-07 | 0.00 | 8.53E-06 | 1.30E-05 | 1.57E-04 |
| Cs-137 | 0.00 | 2.23E-06 | 5.80E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 5.49E-05 | 6.29E-05 |
| Ba-137m | 9.87E-02 | 6.68E-11 | 4.70E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 4.45E-09 | 9.87E-02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.19E-01 | 1.82E-05 | 1.53E-03 | 4.45E-08 | 1.74E-06 | 0.00 | 3.76E-04 | 2.04E-04 | 1.21E-01 |

Table 6G.26. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area J

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 1.68E+02 | 4.93E+04 | 1.52E+04 | 3.35E-02 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 3.63E+03 | 2.56E+01 | 2.27E-01 | 7.27E-01 | 1.45E+00 | 1.47E+00 | 1.03E-03 | 1.03E-03 |
| Sr-90 | 2.66E+03 | 3.88E+01 | 4.31E+01 | 5.32E-01 | 2.25E+01 | 2.25E+01 | 4.66E-04 | 4.66E-03 |
| Y-90 | 2.66E+03 | 3.88E+01 | 4.31E+01 | 5.32E-01 | 2.25E+01 | 2.25E+01 | 4.66E-04 | 4.66E-03 |
| Cs-137 | 4.35E+04 | 4.71E-01 | 3.40E+00 | 8.70E+00 | 3.74E+00 | 3.97E+00 | 5.66E-04 | 1.89E-04 |
| Ba-137m | 4.12E+04 | 4.46E-01 | 3.21E+00 | 8.23E+00 | 3.54E+00 | 3.76E+00 | 5.35E-04 | 1.78E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 1.94E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-05 |
| H-3 | 0.00 | 7.05E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 6.91E-02 | 1.17E-05 | 6.91E-02 |
| Co-60 | 1.41E+03 | 5.22E-02 | 5.23E-02 | 2.27E-05 | 9.07E-05 | 0.00 | 1.51E-02 | 1.07E-01 | 1.41E+03 |
| Sr-90 | 0.00 | 2.27E-01 | 4.29E+00 | 5.45E-05 | 2.18E-03 | 0.00 | 1.21E-01 | 4.15E-01 | 5.05E+00 |
| Y-90 | 0.00 | 1.47E-03 | 3.24E-01 | 4.12E-06 | 1.65E-04 | 0.00 | 9.16E-03 | 3.14E-02 | 3.66E-01 |
| Cs-137 | 0.00 | 9.13E-02 | 2.51E-01 | 2.32E-05 | 3.09E-05 | 0.00 | 5.16E-04 | 2.38E+00 | 2.72E+00 |
| Ba-137m | 4.31E+03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.31E+03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 5.73E+03 | 3.72E-01 | 4.91E+00 | 1.05E-04 | 2.47E-03 | 0.00 | 2.15E-01 | 2.93E+00 | 5.74E+03 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-08 |
| H-3 | 0.00 | 8.59E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 5.94E-05 | 1.01E-08 | 5.94E-05 |
| Co-60 | 8.10E-01 | 3.82E-05 | 2.91E-05 | 1.26E-08 | 5.05E-08 | 0.00 | 8.42E-06 | 5.97E-05 | 8.10E-01 |
| Sr-90 | 0.00 | 9.79E-06 | 9.93E-04 | 1.26E-08 | 5.05E-07 | 0.00 | 2.81E-05 | 9.61E-05 | 1.13E-03 |
| Y-90 | 0.00 | 9.61E-07 | 9.63E-05 | 1.22E-09 | 4.90E-08 | 0.00 | 2.72E-06 | 9.32E-06 | 1.09E-04 |
| Cs-137 | 0.00 | 5.43E-05 | 1.41E-04 | 1.30E-08 | 1.73E-08 | 0.00 | 2.89E-07 | 1.33E-03 | 1.53E-03 |
| Ba-137m | 2.40E+00 | 1.62E-09 | 1.14E-08 | 1.05E-12 | 1.41E-12 | 0.00 | 2.34E-11 | 1.08E-07 | 2.40E+00 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 3.21E+00 | 1.03E-04 | 1.26E-03 | 3.95E-08 | 6.22E-07 | 0.00 | 9.89E-05 | 1.50E-03 | 3.21E+00 |

Table 6G.27. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area K

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 3.72E+01 | 4.25E+03 | 1.52E+04 | 7.44E-03 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 6.45E+02 | 1.81E+00 | 2.27E-01 | 1.29E-01 | 2.57E-01 | 2.61E-01 | 7.25E-05 | 7.25E-05 |
| Sr-90 | 1.67E+03 | 1.18E+01 | 4.31E+01 | 3.34E-01 | 1.42E+01 | 1.42E+01 | 1.41E-04 | 1.41E-03 |
| Y-90 | 1.67E+03 | 1.18E+01 | 4.31E+01 | 3.34E-01 | 1.42E+01 | 1.42E+01 | 1.41E-04 | 1.41E-03 |
| Cs-137 | 4.75E+03 | 5.27E-02 | 3.40E+00 | 9.49E-01 | 4.08E-01 | 4.33E-01 | 6.33E-05 | 2.11E-05 |
| Ba-137m | 4.49E+03 | 4.99E-02 | 3.21E+00 | 8.98E-01 | 3.86E-01 | 4.10E-01 | 5.99E-05 | 2.00E-05 |
| Eu-152 | 3.77E+06 | 3.32E+01 | 0.00 | 7.54E+02 | 4.04E+02 | 4.24E+02 | 6.64E-03 | 6.64E-06 |
| Eu-154 | 4.51E+06 | 2.12E+01 | 0.00 | 9.02E+02 | 4.84E+02 | 5.07E+02 | 4.23E-03 | 4.23E-06 |
| Eu-155 | 6.44E+05 | 5.61E+00 | 0.00 | 1.29E+02 | 6.91E+01 | 7.25E+01 | 1.12E-03 | 1.12E-06 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 1.94E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-05 |
| H-3 | 0.00 | 1.56E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 5.96E-03 | 2.61E-06 | 5.96E-03 |
| Co-60 | 2.51E+02 | 9.26E-03 | 9.28E-03 | 1.60E-06 | 6.42E-06 | 0.00 | 1.07E-03 | 1.90E-02 | 2.51E+02 |
| Sr-90 | 0.00 | 1.43E-01 | 2.69E+00 | 1.65E-05 | 6.61E-04 | 0.00 | 3.67E-02 | 2.61E-01 | 3.13E+00 |
| Y-90 | 0.00 | 9.26E-04 | 2.04E-01 | 1.25E-06 | 5.00E-05 | 0.00 | 2.78E-03 | 1.97E-02 | 2.27E-01 |
| Cs-137 | 0.00 | 9.96E-03 | 2.74E-02 | 2.60E-06 | 3.46E-06 | 0.00 | 5.77E-05 | 2.60E-01 | 2.97E-01 |
| Ba-137m | 4.70E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.70E+02 |
| Eu-152 | 7.18E+05 | 5.47E+01 | 3.52E+00 | 3.53E-05 | 1.41E-07 | 0.00 | 4.71E-03 | 2.67E+01 | 7.18E+05 |
| Eu-154 | 9.36E+05 | 8.48E+01 | 6.20E+00 | 3.32E-05 | 1.33E-07 | 0.00 | 4.42E-03 | 4.72E+01 | 9.36E+05 |
| Eu-155 | 7.90E+03 | 1.75E+00 | 1.42E-01 | 1.41E-06 | 5.63E-09 | 0.00 | 1.88E-04 | 1.08E+00 | 7.90E+03 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.66E+06 | 1.41E+02 | 1.28E+01 | 9.19E-05 | 7.21E-04 | 0.00 | 5.59E-02 | 7.55E+01 | 1.66E+06 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-08 |
| H-3 | 0.00 | 1.91E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 5.12E-06 | 2.24E-09 | 5.12E-06 |
| Co-60 | 1.44E-01 | 6.78E-06 | 5.17E-06 | 8.94E-10 | 3.57E-09 | 0.00 | 5.96E-07 | 1.06E-05 | 1.44E-01 |
| Sr-90 | 0.00 | 6.15E-06 | 6.24E-04 | 3.83E-09 | 1.53E-07 | 0.00 | 8.51E-06 | 6.04E-05 | 6.99E-04 |
| Y-90 | 0.00 | 6.04E-07 | 6.05E-05 | 3.71E-10 | 1.48E-08 | 0.00 | 8.25E-07 | 5.86E-06 | 6.78E-05 |
| Cs-137 | 0.00 | 5.92E-06 | 1.54E-05 | 1.46E-09 | 1.94E-09 | 0.00 | 3.23E-08 | 1.46E-04 | 1.67E-04 |
| Ba-137m | 2.62E-01 | 1.77E-10 | 1.25E-09 | 1.18E-13 | 1.57E-13 | 0.00 | 2.62E-12 | 1.18E-08 | 2.62E-01 |
| Eu-152 | 4.07E+02 | 2.97E+00 | 1.14E-03 | 1.15E-08 | 4.58E-11 | 0.00 | 1.53E-06 | 8.67E-03 | 4.10E+02 |
| Eu-154 | 5.26E+02 | 4.15E-02 | 1.95E-03 | 1.04E-08 | 4.17E-11 | 0.00 | 1.39E-06 | 1.48E-02 | 5.26E+02 |
| Eu-155 | 5.75E+00 | 1.27E-01 | 4.82E-05 | 4.79E-10 | 1.91E-12 | 0.00 | 6.38E-08 | 3.67E-04 | 5.87E+00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0:00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 9.40E+02 | 3.14E+00 | 3.84E-03 | 2.89E-08 | 1.74E-07 | 0.00 | 1.81E-05 | 2.41E-02 | 9.43E+02 |

Table 6G.28. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area L

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 9.64E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 3.30E+04 | 3.25E+06 | 1.52E+04 | 6.61E+00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 3.21E+01 | 4.59E-01 | 2.27E-01 | 6.43E-03 | 1.28E-02 | 1.30E-02 | 1.84E-05 | 1.84E-05 |
| Sr-90 | 1.15E+03 | 4.17E+01 | 4.31E+01 | 2.29E-01 | 9.72E+00 | 9.72E+00 | 5.01E-04 | 5.01E-03 |
| Y-90 | 1.15E+03 | 4.17E+01 | 4.31E+01 | 2.29E-01 | 9.72E+00 | 9.72E+00 | 5.01E-04 | 5.01E-03 |
| Cs-137 | 4.48E+03 | 8.23E+00 | 3.40E+00 | 8.96E-01 | 3.85E-01 | 4.09E-01 | 9.88E-03 | 3.29E-03 |
| Ba-137m | 4.24E+03 | 7.79E+00 | 3.21E+00 | 8.47E-01 | 3.65E-01 | 3.87E-01 | 9.35E-03 | 3.12E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 4.76E+03 | 0.00 | 1.94E-01 | 9.52E-01 | 5.10E-01 | 5.35E-01 | 0.00 | 0.00 |
| U-238 | 8.87E+01 | 0.00 | 7.43E-02 | 1.77E-02 | 9.51E-03 | 9.97E-03 | 0.00 | 0.00 |
| Th-234 | 8.87E+01 | 0.00 | 7.43E-02 | 1.77E-02 | 9.51E-03 | 9.97E-03 | 0.00 | 0.00 |
| Pa-234m | 8.87E+01 | 0.00 | 7.43E-02 | 1.77E-02 | 9.51E-03 | 9.97E-03 | 0.00 | 0.00 |
| Pa-234 | 1.15E-01 | 0.00 | 9.66E-05 | 2.31E-05 | 1.24E-05 | 1.30E-05 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 2.03E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.03E-05 |
| H-3 | 0.00 | 1.39E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 4.55E+00 | 2.31E-03 | 4.55E+00 |
| Co-60 | 1.25E+01 | 4.62E-04 | 4.62E-04 | 4.07E-07 | 1.63E-06 | 0.00 | 2.71E-04 | 9.48E-04 | 1.25E+01 |
| Sr-90 | 0.00 | 9.79E-02 | 1.85E+00 | 5.86E-05 | 2.34E-03 | 0.00 | 1.30E-01 | 1.79E-01 | 2.26E+00 |
| Y-90 | 0.00 | 6.36E-04 | 1.40E-01 | 4.43E-06 | 1.77E-04 | 0.00 | 9.84E-03 | 1.35E-02 | 1.64E-01 |
| Cs-137 | 0.00 | 9.39E-03 | 2.59E-02 | 4.05E-04 | 5.40E-04 | 0.00 | 9.01E-03 | 2.45E-01 | 2.90E-01 |
| Ba-137m | 4.44E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.44E+02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 4.08E-01 | 4.23E+01 | 1.98E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 1.51E+00 | 4.45E+01 |
| U-238 | 9.82E-03 | 6.90E-01 | 3.25E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 2.47E-02 | 7.28E-01 |
| Th-234 | 1.54E-01 | 2.04E-04 | 1.74E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 1.33E-03 | 1.55E-01 |
| Pa-234m | 1.72E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.72E-01 |
| Pa-234 | 3.87E-02 | 6.17E-09 | 3.59E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 2.73E-07 | 3.87E-02 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 4.57E+02 | 4.31E+01 | 2.22E+00 | 4.69E-04 | 3.06E-03 | 0.00 | 4.70E+00 | 1.97E+00 | 5.09E+02 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 2.47E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.47E-08 |
| H-3 | 0.00 | 1.69E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 3.91E-03 | 1.99E-06 | 3.91E-03 |
| Co-60 | 7.16E-03 | 3.38E-07 | 2.57E-07 | 2.26E-10 | 9.06E-10 | 0.00 | 1.51E-07 | 5.28E-07 | 7.16E-03 |
| Sr-90 | 0.00 | 4.22E-06 | 4.28E-04 | 1.36E-08 | 5.43E-07 | 0.00 | 3.02E-05 | 4.15E-05 | 5.05E-04 |
| Y-90 | 0.00 | 4.15E-07 | 4.15E-05 | 1.32E-09 | 5.27E-08 | 0.00 | 2.93E-06 | 4.02E-06 | 4.90E-05 |
| Cs-137 | 0.00 | 5.59E-06 | 1.45E-05 | 2.27E-07 | 3.03E-07 | 0.00 | 5.05E-06 | 1.37E-04 | 1.63E-04 |
| Ba-137m | 2.47E-01 | 1.67E-10 | 1.18E-09 | 1.84E-11 | 2.46E-11 | 0.00 | 4.09E-10 | 1.11E-08 | 2.47E-01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 2.69E-04 | 8.44E-03 | 9.59E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 7.30E-04 | 9.54E-03 |
| U-238 | 6.99E-06 | 1.40E-04 | 1.66E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 1.26E-05 | 1.61E-04 |
| Th-234 | 8.51E-05 | 1.86E-07 | 5.11E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 3.88E-07 | 8.58E-05 |
| Pa-234m | 9.73E-05 | 9.32E-12 | 7.40E-11 | 0.00 | 0.00 | 0.00 | 0.00 | 5.63E-10 | 9.73E-05 |
| Pa-234 | 2.17E-05 | 4.09E-12 | 1.13E-11 | 0.00 | 0.00 | 0.00 | 0.00 | 8.58E-11 | 2.17E-05 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.55E-01 | 8.59E-03 | 5.82E-04 | 2.42E-07 | 9.00E-07 | 0.00 | 3.95E-03 | 9.28E-04 | 2.69E-01 |

Table 6G.29. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area M

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 1.93E+00 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 4.05E+03 | 1.42E+06 | 1.52E+04 | 8.10E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 3.30E+02 | 6.69E-01 | 2.27E-01 | 6.61E-02 | 1.32E-01 | 1.34E-01 | 2.68E-05 | 2.68E-05 |
| Sr-90 | 9.20E+02 | 5.81E+00 | 4.31E+01 | 1.84E-01 | 7.79E+00 | 7.80E+00 | 6.97E-05 | 6.97E-04 |
| Y-90 | 9.20E+02 | 5.81E+00 | 4.31E+01 | 1.84E-01 | 7.79E+00 | 7.80E+00 | 6.97E-05 | 6.97E-04 |
| Cs-137 | 3.42E+03 | 7.91E+00 | 3.40E+00 | 6.84E-01 | 2.94E-01 | 3.12E-01 | 9.49E-03 | 3.16E-03 |
| Ba-137m | 3.23E+03 | 7.48E+00 | 3.21E+00 | 6.47E-01 | 2.78E-01 | 2.95E-01 | 8.98E-03 | 2.99E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 5.04E+01 | 3.92E-01 | 0.00 | 1.01E-02 | 9.03E-03 | 9.29E-03 | 7.83E-05 | 7.83E-08 |
| U-233 | 2.72E+03 | 0.00 | 1.94E-01 | 5.43E-01 | 2.91E-01 | 3.05E-01 | 0.00 | 0.00 |
| U-238 | 3.93E+03 | 4.92E+00 | 7.43E-02 | 7.86E-01 | 4.21E-01 | 4.42E-01 | 9.85E-04 | 2.36E-04 |
| Th-234 | 3.93E+03 | 4.92E+00 | 7.43E-02 | 7.86E-01 | 4.21E-01 | 4.42E-01 | 9.85E-04 | 2.36E-04 |
| Pa-234m | 3.93E+03 | 4.92E+00 | 7.43E-02 | 7.86E-01 | 4.21E-01 | 4.42E-01 | 9.85E-04 | 2.36E-04 |
| Pa-234 | 5.11E+00 | 6.40E-03 | 9.66E-05 | 1.02E-03 | 5.48E-04 | 5.75E-04 | 1.28E-06 | 3.07E-07 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 4.05E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.05E-05 |
| H-3 | 0.00 | 1.70E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 1.99E+00 | 2.84E-04 | 1.99E+00 |
| Co-60 | 1.29E+02 | 4.75E-03 | 4.75E-03 | 5.92E-07 | 2.37E-06 | 0.00 | 3.95E-04 | 9.74E-03 | 1.29E+02 |
| Sr-90 | 0.00 | 7.85E-02 | 1.48E+00 | 8.16E-06 | 3.26E-04 | 0.00 | 1.81E-02 | 1.44E-01 | 1.72E+00 |
| Y-90 | 0.00 | 5.10E-04 | 1.12E-01 | 6.16E-07 | 2.47E-05 | 0.00 | 1.37E-03 | 1.08E-02 | 1.25E-01 |
| Cs-137 | 0.00 | 7.17E-03 | 1.98E-02 | 3.89E-04 | 5.19E-04 | 0.00 | 8.65E-03 | 1.87E-01 | 2.23E-01 |
| Ba-137m | 3.39E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.39E+02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 5.75E-03 | 5.42E+00 | 3.30E-02 | 1.76E-04 | 7.02E-07 | 0.00 | 2.34E-02 | 1.51E-01 | 5.64E+00 |
| U-233 | 2.33E-01 | 2.42E+01 | 1.13E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 8.59E-01 | 2.54E+01 |
| U-238 | 4.35E-01 | 3.06E+01 | 1.44E-01 | 2.06E-04 | 1.98E-04 | 0.00 | 2.75E-02 | 1.10E+00 | 3.23E+01 |
| Th-234 | 6.81E+00 | 9.05E-03 | 7.72E-03 | 1.10E-05 | 1.06E-05 | 0.00 | 1.47E-03 | 5.88E-02 | 6.88E+00 |
| Pa-234m | 7.62E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.62E+00 |
| Pa-234 | 1.72E+00 | 2.73E-07 | 1.59E-06 | 2.27E-09 | 2.18E-09 | 0.00 | 3.03E-07 | 1.21E-05 | 1.72E+00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 4.84E+02 | 6.03E+01 | 1.92E+00 | 7.91E-04 | 1.08E-03 | 0.00 | 2.07E+00 | 2.52E+00 | 5.51E+02 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 4.94E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.94E-08 |
| H-3 | 0.00 | 2.07E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 1.71E-03 | 2.44E-07 | 1.71E-03 |
| Co-60 | 7.36E-02 | 3.47E-06 | 2.65E-06 | 3.30E-10 | 1.32E-09 | 0.00 | 2.20E-07 | 5.43E-06 | 7.36E-02 |
| Sr-90 | 0.00 | 3.39E-06 | 3.44E-04 | 1.89E-09 | 7.56E-08 | 0.00 | 4.20E-06 | 3.33E-05 | 3.84E-04 |
| Y-90 | 0.00 | 3.33E-07 | 3.33E-05 | 1.83E-10 | 7.33E-09 | 0.00 | 4.07E-07 | 3.22E-06 | 3.73E-05 |
| Cs-137 | 0.00 | 4.27E-06 | 1.11E-05 | 2.18E-07 | 2.91E-07 | 0.00 | 4.85E-06 | 1.05E-04 | 1.26E-04 |
| Ba-137m | 1.89E-01 | 1.28E-10 | 8.98E-10 | 1.77E-11 | 2.36E-11 | 0.00 | 3.93E-10 | 8.50E-09 | 1.89E-01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 3.97E-06 | 1.03E-04 | 2.66E-07 | 1.41E-09 | 5.66E-12 | 0.00 | 1.89E-07 | 1.21E-06 | 1.08E-04 |
| U-233 | 1.54E-04 | 4.82E-03 | 5.47E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 4.16E-04 | 5.44E-03 |
| U-238 | 3.10E-04 | 6.20E-03 | 7.36E-05 | 1.05E-07 | 1.01E-07 | 0.00 | 1.40E-05 | 5.60E-04 | 7.16E-03 |
| Th-234 | 3.77E-03 | 8.26E-06 | 2.26E-06 | 3.24E-09 | 3.11E-09 | 0.00 | 4.31E-07 | 1.72E-05 | 3.80E-03 |
| Pa-234m | 4.31E-03 | 4.13E-10 | 3.28E-09 | 4.69E-12 | 4.50E-12 | 0.00 | 6.26E-10 | 2.50E-08 | 4.31E-03 |
| Pa-234 | 9.64E-04 | 1.81E-10 | 5.00E-10 | 7.15E-13 | 6.86E-13 | 0.00 | 9.53E-11 | 3.80E-09 | 9.64E-04 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.72E-01 | 1.11E-02 | 5.21E-04 | 3.30E-07 | 4.79E-07 | 0.00 | 1.73E-03 | 1.14E-03 | 2.86E-01 |

Table 6G.30. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area N

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 2.89E+00 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 8.39E+03 | 4.05E+04 | 1.52E+04 | 1.68E+00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 3.00E+03 | 8.73E-01 | 2.27E-01 | 6.00E-01 | 1.20E+00 | 1.21E+00 | 3.49E-05 | 3.49E-05 |
| Sr-90 | 1.20E+03 | 6.35E+00 | 4.31E+01 | 2.41E-01 | 1.02E+01 | 1.02E+01 | 7.62E-05 | 7.62E-04 |
| Y-90 | 1.20E+03 | 6.35E+00 | 4.31E+01 | 2.41E-01 | 1.02E+01 | 1.02E+01 | 7.62E-05 | 7.62E-04 |
| Cs-137 | 1.60E+03 | 9.04E+00 | 3.40E+00 | 3.20E-01 | 1.38E-01 | 1.46E-01 | 1.08E-02 | 3.61E-03 |
| Ba-137m | 1.51E+03 | 8.55E+00 | 3.21E+00 | 3.02E-01 | 1.30E-01 | 1.38E-01 | 1.03E-02 | 3.42E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 2.08E+03 | 0.00 | 1.94E-01 | 4.16E-01 | 2.23E-01 | 2.34E-01 | 0.00 | 0.00 |
| U-238 | 1.49E+03 | 0.00 | 7.43E-02 | 2.97E-01 | 1.59E-01 | 1.67E-01 | 0.00 | 0.00 |
| Th-234 | 1.49E+03 | 0.00 | 7.43E-02 | 2.97E-01 | 1.59E-01 | 1.67E-01 | 0.00 | 0.00 |
| Pa-234m | 1.49E+03 | 0.00 | 7.43E-02 | 2.97E-01 | 1.59E-01 | 1.67E-01 | 0.00 | 0.00 |
| Pa-234 | 1.93E+00 | 0.00 | 9.66E-05 | 3.86E-04 | 2.07E-04 | 2.17E-04 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 6.08E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.08E-05 |
| H-3 | 0.00 | 3.53E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 5.68E-02 | 5.88E-04 | 5.74E-02 |
| Co-60 | 1.17E+03 | 4.31E-02 | 4.32E-02 | 7.73E-07 | 3.09E-06 | 0.00 | 5.15E-04 | 8.85E-02 | 1.17E+03 |
| Sr-90 | 0.00 | 1.03E-01 | 1.94E+00 | 8.91E-06 | 3.57E-04 | 0.00 | 1.98E-02 | 1.88E-01 | 2.25E+00 |
| Y-90 | 0.00 | 6.67E-04 | 1.47E-01 | 6.74E-07 | 2.69E-05 | 0.00 | 1.50E-03 | 1.42E-02 | 1.63E-01 |
| Cs-137 | 0.00 | 3.35E-03 | 9.24E-03 | 4.45E-04 | 5.93E-04 | 0.00 | 9.89E-03 | 8.74E-02 | 1.11E-01 |
| Ba-137m | 1.58E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.58E+02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 1.78E-01 | 1.85E+01 | 8.66E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 6.59E-01 | 1.94E+01 |
| U-238 | 1.65E-01 | 1.16E+01 | 5.44E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 4.14E-01 | 1.22E+01 |
| Th-234 | 2.57E+00 | 3.42E-03 | 2.92E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 2.22E-02 | 2.60E+00 |
| Pa-234m | 2.88E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.88E+00 |
| Pa-234 | 6.49E-01 | 1.03E-07 | 6.01E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 4.57E-06 | 6.49E-01 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.33E+03 | 3.02E+01 | 2.28E+00 | 4.55E-04 | 9.80E-04 | 0.00 | 8.85E-02 | 1.47E+00 | 1.37E+03 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 7.41E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.41E-08 |
| H-3 | 0.00 | 4.30E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 4.88E-05 | 5.05E-07 | 4.93E-05 |
| Co-60 | 6.69E-01 | 3.16E-05 | 2.40E-05 | 4.30E-10 | 1.72E-09 | 0.00 | 2.87E-07 | 4.93E-05 | 6.69E-01 |
| Sr-90 | 0.00 | 4.43E-06 | 4.49E-04 | 2.06E-09 | 8.26E-08 | 0.00 | 4.59E-06 | 4.35E-05 | 5.02E-04 |
| Y-90 | 0.00 | 4.35E-07 | 4.36E-05 | 2.00E-10 | 8.01E-09 | 0.00 | 4.45E-07 | 4.22E-06 | 4.87E-05 |
| Cs-137 | 0.00 | 2.00E-06 | 5.18E-06 | 2.49E-07 | 3.32E-07 | 0.00 | 5.54E-06 | 4.90E-05 | 6.23E-05 |
| Ba-137m | 8.82E-02 | 5.96E-11 | 4.20E-10 | 2.02E-11 | 2.70E-11 | 0.00 | 4.49E-10 | 3.97E-09 | 8.82E-02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 1.18E-04 | 3.69E-03 | 4.19E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 3.19E-04 | 4.17E-03 |
| U-238 | 1.17E-04 | 2.34E-03 | 2.78E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 2.12E-04 | 2.70E-03 |
| Th-234 | 1.43E-03 | 3.12E-06 | 8.55E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 6.51E-06 | 1.44E-03 |
| Pa-234m | 1.63E-03 | 1.56E-10 | 1.24E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 9.44E-09 | 1.63E-03 |
| Pa-234 | 3.64E-04 | 6.85E-11 | 1.89E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 1.44E-09 | 3.64E-04 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 7.61E-01 | 6.08E-03 | 5.93E-04 | 2.52E-07 | 4.25E-07 | 0.00 | 5.96E-05 | 6.84E-04 | 7.68E-01 |

Table 6G.31. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area O

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 1.93E+00 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 6.98E+03 | 2.54E+05 | 1.52E+04 | 1.40E+00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 2.35E+03 | 8.10E-01 | 2.27E-01 | 4.70E-01 | 9.38E-01 | 9.50E-01 | 3.24E-05 | 3.24E-05 |
| Sr-90 | 1.18E+03 | 6.31E+00 | 4.31E+01 | 2.36E-01 | 1.00E+01 | 1.00E+01 | 7.57E-05 | 7.57E-04 |
| Y-90 | 1.18E+03 | 6.31E+00 | 4.31E+01 | 2.36E-01 | 1.00E+01 | 1.00E+01 | 7.57E-05 | 7.57E-04 |
| Cs-137 | 6.71E+03 | 9.45E+00 | 3.40E+00 | 1.34E+00 | 5.78E-01 | 6.13E-01 | 1.13E-02 | 3.78E-03 |
| Ba-137m | 6.35E+03 | 8.94E+00 | 3.21E+00 | 1.27E+00 | 5.47E-01 | 5.80E-01 | 1.07E-02 | 3.58E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 9.35E+01 | 4.27E+00 | 0.00 | 1.87E-02 | 1.68E-02 | 1.72E-02 | 8.53E-04 | 8.53E-07 |
| U-233 | 0.00 | 0.00 | 1.94E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 1.31E+02 | 0.00 | 7.43E-02 | 2.61E-02 | 1.40E-02 | 1.47E-02 | 0.00 | 0.00 |
| Th-234 | 1.31E+02 | 0.00 | 7.43E-02 | 2.61E-02 | 1.40E-02 | 1.47E-02 | 0.00 | 0.00 |
| Pa-234m | 1.31E+02 | 0.00 | 7.43E-02 | 2.61E-02 | 1.40E-02 | 1.47E-02 | 0.00 | 0.00 |
| Pa-234 | 1.70E-01 | 0.00 | 9.66E-05 | 3.39E-05 | 1.82E-05 | 1.91E-05 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 3.64E+01 | 2.15E+00 | 0.00 | 7.29E-03 | 3.91E-03 | 4.10E-03 | 4.29E-04 | 4.29E-07 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 4.05E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.05E-05 |
| H-3 | 0.00 | 2.93E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 3.56E-01 | 4.89E-04 | 3.57E-01 |
| Co-60 | 9.14E+02 | 3.38E-02 | 3.38E-02 | 7.17E-07 | 2.87E-06 | 0.00 | 4.78E-04 | 6.93E-02 | 9.14E+02 |
| Sr-90 | 0.00 | 1.01E-01 | 1.90E+00 | 8.86E-06 | 3.54E-04 | 0.00 | 1.97E-02 | 1.84E-01 | 2.21E+00 |
| Y-90 | 0.00 | 6.54E-04 | 1.44E-01 | 6.69E-07 | 2.68E-05 | 0.00 | 1.49E-03 | 1.39E-02 | 1.60E-01 |
| Cs-137 | 0.00 | 1.41E-02 | 3.88E-02 | 4.65E-04 | 6.20E-04 | 0.00 | 1.03E-02 | 3.67E-01 | 4.32E-01 |
| Ba-137m | 6.65E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.65E+02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 1.07E-02 | 1.01E+01 | 6.13E-02 | 1.91E-03 | 7.66E-06 | 0.00 | 2.55E-01 | 2.80E-01 | 1.07E+01 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 1.45E-02 | 1.02E+00 | 4.78E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 3.64E-02 | 1.07E+00 |
| Th-234 | 2.26E-01 | 3.00E-04 | 2.57E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 1.95E-03 | 2.29E-01 |
| Pa-234m | 2.53E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.53E-01 |
| Pa-234 | 5.70E-02 | 9.07E-09 | 5.28E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 4.01E-07 | 5.70E-02 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 5.18E-03 | 5.94E-01 | 1.06E-02 | 7.11E-04 | 2.84E-06 | 0.00 | 9.48E-02 | 8.05E-02 | 7.85E-01 |
| Total | 1.58E+03 | 1.18E+01 | 2.20E+00 | 3.10E-03 | 1.01E-03 | 0.00 | 7.38E-01 | 1.03E+00 | 1.60E+03 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 4.94E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.94E-08 |
| H-3 | 0.00 | 3.58E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 3.06E-04 | 4.20E-07 | 3.07E-04 |
| Co-60 | 5.24E-01 | 2.47E-05 | 1.88E-05 | 3.99E-10 | 1.60E-09 | 0.00 | 2.66E-07 | 3.86E-05 | 5.24E-01 |
| Sr-90 | 0.00 | 4.34E-06 | 4.41E-04 | 2.05E-09 | 8.21E-08 | 0.00 | 4.56E-06 | 4.27E-05 | 4.92E-04 |
| Y-90 | 0.00 | 4.27E-07 | 4.27E-05 | 1.99E-10 | 7.96E-09 | 0.00 | 4.42E-07 | 4.14E-06 | 4.73E-05 |
| Cs-137 | 0.00 | 8.38E-06 | 2.17E-05 | 2.61E-07 | 3.48E-07 | 0.00 | 5.80E-06 | 2.06E-04 | 2.42E-04 |
| Ba-137m | 3.70E-01 | 2.50E-10 | 1.76E-09 | 2.12E-11 | 2.82E-11 | 0.00 | 4.70E-10 | 1.67E-08 | 3.70E-01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 7.37E-06 | 1.90E-04 | 4.94E-07 | 1.54E-08 | 6.17E-11 | 0.00 | 2.06E-06 | 2.25E-06 | 2.03E-04 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 1.03E-05 | 2.06E-04 | 2.44E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 1.86E-05 | 2.37E-04 |
| Th-234 | 1.25E-04 | 2.74E-07 | 7.52E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 5.72E-07 | 1.26E-04 |
| Pa-234m | 1.43E-04 | 1.37E-11 | 1.09E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 8.29E-10 | 1.43E-04 |
| Pa-234 | 3.20E-05 | 6.02E-12 | 1.66E-11 | 0.00 | 0.00 | 0.00 | 0.00 | 1.26E-10 | 3.20E-05 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 3.62E-06 | 6.46E-05 | 1.05E-06 | 7.05E-08 | 2.82E-10 | 0.00 | 9.41E-06 | 7.98E-06 | 8.68E-05 |
| Total | 8.94E-01 | 4.99E-04 | 5.28E-04 | 3.49E-07 | 4.40E-07 | 0.00 | 3.29E-04 | 3.21E-04 | 8.96E-01 |

Table 6G.32. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area P

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 9.64E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 1.03E+05 | 9.34E+05 | 1.52E+04 | 2.06E+01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 3.28E+05 | 1.91E+03 | 2.27E-01 | 6.56E+01 | 1.31E+02 | 1.33E+02 | 7.66E-02 | 7.66E-02 |
| Sr-90 | 9.19E+03 | 9.85E+00 | 4.31E+01 | 1.84E+00 | 7.78E+01 | 7.79E+01 | 1.18E-04 | 1.18E-03 |
| Y-90 | 9.19E+03 | 9.85E+00 | 4.31E+01 | 1.84E+00 | 7.78E+01 | 7.79E+01 | 1.18E-04 | 1.18E-03 |
| Cs-137 | 3.91E+05 | 2.74E+01 | 3.40E+00 | 7.82E+01 | 3.37E+01 | 3.57E+01 | 3.29E-02 | 1.10E-02 |
| Ba-137m | 3.70E+05 | 2.59E+01 | 3.21E+00 | 7.40E+01 | 3.18E+01 | 3.38E+01 | 3.11E-02 | 1.04E-02 |
| Eu-152 | 1.08E+07 | 4.38E+01 | 0.00 | 2.16E+03 | 1.16E+03 | 1.22E+03 | 8.76E-03 | 8.76E-06 |
| Eu-154 | 5.81E+06 | 1.69E+02 | 0.00 | 1.16E+03 | 6.23E+02 | 6.53E+02 | 3.37E-02 | 3.37E-05 |
| Eu-155 | 7.75E+05 | 2.34E+00 | 0.00 | 1.55E+02 | 8.31E+01 | 8.71E+01 | 4.69E-04 | 4.69E-07 |
| Th-232 | 6.72E+05 | 0.00 | 0.00 | 1.34E+02 | 1.20E+02 | 1.24E+02 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 1.94E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 2.03E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.03E-05 |
| H-3 | 0.00 | 4.33E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 1.31E+00 | 7.22E-03 | 1.32E+00 |
| Co-60 | 1.28E+05 | 4.71E+00 | 4.72E+00 | 1.69E-03 | 6.78E-03 | 0.00 | 1.13E+00 | 9.67E+00 | 1.28E+05 |
| Sr-90 | 0.00 | 7.84E-01 | 1.48E+01 | 1.38E-05 | 5.53E-04 | 0.00 | 3.07E-02 | 1.43E+00 | 1.71E+01 |
| Y-90 | 0.00 | 5.10E-03 | 1.12E+00 | 1.05E-06 | 4.18E-05 | 0.00 | 2.32E-03 | 1.08E-01 | 1.24E+00 |
| Cs-137 | 0.00 | 8.21E-01 | 2.26E+00 | 1.35E-03 | 1.80E-03 | 0.00 | 3.00E-02 | 2.14E+01 | 2.45E+01 |
| Ba-137m | 3.88E+04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.88E+04 |
| Eu-152 | 2.06E+06 | 1.57E+02 | 1.01E+01 | 4.66E-05 | 1.86E-07 | 0.00 | 6.21E-03 | 7.67E+01 | 2.06E+06 |
| Eu-154 | 1.21E+06 | 1.09E+02 | 7.98E+00 | 2.64E-04 | 1.06E-06 | 0.00 | 3.52E-02 | 6.07E+01 | 1.21E+06 |
| Eu-155 | 9.50E+03 | 2.11E+00 | 1.70E-01 | 5.88E-07 | 2.35E-09 | 0.00 | 7.84E-05 | 1.30E+00 | 9.50E+03 |
| Th-232 | 7.67E+01 | 7.23E+04 | 4.40E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 2.01E+03 | 7.48E+04 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 3.44E+06 | 7.26E+04 | 4.81E+02 | 3.37E-03 | 9.17E-03 | 0.00 | 2.54E+00 | 2.18E+03 | 3.51E+06 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 2.47E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.47E-08 |
| H-3 | 0.00 | 5.28E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 1.12E-03 | 6.21E-06 | 1.13E-03 |
| Co-60 | 7.31E+01 | 3.45E-03 | 2.63E-03 | 9.43E-07 | 3.77E-06 | 0.00 | 6.29E-04 | 5.38E-03 | 7.31E+01 |
| Sr-90 | 0.00 | 3.38E-05 | 3.43E-03 | 3.20E-09 | 1.28E-07 | 0.00 | 7.12E-06 | 3.32E-04 | 3.81E-03 |
| Y-90 | 0.00 | 3.32E-06 | 3.33E-04 | 3.11E-10 | 1.24E-08 | 0.00 | 6.90E-07 | 3.22E-05 | 3.69E-04 |
| Cs-137 | 0.00 | 4.88E-04 | 1.27E-03 | 7.57E-07 | 1.01E-06 | 0.00 | 1.68E-05 | 1.20E-02 | 1.38E-02 |
| Ba-137m | 2.16E+01 | 1.46E-08 | 1.03E-07 | 6.14E-11 | 8.18E-11 | 0.00 | 1.36E-09 | 9.72E-07 | 2.16E+01 |
| Eu-152 | 1.17E+03 | 8.52E+00 | 3.27E-03 | 1.51E-08 | 6.04E-11 | 0.00 | 2.01E-06 | 2.49E-02 | 1.18E+03 |
| Eu-154 | 6.77E+02 | 5.34E-02 | 2.51E-03 | 8.30E-08 | 3.32E-10 | 0.00 | 1.11E-05 | 1.91E-02 | 6.77E+02 |
| Eu-155 | 6.91E+00 | 1.53E-01 | 5.80E-05 | 2.00E-10 | 8.01E-13 | 0.00 | 2.67E-08 | 4.41E-04 | 7.06E+00 |
| Th-232 | 5.30E-02 | 1.37E+00 | 3.55E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 1.62E-02 | 1.44E+00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.95E+03 | 1.01E+01 | 1.70E-02 | 1.80E-06 | 4.92E-06 | 0.00 | 1.79E-03 | 7.83E-02 | 1.96E+03 |

Table 6G.33. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area Q

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 9.64E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 1.44E+02 | 9.30E+03 | 1.52E+04 | 2.88E-02 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 2.02E+03 | 8.14E+00 | 2.27E-01 | 4.04E-01 | 8.07E-01 | 8.18E-01 | 3.26E-04 | 3.26E-04 |
| Sr-90 | 4.00E+03 | 7.08E+00 | 4.31E+01 | 8.00E-01 | 3.39E+01 | 3.39E+01 | 8.49E-05 | 8.49E-04 |
| Y-90 | 4.00E+03 | 7.08E+00 | 4.31E+01 | 8.00E-01 | 3.39E+01 | 3.39E+01 | 8.49E-05 | 8.49E-04 |
| Cs-137 | 2.03E+04 | 2.44E+00 | 3.40E+00 | 4.05E+00 | 1.74E+00 | 1.85E+00 | 2.92E-03 | 9.74E-04 |
| Ba-137m | 1.92E+04 | 2.30E+00 | 3.21E+00 | 3.83E+00 | 1.65E+00 | 1.75E+00 | 2.76E-03 | 9.22E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 1.94E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 2.03E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.03E-05 |
| H-3 | 0.00 | 6.05E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 1.30E-02 | 1.01E-05 | 1.30E-02 |
| Co-60 | 7.87E+02 | 2.90E-02 | 2.91E-02 | 7.20E-06 | 2.88E-05 | 0.00 | 4.80E-03 | 5.96E-02 | 7.87E+02 |
| Sr-90 | 0.00 | 3.41E-01 | 6.45E+00 | 9.93E-06 | 3.97E-04 | 0.00 | 2.21E-02 | 6.24E-01 | 7.43E+00 |
| Y-90 | 0.00 | 2.22E-03 | 4.87E-01 | 7.51E-07 | 3.00E-05 | 0.00 | 1.67E-03 | 4.72E-02 | 5.38E-01 |
| Cs-137 | 0.00 | 4.25E-02 | 1.17E-01 | 1.20E-04 | 1.60E-04 | 0.00 | 2.66E-03 | 1.11E+00 | 1.27E+00 |
| Ba-137m | 2.01E+03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.01E+03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.80E+03 | 4.15E-01 | 7.08E+00 | 1.38E-04 | 6.16E-04 | 0.00 | 4.42E-02 | 1.84E+00 | 2.80E+03 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 2.47E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.47E-08 |
| H-3 | 0.00 | 7.37E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 1.12E-05 | 8.66E-09 | 1.12E-05 |
| Co-60 | 4.51E-01 | 2.13E-05 | 1.62E-05 | 4.01E-09 | 1.60E-08 | 0.00 | 2.67E-06 | 3.32E-05 | 4.51E-01 |
| Sr-90 | 0.00 | 1.47E-05 | 1.49E-03 | 2.30E-09 | 9.21E-08 | 0.00 | 5.11E-06 | 1.45E-04 | 1.66E-03 |
| Y-90 | 0.00 | 1.45E-06 | 1.45E-04 | 2.23E-10 | 8.93E-09 | 0.00 | 4.96E-07 | 1.40E-05 | 1.61E-04 |
| Cs-137 | 0.00 | 2.53E-05 | 6.56E-05 | 6.72E-08 | 8.96E-08 | 0.00 | 1.49E-06 | 6.21E-04 | 7.14E-04 |
| Ba-137m | 1.12E+00 | 7.56E-10 | 5.32E-09 | 5.45E-12 | 7.27E-12 | 0.00 | 1.21E-10 | 5.04E-08 | 1.12E+00 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.57E+00 | 6.27E-05 | 1.72E-03 | 7.38E-08 | 2.07E-07 | 0.00 | 2.10E-05 | 8.13E-04 | 1.57E+00 |

Table 6G.34. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area R

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 2.89E+00 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 9.86E+02 | 2.50E+04 | 1.52E+04 | 1.97E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 1.73E+04 | 1.71E+01 | 2.27E-01 | 3.46E+00 | 6.91E+00 | 7.00E+00 | 6.85E-04 | 6.85E-04 |
| Sr-90 | 2.21E+03 | 2.27E+01 | 4.31E+01 | 4.42E-01 | 1.87E+01 | 1.87E+01 | 2.72E-04 | 2.72E-03 |
| Y-90 | 2.21E+03 | 2.27E+01 | 4.31E+01 | 4.42E-01 | 1.87E+01 | 1.87E+01 | 2.72E-04 | 2.72E-03 |
| Cs-137 | 4.05E+03 | 0.00 | 3.40E+00 | 8.11E-01 | 3.49E-01 | 3.70E-01 | 0.00 | 0.00 |
| Ba-137m | 3.83E+03 | 0.00 | 3.21E+00 | 7.67E-01 | 3.30E-01 | 3.50E-01 | 0.00 | 0.00 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 1.94E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 6.08E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.08E-05 |
| H-3 | 0.00 | 4.15E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 3.50E-02 | 6.91E-05 | 3.51E-02 |
| Co-60 | 6.74E+03 | 2.49E-01 | 2.49E-01 | 1.51E-05 | 6.06E-05 | 0.00 | 1.01E-02 | 5.11E-01 | 6.74E+03 |
| Sr-90 | 0.00 | 1.89E-01 | 3.56E+00 | 3.18E-05 | 1.27E-03 | 0.00 | 7.07E-02 | 3.45E-01 | 4.17E+00 |
| Y-90 | 0.00 | 1.22E-03 | 2.69E-01 | 2.40E-06 | 9.62E-05 | 0.00 | 5.34E-03 | 2.61E-02 | 3.02E-01 |
| Cs-137 | 0.00 | 8.50E-03 | 2.34E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 2.22E-01 | 2.54E-01 |
| Ba-137m | 4.02E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.02E+02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 7.14E+03 | 4.47E-01 | 4.10E+00 | 4.94E-05 | 1.43E-03 | 0.00 | 1.21E-01 | 1.10E+00 | 7.15E+03 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 7.41E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.41E-08 |
| H-3 | 0.00 | 5.05E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 3.01E-05 | 5.94E-08 | 3.02E-05 |
| Co-60 | 3.86E+00 | 1.82E-04 | 1.39E-04 | 8.43E-09 | 3.37E-08 | 0.00 | 5.62E-06 | 2.84E-04 | 3.86E+00 |
| Sr-90 | 0.00 | 8.13E-06 | 8.25E-04 | 7.37E-09 | 2.95E-07 | 0.00 | 1.64E-05 | 7.99E-05 | 9.30E-04 |
| Y-90 | 0.00 | 7.99E-07 | 8.00E-05 | 7.15E-10 | 2.86E-08 | 0.00 | 1.59E-06 | 7.74E-06 | 9.02E-05 |
| Cs-137 | 0.00 | 5.06E-06 | 1.31E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-04 | 1.42E-04 |
| Ba-137m | 2.24E-01 | 1.51E-10 | 1.06E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-08 | 2.24E-01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 4.08E+00 | 1.96E-04 | 1.06E-03 | 1.65E-08 | 3.57E-07 | 0.00 | 5.37E-05 | 4.96E-04 | 4.08E+00 |

Table 6G.35. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area S

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 2.89E+00 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 7.27E+02 | 1.85E+04 | 1.52E+04 | 1.45E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 5.98E-02 | 1.07E+00 | 2.27E-01 | 1.20E-05 | 2.39E-05 | 2.42E-05 | 4.30E-05 | 4.30E-05 |
| Sr-90 | 4.96E-02 | 4.19E+00 | 4.31E+01 | 9.92E-06 | 4.20E-04 | 4.20E-04 | 5.03E-05 | 5.03E-04 |
| Y-90 | 4.96E-02 | 4.19E+00 | 4.31E+01 | 9.92E-06 | 4.20E-04 | 4.20E-04 | 5.03E-05 | 5.03E-04 |
| Cs-137 | 1.13E+00 | 9.63E+00 | 3.40E+00 | 2.25E-04 | 9.69E-05 | 1.03E-04 | 1.16E-02 | 3.85E-03 |
| Ba-137m | 1.07E+00 | 9.11E+00 | 3.21E+00 | 2.13E-04 | 9.17E-05 | 9.73E-05 | 1.09E-02 | 3.64E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 1.94E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 6.08E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.08E-05 |
| H-3 | 0.00 | 3.06E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 2.59E-02 | 5.10E-05 | 2.59E-02 |
| Co-60 | 2.33E-02 | 8.58E-07 | 8.60E-07 | 9.51E-07 | 3.80E-06 | 0.00 | 6.34E-04 | 1.76E-06 | 2.39E-02 |
| Sr-90 | 0.00 | 4.23E-06 | 7.99E-05 | 5.88E-06 | 2.35E-04 | 0.00 | 1.31E-02 | 7.74E-06 | 1.34E-02 |
| Y-90 | 0.00 | 2.75E-08 | 6.04E-06 | 4.45E-07 | 1.78E-05 | 0.00 | 9.88E-04 | 5.85E-07 | 1.01E-03 |
| Cs-137 | 0.00 | 2.36E-06 | 6.51E-06 | 4.74E-04 | 6.32E-04 | 0.00 | 1.05E-02 | 6.16E-05 | 1.17E-02 |
| Ba-137m | 1.12E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.12E-01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.35E-01 | 7.14E-05 | 9.33E-05 | 4.81E-04 | 8.89E-04 | 0.00 | 5.11E-02 | 1.23E-04 | 1.88E-01 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 7.41E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.41E-08 |
| H-3 | 0.00 | 3.73E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 2.22E-05 | 4.38E-08 | 2.23E-05 |
| Co-60 | 1.33E-05 | 6.28E-10 | 4.79E-10 | 5.29E-10 | 2.12E-09 | 0.00 | 3.53E-07 | 9.81E-10 | 1.37E-05 |
| Sr-90 | 0.00 | 1.82E-10 | 1.85E-08 | 1.36E-09 | 5.45E-08 | 0.00 | 3.03E-06 | 1.79E-09 | 3.11E-06 |
| Y-90 | 0.00 | 1.79E-11 | 1.80E-09 | 1.32E-10 | 5.29E-09 | 0.00 | 2.94E-07 | 1.74E-10 | 3.01E-07 |
| Cs-137 | 0.00 | 1.41E-09 | 3.65E-09 | 2.66E-07 | 3.54E-07 | 0.00 | 5.91E-06 | 3.45E-08 | 6.57E-06 |
| Ba-137m | 6.21E-05 | 4.20E-14 | 2.96E-13 | 2.15E-11 | 2.87E-11 | 0.00 | 4.79E-10 | 2.80E-12 | 6.21E-05 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 7.54E-05 | 8.01E-08 | 2.44E-08 | 2.68E-07 | 4.16E-07 | 0.00 | 3.18E-05 | 8.13E-08 | 1.08E-04 |

Table 6G.36. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area T

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 2.89E+00 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 1.38E+03 | 5.39E+04 | 1.52E+04 | 2.76E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 4.96E-03 | 6.76E-01 | 2.27E-01 | 9.93E-07 | 1.98E-06 | 2.01E-06 | 2.71E-05 | 2.71E-05 |
| Sr-90 | 3.89E-01 | 4.50E+00 | 4.31E+01 | 7.79E-05 | 3.30E-03 | 3.30E-03 | 5.40E-05 | 5.40E-04 |
| Y-90 | 3.89E-01 | 4.50E+00 | 4.31E+01 | 7.79E-05 | 3.30E-03 | 3.30E-03 | 5.40E-05 | 5.40E-04 |
| Cs-137 | 3.47E-02 | 4.74E+00 | 3.40E+00 | 6.94E-06 | 2.99E-06 | 3.17E-06 | 5.69E-03 | 1.90E-03 |
| Ba-137m | 3.28E-02 | 4.49E+00 | 3.21E+00 | 6.57E-06 | 2.83E-06 | 3.00E-06 | 5.39E-03 | 1.80E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 1.94E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 6.08E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.08E-05 |
| H-3 | 0.00 | 5.79E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 7.55E-02 | 9.66E-05 | 7.56E-02 |
| Co-60 | 1.93E-03 | 7.13E-08 | 7.14E-08 | 5.98E-07 | 2.39E-06 | 0.00 | 3.99E-04 | 1.46E-07 | 2.33E-03 |
| Sr-90 | 0.00 | 3.32E-05 | 6.28E-04 | 6.31E-06 | 2.52E-04 | 0.00 | 1.40E-02 | 6.07E-05 | 1.50E-02 |
| Y-90 | 0.00 | 2.16E-07 | 4.74E-05 | 4.77E-07 | 1.91E-05 | 0.00 | 1.06E-03 | 4.59E-06 | 1.13E-03 |
| Cs-137 | 0.00 | 7.28E-08 | 2.01E-07 | 2.34E-04 | 3.11E-04 | 0.00 | 5.19E-03 | 1.90E-06 | 5.74E-03 |
| Ba-137m | 3.44E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.44E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 5.37E-03 | 1.00E-04 | 6.75E-04 | 2.41E-04 | 5.85E-04 | 0.00 | 9.62E-02 | 1.64E-04 | 1.03E-01 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 7.41E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.41E-08 |
| H-3 | 0.00 | 7.06E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 6.49E-05 | 8.30E-08 | 6.50E-05 |
| Co-60 | 1.11E-06 | 5.22E-11 | 3.98E-11 | 3.33E-10 | 1.33E-09 | 0.00 | 2.22E-07 | 8.15E-11 | 1.33E-06 |
| Sr-90 | 0.00 | 1.43E-09 | 1.45E-07 | 1.46E-09 | 5.85E-08 | 0.00 | 3.25E-06 | 1.41E-08 | 3.47E-06 |
| Y-90 | 0.00 | 1.41E-10 | 1.41E-08 | 1.42E-10 | 5.67E-09 | 0.00 | 3.15E-07 | 1.36E-09 | 3.37E-07 |
| Cs-137 | 0.00 | 4.33E-11 | 1.12E-10 | 1.31E-07 | 1.75E-07 | 0.00 | 2.91E-06 | 1.06E-09 | 3.22E-06 |
| Ba-137m | 1.91E-06 | 1.29E-15 | 9.12E-15 | 1.06E-11 | 1.42E-11 | 0.00 | 2.36E-10 | 8.63E-14 | 1.91E-06 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 3.02E-06 | 8.28E-08 | 1.60E-07 | 1.33E-07 | 2.40E-07 | 0.00 | 7.16E-05 | 9.96E-08 | 7.53E-05 |

Table 6G.37. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area U

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 9.64E+00 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 1.38E+03 | 4.16E+04 | 1.52E+04 | 2.77E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 2.45E-02 | 1.59E+00 | 2.27E-01 | 4.90E-06 | 9.78E-06 | 9.91E-06 | 6.35E-05 | 6.35E-05 |
| Sr-90 | 6.52E-01 | 6.96E+00 | 4.31E+01 | 1.30E-04 | 5.52E-03 | 5.52E-03 | 8.35E-05 | 8.35E-04 |
| Y-90 | 6.52E-01 | 6.96E+00 | 4.31E+01 | 1.30E-04 | 5.52E-03 | 5.52E-03 | 8.35E-05 | 8.35E-04 |
| Cs-137 | 9.82E-02 | 9.13E+00 | 3.40E+00 | 1.96E-05 | 8.45E-06 | 8.96E-06 | 1.10E-02 | 3.65E-03 |
| Ba-137m | 9.29E-02 | 8.63E+00 | 3.21E+00 | 1.86E-05 | 7.99E-06 | 8.48E-06 | 1.04E-02 | 3.45E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 1.94E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 2.03E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.03E-04 |
| H-3 | 0.00 | 5.81E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 5.84E-02 | 9.69E-05 | 5.85E-02 |
| Co-60 | 9.53E-03 | 3.52E-07 | 3.52E-07 | 1.40E-06 | 5.62E-06 | 0.00 | 9.36E-04 | 7.22E-07 | 1.05E-02 |
| Sr-90 | 0.00 | 5.56E-05 | 1.05E-03 | 9.77E-06 | 3.91E-04 | 0.00 | 2.17E-02 | 1.02E-04 | 2.33E-02 |
| Y-90 | 0.00 | 3.61E-07 | 7.94E-05 | 7.39E-07 | 2.95E-05 | 0.00 | 1.64E-03 | 7.68E-06 | 1.76E-03 |
| Cs-137 | 0.00 | 2.06E-07 | 5.67E-07 | 4.49E-04 | 5.99E-04 | 0.00 | 9.98E-03 | 5.37E-06 | 1.10E-02 |
| Ba-137m | 9.73E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9.73E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.93E-02 | 2.65E-04 | 1.13E-03 | 4.61E-04 | 1.03E-03 | 0.00 | 9.27E-02 | 2.12E-04 | 1.15E-01 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 2.47E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.47E-07 |
| H-3 | 0.00 | 7.09E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 5.02E-05 | 8.33E-08 | 5.02E-05 |
| Co-60 | 5.46E-06 | 2.57E-10 | 1.96E-10 | 7.82E-10 | 3.13E-09 | 0.00 | 5.21E-07 | 4.02E-10 | 5.98E-06 |
| Sr-90 | 0.00 | 2.40E-09 | 2.43E-07 | 2.26E-09 | 9.05E-08 | 0.00 | 5.03E-06 | 2.35E-08 | 5.39E-06 |
| Y-90 | 0.00 | 2.35E-10 | 2.36E-08 | 2.19E-10 | 8.78E-09 | 0.00 | 4.88E-07 | 2.28E-09 | 5.23E-07 |
| Cs-137 | 0.00 | 1.23E-10 | 3.18E-10 | 2.52E-07 | 3.36E-07 | 0.00 | 5.60E-06 | 3.01E-09 | 6.19E-06 |
| Ba-137m | 5.41E-06 | 3.66E-15 | 2.58E-14 | 2.04E-11 | 2.72E-11 | 0.00 | 4.54E-10 | 2.44E-13 | 5.41E-06 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.09E-05 | 2.57E-07 | 2.67E-07 | 2.55E-07 | 4.38E-07 | 0.00 | 6.18E-05 | 1.13E-07 | 7.40E-05 |

Table 6G.38. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area V

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 6.75E+00 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 2.17E+03 | 2.22E+04 | 1.52E+04 | 4.34E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 1.93E+02 | 4.08E-01 | 2.27E-01 | 3.86E-02 | 7.71E-02 | 7.81E-02 | 1.63E-05 | 1.63E-05 |
| Sr-90 | 3.45E+02 | 5.34E+00 | 4.31E+01 | 6.90E-02 | 2.92E+00 | 2.92E+00 | 6.41E-05 | 6.41E-04 |
| Y-90 | 3.45E+02 | 5.34E+00 | 4.31E+01 | 6.90E-02 | 2.92E+00 | 2.92E+00 | 6.41E-05 | 6.41E-04 |
| Cs-137 | 1.30E+03 | 3.16E+00 | 3.40E+00 | 2.61E-01 | 1.12E-01 | 1.19E-01 | 3.80E-03 | 1.27E-03 |
| Ba-137m | 1.23E+03 | 2.99E+00 | 3.21E+00 | 2.46E-01 | 1.06E-01 | 1.13E-01 | 3.59E-03 | 1.20E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 8.56E+02 | 0.00 | 1.94E-01 | 1.71E-01 | 9.18E-02 | 9.63E-02 | 0.00 | 0.00 |
| U-238 | 1.58E+03 | 0.00 | 7.43E-02 | 3.15E-01 | 1.69E-01 | 1.77E-01 | 0.00 | 0.00 |
| Th-234 | 1.58E+03 | 0.00 | 7.43E-02 | 3.15E-01 | 1.69E-01 | 1.77E-01 | 0.00 | 0.00 |
| Pa-234m | 1.58E+03 | 0.00 | 7.43E-02 | 3.15E-01 | 1.69E-01 | 1.77E-01 | 0.00 | 0.00 |
| Pa-234 | 2.05E+00 | 0.00 | 9.66E-05 | 4.10E-04 | 2.20E-04 | 2.31E-04 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.42E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.42E-04 |
| H-3 | 0.00 | 9.12E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 3.11E-02 | 1.52E-04 | 3.13E-02 |
| Co-60 | 7.51E+01 | 2.77E-03 | 2.78E-03 | 3.61E-07 | 1.44E-06 | 0.00 | 2.40E-04 | 5.69E-03 | 7.51E+01 |
| Sr-90 | 0.00 | 2.94E-02 | 5.56E-01 | 7.50E-06 | 3.00E-04 | 0.00 | 1.67E-02 | 5.38E-02 | 6.56E-01 |
| Y-90 | 0.00 | 1.91E-04 | 4.20E-02 | 5.67E-07 | 2.27E-05 | 0.00 | 1.26E-03 | 4.07E-03 | 4.75E-02 |
| Cs-137 | 0.00 | 2.73E-03 | 7.53E-03 | 1.56E-04 | 2.08E-04 | 0.00 | 3.46E-03 | 7.12E-02 | 8.53E-02 |
| Ba-137m | 1.29E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.29E+02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 7.34E-02 | 7.62E+00 | 3.56E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 2.71E-01 | 8.00E+00 |
| U-238 | 1.75E-01 | 1.23E+01 | 5.78E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 4.40E-01 | 1.29E+01 |
| Th-234 | 2.73E+00 | 3.63E-03 | 3.10E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 2.36E-02 | 2.76E+00 |
| Pa-234m | 3.06E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.06E+00 |
| Pa-234 | 6.89E-01 | 1.10E-07 | 6.38E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 4.85E-06 | 6.89E-01 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.11E+02 | 1.99E+01 | 7.05E-01 | 1.64E-04 | 5.32E-04 | 0.00 | 5.28E-02 | 8.69E-01 | 2.32E+02 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.73E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.73E-07 |
| H-3 | 0.00 | 1.11E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 2.68E-05 | 1.31E-07 | 2.69E-05 |
| Co-60 | 4.30E-02 | 2.03E-06 | 1.55E-06 | 2.01E-10 | 8.03E-10 | 0.00 | 1.34E-07 | 3.17E-06 | 4.30E-02 |
| Sr-90 | 0.00 | 1.27E-06 | 1.29E-04 | 1.74E-09 | 6.95E-08 | 0.00 | 3.86E-06 | 1.25E-05 | 1.46E-04 |
| Y-90 | 0.00 | 1.25E-07 | 1.25E-05 | 1.68E-10 | 6.74E-09 | 0.00 | 3.74E-07 | 1.21E-06 | 1.42E-05 |
| Cs-137 | 0.00 | 1.63E-06 | 4.22E-06 | 8.73E-08 | 1.16E-07 | 0.00 | 1.94E-06 | 3.99E-05 | 4.79E-05 |
| Ba-137m | 7.18E-02 | 4.86E-11 | 3.42E-10 | 7.08E-12 | 9.44E-12 | 0.00 | 1.57E-10 | 3.24E-09 | 7.18E-02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 4.84E-05 | 1.52E-03 | 1.73E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 1.31E-04 | 1.72E-03 |
| U-238 | 1.24E-04 | 2.49E-03 | 2.95E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 2.25E-04 | 2.87E-03 |
| Th-234 | 1.51E-03 | 3.32E-06 | 9.08E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 6.91E-06 | 1.53E-03 |
| Pa-234m | 1.73E-03 | 1.66E-10 | 1.32E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00E-08 | 1.73E-03 |
| Pa-234 | 3.87E-04 | 7.27E-11 | 2.01E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 1.53E-09 | 3.87E-04 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.19E-01 | 4.01E-03 | 1.95E-04 | 8.94E-08 | 1.93E-07 | 0.00 | 3.31E-05 | 4.20E-04 | 1.23E-01 |

Table 6G.39. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area W

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E+00 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 6.57E+01 | 6.29E+04 | 1.52E+04 | 1.31E-02 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 1.10E+00 | 0.00 | 2.27E-01 | 2.20E-04 | 4.40E-04 | 4.46E-04 | 0.00 | 0.00 |
| Sr-90 | 8.70E-01 | 2.99E-01 | 4.31E+01 | 1.74E-04 | 7.37E-03 | 7.37E-03 | 3.59E-06 | 3.59E-05 |
| Y-90 | 8.70E-01 | 2.99E-01 | 4.31E+01 | 1.74E-04 | 7.37E-03 | 7.37E-03 | 3.59E-06 | 3.59E-05 |
| Cs-137 | 8.16E-01 | 0.00 | 3.40E+00 | 1.63E-04 | 7.02E-05 | 7.45E-05 | 0.00 | 0.00 |
| Ba-137m | 7.72E-01 | 0.00 | 3.21E+00 | 1.54E-04 | 6.65E-05 | 7.05E-05 | 0.00 | 0.00 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 1.94E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-04 |
| H-3 | 0.00 | 2.76E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 8.82E-02 | 4.61E-06 | 8.82E-02 |
| Co-60 | 4.29E-01 | 1.58E-05 | 1.58E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 3.25E-05 | 4.29E-01 |
| Sr-90 | 0.00 | 7.43E-05 | 1.40E-03 | 4.20E-07 | 1.68E-05 | 0.00 | 9.33E-04 | 1.36E-04 | 2.56E-03 |
| Y-90 | 0.00 | 4.82E-07 | 1.06E-04 | 3.17E-08 | 1.27E-06 | 0.00 | 7.05E-05 | 1.03E-05 | 1.89E-04 |
| Cs-137 | 0.00 | 1.71E-06 | 4.72E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 4.46E-05 | 5.11E-05 |
| Ba-137m | 8.09E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.09E-02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 5.10E-01 | 1.94E-04 | 1.53E-03 | 4.51E-07 | 1.81E-05 | 0.00 | 8.92E-02 | 2.28E-04 | 6.01E-01 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-07 |
| H-3 | 0.00 | 3.37E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 7.58E-05 | 3.96E-09 | 7.58E-05 |
| Co-60 | 2.46E-04 | 1.16E-08 | 8.83E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 1.81E-08 | 2.46E-04 |
| Sr-90 | 0.00 | 3.20E-09 | 3.25E-07 | 9.72E-11 | 3.89E-09 | 0.00 | 2.16E-07 | 3.14E-08 | 5.80E-07 |
| Y-90 | 0.00 | 3.14E-10 | 3.15E-08 | 9.43E-12 | 3.77E-10 | 0.00 | 2.09E-08 | 3.05E-09 | 5.62E-08 |
| Cs-137 | 0.00 | 1.02E-09 | 2.64E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 2.50E-08 | 2.87E-08 |
| Ba-137m | 4.50E-05 | 3.04E-14 | 2.14E-13 | 0.00 | 0.00 | 0.00 | 0.00 | 2.03E-12 | 4.50E-05 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.91E-04 | 1.40E-07 | 3.68E-07 | 1.07E-10 | 4.27E-09 | 0.00 | 7.60E-05 | 8.16E-08 | 3.67E-04 |

Table 6G.40. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area X

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 2.89E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 1.19E+03 | 4.80E+04 | 1.52E+04 | 2.38E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 4.94E+01 | 7.95E-01 | 2.27E-01 | 9.87E-03 | 1.97E-02 | 2.00E-02 | 3.18E-05 | 3.18E-05 |
| Sr-90 | 1.96E+02 | 4.65E+00 | 4.31E+01 | 3.91E-02 | 1.66E+00 | 1.66E+00 | 5.57E-05 | 5.57E-04 |
| Y-90 | 1.96E+02 | 4.65E+00 | 4.31E+01 | 3.91E-02 | 1.66E+00 | 1.66E+00 | 5.57E-05 | 5.57E-04 |
| Cs-137 | 6.26E+01 | 2.57E+00 | 3.40E+00 | 1.25E-02 | 5.39E-03 | 5.72E-03 | 3.08E-03 | 1.03E-03 |
| Ba-137m | 5.92E+01 | 2.43E+00 | 3.21E+00 | 1.18E-02 | 5.10E-03 | 5.41E-03 | 2.92E-03 | 9.72E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 1.94E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 6.08E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.08E-06 |
| H-3 | 0.00 | 5.01E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 6.72E-02 | 8.34E-05 | 6.73E-02 |
| Co-60 | 1.92E+01 | 7.09E-04 | 7.10E-04 | 7.04E-07 | 2.82E-06 | 0.00 | 4.69E-04 | 1.46E-03 | 1.92E+01 |
| Sr-90 | 0.00 | 1.67E-02 | 3.15E-01 | 6.52E-06 | 2.61E-04 | 0.00 | 1.45E-02 | 3.05E-02 | 3.77E-01 |
| Y-90 | 0.00 | 1.08E-04 | 2.38E-02 | 4.93E-07 | 1.97E-05 | 0.00 | 1.10E-03 | 2.31E-03 | 2.74E-02 |
| Cs-137 | 0.00 | 1.31E-04 | 3.62E-04 | 1.26E-04 | 1.69E-04 | 0.00 | 2.81E-03 | 3.42E-03 | 7.02E-03 |
| Ba-137m | 6.20E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.20E+00 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.54E+01 | 1.77E-02 | 3.40E-01 | 1.34E-04 | 4.52E-04 | 0.00 | 8.61E-02 | 3.78E-02 | 2.59E+01 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 7.41E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.41E-09 |
| H-3 | 0.00 | 6.10E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 5.78E-05 | 7.17E-08 | 5.78E-05 |
| Co-60 | 1.10E-02 | 5.19E-07 | 3.96E-07 | 3.92E-10 | 1.57E-09 | 0.00 | 2.61E-07 | 8.11E-07 | 1.10E-02 |
| Sr-90 | 0.00 | 7.20E-07 | 7.31E-05 | 1.51E-09 | 6.04E-08 | 0.00 | 3.36E-06 | 7.07E-06 | 8.43E-05 |
| Y-90 | 0.00 | 7.07E-08 | 7.08E-06 | 1.47E-10 | 5.86E-09 | 0.00 | 3.26E-07 | 6.86E-07 | 8.17E-06 |
| Cs-137 | 0.00 | 7.81E-08 | 2.03E-07 | 7.09E-08 | 9.45E-08 | 0.00 | 1.58E-06 | 1.92E-06 | 3.94E-06 |
| Ba-137m | 3.45E-03 | 2.33E-12 | 1.64E-11 | 5.75E-12 | 7.67E-12 | 0.00 | 1.28E-10 | 1.56E-10 | 3.45E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.45E-02 | 1.40E-06 | 8.07E-05 | 7.30E-08 | 1.62E-07 | 0.00 | 6.33E-05 | 1.06E-05 | 1.46E-02 |

Table 6G.41. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area Y

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 3.86E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 2.03E+04 | 3.31E+04 | 1.52E+04 | 4.06E+00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 6.74E+04 | 3.81E+00 | 2.27E-01 | 1.35E+01 | 2.69E+01 | 2.73E+01 | 1.52E-04 | 1.52E-04 |
| Sr-90 | 1.66E+03 | 3.58E+00 | 4.31E+01 | 3.33E-01 | 1.41E+01 | 1.41E+01 | 4.30E-05 | 4.30E-04 |
| Y-90 | 1.66E+03 | 3.58E+00 | 4.31E+01 | 3.33E-01 | 1.41E+01 | 1.41E+01 | 4.30E-05 | 4.30E-04 |
| Cs-137 | 1.81E+03 | 2.00E+00 | 3.40E+00 | 3.63E-01 | 1.56E-01 | 1.66E-01 | 2.39E-03 | 7.98E-04 |
| Ba-137m | 1.72E+03 | 1.89E+00 | 3.21E+00 | 3.43E-01 | 1.48E-01 | 1.57E-01 | 2.26E-03 | 7.55E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 8.92E+03 | 0.00 | 1.94E-01 | 1.78E+00 | 9.56E-01 | 1.00E+00 | 0.00 | 0.00 |
| U-238 | 1.56E+04 | 0.00 | 7.43E-02 | 3.12E+00 | 1.67E+00 | 1.75E+00 | 0.00 | 0.00 |
| Th-234 | 1.56E+04 | 0.00 | 7.43E-02 | 3.12E+00 | 1.67E+00 | 1.75E+00 | 0.00 | 0.00 |
| Pa-234m | 1.56E+04 | 0.00 | 7.43E-02 | 3.12E+00 | 1.67E+00 | 1.75E+00 | 0.00 | 0.00 |
| Pa-234 | 2.02E+01 | 0.00 | 9.66E-05 | 4.05E-03 | 2.17E-03 | 2.28E-03 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 7.89E+02 | 0.00 | 0.00 | 1.58E-01 | 8.46E-02 | 8.88E-02 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 8.11E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.11E-06 |
| H-3 | 0.00 | 8.53E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 4.64E-02 | 1.42E-03 | 4.79E-02 |
| Co-60 | 2.62E+04 | 9.69E-01 | 9.70E-01 | 3.37E-06 | 1.35E-05 | 0.00 | 2.24E-03 | 1.99E+00 | 2.63E+04 |
| Sr-90 | 0.00 | 1.42E-01 | 2.68E+00 | 5.03E-06 | 2.01E-04 | 0.00 | 1.12E-02 | 2.59E-01 | 3.09E+00 |
| Y-90 | 0.00 | 9.22E-04 | 2.03E-01 | 3.80E-07 | 1.52E-05 | 0.00 | 8.44E-04 | 1.96E-02 | 2.24E-01 |
| Cs-137 | 0.00 | 3.81E-03 | 1.05E-02 | 9.82E-05 | 1.31E-04 | 0.00 | 2.18E-03 | 9.92E-02 | 1.16E-01 |
| Ba-137m | 1.80E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.80E+02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 7.64E-01 | 7.93E+01 | 3.71E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 2.82E+00 | 8.33E+01 |
| U-238 | 1.73E+00 | 1.21E+02 | 5.71E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 4.34E+00 | 1.28E+02 |
| Th-234 | 2.70E+01 | 3.59E-02 | 3.06E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 2.33E-01 | 2.73E+01 |
| Pa-234m | 3.02E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.02E+01 |
| Pa-234 | 6.80E+00 | 1.08E-06 | 6.30E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 4.79E-05 | 6.80E+00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 1.12E-01 | 1.29E+01 | 2.29E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 1.74E+00 | 1.49E+01 |
| Total | 2.65E+04 | 2.15E+02 | 5.06E+00 | 1.07E-04 | 3.61E-04 | 0.00 | 6.29E-02 | 1.15E+01 | 2.67E+04 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 9.88E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9.88E-09 |
| H-3 | 0.00 | 1.04E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 3.99E-05 | 1.22E-06 | 4.12E-05 |
| Co-60 | 1.50E+01 | 7.09E-04 | 5.40E-04 | 1.87E-09 | 7.50E-09 | 0.00 | 1.25E-06 | 1.11E-03 | 1.50E+01 |
| Sr-90 | 0.00 | 6.12E-06 | 6.21E-04 | 1.16E-09 | 4.66E-08 | 0.00 | 2.59E-06 | 6.01E-05 | 6.90E-04 |
| Y-90 | 0.00 | 6.01E-07 | 6.02E-05 | 1.13E-10 | 4.52E-09 | 0.00 | 2.51E-07 | 5.83E-06 | 6.69E-05 |
| Cs-137 | 0.00 | 2.26E-06 | 5.87E-06 | 5.51E-08 | 7.34E-08 | 0.00 | 1.22E-06 | 5.56E-05 | 6.51E-05 |
| Ba-137m | 1.00E-01 | 6.77E-11 | 4.76E-10 | 4.46E-12 | 5.95E-12 | 0.00 | 9.92E-11 | 4.51E-09 | 1.00E-01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 5.05E-04 | 1.58E-02 | 1.80E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 1.37E-03 | 1.79E-02 |
| U-238 | 1.23E-03 | 2.46E-02 | 2.91E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 2.22E-03 | 2.83E-02 |
| Th-234 | 1.50E-02 | 3.27E-05 | 8.97E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 6.82E-05 | 1.51E-02 |
| Pa-234m | 1.71E-02 | 1.64E-09 | 1.30E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 9.89E-08 | 1.71E-02 |
| Pa-234 | 3.82E-03 | 7.18E-10 | 1.98E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 1.51E-08 | 3.82E-03 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 7.85E-05 | 1.40E-03 | 2.27E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 1.73E-04 | 1.67E-03 |
| Total | 1.52E+01 | 4.25E-02 | 1.73E-03 | 5.82E-08 | 1.32E-07 | 0.00 | 4.52E-05 | 5.06E-03 | 1.52E+01 |

Table 6G.42. Radionuclide Concentrations, Dose, and Risk for the 1990 Homesteader in Sub-area Z

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 1.35E+03 | 1.92E+05 | 1.52E+04 | 2.70E-01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 6.82E+01 | 0.00 | 2.27E-01 | 1.36E-02 | 2.72E-02 | 2.76E-02 | 0.00 | 0.00 |
| Sr-90 | 2.78E+03 | 0.00 | 4.31E+01 | 5.56E-01 | 2.35E+01 | 2.36E+01 | 0.00 | 0.00 |
| Y-90 | 2.78E+03 | 0.00 | 4.31E+01 | 5.56E-01 | 2.35E+01 | 2.36E+01 | 0.00 | 0.00 |
| Cs-137 | 5.05E+03 | 0.00 | 3.40E+00 | 1.01E+00 | 4.35E-01 | 4.61E-01 | 0.00 | 0.00 |
| Ba-137m | 4.78E+03 | 0.00 | 3.21E+00 | 9.56E-01 | 4.11E-01 | 4.36E-01 | 0.00 | 0.00 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 1.94E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 7.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 9.66E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-05 |
| H-3 | 0.00 | 5.68E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 2.69E-01 | 9.46E-05 | 2.69E-01 |
| Co-60 | 2.66E+01 | 9.80E-04 | 9.82E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 2.01E-03 | 2.66E+01 |
| Sr-90 | 0.00 | 2.37E-01 | 4.48E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.34E-01 | 5.15E+00 |
| Y-90 | 0.00 | 1.54E-03 | 3.39E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 3.28E-02 | 3.73E-01 |
| Cs-137 | 0.00 | 1.06E-02 | 2.92E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 2.76E-01 | 3.16E-01 |
| Ba-137m | 5.00E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.00E+02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 5.27E+02 | 2.50E-01 | 4.85E+00 | 0.00 | 0.00 | 0.00 | 2.69E-01 | 7.45E-01 | 5.33E+02 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-08 |
| H-3 | 0.00 | 6.92E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 2.31E-04 | 8.13E-08 | 2.31E-04 |
| Co-60 | 1.52E-02 | 7.17E-07 | 5.47E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 1.12E-06 | 1.52E-02 |
| Sr-90 | 0.00 | 1.02E-05 | 1.04E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00E-04 | 1.15E-03 |
| Y-90 | 0.00 | 1.00E-06 | 1.01E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 9.74E-06 | 1.11E-04 |
| Cs-137 | 0.00 | 6.30E-06 | 1.64E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 1.55E-04 | 1.78E-04 |
| Ba-137m | 2.79E-01 | 1.88E-10 | 1.33E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 1.26E-08 | 2.79E-01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.94E-01 | 1.83E-05 | 1.16E-03 | 0.00 | 0.00 | 0.00 | 2.31E-04 | 2.66E-04 | 2.95E-01 |

Table 6G.43. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area A

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 6.75E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 2.58E-01 | 7.36E+01 | 1.81E-03 | 5.15E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 1.30E-02 | 1.98E-03 | 2.10E-05 | 2.60E-06 | 5.18E-06 | 5.25E-06 | 7.93E-08 | 7.93E-08 |
| Sr-90 | 1.89E+03 | 3.49E+02 | 6.05E+01 | 3.78E-01 | 1.60E+01 | 1.60E+01 | 4.18E-03 | 4.18E-02 |
| Y-90 | 1.89E+03 | 3.49E+02 | 6.05E+01 | 3.78E-01 | 1.60E+01 | 1.60E+01 | 4.18E-03 | 4.18E-02 |
| Cs-137 | 9.78E+03 | 4.74E+00 | 2.60E-01 | 1.96E+00 | 8.41E-01 | 8.93E-01 | 5.69E-03 | 1.90E-03 |
| Ba-137m | 9.25E+03 | 4.49E+00 | 2.46E-01 | 1.85E+00 | 7.96E-01 | 8.45E-01 | 5.38E-03 | 1.79E-03 |
| Eu-152 | 5.22E+02 | 2.15E+00 | 0.00 | 1.04E-01 | 5.59E-02 | 5.87E-02 | 4.30E-04 | 4.30E-07 |
| Eu-154 | 5.29E+00 | 1.75E-02 | 0.00 | 1.06E-03 | 5.67E-04 | 5.95E-04 | 3.49E-06 | 3.49E-09 |
| Eu-155 | 2.11E-03 | 2.32E-05 | 0.00 | 4.22E-07 | 2.26E-07 | 2.37E-07 | 4.65E-09 | 4.65E-12 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 2.09E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.42E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.42E-06 |
| H-3 | 0.00 | 1.08E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 1.03E-04 | 1.81E-08 | 1.03E-04 |
| Co-60 | 5.05E-03 | 1.86E-07 | 1.87E-07 | 1.75E-09 | 7.01E-09 | 0.00 | 1.17E-06 | 3.83E-07 | 5.05E-03 |
| Sr-90 | 0.00 | 1.61E-01 | 3.04E+00 | 4.89E-04 | 1.96E-02 | 0.00 | 1.09E+00 | 2.95E-01 | 4.61E+00 |
| Y-90 | 0.00 | 1.05E-03 | 2.30E-01 | 3.70E-05 | 1.48E-03 | 0.00 | 8.22E-02 | 2.23E-02 | 3.37E-01 |
| Cs-137 | 0.00 | 2.05E-02 | 5.65E-02 | 2.33E-04 | 3.11E-04 | 0.00 | 5.19E-03 | 5.35E-01 | 6.17E-01 |
| Ba-137m | 9.69E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9.69E+02 |
| Eu-152 | 9.93E+01 | 7.57E-03 | 4.86E-04 | 2.28E-06 | 9.14E-09 | 0.00 | 3.05E-04 | 3.70E-03 | 9.93E+01 |
| Eu-154 | 1.10E+00 | 9.94E-05 | 7.27E-06 | 2.74E-08 | 1.10E-10 | 0.00 | 3.65E-06 | 5.53E-05 | 1.10E+00 |
| Eu-155 | 2.58E-05 | 5.74E-09 | 4.64E-10 | 5.83E-12 | 2.33E-14 | 0.00 | 7.77E-10 | 3.53E-09 | 2.58E-05 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.07E+03 | 1.90E-01 | 3.33E+00 | 7.62E-04 | 2.14E-02 | 0.00 | 1.18E+00 | 8.55E-01 | 1.07E+03 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.73E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.73E-12 |
| H-3 | 0.00 | 1.32E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 8.87E-08 | 1.55E-11 | 8.87E-08 |
| Co-60 | 2.89E-06 | 1.36E-10 | 1.04E-10 | 9.76E-13 | 3.9[illegible] | 0.00 | 6.51E-10 | 2.13E-10 | 2.89E-06 |
| Sr-90 | 0.00 | 6.95E-06 | 7.05E-04 | 1.13E-07 | 4.[illegible] | 0.00 | 2.52E-04 | 6.83E-05 | 1.04E-03 |
| Y-90 | 0.00 | 6.83E-07 | 6.84E-05 | 1.10E-08 | 4.[illegible] | 0.00 | 2.44E-05 | 6.62E-06 | 1.01E-04 |
| Cs-137 | 0.00 | 1.22E-05 | 3.17E-05 | 1.31E-07 | 1.7[illegible] | 0.00 | 2.91E-06 | 3.00E-04 | 3.47E-04 |
| Ba-137m | 5.39E-01 | 3.65E-10 | 2.57E-09 | 1.06E-11 | 1.4[illegible] | 0.00 | 2.36E-10 | 2.43E-08 | 5.39E-01 |
| Eu-152 | 5.63E-02 | 4.11E-04 | 1.58E-07 | 7.41E-10 | 2.9[illegible] | 0.00 | 9.88E-08 | 1.20E-06 | 5.68E-02 |
| Eu-154 | 6.17E-04 | 4.87E-08 | 2.28E-09 | 8.60E-12 | 3.4[illegible] | 0.00 | 1.15E-09 | 1.74E-08 | 6.17E-04 |
| Eu-155 | 1.88E-08 | 4.15E-10 | 1.58E-13 | 1.98E-15 | 7.9[illegible] | 0.00 | 2.65E-13 | 1.20E-12 | 1.92E-08 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 5.96E-01 | 4.31E-04 | 8.05E-04 | 2.56E-07 | 5.15E-06 | 0.00 | 2.80E-04 | 3.76E-04 | 5.98E-01 |

Table 6G.44. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area B

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 8.68E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 4.54E-01 | 8.61E+01 | 1.81E-03 | 9.07E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 1.05E-02 | 1.01E-03 | 2.10E-05 | 2.11E-06 | 4.21E-06 | 4.27E-06 | 4.03E-08 | 4.03E-08 |
| Sr-90 | 2.98E+03 | 2.04E+02 | 6.05E+01 | 5.95E-01 | 2.52E+01 | 2.52E+01 | 2.45E-03 | 2.45E-02 |
| Y-90 | 2.98E+03 | 2.04E+02 | 6.05E+01 | 5.95E-01 | 2.52E+01 | 2.52E+01 | 2.45E-03 | 2.45E-02 |
| Cs-137 | 9.02E+03 | 5.73E+00 | 2.60E-01 | 1.80E+00 | 7.77E-01 | 8.24E-01 | 6.88E-03 | 2.29E-03 |
| Ba-137m | 8.54E+03 | 5.42E+00 | 2.46E-01 | 1.71E+00 | 7.35E-01 | 7.80E-01 | 6.51E-03 | 2.17E-03 |
| Eu-152 | 3.64E+03 | 6.37E+00 | 0.00 | 7.28E-01 | 3.90E-01 | 4.09E-01 | 1.27E-03 | 1.27E-06 |
| Eu-154 | 1.49E+02 | 2.67E-01 | 0.00 | 2.98E-02 | 1.60E-02 | 1.68E-02 | 5.34E-05 | 5.34E-08 |
| Eu-155 | 2.33E-02 | 1.63E-04 | 0.00 | 4.65E-06 | 2.50E-06 | 2.62E-06 | 3.26E-08 | 3.26E-11 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 2.09E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.82E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.82E-06 |
| H-3 | 0.00 | 1.91E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 1.21E-04 | 3.18E-08 | 1.21E-04 |
| Co-60 | 4.10E-03 | 1.52E-07 | 1.52E-07 | 8.92E-10 | 3.57E-09 | 0.00 | 5.95E-07 | 3.11E-07 | 4.11E-03 |
| Sr-90 | 0.00 | 2.54E-01 | 4.80E+00 | 2.86E-04 | 1.14E-02 | 0.00 | 6.36E-01 | 4.64E-01 | 6.16E+00 |
| Y-90 | 0.00 | 1.65E-03 | 3.62E-01 | 2.16E-05 | 8.65E-04 | 0.00 | 4.81E-02 | 3.51E-02 | 4.48E-01 |
| Cs-137 | 0.00 | 1.89E-02 | 5.21E-02 | 2.82E-04 | 3.76E-04 | 0.00 | 6.27E-03 | 4.94E-01 | 5.72E-01 |
| Ba-137m | 8.94E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.94E+02 |
| Eu-152 | 6.92E+02 | 5.28E-02 | 3.39E-03 | 6.77E-06 | 2.71E-08 | 0.00 | 9.03E-04 | 2.58E-02 | 6.92E+02 |
| Eu-154 | 3.09E+01 | 2.80E-03 | 2.05E-04 | 4.18E-07 | 1.67E-09 | 0.00 | 5.58E-05 | 1.56E-03 | 3.09E+01 |
| Eu-155 | 2.85E-04 | 6.34E-08 | 5.12E-09 | 4.09E-11 | 1.64E-13 | 0.00 | 5.45E-09 | 3.89E-08 | 2.85E-04 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.62E+03 | 3.30E-01 | 5.21E+00 | 5.97E-04 | 1.27E-02 | 0.00 | 6.91E-01 | 1.02E+00 | 1.62E+03 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 2.22E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.22E-12 |
| H-3 | 0.00 | 2.32E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 1.04E-07 | 2.73E-11 | 1.04E-07 |
| Co-60 | 2.35E-06 | 1.11E-10 | 8.45E-11 | 4.97E-13 | 1.99E-12 | 0.00 | 3.31E-10 | 1.73E-10 | 2.35E-06 |
| Sr-90 | 0.00 | 1.09E-05 | 1.11E-03 | 6.63E-08 | 2.65E-06 | 0.00 | 1.47E-04 | 1.08E-04 | 1.38E-03 |
| Y-90 | 0.00 | 1.08E-06 | 1.08E-04 | 6.43E-09 | 2.57E-07 | 0.00 | 1.43E-05 | 1.04E-05 | 1.34E-04 |
| Cs-137 | 0.00 | 1.13E-05 | 2.92E-05 | 1.58E-07 | 2.11E-07 | 0.00 | 3.52E-06 | 2.77E-04 | 3.21E-04 |
| Ba-137m | 4.98E-01 | 3.37E-10 | 2.37E-09 | 1.28E-11 | 1.71E-11 | 0.00 | 2.85E-10 | 2.24E-08 | 4.98E-01 |
| Eu-152 | 3.93E-01 | 2.87E-03 | 1.10E-06 | 2.20E-09 | 8.78E-12 | 0.00 | 2.93E-07 | 8.37E-06 | 3.96E-01 |
| Eu-154 | 1.74E-02 | 1.37E-06 | 6.44E-08 | 1.32E-10 | 5.26E-13 | 0.00 | 1.75E-08 | 4.90E-07 | 1.74E-02 |
| Eu-155 | 2.07E-07 | 4.59E-09 | 1.74E-12 | 1.39E-14 | 5.57E-17 | 0.00 | 1.86E-12 | 1.33E-11 | 2.12E-07 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 9.08E-01 | 2.89E-03 | 1.25E-03 | 2.33E-07 | 3.12E-06 | 0.00 | 1.66E-04 | 4.04E-04 | 9.13E-01 |

Table 6G.45. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area C

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 2.00E-05 | 3.13E-03 | 1.81E-03 | 4.01E-09 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 7.26E-05 | 2.93E-05 | 2.10E-05 | 1.45E-08 | 2.90E-08 | 2.94E-08 | 1.17E-09 | 1.17E-09 |
| Sr-90 | 7.99E+02 | 4.62E+02 | 6.05E+01 | 1.60E-01 | 6.76E+00 | 6.77E+00 | 5.55E-03 | 5.55E-02 |
| Y-90 | 7.99E+02 | 4.62E+02 | 6.05E+01 | 1.60E-01 | 6.76E+00 | 6.77E+00 | 5.55E-03 | 5.55E-02 |
| Cs-137 | 2.80E+02 | 1.49E+00 | 2.60E-01 | 5.59E-02 | 2.41E-02 | 2.55E-02 | 1.79E-03 | 5.98E-04 |
| Ba-137m | 2.65E+02 | 1.41E+00 | 2.46E-01 | 5.29E-02 | 2.28E-02 | 2.42E-02 | 1.70E-03 | 5.65E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 9.36E+02 | 0.00 | 2.09E+00 | 1.87E-01 | 1.00E-01 | 1.05E-01 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 9.11E+01 | 0.00 | 0.00 | 1.82E-02 | 1.09E-03 | 1.57E-03 | 0.00 | 0.00 |
| Cm-244 | 8.38E+00 | 0.00 | 0.00 | 1.68E-03 | 8.99E-04 | 9.43E-04 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-06 |
| H-3 | 0.00 | 8.42E-14 | 0.00 | 0.00 | 0.00 | 0.00 | 4.39E-09 | 1.40E-12 | 4.40E-09 |
| Co-60 | 2.82E-05 | 1.04E-09 | 1.04E-09 | 2.59E-11 | 1.04E-10 | 0.00 | 1.73E-08 | 2.14E-09 | 2.83E-05 |
| Sr-90 | 0.00 | 6.81E-02 | 1.29E+00 | 6.49E-04 | 2.60E-02 | 0.00 | 1.44E+00 | 1.25E-01 | 2.95E+00 |
| Y-90 | 0.00 | 4.43E-04 | 9.73E-02 | 4.90E-05 | 1.96E-03 | 0.00 | 1.09E-01 | 9.42E-03 | 2.18E-01 |
| Cs-137 | 0.00 | 5.87E-04 | 1.62E-03 | 7.36E-05 | 9.81E-05 | 0.00 | 1.63E-03 | 1.53E-02 | 1.93E-02 |
| Ba-137m | 2.77E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.77E+01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 8.02E-02 | 8.33E+00 | 3.89E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 2.96E-01 | 8.74E+00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 4.67E-01 | 2.66E+00 | 5.54E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 3.63E-01 | 3.49E+00 |
| Cm-244 | 1.19E-03 | 1.37E-01 | 2.43E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 1.85E-02 | 1.59E-01 |
| Total | 2.83E+01 | 1.12E+01 | 1.43E+00 | 7.71E-04 | 2.80E-02 | 0.00 | 1.55E+00 | 8.27E-01 | 4.33E+01 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-12 |
| H-3 | 0.00 | 1.03E-16 | 0.00 | 0.00 | 0.00 | 0.00 | 3.78E-12 | 1.21E-15 | 3.78E-12 |
| Co-60 | 1.62E-08 | 7.63E-13 | 5.81E-13 | 1.44E-14 | 5.78E-14 | 0.00 | 9.63E-12 | 1.19E-12 | 1.62E-08 |
| Sr-90 | 0.00 | 2.94E-06 | 2.98E-04 | 1.50E-07 | 6.01E-06 | 0.00 | 3.34E-04 | 2.89E-05 | 6.70E-04 |
| Y-90 | 0.00 | 2.89E-07 | 2.89E-05 | 1.46E-08 | 5.83E-07 | 0.00 | 3.24E-05 | 2.80E-06 | 6.50E-05 |
| Cs-137 | 0.00 | 3.49E-07 | 9.06E-07 | 4.12E-08 | 5.50E-08 | 0.00 | 9.16E-07 | 8.57E-06 | 1.08E-05 |
| Ba-137m | 1.54E-02 | 1.04E-11 | 7.34E-11 | 3.34E-12 | 4.46E-12 | 0.00 | 7.43E-11 | 6.95E-10 | 1.54E-02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0. | 0.00 | 0.00 | 0.00 |
| U-233 | 5.30E-05 | 1.66E-03 | 1.89E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 1.43E-04 | 1.88E-03 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 2.50E-04 | 2.39E-04 | 4.71E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 3.09E-05 | 5.21E-04 |
| Cm-244 | 8.34E-07 | 1.49E-05 | 2.41E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 1.84E-06 | 1.78E-05 |
| Total | 1.57E-02 | 1.92E-03 | 3.48E-04 | 2.06E-07 | 6.65E-06 | 0.00 | 3.67E-04 | 2.16E-04 | 1.86E-02 |

Table 6G.46. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area D

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 8.78E-02 | 1.25E+02 | 1.81E-03 | 1.76E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 2.21E-02 | 4.59E+00 | 2.10E-05 | 4.42E-06 | 8.83E-06 | 8.94E-06 | 1.84E-04 | 1.84E-04 |
| Sr-90 | 3.47E+02 | 1.13E+02 | 6.05E+01 | 6.93E-02 | 2.94E+00 | 2.94E+00 | 1.35E-03 | 1.35E-02 |
| Y-90 | 3.47E+02 | 1.13E+02 | 6.05E+01 | 6.93E-02 | 2.94E+00 | 2.94E+00 | 1.35E-03 | 1.35E-02 |
| Cs-137 | 3.13E+02 | 8.05E-02 | 2.60E-01 | 6.27E-02 | 2.70E-02 | 2.86E-02 | 9.66E-05 | 3.22E-05 |
| Ba-137m | 2.96E+02 | 7.62E-02 | 2.46E-01 | 5.93E-02 | 2.55E-02 | 2.71E-02 | 9.14E-05 | 3.05E-05 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 3.43E+02 | 0.00 | 2.09E+00 | 6.87E-02 | 3.68E-02 | 3.86E-02 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 5.60E-01 | 0.00 | 0.00 | 1.12E-04 | 6.01E-05 | 6.30E-05 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-06 |
| H-3 | 0.00 | 3.69E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 1.75E-04 | 6.16E-09 | 1.75E-04 |
| Co-60 | 8.60E-03 | 3.18E-07 | 3.18E-07 | 4.06E-06 | 1.62E-05 | 0.00 | 2.71E-03 | 6.52E-07 | 1.13E-02 |
| Sr-90 | 0.00 | 2.96E-02 | 5.59E-01 | 1.58E-04 | 6.34E-03 | 0.00 | 3.52E-01 | 5.41E-02 | 1.00E+00 |
| Y-90 | 0.00 | 1.92E-04 | 4.22E-02 | 1.20E-05 | 4.79E-04 | 0.00 | 2.66E-02 | 4.09E-03 | 7.36E-02 |
| Cs-137 | 0.00 | 6.57E-04 | 1.81E-03 | 3.96E-06 | 5.29E-06 | 0.00 | 8.81E-05 | 1.71E-02 | 1.97E-02 |
| Ba-137m | 3.11E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.11E+01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 2.94E-02 | 3.05E+00 | 1.43E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 1.09E-01 | 3.21E+00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 7.96E-05 | 9.12E-03 | 1.63E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-03 | 1.06E-02 |
| Total | 3.11E+01 | 3.09E+00 | 6.17E-01 | 1.78E-04 | 6.84E-03 | 0.00 | 3.82E-01 | 1.85E-01 | 3.54E+01 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-12 |
| H-3 | 0.00 | 4.50E-13 | 0.00 | 0.00 | 0.00 | 0.00 | 1.50E-07 | 5.29E-12 | 1.50E-07 |
| Co-60 | 4.93E-06 | 2.32E-10 | 1.77E-10 | 2.26E-09 | 9.05E-09 | 0.00 | 1.51E-06 | 3.63E-10 | 6.45E-06 |
| Sr-90 | 0.00 | 1.28E-06 | 1.29E-04 | 3.67E-08 | 1.47E-06 | 0.00 | 8.15E-05 | 1.25E-05 | 2.26E-04 |
| Y-90 | 0.00 | 1.25E-07 | 1.25E-05 | 3.56E-09 | 1.42E-07 | 0.00 | 7.91E-06 | 1.21E-06 | 2.19E-05 |
| Cs-137 | 0.00 | 3.91E-07 | 1.01E-06 | 2.22E-09 | 2.96E-09 | 0.00 | 4.94E-08 | 9.61E-06 | 1.11E-05 |
| Ba-137m | 1.73E-02 | 1.17E-11 | 8.23E-11 | 1.80E-13 | 2.40E-13 | 0.00 | 4.00E-12 | 7.79E-10 | 1.73E-02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 1.94E-05 | 6.09E-04 | 6.92E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 5.26E-05 | 6.88E-04 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 5.57E-08 | 9.94E-07 | 1.61E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 1.23E-07 | 1.19E-06 |
| Total | 1.73E-02 | 6.12E-04 | 1.50E-04 | 4.47E-08 | 1.62E-06 | 0.00 | 9.12E-05 | 7.61E-05 | 1.82E-02 |

Table 6G.47. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area E

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 5.48E-05 | 5.92E-02 | 1.81E-03 | 1.10E-08 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 3.17E-05 | 3.48E-05 | 2.10E-05 | 6.35E-09 | 1.27E-08 | 1.28E-08 | 1.39E-09 | 1.39E-09 |
| Sr-90 | 1.44E+01 | 8.00E+00 | 6.05E+01 | 2.89E-03 | 1.22E-01 | 1.22E-01 | 9.60E-05 | 9.60E-04 |
| Y-90 | 1.44E+01 | 8.00E+00 | 6.05E+01 | 2.89E-03 | 1.22E-01 | 1.22E-01 | 9.60E-05 | 9.60E-04 |
| Cs-137 | 6.40E+01 | 4.74E-01 | 2.60E-01 | 1.28E-02 | 5.51E-03 | 5.85E-03 | 5.68E-04 | 1.89E-04 |
| Ba-137m | 6.06E+01 | 4.48E-01 | 2.46E-01 | 1.21E-02 | 5.21E-03 | 5.53E-03 | 5.38E-04 | 1.79E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 6.46E+02 | 7.66E+01 | 2.09E+00 | 1.29E-01 | 6.93E-02 | 7.27E-02 | 1.53E-02 | 3.68E-03 |
| U-238 | 1.12E+03 | 2.05E+02 | 8.36E-01 | 2.25E-01 | 1.20E-01 | 1.26E-01 | 4.09E-02 | 9.83E-03 |
| Th-234 | 1.12E+03 | 2.05E+02 | 8.36E-01 | 2.25E-01 | 1.20E-01 | 1.26E-01 | 4.09E-02 | 9.83E-03 |
| Pa-234m | 1.12E+03 | 2.05E+02 | 8.36E-01 | 2.25E-01 | 1.20E-01 | 1.26E-01 | 4.09E-02 | 9.83E-03 |
| Pa-234 | 1.46E+00 | 2.66E-01 | 1.09E-03 | 2.92E-04 | 1.57E-04 | 1.64E-04 | 5.32E-05 | 1.28E-05 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-06 |
| H-3 | 0.00 | 2.30E-13 | 0.00 | 0.00 | 0.00 | 0.00 | 8.30E-08 | 3.84E-12 | 8.30E-08 |
| Co-60 | 1.24E-05 | 4.56E-10 | 4.57E-10 | 3.08E-11 | 1.23E-10 | 0.00 | 2.05E-08 | 9.36E-10 | 1.24E-05 |
| Sr-90 | 0.00 | 1.23E-03 | 2.33E-02 | 1.12E-05 | 4.49E-04 | 0.00 | 2.50E-02 | 2.25E-03 | 5.22E-02 |
| Y-90 | 0.00 | 8.00E-06 | 1.76E-03 | 8.49E-07 | 3.40E-05 | 0.00 | 1.89E-03 | 1.70E-04 | 3.86E-03 |
| Cs-137 | 0.00 | 1.34E-04 | 3.70E-04 | 2.33E-05 | 3.11E-05 | 0.00 | 5.18E-04 | 3.50E-03 | 4.58E-03 |
| Ba-137m | 6.35E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.35E+00 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 5.54E-02 | 5.75E+00 | 2.69E-02 | 3.64E-03 | 3.49E-03 | 0.00 | 4.85E-01 | 2.05E-01 | 6.53E+00 |
| U-238 | 1.24E-01 | 8.74E+00 | 4.11E-02 | 8.56E-03 | 8.22E-03 | 0.00 | 1.14E+00 | 3.13E-01 | 1.04E+01 |
| Th-234 | 1.94E+00 | 2.59E-03 | 2.21E-03 | 4.59E-04 | 4.41E-04 | 0.00 | 6.12E-02 | 1.68E-02 | 2.03E+00 |
| Pa-234m | 2.18E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.18E+00 |
| Pa-234 | 4.91E-01 | 7.81E-08 | 4.54E-07 | 9.44E-08 | 9.07E-08 | 0.00 | 1.26E-05 | 3.45E-06 | 4.91E-01 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.11E+01 | 1.45E+01 | 9.56E-02 | 1.27E-02 | 1.27E-02 | 0.00 | 1.71E+00 | 5.40E-01 | 2.80E+01 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-12 |
| H-3 | 0.00 | 2.81E-16 | 0.00 | 0.00 | 0.00 | 0.00 | 7.13E-11 | 3.30E-15 | 7.13E-11 |
| Co-60 | 7.07E-09 | 3.34E-13 | 2.54E-13 | 1.71E-14 | 6.86E-14 | 0.00 | 1.14E-11 | 5.21E-13 | 7.09E-09 |
| Sr-90 | 0.00 | 5.31E-08 | 5.39E-06 | 2.60E-09 | 1.04E-07 | 0.00 | 5.78E-06 | 5.21E-07 | 1.19E-05 |
| Y-90 | 0.00 | 5.21E-09 | 5.22E-07 | 2.52E-10 | 1.01E-08 | 0.00 | 5.61E-07 | 5.06E-08 | 1.15E-06 |
| Cs-137 | 0.00 | 7.99E-08 | 2.07E-07 | 1.31E-08 | 1.74E-08 | 0.00 | 2.90E-07 | 1.96E-06 | 2.57E-06 |
| Ba-137m | 3.53E-03 | 2.39E-12 | 1.68E-11 | 1.06E-12 | 1.41E-12 | 0.00 | 2.35E-11 | 1.59E-10 | 3.53E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 3.66E-05 | 1.15E-03 | 1.30E-05 | 1.76E-06 | 1.69E-06 | 0.00 | 2.35E-04 | 9.91E-05 | 1.53E-03 |
| U-238 | 8.86E-05 | 1.77E-03 | 2.10E-05 | 4.37E-06 | 4.20E-06 | 0.00 | 5.83E-04 | 1.60E-04 | 2.63E-03 |
| Th-234 | 1.08E-03 | 2.36E-06 | 6.47E-07 | 1.34E-07 | 1.29E-07 | 0.00 | 1.79E-05 | 4.92E-06 | 1.10E-03 |
| Pa-234m | 1.23E-03 | 1.18E-10 | 9.37E-10 | 1.95E-10 | 1.87E-10 | 0.00 | 2.60E-08 | 7.13E-09 | 1.23E-03 |
| Pa-234 | 2.75E-04 | 5.18E-11 | 1.43E-10 | 2.97E-11 | 2.85E-11 | 0.00 | 3.96E-09 | 1.09E-09 | 2.75E-04 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 6.24E-03 | 2.92E-03 | 4.08E-05 | 6.28E-06 | 6.15E-06 | 0.00 | 8.42E-04 | 2.66E-04 | 1.03E-02 |

Table 6G.48. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area F

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 0.00 | 0.00 | 1.81E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 2.59E-05 | 1.01E-05 | 2.10E-05 | 5.19E-09 | 1.04E-08 | 1.05E-08 | 4.04E-10 | 4.04E-10 |
| Sr-90 | 4.14E+02 | 1.31E+02 | 6.05E+01 | 8.28E-02 | 3.51E+00 | 3.51E+00 | 1.57E-03 | 1.57E-02 |
| Y-90 | 4.14E+02 | 1.31E+02 | 6.05E+01 | 8.28E-02 | 3.51E+00 | 3.51E+00 | 1.57E-03 | 1.57E-02 |
| Cs-137 | 2.18E+02 | 0.00 | 2.60E-01 | 4.36E-02 | 1.88E-02 | 1.99E-02 | 0.00 | 0.00 |
| Ba-137m | 2.06E+02 | 0.00 | 2.46E-01 | 4.13E-02 | 1.78E-02 | 1.89E-02 | 0.00 | 0.00 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 4.98E+02 | 0.00 | 2.09E+00 | 9.97E-02 | 5.34E-02 | 5.60E-02 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-06 |
| H-3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 1.01E-05 | 3.73E-10 | 3.73E-10 | 8.94E-12 | 3.58E-11 | 0.00 | 5.96E-09 | 7.65E-10 | 1.01E-05 |
| Sr-90 | 0.00 | 3.53E-02 | 6.67E-01 | 1.84E-04 | 7.34E-03 | 0.00 | 4.08E-01 | 6.46E-02 | 1.18E+00 |
| Y-90 | 0.00 | 2.30E-04 | 5.04E-02 | 1.39E-05 | 5.55E-04 | 0.00 | 3.08E-02 | 4.88E-03 | 8.70E-02 |
| Cs-137 | 0.00 | 4.58E-04 | 1.26E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 1.19E-02 | 1.37E-02 |
| Ba-137m | 2.16E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.16E+01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 4.27E-02 | 4.43E+00 | 2.07E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 1.58E-01 | 4.65E+00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.17E+01 | 4.47E+00 | 7.40E-01 | 1.97E-04 | 7.90E-03 | 0.00 | 4.39E-01 | 2.39E-01 | 2.76E+01 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-12 |
| H-3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 5.78E-09 | 2.73E-13 | 2.08E-13 | 4.98E-15 | 1.99E-14 | 0.00 | 3.32E-12 | 4.26E-13 | 5.79E-09 |
| Sr-90 | 0.00 | 1.52E-06 | 1.55E-04 | 4.25E-08 | 1.70E-06 | 0.00 | 9.45E-05 | 1.50E-05 | 2.67E-04 |
| Y-90 | 0.00 | 1.50E-07 | 1.50E-05 | 4.12E-09 | 1.65E-07 | 0.00 | 9.16E-06 | 1.45E-06 | 2.59E-05 |
| Cs-137 | 0.00 | 2.72E-07 | 7.07E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 6.69E-06 | 7.67E-06 |
| Ba-137m | 1.20E-02 | 8.14E-12 | 5.73E-11 | 0.00 | 0.00 | 0.00 | 0.00 | 5.43E-10 | 1.20E-02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 2.82E-05 | 8.84E-04 | 1.00E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 7.64E-05 | 9.99E-04 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.21E-02 | 8.86E-04 | 1.80E-04 | 4.66E-08 | 1.87E-06 | 0.00 | 1.04E-04 | 9.95E-05 | 1.33E-02 |

Table 6G.49. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area G

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 1.53E-01 | 2.35E+02 | 1.81E-03 | 3.07E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 2.94E-05 | 3.53E-05 | 2.10E-05 | 5.88E-09 | 1.17E-08 | 1.19E-08 | 1.41E-09 | 1.41E-09 |
| Sr-90 | 4.35E+02 | 2.41E+02 | 6.05E+01 | 8.69E-02 | 3.68E+00 | 3.68E+00 | 2.90E-03 | 2.90E-02 |
| Y-90 | 4.35E+02 | 2.41E+02 | 6.05E+01 | 8.69E-02 | 3.68E+00 | 3.68E+00 | 2.90E-03 | 2.90E-02 |
| Cs-137 | 2.42E+02 | 1.13E+00 | 2.60E-01 | 4.85E-02 | 2.09E-02 | 2.21E-02 | 1.36E-03 | 4.53E-04 |
| Ba-137m | 2.29E+02 | 1.07E+00 | 2.46E-01 | 4.59E-02 | 1.97E-02 | 2.09E-02 | 1.28E-03 | 4.28E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 5.33E+02 | 0.00 | 2.09E+00 | 1.07E-01 | 5.71E-02 | 5.99E-02 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-06 |
| H-3 | 0.00 | 6.45E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 3.29E-04 | 1.08E-08 | 3.29E-04 |
| Co-60 | 1.15E-05 | 4.23E-10 | 4.23E-10 | 3.12E-11 | 1.25E-10 | 0.00 | 2.08E-08 | 8.68E-10 | 1.15E-05 |
| Sr-90 | 0.00 | 3.71E-02 | 7.01E-01 | 3.39E-04 | 1.36E-02 | 0.00 | 7.53E-01 | 6.78E-02 | 1.57E+00 |
| Y-90 | 0.00 | 2.41E-04 | 5.29E-02 | 2.56E-05 | 1.02E-03 | 0.00 | 5.69E-02 | 5.12E-03 | 1.16E-01 |
| Cs-137 | 0.00 | 5.09E-04 | 1.40E-03 | 5.57E-05 | 7.43E-05 | 0.00 | 1.24E-03 | 1.33E-02 | 1.65E-02 |
| Ba-137m | 2.40E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.40E+01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 4.57E-02 | 4.74E+00 | 2.22E-02 | 0.00 | 0.00 | 0.00 | 0.00 | 1.69E-01 | 4.98E+00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.41E+01 | 4.78E+00 | 7.77E-01 | 4.20E-04 | 1.47E-02 | 0.00 | 8.12E-01 | 2.55E-01 | 3.07E+01 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-12 |
| H-3 | 0.00 | 7.86E-13 | 0.00 | 0.00 | 0.00 | 0.00 | 2.83E-07 | 9.24E-12 | 2.83E-07 |
| Co-60 | 6.56E-09 | 3.09E-13 | 2.36E-13 | 1.74E-14 | 6.95E-14 | 0.00 | 1.16E-11 | 4.83E-13 | 6.57E-09 |
| Sr-90 | 0.00 | 1.60E-06 | 1.62E-04 | 7.85E-08 | 3.14E-06 | 0.00 | 1.75E-04 | 1.57E-05 | 3.57E-04 |
| Y-90 | 0.00 | 1.57E-07 | 1.57E-05 | 7.61E-09 | 3.05E-07 | 0.00 | 1.69E-05 | 1.52E-06 | 3.47E-05 |
| Cs-137 | 0.00 | 3.03E-07 | 7.85E-07 | 3.12E-08 | 4.16E-08 | 0.00 | 6.94E-07 | 7.43E-06 | 9.29E-06 |
| Ba-137m | 1.34E-02 | 9.04E-12 | 6.37E-11 | 2.53E-12 | 3.38E-12 | 0.00 | 5.63E-11 | 6.03E-10 | 1.34E-02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 3.02E-05 | 9.45E-04 | 1.07E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 8.17E-05 | 1.07E-03 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.34E-02 | 9.48E-04 | 1.90E-04 | 1.17E-07 | 3.49E-06 | 0.00 | 1.92E-04 | 1.06E-04 | 1.48E-02 |

Table 6G.50. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area H

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 1.98E-01 | 2.09E+02 | 1.81E-03 | 3.97E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 1.19E-03 | 4.63E-04 | 2.10E-05 | 2.39E-07 | 4.76E-07 | 4.83E-07 | 1.85E-08 | 1.85E-08 |
| Sr-90 | 3.24E+02 | 2.28E+02 | 6.05E+01 | 6.48E-02 | 2.74E+00 | 2.75E+00 | 2.73E-03 | 2.73E-02 |
| Y-90 | 3.24E+02 | 2.28E+02 | 6.05E+01 | 6.48E-02 | 2.74E+00 | 2.75E+00 | 2.73E-03 | 2.73E-02 |
| Cs-137 | 8.97E+02 | 7.02E-01 | 2.60E-01 | 1.79E-01 | 7.72E-02 | 8.19E-02 | 8.42E-04 | 2.81E-04 |
| Ba-137m | 8.48E+02 | 6.64E-01 | 2.46E-01 | 1.70E-01 | 7.30E-02 | 7.75E-02 | 7.97E-04 | 2.66E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 2.09E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 5.84E-01 | 0.00 | 0.00 | 1.17E-04 | 6.26E-05 | 6.57E-05 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-06 |
| H-3 | 0.00 | 8.34E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 2.94E-04 | 1.39E-08 | 2.94E-04 |
| Co-60 | 4.64E-04 | 1.71E-08 | 1.72E-08 | 4.10E-10 | 1.64E-09 | 0.00 | 2.73E-07 | 3.52E-08 | 4.65E-04 |
| Sr-90 | 0.00 | 2.77E-02 | 5.22E-01 | 3.20E-04 | 1.28E-02 | 0.00 | 7.10E-01 | 5.05E-02 | 1.32E+00 |
| Y-90 | 0.00 | 1.80E-04 | 3.95E-02 | 2.42E-05 | 9.66E-04 | 0.00 | 5.37E-02 | 3.82E-03 | 9.81E-02 |
| Cs-137 | 0.00 | 1.88E-03 | 5.18E-03 | 3.46E-05 | 4.61E-05 | 0.00 | 7.68E-04 | 4.90E-02 | 5.70E-02 |
| Ba-137m | 8.89E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.89E+01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 8.30E-05 | 9.51E-03 | 1.70E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 1.29E-03 | 1.11E-02 |
| Total | 8.89E+01 | 3.92E-02 | 5.67E-01 | 3.78E-04 | 1.38E-02 | 0.00 | 7.65E-01 | 1.05E-01 | 9.04E+01 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-12 |
| H-3 | 0.00 | 1.02E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 2.52E-07 | 1.19E-11 | 2.52E-07 |
| Co-60 | 2.66E-07 | 1.25E-11 | 9.56E-12 | 2.28E-13 | 9.13E-13 | 0.00 | 1.52E-10 | 1.96E-11 | 2.66E-07 |
| Sr-90 | 0.00 | 1.19E-06 | 1.21E-04 | 7.40E-08 | 2.96E-06 | 0.00 | 1.65E-04 | 1.17E-05 | 3.01E-04 |
| Y-90 | 0.00 | 1.17E-07 | 1.17E-05 | 7.18E-09 | 2.87E-07 | 0.00 | 1.60E-05 | 1.14E-06 | 2.92E-05 |
| Cs-137 | 0.00 | 1.12E-06 | 2.90E-06 | 1.94E-08 | 2.58E-08 | 0.00 | 4.30E-07 | 2.75E-05 | 3.20E-05 |
| Ba-137m | 4.94E-02 | 3.34E-11 | 2.35E-10 | 1.57E-12 | 2.09E-12 | 0.00 | 3.49E-11 | 2.23E-09 | 4.94E-02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 5.81E-08 | 1.04E-06 | 1.68E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 1.28E-07 | 1.24E-06 |
| Total | 4.94E-02 | 3.46E-06 | 1.36E-04 | 1.01E-07 | 3.27E-06 | 0.00 | 1.81E-04 | 4.05E-05 | 4.98E-02 |

Table 6G.51. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area I

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 9.64E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 1.10E-01 | 1.10E+02 | 1.81E-03 | 2.20E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 4.23E-05 | 9.36E-06 | 2.10E-05 | 8.46E-09 | 1.69E-08 | 1.71E-08 | 3.74E-10 | 3.74E-10 |
| Sr-90 | 2.54E+02 | 9.28E+01 | 6.05E+01 | 5.08E-02 | 2.15E+00 | 2.15E+00 | 1.11E-03 | 1.11E-02 |
| Y-90 | 2.54E+02 | 9.28E+01 | 6.05E+01 | 5.08E-02 | 2.15E+00 | 2.15E+00 | 1.11E-03 | 1.11E-02 |
| Cs-137 | 1.41E+02 | 4.58E-01 | 2.60E-01 | 2.82E-02 | 1.21E-02 | 1.29E-02 | 5.49E-04 | 1.83E-04 |
| Ba-137m | 1.33E+02 | 4.33E-01 | 2.46E-01 | 2.67E-02 | 1.15E-02 | 1.22E-02 | 5.19E-04 | 1.73E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 2.09E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 2.03E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.03E-06 |
| H-3 | 0.00 | 4.62E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 1.55E-04 | 7.70E-09 | 1.55E-04 |
| Co-60 | 1.65E-05 | 6.08E-10 | 6.09E-10 | 8.28E-12 | 3.31E-11 | 0.00 | 5.52E-09 | 1.25E-09 | 1.65E-05 |
| Sr-90 | 0.00 | 2.17E-02 | 4.09E-01 | 1.30E-04 | 5.21E-03 | 0.00 | 2.89E-01 | 3.96E-02 | 7.65E-01 |
| Y-90 | 0.00 | 1.41E-04 | 3.09E-02 | 9.84E-06 | 3.94E-04 | 0.00 | 2.19E-02 | 2.99E-03 | 5.64E-02 |
| Cs-137 | 0.00 | 2.96E-04 | 8.15E-04 | 2.25E-05 | 3.00E-05 | 0.00 | 5.01E-04 | 7.71E-03 | 9.38E-03 |
| Ba-137m | 1.40E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.40E+01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.40E+01 | 2.21E-02 | 4.41E-01 | 1.63E-04 | 5.63E-03 | 0.00 | 3.12E-01 | 5.03E-02 | 1.48E+01 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 2.47E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.47E-12 |
| H-3 | 0.00 | 5.63E-13 | 0.00 | 0.00 | 0.00 | 0.00 | 1.33E-07 | 6.61E-12 | 1.33E-07 |
| Co-60 | 9.43E-09 | 4.45E-13 | 3.39E-13 | 4.61E-15 | 1.84E-14 | 0.00 | 3.07E-12 | 6.95E-13 | 9.44E-09 |
| Sr-90 | 0.00 | 9.35E-07 | 9.48E-05 | 3.02E-08 | 1.21E-06 | 0.00 | 6.70E-05 | 9.18E-06 | 1.73E-04 |
| Y-90 | 0.00 | 9.18E-08 | 9.20E-06 | 2.93E-09 | 1.17E-07 | 0.00 | 6.50E-06 | 8.90E-07 | 1.68E-05 |
| Cs-137 | 0.00 | 1.76E-07 | 4.57E-07 | 1.26E-08 | 1.68E-08 | 0.00 | 2.81E-07 | 4.32E-06 | 5.27E-06 |
| Ba-137m | 7.78E-03 | 5.26E-12 | 3.70E-11 | 1.02E-12 | 1.37E-12 | 0.00 | 2.28E-11 | 3.51E-10 | 7.78E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 7.78E-03 | 1.20E-06 | 1.04E-04 | 4.57E-08 | 1.34E-06 | 0.00 | 7.40E-05 | 1.44E-05 | 7.97E-03 |

Table 6G.52. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area J

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 7.71E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 1.04E-01 | 5.12E+01 | 1.81E-03 | 2.08E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 1.89E-03 | 3.01E-04 | 2.10E-05 | 3.79E-07 | 7.57E-07 | 7.67E-07 | 1.20E-08 | 1.20E-08 |
| Sr-90 | 1.83E+02 | 6.17E+01 | 6.05E+01 | 3.66E-02 | 1.55E+00 | 1.55E+00 | 7.40E-04 | 7.40E-03 |
| Y-90 | 1.83E+02 | 6.17E+01 | 6.05E+01 | 3.66E-02 | 1.55E+00 | 1.55E+00 | 7.40E-04 | 7.40E-03 |
| Cs-137 | 3.43E+03 | 5.56E+00 | 2.60E-01 | 6.86E-01 | 2.95E-01 | 3.13E-01 | 6.67E-03 | 2.22E-03 |
| Ba-137m | 3.24E+03 | 5.26E+00 | 2.46E-01 | 6.49E-01 | 2.79E-01 | 2.96E-01 | 6.31E-03 | 2.10E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 2.09E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.62E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.62E-06 |
| H-3 | 0.00 | 4.38E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 7.18E-05 | 7.30E-09 | 7.18E-05 |
| Co-60 | 7.37E-04 | 2.72E-08 | 2.73E-08 | 2.66E-10 | 1.06E-09 | 0.00 | 1.77E-07 | 5.59E-08 | 7.38E-04 |
| Sr-90 | 0.00 | 1.56E-02 | 2.95E-01 | 8.66E-05 | 3.46E-03 | 0.00 | 1.92E-01 | 2.85E-02 | 5.35E-01 |
| Y-90 | 0.00 | 1.01E-04 | 2.23E-02 | 6.54E-06 | 2.62E-04 | 0.00 | 1.45E-02 | 2.16E-03 | 3.94E-02 |
| Cs-137 | 0.00 | 7.19E-03 | 1.98E-02 | 2.74E-04 | 3.65E-04 | 0.00 | 6.08E-03 | 1.88E-01 | 2.21E-01 |
| Ba-137m | 3.40E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.40E+02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 3.40E+02 | 2.29E-02 | 3.37E-01 | 3.67E-04 | 4.09E-03 | 0.00 | 2.13E-01 | 2.18E-01 | 3.41E+02 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.98E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.98E-12 |
| H-3 | 0.00 | 5.34E-13 | 0.00 | 0.00 | 0.00 | 0.00 | 6.17E-08 | 6.27E-12 | 6.17E-08 |
| Co-60 | 4.22E-07 | 1.99E-11 | 1.52E-11 | 1.48E-13 | 5.92E-13 | 0.00 | 9.87E-11 | 3.11E-11 | 4.22E-07 |
| Sr-90 | 0.00 | 6.73E-07 | 6.83E-05 | 2.01E-08 | 8.02E-07 | 0.00 | 4.46E-05 | 6.61E-06 | 1.21E-04 |
| Y-90 | 0.00 | 6.61E-08 | 6.62E-06 | 1.94E-09 | 7.78E-08 | 0.00 | 4.32E-06 | 6.41E-07 | 1.17E-05 |
| Cs-137 | 0.00 | 4.28E-06 | 1.11E-05 | 1.53E-07 | 2.05E-07 | 0.00 | 3.41E-06 | 1.05E-04 | 1.24E-04 |
| Ba-137m | 1.89E-01 | 1.28E-10 | 9.00E-10 | 1.24E-11 | 1.66E-11 | 0.00 | 2.77E-10 | 8.52E-09 | 1.89E-01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.89E-01 | 5.02E-06 | 8.60E-05 | 1.75E-07 | 1.08E-06 | 0.00 | 5.24E-05 | 1.12E-04 | 1.89E-01 |

Table 6G.53. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area K

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 6.75E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 2.07E-02 | 3.96E+00 | 1.81E-03 | 4.15E-06 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 3.34E-04 | 2.07E-05 | 2.10E-05 | 6.67E-08 | 1.33E-07 | 1.35E-07 | 8.27E-10 | 8.27E-10 |
| Sr-90 | 1.15E+02 | 1.65E+01 | 6.05E+01 | 2.30E-02 | 9.74E-01 | 9.74E-01 | 1.98E-04 | 1.98E-03 |
| Y-90 | 1.15E+02 | 1.65E+01 | 6.05E+01 | 2.30E-02 | 9.74E-01 | 9.74E-01 | 1.98E-04 | 1.98E-03 |
| Cs-137 | 3.74E+02 | 2.48E-01 | 2.60E-01 | 7.47E-02 | 3.21E-02 | 3.41E-02 | 2.98E-04 | 9.92E-05 |
| Ba-137m | 3.53E+02 | 2.35E-01 | 2.46E-01 | 7.07E-02 | 3.04E-02 | 3.23E-02 | 2.82E-04 | 9.39E-05 |
| Eu-152 | 1.24E+04 | 2.90E+00 | 0.00 | 2.47E+00 | 1.33E+00 | 1.39E+00 | 5.81E-04 | 5.81E-07 |
| Eu-154 | 7.76E+02 | 1.22E-01 | 0.00 | 1.55E-01 | 8.33E-02 | 8.73E-02 | 2.44E-05 | 2.44E-08 |
| Eu-155 | 1.32E-01 | 4.44E-05 | 0.00 | 2.64E-05 | 1.42E-05 | 1.49E-05 | 8.89E-09 | 8.89E-12 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 2.09E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.42E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.42E-06 |
| H-3 | 0.00 | 8.73E-11 | 0.00 | 0.00 | 0.00 | 0.00 | 5.55E-06 | 1.45E-09 | 5.55E-06 |
| Co-60 | 1.30E-04 | 4.79E-09 | 4.80E-09 | 1.83E-11 | 7.32E-11 | 0.00 | 1.22E-08 | 9.84E-09 | 1.30E-04 |
| Sr-90 | 0.00 | 9.81E-03 | 1.85E-01 | 2.31E-05 | 9.25E-04 | 0.00 | 5.14E-02 | 1.79E-02 | 2.65E-01 |
| Y-90 | 0.00 | 6.37E-05 | 1.40E-02 | 1.75E-06 | 6.99E-05 | 0.00 | 3.88E-03 | 1.36E-03 | 1.94E-02 |
| Cs-137 | 0.00 | 7.84E-04 | 2.16E-03 | 1.22E-05 | 1.63E-05 | 0.00 | 2.71E-04 | 2.04E-02 | 2.37E-02 |
| Ba-137m | 3.70E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.70E+01 |
| Eu-152 | 2.35E+03 | 1.80E-01 | 1.15E-02 | 3.09E-06 | 1.24E-08 | 0.00 | 4.12E-04 | 8.77E-02 | 2.35E+03 |
| Eu-154 | 1.61E+02 | 1.46E-02 | 1.07E-03 | 1.91E-07 | 7.66E-10 | 0.00 | 2.55E-05 | 8.12E-03 | 1.61E+02 |
| Eu-155 | 1.62E-03 | 3.60E-07 | 2.91E-08 | 1.12E-11 | 4.46E-14 | 0.00 | 1.49E-09 | 2.21E-07 | 1.62E-03 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.55E+03 | 2.05E-01 | 2.14E-01 | 4.04E-05 | 1.01E-03 | 0.00 | 5.60E-02 | 1.36E-01 | 2.55E+03 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.73E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.73E-12 |
| H-3 | 0.00 | 1.06E-13 | 0.00 | 0.00 | 0.00 | 0.00 | 4.77E-09 | 1.25E-12 | 4.77E-09 |
| Co-60 | 7.44E-08 | 3.51E-12 | 2.67E-12 | 1.02E-14 | 4.08E-14 | 0.00 | 6.79E-12 | 5.48E-12 | 7.44E-08 |
| Sr-90 | 0.00 | 4.23E-07 | 4.29E-05 | 5.36E-09 | 2.14E-07 | 0.00 | 1.19E-05 | 4.16E-06 | 5.96E-05 |
| Y-90 | 0.00 | 4.16E-08 | 4.16E-06 | 5.19E-10 | 2.08E-08 | 0.00 | 1.15E-06 | 4.03E-07 | 5.78E-06 |
| Cs-137 | 0.00 | 4.66E-07 | 1.21E-06 | 6.85E-09 | 9.13E-09 | 0.00 | 1.52E-07 | 1.15E-05 | 1.33E-05 |
| Ba-137m | 2.06E-02 | 1.39E-11 | 9.81E-11 | 5.55E-13 | 7.40E-13 | 0.00 | 1.23E-11 | 9.29E-10 | 2.06E-02 |
| Eu-152 | 1.34E+00 | 9.75E-03 | 3.74E-06 | 1.00E-09 | 4.01E-12 | 0.00 | 1.34E-07 | 2.84E-05 | 1.35E+00 |
| Eu-154 | 9.05E-02 | 7.14E-06 | 3.35E-07 | 6.02E-11 | 2.41E-13 | 0.00 | 8.02E-09 | 2.55E-06 | 9.05E-02 |
| Eu-155 | 1.18E-06 | 2.60E-08 | 9.89E-12 | 3.80E-15 | 1.52E-17 | 0.00 | 5.06E-13 | 7.52E-11 | 1.20E-06 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.45E+00 | 9.76E-03 | 5.24E-05 | 1.38E-08 | 2.44E-07 | 0.00 | 1.34E-05 | 4.70E-05 | 1.46E+00 |

Table 6G.54. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area L

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 2.89E-04 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 4.41E+00 | 2.26E+03 | 1.81E-03 | 8.83E-04 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 1.59E-05 | 4.00E-06 | 2.10E-05 | 3.17E-09 | 6.33E-09 | 6.41E-09 | 1.60E-10 | 1.60E-10 |
| Sr-90 | 7.77E+01 | 3.25E+01 | 6.05E+01 | 1.55E-02 | 6.58E-01 | 6.59E-01 | 3.90E-04 | 3.90E-03 |
| Y-90 | 7.77E+01 | 3.25E+01 | 6.05E+01 | 1.55E-02 | 6.58E-01 | 6.59E-01 | 3.90E-04 | 3.90E-03 |
| Cs-137 | 3.53E+02 | 1.18E+00 | 2.60E-01 | 7.05E-02 | 3.03E-02 | 3.22E-02 | 1.41E-03 | 4.72E-04 |
| Ba-137m | 3.34E+02 | 1.12E+00 | 2.46E-01 | 6.67E-02 | 2.87E-02 | 3.05E-02 | 1.34E-03 | 4.46E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 4.72E+03 | 3.19E+02 | 2.09E+00 | 9.44E-01 | 5.06E-01 | 5.31E-01 | 6.38E-02 | 1.53E-02 |
| U-238 | 8.87E+01 | 5.25E+00 | 8.36E-01 | 1.77E-02 | 9.51E-03 | 9.97E-03 | 1.05E-03 | 2.52E-04 |
| Th-234 | 8.87E+01 | 5.25E+00 | 8.36E-01 | 1.77E-02 | 9.51E-03 | 9.97E-03 | 1.05E-03 | 2.52E-04 |
| Pa-234m | 8.87E+01 | 5.25E+00 | 8.36E-01 | 1.77E-02 | 9.51E-03 | 9.97E-03 | 1.05E-03 | 2.52E-04 |
| Pa-234 | 1.15E-01 | 6.83E-03 | 1.09E-03 | 2.31E-05 | 1.24E-05 | 1.30E-05 | 1.37E-06 | 3.28E-07 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 6.08E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.08E-06 |
| H-3 | 0.00 | 1.86E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 3.17E-03 | 3.09E-07 | 3.17E-03 |
| Co-60 | 6.17E-06 | 2.28E-10 | 2.28E-10 | 3.54E-12 | 1.42E-11 | 0.00 | 2.36E-09 | 4.68E-10 | 6.17E-06 |
| Sr-90 | 0.00 | 6.63E-03 | 1.25E-01 | 4.57E-05 | 1.83E-03 | 0.00 | 1.01E-01 | 1.21E-02 | 2.47E-01 |
| Y-90 | 0.00 | 4.31E-05 | 9.47E-03 | 3.45E-06 | 1.38E-04 | 0.00 | 7.67E-03 | 9.16E-04 | 1.82E-02 |
| Cs-137 | 0.00 | 7.40E-04 | 2.04E-03 | 5.80E-05 | 7.74E-05 | 0.00 | 1.29E-03 | 1.93E-02 | 2.35E-02 |
| Ba-137m | 3.49E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.49E+01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 4.05E-01 | 4.20E+01 | 1.96E-01 | 1.51E-02 | 1.45E-02 | 0.00 | 2.02E+00 | 1.49E+00 | 4.61E+01 |
| U-238 | 9.82E-03 | 6.90E-01 | 3.25E-03 | 2.20E-04 | 2.11E-04 | 0.00 | 2.93E-02 | 2.47E-02 | 7.57E-01 |
| Th-234 | 1.54E-01 | 2.04E-04 | 1.74E-04 | 1.18E-05 | 1.13E-05 | 0.00 | 1.57E-03 | 1.33E-03 | 1.57E-01 |
| Pa-234m | 1.72E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.72E-01 |
| Pa-234 | 3.87E-02 | 6.17E-09 | 3.59E-08 | 2.42E-09 | 2.33E-09 | 0.00 | 3.23E-07 | 2.73E-07 | 3.87E-02 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 3.57E+01 | 4.27E+01 | 3.36E-01 | 1.55E-02 | 1.68E-02 | 0.00 | 2.16E+00 | 1.55E+00 | 8.25E+01 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 7.41E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.41E-12 |
| H-3 | 0.00 | 2.26E-11 | 0.00 | 0.00 | 0.00 | 0.00 | 2.72E-06 | 2.66E-10 | 2.72E-06 |
| Co-60 | 3.53E-09 | 1.67E-13 | 1.27E-13 | 1.97E-15 | 7.89E-15 | 0.00 | 1.32E-12 | 2.60E-13 | 3.54E-09 |
| Sr-90 | 0.00 | 2.86E-07 | 2.90E-05 | 1.06E-08 | 4.23E-07 | 0.00 | 2.35E-05 | 2.81E-06 | 5.61E-05 |
| Y-90 | 0.00 | 2.81E-08 | 2.81E-06 | 1.03E-09 | 4.10E-08 | 0.00 | 2.28E-06 | 2.72E-07 | 5.44E-06 |
| Cs-137 | 0.00 | 4.40E-07 | 1.14E-06 | 3.25E-08 | 4.34E-08 | 0.00 | 7.23E-07 | 1.08E-05 | 1.32E-05 |
| Ba-137m | 1.94E-02 | 1.31E-11 | 9.26E-11 | 2.64E-12 | 3.52E-12 | 0.00 | 5.86E-11 | 8.77E-10 | 1.94E-02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 2.67E-04 | 8.37E-03 | 9.51E-05 | 7.33E-06 | 7.04E-06 | 0.00 | 9.78E-04 | 7.23E-04 | 1.04E-02 |
| U-238 | 6.99E-06 | 1.40E-04 | 1.66E-06 | 1.12E-07 | 1.08E-07 | 0.00 | 1.50E-05 | 1.26E-05 | 1.76E-04 |
| Th-234 | 8.51E-05 | 1.86E-07 | 5.11E-08 | 3.45E-09 | 3.31E-09 | 0.00 | 4.60E-07 | 3.88E-07 | 8.62E-05 |
| Pa-234m | 9.73E-05 | 9.32E-12 | 7.40E-11 | 5.00E-12 | 4.80E-12 | 0.00 | 6.67E-10 | 5.63E-10 | 9.73E-05 |
| Pa-234 | 2.17E-05 | 4.09E-12 | 1.13E-11 | 7.63E-13 | 7.32E-13 | 0.00 | 1.02E-10 | 8.58E-11 | 2.17E-05 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.99E-02 | 8.51E-03 | 1.30E-04 | 7.49E-06 | 7.66E-06 | 0.00 | 1.02E-03 | 7.50E-04 | 3.04E-02 |

Table 6G.55. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area M

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 3.86E-04 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 1.58E-01 | 2.07E+02 | 1.81E-03 | 3.16E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 1.68E-04 | 1.16E-04 | 2.10E-05 | 3.37E-08 | 6.73E-08 | 6.82E-08 | 4.63E-09 | 4.63E-09 |
| Sr-90 | 6.09E+01 | 4.72E+01 | 6.05E+01 | 1.22E-02 | 5.16E-01 | 5.16E-01 | 5.67E-04 | 5.67E-03 |
| Y-90 | 6.09E+01 | 4.72E+01 | 6.05E+01 | 1.22E-02 | 5.16E-01 | 5.16E-01 | 5.67E-04 | 5.67E-03 |
| Cs-137 | 2.69E+02 | 1.49E+00 | 2.60E-01 | 5.39E-02 | 2.32E-02 | 2.46E-02 | 1.78E-03 | 5.95E-04 |
| Ba-137m | 2.55E+02 | 1.41E+00 | 2.46E-01 | 5.10E-02 | 2.19E-02 | 2.33E-02 | 1.69E-03 | 5.63E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 5.04E+01 | 7.54E-01 | 0.00 | 1.01E-02 | 9.03E-03 | 9.29E-03 | 1.51E-04 | 1.51E-07 |
| U-233 | 2.70E+03 | 0.00 | 2.09E+00 | 5.41E-01 | 2.90E-01 | 3.04E-01 | 0.00 | 0.00 |
| U-238 | 3.93E+03 | 6.88E+02 | 8.36E-01 | 7.86E-01 | 4.21E-01 | 4.42E-01 | 1.38E-01 | 3.30E-02 |
| Th-234 | 3.93E+03 | 6.88E+02 | 8.36E-01 | 7.86E-01 | 4.21E-01 | 4.42E-01 | 1.38E-01 | 3.30E-02 |
| Pa-234m | 3.93E+03 | 6.88E+02 | 8.36E-01 | 7.86E-01 | 4.21E-01 | 4.42E-01 | 1.38E-01 | 3.30E-02 |
| Pa-234 | 5.11E+00 | 8.94E-01 | 1.09E-03 | 1.02E-03 | 5.48E-04 | 5.75E-04 | 1.79E-04 | 4.29E-05 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 8.11E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.11E-06 |
| H-3 | 0.00 | 6.64E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 2.89E-04 | 1.11E-08 | 2.89E-04 |
| Co-60 | 6.56E-05 | 2.42E-09 | 2.42E-09 | 1.02E-10 | 4.10E-10 | 0.00 | 6.83E-08 | 4.97E-09 | 6.56E-05 |
| Sr-90 | 0.00 | 5.20E-03 | 9.82E-02 | 6.63E-05 | 2.65E-03 | 0.00 | 1.47E-01 | 9.50E-03 | 2.63E-01 |
| Y-90 | 0.00 | 3.38E-05 | 7.42E-03 | 5.01E-06 | 2.00E-04 | 0.00 | 1.11E-02 | 7.18E-04 | 1.95E-02 |
| Cs-137 | 0.00 | 5.65E-04 | 1.56E-03 | 7.32E-05 | 9.76E-05 | 0.00 | 1.63E-03 | 1.47E-02 | 1.86E-02 |
| Ba-137m | 2.67E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.67E+01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 5.75E-03 | 5.42E+00 | 3.30E-02 | 3.38E-04 | 1.35E-06 | 0.00 | 4.51E-02 | 1.51E-01 | 5.66E+00 |
| U-233 | 2.32E-01 | 2.40E+01 | 1.12E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 8.55E-01 | 2.52E+01 |
| U-238 | 4.35E-01 | 3.06E+01 | 1.44E-01 | 2.88E-02 | 2.76E-02 | 0.00 | 3.84E+00 | 1.10E+00 | 3.61E+01 |
| Th-234 | 6.81E+00 | 9.05E-03 | 7.72E-03 | 1.54E-03 | 1.48E-03 | 0.00 | 2.06E-01 | 5.88E-02 | 7.09E+00 |
| Pa-234m | 7.62E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.62E+00 |
| Pa-234 | 1.72E+00 | 2.73E-07 | 1.59E-06 | 3.17E-07 | 3.05E-07 | 0.00 | 4.23E-05 | 1.21E-05 | 1.72E+00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 4.35E+01 | 6.01E+01 | 4.04E-01 | 3.08E-02 | 3.21E-02 | 0.00 | 4.25E+00 | 2.19E+00 | 1.10E+02 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 9.88E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9.88E-12 |
| H-3 | 0.00 | 8.10E-13 | 0.00 | 0.00 | 0.00 | 0.00 | 2.49E-07 | 9.52E-12 | 2.49E-07 |
| Co-60 | 3.76E-08 | 1.77E-12 | 1.35E-12 | 5.70E-14 | 2.28E-13 | 0.00 | 3.80E-11 | 2.77E-12 | 3.76E-08 |
| Sr-90 | 0.00 | 2.24E-07 | 2.27E-05 | 1.54E-08 | 6.14E-07 | 0.00 | 3.41E-05 | 2.20E-06 | 5.99E-05 |
| Y-90 | 0.00 | 2.20E-08 | 2.21E-06 | 1.49E-09 | 5.96E-08 | 0.00 | 3.31E-06 | 2.13E-07 | 5.81E-06 |
| Cs-137 | 0.00 | 3.36E-07 | 8.72E-07 | 4.10E-08 | 5.47E-08 | 0.00 | 9.12E-07 | 8.26E-06 | 1.05E-05 |
| Ba-137m | 1.49E-02 | 1.00E-11 | 7.07E-11 | 3.33E-12 | 4.44E-12 | 0.00 | 7.39E-11 | 6.69E-10 | 1.49E-02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 3.97E-06 | 1.03E-04 | 2.66E-07 | 2.72E-09 | 1.09E-11 | 0.00 | 3.63E-07 | 1.21E-06 | 1.08E-04 |
| U-233 | 1.53E-04 | 4.79E-03 | 5.45E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 4.14E-04 | 5.42E-03 |
| U-238 | 3.10E-04 | 6.20E-03 | 7.36E-05 | 1.47E-05 | 1.41E-05 | 0.00 | 1.96E-03 | 5.60E-04 | 9.13E-03 |
| Th-234 | 3.77E-03 | 8.26E-06 | 2.26E-06 | 4.52E-07 | 4.34E-07 | 0.00 | 6.03E-05 | 1.72E-05 | 3.86E-03 |
| Pa-234m | 4.31E-03 | 4.13E-10 | 3.28E-09 | 6.55E-10 | 6.29E-10 | 0.00 | 8.74E-08 | 2.50E-08 | 4.31E-03 |
| Pa-234 | 9.64E-04 | 1.81E-10 | 5.00E-10 | 9.99E-11 | 9.59E-11 | 0.00 | 1.33E-08 | 3.80E-09 | 9.64E-04 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.44E-02 | 1.11E-02 | 1.56E-04 | 1.52E-05 | 1.53E-05 | 0.00 | 2.06E-03 | 1.00E-03 | 3.87E-02 |

Table 6G.56. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area N

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-04 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 0.00 | 0.00 | 1.81E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 1.53E-03 | 3.64E-04 | 2.10E-05 | 3.07E-07 | 6.12E-07 | 6.20E-07 | 1.46E-08 | 1.46E-08 |
| Sr-90 | 8.00E+01 | 2.15E+01 | 6.05E+01 | 1.60E-02 | 6.77E-01 | 6.78E-01 | 2.58E-04 | 2.58E-03 |
| Y-90 | 8.00E+01 | 2.15E+01 | 6.05E+01 | 1.60E-02 | 6.77E-01 | 6.78E-01 | 2.58E-04 | 2.58E-03 |
| Cs-137 | 1.26E+02 | 5.18E-01 | 2.60E-01 | 2.52E-02 | 1.08E-02 | 1.15E-02 | 6.21E-04 | 2.07E-04 |
| Ba-137m | 1.19E+02 | 4.90E-01 | 2.46E-01 | 2.38E-02 | 1.02E-02 | 1.09E-02 | 5.88E-04 | 1.96E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 2.07E+03 | 7.60E+01 | 2.09E+00 | 4.15E-01 | 2.22E-01 | 2.33E-01 | 1.52E-02 | 3.65E-03 |
| U-238 | 1.49E+03 | 4.88E+01 | 8.36E-01 | 2.97E-01 | 1.59E-01 | 1.67E-01 | 9.76E-03 | 2.34E-03 |
| Th-234 | 1.49E+03 | 4.88E+01 | 8.36E-01 | 2.97E-01 | 1.59E-01 | 1.67E-01 | 9.76E-03 | 2.34E-03 |
| Pa-234m | 1.49E+03 | 4.88E+01 | 8.36E-01 | 2.97E-01 | 1.59E-01 | 1.67E-01 | 9.76E-03 | 2.34E-03 |
| Pa-234 | 1.93E+00 | 6.34E-02 | 1.09E-03 | 3.86E-04 | 2.07E-04 | 2.17E-04 | 1.27E-05 | 3.04E-06 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-05 |
| H-3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 5.96E-04 | 2.20E-08 | 2.21E-08 | 3.22E-10 | 1.29E-09 | 0.00 | 2.15E-07 | 4.52E-08 | 5.97E-04 |
| Sr-90 | 0.00 | 6.83E-03 | 1.29E-01 | 3.02E-05 | 1.21E-03 | 0.00 | 6.71E-02 | 1.25E-02 | 2.17E-01 |
| Y-90 | 0.00 | 4.43E-05 | 9.74E-03 | 2.28E-06 | 9.13E-05 | 0.00 | 5.07E-03 | 9.43E-04 | 1.59E-02 |
| Cs-137 | 0.00 | 2.64E-04 | 7.27E-04 | 2.55E-05 | 3.40E-05 | 0.00 | 5.67E-04 | 6.88E-03 | 8.50E-03 |
| Ba-137m | 1.25E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.25E+01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 1.78E-01 | 1.84E+01 | 8.62E-02 | 3.61E-03 | 3.46E-03 | 0.00 | 4.81E-01 | 6.56E-01 | 1.99E+01 |
| U-238 | 1.65E-01 | 1.16E+01 | 5.44E-02 | 2.04E-03 | 1.96E-03 | 0.00 | 2.72E-01 | 4.14E-01 | 1.25E+01 |
| Th-234 | 2.57E+00 | 3.42E-03 | 2.92E-03 | 1.09E-04 | 1.05E-04 | 0.00 | 1.46E-02 | 2.22E-02 | 2.62E+00 |
| Pa-234m | 2.88E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.88E+00 |
| Pa-234 | 6.49E-01 | 1.03E-07 | 6.01E-07 | 2.25E-08 | 2.16E-08 | 0.00 | 3.00E-06 | 4.57E-06 | 6.49E-01 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.89E+01 | 3.00E+01 | 2.83E-01 | 5.81E-03 | 6.86E-03 | 0.00 | 8.40E-01 | 1.11E+00 | 5.12E+01 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-11 |
| H-3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 3.42E-07 | 1.61E-11 | 1.23E-11 | 1.79E-13 | 7.17E-13 | 0.00 | 1.20E-10 | 2.52E-11 | 3.42E-07 |
| Sr-90 | 0.00 | 2.94E-07 | 2.99E-05 | 7.00E-09 | 2.80E-07 | 0.00 | 1.56E-05 | 2.89E-06 | 4.89E-05 |
| Y-90 | 0.00 | 2.89E-08 | 2.90E-06 | 6.79E-10 | 2.71E-08 | 0.00 | 1.51E-06 | 2.80E-07 | 4.74E-06 |
| Cs-137 | 0.00 | 1.57E-07 | 4.08E-07 | 1.43E-08 | 1.91E-08 | 0.00 | 3.18E-07 | 3.86E-06 | 4.77E-06 |
| Ba-137m | 6.94E-03 | 4.69E-12 | 3.30E-11 | 1.16E-12 | 1.55E-12 | 0.00 | 2.58E-11 | 3.13E-10 | 6.94E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 1.17E-04 | 3.68E-03 | 4.18E-05 | 1.75E-06 | 1.68E-06 | 0.00 | 2.33E-04 | 3.18E-04 | 4.39E-03 |
| U-238 | 1.17E-04 | 2.34E-03 | 2.78E-05 | 1.04E-06 | 1.00E-06 | 0.00 | 1.39E-04 | 2.12E-04 | 2.84E-03 |
| Th-234 | 1.43E-03 | 3.12E-06 | 8.55E-07 | 3.21E-08 | 3.08E-08 | 0.00 | 4.27E-06 | 6.51E-06 | 1.44E-03 |
| Pa-234m | 1.63E-03 | 1.56E-10 | 1.24E-09 | 4.65E-11 | 4.46E-11 | 0.00 | 6.20E-09 | 9.44E-09 | 1.63E-03 |
| Pa-234 | 3.64E-04 | 6.85E-11 | 1.89E-10 | 7.09E-12 | 6.80E-12 | 0.00 | 9.45E-10 | 1.44E-09 | 3.64E-04 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.06E-02 | 6.02E-03 | 1.04E-04 | 2.84E-06 | 3.03E-06 | 0.00 | 3.94E-04 | 5.43E-04 | 1.77E-02 |

Table 6G.57. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area O

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-04 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 3.22E-01 | 2.45E+02 | 1.81E-03 | 6.44E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 1.19E-03 | 2.47E-04 | 2.10E-05 | 2.38E-07 | 4.76E-07 | 4.82E-07 | 9.88E-09 | 9.88E-09 |
| Sr-90 | 7.76E+01 | 1.81E+01 | 6.05E+01 | 1.55E-02 | 6.57E-01 | 6.57E-01 | 2.17E-04 | 2.17E-03 |
| Y-90 | 7.76E+01 | 1.81E+01 | 6.05E+01 | 1.55E-02 | 6.57E-01 | 6.57E-01 | 2.17E-04 | 2.17E-03 |
| Cs-137 | 5.29E+02 | 1.01E+00 | 2.60E-01 | 1.06E-01 | 4.55E-02 | 4.83E-02 | 1.21E-03 | 4.05E-04 |
| Ba-137m | 5.00E+02 | 9.57E-01 | 2.46E-01 | 1.00E-01 | 4.30E-02 | 4.57E-02 | 1.15E-03 | 3.83E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 9.35E+01 | 2.07E+00 | 0.00 | 1.87E-02 | 1.68E-02 | 1.72E-02 | 4.15E-04 | 4.15E-07 |
| U-233 | 0.00 | 0.00 | 2.09E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 1.30E+02 | 3.05E+00 | 8.36E-01 | 2.61E-02 | 1.40E-02 | 1.47E-02 | 6.10E-04 | 1.46E-04 |
| Th-234 | 1.30E+02 | 3.05E+00 | 8.36E-01 | 2.61E-02 | 1.40E-02 | 1.47E-02 | 6.10E-04 | 1.46E-04 |
| Pa-234m | 1.30E+02 | 3.05E+00 | 8.36E-01 | 2.61E-02 | 1.40E-02 | 1.47E-02 | 6.10E-04 | 1.46E-04 |
| Pa-234 | 1.69E-01 | 3.96E-03 | 1.09E-03 | 3.39E-05 | 1.82E-05 | 1.91E-05 | 7.93E-07 | 1.90E-07 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 5.39E-01 | 1.60E-02 | 0.00 | 1.08E-04 | 5.78E-05 | 6.06E-05 | 3.20E-06 | 3.20E-09 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-05 |
| H-3 | 0.00 | 1.35E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 3.43E-04 | 2.26E-08 | 3.43E-04 |
| Co-60 | 4.64E-04 | 1.71E-08 | 1.72E-08 | 2.19E-10 | 8.74E-10 | 0.00 | 1.46E-07 | 3.52E-08 | 4.64E-04 |
| Sr-90 | 0.00 | 6.62E-03 | 1.25E-01 | 2.54E-05 | 1.02E-03 | 0.00 | 5.64E-02 | 1.21E-02 | 2.01E-01 |
| Y-90 | 0.00 | 4.30E-05 | 9.45E-03 | 1.92E-06 | 7.68E-05 | 0.00 | 4.27E-03 | 9.15E-04 | 1.48E-02 |
| Cs-137 | 0.00 | 1.11E-03 | 3.05E-03 | 4.98E-05 | 6.64E-05 | 0.00 | 1.11E-03 | 2.89E-02 | 3.43E-02 |
| Ba-137m | 5.24E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.24E+01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 1.07E-02 | 1.01E+01 | 6.13E-02 | 9.30E-04 | 3.72E-06 | 0.00 | 1.24E-01 | 2.80E-01 | 1.05E+01 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 1.44E-02 | 1.01E+00 | 4.78E-03 | 1.27E-04 | 1.22E-04 | 0.00 | 1.70E-02 | 3.63E-02 | 1.09E+00 |
| Th-234 | 2.26E-01 | 3.00E-04 | 2.56E-04 | 6.84E-06 | 6.56E-06 | 0.00 | 9.12E-04 | 1.95E-03 | 2.29E-01 |
| Pa-234m | 2.53E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.53E-01 |
| Pa-234 | 5.69E-02 | 9.06E-09 | 5.27E-08 | 1.41E-09 | 1.35E-09 | 0.00 | 1.88E-07 | 4.01E-07 | 5.69E-02 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 7.66E-05 | 8.78E-03 | 1.56E-04 | 5.29E-06 | 2.12E-08 | 0.00 | 7.06E-04 | 1.19E-03 | 1.09E-02 |
| Total | 5.29E+01 | 1.11E+01 | 2.04E-01 | 1.15E-03 | 1.29E-03 | 0.00 | 2.05E-01 | 3.61E-01 | 6.48E+01 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-11 |
| H-3 | 0.00 | 1.65E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 2.95E-07 | 1.94E-11 | 2.95E-07 |
| Co-60 | 2.66E-07 | 1.25E-11 | 9.55E-12 | 1.22E-13 | 4.87E-13 | 0.00 | 8.11E-11 | 1.96E-11 | 2.66E-07 |
| Sr-90 | 0.00 | 2.85E-07 | 2.90E-05 | 5.88E-09 | 2.35E-07 | 0.00 | 1.31E-05 | 2.80E-06 | 4.54E-05 |
| Y-90 | 0.00 | 2.80E-08 | 2.81E-06 | 5.71E-10 | 2.28E-08 | 0.00 | 1.27E-06 | 2.72E-07 | 4.40E-06 |
| Cs-137 | 0.00 | 6.60E-07 | 1.71E-06 | 2.79E-08 | 3.72E-08 | 0.00 | 6.20E-07 | 1.62E-05 | 1.93E-05 |
| Ba-137m | 2.92E-02 | 1.97E-11 | 1.39E-10 | 2.26E-12 | 3.02E-12 | 0.00 | 5.03E-11 | 1.31E-09 | 2.92E-02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 7.37E-06 | 1.90E-04 | 4.94E-07 | 7.50E-09 | 3.00E-11 | 0.00 | 1.00E-06 | 2.25E-06 | 2.02E-04 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 1.03E-05 | 2.06E-04 | 2.44E-06 | 6.51E-08 | 6.25E-08 | 0.00 | 8.68E-06 | 1.86E-05 | 2.46E-04 |
| Th-234 | 1.25E-04 | 2.74E-07 | 7.50E-08 | 2.00E-09 | 1.92E-09 | 0.00 | 2.67E-07 | 5.71E-07 | 1.26E-04 |
| Pa-234m | 1.43E-04 | 1.37E-11 | 1.09E-10 | 2.90E-12 | 2.79E-12 | 0.00 | 3.87E-10 | 8.28E-10 | 1.43E-04 |
| Pa-234 | 3.20E-05 | 6.01E-12 | 1.66E-11 | 4.43E-13 | 4.25E-13 | 0.00 | 5.90E-11 | 1.26E-10 | 3.20E-05 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 5.36E-08 | 9.56E-07 | 1.55E-08 | 5.25E-10 | 2.10E-12 | 0.00 | 7.00E-08 | 1.18E-07 | 1.21E-06 |
| Total | 2.95E-02 | 3.98E-04 | 3.65E-05 | 1.09E-07 | 3.60E-07 | 0.00 | 2.53E-05 | 4.08E-05 | 3.00E-02 |

Table 6G.58. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area P

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 9.64E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 7.81E+00 | 1.99E+03 | 1.81E-03 | 1.56E-03 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 1.71E-01 | 2.33E-02 | 2.10E-05 | 3.42E-05 | 6.83E-05 | 6.92E-05 | 9.34E-07 | 9.34E-07 |
| Sr-90 | 6.31E+02 | 9.83E+01 | 6.05E+01 | 1.26E-01 | 5.34E+00 | 5.34E+00 | 1.18E-03 | 1.18E-02 |
| Y-90 | 6.31E+02 | 9.83E+01 | 6.05E+01 | 1.26E-01 | 5.34E+00 | 5.34E+00 | 1.18E-03 | 1.18E-02 |
| Cs-137 | 3.08E+04 | 4.65E+01 | 2.60E-01 | 6.16E+00 | 2.65E+00 | 2.81E+00 | 5.58E-02 | 1.86E-02 |
| Ba-137m | 2.92E+04 | 4.40E+01 | 2.46E-01 | 5.83E+00 | 2.51E+00 | 2.66E+00 | 5.28E-02 | 1.76E-02 |
| Eu-152 | 3.54E+04 | 9.70E+01 | 0.00 | 7.09E+00 | 3.80E+00 | 3.99E+00 | 1.94E-02 | 1.94E-05 |
| Eu-154 | 1.00E+03 | 6.77E+00 | 0.00 | 2.00E-01 | 1.07E-01 | 1.12E-01 | 1.35E-03 | 1.35E-06 |
| Eu-155 | 1.59E-01 | 1.07E-03 | 0.00 | 3.18E-05 | 1.70E-05 | 1.79E-05 | 2.15E-07 | 2.15E-10 |
| Th-232 | 6.72E+05 | 0.00 | 0.00 | 1.34E+02 | 1.20E+02 | 1.24E+02 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 2.09E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 2.03E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.03E-06 |
| H-3 | 0.00 | 3.29E-08 | 0.00 | 0.00 | 0.00 | 0.00 | 2.79E-03 | 5.48E-07 | 2.79E-03 |
| Co-60 | 6.66E-02 | 2.46E-06 | 2.46E-06 | 2.07E-08 | 8.26E-08 | 0.00 | 1.38E-05 | 5.05E-06 | 6.66E-02 |
| Sr-90 | 0.00 | 5.38E-02 | 1.02E+00 | 1.38E-04 | 5.52E-03 | 0.00 | 3.07E-01 | 9.84E-02 | 1.48E+00 |
| Y-90 | 0.00 | 3.50E-04 | 7.68E-02 | 1.04E-05 | 4.17E-04 | 0.00 | 2.32E-02 | 7.43E-03 | 1.08E-01 |
| Cs-137 | 0.00 | 6.46E-02 | 1.78E-01 | 2.29E-03 | 3.05E-03 | 0.00 | 5.09E-02 | 1.69E+00 | 1.98E+00 |
| Ba-137m | 3.05E+03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.05E+03 |
| Eu-152 | 6.75E+03 | 5.14E-01 | 3.30E-02 | 1.03E-04 | 4.12E-07 | 0.00 | 1.37E-02 | 2.51E-01 | 6.75E+03 |
| Eu-154 | 2.07E+02 | 1.88E-02 | 1.37E-03 | 1.06E-05 | 4.24E-08 | 0.00 | 1.41E-03 | 1.05E-02 | 2.07E+02 |
| Eu-155 | 1.95E-03 | 4.33E-07 | 3.50E-08 | 2.70E-10 | 1.08E-12 | 0.00 | 3.59E-08 | 2.66E-07 | 1.95E-03 |
| Th-232 | 7.67E+01 | 7.23E+04 | 4.40E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 2.01E+03 | 7.48E+04 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.01E+04 | 7.23E+04 | 4.42E+02 | 2.55E-03 | 8.99E-03 | 0.00 | 3.99E-01 | 2.01E+03 | 8.48E+04 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 2.47E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.47E-12 |
| H-3 | 0.00 | 4.00E-11 | 0.00 | 0.00 | 0.00 | 0.00 | 2.40E-06 | 4.71E-10 | 2.40E-06 |
| Co-60 | 3.81E-05 | 1.80E-09 | 1.37E-09 | 1.15E-11 | 4.60E-11 | 0.00 | 7.67E-09 | 2.81E-09 | 3.81E-05 |
| Sr-90 | 0.00 | 2.32E-06 | 2.35E-04 | 3.20E-08 | 1.28E-06 | 0.00 | 7.10E-05 | 2.28E-05 | 3.33E-04 |
| Y-90 | 0.00 | 2.28E-07 | 2.28E-05 | 3.10E-09 | 1.24E-07 | 0.00 | 6.89E-06 | 2.21E-06 | 3.23E-05 |
| Cs-137 | 0.00 | 3.85E-05 | 9.98E-05 | 1.28E-06 | 1.71E-06 | 0.00 | 2.85E-05 | 9.45E-04 | 1.11E-03 |
| Ba-137m | 1.70E+00 | 1.15E-09 | 8.09E-09 | 1.04E-10 | 1.39E-10 | 0.00 | 2.31E-09 | 7.66E-08 | 1.70E+00 |
| Eu-152 | 3.83E+00 | 2.79E-02 | 1.07E-05 | 3.34E-08 | 1.34E-10 | 0.00 | 4.46E-06 | 8.15E-05 | 3.86E+00 |
| Eu-154 | 1.17E-01 | 9.20E-06 | 4.32E-07 | 3.33E-09 | 1.33E-11 | 0.00 | 4.45E-07 | 3.28E-06 | 1.17E-01 |
| Eu-155 | 1.42E-06 | 3.13E-08 | 1.19E-11 | 9.17E-14 | 3.67E-16 | 0.00 | 1.22E-11 | 9.05E-11 | 1.45E-06 |
| Th-232 | 5.30E-02 | 1.37E+00 | 3.55E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 1.62E-02 | 1.44E+00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 5.70E+00 | 1.40E+00 | 3.92E-03 | 1.35E-06 | 3.11E-06 | 0.00 | 1.14E-04 | 1.72E-02 | 7.11E+00 |

Table 6G.59. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area Q

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 3.86E-04 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 1.63E-02 | 3.08E+00 | 1.81E-03 | 3.25E-06 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 1.05E-03 | 3.97E-04 | 2.10E-05 | 2.10E-07 | 4.20E-07 | 4.26E-07 | 1.59E-08 | 1.59E-08 |
| Sr-90 | 2.75E+02 | 3.84E+01 | 6.05E+01 | 5.49E-02 | 2.32E+00 | 2.33E+00 | 4.60E-04 | 4.60E-03 |
| Y-90 | 2.75E+02 | 3.84E+01 | 6.05E+01 | 5.49E-02 | 2.32E+00 | 2.33E+00 | 4.60E-04 | 4.60E-03 |
| Cs-137 | 1.60E+03 | 1.47E+00 | 2.60E-01 | 3.20E-01 | 1.37E-01 | 1.46E-01 | 1.76E-03 | 5.87E-04 |
| Ba-137m | 1.51E+03 | 1.39E+00 | 2.46E-01 | 3.02E-01 | 1.30E-01 | 1.38E-01 | 1.66E-03 | 5.55E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 2.09E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 8.11E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.11E-06 |
| H-3 | 0.00 | 6.84E-11 | 0.00 | 0.00 | 0.00 | 0.00 | 4.32E-06 | 1.14E-09 | 4.32E-06 |
| Co-60 | 4.09E-04 | 1.51E-08 | 1.51E-08 | 3.52E-10 | 1.41E-09 | 0.00 | 2.34E-07 | 3.10E-08 | 4.10E-04 |
| Sr-90 | 0.00 | 2.34E-02 | 4.42E-01 | 5.39E-05 | 2.15E-03 | 0.00 | 1.20E-01 | 4.28E-02 | 6.31E-01 |
| Y-90 | 0.00 | 1.52E-04 | 3.34E-02 | 4.07E-06 | 1.63E-04 | 0.00 | 9.05E-03 | 3.24E-03 | 4.60E-02 |
| Cs-137 | 0.00 | 3.35E-03 | 9.23E-03 | 7.22E-05 | 9.63E-05 | 0.00 | 1.60E-03 | 8.74E-02 | 1.02E-01 |
| Ba-137m | 1.58E+02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.58E+02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.58E+02 | 2.69E-02 | 4.85E-01 | 1.30E-04 | 2.41E-03 | 0.00 | 1.30E-01 | 1.33E-01 | 1.59E+02 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 9.88E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 9.88E-12 |
| H-3 | 0.00 | 8.33E-14 | 0.00 | 0.00 | 0.00 | 0.00 | 3.71E-09 | 9.79E-13 | 3.71E-09 |
| Co-60 | 2.34E-07 | 1.11E-11 | 8.43E-12 | 1.96E-13 | 7.83E-13 | 0.00 | 1.31E-10 | 1.73E-11 | 2.35E-07 |
| Sr-90 | 0.00 | 1.01E-06 | 1.02E-04 | 1.25E-08 | 4.99E-07 | 0.00 | 2.77E-05 | 9.92E-06 | 1.42E-04 |
| Y-90 | 0.00 | 9.92E-08 | 9.94E-06 | 1.21E-09 | 4.84E-08 | 0.00 | 2.69E-06 | 9.62E-07 | 1.37E-05 |
| Cs-137 | 0.00 | 1.99E-06 | 5.17E-06 | 4.05E-08 | 5.40E-08 | 0.00 | 8.99E-07 | 4.90E-05 | 5.71E-05 |
| Ba-137m | 8.81E-02 | 5.96E-11 | 4.20E-10 | 3.28E-12 | 4.38E-12 | 0.00 | 7.29E-11 | 3.97E-09 | 8.81E-02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 8.81E-02 | 3.10E-06 | 1.18E-04 | 5.42E-08 | 6.02E-07 | 0.00 | 3.13E-05 | 5.99E-05 | 8.83E-02 |

Table 6G.60. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area R

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-04 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 3.11E-01 | 7.01E+01 | 1.81E-03 | 6.22E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 9.03E-03 | 7.54E-04 | 2.10E-05 | 1.81E-06 | 3.61E-06 | 3.65E-06 | 3.01E-08 | 3.01E-08 |
| Sr-90 | 1.52E+02 | 2.65E+01 | 6.05E+01 | 3.04E-02 | 1.29E+00 | 1.29E+00 | 3.18E-04 | 3.18E-03 |
| Y-90 | 1.52E+02 | 2.65E+01 | 6.05E+01 | 3.04E-02 | 1.29E+00 | 1.29E+00 | 3.18E-04 | 3.18E-03 |
| Cs-137 | 3.19E+02 | 2.03E-01 | 2.60E-01 | 6.39E-02 | 2.75E-02 | 2.92E-02 | 2.44E-04 | 8.13E-05 |
| Ba-137m | 3.02E+02 | 1.92E-01 | 2.46E-01 | 6.04E-02 | 2.60E-02 | 2.76E-02 | 2.31E-04 | 7.69E-05 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 2.09E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-05 |
| H-3 | 0.00 | 1.31E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 9.83E-05 | 2.18E-08 | 9.83E-05 |
| Co-60 | 3.51E-03 | 1.30E-07 | 1.30E-07 | 6.67E-10 | 2.67E-09 | 0.00 | 4.45E-07 | 2.66E-07 | 3.52E-03 |
| Sr-90 | 0.00 | 1.30E-02 | 2.45E-01 | 3.72E-05 | 1.49E-03 | 0.00 | 8.26E-02 | 2.37E-02 | 3.66E-01 |
| Y-90 | 0.00 | 8.43E-05 | 1.85E-02 | 2.81E-06 | 1.12E-04 | 0.00 | 6.24E-03 | 1.79E-03 | 2.68E-02 |
| Cs-137 | 0.00 | 6.70E-04 | 1.85E-03 | 1.00E-05 | 1.33E-05 | 0.00 | 2.22E-04 | 1.75E-02 | 2.02E-02 |
| Ba-137m | 3.17E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.17E+01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 3.17E+01 | 1.37E-02 | 2.65E-01 | 5.00E-05 | 1.61E-03 | 0.00 | 8.92E-02 | 4.30E-02 | 3.21E+01 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-11 |
| H-3 | 0.00 | 1.59E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 8.45E-08 | 1.87E-11 | 8.45E-08 |
| Co-60 | 2.01E-06 | 9.49E-11 | 7.24E-11 | 3.71E-13 | 1.49E-12 | 0.00 | 2.48E-10 | 1.48E-10 | 2.01E-06 |
| Sr-90 | 0.00 | 5.59E-07 | 5.68E-05 | 8.61E-09 | 3.45E-07 | 0.00 | 1.91E-05 | 5.49E-06 | 8.23E-05 |
| Y-90 | 0.00 | 5.49E-08 | 5.50E-06 | 8.35E-10 | 3.34E-08 | 0.00 | 1.86E-06 | 5.33E-07 | 7.98E-06 |
| Cs-137 | 0.00 | 3.99E-07 | 1.03E-06 | 5.61E-09 | 7.47E-09 | 0.00 | 1.25E-07 | 9.79E-06 | 1.14E-05 |
| Ba-137m | 1.76E-02 | 1.19E-11 | 8.39E-11 | 4.55E-13 | 6.06E-13 | 0.00 | 1.01E-11 | 7.94E-10 | 1.76E-02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.76E-02 | 1.01E-06 | 6.33E-05 | 1.51E-08 | 3.85E-07 | 0.00 | 2.12E-05 | 1.58E-05 | 1.77E-02 |

Table 6G.61. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area S

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 1.93E-03 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 0.00 | 0.00 | 1.81E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 0.00 | 0.00 | 2.10E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sr-90 | 6.32E-04 | 5.76E-03 | 6.05E+01 | 1.26E-07 | 5.35E-06 | 5.36E-06 | 6.91E-08 | 6.91E-07 |
| Y-90 | 6.32E-04 | 5.76E-03 | 6.05E+01 | 1.26E-07 | 5.35E-06 | 5.36E-06 | 6.91E-08 | 6.91E-07 |
| Cs-137 | 7.72E-02 | 3.04E-01 | 2.60E-01 | 1.54E-05 | 6.64E-06 | 7.05E-06 | 3.65E-04 | 1.22E-04 |
| Ba-137m | 7.30E-02 | 2.88E-01 | 2.46E-01 | 1.46E-05 | 6.28E-06 | 6.67E-06 | 3.45E-04 | 1.15E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 2.09E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 4.05E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.05E-05 |
| H-3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sr-90 | 0.00 | 5.39E-08 | 1.02E-06 | 8.09E-09 | 3.24E-07 | 0.00 | 1.80E-05 | 9.86E-08 | 1.95E-05 |
| Y-90 | 0.00 | 3.50E-10 | 7.70E-08 | 6.11E-10 | 2.45E-08 | 0.00 | 1.36E-06 | 7.45E-09 | 1.47E-06 |
| Cs-137 | 0.00 | 1.62E-07 | 4.46E-07 | 1.50E-05 | 1.99E-05 | 0.00 | 3.32E-04 | 4.22E-06 | 3.72E-04 |
| Ba-137m | 7.65E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.65E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 7.65E-03 | 4.08E-05 | 1.54E-06 | 1.50E-05 | 2.03E-05 | 0.00 | 3.52E-04 | 4.33E-06 | 8.08E-03 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 4.94E-11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.94E-11 |
| H-3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sr-90 | 0.00 | 2.33E-12 | 2.36E-10 | 1.87E-12 | 7.49E-11 | 0.00 | 4.16E-09 | 2.28E-11 | 4.50E-09 |
| Y-90 | 0.00 | 2.28E-13 | 2.29E-11 | 1.82E-13 | 7.27E-12 | 0.00 | 4.04E-10 | 2.21E-12 | 4.37E-10 |
| Cs-137 | 0.00 | 9.63E-11 | 2.50E-10 | 8.39E-09 | 1.12E-08 | 0.00 | 1.86E-07 | 2.37E-09 | 2.09E-07 |
| Ba-137m | 4.26E-06 | 2.88E-15 | 2.03E-14 | 6.80E-13 | 9.07E-13 | 0.00 | 1.51E-11 | 1.92E-13 | 4.26E-06 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 4.26E-06 | 1.48E-10 | 5.09E-10 | 8.39E-09 | 1.13E-08 | 0.00 | 1.91E-07 | 2.39E-09 | 4.47E-06 |

Table 6G.62. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area T

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 1.93E-03 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 2.45E-01 | 7.37E+01 | 1.81E-03 | 4.90E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 0.00 | 0.00 | 2.10E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sr-90 | 1.45E-02 | 4.79E-02 | 6.05E+01 | 2.89E-06 | 1.23E-04 | 1.23E-04 | 5.75E-07 | 5.75E-06 |
| Y-90 | 1.45E-02 | 4.79E-02 | 6.05E+01 | 2.89E-06 | 1.23E-04 | 1.23E-04 | 5.75E-07 | 5.75E-06 |
| Cs-137 | 4.13E-04 | 1.21E-02 | 2.60E-01 | 8.27E-08 | 3.56E-08 | 3.77E-08 | 1.46E-05 | 4.86E-06 |
| Ba-137m | 3.91E-04 | 1.15E-02 | 2.46E-01 | 7.82E-08 | 3.37E-08 | 3.57E-08 | 1.38E-05 | 4.59E-06 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 2.09E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 4.05E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.05E-05 |
| H-3 | 0.00 | 1.03E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 1.03E-04 | 1.72E-08 | 1.03E-04 |
| Co-60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sr-90 | 0.00 | 1.23E-06 | 2.33E-05 | 6.72E-08 | 2.69E-06 | 0.00 | 1.49E-04 | 2.26E-06 | 1.79E-04 |
| Y-90 | 0.00 | 8.02E-09 | 1.76E-06 | 5.08E-09 | 2.03E-07 | 0.00 | 1.13E-05 | 1.71E-07 | 1.34E-05 |
| Cs-137 | 0.00 | 8.67E-10 | 2.39E-09 | 5.98E-07 | 7.97E-07 | 0.00 | 1.33E-05 | 2.26E-08 | 1.47E-05 |
| Ba-137m | 4.10E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.10E-05 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 4.10E-05 | 4.18E-05 | 2.51E-05 | 6.70E-07 | 3.69E-06 | 0.00 | 2.77E-04 | 2.47E-06 | 3.92E-04 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 4.94E-11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.94E-11 |
| H-3 | 0.00 | 1.25E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 8.87E-08 | 1.47E-11 | 8.87E-08 |
| Co-60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sr-90 | 0.00 | 5.32E-11 | 5.40E-09 | 1.56E-11 | 6.23E-10 | 0.00 | 3.46E-08 | 5.23E-10 | 4.12E-08 |
| Y-90 | 0.00 | 5.23E-12 | 5.24E-10 | 1.51E-12 | 6.04E-11 | 0.00 | 3.36E-09 | 5.07E-11 | 4.00E-09 |
| Cs-137 | 0.00 | 5.16E-13 | 1.34E-12 | 3.35E-10 | 4.47E-10 | 0.00 | 7.44E-09 | 1.27E-11 | 8.24E-09 |
| Ba-137m | 2.28E-08 | 1.54E-17 | 1.09E-16 | 2.72E-14 | 3.62E-14 | 0.00 | 6.04E-13 | 1.03E-15 | 2.28E-08 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.28E-08 | 1.10E-10 | 5.93E-09 | 3.52E-10 | 1.13E-09 | 0.00 | 1.34E-07 | 6.01E-10 | 1.65E-07 |

Table 6G.63. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area U

**Concentrations**

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-03 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 4.33E-05 | 2.92E-03 | 1.81E-03 | 8.67E-09 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 0.00 | 0.00 | 2.10E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sr-90 | 4.25E-02 | 2.27E-01 | 6.05E+01 | 8.51E-06 | 3.60E-04 | 3.60E-04 | 2.72E-06 | 2.72E-05 |
| Y-90 | 4.25E-02 | 2.27E-01 | 6.05E+01 | 8.51E-06 | 3.60E-04 | 3.60E-04 | 2.72E-06 | 2.72E-05 |
| Cs-137 | 6.49E-03 | 2.72E-01 | 2.60E-01 | 1.30E-06 | 5.59E-07 | 5.93E-07 | 3.26E-04 | 1.09E-04 |
| Ba-137m | 6.14E-03 | 2.57E-01 | 2.46E-01 | 1.23E-06 | 5.28E-07 | 5.61E-07 | 3.09E-04 | 1.03E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 2.09E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Dose (rem)**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-04 |
| H-3 | 0.00 | 1.82E-13 | 0.00 | 0.00 | 0.00 | 0.00 | 4.09E-09 | 3.04E-12 | 4.10E-09 |
| Co-60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sr-90 | 0.00 | 3.63E-06 | 6.86E-05 | 3.18E-07 | 1.27E-05 | 0.00 | 7.07E-04 | 6.64E-06 | 7.99E-04 |
| Y-90 | 0.00 | 2.36E-08 | 5.18E-06 | 2.41E-08 | 9.62E-07 | 0.00 | 5.35E-05 | 5.02E-07 | 6.02E-05 |
| Cs-137 | 0.00 | 1.36E-08 | 3.75E-08 | 1.34E-05 | 1.78E-05 | 0.00 | 2.97E-04 | 3.55E-07 | 3.29E-04 |
| Ba-137m | 6.43E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.43E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 6.43E-04 | 1.05E-04 | 7.38E-05 | 1.37E-05 | 3.15E-05 | 0.00 | 1.06E-03 | 7.49E-06 | 1.93E-03 |

**Risk**

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-10 |
| H-3 | 0.00 | 2.22E-16 | 0.00 | 0.00 | 0.00 | 0.00 | 3.52E-12 | 2.61E-15 | 3.52E-12 |
| Co-60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sr-90 | 0.00 | 1.57E-10 | 1.59E-08 | 7.37E-11 | 2.95E-09 | 0.00 | 1.64E-07 | 1.54E-09 | 1.84E-07 |
| Y-90 | 0.00 | 1.54E-11 | 1.54E-09 | 7.15E-12 | 2.86E-10 | 0.00 | 1.59E-08 | 1.49E-10 | 1.79E-08 |
| Cs-137 | 0.00 | 8.10E-12 | 2.10E-11 | 7.50E-09 | 1.00E-08 | 0.00 | 1.67E-07 | 1.99E-10 | 1.84E-07 |
| Ba-137m | 3.58E-07 | 2.42E-16 | 1.70E-15 | 6.08E-13 | 8.11E-13 | 0.00 | 1.35E-11 | 1.61E-14 | 3.58E-07 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 3.58E-07 | 3.04E-10 | 1.74E-08 | 7.58E-09 | 1.32E-08 | 0.00 | 3.46E-07 | 1.89E-09 | 7.45E-07 |

Table 6G.64. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area V

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 4.82E-03 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 0.00 | 0.00 | 1.81E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 9.68E-05 | 1.81E-05 | 2.10E-05 | 1.94E-08 | 3.87E-08 | 3.92E-08 | 7.26E-10 | 7.26E-10 |
| Sr-90 | 2.33E+01 | 7.20E+00 | 6.05E+01 | 4.66E-03 | 1.97E-01 | 1.97E-01 | 8.64E-05 | 8.64E-04 |
| Y-90 | 2.33E+01 | 7.20E+00 | 6.05E+01 | 4.66E-03 | 1.97E-01 | 1.97E-01 | 8.64E-05 | 8.64E-04 |
| Cs-137 | 1.03E+02 | 3.10E-01 | 2.60E-01 | 2.05E-02 | 8.83E-03 | 9.37E-03 | 3.72E-04 | 1.24E-04 |
| Ba-137m | 9.71E+01 | 2.93E-01 | 2.46E-01 | 1.94E-02 | 8.35E-03 | 8.86E-03 | 3.52E-04 | 1.17E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 8.52E+02 | 1.63E+01 | 2.09E+00 | 1.70E-01 | 9.13E-02 | 9.58E-02 | 3.27E-03 | 7.84E-04 |
| U-238 | 1.58E+03 | 2.73E+01 | 8.36E-01 | 3.15E-01 | 1.69E-01 | 1.77E-01 | 5.46E-03 | 1.31E-03 |
| Th-234 | 1.58E+03 | 2.73E+01 | 8.36E-01 | 3.15E-01 | 1.69E-01 | 1.77E-01 | 5.46E-03 | 1.31E-03 |
| Pa-234m | 1.58E+03 | 2.73E+01 | 8.36E-01 | 3.15E-01 | 1.69E+01 | 1.77E-01 | 5.46E-03 | 1.31E-03 |
| Pa-234 | 2.05E+00 | 3.55E-02 | 1.09E-03 | 4.10E-04 | 2.20E-04 | 2.30E-04 | 7.09E-06 | 1.70E-06 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.01E-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.01E-04 |
| H-3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 3.77E-05 | 1.39E-09 | 1.39E-09 | 1.61E-11 | 6.42E-11 | 0.00 | 1.07E-08 | 2.86E-09 | 3.77E-05 |
| Sr-90 | 0.00 | 1.99E-03 | 3.75E-02 | 1.01E-05 | 4.04E-04 | 0.00 | 2.25E-02 | 3.63E-03 | 6.60E-02 |
| Y-90 | 0.00 | 1.29E-05 | 2.84E-03 | 7.64E-07 | 3.06E-05 | 0.00 | 1.70E-03 | 2.75E-04 | 4.85E-03 |
| Cs-137 | 0.00 | 2.15E-04 | 5.93E-04 | 1.53E-05 | 2.04E-05 | 0.00 | 3.39E-04 | 5.61E-03 | 6.79E-03 |
| Ba-137m | 1.02E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.02E+01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 7.30E-02 | 7.58E+00 | 3.54E-02 | 7.76E-04 | 7.45E-04 | 0.00 | 1.03E-01 | 2.70E-01 | 8.06E+00 |
| U-238 | 1.75E-01 | 1.23E+01 | 5.77E-02 | 1.14E-03 | 1.10E-03 | 0.00 | 1.52E-01 | 4.39E-01 | 1.31E+01 |
| Th-234 | 2.73E+00 | 3.63E-03 | 3.10E-03 | 6.12E-05 | 5.87E-05 | 0.00 | 8.16E-03 | 2.36E-02 | 2.77E+00 |
| Pa-234m | 3.05E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.05E+00 |
| Pa-234 | 6.88E-01 | 1.10E-07 | 6.37E-07 | 1.26E-08 | 1.21E-08 | 0.00 | 1.68E-06 | 4.85E-06 | 6.88E-01 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.69E+01 | 1.98E+01 | 1.37E-01 | 2.00E-03 | 2.35E-03 | 0.00 | 2.88E-01 | 7.42E-01 | 3.79E+01 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 1.24E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24E-10 |
| H-3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 2.16E-08 | 1.02E-12 | 7.76E-13 | 8.94E-15 | 3.58E-14 | 0.00 | 5.96E-12 | 1.59E-12 | 2.16E-08 |
| Sr-90 | 0.00 | 8.57E-08 | 8.69E-06 | 2.34E-09 | 9.37E-08 | 0.00 | 5.20E-06 | 8.41E-07 | 1.49E-05 |
| Y-90 | 0.00 | 8.41E-09 | 8.43E-07 | 2.27E-10 | 9.08E-09 | 0.00 | 5.05E-07 | 8.16E-08 | 1.45E-06 |
| Cs-137 | 0.00 | 1.28E-07 | 3.32E-07 | 8.56E-09 | 1.14E-08 | 0.00 | 1.90E-07 | 3.15E-06 | 3.82E-06 |
| Ba-137m | 5.66E-03 | 3.83E-12 | 2.69E-11 | 6.94E-13 | 9.25E-13 | 0.00 | 1.54E-11 | 2.55E-10 | 5.66E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 4.82E-05 | 1.51E-03 | 1.72E-05 | 3.76E-07 | 3.61E-07 | 0.00 | 5.01E-05 | 1.31E-04 | 1.76E-03 |
| U-238 | 1.24E-04 | 2.48E-03 | 2.95E-05 | 5.83E-07 | 5.59E-07 | 0.00 | 7.77E-05 | 2.24E-04 | 2.94E-03 |
| Th-234 | 1.51E-03 | 3.31E-06 | 9.07E-07 | 1.79E-08 | 1.72E-08 | 0.00 | 2.39E-06 | 6.90E-06 | 1.53E-03 |
| Pa-234m | 1.73E-03 | 1.66E-10 | 1.32E-09 | 2.60E-11 | 2.50E-11 | 0.00 | 3.47E-09 | 1.00E-08 | 1.73E-03 |
| Pa-234 | 3.86E-04 | 7.27E-11 | 2.00E-10 | 3.96E-12 | 3.80E-12 | 0.00 | 5.28E-10 | 1.53E-09 | 3.86E-04 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 9.46E-03 | 4.00E-03 | 5.74E-05 | 9.87E-07 | 1.05E-06 | 0.00 | 1.36E-04 | 3.66E-04 | 1.40E-02 |

Table 6G.65. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area W

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 2.89E-03 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 4.28E-02 | 5.14E+01 | 1.81E-03 | 8.56E-06 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 0.00 | 1.28E-02 | 2.10E-05 | 0.00 | 0.00 | 0.00 | 5.14E-07 | 5.14E-07 |
| Sr-90 | 5.99E-02 | 5.88E-02 | 6.05E+01 | 1.20E-05 | 5.07E-04 | 5.07E-04 | 7.05E-07 | 7.05E-06 |
| Y-90 | 5.99E-02 | 5.88E-02 | 6.05E+01 | 1.20E-05 | 5.07E-04 | 5.07E-04 | 7.05E-07 | 7.05E-06 |
| Cs-137 | 6.43E-02 | 2.69E-04 | 2.60E-01 | 1.29E-05 | 5.53E-06 | 5.87E-06 | 3.23E-07 | 1.08E-07 |
| Ba-137m | 6.08E-02 | 2.55E-04 | 2.46E-01 | 1.22E-05 | 5.23E-06 | 5.55E-06 | 3.05E-07 | 1.02E-07 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 2.09E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 6.08E-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.08E-05 |
| H-3 | 0.00 | 1.80E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 7.21E-05 | 3.00E-09 | 7.21E-05 |
| Co-60 | 0.00 | 0.00 | 0.00 | 1.14E-08 | 4.55E-08 | 0.00 | 7.58E-06 | 0.00 | 7.63E-06 |
| Sr-90 | 0.00 | 5.11E-06 | 9.65E-05 | 8.25E-08 | 3.30E-06 | 0.00 | 1.83E-04 | 9.34E-06 | 2.98E-04 |
| Y-90 | 0.00 | 3.32E-08 | 7.29E-06 | 6.24E-09 | 2.50E-07 | 0.00 | 1.39E-05 | 7.06E-07 | 2.22E-05 |
| Cs-137 | 0.00 | 1.35E-07 | 3.71E-07 | 1.32E-08 | 1.77E-08 | 0.00 | 2.94E-07 | 3.52E-06 | 4.35E-06 |
| Ba-137m | 6.37E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.37E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 6.37E-03 | 6.61E-05 | 1.04E-04 | 1.13E-07 | 3.61E-06 | 0.00 | 2.77E-04 | 1.36E-05 | 6.84E-03 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 7.41E-11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.41E-11 |
| H-3 | 0.00 | 2.19E-13 | 0.00 | 0.00 | 0.00 | 0.00 | 6.19E-08 | 2.58E-12 | 6.19E-08 |
| Co-60 | 0.00 | 0.00 | 0.00 | 6.33E-12 | 2.53E-11 | 0.00 | 4.22E-09 | 0.00 | 4.25E-09 |
| Sr-90 | 0.00 | 2.20E-10 | 2.24E-08 | 1.91E-11 | 7.65E-10 | 0.00 | 4.25E-08 | 2.16E-09 | 6.80E-08 |
| Y-90 | 0.00 | 2.16E-11 | 2.17E-09 | 1.85E-12 | 7.42E-11 | 0.00 | 4.12E-09 | 2.10E-10 | 6.60E-09 |
| Cs-137 | 0.00 | 8.02E-11 | 2.08E-10 | 7.42E-12 | 9.90E-12 | 0.00 | 1.65E-10 | 1.97E-09 | 2.44E-09 |
| Ba-137m | 3.55E-06 | 2.40E-15 | 1.69E-14 | 6.02E-16 | 8.03E-16 | 0.00 | 1.34E-14 | 1.60E-13 | 3.55E-06 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 3.55E-06 | 3.97E-10 | 2.47E-08 | 3.47E-11 | 8.74E-10 | 0.00 | 1.13E-07 | 4.35E-09 | 3.69E-06 |

Table 6G.66. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area X

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 9.64E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 0.00 | 0.00 | 1.81E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 2.52E-05 | 2.13E-05 | 2.10E-05 | 5.05E-09 | 1.01E-08 | 1.02E-08 | 8.52E-10 | 8.52E-10 |
| Sr-90 | 1.30E+01 | 1.92E+01 | 6.05E+01 | 2.60E-03 | 1.10E-01 | 1.10E-01 | 2.30E-04 | 2.30E-03 |
| Y-90 | 1.30E+01 | 1.92E+01 | 6.05E+01 | 2.60E-03 | 1.10E-01 | 1.10E-01 | 2.30E-04 | 2.30E-03 |
| Cs-137 | 4.92E+00 | 1.43E-01 | 2.60E-01 | 9.85E-04 | 4.24E-04 | 4.50E-04 | 1.72E-04 | 5.73E-05 |
| Ba-137m | 4.66E+00 | 1.35E-01 | 2.46E-01 | 9.31E-04 | 4.01E-04 | 4.25E-04 | 1.63E-04 | 5.42E-05 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 2.09E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 2.03E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.03E-06 |
| H-3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 9.82E-06 | 3.62E-10 | 3.63E-10 | 1.88E-11 | 7.54E-11 | 0.00 | 1.26E-08 | 7.44E-10 | 9.83E-06 |
| Sr-90 | 0.00 | 1.11E-03 | 2.10E-02 | 2.69E-05 | 1.08E-03 | 0.00 | 5.98E-02 | 2.03E-03 | 8.50E-02 |
| Y-90 | 0.00 | 7.21E-06 | 1.58E-03 | 2.03E-06 | 8.14E-05 | 0.00 | 4.52E-03 | 1.53E-04 | 6.35E-03 |
| Cs-137 | 0.00 | 1.03E-05 | 2.84E-05 | 7.05E-06 | 9.40E-06 | 0.00 | 1.57E-04 | 2.69E-04 | 4.81E-04 |
| Ba-137m | 4.88E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.88E-01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 4.88E-01 | 1.13E-03 | 2.26E-02 | 3.60E-05 | 1.17E-03 | 0.00 | 6.45E-02 | 2.45E-03 | 5.80E-01 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 2.47E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.47E-12 |
| H-3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 5.62E-09 | 2.65E-13 | 2.02E-13 | 1.05E-14 | 4.20E-14 | 0.00 | 7.00E-12 | 4.14E-13 | 5.63E-09 |
| Sr-90 | 0.00 | 4.79E-08 | 4.86E-06 | 6.24E-09 | 2.49E-07 | 0.00 | 1.39E-05 | 4.70E-07 | 1.95E-05 |
| Y-90 | 0.00 | 4.70E-09 | 4.71E-07 | 6.05E-10 | 2.42E-08 | 0.00 | 1.34E-06 | 4.56E-08 | 1.89E-06 |
| Cs-137 | 0.00 | 6.15E-09 | 1.59E-08 | 3.95E-09 | 5.27E-09 | 0.00 | 8.78E-08 | 1.51E-07 | 2.70E-07 |
| Ba-137m | 2.71E-04 | 1.84E-13 | 1.29E-12 | 3.20E-13 | 4.27E-13 | 0.00 | 7.12E-12 | 1.22E-11 | 2.71E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.71E-04 | 5.87E-08 | 5.34E-06 | 1.08E-08 | 2.79E-07 | 0.00 | 1.53E-05 | 6.67E-07 | 2.93E-04 |

Table 6G.67. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area Y

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 2.89E-04 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 0.00 | 0.00 | 1.81E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 3.44E-02 | 6.62E-03 | 2.10E-05 | 6.88E-06 | 1.37E-05 | 1.39E-05 | 2.65E-07 | 2.65E-07 |
| Sr-90 | 1.10E+02 | 2.26E+01 | 6.05E+01 | 2.21E-02 | 9.34E-01 | 9.35E-01 | 2.71E-04 | 2.71E-03 |
| Y-90 | 1.10E+02 | 2.26E+01 | 6.05E+01 | 2.21E-02 | 9.34E-01 | 9.35E-01 | 2.71E-04 | 2.71E-03 |
| Cs-137 | 1.43E+02 | 3.28E-01 | 2.60E-01 | 2.86E-02 | 1.23E-02 | 1.30E-02 | 3.93E-04 | 1.31E-04 |
| Ba-137m | 1.35E+02 | 3.10E-01 | 2.46E-01 | 2.70E-02 | 1.16E-02 | 1.23E-02 | 3.72E-04 | 1.24E-04 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 8.91E+03 | 4.33E+01 | 2.09E+00 | 1.78E+00 | 9.56E-01 | 1.00E+00 | 8.65E-03 | 2.08E-03 |
| U-238 | 1.56E+04 | 1.08E+02 | 8.36E-01 | 3.12E+00 | 1.67E+00 | 1.75E+00 | 2.17E-02 | 5.21E-03 |
| Th-234 | 1.56E+04 | 1.08E+02 | 8.36E-01 | 3.12E+00 | 1.67E+00 | 1.75E+00 | 2.17E-02 | 5.21E-03 |
| Pa-234m | 1.56E+04 | 1.08E+02 | 8.36E-01 | 3.12E+00 | 1.67E+00 | 1.75E+00 | 2.17E-02 | 5.21E-03 |
| Pa-234 | 2.02E+01 | 1.41E-01 | 1.09E-03 | 4.05E-03 | 2.17E-03 | 2.28E-03 | 2.82E-05 | 6.77E-06 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 1.17E+01 | 0.00 | 0.00 | 2.33E-03 | 1.25E-03 | 1.31E-03 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 6.08E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.08E-06 |
| H-3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 1.34E-02 | 4.95E-07 | 4.95E-07 | 5.85E-09 | 2.34E-08 | 0.00 | 3.90E-06 | 1.02E-06 | 1.34E-02 |
| Sr-90 | 0.00 | 9.42E-03 | 1.78E-01 | 3.17E-05 | 1.27E-03 | 0.00 | 7.05E-02 | 1.72E-02 | 2.76E-01 |
| Y-90 | 0.00 | 6.12E-05 | 1.34E-02 | 2.40E-06 | 9.60E-05 | 0.00 | 5.33E-03 | 1.30E-03 | 2.02E-02 |
| Cs-137 | 0.00 | 3.00E-04 | 8.25E-04 | 1.61E-05 | 2.15E-05 | 0.00 | 3.58E-04 | 7.81E-03 | 9.33E-03 |
| Ba-137m | 1.42E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.42E+01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 7.64E-01 | 7.93E+01 | 3.71E-01 | 2.05E-03 | 1.97E-03 | 0.00 | 2.74E-01 | 2.82E+00 | 8.35E+01 |
| U-238 | 1.73E+00 | 1.21E+02 | 5.71E-01 | 4.53E-03 | 4.35E-03 | 0.00 | 6.05E-01 | 4.34E+00 | 1.28E+02 |
| Th-234 | 2.70E+01 | 3.59E-02 | 3.06E-02 | 2.43E-04 | 2.33E-04 | 0.00 | 3.24E-02 | 2.33E-01 | 2.73E+01 |
| Pa-234m | 3.02E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.02E+01 |
| Pa-234 | 6.80E+00 | 1.08E-06 | 6.30E-06 | 5.00E-08 | 4.80E-08 | 0.00 | 6.67E-06 | 4.79E-05 | 6.80E+00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 1.66E-03 | 1.90E-01 | 3.38E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 2.57E-02 | 2.21E-01 |
| Total | 8.06E+01 | 2.01E+02 | 1.17E+00 | 6.88E-03 | 7.94E-03 | 0.00 | 9.87E-01 | 7.45E+00 | 2.91E+02 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 7.41E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.41E-12 |
| H-3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 7.67E-06 | 3.62E-10 | 2.76E-10 | 3.26E-12 | 1.30E-11 | 0.00 | 2.17E-09 | 5.65E-10 | 7.68E-06 |
| Sr-90 | 0.00 | 4.06E-07 | 4.12E-05 | 7.35E-09 | 2.94E-07 | 0.00 | 1.63E-05 | 3.99E-06 | 6.22E-05 |
| Y-90 | 0.00 | 3.99E-08 | 4.00E-06 | 7.13E-10 | 2.85E-08 | 0.00 | 1.58E-06 | 3.87E-07 | 6.04E-06 |
| Cs-137 | 0.00 | 1.78E-07 | 4.63E-07 | 9.04E-09 | 1.21E-08 | 0.00 | 2.01E-07 | 4.38E-06 | 5.24E-06 |
| Ba-137m | 7.88E-03 | 5.33E-12 | 3.75E-11 | 7.33E-13 | 9.77E-13 | 0.00 | 1.63E-11 | 3.55E-10 | 7.88E-03 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 5.04E-04 | 1.58E-02 | 1.80E-04 | 9.95E-07 | 9.55E-07 | 0.00 | 1.33E-04 | 1.37E-03 | 1.80E-02 |
| U-238 | 1.23E-03 | 2.46E-02 | 2.91E-04 | 2.32E-06 | 2.22E-06 | 0.00 | 3.09E-04 | 2.22E-03 | 2.86E-02 |
| Th-234 | 1.50E-02 | 3.27E-05 | 8.97E-06 | 7.12E-08 | 6.84E-08 | 0.00 | 9.50E-06 | 6.82E-05 | 1.51E-02 |
| Pa-234m | 1.71E-02 | 1.64E-09 | 1.30E-08 | 1.03E-10 | 9.92E-11 | 0.00 | 1.38E-08 | 9.89E-08 | 1.71E-02 |
| Pa-234 | 3.82E-03 | 7.18E-10 | 1.98E-09 | 1.57E-11 | 1.51E-11 | 0.00 | 2.10E-09 | 1.51E-08 | 3.82E-03 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 1.16E-06 | 2.07E-05 | 3.36E-07 | 0.00 | 0.00 | 0.00 | 0.00 | 2.55E-06 | 2.47E-05 |
| Total | 4.55E-02 | 4.04E-02 | 5.26E-04 | 3.40E-06 | 3.58E-06 | 0.00 | 4.69E-04 | 3.66E-03 | 9.06E-02 |

Table 6G.68. Radionuclide Concentrations, Dose, and Risk for the 2100 Homesteader in Sub-area Z

Concentrations

| Radio-nuclide | Soil (pCi/g) | Ground Water (pCi/L) | Surface Water (pCi/L) | Air (pCi/m$^3$) | Non-leafy Vegtables (pCi/g) | Leafy Vegetables (pCi/g) | Meat (pCi/g) | Milk (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 0.00 | 0.00 | 2.89E-04 | 0.00 | 0.00 | 0.00 | 0.00 |
| H-3 | 4.88E-01 | 9.42E+01 | 1.81E-03 | 9.75E-05 | 0.00 | 0.00 | 0.00 | 0.00 |
| Co-60 | 2.81E-05 | 5.24E-04 | 2.10E-05 | 5.63E-09 | 1.12E-08 | 1.14E-08 | 2.10E-08 | 2.10E-08 |
| Sr-90 | 1.89E+02 | 2.01E+01 | 6.05E+01 | 3.78E-02 | 1.60E+00 | 1.60E+00 | 2.42E-04 | 2.42E-03 |
| Y-90 | 1.89E+02 | 2.01E+01 | 6.05E+01 | 3.78E-02 | 1.60E+00 | 1.60E+00 | 2.42E-04 | 2.42E-03 |
| Cs-137 | 3.98E+02 | 0.00 | 2.60E-01 | 7.95E-02 | 3.42E-02 | 3.63E-02 | 0.00 | 0.00 |
| Ba-137m | 3.76E+02 | 0.00 | 2.46E-01 | 7.52E-02 | 3.24E-02 | 3.43E-02 | 0.00 | 0.00 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 2.09E+00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 8.36E-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 1.09E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Dose (rem)

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 6.08E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.08E-06 |
| H-3 | 0.00 | 2.05E-09 | 0.00 | 0.00 | 0.00 | 0.00 | 1.32E-04 | 3.42E-08 | 1.32E-04 |
| Co-60 | 1.10E-05 | 4.04E-10 | 4.05E-10 | 4.64E-10 | 1.86E-09 | 0.00 | 3.09E-07 | 8.30E-10 | 1.13E-05 |
| Sr-90 | 0.00 | 1.61E-02 | 3.04E-01 | 2.83E-05 | 1.13E-03 | 0.00 | 6.28E-02 | 2.94E-02 | 4.14E-01 |
| Y-90 | 0.00 | 1.05E-04 | 2.30E-02 | 2.14E-06 | 8.55E-05 | 0.00 | 4.75E-03 | 2.23E-03 | 3.02E-02 |
| Cs-137 | 0.00 | 8.34E-04 | 2.30E-03 | 0.00 | 0.00 | 0.00 | 0.00 | 2.17E-02 | 2.49E-02 |
| Ba-137m | 3.94E+01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.94E+01 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 3.94E+01 | 1.71E-02 | 3.30E-01 | 3.04E-05 | 1.22E-03 | 0.00 | 6.77E-02 | 5.34E-02 | 3.99E+01 |

Risk

| Radio-nuclide | External Exposure | Inhala-tion | Fruits & Vegetables | Meat | Milk | Fish | Drinking Water | Soil Ingestion | Total |
|---|---|---|---|---|---|---|---|---|---|
| H-3 vapor | 0.00 | 7.41E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.41E-12 |
| H-3 | 0.00 | 2.50E-12 | 0.00 | 0.00 | 0.00 | 0.00 | 1.13E-07 | 2.94E-11 | 1.13E-07 |
| Co-60 | 6.27E-09 | 2.96E-13 | 2.25E-13 | 2.58E-13 | 1.03E-12 | 0.00 | 1.72E-10 | 4.62E-13 | 6.45E-09 |
| Sr-90 | 0.00 | 6.95E-07 | 7.05E-05 | 6.55E-09 | 2.62E-07 | 0.00 | 1.46E-05 | 6.82E-06 | 9.28E-05 |
| Y-90 | 0.00 | 6.82E-08 | 6.83E-06 | 6.35E-10 | 2.54E-08 | 0.00 | 1.41E-06 | 6.62E-07 | 9.00E-06 |
| Cs-137 | 0.00 | 4.96E-07 | 1.29E-06 | 0.00 | 0.00 | 0.00 | 0.00 | 1.22E-05 | 1.40E-05 |
| Ba-137m | 2.19E-02 | 1.48E-11 | 1.04E-10 | 0.00 | 0.00 | 0.00 | 0.00 | 9.88E-10 | 2.19E-02 |
| Eu-152 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-154 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eu-155 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-232 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-233 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| U-238 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Th-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234m | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pa-234 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Am-241 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cm-244 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 2.19E-02 | 1.26E-06 | 7.86E-05 | 7.18E-09 | 2.87E-07 | 0.00 | 1.61E-05 | 1.97E-05 | 2.20E-02 |

# APPENDIX 6H. CONCENTRATIONS OF CONTAMINANTS OF POTENTIAL CONCERN IN SURFACE WATER AND SOIL OFF-WAG

This appendix supplements Sect. 6.3 of the main report. It states the method by which concentrations of contaminants were determined for Clinch River water and garden soils assumed to affect an off-WAG homesteader.

The baseline human health evaluation includes a receptor who lives for a period of 30 years on a site next to the Clinch River downstream from WAG 6 (at Clinch River Mile 9.5) and who irrigates a garden and a yard with water from the river. In assessing risk for this off-WAG homesteader concentrations of chemicals and radionuclides in the irrigation water were assumed to result exclusively from migration of contaminants from the WAG; soil in the garden and yard was assumed to become contaminated as a result of this irrigation.

Concentrations were quantified for six volatile organics (1,2-dichloroethylene, chloroform, acetone, tetrachloroethene, trichloroethene, and carbon disulfide) and one inorganic (silver). These chemicals were of potential concern in surface water (see Appendix 6E). The radionuclides quantified were tritium, cobalt-60, strontium-90, cesium-137, europium-152, europium-154, thorium-232, uranium-233, and uranium-235, all of which were identified as being of potential concern (see Appendix 6B). Two other radionuclides of potential concern, americium-241 and curium-244, were not included in the risk characterization for the off-WAG homesteader because the risk values for on-WAG receptors associated with these radionuclides were low or nonexistent.

## 6H.1 CONTAMINANT CONCENTRATIONS IN THE CLINCH RIVER

The procedure used to compute contaminant concentrations in the Clinch River resulting from migration of WAG 6 contaminants was the:

- Determination of WAG 6 boundary fluxes of chemicals and radionuclides
- Determination of chemical and radionuclide concentrations in the White Oak Creek discharge (over White Oak Dam)
- Consideration of dilution in the Clinch River

Boundary fluxes of the chemicals were computed by multiplying their concentrations in surface water on-WAG by the volume flow rate of water discharged from the WAG. Concentrations used were:

| Chemical | Concentration (mg/L) |
|---|---|
| 1,2-Dichloroethylene | 0.005 |
| chloroform | 0.005 |
| acetone | 0.01 |
| tetrachlorethane | 0.005 |
| trichloroethene | 0.005 |
| carbon disulfide | 0.005 |
| silver | 0.027 |

These concentrations represent the areal average of current concentrations for WAG 6 surface waters as determined by the median of the surface water sampling data (see Appendix 4C for a discussion of surface water sampling results). Boundary fluxes of radionuclides were obtained from water modeling results presented in Sect. 5 of the main report.

Concentrations of chemicals and radionuclides in the White Oak Creek discharge over the White Oak Dam were then computed by dividing the respective fluxes by the volume flow rate of the discharge.

Finally, concentrations in the Clinch River were computed by multiplying the White Oak Dam discharge concentrations by a dilution factor to account for dilution in the waters of the river. The dilution factor (ORNL 1991b) was derived from an advective-dispersion modeling in the Clinch River for 'dry' climatic conditions. The concentrations of radionuclides and chemicals in surface water at Clinch River Mile 9.5 are given in appendices 6G and 6I, respectively.

## 6H.2 CHEMICAL CONCENTRATIONS IN SOIL

The concentrations of chemicals in the soil were computed using the mass-balance equation shown below:

$$Cs = \frac{Z}{ST + WT/K_d}$$

where:

- Cs = concentration in soil
- Z = total amount of chemical
- ST = total mass of soil
- WT = total volume of water in the soil
- $K_d$ = distribution coefficient

The total amount of chemical introduced into the soil by irrigation water was computed as the volume of irrigation water multiplied by the concentration of the chemical in the water. It was assumed that the amount of irrigation water was 11 in., the amount necessary to compensate for shortfalls in rainfall during the summer months. The total mass of soil was that corresponding to the upper 15 cm of the garden or the yard. Distribution coefficients used are shown in Table 6H.1. The computed concentrations of chemicals in soil are given in Table 6H.2.

## 6H.3 RADIONUCLIDE CONCENTRATIONS IN SOIL

Radionuclide concentrations in garden soil were computed yearly for the 30-year period for which radionuclide fluxes out of WAG 6 were available (see Appendix 5D). The computation accounted for accumulation of radionuclides introduced by irrigation water into the soil, their leaching out of the garden plot, and their decay.

$$Z_t = \left[ Z_{t-1} \; e^{-\left( \frac{RF - RO + I}{D \, K_d (1-p) + p} \right)} \right] e^{-\lambda t} + A$$

where:

$Z_t$ = amount of radionuclide in soil in year t
$Z_{t-1}$ = amount of radionuclide in soil in year t-1
RF = annual rainfall
RO = annual runoff
I = annual amount of irrigation water
D = soil particle density
$K_d$ = distribution coefficient
p = soil porosity
$\lambda$ = radioactive decay constant
A = amount of radionuclide brought in

Annual rainfall, runoff, and irrigation water amounts were assumed to be 52, 12, and 11 in., respectively.. The $K_d$ coefficients for radionuclides are presented in Table 6H.1 The radionuclide concentrations are presented in Appendix 6G.

# Appendix 6H Tables

**Table 6H.1. Distribution coefficients used in calculating concentrations of chemicals and radionuclides in soil cultivated by the off-WAG homesteader**

| Chemicals | $K_d$ (L/kg) |
|---|---|
| 1,2-Dichloroethylene | 1.5 |
| Chloroform | 0.012 |
| Acetone | 0.0073 |
| Tetrachlorethane | 5.0 |
| Trichlorethene | 3.0 |
| Carbon disulfide | 1.3 |
| Silver | 80.9 |
| **Radionuclides** | |
| Tritium | 0 |
| Cobalt-60 | 1000 |
| Strontium-90 | 500 |
| Cesium-137 | 3000 |
| Europium-152 | 1000 |
| Europium-154 | 1000 |
| Thorium-232 | 3000 |
| Uranium-233 | 1000 |
| Uranium-238 | 1000 |

**Table 6H.2. Concentrations of chemicals in soil irrigated by off-WAG homesteader**

| Chemicals | Concentration (mg/kg) |
|---|---|
| **Volatile organics** | |
| 1,2-Dichloroethylene | $5.3 \times 10^{-5}$ |
| Chloroform | $2.26 \times 10^{-6}$ |
| Acetone | $2.8 \times 10^{-5}$ |
| Tetrachloroethene | $6.1 \times 10^{-5}$ |
| Trichloroethene | $5.8 \times 10^{-5}$ |
| Carbon disulfide | $5.2 \times 10^{-5}$ |
| **Metals** | |
| Silver | $3.5 \times 10^{-4}$ |

# APPENDIX 6.I. CHEMICAL RISK ASSESSMENT METHODOLOGY AND RESULTS

This Appendix supplements Sect. 6.3 of the main report. It presents the methods for calculating concentrations of chemicals in and media-specific chemical intakes for exposure pathways identified in Sect. 6.3 (groundwater, surface water, soil, sediment, and air). Resultant values for chemical intakes, hazard indices, and risk are also presented. Estimation of concentrations in biota was determined by using an environmental partitioning model. Chemical concentrations were calculated for fruits, vegetables, milk, beef, deer, and fish utilizing chemical-specific biotransfer and bioconcentration factors. Reasonable maximum intakes to hypothetical receptors were generally calculated using upper-bound pathway-specific variable values.

## 6I.1 QUANTIFICATION OF EXPOSURE - DETERMINATION OF CONTAMINANT CONCENTRATIONS IN MEDIA

### 6I.1.1 Concentrations in Biota

Concentrations of chemicals in biota were determined using an environmental partitioning model (Travis and Hattemer-Frey 1987, 1988). This model estimates the transport and accumulation of contaminants between environmental media utilizing contaminant-specific input parameters to predict the amount of chemicals entering the food chain. Input parameters include physico-chemical parameters (e.g., octanol-water partition coefficients) and bioconcentration or biotransfer factors.

Estimation of chemical concentrations in biota is dependent on bioaccumulation properties of the biota. This potential is quantified by using biotransfer factors (BTF) for milk and meat and bioconcentration factors (BCF) for vegetation and fish. When factors were not available for organic contaminants considered in the WAG 6 baseline human health evaluation, regression equations based on octanol-water partition coefficients ($K_{ow}$) were used to calculate bioconcentration or biotransfer factors (Travis and Arms 1988).

Octanol-water partition coefficients and resulting bioconcentration/biotransfer factors for organic chemicals are presented in Table 6I.1. The potential for inorganic chemicals to bioaccumulate is measured using elemental bioconcentration/biotransfer factors (ANL 1989; Ng et al. 1977) also listed in Table 6I.1. The regression equations used to estimate the biotransfer factors for milk and meat and bioconcentration factors for vegetation and fish are presented in Table 6I.2.

Concentrations of chemicals in the tissues of vegetables and fruits, milk, beef, deer meat, and fish were calculated by multiplying the concentrations of chemicals in these media by the bioconcentration or biotransfer factors (and for cows and deer, these parameters were multiplied by their steady state daily intakes).

Table 6I.3 summarizes the factors contributing to the estimation of chemical concentrations in tissue. For vegetables and fruits, the three contributors are: (1) direct deposition onto plant surfaces, (2) soil uptake, and (3) air-to-leaf uptake (Hattemer-Frey and Travis 1989; Travis and Hattemer-Frey, 1987; 1988). The equation for calculating chemical concentrations in vegetation is presented in Table 6I.4. Following deposition, the particulates are susceptible to removal by weathering. The half-life for particulate weathering on foliage surfaces is estimated to be 17 days (Baes et al. 1984). To account for the accumulation of organic and inorganic chemicals in plant tissues from the soil, the contaminant concentration in soil was multiplied by the appropriate bioconcentration factor. Vegetative concentrations from air-to-leaf transfer were calculated by multiplying the concentration of the particular chemical in ambient air by the chemical-specific bioconcentration factor (Travis and Hattemer-Frey, 1988).

Concentrations of chemicals in meat from cows and deer and milk from cows were quantified by multiplying biotransfer factors by a steady state daily intake for the animal by the concentration of chemicals in the appropriate environmental medium. (Hattemer-Frey and Travis 1989, Travis and Hattemer-Frey 1987). Concentrations in cow milk and meat were estimated from ingestion of groundwater on-WAG and surface water off-WAG. The predicted concentrations in deer meat resulted from exposures to surface water on-WAG. Tables 6I.5 and 6I.6 present the equations for calculating chemical concentrations in cow and deer meat and cow's milk, respectively. As shown in Table 6I.7, the concentration in fish tissue was calculated by multiplying the chemical bioconcentration factor by surface water chemical concentrations in the Clinch River (EPA 1986d).

### 6I.1.2 Concentrations in Air

Exposure to chemicals in the air occurs through inhalation of vapors and particulates. The following describes the basic approach for quantifying concentrations of contaminants for the vapor phase while showering and for chemicals in the particulate phase.

Estimation of chemical concentrations in the vapor phase from showering is dependent on the water contaminant concentration, the volatilization fraction, the water consumption, and the capacity of the shower area (EPA 1990d). The method for measuring the volatilization of chemical contaminants suspended in the particulate phase is presented in Table 6I.8.

Quantification of the concentrations chemical contaminants suspended in the particulate phase is also presented in Table 6I.8. The model uses a mass loading factor to predict the particulate chemical concentration. The dust is assumed to have originated exclusively from contaminated soil at WAG 6.

## 6I.2 QUANTIFICATION OF EXPOSURE - ESTIMATION OF CHEMICAL INTAKES

This section describes the basic approach to and methods for determining chemical-specific intakes for the receptors and exposure pathways identified in Sect. 6.3. Standard assumptions used to estimate chemical intakes for each route of exposure were (EPA 1989b):

- For carcinogens, exposure is averaged over body weight and a 70-year lifetime.
- For noncarcinogens, exposure is averaged over body weight and the time over which exposure actually occurs (i.e., exposure duration).
- Exposure duration is assumed to be 30 years (national upper-bound time at one residence) for adult receptors (EPA 1989b).
- Exposure duration is assumed to be 7 years (chronic exposure) for children (EPA 1989b).
- Average adult body weight for the exposed population is 70 Kg (EPA 1989b).
- Average body weight for 1- to 6-year-old children is 16 Kg (EPA 1989b).
- Exposure intakes are expressed in units of mg/Kg-day at the exchange boundary and are available for absorption.

### 6I.2.1 Inhalation Exposure

Exposure to chemical contaminants suspended in ambient air occurs through inhalation of both vapors and particulates. For the purpose of this human health evaluation, pollutants adsorbed to inhaled particulates were considered completely absorbed in the lungs, thus yielding a conservative estimate of exposure. Likewise, vapors (i.e., volatile organic compounds) were assumed to be entirely absorbed.

Exposure equations and variables used to estimate intakes of inhaled chemicals from the vapor phase, particulate phase, and from volatile organic compounds (which volatilized during showering) are presented in Table 6I.9 for an adult homesteader and Table 6I.10 for a child homesteader, respectively. A constant inhalation rate of 1.25 $m^3/h$ (30 $m^3/d$) was assumed for an adult receptor. A 0.6 $m^3/h$ (14.4 $m^3/d$) inhalation rate (light, nonoccupational, and resting activities for a 10-year-old child) was assumed for the child receptor. An inhalation rate of 0.6 $m^3/h$ was assumed during showering for all age groups (EPA 1989a). For the showering scenario, the 90 percentile exposure duration of 12 minutes (0.20 hours) was used for all age groups (EPA 1989b). It was also assumed that a homesteader showers once per day for 365 days per year.

Intake variables from the inhalation of vapor phase chemicals by an on-WAG ORNL employee are presented in Table 6I.11. For this receptor, the exposure time was assumed to be 8 hours per day and the exposure frequency 156 days per year. (Temeshy 1990).

For the boundary receptor, a constant 1.25 $m^3/h$ (30 $m^3/d$) inhalation rate and a 70-year exposure duration (lifetime) was assumed. In addition, this receptor was evaluated at the same location and with respect to the same ambient concentration throughout the 70-year

exposure period. Values for pathway-specific variable for this receptor are presented in Table 6I.12.

### 6I.2.2 Dermal Contact with Soil

Another potential route of exposure is dermal absorption of contaminants through the skin. It was assumed that receptors were exposed to soil contaminants as a result of outdoor activities. Adult receptors were assumed to be in contact with soil 43 days per year (two days per week from May to October) (EPA 1989g). Children were presumed to be in contact with soil 141 days per year, from May to September (EPA 1989g).

To calculate exposure from this pathway it is necessary to know the amount of soil that adheres to exposed skin. A kaolin clay soil adherence factor of 2.77 $mg/cm^2$ of skin was used. The amount of skin exposed was assumed to be that on the hands and arms, or 3120 $cm^2$ (EPA 1989g). For children, skin exposed during play was assumed to be that on the arms, legs, and hands, or 2960 $cm^2$ (Hawley 1985). Absorption factors (ABS) reflect the desorption of chemicals from soil and the absorption of the chemicals across the skin. For this evaluation, maximum absorption factors were used to quantify dermal absorption (Ryan 1987). The equations in Tables 6I.13 and 6I.14 were used to calculate resulting chemical intakes from dermal contact with soil for the adult and child receptors, respectively.

### 6I.2.3 Dermal Contact with Sediments

This scenario assumed that a receptor was exposed to sediments while swimming. EPA Region IV recommends an exposure frequency of 45 days/year for the swimming scenario for the southeast region (including Tennessee) (EPA 1991). Tables 6I.13 and 6I.14 present chemical intakes from dermal contact with sediments for an adult and child, respectively.

### 6I.2.4 Dermal Contact with Groundwater and Surface Water while Showering

For this scenario it was assumed that contaminated water was not treated prior to use by the receptor and that the receptor's entire body surface area was exposed. Chemical-specific dermal permeability factors are not available for most chemicals. A default value of 8.4e-4 cm/hr was therefore used as the dermal permeability constant (EPA 1989b). The homesteader was assumed to shower for 12 minutes (0.20 hours) (90 percentile), each day, 365 days per year. The equations in Table 6I.15 and 6I.16 were used to calculate resultant exposures from dermal contact for adult and child receptors, respectively.

### 6I.2.5 Dermal Contact with Surface Water while Swimming

Dermal absorption from water is a function of the concentrations of chemicals in the water, the amount of skin in contact with the water, the duration and frequency of the contact, and the type of chemical. In quantifying exposures from dermal contact with surface water during swimming, it was assumed that the entire body surface came in contact with the

water. Exposure frequency was assumed to be 45 days per year as recommended by EPA Region IV for the southeast region (EPA 1991). Exposure intakes for an adult and child were estimated according to the equations and pathway-specific variables presented in Tables 6I.15 and 6I.16, respectively.

### 6I.2.6 Ingestion of Contaminated Drinking Water

Homesteaders would potentially be directly exposed to chemicals through the ingestion of tap water. It was assumed that homesteaders on-WAG ingested groundwater, while the off-WAG homesteader ingested surface water. The adult was assumed to consume 2 l/day (EPA 1989b) from the contaminated source. For children, a one liter of water per day was the ingestion rate assumed. It was also assumed that the contaminated water was not treated prior to ingestion. Equations presented in Tables 6I.17 and 6I.18 were used to calculate intakes from the ingestion of chemically contaminated drinking water by an adult and child, respectively.

### 6I.2.7 Ingestion of Fruits and Vegetables

Produce grown from the homesteader's garden would be subject to chemical accumulation through deposition, air-to-leaf transfer, and root absorption. EPA has reported daily consumption rates of fruits and vegetables by adults. A national average "reasonable worst-case" ingestion of 140 g/day for fruits and 200 g/day for vegetables were used as typical adult consumption rates (EPA 1989b). The proportion of consumed produce assumed to be homegrown was 40 percent for vegetables and 30 percent for fruits (EPA 1989g). To estimate intakes for the homesteader child, the mean consumption rate for each food group (vegtables and fruits) was calculated for an average 1- to 8-year-old child (USDA 1983), yielding a rate of 107.5 g/day for vegetables and 147.3 g/day for fruits. Tables 6I.19 and 6I.20 present the specific pathway variables and equations that correspond to the ingestion of produce by an adult and a child homesteader, respectively.

### 6I.2.8 Ingestion of Beef and Milk

Homesteaders were assumed to raise livestock for home consumption; further, the livestock were assumed to drink contaminated water. The EPA provides daily adult consumption rates for beef and milk. For the adult WAG 6 homesteader a national average "reasonable worst-case" consumption rate of 100 g/day for beef and 400 g/day milk were used (EPA 1989g). It was assumed that 75 percent of the consumed beef and milk was homegrown (EPA 1989g). To estimate intakes for the homesteader child, the mean consumption rate for each food group (beef and milk) was calculated for an average 1- to 8-year-old child (USDA 1983), yielding a rate of 21.8 grams of beef per day and 382.5 grams of milk per day. Tables 6I.21 and 6I.22 present the equations and pathway-specific variables used to estimate resultant intakes for an adult and child, respectively.

### 6I.2.9 Ingestion of Fish

This pathway was evaluated for the ingestion of fish from the potentially contaminated Clinch River, which is large enough to produce a consistent supply of edible-sized fish. EPA recommends an average fish consumption rate of 54 g/day (EPA 1989g) for an adult receptor. A mean daily consumption rate of 5.67 grams was estimated for an average 1- to 8-year-old child. It was assumed that all fish ingested originated from the river. Tables 6I.21 and 6I.22 present the equations used to calculate resultant intakes for an adult and child, respectively.

### 6I.2.10 Ingestion of Deer

The assumption was made that a deer hunter is directly exposed to site contaminants via the ingestion of deer meat. A consumption rate of 16.4 Kg/yr was calculated for this receptor, assuming a two-deer yield at 40 pounds per deer for a family of three. The scenario also assumed that all deer ingested by the receptor drank contaminated water exclusively from WAG 6. Table 6I.23 details the associated calculation.

### 6I.2.11 Incidental Ingestion of Soil

Contaminants in surface soil serve as pathway for several ingestion routes of exposure. Incidental soil ingestion by children and adults can occur as a result of both indoor and outdoor activities. EPA specifies upper-bound incidental ingestion rates for soil and dust of 200 mg/day for children ages 1 through 6 and 100 mg/day for adults (EPA 1989b). This assumes a constant exposure to soil and dust over 365 days per year. Tables 6I.24 and 6I.25 present the specific pathway variables and equations that correspond to the incidental ingestion of soil by an adult and child homesteader, respectively.

### 6I.2.12 Incidental Ingestion of Sediments

Homesteader receptors were assumed to be exposed to the incidental ingestion of sediments as a result of swimming activities; the ingestion rate was assumed to equal that for soil. Exposure frequency was assumed to be 45 days per year as recommended by EPA Region IV for swimming in the southeastern U.S. (EPA 1991). Tables 6I.24 and 6I.25 detail the associated calculations for an adult and child homesteader, respectively.

### 6I.2.13 Incidental Ingestion of Surface Water While Swimming

Incidental ingestion of surface water by an adult and child homesteader while swimming at a contaminated water body was evaluated assuming a contact rate of 0.05 liters of water per hour, an exposure frequency of 45 days per year (EPA 1991), and an exposure time of 2.6 hours per swimming event (EPA 1989b) as presented in Tables 6I.26 and 6I.27.

## 6I.3 RESULTS OF EXPOSURE INTAKE AND RISK CHARACTERIZATION

Tables 6I.28 through 6I.33 summarize chemical noncarcinogenic hazard indices, chemical inhalation noncarcinogenic hazard indices, and the excess lifetime chemical carcinogenic risks for adult and child homesteaders at WAG 6. Tables 6I.34 through 6I.39 summarize chemical noncarcinogenic hazard indices, chemical inhalation noncarcinogenic hazard indices and the excess lifetime chemical carcinogenic risk for adult and child homesteaders at the high-activity auger hole area at WAG 6. Risk and hazard index calculations for the particulate phase (inorganic contaminants) were considered for the on-WAG and off-WAG homesteaders. Results are not presented as this pathway does not quantify into a risk or hazard index.

Tables 6I.40 through 6I.43 summarize chemical noncarcinogenic hazard indices and the excess lifetime chemical carcinogenic risks for adult and child off-WAG homesteaders downstream along the Clinch River; those for an on-WAG ORNL employee are summarized in Tables 6I.44 and 6I.45.

Tables 6I.46 and 6I.47 present the chemical noncarcinogenic hazard index and excess lifetime chemical carcinogenic risk for the adult deer hunter; those for a boundary receptor are summarized in Tables 6I.48 and 6I.49.

Tables 6I.50 through 6I.120 present detailed information on which Tables 6I.28 through 6I.49 were based.

# Appendix 6I Tables

Table 6.I.1

Octanol-water partition coefficients and bioconcentration/bioaccumulation factors

| COMPOUND | CAS | LOG KOW | KOW | Bf | Bm | Bv | BVA | BCF |
|---|---|---|---|---|---|---|---|---|
| 1,1,1-Trichloroethane | 71-55-6 | 2.5e+000 | 3.1e+002 | 7.8e-006 | 2.5e-006 | 1.4e+000 | 5.3e+002 | 4.6e+001 |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | 2.4e+000 | 2.5e+002 | 6.2e-006 | 1.9e-006 | 1.6e+000 | 4.5e+002 | 3.9e+001 |
| 1,1,2-Trichloroethane | 79-00-5 | 2.5e+000 | 3.0e+002 | 7.4e-006 | 2.3e-006 | 1.4e+000 | 5.2e+002 | 4.4e+001 |
| 1,1-Dichloroethane | 75-34-3 | 1.8e+000 | 6.2e+001 | 1.5e-006 | 4.9e-007 | 3.6e+000 | 1.7e+002 | 1.4e+001 |
| 1,1-Dichlorethene | 75-35-4 | 1.8e+000 | 6.9e+001 | 1.7e-006 | 5.5e-007 | 3.3e+000 | 1.8e+002 | 1.5e+001 |
| 1,2-Dichlorethene(total) | 540-59-0 | 2.1e+000 | 3.0e+001 | 3.1e-006 | 9.8e-007 | 2.4e+000 | 1.0e+002 | 2.3e+001 |
| 1,2-Dichloroethane | 107-06-2 | 1.5e+000 | 1.2e+002 | 7.6e-007 | 2.4e-007 | 5.4e+000 | 2.8e+002 | 7.8e+000 |
| 2-butanone | 78-93-3 | 2.9e-001 | 1.9e+000 | 4.9e-008 | 1.5e-008 | 2.6e+001 | 0.0e+000 | 9.8e-001 |
| 2-Methylphenol | 95-48-7 | 2.0e+000 | 1.5e+001 | 2.2e-006 | 7.1e-007 | 2.9e+000 | 6.4e+001 | 1.8e+001 |
| Acetone | 67-64-1 | -2.4e-001 | 1.3e+002 | 1.4e-008 | 4.6e-009 | 5.3e+001 | 2.9e+002 | 3.9e-001 |
| Aroclor 1254 | 11097-69-1 | 6.0e+000 | 1.0e+002 | 2.7e-002 | 8.5e-003 | 1.3e-002 | 2.4e+002 | 2.3e+004 |
| Benzene | 71-43-2 | 2.1e+000 | 4.4e+002 | 3.3e-006 | 1.0e-006 | 2.3e+000 | 6.8e+002 | 2.4e+001 |
| Benzyl alcohol | 100-51-6 | 1.1e+000 | 1.3e+001 | 3.2e-007 | 1.0e-007 | 9.0e+000 | 5.5e+001 | 4.0e+000 |
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 5.1e+000 | 5.4e+002 | 3.2e-003 | 1.0e-003 | 4.3e-002 | 7.9e+002 | 4.5e+003 |
| Carbon disulfide | 75-15-0 | 2.0e+000 | 2.4e+002 | 2.5e-006 | 7.9e-007 | 2.7e+000 | 4.5e+002 | 1.9e+001 |
| Carbon tetrachloride | 56-23-5 | 2.6e+000 | 5.4e+000 | 1.1e-005 | 3.5e-006 | 1.2e+000 | 0.0e+000 | 6.0e+001 |
| Chlroethane | 75-00-3 | 1.4e+000 | 1.8e+003 | 6.8e-007 | 2.1e-007 | 5.8e+000 | 1.9e+003 | 7.2e+000 |
| Chloroform | 67-66-3 | 2.0e+000 | 8.9e+001 | 2.3e-006 | 7.4e-007 | 2.8e+000 | 2.2e+002 | 1.9e+001 |
| Di-n-butylphatalate | 84-74-2 | 4.7e+000 | 5.2e+004 | 1.3e-003 | 4.2e-004 | 7.2e-002 | 2.0e+004 | 2.3e+003 |
| diethylphatalate | 84-66-2 | 2.5e+000 | 1.1e+006 | 7.4e-006 | 2.3e-006 | 1.4e+000 | 1.8e+005 | 4.4e+001 |
| Ethyl benzene | 100-41-4 | 3.2e+000 | 1.1e+006 | 3.5e-005 | 1.1e-005 | 5.9e-001 | 1.8e+005 | 1.5e+002 |
| Methylene chloride | 75-09-2 | 1.3e+000 | 1.0e+000 | 5.0e-007 | 1.6e-007 | 6.9e+000 | 9.1e+000 | 5.7e+000 |
| Naphtalene | 91-20-3 | 3.3e+000 | 4.1e+005 | 5.0e-005 | 1.6e-005 | 4.8e-001 | 8.8e+004 | 1.9e+002 |
| Tetrachloroethene | 127-18-4 | 2.6e+000 | 1.6e+005 | 1.0e-005 | 3.2e-006 | 1.2e+000 | 4.5e+004 | 5.6e+001 |
| Toluene | 108-88-3 | 2.7e+000 | 1.6e+009 | 1.3e-005 | 4.3e-006 | 1.0e+000 | 3.1e+007 | 7.0e+001 |
| Trichloroethene | 79-01-6 | 2.4e+000 | 2.0e+003 | 6.0e-006 | 1.9e-006 | 1.6e+000 | 2.0e+003 | 3.8e+001 |
| Vinyl chloride | 75-01-4 | 1.4e+000 | 2.9e+001 | 6.0e-007 | 1.9e-007 | 6.2e+000 | 9.9e+001 | 6.6e+000 |
| Xylenes(total) | 1330-20-7 | 3.3e+000 | 1.1e+006 | 4.6e-005 | 1.4e-005 | 5.1e-001 | 1.7e+005 | 1.8e+002 |
| 2,4,5-T | 93-76-5 | 3.1e+000 | 1.3e+003 | 3.4e-005 | 1.1e-005 | 6.0e-001 | 1.5e+003 | 1.4e+002 |
| 2,4,5-TP | 93-72-1 | 4.0e+000 | 1.0e+004 | 2.5e-004 | 7.9e-005 | 1.9e-001 | 6.3e+003 | 6.5e+002 |
| 2,4-D | 94-75-7 | 2.8e+000 | 6.5e+002 | 1.6e-005 | 5.1e-006 | 9.2e-001 | 9.0e+002 | 8.0e+001 |
| Aluminum | 7429-90-5 | - | - | - | 2.0e-004 | - | - | - |
| Cadmium | 7440-43-9 | - | - | 1.6e-002 | 6.2e-005 | 3.0e-001 | - | 2.0e+002 |
| Cobolt | 7440-48-4 | - | - | 1.0e-003 | 5.0e-004 | 9.4e-003 | - | 5.0e+001 |
| Chromium | 7440-47-3 | - | - | 9.9e-004 | 1.1e-003 | 2.5e-004 | - | 2.0e+001 |
| Mercury | 7439-97-6 | - | - | 1.0e-001 | 1.9e-002 | 3.8e-001 | - | 2.0e+004 |
| Manganese | 7439-96-5 | - | - | 5.0e-003 | 1.0e-004 | 3.0e-002 | - | 4.0e+002 |
| Nickel | 7440-02-0 | - | - | 1.0e-003 | 3.4e-003 | 1.9e-002 | - | 1.0e+002 |
| Silver | 7440-22-4 | - | - | 9.9e-004 | 2.5e-002 | 1.5e-001 | - | 2.3e+000 |
| Thallium | 7440-28-0 | - | - | - | 1.9e-003 | - | - | - |
| Vanadium | 7440-62-2 | - | - | - | 2.0e-005 | - | - | - |

Sources: ANL 1989; S. Caldwell 1990a,b; Callahan et al. 1979; P.H.Howard 1990; Ng et al. 1977.

**Table 6I.2. Biotransfer/bioconcentration factor regression equations for organic contaminants**

| Biota | Type | Regression equation |
|---|---|---|
| Vegetables/fruit | Soil-to-root | $\log Bv = 1.588 - 0.578 \log Kow$ |
| | Air-to-leaf | $\log BVA = 9.1 \times Kow^{0.71}$ |
| Milk | | $\log Bm = -8.10 + \log Kow$ |
| Meat | | $\log Bf = -7.6 + \log Kow$ |
| Fish | | $\log BCF = 0.76 \log Kow - 0.23$ |

**Table 6I.3. Contributing factors in the estimation of tissue exposure concentrations for chemical contaminants**

| Biota | Factor |
|---|---|
| Vegetables/fruits | Direct deposition + root uptake + air-to-leaf transfer |
| Milk | Groundwater or surface water ingestion |
| Meat | Groundwater or surface water ingestion |
| Fish | Bioconcentration of contaminants in surface water |

**Table 6I.4. Contaminant concentration in vegetation**

$$CV\ (mg/kg) = CVD + CVR + CVA$$

where:

CVD = contaminant concentration due to deposition (mg/kg)
CVR = contaminant concentration due to root uptake(mg/kg)
CVA = contaminant concentration due to air-to-leaf transfer (mg/kg)

**Contaminant concentration due to deposition: (mg/kg)**

$$CVD = \frac{Ca \times Vd \times r/y}{\lambda}$$

where:

Ca = Air contaminant concentration ($mg/m^3$)
Vd = Atmospheric velocity deposition (m/sec)
0.003 m/sec (Hattemer-Frey, Travis, 1989)
r/y = Intercept fraction to productivity ratio (Hattemer-Frey, Travis, 1989)
0.4 $m^2/kg$ for vegetation consumed by animals
0.04 $m^2/kg$ for vegetation consumed by humans
$\lambda$ = Contaminant weathering removal loss constant (Baes et al., 1984)
$4.72 \times 10^{-7}$ $sec^{-1}$ - for a half time (T) of 17 d

where :

$$\lambda = \ln 2 / (T \times 86400)$$

**Contaminant concentration due to root uptake: (mg/kg)**

$$CVR = Cs \times Bv$$

where:

Cs = Soil contaminant concentration (mg/kg)
Bv = Soil-to-root bioconcentration factor (unitless)

For organic contaminants: (Travis and Arms 1988)

$$\log Bv = 1.588 - 0.578 \log K_{ow}$$

$$Bv = 10^{(1.588 - 0.578 \log Kow)}$$

$K_{ow}$ = Octanol-water partition coefficient

For inorganic contaminants:
Bv = stable elements biotransfer factors

**Contaminant concentration due to air-to-leaf transfer: (mg/kg)**
(Travis and Hattemer-Frey 1988)

$$CVA = Ca \times Bva \times (0.001)(m^3/kg)$$

where:

Ca = Air contaminant concentration ($mg/m^3$)
Bva = Air-to-leaf bioconcentration factor

For organic contaminants(volatile,semi-volatile):

$$Bva = 9.1 \times K_{ow}^{0.71}$$

$K_{ow}$ = Octanol-water partition coefficient

**Table 6I.5. Contaminant concentration in meat**

$$CB\ (mg/kg) = (Cw \times Qw \times Bf)$$

where:

Environmental Media Contaminant Concentration
Cw = Contaminant concentration in water (mg/kg)

Environmental Media Intake
Qw = Water intake (kg/d)
Beef cattle: 40.0 (NAC 1976)
Deer: 3 (IT/MRI 1990)

Biotransformation Factor = Bf (d/kg)

**A.** For Organic Contaminants

$$\log Bf = -7.6 + \log K_{ow}$$ (Travis and Arms 1988)

$$Bf = 10^{(-7.6 + \log Kow)}$$

where:

Bf: Beef biotransformation factor
$K_{ow}$ = Octanol-water partition coefficient

**B.** For Inorganic Contaminants:

Bf = stable elements biotransfer factors

**Table 6I.6. Contaminant concentration in milk**

$Cm\ (mg/kg) = (Cw \times Qw \times Bm)$

where:

Environmental Media Concentration
Cw = Contaminant concentration in water (mg/kg)

Environmental Media Intake
Qw = Water intake (kg/d)(NAC 1976)
Dairy cattle: 80 L

Biotransformation Factor = Bm (d/kg)

**A.** For Organic Contaminants

$\log Bm = -8.10 + \log K_{ow}$ (Travis and Arms 1988)
$B_m = 10^{(-8.10 + \log Kow)}$

where:

Bm = biotransfer factor
$K_{ow}$ = Octanol-water partition coefficient

**B.** For Inorganic Contaminants:

Bm = stable elements biotransfer factors

**Table 6I.7. Contaminant concentration in fish**

$$CF\ (mg/kg) = C_w \times BCF$$

where:

$C_w$ = Contaminant concentration in water (mg/L)
BCF = Bioconcentration factor in fish (L/kg)

where:

**A.** For Organic Contaminants (USEPA 1986)

$$\log BFC = 0.76 \log K_{ow} - 0.23$$

$$BCF = 10^{(0.76 \text{ Log Kow} - 0.23)}$$

**B.** For Inorganic Contaminants

BCF = stable elements bioconcentration factors

**Table 6I.8. Contaminant concentration in air from showering and particulate phase**

contaminant concentration in vapor phase from showering (EPA 1990)

$CA\ (mg/m^3) = CW \times VF \times WC / SA$

where:

CW = contaminant concentration in water - mg/L
VF = volatuzation fraction - 0.5
WC = water consumption - 180 L
SA = shower area capacity - 12 $m^3$

contaminant concentration in particulate phase

$CA\ (mg/m^3) = CS \times CF \times UF$

where:

CS = contaminant concentration in soil - mg/kg
CF = conversion factor - 0.001 kg/mg
ML = mass loading - $2 \times 10^{-4}$ $g/m^3$

**Table 6I.9. Intake from inhalation for an adult homesteader**

| Intake variables | Vapor-Phase | | Particulate |
|---|---|---|---|
| | Vapor-phase | Showering | |
| CA ($mg/m^3$) | | | |
| IR ($m^3/h$) | 1.25 | 0.6 | 1.25 |
| ET (h/d) | 24 | 0.2 | 24 |
| EF (d/year) | 365 | 365 | 365 |
| ED (year) | 30 | 30 | 30 |
| BW (kg) | 70 | 70 | 70 |
| AT-C (d) | 70 × 365 | 70 × 365 | 70 × 365 |
| AT-NC (d) | 30 × 365 | 30 × 365 | 30 × 365 |

Intake (mg/kg × d) = (CA × IR × ET × EF × ED)/(BW × AT)

where:

CA = Contaminant Concentration in Air ($mg/m^3$)
Vapor Phase: modeled
Particulate: estimated - Table 6I.8
Showering: estimated - Table 6I.8

IR = Inhalation Rate ($m^3/h$)
inhalation: 1.25 $m^3/h$ = 30 $m^3/d$—adult upper-bound value
showering: 0.6 $m^3/h$—all age groups

ET = Exposure Time (h/d)
inhalation: 24 h/d—adult homesteader
showering: 0.2 h/d = 12 min—90th percentile

EF = Exposure Frequency d/year
365 d/year

ED = Exposure Duration (year)
30-year—upper-bound time (90th percentile) at one residence

BW = Body Weight (kg)
70 kg—average adult

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = Noncarcinogens: ED × 365 d/year
AT-C = Carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

**Table 6I.10. Intake from inhalation for a child homesteader**

| | Vapor phase | | |
|---|---|---|---|
| Intake variables | Vapor-Phase | Showering | Particulate |
| CA ($mg/m^3$) | | | |
| IR ($m^3/h$) | 0.6 | 0.6 | 0.6 |
| ET (h/d) | 24 | 0.2 | 24 |
| EF (d/year) | 365 | 365 | 365 |
| ED (year) | 7 | 365 | 365 |
| BW (kg) | 16 | 16 | 16 |
| AT-C (d) | 70 × 365 | 70 × 365 | 7 × 365 |
| AT-NC (d) | 7 × 365 | 70 × 365 | 70 × 365 |

Intake (mg/kg × d) = (CA × IR × ET × EF × ED)/(BW × AT)

where:

CA = Contaminant Concentration in Air ($mg/m^3$)
air: Modeled
particulate: estimated - Table 6I.8
showering: estimated - Table 6I.8

IR = Inhalation Rate ($m^3/h$)
inhalation: 0.6 $m^3/h$—10 year-old child—light, nonoccupational and resting activities (ICRP #23)
showering: 0.6 $m^3/h$—all age groups

ET = Exposure Time (h/d)
inhalation: 24 h/d
showering: 0.2 h/d = 12 min—90th percentile

EF = Exposure Frequency (d/year)
365—d/year

ED = Exposure Duration (year)
7-year—chronic exposure

BW = Body Weight (kg)
16 kg—average 1- to 6-year-old child

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens: ED × 365 d/year
AT-C = carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

Table 6I.11. Intake from inhalation by an adult ORNL employee at WAG 6

| Intake variables | Vapor-phase |
|---|---|
| CA ($mg/m^3$) | 1.25 |
| IR ($m^3/h$) | 8 |
| ET (h/d) | 156 |
| EF (d/year) | 30 |
| ED (year) | 70 |
| BW (kg) | 70 × 365 |
| AT-C (d) | 30 × 365 |
| AT-NC (d) | |

Intake (mg/kg × d) = (CA × IR × ET × EF × ED)/(BW × AT)

where:

CA = Contaminant Concentration in Air ($mg/m^3$)
vapor-phase: modeled

IR = Inhalation Rate ($m^3/h$)
1.25 $m^3/h$ = 30 $m^3/d$—adult upper-bound value

ET = Exposure Time (h/d) (Temeshy, 1990)
8 h/d

EF = Exposure Frequency (d/year) (Temeshy, 1990)
156 d/year = 3 work d/week

ED = Exposure Duration (year)
30-year—upper-bound time (90th percentile) at one residence

BW = Body Weight (kg)
70 kg—average adult

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens: ED × 365 d/year
AT-C = carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

**Table 6I.12. Intake from inhalation for an adult fencepost receptor on WAG 6 boundary**

| Intake variables | Vapor-phase |
|---|---|
| CA ($mg/m^3$) | |
| IR ($m^3/h$) | 1.25 |
| ET (h/d) | 24 |
| EF (d/year) | 365 |
| ED (year) | 70 |
| BW (kg) | 70 |
| AT-C (d) | 70 × 365 |
| AT-NC (d) | 70 × 365 |

Intake (mg/kg × d) = (CA × IR × ET × EF × ED)/(BW × AT)

where:

CA = Contaminant Concentration in Air ($mg/m^3$)
vapor-phase: modeled

IR = Inhalation Rate ($m^3/h$)
30 $m^3/d$ = 1.25 $m^3/h$—upper-bound value

ET = Exposure Time (h/d)
24 h/d—upper-bound time

EF = Exposure Frequency (d/year)
365 d/year

ED = Exposure Duration (year)
70-year—upper-bound duration

BW = Body Weight (kg)
70 kg—average adult

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens ED × 365 d/year
AT-C = carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

Table 6I.13. Intake from dermal contact with soil and sediments for an adult homesteader

| | Soil | | | Sediment | | |
|---|---|---|---|---|---|---|
| CS (mg/kg) | | | | | | |
| CF (kg/mg) | $10^{-6}$ | | | $10^{-6}$ | | |
| SA ($cm^2$/event) | 3120 | | | 18,150 | | |
| AF ($mg/cm^2$) | 2.77 | | | 2.77 | | |
| ABS | VOC | SVOC | INORG | VOC | SVOC | INORG |
| | 0.25 | 0.1 | 0.01 | 0.25 | 0.1 | 0.01 |
| EF (event/year) | 43 | | | 45 | | |
| ED (year) | 30 | | | 30 | | |
| BW (kg) | 70 | | | 70 | | |
| AT-C | 70 × 365 | | | 70 × 365 | | |
| AT-NC | 30 × 365 | | | 30 × 365 | | |

Absorbed Dose (mg/kg × d) = (CS × CF × SA × AF × ABS × EF × ED)/(BW × AT)

where:

CS = Chemical Concentration in Soil or sediment (mg/kg)

CF = Conversion Factor ($10^{-6}$ kg/mg)

SA = Skin Surface Area Available for Contact ($cm^2$/event)
soil: 3120 $cm^2$—hands 820 $cm^2$, arms 2300 $cm^2$
sediment: 18,150 $cm^2$—total average body surface area

AF = Soil to Skin Adherence Factor ($mg/cm^2$)
2.77 $mg/cm^2$—kaolin clay

ABS = Absorption Factor (unitless) (Ryan, 1987)
VOC: 0.25
SVOC: 0.10
INOR: 0.01

EF = Exposure Frequency (EPA, 1989b)
soil: 43 events/year—outdoor summer work from May to October, 2 d/week, 8 h/d
sediment: 45 events/year—Region IV swimming average (EPA, 1991)

ED = Exposure Duration (year)
30-year—upper-bound time (90th percentile) at one residence

BW = Body Weight (kg)
70 kg—average adult

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens: ED × 365 d/year
AT-C = carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

Table 6I.14. Intake from dermal contact with soil and sediments for a child homesteader

| Intake variables | Soil | | | Sediment | | |
|---|---|---|---|---|---|---|
| CF (kg/mg) | $10^{-6}$ | | | $10^{-6}$ | | |
| SA ($cm^2$/event) | 2960 | | | 6950 | | |
| AF ($mg/cm^2$) | 2.77 | | | 2.77 | | |
| ABS | VOC | SVOC | INORG | VOC | SVOC | INOR |
| | 0.25 | 0.1 | 0.01 | 0.25 | 0.1 | 0.01 |
| EF (event/year) | 141 | | | 45 | | |
| ED (year) | 7 | | | 7 | | |
| BW (kg) | 16 | | | 16 | | |
| AT-C (d) | 70 × 365 | | | 70 × 365 | | |
| AT-NC (d) | 7 × 365 | | | 7 × 365 | | |

Absorbed Dose (mg/kg × d) = (CS × CF × SA × AF × ABS × EF × ED)/(BW × AT)

where:

CS = Chemical Concentration in Soil or Sediments (mg/kg)

CF = Conversion Factor ($10^{-6}$ kg/mg)

SA = Skin Surface Area Available for Contact ($cm^2$/event) (Hawley 1985)
for average 2.5—6-year-old child
soil: 2960 $cm^2$—1130 $cm^2$, arms and hand, 1830 $cm^2$ legs
sediment: 6950 $cm^2$—total average body surface area

AF = Soil to Skin Adherence Factor ($mg/cm^2$)
2.77 $mg/cm^2$ kaolin clay

ABS = Absorption Factor (unitless) (Ryan, 1987)
VOC: 0.25
SVOC: 0.1
INOR: 0.01

EF = Exposure Frequency (average 2.5—6-year-old child)
soil: 141 d/year—outdoor activity from May to September (EPA, 1989b)
sediment: 45 d/year—Region IV swimming average (EPA, 1991)

ED = Exposure Duration (year)
7-year—chronic exposure

BW = Body Weight (kg)
16 kg—average 1- to 6-year-old child

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = Noncarcinogens ED × 365 d/year
AT-C = Carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

Table 6I.15. Intake from dermal contact for an adult homesteader

| Intake variables | Swimming (surface water) | Showering (groundwater or surface water) |
|---|---|---|
| CW (mg/L) | | |
| CF ($L/cm^3$) | 1/1000 | 1/1000 |
| SA ($cm^2$/event) | 18150 | 18150 |
| PC (cm/h) | $8.4 \times 10^{-4}$ | $8.4 \times 10^{-4}$ |
| ET (h/d) | 2.6 | 0.2 |
| EF (d/year) | 45 | 365 |
| ED (year) | 30 | 30 |
| BW (kg) | 70 | 70 |
| AT-C | 70 × 365 | 70 × 365 |
| AT-NC | 30 × 365 | 30 × 365 |

Absorbed Dose (mg/kg × d) = (CW × CF × SA × PC × ET × EF × ED)/(BW × AT)

where:

CW = Chemical Concentration in Water (mg/L)

CF = Volumetric Conversion Factor for Water
1 L/1000 $cm^2$

SA = Skin Surface Area Available for Contact ($cm^2$)
18150 $cm^2$: total skin surface area

PC = Chemical-specific Dermal Permeability Constant (cm/h)
8.4 E-4: permeability of water

ET = Exposure time (h/d)
swimming: 2.6 h/d—national average for swimming
showering: 0.2 h/d—90th percentile

EF = Exposure Frequency (d/year)
swimming: 45d/year—Region IV swimming average (EPA, 1991)
showering: 365 d/year

ED = Exposure Duration (year)
30-year—upper-bound time (90th percentile) at one residence

BW = Body Weight (kg)
70 kg—average adult

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens: ED × 365 d/year
AT-C = carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

Table 6I.16. Intake from dermal contact for a child homesteader

| Intake variables | Swimming (surface water) | Showering (groundwater or surface water) |
|---|---|---|
| CW (mg/L) | | |
| CF ($L/cm^3$) | 1/1000 | 1/1000 |
| SA ($cm^2$/event) | 6950 | 6950 |
| PC (cm/h) | $8.4 \times 10^{-4}$ | $8.4 \times 10^{-4}$ |
| ET (h/d) | 2.6 | 0.20 |
| EF (d/year) | 45 | 365 |
| ED (year) | 7 | 7 |
| BW (kg) | 16 | 16 |
| AT-C (d) | 70 × 365 | 70 × 365 |
| AT-NC (d) | 7 × 365 | 7 × 365 |

Absorbed Dose (mg/kg × d) = (CW × SA × PC × ET × EF × ED × CF)/(BW × AT)

where:

CW = Chemical Concentration in Water (mg/L)

SA = Skin Surface Area Available for Contact ($cm^2$) (Hawley, 1985)
6950 $cm^2$: Total average body surface area for 2.5—6-year-old child

PC = Chemical-specific Dermal Permeability Constant (cm/h)
8.4 E -4

ET = Exposure time (h/d)
swimming: 2.6 h/d—national average
showering: 0.2 h/d—90th percentile

EF = Exposure Frequency (d/year)
swimming: 45 d/year — Region IV swimming average (EPA, 1991)
showering: 365 d/year

ED = Exposure Duration (year)
7-year—chronic exposure

CF = Volumetric Conversion Factor for Water (1 liter/1000 $cm^2$)

BW = Body Weight (kg)
16 kg—average 1- to 6-year-old child

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens: ED × 365 d/year
AT-C = carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

Table 6I.17. Intake from the ingestion of drinking water for an adult homesteader

| Intake variables | Drinking Water |
|---|---|
| CW (mg/L) | |
| IR (L/d) | 2 |
| EF (d/year) | 365 |
| ED (year) | 30 |
| BW (kg) | 70 |
| AT-C (d) | 70 × 365 |
| AT-NC (d) | 30 × 365 |

Intake (mg/kg × d) = (CW × IR × EF × ED)/(BW × AT)

where:

CW = Chemical Concentration in Water (mg/L)

IR = Ingestion Rate (L/d)
2 L/d—adult (90th percentile)

EF = Exposure Frequency (d/year)
365 d/year for residents

ED = Exposure Duration (year) assume 100% use
30-year—upper-bound time (90th percentile) at one residence

BW = Body Weight (kg)
70 kg—average adult

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens: ED × 365 d/year
AT-C = carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

Table 6I.18. Intake from the ingestion of drinking water for a child homesteader

| Intake variables | Drinking Water |
|---|---|
| CW (mg/L) | |
| IR (L/d) | 1.0 |
| EF (d/y) | 365 |
| ED (y) | 7 |
| BW (kg) | 16 |
| AT-C (d) | 70 × 365 |
| AT-NC (d) | 7 × 365 |

Intake (mg/kg × d) = (CW × IR × EF × ED)/(BW × AT)

where:

CW = Chemical Concentration in Water (mg/L)

IR = Ingestion Rate (L/d) (EPA, 1989b)
1 L/d

EF = Exposure Frequency (d/year)
365 d/year for residents

ED = Exposure Duration (year) assume 100% use
7-year—chronic exposure

BW = Body Weight (kg)
16 kg—average 1- to 6-year-old child

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens: ED × 365 d/year
AT-C = carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

**Table 6I.19. Intake from the ingestion of fruits and vegetables for an adult homesteader**

| | Flora | |
|---|---|---|
| Intake variables | Fruits | Vegetables |
| CF (mg/kg) | | |
| CR (kg/year) | 51.1 | 73 |
| FI (unitless) | 0.3 | 0.4 |
| ED (year) | 30 | 30 |
| BW (kg) | 70 | 70 |
| AT-C (d) | 70 × 365 | 70 × 365 |
| AT-NC (d) | 30 × 365 | 30 × 365 |

Intake (mg/kg × d) = (CF × CR × FI × ED)/(BW × AT)

where:

CF = Contaminant Concentration in Vegetation (mg/kg)
estimated - Table 6I.4

CR = Consumption Rate (kg/year) (EPA, 1989b)
vegetables: reasonable worst case—73 kg/year = 200 g/d
fruits: reasonable worst case—51.1 kg/year = 140 g/d

FI = Contaminated Fraction Ingested (unitless) (EPA, 1989b)
homegrown fraction, reasonable worst case
vegetables: 40%
fruits: 30%

ED = Exposure Duration (years)
30-year—upper-bound time (90th percentile) at one residence

BW = Body Weight (kg)
70 kg—average adult

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens: ED × 365 d year
AT-C = carcinogens: 70 year × 365 d year

NOTE: All variables are from EPA 1989a unless otherwise noted.

Table 6I.20. Intake from the ingestion of fruits and vegetables for a child homesteader

| | Flora | |
|---|---|---|
| Intake variables | Fruits | Vegetables |
| CF (mg/kg) | | |
| CR (kg/year) | 53.8 | 39.2 |
| FI (unitless) | 0.3 | 0.4 |
| ED (year) | 7 | 7 |
| BW (kg) | 16 | 16 |
| AT-C (d) | 70 × 365 | 70 × 365 |
| AT-NC (d) | 7 × 365 | 7 × 365 |

Intake (mg/kg × d) = (CF × CR × FI × ED)/(BW × AT)

where:

CF = Contaminant Concentration in fruits and vegetables (mg/kg)
estimated - Table 6I.4

CR = Consumption Rate (kg/year) (USDA, 1983)
vegetables: average 1- to 8-year-old child-39.2 kg/year = 107.5 g/d
fruits: Average 1- to 8-year-old child-53.8 kg/year = 147.3 g/d

FI = Ingested Fraction (unitless) (EPA, 1989b)
homegrown fraction, reasonable worst case
vegetables: 40%
fruits: 30%

ED = Exposure Duration (years)
7-year—chronic exposure

BW = Body Weight (kg)
16 kg—average 1- to 6-year-old child

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens: ED × 365 d/year
AT-C = carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

**Table 6I.21. Intake from the ingestion of meat, milk, and fish for an adult homesteader**

| Biota | Fauna-Cows | | Aquatic Fauna |
|---|---|---|---|
| Intake variables | Meat | Milk | Fish |
| CF (mg/kg) | | | |
| CR (kg/y) | 36.5 | 146 | 19.7 |
| FI (unitless) | 0.75 | 0.75 | 1.0 |
| ED (y) | 30 | 30 | 30 |
| BW (kg) | 70 | 70 | 70 |
| AT-C (d) | 70 × 365 | 70 × 365 | 70 × 365 |
| AT-NC (d) | 30 × 365 | 30 × 365 | 30 × 365 |

Intake (mg/kg × d) = (CF × CR × FI × ED)/(BW × AT)

where:

CF = Contaminant Concentration in Food (i.e., meat, milk, and fish) (mg/kg)
beef: estimated - Table 6I.5
milk: estiamted - Table 6I.6
fish: estimated - Table 6I.7

CR = Consumption Rate (kg/year) (EPA, 1989b)
beef: 36.5 kg/year = 100 g/d—reasonable worst case
milk: 146 kg/year = 400 g/d—reasonable worst case
fish: 19.7 kg/year = 54 g/d—reasonable worst-case

FI = Contaminated Fraction Ingested (unitless) (EPA, 1989b)
homegrown fraction - reasonable worst case
beef: 75%
milk: 75%
fish: 100%

ED = Exposure Duration (year)
30-year—upper-bound time (90th percentile) at one residence

BW = Body Weight (kg)
70 kg—average adult

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens: ED × 365 d/year
AT-C = carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

Table 6I.22. Intake from the ingestion of meat, milk, and fish for a child homesteader

| Intake variables | | | |
|---|---|---|---|
| Biota | Fauna-Cows | | Aquatic Fauna |
| | Meat | Milk | Fish |
| CF (mg/kg) | | | |
| CR (kg/year) | 7.9 | 139.6 | 2.1 |
| FI (unitless) | 0.75 | 0.75 | 1.0 |
| ED (year) | 7 | 7 | 7 |
| BW (kg) | 16 | 16 | 16 |
| AT-C (d) | 70 × 365 | 70 × 365 | 70 × 365 |
| AT-NC (d) | 7 × 365 | 7 × 365 | 7 × 365 |

Intake (mg/kg × d) = (CF × CR × FI × ED)/(BW × AT))

where:

CF = Contaminant Concentration in Food (i.e., meat, milk) (mg/kg)
beef: estimated - Table 6I.5
milk: estimated - Table 6I.6
fish: estimated - Table 6I.7

CR = Consumption Rate (kg/year) (USDA, 1983)
beef: 7.9 kg/year = 21.8 g/d—average for 1- to 8-year-old
milk: 139.6 kg/year = 382.5 g/d—average for 1- to 8-year-old
fish: 2.1 kg/year = 5.69 g/d—average for 1- to 8-year-old

FI = Fraction Ingested (unitless) (EPA, 1989b)
homegrown fraction, reasonable worst case
beef: 75%
milk: 75%
fish: 100%

ED = Exposure Duration (year)
7-year—chronic exposure

BW = Body Weight (kg)
16 kg—average 1- to 6-year-old child

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens: ED × 365 d/year
AT-C = carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

Table 6I.23. Intake from the ingestion of deer meat for an adult deer hunter

| Intake variables | Fauna (deer meat) |
|---|---|
| CF (mg/kg) | |
| CR (kg/year) | 16.4 |
| FI (unitless) | 1.0 |
| ED (year) | 30 |
| BW (kg) | 70 |
| AT-C (d) | 70 × 365 |
| AT-NC (d) | 30 × 365 |

Intake (mg/kg × d) = (CF × CR × FI × ED)/(BW × AT)

where:

CF = Contaminant Concentration in deer (mg/kg)
estimated - Table 6I.5

CR = Consumption Rate (kg/year)
meat: 16.4 kg/year = 2 deer yield at 40 lb/deer for a family of three

FI = Contaminated Fraction Ingested (unitless) (EPA, 1989b)
1.0—reasonable worst case

ED = Exposure Duration (year)
30-year—upper-bound time (90th percentile) at one residence

BW = Body Weight (kg)
70 kg—average adult

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens: ED × 365 d/year
AT-C = carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

Table 6I.24. Intake from the incidental ingestion of soil and sediment for an adult homesteader

| Intake variables | Soil | Sediment (swimming) |
|---|---|---|
| CS (mg/d) | | |
| IR (mg/d) | 100 | 100 |
| CF (kg/mg) | $10^{-6}$ | $10^{-6}$ |
| FI (unitless) | 1.0 | 1.0 |
| EF (d/year) | 365 | 45 |
| ED (year) | 30 | 30 |
| BW (kg) | 70 | 70 |
| AT-C (d) | 70 × 365 | 70 × 365 |
| AT-NC (d) | 30 × 365 | 30 × 365 |

Intake (mg/kg × d) = (CS × IR × CF × FI × EF × ED)/(BW × AT)

where:

CS = Chemical Concentration in Soil or Sediment (mg/kg)

IR = Ingestion Rate (mg/d)
soil: 100 mg/d
sediment: 100 mg/d

CF = Conversion Factor (10e-6 kg/mg)

FI = Fraction Ingested from Contaminated Source (unitless)
1.0 Assumes all soil ingested came from contaminated source

EF = Exposure Frequency (d/year)
soil: 365 d/year
sediment: 45 d/year—Region IV swimming average (EPA 1991)

ED = Exposure Duration (years)
30-year—upper-bound time (90th percentile) at one residence

BW = Body Weight
70 kg—average adult

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens: ED × 365 d/year
AT-C = carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

Table 6I.25. Intake from the incidental ingestion of soil and sediment for a child homesteader

| Intake variables | Soil | Sediment (swimming) |
|---|---|---|
| CS (mg/d) | | |
| IR (mg/d) | 200 | 200 |
| CF (kg/mg) | $10^{-6}$ | $10^{-6}$ |
| FI (unitless) | 1.0 | 1.0 |
| EF (d/year) | 365 | 45 |
| ED (year) | 7 | 7 |
| BW (kg) | 16 | 16 |
| AT-C (d) | 70 × 365 | 70 × 365 |
| AT-NC (d) | 7 × 365 | 7 × 365 |

Intake (mg/kg × d) = (CS × IR × CF × FI × EF × ED)/(BW × AT)

where:

CS = Chemical Concentration in Soil or Sediment (mg/kg)

IR = Ingestion Rate (mg/d)
soil: 200 mg/d
sediment: 200 mg/d (EPA 1989b)

CF = Conversion Factor ($10^{-6}$ kg/mg)

FI = Fraction Ingested from Contaminated Source (unitless)
1.0—all incidental ingestion from source

EF = Exposure Frequency (d/year)
soil: 365 d/year
sediment: 45 d/year—Region IV swimming average (EPA, 1991)

ED = Exposure Duration (years)
7-year—chronic exposure

BW = Body Weight (kg)
16 kg—average 1- to 6-year-old child

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens: ED × 365 d/year
AT-C = carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

**Table 6I.26. Intake from the incidental ingestion of surface water while swimming for an adult homesteader**

| Intake variables | Surface water |
|---|---|
| CW (mg/L) | 0.05 |
| CR (L/h) | 2.6 |
| ET (h/event) | 45 |
| EF (event/year) | 30 |
| ED (year) | 70 |
| BW (kg) | 70 × 365 |
| AT-C (d) | 30 × 365 |
| AT-NC (d) | |

Intake (mg/kg × d) = (CW × CR × ET × EF × ED)/(BW × AT)

where:

CW = Chemical Concentration in Water (mg/L)

CR = Contact Rate (L/h)
0.05 L/h = 50 mL/h

ET = Exposure Time (h/d)
2.6 h/d—national average for swimming

EF = Exposure Frequency (d/year) (EPA, 1991)
45 d/year—Region IV average for swimming

ED = Exposure Duration (years)
30-year—upper-bound time (90th percentile) at one residence

BW = Body Weight
70 kg—average adult

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens: ED × 365 d/year
AT-C = carcinogens: 70 year lifetime × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

Table 6I.27. Intake from the incidental ingestion of surface water while swimming for a child homesteader

| Intake variables | Surface water |
|---|---|
| CW (mg/L) | |
| CR (L/h) | 0.05 |
| ET (h/event) | 2.6 |
| EF (d/year) | 45 |
| ED (year) | 7 |
| BW (kg) | 16 |
| AT-C | 70 × 365 |
| AT-NC | 7 × 365 |

Intake (mg/kg × d) = (CW × CR × ET × EF × ED)/(BW × AT)

where:

CW = Chemical Concentration in Water (mg/L)

CR = Contact Rate (L/h)
0.05 L/h = 50 mL/h

ET = Exposure Time (h/d)
2.6 h/d national average for swimming

EF = Exposure Frequency (d/year) (EPA 1991)
45 d/year—Region IV average for swimming

ED = Exposure Duration (years)
7-year—chronic exposure

BW = Body Weight (kg)
16 kg—average 1- to 6-year-old child

AT = Averaging Time (period over which exposure is averaged: days)
AT-NC = noncarcinogens: ED × 365 d/year
AT-C = carcinogens: 70 year × 365 d/year

NOTE: All variables are from EPA 1989a unless otherwise noted.

Table 6I.28.

CHEMICAL NONCARCINOGENIC HAZARD INDEX FOR THE ADULT ON-WAG 6 HOMESTEADER
Exposure Interval = 1990 - 2019, 2100 - 2129(1)

| Effect | Chemical | CAS No. | PATHWAYS: Incidental Ingestion Soil | Incidental Ingestion Sediment (2) | Ingestion of Drinking Water (Groundwater) | Ingestion of Fruit | Ingestion of Vegetables | Ingestion of Beef | Ingestion of Milk | Dermal Contact with Groundwater | Dermal Contact with Soil | Dermal Contact with Sediment(2) | CHEMICAL TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Liver | Carbon tetrachloride | 56-23-5 | | | 2.0e-001 | | | 3.4e-006 | 8.5e-006 | 6.2e-003 | | | 2.1e-001 |
| | Chloroform | 67-66-3 | | 2.3e-007 | 1.4e-002 | 9.1e-011 | 1.7e-010 | 5.0e-008 | 1.3e-007 | 4.4e-004 | | 5.8e-004 | 1.5e-002 |
| | 1,1,1-Trichloroethane | 71-55-6 | | | 1.6e-003 | | | 1.8e-008 | 4.7e-008 | 4.8e-005 | | | 1.6e-003 |
| | Methylene chloride | 75-09-2 | 7.9e-007 | 9.1e-008 | 2.4e-003 | 2.3e-003 | 4.3e-003 | 1.8e-009 | 4.5e-009 | 7.3e-005 | 4.0e-005 | 2.3e-004 | 9.3e-003 |
| | 1,1-Dichloroethene | 75-35-4 | | | 1.6e-002 | | | 4.1e-008 | 1.0e-007 | 4.8e-004 | | | 1.6e-002 |
| | 1,1,2-Trichloroethane | 79-00-5 | | | 3.6e-002 | | | 4.0e-007 | 1.0e-006 | 1.1e-003 | | | 3.7e-002 |
| | Diethylphtalate | 84-66-2 | | | 3.9e-004 | | | 4.4e-009 | 1.1e-008 | 1.2e-005 | | | 4.0e-004 |
| | Di-n-butylphtalate | 84-74-2 | | | 2.9e-003 | | | 5.6e-006 | 1.4e-005 | 8.7e-005 | | | 3.0e-003 |
| | 2,4,5-TP | 93-72-1 | | | 3.6e-004 | | | 1.3e-007 | 3.4e-007 | 1.1e-005 | | | 3.7e-004 |
| | Ethyl benzene | 100-41-4 | 8.6e-008 | | 1.4e-003 | 2.1e-005 | 4.0e-005 | 7.6e-008 | 1.9e-007 | 4.4e-005 | 4.4e-006 | | 1.5e-003 |
| | Toluene | 108-88-3 | 4.3e-008 | 5.3e-009 | 7.1e-004 | 1.9e-005 | 3.7e-005 | 1.4e-008 | 3.7e-008 | 2.2e-005 | 2.2e-006 | 1.3e-005 | 8.0e-004 |
| | Bis(2-ethylhexyl)phatalate | 117-81-7 | | | 1.6e-002 | | | 7.6e-005 | 1.9e-004 | 4.8e-004 | | | 1.7e-002 |
| | Tetrachloroethene | 127-18-4 | | | 1.4e-002 | 8.9e-008 | 1.7e-007 | 2.1e-007 | 5.4e-007 | 4.4e-004 | | | 1.4e-002 |
| | Total | | 9.2e-007 | 3.3e-007 | 3.1e-001 | 2.3e-003 | 4.4e-003 | 8.6e-005 | 2.1e-004 | 9.4e-003 | 4.7e-005 | 8.2e-004 | 3.2e-001 |
| Kidney | Acetone | 67-64-1 | 2.1e-007 | 2.3e-008 | 2.9e-003 | 4.8e-003 | 9.1e-003 | 6.2e-011 | 1.6e-010 | 8.7e-005 | 1.1e-005 | 5.8e-005 | 1.7e-002 |
| | 1,1-Dichloroethene | 75-34-3 | | | 1.4e-003 | | | 3.3e-009 | 8.4e-009 | 4.4e-005 | | | 1.4e-003 |
| | Diethylphtalate | 84-66-2 | | | 3.9e-004 | | | 4.4e-009 | 1.1e-008 | 1.2e-005 | | | 4.0e-004 |
| | Di-n-butylphtalate | 84-74-2 | | | 2.9e-003 | | | 5.6e-006 | 1.4e-005 | 8.7e-005 | | | 3.0e-003 |
| | Naphtalene | 91-20-3 | | | 7.9e-002 | | | 5.9e-006 | 1.5e-005 | 2.4e-003 | | | 8.1e-002 |
| | 2,4,5-T | 93-76-5 | | | 2.9e-004 | | | 1.5e-008 | 3.8e-008 | 8.7e-006 | | | 3.0e-004 |
| | 2,4-D | 94-75-7 | | | 5.7e-004 | | | 1.4e-008 | 3.5e-008 | 1.7e-005 | | | 5.9e-004 |
| | Ethyl benzene | 100-41-4 | 8.6e-008 | | 1.4e-003 | 2.1e-005 | 4.0e-005 | 7.6e-008 | 1.9e-007 | 4.4e-005 | 4.4e-006 | | 1.5e-003 |
| | Toluene | 108-88-3 | 4.3e-008 | 5.3e-009 | 7.1e-004 | 1.9e-005 | 3.7e-005 | 1.4e-008 | 3.7e-008 | 2.2e-005 | 2.2e-006 | | 7.9e-004 |
| | Bis(2-ethylhexyl)phatalate | 117-81-7 | | | 1.6e-002 | | | 7.6e-005 | 1.9e-004 | 4.8e-004 | | | 1.7e-002 |
| | Mercury | 7439-97-6 | | | 1.9e-002 | | | 2.9e-003 | 4.3e-003 | 5.8e-004 | | | 2.7e-002 |
| | Nickel | 7440-02-0 | | | 2.9e-002 | | | 4.3e-005 | 1.2e-003 | 8.7e-004 | | | 3.1e-002 |
| | Cadmium | 7440-43-9 | | | 1.1e-001 | | | 1.4e-003 | 4.3e-005 | 3.5e-003 | | | 1.1e-001 |
| | Vanadium | 7440-62-2 | 4.5e-003 | | 4.5e-002 | | | | 1.1e-005 | 1.4e-003 | 9.1e-003 | | 6.0e-002 |
| | Total | | 4.5e-003 | 2.8e-008 | 3.1e-001 | 4.8e-003 | 9.2e-003 | 4.4e-003 | 5.8e-003 | 9.6e-003 | 9.1e-003 | 5.8e-005 | 3.6e-001 |
| Fetotoxicity | Carbon disulfide | 75-15-0 | | | 1.4e-003 | 9.1e-011 | 1.7e-010 | 5.4e-009 | 1.4e-008 | 4.4e-005 | | | 1.4e-003 |
| | 2 Butanone | 78 98 3 | | 4.9e-007 | 5.7e-003 | | | 4.2e-010 | 1.1e-009 | 1.7e-004 | | 1.2e-003 | 7.1e-003 |
| | 2,4,5 T | 93-76-5 | | | 2.9e-004 | | | 1.5e-008 | 3.8e-008 | 8.7e-006 | | | 3.0e-004 |
| | Total | | | 4.9e-007 | 7.4e-003 | 9.1e-011 | 1.7e-010 | 2.1e-008 | 5.3e-008 | 2.2e-004 | | 1.2e-003 | 8.8e-003 |
| Neurotoxicity | 2-Methylphenol | 95-48-7 | | | 6.3e-003 | | | 2.1e-008 | 5.3e-008 | 1.9e-004 | | | 6.5e-003 |
| | Xylenes(total) | 1330-20-7 | 4.3e-009 | | 7.1e-005 | 9.1e-007 | 1.7e-006 | 4.9e-009 | 1.2e-008 | 2.2e-006 | 2.2e-007 | | 7.6e-005 |
| | Manganese | 7439-96-5 | | | | | | 1.9e-004 | 3.1e-005 | | | | 2.2e-004 |
| | Chromium | 7440-47-3 | | | 1.1e-001 | | | 1.7e-004 | 1.5e-003 | 3.5e-003 | | | 1.2e-001 |
| | Total | | 4.3e-009 | | 1.2e-001 | 9.1e-007 | 1.7e-006 | 3.6e-004 | 1.5e-003 | 3.7e-003 | 2.2e-007 | | 1.2e-001 |
| Skin | Silver | 7440-22-4 | | 1.5e-004 | 4.8e-002 | | | 7.1e-005 | 1.4e-002 | 1.5e-003 | | 1.5e-002 | 7.9e-002 |
| | Thallium | 7440-28-0 | 1.0e-002 | | | | | | | | 2.1e-002 | | 3.1e-002 |
| | Total | | 1.0e-002 | 1.5e-004 | 4.8e-002 | | | 7.1e-005 | 1.4e-002 | 1.5e-003 | 2.1e-002 | 1.5e-002 | 1.1e-001 |
| Hematologic | 1,1,2-Trichloroethane | 79-00-5 | | | 3.6e-002 | | | 4.0e-007 | 1.0e-006 | 1.1e-003 | | | 3.7e-002 |
| | 2,4-D | 94-75-7 | | | 5.7e-004 | | | 1.4e-008 | 3.5e-008 | 1.7e-005 | | | 5.9e-004 |
| | Total | | | | 3.7e-002 | | | 4.1e-007 | 1.0e-006 | 1.1e-003 | | | 3.8e-002 |
| Cardiovascular(3) | Trichlorofluoromethane | 75-69-4 | | 4.2e-008 | | | | | | | | 1.1e-004 | 1.1e-004 |
| Respiratory(3) | Trichlorofluoromethane | 75-69-4 | | 4.2e-008 | | | | | | | | 1.1e-004 | 1.1e-004 |
| Immune(3) | 1,1,2-Trichloroethane | 79-00-5 | | | 3.6e-002 | | | 4.0e-007 | 1.0e-006 | 1.1e-003 | | | 3.7e-002 |
| Digestive(3) | Benzyl alcohol | 100-51-6 | 2.0e-006 | | | 7.6e-003 | 1.4e-002 | | | | 1.0e-004 | | 2.2e-002 |
| Mortality(3) | Xylenes(total) | 1330-20-7 | 4.3e-009 | | 7.1e-005 | 9.1e-007 | 1.7e-006 | 4.9e-009 | 1.2e-008 | 2.2e-006 | 2.2e-007 | | 7.6e-005 |
| | PATHWAY TOTAL | | 1.5e-002 | 1.5e-004 | 8.6e-001 | 1.5e-002 | 2.8e-002 | 4.9e-003 | 2.2e-002 | 2.7e-002 | 3.0e-002 | 1.7e-002 | 1.0e+000 |

Footnotes:
(1) = Steady state conditions assumed
(2) = Exposure occurs at the Emergency Waste Basin
(3) = For effects which have only one chemical contributing to them a separate total row was not included (i.e., the noncarcinogenic hazard indices for that chemical is the total)

able 6I.29.

CHEMICAL NONCARCINOGENIC HAZARD INDEX FOR THE CHILD ON-WAG 6 HOMESTEADER
Exposure Interval = 1990 - 2019, 2100 - 2129(1)

| Effect | Chemical | CAS No. | PATHWAYS: Incidental Ingestion Soil | Incidental Ingestion Sediment (2) | Ingestion of Drinking Water (Groundwater) | Ingestion of Fruit | Ingestion of Vegetables | Ingestion of Beef | Ingestion of Milk | Dermal Contact with Groundwater | Dermal Contact with Soil | Dermal Contact with Sediment(2) | CHEMICAL TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Liver | Carbon tetrachloride | 56-23-5 | | | 4.5e-001 | | | 3.2e-006 | 3.6e-005 | 1.0e-002 | | | 4.6e-001 |
| | Chloroform | 67-66-3 | | 2.0e-006 | 3.1e-002 | 4.2e-010 | 4.1e-010 | 4.8e-008 | 5.3e-007 | 7.3e-004 | | 9.6e-004 | 3.3e-002 |
| | 1,1,1-Trichloroethane | 71-55-6 | | | 3.5e-003 | | | 1.8e-008 | 2.0e-007 | 8.1e-005 | | | 3.6e-003 |
| | Methylene chloride | 75-09-2 | 6.9e-006 | 8.0e-007 | 5.2e-003 | 1.0e-002 | 1.0e-002 | 1.7e-009 | 1.9e-008 | 1.2e-004 | 5.4e-004 | 3.8e-004 | 2.6e-002 |
| | 1,1-Dichloroethene | 75-35-4 | | | 3.5e-002 | | | 3.9e-008 | 4.4e-007 | 8.1e-004 | | | 3.6e-002 |
| | 1,1,2-Trichloroethane | 79-00-5 | | | 7.8e-002 | | | 3.8e-007 | 4.2e-006 | 1.8e-003 | | | 8.0e-002 |
| | Diethylphtalate | 84-66-2 | | | 8.6e-004 | | | 4.1e-009 | 4.6e-008 | 2.0e-005 | | | 8.8e-004 |
| | Di-n-butylphtalate | 84-74-2 | | | 6.3e-003 | | | 5.3e-006 | 6.0e-005 | 1.5e-004 | | | 6.5e-003 |
| | 2,4,5-TP | 93-72-1 | | | 7.8e-004 | | | 1.3e-007 | 1.4e-006 | 1.8e-005 | | | 8.0e-004 |
| | Ethyl benzene | 100-41-4 | 7.5e-007 | | 3.1e-003 | 9.7e-005 | 9.4e-005 | 7.2e-008 | 8.0e-007 | 7.3e-005 | 5.9e-005 | | 3.4e-003 |
| | Toluene | 108-88-3 | 3.8e-007 | 4.6e-008 | 1.6e-003 | 8.9e-005 | 8.7e-005 | 1.4e-008 | 1.5e-007 | 3.6e-005 | 3.0e-005 | 2.2e-005 | 1.9e-003 |
| | Bis(2-ethylhexyl)phatalate | 117-81-7 | | | 3.4e-002 | | | 7.2e-005 | 8.1e-004 | 8.0e-004 | | | 3.6e-002 |
| | Tetrachloroethene | 127-18-4 | | | 3.1e-002 | 4.1e-007 | 4.0e-007 | 2.0e-007 | 2.3e-006 | 7.3e-004 | | | 3.2e-002 |
| | Total | | 8.0e-006 | 2.8e-006 | 6.8e-001 | 1.0e-002 | 1.0e-002 | 8.1e-005 | 9.2e-004 | 1.5e-002 | 6.3e-004 | 1.4e-003 | 7.2e-001 |
| Kidney | Acetone | 67-64-1 | 1.9e-006 | 2.0e-007 | 6.3e-003 | 2.2e-002 | 2.1e-002 | 5.9e-011 | 6.6e-010 | 1.5e-004 | 1.5e-004 | 9.6e-005 | 5.0e-002 |
| | 1,1-Dichloroethane | 75-34-3 | | | 3.1e-003 | | | 3.1e-009 | 3.5e-008 | 7.3e-005 | | | 3.2e-003 |
| | Diethylphtalate | 84-66-2 | | | 8.6e-004 | | | 4.1e-009 | 4.6e-008 | 2.0e-005 | | | 8.8e-004 |
| | Di-n-butylphtalate | 84-74-2 | | | 6.3e-003 | | | 5.3e-006 | 6.0e-005 | 1.5e-004 | | | 6.5e-003 |
| | Naphtalene | 91-20-3 | | | 1.7e-001 | | | 5.6e-006 | 6.3e-005 | 4.0e-003 | | | 1.7e-001 |
| | 2,4,5-T | 93-76-5 | | | 6.3e-004 | | | 1.4e-008 | 1.6e-007 | 1.5e-005 | | | 6.5e-004 |
| | 2,4-D | 94-75-7 | | | 1.3e-003 | | | 1.3e-008 | 1.5e-007 | 2.9e-005 | | | 1.3e-003 |
| | Ethyl benzene | 100-41-4 | 7.5e-007 | | 3.1e-003 | 9.7e-005 | 9.4e-005 | 7.2e-008 | 8.0e-007 | 7.3e-005 | 5.9e-005 | | 3.4e-003 |
| | Toluene | 108-88-3 | 3.8e-007 | 4.6e-008 | 1.6e-003 | 8.9e-005 | 8.7e-005 | 1.4e-008 | 1.5e-007 | 3.6e-005 | 3.0e-005 | 2.2e-005 | 1.9e-003 |
| | Bis(2-ethylhexyl)phatalate | 117-81-7 | | | 3.4e-002 | | | 7.2e-005 | 8.1e-004 | 8.0e-004 | | | 3.6e-002 |
| | Mercury | 7439-97-6 | | | 4.2e-002 | | | 2.7e-003 | 1.8e-002 | 9.7e-004 | | | 6.4e-002 |
| | Nickel | 7440-02-0 | | | 6.3e-002 | | | 4.1e-005 | 4.9e-003 | 1.5e-003 | | | 6.9e-002 |
| | Cadmium | 7440-43-9 | | | 2.5e-001 | | | 1.3e-003 | 1.8e-004 | 5.8e-003 | | | 2.6e-001 |
| | Vanadium | 7440-62-2 | 3.9e-002 | | 9.8e-002 | | | | 4.5e-005 | 2.3e-003 | 1.2e-001 | | 2.6e-001 |
| | Total | | 9.9e-002 | 8.9e-007 | 6.8e-001 | 2.2e-002 | 2.1e-002 | 4.1e-003 | 2.4e-002 | 1.6e-002 | 1.2e-001 | 1.2e-004 | 9.3e-001 |
| Fetotoxicity | [illegible] | [illegible] | | | 3.1e-003 | 4.2e-010 | 4.1e-010 | 5.1e-009 | 5.7e-008 | 7.3e-005 | | | 3.2e-003 |
| | [illegible] | [illegible] | | 4.3e-006 | 1.3e-002 | | | 4.0e-010 | 4.4e-009 | 2.9e-004 | | 2.1e-003 | 1.5e-002 |
| | [illegible] | [illegible] | | | 6.5e-004 | | | 1.4e-008 | 1.6e-007 | 1.5e-005 | | | 6.5e-004 |
| | Total | | | 4.3e-006 | 1.7e-002 | 4.2e-010 | 4.1e-010 | 2.0e-008 | 2.2e-007 | 3.8e-004 | | 2.1e-003 | 1.9e-002 |
| Neurotoxicity | 2-Methylphenol | 95-48-7 | | | 1.4e-002 | | | 2.0e-008 | 2.2e-007 | 3.2e-004 | | | 1.4e-002 |
| | Xylenes(total) | 1330-20-7 | 3.8e-008 | | 1.6e-004 | 4.2e-006 | 4.1e-006 | 4.6e-009 | 5.2e-008 | 3.6e-006 | 3.0e-006 | | 1.7e-004 |
| | Manganese | 7439-96-5 | | | | | | 1.8e-004 | 1.3e-004 | | | | 3.1e-004 |
| | Chromium | 7440-47-3 | | | 2.5e-001 | | | 1.6e-004 | 6.3e-003 | 5.8e-003 | | | 2.6e-001 |
| | Total | | 3.8e-008 | | 2.6e-001 | 4.2e-006 | 4.1e-006 | 3.4e-004 | 6.4e-003 | 6.1e-003 | 3.0e-006 | | 2.8e-001 |
| Skin | Silver | 7440-22-4 | | 1.3e-003 | 1.0e-001 | | | 6.7e-005 | 6.0e-002 | 2.4e-003 | | 2.5e-002 | 1.9e-001 |
| | Thallium | 7440-28-0 | 8.9e-002 | | | | | | | | 2.8e-001 | | 3.7e-001 |
| | Total | | 8.9e-002 | 1.3e-003 | 1.0e-001 | | | 6.7e-005 | 6.0e-002 | 2.4e-003 | 2.8e-001 | 2.5e-002 | 5.6e-001 |
| Hematologic | 1,1,2-Trichloroethane | 79-00-5 | | | 7.8e-002 | | | 3.8e-007 | 4.2e-006 | 1.8e-003 | | | 8.0e-002 |
| | 2,4-D | 94-75-7 | | | 1.3e-003 | | | 1.3e-008 | 1.5e-007 | 2.9e-005 | | | 1.3e-003 |
| | Total | | | | 7.9e-002 | | | 3.9e-007 | 4.4e-006 | 1.8e-003 | | | 8.1e-002 |
| Cardiovascular(3) | Trichlorofluoromethane | 75-69-4 | | 3.7e-007 | | | | | | | | 1.8e-004 | 1.8e-004 |
| Respiratory(3) | Trichlorofluoromethane | 75-69-4 | | 3.7e-007 | | | | | | | | 1.8e-004 | 1.8e-004 |
| Immune(3) | 1,1,2-Trichloroethane | 79-00-5 | | | 7.8e-002 | | | 3.8e-007 | 4.2e-006 | 1.8e-003 | | | 8.0e-002 |
| Digestive(3) | Benzyl alcohol | 100-51-6 | 1.8e-005 | | | 3.5e-002 | 3.4e-002 | | | | 1.4e-003 | | 7.0e-002 |
| Mortality(3) | Xylenes(total) | 1330-20-7 | 3.8e-008 | | 1.6e-004 | 4.2e-006 | 4.1e-006 | 4.6e-009 | 5.2e-008 | 3.6e-006 | 3.0e-006 | | 1.7e-004 |
| | PATHWAY TOTAL | | 1.3e-001 | 1.3e-003 | 1.9e+000 | 6.7e-002 | 6.5e-002 | 4.6e-003 | 9.1e-002 | 4.4e-002 | 4.0e-001 | 2.9e-002 | 2.7e+000 |

Footnotes:
(1) = Steady state conditions assumed
(2) = Exposure occurs at the Emergency Waste Basin
(3) = For effects which have only one chemical contributing to them a separate total row was not included

Table 6I.30

CHEMICAL INHALATION NONCARCINOGENIC HAZARD INDEX FOR THE ADULT ON-WAG 6 HOMESTEADER
Exposure Interval = 1990 - 2019, 2100 - 2129(1)

| Effect | Chemical | CAS No. | PATHWAYS: Inhalation of Vapor Phase | PATHWAYS: Inhalation of Vapor Phase (Groundwater) | CHEMICAL TOTAL |
|---|---|---|---|---|---|
| Liver | 1,1,1-Trichloroethane | 71-55-6 | | 2.1e-004 | 2.1e-004 |
| | Methylene chloride | 75-09-2 | | 7.1e-005 | 7.1e-005 |
| | Total | | | 2.8e-004 | 2.8e-004 |
| Fetotoxicity | Chloroethane | 75-00-3 | | 4.3e-004 | 4.3e-004 |
| | Ethyl benzene | 100-41-4 | 1.2e-008 | 2.1e-004 | 2.1e-004 |
| | Total | | 1.2e-008 | 6.4e-004 | 6.4e-004 |
| Neurotoxicity | 2-Butanone | 78-93-3 | | 1.3e-003 | 1.3e-003 |
| | Toluene | 108-88-3 | 7.4e-009 | 1.1e-004 | 1.1e-004 |
| | Xylenes(total) | 1330-20-7 | 1.0e-007 | 6.4e-004 | 6.4e-004 |
| | Total | | 1.1e-007 | 2.1e-003 | 2.1e-003 |
| Kidney(2) | 1,1-Dichloroethane | 75-34-3 | | 6.4e-004 | 6.4e-004 |
| | PATHWAY TOTAL | | 1.2e-007 | 3.6e-003 | 3.6e-003 |

Footnotes:
(1) = Steady state conditions assumed
(2) = For effects which have only one chemical contributing to them a separate total row was not included (i.e., the noncarcinogenic hazard indices for that chemical is the total)

**Table 6I.31**

CHEMICAL INHALATION NONCARCINOGENIC HAZARD INDEX FOR THE CHILD ON-WAG 6 HOMESTEADER
Exposure Interval = 1990 - 2019, 2100 - 2129(1)

| Effect | Chemical | CAS No. | PATHWAYS: Inhalation of Vapor Phase | PATHWAYS: Inhalation of Vapor Phase (Groundwater) | CHEMICAL TOTAL |
|---|---|---|---|---|---|
| Liver | 1,1,1-Trichloroethane | 71-55-6 | | 9.4e-004 | 9.4e-004 |
| | Methylene chloride | 75-09-2 | | 3.1e-004 | 3.1e-004 |
| | Total | | | 1.3e-003 | 1.3e-003 |
| Fetotoxicity | Chloroethane | 75-00-3 | | 1.9e-003 | 1.9e-003 |
| | Ethyl benzene | 100-41-4 | 2.6e-008 | 9.4e-004 | 9.4e-004 |
| | Total | | 2.6e-008 | 2.8e-003 | 2.8e-003 |
| Neurotoxicity | 2-Butanone | 78-93-3 | | 5.6e-003 | 5.6e-003 |
| | Toluene | 108-88-3 | 1.6e-008 | 4.7e-004 | 4.7e-004 |
| | Xylenes(total) | 1330-20-7 | 2.1e-007 | 2.8e-003 | 2.8e-003 |
| | Total | | 2.3e-007 | 8.9e-003 | 8.9e-003 |
| Kidney(2) | 1,1-Dichloroethane | 75-34-3 | | 2.8e-003 | 2.8e-003 |
| | PATHWAY TOTAL | | 2.5e-007 | 1.6e-002 | 1.6e-002 |

Footnotes:
(1) = Steady state conditions assumed
(2) = For effects which have only one chemical contributing to them a separate total row was not included (i.e., the noncarcinogenic hazard indices for that chemical is the total)

**Table 6I.32**

EXCESS LIFETIME CHEMICAL CARCINOGENIC RISK FOR THE ADULT ON-WAG 6 HOMESTEADER
Exposure Interval = 1990-2019, 2100-2129(1)

| Chemical | CAS No. | PATHWAYS | | | | | | | | | | | | CHEMICAL TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Incidental Ingestion Soil | Incidental Ingestion Sediment (2) | Inhalation Vapor Phase | Inhalation Vapor Phase (Showering) | Ingestion of Drinking Water (Groundwater) | Ingestion of Fruit | Ingestion of Vegetables | Ingestion of Beef | Ingestion of Milk | Dermal Contact with Groundwater | Dermal Contact with Soil | Dermal Contact with Sediment(2) | |
| Carbon Tetrachloride | 56-23-5 | | | | 3.6e-006 | 8.0e-006 | | | 1.3e-010 | 3.3e-010 | 2.4e-007 | | | 1.2e-005 |
| Chloroform | 67-66-3 | | 6.0e-012 | 1.0e-010 | 2.2e-006 | 3.7e-007 | 2.4e-015 | 4.5e-015 | 1.3e-012 | 3.3e-012 | 1.1e-008 | | 1.5e-008 | 2.6e-006 |
| Benzene | 71-43-2 | | | 5.1e-011 | 8.0e-007 | 1.8e-006 | 4.8e-014 | 9.2e-014 | 8.8e-012 | 2.2e-011 | 5.4e-008 | | | 2.7e-006 |
| Chloromethane | 74-87-3 | | | 3.0e-011 | | | 3.7e-015 | 7.1e-015 | | | | | | 3.0e-011 |
| Vinyl Chloride | 75-01-4 | | | | 1.6e-005 | 2.3e-004 | | | 2.1e-010 | 5.3e-010 | 7.1e-006 | | | 2.5e-004 |
| Methylene Chloride | 75-09-2 | 1.5e-010 | 1.8e-011 | | 4.5e-008 | 4.6e-007 | 4.4e-007 | 8.3e-007 | 3.5e-013 | 8.7e-013 | 1.4e-008 | 7.7e-009 | 4.4e-008 | 1.8e-006 |
| 1,1-Dichloroethane | 75-34-3 | | | | | 5.6e-006 | | | 1.3e-011 | 3.3e-011 | 1.7e-007 | | | 5.8e-006 |
| 1,1-Dichloroethene | 75-35-4 | | | | 3.3e-005 | 3.7e-005 | | | 9.6e-011 | 2.4e-010 | 1.1e-006 | | | 7.1e-005 |
| 1,1,2-Trichloroethane | 79-00-5 | | | | 1.6e-006 | 3.5e-006 | | | 3.9e-011 | 9.8e-011 | 1.1e-007 | | | 5.2e-006 |
| Trichloroethene | 79-01-6 | 4.0e-011 | 5.0e-012 | 3.9e-011 | 4.7e-007 | 6.7e-007 | 2.8e-008 | 5.3e-008 | 6.1e-012 | 1.5e-011 | 2.1e-008 | 2.1e-009 | 1.3e-008 | 1.3e-006 |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | | | | 5.5e-006 | 1.2e-005 | | | 1.1e-010 | 2.9e-010 | 3.7e-007 | | | 1.8e-005 |
| 1,2-Dichloroethane | 107-06-2 | | | 4.2e-011 | 2.5e-006 | 5.6e-006 | 1.6e-014 | 3.1e-014 | 6.3e-012 | 1.6e-011 | 1.7e-007 | | | 8.3e-006 |
| Bis(2-Ethylhexyl)Phthalate | 117-81-7 | | | | | 2.0e-006 | | | 9.2e-009 | 2.3e-008 | 5.7e-008 | | | 2.0e-006 |
| Tetrachloroethene | 127-18-4 | | | 1.1e-011 | 5.0e-008 | 3.1e-006 | 1.9e-011 | 3.7e-011 | 4.7e-011 | 1.2e-010 | 9.5e-008 | | | 3.2e-006 |
| PATHWAY TOTAL | | 1.9e-010 | 2.9e-011 | 2.7e-010 | 6.6e-005 | 3.1e-004 | 4.7e-007 | 8.8e-007 | 9.9e-009 | 2.5e-008 | 9.5e-006 | 9.8e-009 | 7.2e-008 | 3.9e-004 |

Footnotes:
(1) = Steady state conditions assumed
(2) = Exposure occurs at the Emergency Waste Basin

Table 6I.33

EXCESS LIFETIME CHEMICAL CARCINOGENIC RISK FOR THE CHILD ON-WAG 6 HOMESTEADER
Exposure Interval = 1990-2019, 2100-2129(1)

| Chemical | CAS No. | PATHWAYS | | | | | | | | | | | | CHEMICAL TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Incidental Ingestion Soil | Incidental Ingestion Sediment (2) | Inhalation Vapor Phase | Inhalation Vapor Phase (Showering) | Ingestion of Drinking Water (Groundwater) | Ingestion of Fruit | Ingestion of Vegetables | Ingestion of Beef | Ingestion of Milk | Dermal Contact with Groundwater | Dermal Contact with Soil | Dermal Contact with Sediment(2) | |
| Carbon Tetrachloride | 56-23-5 | | | | 3.7e-006 | 4.1e-006 | | | 2.9e-011 | 3.2e-010 | 9.5e-008 | | | 7.9e-006 |
| Chloroform | 67-66-3 | | 1.2e-011 | 5.0e-011 | 2.3e-006 | 1.9e-007 | 2.5e-015 | 2.5e-015 | 2.9e-013 | 3.2e-012 | 4.5e-009 | | 5.9e-009 | 2.5e-006 |
| Benzene | 71-43-2 | | | 2.5e-011 | 8.2e-007 | 9.1e-007 | 5.2e-014 | 5.1e-014 | 1.9e-012 | 2.2e-011 | 2.1e-008 | | | 1.8e-006 |
| Chloromethane | 74-87-3 | | | 1.5e-011 | | | 4.0e-015 | 3.9e-015 | | | | | | 1.5e-011 |
| Vinyl Chloride | 75-01-4 | | | | 1.7e-005 | 1.2e-004 | | | 4.6e-011 | 5.2e-010 | 2.8e-006 | | | 1.4e-004 |
| Methylene Chloride | 75-09-2 | 3.1e-010 | 3.6e-011 | | 4.6e-008 | 2.3e-007 | 4.7e-007 | 4.6e-007 | 7.6e-014 | 8.5e-013 | 5.5e-009 | 2.4e-008 | 1.7e-008 | 1.3e-006 |
| 1,1-Dichloroethane | 75-34-3 | | | | | 2.8e-006 | | | 2.9e-012 | 3.2e-011 | 6.6e-008 | | | 2.9e-006 |
| 1,1-Dichloroethene | 75-35-4 | | | | 3.4e-005 | 1.9e-005 | | | 2.1e-011 | 2.4e-010 | 4.4e-007 | | | 5.3e-005 |
| 1,1,2-Trichloroethane | 79-00-5 | | | | 1.6e-006 | 1.8e-006 | | | 8.6e-012 | 9.6e-011 | 4.2e-008 | | | 3.4e-006 |
| Trichlorothene | 79-01-6 | 8.3e-011 | 1.0e-011 | 1.9e-011 | 4.8e-007 | 3.4e-007 | 3.0e-008 | 2.9e-008 | 1.3e-012 | 1.5e-011 | 8.0e-009 | 6.5e-009 | 4.9e-009 | 9.0e-007 |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | | | | 5.6e-006 | 6.3e-006 | | | 2.5e-011 | 2.8e-010 | 1.5e-007 | | | 1.2e-005 |
| 1,2-Dichloroethane | 107-06-2 | | | 2.1e-011 | 2.6e-006 | 2.8e-006 | 1.7e-014 | 1.7e-014 | 1.4e-012 | 1.6e-011 | 6.6e-008 | | | 5.5e-006 |
| Bis(2-Ethylhexyl)Phatalate | 117-81-7 | | | | | 9.6e-007 | | | 2.0e-009 | 2.3e-008 | 2.2e-008 | | | 1.0e-006 |
| Tetrachloroethene | 127-18-4 | | | 5.4e-012 | 5.1e-008 | 1.6e-006 | 2.1e-011 | 2.0e-011 | 1.0e-011 | 1.2e-010 | 3.7e-008 | | | 1.7e-006 |
| PATHWAY TOTAL | | 3.9e-010 | 5.8e-011 | 1.4e-010 | 6.8e-005 | 1.6e-004 | 5.0e-007 | 4.9e-007 | 2.1e-009 | 2.5e-008 | 3.8e-006 | 3.1e-008 | 2.8e-008 | 2.3e-004 |

Footnotes:
(1) = Steady state conditions assumed
(2) = Exposure occurs at the Emergency Waste Basin

**Table 6I.34.**

CHEMICAL NONCARCINOGENIC HAZARD INDEX FOR THE ADULT ON-WAG & AUGER HOLE SUB AREA HOMESTEADER
Exposure Interval = 1990 - 2019, 2100 - 2129(1)

| Effect | Chemical | CAS No. | PATHWAYS: Incidental Ingestion Soil | Incidental Ingestion Sediment (2) | Ingestion of Drinking Water (Groundwater) | Ingestion of Fruit | Ingestion of Vegetables | Ingestion of Beef | Ingestion of Milk | Dermal Contact with Groundwater | Dermal Contact with Soil | Dermal Contact with Sediment(2) | CHEMICAL TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Liver | Carbon tetrachloride | 56-23-5 | | | 2.1e+000 | | | 3.5e-005 | 8.8e-005 | 6.5e-002 | | | 2.2e+000 |
| | Chloroform | 67-66-3 | | 2.3e-007 | 1.7e-001 | 9.1e-011 | 1.7e-010 | 6.1e-007 | 1.6e-006 | 5.3e-003 | | 5.8e-004 | 1.8e-001 |
| | Methylene chloride | 75-09-2 | | 9.1e-008 | 2.4e-003 | | | 1.8e-009 | 4.5e-009 | 2.3e-005 | | 2.3e-004 | 2.7e-003 |
| | Diethylphatalate | 84-66-2 | | | 3.9e-004 | | | 4.4e-009 | 1.1e-008 | 1.2e-005 | | | 4.0e-004 |
| | Di-n-butylphatalate | 84-74-2 | | | 3.1e-003 | | | 6.1e-006 | 1.6e-005 | 9.6e-005 | | | 3.2e-003 |
| | 2,4,5-TP | 93-72-1 | | | 3.6e-004 | | | 1.3e-007 | 3.4e-007 | 1.1e-005 | | | 3.7e-004 |
| | Ethyl benzene | 100-41-4 | | | | 9.3e-009 | 1.8e-008 | | | | | | 2.7e-008 |
| | Toluene | 108-88-3 | | 5.3e-009 | | 9.6e-007 | 1.8e-006 | | | | | 1.3e-005 | 1.6e-005 |
| | Bis(2-ethylhexyl)phatalate | 117-81-7 | | | 1.6e-002 | | | 7.6e-005 | 1.9e-004 | 4.8e-004 | | | 1.7e-002 |
| | Tetrachloroethene | 127-18-4 | | | 1.4e-002 | 8.9e-008 | 1.7e-007 | 2.1e-007 | 5.4e-007 | 4.4e-004 | | | 1.4e-002 |
| | Total | | | 3.3e-007 | 2.3e+000 | 1.1e-006 | 2.0e-006 | 1.2e-004 | 3.0e-004 | 7.1e-002 | | 8.2e-004 | 2.4e+000 |
| Kidney | Acetone | 67-64-1 | | 2.3e-008 | | | | | | | | | |
| | 1,1-Dichloroethane | 75-34-3 | | | 1.4e-003 | | | 3.3e-009 | 8.4e-009 | 4.4e-005 | | 5.8e-005 | 5.8e-005 |
| | Diethylphatalate | 84-66-2 | | | 3.9e-004 | | | 4.4e-009 | 1.1e-008 | 1.2e-005 | | | 1.4e-003 |
| | Di-n-butylphatalate | 84-74-2 | | | 3.1e-003 | | | 6.1e-006 | 1.6e-005 | 9.6e-005 | | | 4.0e-004 |
| | 2,4-D | 94-75-7 | | | 5.7e-004 | | | 1.4e-008 | 3.5e-008 | 1.7e-005 | | | 3.2e-003 |
| | Ethyl benzene | 100-41-4 | | | | 9.3e-009 | 1.8e-008 | | | | | | 5.9e-004 |
| | Toluene | 108-88-3 | | 5.3e-009 | | 9.6e-007 | 1.8e-006 | | | | | 1.3e-005 | 2.7e-008 |
| | Bis(2-ethylhexyl)phatalate | 117-81-7 | | | 1.6e-002 | | | 7.6e-005 | 1.9e-004 | 4.8e-004 | | | 1.6e-005 |
| | Nickel | 7440-02-0 | | | 2.9e-002 | | | 4.3e-005 | 1.2e-003 | 8.7e-004 | | | 1.7e-002 |
| | Cadmium | 7440-43-9 | | | 2.9e-001 | | | 3.4e-003 | 1.1e-004 | 8.7e-003 | | | 3.1e-002 |
| | Vanadium | 7440-62-2 | 4.7e-003 | | 4.5e-002 | | | | 1.1e-005 | 1.4e-003 | 9.6e-003 | | 3.0e-001 |
| | Total | | 4.7e-003 | 2.8e-008 | 3.9e-001 | 9.7e-007 | 1.8e-006 | 3.5e-003 | 1.5e-003 | 1.2e-002 | 9.6e-003 | 7.1e-005 | 6.1e-002 |
| Fetotoxicity | Carbon disulfide | 75-15-0 | | | | 9.1e-011 | 1.7e-010 | | | | | | 4.2e-001 |
| | 2-Butanone | 78-98-3 | | 4.9e-007 | | | | | | | | 1.2e-003 | 2.6e-010 |
| | Total | | | 4.9e-007 | | 9.1e-011 | 1.7e-010 | | | | | 1.2e-003 | 1.2e-003 |
| Neurotoxicity | Xylenes(total) | 1330-20-7 | | | | 1.2e-009 | 2.4e-009 | | | | | 1.2e-003 | 1.2e-003 |
| | Manganese | 7439-96-5 | | | | | | 1.4e-004 | 2.2e-005 | | | | 3.6e-009 |
| | Chromium | 7440-47-3 | | | 1.1e-001 | | | 1.7e-004 | 1.5e-003 | 3.5e-003 | | | 1.6e-004 |
| | Total | | | | 1.1e-001 | 1.2e-009 | 2.4e-009 | 3.1e-004 | 1.5e-003 | 3.5e-003 | | | 1.2e-001 |
| Cardiovascular(3) | Trichlorofluoromethane | 75-69-4 | | 4.2e-008 | | | | | | | | 1.1e-004 | 1.1e-004 |
| Respiratory(3) | Trichlorofluoromethane | 75-69-4 | | 4.2e-008 | | | | | | | | 1.1e-004 | 1.1e-004 |
| Hematologic(3) | 2,4-D | 94-75-7 | | | 5.7e-004 | | | 1.4e-008 | 3.5e-008 | 1.7e-005 | | | 5.9e-004 |
| Mortality(3) | Xylenes(total) | 1330-20-7 | | | | 1.2e-009 | 2.4e-009 | | | | | | 3.6e-009 |
| Skin(3) | Silver | 7440-22-4 | | 1.5e-004 | | | | | | | | 1.5e-002 | 1.5e-002 |
| | PATHWAY TOTAL | | 4.7e-003 | 1.5e-004 | 2.8e+000 | 2.0e-006 | 3.8e-006 | 4.0e-003 | 3.3e-003 | 8.6e-002 | 9.6e-003 | 1.7e-002 | 2.9e+000 |

Footnotes:
(1) = Steady state conditions assumed
(2) = Exposure occurs at the Emergency Waste Basin
(3) = For effects which have only one chemical contributing to them a separate total row was not included (i.e., the noncarcinogenic hazard indices for that chemical is the total)

Table 6I.35.

CHEMICAL NONCARCINOGENIC HAZARD INDEX FOR THE CHILD ON-WAG 6 AUGER HOLE SUB AREA HOMESTEADER
Exposure Interval = 1990 - 2019, 2100 - 2129(1)

| Effect | Chemical | CAS No. | PATHWAYS: Incidental Ingestion Soil | Incidental Ingestion Sediment (2) | Ingestion of Drinking Water (Groundwater) | Ingestion of Fruit | Ingestion of Vegetables | Ingestion of Beef | Ingestion of Milk | Dermal Contact with Groundwater | Dermal Contact with Soil | Dermal Contact with Sediment(2) | CHEMICAL TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Liver | Carbon tetrachloride | 56-23-5 | | | 4.6e+000 | | | 3.3e-005 | 3.7e-004 | 1.1e-001 | | | 4.7e+000 |
| | Chloroform | 67-66-3 | | 2.0e-006 | 3.8e-001 | 4.2e-010 | 4.1e-010 | 5.8e-007 | 6.5e-006 | 8.9e-003 | | 9.6e-004 | 3.9e-001 |
| | Methylene chloride | 75-09-2 | | 8.0e-007 | 5.2e-003 | | | 1.7e-009 | 1.9e-008 | 1.2e-004 | | 3.8e-004 | 5.7e-003 |
| | Diethylphatalate | 84-66-2 | | | 8.6e-004 | | | 4.1e-009 | 4.6e-008 | 2.0e-005 | | | 8.8e-004 |
| | Di-n-butylphatalate | 84-74-2 | | | 6.9e-003 | | | 5.8e-006 | 6.6e-005 | 1.6e-004 | | | 7.1e-003 |
| | 2,4,5-TP | 93-72-1 | | | 7.8e-004 | | | 1.3e-007 | 1.4e-006 | 1.8e-005 | | | 8.0e-004 |
| | Ethyl benzene | 100-41-4 | | | | 4.3e-008 | 4.2e-008 | | | | | | 8.5e-008 |
| | Toluene | 108-88-3 | | 4.6e-008 | | 4.4e-006 | 4.3e-006 | | | | | 2.2e-005 | 3.1e-005 |
| | Bis(2-ethylhexyl)phatalate | 117-81-7 | | | 3.4e-002 | | | 7.2e-005 | 8.1e-004 | 8.0e-004 | | | 3.6e-002 |
| | Tetrachloroethene | 127-18-4 | | | 3.1e-002 | 4.1e-007 | 4.0e-007 | 2.0e-007 | 2.3e-006 | 7.3e-004 | | | 3.2e-002 |
| | Total | | | 2.8e-006 | 5.1e+000 | 4.9e-006 | 4.7e-006 | 1.1e-004 | 1.3e-003 | 1.2e-001 | | 1.4e-003 | 5.2e+000 |
| Kidney | Acetone | 67-64-1 | | 2.0e-007 | | | | | | | | 9.6e-005 | 9.6e-005 |
| | 1,1-Dichloroethane | 75-34-3 | | | 3.1e-003 | | | 3.1e-009 | 3.5e-008 | 7.3e-005 | | | 3.2e-003 |
| | Diethylphatalate | 84-66-2 | | | 8.6e-004 | | | 4.1e-009 | 4.6e-008 | 2.0e-005 | | | 8.8e-004 |
| | Di-n-butylphatalate | 84-74-2 | | | 6.9e-003 | | | 5.8e-006 | 6.6e-005 | 1.6e-004 | | | 7.1e-003 |
| | 2,4-D | 94-75-7 | | | 1.3e-003 | | | 1.3e-008 | 1.5e-007 | 2.9e-005 | | | 1.3e-003 |
| | Ethyl benzene | 100-41-4 | | | | 4.3e-008 | 4.2e-008 | | | | | | 8.5e-008 |
| | Toluene | 108-88-3 | | 4.6e-008 | | 4.4e-006 | 4.3e-006 | | | | | 2.2e-005 | 3.1e-005 |
| | Bis(2-ethylhexyl)phatalate | 117-81-7 | | | 3.4e-002 | | | 7.2e-005 | 8.1e-004 | 8.0e-004 | | | 3.6e-002 |
| | Nickel | 7440-02-0 | | | 6.3e-002 | | | 4.1e-005 | 4.9e-003 | 1.5e-003 | | | 6.9e-002 |
| | Cadmium | 7440-43-9 | | | 6.3e-001 | | | 3.2e-003 | 4.4e-004 | 7.3e-003 | | | 6.4e-001 |
| | Vanadium | 7440-62-2 | 4.1e-002 | | 9.8e-002 | | | | 4.5e-005 | 2.3e-003 | 1.3e-001 | | 2.7e-001 |
| | Total | | 4.1e-002 | 2.5e-007 | 8.4e-001 | 4.4e-006 | 4.3e-006 | 3.3e-003 | 6.3e-003 | 1.2e-002 | 1.3e-001 | 1.2e-004 | 1.0e+000 |
| Fetotoxicity | Carbon disulfide | 75-15-0 | | | | 4.2e-010 | 4.1e-010 | | | | | 2.1e-003 | 8.3e-010 |
| | 2-Butanone | 78-98-3 | | 4.3e-006 | | | | | | | | | 2.1e-003 |
| | Total | | | 4.3e-006 | | 4.2e-010 | 4.1e-010 | | | | | 2.1e-003 | 2.1e-003 |
| Neurotoxicity | Xylenes(total) | 1330-20-7 | | | | 5.7e-009 | 5.5e-009 | | | | | | 1.1e-008 |
| | Manganese | 7439-96-5 | | | 2.5e-001 | | | 1.3e-004 | 9.0e-005 | | | | 2.2e-004 |
| | Chromium | 7440-47-3 | | | | | | 1.6e-004 | 6.3e-003 | 5.8e-003 | | | 2.6e-001 |
| | Total | | | | 2.5e-001 | 5.7e-009 | 5.5e-009 | 2.9e-004 | 6.4e-003 | 5.8e-003 | | | 2.6e-001 |
| Cardiovascular(3) | Trichlorofluoromethane | 75-69-4 | | 3.7e-007 | | | | | | | | 1.8e-004 | 1.8e-004 |
| Respiratory(3) | Trichlorofluoromethane | 75-69-4 | | 3.7e-007 | | | | | | | | 1.8e-004 | 1.8e-004 |
| Hematologic(3) | 2,4-D | 94-75-7 | | | 1.3e-003 | | | 1.3e-008 | 1.5e-007 | 2.9e-005 | | | 1.3e-003 |
| Mortality(3) | Xylenes(total) | 1330-20-7 | | | | 5.7e-009 | 5.5e-009 | | | | | | 1.1e-008 |
| Skin(3) | Silver | 7440-22-4 | | 1.3e-003 | | | | | | | | 2.5e-002 | 2.6e-002 |
| | PATHWAY TOTAL | | 4.1e-002 | 1.3e-003 | 6.1e+000 | 9.3e-006 | 9.1e-006 | 3.7e-003 | 1.4e-002 | 1.4e-001 | 1.3e-001 | 2.9e-002 | 6.5e+000 |

Footnotes:
(1) = Steady state conditions assumed
(2) = Exposure occurs at the Emergency Waste Basin
(3) = For effects which have only one chemical contributing to them a separate total row was not included

Table 6I.36.

CHEMICAL INHALATION NONCARCINOGENIC HAZARD INDEX FOR THE ADULT ON-WAG 6 HOMESTEADER AT THE AUGER HOLE SUB AREA
Exposure Interval = 1990 - 2019, 2100 - 2129(1)

| Effect | Chemical | CAS No. | PATHWAYS: Inhalation of Vapor Phase | PATHWAYS: Inhalation of Vapor Phase (Groundwater) | CHEMICAL TOTAL |
|---|---|---|---|---|---|
| Neurotoxicity | Toluene | 108-88-3 | 7.4e-009 | | 7.4e-009 |
| | Xylenes(total) | 1330-20-7 | 1.0e-007 | | 1.0e-007 |
| | | | 1.1e-007 | | 1.1e-007 |
| Liver(2) | Methylene chloride | 75-09-2 | | 7.1e-005 | 7.1e-005 |
| Kidney(2) | 1,1-Dichloroethane | 75-34-3 | | 6.4e-004 | 6.4e-004 |
| Fetotoxicity(2) | Ethyl benzene | 100-41-4 | 1.2e-008 | | 1.2e-008 |
| | PATHWAY TOTAL | | 1.2e-007 | 7.1e-004 | 7.1e-004 |

Footnotes:
(1) = Steady state conditions assumed
(2) = For effects which have only one chemical contributing to them a separate total row was not included (i.e., the noncarcinogenic hazard indices for that chemical is the total)

Table 6I.37.

CHEMICAL INHALATION NONCARCINOGENIC HAZARD INDEX FOR THE CHILD ON-WAG 6 HOMESTEADER AT THE AUGER HOLE SUB AREA
Exposure Interval = 1990 - 2019, 2100 - 2129(1)

| Effect | Chemical | CAS No. | PATHWAYS: Inhalation of Vapor Phase | PATHWAYS: Inhalation of Vapor Phase (Groundwater) | CHEMICAL TOTAL |
|---|---|---|---|---|---|
| Neurotoxicity | Toluene | 108-88-3 | 1.6e-008 | | 1.6e-008 |
| | Xylenes(total) | 1330-20-7 | 2.1e-007 | | 2.1e-007 |
| | | | 2.3e-007 | | 2.3e-007 |
| Liver(2) | Methylene chloride | 75-09-2 | | 3.1e-004 | 3.1e-004 |
| Kidney(2) | 1,1-Dichloroethane | 75-34-3 | | 2.8e-003 | 2.8e-003 |
| Fetotoxicity(2) | Ethyl benzene | 100-41-4 | 2.6e-008 | | 2.6e-008 |
| | PATHWAY TOTAL | | 2.5e-007 | 3.1e-003 | 3.1e-003 |

Footnotes:
(1) = Steady state conditions assumed
(2) = For effects which have only one chemical contributing to them a separate total row was not included (i.e., the noncarcinogenic hazard indices for that chemical is the total)

Table 6I.38.

EXCESS LIFETIME CHEMICAL CARCINOGENIC RISK FOR THE ADULT HOMESTEADER ON WAG 6 AUGER HOLE SUB AREA
Exposure Interval = 1990 - 2019, 2100 - 2129 (1)

PATHWAYS

| Chemical | CAS No. | Incidental Ingestion Sediment (2) | Inhalation Vapor Phase | Inhalation Vapor Phase (Showering) | Ingestion of Drinking Water (Groundwater) | Ingestion of Fruit | Ingestion of Vegetables | Ingestion of Beef | Ingestion of Milk | Dermal Contact with Groundwater | Dermal Contact with Sediment(2) | CHEMICAL TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Carbon Tetrachloride | 56-23-5 | | | 3.7e-005 | 8.3e-005 | | | 1.4e-009 | 3.4e-009 | 2.5e-006 | | 1.2e-004 |
| Chloroform | 67-66-3 | 6.0e-012 | 1.0e-010 | 2.7e-005 | 4.6e-006 | 2.4e-015 | 4.5e-015 | 1.6e-011 | 4.1e-011 | 1.4e-007 | 1.5e-008 | 3.2e-005 |
| Benzene | 71-43-2 | | 5.1e-011 | | | 4.8e-014 | 9.2e-014 | | | | | 5.1e-011 |
| Chloromethane | 74-87-3 | | 3.0e-011 | | | 3.7e-015 | 7.1e-015 | | | | | 3.0e-011 |
| Methylene Chloride | 75-09-2 | 1.8e-011 | | 4.5e-008 | 4.6e-007 | | | 3.5e-013 | 8.7e-013 | 1.4e-008 | 4.4e-008 | 5.6e-007 |
| 1,1-Dichloroethane | 75-34-3 | | | | 5.6e-006 | | | 1.3e-011 | 3.3e-011 | 1.7e-007 | | 5.8e-006 |
| Trichlorothene | 79-01-6 | 5.0e-012 | 3.9e-011 | 3.0e-005 | 4.3e-005 | 7.1e-014 | 1.4e-013 | 3.9e-010 | 9.9e-010 | 1.3e-006 | 1.3e-008 | 7.4e-005 |
| 1,2-Dichloroethane | 107-06-2 | | 4.2e-011 | 9.5e-006 | 2.1e-005 | 1.6e-014 | 3.1e-014 | 2.4e-011 | 6.1e-011 | 6.5e-007 | | 3.1e-005 |
| Bis(2-Ethylhexyl)Phatalate | 117-81-7 | | | | 1.9e-006 | | | 9.2e-009 | 2.3e-008 | 5.7e-008 | | 2.0e-006 |
| Tetrachloroethene | 127-18-4 | | 1.1e-011 | 5.0e-008 | 3.1e-006 | 1.9e-011 | 3.7e-011 | 4.7e-011 | 1.2e-010 | 9.5e-008 | | 3.2e-006 |
| PATHWAY TOTAL | | 2.9e-011 | 2.7e-010 | 1.0e-004 | 1.6e-004 | 1.9e-011 | 3.7e-011 | 1.1e-008 | 2.8e-008 | 4.9e-006 | 7.2e-008 | 2.7e-004 |

Footnotes:

(1) = Steady state conditions assumed
(2) = Exposure occurs at the Emergency Waste Basin

Table 6I.39.

EXCESS LIFETIME CHEMICAL CARCINOGENIC RISK FOR THE CHILD HOMESTEADER ON WAG 6 AUGER HOLE SUB AREA
Exposure Interval = 1990 - 2019, 2100 - 2129 (1)

| | | PATHWAYS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chemical | CAS No. | Incidental Ingestion Sediment (2) | Inhalation Vapor Phase | Inhalation Vapor Phase (Showering) | Ingestion of Drinking Water (Groundwater) | Ingestion of Fruit | Ingestion of Vegetables | Ingestion of Beef | Ingestion of Milk | Dermal Contact with Groundwater | Dermal Contact with Sediment(2) | CHEMICAL TOTAL |
| Carbon Tetrachloride | 56-23-5 | | | 3.8e-005 | 4.2e-005 | | | 3.0e-010 | 3.4e-009 | 9.9e-007 | | 8.1e-005 |
| Chloroform | 67-66-3 | 1.2e-011 | 5.0e-011 | 2.8e-005 | 2.3e-006 | 2.5e-015 | 2.5e-015 | 3.5e-012 | 4.0e-011 | 5.4e-008 | 5.9e-009 | 3.0e-005 |
| Benzene | 71-43-2 | | 2.5e-011 | | | 5.2e-014 | 5.1e-014 | | | | | 2.5e-011 |
| Chloromethane | 74-87-3 | | 1.5e-011 | | | 4.0e-015 | 3.9e-015 | | | | | 1.5e-011 |
| Methylene Chloride | 75-09-2 | 3.6e-011 | | 4.6e-008 | 2.3e-007 | | | 7.6e-014 | 8.5e-013 | 5.5e-009 | 1.7e-008 | 3.0e-007 |
| 1,1-Dichloroethane | 75-34-3 | | | | 2.8e-006 | | | 2.9e-012 | 3.2e-011 | 6.6e-008 | | 2.9e-006 |
| Trichlorothene | 79-01-6 | 1.0e-011 | 1.9e-011 | 3.1e-005 | 2.2e-005 | 7.6e-014 | 7.4e-014 | 8.6e-011 | 9.6e-010 | 5.1e-007 | 4.9e-009 | 5.4e-005 |
| 1,2-Dichloroethane | 107-06-2 | | 2.1e-011 | 9.7e-006 | 1.1e-005 | 1.7e-014 | 1.7e-014 | 5.3e-012 | 5.9e-011 | 2.5e-007 | | 2.1e-005 |
| Bis(2-Ethylhexyl)Phtalate | 117-81-7 | | | | 9.6e-007 | | | 2.0e-009 | 2.3e-008 | 2.2e-008 | | 1.0e-006 |
| Tetrachloroethene | 127-18-4 | | 5.4e-012 | 5.1e-008 | 1.6e-006 | 2.1e-011 | 2.0e-011 | 1.0e-011 | 1.2e-010 | 3.7e-008 | | 1.7e-006 |
| PATHWAY TOTAL | | 5.8e-011 | 1.4e-010 | 1.1e-004 | 8.3e-005 | 2.1e-011 | 2.0e-011 | 2.4e-009 | 2.8e-008 | 1.9e-006 | 2.8e-008 | 1.9e-004 |

Footnotes:
(1) = [illegible]
(2) = [illegible] of the Emergency Waste Basin

## Table 6I.40.

CHEMICAL NONCARCINOGENIC HAZARD INDEX FOR THE ADULT OFF WAG HOMESTEADER
Exposure Interval = 1990 - 2019, 2100 - 2129(1)

| Effect | Chemical | CAS No. | PATHWAYS: Incidental Ingestion Soil | Ingestion of Drinking Water (surface water) | Ingestion of Fruit | Ingestion of Vegetables | Ingestion of Beef | Ingestion of Milk | Ingestion of Fish | Dermal Contact w/ Surfacewater Swimming | Dermal Contact w/ Surfacewater Showering | Dermal Contact with Soil | CHEMICAL TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Liver | Chloroform | 67-66-3 | 3.2e-010 | 1.5e-004 | 3.8e-007 | 7.3e-007 | 5.4e-010 | 1.4e-009 | 7.6e-005 | 7.4e-006 | 4.6e-006 | 1.6e-008 | 2.4e-004 |
| | Tetrachloroethene | 127-18-4 | 8.7e-009 | 1.5e-004 | 4.5e-006 | 8.5e-006 | 2.3e-009 | 5.8e-009 | 2.3e-004 | 7.4e-006 | 4.6e-006 | 4.4e-007 | 4.1e-004 |
| | Total | | 9.0e-009 | 3.0e-004 | 4.9e-006 | 9.2e-006 | 2.8e-009 | 7.2e-009 | 3.1e-004 | 1.5e-005 | 9.2e-006 | 4.6e-007 | 6.4e-004 |
| Kidney(2) | Acetone | 67-64-1 | 4.0e-010 | 3.0e-004 | 9.0e-006 | 1.7e-005 | 6.6e-012 | 1.7e-011 | 3.2e-006 | 1.5e-005 | 9.3e-006 | 2.0e-008 | 3.5e-004 |
| Fetotoxicity(2) | Carbon disulfide | 75-15-0 | 7.4e-010 | 1.4e-003 | 8.4e-007 | 1.6e-006 | 5.4e-009 | 1.4e-008 | 7.5e-004 | 7.0e-005 | 4.4e-005 | 3.8e-008 | 2.3e-003 |
| Skin(2) | Silver | 7440-22-4 | 1.7e-007 | 2.7e-003 | 1.1e-005 | 2.0e-005 | 4.1e-006 | 8.2e-004 | 1.7e-004 | 1.3e-004 | 8.4e-005 | 3.4e-007 | 3.9e-003 |
| | PATHWAY TOTAL | | 1.8e-007 | 4.7e-003 | 2.6e-005 | 4.8e-005 | 4.1e-006 | 8.2e-004 | 1.2e-003 | 2.3e-004 | 1.5e-004 | 8.5e-007 | 7.2e-003 |

Footnotes:
(1) = Steady state conditions assumed
(2) = For effects which have only one chemical contributing to them a separate total row was not included (i.e., the noncarcinogenic hazard indices for that chemical is the total)

## Table 6I.41.

CHEMICAL NONCARCINOGENIC HAZARD INDEX FOR THE CHILD OFF WAG HOMESTEADER
Exposure Interval = 1990 - 2019, 2100 - 2129(1)

| | | | PATHWAYS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Effect | Chemical | CAS No. | Incidental Ingestion Soil | Ingestion of Drinking Water (surface water) | Ingestion of Fruit | Ingestion of Vegetables | Ingestion of Beef | Ingestion of Milk | Ingestion of Fish | Dermal Contact w/ Surfacewater Swimming | Dermal Contact w/ Surfacewater Showering | Dermal Contact with Soil | CHEMICAL TOTAL |
| Liver | Chloroform | 67-66-3 | 2.8e-009 | 3.3e-004 | 1.8e-006 | 1.7e-006 | 5.1e-010 | 5.7e-009 | 3.5e-005 | 1.2e-005 | 7.8e-006 | 2.2e-007 | 3.9e-004 |
| | Tetrachloroethene | 127-18-4 | 7.6e-008 | 3.3e-004 | 2.1e-005 | 2.0e-005 | 2.2e-009 | 2.4e-008 | 1.1e-004 | 1.2e-005 | 7.8e-006 | 6.0e-006 | 5.1e-004 |
| | Total | | 7.9e-008 | 6.6e-004 | 2.3e-005 | 2.2e-005 | 2.7e-009 | 3.0e-008 | 1.5e-004 | 2.4e-005 | 1.6e-005 | 6.2e-006 | 9.0e-004 |
| Kidney(2) | Acetone | 67-64-1 | 3.5e-009 | 6.7e-004 | 4.1e-005 | 4.0e-005 | 6.3e-012 | 7.0e-011 | 1.5e-006 | 2.5e-005 | 1.6e-005 | 2.8e-007 | 7.9e-004 |
| Fetotoxicity(2) | Carbon disulfide | 75-15-0 | 6.5e-009 | 3.1e-003 | 3.9e-006 | 3.8e-006 | 5.1e-009 | 5.7e-008 | 3.5e-004 | 1.2e-004 | 7.3e-005 | 5.1e-007 | 3.7e-003 |
| Skin(2) | Silver | 7440-22-4 | 1.5e-006 | 6.0e-003 | 4.8e-005 | 4.7e-005 | 3.9e-006 | 3.4e-003 | 7.9e-005 | 2.2e-004 | 1.4e-004 | 4.6e-006 | 9.9e-003 |
| | PATHWAY TOTAL | | 1.6e-006 | 1.0e-002 | 1.2e-004 | 1.1e-004 | 3.9e-006 | 3.4e-003 | 5.8e-004 | 3.9e-004 | 2.4e-004 | 1.2e-005 | 1.5e-002 |

Footnotes:
(1) = Steady state conditions assumed
(2) = For effects which have only one chemical contributing to them a separate total row was not included (i.e., the noncarcinogenic hazard indices for that chemical is the total)

## Table 6I.42.

EXCESS LIFETIME CHEMICAL CARCINOGENIC RISK FOR THE ADULT OFF WAG HOMESTEADER
Exposure Interval = 1990 - 2019, 2100 - 2129(1)

| | | PATHWAYS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chemical | CAS No. | Incidental Ingestion Soil | Ingestion of Drinking Water (surface water) | Ingestion of Fruit | Ingestion of Vegetables | Ingestion of Beef | Ingestion of Milk | Ingestion of Fish | Dermal Contact w/ Surfacewater Swimming | Dermal Contact w/ Surfacewater Showering | Dermal Contact with Soil | CHEMICAL TOTAL |
| Chloroform | 67-66-3 | 8.4e-015 | 4.0e-009 | 1.0e-011 | 1.9e-011 | 1.4e-014 | 3.5e-014 | 2.0e-009 | 1.9e-010 | 1.2e-010 | 4.3e-013 | 6.3e-009 |
| Trichloroethene | 79-01-6 | 3.9e-013 | 7.2e-009 | 2.7e-010 | 5.1e-010 | 6.5e-014 | 1.6e-013 | 7.3e-009 | 3.5e-010 | 2.2e-010 | 2.0e-011 | 1.6e-008 |
| Tetrachloroethene | 127-18-4 | 1.9e-012 | 3.3e-008 | 9.7e-010 | 1.9e-009 | 5.0e-013 | 1.3e-012 | 5.0e-008 | 1.6e-009 | 1.0e-009 | 9.7e-011 | 8.9e-008 |
| PATHWAY TOTAL | | 2.3e-012 | 4.4e-008 | 1.3e-009 | 2.4e-009 | 5.8e-013 | 1.5e-012 | 5.9e-008 | 2.1e-009 | 1.3e-009 | 1.2e-010 | 1.1e-007 |

Footnotes:
(1) = Steady state conditions assumed

Table 6I.43.

EXCESS LIFETIME CHEMICAL CARCINOGENIC RISK FOR THE CHILD OFF WAG HOMESTEADER
Exposure Interval = 1990 - 2019, 2100 - 2129(1)

| | | PATHWAYS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chemical | CAS No. | Incidental Ingestion Soil | Ingestion of Drinking Water (surface water) | Ingestion of Fruit | Ingestion of Vegetables | Ingestion of Beef | Ingestion of Milk | Ingestion of Fish | Dermal Contact w/ Surfacewater Swimming | Dermal Contact w/ Surfacewater Showering | Dermal Contact with Soil | CHEMICAL TOTAL |
| Chloroform | 67-66-3 | 1.7e-014 | 2.0e-009 | 1.1e-011 | 1.0e-011 | 3.1e-015 | 3.5e-014 | 5.4e-009 | 7.6e-011 | 4.7e-011 | 1.4e-012 | 7.5e-009 |
| Trichloroethene | 79-01-6 | 8.0e-013 | 3.7e-009 | 2.9e-010 | 2.8e-010 | 1.4e-014 | 1.6e-013 | 8.0e-010 | 1.4e-010 | 8.6e-011 | 6.3e-011 | 5.4e-009 |
| Tetrachloroethene | 127-18-4 | 3.9e-012 | 1.7e-008 | 1.0e-009 | 1.0e-009 | 1.1e-013 | 1.2e-012 | 2.2e-010 | 6.4e-010 | 4.0e-010 | 3.1e-010 | 2.1e-008 |
| PATHWAY TOTAL | | 4.7e-012 | 2.3e-008 | 1.3e-009 | 1.3e-009 | 1.3e-013 | 1.4e-012 | 6.4e-009 | 8.6e-010 | 5.3e-010 | 3.7e-010 | 3.3e-008 |

Footnotes:
(1) = Steady state conditions assumed

Table 61.44

CHEMICAL INHALATION NONCARCINOGENIC HAZARD INDEX FOR THE ON-WAG
EMPLOYEE
Exposure Interval = 1990 - 2019, 2100 - 2129(1)

| Effect | Chemical | CAS No. | PATHWAYS<br>Inhalation of Vapor Phase |
|---|---|---|---|
| Neurotoxicity | Toluene | 108-88-3 | 1.1e-009 |
| | Xylenes(total) | 1330-20-7 | 1.4e-008 |
| | Total | | 1.5e-008 |
| Fetotoxicity(1) | Ethyl benzene | 100-41-4 | 1.7e-009 |
| | PATHWAY TOTAL | | 1.7e-008 |

Footnotes:

(1) = For effects which have only one chemical contributing to them a separate total row was not included (i.e., the noncarcinogenic hazard indices for that chemical is not included)

**Table 6I.45**

EXCESS LIFETIME CHEMICAL CARCINOGENIC RISK FOR THE ON-WAG EMPLOYEE
Exposure Interval = 1990-2019

| Chemical | CAS No. | PATHWAY<br>Inhalation of Vapor Phase |
|---|---|---|
| Chloroform | 67-66-3 | 1.5e-011 |
| Benzene | 71-43-2 | 7.2e-012 |
| Chloromethane | 74-87-3 | 4.3e-012 |
| Trichlorothene | 79-01-6 | 5.6e-012 |
| 1,2-Dichloroethane | 107-06-2 | 6.0e-012 |
| Tetrachloroethene | 127-18-4 | 1.6e-012 |
| PATHWAY TOTAL | | 4.0e-011 |

Table 6I.46

CHEMICAL NONCARCINOGENIC HAZARD INDEX FOR THE HUNTER
Exposure Interval = 1990-2019

| Effect | Chemical | CAS No. | PATHWAY<br>Ingestion of Deer |
|---|---|---|---|
| Liver | Chloroform | 67-66-3 | 2.3e-009 |
| | Tetrachloroethene | 127-18-4 | 9.6e-009 |
| | Total | | 1.2e-008 |
| Kidney(1) | Acetone | 67-64-1 | 2.8e-012 |
| Fetotoxicity(1) | Carbon disulfide | 75-15-0 | 2.4e-010 |
| Skin(1) | Silver | 7440-22-4 | 1.7e-005 |
| | PATHWAY TOTAL | | 1.7e-005 |

Footnotes:

(1) = For effects which have only one chemical contributing to them a separate total row was not included (i.e., the noncarcinogenic hazard indices for that chemical is not included)

Table 6I.47

EXCESS LIFETIME CHEMICAL CARCINOGENIC RISK FOR THE HUNTER
Exposure Interval = 1990-2019

| Chemical | CAS No. | PATHWAY<br>Ingestion of Deer |
|---|---|---|
| Chloroform | 67-66-3 | 5.9e-014 |
| Trichloroethene | 79-01-6 | 2.7e-013 |
| Tetrachloroethene | 127-18-4 | 2.1e-012 |
| PATHWAY TOTAL | | 2.4e-012 |

Table 6I.48

CHEMICAL NONCARCINOGENIC HAZARD INDEX FOR THE BOUNDARY RECEPTOR
xposure Interval = 1990-2019

| Effect | Chemical | CAS No. | PATHWAY<br>Inhalation of Vapor Phase |
|---|---|---|---|
| Neurotoxicity | Toluene | 108-88-3 | 2.2e-009 |
| | Xylenes(total) | 1330-20-7 | 3.0e-008 |
| | Total | | 3.2e-008 |
| Fetotoxicity(1) | Ethyl benzene | 100-41-4 | 3.6e-009 |
| | PATHWAY TOTAL | | 3.6e-008 |

Footnotes:

(1) = For effects which have only one chemical contributing to them a separate total row was not included (i.e., the noncarcinogenic hazard indices for that chemical is not included)

Table 61.49

EXCESS LIFETIME CHEMICAL CARCINOGENIC RISK FOR THE BOUNDARY RECEPTOR

Exposure Interval = 1990-2019

| Chemical | CAS No. | PATHWAY<br>Inhalation Vapor Phase |
|---|---|---|
| Chloroform | 67-66-3 | 7.1e-011 |
| Benzene | 71-43-2 | 3.5e-011 |
| Chloromethane | 74-87-3 | 2.1e-011 |
| Trichlorothene | 79-01-6 | 2.7e-011 |
| 1,2-Dichloroethane | 107-06-2 | 2.9e-011 |
| Tetrachloroethene | 127-18-4 | 7.7e-012 |
| PATHWAY TOTAL | | 1.9e-010 |

Table 6I.50.

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 from the incidental ingestion of soil

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Soil (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Benzyl alcohol | 100-51-6 | 4.2e-001 | | | | | 6.0e-007 | 3.0e-001 | digestive | 2.0e-006 |
| Methylene Chloride | 75-09-2 | 3.3e-002 | 2.0e-008 | B2 | 7.5e-003 | 1.5e-010 | 4.7e-008 | 6.0e-002 | liver | 7.9e-007 |
| Acetone | 67-64-1 | 1.5e-002 | | | | | 2.1e-008 | 1.0e-001 | kidney | 2.1e-007 |
| Ethyl benzene | 100-41-4 | 6.0e-003 | | | | | 8.6e-009 | 1.0e-001 | kidney/liver | 8.6e-008 |
| Toluene | 108-88-3 | 6.0e-003 | | | | | 8.6e-009 | 2.0e-001 | liver/kidney | 4.3e-008 |
| Xylenes(total) | 1330-20-7 | 6.0e-003 | | | | | 8.6e-009 | 2.0e+000 | neurotx/mort | 4.3e-009 |
| Trichloroethene | 79-01-6 | 6.0e-003 | 3.7e-009 | B2 | 1.1e-002 | 4.0e-011 | | | | |
| Vanadium | 7440-62-2 | 2.2e+001 | | | | | 3.1e-005 | 7.0e-003 | kidney | 4.5e-003 |
| Thallium | 7440-28-0 | 5.0e-001 | | | | | 7.1e-007 | 7.0e-005 | skin | 1.0e-002 |
| Sum Of Risks | | | | | | 1.9e-010 | | | | |
| Hazard Index | | | | | | | | | | 1.5e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Ingestion Rate (mg/d) | 100 |
| Conversion Factor (kg/mg) | 1.0e-006 |
| Fraction Ingested (unitless) | 1 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.51.

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 from the incidental ingestion of sediment while swimming at the EWB

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Sediment (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| 2-Butanone | 78-93-3 | 1.4e-001 | | | | | 2.5e-008 | 5.0e-002 | fetotoxicity | 4.9e-007 |
| Trichlorofluoromethane | 75-69-4 | 7.2e-002 | | | | | 1.3e-008 | 3.0e-001 | resp/cardiova | 4.2e-008 |
| Methylene Chloride | 75-09-2 | 3.1e-002 | 2.3e-009 | B2 | 7.5e-003 | 1.8e-011 | 5.5e-009 | 6.0e-002 | liver | 9.1e-008 |
| Acetone | 67-64-1 | 1.3e-002 | | | | | 2.3e-009 | 1.0e-001 | kidney | 2.3e-008 |
| Chloroform | 67-66-3 | 1.3e-002 | 9.8e-010 | B2 | 6.1e-003 | 6.0e-012 | 2.3e-009 | 1.0e-002 | liver | 2.3e-007 |
| Trichloroethene | 79-01-6 | 6.0e-003 | 4.5e-010 | B2 | 1.1e-002 | 5.0e-012 | | | | |
| Toluene | 108-88-3 | 6.0e-003 | | | | | 1.1e-009 | 2.0e-001 | liver/kidney | 5.3e-009 |
| Silver | 7440-22-4 | 2.5e+000 | | | | | 4.4e-007 | 3.0e-003 | skin | 1.5e-004 |
| Sum Of Risks | | | | | | 2.9e-011 | | | | |
| Hazard Index | | | | | | | | | | 1.5e-004 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Ingestion Rate (mg/d) | 100 |
| Conversion Factor (kg/mg) | 1.0e-006 |
| Fraction Ingested | 1 |
| Exposure Frequency (d/y) | 45 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.52.

Excess Lifetime Cancer Risk and Hazard Index for an adult homesteader on WAG 6 from the inhalation of vapors

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Air (mg/m^3) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Target Organ | Hazard Quotient |
| Tetrachloroethene | 127-18-4 | 3.3e-008 | 6.1e-009 | B2 | 1.8e-003 | 1.1e-011 | | | | |
| Chloromethane | 74-87-3 | 2.6e-008 | 4.8e-009 | C | 6.3e-003 | 3.0e-011 | | | | |
| *Xylenes(total) | 1330-20-7 | 2.4e-008 | | | | | 1.0e-008 | 1.0e-001 | neurotoxicity | 1.0e-007 |
| Trichloroethene | 79-01-6 | 1.3e-008 | 2.3e-009 | B2 | 1.7e-002 | 3.9e-011 | | | | |
| Toluene | 108-88-3 | 1.0e-008 | | | | | 4.4e-009 | 6.0e-001 | neurotoxicity | 7.4e-009 |
| Benzene | 71-43-2 | 9.5e-009 | 1.7e-009 | A | 2.9e-002 | 5.1e-011 | | | | |
| Ethyl benzene | 100-41-4 | 8.5e-009 | | | | | 3.7e-009 | 3.0e-001 | fetotoxicity | 1.2e-008 |
| Chloroform | 67-66-3 | 6.8e-009 | 1.3e-009 | B2 | 8.1e-002 | 1.0e-010 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 2.5e-009 | 4.6e-010 | B2 | 9.1e-002 | 4.2e-011 | | | | |
| Sum Of Risks | | | | | | 2.7e-010 | | | | |
| Hazard Index | | | | | | | | | | 1.2e-007 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Inhalation Rate (m^3/h) | 1.25 |
| Exposure Time (h/d) | 24 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.53.

Excess lifetime cancer risk and hazard index for and adult homesteader on WAG 6 from the inhalation of chemicals while showering with groundwater

| Analyte Name | CAS Number | Concentration in Groundwater (mg/L) | CARCINOGENS Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | NONCARCINOGENS Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| Chloroethane | 75-00-3 | 1.0e-002 | | | | | 1.3e-004 | 3.0e-001 | fetotoxicity | 4.3e-004 |
| Vinyl chloride | 75-01-4 | 1.0e-002 | 5.5e-005 | A | 2.9e-001 | 1.6e-005 | | | | |
| 2-Butanone | 78-93-3 | 1.0e-002 | | | | | 1.3e-004 | 1.0e-001 | neurotoxicity | 1.3e-003 |
| Methylene Chloride | 75-09-2 | 5.0e-003 | 2.8e-005 | B2 | 1.6e-003 | 4.5e-008 | 6.4e-005 | 9.0e-001 | liver | 7.1e-005 |
| Tetrachloroethene | 127-18-4 | 5.0e-003 | 2.8e-005 | B2 | 1.8e-003 | 5.0e-008 | | | | |
| Trichloroethene | 79-01-6 | 5.0e-003 | 2.8e-005 | B2 | 1.7e-002 | 4.7e-007 | | | | |
| Toluene | 108-88-3 | 5.0e-003 | | | | | 6.4e-005 | 6.0e-001 | neurotoxicity | 1.1e-004 |
| Ethyl benzene | 100-41-4 | 5.0e-003 | | | | | 6.4e-005 | 3.0e-001 | fetotoxicity | 2.1e-004 |
| 1,1-Dichloroethane | 75-34-3 | 5.0e-003 | | | | | 6.4e-005 | 1.0e-001 | kidney | 6.4e-004 |
| 1,1,1-Trichloroethane | 71-55-6 | 5.0e-003 | | | | | 6.4e-005 | 3.0e-001 | liver | 2.1e-004 |
| Benzene | 71-43-2 | 5.0e-003 | 2.8e-005 | A | 2.9e-002 | 8.0e-007 | | | | |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | 5.0e-003 | 2.8e-005 | C | 2.0e-001 | 5.5e-006 | | | | |
| Xylenes(total) | 1330-20-7 | 5.0e-003 | | | | | 6.4e-005 | 1.0e-001 | neurotoxicity | 6.4e-004 |
| 1,1-Dichloroethene | 75-35-4 | 5.0e-003 | 2.8e-005 | C | 1.2e+000 | 3.3e-005 | | | | |
| Carbon tetrachloride | 56 23 5 | 5.0e-003 | 2.8e-005 | B2 | 1.3e-001 | 3.6e-006 | | | | |
| 1,1,2-Trichloroethane | 79 00 5 | 5.0e-003 | 2.8e-005 | C | 5.7e-002 | 1.6e-006 | | | | |
| Chloroform | 67 66 3 | 5.0e-003 | 2.8e-005 | B2 | 8.1e-002 | 2.2e-006 | | | | |
| 1,2-Dichloroethane | 107 06 2 | 5.0e-003 | 2.8e-005 | B2 | 9.1e-002 | 2.5e-006 | | | | |
| Sum Of Risks | | | | | | 6.6e-005 | | | | |
| Hazard Index | | | | | | | | | | 3.6e-003 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Shower Water Consumption (L) | 180 |
| Volatilization Fraction (unitless) | 0.5 |
| Shower area Capacity (m^3) | 12 |
| Inhalation Rate (m^3/h) | 0.6 |
| Exposure Time (h/d) | 0.2 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |

| Averaging Time (d) | |
|---|---|
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 61.54.

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 from the ingestion of groundwater as drinking water

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Groundwater (mg/L) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| 2-Methylphenol | 95-48-7 | 1.1e-002 | | | | | 3.1e-004 | 5.0e-002 | neurotoxicity | 6.3e-003 |
| Diethylphatalate | 84-66-2 | 1.1e-002 | | | | | 3.1e-004 | 8.0e-001 | liver/kidney | 3.9e-004 |
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 1.1e-002 | 1.3e-004 | B2 | 1.4e-002 | 1.9e-006 | 3.1e-004 | 2.0e-002 | liver/kidney | 1.6e-002 |
| Naphthalene | 91-20-3 | 1.1e-002 | | | | | 3.1e-004 | 4.0e-003 | kidney | 7.9e-002 |
| Di-n-butylphatalate | 84-74-2 | 1.0e-002 | | | | | 2.9e-004 | 1.0e-001 | liver/kidney | 2.9e-003 |
| 2-Butanone | 78-93-3 | 1.0e-002 | | | | | 2.9e-004 | 5.0e-002 | fetotoxicity | 5.7e-003 |
| Vinyl chloride | 75-01-4 | 1.0e-002 | 1.2e-004 | A | 1.9e+000 | 2.3e-004 | | | | |
| Acetone | 67-64-1 | 1.0e-002 | | | | | 2.9e-004 | 1.0e-001 | kidney | 2.9e-003 |
| Toluene | 108-88-3 | 5.0e-003 | | | | | 1.4e-004 | 2.0e-001 | liver/kidney | 7.1e-004 |
| Xylenes(total) | 1330-20-7 | 5.0e-003 | | | | | 1.4e-004 | 2.0e+000 | neurotx/mort | 7.1e-005 |
| 1,1,1-Trichloroethane | 71-55-6 | 5.0e-003 | | | | | 1.4e-004 | 9.0e-002 | liver | 1.6e-003 |
| Carbon disulfide | 75-15-0 | 5.0e-003 | | | | | 1.4e-004 | 1.0e-001 | fetotoxicity | 1.4e-003 |
| Ethyl benzene | 100-41-4 | 5.0e-003 | | | | | 1.4e-004 | 1.0e-001 | kidney/liver | 1.4e-003 |
| 1,1-Dichloroethane | 75-34-3 | 5.0e-003 | 6.1e-005 | B2 | 9.1e-002 | 5.6e-006 | 1.4e-004 | 1.0e-001 | kidney | 1.4e-003 |
| 1,2-Dichloroethane | 107-06-2 | 5.0e-003 | 6.1e-005 | B2 | 9.1e-002 | 5.6e-006 | | | | |
| Carbon tetrachloride | 56-23-5 | 5.0e-003 | 6.1e-005 | B2 | 1.3e-001 | 8.0e-006 | 1.4e-004 | 7.0e-004 | liver | 2.0e-001 |
| 1,1-Dichloroethene | 75-35-4 | 5.0e-003 | 6.1e-005 | C | 6.0e-001 | 3.7e-005 | 1.4e-004 | 9.0e-003 | liver | 1.6e-002 |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | 5.0e-003 | 6.1e-005 | C | 2.0e-001 | 1.2e-005 | | | | |
| 1,1,2-Trichloroethane | 79-00-5 | 5.0e-003 | 6.1e-005 | C | 5.7e-002 | 3.5e-006 | 1.4e-004 | 4.0e-003 | immu/liv/hema | 3.6e-002 |
| Methylene Chloride | 75-09-2 | 5.0e-003 | 6.1e-005 | B2 | 7.5e-003 | 4.6e-007 | 1.4e-004 | 6.0e-002 | liver | 2.4e-003 |
| Chloroform | 67-66-3 | 5.0e-003 | 6.1e-005 | B2 | 6.1e-003 | 3.7e-007 | 1.4e-004 | 1.0e-002 | liver | 1.4e-002 |
| Trichloroethene | 79-01-6 | 5.0e-003 | 6.1e-005 | B2 | 1.1e-002 | 6.7e-007 | | | | |
| Tetrachloroethene | 127-18-4 | 5.0e-003 | 6.1e-005 | B2 | 5.1e-002 | 3.1e-006 | 1.4e-004 | 1.0e-002 | liver | 1.4e-002 |
| Benzene | 71-43-2 | 5.0e-003 | 6.1e-005 | A | 2.9e-002 | 1.8e-006 | | | | |
| 2,4-D | 94-75-7 | 2.0e-004 | | | | | 5.7e-006 | 1.0e-002 | Hemato/kidney | 5.7e-004 |
| 2,4,5-TP | 93-72-1 | 1.0e-004 | | | | | 2.9e-006 | 8.0e-003 | liver | 3.6e-004 |
| 2,4,5-T | 93-76-5 | 1.0e-004 | | | | | 2.9e-006 | 1.0e-002 | fetotox/kidney | 2.9e-004 |
| Chromium | 7440-47-3 | 2.0e-002 | | | | | 5.7e-004 | 5.0e-003 | neurotoxicity | 1.1e-001 |
| Nickel | 7440-02-0 | 2.0e-002 | | | | | 5.7e-004 | 2.0e-002 | kidney | 2.9e-002 |
| Vanadium | 7440-62-2 | 1.1e-002 | | | | | 3.1e-004 | 7.0e-003 | kidney | 4.5e-002 |
| Silver | 7440-22-4 | 5.0e-003 | | | | | 1.4e-004 | 3.0e-003 | skin | 4.8e-002 |
| Cadmium | 7440-43-9 | 2.0e-003 | | | | | 5.7e-005 | 5.0e-004 | kidney | 1.1e-001 |
| Mercury | 7439-97-6 | 2.0e-004 | | | | | 5.7e-006 | 3.0e-004 | kidney | 1.9e-002 |
| Sum Of Risks | | | | | | 3.1e-004 | | | | |
| Hazard Index | | | | | | | | | | 7.8e-001 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Ingestion Rate (L/d) | 2 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |

| Averaging Time (d) | |
|---|---|
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.55.

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 from the ingestion of fruit

| Analyte Name | CAS Number | Concentration in Fruit (mg/kg) | CARCINOGENS Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | NONCARCINOGENS Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| Benzyl alcohol | 100-51-6 | 3.8e+000 | | | | | 2.3e-003 | 3.0e-001 | digestive | 7.6e-003 |
| Acetone | 67-64-1 | 8.0e-001 | | | | | 4.8e-004 | 1.0e-001 | kidney | 4.8e-003 |
| Methylene Chloride | 75-09-2 | 2.3e-001 | 5.8e-005 | B2 | 7.5e-003 | 4.4e-007 | 1.4e-004 | 6.0e-002 | liver | 2.3e-003 |
| Trichloroethene | 79-01-6 | 9.8e-003 | 2.5e-006 | B2 | 1.1e-002 | 2.8e-008 | | | | |
| Toluene | 108-88-3 | 6.5e-003 | | | | | 3.9e-006 | 2.0e-001 | liver/kidney | 1.9e-005 |
| Ethyl benzene | 100-41-4 | 3.5e-003 | | | | | 2.1e-006 | 1.0e-001 | kidney/liver | 2.1e-005 |
| Xylenes(total) | 1330-20-7 | 3.0e-003 | | | | | 1.8e-006 | 2.0e+000 | neurotx/mort | 9.1e-007 |
| Tetrachloroethene | 127-18-4 | 1.5e-006 | 3.8e-010 | B2 | 5.1e-002 | 1.9e-011 | 8.9e-010 | 1.0e-002 | liver | 8.9e-008 |
| Carbon disulfide | 75-15-0 | 1.5e-008 | | | | | 9.1e-012 | 1.0e-001 | fetotoxicity | 9.1e-011 |
| Benzene | 71-43-2 | 6.5e-009 | 1.7e-012 | A | 2.9e-002 | 4.8e-014 | | | | |
| Chloroform | 67-66-3 | 1.5e-009 | 3.9e-013 | B2 | 6.1e-003 | 2.4e-015 | 9.1e-013 | 1.0e-002 | liver | 9.1e-011 |
| Chloromethane | 74-87-3 | 1.1e-009 | 2.9e-013 | C | 1.3e-002 | 3.7e-015 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 6.9e-010 | 1.8e-013 | B2 | 9.1e-002 | 1.6e-014 | | | | |
| Sum Of Risks | | | | | | 4.6e-007 | | | | |
| Hazard Index | | | | | | | | | | 1.5e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/yr) | 51.1 |
| Fraction Ingested (unitless) | 0.3 |
| Exposure Duration (years) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.56.

Excess Lifetime Cancer Risk and Hazard Index for an adult homesteader on WAG 6 from the ingestion of Vegetables

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Vegetables (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Benzyl alcohol | 100-51-6 | 3.8e+000 | | | | | 4.3e-003 | 3.0e-001 | digestive | 1.4e-002 |
| Acetone | 67-64-1 | 8.0e-001 | | | | | 9.1e-004 | 1.0e-001 | kidney | 9.1e-003 |
| Methylene Chloride | 75-09-2 | 2.3e-001 | 1.1e-004 | B2 | 7.5e-003 | 8.3e-007 | 2.6e-004 | 6.0e-002 | liver | 4.3e-003 |
| Trichloroethene | 79-01-6 | 9.8e-003 | 4.8e-006 | B2 | 1.1e-002 | 5.3e-008 | | | | |
| Toluene | 108-88-3 | 6.5e-003 | | | | | 7.4e-006 | 2.0e-001 | liver/kidney | 3.7e-005 |
| Ethyl benzene | 100-41-4 | 3.5e-003 | | | | | 4.0e-006 | 1.0e-001 | kidney/liver | 4.0e-005 |
| Xylenes(total) | 1330-20-7 | 3.0e-003 | | | | | 3.5e-006 | 2.0e+000 | neurotx/mort | 1.7e-006 |
| Tetrachloroethene | 127-18-4 | 1.5e-006 | 7.3e-010 | B2 | 5.1e-002 | 3.7e-011 | 1.7e-009 | 1.0e-002 | liver | 1.7e-007 |
| Carbon disulfide | 75-15-0 | 1.5e-008 | | | | | 1.7e-011 | 1.0e-001 | fetotoxicity | 1.7e-010 |
| Benzene | 71-43-2 | 6.5e-009 | 3.2e-012 | A | 2.9e-002 | 9.2e-014 | | | | |
| Chloroform | 67-66-3 | 1.5e-009 | 7.4e-013 | B2 | 6.1e-003 | 4.5e-015 | 1.7e-012 | 1.0e-002 | liver | 1.7e-010 |
| Chloromethane | 74-87-3 | 1.1e-009 | 5.5e-013 | C | 1.3e-002 | 7.1e-015 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 6.9e-010 | 3.4e-013 | B2 | 9.1e-002 | 3.1e-014 | | | | |
| Sum Of Risks | | | | | | 8.8e-007 | | | | |
| Hazard Index | | | | | | | | | | 2.8e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 73 |
| Fraction Ingested (unitless) | 0.4 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

**Table 6I.57.**

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 from the ingestion of beef

| Analyte Name | CAS Number | Concentration in Beef (mg/kg) | CARCINOGENS Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | NONCARCINOGENS Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 1.4e-003 | 6.5e-007 | B2 | 1.4e-002 | 9.2e-009 | 1.5e-006 | 2.0e-002 | liver/kidney | 7.6e-005 |
| Di-n-butylphatalate | 84-74-2 | 5.2e-004 | | | | | 5.6e-007 | 1.0e-001 | liver/kidney | 5.6e-006 |
| Naphthalene | 91-20-3 | 2.2e-005 | | | | | 2.4e-008 | 4.0e-003 | kidney | 5.9e-006 |
| Xylenes(total) | 1330-20-7 | 9.1e-006 | | | | | 9.8e-009 | 2.0e+000 | neurotx/mort | 4.9e-009 |
| Ethyl benzene | 100-41-4 | 7.1e-006 | | | | | 7.6e-009 | 1.0e-001 | kidney/liver | 7.6e-008 |
| Diethylphatalate | 84-66-2 | 3.3e-006 | | | | | 3.5e-009 | 8.0e-001 | liver/kidney | 4.4e-009 |
| Toluene | 108-88-3 | 2.7e-006 | | | | | 2.9e-009 | 2.0e-001 | liver/kidney | 1.4e-008 |
| Carbon tetrachloride | 56-23-5 | 2.2e-006 | 1.0e-009 | B2 | 1.3e-001 | 1.3e-010 | 2.3e-009 | 7.0e-004 | liver | 3.4e-006 |
| Tetrachloroethene | 127-18-4 | 2.0e-006 | 9.2e-010 | B2 | 5.1e-002 | 4.7e-011 | 2.1e-009 | 1.0e-002 | liver | 2.1e-007 |
| 1,1,1-Trichloroethane | 71-55-6 | 1.6e-006 | | | | | 1.7e-009 | 9.0e-002 | liver | 1.8e-008 |
| 1,1,2-Trichloroethane | 79-00-5 | 1.5e-006 | 6.8e-010 | C | 5.7e-002 | 3.9e-011 | 1.6e-009 | 4.0e-003 | immu/liv/hema | [illegible].0e-007 |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | 1.2e-006 | 5.7e-010 | C | 2.0e-001 | 1.1e-010 | | | | |
| Trichloroethene | 79-01-6 | 1.2e-006 | 5.5e-010 | B2 | 1.1e-002 | 6.1e-012 | | | | |
| 2,4,5-TP | 93-72-1 | 1.0e-006 | | | | | 1.1e-009 | 8.0e-003 | liver | 1.3e-007 |
| 2-Methylphenol | 95-48-7 | 9.9e-007 | | | | | 1.1e-009 | 5.0e-002 | neurotoxicity | 2.1e-008 |
| Benzene | 71-43-2 | 6.6e-007 | 3.0e-010 | A | 2.9e-002 | 8.8e-012 | | | | |
| Carbon disulfide | 75-15-0 | 5.0e-007 | | | | | 5.4e-010 | 1.0e-001 | fetotoxicity | 5.4e-009 |
| Chloroform | 67-66-3 | 4.7e-007 | 2.2e-010 | B2 | 6.1e-003 | 1.3e-012 | 5.0e-010 | 1.0e-002 | liver | 5.0e-008 |
| 1,1-Dichloroethene | 75-35-4 | 3.5e-007 | 1.6e-010 | C | 6.0e-001 | 9.6e-011 | 3.7e-010 | 9.0e-003 | liver | 4.1e-008 |
| 1,1-Dichloroethane | 75-34-3 | 3.1e-007 | 1.4e-010 | B2 | 9.1e-002 | 1.3e-011 | 3.3e-010 | 1.0e-001 | kidney | 3.3e-009 |
| Vinyl chloride | 75-01-4 | 2.4e-007 | 1.1e-010 | A | 1.9e+000 | 2.1e-010 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 1.5e-007 | 7.0e-011 | B2 | 9.1e-002 | 6.3e-012 | | | | |
| 2,4,5-T | 93-76-5 | 1.4e-007 | | | | | 1.5e-010 | 1.0e-002 | fetotx/kidney | 1.5e-008 |
| 2,4-D | 94-75-7 | 1.3e-007 | | | | | 1.4e-010 | 1.0e-002 | Hemato/kidney | 1.4e-008 |
| Methylene Chloride | 75-09-2 | 1.0e-007 | 4.6e-011 | B2 | 7.5e-003 | 3.5e-013 | 1.1e-010 | 6.0e-002 | liver | 1.8e-009 |
| 2-Butanone | 78-93-3 | 2.0e-008 | | | | | 2.1e-011 | 5.0e-002 | fetotoxicity | 4.2e-010 |
| Acetone | 67-64-1 | 5.8e-009 | | | | | 6.2e-012 | 1.0e-001 | kidney | 6.2e-011 |
| Manganese | 7439-96-5 | 1.8e-002 | | | | | 1.9e-005 | 1.0e-001 | neurotoxicity | 1.9e-004 |
| Cadmium | 7440-43-9 | 1.3e-003 | | | | | 1.4e-006 | 1.0e-003 | kidney | 1.4e-003 |
| Mercury | 7439-97-6 | 8.0e-004 | | | | | 8.6e-007 | 3.0e-004 | kidney | 2.9e-003 |
| Nickel | 7440-02-0 | 8.0e-004 | | | | | 8.6e-007 | 2.0e-002 | kidney | 4.3e-005 |
| Chromium | 7440-47-3 | 7.9e-004 | | | | | 8.5e-007 | 5.0e-003 | neurotoxicity | 1.7e-004 |
| Silver | 7440-22-4 | 2.0e-004 | | | | | 2.1e-007 | 3.0e-003 | skin | 7.1e-005 |
| Sum Of Risks | | | | | | 9.8e-009 | | | | |
| Hazard Index | | | | | | | | | | 4.8e-003 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 36.5 |
| Fraction Ingested (unitless) | 0.75 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |

| Averaging Time (d) | |
|---|---|
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.58.

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 from the ingestion of milk

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Milk (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 9.0e-004 | 1.7e-006 | B2 | 1.4e-002 | 2.3e-008 | 3.9e-006 | 2.0e-002 | liver/kidney | 1.9e-004 |
| Di-n-butylphatalate | 84-74-2 | 3.4e-004 | | | | | 1.4e-006 | 1.0e-001 | liver/kidney | 1.4e-005 |
| Naphthalene | 91-20-3 | 1.4e-005 | | | | | 6.0e-008 | 4.0e-003 | kidney | 1.5e-005 |
| Xylenes(total) | 1330-20-7 | 5.8e-006 | | | | | 2.5e-008 | 2.0e+000 | neurotx/mort | 1.2e-008 |
| Ethyl benzene | 100-41-4 | 4.5e-006 | | | | | 1.9e-008 | 1.0e-001 | kidney/liver | 1.9e-007 |
| Diethylphatalate | 84-66-2 | 2.1e-006 | | | | | 8.8e-009 | 8.0e-001 | liver/kidney | 1.1e-008 |
| Toluene | 108-88-3 | 1.7e-006 | | | | | 7.3e-009 | 2.0e-001 | liver/kidney | 3.7e-008 |
| Carbon tetrachloride | 56-23-5 | 1.4e-006 | 2.5e-009 | B2 | 1.3e-001 | 3.3e-010 | 5.9e-009 | 7.0e-004 | liver | 8.5e-006 |
| Tetrachloroethene | 127-18-4 | 1.3e-006 | 2.3e-009 | B2 | 5.1e-002 | 1.2e-010 | 5.4e-009 | 1.0e-002 | liver | 5.4e-007 |
| 1,1,1-Trichloroethane | 71-55-6 | 9.8e-007 | | | | | 4.2e-009 | 9.0e-002 | liver | 4.7e-008 |
| 1,1,2-Trichloroethane | 79-00-5 | 9.4e-007 | 1.7e-009 | C | 5.7e-002 | 9.8e-011 | 4.0e-009 | 4.0e-003 | immu/liv/hema | 1.0e-006 |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | 7.8e-007 | 1.4e-009 | C | 2.0e-001 | 2.9e-010 | | | | |
| Trichloroethene | 79-01-6 | 7.6e-007 | 1.4e-009 | B2 | 1.1e-002 | 1.5e-011 | | | | |
| 2,4,5-TP | 93-72-1 | 6.3e-007 | | | | | 2.7e-009 | 8.0e-003 | liver | 3.4e-007 |
| 2-Methylphenol | 95-48-7 | 6.2e-007 | | | | | 2.7e-009 | 5.0e-002 | neurotoxicity | 5.3e-008 |
| Benzene | 71-43-2 | 4.2e-007 | 7.7e-010 | A | 2.9e-002 | 2.2e-011 | | | | |
| Carbon disulfide | 75-15-0 | 3.2e-007 | | | | | 1.4e-009 | 1.0e-001 | fetotoxicity | 1.4e-008 |
| Chloroform | 67-66-3 | 3.0e-007 | 5.4e-010 | B2 | 6.1e-003 | 3.3e-012 | 1.3e-009 | 1.0e-002 | liver | 1.3e-007 |
| 1,1-Dichloroethene | 75-35-4 | 2.2e-007 | 4.0e-010 | C | 6.0e-001 | 2.4e-010 | 9.4e-010 | 9.0e-003 | liver | 1.0e-007 |
| 1,1-Dichloroethane | 75-34-3 | 2.0e-007 | 3.6e-010 | B2 | 9.1e-002 | 3.3e-011 | 8.4e-010 | 1.0e-001 | kidney | 8.4e-009 |
| Vinyl chloride | 75-01-4 | 1.5e-007 | 2.8e-010 | A | 1.9e+000 | 5.3e-010 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 9.6e-008 | 1.8e-010 | B2 | 9.1e-002 | 1.6e-011 | | | | |
| 2,4,5-T | 93-76-5 | 8.8e-008 | | | | | 3.8e-010 | 1.0e-002 | fetotox/kidne | 3.8e-008 |
| 2,4-D | 94-75-7 | 8.2e-008 | | | | | 3.5e-010 | 1.0e-002 | Hemato/kidney | 3.5e-008 |
| Methylene Chloride | 75-09-2 | 6.3e-008 | 1.2e-010 | B2 | 7.5e-003 | 8.7e-013 | 2.7e-010 | 6.0e-002 | liver | 4.5e-009 |
| 2-Butanone | 78-93-3 | 1.2e-008 | | | | | 5.3e-011 | 5.0e-002 | fetotoxicity | 1.1e-009 |
| Acetone | 67-64-1 | 3.7e-009 | | | | | 1.6e-011 | 1.0e-001 | kidney | 1.6e-010 |
| Silver | 7440-22-4 | 1.0e-002 | | | | | 4.3e-005 | 3.0e-003 | skin | 1.4e-002 |
| Nickel | 7440-02-0 | 5.4e-003 | | | | | 2.3e-005 | 2.0e-002 | kidney | 1.2e-003 |
| Chromium | 7440-47-3 | 1.8e-003 | | | | | 7.5e-006 | 5.0e-003 | neurotoxicity | 1.5e-003 |
| Manganese | 7439-96-5 | 7.2e-004 | | | | | 3.1e-006 | 1.0e-001 | neurotoxicity | 3.1e-005 |
| Mercury | 7439-97-6 | 3.0e-004 | | | | | 1.3e-006 | 3.0e-004 | kidney | 4.3e-003 |
| Vanadium | 7440-62-2 | 1.8e-005 | | | | | 7.5e-008 | 7.0e-003 | kidney | 1.1e-005 |
| Cadmium | 7440-43-9 | 9.9e-006 | | | | | 4.3e-008 | 1.0e-003 | kidney | 4.3e-005 |
| Sum Of Risks | | | | | | 2.5e-008 | | | | |
| Hazard Index | | | | | | | | | | 2.2e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 146 |
| Fraction Ingested (unitless) | 0.75 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |

| Averaging Time (d) | |
|---|---|
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

**Table 6I.59.**

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 from dermal contact with groundwater while showering

| Analyte Name | CAS Number | Concentration in Groundwater (mg/L) | CARCINOGENS Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | NONCARCINOGENS Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| 2-Methylphenol | 95-48-7 | 1.1e-002 | | | | | 4.8e-007 | 2.5e-003 | neurotoxicity | 1.9e-004 |
| Diethylphatalate | 84-66-2 | 1.1e-002 | | | | | 4.8e-007 | 4.0e-002 | liver/kidney | 1.2e-005 |
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 1.1e-002 | 2.1e-007 | B2 | 2.8e-001 | 5.7e-008 | 4.8e-007 | 1.0e-003 | liver/kidney | 4.8e-004 |
| Naphthalene | 91-20-3 | 1.1e-002 | | | | | 4.8e-007 | 2.0e-004 | kidney | 2.4e-003 |
| Di-n-butylphatalate | 84-74-2 | 1.0e-002 | | | | | 4.4e-007 | 5.0e-003 | liver/kidney | 8.7e-005 |
| 2-Butanone | 78-93-3 | 1.0e-002 | | | | | 4.4e-007 | 2.5e-003 | fetotoxicity | 1.7e-004 |
| Vinyl chloride | 75-01-4 | 1.0e-002 | 1.9e-007 | A | 3.8e+001 | 7.1e-006 | | | | |
| Acetone | 67-64-1 | 1.0e-002 | | | | | 4.4e-007 | 5.0e-003 | kidney | 8.7e-005 |
| Toluene | 108-88-3 | 5.0e-003 | | | | | 2.2e-007 | 1.0e-002 | liver/kidney | 2.2e-005 |
| Xylenes(total) | 1330-20-7 | 5.0e-003 | | | | | 2.2e-007 | 1.0e-001 | neurotx/mort | 2.2e-006 |
| 1,1,1-Trichloroethane | 71-55-6 | 5.0e-003 | | | | | 2.2e-007 | 4.5e-003 | liver | 4.8e-005 |
| Carbon disulfide | 75-15-0 | 5.0e-003 | | | | | 2.2e-007 | 5.0e-003 | fetotoxicity | 4.4e-005 |
| Ethyl benzene | 100-41-4 | 5.0e-003 | | | | | 2.2e-007 | 5.0e-003 | kidney/liver | 4.4e-005 |
| 1,1-Dichloroethane | 75-34-3 | 5.0e-003 | 9.3e-008 | B2 | 1.8e+000 | 1.7e-007 | 2.2e-007 | 5.0e-003 | kidney | 4.4e-005 |
| 1,2-Dichloroethane | 107-06-2 | 5.0e-003 | 9.3e-008 | B2 | 1.8e+000 | 1.7e-007 | | | | |
| Carbon tetrachloride | 56-23-5 | 5.0e-003 | 9.3e-008 | B2 | 2.6e+000 | 2.4e-007 | 2.2e-007 | 3.5e-005 | liver | 6.2e-003 |
| 1,1-Dichloroethene | 75-35-4 | 5.0e-003 | 9.3e-008 | C | 1.2e+001 | 1.1e-006 | 2.2e-007 | 4.5e-004 | liver | 4.8e-004 |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | 5.0e-003 | 9.3e-008 | C | 4.0e+000 | 3.7e-007 | | | | |
| 1,1,2-Trichloroethane | 79-00-5 | 5.0e-003 | 9.3e-008 | C | 1.1e+000 | 1.1e-007 | 2.2e-007 | 2.0e-004 | immu/liv/hema | 1.1e-003 |
| Methylene Chloride | 75-09-2 | 5.0e-003 | 9.3e-008 | B2 | 1.5e-001 | 1.4e-008 | 2.2e-007 | 3.0e-003 | liver | 7.3e-005 |
| Chloroform | 67-66-3 | 5.0e-003 | 9.3e-008 | B2 | 1.2e-001 | 1.1e-008 | 2.2e-007 | 5.0e-004 | liver | 4.4e-004 |
| Trichloroethene | 79-01-6 | 5.0e-003 | 9.3e-008 | B2 | 2.2e-001 | 2.1e-008 | | | | |
| Tetrachloroethene | 127-18-4 | 5.0e-003 | 9.3e-008 | B2 | 1.0e+000 | 9.5e-008 | 2.2e-007 | 5.0e-004 | liver | 4.4e-004 |
| Benzene | 71-43-2 | 5.0e-003 | 9.3e-008 | A | 5.8e-001 | 5.4e-008 | | | | |
| 2,4-D | 94-75-7 | 2.0e-004 | | | | | 8.7e-009 | 5.0e-004 | Hemato/kidney | 1.7e-005 |
| 2,4,5-TP | 93-72-1 | 1.0e-004 | | | | | 4.4e-009 | 4.0e-004 | liver | 1.1e-005 |
| 2,4,5-T | 93-76-5 | 1.0e-004 | | | | | 4.4e-009 | 5.0e-004 | fetotx/kidney | 8.7e-006 |
| Chromium | 7440-47-3 | 2.0e-002 | | | | | 8.7e-007 | 2.5e-004 | neurotoxicity | 3.5e-003 |
| Nickel | 7440-02-0 | 2.0e-002 | | | | | 8.7e-007 | 1.0e-003 | kidney | 8.7e-004 |
| Vanadium | 7440-62-2 | 1.1e-002 | | | | | 4.8e-007 | 3.5e-004 | kidney | 1.4e-003 |
| Silver | 7440-22-4 | 5.0e-003 | | | | | 2.2e-007 | 1.5e-004 | skin | 1.5e-003 |
| Cadmium | 7440-43-9 | 2.0e-003 | | | | | 8.7e-008 | 2.5e-005 | kidney | 3.5e-003 |
| Mercury | 7439-97-6 | 2.0e-004 | | | | | 8.7e-009 | 1.5e-005 | kidney | 5.8e-004 |
| Sum Of Risks | | | | | | 9.5e-006 | | | | |
| Hazard Index | | | | | | | | | | 2.4e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (L/cm^3) | 0.001 |
| Skin Surface Area (cm^2/event) | 18150 |
| Dermal Perm. Constant (cm/h) | 0.00084 |
| Exposure Time (h/d) | 0.2 |
| Exposure Frequency (d/y) | 365 |

| | |
|---|---|
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.60.

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 from dermal contact with soil

| Analyte Name | CAS Number | Concentration in Soil (mg/kg) | CARCINOGENS Daily Intake (mg/kg/day) | USEPA Class | Slope Factor (mg/kg-day) | Excess Lifetime Cancer Risk | NONCARCINOGENS Daily Intake (mg/kg/day) | Reference Dose RfD (mg/kg-day) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| Benzyl alcohol | 100-51-6 | 4.2e-001 | | | | | 1.5e-006 | 1.5e-002 | digestive | 1.0e-004 |
| Methylene Chloride | 75-09-2 | 3.3e-002 | 5.1e-008 | B2 | 1.5e-001 | 7.7e-009 | 1.2e-007 | 3.0e-003 | liver | 4.0e-005 |
| Acetone | 67-64-1 | 1.5e-002 | | | | | 5.5e-008 | 5.0e-003 | kidney | 1.1e-005 |
| Ethyl benzene | 100-41-4 | 6.0e-003 | | | | | 2.2e-008 | 5.0e-003 | kidney/liver | 4.4e-006 |
| Toluene | 108-88-3 | 6.0e-003 | | | | | 2.2e-008 | 1.0e-002 | liver/kidney | 2.2e-006 |
| Xylenes(total) | 1330-20-7 | 6.0e-003 | | | | | 2.2e-008 | 1.0e-001 | neurotx/mort | 2.2e-007 |
| Trichloroethene | 79-01-6 | 6.0e-003 | 9.4e-009 | B2 | 2.2e-001 | 2.1e-009 | | | | |
| Vanadium | 7440-62-2 | 2.2e+001 | | | | | 3.2e-006 | 3.5e-004 | kidney | 9.1e-003 |
| Thallium | 7440-28-0 | 5.0e-001 | | | | | 7.3e-008 | 3.5e-006 | skin | 2.1e-002 |
| Sum Of Risks | | | | | | 9.8e-009 | | | | |
| Hazard Index | | | | | | | | | | 3.0e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (kg/mg) | 1.0e-006 |
| Skin Surface Area (cm^2/event) | 3120 |
| Adherence Factor (mg/cm^3) | 2.77 |
| Absorption Factor | |
| Voc | 0.25 |
| Svoc | 0.1 |
| Inorganic | 0.01 |

| | |
|---|---|
| Exposure Frequency (event/y) | 43 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.61.

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 from dermal contact with sediment

| Analyte Name | CAS Number | Concentration in Sediment (mg/kg) | CARCINOGENS Daily Intake (mg/kg/day) | USEPA Class | Slope Factor (mg/kg-day) | Excess Lifetime Cancer Risk | NONCARCINOGENS Daily Intake (mg/kg/day) | Reference Dose RfD (mg/kg-day) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| 2-Butanone | 78-93-3 | 1.4e-001 | | | | | 3.1e-006 | 2.5e-003 | fetotoxicity | 1.2e-003 |
| Trichlorofluoromethane | 75-69-4 | 7.2e-002 | | | | | 1.6e-006 | 1.5e-002 | resp/cardiova | 1.1e-004 |
| Methylene Chloride | 75-09-2 | 3.1e-002 | 2.9e-007 | B2 | 1.5e-001 | 4.4e-008 | 6.9e-007 | 3.0e-003 | liver | 2.3e-004 |
| Acetone | 67-64-1 | 1.3e-002 | | | | | 2.9e-007 | 5.0e-003 | kidney | 5.8e-005 |
| Chloroform | 67-66-3 | 1.3e-002 | 1.2e-007 | B2 | 1.2e-001 | 1.5e-008 | 2.9e-007 | 5.0e-004 | liver | 5.8e-004 |
| Trichloroethene | 79-01-6 | 6.0e-003 | 5.7e-008 | B2 | 2.2e-001 | 1.3e-008 | | | | |
| Toluene | 108-88-3 | 6.0e-003 | | | | | 1.3e-007 | 1.0e-002 | liver/kidney | 1.3e-005 |
| Silver | 7440-22-4 | 2.5e+000 | | | | | 2.2e-006 | 1.5e-004 | skin | 1.5e-002 |
| Sum Of Risks | | | | | | 7.2e-008 | | | | |
| Hazard Index | | | | | | | | | | 1.7e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (kg/mg) | 1.0e-006 |
| Skin Surface Area (cm^2/event) | 18150 |
| Adherence Factor (mg/cm^3) | 2.77 |
| Absorption Factor | |
| Voc | 0.25 |
| Svoc | 0.1 |
| Inorganics | 0.01 |

| | |
|---|---|
| Exposure Frequency (event/y) | 45 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogen | 70 y * 365 d/y |
| Noncarcinogen | 30 y * 365 d/y |

Table 6I.62.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 from the incidental ingestion of soil

| Analyte Name | CAS Number | Concentration in Soil (mg/kg) | CARCINOGENS Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | NONCARCINOGENS Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| Benzyl alcohol | 100-51-6 | 4.2e-001 | | | | | 5.3e-006 | 3.0e-001 | digestive | 1.8e-005 |
| Methylene Chloride | 75-09-2 | 3.3e-002 | 4.1e-008 | B2 | 7.5e-003 | 3.1e-010 | 4.1e-007 | 6.0e-002 | liver | 6.9e-006 |
| Acetone | 67-64-1 | 1.5e-002 | | | | | 1.9e-007 | 1.0e-001 | kidney | 1.9e-006 |
| Ethyl benzene | 100-41-4 | 6.0e-003 | | | | | 7.5e-008 | 1.0e-001 | kidney/liver | 7.5e-007 |
| Toluene | 108-88-3 | 6.0e-003 | | | | | 7.5e-008 | 2.0e-001 | liver/kidney | 3.8e-007 |
| Xylenes(total) | 1330-20-7 | 6.0e-003 | | | | | 7.5e-008 | 2.0e+000 | neurotx/mort | 3.8e-008 |
| Trichloroethene | 79-01-6 | 6.0e-003 | 7.5e-009 | B2 | 1.1e-002 | 8.3e-011 | | | | |
| Vanadium | 7440-62-2 | 2.2e+001 | | | | | 2.8e-004 | 7.0e-003 | kidney | 3.9e-002 |
| Thallium | 7440-28-0 | 5.0e-001 | | | | | 6.3e-006 | 7.0e-005 | skin | 8.9e-002 |
| Sum Of Risks | | | | | | 3.9e-010 | | | | |
| Hazard Index | | | | | | | | | | 1.3e-001 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Ingestion Rate (mg/d) | 200 |
| Conversion Factor (kg/mg) | 1.0e-006 |
| Fraction Ingested (unitless) | 1 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.63.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 from the incidental ingestion of sediment while swimming at the EWB

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Sediment (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| 2-Butanone | 78-93-3 | 1.4e-001 | | | | | 2.2e-007 | 5.0e-002 | fetotoxicity | 4.3e-006 |
| Trichlorofluoromethane | 75-69-4 | 7.2e-002 | | | | | 1.1e-007 | 3.0e-001 | resp/cardiova | 3.7e-007 |
| Methylene Chloride | 75-09-2 | 3.1e-002 | 4.8e-009 | B2 | 7.5e-003 | 3.6e-011 | 4.8e-008 | 6.0e-002 | liver | 8.0e-007 |
| Acetone | 67-64-1 | 1.3e-002 | | | | | 2.0e-008 | 1.0e-001 | kidney | 2.0e-007 |
| Chloroform | 67-66-3 | 1.3e-002 | 2.0e-009 | B2 | 6.1e-003 | 1.2e-011 | 2.0e-008 | 1.0e-002 | liver | 2.0e-006 |
| Trichloroethene | 79-01-6 | 6.0e-003 | 9.2e-010 | B2 | 1.1e-002 | 1.0e-011 | | | | |
| Toluene | 108-88-3 | 6.0e-003 | | | | | 9.2e-009 | 2.0e-001 | liver/kidney | 4.6e-008 |
| Silver | 7440-22-4 | 2.5e+000 | | | | | 3.9e-006 | 3.0e-003 | skin | 1.3e-003 |
| Sum Of Risks | | | | | | 5.8e-011 | | | | |
| Hazard Index | | | | | | | | | | 1.3e-003 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Ingestion Rate (mg/d) | 200 |
| Conversion Factor (kg/mg) | 1.0e-006 |
| Fraction Ingested | 1 |
| Exposure Frequency (d/y) | 45 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 61.64.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 from the inhalation of the vapor phase

| Analyte Name | CAS Number | Concentration in Air (mg/m^3) | CARCINOGENS Daily Intake (mg/kg-d) | USEPA CLass | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | NONCARCINOGENS Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| Tetrachloroethene | 127-18-4 | 3.3e-008 | 3.0e-009 | B2 | 1.8e-003 | 5.4e-012 | | | | |
| Chloromethane | 74-87-3 | 2.6e-008 | 2.3e-009 | C | 6.3e-003 | 1.5e-011 | | | | |
| Xylenes(total) | 1330-20-7 | 2.4e-008 | | | | | 2.1e-008 | 1.0e-001 | neurotoxicity | 2.1e-007 |
| Trichloroethene | 79-01-6 | 1.3e-008 | 1.1e-009 | B2 | 1.7e-002 | 1.9e-011 | | | | |
| Toluene | 108-88-3 | 1.0e-008 | | | | | 9.3e-009 | 6.0e-001 | neurotoxicity | 1.6e-008 |
| Benzene | 71-43-2 | 9.5e-009 | 8.6e-010 | A | 2.9e-002 | 2.5e-011 | | | | |
| Ethyl benzene | 100-41-4 | 8.5e-009 | | | | | 7.7e-009 | 3.0e-001 | fetotoxicity | 2.6e-008 |
| Chloroform | 67-66-3 | 6.8e-009 | 6.2e-010 | B2 | 8.1e-002 | 5.0e-011 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 2.5e-009 | 2.3e-010 | B2 | 9.1e-002 | 2.1e-011 | | | | |
| Sum Of Risks | | | | | | 1.3e-010 | | | | |
| Hazard Index | | | | | | | | | | 2.5e-007 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Inhalation Rate (m^3/h) | 0.6 |
| Exposure Time (h/d) | 24 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

**Table 6I.65.**

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 from the inhalation of groundwater chemicals while showering

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Groundwater (mg/L) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Chloroethane | 75-00-3 | 1.0e-002 | | | | | 5.6e-004 | 3.0e-001 | fetotoxicity | 1.9e-003 |
| Vinyl chloride | 75-01-4 | 1.0e-002 | 5.6e-005 | A | 2.9e-001 | 1.7e-005 | | | | |
| 2-Butanone | 78-93-3 | 1.0e-002 | | | | | 5.6e-004 | 1.0e-001 | neurotoxicity | 5.6e-003 |
| Methylene Chloride | 75-09-2 | 5.0e-003 | 2.8e-005 | B2 | 1.6e-003 | 4.6e-008 | 2.8e-004 | 9.0e-001 | liver | 3.1e-004 |
| Tetrachloroethene | 127-18-4 | 5.0e-003 | 2.8e-005 | B2 | 1.8e-003 | 5.1e-008 | | | | |
| Trichloroethene | 79-01-6 | 5.0e-003 | 2.8e-005 | B2 | 1.7e-002 | 4.8e-007 | | | | |
| Toluene | 108-88-3 | 5.0e-003 | | | | | 2.8e-004 | 6.0e-001 | neurotoxicity | 4.7e-004 |
| Ethyl benzene | 100-41-4 | 5.0e-003 | | | | | 2.8e-004 | 3.0e-001 | fetotoxicity | 9.4e-004 |
| 1,1-Dichloroethane | 75-34-3 | 5.0e-003 | | | | | 2.8e-004 | 1.0e-001 | kidney | 2.8e-003 |
| 1,1,1-Trichloroethane | 71-55-6 | 5.0e-003 | | | | | 2.8e-004 | 3.0e-001 | liver | 9.4e-004 |
| Benzene | 71-43-2 | 5.0e-003 | 2.8e-005 | A | 2.9e-002 | 8.2e-007 | | | | |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | 5.0e-003 | 2.8e-005 | C | 2.0e-001 | 5.6e-006 | | | | |
| Xylenes(total) | 1330-20-7 | 5.0e-003 | | | | | 2.8e-004 | 1.0e-001 | neurotoxicity | 2.8e-003 |
| 1,1-Dichloroethene | 75-35-4 | 5.0e-003 | 2.8e-005 | C | 1.2e+000 | 3.4e-005 | | | | |
| Carbon tetrachloride | 56-23-5 | 5.0e-003 | 2.8e-005 | B2 | 1.3e-001 | 3.7e-006 | | | | |
| 1,1,2-Trichloroethane | 79-00-5 | 5.0e-003 | 2.8e-005 | C | 5.7e-002 | 1.6e-006 | | | | |
| Chloroform | 67-66-3 | 5.0e-003 | 2.8e-005 | B2 | 8.1e-002 | 2.3e-006 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 5.0e-003 | 2.8e-005 | B2 | 9.1e-002 | 2.6e-006 | | | | |
| Sum Of Risks | | | | | | 6.7e-005 | | | | |
| Hazard Index | | | | | | | | | | 1.6e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Inhalation Rate (m^3/hr) | 0.6 |
| Shower Water Consumption (L) | 180 |
| Volatilization Fraction(unitless) | 0.5 |
| Shower Area Capacity (m^3) | 12 |
| Exposure Time (h/day) | 0.2 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |

| Averaging Time (d) | |
|---|---|
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

**Table 6I.66.**

Excess Lifetime Cancer Risk and Hazard Index for a child homesteader on WAG 6 from the ingestion of groundwater as drinking water

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Groundwater (mg/L) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| 2-Methylphenol | 95-48-7 | 1.1e-002 | | | | | 6.9e-004 | 5.0e-002 | neurotoxicity | 1.4e-002 |
| Diethylphatalate | 84-66-2 | 1.1e-002 | | | | | 6.9e-004 | 8.0e-001 | liver/kidney | 8.6e-004 |
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 1.1e-002 | 6.9e-005 | B2 | 1.4e-002 | 9.6e-007 | 6.9e-004 | 2.0e-002 | liver/kidney | 3.4e-002 |
| Naphthalene | 91-20-3 | 1.1e-002 | | | | | 6.9e-004 | 4.0e-003 | kidney | 1.7e-001 |
| Di-n-butylphatalate | 84-74-2 | 1.0e-002 | | | | | 6.3e-004 | 1.0e-001 | liver/kidney | 6.3e-003 |
| 2-Butanone | 78-93-3 | 1.0e-002 | | | | | 6.3e-004 | 5.0e-002 | fetotoxicity | 1.3e-002 |
| Vinyl chloride | 75-01-4 | 1.0e-002 | 6.3e-005 | A | 1.9e+000 | 1.2e-004 | | | | |
| Acetone | 67-64-1 | 1.0e-002 | | | | | 6.3e-004 | 1.0e-001 | kidney | 6.3e-003 |
| Toluene | 108-88-3 | 5.0e-003 | | | | | 3.1e-004 | 2.0e-001 | liver/kidney | 1.6e-003 |
| Xylenes(total) | 1330-20-7 | 5.0e-003 | | | | | 3.1e-004 | 2.0e+000 | neurotx/mort | 1.6e-004 |
| 1,1,1-Trichloroethane | 71-55-6 | 5.0e-003 | | | | | 3.1e-004 | 9.0e-002 | liver | 3.5e-003 |
| Carbon disulfide | 75-15-0 | 5.0e-003 | | | | | 3.1e-004 | 1.0e-001 | fetotoxicity | 3.1e-003 |
| Ethyl benzene | 100-41-4 | 5.0e-003 | | | | | 3.1e-004 | 1.0e-001 | kidney/liver | 3.1e-003 |
| 1,1-Dichloroethane | 75-34-3 | 5.0e-003 | 3.1e-005 | B2 | 9.1e-002 | 2.8e-006 | 3.1e-004 | 1.0e-001 | kidney | 3.1e-003 |
| 1,2-Dichloroethane | 107-06-2 | 5.0e-003 | 3.1e-005 | B2 | 9.1e-002 | 2.8e-006 | | | | |
| Carbon tetrachloride | 56-23-5 | 5.0e-003 | 3.1e-005 | B2 | 1.3e-001 | 4.1e-006 | 3.1e-004 | 7.0e-004 | liver | 4.5e-001 |
| 1,1-Dichloroethene | 75-35-4 | 5.0e-003 | 3.1e-005 | C | 6.0e-001 | 1.9e-005 | 3.1e-004 | 9.0e-003 | liver | 3.5e-002 |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | 5.0e-003 | 3.1e-005 | C | 2.0e-001 | 6.3e-006 | | | | |
| 1,1,2-Trichloroethane | 79-00-5 | 5.0e-003 | 3.1e-005 | C | 5.7e-002 | 1.8e-006 | 3.1e-004 | 4.0e-003 | immu/liv/hema | 7.8e-002 |
| Methylene Chloride | 75-09-2 | 5.0e-003 | 3.1e-005 | B2 | 7.5e-003 | 2.3e-007 | 3.1e-004 | 6.0e-002 | liver | 5.2e-003 |
| Chloroform | 67-66-3 | 5.0e-003 | 3.1e-005 | B2 | 6.1e-003 | 1.9e-007 | 3.1e-004 | 1.0e-002 | liver | 3.1e-002 |
| Trichloroethene | 79-01-6 | 5.0e-003 | 3.1e-005 | B2 | 1.1e-002 | 3.4e-007 | | | | |
| Tetrachloroethene | 127-18-4 | 5.0e-003 | 3.1e-005 | B2 | 5.1e-002 | 1.6e-006 | 3.1e-004 | 1.0e-002 | liver | 3.1e-002 |
| Benzene | 71-43-2 | 5.0e-003 | 3.1e-005 | A | 2.9e-002 | 9.1e-007 | | | | |
| 2,4-D | 94-75-7 | 2.0e-004 | | | | | 1.3e-005 | 1.0e-002 | Hemato/kidney | 1.3e-003 |
| 2,4,5-TP | 93-72-1 | 1.0e-004 | | | | | 6.3e-006 | 8.0e-003 | liver | 7.8e-004 |
| 2,4,5-T | 93-76-5 | 1.0e-004 | | | | | 6.3e-006 | 1.0e-002 | fetotox/kidne | 6.3e-004 |
| Chromium | 7440-47-3 | 2.0e-002 | | | | | 1.3e-003 | 5.0e-003 | neurotoxicity | 2.5e-001 |
| Nickel | 7440-02-0 | 2.0e-002 | | | | | 1.3e-003 | 2.0e-002 | kidney | 6.3e-002 |
| Vanadium | 7440-62-2 | 1.1e-002 | | | | | 6.9e-004 | 7.0e-003 | kidney | 9.8e-002 |
| Silver | 7440-22-4 | 5.0e-003 | | | | | 3.1e-004 | 3.0e-003 | skin | 1.0e-001 |
| Cadmium | 7440-43-9 | 2.0e-003 | | | | | 1.3e-004 | 5.0e-004 | kidney | 2.5e-001 |
| Mercury | 7439-97-6 | 2.0e-004 | | | | | 1.3e-005 | 3.0e-004 | kidney | 4.2e-002 |
| Sum Of Risks | | | | | | 1.6e-004 | | | | |
| Hazard Index | | | | | | | | | | 1.7e+000 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Ingestion Rate (L/d) | 1 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |

| Averaging Time (d) | |
|---|---|
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.67.

Excess lifetime cancer risk and hazard quotient for a child homesteader on WAG 6 form the ingestion of fruit

| Analyte Name | CAS Number | Concentration in Fruit (mg/kg) | CARCINOGENS Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | NONCARCINOGENS Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| Benzyl alcohol | 100-51-6 | 3.8e+000 | | | | | 1.0e-002 | 3.0e-001 | digestive | 3.5e-002 |
| Acetone | 67-64-1 | 8.0e-001 | | | | | 2.2e-003 | 1.0e-001 | kidney | 2.2e-002 |
| Methylene Chloride | 75-09-2 | 2.3e-001 | 6.3e-005 | B2 | 7.5e-003 | 4.7e-007 | 6.3e-004 | 6.0e-002 | liver | 1.0e-002 |
| Trichloroethene | 79-01-6 | 9.8e-003 | 2.7e-006 | B2 | 1.1e-002 | 3.0e-008 | | | | |
| Toluene | 108-88-3 | 6.5e-003 | | | | | 1.8e-005 | 2.0e-001 | liver/kidney | 8.9e-005 |
| Ethyl benzene | 100-41-4 | 3.5e-003 | | | | | 9.7e-006 | 1.0e-001 | kidney/liver | 9.7e-005 |
| Xylenes(total) | 1330-20-7 | 3.0e-003 | | | | | 8.4e-006 | 2.0e+000 | neurotx/mort | 4.2e-006 |
| Tetrachloroethene | 127-18-4 | 1.5e-006 | 4.1e-010 | B2 | 5.1e-002 | 2.1e-011 | 4.1e-009 | 1.0e-002 | liver | 4.1e-007 |
| Carbon disulfide | 75-15-0 | 1.5e-008 | | | | | 4.2e-011 | 1.0e-001 | fetotoxicity | 4.2e-010 |
| Benzene | 71-43-2 | 6.5e-009 | 1.8e-012 | A | 2.9e-002 | 5.2e-014 | | | | |
| Chloroform | 67-66-3 | 1.5e-009 | 4.2e-013 | B2 | 6.1e-003 | 2.5e-015 | 4.2e-012 | 1.0e-002 | liver | 4.2e-010 |
| Chloromethane | 74-87-3 | 1.1e-009 | 3.1e-013 | C | 1.3e-002 | 4.0e-015 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 6.9e-010 | 1.9e-013 | B2 | 9.1e-002 | 1.7e-014 | | | | |
| Sum Of Risks | | | | | | 5.0e-007 | | | | |
| Hazard Index | | | | | | | | | | 6.8e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 53.8 |
| Fraction Ingested (unitless) | 0.3 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.68.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 from the ingestion of vegetables

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Vegetables (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Benzyl alcohol | 100-51-6 | 3.8e+000 | | | | | 1.0e-002 | 3.0e-001 | digestive | 3.4e-002 |
| Acetone | 67-64-1 | 8.0e-001 | | | | | 2.1e-003 | 1.0e-001 | kidney | 2.1e-002 |
| Methylene Chloride | 75-09-2 | 2.3e-001 | 6.1e-005 | B2 | 7.5e-003 | 4.6e-007 | 6.1e-004 | 6.0e-002 | liver | 1.0e-002 |
| Trichloroethene | 79-01-6 | 9.8e-003 | 2.6e-006 | B2 | 1.1e-002 | 2.9e-008 | | | | |
| Toluene | 108-88-3 | 6.5e-003 | | | | | 1.7e-005 | 2.0e-001 | liver/kidney | 8.7e-005 |
| Ethyl benzene | 100-41-4 | 3.5e-003 | | | | | 9.4e-006 | 1.0e-001 | kidney/liver | 9.4e-005 |
| Xylenes(total) | 1330-20-7 | 3.0e-003 | | | | | 8.2e-006 | 2.0e+000 | neurotx/mort | 4.1e-006 |
| Tetrachloroethene | 127-18-4 | 1.5e-006 | 4.0e-010 | B2 | 5.1e-002 | 2.0e-011 | 4.0e-009 | 1.0e-002 | liver | 4.0e-007 |
| Carbon disulfide | 75-15-0 | 1.5e-008 | | | | | 4.1e-011 | 1.0e-001 | fetotoxicity | 4.1e-010 |
| Benzene | 71-43-2 | 6.5e-009 | 1.7e-012 | A | 2.9e-002 | 5.1e-014 | | | | |
| Chloroform | 67-66-3 | 1.5e-009 | 4.1e-013 | B2 | 6.1e-003 | 2.5e-015 | 4.1e-012 | 1.0e-002 | liver | 4.1e-010 |
| Chloromethane | 74-87-3 | 1.1e-009 | 3.0e-013 | C | 1.3e-002 | 3.9e-015 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 6.9e-010 | 1.9e-013 | B2 | 9.1e-002 | 1.7e-014 | | | | |
| Sum Of Risks | | | | | | 4.9e-007 | | | | |
| Hazard Index | | | | | | | | | | 6.6e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 39.2 |
| Fraction Ingested (unitless) | 0.4 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

**Table 6I.69.**

Excess Lifetime Cancer Risk and Hazard Index for a child homesteader on WAG 6 from the ingestion of beef

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Beef (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 1.4e-003 | 1.4e-007 | B2 | 1.4e-002 | 2.0e-009 | 1.4e-006 | 2.0e-002 | liver/kidney | 7.2e-005 |
| Di-n-butylphatalate | 84-74-2 | 5.2e-004 | | | | | 5.3e-007 | 1.0e-001 | liver/kidney | 5.3e-006 |
| Naphthalene | 91-20-3 | 2.2e-005 | | | | | 2.2e-008 | 4.0e-003 | kidney | 5.6e-006 |
| Xylenes(total) | 1330-20-7 | 9.1e-006 | | | | | 9.3e-009 | 2.0e+000 | neurotx/mort | 4.6e-009 |
| Ethyl benzene | 100-41-4 | 7.1e-006 | | | | | 7.2e-009 | 1.0e-001 | kidney/liver | 7.2e-008 |
| Diethylphatalate | 84-66-2 | 3.3e-006 | | | | | 3.3e-009 | 8.0e-001 | liver/kidney | 4.1e-009 |
| Toluene | 108-88-3 | 2.7e-006 | | | | | 2.7e-009 | 2.0e-001 | liver/kidney | 1.4e-008 |
| Carbon tetrachloride | 56-23-5 | 2.2e-006 | 2.2e-010 | B2 | 1.3e-001 | 2.9e-011 | 2.2e-009 | 7.0e-004 | liver | 3.2e-006 |
| Tetrachloroethene | 127-18-4 | 2.0e-006 | 2.0e-010 | B2 | 5.1e-002 | 1.0e-011 | 2.0e-009 | 1.0e-002 | liver | 2.0e-007 |
| 1,1,1-Trichloroethane | 71-55-6 | 1.6e-006 | | | | | 1.6e-009 | 9.0e-002 | liver | 1.8e-008 |
| 1,1,2-Trichloroethane | 79-00-5 | 1.5e-006 | 1.5e-010 | C | 5.7e-002 | 8.6e-012 | 1.5e-009 | 4.0e-003 | immu/liv/hema | 3.8e-007 |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | 1.2e-006 | 1.3e-010 | C | 2.0e-001 | 2.5e-011 | | | | |
| Trichloroethene | 79-01-6 | 1.2e-006 | 1.2e-010 | B2 | 1.1e-002 | 1.3e-012 | | | | |
| 2,4,5-TP | 93-72-1 | 1.0e-006 | | | | | 1.0e-009 | 8.0e-003 | liver | 1.3e-007 |
| 2-Methylphenol | 95-48-7 | 9.9e-007 | | | | | 1.0e-009 | 5.0e-002 | neurotoxicity | 2.0e-008 |
| Benzene | 71-43-2 | 6.6e-007 | 6.7e-011 | A | 2.9e-002 | 1.9e-012 | | | | |
| Carbon disulfide | 75-15-0 | 5.0e-007 | | | | | 5.1e-010 | 1.0e-001 | fetotoxicity | 5.1e-009 |
| Chloroform | 67-66-3 | 4.7e-007 | 4.8e-011 | B2 | 6.1e-003 | 2.9e-013 | 4.8e-010 | 1.0e-002 | liver | 4.8e-008 |
| 1,1-Dichloroethene | 75-35-4 | 3.5e-007 | 3.5e-011 | C | 6.0e-001 | 2.1e-011 | 3.5e-010 | 9.0e-003 | liver | 3.9e-008 |
| 1,1-Dichloroethane | 75-34-3 | 3.1e-007 | 3.1e-011 | B2 | 9.1e-002 | 2.9e-012 | 3.1e-010 | 1.0e-001 | kidney | 3.1e-009 |
| Vinyl chloride | 75-01-4 | 2.4e-007 | 2.4e-011 | A | 1.9e+000 | 4.6e-011 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 1.5e-007 | 1.5e-011 | B2 | 9.1e-002 | 1.4e-012 | | | | |
| 2,4,5-T | 93-76-5 | 1.4e-007 | | | | | 1.4e-010 | 1.0e-002 | fetotx/kidney | 1.4e-008 |
| 2,4-D | 94-75-7 | 1.3e-007 | | | | | 1.3e-010 | 1.0e-002 | Hemato/kidney | 1.3e-008 |
| Methylene Chloride | 75-09-2 | 1.0e-007 | 1.0e-011 | B2 | 7.5e-003 | 7.6e-014 | 1.0e-010 | 6.0e-002 | liver | 1.7e-009 |
| 2-Butanone | 78-93-3 | 2.0e-008 | | | | | 2.0e-011 | 5.0e-002 | fetotoxicity | 4.0e-010 |
| Acetone | 67-64-1 | 5.8e-009 | | | | | 5.9e-012 | 1.0e-001 | kidney | 5.9e-011 |
| Manganese | 7439-96-5 | 1.8e-002 | | | | | 1.8e-005 | 1.0e-001 | neurotoxicity | 1.8e-004 |
| Cadmium | 7440-43-9 | 1.3e-003 | | | | | 1.3e-006 | 1.0e-003 | kidney | 1.3e-003 |
| Mercury | 7439-97-6 | 8.0e-004 | | | | | 8.1e-007 | 3.0e-004 | kidney | 2.7e-003 |
| Nickel | 7440-02-0 | 8.0e-004 | | | | | 8.1e-007 | 2.0e-002 | kidney | 4.1e-005 |
| Chromium | 7440-47-3 | 7.9e-004 | | | | | 8.0e-007 | 5.0e-003 | neurotoxicity | 1.6e-004 |
| Silver | 7440-22-4 | 2.0e-004 | | | | | 2.0e-007 | 3.0e-003 | skin | 6.7e-005 |
| Sum Of Risks | | | | | | 2.2e-009 | | | | |
| Hazard Index | | | | | | | | | | 4.5e-003 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/yr) | 7.9 |
| Fraction Ingested (unitless) | 0.75 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |

| Averaging Time (d) | |
|---|---|
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

.e 61.70.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 from the ingestion of milk

| Analyte Name | CAS Number | Concentration in Milk (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 9.0e-004 | 1.6e-006 | B2 | 1.4e-002 | 2.3e-008 | 1.6e-005 | 2.0e-002 | liver/kidney | 8.1e-004 |
| Di-n-butylphatalate | 84-74-2 | 3.4e-004 | | | | | 6.0e-006 | 1.0e-001 | liver/kidney | 6.0e-005 |
| Naphthalene | 91-20-3 | 1.4e-005 | | | | | 2.5e-007 | 4.0e-003 | kidney | 6.3e-005 |
| Xylenes(total) | 1330-20-7 | 5.8e-006 | | | | | 1.0e-007 | 2.0e+000 | neurotx/mort | 5.2e-008 |
| Ethyl benzene | 100-41-4 | 4.5e-006 | | | | | 8.0e-008 | 1.0e-001 | kidney/liver | 8.0e-007 |
| Diethylphatalate | 84-66-2 | 2.1e-006 | | | | | 3.7e-008 | 8.0e-001 | liver/kidney | 4.6e-008 |
| Toluene | 108-88-3 | 1.7e-006 | | | | | 3.1e-008 | 2.0e-001 | liver/kidney | 1.5e-007 |
| Carbon tetrachloride | 56-23-5 | 1.4e-006 | 2.5e-009 | B2 | 1.3e-001 | 3.2e-010 | 2.5e-008 | 7.0e-004 | liver | 3.6e-005 |
| Tetrachloroethene | 127-18-4 | 1.3e-006 | 2.3e-009 | B2 | 5.1e-002 | 1.2e-010 | 2.3e-008 | 1.0e-002 | liver | 2.3e-006 |
| 1,1,1-Trichloroethane | 71-55-6 | 9.8e-007 | | | | | 1.8e-008 | 9.0e-002 | liver | 2.0e-007 |
| 1,1,2-Trichloroethane | 79-00-5 | 9.4e-007 | 1.7e-009 | C | 5.7e-002 | 9.6e-011 | 1.7e-008 | 4.0e-003 | immu/liv/hema | 4.2e-006 |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | 7.8e-007 | 1.4e-009 | C | 2.0e-001 | 2.8e-010 | | | | |
| Trichloroethene | 79-01-6 | 7.6e-007 | 1.4e-009 | B2 | 1.1e-002 | 1.5e-011 | | | | |
| 2,4,5-TP | 93-72-1 | 6.3e-007 | | | | | 1.1e-008 | 8.0e-003 | liver | 1.4e-006 |
| 2-Methylphenol | 95-48-7 | 6.2e-007 | | | | | 1.1e-008 | 5.0e-002 | neurotoxicity | 2.2e-007 |
| Benzene | 71-43-2 | 4.2e-007 | 7.5e-010 | A | 2.9e-002 | 2.2e-011 | | | | |
| Carbon disulfide | 75-15-0 | 3.2e-007 | | | | | 5.7e-009 | 1.0e-001 | fetotoxicity | 5.7e-008 |
| Chloroform | 67-66-3 | 3.0e-007 | 5.3e-010 | B2 | 6.1e-003 | 3.2e-012 | 5.3e-009 | 1.0e-002 | liver | 5.3e-007 |
| 1,1-Dichloroethene | 75-35-4 | 2.2e-007 | 3.9e-010 | C | 6.0e-001 | 2.4e-010 | 3.9e-009 | 9.0e-003 | liver | 4.4e-007 |
| 1,1-Dichloroethane | 75-34-3 | 2.0e-007 | 3.5e-010 | B2 | 9.1e-002 | 3.2e-011 | 3.5e-009 | 1.0e-001 | kidney | 3.5e-008 |
| Vinyl chloride | 75-01-4 | 1.5e-007 | 2.7e-010 | A | 1.9e+000 | 5.2e-010 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 9.6e-008 | 1.7e-010 | B2 | 9.1e-002 | 1.6e-011 | | | | |
| 2,4,5-T | 93-76-5 | 8.8e-008 | | | | | 1.6e-009 | 1.0e-002 | fetotox/kidne | 1.6e-007 |
| 2,4-D | 94-75-7 | 8.2e-008 | | | | | 1.5e-009 | 1.0e-002 | Hemato/kidney | 1.5e-007 |
| Methylene Chloride | 75-09-2 | 6.3e-008 | 1.1e-010 | B2 | 7.5e-003 | 8.5e-013 | 1.1e-009 | 6.0e-002 | liver | 1.9e-008 |
| 2-Butanone | 78-93-3 | 1.2e-008 | | | | | 2.2e-010 | 5.0e-002 | fetotoxicity | 4.4e-009 |
| Acetone | 67-64-1 | 3.7e-009 | | | | | 6.6e-011 | 1.0e-001 | kidney | 6.6e-010 |
| Silver | 7440-22-4 | 1.0e-002 | | | | | 1.8e-004 | 3.0e-003 | skin | 6.0e-002 |
| Nickel | 7440-02-0 | 5.4e-003 | | | | | 9.8e-005 | 2.0e-002 | kidney | 4.9e-003 |
| Chromium | 7440-47-3 | 1.8e-003 | | | | | 3.2e-005 | 5.0e-003 | neurotoxicity | 6.3e-003 |
| Manganese | 7439-96-5 | 7.2e-004 | | | | | 1.3e-005 | 1.0e-001 | neurotoxicity | 1.3e-004 |
| Mercury | 7439-97-6 | 3.0e-004 | | | | | 5.5e-006 | 3.0e-004 | kidney | 1.8e-002 |
| Vanadium | 7440-62-2 | 1.8e-005 | | | | | 3.2e-007 | 7.0e-003 | kidney | 4.5e-005 |
| Cadmium | 7440-43-9 | 9.9e-006 | | | | | 1.8e-007 | 1.0e-003 | kidney | 1.8e-004 |
| Sum Of Risks | | | | | | 2.4e-008 | | | | |
| Hazard Index | | | | | | | | | | 9.0e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 139.6 |
| Fraction Ingested (unitless) | 0.75 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |

| Averaging Time (d) | |
|---|---|
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.71.

Excess lifeti · ·ncer risk and hazard index for a child homesteader on WAG 6 from dermal contact with groundwater while showering

| Analyte Name | CAS Number | Concentration in Groundwater (mg/L) | CARCINOGENS Daily Intake (mg/kg/day) | USEPA Class | Slope Factor (mg/kg-day) | Excess Lifetime Cancer Risk | NONCARCINOGENS Daily Intake (mg/kg/day) | Reference Dose RfD (mg/kg-day) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| 2-Methylphenol | 95-48-7 | 1.1e-002 | | | | | 8.0e-007 | 2.5e-003 | neurotoxicit | 3.2e-004 |
| Diethylphatalate | 84-66-2 | 1.1e-002 | | | | | 8.0e-007 | 4.0e-002 | liver/kidney | 2.0e-005 |
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 1.1e-002 | 8.0e-008 | B2 | 2.8e-001 | 2.2e-008 | 8.0e-007 | 1.0e-003 | liver/kidney | 8.0e-004 |
| Naphthalene | 91-20-3 | 1.1e-002 | | | | | 8.0e-007 | 2.0e-004 | kidney | 4.0e-003 |
| Di-n-butylphatalate | 84-74-2 | 1.0e-002 | | | | | 7.3e-007 | 5.0e-003 | liver/kidney | 1.5e-004 |
| 2-Butanone | 78-93-3 | 1.0e-002 | | | | | 7.3e-007 | 2.5e-003 | fetotoxicity | 2.9e-004 |
| Vinyl chloride | 75-01-4 | 1.0e-002 | 7.3e-008 | A | 3.8e+001 | 2.8e-006 | | | | |
| Acetone | 67-64-1 | 1.0e-002 | | | | | 7.3e-007 | 5.0e-003 | kidney | 1.5e-004 |
| Toluene | 108-88-3 | 5.0e-003 | | | | | 3.6e-007 | 1.0e-002 | liver/kidney | 3.6e-005 |
| Xylenes(total) | 1330-20-7 | 5.0e-003 | | | | | 3.6e-007 | 1.0e-001 | neurotx/mort | 3.6e-006 |
| 1,1,1-Trichloroethane | 71-55-6 | 5.0e-003 | | | | | 3.6e-007 | 4.5e-003 | liver | 8.1e-005 |
| Carbon disulfide | 75-15-0 | 5.0e-003 | | | | | 3.6e-007 | 5.0e-003 | fetotoxicity | 7.3e-005 |
| Ethyl benzene | 100-41-4 | 5.0e-003 | | | | | 3.6e-007 | 5.0e-003 | kidney/liver | 7.3e-005 |
| 1,1-Dichloroethane | 75-34-3 | 5.0e-003 | 3.6e-008 | B2 | 1.8e+000 | 6.6e-008 | 3.6e-007 | 5.0e-003 | kidney | 7.3e-005 |
| 1,2-Dichloroethane | 107-06-2 | 5.0e-003 | 3.6e-008 | B2 | 1.8e+000 | 6.6e-008 | | | | |
| Carbon tetrachloride | 56-23-5 | 5.0e-003 | 3.6e-008 | B2 | 2.6e+000 | 9.5e-008 | 3.6e-007 | 3.5e-005 | liver | 1.0e-002 |
| 1,1-Dichloroethene | 75-35-4 | 5.0e-003 | 3.6e-008 | C | 1.2e+001 | 4.4e-007 | 3.6e-007 | 4.5e-004 | liver | 8.1e-004 |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | 5.0e-003 | 3.6e-008 | C | 4.0e+000 | 1.5e-007 | | | | |
| 1,1,2-Trichloroethane | 79-00-5 | 5.0e-003 | 3.6e-008 | C | 1.1e+000 | 4.2e-008 | 3.6e-007 | 2.0e-004 | immu/liv/hem | 1.8e-003 |
| Methylene Chloride | 75-09-2 | 5.0e-003 | 3.6e-008 | B2 | 1.5e-001 | 5.5e-009 | 3.6e-007 | 3.0e-003 | liver | 1.2e-004 |
| Chloroform | 67-66-3 | 5.0e-003 | 3.6e-008 | B2 | 1.2e-001 | 4.5e-009 | 3.6e-007 | 5.0e-004 | liver | 7.3e-004 |
| Trichloroethene | 79-01-6 | 5.0e-003 | 3.6e-008 | B2 | 2.2e-001 | 8.0e-009 | | | | |
| Tetrachloroethene | 127-18-4 | 5.0e-003 | 3.6e-008 | B2 | 1.0e+000 | 3.7e-008 | 3.6e-007 | 5.0e-004 | liver | 7.3e-004 |
| Benzene | 71-43-2 | 5.0e-003 | 3.6e-008 | A | 5.8e-001 | 2.1e-008 | | | | |
| 2,4-D | 94-75-7 | 2.0e-004 | | | | | 1.5e-008 | 5.0e-004 | Hemato/kidne | 2.9e-005 |
| 2,4,5-TP | 93-72-1 | 1.0e-004 | | | | | 7.3e-009 | 4.0e-004 | liver | 1.8e-005 |
| 2,4,5-T | 93-76-5 | 1.0e-004 | | | | | 7.3e-009 | 5.0e-004 | fetotox/kidn | 1.5e-005 |
| Chromium | 7440-47-3 | 2.0e-002 | | | | | 1.5e-006 | 2.5e-004 | neurotoxicit | 5.8e-003 |
| Nickel | 7440-02-0 | 2.0e-002 | | | | | 1.5e-006 | 1.0e-003 | kidney | 1.5e-003 |
| Vanadium | 7440-62-2 | 1.1e-002 | | | | | 8.0e-007 | 3.5e-004 | kidney | 2.3e-003 |
| Silver | 7440-22-4 | 5.0e-003 | | | | | 3.6e-007 | 1.5e-004 | skin | 2.4e-003 |
| Cadmium | 7440-43-9 | 2.0e-003 | | | | | 1.5e-007 | 2.5e-005 | kidney | 5.8e-003 |
| Mercury | 7439-97-6 | 2.0e-004 | | | | | 1.5e-008 | 1.5e-005 | kidney | 9.7e-004 |
| Sum Of Risks | | | | | | 3.7e-006 | | | | |
| Hazard Index | | | | | | | | | | 4.0e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (L/cm^3) | 0.001 |
| Skin Surface Area (cm^2/event) | 6950 |
| Dermal Perm. Constant (cm/h) | 0.00084 |
| Exposure Time (h/d) | 0.2 |
| Exposure Frequency (d/y) | 365 |

| | |
|---|---|
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.72.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 from dermal contact with soil

| Analyte Name | CAS Number | Concentration in Soil (mg/kg) | CARCINOGENS Daily Intake (mg/kg/day) | USEPA Class | Slope Factor (mg/kg-day) | Excess Lifetime Cancer Risk | NONCARCINOGENS Daily Intake (mg/kg/day) | Reference Dose RfD (mg/kg-day) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| Benzyl alcohol | 100-51-6 | 4.2e-001 | | | | | 2.1e-005 | 1.5e-002 | digestive | 1.4e-003 |
| Methylene Chloride | 75-09-2 | 3.3e-002 | 1.6e-007 | B2 | 1.5e-001 | 2.4e-008 | 1.6e-006 | 3.0e-003 | liver | 5.4e-004 |
| Acetone | 67-64-1 | 1.5e-002 | | | | | 7.4e-007 | 5.0e-003 | kidney | 1.5e-004 |
| Ethyl benzene | 100-41-4 | 6.0e-003 | | | | | 3.0e-007 | 5.0e-003 | kidney/liver | 5.9e-005 |
| Toluene | 108-88-3 | 6.0e-003 | | | | | 3.0e-007 | 1.0e-002 | liver/kidney | 3.0e-005 |
| Xylenes(total) | 1330-20-7 | 6.0e-003 | | | | | 3.0e-007 | 1.0e-001 | neurotx/mort | 3.0e-006 |
| Trichloroethene | 79-01-6 | 6.0e-003 | 3.0e-008 | B2 | 2.2e-001 | 6.5e-009 | | | | |
| Vanadium | 7440-62-2 | 2.2e+001 | | | | | 4.4e-005 | 3.5e-004 | kidney | 1.2e-001 |
| Thallium | 7440-28-0 | 5.0e-001 | | | | | 9.9e-007 | 3.5e-006 | skin | 2.8e-001 |
| Sum Of Risks | | | | | | 3.1e-008 | | | | |
| Hazard Index | | | | | | | | | | 4.1e-001 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (kg/mg) | 1.e-06 |
| Skin Surface Area (cm^2/event) | 2960 |
| Adherence Factor (mg/cm^3) | 2.77 |
| Absorption Factor | |
| Voc | 0.25 |
| Svoc | 0.10 |
| Inorganics | 0.01 |

| | |
|---|---|
| Exposure Frequency (event/y) | 141 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.73.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 from dermal contact with sediment

| Analyte Name | CAS Number | Concentration in Sediment (mg/kg) | CARCINOGENS Daily Intake (mg/kg/day) | USEPA Class | Slope Factor (mg/kg-day) | Excess Lifetime Cancer Risk | NONCARCINOGENS Daily Intake (mg/kg/day) | Reference Dose RfD (mg/kg-day) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| 2-Butanone | 78-93-3 | 1.4e-001 | | | | | 5.2e-006 | 2.5e-003 | fetotoxicity | 2.1e-003 |
| Trichlorofluoromethane | 75-69-4 | 7.2e-002 | | | | | 2.7e-006 | 1.5e-002 | resp/cardiova | 1.8e-004 |
| Methylene Chloride | 75-09-2 | 3.1e-002 | 1.1e-007 | B2 | 1.5e-001 | 1.7e-008 | 1.1e-006 | 3.0e-003 | liver | 3.8e-004 |
| Acetone | 67-64-1 | 1.3e-002 | | | | | 4.8e-007 | 5.0e-003 | kidney | 9.6e-005 |
| Chloroform | 67-66-3 | 1.3e-002 | 4.8e-008 | B2 | 1.2e-001 | 5.9e-009 | 4.8e-007 | 5.0e-004 | liver | 9.6e-004 |
| Trichloroethene | 79-01-6 | 6.0e-003 | 2.2e-008 | B2 | 2.2e-001 | 4.9e-009 | | | | |
| Toluene | 108-88-3 | 6.0e-003 | | | | | 2.2e-007 | 1.0e-002 | liver/kidney | 2.2e-005 |
| Silver | 7440-22-4 | 2.5e+000 | | | | | 3.7e-006 | 1.5e-004 | skin | 2.5e-002 |
| Sum Of Risks | | | | | | 2.8e-008 | | | | |
| Hazard Index | | | | | | | | | | 2.8e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (kg/mg) | 1.e-06 |
| Skin Surface Area (cm^2/event) | 6950 |
| Adherence Factor (mg/cm^3) | 2.77 |
| Absorption Factor | |
| Voc | 0.25 |
| Svoc | 0.10 |
| Inorganics | 0.01 |

| | |
|---|---|
| Exposure Frequency (event/y) | 45 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (day) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.74.

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 auger hole sub area from the incidental ingestion of soil

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Soil (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Vanadium | 7440-62-2 | 2.3e+001 | | | | | 3.3e-005 | 7.0e-003 | kidney | 4.7e-003 |
| Sum Of Risks | | | | | | | | | | |
| Hazard Index | | | | | | | | | | 4.7e-003 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Ingestion Rate (mg/d) | 100 |
| Conversion Factor (kg/mg) | 1.0e-006 |
| Fraction Ingested (unitless) | 1 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.75.

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 auger hole sub area from the incidental ingestion of sediment while swimming at the EWB

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Sediment (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| 2-Butanone | 78-93-3 | 1.4e-001 | | | | | 2.5e-008 | 5.0e-002 | fetotoxicity | 4.9e-007 |
| Trichlorofluoromethane | 75-69-4 | 7.2e-002 | | | | | 1.3e-008 | 3.0e-001 | resp/cardiova | 4.2e-008 |
| Methylene Chloride | 75-09-2 | 3.1e-002 | 2.3e-009 | B2 | 7.5e-003 | 1.8e-011 | 5.5e-009 | 6.0e-002 | liver | 9.1e-008 |
| Acetone | 67-64-1 | 1.3e-002 | | | | | 2.3e-009 | 1.0e-001 | kidney | 2.3e-008 |
| Chloroform | 67-66-3 | 1.3e-002 | 9.8e-010 | B2 | 6.1e-003 | 6.0e-012 | 2.3e-009 | 1.0e-002 | liver | 2.3e-007 |
| Trichloroethene | 79-01-6 | 6.0e-003 | 4.5e-010 | B2 | 1.1e-002 | 5.0e-012 | | | | |
| Toluene | 108-88-3 | 6.0e-003 | | | | | 1.1e-009 | 2.0e-001 | liver/kidney | 5.3e-009 |
| Silver | 7440-22-4 | 2.5e+000 | | | | | 4.4e-007 | 3.0e-003 | skin | 1.5e-004 |
| Sum Of Risks | | | | | | 2.9e-011 | | | | |
| Hazard Index | | | | | | | | | | 1.5e-004 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Ingestion Rate (mg/d) | 100 |
| Conversion Factor (kg/mg) | 1.0e-006 |
| Fraction Ingested | 1 |
| Exposure Frequency (d/y) | 45 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.76.

Excess Lifetime Cancer Risk and Hazard Index for an adult homesteader on WAG 6 auger hole sub area from the inhalation of vapors

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Air (mg/m^3) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Target Organ | Hazard Quotient |
| Tetrachloroethene | 127-18-4 | 3.3e-008 | 6.1e-009 | B2 | 1.8e-003 | 1.1e-011 | | | | |
| Chloromethane | 74-87-3 | 2.6e-008 | 4.8e-009 | C | 6.3e-003 | 3.0e-011 | | | | |
| Xylenes(total) | 1330-20-7 | 2.4e-008 | | | | | 1.0e-008 | 1.0e-001 | neurotoxicity | 1.0e-007 |
| Trichloroethene | 79-01-6 | 1.3e-008 | 2.3e-009 | B2 | 1.7e-002 | 3.9e-011 | | | | |
| Toluene | 108-88-3 | 1.0e-008 | | | | | 4.4e-009 | 6.0e-001 | neurotoxicity | 7.4e-009 |
| Benzene | 71-43-2 | 9.5e-009 | 1.7e-009 | A | 2.9e-002 | 5.1e-011 | | | | |
| Ethyl benzene | 100-41-4 | 8.5e-009 | | | | | 3.7e-009 | 3.0e-001 | fetotoxicity | 1.2e-008 |
| Chloroform | 67-66-3 | 6.8e-009 | 1.3e-009 | B2 | 8.1e-002 | 1.0e-010 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 2.5e-009 | 4.6e-010 | B2 | 9.1e-002 | 4.2e-011 | | | | |
| Sum Of Risks | | | | | | 2.7e-010 | | | | |
| Hazard Index | | | | | | | | | | 1.2e-007 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Inhalation Rate (m^3/h) | 1.25 |
| Exposure Time (h/d) | 24 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.77.

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 auger hole sub area from the inhalation of chemicals while showering with groundwater

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Groundwater (mg/L) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Trichloroethene | 79-01-6 | 3.2e-001 | 1.8e-003 | B2 | 1.7e-002 | 3.0e-005 | | | | |
| Chloroform | 67-66-3 | 6.1e-002 | 3.4e-004 | B2 | 8.1e-002 | 2.7e-005 | | | | |
| Carbon tetrachloride | 56-23-5 | 5.2e-002 | 2.9e-004 | B2 | 1.3e-001 | 3.7e-005 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 1.9e-002 | 1.0e-004 | B2 | 9.1e-002 | 9.5e-006 | | | | |
| Tetrachloroethene | 127-18-4 | 5.0e-003 | 2.8e-005 | B2 | 1.8e-003 | 5.0e-008 | | | | |
| 1,1-Dichloroethane | 75-34-3 | 5.0e-003 | | | | | 6.4e-005 | 1.0e-001 | kidney | 6.4e-004 |
| Methylene Chloride | 75-09-2 | 5.0e-003 | 2.8e-005 | B2 | 1.6e-003 | 4.5e-008 | 6.4e-005 | 9.0e-001 | liver | 7.1e-005 |
| Sum Of Risks | | | | | | 1.0e-004 | | | | |
| Hazard Index | | | | | | | | | | 7.1e-004 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Shower Water Consumption (L) | 180 |
| Volatilization Fraction (unitless) | 0.5 |
| Shower area Capacity (m^3) | 12 |
| Inhalation Rate (m^3/h) | 0.6 |
| Exposure Time (h/d) | 0.2 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |

| | |
|---|---|
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.78.

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 auger hole sub area from the ingestion of groundwater as drinking water

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Groundwater (mg/L) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Trichloroethene | 79-01-6 | 3.2e-001 | 3.9e-003 | B2 | 1.1e-002 | 4.3e-005 | | | | |
| Chloroform | 67-66-3 | 6.1e-002 | 7.5e-004 | B2 | 6.1e-003 | 4.6e-006 | 1.7e-003 | 1.0e-002 | liver | 1.7e-001 |
| Carbon tetrachloride | 56-23-5 | 5.2e-002 | 6.4e-004 | B2 | 1.3e-001 | 8.3e-005 | 1.5e-003 | 7.0e-004 | liver | 2.1e+000 |
| 1,2-Dichloroethane | 107-06-2 | 1.9e-002 | 2.3e-004 | B2 | 9.1e-002 | 2.1e-005 | | | | |
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 1.1e-002 | 1.3e-004 | B2 | 1.4e-002 | 1.9e-006 | 3.1e-004 | 2.0e-002 | liver/kidney | 1.6e-002 |
| Di-n-butylphatalate | 84-74-2 | 1.1e-002 | | | | | 3.1e-004 | 1.0e-001 | liver/kidney | 3.1e-003 |
| Diethylphatalate | 84-66-2 | 1.1e-002 | | | | | 3.1e-004 | 8.0e-001 | liver/kidney | 3.9e-004 |
| 1,1-Dichloroethane | 75-34-3 | 5.0e-003 | 6.1e-005 | B2 | 9.1e-002 | 5.6e-006 | 1.4e-004 | 1.0e-001 | kidney | 1.4e-003 |
| Tetrachloroethene | 127-18-4 | 5.0e-003 | 6.1e-005 | B2 | 5.1e-002 | 3.1e-006 | 1.4e-004 | 1.0e-002 | liver | 1.4e-002 |
| Methylene Chloride | 75-09-2 | 5.0e-003 | 6.1e-005 | B2 | 7.5e-003 | 4.6e-007 | 1.4e-004 | 6.0e-002 | liver | 2.4e-003 |
| 2,4-D | 94-75-7 | 2.0e-004 | | | | | 5.7e-006 | 1.0e-002 | Hemato/kidney | 5.7e-004 |
| 2,4,5-TP | 93-72-1 | 1.0e-004 | | | | | 2.9e-006 | 8.0e-003 | liver | 3.6e-004 |
| Chromium | 7440-47-3 | 2.0e-002 | | | | | 5.7e-004 | 5.0e-003 | neurotoxicity | 1.1e-001 |
| Nickel | 7440-02-0 | 2.0e-002 | | | | | 5.7e-004 | 2.0e-002 | kidney | 2.9e-002 |
| Vanadium | 7440-62-2 | 1.1e-002 | | | | | 3.1e-004 | 7.0e-003 | kidney | 4.5e-002 |
| Cadmium | 7440-43-9 | 5.0e-003 | | | | | 1.4e-004 | 5.0e-004 | kidney | 2.9e-001 |
| Sum Of Risks | | | | | | 1.6e-004 | | | | |
| Hazard Index | | | | | | | | | | 2.8e+000 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Ingestion Rate (L/d) | 2 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.79.

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 auger hole sub area from the ingestion of fruit

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Fruit (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Toluene | 108-88-3 | 3.2e-004 | | | | | 1.9e-007 | 2.0e-001 | liver/kidney | 9.6e-007 |
| Xylenes(total) | 1330-20-7 | 4.1e-006 | | | | | 2.5e-009 | 2.0e+000 | neurotx/mort | 1.2e-009 |
| Ethyl benzene | 100-41-4 | 1.6e-006 | | | | | 9.3e-010 | 1.0e-001 | kidney/liver | 9.3e-009 |
| Tetrachloroethene | 127-18-4 | 1.5e-006 | 3.8e-010 | B2 | 5.1e-002 | 1.9e-011 | 8.9e-010 | 1.0e-002 | liver | 8.9e-008 |
| Trichloroethene | 79-01-6 | 2.5e-008 | 6.5e-012 | B2 | 1.1e-002 | 7.1e-014 | | | | |
| Carbon disulfide | 75-15-0 | 1.5e-008 | | | | | 9.1e-012 | 1.0e-001 | fetotoxicity | 9.1e-011 |
| Benzene | 71-43-2 | 6.5e-009 | 1.7e-012 | A | 2.9e-002 | 4.8e-014 | | | | |
| Chloroform | 67-66-3 | 1.5e-009 | 3.9e-013 | B2 | 6.1e-003 | 2.4e-015 | 9.1e-013 | 1.0e-002 | liver | 9.1e-011 |
| Chloromethane | 74-87-3 | 1.1e-009 | 2.9e-013 | C | 1.3e-002 | 3.7e-015 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 6.9e-010 | 1.8e-013 | B2 | 9.1e-002 | 1.6e-014 | | | | |
| Sum Of Risks | | | | | | 2.0e-011 | | | | |
| Hazard Index | | | | | | | | | | 1.1e-006 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 51.1 |
| Fraction Ingested (unitless) | 0.3 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.80.

Excess Lifetime Cancer Risk and Hazard Index for an adult homesteader on WAG 6 auger hole sub area from the ingestion of Vegetables

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Vegetables (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Toluene | 108-88-3 | 3.2e-004 | | | | | 3.7e-007 | 2.0e-001 | liver/kidney | 1.8e-006 |
| Xylenes(total) | 1330-20-7 | 4.1e-006 | | | | | 4.7e-009 | 2.0e+000 | neurotx/mort | 2.4e-009 |
| Ethyl benzene | 100-41-4 | 1.6e-006 | | | | | 1.8e-009 | 1.0e-001 | kidney/liver | 1.8e-008 |
| Tetrachloroethene | 127-18-4 | 1.5e-006 | 7.3e-010 | B2 | 5.1e-002 | 3.7e-011 | 1.7e-009 | 1.0e-002 | liver | 1.7e-007 |
| Trichloroethene | 79-01-6 | 2.5e-008 | 1.2e-011 | B2 | 1.1e-002 | 1.4e-013 | | | | |
| Carbon disulfide | 75-15-0 | 1.5e-008 | | | | | 1.7e-011 | 1.0e-001 | fetotoxicity | 1.7e-010 |
| Benzene | 71-43-2 | 6.5e-009 | 3.2e-012 | A | 2.9e-002 | 9.2e-014 | | | | |
| Chloroform | 67-66-3 | 1.5e-009 | 7.4e-013 | B2 | 6.1e-003 | 4.5e-015 | 1.7e-012 | 1.0e-002 | liver | 1.7e-010 |
| Chloromethane | 74-87-3 | 1.1e-009 | 5.5e-013 | C | 1.3e-002 | 7.1e-015 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 6.9e-010 | 3.4e-013 | B2 | 9.1e-002 | 3.1e-014 | | | | |
| Sum Of Risks | | | | | | 3.7e-011 | | | | |
| Hazard Index | | | | | | | | | | 2.0e-006 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 73 |
| Fraction Ingested (unitless) | 0.4 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

**Table 6I.81.**

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 auger hole sub area from the ingestion of beef

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Beef (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 1.4e-003 | 6.5e-007 | B2 | 1.4e-002 | 9.2e-009 | 1.5e-006 | 2.0e-002 | liver/kidney | 7.6e-005 |
| Di-n-butylphatalate | 84-74-2 | 5.7e-004 | | | | | 6.1e-007 | 1.0e-001 | liver/kidney | 6.1e-006 |
| Trichloroethene | 79-01-6 | 7.7e-005 | 3.5e-008 | B2 | 1.1e-002 | 3.9e-010 | | | | |
| Carbon tetrachloride | 56-23-5 | 2.3e-005 | 1.0e-008 | B2 | 1.3e-001 | 1.4e-009 | 2.4e-008 | 7.0e-004 | liver | 3.5e-005 |
| Chloroform | 67-66-3 | 5.7e-006 | 2.6e-009 | B2 | 6.1e-003 | 1.6e-011 | 6.1e-009 | 1.0e-002 | liver | 6.1e-007 |
| Diethylphatalate | 84-66-2 | 3.3e-006 | | | | | 3.5e-009 | 8.0e-001 | liver/kidney | 4.4e-009 |
| Tetrachloroethene | 127-18-4 | 2.0e-006 | 9.2e-010 | B2 | 5.1e-002 | 4.7e-011 | 2.1e-009 | 1.0e-002 | liver | 2.1e-007 |
| 2,4,5-TP | 93-72-1 | 1.0e-006 | | | | | 1.1e-009 | 8.0e-003 | liver | 1.3e-007 |
| 1,2-Dichloroethane | 107-06-2 | 5.8e-007 | 2.6e-010 | B2 | 9.1e-002 | 2.4e-011 | | | | |
| 1,1-Dichloroethane | 75-34-3 | 3.1e-007 | 1.4e-010 | B2 | 9.1e-002 | 1.3e-011 | 3.3e-010 | 1.0e-001 | kidney | 3.3e-009 |
| 2,4-D | 94-75-7 | 1.3e-007 | | | | | 1.4e-010 | 1.0e-002 | Hemato/kidney | 1.4e-008 |
| Methylene Chloride | 75-09-2 | 1.0e-007 | 4.6e-011 | B2 | 7.5e-003 | 3.5e-013 | 1.1e-010 | 6.0e-002 | liver | 1.8e-009 |
| Manganese | 7439-96-5 | 1.3e-002 | | | | | 1.4e-005 | 1.0e-001 | neurotoxicity | 1.4e-004 |
| Cadmium | 7440-43-9 | 3.2e-003 | | | | | 3.4e-006 | 1.0e-003 | kidney | 3.4e-003 |
| Nickel | 7440-02-0 | 8.0e-004 | | | | | 8.6e-007 | 2.0e-002 | kidney | 4.3e-005 |
| Chromium | 7440-47-3 | 7.9e-004 | | | | | 8.5e-007 | 5.0e-003 | neurotoxicity | 1.7e-004 |
| Sum Of Risks | | | | | | 1.1e-008 | | | | |
| Hazard Index | | | | | | | | | | 3.9e-003 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 36.5 |
| Fraction Ingested (unitless) | 0.75 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.82.

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 auger hole sub area from the ingestion of milk

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Milk (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 9.0e-004 | 1.7e-006 | B2 | 1.4e-002 | 2.3e-008 | 3.9e-006 | 2.0e-002 | liver/kidney | 1.9e-004 |
| Di-n-butylphatalate | 84-74-2 | 3.7e-004 | | | | | 1.6e-006 | 1.0e-001 | liver/kidney | 1.6e-005 |
| Trichloroethene | 79-01-6 | 4.9e-005 | 9.0e-008 | B2 | 1.1e-002 | 9.9e-010 | | | | |
| Carbon tetrachloride | 56-23-5 | 1.4e-005 | 2.6e-008 | B2 | 1.3e-001 | 3.4e-009 | 6.2e-008 | 7.0e-004 | liver | 8.8e-005 |
| Chloroform | 67-66-3 | 3.6e-006 | 6.6e-009 | B2 | 6.1e-003 | 4.1e-011 | 1.6e-008 | 1.0e-002 | liver | 1.6e-006 |
| Diethylphatalate | 84-66-2 | 2.1e-006 | | | | | 8.8e-009 | 8.0e-001 | liver/kidney | 1.1e-008 |
| Tetrachloroethene | 127-18-4 | 1.3e-006 | 2.3e-009 | B2 | 5.1e-002 | 1.2e-010 | 5.4e-009 | 1.0e-002 | liver | 5.4e-007 |
| 2,4,5-TP | 93-72-1 | 6.3e-007 | | | | | 2.7e-009 | 8.0e-003 | liver | 3.4e-007 |
| 1,2-Dichloroethane | 107-06-2 | 3.6e-007 | 6.7e-010 | B2 | 9.1e-002 | 6.1e-011 | | | | |
| 1,1-Dichloroethane | 75-34-3 | 2.0e-007 | 3.6e-010 | B2 | 9.1e-002 | 3.3e-011 | 8.4e-010 | 1.0e-001 | kidney | 8.4e-009 |
| 2,4-D | 94-75-7 | 8.2e-008 | | | | | 3.5e-010 | 1.0e-002 | Hemato/kidney | 3.5e-008 |
| Methylene Chloride | 75-09-2 | 6.3e-008 | 1.2e-010 | B2 | 7.5e-003 | 8.7e-013 | 2.7e-010 | 6.0e-002 | liver | 4.5e-009 |
| Nickel | 7440-02-0 | 5.4e-003 | | | | | 2.3e-005 | 2.0e-002 | kidney | 1.2e-003 |
| Chromium | 7440-47-3 | 1.8e-003 | | | | | 7.5e-006 | 5.0e-003 | neurotoxicity | 1.5e-003 |
| Manganese | 7439-96-5 | 5.0e-004 | | | | | 2.2e-006 | 1.0e-001 | neurotoxicity | 2.2e-005 |
| Cadmium | 7440-43-9 | 2.5e-005 | | | | | 1.1e-007 | 1.0e-003 | kidney | 1.1e-004 |
| Vanadium | 7440-62-2 | 1.8e-005 | | | | | 7.5e-008 | 7.0e-003 | kidney | 1.1e-005 |
| Sum Of Risks | | | | | | 2.8e-008 | | | | |
| Hazard Index | | | | | | | | | | 3.1e-003 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 146 |
| Fraction Ingested (unitless) | 0.75 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.83.

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 auger hole sub area from dermal contact with groundwater while showering

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Groundwater (mg/L) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Trichloroethene | 79-01-6 | 3.2e-001 | 6.0e-006 | B2 | 2.2e-001 | 1.3e-006 | | | | |
| Chloroform | 67-66-3 | 6.1e-002 | 1.1e-006 | B2 | 1.2e-001 | 1.4e-007 | 2.7e-006 | 5.0e-004 | liver | 5.3e-003 |
| Carbon tetrachloride | 56-23-5 | 5.2e-002 | 9.7e-007 | B2 | 2.6e+000 | 2.5e-006 | 2.3e-006 | 3.5e-005 | liver | 6.5e-002 |
| 1,2-Dichloroethane | 107-06-2 | 1.9e-002 | 3.5e-007 | B2 | 1.8e+000 | 6.5e-007 | | | | |
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 1.1e-002 | 2.1e-007 | B2 | 2.8e-001 | 5.7e-008 | 4.8e-007 | 1.0e-003 | liver/kidney | 4.8e-004 |
| Di-n-butylphatalate | 84-74-2 | 1.1e-002 | | | | | 4.8e-007 | 5.0e-003 | liver/kidney | 9.6e-005 |
| Diethylphatalate | 84-66-2 | 1.1e-002 | | | | | 4.8e-007 | 4.0e-002 | liver/kidney | 1.2e-005 |
| 1,1-Dichloroethane | 75-34-3 | 5.0e-003 | 9.3e-008 | B2 | 1.8e+000 | 1.7e-007 | 2.2e-007 | 5.0e-003 | kidney | 4.4e-005 |
| Tetrachloroethene | 127-18-4 | 5.0e-003 | 9.3e-008 | B2 | 1.0e+000 | 9.5e-008 | 2.2e-007 | 5.0e-004 | liver | 4.4e-004 |
| Methylene Chloride | 75-09-2 | 5.0e-003 | 9.3e-008 | B2 | 1.5e-001 | 1.4e-008 | 2.2e-007 | 3.0e-003 | liver | 7.3e-005 |
| 2,4-D | 94-75-7 | 2.0e-004 | | | | | 8.7e-009 | 5.0e-004 | Hemato/kidney | 1.7e-005 |
| 2,4,5-TP | 93-72-1 | 1.0e-004 | | | | | 4.4e-009 | 4.0e-004 | liver | 1.1e-005 |
| Chromium | 7440-47-3 | 2.0e-002 | | | | | 8.7e-007 | 2.5e-004 | neurotoxicity | 3.5e-003 |
| Nickel | 7440-02-0 | 2.0e-002 | | | | | 8.7e-007 | 1.0e-003 | kidney | 8.7e-004 |
| Vanadium | 7440-62-2 | 1.1e-002 | | | | | 4.8e-007 | 3.5e-004 | kidney | 1.4e-003 |
| Cadmium | 7440-43-9 | 5.0e-003 | | | | | 2.2e-007 | 2.5e-005 | kidney | 8.7e-003 |
| Sum Of Risks | | | | | | 5.0e-006 | | | | |
| Hazard Index | | | | | | | | | | 8.6e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (L/cm^3) | 0.001 |
| Skin Surface Area (cm^2/event) | 18150 |
| Dermal Perm. Constant (cm/h) | 0.00084 |
| Exposure Time (h/d) | 0.2 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |

| Averaging Time (d) | |
|---|---|
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.84.

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 auger hole sub area from dermal contact with soil

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Soil (mg/kg) | Daily Intake (mg/kg/day) | USEPA Class | Slope Factor (mg/kg-day) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg/day) | Reference Dose RfD (mg/kg-day) | Effect | Hazard Quotient |
| Vanadium | 7440-62-2 | 2.3e+001 | | | | | 3.3e-006 | 3.5e-004 | kidney | 9.6e-003 |
| Sum Of Risks | | | | | | | | | | 9.6e-003 |
| Hazard Index | | | | | | | | | | |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (kg/mg) | 1.0e-006 |
| Skin Surface Area (cm^2/event) | 3120 |
| Adherence Factor (mg/cm^3) | 2.77 |
| Absorption Factor | |
| Voc | 0.25 |
| Svoc | 0.1 |
| Inorganic | 0.01 |
| Exposure Frequency (event/y) | 43 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.85.

Excess lifetime cancer risk and hazard index for an adult homesteader on WAG 6 auger hole sub area from dermal contact with sediment

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Sediment (mg/kg) | Daily Intake (mg/kg/day) | USEPA Class | Slope Factor (mg/kg-day) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg/day) | Reference Dose RfD (mg/kg-day) | Effect | Hazard Quotient |
| 2-Butanone | 78-93-3 | 1.4e-001 | | | | | 3.1e-006 | 2.5e-003 | fetotoxicity | 1.2e-003 |
| Trichlorofluoromethane | 75-69-4 | 7.2e-002 | | | | | 1.6e-006 | 1.5e-002 | resp/cardiov | 1.1e-004 |
| Methylene Chloride | 75-09-2 | 3.1e-002 | 2.9e-007 | B2 | 1.5e-001 | 4.4e-008 | 6.9e-007 | 3.0e-003 | liver | 2.3e-004 |
| Acetone | 67-64-1 | 1.3e-002 | | | | | 2.9e-007 | 5.0e-003 | kidney | 5.8e-005 |
| Chloroform | 67-66-3 | 1.3e-002 | 1.2e-007 | B2 | 1.2e-001 | 1.5e-008 | 2.9e-007 | 5.0e-004 | liver | 5.8e-004 |
| Trichloroethene | 79-01-6 | 6.0e-003 | 5.7e-008 | B2 | 2.2e-001 | 1.3e-008 | | | | |
| Toluene | 108-88-3 | 6.0e-003 | | | | | 1.3e-007 | 1.0e-002 | liver/kidney | 1.3e-005 |
| Silver | 7440-22-4 | 2.5e+000 | | | | | 2.2e-006 | 1.5e-004 | skin | 1.5e-002 |
| Sum Of Risks | | | | | | 7.2e-008 | | | | |
| Hazard Index | | | | | | | | | | 1.7e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (kg/mg) | 1.0e-006 |
| Skin Surface Area (cm 2/event) | 18150 |
| Adherence Factor (mg/cm^3) | 2.77 |
| Absorption Factor | |
| Voc | 0.25 |
| Svoc | 0.1 |
| Inorganics | 0.01 |

| | |
|---|---|
| Exposure Frequency (event/y) | 45 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogen | 70 y * 365 d/y |
| Noncarcinogen | 30 y * 365 d/y |

Table 6I.86.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 auger hole sub area from the incidental ingestion of soil

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Soil (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Vanadium | 7440-62-2 | 2.3e+001 | | | | | 2.9e-004 | 7.0e-003 | kidney | 4.1e-002 |
| Sum Of Risks | | | | | | | | | | |
| Hazard Index | | | | | | | | | | 4.1e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Ingestion Rate (mg/d) | 200 |
| Conversion Factor (kg/mg) | 1.0e-006 |
| Fraction Ingested (unitless) | 1 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.87.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 auger hole sub area from the incidental ingestion of sediment while swimming at the EWB

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Sediment (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| 2-Butanone | 78-93-3 | 1.4e-001 | | | | | 2.2e-007 | 5.0e-002 | fetotoxicity | 4.3e-006 |
| Trichlorofluoromethane | 75-69-4 | 7.2e-002 | | | | | 1.1e-007 | 3.0e-001 | resp/cardiova | 3.7e-007 |
| ·Methylene Chloride | 75-09-2 | 3.1e-002 | 4.8e-009 | B2 | 7.5e-003 | 3.6e-011 | 4.8e-008 | 6.0e-002 | liver | 8.0e-007 |
| Acetone | 67-64-1 | 1.3e-002 | | | | | 2.0e-008 | 1.0e-001 | kidney | 2.0e-007 |
| Chloroform | 67-66-3 | 1.3e-002 | 2.0e-009 | B2 | 6.1e-003 | 1.2e-011 | 2.0e-008 | 1.0e-002 | liver | 2.0e-006 |
| Trichloroethene | 79-01-6 | 6.0e-003 | 9.2e-010 | B2 | 1.1e-002 | 1.0e-011 | | | | |
| Toluene | 108-88-3 | 6.0e-003 | | | | | 9.2e-009 | 2.0e-001 | liver/kidney | 4.6e-008 |
| Silver | 7440-22-4 | 2.5e+000 | | | | | 3.9e-006 | 3.0e-003 | skin | 1.3e-003 |
| Sum Of Risks | | | | | | 5.8e-011 | | | | |
| Hazard Index | | | | | | | | | | 1.3e-003 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Ingestion Rate (mg/d) | 200 |
| Conversion Factor (kg/mg) | 1.0e-006 |
| Fraction Ingested | 1 |
| Exposure Frequency (d/y) | 45 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |

| Averaging Time (d) | |
|---|---|
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.88.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 auger hole sub area from the inhalation of the vapor phase

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Air (mg/m^3) | Daily Intake (mg/kg-d) | USEPA CLass | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Tetrachloroethene | 127-18-4 | 3.3e-008 | 3.0e-009 | B2 | 1.8e-003 | 5.4e-012 | | | | |
| Chloromethane | 74-87-3 | 2.6e-008 | 2.3e-009 | C | 6.3e-003 | 1.5e-011 | | | | |
| Xylenes(total) | 1330-20-7 | 2.4e-008 | | | | | 2.1e-008 | 1.0e-001 | neurotoxicity | 2.1e-007 |
| Trichloroethene | 79-01-6 | 1.3e-008 | 1.1e-009 | B2 | 1.7e-002 | 1.9e-011 | | | | |
| Toluene | 108-88-3 | 1.0e-008 | | | | | 9.3e-009 | 6.0e-001 | neurotoxicity | 1.6e-008 |
| Benzene | 71-43-2 | 9.5e-009 | 8.6e-010 | A | 2.9e-002 | 2.5e-011 | | | | |
| Ethyl benzene | 100-41-4 | 8.5e-009 | | | | | 7.7e-009 | 3.0e-001 | fetotoxicity | 2.6e-008 |
| Chloroform | 67-66-3 | 6.8e-009 | 6.2e-010 | B2 | 8.1e-002 | 5.0e-011 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 2.5e-009 | 2.3e-010 | B2 | 9.1e-002 | 2.1e-011 | | | | |
| Sum Of Risks | | | | | | 1.3e-010 | | | | |
| Hazard Index | | | | | | | | | | 2.5e-007 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Inhalation Rate (m^3/h) | 0.6 |
| Exposure Time (h/d) | 24 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.89.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 auger hole sub area from the inhalation of chemicals while showering with groundwater

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Groundwater (mg/L) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Trichloroethene | 79-01-6 | 3.2e-001 | 1.8e-003 | B2 | 1.7e-002 | 3.1e-005 | | | | |
| Chloroform | 67-66-3 | 6.1e-002 | 3.4e-004 | B2 | 8.1e-002 | 2.8e-005 | | | | |
| Carbon tetrachloride | 56-23-5 | 5.2e-002 | 2.9e-004 | B2 | 1.3e-001 | 3.8e-005 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 1.9e-002 | 1.1e-004 | B2 | 9.1e-002 | 9.7e-006 | | | | |
| Tetrachloroethene | 127-18-4 | 5.0e-003 | 2.8e-005 | B2 | 1.8e-003 | 5.1e-008 | | | | |
| 1,1-Dichloroethane | 75-34-3 | 5.0e-003 | | | | | 2.8e-004 | 1.0e-001 | kidney | 2.8e-003 |
| Methylene Chloride | 75-09-2 | 5.0e-003 | 2.8e-005 | B2 | 1.6e-003 | 4.6e-008 | 2.8e-004 | 9.0e-001 | liver | 3.1e-004 |
| Sum Of Risks | | | | | | 1.1e-004 | | | | |
| Hazard Index | | | | | | | | | | 3.1e-003 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Inhalation Rate (m^3/h) | 0.6 |
| Shower Water Consumption (L) | 180 |
| Volatilization Fraction(unitless) | 0.5 |
| Shower Area Capacity (m^3) | 12 |
| Exposure Time (h/d) | 0.2 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |

| Averaging Time (d) | |
|---|---|
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 61.90.

Excess Lifetime Cancer Risk and Hazard Index for a child homesteader on WAG 6 auger hole sub area from the ingestion of groundwater as drinking water

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Groundwater (mg/L) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Trichloroethene | 79-01-6 | 3.2e-001 | 2.0e-003 | B2 | 1.1e-002 | 2.2e-005 | | | | |
| Chloroform | 67-66-3 | 6.1e-002 | 3.8e-004 | B2 | 6.1e-003 | 2.3e-006 | 3.8e-003 | 1.0e-002 | liver | 3.8e-001 |
| Carbon tetrachloride | 56-23-5 | 5.2e-002 | 3.3e-004 | B2 | 1.3e-001 | 4.2e-005 | 3.3e-003 | 7.0e-004 | liver | 4.6e+000 |
| 1,2-Dichloroethane | 107-06-2 | 1.9e-002 | 1.2e-004 | B2 | 9.1e-002 | 1.1e-005 | | | | |
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 1.1e-002 | 6.9e-005 | B2 | 1.4e-002 | 9.6e-007 | 6.9e-004 | 2.0e-002 | liver/kidney | 3.4e-002 |
| Di-n-butylphatalate | 84-74-2 | 1.1e-002 | | | | | 6.9e-004 | 1.0e-001 | liver/kidney | 6.9e-003 |
| Diethylphatalate | 84-66-2 | 1.1e-002 | | | | | 6.9e-004 | 8.0e-001 | liver/kidney | 8.6e-004 |
| 1,1-Dichloroethane | 75-34-3 | 5.0e-003 | 3.1e-005 | B2 | 9.1e-002 | 2.8e-006 | 3.1e-004 | 1.0e-001 | kidney | 3.1e-003 |
| Tetrachloroethene | 127-18-4 | 5.0e-003 | 3.1e-005 | B2 | 5.1e-002 | 1.6e-006 | 3.1e-004 | 1.0e-002 | liver | 3.1e-002 |
| Methylene Chloride | 75-09-2 | 5.0e-003 | 3.1e-005 | B2 | 7.5e-003 | 2.3e-007 | 3.1e-004 | 6.0e-002 | liver | 5.2e-003 |
| 2,4-D | 94-75-7 | 2.0e-004 | | | | | 1.3e-005 | 1.0e-002 | Hemato/kidney | 1.3e-003 |
| 2,4,5-TP | 93-72-1 | 1.0e-004 | | | | | 6.3e-006 | 8.0e-003 | liver | 7.8e-004 |
| Chromium | 7440-47-3 | 2.0e-002 | | | | | 1.3e-003 | 5.0e-003 | neurotoxicity | 2.5e-001 |
| Nickel | 7440-02-0 | 2.0e-002 | | | | | 1.3e-003 | 2.0e-002 | kidney | 6.3e-002 |
| Vanadium | 7440-62-2 | 1.1e-002 | | | | | 6.9e-004 | 7.0e-003 | kidney | 9.8e-002 |
| Cadmium | 7440-43-9 | 5.0e-003 | | | | | 3.1e-004 | 5.0e-004 | kidney | 6.3e-001 |
| Sum Of Risks | | | | | | 8.3e-005 | | | | |
| Hazard Index | | | | | | | | | | 6.1e+000 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Ingestion Rate (L/d) | 1 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.91.

Excess lifetime cancer risk and hazard quotient for a child homesteader on WAG 6 auger hole sub area from the ingestion of fruit

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Fruit (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Toluene | 108-88-3 | 3.2e-004 | | | | | 8.9e-007 | 2.0e-001 | liver/kidney | 4.4e-006 |
| Xylenes(total) | 1330-20-7 | 4.1e-006 | | | | | 1.1e-008 | 2.0e+000 | neurotx/mort | 5.7e-009 |
| Ethyl benzene | 100-41-4 | 1.6e-006 | | | | | 4.3e-009 | 1.0e-001 | kidney/liver | 4.3e-008 |
| Tetrachloroethene | 127-18-4 | 1.5e-006 | 4.1e-010 | B2 | 5.1e-002 | 2.1e-011 | 4.1e-009 | 1.0e-002 | liver | 4.1e-007 |
| Trichloroethene | 79-01-6 | 2.5e-008 | 6.9e-012 | B2 | 1.1e-002 | 7.6e-014 | | | | |
| Carbon disulfide | 75-15-0 | 1.5e-008 | | | | | 4.2e-011 | 1.0e-001 | fetotoxicity | 4.2e-010 |
| Benzene | 71-43-2 | 6.5e-009 | 1.8e-012 | A | 2.9e-002 | 5.2e-014 | | | | |
| Chloroform | 67-66-3 | 1.5e-009 | 4.2e-013 | B2 | 6.1e-003 | 2.5e-015 | 4.2e-012 | 1.0e-002 | liver | 4.2e-010 |
| Chloromethane | 74-87-3 | 1.1e-009 | 3.1e-013 | C | 1.3e-002 | 4.0e-015 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 6.9e-010 | 1.9e-013 | B2 | 9.1e-002 | 1.7e-014 | | | | |
| Sum Of Risks | | | | | | 2.1e-011 | | | | |
| Hazard Index | | | | | | | | | | 4.9e-006 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 53.8 |
| Fraction Ingested (unitless) | 0.3 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.92.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 auger hole sub area from the ingestion of vegetables

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Vegetables (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Toluene | 108-88-3 | 3.2e-004 | | | | | 8.6e-007 | 2.0e-001 | liver/kidney | 4.3e-006 |
| Xylenes(total) | 1330-20-7 | 4.1e-006 | | | | | 1.1e-008 | 2.0e+000 | neurotx/mort | 5.5e-009 |
| Ethyl benzene | 100-41-4 | 1.6e-006 | | | | | 4.2e-009 | 1.0e-001 | kidney/liver | 4.2e-008 |
| Tetrachloroethene | 127-18-4 | 1.5e-006 | 4.0e-010 | B2 | 5.1e-002 | 2.0e-011 | 4.0e-009 | 1.0e-002 | liver | 4.0e-007 |
| Trichloroethene | 79-01-6 | 2.5e-008 | 6.7e-012 | B2 | 1.1e-002 | 7.4e-014 | | | | |
| Carbon disulfide | 75-15-0 | 1.5e-008 | | | | | 4.1e-011 | 1.0e-001 | fetotoxicity | 4.1e-010 |
| Benzene | 71-43-2 | 6.5e-009 | 1.7e-012 | A | 2.9e-002 | 5.1e-014 | | | | |
| Chloroform | 67-66-3 | 1.5e-009 | 4.1e-013 | B2 | 6.1e-003 | 2.5e-015 | 4.1e-012 | 1.0e-002 | liver | 4.1e-010 |
| Chloromethane | 74-87-3 | 1.1e-009 | 3.0e-013 | C | 1.3e-002 | 3.9e-015 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 6.9e-010 | 1.9e-013 | B2 | 9.1e-002 | 1.7e-014 | | | | |
| Sum Of Risks | | | | | | 2.0e-011 | | | | |
| Hazard Index | | | | | | | | | | 4.8e-006 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 39.2 |
| Fraction Ingested (unitless) | 0.4 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.93.

Excess Lifetime Cancer Risk and Hazard Index for a child homesteader on WAG 6 auger hole sub area from the ingestion of beef

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Beef (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 1.4e-003 | 1.4e-007 | B2 | 1.4e-002 | 2.0e-009 | 1.4e-006 | 2.0e-002 | liver/kidney | 7.2e-005 |
| Di-n-butylphatalate | 84-74-2 | 5.7e-004 | | | | | 5.8e-007 | 1.0e-001 | liver/kidney | 5.8e-006 |
| Trichloroethene | 79-01-6 | 7.7e-005 | 7.8e-009 | B2 | 1.1e-002 | 8.6e-011 | | | | |
| Carbon tetrachloride | 56-23-5 | 2.3e-005 | 2.3e-009 | B2 | 1.3e-001 | 3.0e-010 | 2.3e-008 | 7.0e-004 | liver | 3.3e-005 |
| Chloroform | 67-66-3 | 5.7e-006 | 5.8e-010 | B2 | 6.1e-003 | 3.5e-012 | 5.8e-009 | 1.0e-002 | liver | 5.8e-007 |
| Diethylphatalate | 84-66-2 | 3.3e-006 | | | | | 3.3e-009 | 8.0e-001 | liver/kidney | 4.1e-009 |
| Tetrachloroethene | 127-18-4 | 2.0e-006 | 2.0e-010 | B2 | 5.1e-002 | 1.0e-011 | 2.0e-009 | 1.0e-002 | liver | 2.0e-007 |
| 2,4,5-TP | 93-72-1 | 1.0e-006 | | | | | 1.0e-009 | 8.0e-003 | liver | 1.3e-007 |
| 1,2-Dichloroethane | 107-06-2 | 5.8e-007 | 5.8e-011 | B2 | 9.1e-002 | 5.3e-012 | | | | |
| 1,1-Dichloroethane | 75-34-3 | 3.1e-007 | 3.1e-011 | B2 | 9.1e-002 | 2.9e-012 | 3.1e-010 | 1.0e-001 | kidney | 3.1e-009 |
| 2,4-D | 94-75-7 | 1.3e-007 | | | | | 1.3e-010 | 1.0e-002 | Hemato/kidney | 1.3e-008 |
| Methylene Chloride | 75-09-2 | 1.0e-007 | 1.0e-011 | B2 | 7.5e-003 | 7.6e-014 | 1.0e-010 | 6.0e-002 | liver | 1.7e-009 |
| Manganese | 7439-96-5 | 1.3e-002 | | | | | 1.3e-005 | 1.0e-001 | neurotoxicity | 1.3e-004 |
| Cadmium | 7440-43-9 | 3.2e-003 | | | | | 3.2e-006 | 1.0e-003 | kidney | 3.2e-003 |
| Nickel | 7440-02-0 | 8.0e-004 | | | | | 8.1e-007 | 2.0e-002 | kidney | 4.1e-005 |
| Chromium | 7440-47-3 | 7.9e-004 | | | | | 8.0e-007 | 5.0e-003 | neurotoxicity | 1.6e-004 |
| Sum Of Risks | | | | | | 2.4e-009 | | | | |
| Hazard Index | | | | | | | | | | 3.7e-003 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/yr) | 7.9 |
| Fraction Ingested (unitless) | 0.75 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.94.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 auger hole sub area from the ingestion of milk

| Analyte Name | CAS Number | Concentration in Milk (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 9.0e-004 | 1.6e-006 | B2 | 1.4e-002 | 2.3e-008 | 1.6e-005 | 2.0e-002 | liver/kidney | 8.1e-004 |
| Di-n-butylphatalate | 84-74-2 | 3.7e-004 | | | | | 6.6e-006 | 1.0e-001 | liver/kidney | 6.6e-005 |
| Trichloroethene | 79-01-6 | 4.9e-005 | 8.7e-008 | B2 | 1.1e-002 | 9.6e-010 | | | | |
| Carbon tetrachloride | 56-23-5 | 1.4e-005 | 2.6e-008 | B2 | 1.3e-001 | 3.4e-009 | 2.6e-007 | 7.0e-004 | liver | 3.7e-004 |
| Chloroform | 67-66-3 | 3.6e-006 | 6.5e-009 | B2 | 6.1e-003 | 4.0e-011 | 6.5e-008 | 1.0e-002 | liver | 6.5e-006 |
| Diethylphatalate | 84-66-2 | 2.1e-006 | | | | | 3.7e-008 | 8.0e-001 | liver/kidney | 4.6e-008 |
| Tetrachloroethene | 127-18-4 | 1.3e-006 | 2.3e-009 | B2 | 5.1e-002 | 1.2e-010 | 2.3e-008 | 1.0e-002 | liver | 2.3e-006 |
| 2,4,5-TP | 93-72-1 | 6.3e-007 | | | | | 1.1e-008 | 8.0e-003 | liver | 1.4e-006 |
| 1,2-Dichloroethane | 107-06-2 | 3.6e-007 | 6.5e-010 | B2 | 9.1e-002 | 5.9e-011 | | | | |
| 1,1-Dichloroethane | 75-34-3 | 2.0e-007 | 3.5e-010 | B2 | 9.1e-002 | 3.2e-011 | 3.5e-009 | 1.0e-001 | kidney | 3.5e-008 |
| 2,4-D | 94-75-7 | 8.2e-008 | | | | | 1.5e-009 | 1.0e-002 | Hemato/kidney | 1.5e-007 |
| Methylene Chloride | 75-09-2 | 6.3e-008 | 1.1e-010 | B2 | 7.5e-003 | 8.5e-013 | 1.1e-009 | 6.0e-002 | liver | 1.9e-008 |
| Nickel | 7440-02-0 | 5.4e-003 | | | | | 9.8e-005 | 2.0e-002 | kidney | 4.9e-003 |
| Chromium | 7440-47-3 | 1.8e-003 | | | | | 3.2e-005 | 5.0e-003 | neurotoxicity | 6.3e-003 |
| Manganese | 7439-96-5 | 5.0e-004 | | | | | 9.0e-006 | 1.0e-001 | neurotoxicity | 9.0e-005 |
| Cadmium | 7440-43-9 | 2.5e-005 | | | | | 4.4e-007 | 1.0e-003 | kidney | 4.4e-004 |
| Vanadium | 7440 62-2 | 1.8e-005 | | | | | 3.2e-007 | 7.0e-003 | kidney | 4.5e-005 |
| Sum Of Risks | | | | | | 2.7e-008 | | | | |
| Hazard Index | | | | | | | | | | 1.3e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 139.6 |
| Fraction Ingested (unitless) | 0.75 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.95.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 auger hole sub area from dermal contact with groundwater while showering

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Groundwater (mg/L) | Daily Intake (mg/kg/day) | USEPA Class | Slope Factor (mg/kg-day) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg/day) | Reference Dose RfD (mg/kg-day) | Effect | Hazard Quotient |
| Trichloroethene | 79-01-6 | 3.2e-001 | 2.3e-006 | B2 | 2.2e-001 | 5.1e-007 | | | | |
| Chloroform | 67-66-3 | 6.1e-002 | 4.5e-007 | B2 | 1.2e-001 | 5.4e-008 | 4.5e-006 | 5.0e-004 | liver | 8.9e-003 |
| Carbon tetrachloride | 56-23-5 | 5.2e-002 | 3.8e-007 | B2 | 2.6e+000 | 9.9e-007 | 3.8e-006 | 3.5e-005 | liver | 1.1e-001 |
| 1,2-Dichloroethane | 107-06-2 | 1.9e-002 | 1.4e-007 | B2 | 1.8e+000 | 2.5e-007 | | | | |
| Bis(2-ethylhexyl)phatalate | 117-81-7 | 1.1e-002 | 8.0e-008 | B2 | 2.8e-001 | 2.2e-008 | 8.0e-007 | 1.0e-003 | liver/kidney | 8.0e-004 |
| Di-n-butylphatalate | 84-74-2 | 1.1e-002 | | | | | 8.0e-007 | 5.0e-003 | liver/kidney | 1.6e-004 |
| Diethylphatalate | 84-66-2 | 1.1e-002 | | | | | 8.0e-007 | 4.0e-002 | liver/kidney | 2.0e-005 |
| 1,1-Dichloroethane | 75-34-3 | 5.0e-003 | 3.6e-008 | B2 | 1.8e+000 | 6.6e-008 | 3.6e-007 | 5.0e-003 | kidney | 7.3e-005 |
| Tetrachloroethene | 127-18-4 | 5.0e-003 | 3.6e-008 | B2 | 1.0e+000 | 3.7e-008 | 3.6e-007 | 5.0e-004 | liver | 7.3e-004 |
| Methylene Chloride | 75-09-2 | 5.0e-003 | 3.6e-008 | B2 | 1.5e-001 | 5.5e-009 | 3.6e-007 | 3.0e-003 | liver | 1.2e-004 |
| 2,4-D | 94-75-7 | 2.0e-004 | | | | | 1.5e-008 | 5.0e-004 | Hemato/kidney | 2.9e-005 |
| 2,4,5-TP | 93-72-1 | 1.0e-004 | | | | | 7.3e-009 | 4.0e-004 | liver | 1.8e-005 |
| Chromium | 7440-47-3 | 2.0e-002 | | | | | 1.5e-006 | 2.5e-004 | neurotoxicity | 5.8e-003 |
| Nickel | 7440-02-0 | 2.0e-002 | | | | | 1.5e-006 | 1.0e-003 | kidney | 1.5e-003 |
| Vanadium | 7440-62-2 | 1.1e-002 | | | | | 8.0e-007 | 3.5e-004 | kidney | 2.3e-003 |
| Cadmium | 7440-43-9 | 5.0e-003 | | | | | 3.6e-007 | 5.0e-005 | kidney | 7.3e-003 |
| Sum Of Risks | | | | | | 1.9e-006 | | | | |
| Hazard Index | | | | | | | | | | 1.4e-001 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (L/cm^3) | 0.001 |
| Skin Surface Area (cm^2/event) | 6950 |
| Dermal Perm. Constant (cm/h) | 0.00084 |
| Exposure Time (h/d) | 0.2 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |

| Averaging Time (d) | |
|---|---|
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.96.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 auger hole sub area from dermal contact with soil

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Soil (mg/kg) | Daily Intake (mg/kg/day) | USEPA Class | Slope Factor (mg/kg-day) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg/day) | Reference Dose RfD (mg/kg-day) | Effect | Hazard Quotient |
| Vanadium | 7440-62-2 | 2.3e+001 | | | | | 4.6e-005 | 3.5e-004 | kidney | 1.3e-001 |
| Sum Of Risks | | | | | | | | | | |
| Hazard Index | | | | | | | | | | 1.3e-001 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (kg/mg) | 1.e-06 |
| Skin Surface Area (cm^2/event) | 2960 |
| Adherence Factor (mg/cm^3) | 2.77 |
| Absorption Factor | |
| Voc | 0.25 |
| Svoc | 0.10 |
| Inorganics | 0.01 |

| | |
|---|---|
| Exposure Frequency (event/y) | 141 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.97.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 auger hole sub area from dermal contact with sediment

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Sediment (mg/kg) | Daily Intake (mg/kg/day) | USEPA Class | Slope Factor (mg/kg-day) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg/day) | Reference Dose RfD (mg/kg-day) | Effect | Hazard Quotient |
| 2-Butanone | 78-93-3 | 1.4e-001 | | | | | 5.2e-006 | 2.5e-003 | fetotoxicity | 2.1e-003 |
| Trichlorofluoromethane | 75-69-4 | 7.2e-002 | | | | | 2.7e-006 | 1.5e-002 | resp/cardiova | 1.8e-004 |
| Methylene Chloride | 75-09-2 | 3.1e-002 | 1.1e-007 | B2 | 1.5e-001 | 1.7e-008 | 1.1e-006 | 3.0e-003 | liver | 3.8e-004 |
| Acetone | 67-64-1 | 1.3e-002 | | | | | 4.8e-007 | 5.0e-003 | kidney | 9.6e-005 |
| Chloroform | 67-66-3 | 1.3e-002 | 4.8e-008 | B2 | 1.2e-001 | 5.9e-009 | 4.8e-007 | 5.0e-004 | liver | 9.6e-004 |
| Trichloroethene | 79-01-6 | 6.0e-003 | 2.2e-008 | B2 | 2.2e-001 | 4.9e-009 | | | | |
| Toluene | 108-88-3 | 6.0e-003 | | | | | 2.2e-007 | 1.0e-002 | liver/kidney | 2.2e-005 |
| Silver | 7440-22-4 | 2.5e+000 | | | | | 3.7e-006 | 1.5e-004 | skin | 2.5e-002 |
| Sum Of Risks | | | | | | 2.8e-008 | | | | |
| Hazard Index | | | | | | | | | | 2.8e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (kg/mg) | 1.e-06 |
| Skin Surface Area (cm^2/event) | 6950 |
| Adherence Factor (mg/cm^3) | 2.77 |
| Absorption Factor | |
| Voc | 0.25 |
| Svoc | 0.10 |
| Inorganics | 0.01 |

| | |
|---|---|
| Exposure Frequency (event/y) | 45 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.98.

Excess lifetime cancer risk and hazard index for an adult homesteader off WAG 6 at the Clinch river from the incidental ingestion of soil

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Soil (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Tetrachloroethene | 127-18-4 | 6.1e-005 | 3.7e-011 | B2 | 5.1e-002 | 1.9e-012 | 8.7e-011 | 1.0e-002 | liver | 8.7e-009 |
| Trichloroethene | 79-01-6 | 5.8e-005 | 3.6e-011 | B2 | 1.1e-002 | 3.9e-013 | | | | |
| Carbon disulfide | 75-15-0 | 5.2e-005 | | | | | 7.4e-011 | 1.0e-001 | fetotoxicity | 7.4e-010 |
| Acetone | 67-64-1 | 2.8e-005 | | | | | 4.0e-011 | 1.0e-001 | kidney | 4.0e-010 |
| Chloroform | 67-66-3 | 2.3e-006 | 1.4e-012 | B2 | 6.1e-003 | 8.4e-015 | 3.2e-012 | 1.0e-002 | liver | 3.2e-010 |
| Silver | 7440-22-4 | 3.5e-004 | | | | | 5.0e-010 | 3.0e-003 | skin | 1.7e-007 |
| Sum Of Risks | | | | | | 2.3e-012 | | | | |
| Hazard Index | | | | | | | | | | 1.8e-007 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Ingestion Rate (mg/d) | 100 |
| Conversion Factor (kg/mg) | 1.0e-006 |
| Fraction Ingested (unitless) | 1 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.99.

Excess lifetime cancer risk and hazard index for an adult homesteader off WAG 6 at the Clinch river from the ingestion of surface water as drinking water

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Surface water (mg/L) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Carbon disulfide | 75-15-0 | 5.0e-003 | | | | | 1.4e-004 | 1.0e-001 | fetotoxicity | 1.4e-003 |
| Acetone | 67-64-1 | 1.1e-003 | | | | | 3.0e-005 | 1.0e-001 | kidney | 3.0e-004 |
| Chloroform | 67-66-3 | 5.3e-005 | 6.5e-007 | B2 | 6.1e-003 | 4.0e-009 | 1.5e-006 | 1.0e-002 | liver | 1.5e-004 |
| Tetrachloroethene | 127-18-4 | 5.3e-005 | 6.5e-007 | B2 | 5.1e-002 | 3.3e-008 | 1.5e-006 | 1.0e-002 | liver | 1.5e-004 |
| Trichloroethene | 79-01-6 | 5.3e-005 | 6.5e-007 | B2 | 1.1e-002 | 7.2e-009 | | | | |
| Silver | 7440-22-4 | 2.9e-004 | | | | | 8.2e-006 | 3.0e-003 | skin | 2.7e-003 |
| Sum Of Risks | | | | | | 4.4e-008 | | | | |
| Hazard Index | | | | | | | | | | 4.8e-003 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Ingestion Rate (L/d) | 2 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.100.

Excess lifetime cancer risk and hazard index for an adult homesteader off WAG 6 from the ingestion of fruit

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Fruit (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Acetone | 67-64-1 | 1.5e-003 | | | | | 9.0e-007 | 1.0e-001 | kidney | 9.0e-006 |
| Carbon disulfide | 75-15-0 | 1.4e-004 | | | | | 8.4e-008 | 1.0e-001 | fetotoxicity | 8.4e-007 |
| Trichloroethene | 79-01-6 | 9.5e-005 | 2.4e-008 | B2 | 1.1e-002 | 2.7e-010 | | | | |
| Tetrachloroethene | 127-18-4 | 7.4e-005 | 1.9e-008 | B2 | 5.1e-002 | 9.7e-010 | 4.5e-008 | 1.0e-002 | liver | 4.5e-006 |
| Chloroform | 67-66-3 | 6.4e-006 | 1.6e-009 | B2 | 6.1e-003 | 1.0e-011 | 3.8e-009 | 1.0e-002 | liver | 3.8e-007 |
| Silver | 7440-22-4 | 5.3e-005 | | | | | 3.2e-008 | 3.0e-003 | skin | 1.1e-005 |
| Sum Of Risks | | | | | | 1.3e-009 | | | | |
| Hazard Index | | | | | | | | | | 2.5e-005 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/yr) | 51.1 |
| Fraction Ingested (unitless) | 0.3 |
| Exposure Duration (years) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

**Table 6I.101.**

Excess Lifetime Cancer Risk and Hazard Index for an adult homesteader off WAG 6 from the ingestion of Vegetables

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Vegetables (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Acetone | 67-64-1 | 1.5e-003 | | | | | 1.7e-006 | 1.0e-001 | kidney | 1.7e-005 |
| Carbon disulfide | 75-15-0 | 1.4e-004 | | | | | 1.6e-007 | 1.0e-001 | fetotoxicity | 1.6e-006 |
| Trichloroethene | 79-01-6 | 9.5e-005 | 4.6e-008 | B2 | 1.1e-002 | 5.1e-010 | | | | |
| Tetrachloroethene | 127-18-4 | 7.4e-005 | 3.6e-008 | B2 | 5.1e-002 | 1.9e-009 | 8.5e-008 | 1.0e-002 | liver | 8.5e-006 |
| Chloroform | 67-66-3 | 6.4e-006 | 3.1e-009 | B2 | 6.1e-003 | 1.9e-011 | 7.3e-009 | 1.0e-002 | liver | 7.3e-007 |
| Silver | 7440-22-4 | 5.3e-005 | | | | | 6.0e-008 | 3.0e-003 | skin | 2.0e-005 |
| Sum Of Risks | | | | | | 2.4e-009 | | | | |
| Hazard Index | | | | | | | | | | 4.8e-005 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 73 |
| Fraction Ingested (unitless) | 0.4 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.102.

Excess lifetime cancer risk and hazard index for an adult homesteader off WAG 6 at the Clinch river from the ingestion of milk

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Milk (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Carbon disulfide | 75-15-0 | 3.2e-007 | | | | | 1.4e-009 | 1.0e-001 | fetotoxicity | 1.4e-008 |
| Tetrachloroethene | 127-18-4 | 1.3e-008 | 2.5e-011 | B2 | 5.1e-002 | 1.3e-012 | 5.8e-011 | 1.0e-002 | liver | 5.8e-009 |
| Trichloroethene | 79-01-6 | 8.1e-009 | 1.5e-011 | B2 | 1.1e-002 | 1.6e-013 | | | | |
| Chloroform | 67-66-3 | 3.2e-009 | 5.8e-012 | B2 | 6.1e-003 | 3.5e-014 | 1.4e-011 | 1.0e-002 | liver | 1.4e-009 |
| Acetone | 67-64-1 | 3.9e-010 | | | | | 1.7e-012 | 1.0e-001 | kidney | 1.7e-011 |
| Silver | 7440-22-4 | 5.8e-004 | | | | | 2.5e-006 | 3.0e-003 | skin | 8.2e-004 |
| Sum Of Risks | | | | | | 1.5e-012 | | | | |
| Hazard Index | | | | | | | | | | 8.2e-004 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 146 |
| Fraction Ingested (unitless) | 0.75 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.103.

Excess lifetime cancer risk and hazard index for an adult homesteader off WAG 6 at the Clinch river from the ingestion of beef

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Beef (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Carbon disulfide | 75-15-0 | 5.0e-007 | | | | | 5.4e-010 | 1.0e-001 | fetotoxicity | 5.4e-009 |
| Tetrachloroethene | 127-18-4 | 2.1e-008 | 9.8e-012 | B2 | 5.1e-002 | 5.0e-013 | 2.3e-011 | 1.0e-002 | liver | 2.3e-009 |
| Trichloroethene | 79-01-6 | 1.3e-008 | 5.9e-012 | B2 | 1.1e-002 | 6.5e-014 | | | | |
| Chloroform | 67-66-3 | 5.0e-009 | 2.3e-012 | B2 | 6.1e-003 | 1.4e-014 | 5.4e-012 | 1.0e-002 | liver | 5.4e-010 |
| Acetone | 67-64-1 | 6.2e-010 | | | | | 6.6e-013 | 1.0e-001 | kidney | 6.6e-012 |
| Silver | 7440-22-4 | 1.1e-005 | | | | | 1.2e-008 | 3.0e-003 | skin | 4.1e-006 |
| Sum Of Risks | | | | | | 5.8e-013 | | | | |
| Hazard Index | | | | | | | | | | 4.1e-006 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 36.5 |
| Fraction Ingested (unitless) | 0.75 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.104.

Excess lifetime cancer risk and hazard index for an adult homesteader off WAG 6 from the ingestion of Clinch river fish

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Fish (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Carbon disulfide | 75-15-0 | 9.7e-002 | | | | | 7.5e-005 | 1.0e-001 | fetotoxicity | 7.5e-004 |
| Tetrachloroethene | 127-18-4 | 3.0e-003 | 9.8e-007 | B2 | 5.1e-002 | 5.0e-008 | 2.3e-006 | 1.0e-002 | liver | 2.3e-004 |
| Trichloroethene | 79-01-6 | 2.0e-003 | 6.7e-007 | B2 | 1.1e-002 | 7.3e-009 | | | | |
| Chloroform | 67-66-3 | 9.9e-004 | 3.3e-007 | B2 | 6.1e-003 | 2.0e-009 | 7.6e-007 | 1.0e-002 | liver | 7.6e-005 |
| Acetone | 67-64-1 | 4.1e-004 | | | | | 3.2e-007 | 1.0e-001 | kidney | 3.2e-006 |
| Silver | 7440-22-4 | 6.6e-004 | | | | | 5.1e-007 | 3.0e-003 | skin | 1.7e-004 |
| Sum Of Risks | | | | | | 5.9e-008 | | | | |
| Hazard Index | | | | | | | | | | 1.2e-003 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 19.7 |
| Fraction Ingested (unitless) | 1 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

**Table 6I.105.**

Excess lifetime cancer risk and hazard index for an adult homesteader off WAG 6 from dermal contact with surface water while swimming at the Clinch river

| Analyte Name | CAS Number | Concentration in Surface water (mg/L) | CARCINOGENS Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | NONCARCINOGENS Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| Carbon disulfide | 75-15-0 | 5.0e-003 | | | | | 3.5e-007 | 5.0e-003 | fetotoxicity | 7.0e-005 |
| Acetone | 67-64-1 | 1.1e-003 | | | | | 7.4e-008 | 5.0e-003 | kidney | 1.5e-005 |
| Chloroform | 67-66-3 | 5.3e-005 | 1.6e-009 | B2 | 1.2e-001 | 1.9e-010 | 3.7e-009 | 5.0e-004 | liver | 7.4e-006 |
| Tetrachloroethene | 127-18-4 | 5.3e-005 | 1.6e-009 | B2 | 1.0e+000 | 1.6e-009 | 3.7e-009 | 5.0e-004 | liver | 7.4e-006 |
| Trichloroethene | 79-01-6 | 5.3e-005 | 1.6e-009 | B2 | 2.2e-001 | 3.5e-010 | | | | |
| Silver | 7440-22-4 | 2.9e-004 | | | | | 2.0e-008 | 1.5e-004 | skin | 1.3e-004 |
| Sum Of Risks | | | | | | 2.2e-009 | | | | |
| Hazard Index | | | | | | | | | | 2.3e-004 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (l/cm^3) | 1.0e-003 |
| Skin Surface Area (cm^2/event) | 18150 |
| Dermal Perm. Constant (cm/h) | 8.4e-004 |
| Exposure Time (h/d) | 2.6 |
| Exposure Frequency (d/y) | 45 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |

| Averaging Time (day) | |
|---|---|
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.106.

Excess lifetime cancer risk and hazard index for an adult homesteader off WAG 6 at the clinch river from dermal contact with surface water while showering

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Groundwater (mg/L) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Carbon disulfide | 75-15-0 | 5.0e-003 | | | | | 2.2e-007 | 5.0e-003 | fetotoxicity | 4.4e-005 |
| Acetone | 67-64-1 | 1.1e-003 | | | | | 4.6e-008 | 5.0e-003 | kidney | 9.3e-006 |
| Chloroform | 67-66-3 | 5.3e-005 | 1.0e-009 | B2 | 1.2e-001 | 1.2e-010 | 2.3e-009 | 5.0e-004 | liver | 4.6e-006 |
| Tetrachloroethene | 127-18-4 | 5.3e-005 | 1.0e-009 | B2 | 1.0e+000 | 1.0e-009 | 2.3e-009 | 5.0e-004 | liver | 4.6e-006 |
| Trichloroethene | 79-01-6 | 5.3e-005 | 1.0e-009 | B2 | 2.2e-001 | 2.2e-010 | | | | |
| Silver | 7440-22-4 | 2.9e-004 | | | | | 1.3e-008 | 1.5e-004 | skin | 8.4e-005 |
| Sum Of Risks | | | | | | 1.4e-009 | | | | |
| Hazard Index | | | | | | | | | | 1.5e-004 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (L/cm^3) | 0.001 |
| Skin Surface Area (cm^2/event) | 18150 |
| Dermal Perm. Constant (cm/h) | 0.00084 |
| Exposure Time (h/d) | 0.2 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |

| Averaging Time (d) | |
|---|---|
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.107.

Excess lifetime cancer risk and hazard index for an adult homesteader off WAG 6 at the clinch river from dermal contact with soil

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Soil (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Tetrachloroethene | 127-18-4 | 6.1e-005 | 9.5e-011 | B2 | 1.0e+000 | 9.7e-011 | 2.2e-010 | 5.0e-004 | liver | 4.4e-007 |
| Trichloroethene | 79-01-6 | 5.8e-005 | 9.0e-011 | B2 | 2.2e-001 | 2.0e-011 | | | | |
| Carbon disulfide | 75-15-0 | 5.2e-005 | | | | | 1.9e-010 | 5.0e-003 | fetotoxicity | 3.8e-008 |
| Acetone | 67-64-1 | 2.8e-005 | | | | | 1.0e-010 | 5.0e-003 | kidney | 2.0e-008 |
| Chloroform | 67-66-3 | 2.3e-006 | 3.5e-012 | B2 | 1.2e-001 | 4.3e-013 | 8.2e-012 | 5.0e-004 | liver | 1.6e-008 |
| Silver | 7440-22-4 | 3.5e-004 | | | | | 5.1e-011 | 1.5e-004 | skin | 3.4e-007 |
| Sum Of Risks | | | | | | 1.2e-010 | | | | |
| Hazard Index | | | | | | | | | | 8.6e-007 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (kg/mg) | 1.0e-006 |
| Skin Surface Area (cm^2/event) | 3120 |
| Adherence Factor (mg/cm^3) | 2.77 |
| Absorption Factor | |
| Voc | 0.25 |
| Svoc | 0.1 |
| Inorganic | 0.01 |

| | |
|---|---|
| Exposure Frequency (event/y) | 43 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

Table 6I.108.

Excess lifetime cancer risk and hazard index for a child homesteader off WAG 6 at the Clinch river from the incidental ingestion of soil

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Soil (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Tetrachloroethene | 127-18-4 | 6.1e-005 | 7.6e-011 | B2 | 5.1e-002 | 3.9e-012 | 7.6e-010 | 1.0e-002 | liver | 7.6e-008 |
| Trichloroethene | 79-01-6 | 5.8e-005 | 7.3e-011 | B2 | 1.1e-002 | 8.0e-013 | | | | |
| Carbon disulfide | 75-15-0 | 5.2e-005 | | | | | 6.5e-010 | 1.0e-001 | fetotoxicity | 6.5e-009 |
| Acetone | 67-64-1 | 2.8e-005 | | | | | 3.5e-010 | 1.0e-001 | kidney | 3.5e-009 |
| Chloroform | 67-66-3 | 2.3e-006 | 2.8e-012 | B2 | 6.1e-003 | 1.7e-014 | 2.8e-011 | 1.0e-002 | liver | 2.8e-009 |
| Silver | 7440-22-4 | 3.5e-004 | | | | | 4.4e-009 | 3.0e-003 | skin | 1.5e-006 |
| Sum Of Risks | | | | | | 4.7e-012 | | | | |
| Hazard Index | | | | | | | | | | 1.5e-006 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Ingestion Rate (mg/d) | 200 |
| Conversion Factor (kg/mg) | 1.0e-006 |
| Fraction Ingested (unitless) | 1 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

**Table 6I.109.**

Excess Lifetime Cancer Risk and Hazard Index for a child homesteader off WAG 6 at the clinch river from the ingestion of surface water as drinking water

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Groundwater (mg/L) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Carbon disulfide | 75-15-0 | 5.0e-003 | | | | | 3.1e-004 | 1.0e-001 | fetotoxicity | 3.1e-003 |
| Acetone | 67-64-1 | 1.1e-003 | | | | | 6.7e-005 | 1.0e-001 | kidney | 6.7e-004 |
| Chloroform | 67-66-3 | 5.3e-005 | 3.3e-007 | B2 | 6.1e-003 | 2.0e-009 | 3.3e-006 | 1.0e-002 | liver | 3.3e-004 |
| Tetrachloroethene | 127-18-4 | 5.3e-005 | 3.3e-007 | B2 | 5.1e-002 | 1.7e-008 | 3.3e-006 | 1.0e-002 | liver | 3.3e-004 |
| Trichloroethene | 79-01-6 | 5.3e-005 | 3.3e-007 | B2 | 1.1e-002 | 3.7e-009 | | | | |
| Silver | 7440-22-4 | 2.9e-004 | | | | | 1.8e-005 | 3.0e-003 | skin | 6.0e-003 |
| Sum Of Risks | | | | | | 2.3e-008 | | | | |
| Hazard Index | | | | | | | | | | 1.0e-002 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Ingestion Rate (L/d) | 1 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.110.

Excess lifetime cancer risk and hazard quotient for a child homesteader off WAG 6 form the ingestion of fruit

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Fruit (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Acetone | 67-64-1 | 1.5e-003 | | | | | 4.1e-006 | 1.0e-001 | kidney | 4.1e-005 |
| Carbon disulfide | 75-15-0 | 1.4e-004 | | | | | 3.9e-007 | 1.0e-001 | fetotoxicity | 3.9e-006 |
| Trichloroethene | 79-01-6 | 9.5e-005 | 2.6e-008 | B2 | 1.1e-002 | 2.9e-010 | | | | |
| Tetrachloroethene | 127-18-4 | 7.4e-005 | 2.1e-008 | B2 | 5.1e-002 | 1.0e-009 | 2.1e-007 | 1.0e-002 | liver | 2.1e-005 |
| Chloroform | 67-66-3 | 6.4e-006 | 1.8e-009 | B2 | 6.1e-003 | 1.1e-011 | 1.8e-008 | 1.0e-002 | liver | 1.8e-006 |
| Silver | 7440-22-4 | 5.3e-005 | | | | | 1.5e-007 | 3.0e-003 | skin | 4.8e-005 |
| Sum Of Risks | | | | | | 1.3e-009 | | | | |
| Hazard Index | | | | | | | | | | 1.2e-004 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 53.8 |
| Fraction Ingested (unitless) | 0.3 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

**Table 6I.111.**

Excess lifetime cancer risk and hazard index for a child homesteader off WAG 6 from the ingestion of vegetables

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Vegetables (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Acetone | 67-64-1 | 1.5e-003 | | | | | 4.0e-006 | 1.0e-001 | kidney | 4.0e-005 |
| Carbon disulfide | 75-15-0 | 1.4e-004 | | | | | 3.8e-007 | 1.0e-001 | fetotoxicity | 3.8e-006 |
| Trichloroethene | 79-01-6 | 9.5e-005 | 2.5e-008 | B2 | 1.1e-002 | 2.8e-010 | | | | |
| Tetrachloroethene | 127-18-4 | 7.4e-005 | 2.0e-008 | B2 | 5.1e-002 | 1.0e-009 | 2.0e-007 | 1.0e-002 | liver | 2.0e-005 |
| Chloroform | 67-66-3 | 6.4e-006 | 1.7e-009 | B2 | 6.1e-003 | 1.0e-011 | 1.7e-008 | 1.0e-002 | liver | 1.7e-006 |
| Silver | 7440-22-4 | 5.3e-005 | | | | | 1.4e-007 | 3.0e-003 | skin | 4.7e-005 |
| Sum Of Risks | | | | | | 1.3e-009 | | | | |
| Hazard Index | | | | | | | | | | 1.1e-004 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 39.2 |
| Fraction Ingested (unitless) | 0.4 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

**Table 6I.112.**

Excess Lifetime Cancer Risk and Hazard Index for a child homesteader off WAG 6 at the Clinch river from the ingestion of beef

| Analyte Name | CAS Number | Concentration in Beef (mg/kg) | CARCINOGENS Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | NONCARCINOGENS Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| Carbon disulfide | 75-15-0 | 5.0e-007 | | | | | 5.1e-010 | 1.0e-001 | fetotoxicity | 5.1e-009 |
| Tetrachloroethene | 127-18-4 | 2.1e-008 | 2.2e-012 | B2 | 5.1e-002 | 1.1e-013 | 2.2e-011 | 1.0e-002 | liver | 2.2e-009 |
| Trichloroethene | 79-01-6 | 1.3e-008 | 1.3e-012 | B2 | 1.1e-002 | 1.4e-014 | | | | |
| Chloroform | 67-66-3 | 5.0e-009 | 5.1e-013 | B2 | 6.1e-003 | 3.1e-015 | 5.1e-012 | 1.0e-002 | liver | 5.1e-010 |
| Acetone | 67-64-1 | 6.2e-010 | | | | | 6.3e-013 | 1.0e-001 | kidney | 6.3e-012 |
| Silver | 7440-22-4 | 1.1e-005 | | | | | 1.2e-008 | 3.0e-003 | skin | 3.9e-006 |
| Sum Of Risks | | | | | | 1.3e-013 | | | | |
| Hazard Index | | | | | | | | | | 3.9e-006 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/yr) | 7.9 |
| Fraction Ingested (unitless) | 0.75 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.113.

Excess lifetime cancer risk and hazard index for a child homesteader off WAG 6 at the Clinch river from the ingestion of milk

| Analyte Name | CAS Number | Concentration in Milk (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| Carbon disulfide | 75-15-0 | 3.2e-007 | | | | | 5.7e-009 | 1.0e-001 | fetotoxicity | 5.7e-008 |
| Tetrachloroethene | 127-18-4 | 1.3e-008 | 2.4e-011 | B2 | 5.1e-002 | 1.2e-012 | 2.4e-010 | 1.0e-002 | liver | 2.4e-008 |
| Trichloroethene | 79-01-6 | 8.1e-009 | 1.5e-011 | B2 | 1.1e-002 | 1.6e-013 | | | | |
| Chloroform | 67-66-3 | 3.2e-009 | 5.7e-012 | B2 | 6.1e-003 | 3.5e-014 | 5.7e-011 | 1.0e-002 | liver | 5.7e-009 |
| Acetone | 67-64-1 | 3.9e-010 | | | | | 7.0e-012 | 1.0e-001 | kidney | 7.0e-011 |
| Silver | 7440-22-4 | 5.8e-004 | | | | | 1.0e-005 | 3.0e-003 | skin | 3.4e-003 |
| Sum Of Risks | | | | | | 1.4e-012 | | | | |
| Hazard Index | | | | | | | | | | 3.4e-003 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 139.6 |
| Fraction Ingested (unitless) | 0.75 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.114.

Excess lifetime cancer risk and hazard index for a child homesteader on WAG 6 from the ingestion of Clinch river fish

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Fish (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Carbon disulfide | 75-15-0 | 9.7e-002 | | | | | 3.5e-005 | 1.0e-001 | fetotoxicity | 3.5e-004 |
| Tetrachloroethene | 127-18-4 | 3.0e-003 | 1.1e-007 | B2 | 5.1e-002 | 5.4e-009 | 1.1e-006 | 1.0e-002 | liver | 1.1e-004 |
| Trichloroethene | 79-01-6 | 2.0e-003 | 7.3e-008 | B2 | 1.1e-002 | 8.0e-010 | | | | |
| Chloroform | 67-66-3 | 9.9e-004 | 3.5e-008 | B2 | 6.1e-003 | 2.2e-010 | 3.5e-007 | 1.0e-002 | liver | 3.5e-005 |
| Acetone | 67-64-1 | 4.1e-004 | | | | | 1.5e-007 | 1.0e-001 | kidney | 1.5e-006 |
| Silver | 7440-22-4 | 6.6e-004 | | | | | 2.4e-007 | 3.0e-003 | skin | 7.9e-005 |
| Sum Of Risks | | | | | | 6.5e-009 | | | | |
| Hazard Index | | | | | | | | | | 5.7e-004 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/yr) | 2.1 |
| Fraction Ingested | 1.0 |
| Exposure Duration (years) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time | |
| Carcinogens | 25550 = (70 * 365) |
| Noncarcinogens | 2555 = (7 * 365) |

**Table 6I.115.**

Excess lifetime cancer risk and hazard index for a child homesteader off WAG 6 from dermal contact with surface water while swimming at the Clinch river

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Surface Water (mg/L) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Carbon disulfide | 75-15-0 | 5.0e-003 | | | | | 5.8e-007 | 5.0e-003 | fetotoxicity | 1.2e-004 |
| Acetone | 67-64-1 | 1.1e-003 | | | | | 1.2e-007 | 5.0e-003 | kidney | 2.5e-005 |
| Chloroform | 67-66-3 | 5.3e-005 | 6.2e-010 | B2 | 1.2e-001 | 7.6e-011 | 6.2e-009 | 5.0e-004 | liver | 1.2e-005 |
| Tetrachloroethene | 127-18-4 | 5.3e-005 | 6.2e-010 | B2 | 1.0e+000 | 6.4e-010 | 6.2e-009 | 5.0e-004 | liver | 1.2e-005 |
| Trichloroethene | 79-01-6 | 5.3e-005 | 6.2e-010 | B2 | 2.2e-001 | 1.4e-010 | | | | |
| Silver | 7440-22-4 | 2.9e-004 | | | | | 3.4e-008 | 1.5e-004 | skin | 2.2e-004 |
| Sum Of Risks | | | | | | 8.5e-010 | | | | |
| Hazard Index | | | | | | | | | | 3.9e-004 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (L/cm^3) | 0.001 |
| Skin Surface Area (cm^2/event) | 6950 |
| Dermal Perm. Constant (cm/h) | 0.00084 |
| Exposure Time (h/d) | 2.6 |
| Exposure Frequency (d/y) | 45 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |

| Averaging Time (d) | |
|---|---|
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

**Table 6I.116.**

Excess lifetime cancer risk and hazard index for a child homesteader off WAG 6 at the Clinch river from dermal contact with surface water while showering

| Analyte Name | CAS Number | Concentration in Groundwater (mg/L) | CARCINOGENS Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | NONCARCINOGENS Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
|---|---|---|---|---|---|---|---|---|---|---|
| Carbon disulfide | 75-15-0 | 5.0e-003 | | | | | 3.6e-007 | 5.0e-003 | fetotoxicity | 7.3e-005 |
| Acetone | 67-64-1 | 1.1e-003 | | | | | 7.8e-008 | 5.0e-003 | kidney | 1.6e-005 |
| Chloroform | 67-66-3 | 5.3e-005 | 3.9e-010 | B2 | 1.2e-001 | 4.7e-011 | 3.9e-009 | 5.0e-004 | liver | 7.8e-006 |
| Tetrachloroethene | 127-18-4 | 5.3e-005 | 3.9e-010 | B2 | 1.0e+000 | 4.0e-010 | 3.9e-009 | 5.0e-004 | liver | 7.8e-006 |
| Trichloroethene | 79-01-6 | 5.3e-005 | 3.9e-010 | B2 | 2.2e-001 | 8.6e-011 | | | | |
| Silver | 7440-22-4 | 2.9e-004 | | | | | 2.1e-008 | 1.5e-004 | skin | 1.4e-004 |
| Sum Of Risks | | | | | | 5.3e-010 | | | | |
| Hazard Index | | | | | | | | | | 2.4e-004 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (L/cm^3) | 0.001 |
| Skin Surface Area (cm^2/event) | 6950 |
| Dermal Perm. Constant (cm/h) | 0.00084 |
| Exposure Time (h/d) | 0.2 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |

| Averaging Time (d) | |
|---|---|
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

**Table 6I.117.**

Excess lifetime cancer risk and hazard index for a child homesteader off WAG 6 at hte Clinch river from dermal contact with soil

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Soil (mg/kg) | Daily Intake (mg/kg/day) | USEPA Class | Slope Factor (mg/kg-day) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg/day) | Reference Dose RfD (mg/kg-day) | Effect | Hazard Quotient |
| Tetrachloroethene | 127-18-4 | 6.1e-005 | 3.0e-010 | B2 | 1.0e+000 | 3.1e-010 | 3.0e-009 | 5.0e-004 | liver | 6.0e-006 |
| Trichloroethene | 79-01-6 | 5.8e-005 | 2.9e-010 | B2 | 2.2e-001 | 6.3e-011 | | | | |
| Carbon disulfide | 75-15-0 | 5.2e-005 | | | | | 2.6e-009 | 5.0e-003 | fetotoxicity | 5.1e-007 |
| Acetone | 67-64-1 | 2.8e-005 | | | | | 1.4e-009 | 5.0e-003 | kidney | 2.8e-007 |
| Chloroform | 67-66-3 | 2.3e-006 | 1.1e-011 | B2 | 1.2e-001 | 1.4e-012 | 1.1e-010 | 5.0e-004 | liver | 2.2e-007 |
| Silver | 7440-22-4 | 3.5e-004 | | | | | 6.9e-010 | 1.5e-004 | skin | 4.6e-006 |
| Sum Of Risks | | | | | | 3.7e-010 | | | | |
| Hazard Index | | | | | | | | | | 1.2e-005 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Conversion Factor (kg/mg) | 1.e-06 |
| Skin Surface Area (cm^2/event) | 2960 |
| Adherence Factor (mg/cm^3) | 2.77 |
| Absorption Factor | |
| Voc | 0.25 |
| Svoc | 0.10 |
| Inorganics | 0.01 |

| | |
|---|---|
| Exposure Frequency (event/y) | 141 |
| Exposure Duration (y) | 7 |
| Body Weight (kg) | 16 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 7 y * 365 d/y |

Table 6I.118.

Excess Lifetime Cancer Risk and Hazard Index for an employee on WAG 6 from the inhalation of vapors

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Air (mg/m^3) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Tetrachloroethene | 127-18-4 | 3.3e-008 | 8.7e-010 | B2 | 1.8e-003 | 1.6e-012 | | | | |
| Chloromethane | 74-87-3 | 2.6e-008 | 6.8e-010 | C | 6.3e-003 | 4.3e-012 | | | | |
| Xylenes(total) | 1330-20-7 | 2.4e-008 | | | | | 1.4e-009 | 1.0e-001 | neurotoxicity | 1.4e-008 |
| Trichloroethene | 79-01-6 | 1.3e-008 | 3.3e-010 | B2 | 1.7e-002 | 5.6e-012 | | | | |
| Toluene | 108-88-3 | 1.0e-008 | | | | | 6.3e-010 | 6.0e-001 | neurotoxicity | 1.1e-009 |
| Benzene | 71-43-2 | 9.5e-009 | 2.5e-010 | A | 2.9e-002 | 7.2e-012 | | | | |
| Ethyl benzene | 100-41-4 | 8.5e-009 | | | | | 5.2e-010 | 3.0e-001 | fetotoxicity | 1.7e-009 |
| Chloroform | 67-66-3 | 6.8e-009 | 1.8e-010 | B2 | 8.1e-002 | 1.5e-011 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 2.5e-009 | 6.6e-011 | B2 | 9.1e-002 | 6.0e-012 | | | | |
| Sum Of Risks | | | | | | 3.9e-011 | | | | |
| Hazard Index | | | | | | | | | | 1.7e-008 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Inhalation Rate (m^3/h) | 1.25 |
| Exposure Time (h/d) | 8 |
| Exposure Frequency (d/y) | 156 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

**Table 6I.119**

File: ING-DEER-BND-A

Excess lifetime cancer risk and hazard index for a hunter from the ingestion of deer

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Deer (mg/kg) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Tetrachloroethene | 127-18-4 | 1.5e-007 | 4.1e-011 | B2 | 5.1e-002 | 2.1e-012 | 9.6e-011 | 1.0e-002 | liver | 9.6e-009 |
| Trichloroethene | 79-01-6 | 9.0e-008 | 2.5e-011 | B2 | 1.1e-002 | 2.7e-013 | | | | |
| Carbon disulfide | 75-15-0 | 3.8e-008 | | | | | 2.4e-011 | 1.0e-001 | fetotoxicity | 2.4e-010 |
| Chloroform | 67-66-3 | 3.5e-008 | 9.7e-012 | B2 | 6.1e-003 | 5.9e-014 | 2.3e-011 | 1.0e-002 | liver | 2.3e-009 |
| Acetone | 67-64-1 | 4.3e-010 | | | | | 2.8e-013 | 1.0e-001 | kidney | 2.8e-012 |
| Silver | 7440-22-4 | 8.0e-005 | | | | | 5.1e-008 | 3.0e-003 | skin | 1.7e-005 |
| Sum Of Risks | | | | | | 2.4e-012 | | | | |
| Hazard Index | | | | | | | | | | 1.7e-005 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Consumption Rate (kg/y) | 16.4 |
| Fraction Ingested (unitless) | 1 |
| Exposure Duration (y) | 30 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 30 y * 365 d/y |

File: INH-VAP-FENCE-A

Excess lifetime cancer risk and hazard index for a boundary receptor at the WAG 6 boundary from the inhalation of the vapor phase

| | | | CARCINOGENS | | | | NONCARCINOGENS | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Analyte Name | CAS Number | Concentration in Air (mg/m^3) | Daily Intake (mg/kg-d) | USEPA Class | Slope Factor (kg-d/mg) | Excess Lifetime Cancer Risk | Daily Intake (mg/kg-d) | Reference Dose RfD (mg/kg-d) | Effect | Hazard Quotient |
| Tetrachloroethene | 127-18-4 | 9.9e-009 | 4.2e-009 | B2 | 1.8e-003 | 7.7e-012 | | | | |
| Chloromethane | 74-87-3 | 7.8e-009 | 3.3e-009 | C | 6.3e-003 | 2.1e-011 | | | | |
| Xylenes(total) | 1330-20-7 | 7.1e-009 | | | | | 3.0e-009 | 1.0e-001 | neurotoxicity | 3.0e-008 |
| Trichloroethene | 79-01-6 | 3.8e-009 | 1.6e-009 | B2 | 1.7e-002 | 2.7e-011 | | | | |
| Toluene | 108-88-3 | 3.1e-009 | | | | | 1.3e-009 | 6.0e-001 | neurotoxicity | 2.2e-009 |
| Benzene | 71-43-2 | 2.9e-009 | 1.2e-009 | A | 2.9e-002 | 3.5e-011 | | | | |
| Ethyl benzene | 100-41-4 | 2.6e-009 | | | | | 1.1e-009 | 3.0e-001 | fetotoxicity | 3.6e-009 |
| Chloroform | 67-66-3 | 2.1e-009 | 8.8e-010 | B2 | 8.1e-002 | 7.1e-011 | | | | |
| 1,2-Dichloroethane | 107-06-2 | 7.5e-010 | 3.2e-010 | B2 | 9.1e-002 | 2.9e-011 | | | | |
| Sum Of Risks | | | | | | 1.9e-010 | | | | |
| Hazard Index | | | | | | | | | | 3.6e-008 |

| EXPOSURE ASSUMPTIONS | VALUE |
|---|---|
| Inhalation Rate (m^3/hr) | 1.25 |
| Exposure Time (h/d) | 24 |
| Exposure Frequency (d/y) | 365 |
| Exposure Duration (y) | 70 |
| Body Weight (kg) | 70 |
| Averaging Time (d) | |
| Carcinogens | 70 y * 365 d/y |
| Noncarcinogens | 70 y * 365 d/y |

# APPENDIX 6J. TOXICOLOGICAL EFFECTS ASSOCIATED WITH HUMAN EXPOSURE TO CONTAMINANTS OF POTENTIAL CONCERN AT WAG 6

This Appendix supplements Sect. 6.4, the toxicity assessment in the main report. Specifically this appendix discusses the potential toxicological effects associated with human exposure to radionuclides and chemicals of potential concern at WAG 6.

The toxicity assessment is completed in two steps: a hazard identification and a dose-response assessment. The hazard identification is the process of determining whether exposure to an agent can cause an increase in the incidence of a particular adverse health effect (e.g., cancer, birth defect). The second step, the dose response evaluation, is the process of quantitatively evaluating the toxicity information and characterizing the relationship between the dose of the contaminant administered or received and incidence of adverse health effects in the exposed population. From this quantitative dose-response relationship, toxicity values are derived that can be used to estimate the incidence of adverse effects. This section summarizes the hazard identification, the dose-response relationship, and the toxicity values that express these relationships for radionuclides and chemicals of concern at WAG 6.

## 6J.1 RADIONUCLIDE TOXICITY ASSESSMENT

### 6J.1.1 Radionuclide Hazard Identification

There are many types of ionizing radiation (e.g., alpha, beta, gamma, neutron, and positron) that are capable of producing damage in the human body. This damage is caused by the interaction of radiation with atoms that make up the body's cells, fluids, and tissues. These interactions result in the removal or rearrangement of the atom's orbital electrons, and/or changes in the atoms's nucleus. Such alterations of the atom's structure often result in molecular changes. A sufficient number of these molecular changes may result in either changes in a cell's function or in cell death. If a large enough number of cells are so affected, certain "effects" can be observed in the body.

The degree of damage caused varies in proportion to how much energy is transferred to the tissue over a linear track length by the radiation. This concept is referred to as linear energy transfer (LET). High LET radiation causes a high degree of ionization by depositing a large amount of energy over a short distance Low LET radiations deposit energy over a much longer range and create less densely ionized regions. For a given amount of deposited total energy, high LET radiation will produce significantly greater biological damage than low LET radiation will.

There are two broad classes of effects resulting from radiation exposures: stochastic and nonstochastic. Nonstochastic effects are those that have protective mechanisms that must be overcome before an observable adverse effect occurs. This concept is referred to as an "observable threshold." Nonstochastic effects increase in severity with increasing dose. Some examples of nonstochastic effects include cell death, clouding of the lens of the eye,

cosmetically-unacceptable changes in the skin, and premature menopause. For radionuclides, these effects are observable only at relatively high doses. Human exposures below about 10 to 20 rem usually do not result in detectable nonstochastic effects.

Stochastic effects are those effects that are random (e.g., probabilistic) in nature and conservatively regarded as having no threshold. In the nonthreshold hypothesis (stochastic effects), no dose is thought to be risk free. Stochastic effects can be further divided into carcinogenic and noncarcinogenic effects.

Carcinogenic effects result in cancer. Among noncarcinogenic effects are genetic and teratological effects. The effects that are passed on through biologic mechanisms of inheritance are termed genetic effects. Teratological effects are commonly known as birth defects.

Carcinogenic effects are the major endpoints for risk assessment from radionuclides. Radiation-induced effects (i.e., cancer) are assumed to be linearly proportional to dose by the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP). No threshold associated with exposure to ionizing radiation was assumed, so that any exposure, no matter how small, might give rise to cancer.

Genetic and teratologic effects are not considered to be of primary concern relative to the WAG 6 human health assessment. The ICRP places the risk of genetic effects at approximately a factor of two lower than the risk of carcinogenic effects (e.g., $4 \times 10^{-5}$ $rem^{-1}$ versus $10^{-4}$ $rem^{-1}$) (ICRP 1977). It has been observed that very low doses of low linear energy transfer radiations (i.e., x-rays, electrons, and gamma rays) probably do not significantly increase mutational frequency or at least that such lesions are repairable. Further, ICRP states that risk assessment due to genetic effects should be made over the total population and most risk assessment scenarios do not include populations sufficiently large enough to represent a potential threat to the gene pool. For teratogens, current data on teratological effects are insufficient to predict a relationship at low doses (UNSCEAR 1977).

There are 12 radionuclides which are modeled at WAG 6 for further quantitative analyses. Included with these 12 radionuclides are 5 daughters which are assumed to be in equilibrium with the parent. All of these radionuclides are classified as carcinogens by the EPA (1986) or the International Agency for Research on Cancer (IARC 1982). Table 6.1 in Sect. 6 of the main report lists the radionuclides included in the baseline human health evaluation at WAG 6.

### 6J.1.2 Dose-Response Evaluation for Radionuclides

To provide a meaningful measurement for radiation exposure, units were derived based on the amount of energy transferred to the exposed material by radiation. This special unit of absorbed dose is a rad. To account for different ionizing capabilities of radiation, the

absorbed dose in rad is multiplied by modifying factors resulting in a dose equivalent unit termed a rem.

There have been many compilations of data relating the human exposure in an environmental media to a resultant dose equivalent in an exposed individual. This work has resulted in dose conversion factors (DCFs) which are used to convert human exposure to dose equivalent. The DCFs for radionuclides are provided in Table 6J.1. Because the factors converting from absorbed dose to dose equivalent were designed for control of occupational exposures they are not readily applicable to the prediction of cancer risk. However, an appropriate risk factor (risk per rem) may be multiplied by those dose equivalents (rem) to yield an estimate of risk, they do not take into account the observed cancer risk differences between high and low LET radiation presented in Table 6J.2.

Another estimate of risk is obtained using slope factors to quantify the dose response relationship. The slope factors attempt to take the observed cancer risk differences between high and low LET radiation into account. Slope factors are computed using age- and sex-specific coefficients for individual organs receiving significant radiation doses. This information is then used along with organ-specific dose conversion factors to derive slope factors that represent the age-averaged lifetime excess cancer incidence per unit intake for radionuclides of concern. Table 6J.3 lists the slope factors for the three major exposure pathways at WAG 6 (inhalation, ingestion and ground-surface irradiation).

## 6J.2 CHEMICAL TOXICITY ASSESSMENT

### 6J.2.1 Chemical Hazard Identification

The chemical hazard identification separates the potential chemicals of concern into toxicologic categories, depending on their toxicodynamic behavior in biological systems. The basis of categorization is whether a chemical exhibits noncarcinogenic or carcinogenic effects. This distinction relates to the currently-held scientific consensus that the mechanisms of toxic action differ for these two classes. For carcinogens, it is assumed that there is no level of exposure below which cancer will not occur in some individuals (i.e., there is no threshold dose for carcinogenic effects). For chemicals with noncarcinogenic effects, it is believed that organisms have protective mechanisms that must be overcome before a toxic endpoint is produced (i.e., there is a threshold dose for a response to a toxicant). This threshold view for noncarcinogenic effects holds that a range of exposures up to a defined threshold can be tolerated by an organism without appreciable risk of causing the toxic effect. Noncarcinogenic effects cover a broad range of toxicological end points ranging from effects on specific organ systems (e.g., neurotoxicity) to effects on reproduction and offspring (e.g., fetotoxicity). Chemicals considered to be potential carcinogens are also capable of causing noncarcinogenic effects.

There are 14 chemicals of potential concern at WAG 6 (identified in Sect. 6.2 of the main report) that are classified as known or probable human carcinogens by the EPA Carcinogenic Assessment Group or the International Agency for Research on Cancer. Table 6J.4 lists the chemicals classified as carcinogens at WAG 6.

There are 33 chemicals of potential concern at WAG 6 that are classified in the general category of chemicals with noncarcinogenic effects. Nine chemicals exhibit both noncarcinogenic and carcinogenic effects. Table 6J.4 also lists these chemicals.

Summary toxicity profiles for carcinogenic and noncarcinogenic chemicals of concern at WAG 6 are summarized in Attachment 6J.1. These profiles summarize the potential health effects associated with the chemicals. They are not intended to include all the toxicity characteristics of a chemical. The toxicity profiles contain specific toxic effects associated with specific exposures, general toxicity information, cancer potential information, and symptoms of exposure. Further toxicological information may be found in the open literature.

### 6J.2.2 Dose-Response Evaluation for Chemicals

The dose-response evaluation for chemicals is completed for both carcinogens and chemicals with noncarcinogenic effects. The EPA assigns a weight-of-evidence classification (EPA 1986c) to potential human carcinogens. Information considered in development the classification was based on human and animal studies. Both studies investigate the relationship between exposure and the development of cancer. Other supporting evidence may include short-term tests for genotoxicity, metabolic and pharmacokinetic properties, toxicological effects other than cancer, structure-activity relationships, and physicochemical properties of the chemical. The EPA classification system for weight-of-evidence is shown in Table 6J.5.

In this human health evaluation, chemicals placed in groups A and B are considered carcinogenic and have an appropriate toxicity value to quantitatively evaluate the risk. Table 6J.6 identifies the weight-of-evidence class for carcinogens at WAG 6.

The quantitative toxicity factor that defines the relationship between dose and response for carcinogens is the slope factor, also known as the carcinogenic potency factor. Slope factors are generally calculated for carcinogens in EPA weight-of-evidence classes A, B1, and B2. The slope factor is used to estimate an upper bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen. The carcinogenic slope factors are expressed in units of $(mg/kg\text{-}day)^{-1}$. Slope factors are derived from the results of animal and human studies. Animal studies are usually conducted at dose levels that are much higher than those likely to be produced by human exposure to environmental media, in order to detect possible adverse effects in the animal test populations. Since humans are generally exposed at lower doses, the animal data are adjusted using mathematical models, such as the linearized multistage model to obtain a dose-response relationship. This model assumes that there is no threshold for carcinogenesis (i.e., no level of exposure to a carcinogen that does not pose a probability of generating a carcinogenic response). The slope factors for carcinogens at WAG 6 are summarized in Table 6J.6.

The quantitative toxicity factor that defines the relationship between dose and response for chemicals with noncarcinogenic effects is the reference dose (RfD). The RfD, expressed

in units of milligrams per kilogram of body weight per day (mg/kg/day), is an estimate of the maximum human chronic daily exposure level that is likely to be without an appreciable risk of adverse effect during a lifetime. In accordance with the exposure assessment, all of the exposure durations are 7 years or greater requiring the use of chronic values. The RfDs are usually derived either from human or animal studies and are adjusted using uncertainty factors. The RfDs for the potential chemicals of concern on WAG 6 are presented in Tables 6J.7 and 6J.8.

The toxicity value for chromium (VI) will be used to represent chromium (total) for the water pathways at WAG 6. This assumes that all of the total chromium is in the chromium (VI) form for water. In freshwater, chromium can be present in the chromium (III) (less toxic) and chromium (VI) (more toxic) forms (Towill et al. 1978). In water, to be conservative in the baseline human health evaluation the chromium (VI) form is assumed. In soil, chromium (VI) is easily converted to chromium (III) in the presence of organic matter, even at alkaline pH (Barlett and Kimble 1976). At WAG 6, the soil is low in organic matter, however has an acidic pH (Lietzke, Lee, and Tamura 1988). Therefore it is assumed that the chromium (III) form is present in the WAG 6 soils.

The toxicity values presented in Tables 6J.6, 6J.7, and 6J.8 are expressed as administered doses. These are used directly for the quantification of risk for all pathways in the exposure assessment except for the dermal route of exposure. The dermal route requires a toxicity value based on an absorbed dose. Toxicity values for an absorbed dose could be found. The oral toxicity values are adjusted to absorbed doses. In the absence of appropriate information a 5% absorption efficiency is conservatively assumed (i.e., .05 is multiplied by the oral RfD and the oral slope factor is divided by .05) (EPA 1989b).

All chemicals were evaluated that had appropriate toxicity information available. There were 2 organics and 4 inorganics that had no toxicity values and were not considered further in the assessment. The organics included 1,2-dichloroethene (CAS 540-59-0) and arochlor 1254 (CAS 11097-69-1) and the inorganics included aluminum (CAS 7429-90-5), strontium (CAS 7440-24-6), titanium (CAS 7440-32-6) and cobalt (CAS 7440-48-4).

# Appendix 6J Tables

Table 6J.1. Dose conversion factors for radionuclides at WAG 6

| Nuclide | Inhaled[a] (mrem/pCi) | Ingested[a] (mrem/pCi) | Direct[b] (mrem/y) per (pCi/m²) |
|---|---|---|---|
| H-3 | 6.40e-08 | 6.40e-08 | 0.00 |
| Co-60 | 2.19e-04 | 2.69e-05 | 2.27e-04 |
| Sr-90 | 1.30e-03 | 1.42e-04 | 0.00 |
| Y-90 | 8.44e-06 | 1.08e-05 | 0.00 |
| Cs-137 | 3.19e-05 | 5.00e-05 | 0.00 |
| Ba-137m | 0.00 | 0.00 | 6.11e-05 |
| Eu-152 | 2.21e-04 | 6.48e-06 | 1.11e-04 |
| Eu-154 | 2.86e-04 | 9.55e-06 | 1.21e-04 |
| Eu-155 | 4.14e-05 | 1.53e-06 | 7.15e-06 |
| Th-232 | 1.64e+00 | 2.73e-03 | 6.66e-08 |
| U-233 | 1.35e-01 | 2.89e-04 | 5.00e-08 |
| U-238 | 1.18e-01 | 2.55e-04 | 6.46e-08 |
| Th-234 | 3.50e-05 | 1.37e-05 | 1.01e-06 |
| Pa-234m | 0.00 | 0.00 | 1.13e-06 |
| Pa-234 | 8.14e-07 | 2.16e-06 | 1.96e-04 |
| Am-241 | 4.44e-01 | 3.64e-03 | 2.99e-06 |
| Cm-244 | 2.48e-01 | 2.02e-03 | 8.29e-08 |

[a]*Source*: EPA 1988d
[b]*Source*: Kocher 1988

Table 6J.2. Summary of current EPA-recommended radiation risk factors

| Risk | Significant exposure period | Risk factor effect/$10^6$ rad | |
|---|---|---|---|
| | | Nominal | Range |
| **Low LET** | | | |
| Carcinogenic effects | | | |
| • Fatal cancers | lifetime | 390 | 120-1,200 |
| • All cancers | lifetime | 620 | 190-1,900 |
| Genetic effects | | | |
| • Severe hereditary defects, all generators | 30-year reproductive generation | 260 | 60-1,100 |
| Teratogenic effects | | | |
| • Severe mental retardation | weeks 8 to 15 of gestation | 4,000 | 2,500-5,500 |
| • Malformation | weeks 2-8 of gestation | 5,000 | -- |
| • Pre-implantation loss | weeks 0-2 of gestation | 10,000 | -- |
| **High LET** | | | |
| Carcinogenic effects | | | |
| • Fatal cancers | lifetime | 3,100 | 960-9,600 |
| • All cancers | lifetime | 5,000 | 1,500-15,000 |
| Genetic effects | | | |
| • Severe hereditary defects, all generators | 30-year reproductive generation | 690 | 160-2,900 |

**Table 6J.3 Slope factors for radionuclides at WAG 6**

| Nuclide | Inhale 1/pCi | Ingest 1/pCi | External (1/y)/ (pCi/m²) |
|---|---|---|---|
| H-3 | 7.8e-14 | 5.5e-14 | 0.0 |
| Co-60 | 1.6e-10 | 1.5e-11 | 1.3e-10 |
| Sr-90 | 5.6e-11 | 3.3e-11 | 0.0 |
| Y-90 | 5.5e-12 | 3.2e-12 | 0.0 |
| Cs-137 | 1.9e-11 | 2.8e-11 | 0.0 |
| Ba-137m | 6.0e-16 | 2.4e-15 | 3.4e-11 |
| Eu-152 | 1.2e-08 | 2.1e-12 | 6.3e-11 |
| Eu-154 | 1.4e-10 | 3.0e-12 | 6.8e-11 |
| Eu-155 | 3.0e-09 | 5.2e-13 | 5.2e-12 |
| Th-232 | 3.1e-08 | 2.2e-11 | 4.6e-14 |
| U-233 | 2.7e-08 | 1.4e-10 | 3.3e-14 |
| U-238 | 2.4e-08 | 1.3e-10 | 4.6e-14 |
| Th-234 | 3.2e-11 | 4.0e-12 | 5.6e-13 |
| Pa-234m | 1.6e-15 | 5.8e-15 | 6.4e-13 |
| Pa-234 | 5.4e-13 | 6.8e-13 | 1.1e-10 |
| Am-241 | 4.0e-08 | 3.1e-10 | 1.6e-12 |
| Cm-244 | 2.7e-08 | 2.0e-10 | 5.8e-14 |

*Source*: EPA 1990b

Table 6J.4. Chemicals classified as carcinogens and noncarcinogens at WAG 6

| Chemical | | Carcinogen | Noncarcinogen |
|---|---|---|---|
| **Organics** | | | |
| Carbon Tetrachloride | 56-23-5 | X | |
| Acetone | 67-64-1 | | X |
| Chloroform | 67-66-3 | X | |
| Benzene | 71-43-2 | X | |
| 1,1,1-Trichloroethane | 71-55-6 | | X |
| Ethyl Chloride | 75-00-3 | | X |
| Vinyl Chloride | 75-01-4 | X | |
| Methylene Chloride | 75-09-2 | X | |
| Carbon Disulfide | 75-15-0 | | X |
| 1,1-Dichloroethane | 75-34-3 | | X |
| 1,1-Dichloroethene | 75-35-4 | X | |
| Trichlorofluoromethane | 75-69-4 | | X |
| 2-Butanone | 78-93-3 | | X |
| 1,1,2-Trichloroethene | 79-00-5 | X | |
| Trichloroethene | 79-01-6 | X | |
| 1,1,2,2-Tetrachloroethene | 79-34-5 | X | |
| Diethylphthalate | 84-66-2 | | X |
| Di-N-Butylphthalate | 84-74-2 -2 | | X |
| Napthalene | 91-20-3 | | X |
| 2,4,5-TP | 93-72-1 | | X |
| 2,4,5-T | 93-76-5 | | X |
| 2,4-D | 94-75-7 | | X |
| 2-Methlyphenol | 95-48-7 | | X |
| Ethylbenzene | 100-41-4 | | X |
| Benzyl Alcohol | 100-51-6 | | X |
| 1,2-Dichloroethene | 107-06-2 | X | |
| Toluene | 108-88-3 | | X |
| Bis (2-Ethylhexyl) phthalate | 117-81-7 | X | X |
| Tetrachloroethene | 127-18-4 | X | X |
| 1,2- Dichloroethene | 540-59-0 | | |
| Xylene (total) | 1330-20-7 | | X |
| Arochlor 1254 | 11097-69-1 | | |
| **Inorganics** | | | |
| Aluminum | 7429-90-5 | | |
| Manganese | 7439-96-5 | | X |
| Mercury | 7439-97-6 | | X |
| Nickel | 7440-02-0 | | X |
| Silver | 7440-22-4 | | X |
| Strontium | 7440-24-6 | | |

Table 6J.4 (continued)

| Chemical | | Carcinogen | Noncarcinogen |
|---|---|---|---|
| Thallium | 7440-28-0 | | X |
| Titanium | 7440-32-6 | | |
| Cadmium | 7440-43-9 | X | X |
| Chromium | 7440-47-3 | | |
| Chromium VI | 18540-29-9 | X | X |
| Cobalt | 7440-48-4 | | |
| Vanadium | 7440-62-2 | | X |

Table 6J.5. EPA Weight-of-evidence for chemicals

| Group | Description |
|---|---|
| A | Human carcinogen. |
| B1 or B2 | Probable human carcinogen.<br>B1 indicates that limited human data are available.<br>B2 indicates sufficient evidence in animals and inadequate or no evidence in humans. |
| C | Possible human carcinogen. |
| D | Not classifiable as to human carcinogenicity. |
| E | Evidence of non-carcinogenicity for humans. |

*Source*: EPA 1989b.

Table 6J.6. Slope factors for carcinogenic chemicals of potential concern at WAG 6

| CAS No. | Chemical | Weight of evidence (class) | Oral slope factor $(mg/kg\text{-}day)^{-1}$ | Inhalation slope factor $(mg/kg\text{-}day)^{-1}$ | Type of cancer, Oral/inhalation | Oral slope factor source | Inhalation slope factor source |
|---|---|---|---|---|---|---|---|
| **Organics** | | | | | | | |
| 56-23-5 | Carbon tetrachloride | B2 | .13 | .13 | Liver/liver | Gavage/ IRIS | Gavage/ HEAST |
| 67-66-3 | Chloroform | B2 | .0061 | .081 | Kidney/liver | Animal, water/ IRIS | Animal, gavage/ HEAST |
| 71-43-2 | Benzene | A | 0.029 | 0.029 | Leukemia/ leukemia | Occupa-tional/ IRIS | Occupa-tional/ HEAST |
| 75-01-4 | Vinyl chloride | A | 1.9 | .29 | Lung/liver | Animal, inhalation/ HEAST | Animal, inhalation/ HEAST |
| 75-09-2 | Methylene chloride | B2 | 0.0075 | .0016 | Liver/lung, liver | Animal, water/ IRIS | - |
| 75-35-4 | 1,1-Dichloroethene | C | 0.6 | 1.2 | Adrenal/kidney | Animal, gavage/ IRIS | Animal, diet/ HEAST |
| 79-00-5 | 1,1,2-Trichloroethane | C | .057 | .057 | Liver/liver | Animal, gavage/ IRIS | Animal, gavage/ HEAST |
| 79-01-6 | Trichloroethene | B2 | 0.011 | .017 | Liver/lung | Animal, gavage/ IRIS | Animal, inhalation/ HEAST |
| 79-34-5 | 1,1,2,2-Tetrachloroethane | C | .2 | .2 | Liver/liver | Animal, gavage/ IRIS | Animal, gavage/ HEAST |
| 107-06-2 | 1,2-Dichloroethane | B2 | .091 | .091 | Circulatory system/circulatory system | Animal, gavage/ IRIS | Animal, gavage/ HEAST |
| 117-81-7 | Bis (2-Ethylhexyl) phthalate | B2 | .014 | - | Liver/- | Animal, dietary/ IRIS | - |
| 127-18-4 | Tetrachloroethene | B2 | .051 | .0018 | Liver/leukemia | Animal, gavage/ HEAST | Animal, inhalation/ HEAST |
| **Inorganics** | | | | | | | |

Table 6J.6 (continued)

| CAS No. | Chemical | Weight of evidence (class) | Oral slope factor $(mg/kg\text{-}day)^{-1}$ | Inhalation slope factor $(mg/kg\text{-}day)^{-1}$ | Type of cancer, Oral/inhalation | Oral slope factor source | Inhalation slope factor source |
|---|---|---|---|---|---|---|---|
| 7440-43-9 | Cadmium | B1 | - | 6.1 | -/Respiratory tract | - | Occupational/ HEAST |
| 18540-29-9 | Chromium VI | A | - | 41 | -/Lung | - | Occupational/ HEAST |

- = No data available.

*Sources*: EPA 1991a
EPA 1991b

Table 6J.7. Oral reference doses for noncarcinogenic chemicals of potential concern at WAG 6

| CAS No. | Chemical | Oral Rfd (mg/kg-day) | Confidence in Rfd (a) | Critical effect | Rfd Critical study/ source | Uncertainty factor/ modifying factor |
|---|---|---|---|---|---|---|
| Organics | | | | | | |
| 56-23-5 | Carbon Tetrachloride | 0.0007 | Medium | Liver effects | Animal, gavage/IRIS | uf=1000 mf=1 |
| 67-66-3 | Chloroform | .01 | Medium | Liver effects | Animal, diet/IRIS | uf=1000 mf=1 |
| 71-55-6 | 1,1,1-Trichloroethane | 0.09 | Medium | Liver effects | Animal, inhalation/IRIS | uf=1000 mf=1 |
| 75-15-0 | Carbon disulfide | 0.1 | Medium | Fetal effects | Animal, inhalation/ IRIS | uf=100 mf=1 |
| 75-34-3 | 1,1-Dichloroethane | 0.1 | - | Kidney effects (b,c) | Animal, inhalation /HEAST | uf=1000 |
| 75-09-2 | Methylene chloride | 0.06 | Medium | Liver effects | Animal, water/IRIS | uf=100 mf=1 |
| 75-35-4 | 1,1-Dichloroethene | .009 | Medium | Liver effects | Animal, water/IRIS | uf=1000 mf=1 |
| 67-64-1 | Acetone | 0.1 | Low | Kidney effects | Animal, gavage/IRIS | uf=1000 mf=1 |
| 75-69-4 | Trichlorofluoro-methane | .3 | Medium | Respiratory & cardiovascular effects | Animal, diet/IRIS | uf=1000 mf=1 |
| 78-93-3 | 2-Butanone | .05 | Medium | Fetal toxicity | Animal, diet/IRIS | uf=1000 mf=1 |
| 79-00-5 | 1,1,2-Trichloroethane | .004 | Medium | Immune System, liver, hematologic effects | Animal, water/IRIS | uf=1000 mf=1 |
| 84-74-2 | Di-n-butylphthalate | .1 | Low | Liver & kidney effects (c) | Animal, diet/IRIS | uf=1000 mf=1 |
| 93-76-5 | 2,4,5-T | .01 | Medium | Fetal effects, kidney | Animal, diet/IRIS | uf=300 mf=1 |
| 100-41-4 | Ethylbenzene | 0.1 | Low | Liver & kidney effects | Animal, diet/IRIS | uf=1000 mf=1 |
| 100-51-6 | Benzyl Alcohol | .3 | - | Digestive effects | Animal, gavage/HEAST | uf=1000 |
| 108-88-3 | Toluene | 0.2 | Medium | Liver & kidney effects | Animal, diet/IRIS | uf=1000 mf=1 |
| 84-66-2 | Diethylphthalate | 0.8 | Low | Liver & kidney effects (c) | Animal, diet/IRIS | uf=1000 mf=1 |
| 117-81-7 | Bis(2-ethyhexyl) phthalate | .02 | Medium | Liver & kidney effects | Animal, diet/IRIS | uf=1000 mf=1 |

## Table 6J.7 (continued)

| CAS No. | Chemical | Oral Rfd (mg/kg-day) | Confidence in Rfd (a) | Critical effect | Rfd Critical study/ source | Uncertainty factor/ modifying factor |
|---|---|---|---|---|---|---|
| 127-18-4 | Tetrachloroethene | .01 | Medium | Liver effects | Animal, gavage/IRIS | uf=1000 mf=1 |
| 95-48-7 | 2-Methylphenol | 0.05 | Medium | Neurotoxicity | Animal, gavage/IRIS | uf=1000 mf=1 |
| 91-20-3 | Naphthalene | .004 | - | Kidney (d) | Animal,gavage/ HEAST | uf=10000 |
| 93-72-1 | 2,4,5-TP | .008 | Medium | Liver effects | Animal, diet/IRIS | uf=100 mf=1 |
| 94-75-7 | 2,4-D | .01 | Medium | Hematologic effects, kidney | Animal, diet/IRIS | uf=100 mf=1 |
| 1330-20-7 | Xylene (total) | 2 | Medium | Neurotoxicity | Animal, gavage/IRIS | uf=100 mf=1 |
| Inorganics | | | | | | |
| 7440-43-9 | Cadmium | .001 food .0005 water | High | Kidney effects | Human/IRIS | uf=10 mf=1 |
| 18540-29-9 | Chromium VI | 0.005 | Low | Neurotoxicity (e) | Animal, water/IRIS | uf=500 mf=1 |
| 7439-96-5 | Manganese | 0.1 | Medium | Neurotoxicity (e) | Human, diet/IRIS | uf=1 mf=1 |
| 7439-97-6 | Mercury | 0.0003 | - | Kidney effects | Animal/HEAST | uf=1000 |
| 7440-02-0 | Nickel (soluble salts) | 0.02 | Medium | Kidney effects (e) | Animal, diet/IRIS | uf=300 mf=3 |
| 7440-22-4 | Silver | .003 | Medium | Skin effects | Human/IRIS | uf=2 mf=1 |
| 7440-28-0 | Thallium | 0.00007 | Low | Skin effects | Animal, gavage/IRIS | uf=3000 |
| 7440-62-2 | Vanadium | .007 | - | Kidney effects (e) | Animal, water/HEAST | uf=100 |

- = No data available.
a = Confidence level from IRIS, either low, medium, or high.
b = Based on animal inhalation study.
c = Based on phthalic acid ester data.
d = Based on 1988 HEA (EPA 1988c)
e = Critical effect is not clearly defined in IRIS or HEAST. The listed critical effect was selected after a review of the toxicity information in IRIS and HEAST.

uf = Uncertainty factors used to represent adjustments for variation in human sensitivity, animal to human extrapolation, extrapolation from subchronic to chronic NOAEL, extrapolation from LOAEL to NOAEL.

mf = Modifying factors based on judgement to account for uncertainty not addressed by the uf's.

*Sources*: EPA 1991b, c

Table 6J.8 Inhalation reference doses for noncarcinogenic chemicals of potential concern at WAG 6

| CAS No. | Chemical | Inhalation Rfd (mg/kg-day)(a) | Confidence in Rfd (b) | Critical effect | Rfd Critical study /source | Uncertainty factor/ modifying factor |
|---|---|---|---|---|---|---|
| **Organics** | | | | | | |
| 71-55-6 | 1,1,1-Trichloroethane | .3 | NA | Liver effects | Animal, inhalation/HEAST | uf=1000 |
| 75-00-3 | Ethyl Chloride | .3 | Medium | Fetal effects | Animal, inhation/IRIS | uf=300 mf=1 |
| 75-34-3 | 1,1-Dichloroethane | 0.1 | NA | Kidney effects | Animal, inhalation/ HEAST | uf=1000 |
| 75-09-2 | Methylene chloride | .9 | NA | Liver effects | Animal, inhalation/ HEAST | uf=100 |
| 75-69-4 | Trichlorofluoro-methane | .2 | NA | Respiratory effects | Animal, inhalation/ HEAST | uf=10000 |
| 78-93-3 | 2-Butanone | .1 | NA | Central nervous system effects | Animal, inhalation/ HEAST | uf=1000 |
| 100-41-4 | Ethylbenzene | .3 | Low | Developmental effects | Animal, inhalation/IRIS | uf=300 |
| 108-88-3 | Toluene | .6 | NA | Neurotoxicity | Human, inhalation/ HEAST | uf=100 |
| 1330-20-7 | Xylene (total) | .1 | NA | Central nervous system effects | Human, inhalation/HEAST | uf=100 |
| **Inorganics** | | | | | | |
| 18540-29-9 | Chromium VI | .0000006 | NA | Respiratory effects | Human/HEAST | uf=300 |
| 7439-96-5 | Manganese | .0001 | Medium | Neurotoxicity | Human, occupational/IRIS | uf=300 mf=3 |
| 7439-97-6 | Mercury | 0.00009 | NA | Central nervous system | Human, occupational /HEAST | uf=30 |

- = No data available.
a = Levels were converted to Rfds from Reference concentrations ($\mu g/m^3$) by dividing by 70 kg (assumed body weight) and multiplying by 20 $m^3$/day
b = Confidence level from IRIS, either low, medium, or high.

uf = Uncertainty factors used to represent adjustments for variation in human sensitivity, animal to human extrapolation, extrapolation from subchronic to chronic NOAEL, extrapolation from LOAEL to NOAEL.

MF = Modifying factors based on judgement to account for uncertainty not addressed by the UFs.

*Source:* EPA, 1991b, c

## ATTACHMENT 6J.1. TOXICITY PROFILES FOR CONTAMINANTS OF CONCERN

### VOLATILE ORGANICS

**Carbon Disulfide (75-15-0)**

Toxicity Potential

Symptoms: Carbon disulfide affects the gastrointestinal tract, the central nervous system, the cardiovascular system, the eyes, the kidneys, the liver, and the skin. Symptoms of exposure include an early excitation of the central nervous system, followed by depression with stupor, restlessness, and unconsciousness. Also possible are motor disturbances of the bowel, anemia, disturbances of cardiac rhythm, ocular changes, anorexia, loss of weight, polyuria, and menstrual disorders.

Exposure: Oral
Species: Rabbit

| | |
|---|---|
| Effect of Concern: | fetal toxicity; malformation |
| Subchronic: | 20 ppm (62.3 mg/m$^3$) inhalation 6 hours/day during pregnancy and before breeding (1.6 m$^3$/day breathing rate and 0.5 absorption factor used to calculate dose of 11.0 mg/kg/day) |
| Effect of Concern: | fetal toxicity; malformation |
| Chronic: | 20 ppm (62.3 mg/m$^3$) inhalation 6 hours/day during pregnancy and before breeding (1.6 m$^3$/day breathing rate and 0.5 absorption factor used to calculate dose of 11.0 mg/kg/day) |

Source: 1, 4, 5

**Carbon Tetrachloride (56-23-5)**

Toxicity Potential

Symptoms: The short-term minimum risk level (MRL) for inhalation is 1 ppm for a period of 14 days. Inhalation of 250 ppm will result in death in sensitive individuals. The long-term MRL for inhalation is 0.015 ppm. For ingestion, the short-term MRL is 0.6 ppm for a period of 1 to 14 days. The long-term MRL for inhalation is 0.25 ppm for 15 days to a lifetime. The primary result of carbon tetrachloride ingestion is liver lesions. One study showed death resulted from ingesting levels of 100-200 mg/kg body weight. Symptoms of carbon tetrachloride exposure include central nervous system depression, nausea, vomiting, liver and kidney damage, and skin irritations.

Carbon tetrachloride is classed as a level B2 probable human carcinogen by the Carcinogen Assessment Group (CAG) based on animal studies. There have been three case reports of liver tumors resulting after carbon tetrachloride inhalation exposure. Tumors resulting from inhalation and ingestion are located in the liver.

Exposure: Oral
Species: Rat

| | |
|---|---|
| Effect of Concern: | Liver lesions |
| Subchronic: | 1 mg/day, 5 days/week for 12 weeks (0.71 mg/kg/day) |

| | |
|---|---|
| Effect of Concern: | Liver lesions |
| Chronic: | 1 mg/day, 5 days/week for 12 weeks (0.71 mg/kg/day) |

**Cancer Potential**

| | |
|---|---|
| Exposure: | Inhalation; oral |
| | Several gavage studies; several gavage studies |
| Species: | Several; several |
| Tumor Site: | Liver; liver |

**Source:** 1, 3, 4, 5

**Chloroform (67-66-3)**

**Toxicity Potential**

Inhalation exposures of 20,000 to 40,000 ppm produce amnesia. A single ingested dose of 211 mg/kg is lethal for a 70-kg human.

Chronic and Subchronic: The primary concerns resulting from chloroform ingestion are liver lesions and kidney effects.

Acute: Chloroform is a moderately toxic central nervous system depressant and a gastrointestinal irritant. Chloroform has caused rapid death attributable to cardiac arrest.

Symptoms of chloroform exposure include loss of appetite, hallucinations, moodiness, and physical and mental sluggishness. Liquid chloroform in the eye causes tearing and conjunctivitis.

Chloroform is classed by the CAG as a level B2 probable human carcinogen based on animal data. Human carcinogenicity data are inadequate, and studies indicate small significant increases in the probability of rectal, bladder, or colon cancer on an intermittent basis. Tumors resulting from inhalation and ingestion of chloroform are located in the liver and kidney, respectively.

Exposure: Oral
Species: Dog

| | |
|---|---|
| Effect of Concern: | Liver lesions |
| Subchronic: | 15 mg/kg, 6 days/week for 7.5 years (12.9 mg/kg/day) |

| | |
|---|---|
| Effect of Concern: | Liver lesions |
| Chronic: | 15 mg/kg, 6 days/week for 7.5 years (12.9 mg/kg/day) |

**Cancer Potential**

| | |
|---|---|
| Exposure: | Inhalation; oral<br>138-477 mg/kg/day; 200-188 ppm in drinking water for 104 weeks |
| Species: | Mouse; rat |
| Tumor Site: | Liver/kidney |

**Source:** 1, 3, 4

## 1,1 Dichloroethane (75-34-3)

**Toxicity Potential**

The human health effects resulting from inhaling or ingesting specific levels of 1,1-dichloroethane are not known. ATSDR, in conjunction with EPA, is currently evaluating the inhalation exposure database. The primary result of inhalation of 1,1-dichloroethane is kidney damage.

Symptoms of 1,1-dichloroethane exposure include central nervous system depression, skin irritation, drowsiness, unconsciousness, liver damage, and kidney damage.

1,1-Dichloroethane is classed by the CAG as a level C possible human carcinogen based on animal data. Tumors resulting from inhalation and ingestion are located in the circulatory system.

Exposure: Inhalation; Oral
Species: Cat; rat

| | |
|---|---|
| Effect of Concern: | Kidney damage; none |
| Subchronic: | 500 ppm (2025 mg/m$^3$) 6 hours/day, 5 days/week for 13 weeks (138 mg/kg/day); 500 ppm (2025 mg/m$^3$) 6 hours/day, 5 days/week for 13 weeks (138 mg/kg/day) |

| | |
|---|---|
| Effect of Concern: | Kidney damage; none |
| Chronic: | 500 ppm (2025 mg/m$^3$) 6 hours/day, 5 days/week for 13 weeks (138 mg/kg/day); 500 ppm (2025 mg/m$^3$) 6 hours/day, 5 days/week for 13 weeks (138 mg/kg/day) |

**Cancer Potential**

| | |
|---|---|
| Exposure: | Oral<br>Gavage |
| Species: | Rat |
| Tumor Site: | Hemangiosarcoma |

**Source:** 1, 3, 5

**1,2 Dichloroethane (107-06-2)**

**Toxicity Potential:**
Based on animal studies, the short-term MRL for inhalation of 1,2-dichloroethane is 0.025 ppm and the long-term MRL is 0.021 ppm. Inhalation of 1,2-dichloroethane can be lethal. One study reported the death of a 51-year-old man who had inhaled thick 1,2-dichloroethane vapor of unknown concentration. Based on animal studies, the short-term MRL for water ingestion is 0.026 ppm, and the long-term MRL for food ingestion is 0.5 ppm.

1,2-Dichloroethane is classed by the CAG as a level B2 probable human carcinogen based on animal data. Tumors resulting from inhalation and ingestion are located in the circulatory system.

**Cancer Potential:**

| | |
|---|---|
| Exposure: | Inhalation; oral<br>Gavage; gavage |
| Species: | Rat; rat |
| Tumor Site: | Circulatory system; circulatory system |

**Source:** 1, 3, 4, 5

**1,1 Dichloroethene (75-35-4)**

**Toxicity Potential**
Based on animal studies, the short-term inhalation MRL for 1,1-dichloroethene is 0.1 ppm. The inhalation of 4000 ppm of 1,1-dichloroethene induces temporary nervous system disorders. The long-term inhalation MRL is 0.004 ppm. The short-term and long-term ingestion MRL is 40 ppm. The primary result of the ingestion of 1,1-dichloroethene is liver lesions.

1,1-Dichloroethene is classed by the CAG as a level C possible human carcinogen based on animal data. Tumors resulting from inhalation and ingestion are located in the kidneys and adrenal gland, respectively. An epidemiological study of 138 workers revealed no carcinogenic effect associated with 1,1-dichloroethene exposure. This study is inadequate for assessing cancer risk in humans.

| | |
|---|---|
| Exposure: | Oral |
| Species: | Rat |

| | |
|---|---|
| Effect of Concern: | Liver lesions |
| Subchronic: | 50 ppm in drinking water for 2 years (9 mg/kg/day) |
| Chronic: | 50 ppm in drinking water for 2 years (9 mg/kg/day) |

**Cancer Potential**

| | |
|---|---|
| Exposure: | Inhalation; oral<br>10 and 25 ppm for 12 months; gavage |
| Species: | Mouse; rat |
| Tumor Site: | Kidney; adrenal |

**Source:** 1, 4

**1,2-Dichloroethene (540-59-0)**

**Toxicity Potential**

Chronic - Limited data are available. There are some accounts of 1,2-dichloroethene affecting the liver and the lungs. Data are inadequate for quantitative risk assessment of cis-1,2-dichloroethene. Effects of concern for trans-1,2-dichloroethene include increased serum alkaline phosphatase.

| | |
|---|---|
| Exposure: | Oral |
| Species: | Rat |

| | |
|---|---|
| Effect of Concern: | Decreased hematocrit and hemoglobin |
| Subchronic: | Gavage for 90 days (32 mg/kg/day) |

| | |
|---|---|
| Effect of Concern: | Decreased hematocrit and hemoglobin |
| Chronic: | Gavage for 90 days (32 mg/kg/day) |

**Source:** 1, 2

**Ethyl Chloride (75-00-3) (Chloroethane)**

**Toxicity Potential**

Based on human studies, the short-term inhalation MRL for chloroethane would be 1300 ppm. Based on animal studies, the long-term inhalation MRL would be 76 ppm. Exposure effects from ingestion (MRL) are not known.

Chloroethane has been known to be carcinogenic in animals via the inhalation pathway. There are no inhalation data available from human studies. For the ingestion pathway, no studies were cited which listed the carcinogenic effects to humans or animals.

Cancer Potential
Based on human studies, the short-term inhalation minimum risk level (MRL) for chloroethane would be 1300 ppm. Based on animal studies, the long-term inhalation MRL would be 76 ppm. Exposure effects from ingestion (MRL) are not known.

Chloroethane has been known to be carcinogenic in animals via the inhalation pathway. There are no inhalation data available from human studies. For the ingestion pathway, no studies were cited which listed the carcinogenic effects to humans or animals.

Source: 3

**Methylene Chloride (75-09-2)**

Toxicity Potential
The major manifestation of short-term inhalation of methylene chloride in humans is impairment in the functioning of the central nervous system. The inhalation LD50 is estimated at 11,000 to 16,000 ppm. One study reported the long-term exposure of a worker to 660 to 3,600 ppm for several hours per day for 5 years, resulting in toxic encephalosis. The oral LD50 is estimated at 1,000 to 4,000 ppm.

Chronic: The primary effects of concern for methylene chloride exposure are liver toxicity and central nervous system effects.

Symptoms of methylene chloride exposure include sluggishness, irritability, lightheadedness, nausea, and headaches.

Methylene chloride is classed by the CAG as a level B2 probable human carcinogen based on animal data. Human carcinogenicity data are inadequate but suggest an increased incidence of pancreatic tumors. Tumors resulting from inhalation and ingestion are located in the lung and liver, respectively.

The symptoms of 1,2-dichloroethane exposure include central nervous system depression, dermatitis, irritated eyes, and corneal opacity.

| | |
|---|---|
| Exposure: | Inhalation; oral |
| Species: | Rat; rat |
| Effect of Concern: | NA; liver toxicity |
| Subchronic: | 200 ppm (694.8 mg/m$^3$) 6 hours/day, 5 days/week for 2 years; 24-month drinking water study [5.85 mg/kg/day (males) 6.47 mg/kg/day (females)] |

| | |
|---|---|
| Effect of Concern: | NA; Liver toxicity |
| Chronic: | 200 ppm (694.8 mg/m$^3$) 6 hours/day, 5 days/week for 2 years; 24-month drinking water study [5.85 mg/kg/day (males) 6.47 mg/kg/day (females)] |

**Cancer Potential**

| | |
|---|---|
| Exposure: | Inhalation; oral<br>Inhalation study; inhalation and drinking water studies |
| Species: | Mouse; mouse |
| Tumor Site: | Lung, liver; liver |

**Source:** 1, 3, 4, 5

**1,1,2,2-Tetrachloroethane (79-34-5)**

**Toxicity Potential**

Symptoms of 1,1,2,2-tetrachloroethane exposure include nausea and vomiting, abdominal pain, jaundice, enlargement and tenderness of the liver, monocytosis, dermatitis, kidney damage, and paresthesia.

1,1,2,2-Trichloroethane is classed by the CAG as a level C possible human carcinogen based on animal data. Tumors resulting from inhalation and ingestion are located in the liver.

**Cancer Potential**

| | |
|---|---|
| Exposure: | Inhalation; oral<br>Gavage; gavage |
| Species: | Mouse; mouse |
| Tumor Site: | Liver; liver |

**Source:** 1, 4, 5

**Tetrachloroethene (127-18-4)**

**Toxicity Potential**

Chronic and Subchronic: The primary effects of tetrachloroethene ingestion and inhalation are hepatoxicity and central nervous system effects.

Symptoms of tetrachloroethene exposure include dizziness, headache, sleepiness, confusion, nausea, and difficulty in speaking and walking, leading possibly to unconsciousness and death.

Tetrachloroethene is under review for human carcinogenic potential by an inter-office EPA work group. Tumors resulting from inhalation and ingestion are located in the liver. Leukemia is also an effect from inhalation of tetrachloroethene.

| | |
|---|---|
| Exposure: | Oral |
| Species: | Mouse |
| Effect of Concern: | Hepatotoxicity |
| Subchronic: | 20 mg/kg 5 days/week for 6 weeks (14 mg/kg/day) |
| Chronic: | 20 mg/kg 5 days/week for 6 weeks (14 mg/kg/day) |

**Cancer Potential**

| | |
|---|---|
| Exposure: | Inhalation; oral<br>Inhalation; gavage |
| Species: | Rat; mouse |
| Tumor Site: | Leukemia, liver; liver |

**Source:** 1, 3, 4, 5

**1,1,1-Trichloroethane (71-55-6)**

**Toxicity Potential**

The short-term MRL for inhalation of 1,1,1-trichloroethane is 0.255 ppm. At a level of 10,000 ppm, unconsciousness and decreased blood pressure results. The health effects resulting from ingesting specific levels of 1,1,1-trichloroethane are not known. Chronic and subchronic effects include hepatotoxicity for both the inhalation and ingestion pathways. Symptoms of 1,1,1-trichloroethane exposure include headache, central nervous system depression, poor equilibrium, irritated eyes, dermatitis, and cardiac arrhythmias.

1,1,1-Trichloroethane is non-classifiable as to human carcinogenicity (Level D) by the CAG. Evidence is inadequate to determine carcinogenicity to humans. Technical grade 1,1,1-trichloroethane is commonly contaminated with 1,4-dioxane, a known animal carcinogen. 1,4-dioxane may be responsible for the weak mutagenic effects of 1,1,1-trichloroethane.

| | |
|---|---|
| Exposure: | Inhalation; oral |
| Species: | Guinea pig |
| Effect of Concern: | Hepatotoxicity |
| Subchronic: | 500 ppm (2730 mg/m$^3$) 7 hours/day, 5 days/week for 6 months (304 mg/kg/day); 500 ppm (2730 mg/m$^3$) 7 hours/day for 6 months (90 mg/kg/day) |

| | |
|---|---|
| Effect of Concern: | Hepatotoxicity |
| Chronic: | 500 ppm (2730 mg/m$^3$) 7 hours/day, 5 days/week for 6 months (304 mg/kg/day); 500 ppm (2730 mg/m$^3$) 7 hours/day for 6 months (90 mg/kg/day) |

**Source:** 1, 4, 5

**1,1,2-Trichloroethane (79-00-5)**

**Toxicity Potential**
The health effects resulting from human exposure to air containing specific levels of 1,1,2-trichloroethane are not known. Chronic and subchronic effects for the ingestion pathway include clinical chemistry alterations (blood chemistry effects). Based on animal studies, the oral MRL in water is 1.4 ppm. Symptoms of 1,1,2-trichloroethane exposure include irritated nose and eyes, central nervous depression, liver damage, and kidney damage.

1,1,2-Trichloroethane is non-classifiable as to human carcinogenicity (Level D) by the CAG. Evidence is inadequate to determine carcinogenicity to humans. Technical grade 1,1,1-trichloroethane is commonly contaminated with 1,4-dioxane, a known animal carcinogen. 1,4-Dioxane may be responsible for the weak mutagenic effects of 1,1,1-trichloroethane.

| | |
|---|---|
| Exposure: | Oral |
| Species: | Mouse |
| Effect of Concern: | Clinical chemistry alterations |
| Subchronic: | 3.9 mg/kg/day by drinking water for 90 days |
| Effect of Concern: | Clinical chemistry alterations |
| Chronic: | 3.9 mg/kg/day by drinking water for 90 days |

**Cancer Potential**

| | |
|---|---|
| Exposure: | Inhalation; oral<br>Gavage; gavage |
| Species: | Mouse; mouse |
| Tumor Site: | Liver; liver |

**Source:** 1, 4, 5

**Trichloroethene (79-01-6)**

**Toxicity Potential**
Chronic, Subchronic, and Acute: The primary results from trichloroethene exposure include liver damage, kidney damage, and adverse effects on the immune system and blood. A risk assessment for trichloroethene is under review by an EPA work group.

Symptoms of trichloroethene oral exposure include dizziness, headache, slowed reaction times, sleepiness, and facial numbness. Symptoms more predominant for longer exposures include eye, nose, and throat irritation.

Trichloroethene is classed by the CAG as a level B2 probable human carcinogen based on animal data. Tumors resulting from inhalation and ingestion are located in the lung and liver, respectively.

**Cancer Potential**

| | |
|---|---|
| Exposure: | Inhalation; oral<br>Two inhalation studies; two gavage studies |
| Species: | Mouse; mouse |
| Tumor Site: | Lung; liver |

**Source:** 1, 3, 4, 5

**Trichlorofluoromethane (75-69-4)**

**Toxicity Potential:**

| | |
|---|---|
| Exposure: | Inhalation; oral |
| Species: | Dog; rat |
| Effect of Concern: | Elevated blood urea nitrogen (BUN), lung lesions; mortality |
| Subchronic: | 5600 mg/m$^3$ continuously for 90 days (1940 mg/kg/day); 1000 mg/kg/day, 5 days/week for 6 weeks (714.3 mg/kg/day) |
| Effect of Concern: | Elevated BUN, lung lesions; mortality |
| Chronic: | 5600 mg/m$^3$ continuously for 90 days (1940 mg/kg/day); 488 mg/kg/day, 5 days/week for 66 weeks (348.6 mg/kg/day) |

**Source:** 1

**Vinyl Chloride (75-01-4) (Chloroethene)**

**Toxicity Potential**

Based on animal studies, the short-term inhalation of 0.7 ppm chloroethene would result in minimal risk from effects other than cancer. For the ingestion pathway, minimal risks of effects are expected for lifetime doses of 0.0013 mg/kg/day.

Chloroethene is a level A human carcinogen. EPA has estimated that the inhalation of 1 ppm chloroethene every day, all day, for 70 years, increases the risk of 11[illegible]0 in 10,000 exposed individuals developing cancer. The ingestion of 1.0 $\mu$g/kg/day for 70 years would increase the risk of 23 in 10,000 exposed individuals developing cancer. Tumors resulting from inhalation and ingestion of chloroethene are located in the liver and lung, respectively.

**Cancer Potential**

| | |
|---|---|
| Exposure: | Inhalation; oral<br>1-year inhalation study; 10-50 ppm diet |
| Species: | Rat; rat |
| Tumor Site: | Liver; lung |

**Source:** 1, 3

**Ketones**

**Acetone (67-64-1) (2-Propanone)**

**Toxicity Potential**

Chronic and Subchronic: The primary effects of 2-propanone ingestion are increased liver and kidney weight and nephrotoxicity.

Symptoms: Limited human studies have shown that workers exposed to acetone vapors (600 - 2150 ppm) experience transient eye and nose irritation.

| | |
|---|---|
| Exposure: | Oral |
| Species: | Rat |
| Effect of Concern: | Increased liver and kidney weight, nephrotoxicity |
| Subchronic: | 100 mg/kg/day for 90 days by gavage |
| Effect of Concern: | Increased liver and kidney weight, nephrotoxicity |
| Chronic: | 100 mg/kg/day for 90 days by gavage |

**Source:** 1, 4

**2-Butanone (78-93-3)**

**Toxicity Potential**

Chronic and Subchronic: The primary result of 2-butanone ingestion is fetotoxicity. The primary results of inhalation of 2-butanone are central nervous system (CNS) depression and narcosis.

Exposure to 2-Butanone in high atmospheric concentrations may result in eye, nose, and throat irritations.

| | |
|---|---|
| Exposure: | Inhalation; oral |
| Species: | Rat; rat |

| | |
|---|---|
| Effect of Concern: | CNS; fetotoxicity |
| Subchronic: | 235 ppm (693 mg/m$^3$) 7 hours/day, 5 days/week for 12 weeks (92 mg/kg/day); 235 ppm (693 mg/m$^3$) 7 hours/day, 5 days/week for 12 weeks (46 mg/kg/day) |

| | |
|---|---|
| Effect of Concern: | CNS; fetotoxicity |
| Chronic: | 235 ppm (693 mg/m$^3$) 7 hours/day, 5 days/week for 12 weeks (92 mg/kg/day); 235 ppm (693 mg/m$^3$) 7 hours/day, 5 days/week for 12 weeks (46 mg/kg/day) |

**Source:** 1, 2, 4, 5

**BTX Compounds**

**Benzene (71-43-2)**

**Toxicity Potential**
Acute toxic effects may lead to CNS depression. Ingestion of benzene can cause vomiting, unconsciousness, and death. The major chronic toxic effects are disorders of the blood.

Benzene is classed as a level A human carcinogen by the CAG based on human and animal studies. The primary result of benzene inhalation and ingestion is leukemia. Various studies show increased incidence or causal relationship between benzene exposure and leukemia.

**Cancer Potential**

| | |
|---|---|
| Exposure: | Inhalation; oral |
| | Occupational; occupational |
| Species: | Human; human |
| Tumor Site: | Leukemia; leukemia |

**Source:** 1, 3, 4

**Ethylbenzene (100-41-4)**

**Toxicity Potential**
Based on animal studies, the long-term MRL for inhalation of ethylbenzene is 0.29 ppm. ATSDR, in conjunction with EPA, is currently evaluating the inhalation exposure database. The health effects of ingesting specific levels of ethylbenzene are not known.
Chronic and Subchronic: The primary results of ethylbenzene ingestion include hepatotoxicity and nephrotoxicity. Symptoms of ethylbenzene exposure include irritated eyes and mucous membranes, headache, dermatitis, narcosis, and coma.

| | |
|---|---|
| Exposure: | Oral |
| Species: | Rat |

| | |
|---|---|
| Effect of Concern: | Hepatotoxicity and nephrotoxicity |
| Subchronic: | 136 mg/kg 5 days/week for 182 days (97.1 mg/kg/day) |
| Effect of Concern: | Hepatotoxicity and nephrotoxicity |
| Chronic: | 136 mg/kg 5 days/week for 182 days (97.1 mg/kg/day) |

Source: 1, 3, 4, 5

**Toluene (108-88-3)**

Toxicity Potential

The health effects resulting from exposure to 600 ppm of toluene vapor for 8 hours include extreme fatigue, confusion, dizziness, and intoxicated behavior. The long-term MRL for inhalation is 0.3 ppm and the short-term MRL is 1.0 ppm. For oral exposures, the long-term MRL is 460 ppm and the short-term MRL is 84 ppm.

Chronic and Subchronic: The primary effects results of toluene inhalation and ingestion are on the central nervous system. Toluene is most likely a respiratory hazard.

Symptoms of toluene exposure include eye and nose irritation, fatigue and weakness, confusion, dizziness, headache, dilated pupils, insomnia, euphoria, and nervousness.

| | |
|---|---|
| Exposure: | Inhalation; oral |
| Species: | Human; rat |
| Effect of Concern: | CNS effects, eyes and nose irritation; changes in liver and kidney weights |
| Subchronic: | 40 ppm for 6 hours (151 mg/m$^3$); 312 mg/kg 5 days/week for 13 weeks (233 mg/kg/day) |
| Effect of Concern: | CNS effects, eyes and nose irritation; changes in liver and kidney weights |
| Chronic: | 40 ppm for 6 hours (151 mg/m$^3$); 312 mg/kg 5 days/week for 13 weeks (233 mg/kg/day) |

Source: 1, 3, 4, 5

**Xylene (total) (1330-20-7)**

Toxicity Potential

Acute exposures to inhaled xylene can depress the CNS and irritate mucous membranes. The health effects resulting from long-term exposure to inhaled xylene vapor are not known. the short- and long-term effects resulting from eating/drinking food/water contaminated with xylene are not known.

| | |
|---|---|
| Exposure: | Inhalation; oral |
| Species: | Human; rat |
| Effect of Concern: | CNS effects, nose and throat irritation; none observed |
| Subchronic: | 20 ppm 7.5 hours/day for 5 days (27 mg/m$^3$); 500 mg/kg mixed xylenes 5 days/week by gavage for 13 weeks (357 mg/kg/day mixed xylenes) |
| Effect of Concern: | CNS effects, nose and throat irritation; hyperactivity, decreased body weight and increased mortality at higher dosage |
| Chronic: | 200 ppm 7.5 hours/day for 5 days (27 mg/m$^3$); 250 mg/kg mixed xylenes 5 days/week for 103 weeks (179 mg/kg/day mixed xylenes) |

**Source:** 1, 3, 4, 5

## SEMIVOLATILE ORGANICS

### Phthalates

**Bis(2-ethylhexyl)phthalate (117-81-7)**

**Toxicity Potential**

| | |
|---|---|
| Exposure: | Oral |
| Species: | Guinea pig |
| Effect of Concern: | Increased relative liver weight |
| Subchronic: | 0.04% of diet for 1 year (19 mg/kg/day) |
| Effect of Concern: | Increased relative liver weight |
| Chronic: | 0.04% of diet for 1 year (19 mg/kg/day) |

**Cancer Potential**

| | |
|---|---|
| Exposure: | 103-week dietary study; oral |
| Species: | Mouse |
| Tumor Site: | Liver |

**Source:** 1

**Diethylphthalate (84-66-2)**

**Toxicity Potential**

Exposure: Oral
Species: Rat

Effect of Concern: Reduced terminal body weight
Subchronic: 1% in diet for 16 weeks (750 mg/kg/day)

Effect of Concern: Reduced terminal body weight
Chronic: 1% in diet for 16 weeks (750 mg/kg/day)

**Source:** 1

**Di-N-Butylphthalate (84-74-2)**

**Toxicity Potential**

Chronic: Animal studies have indicated increased fetotoxicity, degeneration of the seminiferous tubules, and increased mortality.
Subchronic: The primary effect of di-N-butyl phthalate ingestion is increased mortality.

Symptoms: Di-N-butyl phthalate is generally non-irritating to humans. Contact with the surface of the eye has caused severe stinging pain with profuse tearing. Mild throat irritation has been observed, and ingestion has caused nausea, dizziness, photophobia, lachrymation, and conjunctivitis.

Exposure: Oral
Species: Rat

Effect of Concern: Mortality
Subchronic: 0.25% of diet for 52 weeks (125 mg/kg/day) (89 mg/kg/day)

Effect of Concern: Mortality
Chronic: 0.25% of diet for 52 weeks (125 mg/kg/day)

**Source:** 1, 4

## PAHS

### Naphthalene (91-20-3)

**Toxicity Potential**
The health effects resulting from inhaling or ingesting specific concentrations of naphthalene are not known.

Chronic and Subchronic: The primary effects of naphthalene ingestion are ocular and internal lesions.

Symptoms of naphthalene exposure include irritated eyes, headache, confusion, excitement, nausea, vomiting, abdominal pain, irritable bladder, profuse sweating, jaundice, renal shutdown, hematuria, and hemoglobinuria.

| | |
|---|---|
| Exposure: | Oral |
| Species: | Rat |

| | |
|---|---|
| Effect of Concern: | Decreased body weight gain |
| Subchronic: | 50 mg/kg/day by gavage 5 days/week for 13 weeks (35.7 mg/kg/day) |

| | |
|---|---|
| Effect of Concern: | Decreased body weight gain |
| Chronic: | 50 mg/kg/day by gavage 5 days/week for 13 weeks (35.7 mg/kg/day) |

**Source:** 1, 5

## Phenols

### 2-Methylphenol (95-48-7)

**Toxicity Potential**
Chronic and Subchronic: The primary results of 2-Methylphenol exposure include reduced body weight gain and neurotoxicity.

**Cancer Potential**

**Source:** 1

## OTHER

### PCBs (Aroclor 1254) (11097-69-1)

**Toxicity Potential**
The inhalation of approximately 0.1 to 10 mg/m$^3$ of PCBs results in chloracne and liver effects. Oral studies show that the liver and cutaneous tissues are the primary target organs. Symptoms of Aroclor 1254 exposure include irritated eyes and skin, chloracne, jaundice, and dark urine.

Polychlorinated biphenyls are classed as a level B2 probable human carcinogen by the CAG based on animal data. The available epidemiological data do not indicate a consistent tumorigenic effect among people exposed to PCBs.

**Cancer Potential**

**Source:** 1, 3, 5

### 2(2,4,5-Trichlorophenoxy) Propionic acid (Silvex) (93-72-1)

**Toxicity Potential**

| | |
|---|---|
| Exposure: | Oral |
| Species: | Dog |
| Effect of Concern: | Histopathological changes in liver |
| Subchronic: | 30 ppm in diet for 2 years (0.75 mg/kg/day) |
| chronic: | 30 ppm in diet for 2 years (0.75 mg/kg/day) |

**Cancer Potential**

**Source:** 1

### 2,4,5-Trichlorophenoxyacetic acid (93-76-5)

**Toxicity Potential**

| | |
|---|---|
| Exposure: | Oral |
| Species: | Rat |
| Effect of Concern: | Liver and kidney weights; decreased survival |
| Subchronic: | 10 mg/kg/day for 90 days |
| Chronic: | 3 mg/kg/day, 3-generation study |

Cancer Potential

Source: 1

## TENTATIVELY IDENTIFIED COMPOUNDS

### Alcohols

Toxicity Potential
The alcohols have a variety of uses depending on their chemical and physical properties. Generally they are used as solvents, cosolvents, and chemical intermediates.

Eye Contact

The material is severely irritating to the eyes of rabbits; effects included persistent widespread corneal opacity, which cleared within a week.

Skin Contact

Confinement of isooctanol to the abdominal skin of rabbits for 24 hr resulted in appreciable irritation including some necrosis. Sufficient amounts were absorbed to cause CNS depression, with labored breathing and ataxia. The $LD_{50}$ was greater than 2.6 g/kg; one of four treated animals died at the 3.16 g/kg dose level.

Inhalation

Mice, rats, and guinea pigs were exposed for 6 hr to essentially saturated vapors (~200 ppm). Moderate local irritation of the mucous membranes of the upper respiratory tract (but no signs of systemic effects) were noted.

Source: 2

### Aliphatic Hydrocarbons (Alkanes)

Toxicity Potential
Paraffin mixtures are used extensively as fuels, refrigerants, propellants, pesticides, lubricants, solvents for paints, protective coatings, and plastics, in degreasing operations, and in purified form as food additives.

The toxicity characteristics of the alkanes are minimal for the gases and solids but are moderate for the liquid materials. The paraffin gases $C_1$ to $C_4$ are practically nontoxic below the lower flammability limit (18,000 to 50,000 ppm); above this level, low to moderate

incidental effects such as CNS depression and irritation occur but are completely reversible upon cessation of the exposure. The $C_3$ to iso-$C_5$ hydrocarbons show increasing narcotic properties; branching of the chain also enhances this effect. The fluid members $C_5$ to $C_9$ have anesthetic and CNS depressant actions; the $C^6$ (and, to a lesser extent the $C_5$ and $C_7$) members have neurotoxic properties. They are fat solvents and on repeated, prolonged direct skin contact may cause chemical dermatitis. Direct aspiration into the lungs of paraffins with carbon numbers $C_6$ to $C_{16}$ may cause chemical pneumonitis, pulmonary edema, and hemorrhaging.

The branched chain derivatives appear less toxic than the parent linear chain members. Dermal and pulmonary irritancy increase with increasing carbon chain length, particularly from the $C_5$ to the iso-$C_8$ alkane. When ingested, an aspiration hazard exists for the compounds hexane through tetradecane and, to a lesser extent, for the $C_{16}$ derivative, but none exists for the higher members, as shown in studies with rats. The lower members, $C_6$ to $C_8$, when aspirated into rat lungs, caused almost immediate death due to respiratory paralysis, asphyxia, and cardiac arrest. With higher members, death occurred more slowly, following the development of pulmonary edema. Signs were dyspnea, cyanosis, and nasal hemorrhaging.

**2-Methylpentane, Isohexane**

Toxicologically, the isohexanes are expected to be mucous membrane irritants and to have a low oral toxicity, but to be aspirated into the lungs and absorbed through the skin. Isohexanes are predicted to have narcotic properties and are documented to be cardiac sensitizers, but are not expected to have neurotoxic properties.

**Cancer Potential**

Presently, studies indicate that none of the alkanes possess teratogenic, mutagenic, or carcinogenic properties.

**Source:** 2

**Alicyclic Hydrocarbons**

**Toxicity Potential**

To this chemical category belong the cycloparaffins, also named the cycloalkanes, cyclanes, or naphthenes. Some naturally occurring alkanyl- or alkenyl-substituted mono-, di-, or polycyclenes are commonly known as terpenes, which occur in assorted plants. Cyclanes are extensively used to produce reformed aromatic. Some are utilized as inhalation anesthetics and are synthesized in pure form by the reduction of dihalogenated propane precursors.

The lower cycloparaffins are gases and have been used as anesthetics, especially cyclopropane, the simplest cyclane. The $C_5$ and higher members are liquids with narcotic properties. However, from $C_6$ on, the margin between narcosis and death is very narrow and symptomatically barely recognizable. The alicyclics, in general, are CNS depressants with low acute and chronic toxicities, owing to their rapid excretion in unchanged form or prompt conversion into water-soluble metabolites. Inhalation by humans and laboratory animals at high concentrations may cause excitement, loss of equilibrium, stupor, and coma, but rarely death. Oral administration in animals has resulted in severe diarrhea and vascular collapse, in turn leading to heart, lung, liver, and brain degeneration. Cycloparaffins are dermal irritants; they defat the skin to cause morphological changes and hypothermia, as does, for example, methylcyclohexane. The liquid members up to $C_8$ and possibly to $C_{12}$, when ingested, represent lung aspiration hazards.

**Beta-pinene**

Pinene is obtained from turpentine or pine oil by distillation and is widely used in the manufacture of camphor as an insect attractant and repressant and in insecticides, perfume bases, plasticizers, solvents, and synthetic pine oil. The pinenes' antibacterial action has been utilized medicinally.

Pinene is easily absorbed through the pulmonary system, the skin, and the intestine. It is an irritant to the skin and mucous membranes and may cause dermal eruption and occasional benign tumors. Absorption of large doses may result in delirium, ataxia, and kidney damage. Inhalation may cause palpitation, dizziness, nervous disturbances, chest pain, bronchitis, and nephritis. About 150 ml may constitute a human oral fatal dose.

**Cancer Potential**

Source: 2

**Aromatic Hydrocarbons**

**Toxicity Potential**

The aromatic hydrocarbons are of considerable economic importance as industrial raw materials, solvents, and components of innumerable commercial and consumer products. The aromatics are more highly toxic to the mammalian system.

Chemically, the aromatic hydrocarbons can be divided into three groups: (a) the alkyl-, aryl-, and alicyclic-substituted benzene derivatives, (b) the di- and polyphenyls, and (c) the polynuclear compounds composed of two or more fused benzene ring systems.

The aromatic hydrocarbons are used widely as chemical raw materials, intermediates, or solvents, industrially in oil and rosin extractions, as components of multipurpose additives, and, owing to their rapid drying characteristics, extensively in the glue and veneer industries. Aromatics serve in the drycleaning business, in the printing and metal processing industries, and for many more similar applications. They serve as important constituents of aviation and motor gasolines and represent important raw materials in the preparation of pharmaceutical products.

Acute Toxicity. Overall, benzene is more highly toxic than any of the substituted benzene derivatives, except for toluene and vinylbenzene. Aromatic hydrocarbons cause local irritation and changes in endothelial cell permeability and are absorbed rapidly. Secondary effects have been observed in the liver, kidney, spleen, bladder, thymus, brain, and spinal cord in animals after dosing with some alkylbenzenes. The aromatic hydrocarbons, even from a single dose, exhibit a special affinity for nerve tissue. Animals dosed with alkylbenzene may show signs of CNS depression, sluggishness, stupor, anesthesia, narcosis, and coma. This is in sharp contrast with benzene, which is a neuroconvulsant, producing stimulation characterized by tremors and convulsions. The narcotic potency of the alkylbenzenes depends on branching or side chain length. It diminishes with the number of substituents and increasing side chain carbon number up to dodecylbenzene, which has practically no narcotic activity. The concentration required to produce narcosis in barnacle larvae after immersion for 15 min was 3.1 percent for benzene and 4.5 percent for toluene.

Chronic Toxicity. Benzene in repeated doses is considered more toxic than any alkylbenzene, owing to its affinity for blood-forming tissue and its myelotoxic activity. It appears that substituted benzene derivatives are devoid of this characteristic.

**Trimethylbenzenes**

Little experimental work has been carried out with trimethylbenzene since Lazarew published basic acute studies in 1929. He observed loss of righting response in the mouse after exposure to 1,2,4-trimethylbenzene at 40 mg/liter (8130 ppm) and loss of reflexes at 40 to 45 mg/liter (8130 to 9140 ppm); for the 1,3,5 isomer these losses were 25 to 35 mg/liter (7110 to 9140 ppm) and 35 to 45 mg/liter (7110 to 9140 ppm), respectively. The intraperitoneal fatal dose in the guinea pig is 1.788 g/kg.

Subacute experiments by Woronow in 1929, as quoted by Von Oettingen, demonstrated that daily subcutaneous injections of rabbits with 2 to 3 g/kg 1,2,4-trimethylbenzene in olive oil caused local infiltration and necrosis. After three weeks, a slight reduction of the erythrocytes occurred (as was observed after xylene and toluene injections), with a temporary leukopenia and leukocytosis. Daily subcutaneous injections of 0.12 ml/kg of the 1,3,5 isomer caused moderate thrombocytosis in the rabbit, while 0.2 ml/kg produced primary thrombopenia.

Inhalation of mixed trimethylbenzene by rats at 1 mg/liter for 4 hr/day during 6 months caused an inhibition of phagocytic activity of the leukocytes.

The aquatic toxicity rating for the three isomers was less than 1000 to 100 ppm. However Brenniman et al. determined a 96-hr $LC_{50}$ of 13 ppm for the mixed compound.

Source: 2

## Aromatic Amino Compounds

Toxicity Potential
The most dominant toxic effects are methemoglobin formation and cancer of the urinary tract. Other toxic effects include hematuria, cystitis, anemia, and skin sensitization.

### 1-Methylethylbenzene

Cumene appears slightly less toxic than its n-propyl isomer, but more toxicthan benzene or toluene. Like its lower homologues, it may be irritant to the eyes and skin. It is a CNS depressant and narcotic, characterized by slow induction and long duration of effects. Thus inhalation of large vapor concentrations may cause dizziness, slight incoordination, and unconsciousness. Prolonged skin contact may result in skin rashes. In some short-term high dose experiments, animals exhibited damage to the spleen and fatty changes in the liver, but no renal nor pulmonary irritancy. Subacute inhalation experiments showed no significant changes in peripheral block but some liver, kidney, and lung effects.

## Carboxylic Acids

Toxicity Potential
Saturated, aliphatic monocarboxylic acids are used in a variety of applications. Many are employed in the production of synthetic fiber materials, resins, plastics, and dyestuffs. A number of the acids or their esters are important chemical intermediates or solvents and are used in cosmetics or food applications.

The major physiologic effect associated with the monocarboxylic acids is that of primary irritation of the eye, skin, or mucous membranes.

### 2-Methylpentanoic Acid

2-Methylpentenoic acid is used in the production of plasticizers, vinyl stabilizers, metallic salts, and alkyd resins.

The compound caused only a mild irritation in rabbit skin (500 mg) but elicited a severe reaction in guinea pigs (unspecified quantity of undiluted acid). Application of a 5-percent solution to rabbit eyes (specified volume) caused severe necrosis.

**Palmitic Acid**

The major uses are in the manufacture of soaps, lubricating oils, and waterproofing material and in the synthesis of metal palmitates and food-grade additives.

Palmitic acid was a mild irritant when applied to human skin (75 mg total over 3 days).

Studies on the carcinogenic potential of palmitic acid were negative.

**Stearic Acid**

The primary uses are in pharmaceuticals, cosmetics, metal stearates (as polymer stabilizers), plastics, lubricants, coatings, food packaging, rubber softeners, baked goods, and confectioneries.

Single intraperitoneal doses of stearic acid in mice, ranging from 1.4 to 44 $\mu$mol (approximately 15 to 500 mg/kg), caused no fatalities, but at the highest dose caused a loss of body weight. In cats, low doses of stearic acid produced elevated pulmonary (but decreased systemic) blood pressure. Doses greater than 5 mg caused apnea, a fall in blood pressure, and convulsions leading to death.

Intravenous infusion of large doses of stearic acid were thrombogenic in rats, rabbits, and dogs, causing blood platelet aggregation and acute heart failure.

In the occluded patch test, undiluted stearic acid was a moderate irritant to intact or abraded rabbit skin after 24 hr.

**Heterocyclic and Miscellaneous Nitrogen Compounds**

**Toxicity Potential**

**Piperidine**

Piperidine causes moderately severe skin irritation when applied to guinea pig skin, and markedly severe eye damage, with permanent corneal injury, results from instillation in the rabbit eye. Oral administration results in weakness, nausea, vomiting, salivation, labored respirations, muscular paralysis, and asphyxia It has been stated that 30 to 60 mg/kg may cause symptoms in man. The information available on other simple alkyl piperidine derivatives is incomplete.

**Hydrazines**

The hydrazine derivatives tend to be local irritants, convulsants, hepatotoxins, and hemolytic agents, which are absorbed by all routes of administration.

Liver damage is an important feature of hydrazine toxicity, particularly after chronic exposure.

Source: 2

The principal hazard associated with exposure to ketone vapors is irritation of the eyes, nose, and throat.

The classic symptoms produced by an overexposure to ketones include, progressively, irritation of the eyes, nose, and throat, headache, nausea, vertigo, incoordination, central nervous system depression, narcosis, and cariorespiratory failure.

**Phenols and Phenolic Compounds**

Toxicity Potential

Phenol is used in the production or manufacture of a large variety of aromatic compounds, including explosives, fertilizers, coke, illuminating gas, lampblack, paints, paint removers, rubber, asbestos goods, wood preservatives, synthetic resins, textiles, drugs, pharmaceutical preparations, perfumes, bakelite, and other plastics (phenol-formaldehyde resins). Phenol also finds use in the petroleum, leather, paper, soap, toy, tanning, dye, and agricultural industries.

| Species | Route | Dose Killing 50% of $LD_{50}$ animals (g/kg) |
|---|---|---|
| Mouse | SC $LD_{50}$ | 0.3-0.35 |
| Rat | SC | 0.45 |
| | Oral $LD_{50}$ | 0.53[a] |
| | Cut $LD_{50}$ | 2.5 |
| Guinea pig | SC $LD_{50}$ | 0.68 |
| Rabbit | IV $LD_{50}$ | 0.18 |
| | SC $LD_{50}$ | 0.5-0.6 |
| | Oral $LD_{50}$ | 0.6 |
| | Oral $LD_{50}$ | 0.4-0.6 |
| | IP $LD_{50}$ | 0.5-0.6 |
| Cat | SC $LD_{50}$ | 0.09 |
| | Oral $LD_{50}$ | 0.1 |
| Dog | Oral $LD_{50}$ | 0.5 |

| Species | Route | Dose Killing 50% of $LD_{50}$ animals (g/kg) |
|---|---|---|
| Monkey | Toxicity is similar in order of magnitude to that for rabbit | |

Source: 2

## INORGANICS

### Aluminum (7429-90-5)

Toxicity Potential

The acute toxic response is confined to the more soluble forms of aluminum, the chloride and simple and complex sulfates for which the acute toxicity for laboratory animals has been determined. The oral $LD_{50}$ of $AlCl_3$ for mice is reported to be 770 mg/kg as aluminum; for $Al_2(SO_4)_3$, 980 mg aluminum per/kg: Intraperitoneally, the sulfate was considerably more toxic, the mouse $LD_{50}$ being 140 mg aluminum/kg. Acute $AlCl_3$ poisoning resulted in increased blood glucose, decreased liver glycogen, and increased incorporation of $^{32}P$ in the liver of rats. The acute oral toxicity of the complex sulfates, the alums (for example, anhydrous sodium aluminum sulfate) appears to be somewhat less than that of the simple sulfate, the lethal dose for the rabbit being of the order of 225 mg aluminum per kg. For $ALF_3$, the lowest oral dose ($LD_{LO}$) resulting in death for in the guinea pig was 190 mg aluminum per kg; subcutaneously, 965 aluminum per kg. The complex sodium aluminum fluoride, natural cryolite, has a reported $LD_{LO}$ for the rabbit of 9000 mg/kg indicating essential nontoxicity by this route; the synthetic form is somewhat more toxic. Intrapertioneally, however, the $LD_{50}$ for the rat is 59 mg/kg, indicating high toxicity. One of the most acutely toxic aluminum containing compounds is the phosphide, which has an inhalation $LC_{LO}$ of 1 ppm for the rat.

In contrast to the appreciable toxicity of the soluble forms, the insoluble forms of aluminum produce no measurable acute response, provided their administration is not associated with tissue irritants.

Source: 2

### Cadmium (7440-43-9)

Toxicity Potential

Cadmium is a powerful emetic; the minimal effective dose for $CdCl_2$ in cats is 4 mg/kg. As little as 14.5 mg of cadmium taken orally by man has caused nausea and vomiting, but as much as 326 mg was not fatal. Thirteen to 15 ppm cadmium in popsicles has sickened

children, as has 67 ppm in punch or 530 ppm in gelatin. The lethal oral dose for rabbits has been reported as 150 to 300 mg/kg. The ingestion of cadmium salts induces salivating, choking attacks, persistent vomiting, abdominal pains, tenesmus and diarrhea, vertigo, and loss of consciousness. Catarrhal and ulcerative gastroenteritis, congestion, pulmonary infarcts, and subdural hemorrhages are found at necropsy.

When injected subcutaneously, cadmium salts induce inflammation and coagulation necrosis at the site of injection. $LC_{50}$ values for inhaled fumes from a cadmium arc expressed at CT (the product of time of exposure in minutes and concentration in $mg/m^3$ are 500 for rats; <700 for mice; 2500 for rabbits; 350 for guinea pigs; 4000 for dogs; and 15,000 for monkeys. The estimated CT value for 2 fatal human exposures was between 2500 and 2900 $mg\text{-}min/m^3$. The corresponding CT value for dogs exposed to $CdCl_2$ aerosol was 9600; death in all cases resulted from pulmonary injury.

**Cancer Potential**

Potts (19-) had previously reported that of five of eight deaths, three were due to carcinoma of the prostate, one of the bronchus, and one, carcinomatosis. These cancers occurred in a group of 74 alkaline cadmium battery workers who had been exposed to CdO dust for 10 or more years.

Kipling and Waterhouse (19-), in surveying 248 workers exposed to CdO for a minimum of 1 year, found four deaths from prostatic cancer.

**Source:** 2

**Chromium (7440-47-3)**

**Toxicity Potential**

| | |
|---|---|
| Exposure: | Inhalation; oral |
| Species: | Human; rat |
| Effect of Concern: | Nasal mucosa atrophy; hepatotoxicity |
| Subchronic: | LOAEL of 0.002 mg chromium (VI) per $m^3$ (as chromic acid) LOAEL(HEC)=0.000714 $mg/m^3$; 5% $Cr_2O_3$ in diet 5 days/week for 90 days (1400 mg chromium per kg per day) |
| Effect of Concern: | Nasal mucosa atrophy; hepatotoxicity |
| Chronic: | LOAEL: 0.002 mg chromium (VI) per $m^3$ (as chromic acid) LOAEL (HEC) = 0.000714 $mg/m^3$; 5% $Cr_2O_3$ in diet 5 days/week for 600 feedings (1468 mg chromium per kg per day) |

**Source:** 1

**Chromium VI (18540-29-9)**

**Toxicity Potential**

| | |
|---|---|
| Exposure: | Inhalation; oral |
| Species: | Human; rat |
| Effect of Concern: | Nasal mucosa atrophy; not defined |
| Subchronic: | LOAEL: 0.002 mg Cr(VI)/$m^3$ (as chromic acid) LOAEL (HEC)=0.000714 mg/$m^3$; 25 ppm Cr VI in drinking water for 1 year (2.4 mg/kg/day) |
| Effect of Concern: | Nasal mucosa atrophy; not defined |
| Chronic: | LOAEL: 0.002 mg Cr(VI)/$m^3$ (as chromic acid) LOAEL (HEC)=0.000714 mg/$m^3$; 25 ppm Cr VI in drinking water for 1 year (2.4 mg/kg/day) |

**Cancer Potential**

| | |
|---|---|
| Exposure: | Inhalation<br>Occupational |
| Species: | Human |
| Tumor Site: | Lung |

**Source:** 1

**Cobalt (7440-48-4)**

**Toxicity Potential**

The acute toxicity of cobalt metal powder by all tested routes reported in the literature through 1950 indicates a relatively low order of magnitude (100 mg/kg intravenous, or up to 1500 mg/kg orally) in small laboratory animals; later determinations made during 1960 to 1967 by several investigators indicate a high order of toxicity (22 to 25 mg/kg intratracheally and intraperitoneally in the mouse and rat to 112 mg/kg intramuscularly in the rat).

The acute toxicity of cobaltous oxide, determined in the 1960s, showed a low order orally in the rat (1700 mg cobalt per kg), but a considerably higher order in the rat and mouse (135 and 800 mg/kg). Cobaltic oxide ($Co_2O_3$), however, was reported by Fredrick and Bradley to be essentially nontoxic even intraperitoneally in the rat (5000 mg cobalt per kg); for $CoCO_3$ also a low order of intraperitoneal toxicity was found in this species (1000 mg cobalt per $m^3$).

Only one determination of acute toxicity of $Co(NO_3)_2$ and $CoSO_4$ has been reported in the literature; the oral $LD_{LO}$ for the nitrate in the rabbit was 400 mg/kg, and the intraperitoneal $LD_{50}$ for the sulfate in the mouse was 54 mg/kg.

The paint drier cobalt naphthenate had a very low oral toxicity for the rat and an $LD_{50}$ of 3900 mg/kg. Organic salts and protein complexes appear to have the same order of toxicity as the soluble inorganic salts, independent of route of administration. The lethal dose of cobalt lactate and albuminate is of the order of 10 mg cobalt pr kg when parenterally administered to the rat and mouse.

Source: 2

**Iron (7439-89-6)**

Toxicity Potential

The intraperitoneal $LD_{50}$ of anhydrous ferric chloride for the mouse is 68 mg/kg and orally it is 400 mg/kg; the corresponding intraperitoneal $LD_{50}$ of the hexahydrate, $FeCl_3.6H_2O$, is 260 mg/kg.

The oral rat $LD_{50}$ for $Fe(NO_3)_3.9H_2O$ is reported as 3250 mg/kg, and the corresponding $LD_{50}$ for $FeSO_4$ is 1480 mg/kg; the lowest toxic dose, ($TD_{LO}$) by mouth for an infant is given for $FeSO_4$ as 600 mg/kg, with effects on the gastrointestinal tract; for an adult female, the $TD_{LO}$ value is 60 mg/kg, with effects primarily on the CNS. The acute toxicity of reduced Fe powder, by comparison, was very low as determined orally in the rat; the $LD_{50}$ was 98.6 g/kg, or about 1/100 that of $FeSO_4$ determined under the same conditions.

Source: 2

**Magnesium (7439-95-4)**

Toxicity Potential

Inspection of the data shows that whereas most magnesium compounds taken orally (e.g) $MgSO_4.7H_2O$ (Epsom salts), have minimal toxicity, several magnesium compounds (Mg fluoroacetate, magnesium chloride, acetate, and lactate) are extremely toxic intravenously, with $LD_{50}$ values of 2, 14, 16, and 45 mg/kg, respectively. By the respiratory route, the few available data indicate moderate toxicity ($TC_{LO}$ of MgO for man, 400 mg/m$^3$). The acute toxicity of MgC/2 is from 16 to 24 times less toxic intraperitoneal [depending on species (rat or mouse)] and about 65 times less toxic subcutaneously than when administered by vein. Less dramatic differences between the different routes were reported for the sulfate, which was about twice as toxic by the intraperitoneal route and 2.5 times less toxic subcutaneously than by vein, and the hydrated salt, $MgCl_2.65H_2O$, which was only one-third as toxic as the unhydrated salt.

The acute toxicity of the defoliant $Mg(ClO_3)_2$ was for the most part of a low order for the rat, mouse, and guinea pig, with $LD_{LO}$ values ranging from 5250 mg/kg orally to 500 to 700 g/kg intratracheally. The oxidizer magnesium perchlorate [$Mg(ClO_4)_2$] has a similar order of toxicity.

The few data on exposure by inhalation indicate an intermediate toxicity even for the physiologically unstable magnesium phosphide; the 2-hr $LC_{50}$ values for the cat and guinea pig were reported as 173 and 288 mg/m$^3$, respectively.

**Source:** 2

**Manganese (7439-96-5)**

**Toxicity Potential**

Exposure: Inhalation; oral
Species: Human; human

Effect of Concern: Respiratory symptoms and psychomotor disturbances; no effect
Subchronic: 0.97 mg/m$^3$ occupational $LOAEL_{HEC}$=0.34 mg/m$^3$; 0.03-0.16 mg Mn/kg/day chronic dietary intake

Effect of Concern: Respiratory symptoms and psychomotor disturbances; no effect
Chronic: 0.97 mg/m$^3$ occupational $LOAEL_{HEC}$=0.34 mg/m$^3$; 0.03-0.16 mg Mn/kg/day chronic dietary intake

Subcutaneous doses of 50 mg/kg as $MnCl_2$ were fatal to mice, guinea pigs, and rabbits; 18 mg/kg of the same preparation was lethal to rabbits by the intravenous route; and 56 mg/kg was required for dogs. Hydrated salts are less acutely toxic; Mn $SO_4.4H_2O$ had a reported mouse intraperitoneal $LD_{50}$ of 534 mg/kg versus 120 mg/kg for $MnSO_4$. Similarly, hydrated $Mn(Ac)_2.4H_2O$ was practically nontoxic orally for the rat ($LD_{50}$ = 3730 mg/kg).

Surprisingly, there is only one recorded acute lethal dose determination (intravenous rabbit $LD_{LO}$ of 45 mg/kg) for one of the most important manganese compounds, $MnO_2$.

The oral rat $LD_{50}$ of $KMnO_4$ is reported to be 1090 mg/kg; the subcutaneous $LD_{50}$ for the mouse, 500 mg/kg.

**Source:** 1, 2

**Mercury (7439-97-6)**

**Toxicity Potential**

Exposure: Inhalation; oral
Species: Human; rat

Effect of Concern: Neurotoxicity; kidney effects
Subchronic: 0.009 mg/m$^3$, several occupational studies; several oral and parenteral studies in the Brown Norway rat

Effect of Concern: Neurotoxicity; kidney effects
Chronic: 0.009 mg/m$^3$, several occupational studies; several oral and parenteral studies in the Brown Norway rat

Eighteen cases of poisoning from oral intake of $HgCl_2$ (corrosive sublimate) had been reported in 1951, with the common finding of mild to severe erosion of the gastrointestinal tract according to dosage, the lowest lethal dose ($LD_{LO}$) being 29 mg/kg. By comparison, the $LD_{LO}$ for the largely un-ionized $HgI_2$ for man was 357 mg/kg. Other Hg salts that ionize to a lesser extent than $HgC1_2$ (such as Hg salicylate) are less irritating and toxic than $HgC1_2$; $Hg(CN)_2$ is an exception, the oral $TD_{LO}$ for man being 10 mg/kg. Corresponding data for mercurous salts exist only for animals. These data would indicate a considerably lower toxicity of the monovalent salts. The rat oral $LD_{50}$ for HgC1 (calomel) is 210 mg/kg, the mouse oral $LD_{50}$ for HgI is 110 mg/kd; and the mouse oral $LD_{50}$ for $HgNO_3$ is 388 mg/kg, versus 8 mg/kg for the mouse intraperitoneal $LD_{50}$ for $Hg(NO_3)_2$. In addition to the greater toxicity of divalent Hg, these data indicate the greater toxicity by the parenteral route. Other comparative data show that the oral route is the less toxic; the oral $LD_{50}$ for HgO in the rat is 8 mg/kg, versus 2.5 mg/kg intramuscularly.

Source: 1, 2

**Nickel (7440-02-0)**

Toxicity Potential
Exposure: Oral
Species: Rat

Effect of Concern: Reduced body and organ weight
Subchronic: 100 ppm Ni from nickel sulfate in diet for 2 years (5 mg Ni/kg/day)
Chronic: 100 ppm Ni from nickel sulfate in diet for 2 years (5 mg/Ni/kg/day)

| Route of Adm. | Animal | Data |
|---|---|---|
| I.M. | Rat | $TD_{LO}$ 110 mg/kg |
| I.M. | Mouse | $TD_{LO}$ 800 mg/kg |
| I.V. | Dog | $LD_{LO}$ 10 mg/kg |
| Oral | Guinea pig | $LD_{LO}$ 5 mg/kg |

Cancer Potential
Exposure: Inhalation; occupational
Species: Human
Tumor Site: Respiratory tract

Cancers of the lung and nasal sinuses in nickel workers have been known for more than 50 years to be associated with nickel refining (calcination, smelting, roasting, and electrolysis,

and from nickel plating and polishing (electrolysis and grinding). The most common types are cancers of the respiratory tract.

Of the respiratory tract cancers, 69 percent were squamous cell carcinomas and 27 percent anaplastic, undifferentiated carcinomas, with occasional alveolar cell carcinoma and adenocarcinoma. Of the nasal cancers, 45 percent were squamous cell carcinomas, 31 percent pleomorphic, 12 percent undifferentiated, and another 12 percent scattered among columnar, spheroidal, and spindle cell carcinoma and scirrhus carcinoma.

**Source:** 1, 2

**Silver (7440-22-4)**

**Toxicity Potential**

Exposure: Oral
Species: Human

| | |
|---|---|
| Effect of Concern: | Argyria |
| Subchronic: | 0.9-1.5 g silver arsphenamine, intravenously (i.v.) for 2-3 years (average, 0.0031 mg/kg/day); 6.4 g total dosage silver acetate over 2.5 years (0.0048 mg/kg/day) Average of 3 studies, 0.0052 mg/kg/day |
| Effect of Concern: | Argyria |
| Chronic: | 0.9-1.5 g silver arsphenamine, i.v. for 2-3 years (average, 0.0031 mg/kg/day); 6.4 g total dosage silver nitrate in 1 year (0.077 mg/kg/day); 6.4 g total dosage silver acetate over 2.5 years (0.0048 mg/kg/day) Average of 3 studies, 0.0052 mg/kg/day |

Silver as a colloid, a form commercially available, is reported to be highly toxic by vein to man, with 700 $\mu$g/kg, or about 0.05 g, being the lowest lethal dose ($LD_{LO}$).

In general, the acute toxicity is high by all routes tested, except for the relatively insoluble oxide, $Ag_2O$, which has an oral $LD_{LO}$ for the rat of 2820 mg/kg. By comparison, silver nitrate, the most toxic in animals the silver compounds tested, had an oral $LD_{50}$ for the mouse of 50 mg/kg, or almost 60 the toxicity of the oxide by this route. By the intraperitoneal route, the nitrate was even more toxic, the mouse $LD_{50}$ being 0.129 mg/kg. Interestingly, the simple cyanide AgCN appeared to be less toxic than the nitrate (again probably because of its low solubility), having an oral rat $LD_{50}$ of 123 mg/kg, but the complex cyanide $AgK(CN)_2$ was more toxic than the nitrate by a factor of about 2 (oral rat $LD_{50}$ = 21 mg/kg). The fluoride appears to be about one-sixth as toxic as the nitrate, having an oral $LD_{LO}$ for the guinea pig of 300 mg/kg. Surprisingly, the fluoride was considerably less toxic by the subcutaneous route, with an $LD_{LO}$ of 800 mg/kg.

Source: 1, 2

**Strontium (7740-26-6)**

Toxicity Potential

The rat intraperitoneal $LD_{50}$ of five strontium compounds (nitrate, iodide, bromide, lactate, and salicylate) ranged from 400 to 1000 mg/kg (88 to 247 mg of strontium per kg). The salicylate was the most toxic, and the lactate and bromide were the least toxic. For $SrCl_2$, the $LD_{LO}$ (minimal lethal dose) for rats was 123 mg Sr/kg and for rabbits was 590 mg strontium per kg administered intravenously; for strontium acetate, the intravenous $LD_{50}$ for rats was 105 mg strontium per kg and for mice was 168 mg. Strontium acetate was considerably less toxic than calcium acetate for mice; at equal concentrations (millimoles of compound per kg), the mortality was 5 percent, for strontium acetate versus 70 percent for calcium acetate.

Strontium fluoride, with a rat intravenous $LD_{LO}$ of 625 mg/kg, was of about the same order of toxicity as the iodide hexahydrate (rat intravenous $LD_{LO}$ = 500 mg/kg) and the iodide (rat intraperitoneal $LD_{50}$ = 800 mg/kg). However, the fluoroborate ($SrBF_5$) and fluorosilicate ($SrSiF_6.2H_2O$) appear to be more toxic; the rat oral $LD_{LO}$ values were 500 and 250 mg/kg, respectively. For the mouse, the 10-min inhalation $LC_{LO}$ of the fluoroborate was 650 mg/m$^3$, whereas the 1-hr rat inhalation $LC_{LO}$ for the phosphide ($Sr_3P_2$) was 6800 mg/m$^3$.

The chief sign of acute strontium toxicity is respiratory failure.

Source: 2

**Thallium (7440-28-0)**

Toxicity Potential

Exposure: Oral
Species: Rat

| | |
|---|---|
| Effect of Concern: | Increased SGOT and serum LDH levels, alopecia |
| Subchronic: | 0.20 mg thallium/kg/day (from thallium sulfate) for 90 days |
| Effect of Concern: | Increased SGOT and serum LDH levels, alopecia |
| Chronic: | 0.20 mg thallium/kg/day (from thallium sulfate) for 90 days |

Regardless of the route of intake, thallium is one of the more toxic elements. The range of doses representing the lowest lethal dose ($LD_{LO}$) and the $LD_{50}$ of the 14 compounds (whether soluble, such as the acetate, nitrate, sulfate, or carbonates or insoluble, such as thallic oxide) by all administered routes to several species was very narrow (from about 15 to 50 mg thallium per kg), indicating an extremely hazardous element. The guinea pig was

a toxicologic anomaly in that the oral route was more toxic than the intraperitoneal route; the oral $LD_{LO}$ for thallic oxide was 5 mg thallium per kg, versus the intraperitoneal $LD_{LO}$ of 30 mg thallium per kg. Excluding this anomly, there was little difference between the toxicities of $Tl^{1+}$ and $T^{3+}$ (e.g., thallous and thallic sulfates); the rat oral $LD_{50}$ was 16 mg thallium per kg for $Tl^{1+}$ versus 23 mg thallium per kg for $Tl^{3+}$. However, the toxicities of thallium fluoroborate, Tl silicate, and thallium selenite were somewhat lower than those of the simple salts (rat oral $LD_{LO}$ = 50 mg thallium per kg). The thallium halides (fluoride, chloride, bromide, and iodide) showed little difference in toxicity; the oral mouse $LD_{LO}$ values were 50, 24, 29, and 28 mg thallium per kg, respectively.

Source: 1, 2

**Titanium (7440-32-6)**

Toxicity Potential

Of more than 18 commercially available titanium compounds, only eight have been tested for acute toxicity. Some (e.g. the oxide, diboride, and carbide) are virtually inert and did not require testing. Among the more toxic titanium compounds, the tetrachloride had an $LC_{LO}$ of 10 mg/m$^3$ for the mouse, one of the more resistant species, in a 2-hr inhalation exposure. Titanium dicyclopentadienyl dichloride had an intramuscular $LD_{LO}$ of 83 mg/kg for the hamster and an intraperitoneal $LD_{50}$ of 30 mg/kg for the rat. Potassium hexafluorotitanate ($TiK_2F_6$) had an oral $LD_{LO}$ of 200 mg/kg for the guinea pig and a subcutaneous $LD_{LO}$ of 450 mg/kg. Titanium acetylacetonate, $TiO[OC(CH_3):CHCOCH_3]_2$, had an intraperitoneal $LD_{50}$ of 650 mg/kg for the rat.

Cancer Potential

Titanium dioxide of the anatase variety, approved by the FDA for use in foods, when fed to Fischer 344 rats and $B6C3F_1$ mice at levels of 25,000 and 50,000 ppm for 103 weeks showed no evidence of toxicity and produced no tumors in excess of those occurring spontaneously in the control rats and mice. Accordingly, it was concluded that $TiO_2$ is not a carcinogen in rats and mice. No evidence of carcinogenicity was found when another inorganic compound, TiK oxalate, was administered to Swiss albino mice at 5 ppm in the drinking water for their life-span.

However, when the organic Ti compound titanocene (a dicyclopentadiene dichloride) was injected intramuscularly into C57 Blk mice, a strain resistant to tumors, a variety of tumors, hepatomas, fibrosarcoma, and lymphoblastoma, developed at the injection site and in organs some distance away.

Source: 2

**Vanadium (7440-62-2)**

Toxicity Potential

| | |
|---|---|
| Exposure: | Oral |
| Species: | Rat |
| Effect of Concern: | None observed |
| Subchronic: | 5 ppm vanadium from vanadyl sulfate in drinking water for lifetime (0.7 mg/kg/day) |
| Effect of Concern: | None observed |
| Chronic: | 5 ppm vanadium from vanadyl sulfate in drinking water for lifetime (0.7 mg/kg/day) |

The intraperitoneal $LD_{50}$ of $NaVO_3.H_20$ is about 11 mg V/kg for mice and slightly greater for rats on commercial laboratory diets; intramuscularly, the MLD of the metavanadate for dogs on laboratory chow and milk is 3.7 mg V/kg. Sjoberg found $V_20_5$ dust to be lethal to rabbits following a single 7-hr exposure to 205 mg of $V_20_5/m^3$; the animals died of pulmonary edema, presumably resulting from the combined nonspecific irritancy and specific toxicity of $V_20_5$.

Among vanadium compounds of lesser industrial interest in the United States, vanadium trioxide ($V_20_3$) was reported to have an oral $LD_{50}$ for mice of 130 mg V/kg; vanadium trichloride ($VC1_3$), with an oral $LD_{50}$ of 23 mg V/kg, was about six times as acutely toxic as the trioxide.

Source: 1, 2


1 EPA 1990b.
2 Glayton, G. and F. 1978.
3 Agency for Toxic Substances and Disease Registry.
4 EPA 1989h.
5 US Department of Health and Human Services 1985.


Additional information is available in "Registry of Toxic Effects of Chemical Substances 1985-86". The large amount of data available from this source makes inclusion in the table undesirable.

# APPENDIX 6K. IDENTIFICATION OF UNCERTAINTIES

This appendix identifies uncertainty factors for the following components of the baseline human health evaluation: selection of contaminants of potential concern, exposure assessment, toxicity assessment, and risk characterization. A qualitative approach was used to identify variables and assumptions that contributed to uncertainty and their influence on final risk estimates. The uncertainty factors are listed in Table 6K.1 and are qualitatively assessed as over-estimating risk or under-estimating risk to receptors at WAG 6.

Section 6.5 of the main report presents the final risk values for all receptors. The greatest risk values were for the hypothetical on-WAG homesteaders. These risks were either 1 or approaching 1 (i.e., the probability of developing cancer is 100%) from exposure to radionuclides.

Upon review of the results from the qualitative evaluation of uncertainty, it was determined that the factor which contributed most significantly to the final risk values for the on-WAG homesteader was the assumption of waste exhumation. Under this assumption radioactive waste was excavated and mixed in the garden and yard.

In order to assess the significance of waste exhumation, a semi-quantitative approach was used in the uncertainty analysis to estimate a lower bound of risk. Risks were calculated assuming that no wastes were exhumed and that a homesteader built a house on a slab on WAG 6. In the evaluation of this receptor the following pathways were included:

- External exposure from radionuclides in subsurface soil
- Ingestion of radionuclides in groundwater
- Ingestion of biota which consume groundwater contaminated with radionuclides

Risk values for the current and future day homesteaders were 9E-3 and 4E-4, respectively. The risks attributable to individual pathways are presented in Table 6K.2. The risk to these homesteaders for the current and future day still exceeded the upper bound of EPA's carcinogenic target risk range (i.e., 1E-04). These risk values, however, were considerably less (i.e., by 3 or 4 orders of magnitude) than those calculated for the homesteaders assuming waste exhumation (Table 6K.3). This comparison of risk values for the homesteaders when waste is exhumed and not exhumed illustrates that this assumption contributes significantly to uncertainty in the baseline human health evaluation.

# Appendix 6K Tables

**Table 6K.1. Uncertainty factors specific to the WAG 6 baseline human health evaluation**

| Uncertainty factor | Effect of uncertainty | | |
|---|---|---|---|
| | May over-estimate risk | May under-estimate risk | Either |
| **Selection of contaminants of potential concern** | | | |
| Inventory information: | | | |
| Reliability of radionuclide inventory information (missing information estimated from existing inventory) | | | X |
| Assumption that inventory represents waste disposed of | X | | |
| Sampling and analysis: | | | |
| Variability in sampling and analysis | | | X |
| Representativeness of field samples (could not directly sample source areas) | | X | |
| Nonexistent chemical inventory information (field data used to represent source data) | | | |
| Possible loss of contaminant VOCs in media sample | | X | |
| Use of detection limit for undetected results | X | | |
| Statistical Method: | | | |
| Use of a 0.05 level of significance for identifying contaminants of concern | | | X |
| Elimination of chemicals from the list of potential contaminants of concern when concentrations were comparable with background concentrations | | X | |

Table 6K.1. (continued)

| Uncertainty factor | Effect of uncertainty | | |
|---|---|---|---|
| | May over-estimate risk | May under-estimate risk | Either |
| Inclusion of all chemical volatiles as contaminants potential concern (even if not statistically significant) | | X | |
| **Exposure assessment** | | | |
| Receptors and Exposure Pathways: | | | |
| Radioactive waste exhumed and mixed in the garden and yard; indistinguishable from native soil | X | | |
| Hypothetical exposure assumptions (do not reflect actual characteristics of the exposed population) | X | | |
| Assumption of residential development on the WAG (current conditions at the site preclude homesteading) | X | | |
| Assumption that hunter ingests meat from deer that have drunk contaminated water exclusively from WAG 6 | X | | |
| Assumption of lifetime exposure duration for the boundary receptor | X | | |
| Conservative assumptions for exposure time and frequency for the on-WAG ORNL employee | X | | |
| Assumption that off-WAG homesteader irrigates his garden and yard and supplies his cows with contaminated water from the Clinch River | X | | |
| Concentrations of contaminants in media: | | | |
| Quantifification of the maximum annual average air contaminant concentrations | X | | |
| Nonuniform distribution of radionuclide concentrations in the wastes | | | X |

Table 6K.1. (continued)

| Uncertainty factor | Effect of uncertainty | | |
|---|---|---|---|
| | May over-estimate risk | May under-estimate risk | Either |
| Assumption that chemical concentrations remain constant over time | X | | |
| Use of $k_{ow}$ values in the estimating concentrations of contaminants in biota | X | | |
| Analysis of total metals only (metals assumed in their most toxic form) | X | | |
| Estimating intake: | | | |
| Use of upper bound values to estimate reasonable maximum exposures for many of the intake factors | X | | |
| Toxicity Assessment | | | |
| Carcinogens: | | | |
| Derivation of slope factors and reference doses primarily from laboratory studies extrapolation of data from high doses to low doses and from one species to another | | | X |
| Predicted effects from low doses of radiation (not as well known as effects from high doses) | | | X |
| Noncarcinogens: | | | |
| Use of chronic-exposure toxicity values | X | | |
| Lack of toxicity values for all chemicals (led to exclusion of such chemicals from risk characterization) | | X | |
| Application of uncertainty and modifying factors to reference doses from no-observed-adverse-effect levels or lowest-observed-adverse-effect levels | | | X |

Table 6K.1. (continued)

| Uncertainty factor | Effect of uncertainty | | |
|---|---|---|---|
| | May over-estimate risk | May under-estimate risk | Either |
| Unavailability of dermal toxicity factors (used oral toxicity factors, which are administered not absorbed) | X | | |
| **Risk Characterization** | | | |
| Carcinogens: | | | |
| Estimation of risk to the on-WAG ORNL employee and boundary from gamma radiation using a radiation shielding model (assumes clean soil over waste disposal area) | | | X |
| Assumption that carcinogenic risks are additive for multiple contaminants and pathways for the same receptor and exposure period (risks may not be additive due to synergistic or antagonistic effects) | | | X |
| Noncarcinogens: | | | |
| Assumption that noncarcinogenic hazard indices are additive by effect for multiple chemicals and pathways for the same receptor and exposure period (may not be additive due to synergistic or antagonistic effects) | | | X |
| Use of hazard quotient (HQ) values for multiple effects in calculating the hazard index (HI) for each effect (e.g., the HQ for effects to the kidney and liver is considered twice, once as part of the HI for the kidney and again as part of the HI for the liver, with no attempt to segregate the effects) | X | | |

**Table 6K.2 Radionuclide Risk Estimated for the On-WAG Homesteader With no Waste Exhumed [a]**

| Pathway | Current Day Homesteader Risk[b] | Future Day Homesteader Risk[b] |
|---|---|---|
| External Exposure | 8E-3[c] | 8E-5[d] |
| Inhalation of Tritium | 5E-8 | 2E-11 |
| Ingestion of Meat and Milk | 1E-4 | 2E-5 |
| Ingestion of Groundwater | 6E-4 | 3E-4 |
| Total | 9E-3 | 4E-4 |

[a]Potential exposure pathways are for the on-WAG homesteader which does not have wastes exhumed and mixed in the garden and yard.

[b]Excess probability of an individual developing cancer calculated using the linear low dose cancer equation.

[c]Value is calculated from on-WAG worker's external exposure pathway risk adjusted for a homesteader living on-WAG 365 days/yr., 8 hours/day for 30 years.

[d]Estimated from the current day homesteaders risk from the external exposure pathway, and decreasing the risk by 1E-2 based on the decrease in the on-WAG homesteaders risk from the external exposure pathway when the waste is exhumed (Appendix G).

Table 6K.3. Comparison of risks for the on-WAG homesteader when waste is and is not exhumed

| Period | Risk to the on-WAG homesteader with wastes exhumed[a] | Risk to the on-WAG homesteader with wastes not exhumed[a] |
|---|---|---|
| Current day | 1[b] | 9E-3[b] |
| Future | 3E-1[c] | 4E-4[c] |

[a] Excess probability of an individual developing cancer.
[b] Calculated using the linear low-dose equation.
[c] Calculated using the one hit equation.

received 5/21/90

May 15, 1990

TO: J. M. Loar, ESD
FROM: M. G. Ryon, ESD
RE: Fish Survey of SWSA 6

On May 10 1990, a fish survey was made of suitable aquatic habitats within the boundaries of SWSA 6. Sections of streams were surveyed adjacent to the establish benthic invertebrate sampling sites (Fig 1 in Loar et al. 1989). The survey consisted of a qualitative electrofishing sample and a determination of the presence of potential fish habitat. The electrofishing was conducted using a Smith-Root battery-powered backpack electrofisher (operated by E. M. Schilling) and a netter (M. G. Ryon). A 12-minute electrofishing sample was made at each of the three benthic sites within the SWSA 6 and covered roughly 50 to 100 m of stream, depending on the stream width and complexity of the habitat. The presence of potential habitat was determined by M. G. Ryon based on comparisons with similar-sized streams within the Oak Ridge Reservation (Ryon and Loar 1988).

The three electrofishing surveys failed to locate any fish. Several crawfish were stunned during the survey indicating that the unit was functioning effectively. The habitat evaluation suggested that the east tributary did not contain sufficient quality habitat to maintain a fish population; however, the two branches of the west tributary did contain suitable habitat. In comparison with area streams, the west tributary had pools of sufficient depth, appropriate undercut banks for refuge, and established pool-riffle sequences. With these physical habitat characteristics, fish species such as creek chubs (Semotilus atromaculatus) and blacknose dace (Rhinichthys atratulus) could potentially survive and reproduce in the west tributary. Absence of these species could be related to the intermittent nature of the stream in combination with the isolation barrier that White Oak Lake represents. Once driven from the stream by low water conditions, recolonization of the tributary would be prevented by the lake, which is not a suitable habitat for these species. The absence of all fish would of course preclude the existence of any endangered, threatened, or special concern fish species.

Ryon, M. G. and J. M. Loar. 1988. A checklist of fishes on the Department of Energy Oak Ridge Reservation. J Tn Acad Sci 63:97-102.

Loar, J. M., J. G. Smith, G. R. Southworth, and A. J. Stewart. 1989. Biological monitoring of streams in SWSA 6. Unpublished memo to T. L. Ashwood, Environmental Sciences Division. November 7, 1989.

ORNL-DWG 87-12277

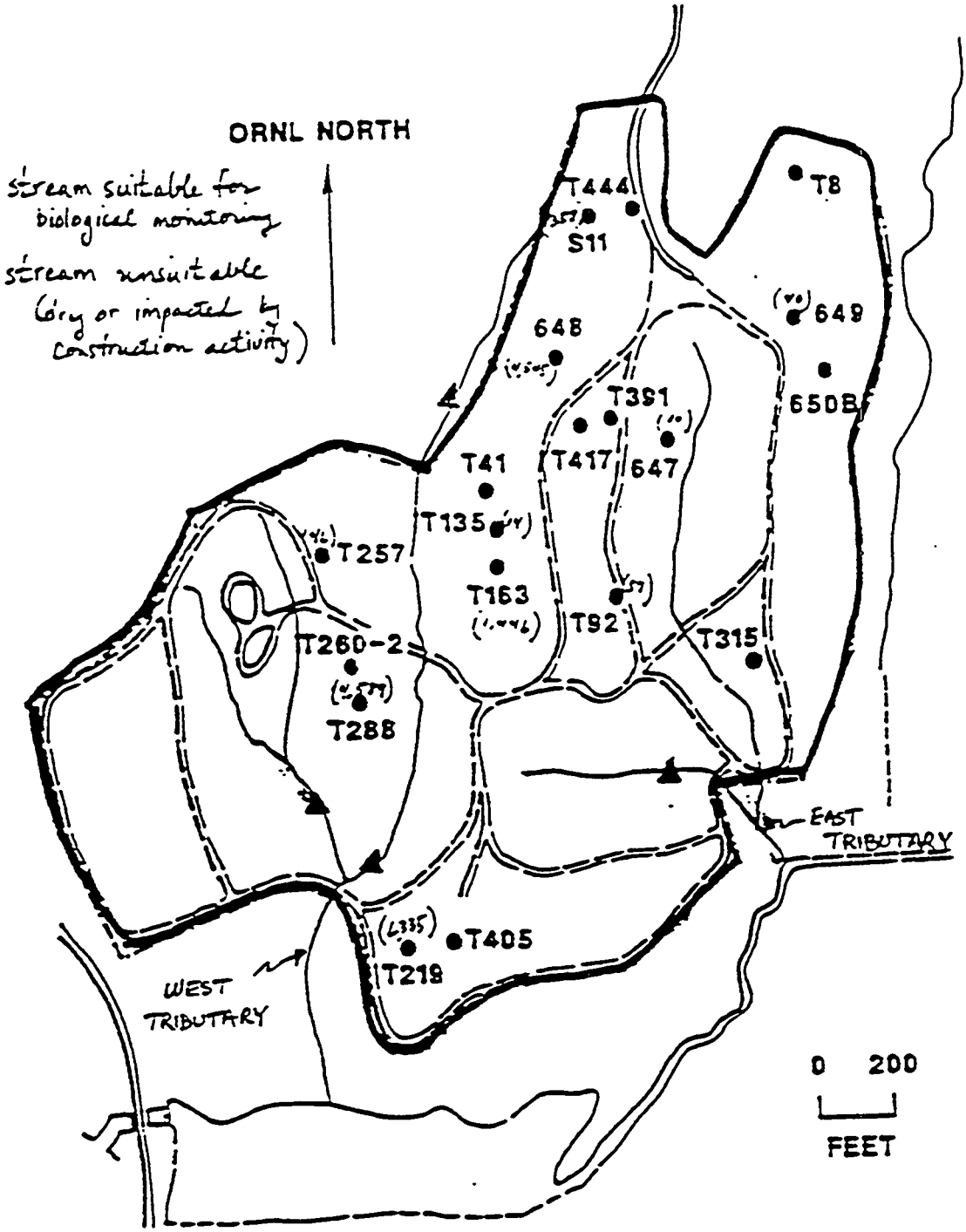



Fig. 1 Locations of proposed benthic macroinvertebrate sampling sites (▲) on East and West Tributary in SWSA 6. Also shown are locations of trench and groundwater monitoring wells (●). Numbers in parentheses refer to the concentration of total organic compounds (ppb) observed in 1986-1987 (Solomon et al. 1988).

MARTIN MARIETTA

Internal Correspondence

rec'd 5-30-90 JMC

MARTIN MARIETTA ENERGY SYSTEMS, INC.

May 28, 1990

J. M. Loar

Rare Plant Survey of SWSA-6

A survey for rare plant species in the SWSA-6 area was conducted on May 10, 1990. The area surveyed was limited to the fenced enclosure; no attempt was made to look at wetland species at the edge of White Oak Lake just outside the fence.

Given the level of development and disturbance at the site a surprising number of woody and herbaceous species are present, primarily in small patches of forest at the edges of the area. A forest at the southwestern corner of the site was in the process of being bulldozed at the time of the survey. The tract had not been surveyed for rare species prior to destruction.

No listed species were observed. Site visits later in the season will not be required to complete the survey. Please phone me if you have questions or need additional information.

Maureen Cunningham

M. Cunningham, 1505, MS-6038, ORNL (6-8123)

cc: P. D. Parr
J. G. Rogers
M. J. Tate

[redacted]

Internal Correspondence

MARTIN MARIETTA ENERGY SYSTEMS, INC.

May 31, 1990

J. M. Loar

SWSA 6 Survey for Threatened and Endangered Invertebrate Species

Along with the first annual collection of invertebrates for the Biological Monitoring Program (BMP) for SWSA 6, A. W. McWhorter and J. G. Smith conducted a survey on Thursday May 10, 1990, for threatened or endangered invertebrate species in streams located on the site. Qualitative invertebrate samples were collected with an aquatic dip net (mesh of 500 μm) from an approximately 50 m reach of each stream site as identified in the monitoring plan (J. M. Loar, ORNL, memorandum to T. L. Ashwood, ORNL, November 7, 1989); all distinct habitat types (eg., riffles, pools, leaf packs, etc.) were sampled. The samples were then placed into a white 8" X 10" plastic tray and visually inspected for species listed by the State of Tennessee and the U. S. Fish and Wildlife Service as threatened or endangered (TWRC 1990; Saylor et al. 1990). After scanning, samples were placed into prelabeled polypropylene coated glass jars and returned to the lab for further processing as specified by the monitoring plan.

None of the freshwater invertebrate species listed by the State of Tennessee or the U. S. Fish and Wildlife Service have been found on, or are known to occur on the ORR, and none were found in the streams at SWSA 6. Most of the aquatic invertebrate taxa listed by these agencies have relatively limited habitat requirements (i.e., the listed snails and crayfish), or live in streams/rivers larger than those that exist on the ORR, including those streams draining SWSA 6 (i.e., bivalve mussels).

J. G. Smith, Bldg. 1505, (6-4163)

cc: A. W. McWhorter

WAG-6 Field Survey June 1, 1990 7-8 a.m. R. Kroodsma and T. Ashwood

(some of the bird species listed below were outside the fence)

**Birds**

yellow-breasted chat
red-eyed vireo
indigo bunting
starling
crow — American
eastern phoebe
blue-gray gnatcatcher
chickadee — Carolina
pine warbler
downy woodpecker
hairy woodpecker
red-bellied woodpecker
flicker — common
song sparrow
cardinal — northern
cowbird — brown-headed
bobwhite — northern
grackle — common
carolina wren
eastern meadowlark
tufted titmouse
rufous-sided towhee
~~bluejay~~ blue jay
~~parula warbler~~ northern parula
bluebird — eastern
mockingbird
summer tanager
scarlet tanager
red-winged blackbird
yellowthroat — common
mourning dove
sparrow hawk
barn swallow

**Mammals**

cottontail rabbit

Internal Correspondence

MARTIN MARIETTA ENERGY SYSTEMS, INC.

June 1, 1990

J. M. Loar, 1505, MS-6036

Threatened and Endangered Animal Species on the WAG-6 Site

On June 1, 1990 I visited the WAG-6 site to look for potential habitat for threatened or endangered animal species and to briefly survey the wildlife present at the site. The site consists mainly of grassy fields and liner-covered waste disposal areas with small amounts of relatively young woods along several drainages. Thirty-three bird species and one mammal species were observed on the site and in the vicinity, and many other bird and mammal species that were not observed during this very brief survey probably also occur there as breeding residents at this time of year.

No threatened or endangered animal species or critical habitat listed, or proposed to be listed, by the U.S. Fish and Wildlife Service is known to be present on the Oak Ridge Reservation. Therefore, no such species or habitat should be present on WAG-6.

The site also appears to be relatively unimportant for species listed as threatened or endangered by the State of Tennessee. Such species that could occasionally occur on the site include the Cooper's hawk and sharp-shinned hawk. Although these species may occasionally hunt for prey on the site, they are not known to nest there and would not be expected to nest there because of the lack of suitable forest for nesting and the existing disturbance.

A few other protected species, which are listed by the State of Tennessee as "in need of management" (e.g., the black vulture and red-shouldered hawk), occur on the Oak Ridge Reservation and may occasionally visit the WAG-6 site. However, the site does not appear to provide good habitat for these species, and construction activities on the site should have no significant impact on these species.

In conclusion, waste disposal and associated activities on WAG-6 should have no significant impact on animal species listed as threatened, endangered, or in need of management.

R

R. Kroodsma, Bldg 1505, MS-6038, 4-7310
Endangered Animals Representative, Oak Ridge Reservation Resource Management Organization

MARTIN MARIETTA

Internal Correspondence

MARTIN MARIETTA ENERGY SYSTEMS, INC.

June 27, 1990

Jane Tate

Results of Ecological Surveys of Solid Waste Storage Area (SWSA) 6

Attached are the results of the surveys for threatened and endangered (T&E) species in SWSA 6. As I mentioned previously, the results of each survey are presented in a memo from the Principal Investigator to myself, so proper citation in the WAG RI report should not be a problem.

I have also included a letter from the regional office of the U.S. Fish and Wildlife Service (USFWS) regarding the occurrence of T&E species on the Oak Ridge Reservation. Their discussion of potential construction-related impacts is especially noteworthy. I do not know if this letter can be used as documentation from USFWS of the absence of T&E species in SWSA 6; additional consultation with the USFWS that is specifically related to this particular site may be required. You need to explore this issue further.

If you have any specific questions about these results (e.g., clarification of sampling methods), please feel free to contact the individuals who conducted the surveys.

J. M. Loar, 1505, MS-6036, ORNL (4-7323)

JML:tks

Attachment

cc/att: J. Freeman, ERC
C. Hickey, BNI
R. Moos, CH2M Hill
R. Roop, LA

cc: S. B. Garland
C. W. Gehrs
D. D. Huff
L. D. Hyde
R. K. White

Internal Correspondence

MARTIN MARIETTA ENERGY SYSTEMS, INC.

July 26, 1990

J. M. Loar

Wetland Survey for SWSA-6

A survey for wetland communities within the SWSA-6 area was conducted by Larry Pounds on July 25, 1990. The survey was confined to stream drainages within the fenced area outlined on the attached map. Although a few wetland species were found (Scirpus and Carex), there was essentially no wetland community development.

Please phone me if you need additonal information.

Maureen Cunningham

M. Cunningham, 1505, MS-6038, ORNL (6-8123)

cc: J. G. Rogers
M. J. Tate

OAK RIDGE NATIONAL LABORATORY
OPERATED BY MARTIN MARIETTA ENERGY SYSTEMS INC

POST OFFICE BOX 2006
OAK RIDGE, TENNESSEE 37831-6038

July 26, 1990

Jenny Freeman
EFC
Suite 103
800 Oak Ridge Turnpike
Oak Ridge, TN 37830

Dear Jenny:

As you requested in our phone conservation several weeks ago, I am sending a description of the methods used to report on the presence/absence of rare plant species on SWSA-6 on the Oak Ridge Reservation (ORR).

A field survey of the site was conducted on May 10, 1990. This included a walk-through of all the currently undisturbed areas (areas not planted in fescue or covered by tarp) on the site. The search was for rare plant species known to occur on the ORR, as well as any unknown taxa. No rare plant species were observed; the only unknown species was later identified as a depauperate form of Plantoo aristata.

A copy of a memo reporting the resluts of the wetlands survey for SWSA -6 conducted on July 25, 1990, is enclosed. Methods were similar to those described above but the survey area was confined to stream drainages within the SWSA-6 fence. Please note that both surveys were within the fenced area . White Oak lake was not included.

Please phone me (576-8123) if you need additional information.

Sincerely,

Maureen Cunningham

Maureen Cunningham

# APPENDIX 7B. EXPOSURE SCENARIOS

The populations of flora and fauna on WAG 6 potentially exposed to site contamination were subject to different uptake levels and concentrations of contaminants as those contaminants progressed from one trophic level to another or from one medium to another. Of the four terrestrial exposure scenarios selected for the WAG 6 environmental evaluation, three of the target species experienced similar routes of contamination: ingestion, inhalation, and direct exposure. However, effects from inhalation or direct exposure were expected to be minimal. No air data were collected for WAG 6, but the following equation was used to assess air contaminants:

Air Particulate Contamination = Concentration in Soil (mg/kg) × Mass Loading Factor ($2 \times 10^{-4}$ g/m$^3$) × Unit Conversion Factor (.001 kg/m)

When compared to background levels in the soil, none of the selected WAG 6 contaminants were of significant concentrations to cause either air or direct contact to be important pathways to WAG 6 ecological receptors. Therefore, ingestion was the only route considered to be of primary importance for contaminant transport for WAG 6.

The exposure scenario for terrestrial flora is described in Sect. 7B.1. Exposure scenarios for terrestrial fauna appear in Sect. 7B.2. Section 7B.3 and Sect. 7B.4 contain scenarios for aquatic vertebrates and invertebrates, respectively. And the general limitations imposed on the entire environmental risk analysis are summarized in Sect. 7B.5.

## 7B.1 TERRESTRIAL FLORA

### 7B.1.1 Tulip Poplar

The tulip poplar tree is endemic to Tennessee and is common throughout the eastern United States. It is a fast-growing pioneer species that quickly inhabits a disturbed site, such as an abandoned field, and matures rapidly to full height (60 ft) and diameter (3-4 ft) (Brockman 1968). It dominates the forest canopy until shaded out by slower growing, shade-tolerant species such as oaks, hickories, and hemlocks.

As shown in Fig. 7B.1, the four routes of contamination to a tulip poplar tree growing on WAG 6 are assimilation from the soil, gas exchange with the atmosphere, bioaccumulation from surface water, and surface deposition (IT Corp. 1990). Important pathways of transfer to the forest floor from tree boles are rain leaching and passage through the roots. In trees tagged with cesium-134, translocation of the contaminant was very rapid (Witherspoon 1964).

#### 7B.1.1.2 Toxicity assessment—tulip poplar

The data available in the literature for the selected contaminants for the terrestrial flora of WAG 6 characterize uptake, accumulation, transport, distribution, and recycling. Virtually no data were found that describe biological effects of contaminants on terrestrial

floristic organisms, including the tulip poplar. During the course of this evaluation, several authorities were questioned concerning effects or specific toxicity data that could be applied to an analysis of contamination of WAG 6. The following authorities were contacted: Dr. Frank McCormick, Ecology Program, University of Tennessee; J. Thomas Kitchings and Keith Owenby, ERCE, Denver, CO; Jackie Cunningham, ESD, ORNL; Dr. Liz Etnier, ESD, ORNL; C.T. Garten, ORNL; Ann West, CH2M Hill, Fairfax, VA; Charles Murphy, SRL, Aiken, SC; Elizabeth Deming, Agricultural Engineering, University of Tennessee; Diane Beeman, U.S. Fish and Wildlife Service, Raleigh, NC; and Earl Leming, Tennessee Division of Solid Waste Management. These people either referred to information specific to humans or expressed doubt about the potential to derive an exposure dose and calculate the likely effects from the available data.

#### 7B.1.1.1.3 Risk characterization—tulip poplar

No risk characterization for any terrestrial flora on WAG 6 can be performed at this time because no data exist that describe the effects of known concentrations of contaminants on the exposure scenario discussed above.

## 7B.2 TERRESTRIAL FAUNA

### 7B.2.1 White-Tailed Deer

#### 7B.2.1.1 Exposure assessment—white-tailed deer

The white-tailed deer (Odocoileus virginianus) is a common large mammal in Tennessee. Weighing an average of 50 kg, deer are excellent biological monitors, according to Wren (1986), because they are widely distributed and abundant. Deer inhabit upland and bottomland forests and have a remarkably adaptable diet (Kitchings and Mann 1976). They are completely herbivorous, consuming approximately 3500 g of vegetation daily, and they eat according to seasonal availability (Table 7B.1) (IT Corp. 1990).

In spring, they eat green leaves and stems from both woody and herbaceous species, fruit of the hawthorne, tulip poplar flowers, mushrooms, and acorns. Acorns dominate the deer's diet in autumn, followed by honeysuckle, mushrooms, grapes, apples, sumac, and blueberry. In winter, they eat acorns, grasses, honeysuckle, and mushrooms - all of which are subject to contamination from soil assimilation, gas exchange with the atmosphere, bioaccumulation from surface water, and surface deposition. Deer also typically consume 3000 ml of water and 5 g of soil, both of which are sources of additional uptake of contaminants. The white-tailed deer was selected for the WAG 6 environmental risk assessment because it is a large herbivorous mammal and is common throughout the ORR and the WAG 6 environs.

As shown in Fig. 7B.2, there are three routes of contamination to a white-tailed deer inhabiting WAG 6. They are inhalation, ingestion, and direct exposure (IT Corp. 1990).

### 7B.2.1.2 Toxicity assessment—white-tailed deer

The toxicity assessments for the various contaminants are summarized below. A more detailed discussion is presented in Appendix 7C.

Because cesium-137 is not readily uptaken by plants (see Sect. 7B.1), its toxic effects on white-tailed deer are negligible. Deer incidentally consume soil as they graze or browse; therefore, soil containing cesium-137 becomes another source of contamination. However, because of the small amounts of soil consumed, cesium-137 likely does not pose a threat to the deer.

Under conditions of chronic exposure to tritium as either liquid or vapor, an equilibrium concentration between body-water tritium and environmental tritium is rapidly attained (Elwood 1971). Deer killed at the Savannah River Plant site were found to have generally the same tritium concentrations in their body water and tissue-bound components. However, tritium does not bioaccumulate, and potential effects of tritium on white-tailed deer are from ionizing radiation.

Strontium-90 levels in honeysuckle and blackberry are described in Appendix 7C. The significance of the concentrations found in honeysuckle and blackberry on SWSA 5 is that if a 45-kg deer consumed this contaminated vegetation, the strontium-90 level in deer bone could easily exceed the TWRA confiscation limit of 30 pCi/g after browsing times of 1 week to 1 year (Garten and Lomax 1987). The standard 30 pCi/g was set to protect consumers of deer meat obtained in hunts on the ORR. Although the standard relates to human health, the assumption can be made, based on effects data of strontium-90 on bone, that 30 pCi/g of strontium-90 in deer bone pose potential risk to deer.

A discussion of the biological behavior and environmental cycling of cadmium and chromium is presented in Appendix 7C. Cadmium is primarily associated with the soil and has not been shown to accumulate in vegetation. Chromium, in the hexavalent state, is generally not available for incorporation into plant tissues. Because of the unavailability of either metal in plant tissue, cadmium and chromium are not transported into the trophic level represented by white-tailed deer.

No data were found in the literature from which to draw conclusions or base inferences about effects of these contaminants on the exposure scenario represented by a white-tailed deer.

### 7B.2.1.3 Risk characterization—white-tailed deer

Of the selected contaminants, strontium-90 is the one most likely to impact a white-tailed deer on WAG 6. Strontium-90 bioaccumulates and is readily taken up by deer through the route of ingestion. Strontium levels on WAG 6 in both soil and surface water are high - a mean of 9.26 pCi/g for soils and a mean of 980.69 pCi/L for surface water compared to a standard of 8 pCi/L (SDWA MCL) (Table 7B.2). This mean value was derived from the number of samples found to be contaminated. Concentrations of strontium-90 in vegetation at WAG 6 are not known, but given the high levels of strontium-90 in soil and surface water

at WAG 6, it is likely that this contaminant poses the most risk to a white-tailed deer living there.

Cesium-137 is irreversibly bound up in soil, is not uptaken by vegetation, and, therefore, poses no risk to a deer through the route of ingestion. Tritium, although found at very high levels in WAG 6 surface water, reaches equilibrium in an organism rapidly and does not bioaccumulate. Cadmium and chromium are not available for incorporation into plant tissues. For the volatile organic compounds, no data exist for characterizing the risk to white-tailed deer on WAG 6.

### 7B.2.2 Red-Tailed Hawk

#### 7B.2.2.1 Exposure assessment—red-tailed hawk

Red-tailed hawks are at the top of the food chain. Their preferred habitat is open country mixed with woodlands, nesting in the forests but hunting in more open terrain. Unlike other secondary consumers, such as raccoons, red-tailed hawks do not supplement their diet with any herbaceous material. As secondary consumers, hawks have many pathways through which they may become contaminated, beginning with lower trophic levels and culminating with the prey that make up the diet of this raptor (Fig. 7B.3). The estimated daily intake of food, water, and air for these species is also presented in Table 7B.1. In addition to ingestion, red-tailed hawks are exposed to contamination through inhalation and direct exposure.

Vegetation growing in the contaminated areas may bioaccumulate some of the constituents and be ingested by rabbits and other small mammals consumed by hawks. Earthworms ingest the soil and then are eaten by shrews, which consume from 7 to 36 g of earthworms per day, a major portion of their diet. As cesium-137 becomes tightly bound to the clay fractions of soils, a large percentage of radioactivity accumulated by earthworms is ingested (Crossley, Reichle, and Edwards 1971), creating a potentially significant source of contamination in the pathway of a red-tailed hawk.

Eastern cottontail rabbits are herbivorous, feeding on a great diversity of plant species. They consume primarily herbaceous species during summer and woody plants during winter. Their preferred habitat is heavy brush, strips of forest with open areas nearby, and weed patches. These rabbits have an average life span of 6 to 15 months, with a maximum of 3 years. Their average body weight is from 0.9 to 1.8 kg. Rabbits can be exposed to contaminants through inhalation, ingestion of vegetation and surface water, and direct exposure.

Shorttail shrews, the second major component of the diet for red-tailed hawks for this environmental risk assessment, are small insectivorous animals that feed on earthworms, insects, snails, various invertebrates, and possibly young mice (Burt and Grossenheider 1964). They are active both day and night and make their own tunnels (or use those of other animals) in the earth. Their preferred habitat is not restrictive and includes forests, grasslands, marshes, and brushy areas. With a lifespan of 12 to 18 months, their average body weight is from 11 to 22 g. Because of their burrowing habits, shrews can ingest

contaminated soil or wastes directly. Other avenues of exposure include ingestion of prey and surface water, inhalation of air, and direct exposure.

### 7B.2.2.2 Toxicity assessment—red-tailed hawk

This section contains a brief synopsis of the documented or likely toxic effects of the selected contaminants on the same or similar species as those that comprise the elements of the food chain for the red-tailed hawk. A more complete literature review of these toxic effects on terrestrial species is presented in Appendix 7C.

Cadmium is a naturally occurring element; however, at sufficient concentrations, it exhibits toxic effects. The U.S. Fish and Wildlife Service estimates that adverse effects on fish and wildlife are either pronounced or probable when cadmium concentrations exceed 3 ppb in freshwater or 100 ppb in the diet. Whereas mammals and birds are comparatively resistant to the biocidal properties of cadmium, teratogenic, mutagenic, and carcinogenic effects have been documented in laboratory studies on rodents. Cadmium has a strong affinity for soft body tissues, especially the liver and kidney. Species differences in accumulation of cadmium have been related to diet, with herbivores having lowest concentrations and carnivores having the highest. Relative influence of sex and age on metal accumulation and retention is not well-defined, but cadmium levels appear to consistently increase with age. Moreover, deficient intake of some essential nutrients may increase the absorption rate of cadmium.

Chromium is most frequently found in the environment in the trivalent and hexavalent states. In general the toxicity of trivalent chromium is low, but hexavalent chromium is more toxic because it easily penetrates biological membranes. Little is known about the relation between concentrations of total chromium in the environment and the biological effects on the organisms living there. However, it is generally agreed that hexavalent chromium in air and water is hazardous to fish and wildlife. Laboratory studies have documented teratogenic effects, morphological changes in liver, skin ulceration, irritative dermatitis, ulcerations in mucous membranes, and perforations in the nasal septum in a variety of species. The significance of chromium residues is unclear, but available evidence suggests that organs and tissues of fish and wildlife that contain >4 mg total Cr/kg dry weight should be viewed as presumptive evidence of chromium contamination.

Like metals, radionuclides are transferred through components of ecosystems, often collecting in target tissues. For this environmental evaluation, the selected radionuclides are strontium-90, cesium-137, and tritium. Strontium-90 can be uptaken by both plants and animals, accumulating in various plant tissues and in bone tissue in animals. It is a beta-emitting fission product with a relatively long half-life. As a metallic analog of calcium, strontium-90 is readily absorbed from the gastrointestinal tract and lungs into the bloodstream and deposited in bone. In experimental animals, chronic ingestion of strontium-90 resulted in leukemia and bone tumors. Similarly, Talmage and Walton (1990) found that all small mammals collected from sites contaminated with strontium-90 had detectable levels of that radionuclide in bone tissue.

Although tritium also has the potential for uptake by terrestrial vegetation, it does not appear to bioaccumulate in the environment or in food chains. In fact, the transfer coefficient for tritium from soil to vegetation is 0 (Argonne National Laboratory 1989), indicating that it is not uptaken by the roots of plants. In animals, tritium rapidly reaches equilibrium. A laboratory study of rats resulted in an equilibrium being established for intake, accumulation, and elimination within 20 days. After administration ceased, approximately 99% of the tritium was eliminated with a half-life of 3 to 4.3 days.

Cesium-137, which is a chemical analog of potassium, concentrates in soft tissues in biota. In the environment, it becomes tightly bound to the soil and is ingested by earthworms and arthropods, which in turn are consumed by small mammals. The daily turnover of soil is equal to 29% of the live weight of the worm, and the assimilation of radiocesium from litter by earthworms appears to be much lower than for arthropods (Crossley, Reichle, and Edwards 1971). In addition to consuming earthworms and arthropods, small mammals may also be an important avenue for radioactive transport because of their burrowing activity, mobility, and potentially high population numbers. Arthur et al. (1986) found that radiation dose rates received by animals from radioactive waste disposal areas varied from 0.4 to 42,000 mrad/day and were significantly higher than the dose rate received by control animals. The highest doses received by small mammals were of sufficient magnitude to cause premature deaths.

Limited information is available concerning the effects of volatile organic compounds on terrestrial wildlife; most studies on their toxicity focused on laboratory animals or humans. Most xylenes are released into the atmosphere where they photochemically degrade. In water the dominant removal process is volatilization. They are moderately mobile in soil and may leach into groundwater where they may persist for years, despite some evidence that xylenes biodegrade in both soil and groundwater. However, the potential for bioconcentration is expected to be insignificant. Xylenes are absorbed primarily through the mucous membranes and pulmonary system, where they are metabolized to a toxic aldehyde, methylbenzaldehyde. Almost total excretion via the urinary tract occurs within 24 hours. In human studies, known toxic effects include fetotoxicity, hepatomegaly, hyperactivity, decreased body weight, central nervous system effects, nose and throat irritation, and increased mortality at higher doses.

Like xylenes, toluene volatilizes rapidly from water and is also expected to volatilize fairly rapidly from dry soils because of its high vapor pressure. In the atmosphere it degrades photochemically. Toluene vapor is readily absorbed by inhalation and the liquid by the gastrointestinal tract; however, it is absorbed poorly by the skin. Toluene concentrates in lipid-rich tissues (brain and fat) and well-perfused organs (liver and kidney) but is rapidly eliminated.

Tetrachloroethylene photooxidizes in the atmosphere and undergoes slow biodegradation in anaerobic soils when microorganisms have been acclimated. When tetrachloroethylene is released to soils, it is subject to evaporation into the atmosphere and leaching into groundwater. Tetrachloroethylene is readily absorbed through the lungs and to a much lesser degree through skin or mucous membranes or following ingestion. Metabolism is relatively slow, and elimination through exhalation is slow because of continuing release from fat stores, where it tends to distribute once in the bloodstream.

Once in the environment, trichloroethylene is fairly persistent. It is not hydrolized by water under normal conditions, does not appear to biodegrade in groundwater, and should not photooxidize because it does not absorb light less than 290 nm. Biodegradation under anaerobic conditions has been noted. Trichloroethylene has a low adsorption coefficient and is, therefore, readily transported through the soil. It is a probable human carcinogen and is known to significantly increase the incidence of liver tumors, malignant lymphomas, and pulmonary adenocarcinomas in mice.

### 7B.2.2.3 Risk characterization—red-tailed hawk

Of the metal contaminants selected for the terrestrial environmental evaluation, neither cadmium nor chromium exceeded regulatory standards in soil/sediments; however, cadmium levels in unfiltered surface water were 30 $\mu$g/L compared to the SDWA MCL of 5 $\mu$g/L. The U.S. Fish and Wildlife Service suggests more stringent standards and estimates that adverse effects are either pronounced or probable when cadmium concentrations exceed 3 ppb in freshwater or 100 ppb in the diet. Using these estimates, the red-tailed hawk could become adversely affected by drinking water from WAG 6, as could its prey species, shorttail shrews and rabbits. Another avenue of cadmium contamination is through ingestion of shrews, which are known to concentrate cadmium in liver and kidney tissues by factors ranging from 15 to 33 times the levels found in soil. The shrews in turn consume earthworms, for which the concentration factor of soil:earthworms is approximately 1. Thus, the potential exists for adverse cadmium effects to the soft tissues (primarily liver and kidney) of the red-tailed hawk through bioaccumulation through the food chain from earthworms to shrews, where cadmium is bioconcentrated.

Whereas cadmium is apparently associated with the soil and does not accumulate in vegetation, herbivorous animals have been shown to accumulate cadmium in soft tissues when that contaminant is deposited directly on vegetation. However, direct deposition of cadmium on vegetation on WAG 6 where it could be ingested by the herbivorous rabbit is not considered a major pathway.

By using a conservative approach and allowing the red-tailed hawk to feed only upon prey species from WAG 6 and drink water only from WAG 6, the potential exists for adverse effects to the soft tissues of this species from cadmium.

While hexavalent chromium is known to be toxic to wildlife because it easily penetrates biological membranes, the significance of chromium residues is unclear. Evidence suggests that organs and tissues of wildlife containing more than 4 mg total Cr/kg dry weight should be presumed to have chromium contamination. Chromium levels at WAG 6 do not exceed regulatory standards (Table 7B.2); however, information is insufficient to determine whether chromium poses a risk to red-tailed hawks inhabiting WAG 6.

Radionuclides can adversely affect wildlife because they can become sources of both internal and external ionizing radiation. Of the three radionuclides selected for this environmental evaluation, strontium-90 likely poses the greatest risk to wildlife at WAG 6. The SDWA MCL is 8 pCi/L, and the maximum concentration detected at WAG 6 was 10,222 pCi/L, several orders of magnitude above the standard. Strontium-90 is a beta

emitter with a relatively long half-life of 28 years. As an analog of calcium, it is readily absorbed and deposited in bone tissue. Chronic ingestion results in leukemia and bone tumors. Because of the high concentrations of strontium-90, shrews and rabbits are likely to suffer adverse effects, to bioconcentrate strontium-90 in their bone tissue, and to result in contamination of the red-tailed hawk that preys upon them.

Cesium becomes tightly bound to the clay fraction of soil and is not taken up by vegetation. Therefore, the herbivorous rabbit feeding on WAG 6 is not likely to present a major pathway for contaminant transport. Conversely, earthworms can ingest the contaminated soil; they can then be consumed by shrews, which subsequently can be consumed by red-tailed hawks. All of these species can potentially be exposed to adverse effects of cesium-137 by drinking contaminated water. The maximum level of cesium-137 detected at WAG 6 was 4.57 pCi/g in soil/sediment and 11.2 pCi/L in surface water. However, there are no regulatory standards to which to compare these concentrations, and no information was available in the literature to indicate the likely effects of these concentrations on the target species. Therefore, the environmental risks of cesium-137 cannot be assessed at this time.

Tritium is present at WAG 6 at levels up to 14,000,000 pCi/L in surface water, greatly exceeding the regulatory standard of 20,000 pCi/L (Table 7B.2). However, tritium does not bioaccumulate in the environment, quickly reaches equilibrium in organisms, and has a relatively short half-life. Tritium may have some adverse radiation effects upon the inhabitant species of WAG 6, but these effects are likely to be far less damaging than those from strontium-90 exposure.

Of the volatile organic compounds selected for this environmental evaluation, tetrachloroethylene and trichloroethylene exceeded regulatory guidelines (Table 7B.2) and xylene and toluene are known to have been disposed in large quantities there. In human studies of xylene, known toxic effects include fetotoxicity, hepatomegaly, hyperactivity, decreased body weight, increased mortality at higher doses, central nervous system effects, and nose and throat irritation. It is possible that release of large quantities of xylene might cause similar reactions in small mammals such as shrews and rabbits at WAG 6. Toluene is readily absorbed by inhalation and through the gastrointestinal tract and tends to reach highest concentrations in lipid-rich tissues and well-perfused organs. However, toluene is rapidly eliminated. Studies on the effects of tetrachloroethylene on laboratory animals showed that metabolism is relatively slow, that most was exhaled unchanged, and that hepatoxic effects occurred. Trichloroethylene is known to significantly increase the incidence of liver tumors, malignant lymphomas, and pulmonary adenocarcinomas in mice.

While these results of studies on humans and laboratory animals indicate that these volatile organic compounds could pose a potential risk if there were extensive or persistent releases, they should volatilize fairly rapidly from surface water or soils and should not present a major risk to terrestrial wildlife. However, toxicological information about effects of these contaminants on terrestrial wildlife is not available, which precludes an assessment of their true environmental risk.

### 7B.2.3 Raccoon

#### 7B.2.3.1 Exposure assessment—raccoon

Unlike the totally predacious red-tailed hawk, raccoons are omnivorous, consuming both aquatic and terrestrial prey species as well as vegetation. Raccoons prefer habitat along streams and lake borders with nearby wooded areas or rock cliffs. They are chiefly nocturnal and feed along streams and lakes (Burt and Grossenheider 1964). Vegetation generally comprises more than half of their diet, with acorns being a principal component. Crayfish are also preferred food (Ewer 1973). Raccoons consume approximately .5 kg of food per day, 40% of which is animal matter (Table 7B.1). Of this amount, crustaceans comprise 15%, fish 5%, and voles 20% (Newell, Johnson, and Allen 1987; Ewer 1973). In addition to the food chain, raccoons can be exposed to contaminants through ingestion of water, incidental ingestion of leaf litter and soil, inhalation, and direct exposure (Figure 7B.4).

Voles, which are favorite prey of raccoons, are active during both day and night (Burt and Grossenheider 1964). They are usually found where there is good grass cover and feed on rasses, sedges, seeds, grain, bark, and other vegetation. Voles can be exposed to contaminants not only through the foods that they consume but also directly as they burrow through contaminated soil and vegetation.

Crayfish, which also comprise a major portion of the diet of raccoons, complete their life cycle within contaminated aquatic and floodplain environs and directly contact contaminated mud. They feed upon filamentous algae, vascular aquatics, animal matter, and detritus. Since organic residues frequently contain elevated levels of nutrients and contaminants, there is an increased potential for the presence of contaminants in the food web leading to the crayfish. Crayfish are important in the detrital trophic level because they ingest material that otherwise would be very slowly decomposed.

#### 7B.2.3.2 Toxicity assessment—raccoon

This section contains a brief synopsis of the documented or likely toxic effects of the selected contaminants on the same or similar species as those that comprise the elements of the food chain for the raccoon. A more complete literature review of these toxic effects on terrestrial species is presented in Appendix 7C.

Cadmium has a strong affinity for soft body tissues, especially kidney and liver, and there appears to be a positive relationship between concentrations of cadmium in the soil and in the soft tissues of small mammals. Mammals and birds seem relatively resistant to the biocidal properties of cadmium, but a review of its teratogenic, mutagenic, and carcinogenic effects is in Appendix 7C. Adverse effects on fish and wildlife are either pronounced or probable when cadmium concentrations exceed 3 ppb in freshwater, or 100 ppb in diet (Eisler 1986).

There are species differences in accumulation related to diet and trophic level. Of particular relevance to this exposure scenario is that whole body concentrations in Microtus

agrestis, an exclusive herbivore and representative of the voles used in this food chain, were less than those in the surrounding soil. Talmage and Walton (1990) reported that for the mouse and vole, concentration factors of kidney:soil or kidney:invertebrates were similar and ranged from 0.5 to 1.5. An exception occurred at a site where cadmium was deposited directly on the vegetation. Here concentration factors of kidney:soil and kidney:vegetation were 2.7 and 11.7, respectively, for the vole. In Wales, where voles from abandoned metalliferous mines had elevated cadmium levels in kidney and liver tissue, Johnson, Schreiber, and Burgess (1979) stated that the metal levels in herbaceous vegetation samples were indicative of dietary metal intake by voles.

Freshwater biota are most sensitive to cadmium; concentrations of 0.8 to 9.9 $\mu$g Cd/L (ppb) were lethal to several species of aquatic insects, crustaceans, and teleosts, and concentrations of 0.7 to 5.0 ppb were associated with sublethal effects such as decreased growth, inhibited reproduction, and population alterations (Eisler 1986).

Chromium is most often found in the environment in trivalent and hexavalent states, with hexavalent chromium being more toxic because it easily penetrates biological membranes. Under laboratory conditions, chromium is mutagenic, carcinogenic, and teratogenic to a wide variety of organisms (Eisler 1986). The significance of chromium residues is unclear, but available evidence suggests that organs and tissues of fish and wildlife that contain $>4$ mg total Cr/kg dry weight should be presumed to have chromium contamination.

Taylor and Parr (1978) found that concentrations of chromium in pelt, hair, and bone of cotton rats trapped near the cooling towers at Oak Ridge Gaseous Diffusion Plant were significantly higher ($P<0.01$) than concentrations in control animals. Chromium in pelt and hair resulted from direct deposition of drift or removal from plant materials during feeding or during movements along pathways. Chromium is an essential trace element to some mammalian species, and irreversible metabolic damage may result from long-term deficiency. Increased chromium levels may produce deleterious effects. However, cotton rats had a low assimilation rate (0.8%) and rapid initial loss of hexavalent chromium, suggesting that it is nonessential in this species.

In aquatic systems, chromium seldom exceeds 0.3 mg/kg fresh weight in edible crustacean tissues (Eisler 1981). The highest value reported was 0.6 mg Cr/kg fresh weight for rock crab collected near an ocean dump receiving large quantities of metals.

One of the principal effects of chromium contamination in aquatic systems is damage to shells. Massive cuticular lesions suggestive of shell disease characterized up to 30% of the lobsters, crabs, and shrimp collected from the New York Bight, where chromium concentrations greater than 100 ppm have been recorded.

Radionuclides are transferred through components of ecosystems and often accumulate in target tissues. Strontium-90, as an analog of calcium, is readily absorbed by bone tissue, and cesium-137 accumulates in soft tissue, especially kidney and liver. Although tritium also has the potential for marked uptake by terrestrial vegetation, and subsequently being incorporated into other trophic levels, it apparently does not bioaccumulate in the environment or in food chains (Shoup 1976). Cesium-137 is not expected to reach

appreciable concentrations in vegetation because of its low transfer coefficient from soil. However, it can be rapidly translocated through major plant components of a forest when injected into trees. In addition to uptake by vegetation, small mammals may be an important vector for radioactive transport because of their burrowing activity, mobility, and potentially high population numbers.

As part of the Biological Monitoring and Abatement Program, Loar et al. (1988) found that all field-collected mammals from SWSA 4 and the WOC floodplain had detectable levels of strontium-90 in bone tissue. Two pine voles (Microtus pinetorum) trapped at SWSA 4 had strontium-90 levels of 1450 Bq/kg and 31,810 Bq/kg, illustrating that this species is also capable of bioaccumulating this contaminant. In a study of consumption of radioactively labeled pine seeds by small mammals, Mathies et al. (1972) reported body burdens of cesium-137 in pine voles ranging from $5.89 \times 10^3$ to $13.37 \times 10^3$ dpm/g, indicating a significant uptake of radioisotopes.

Crayfish are a major component of the diet of raccoons, which ingest the soft tissues and digestive tract. Tanner (1964) found that crayfish from White Oak Creek had cobalt-60, ruthenium-106, and cesium-137 associated with their exoskeletons. Furthermore, Schurr and Stamper (1962) found that 90% of the strontium-85 found in crayfish was in the exoskeleton. Not only was 55-80% of the available strontium-85 retained in the body tissues after molting in young-of-the-year (Momot, Gowing, and Jones 1978), but uptake of strontium-85 was enhanced in recently molted crayfish (Schurr and Stamper 1962).

The volatile organic compounds selected for the WAG 6 environmental risk assessment are toluene, xylene, tetrachloroethylene, and trichloroethylene. Some characteristics of these compounds, their behavior in the environment, and known toxic effects based upon studies of humans and/or laboratory animals are presented in Appendix 7C. Information concerning their effects upon terrestrial species is essentially nonexistent; effects upon these organisms can only be assumed to be similar to those found in laboratory animals.

### 7B.2.3.3 Risk characterization—raccoon

The omnivorous raccoon has the potential for becoming contaminated through both aquatic and terrestrial food chains. Raccoons can attain body burdens of contaminants through the ingestion of contaminated vegetation and drinking contaminated water. Voles, which are a major component of their diet, are herbivorous and can also become contaminated by ingesting contaminated vegetation. Fish and crayfish are exposed to the contaminants in the surface water and sediments at WAG 6 and can bioaccumulate them, resulting in even higher body burdens in raccoons that prey upon them.

Of the metal contaminants selected for this terrestrial environmental evaluation, chromium did not exceed regulatory standards; however, cadmium levels in unfiltered surface water were 30 $\mu$g/L, compared to the regulatory standard of 5 $\mu$g/L (Table 7B.2). More stringent U.S. Fish and Wildlife Service guidelines suggest that adverse effects are likely when cadmium concentrations exceed 3 ppb in freshwater and 100 ppb in the diet. Using these values, the raccoon could be adversely affected by drinking water from WAG 6, as could its prey species. The aquatic prey species have the potential to be impacted by levels

of cadmium in surface water and sediments and serving as a pathway for contaminant transport to the raccoon.

Cadmium is apparently associated with the soil and is not taken up by vegetation, suggesting that the ingestion of vegetation by either the raccoon or its herbivorous prey, the vole, is not likely to result in contaminant body burdens. In fact, whole body concentrations of voles have been shown to be less than those in the surrounding soil. The greatest potential for adverse effects from cadmium to the soft tissues (liver and kidney) of the raccoon is through ingestion of surface water by the raccoon itself and by voles upon which it preys and from ingestion of contaminated aquatic organisms.

The significance of chromium residues in wildlife is unclear. Chromium levels at WAG 6 do not exceed regulatory standards; however, information is insufficient to determine whether chromium poses a risk to raccoons inhabiting WAG 6. In a study of cotton rats, Taylor and Parr (1978) found that this species had a low assimilation rate and rapid initial loss of hexavalent chromium, suggesting that it is nonessential. Whether chromium is an essential element to voles or raccoons (which would enhance its assimilation) is not known.

The ionizing effects of radiation can adversely affect wildlife at WAG 6, with strontium-90 posing the greatest risk of the three radionuclides selected for this environmental evaluation. The maximum concentration detected (10,222 pCi/L) greatly exceeds the regulatory standard of 8 pCi/L (Table 7B.2). Strontium-90 readily accumulates in bone tissue and can be expected to adversely affect the raccoon directly and through ingestion of voles with body burdens in bone tissue. Both strontium-90 and cesium-137 are known to accumulate in the exoskeletons of crayfish; however, raccoons consume the soft tissues and digestive tract of this species. Normal ingestion of crayfish should not provide a major pathway. The exception is that molting crayfish retain the majority of strontium-90 in their body tissues and, if ingested during molting, could contribute to increased radionuclide levels in raccoons. Another potential pathway that should be considered is the direct radiation exposure to the raccoon that encounters contaminated crayfish while consuming them and the direct exposure from discarded molted exoskeletons.

As discussed in Sect. 7B.2.3, information concerning the toxic effects of volatile organic compounds on terrestrial wildlife is essentially nonexistent. While some inferences may be possible from laboratory studies, a true assessment of their likely effects on WAG 6 cannot be ascertained. Because of their volatility from soils and surface water, however, they are not likely to pose a major risk.

## 7B.3 AQUATIC VERTEBRATES—FISH

Bluegill sunfish and fathead minnows were selected as representative species to assess the potential impact of contaminants from WAG 6 on aquatic vertebrates. This section presents the potential impact of six contaminants on the bluegill and fathead minnow: two metals—cadmium and copper, two volatile organics—xylene and toluene, and two radionuclides—cesium-137 and strontium-90. (The rationale for selecting these contaminants was discussed in Sect. 7.3.2 of the main report).

## 7B.3.1 Exposure Assessment—Aquatic Vertebrates

### 7B.3.1.1 Bluegill sunfish and fathead minnows

Bluegill sunfish and fathead minnows were selected as key species representing the fish communities because both are common in the WOC watershed and because there is substantial literature on the toxicity of contaminants for these two species. Although both species were introduced to WOC, they are native to other waters in Tennessee and have probably established reproducing populations in WOC. Bluegills feed on a wide variety of food sources, including algae and aquatic plants, but rely primarily on aquatic macroinvertebrates. Bluegills mature in their second year and spawn from spring through summer in nests on sand/gravel substrates. The male constructs the nest and guards the eggs and young. Fathead minnows feed on algae and aquatic insects, mature in their second year, and spawn throughout the spring and summer. The eggs are deposited on the underside of suspended objects or rocks, and males guard the nests. Bluegills and fathead minnows are common forage fish in southern waters, with bass species as the top predator.

**Characteristics of the contaminants.** Cadmium and copper are naturally occurring divalent elements that are relatively soluble in water and may be found in high concentrations in sediments. Copper is a required minor nutrient for both plants and animals. It is an essential element for enzyme activity and required for electron transport during oxidative phosphorylation. However, at concentrations over a few ppb it can be toxic to aquatic plants and animals. There is no evidence that cadmium is biologically essential or beneficial to living organisms. At sufficient concentrations, cadmium is toxic to all forms of life. Freshwater biota are generally more sensitive to the toxic effects of cadmium and copper than marine organisms and terrestrial life forms. The toxicity of copper and cadmium are related primarily to the activity of the divalent ion ($Cu^{+2}$ and $Cd^{+2}$) and possibly some metal hydroxy complexes.

In unpolluted freshwater systems, cadmium concentrations in water are reported to range from 0.05 to 0.2 ppb while copper concentrations are commonly in the 1 to 10 ppb range. Sediments in lakes and streams may contain a few thousand ppb of cadmium and copper (Eisler 1985). In areas where cadmium and copper are comparatively bioavailable, these metals can be chronically toxic to some fish and benthic macroinvertebrate species at concentrations slightly higher than the normal background ranges.

Toluene and xylene are main components in the scintillation fluids used in the radiological laboratories at ORNL. A large quantity of scintillation fluid, containing radioactive material, was buried in trenches at WAG 6. Toluene and xylene are moderately toxic in aquatic ecosystems in comparison to the more highly substituted benzene-type compounds. Their impact on surface water systems is limited because of their high volatility. In natural unpolluted waters, xylene and toluene may be present at low ppb concentrations. They are acutely toxic to fish at concentrations of about 10 mg/L (ppm) and up.

The radionuclides cesium-137 and strontium-90 are long-lived fission products. Strontium-90 is chemically similar to calcium and is metabolized by plants and animals as if it were calcium. Strontium-90 is transported in fresh water systems as a free ion or

exchangeable cation similar to many metals and is one of the more mobile radionuclides. In animals, strontium-90, like calcium, concentrates in bones and shells. Cesium-137 is chemically similar to potassium, and in animals concentrates in the soft tissues. Cesium-137 has a high affinity for clays, gravels, and organic material and migrates in surface water systems as particulates or bound to sediments. In contaminated environments they are a hazard because they accumulate in living organisms and become internal sources of ionizing radiation, as well as external sources of gamma radiation.

In uncontaminated freshwater ecosystems, stable strontium and cesium exist in low concentrations, generally less than one ppm for cesium and less than one-fourth ppm for strontium (Vanderploeg et al. 1975; Kolehmainen and Nelson 1969). Strontium in freshwater ecosystems is generally equally distributed among three components: water, biota, and sediments (Klechkovskii, Polikarpov, and Aleksakhin 1973). Cesium, on the other hand, is found primarily in bottom sediments and suspended particulates (Chittenden 1983; Klechkovskii, Polikarpov, and Aleksakhin 1973). Two or more groundwater seeps have been identified at SWSA 6 that are sources of strontium-90 to the tributaries draining the WAG 6 area (Cerling and Spalding 1981).

**Mode of uptake.** Fish will accumulate metals, radionuclides, and organic contaminants from their environment primarily by absorption of dissolved materials across gill membranes and by ingesting contaminated food and sediments. The relative importance of these two avenues of contaminant uptake is sometimes in question (Dallinger et al. 1987). However, experiments comparing uptake of metals, radionuclides, and monocyclic aromatics via food versus direct uptake from water indicate that direct uptake is usually the principal route (Berry and Fisher 1979; Polikarpov 1966; Hatakeyama and Yasuno 1987). Uptake of cesium-137 by fish and macroinvertebrates, however, is primarily via the food chain (Kolehmainen 1972; Preston, Jefferies, and Dutton 1967). Because of the importance of direct uptake from water, the toxicity of contaminants in surface water ecosystems is usually based on the concentration of the contaminant in the water column, rather than estimating the contaminant concentration in food and then estimating the rate of food uptake. Acute and chronic toxicity values, therefore, are expressed as the lethal or harmful concentrations of the contaminant in water.

**Factors affecting transport and bioavailability.** Field investigations and laboratory experiments have shown that numerous factors can affect the transport and eventual fate of metals, simple aromatic compounds, and radionuclides in freshwater ecosystems. These factors are summarized in the following section and presented in greater detail in Appendix 7D.

The mobility and toxicity of cadmium, copper, strontium-90, and cesium-137 are related primarily to the amount of the free metal ions in the water, and possibly some hydroxy or other bioavailable complexes. Therefore, factors that reduce the proportion of free ions and exchangeable cations of these elements reduces the mobility, and generally the toxicity, of these metals and radionuclides. The toxicity of metals is also influenced by water hardness, humic acid, and total organic carbon. Alkalinity, temperature, and pH may also influence the toxicity of cadmium and copper and the bioavailability of strontium-90. The

bioavailibility of cesium-137 and strontium-90 from water by living organisms is also closely linked to the concentrations of their nonisotopic carriers, potassium and calcium.

Xylene and toluene are among the more toxic components in the water soluble fraction of refined petroleum products; however, these low molecular weight hydrocarbons volatilize relatively quickly in surface water systems.

**Sensitive populations.** Different life stages of fish exhibit different sensitivity to various contaminants. This information is summarized in this section and presented in more detail in Appendix 7D. The scientific literature indicates that for bluegills and fathead minnows the most sensitive life stage to metal and organic contaminants is the early larvae. The embryo and adult fish are generally the most tolerant (Benoit 1975; McKim 1977; Eaton, McKim, and Holcombe 1978; Fisher, Dilego, and Paulos 1984; Devlin, Brammer, and Puyear 1982). This is true for cadmium and copper and the simple monocyclic aromatics.

Fish are apparently capable of metabolizing toluene and xylene in the liver, storing metabolites in the gall bladder, and excreting these substances via the gut (Berry 1980; Berry and Fisher 1979). Aquatic organisms with the ability to metabolize the aromatic hydrocarbons and produce nontoxic metabolites would be less vulnerable to the toxic effects of these organic compounds.

There is very little information in the scientific literature concerning the relative sensitivities of different biotic subpopulations (such as life stage or size) to the harmful effects of radiation. Generally, simpler forms of life such as bacteria and algae are more resistant than the more complex plants and animals. Bacteria are especially resistant to ionizing radiation (Klechkovskii, Polikarpov, and Aleksakhin 1973). King (1964) stated that humans are at least twice as sensitive as fish to roentgen dosages.

Several investigators have studied the effect of radionuclides on fish eggs. They presented the effects of radiation on fish embryos, but the data on sensitivities of fish eggs relative to other life stages or fish species are very variable (Klechkovskii, Polikarpov, and Aleksakhin 1973). Kolehmainen (1972) found that the concentration of cesium-137 in bluegills in WOL increased with size up to 70g, apparently because assimilation of the radionuclide from food increased and elimination decreased with size. Thus, older fish would be more at risk because of higher body burdens as well as longer exposure. Fish species with shorter life cycles and higher reproductive potential are less susceptible to the harmful effects of radiation because of shorter exposure and the ability to cope with reduced fertility and/or fecundity (Krumholtz 1954).

### 7B.3.2 Toxicity Assessment—Aquatic Vertebrates

The toxicity assessment for fish is based upon a literature review of the effects of the selected contaminants upon the target species or similar species. This section contains a brief summary of the documented or likely toxic effects upon bluegills and fathead minnows. A more complete literature review of these toxic effects upon aquatic species is presented in Appendix 7D.

### 7B.3.2.1 Mode of action

Elevated concentrations of cadmium, copper, toluene, and xylene can affect fish through various mechanisms. In some cases, the specific biochemical or physiological process is known, and in other cases, the observable reaction by the fish may be measured, such as a change in ventilatory activity, but the specific mechanism or cause is unknown.

Toluene and xylene, like many organic chemicals used in industry, produce a nonspecific narcosis effect on fish. Narcosis is a reversible condition up to a point, but prolonged exposure may cause death (Veith, Call, and Brooke 1983; Broderius and Kahl 1985). Exposure to aromatic hydrocarbons such as toluene during the embryo stage was observed to cause developmental abnormalities and premature hatching.

Heavy metals such as cadmium and copper can affect behavior, may interfere with or inhibit biochemical processes, can cause structural damage to tissues, and have teratogenic effects. Chronic exposure to cadmium and copper can produce changes in behavior and ventilatory activity at concentrations well below those causing death (Bishop and McIntosh 1981; Diamond, Parson, and Gruber 1990; Ellgaard and Guillot 1988; Ellgaard, Tusa, and Malizia 1978).

The selected radionuclides at WAG 6, cesium-137 and strontium-90, are potentially harmful to fish because they bioconcentrate in internal tissues and may become significant internal sources of ionizing radiation. Therefore, the mode of action is the same as the effect of radiation on humans. At high dosages, usually from external sources, radionuclides can cause acute mortality. King (1964) and Foster et al. (1949, cited by Krumholtz 1954) observed fish mortalities at exposures of 1000 to 3000 roentgens. However, the effect of radionuclides in most cases, including the impact of cesium-137 and strontium-90 at ORNL, is more chronic. The effect of specific radionuclides, however, is impossible to measure in natural environments because the radiation from multiple radionuclides, both external and internal, is cumulative to some extent.

### 7B.3.2.2 Toxicity of contaminants

Several different toxicity values are presented to assess the toxicity of the selected contaminants to freshwater fishes. These include the EPA ambient water quality criteria for the protection of aquatic life, acute toxicity values from several studies, and various measures of chronic toxicity. Acute toxicity is most frequently expressed as the concentration of a contaminant that will be lethal to 50% of the test population within a given time period, such as 96 hours (96 hour $LC_{50}$). Some of the more standard expressions of chronic toxicity include the highest concentration of a contaminant that results in no observable effect (the NOEL), and the lowest concentration of a contaminant that produces a significant difference between test and control populations (the LOEL). These two values theoretically bracket the "safe" concentration for that contaminant. The term "chronic" usually implies long duration, low severity, and high sensitivity, and is measured in numerous ways. Therefore, chronic toxicity is usually expressed as the concentration that produces some measurable response (e.g., decreased growth) over a defined exposure period. The harmful effect of radionuclides is expressed as a radiation dose.

**Ambient water quality criteria.** EPA (1986) has established acute and chronic ambient water quality criteria for cadmium and copper and acute criteria for benzene and toluene. Freshwater organisms (both fish and macroinvertebrates) and their habitat should not be affected unacceptably if the acute (Criterion Maximum Concentration, a 1-hour average) and chronic (Criterion Continuous Concentration, a 4-day average) criteria are not exceeded more than once every 3 years. Table 7B.3 presents these criteria.

**Acute and chronic toxicity of cadmium.** Some acute toxicity values for cadmium to bluegills and fathead minnows are given in Table 7B.4. All values are for 96-hour $LC_{50}$s. Eisler (1985), Mance (1987), Suter, Vaughan, and Gardner (1983), and other investigators present $LC_{50}$s and $LC_{10}$s for time periods of 24 hours to a month or more. Note that an increase in hardness can change the $LC_{50}$ by an order of magnitude or more. The lowest acute toxicity value was 13.2 $\mu$g/L, for the larval life stage of fathead minnows in soft water (Spehar and Fiandt 1986). Generally, concentrations acutely toxic to bluegills and fathead minnows ranged between 340 and 21,100 $\mu$g/L and varied with life stage, water hardness, and other variables.

The concentrations of cadmium that are chronically toxic to bluegills and fathead minnows are shown in Table 7B.5. Fathead minnows may be slightly more sensitive to cadmium than bluegills, with chronic toxicity values between 57-110 $\mu$g/L. However, cadmium at 5 $\mu$g/L produced lethal effects when mixed with five other metals in experiments by Spehar and Fiandt (1986) (Table 7B.5). Concentrations chronically toxic to bluegills generally ranged between 50 and 250 $\mu$g/L, but concentrations as low as 4 $\mu$g/L induced changes in ventilatory response (Diamond, Parson, and Gruber 1990). The larval stage is probably the most sensitive to metal contaminants. For larval fathead minnows, the NOEL and LOEL are 37 and 57 $\mu$g/L, respectively (Pickering and Gast 1972). For bluegills the NOEL and LOEL were reported by Eaton (1974) as 31 and 80 $\mu$g/L.

**Acute and chronic toxicity of copper.** Copper concentrations that are acutely toxic to bluegills and fathead minnows are shown in Table 7B.6. As with cadmium, fathead minnows may be slightly more sensitive to copper than bluegills. Copper concentrations causing 50 percent mortality over a 96-hour exposure period ranged between 75 and 1,000 $\mu$g/L for fathead minnows and between 740 to over 4,000 $\mu$g/L for bluegills. Copper was more toxic in soft water, and the larvae of both species are more sensitive than the adults. Copper concentrations as low as 18.4 $\mu$g/L were reported to be chronically toxic to fathead minnow larvae in soft water (Mount and Stephan 1969); concentrations as low as 40 $\mu$g/L reduced growth and survival in bluegills (Table 7B.7). The NOEL and LOEL for copper for juvenile bluegills were reported as 21 and 40 $\mu$g/L by Benoit (1975), and for fathead minnow larvae as 31 and 80 $\mu$g/L by Pickering, Brungs, and Gast (1977). Mount and Stephan (1969) reported NOEL and LOEL values for fathead minnow fry of 10.6 and 18.4 $\mu$g/L.

**Acute and chronic toxicity of benzene, toluene, and xylene.** Toxicity tests by several investigators using fathead minnows and bluegills indicate that concentrations of toluene and benzene between 13 and 42 mg/L are acutely toxic to larval and juvenile fish (Table 7B.8). Concentrations between 57 and 72 mg/L were acutely toxic to fathead minnow embryos. Devlin et al. (1982) and Moles, Rice, and Korn (1979) found that the embryo life stage was relatively tolerant to the monocyclic aromatics, while early larvae were more sensitive. The

more highly substituted benzenes are more toxic than toluene and xylene. The potencies of the chlorinated toluenes correlated closely with log octanal/water partition coefficients, and the toxicities of substituted benzenes can be predicted based on Quantitative Structure Activity Relationships (QSAR) (Babich and Barenfreund 1987; Hall, Maynard, and Kier 1989).

Data on chronic toxicity of benzene, toluene, and xylene are limited, probably reflecting the high volatility of these low molecular weight aromatics. In shallow freshwater systems, toluene and xylene would be reduced significantly within 2 or 3 days as they evaporate into the atmosphere. Chronic toxicities for toluene and benzene between 5 and 45 mg/L (Table 7B.8) have been reported by Devlin et al. (1982), Berry (1980), and Fisher, Dilego, and Paulos (1984). Jori et al. (1986) proposed a provisional water quality criterion of 0.02 mg/L for xylenes as a "safe level" for aquatic organisms in light of the limited chronic toxicity data in the literature.

**Harmful effects of cesium-137 and strontium-90.** To estimate the effect of radiation on aquatic organisms at WAG 6, at least six pieces of information are needed. These include: 1) the concentration of each radionuclide in the water, 2) the capacity of the organisms to concentrate the respective radionuclides, 3) the types of radiation emitted by each radionuclide, 4) the tissues where the radionuclides will accumulate, 5) the body geometry of the receptors, and 6) the additive effect of the different radionuclides. The harmful effect of radiation results from all radiation sources present, both internal and external. Therefore, the estimation of dose can be very complex, and it is almost impossible to isolate the effect of a single radionuclide when several are present. Additionally, most studies on aquatic organisms have been concerned with the potential impacts on humans rather on the fish or other aquatic organisms, so there are very few data on what radiation doses are harmful to the fish themselves. Relevant studies on the effects of radiation on fish are summarized in this section and reported in more detail in Appendix 7D.

Radiation dosages in the range of 100 to several thousand roentgens are known to produce harmful effects in fish, ranging from reduced growth to abnormal development of ova to death at the highest dosages (King 1964; Krumholz 1954). However, Krumholz and others have indicated that it is impossible to determine the significance of one or a few radionuclides in light of all the radiological and non-radiological contaminants in the WOC ecosystem (Krumholz 1954; Kolehmainen and Nelson 1969; Kolehmainen 1972).

The body burdens of cesium-137 in bluegills and carp from WOL (20 to 63 pCi/g fresh weight) reported by Kolehmainen and Nelson (1969) and Edwards (1986) are in the same range or higher than the body burdens reported in brown trout and perch in Scotland and Finland (Preston, Jefferies, and Dutton 1967). The latter found some of the highest body burdens occurred in Finnish lakes (26.8 pCi/g) because the low mineral content of these lakes (low Ca and K) were conducive to high cesium bioconcentration factors. Although cesium-137 bioconcentration factors may be high (the ratio of cesium concentrations in fish tissue vs the concentrations in water), most investigations agree that the bioaccumulation of cesium-137 through the food chain (that is, between successive trophic levels) is not very significant.

Klechkovskii, Polikarpov, and Aleksakhin (1973) reported that strontium-90 levels of $10^{-4}$ Ci/L caused some increase in morphological deformities in pike eggs and disrupted

development of mollusc embryos. Edwards (1986) reported strontium-90 concentrations of 46 to 240 pCi/g wet weight in carp from WOL, in sharp contrast to concentrations of 0.001 to 0.11 pCi/g observed in brown trout in several rivers in England by Preston, Jefferies, and Dutton (1967). Strontium-90 can be especially harmful because it concentrates in bone tissue where replacement is slow.

### 7B.3.3 Risk Characterization—Aquatic Vertebrates

Fish populations in the EWB or tributaries draining WAG 6 could potentially be impacted by metals, organics, and radionuclides that are leaching from underground disposal areas at WAG 6. Of the six selected contaminants addressed in this assessment, cadmium, copper, and strontium-90 would be of the most concern because of prevailing concentrations reported in the WAG 6 tributaries and the scientific literature that indicates these contaminants can cause chronic effects at relatively low part per billion concentrations. Cadmium and copper are reported to cause chronic effects at the 40 to 80 $\mu$g/L level or lower (for example, a LOEL of 18.4 $\mu$g/L for copper to fathead minnow fry), and the ambient water quality criteria for these two metals for protection of aquatic organisms are around 1.5 and 15 $\mu$g/L, respectively (assuming a water hardness of 150 mg/L as $CaCO_3$). Strontium-90 is a concern because two or more seeps at WAG 6 have been reported to contain strontium-90, concentrations of strontium-90 in WOL fish are elevated, and strontium-90 concentrates in bone tissue where the biological half-life may be long. Toluene and xylene potentially do not pose as great a hazard because concentrations causing chronic effects in fish are in the ppm rather than ppb range, and these organics will volatilize from the shallow surface waters at WAG 6 quickly. Cesium-137 could be potentially hazardous, but no significant levels of cesium-137 have been reported in WAG 6 tributaries recently.

## 7B.4 AQUATIC INVERTEBRATES—INSECTS, CRUSTACEANS, WORMS

Benthic macroinvertebrates are the most frequently sampled group of organisms for assessing the biological effects of pollutant discharges in aquatic ecosystems. Additionally, there is a substantial volume of literature on the toxic effects of metals and some organic compounds to invertebrates. This section addresses the potential impacts of the six selected contaminants on several indigenous aquatic species in the WOC watershed.

### 7B.4.1 Exposure Assessment—Aquatic Invertebrates

Because of their abundance, relatively sedentary nature, close association with bottom substrates, and life spans of a few weeks to a year or more, benthic macroinvertebrates are good integrators of contaminant releases into aquatic ecosystems. These benthic communities are also relatively easy to sample and quantify and represent a wide range of trophic relationships. Aquatic macroinvertebrates feed on plants, bacteria, organic detritus, and other invertebrates. They range from active predators to grazers to net spinners. (Benthic macroinvertebrates, in turn, are a major food component for many fish.) For assessing potential toxicity of contaminants at WAG 6, four orders of aquatic insects were emphasized: mayflies (Ephemeroptera), caddisflies (Trichoptera), stoneflies (Plecoptera), and true flies (Diptera). These aquatic insects molt through several larval forms (instars) until the terrestrial adult form emerges. The aquatic stages of the life cycle range from a few weeks

to a year or more, while the adult terrestrial stage usually lasts for a few days to a month. Many species of Diptera are more tolerant of organic pollution and toxic contaminants than the Ephemeroptera - Plecoptera - Trichoptera (EPT) complex. Two Crustacea, isopods and amphipods (Gammaridae), and aquatic worms (Oligochaeta) were also emphasized because of their relative abundance in tributaries at WAG 6. The crustaceans are relatively sensitive to metal and organic contaminants, whereas many oligochaetes are relatively resistant.

### 7B.4.1.1 Characteristics of the contaminants

The physical and chemical characteristics of the contaminants of concern have been outlined in Sect. 7B.3.1. In summary, both cadmium and copper are toxic to aquatic plants and animals at ppb concentrations. Xylene and toluene are toxic in the ppm range, but concentrations in shallow surface waters are typically low due to their high volatilities. The two radionuclides cesium-137 and strontium-90 are chemically similar to potassium and calcium, respectively. They are hazardous to living organisms because they emit ionizing radiation. These radionuclides can bioaccumulate in aquatic organisms since they are metabolized like potassium and calcium, and then become internal sources of ionizing radiation.

### 7B.4.1.2 Mode of uptake

Like fish, aquatic invertebrates may be exposed to contaminants from their environment by several different routes including ingestion of contaminated sediments and food and absorption of dissolved contaminants across respiratory surfaces. Additionally, contaminants may be absorbed through the integument, especially during molting and emergence. Finally, contaminants, particularly metals and strontium-90, may be accumulated by adsorption to the body wall or exoskeleton. Adsorbed metals may not be toxic to the organism itself, but the route has important implications because of the potential for bioaccumulation via the food chain. Radionuclides adsorbed to the exoskeleton may represent a hazardous radiation source. The principal mode of uptake by macroinvertebrates for the selected contaminants is direct uptake from water across the gills and integument, with the exception of cesium-137 which is taken up by eating contaminated food and sediments (Kolehmainen 1972; Vanderploeg et al. 1975).

### 7B.4.1.3 Factors affecting transport and bioavailability

The fate and transport of metals, aromatic hydrocarbons, and radionuclides is influenced by several controlling factors which ultimately affect their respective toxicities to aquatic macroinvertebrates. These factors include water hardness, pH, total organic or humic acid concentrations, calcium and potassium concentrations (for strontium-90 and cesium-137), adsorption/desorption, and biodegradation. A more detailed discussion of these factors is provided in Appendix 7D.

In addition to the physical and chemical factors of the transporting medium (e.g., water or sediment), biological parameters such as the presence of metal-binding proteins also influence bioavailability and toxicity. Metallothioneins are present in a wide variety of organisms, from yeasts to mammals, but were only recently confirmed in freshwater

invertebrates by Everard and Swain (1983). Metallothioneins bind selectively to Group II metals, particularly cadmium and zinc, allowing organisms to store metals in a nontoxic form.

### 7B.4.1.4 Sensitive populations

The relative intraspecfic susceptibility of aquatic macroinvertebrates to the toxic effects of contaminants depends upon the organism's lifestage or body size. In general, smaller organisms are more sensitive to metals and monocyclic aromatics than larger ones, and early instars are more sensitive than older instars. The difference in sensitivity of early and late instars can be significant (Williams et al. 1986; Gauss et al. 1985; McCahon, Whiles, and Pascoe 1989). Scott and Guthrie (1972) presented data showing that the first instar of mosquito larvae accumulated more radiophosphorus than later instars, while the fourth instar concentrated more cesium-137, strontium-90, and yttrium-90 than the earlier instars. Thus, the total radiation dose may be related to the biological processes ongoing in different instars as well as the radionuclide concentration in the water. Also, exposure duration is a major factor with respect to all radiation sources, so the length of the life stage must be considered.

Microhabitat may also be an important factor influencing the sensitivity of benthic macroinvertebrates to contaminants. McCahon, Whiles, and Pascoe (1989) reported that cased caddisflies, Agapetus fuscipes, were more vulnerable to cadmium as they grew and left their cases to build bigger ones. Cased and uncased larvae would also differ in their vulnerability to external radiation sources.

Interspecific susceptibility of benthic macroinvertebrates to organic and metal contamination has been described by several investigators. In flowing streams and rivers the macroinvertebrate community structure frequently exhibits a predictable graded response to point source pollution. The transition of dominant groups from unimpacted to impacted to recovery zones corresponds closely with the relative tolerance of different taxonomic groups to the metal or organic contaminants. A more detailed discussion is presented in Appendix 7D.

There is very little information on susceptibility of different species of benthic macroinvertebrates to radionuclides. King (1964) reported that Daphnia pulex bioconcentrated more cesium-137 than D. magna, apparently due to different capabilities to assimilate this radionuclide from the tagged food source, Chlamydomonas. However, both species may be equally sensitive to the effects of ionizing radiation itself. In general, the less complex benthic organisms and those with short life cycles are more resistant to ionizing radiation.

### 7B.4.2 Toxicity Assessment—Aquatic Invertebrates

The toxicity assessment for aquatic invertebrates is based upon a literature review of the effects of the selected contaminants upon target species or similar species. This section contains a brief summary of the documentated or likely toxic effects upon benthic macroinvertebrates. A more complete review of these toxic effects upon aquatic species is presented in Appendix 7D.

### 7B.4.2.1 Mode of action

As with fish, elevated concentrations of metals, organics, and radionuclides can cause both direct and indirect effects on aquatic macroinvertebrates. Exposure to these contaminants may adversely affect biochemical and physiological processes. Since numerous metabolic (biochemical) processes are the same in fish and invertebrates, the cellular level effects of toxicants are frequently the same. For example, the inhabitation of oxidative phosphorylation by high copper levels is common to many types of living organisms. In many cases, the toxicological endpoint, such as behavior or decreased growth, has been described for invertebrates, but the actual cause of toxicity at the cellular level is unknown.

Copper is generally more toxic than cadmium to freshwater macroinvertebrates (Khangarot and Ray 1989). Acute and chronic effects of copper exposure to aquatic insect larvae include reproductive effects such as teratogenicity (Kosalwat and Knight 1987b) and reduced larval growth (Hatakeyama 1989).

The chronic or sublethal effects of cadmium on freshwater invertebrates have been studied by numerous investigators and include reductions in percent emergence, abnormal behavior, reduced ability to construct cases (by caddisflies), and various effects on reproduction (Hatakeyama and Yasuno 1987; Gerhart 1990; Spehar, Anderson, and Fiandt 1978; McCahon, Whiles, and Pascoe 1989; Williams et al. 1987).

Extensive data concerning the mode of action and general toxicities for xylene and toluene to macroinvertebrates were not encountered; however, some information is available. The total mode of action of xylene is not completely understood, but increased cellular permeability has been noted by Berry et al. [1978, as cited in Jori et al. (1986)]. Simpson [1980, as cited in Woodward and Riley (1983)] reported that Plecoptera and Trichoptera exposed to oil (xylene and toluene are major constituents) resulted in abnormalities in tracheal gills, which probably resulted in respiratory interference.

Exposure of aquatic macroinvertebrates to radiation sources has been reported to cause genetic anomalies, chromosomal aberrations, development abnormalities, depressed reproduction, decreased swimming activity, and sterilization (Klechkovshkii, Polikarpov, and Aleksakhin 1973; King 1964; Scott and Guthrie 1972). The specific mode of action of ionizing radiation in aquatic macroinvertebrates is the same effect that radiation has on all living organisms.

### 7B.4.2.2 Toxicity of contaminants

In the following discussion, the toxicity of copper, cadmium, xylene, toluene, cesium-137, and strontium-90 to freshwater invertebrates is assessed based on the ambient water quality criteria and the acute and chronic toxicity values reported in the literature. Acute toxicity is most frequently expressed as the 96-hour $LC_{50}$. Chronic toxicity values for freshwater invertebrates are not reported in terms of the NOEL and LOEL as much as for fish, probably because of the shorter life spans and more numerous lifestages. The lowest observable end points may be changes in growth, egg production, emergence success, behavior, mortality, or other measurable signs of stress.

**Ambient water quality criteria.** Ambient water quality criteria for cadmium, copper, benzene, and toluene are depicted in Table 7B.3 and discussed in Appendix 7D. Criteria for xylene, cesium-137, and strontium-90 are not available.

**Acute and chronic toxicity of cadmium.** The acute toxicity values for cadmium are given in Table 7B.9. Values are for 96-hour $LC_{50}$ where possible to avoid the confusion of comparing different duration tests. Eisler (1985), Mance (1987), Williams et al. (1986) and others present $LC_{50}$ values for test durations between 24 hours and a month or more. The stoneflies (Plecoptera) and caddisflies (Trichoptera) are among the more tolerant groups of invertebrates. The cladocerans, freshwater shrimp, and crustaceans such as *Asellus aquaticus* are the least tolerant, with $LC_{50}$s frequently less than 1 mg/L. Mayflies and midges (Chironomidae) both exhibit a wide range of sensitivities among the species within these groups (Table 7B.9). The sensitivities of the different life stages of the Crustacea reflect the higher tolerance of the embryos and adults seen in many benthic invertebrates.

The chronic or sublethal effects of cadmium on freshwater invertebrates have been studied by numerous investigators and include reductions in percent emergence, abnormal behavior, reduced ability to construct cases (by caddisflies), and various effects on reproduction (Table 7B.10). Although the 96-hour $LC_{50}$ for the fourth instar of the midge larvae, Polypedilum nubifer, was 372 mg/L, reproductive impairment was observed at concentrations as low as 0.02 mg/L. Sublethal exposures in the range of 46 to 186 mg/L reduced case building activities in the caddisfly Agapetus fuscipes, and at the highest end of this range the strength of the cases deteriorated. The net spinning capabilities of another caddisfly, Hydropsyche angustipennis, were reduced by cadmium concentrations as low as 0.3 mg/L (Table 7B.10).

In summary, the Plecoptera and Trichoptera are generally tolerant of cadmium concentrations below 10 mg/L, and older larva of chironomids may be nearly as tolerant (Table 7B.10). Cadmium concentrations less than 1 mg/L may have chronic effects on other invertebrate groups such as mayflies, some species of chironomids, cladocerans, and snails. The emergence of some species of mayflies, Leptophlebia marginata and Baetis rhodani, and midge larvae, Polypedilum nubifer and Chironomus yoshimatsui, may be adversely affected by cadmium concentrations between 0.02 and 0.2 mg/L. Within the literature reviewed, the lowest concentration of cadmium reported to affect aquatic invertebrates was 3 $\mu$g/L, which represented an $LC_{50}$ for a mayfly, Ephemerella sp., over a 28-day exposure period.

**Acute and chronic toxicity of copper.** As with cadmium, the range of acute and chronic toxicities of copper is broad for aquatic macroinvertebrates as depicted in Tables 7B.11 and 7B.12. Acute 96-hour toxicities range from 16.7 $\mu$g/L for the first instar of the chironomid Chironomus tentans to 8300 $\mu$g/L for the Plecopteran Acroneria lycorlas under similar water hardness conditions. The range of acute toxicities within the midge family Chironomidae (16.7 to 1690 $\mu$g/L) is as broad as the range of toxicities among the different types of aquatic invertebrates presented in Table 7C.9. Similar to cadmium, the stoneflies and caddisflies are relatively tolerant of copper. The different sensitivities of the four instars of Chironomus tentans illustrates that the youngest larval stage is the most sensitive. This has also been observed in other insect larvae.

Copper is chronically toxic to mayflies and midges at concentrations between 10 and 25 $\mu$g/L (Table 7B.12). Midge larvae in the taxonomic tribe Tanytarsiini represent some of the more sensitive groups. Caddisflies and stoneflies are very tolerant of copper, especially the older instars. Exposure to copper via ingestion of food is apparently less detrimental and may be insignificant in comparison to exposure to copper in water (Kosalwat and Knight 1987a).

**Acute and chronic exposure to benzene, toluene, and xylene.** Data regarding the acute and chronic toxicities of organic compounds to aquatic invertebrates are limited (Table 7B.13). Benville and Korn (1977) reported acute 96-hour $LC_{50}$s for bay shrimp as 20 and 4.3 $\mu$g/L for benzene and toluene, respectively. $LC_{50}$s for xylenes were broken down into their meta, ortho, and para isomers; these values were 3.7, 1.3, and 2.0 $\mu$g/L, respectively. Twenty-four hour $LC_{50}$s for xylene were reported by Jori et al. (1986) who reviewed the work of several investigators. The 24-hour $LC_{50}$ for Daphnia magna was between 100 and 1000 mg/L (Dowden and Bennett 1965, as cited in Jori 1986). Mosquito larvae, Aedes aegipti, appear to be more sensitive with a reported 24-hour $LC_{50}$ of 14 mg/L (Berry and Brammer 1977, as cited in Jori 1986). Woodward and Riley (1983) studied changes in macroinvertebrate populations downstream of oil field discharges and stated that oil-in-water concentrations above 24 $\mu$g/L were biologically unsuitable. They noted that Plecoptera and Trichoptera were nearly eliminated by oil field contaminants, while one species of mayfly and two species of Diptera became relatively dominant at stations downgradient of the discharge area. Other investigators have also noted the sensitivity of Trichoptera and Plecoptera to oil contaminants (Snow and Rosenberg 1975 and Simpson 1980, as cited by Woodward and Riley 1983).

**Harmful effects of cesium-137 and strontium-90.** There is very little information regarding the harmful effects of cesium-137 and strontium-90 on aquatic organisms. King (1964) reviewed available literature and found a few estimates of roentgen dosages harmful to aquatic organisms, and reported $LD_{50}$ values for crustaceans and fish ranged from 500 to 90,000r and 600 to 3,000r, respectively. A radiation dosage of 70r/hour reduced swimming activity in the cladoceran Daphnia magna within 16 days, and an accumulated dose of 10,500r caused permanent sterility (King 1964). Sterility in the adult mosquito was apparently caused by lower levels; Guthrie and Brust (1971, cited by Scott and Guthrie 1972) estimated that mosquitos were sterilized by a total beta radiation of about 90 rad from the media in which they were reared. Depressed reproduction was observed in D. magna populations exposed to $10^{-5}$ Ci/L radiation for 80 days, and slightly higher levels of strontium-90 + yttrium-90 ($10^{-4}$ to $10^{-3}$ Ci/L) disrupted development in molluscs (Klechkovskii, Polikarpov, and Aleksakhin 1973). A search of available literature did not produce any radiological effect levels for stoneflies, caddisflies, mayflies, or chironomids.

Aquatic macroinvertebrates are less susceptible to cesium-137 and strontium-90 than fish because of their shorter life cycle and other aspects of their life history and morphology. The exoskeleton of most macroinvertebrates, except molluscs, has a low mineral content and, therefore, does not accumulate strontium-90 as much as fish bone and scales. Also, more than 50% of the radioactivity in macroinvertebrate larvae may by lost during molting and emergence, and considerable radioactivity may also be lost by elimination (Wilhm 1970; Harvey 1971). Since up to half of the body burden of radioactive material is lost at each

molting, the total accumulation of both adsorbed and absorbed radionuclides over the entire life cycle is significantly reduced. Also, the harmful effects of radiation on a single generation can be offset by the high reproductive potential of many aquatic macroinvertebrates.

### 7B.4.3 Risk Characterization—Aquatic Invertebrates

Aquatic macroinvertebrate populations in surface waters at WAG 6 could potentially be impacted by metals, organics, and radionuclides that are leaching from underground disposal areas. Of the six selected contaminants addressed in this assessment, cadmium and copper are most likely to impact the macroinvertebrate communities. Both cadmium and copper are acutely toxic to a few species of mayflies and chironomids at concentrations near or below 1 mg/L, and are acutely toxic to some cladocerans, crustaceans, and snails at concentrations below 1 mg/L. These two metals produce chronic effects at concentrations ranging from around 0.01 mg/L up to 30-32 mg/L and higher. Stoneflies and caddisflies are relatively resistant to cadmium and copper in comparison to other macroinvertebrate groups, but chronic toxicity occurs in the 1 to 100 mg/L range for many species.

## 7B.5 LIMITATIONS OF ANALYSIS

The primary limitation of the environmental risk analysis for WAG 6 is the lack of site-specific and contaminant-effects data. The reasons for the lack of site-specific data are documented in this summary section. There are few contaminant-effects data because the concentrations are sufficiently low that obvious, visible effects would not be expected, and it is extremely difficult to describe an anomaly between a contaminated area and a reference area.

The lack of specific quantifiable data resulted in a reliance on data found in the literature and data derived from studies on laboratory animals or agricultural crop species. The problems associated with making inferences from laboratory studies to the natural world, (specifically WAG 6), are numerous:

- Toxicity in a natural setting is independent of a dosing schedule. An organism in nature is exposed continuously throughout the daily eating period and not in a single oral dose, as is typical in a laboratory (IT Corp. 1990).

- Feed consumption by organisms in the natural world will vary with body weight, ambient temperature, disease conditions, type of feed, and a number of other natural conditions (i.e., hibernation, growth, location, and reproduction). In a laboratory setting, an average daily food intake, which assumes no variation, is used for all calculations.

- Endemic fauna are assumed to have unlimited access to a constant quantity of water and, therefore, constant daily uptake. Water consumption is usually more variable than food consumption. Factors such as ambient temperature and access to watering holes play a major role in determining the quantity of consumption in wild species.

- The influence of water quality on toxicity and/or bioavailability of contaminants is important. Since the water quality of WAG 6 is different from other laboratory and field studies, and variable through time, there is uncertainty in determining real on-site toxicity.

- In nature, there are mixtures of metals, organics, and radionuclides that constantly change through space and time. Data from laboratory studies usually reflect a single contaminant.

- There are wide variations in toxicity among different species, even closely related species. The toxicological literature available (primarily for invertebrates) is frequently about species not present at WAG 6. Therefore, there are uncertainties when the toxicity of species A from the literature is used to estimate impacts on species B at WAG 6.

- There are very limited data available to translate toxicity effects on individuals or populations to higher ecological levels, such as communities and ecosystems. For example, a 30% mortality in a population of short-lived invertebrates may have no real effect on an ecosystem because of the high reproductive capacity of that species; however, a 30% mortality in another population could impact the ecosystem.

# Appendix 7B Tables

Table 7B.1. Estimated diets for selected target species

| Species | Avg. Body Weight kg | Water mL/day | Soil g/day | Inhalation L/air/day | Arthropods Earthworms g/day | Vegetation g/day | Mammalian prey g/day | Aquatic prey g/day |
|---|---|---|---|---|---|---|---|---|
| Red-tailed hawk | 0.75 | 45 | -- | 360 | -- | -- | 112 | -- |
| White-tailed deer | 50 | 3000 | 5 | 22,454 | -- | 3500 | -- | -- |
| Eastern cottontail | 1.45 | 210 | 0.145 | 470 | -- | 87 | -- | -- |
| Shorttail shrew | 0.02 | 3.2 | 0.002 | 10 | 22 | -- | -- | -- |
| Raccoon | 10 | -- | -- | -- | -- | 300 | 100 | 100 |

Table 7B.2. Comparision of contaminant levels to regulatory standards and background

| Contaminant | Units | Maximum | Minimum | Mean | No. of hits | Std./ref.[a] | Background |
|---|---|---|---|---|---|---|---|
| | | | | Soil/Sediment | | | |
| Cs-137 | pCi/g | 4.57 | 0.24 | 1.05 | 22/30 | | 0.04-0.04 - sediment<br>0.34-0.38 - soils |
| Sr-90 | pCi/g | 25.50 | 0.79 | 9.26 | 3/3 | | 0.92-0.92 - sediment<br>0.70-0.80 - soils |
| H-3 | pCi/g | 840 | 66.7 | 300.7 | 13/30 | | |
| Cd | mg/kg | 4.0 | 1.10 | 2.72 | 26/32 | 40/2 | 3.30 - sediment<br>2.50-4.4 - soils |
| Cr | mg/kg | 42.4 | 13.1 | 25.29 | 32/32 | 400/2 | 5.0-87.0 - sediment<br>19.8-36.9 - soils |
| | | | | Surface Water | | | |
| Cs-137 | pCi/L | 11.2 | 11.2 | 11.2 | 1/64 | | None |
| Sr-90 | pCi/L | 10,222.0 | 5.1 | 980.69 | 42/91 | 8/1 | None |
| H-3 | pCi/L | 14,000,000.0 | 1080 | 1,185,279 | 104/104 | 20,000/1 | 749-877 |
| PCE | µg/L | 83 | 1.0 | 26.73 | 15/59 | 5/1 | None |
| TCE | µg/L | 2200 | 1.00 | 257.88 | 26/59 | 5/1 | None |
| | | | | Surface Water-Filtered | | | |
| Cd | µg/L | 2.0 | 4.6 | 15/53 | 5/1 | | None |
| Cr | µg/L | 10.3 | 20.11 | 334/53 | 100/1 | | None |

Table 7B.2. (continued)

| Contaminant | Units | Maximum | Minimum | Mean | No. of Hits | Std./ref.[a] | Background |
|---|---|---|---|---|---|---|---|
| | | | | **Surface Water-Unfiltered** | | | |
| Cd | µg/L | 30 | 2.0 | 5.42 | 24/119 | 5/1 | None |
| Cr | µg/L | 58.3 | 10.2 | 22.17 | 60/119 | 100/1 | None |
| | | | | **Groundwater** | | | |
| Sr-90 | pCi/L | 5400 | 5.98 | 1836.16 | 9/63 | 8/1 | None |
| H-3 | pCi/L | 4,300,000 | 688 | 417099.46 | 56/64 | 20,000/1 | 2.67 |
| PCE | µg/L | 6800 | 1 | 2071.5 | 14/63 | 5/1 | 1-5 |
| TCE | µg/L | 1300 | 6 | 560.27 | 11/62 | 5/1 | None |
| | | | | **Groundwater-Filtered** | | | |
| Cd | µg/L | 86 | 2.3 | 9.07 | 32/86 | 5/1 | |
| Cr | µg/L | 103 | 10 | 25.68 | 42/86 | 100/1 | |
| | | | | **Groundwater-Unfiltered** | | | |
| Cd | µg/L | 94.5 | 2.1 | 10.83 | 30/91 | 5/1 | 2-3 |
| Cr | µg/L | 216 | 10.1 | 55.83 | 56/90 | 100/1 | None |

[a]Reference Codes:

1. Safe Drinking Water Act Maximum Contaminant Level (MCLs) (in Table 4.3 as RCRA Subparts).
2. Federal Register - July 27, 1990 - Appendix A, Action Levels.

**Table 7B.3. Acute and chronic ambient water quality criteria for selected contaminants**

| Contaminant | Hardness (mg/L $CaCO_3$) | Acute Criteria ($\mu$g/L) | Chronic Criteria ($\mu$g/L) |
|---|---|---|---|
| Cadmium | 50 | 1.8 | 0.66 |
| | 200 | 8.6 | 2.0 |
| Copper | 50 | 9.2 | 6.5 |
| | 200 | 34.0 | 21.0 |
| Benzene | N/A | 17,500 | 20.0[a] |
| Toluene | N/A | 5,300 | 20.0[a] |

[a]Criterion proposed by Jori et al. (1986) for long-term exposure to xylenes.

**Table 7B.4. Acute toxicity ($LC_{50}$) of cadmium to bluegill and fathead minnows**

| Fish species life stage | Water hardness (mg/L-$CaCO_3$) | 96-hour $LC_{50}$ ($\mu$g/L) | Reference |
|---|---|---|---|
| **Bluegill** | | | EPA |
| Yearling | 207 | 21,100 | Eaton 1974 |
| Adult | 18 | 2,300 | Bishop and McIntosh 1981 |
| Adult | 20 | 1,940 | Pickering and Henderson 1966 |
| **Fathead Minnow** | | | |
| Immature | 202 | 30,000-32,000 | Pickering and Gast 1972 (static tests) |
| Immature | 202 | 1,400-19,000 | Pickering and Gast 1972 (flow-through tests) |
| Larvae | 44 | 13.2 | Spehar and Fiandt 1986 |

Table 7B.5. Sublethal (chronic) effects of cadmium to bluegill and fathead minnow

| Fish species life stage | Water hardness | Exposure period | Cadmium concentration (ppb) | Effect | Reference |
|---|---|---|---|---|---|
| **Bluegill** | | | | | |
| Adult | 14-20 | 24-hour | 50 and 84 | Significant increase in ventilation frequency and cough rates | Bishop and McIntosh 1981 |
| Young-of-the-year | 180 | 6-month | 850 | Abnormal behavior after 13 weeks exposure | Cearly and Coleman 1974 |
| Yearling | 191-224 | 330 days | 80 | Ten percent mortality, mortality started at 240 days | Eaton 1974 |
| Eggs/Larvae | 191-224 | 6 days | 239 | Spawning reduced, 36 percent embryo mortality | Eaton 1974 |
| Young-of-the-year | | 2 hours | 4.0 | Significant change in ventilatory response observed within 20 minutes of exposure | Diamond, Parson, and Gruber 1990 |
| Adult | 105 | 2 weeks | 250 | Bluegill were 7.8 times more active than control fish | Ellgaard, Tusa, and Malizia 1978 |
| Adult | 340 | 15 days | 21 to 235 | Changes observed in nine different behaviors associated with social behavior and rank | Henry and Atchison 1979 |
| Adult | 363 | 163 days | 3,900 | Significant reduction in growth and lesions in gill tissue | Versteeg and Giesy 1986 |
| **Fathead Minnow** | | | | | |
| Immature | 201 | 270 days | 68 | 50 percent mortality over a 9-month period | Pickering and Gast 1972 |
| Fry (spawned and reared in cadmium) | 204 | 30 days | 110 | 80 percent mortality, growth unaffected | Pickering and Gast 1972 |
| Eggs | 204 | 7 days | 57 | Hatchability reduced 15 percent | Pickering and Gast 1972 |
| Juveniles | 44 | 32 days | 5 | 40 percent mortality observed at 5 ppb cadmium mixed with five other metals—each metal was at one-half MATC concentration | Spehar and Fiandt 1986 |

Table 7B.6. Acute toxicity ($LC_{50}$) of copper to bluegill and fathead minnow

| Fish species life stage | Water hardness (mg/L) ($CaCO_3$) | 96-hour $LC_{50}$ (ppb) | Reference |
|---|---|---|---|
| **Bluegill** | | | |
| Immature | 119 | 4,000 to 16,000 | Ellgard and Guillot 1988 |
| _____ | 20 | 660 | Pickering and Henderson 1966 |
| Juvenile-adult | 45 | 1,100 | Benoit 1975 |
| 1 to 2-gram larvae | 125 | 1,240 | Spear and Anderson 1975 |
| Immature | 21 to 59 | 850 to 1,200 | Thompson, Hendricks, and Carins 1980 |
| _____ | | 740 | Trama 1954 |
| Adult (?) | soft | 1,250 | Cairns and Scheier 1968 |
| _____ | | 2,400 | O'Hara 1971 |
| **Fathead Minnow** | | | |
| 3.2 to 4.2 cm st. length | 40 to 48 | 660 (measured) | Curtis, Copeland, and Ward 1979 |
| _____ | 40 to 48 | 390 (nominal) | Curtis, Copeland, and Ward 1979 |
| Larvae | 44 | 96 | Spehar and Fiandt 1986 |
| _____ | 31.4 | 75 and 84 | Mount and Stephan 1969 |
| Subadults | 200 | 460 | Pickering, Brungs, and Gast 1977 |
| Fry | 200 | 490 | Pickering, Brungs, and Gast 1977 |
| _____ | 120 to 336 | 600 to 980 | Brungs, Geckler, and Gast 1976 |
| _____ | _____ | 520 to 1,000 | Brungs, Geckler, and Gast 1976 |
| _____ | _____ | 430 | Mount 1968 |

Table 7B.7. Sublethal (chronic) effects of copper to bluegill and fathead minnow

| Fish species life stage | Water hardness (mg/L) ($CaCO_3$) | Exposure period | Concentration µg/L or ppb | Effect | Reference |
|---|---|---|---|---|---|
| **Fathead Minnow** | | | | | |
| Larvae and adults | 88 to 352 | 9 months | 320 | 50% mortality during first month of test | Brungs, Geckler and Gast 1976 |
| (29 to 69 mm TL) | | | 180 | Some mortality, spawning totally blocked | Brungs, Geckler, and Gast 1976 |
| | | | 120 | Egg production reduced | Brungs, Geckler, and Gast 1976 |
| Larvae-adults | 31.4 | 9 months | 18.4 | 50% mortality, retarded growth, prevented spawning | Mount and Stephan 1969 |
| Fry | 31.4 | 30 days | 18.4 | 100% mortality | Mount and Stephan 1969 |
| Adults | 200 | | 95 | approximately 50% mortality, retarded sexual development, and prevented spawning | Mount 1968 |
| Adults | | | 33 | Prevented spawning | Mount 1968 |
| Larvae and adults | 200 | 0 to 6 months | 37 | Egg production significantly lower than at 24 µg/l or controls | Pickering, Brungs, and Gast 1977 |
| Adult females | 200 | 3 to 6 months | 98 | Growth of females reduced due to 6-month exposure | Pickering, Brungs, and Gast 1977 |
| Embryo | ~200 | 2 days | 338 | Embryos hatched 2 to 3 days early, before development was complete | Saudder, Carter, and Leland 1988 |
| | | 8 days | 621 | Significant decrease in survival ant total hatch | Saudder, Carter, and Leland 1988 |
| Larvae | | 28 days | 61 to 204 | Concentration dependent decrease in survival | Saudder, Carter, and Leland 1988 |
| | | | 61 | Decreased length, weight, and coefficient of condition | Saudder, Carter, and Leland 1988 |

Table 7B.7. (continued)

| Fish species life stage | Water hardness (mg/L) ($CaCO_3$) | Exposure period | Concentration $\mu$g/L or ppb | Effect | Reference |
|---|---|---|---|---|---|
| **Bluegill** | | | | | |
| Juvenile—adult | 44 to 50 | 22 months | 40 to 162 | Gill and liver tissue accumulated copper | Benoit 1975 |
| ——— | 44 to 50 | 22 months | 162 | Reduced survival, retarded growth, inhibited spawning. | Benoit 1975 |
| Larvae | 44 to 50 | 90 days | 40 and 77 | larvae survival significantly lower than controls | Benoit 1975 |
| 3 to 4 cm juveniles | 119 | 6 to 8 days | 40 to 400 | Produced lower than normal locomotor response, with dramatic decrease within first four days of exposure. | Elgaard and Guillot 1988 |
| Adult | 40 | 24 to 96 hours | 2,000 | Water content of muscle and liver tissue increased and ATP, ADP, and total adenylates in muscle tissue decreased. | Heath 1984 |
| Juvenile | 59 | 32 days | 210 | Whole body oxygen consumption decreased after 9 days exposure. Difference was significant by 32 days. | Felts and Heath 1984 |
| Juvenile | 34 | 10 days | 500 to 1,300 | Ventilatory rates increased and amplitude decreased. | Thompson et al. 1983 |

Table 7B.8. Acute and chronic toxicity values for benzene and substituted benzenes, including toluene and xylene for bluegill and fathead minnow

| Fish species | Toxicant | Toxicity value (mg/L) | | Comments | Reference |
|---|---|---|---|---|---|
| Fathead minnow | Toluene | 57-72 | 96-h $LC_{50}$ | Embryo life stage | Devlin et al. 1982 |
| | Toluene | 25-35 | 96-h $LC_{50}$ | Protolarvae | Devlin et al. 1982 |
| | Toluene | 26-31 | 96-h $LC_{50}$ | 30-day old larva | Devlin et al. 1982 |
| | Toluene | 18 | 96-h $LC_{50}$ | 32-day long embryo-larval test | Devlin et al. 1982 |
| | Toluene | 6 | NOEL | No observable effect | Devlin et al. 1982 |
| | Toluene | 30-45 | Chronic | Concentrations producing abnormal development in embryos | Devlin et al.1985 |
| | Toluene | 34.3-42.3 | 96-h $TL^m$ | Adult $TL_m = LC_{50}$ | Pickering & Henderson 1966 |
| | Benzene | 32.0-33.5 | 96-h $Tl_m$ | Adult $TL_m = LC_{50}$ | Pickering & Henderson 1966 |
| | Xylene | 26.7-28.8 | 96-h $TL_m$ | Adult $TL_m = LC_{50}$ | Pickering & Henderson 1966 |
| | Benzene | 15.1 | acute | | Fisher, Dilego, and Paulos 1984 (p. 31) |
| | Trinitrotoluene | 2.58 | 96-h $LC_{50}$ | | Smock et al. 1976 |
| | Trinitrotoluene | 0.05 | NOEL | No death or behavioral response | Smock et al. 1976 |
| | 3,4-Dichlorotoluene | 2.91 | 96-h $LC_{50}$ | | Veith, Call, & Brooke 1983 |
| | 1,3 Dichlorobenzene | 9.1 | 96-h $LC_{50}$ | | Broderius & Kahl 1985 |
| Bluegill | Toluene | 13 | 96-h $LC_{50}$ | | Babich & Barenfreund 1987 |
| | Toluene | 8.7 | NOEL | Highest concentration observed that was nonlethal | Berry 1980 |
| | Toluene | 24.0 | 96-h $TL_m$ | $TL_m = LC_{50}$ | Pickering & Henderson 1966 |
| | Benzene | 5-9 | chronic | Dose-related behavioral response, activity increased soon after exposure | Fisher, Dilego, and Paulos 1984 |
| Bluegill | Benzene | 22.5 | 96-h $TL_m$ | $TL_m = LC_{50}$ | Pickering & Henderson 1966 |
| | Xylene | 20.9 | 96-h $TL_m$ | $TL_m = LC_{50}$ | Pickering & Henderson 1966 |
| | Trinitrotoluene | 2.3-2.8 | 96-h $LC_{50}$ | | Smock et al. 1976 |
| | 2,4 Dinitrotoluene | 0.33 | 96-h $LC_{50}$ | | Babich & Barenfreund 1987 |

Table 7B.9. Acute toxicity ($LC_{50}$) of cadmium to freshwater invertebrates

| Invertebrate group species | Water hardness (mg/L-$CaCO_3$) | 96-hour $LC_{50}$ (mg/L) | Comments/life stage | Reference |
|---|---|---|---|---|
| **Ephemeroptera** | | | | |
| *Ephemerella subvaria* | 50 | 2.0 | Larvae | Clubb et al. 1975 |
| *E. grandis* | 180 | 28.0 | Larvae | Clubb et al. 1975 |
| *E. ignita* | 152 | 13.0 | | Clubb et al. 1975 |
| *Baetis rhodani* | 152 | 0.5 | | Clubb et al. 1975 |
| **Plecoptera** | | | | |
| *Pteronarcella badia* | 180 | 18.0 | Larvae | Clubb et al. 1975 |
| *Leuctra imermis* | 152 | 32.0 | | Clubb et al. 1975 |
| **Trichoptera** | | | | |
| *Agapetus fuscipes* | 115 | 210 to 320 | First through fourth instars | McCahon et al. 1989 |
| *Hydropsyche angustipennis* | 152 | 520 | | Williams et al. 1985 |
| **Chironomidae** | | | | |
| *Polypedilum nubifer* | 68 | 372 | Fourth Instar | Hatakeyama 1987 |
| *Chironomus tentans* | 18 to 35 | 8.05 | Third Instar (48-hour $EC_{50}$) | Khangarot and Ray 1989 |
| *C. riparius* (4th-Instar) | 152 | 300 | | Williams et al. 1985 |
| *Chironomus sp* | 50 | 1.2 | Larvae | Williams et al. 1985 |
| *C. tentans* | 50 | 1030 | Cadmium concentration in sediment | Williams et al. 1985 |
| *C. riparious* —1st Instar | 100 | 2.1 | 24-hour $LC_{50}$ due to short duration of the 1st instar | Williams et al. 1986 |
| —2nd Instar | 100 | 13 | | Williams et al. 1986 |
| —3rd Instar | 100 | 22 | | Williams et al. 1986 |
| —4th Instar | 100 | 54 | | Williams et al. 1986 |
| **Cladocerans** | | | | |
| *Daphnia magna* | 51 | 9.9 | | EPA 1980, Eisler 1985 |
| *Ceriodaphnia dubia* | 44 | 27.3 | 96-hour $LC_{50}$ | Spehar and Fiandt 1986 |

Table 7B.9. (continued)

| Invertebrate group species | Water hardness (mg/L-$CaCO_3$) | 96-hour $LC_{50}$ (mg/L) | Comments/life stage | Reference |
|---|---|---|---|---|
| **Ephemeroptera** | | | | |
| *Simocephalus serrulatus* | 11 | 3.5 to 8.6 | | Gresy et al. 1977, Eisler 1985 |
| *Daphnia magna* | 130 | 0.005 | 1-day old initially, 4-day $LC_{50}$ | Mance 1987 |
| *D. pulex* | 106 | 0.082 to 0.107 | 1-day old initially, 3-day $LC_{50}$ | Mance 1987 |
| **Crustaceans** | | | | |
| *Asellus aquaticus* | | | | Green et al. 1986 |
| Embryo | 105 | 2.0 | | Green et al. 1986 |
| Early juvenile | 105 | 0.080 | | Green et al. 1986 |
| Juvenile 3.5 mm length | 105 | 0.320 | | Green et al. 1986 |
| Adult | 105 | 1.0 | | Green et al. 1986 |
| —— | 152 | 0.6 | | Williams et al. 1985 |
| **Freshwater Shrimp** | | | | |
| *Gammarus pulex* | ~60 | 0.68 | Adult | Mance 1987 |
| *Gammarus sp* | 50 | 0.14 | | Williams et al. 1985 |
| *Gammarus pulex* | 152 | 0.02 | Freshwater shrimp | Williams et at. 1985 |
| **Snails** | | | | |
| *Physa fontinalis* | 152 | 0.80 | Snail | Williams et al. 1985 |
| *Physa gyrina* | 200 | 1.37 | Adult snail | Williams et al. 1985 |
| *Physa gyrina* | — | 0.43 to 1.37 | Juvenile and adult, respective | Williams et al. 1986 |
| **Annelida** | | | | |
| *Tubifex tubifex* | 224 | 0.650 | Adult, test at 20°C | Mance 1987 |
| *Limnodrilus hoffmeisteri* | 224 | 0.110 | Adult, test at 20°C | Mance 1987 |
| *L. hoffmeisteri* | 152 | 2.4 | | Williams et al. 1985 |
| *L. hoffmeisteri* | soft | 3.5 | | Williams et al. 1985 |
| *Ceriodaphnia dubia* | 44 | 27.3 | 96-hour $LC_{50}$ | Spehar and Fiandt 1986 |

Table 7B.10. Sublethal (chronic) effects of cadmium to freshwater invertebrates

| Species life stage | Water hardness mg/L $CaCO_3$ | Exposure period | Concentration mg/L | Effect | Reference |
|---|---|---|---|---|---|
| **Ephemeroptera** | | | | | |
| *Ephemerella Sp.* | 44-48 | 28 days | <0.003 | 50 percent mortality observed over 28 days. | Spehar, Anderson, and Fiandt 1978 |
| *Baetis rhodani* | ____ | 19 days | 0.02 | Reduced emergence and locomotor activity at pH5.2. | Gerhardt 1990 |
| *Leptophlebia marginata* | ____ | 27 days | 0.20 | Emergence slightly decreased at pH5. | Gerhardt 1990 |
| Plecoptera | | | | | |
| *Acroneuria pacifica* | 180 | 21 days | 17.5 | 10 percent survival. | Clubb et al. 1975 |
| *Pteronarcys californica* | 180 | 14 days | 14.0 | 100 percent survival. | Clubb et al. 1975 |
| *Pteronarcys dorsata* | 44-48 | 28 days | 0.238 | No significant difference in survival. | Spehar et al. 1990 |
| Trichoptera | | | | | |
| *Brachycentrus americanus* | 180 | 7 days | 42.5 | 100 percent survival. | Clubb et al. 1975 |
| *Hydropsyche betteni* | 50 | 10 days | 32 | 50 percent mortality during 10-day exposure. | Warnick and Bell 1969 (WGP 1985) |
| *Agapetus fuscipes* | 115 | up to 96 hours | 97 and 186 | Reduced case building and reduced strength of cases built by fourth instar larvae. | McCahon et al. 1989 |
| *H. angustipennis* | ____ | ____ | 0.3 | Reduced net-spinning capability. | Williams et al. 1985 |
| *H. betteni* | | | | Abnormal behavior; usually out of cases and exhibited vigorous curling motion. | |
| *Brachycentrus Sp.* | 44-48 | 28 days | 0.085 | | |
| Chironomidae | | | | | |

Table 7B.10. (continued)

| Species life stage | Water hardness mg/L $CaCO_3$ | Exposure period | Concentration mg/L | Effect | Reference |
|---|---|---|---|---|---|
| **Ephemeroptera** | | | | | |
| *Tanytarsus dissimilis* | 47 | 10 days | 3.8 | 50 percent mortality over 10 days. Total life cycle compete in 14-19 days at 21-28°C. | Anderson, Walbridge, and Fiaudt 1980 |
| *T. dissimilis* | 47 | 10 days | 8 | 100 percent mortality. | Anderson, Walbridge, and Fiandt 1980 |
| *Polypedilum nubifer* | 68 | ≈40 days | 0.080 | Emergence success less than 3 percent of control group. | Hatakeyama 1987 |
| | 68 | ≈40 days | 0.020 | Emergence success 74 percent of controls. | Hatakeyama 1987 |
| *Chironomus yoshimatsui* | —— | 2 days | 0.025 | Small influence on mortality. | Yamamura et al. 1983 |
| *C. riparius* | 98 | 10 days | 30. | Percent hatching fell to less than 50 percent. | Williams et al. 1987 |
| *C. riparius* | 98 | 10 days | 100. | Significantly fewer eggs laid by adult females in water containing 100 and 300 mg/l Cd. | Williams et al. 1987 |
| Cladocerans | | | | | |
| *Daiphnia pulex* | | 21 days | 0.7 | Reduced reproduction 50 percent. | Eiser 1985 |
| | | 21 days | 2.6 | Immobilization threshold. | |
| Annelida | | | | | |
| *Pristena Sp.* | | 52 weeks | 5.0 | Reduced population. | Eiser 1985 |
| Snail | | | | | |
| *Physa integra* | 45 | 28 days | 0.0275 | Lowest effect concentration, decreased survival. | Spehar, Anderson, and Fiandt 1978 |
| *P. integra* | 45 | 28 days | 0.0104 | 50 percent mortality during 28-day exposure. | Spehar, Anderson, and Fiandt 1978 |
| *P. integra* | 45 | 7 days | 0.114 | 50 percent mortality during 7-day exposure. | Spehar, Anderson, and Fiandt 1978 |

Table 7B.11. Acute toxicity ($LC_{50}$) of copper to freshwater invertebrates

| Species life stage | Water hardness (mg/L $CaCO_3$) | 96-hour $LC_{50}$ (ppb) | Comments | Reference |
|---|---|---|---|---|
| Ephemeroptera | | | | |
| *Ephemerella subvaria* | 50 | 320 | Larvae | Anderson, Walbridge, and Fiandt 1980 (Warnick and Bell 1969) |
| *E. grandis* | 50 | 180 | | Anderson, Walbridge, and Fiandt 1980 |
| Trichoptera | | | | |
| *Unidentified* | 50 | 6,200 | | EPA 1985b |
| Plecoptera | | | | |
| *Acroneria lycorlas* | 40 | 8,300 | | EPA 1985b |
| Chironomidae | | | | |
| *Chironomus tentans* | 18 to 35 | 327 | Third Instar, 48-hr $EC_{50}$ | Khangarot and Ray 1989 |
| *C. tentans* | 43 | 16.7 | First Instar in soft, medium, and hard water | Gauss et al. 1985 |
| *C. tentans* | medium | 36.5 | First Instar in soft, medium, and hard water | Gauss et al. 1985 |
| *C. tentans* | 172 | 98.2 | First Instar in soft, medium, and hard water | Gauss et al. 1985 |
| *C. tentans* | 43 | 211 | Fourth Instar in soft, medium, and hard water | Gauss et al. 1985 |
| *C. tentans* | medium | 977 | Fourth Instar in soft, medium, and hard water | Gauss et al. 1985 |
| *C. tentans* | 172 | 1,184 | Fourth Instar in soft, medium, and hard water | Gauss et al. 1985 |
| *C. tentans* | 71 to 84 | 298 | First Instar | Mance 1987 |
| *C. tentans* | 71 to 84 | 773 | Second Instar | Mance 1987 |
| *C. tentans* | 71 to 84 | 1,446 | Third Instar | Mance 1987 |

Table 7B.11. (continued)

| Species life stage | Water hardness (mg/L $CaCO_3$) | 96-hour $LC_{50}$ (ppb) | Comments | Reference |
|---|---|---|---|---|
| *C. tentans* | 71 to 84 | 1,690 | Fourth Instar | Mance 1987 |
| *C. decorus* | | 739 | 48-hour $LC_{50}$ | Kosalwat and Knight 1987a |
| *Chironomus* | | 500 | | Kosalwat and Knight 1987a |
| *Chironomus* | 50 | 30 | | EPA, 1985b |
| Mollusca | | | | |
| *Physa heterostropha* | 100 | 53 | Young | Williams, et al. 1986 |
| *P. heterostropha* | 100 | 69 | Adult | |
| *Physa integra* | 45 | 37 to 41 | Adult | Arthur and Leonard 1970 |
| *Corbicula fluminia* | 64 | 490 | 1 to 2 cm | Mance 1987 |
| Annelida | | | | |
| *Limnodrilus hoffmeisteri* | 100 | 10 | Adult | Mance 1987 |

## Table 7B.12. Sublethal (chronic) effects of copper to freshwater invertebrates

| Species life stage | Water hardness mg/L $CaCO_3$ | Exposure period | Concentration (µg/L) | Effect | Reference |
|---|---|---|---|---|---|
| Ephemeroptera | | | | | |
| *Ephemerella grandis* | | | 180 to 200 | 14-day $LC_{50}$. | Anderson, Walbridge, and Fiandt 1980 |
| *Epeorus latifolum* | 83 | 8 weeks | 10 to 15 | Lowest concentration of copper to significantly effect growth. | Hatakeyama 1989 |
| *Epeorus latifolum* | | | 25 | Density in metal laden river reduced to near zero. | Hatakeyama 1989 |
| *Epeorus latifolum* | 83 | 2 weeks | 100 | 100 percent mortality when water concentrations were 100 µg/l. | Hatakeyama 1989 |
| *Epeorus latifolum* | | 8 weeks | 1,140 (food) | Growth rate only 50 percent of controls when mayfly fed food containing 1,140 µg/l dry weight, copper. | Hatakeyama 1989 |
| Trichoptera | | | | | |
| *Clistornia magnifica* | | | 10.4 | Life cycle tests. | EPA 1985b |
| *Hydropsyche betteni* | | | 32,000 | 50 percent mortality over 14 days. | EPA 1985 |
| Plecoptera | | | | | |
| *Pteronarcys californica* | | | 10,100 to 13,900 | 50 percent mortality over 14 days. | EPA 1985b |
| Chironomidae | | | | | |
| *Tanylarsus dissimilis* | 47 | 10 days | 16.3 | 50 percent mortality over 10 days; total life cycle completed in 14 to 19 days at 21 to 28°C. | Anderson, Walbridge, and Fiandt 1980 |
| *T. dissimilis* | 47 | 10 days | >28 | 100 percent mortality. | Anderson, Walbridge, and Fiandt 1980 |
| *Tanytarsiini* | 150 to 157 | 10 days | 13 to 19 | Abundance reduced by 23 to 35 percent. | Clements et al 1989 |
| *Chironomus decorus* | soft | 72 hr | 5,000 | Development and hatchability of eggs not affected, but larvae died as they emerged from egg. | Kosalwat and Knight 1987b |
| *Chironomus decorus* | NA | | >4,000 mg/kg (food) | Mortality occurred when food contained 4,000 mg/kg copper. | Kosalwat and Knight 1987a |
| *Chironomus decorus* | NA | 1 to 15 days | 1,602 mg/kg (food) | Growth reduced to 50 percent when larvae reared in copper-laden substrate. | Kosalwat and Knight 1987b |
| *Chironomus decorus* | NA | 1 to 15 days | 1,800 mg/kg (food) | Adult emergence delayed when larvae reared in copper-laden substrate. | Kosalwat and Knight 1987b |
| *Chironomus decorus* | NA | 1 to 15 days | 3,400 mg/kg (food) | Very little growth occurred when substrate copper exceeded 3,400 mg/kg. | Kosalwat and Knight 1987b |
| *Chironomus tentans* | | 20 days | 77.5 | 20 days $EC_{50}$, 50 percent of population immobilized. | EPA 1985b |
| Cladoceran | | | | | |
| *Daphnia magna* | | | 29.3 | | EPA 1985b |

Table 7B.12. (continued)

| Species life stage | Water hardness mg/L $CaCO_3$ | Exposure period | Concentration ($\mu$g/L) | Effect | Reference |
|---|---|---|---|---|---|
| Ephemeroptera | | | | | |
| Amphipod | | | | | |
| *Gammarus pseudolimnaeus* | | | 6,066 | | EPA 1985 |
| Mollusca | | | | | |
| *Sphaerium transversum* | | chronic | 5.2 | Clam disappeared from Illinois River over last 20 years. | EPA 1985b |
| *Physa integra* | | | 10.9 | | |
| *Corbicula manilensis* | | | 25 | 53 percent mortality to larvae. | EPA 1985b |

Table 7B.13. Acute and chronic toxicity values for toluene and xylene for freshwater invertebrates

| Invertebrate species | Toxicant | Toxicity value | | Comments | Reference |
|---|---|---|---|---|---|
| **Crayfish** | Toluene | 104.4 mg/L | NOEL | Upper non-lethal concentration | Berry 1980 |
| **Mosquito** | | | | | |
| *Aedes aegypti* | Xylene | 14 mg/L | 24-h $LC_{50}$ | Larvae | Jori et al. 1986 (p. 66) |
| *Cladoceran* | | | | | |
| *Daphnia magna* | Xylene | 100 to 1,000 mg/L | 24-h $LC_{50}$ | Acute toxicity somewhere between 100 and 1,000, based on range-finding test | Jori et al. 1986 (p. 66) |
| **Algae** | | | | | |
| *Dunaliella* | Xylene | 10 mg/L | 24-h $IGC_{50}$ | 50 percent inhibition growth concentration | Jori et al. 1986 |
| *Chlorella* | Xylene | 55 mg/L | 24-h $IGC_{50}$ | 50 percent inhibition growth concentration | Jori et al. 1986 |
| *Chlorella* | Xylene | 104 mg/L | chronic | 50 percent reduction in photosynthesis | Jori et al. 1986 |
| Algae | Trinitrotoluene | 5 to 15 mg/L | chronic | Growth inhibited | Smock et al. 1976 |

# Appendix 7B Figures

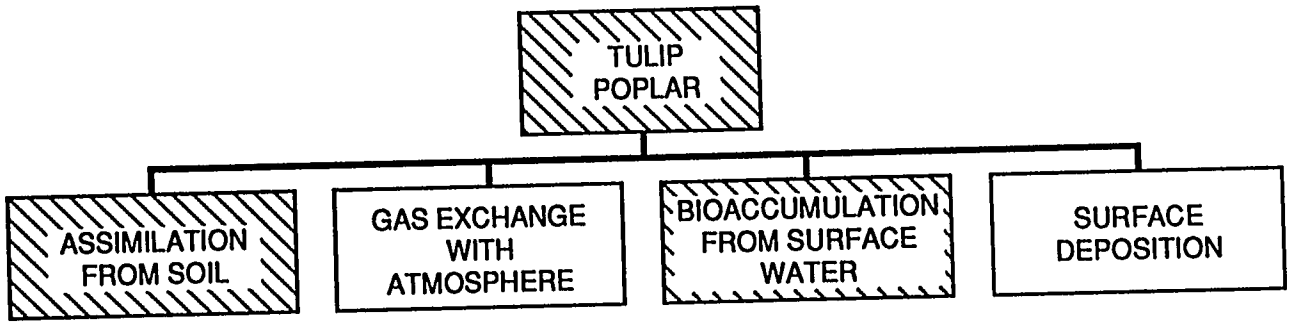



**Fig. 7B.1. Exposure scenario with the tulip poplar as the target species. (Highlighted boxes indicate primary exposure routes.)**

5.18B 4104.78

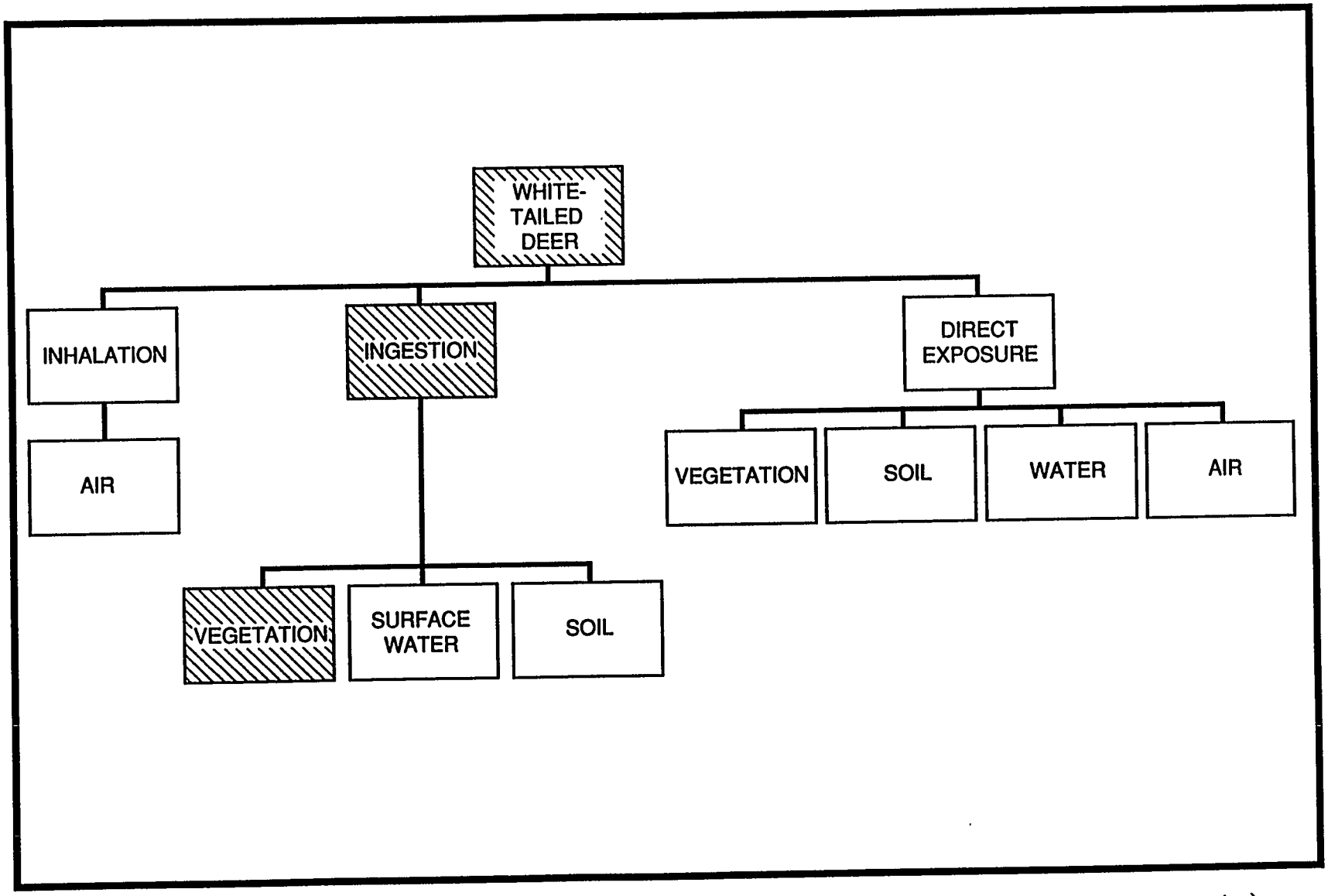



**Fig. 7B.2. Exposure scenario with the white-tailed deer as the target species. (Highlighted boxes indicate primary exposure routes.)**

5.18B 4104.76

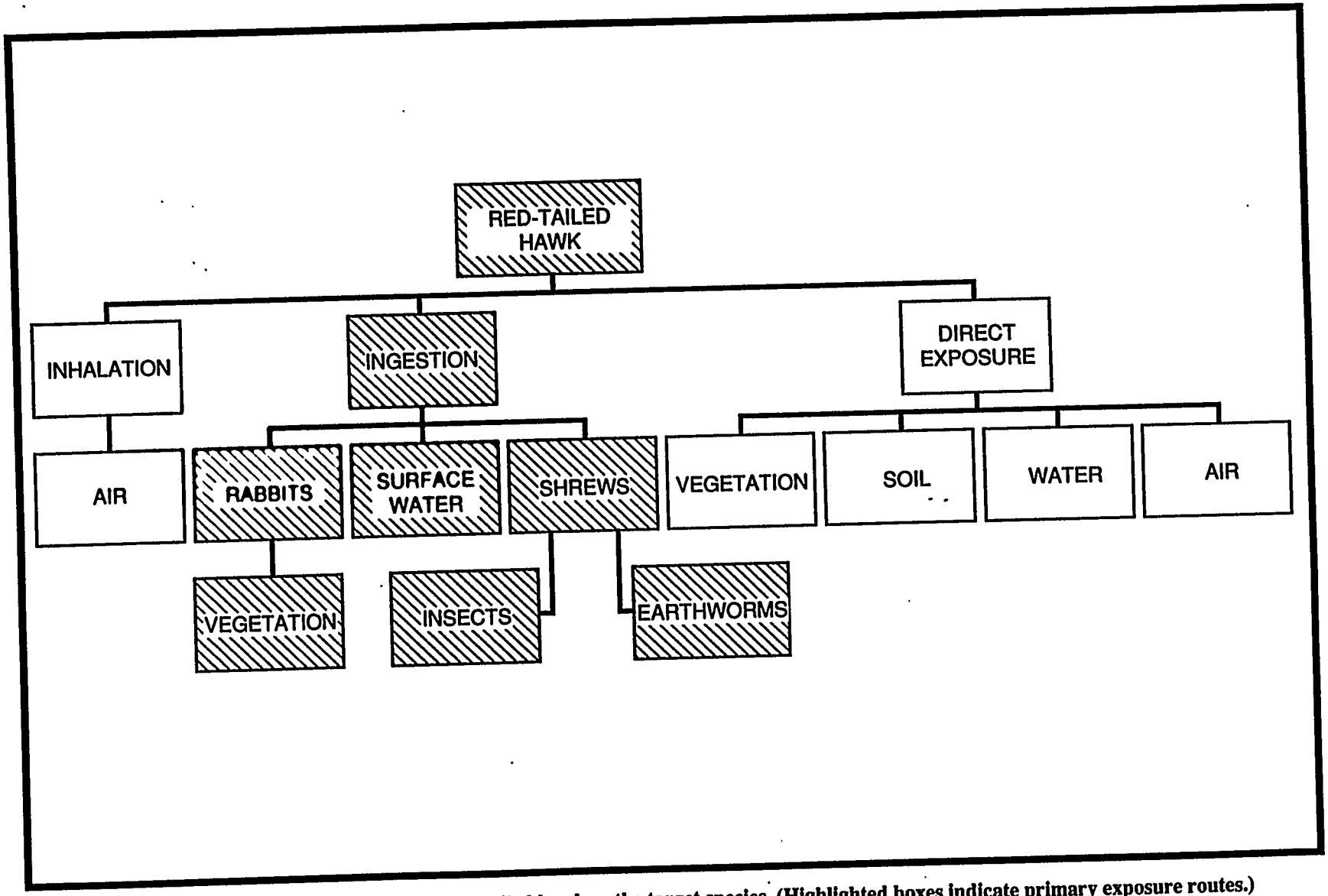



Fig. 7B.3. Exposure scenario with the red-tailed hawk as the target species. (Highlighted boxes indicate primary exposure routes.)

5.18B 4104.77

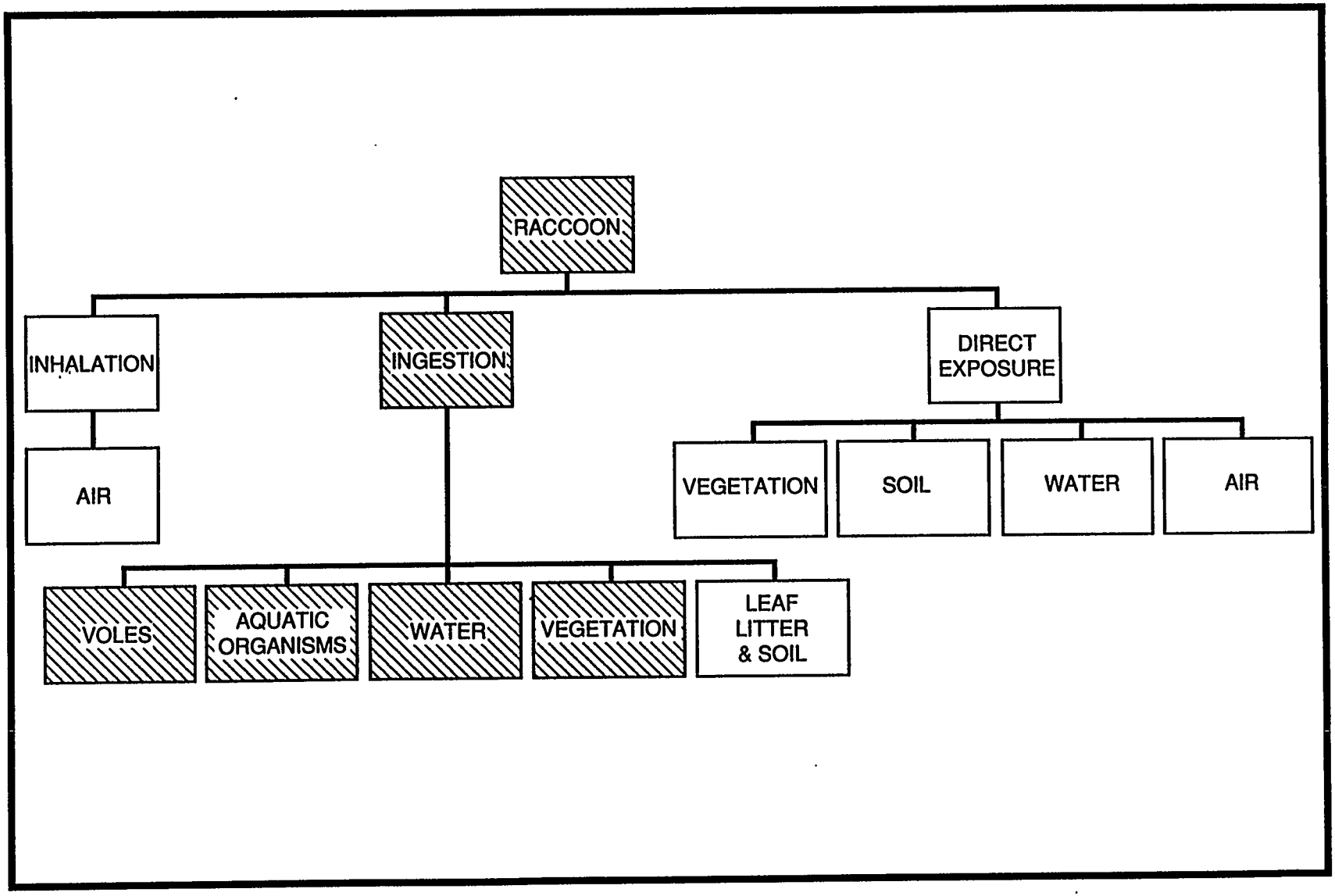



**Fig. 7B.4. Exposure scenario with the raccoon as the target species. (Highlighted boxes indicate primary exposure routes.)**

# APPENDIX 7C. EXPOSURE AND TOXICITY ASSESSMENTS FOR TERRESTRIAL SPECIES

The exposure and toxicity assessments for terrestrial species rely upon evidence from the scientific literature of documented or suspected effects of the selected contaminants upon the same or similar species within the food chain. Appendix 7C presents a review of the relevant literature on which this environmental evaluation is based.

## 7C.1 TERRESTRIAL FLORA

The four known routes of contamination to a tulip poplar tree growing on WAG 6 are assimilation from the soil, gas exchange with the atmosphere, bioaccumulation from surface water, and surface deposition (IT Corp. 1990). Work done by Witherspoon, Auerbach, and Olson (1962), Witherspoon (1964), Witkamp and Frank (1964), Waller and Olson (1967), and others describe how certain contaminants are accumulated, dispersed, and recycled throughout trees in a compartmentalized fashion.

### 7C.1.1 Effects of Radionuclides

#### 7C.1.1.1 Cesium-137

An analysis of the literature reveals that one of the WAG 6 selected contaminants, cesium-137, was used extensively in early studies on the ORR to trace the route of contamination in tulip poplar trees (Waller and Olson 1967). Tulip poplar trees tagged with cesium-137 showed that the important paths of transfer to the forest floor are rain leaching and passage through the roots. Cesium-137 moves rapidly throughout the tree with 40% of the inoculant found in the litter, soil, and smaller root components 5 months after initial injection into the trees. The maximum burden (27%) was found in the canopy about 4 weeks after inoculation, and this was reduced to 12.5% 3 months later. Of the maximum burden, the remaining two-thirds moved back into woody tissue (stem and roots) before leaf fall. Losses of radiocesium from the foliage and stems through litterfall and rain leaching accounted for almost 8% of total cesium-137 introduced into the tree boles.

When white oak trees were inoculated with cesium-134, loss of the radionuclide began with the first rains after inoculation. However, the cesium-134 transferred from the trees via annual leaf fall was two times greater than that exported by rain. Translocation of cesium-134 through trees, litter, and roots was found to be very rapid, and 92% of the total soil cesium-134 remained in the top 4 in. of soil under inoculated trees 19 months after inoculation (Witherspoon 1964).

Cesium-137 is not expected to reach appreciable concentrations in vegetation because of its low transfer coefficient from soil. Illitic clays such as those on the ORR have been shown

to reduce the bioavailability of cesium-137 because it becomes tightly bound to the clay fraction of the soil (Fredriksson and Eriksson 1958; Crossley, Reichle, and Edwards 1971). Dahlman and Van Voris (1976) measured plant:soil ratios of 0.03 where cesium-137 concentrations were in excess of 20,000 pCi/g in soil.

Crossley and Reichle (1969) found a similar concentration factor of 0.027 for cesium-137. In areas where cesium-137 is more bioavailable, it and strontium-90 are the fission products most readily uptaken by plants. Moss has a high ability to absorb and retain radionuclides from fallout, and lichens also show an accumulation efficiency of about 100% for cesium-137 (Svenson and Liden 1965).

### 7C.1.1.2 Strontium-90

Honeysuckle (Lonicera japonica) and blackberry (Rubus spp.) provided an avenue for analysis of concentrations of strontium-90, another WAG 6 selected contaminant, and illustrated that this contaminant can be uptaken in plant tissues. Honeysuckle and blackberry grow in profusion on the ORR and can be found in open areas that are in the secondary stages of succession. Strontium-90 is one of the most important fission products that can be readily taken up by plants, according to Oakes et al. (1982). It is a bone-seeking radionuclide and poses potential harm to the organisms which consume contaminated plants. At nearby SWSA 5, studies show that the maximum concentration of strontium-90 in herbaceous vegetation was 90 nCi/g dry weight and averaged as high as 30 and 19 nCi/g in honeysuckle and blackberry shoots, respectively, at two seeps (Garten and Lomax 1987). The significance of these concentrations of strontium-90 is that they are sufficiently high to enable a 45-kg buck deer that browses on contaminated vegetation on a regular basis for 1 week to 1 year to exceed the limit of 30 Ci/g in bone that was established for the confiscation of deer harvested during the TWRA managed hunts that are held on the ORR annually.

The influence of soils on plant uptake of radionuclides has been demonstrated throughout the literature. Baes, Garten, and Tolbert (1987) reviewed existing literature on the plant:soil concentration ratios of various radionuclides and determined that the range of reference mean values for the plant:soil concentration ratio of strontium-90 was 0.077 to 17, with a geometric mean of 2.7. Variability in the ratio arises from regional variation in soil parameters affecting strontium-90 uptake by plants. The soil property that most influences the plant uptake of strontium-90 is the exchangeable calcium status (Francis 1978). For some soils, other properties such as pH, texture, and organic matter dominate strontium-90 uptake processes. WAG 6 soils are generally acidic and heavily reworked. Because the site is an active waste disposal site, native soil properties have been altered by the importation of other soils as backfill. Strontium-90 is found in WAG 6 soils in amounts exceeding background levels for soils (25.5 pCi/g maximum concentration; 0.70-0.80 pCi/g background level) (Table 7B.2). The assumption is that it has been taken up by flora growing in isolated areas on WAG 6, particularly by fast-growing pioneer species such as honeysuckle and blackberry.

### 7C.1.1.3 Tritium

There are numerous potential modes of tritium uptake by organisms (Elwood 1971). Plants can obtain tritium from both foliar deposition and the transpirational process. The initial source of tritium exposure is primarily tritiated water, although exposure to tritiated vapor does occur. Uptake by plants in the transpirational stream is quite rapid. In one study, tritium was detected in transpired water from small oak (Quercus spp.) trees four hours after tritiated water was placed in the soil (Woods and O'Neal 1965). In another study, tritium was detected in plant water collected from all parts of the plants including leaves, stems, and roots after exposure of leaves to tritiated vapor for five hours. The highest concentrations measured were in the exposed leaves (Elwood 1971). Although tritium is taken up by terrestrial vegetation, it apparently does not bioaccumulate in the environment or in food chains (Rohwer and Wilcox 1976).

## 7C.1.2 Effects of Metals

### 7C.1.2.1 Cadmium and chromium

Cadmium and chromium are the heavy metal contaminants selected for WAG 6. Both metals have been studied extensively. The biological behavior and environmental cycling of both, particularly chromium, are poorly characterized. In an exposure assessment of terrestrial flora, cadmium is primarily associated with the soil and has not been shown to accumulate in vegetation. In fact, concentrations in litter and vegetation are always less than those of soils (Talmage and Walton 1990). A study on uptake and movement was conducted by Witherspoon and Gaskins (1972) in which the trunk of a cedar tree (Juniperus virginianus) was inoculated with cadmium, and the resultant activity was determined in the various parts of the tree and in the understory vegetation, litter, and soil. About 65% of the cadmium was transported to the crown. Over an 8-week period, only 0.1% of the cadmium in the crown was leached out to the forest floor, whereas about 68% remained in the litter under the canopy. Uptake by the understory vegetation was low, about 3%, and the remaining 29% entered the soil, where most of it remained in the top 2 cm.

Chromium is a transitional element that occurs in two environmentally important oxidation states: trivalent and hexavalent. Trivalent chromium does not migrate significantly and thus should only be a problem at the source; conversely, hexavalent chromium migrates quite readily. Furthermore, trivalent chromium is poorly absorbed by biota and is considered biologically insignificant, but hexavalent compounds are toxic when ingested, absorbed, or inhaled. Hexavalent chromium is generally not available for incorporation into plant tissues as shown in a study by Taylor (1983). Only 1% of the chromium deposition mass was incorporated into foliage, with the remaining fraction being transferred to the soil-litter compartment by weathering, plant fragmentations, or direct deposition. Approximately 5% of the hexavalent chromium reaching the soil compartment is available to vegetation by root uptake. The majority (94%) is unavailable for incorporation into plant tissues (Taylor 1983).

Chronic deposition or elemental pools do not pose a serious threat for the terrestrial ecosystem because hexavalent chromium is essentially nonbioavailable.

### 7C.1.3 Other Contaminants

Other WAG 6 selected contaminants that are of significant concentrations to potentially impact target species are the volatile organic chemicals, xylene, toluene, tetrachloroethylene, and trichloroethylene. However, no data were found in the literature from which to draw conclusions or inferences about effects of these contaminants on vegetation.

### 7C.1.4 Toxicity Assessment for Tulip Poplar

The data that are available in the literature on the contaminants of concern for the terrestrial flora of WAG 6 characterize contaminant uptake, accumulation, transport, distribution, and recycling. Virtually no data were found that describe the biological effects of contaminants on terrestrial floristic organisms, including the tulip poplar. During the course of this evaluation, several authorities were questioned concerning effects, or specific toxicity data that could be applied to an analysis of contamination of WAG 6. The following authorities were contacted: Dr. Frank McCormick, Ecology Program, University of Tennessee; J. Thomas Kitchings and Keith Owenby, ERCE, Denver, CO; Jackie Cunningham, ESD, ORNL; Dr. Liz Etnier, ESD, ORNL; C. T. Garten, ORNL; Ann West, $CH_2M$ Hill, Fairfax, VA; Charles Murphy, SRL, Aiken, SC; Elizabeth Deming, Agricultural Engineering, University of Tennessee; Diane Beeman, U.S. Fish and Wildlife Service, Raleigh, NC; and Earl Leming, Tennessee Division of Solid Waste Management. These people either referred to information specific to humans or expressed doubt about the potential to derive an exposure dose and calculate the likely effects from the available data.

## 7C.2 TERRESTRIAL FAUNA

### 7C.2.1 Pathways

The white-tailed deer (Odocoileus virginianus) is a common large mammal in Tennessee. Weighing an average of 50 kg, deer are excellent biological monitors, according to Wren (1986), because they are widely distributed and abundant. Deer inhabit upland and bottomland forests and have a remarkably adaptable diet (Kitchings and Mann 1976). They are completely herbivorous, consuming approximately 3500 g of vegetation daily, and eat according to seasonal availability (IT Corp. 1990). In spring, they eat green leaves and stems from both woody and herbaceous species, fruit of the hawthorne, tulip poplar flowers, mushrooms, and acorns. In summer, they prefer succulent green plants, mushrooms, and acorns. Acorns dominate the deer's diet in autumn, followed by honeysuckle, mushrooms, grapes, apples, sumac, and blueberry. In winter, they eat acorns, grasses, honeysuckle, and mushrooms—all of which are subject to contamination from soil assimilation, gas exchange with the atmosphere, bioaccumulation from surface water, and surface deposition. Deer also typically consume 3000 mL of water and 5 g of soil, both of which are sources of additional

uptake of contaminants. They inhale an estimated 22,454 L of air/day. The white-tailed deer was selected for the WAG 6 environmental risk assessment because it is a large herbivorous mammal and is common throughout the ORR and WAG 6 environs.

There are three routes of contamination to a white-tailed deer inhabiting WAG 6. They are inhalation, ingestion, and direct exposure (IT Corp. 1990). A deer is directly exposed to contamination when it brushes against vegetation, when it lies on the ground or paws the dirt to create beds, walks through water, or brushes against vegetation that holds water. A deer is also directly exposed to the air around it. Of the three routes of contamination, as mentioned earlier in this report, ingestion is the only route for which there are data available for characterization.

### 7C.2.2 Exposure Assessment

Because cesium-137 is a radionuclide that is strongly attracted to the illitic clays that underlie WAG-6 soils, it is not readily available for uptake by plants (see Appendix 7B). Deer incidentally consume soil as they graze or browse; therefore, soil contaminated by cesium-137 becomes another source of contamination.

According to Amano and Garten (1991), plants can absorb tritium from the soil and the atmosphere. If the source of tritium is atmospheric, then it is absorbed by plant leaves by diffusional processes. If the source of tritium to the plant is soil water, plants will absorb tritium and transpire it into the atmosphere. Tritium concentrations in soil water at SWSA 5 range from 370 to 14,000 Bq/L during the growing season. Monthly changes in groundwater levels and soil water tritium concentrations indicate that tritium at this site migrates upward to the surface soil from the subsurface due to rise in groundwater levels during the wet season (Amano, Garten, and Lomax 1987). Tritium in the surface soil gives rise to tritium concentrations in the atmosphere by evaporation of surface soil water. Under conditions of chronic exposure to tritium as either liquid or vapor, an equilibrium concentration between body-water tritium and environmental tritium is rapidly attained (Elwood 1971). Deer killed at the Savannah River Plant site were found to have generally the same tritium concentrations in both their body water and tissue-bound components. Likely effects from tritium on a white-tailed deer on WAG 6 will come from ionizing radiation and not from bioaccumulation.

Strontium-90 levels in honeysuckle and blackberry were described in Appendix 7B. The significance of these concentrations is that if 45-kg deer consumed this contaminated vegetation, the strontium-90 level in deer bone could easily exceed the confiscation limit of 30 pCi/g after browsing times of 1 week to 1 year (Garten and Lomax 1987).

In the late 1950s, strontium-90 was recognized as a potential accumulator in terrestrial ecosystem components of the WOL bed. Mean concentrations in the lake bed from 1956-1960 were 0.31, 0.77, and 0.56 nCi/g dry weight, respectively (DeSelm and Shanks 1963). Strontium-90 concentrations were higher in leaves than in stems and higher in forbs and woody plants than in herbaceous plants. DeSelm and Shanks estimated that approximately

7% and 2% of the soil strontium was removed by lake bed willows and herbaceous vegetation, respectively. Much of this was recycled back onto the topsoil as accumulated litter.

Garten and Lomax (1987) report that there are few empirical data from which to derive representative plant:soil concentration ratios for strontium-90 in the WOC watershed. A plant:soil concentration ratio of approximately 1.5 is representative of strontium-90 uptake by herbaceous plants from the WOL bed and WOC floodplain. The ratio may be greater for forbs and woody browse vegetation growing on more acidic soils in the watershed.

A discussion of the biological behavior and environmental cycling of cadmium and chromium is presented in Appendix 7B. In another study, baseline data on cadmium accumulation in organs and tissues of Japanese serows showed that the mean cadmium concentration in muscle, liver, kidneys, and the whole body of fetuses was 1.0 ng/g; in fawns was 18, 29, 60, and 22 ng/g, respectively; in yearlings was 9, 51, 60, and 31 ng/g, respectively; in adults (2.5 to 10 years) was 16,130, 950, and 42 ng/g, respectively; and in adults (10 to 17.5 years) was 20,131, 1080, and 52 ng/g. The body burdens of fetuses were low (<1%) compared with those of their mothers. The placental transfer of cadmium was negligible; after birth, cadmium levels increased each year. There was a significant difference in cadmium concentrations between collection locations, which was attributed to direct intake of cadmium in the soil.

Cadmium has a strong affinity for soft body tissues, especially the kidney and liver, and in general there appears to be a positive relationship between concentrations of cadmium in the soil and in the soft tissues of small mammals. The U.S. Fish and Wildlife Service estimates that adverse effects on fish and wildlife are either pronounced or probable when cadmium concentrations exceed 3 ppb in freshwater, 100 ppb in the diet, or 100 ug $Cd/m^3$ in air (Eisler 1986). At low doses the concentration in the kidney is approximately ten times that in the liver; however, at high exposures, the concentration in the liver may exceed that in the kidneys. The tissue concentration pattern is kidney > liver > muscle > heart > bone > brain. Cadmium residues in vertebrate kidney or liver that exceed 10 ppm fresh weight or 2 ppm whole body fresh weight should be viewed as evidence of cadmium contamination; residues of 200 ppm fresh weight kidney or more than 5 ppm whole animal fresh weight are probably life-threatening to the animal (Eisler 1986).

Mammals and birds are comparatively resistant to the biocidal properties of cadmium. The lowest oral doses producing death in rats and guinea pigs ranged from 150 to 250 mg Cd/kg body weight (ppm). Sublethal effects of cadmium include growth retardation, anemia, and testicular damage (Eisler 1986). Teratogenic effects on animals appears to be higher for cadmium than for other metals. Rats subjected to >6 mg Cd/kg body weight daily during pregnancy produced fetuses with jaw defects, cleft palates, club feet, and pulmonary hyperplasia (Ferm and Layton 1981). Cadmium has also been demonstrated to have mutagenic effects. Mice injected with 3 or 6 mg $CdCl_2$/kg body weight showed changes in chromosome number 12 hours later. In assessing the carcinogenic effects of cadmium,

laboratory studies have shown that the injection of cadmium metal or salts causes malignancies at the site of injection and testicular tumors.

There are species differences in accumulation related to diet and tropic livel. At a site in Wales that was heavily contaminated with cadmium, average whole body concentrations were lowest in Microtus agrestis, an exclusive herbivore, and highest in Sorex araneus, which feeds primarily on insects, insect larvae, snails, and slugs (Talmage and Walton 1990).

In the environment, cadmium is primarily associated with the soil and apparently does not accumulate in vegetation. It is present in invertebrates such as earthworms and insects, where the concentration factor of soil:invertebrates is approximately 1.

Talmage and Walton (1990) reported that for the mouse and vole, concentration factors of kidney:soil or kidney:invertebrates were similar and ranged form 0.5 to 1.5. An exception occurred at a site where cadmium was deposited directly on the vegetation. Here concentration factors of kidney:soil and kidney:vegetation were 2.7 and 11.7, respectively, for the vole. In Wales, where voles from abandoned metalliferous mines had elevated cadmium levels in kidney and lever tissue, Johnson et al. (1979) stated that the metal levels in herbaceous vegetation samples were indicative of dietary metal intake by voles.

For the shrew, concentration factors for liver and kidney compared to soil or invertebrates ranged from 15 to 33 (Talmage and Walton 1990). Wren (1986) found that while cadmium levels in soft tissues were highly correlated with levels in soil and vegetation, cadmium levels in bone were not related to environmental concentrations. Furthermore, Andrews, Johnson, and Cooke (1984) postulated that cadmium in insects may be in a more biologically available form than that in vegetation.

Shrews consume approximately their body weight (22 g) each day, with their diet consisting primarily of earthworms (32%), slugs/snails (22%), insect larvae (19.5%), and adult insects (16.5%). At a mine site in Wales where concentration of cadmium in the soil was 92 ppb, the whole body concentration in a shrew (Sorex araneus) was 40 ppb and in its invertebrate prey was 19 ppb. Total body concentration of cadmium:diet in S. araneus was 2.2. At another contaminated site, concentrations of cadmium in liver tissue of shrews averaged 236 ppb and 280 ppb.

Deficient intake of some essential nutrients may increase the absorption rate of cadmium. For example, some essential elements including zinc and copper do not bioaccumulate in mammalian tissue relative to environmental levels as do some non-essential elements such as cadmium, lead, and mercury. Moreover, the relative influence of sex and age on metal accumulation and retention is not clear, but only cadmium levels appear to consistently increase with age.

Freshwater biota are most sensitive to cadmium; concentrations of 0.8 to 9.9 ugC/L (ppb) were lethal to several species of aquatic insects, crustaceans, and teleosts, and concentrations of 0.7 to 5.0 ppb were associated with sublethal effects such as decreased growth, inhibited reproduction, and population alterations (Eisler 1986). In oysters held for 40 weeks in flowing seawater containing 5 ppb of Cd, edible meats contained 13.6 ppm Cd fresh weight, a level considered an emetic threshold for human consumers. These oysters retained virtually all accumulated Cd (12.5 ppm) during a 16-week posttreatment immersion in clean seawater. Emetic thresholds were surpassed in 5 weeks at 25 ppb and in 2 weeks at 100 ppb.

### 7C.2.3 Contaminant Effect

#### 7C.2.3.1 Chromium

The biological implications of metal pollution are not necessarily related to the abundance of contaminants but rather to their transfer potential and mobility within terrestrial ecosystems. Chromium, for instance, is most frequently found in the environment in the trivalent and hexavalent oxidation states. In general, the toxicity of trivalent chromium to mammals is low because its membrane permeability is poor and it is noncorrosive; furthermore, there is little tendency for trivalent chromium to bioaccumulate in food chains in the organic form (Eisler 1986). Organo-trivalent chromium compounds may have significantly different accumulation tendencies although little is known about these compounds (Steven et al. 1976). Hexavalent chromium is more toxic than the trivalent form, and it easily penetrates biological membranes (Steven et al. 1976; Taylor and Parr 1978; Langard and Norseth 1979; Ecological Analysts, Inc. 1981). However, Taylor and Parr (1978) found a low assimilation rate and a rapid initial loss of hexavalent chromium by cotton rats, suggesting the nonessential nature of the element and indicating the lack of bioaccumulation.

Little is known about the relation between concentrations of total chromium in a given environment and the biological effects on the organisms living there (Eisler 1986). Depending upon the physical and chemical state of the chromium, its concentration has a wide variety of mobilities and reactivities and, thus, has different effects (Steven et al. 1976). Chromium toxicity to aquatic biota is significantly influenced by abiotic variables such as hardness, temperature, pH, and salinity of water and biological factors such as species, life stage, and potential differences in sensitivities of local populations (Ecological Analysts, Inc. 1981).

Data on the environmental cycling of chromium are lacking, but it is generally agreed that suspended particulates are a major source of transport in aquatic systems, that most chromium in soil and sediment is unavailable to living organisms, and that hexavalent chromium in air and water is hazardous to fish and wildlife (Eisler 1986).

Studies conducted in India showed that a concentration of 10 to 15 ppm of hexavalent chromium in irrigation water applied to soils was lethal to two species of earthworms in 58 to 60 days (Soni and Abbasi 1981; Abbasi and Soni 1983).

Acute and chronic adverse effects of chromium to warm-blooded animals are caused mainly by hexavalent chromium compounds. The LD-50s for mice were 260 mg/kg body weight for trivalent chromium, but only 5 mg/kg for hexavalent chromium (Steven et al. 1976). For most mammalian experimental animals including mice, dogs, rabbits, cats, and guinea pigs, the minimum injected fatal dose of hexavalent chromium ranged from 1 to 5 mg/kg body weight although doses of 0.2 to 0.5 mg/kg body weight produced marked kidney damage.

Under laboratory conditions, chromium is mutagenic, carcinogenic, and teratogenic to a wide variety of organisms (Eisler 1986). Teratogenic effects were documented in chicken embryos after eggs were injected with hexavalent chromium. Deformities included short and twisted limbs, microphthalmia, exencephaly, everted viscera, growth stunting, and parrot beaks (Ridgeway and Karnofsky 1952; Gilani and Marano 1979). In rabbits, both trivalent chromium and hexavalent chromium, given 1.7 mg/kg body weight daily for 6 weeks, adversely affected blood and serum chemistry and both produced significant morphological changes in liver (Tandon et al. 1978). Similar effects were observed in rats (Laj, Jain, and Tandon 1984). Hexavalent chromium compounds may cause skin ulceration, irritative dermatitis, ulcerations in mucous membranes, and perforations in the nasal septum. Kidney and liver lesions in rats were observed when the drinking water contained 134 ppm of hexavalent chromium for 2 to 3 months (Steven et al. 1976). Tissue accumulations were significant in dogs exposed to drinking water concentrations of 11.2 ppm chromium but were nil at 6 ppm. Although both trivalent chromium and hexavalent chromium accumulated in brain, kidney, and myocardium of rabbits, the accumulation of hexavalent chromium was highest in brain and that of trivalent chromium in the kidney; for both valence states there was no correlation between dose and concentration of stored chromium or extent of tissue damage (Hatherill 1981).

Taylor and Parr (1978) found that concentrations of chromium in pelt, hair, and bone of cotton rats trapped near the cooling towers at Oak Ridge Gaseous Diffusion Plant were significantly higher ($P<0.01$) than concentrations in control animals. Chromium in pelt and hair resulted from direct deposition of drift or removal from plant materials during feeding or during movements along pathways. Increased concentrations within tissues or organs likely resulted from dietary intake. Chromium is an essential trace element to some mammalian species, and irreversible metabolic damage may result from long-term deficiency. Increased chromium levels may produce deleterious effects. However, cotton rats had a low assimilation rate (0.8%) and rapid initial loss of hexavalent chromium, suggesting that it is nonessential in this species.

In aquatic systems, chromium seldom exceeds 0.3 mg/kg fresh weight in edible crustacean tissues (Eisler 1981). The highest value reported was 0.6 mg Cr/kg fresh weight

for rock crab collected near an ocean dump receiving large quantities of metals. Tennant and Forster (1969) reported that chromium concentrated in setae, gills, and hepatopancreas of Dungeness crab and suggested that surface adsorption and physiological processes were both instrumental in chromium accumulation.

One of the principal effects of chromium contamination in aquatic systems is damage to shells. Massive cuticular lesions suggestive of shell disease characterized up to 30% of the lobsters, crabs, and shrimp collected from the New York Bight, where chromium concentrations greater than 100 ppm have been recorded. Chromium apparently interferes with the normal functions of subcuticular epithelium, particularly cuticle formation, and subsequently causes structural weaknesses or perforations to develop in the cuticle of newly molted shrimp. These chromium-induced exoskeleton deficiencies provide an avenue for pathogenic bacteria and direct chromium influx that perpetuates the development of the lesion. This shell syndrome was induced in 41% of grass shrimp (Palaemonetes pugio) during exposure to 0.5 ppm of hexavalent chromium for 28 days.

The significance of chromium residues is unclear, but available evidence suggests that organs and tissues of fish and wildlife that contain >4 mg total Cr/kg dry weight should be viewed as presumptive evidence of chromium contamination (Eisler 1986).

### 7C.2.3.2 Radionuclides: strontium-90, cesium-137, and tritium

As with metals, radionuclides are transferred through components of ecosystems, often collecting in target tissues. The most significant radionuclide released by the water pathway is strontium-90 because of its radiotoxicity, environmental availability, and the quantities released at ORNL (Ohnesorge 1986). Other significant radionuclides are tritium, cesium-137, and the transuranics. Strontium-90 can be uptaken by both plants and animals, accumulating in various plant tissues and in bone tissue in animals. It is a beta-emitting fission product with a relatively long half life (28 years). As a metallic analog of calcium, it is readily absorbed from the gastrointestinal tract and lungs into the bloodstream and deposited in bone. In experimental animals, chronic ingestion of strontium-90 resulted in leukemia and bone tumors.

As part of the Biological Monitoring and Abatement Program, Loar et al. (1988) found that all field collected mammals from SWSA 4 and the WOC floodplain had detectable levels of strontium-90 in bone tissue. Highest levels were found in Eastern harvest mice (Reithrodontomys humilis), which were trapped in the grass immediately adjacent to the seeps in SWSA 4 and feed primarily on seeds found in the fescue grass that they inhabit. Levels ranged from 10,000 Bq/kg dry weight of bone to 281,000 Bq/kg, with the mean being 71,500 Bq/kg. Two pine voles (Microtus pinetorum) trapped at SWSA 4 had strontium-90 levels of 1450 Bq/kg and 31,810 Bq/kg, illustrating that this species is also capable of bioaccumulating this contaminant.

Although tritium also has the potential for marked uptake by terrestrial vegetation, it does not appear to bioaccumulate in the environment or in food chains (Shoup 1976). The transfer coefficient for tritium from soil to vegetation is 0 (Argonne National Laboratory 1989), indicating that this radionuclide is not taken up by the roots of plants. In a study of the kinetics of tritium accumulation in adult rats, Istomina and Moskalev (1972) found that with chronic intake of varying activities, an equilibrium was established for intake, accumulation, and elimination of $^3$HOH within the organism by day 20. After administration ceased, 98.6 to 99% of the $^3$HOH was eliminated with a half-life of 3 to 4.3 days.

Because cesium-137 becomes tightly bound to the clay fraction of the soil, the major portion of radioactivity accumulated by earthworms was ingested. The daily turnover of soil is equal to 29% of the live weight of the worm. No detectable cesium-137 was assimilated from tagged soil ingested by earthworms. In addition, assimilation of radiocesium from litter by earthworms appears to be much lower than for arthropods (Crossley, Reichle, and Edwards 1971). These earthworms and arthropods may then be consumed by small mammals, adding to the exposure pathways for contaminant transport in the ecosystem. In a study of consumption of radioactively labeled pine seeds by small mammals, Mathies et al. (1972) reported body burdens of cesium-137 in pine voles ranging from $5.89 \times 10^3$ to $13.37 \times 10^3$ dpm/g, indicating a significant uptake of radioisotopes.

Small mammals may be an important vector for radioactive transport because of their burrowing activity, mobility, and potentially high population numbers. In addition to animals becoming contaminated and transporting radionuclides to the surface, other potential problems are increased water infiltration due to excavations, soil erosion processes, and increased water holding capacity. These could result in increased deterioration of disposed waste containers (Arthur et al. 1986; Arthur and Markham 1983). Ninety-six percent of mice in waste disposal areas in southeastern Idaho had higher radiation doses than did control animals in fall-winter; in spring-summer, 73% of the mice had higher dose rates than the controls. These seasonal differences appear to be related to increased subsurface time in colder weather. The autumn-winter dose rates received by kangaroo rats were significantly greater than the spring-summer rate. This seasonal difference was attributed to the species entering torpor beneath the soil surface during winter (Arthur et al. 1986).

Arthur et al. (1986) found that radiation dose rates received by animals from radioactive waste disposal areas varied from 0.4 to 42,000 mrad/day and were significantly higher than the dose rate of 0.4 mrad/day received by control animals. Doses resulted primarily from radiation from buried activation and fission products and not from radionuclides in/on tissues. The higher dose rates received by deer mice over those received by kangaroo rats were likely a result of more frequent habitation or deeper burrowing and subsequent higher radiation exposure from disposed waste or contaminated soil. The highest doses received by small mammals were of sufficient magnitude to cause premature deaths. French et al. (1974) found chronic yearly doses of 2.11 - 3.60 Gy sufficient to increase the death rate. At Idaho National Engineering Laboratory deer mice and kangaroo rats received annual median dose rates of 7300 $\mu$Gy and 3190 $\mu$Gy. Previous studies on the physiological effects of radiation

on mice suggested that acute (0.02 Gy) and chronic (0.001 Gy) exposures caused loss of body weight and a decrease in the weight and size of spleen and adrenal glands.

Kaye and Dunaway (1962) found that concentrations of strontium-90 were higher in teeth and bone of muskrats than in stomach contents, indicating that this radionuclide, as an analog of calcium, is accumulated in tissues to concentrations exceeding those in the diet.

While higher trophic levels generally have higher contaminant levels, concentrations of radionuclides can also be diluted as trophic level increases. In a study at Idaho National Engineering Laboratory, concentrations of radionuclides were much lower in red-tailed hawks, who inhabit large home ranges, than in their prey items, indicating that while radionuclides were transferred to higher trophic levels, concentration was diluted by consumption of uncontaminated animals (Craig, Halford, and Markham 1979). In fact, it was found that the mean concentration of radionuclides in rodents was approximately 4 to 290 times greater than in the raptors that preyed upon them.

Crayfish are a major component of the diet of raccoons, which ingest the soft tissues and digestive tract. Tanner (1964) found that crayfish from White Oak Creek had cobalt-60, ruthenium-106, and cesium-137 associated with their exoskeletons. Furthermore, Schurr and Stamper (1962) found that 90% of the strontium-85 found in crayfish was in the exoskeleton. Not only was 55-80% of the available strontium-85 retained in the body tissues after molting in young-of-the-year (Momot, Gowing, and Jones 1973), but uptake of strontium-85 was enhanced in recently molted crayfish (Schurr and Stamper, 1962).

### 7C.2.3.3 Volatile organic compounds

Xylene (total) is designated as a hazardous substance under Sect. 311(b)(2)(A) of the Federal Water Pollution Control Act and further regulated by the Clean Water Act Amendments of 1977 and 1978. Most xylenes are released into the atmosphere where they photochemically degrade by reacting with hydroxyl radicals. Their half-life ranges from 1 to 1.7 hours in summer and 10 to 18 hours in winter, or a typical loss of 67 to 86% per day. In water the dominant removal process is volatilization. Xylenes are moderately mobile in the soil and may leach into groundwater where they may persist for years, despite some evidence that they biodegrade in both soil and groundwater. The potential for bioconcentration is expected to be insignificant.

Xylenes are absorbed primarily through the mucous membranes and pulmonary system, where they are metabolized to a toxic aldehyde, methylbenzaldehyde. However, almost total excretion via the urinary tract occurs within 24 hours. The plasma half-life is 4 hours, and this rapid clearance from blood prevents adequate biological monitoring of serum. The LD50 for ingestion by rats is 4.3g/kg. The LC50 for rat inhalation is 6350 ppm/4 hr and for mouse inhalation is 3907 ppm/6 hr. In human studies, known toxic effects include fetotoxicity, hepatomegaly, hyperactivity, decreased body weight, increased mortality at higher dosages, central nervous system effects, and nose and throat irritation (EPA 1990b).

Like xylenes, toluene is designated as a hazardous substance under Sect. 311(b)(2)(A) of the Federal Water Pollution Control Act and further regulated by the Clean Water Act Amendments of 1977 and 1978. As a toxic pollutant under Sect. 307(a)(1) of the Clean Water Act, it is subject to effluent limitations. The recommended Ambient Water Quality Criterion to protect freshwater aquatic life is 2300 $\mu$g/L as a 24-h average, with a ceiling of 5200 $\mu$g/L.

Toluene volatilizes rapidly from water; the expected evaporation half-lives from a river and lake are 1 and 4 days, respectively. It completely degraded in groundwater in 8 days in one study while other investigators found that only 1 to 2% degraded in the subsurface environment and more than 90% degraded in four weeks in soil cores at various depths both above and below the water table. Because of its high vapor pressure, toluene is also expected to volatilize fairly rapidly from dry soils. In the atmosphere, toluene degraded by reaction with photochemically produced hydroxyl radicals with a half-life of slightly more than a day and a degradation rate of 41%/day.

Toluene vapor is readily absorbed by inhalation and the liquid by the gastrointestinal tract; however, it is absorbed poorly by the skin. No simple relationship exists between uptake rate and peripheral venous concentration, indicating that no calculation can be made for toxic doses to internal organs. In dogs subjected to inhalation, the highest concentrations were found in the adrenals, brain, and bone marrow. Following a single intraperitoneal administration of carbon-14 labelled toluene (290 $\mu$g/kg) to mice, the highest level of radioactivity was found in adipose tissue, followed in descending order by kidney, liver, and lung. The distribution of radioactivity in pregnant mice was measured at different time intervals (0 to 24 hrs) after a 10-minute period of inhalation of toluene. Toluene reached high concentrations immediately after inhalation in lipid-rich tissues (brain and fat) and well-perfused organs (liver and kidney) but was rapidly eliminated resulting in low concentrations at 1 hr in all maternal tissues except fat.

Tetrachloroethylene is designated as a toxic pollutant under Sect. 307(a)(1) of the Clean Water Act. When tetrachloroethylene is released to soil, it is subject to evaporation into the atmosphere and leaching into the groundwater. Photooxidation occurs in the atmosphere when tetrachloroethylene reacts with hydroxyl radicals that are produced by sunlight in the troposphere; it has an estimated half-life of about 2 months or a loss of 1.5% per sunlit day. In anaerobic soils, there is evidence that slow biodegradation of tetrachloroethylene may occur when microorganisms have been acclimated, yielding trichloroethylene as a product. In fact, tetrachloroethylene can be transformed by reductive dehalogenation to trichloroethylene, dichloroethylene, and vinyl chloride in anaerobic conditions. Because of its high vapor pressure (18.47 mm Hg at 25°C) and low adsorption, volatilization of tetrachloroethylene from dry soil should be rapid. If tetrachloroethylene is released to water, it will rapidly volatilize, with estimated half-lives ranging from less than one day to several weeks. Tetrachloroethylene is expected to exhibit low to medium mobility in soil, allowing it to leach slowly into groundwater. It is also slightly adsorbed on sand and clay minerals.

Tetrachloroethylene is readily absorbed through the lungs and to a much slower degree through skin or mucous membranes or following ingestion. Metabolism is relatively slow with only a small amount of the dose being excreted as metabolites, the primary of which is trichloroacetic acid. Elimination through exhalation is slow (biological half-life of 65 hours for exhaled tetrachloroethylene) because of continuing release of tetrachloroethylene from fat stores, where it tends to distribute once in the bloodstream. Male Sprague-Dawley rats exposed to tetrachloroethylene by either gavage (1.0 mg/kg) or inhalation (10 ppm) excreted 70% of the dose unchanged in expired air. Approximately 3% was excreted as carbon dioxide and approximately 23% was excreted in the urine and feces as nonvolatile metabolites. The hepatoxicity of both tetrachloroethylene and trichloroethylene in mice is directly related to the extent of their metabolism. Four parameters of hepatoxicity were assessed: liver weight, triglycerides, glucose-6-phosphatase activity, and serum glutamic-pyruvic transaminase activity; tetrachloroethylene affected all four parameters. Intubation of rats with mixtures of benzene and tetrachloroethylene yielded a combined toxicity which was only slightly less than additive; however, mixtures of toluene with tetrachloroethylene resulted in LD50 values of less than predicted for simple additivity, indicating synergistic effects. In another study of adverse effects of tetrachloroethylene, it was shown to release lysosomal enzymes from granular fractions prepared from nematodes. The gut of nematodes seems to be specialized for lysosomal intracellular digestion of nutrients, and tetrachloroethylene may interfere with this activity.

Trichloroethylene is designated as a hazardous substance under Sect. 311(b)(2)(A) of the Federal Water Pollution Control Act and Sect. 307(a)(1) of the Clean Water Act as well as the Clean Water Act Amendments of 1977 and 1978.

Once in the environment, trichloroethylene is fairly persistent. It is not hydrolized by water under normal conditions. In laboratory studies, trichloroethylene does not appear to biodegrade in groundwater. However, in field studies, cis- and trans-1,2,-dichloroethylene were detected in monitoring wells near trichloroethylene-contaminated sites, suggesting that biodegradation was occurring. Only a few studies have noted significant aerobic biodegradation of trichloroethylene, but acclimation was slow. Biodegradation under anaerobic conditions has been noted and ranged from very little after 12 weeks to 40% after 8 weeks. Trichloroethylene has a low adsorption coefficient (log Koc = 2.0) to a number of soil types, which indicates ready transport through soil and low potential adsorption to sediments. Because trichloroethylene does not adsorb light less than 290 nm, it should not directly photodegrade. However, slow (half-life 10.7 months) photo-oxidation in water has been noted.

Trichloroethylene is an uncharged, nonpolar, and highly lipophilic compound that can be expected to cross the gastrointestinal mucosa by passive diffusion. It is a probable human carcinogen and is known to significantly increase the incidence of liver tumors, malignant lymphomas, and pulmonary adenocarcinomas in mice. The metabolism of trichloroethylene in rats involves oxidation by the liver, producing an epoxide intermediate, which binds covalently to proteins and causes centrilobular damage to the liver. A comparison of

metabolized trichloroethylene on a weight basis indicated that the mouse metabolized 2.2 times more than the rat at 10 ppm and 3.6 times 600 at ppm. Studies with rats indicated that the effects of trichloroethylene were more pronounced in animals that were fed a high carbohydrate diet than those on a high protein diet.

# APPENDIX 7D. EXPOSURE AND TOXICITY ASSESSMENTS FOR AQUATIC SPECIES

The exposure and toxicity assessments for aquatic species is based upon evidence from the scientific literature of the effects of the selected contaminants on the same or similar species. Appendix 7D presents a review of the literature on which this environmental evaluation is based.

## 7D.1 EXPOSURE ASSESSMENT—AQUATIC VERTEBRATES

### 7D.1.1 Factors Affecting Transport and Bioavailability

The mobility and toxicity of cadmium, copper, strontium-90, and cesium-137 are related primarily to the amount of the free metal ions in the water, and possibly some hydroxy or other bioavailable complexes. Therefore, factors that reduce the proportion of free ions and exchangeable cations of these elements reduces the mobility, and generally the toxicity, of these metals and radionuclides. For example, cesium-137 has a high affinity for sediments, especially clays (Klechkovskii, Polikarpov, and Aleksakhin 1973), and in the surface water systems at ORNL this radionuclide is held irreversibly to the illitic minerals in the sediments (Cerling and Spalding 1981; Huff 1986). Its movement in the surface water environment, therefore, reflects sediment transport mechanisms and movement of suspended particulates in the water column. Copper, cadmium, and strontium-90, on the other hand, are relatively soluble in water and exist as free ions or exchangeable cations that are bioavailable. Adsorption to clays and humic materials, however, may remove some proportion of these elements from the water column. Generally, the higher the distribution coefficients are for these elements (between sediments and water), the more effective adsorption processes are in reducing their concentrations in the water column. Humic materials in bottom sediments are one of the main components responsible for adsorption of cadmium and possibly copper. Changes in physicochemical conditions such as pH and the redox potential can also effect the proportion of cadmium, copper, and strontium-90 in the water column versus in the sediments and suspended particulates (Eisler 1985; Klechkovskii, Polikarpov, and Aleksakhin 1973).

Water hardness has a major effect on the toxicity of cadmium and copper. This effect may be due to the complexing capacity of the natural waters (Davies and Woodling 1980) or actual competition between calcium and cadmium/copper for binding sites (Versteeg and Giesy 1986). An increase in hardness from 50 to 200 mg/L (as $CaCO_3$) can reduce the toxicity of cadmium and copper by an order of magnitude or more (Eisler 1985; EPA 1986). Several investigations have stated that hardness may not be the only factor influencing the toxicity of metals. Winner and Gauss (1986) found that humic acid was also important and EPA (1985) stated that total organic carbon may be more important than hardness in some situations. Alkalinity, temperature, and pH may also influence the toxicity of cadmium and copper and the bioavailability of strontium-90.

Benzene, toluene, and xylene are among the more toxic components in the water soluble fraction of refined petroleum products. These low molecular weight hydrocarbons,

however, volatilize relatively quickly in surface water systems. For example, Jori et al. (1986) estimated that the mean residence time for xylene was 30 minutes, assuming a flowing water system 1 meter deep. During bioassay tests with six monocyclic aromatics, Benville and Korn (1977) observed 30 to 50 percent losses within 48 hours and 60 to 90 percent within 72 hours. These monocyclic aromatics are also sorbed onto suspended particulates and sediments, especially by organic matter. Toluene and xylenes are degraded rather rapidly in the atmosphere by photo-induced oxidation (Jori et al. 1986), and this process also occurs in near-surface zones in clear surface waters. Biodegradation processes in soil and sediments may be more important than adsorption in removing toluene and xylene from natural ecosystems.

The uptake (i.e., bioavailability) of cesium-137 and strontium-90 from water by living organisms is closely linked to the concentrations of their nonisotopic carriers, potassium and calcium respectively. Cesium-137 acts chemically very much like potassium, and the accumulation of cesium-137 by aquatic plants and animals is inversely related to the concentration of potassium in the water. Similarly, the uptake of strontium-90 is inversely related to calcium concentration. Therefore, in aquatic ecosystems, the bioconcentration factors of cesium-137 and strontium-90 will be lower in waters with high concentrations of calcium and potassium. The influence of potassium on cesium-137 uptake is most important for the primary producers (algae and macrophytes), while factors that influence uptake via food chains (such as feeding rates and assimilation/elimination) are more important in the uptake of cesium-137 by secondary and higher consumers.

### 7D.1.2 Sensitive Populations

Sexual maturity is attained within 1 to 2 years and the adults live for a few years (fathead minnows) to several years (bluegills). The scientific literature indicates that for bluegills and fathead minnows (and several other species), the most sensitive life stage to metal and organic contaminants is the early larvae. The embryo and adult fish are generally the most tolerant (Benoit 1975; McKim 1977; Eaton, McKim, and Holcombe 1978; Fisher, Dilego, and Paulos 1984; Devlin, Brammer, and Puyear 1982). This holds true for cadmium and copper and the simple monocyclic aromatics. The early larval stage is not necessarily the most sensitive stage for all metals or other contaminants, and early life stage mortality is not necessarily the most sensitive indicator of toxicity.

Field and laboratory studies have indicated that some aquatic organisms may be more tolerant of metal contaminants if they have been residing in a system with elevated metal concentrations (Davies and Woodling 1980; EPA 1985; Bishop and McIntosh 1981). Acclimation to copper and cadmium toxicity generally requires protracted exposure to sublethal concentrations for days or weeks, and fish may become unacclimated if transferred to clean water for several weeks (Mance 1987). Acclimation in some cases may be related to the induction of metal-binding proteins or storage of the contaminants in various non-toxic forms (EPA 1985).

Fish are apparently capable of metabolizing toluene and xylene in the liver, storing metabolites in the gall bladder, and excreting these substances via the gut (Berry 1980; Berry

and Fisher 1979). Aquatic organisms with the ability to metabolize the aromatic hydrocarbons and produce nontoxic metabolites would be less vulnerable to the toxic effects of these organic compounds.

There is a relatively wide variation in the sensitivity of different fish species to metals, and to a lesser extent, to organics. For example, salmonid teleosts such as brook trout and Atlantic salmon are about 10 times more sensitive to cadmium than sunfish and minnows. There is little difference in the sensitivities of bluegills and fathead minnows to cadmium, copper, toluene, or xylene.

There is very little information in the scientific literature concerning the relative sensitivities of different biotic subpopulations (such as life stage or size) to the harmful effects of radiation. Generally, simpler forms of life such as bacteria and algae are more resistant than the more complex plants and animals. Bacteria are especially resistant to ionizing radiation (Klechkovskii, Polikarpov, and Aleksakhin 1973). King (1964) stated that humans are at least twice as sensitive as fish to roentgen dosages.

Several investigators have studied the effect of radionuclides on fish eggs. They presented the effects of radiation on fish embryos, but the data on sensitivities of fish eggs relative to other life stages or fish species are very variable (Klechkovskii, Polikarpov, and Aleksakhin 1973). Kolehmainen (1972) found that the concentration of cesium-137 in bluegills in WOL increased with size up to 70g, apparently because assimilation of the radionuclide from food increased and elimination decreased with size. Thus, older fish would be more at risk because of higher body burdens as well as longer exposure. Fish species with shorter life cycles and higher reproductive potential are less susceptible to the harmful effects of radiation because of shorter exposure and the ability to cope with reduced fertility and/or fecundity (Krumholtz 1954).

## 7D.2 TOXICITY ASSESSMENT—AQUATIC VERTEBRATES

### 7D.2.1 Mode of Action

Elevated concentrations of cadmium, copper, toluene, and xylene can affect fish through various mechanisms. In some cases, the specific biochemical or physiological process is known, and in other cases, the observable reaction by the fish may be measured, such as a change in ventilatory activity, but the specific mechanism or cause is unknown.

Toluene and xylene, like many organic chemicals used in industry, produce a nonspecific narcosis effect on fish. Narcosis is a reversible condition up to a point, but prolonged exposure may cause death (Veith, Call, and Brooke 1983; Broderius and Kahl 1985). Several investigators also observed initial behavioral changes (swimming activity) early in the exposure period, and with benzene compounds the fish exhibited erratic swimming behavior just prior to death (Broderius and Kahl 1985; Fisher, Dilego, and Paulus 1984; Norton, Mattie, and Kearns 1985). Exposure to aromatic hydrocarbons such as toluene during the embryo stage was observed to cause developmental abnormalities and premature hatching.

Heavy metals such as cadmium and copper can affect behavior, may interfere with or inhibit biochemical processes, can cause structural damage to tissues, and have teratogenic effects. Cadmium at relatively high concentrations can coagulate the mucous covering on the gill membranes, thereby inhibiting oxygen transport into the blood (Doudoroff and Katz 1953). Sublethal concentrations of both copper and cadmium over long exposure periods are known to cause structural damage to gill tissue (Dallinger et al. 1987; Versteeg and Giesy 1985, 1986). Many of the metals can interfere with biochemical processes, and inhibition of enzyme systems is the specific cause for some of these effects. Different metals, however, generally affect different enzyme systems. Copper, for example, can alter the production of high energy phosphate bonds by disrupting enzymes involved in oxidative phosphorylation, and can also disrupt osmoregulation by inhibiting active transport of salts across the gill membrane. Cadmium disrupts normal lysosome membrane activity (Versteeg and Giesy 1985), and both cadmium and copper may interfere with metabolic processes in liver mitochondria.

Chronic exposure to cadmium and copper can produce changes in behavior and ventilatory activity at concentrations well below those causing death (Bishop and McIntosh 1981; Diamond, Parson, and Gruber 1990; Ellgaard and Guillot 1988; Ellgaard, Tusa, and Malizia 1978). Changes in the frequency and amplitude of breathing and frequency of coughing have been observed by several investigators, and these responses may be directly proportional to the metal concentration (Bishop and McIntosh 1981). While several metals, including cadmium and zinc, cause hyperactivity, copper induces hypoactivity. These results indicate that copper causes a decrease in metabolic rate while cadmium increases metabolic processes. This agrees with studies that show that copper causes a decrease in production of high energy phosphate bonds (Heath 1984).

The selected radionuclides at WAG 6, cesium-137 and strontium-90, are potentially harmful to fish because they bioconcentrate in internal tissues and may become significant internal sources of ionizing radiation. Therefore, the mode of action is the same as the effect of radiation on humans. At high dosages, usually from external sources, radionuclides can cause acute mortality. King (1964) and Foster et al. (1949, cited by Krumholtz 1954) observed fish mortalities at exposures of 1000 to 3000 roentgens. However, the effect of radionuclides in most cases, including the impact of cesium-137 and strontium-90 at ORNL, is more chronic. Krumholtz (1954) noted that exposure to radionuclides resulted in malformed ova and reduced growth rates. Ionizing radiation can cause genetic mutations, chromosomal aberrations, abnormal development, and reduced reproductive success (Klechkovskii, Polikarpov, and Aleksakhin 1973; King 1964). The effect of specific radionuclides, however, is impossible to measure in natural environments because the radiation from multiple radionuclides, both external and internal, is cumulative to some extent.

### 7D.2.2 Toxicity of Contaminants

Several different toxicity values are presented to assess the toxicity of the selected contaminants to freshwater fishes. These include the U.S. EPA ambient water quality criteria for the protection of aquatic life, acute toxicity values from several studies, and various

measures of chronic toxicity. Acute toxicity is most frequently expressed as the concentration of a contaminant that will be lethal to 50 % of the test population within a given time period, such as 96 hours (96 hour $LC_{50}$). Some of the more standard expressions of chronic toxicity include the highest concentration of a contaminant that results in no observable effect (the NOEL), and the lowest concentration of a contaminant that produces a significant difference between test and control populations (the LOEL). These two values theoretically bracket the "safe" concentration for that contaminant. The term "chronic" usually implies long duration, low severity, and high sensitivity, and is measured in numerous ways. Therefore, chronic toxicity is usually expressed as the concentration that produces some measurable response (e.g., decreased growth) over a defined exposure period. The harmful effect of radionuclides is expressed as a radiation dose.

### 7D.2.2.1 Ambient water quality criteria

EPA (1986e) has established acute and chronic ambient water quality criteria for cadmium and copper, and acute criteria for benzene and toluene. Freshwater organisms (both fish and macroinvertebrates) and their habitat should not be affected unacceptably if the acute (Criterion Maximum Concentration, a 1-hour average) and chronic (Criterion Continuous Concentration, a 4-day average) criteria are not exceeded more than once every 3 years. These criteria are presented in Appendix 7B.

### 7D.2.2.2 Acute and chronic toxicity of cadmium

Some acute toxicity values for cadmium to bluegills and fathead minnows are presented in Appendix 7B. All values are for 96-hour $LC_{50}$s. Eisler (1985), Mance (1987), Suter, Vaughan, and Gardner (1983), and other investigators present $LC_{50}$s and $LC_{10}$s for time periods of 24 hours to a month or more. Note that an increase in hardness can change the $LC_{50}$ by an order of magnitude or more. The lowest acute toxicity value was 13.2 $\mu$g/L, for the larval life stage of fathead minnow in soft water (Spehar and Fiandt 1986). Generally, concentrations acutely toxic to bluegills and fathead minnows ranged between 340 and 21,100 $\mu$g/L and varied with life stage, water hardness, and other variables.

The concentrations of cadmium that are chronically toxic to bluegills and fathead minnows are shown in Appendix 7B. Fathead minnows may be slightly more sensitive to cadmium than bluegills, with chronic toxicity values between 57-110 $\mu$g/L. However, cadmium at 5 $\mu$g/L produced lethal effects when mixed with five other metals in experiments by Spehar and Fiandt Appendix 7B. Concentrations chronically toxic to bluegills generally ranged between 50 and 250 $\mu$g/L, but concentrations as low as 4 $\mu$g/L induced changes in ventilatory response (Diamond, Parson, and Gruber 1990). The larvae are probably the most sensitive life stage to metal contaminants. For larval fathead minnow, the NOEL and LOEL are 37 and 57 $\mu$g/L, respectively (Pickering and Gast 1972). For bluegills the NOEL and LOEL were reported by Eaton (1974) as 31 and 80 $\mu$g/L.

### 7D.2.2.3 Acute and chronic toxicity of copper

Copper concentrations that are acutely toxic to bluegills and fathead minnows are shown in Appendix 7B. As with cadmium, fathead minnows may be slightly more sensitive to copper than bluegills. Copper concentrations causing 50 percent mortality over a 96-hour exposure period ranged between 75 and 1,000 $\mu$g/L for fathead minnows and between 740 to over 4,000 $\mu$g/L for bluegills. Copper was more toxic in soft water, and the larvae of both species are more sensitive than the adults. Copper concentrations as low as 18.4 $\mu$g/L were reported to be chronically toxic to fathead minnows larvae in soft water (Mount and Stephan 1969); concentrations as low as 40 $\mu$g/L reduced growth and survival in bluegills (Appendix 7B). The NOEL and LOEL for copper for juvenile bluegills were reported as 21 and 40 $\mu$g/L by Benoit (1975), and for fathead minnow larvae as 31 and 80 $\mu$g/L by Pickering, Brungs, and Gast (1977). Mount and Stephan (1969) reported NOEL and LOEL values for fathead minnow fry of 10.6 and 18.4 $\mu$g/L.

### 7D.2.2.4 Acute and chronic toxicity of benzene, toluene, and xylene

Toxicity tests by several investigators using fathead minnows and bluegills indicate that concentrations of toluene and benzene between 13 and 42 mg/L are acutely toxic to larval and juvenile fish (Appendix 7B). Concentrations between 57 and 72 mg/L were acutely toxic to fathead minnow embryos. Devlin, Brammer, and Puyear (1982) and Moles, Rice, and Korn (1979) found that the embryo life stage was relatively tolerant to the monocyclic aromatics, while early larvae were more sensitive. The more highly substituted benzenes are more toxic than toluene and xylene. The potencies of the chlorinated toluenes correlated closely with log octanal/water partition coefficients, and the toxicities of substituted benzenes can be predicted based on Quantitative Structure Activity Relationships (QSAR) (Babich and Barenfreund 1987; Hall, Maynard, and Kier 1989).

Data on chronic toxicity of benzene, toluene, and xylene are limited probably reflecting the high volatility of these low molecular weight aromatics. In shallow freshwater systems, toluene and xylene would be reduced significantly within 2 or 3 days as they evaporate into the atmosphere. Chronic toxicities for toluene and benzene between 5 and 45 mg/L (Appendix 7B) have been reported by Devlin, Brammer, and Puyear (1982), Berry (1980), and Fisher, Dilego, and Paulos (1984). Jori et al. (1986) proposed a provisional water quality criterion of 0.02 mg/L for xylenes as a "safe level" for aquatic organisms in light of the limited chronic toxicity data in the literature.

### 7D.2.2.5 Harmful effects of cesium-137 and strontium-90

To estimate the effects of radiation on aquatic organisms at WAG 6, at least six pieces of information are needed. These include: 1) the concentration of each radionuclide in the water, 2) the capacity of the organisms to concentrate the respective radionuclides, 3) the types of radiation emitted by each radionuclide, 4) the tissues where the radionuclides will accumulate, 5) the body geometry of the receptors, and 6) the additive effect of the different radionuclides. The harmful effect of radiation results from all radiation sources present, both internal and external. Therefore, the estimation of dose can be very complex, and it is

almost impossible to isolate the effect of a single radionuclide when several are present. Additionally, most studies on aquatic organisms have been concerned with the potential impacts on humans rather on the fish or other aquatic organisms, so there are very few data on what radiation doses are harmful to the fish themselves.

Radiation dosages in the range of 100 to several thousand roentgens are known to produce harmful effects in fish, ranging from reduced growth to abnormal development of ova to death at the highest dosages (King 1964; Krumholz 1954). Krumholz (1954) found that radiophosphorus along with cesium-137 and strontium-90 were main sources in the WOC system at ORNL and estimated that long-lived vertebrates such as fish and turtles in WOL may receive the equivalent of more than 50 roentgens of external radiation per year and more than 50r/yr as internal irradiation. Krumholz also noted that the overall fitness of the aquatic vertebrate population in the WOC system was probably seriously impaired. However, Krumholz and others have indicated that it is impossible to determine the significance of one or a few radionuclides in light of all the radiological and non-radiological contaminants in the WOC ecosystem (Krumholz 1954; Kolehmainen and Nelson 1969; Kolehmainen 1972).

The body burdens of cesium-137 in bluegills and carp from WOL (20 to 63 pCi/g fresh weight) reported by Kolehmainen and Nelson (1969) and Edwards (1986) are in the same range or higher than the body burdens reported in brown trout and perch in Scotland and Finland (Preston, Jefferies, and Dutton 1967). Preston, Jefferies and Dutton (1967) found some of the highest body burdens occurred in Finnish lakes (26.8 pCi/g) because the low mineral content of these lakes (low Ca and K) was conducive to high cesium bioconcentration factors. Kolehmainen and Nelson (1969) reported bioconcentration factors for cesium-137 between 460 to 1080, depending on the species of fish. Vanderploeg et al. (1975) reported a bioconcentration factor of 140 for cesium-137 in bluegills from the Clinch River, and King (1964) and Polikarpov (1966) reported bioconcentration factors in the hundreds and thousands, depending upon the fish species. Although cesium-137 bioconcentration factors may be high (the ratio of cesium concentrations in fish tissue vs the concentrations in water), most investigations agree that the bioaccumulation of cesium-137 through the food chain (that is, between successive trophic levels) is not very significant.

Klechkovskii, Polikarpov, and Aleksakhin (1973) reported that strontium-90 levels of $10^{-4}$ Ci/L caused some increase in morphological deformities in pike eggs and disrupted development of mollusc embryos. Edwards (1986) reported strontium-90 concentrations of 46 to 240 pCi/g wet weight in carp from WOL, in sharp contrast to concentrations of 0.001 to 0.11 pCi/g observed in brown trout in several rivers in England by Preston, Jefferies, and Dutton (1967). Strontium-90 can be especially harmful because it concentrates in bone tissue where replacement is slow.

## 7D.3 EXPOSURE ASSESSMENT—AQUATIC INVERTEBRATES

### 7D.3.1 Factors Affecting Transport and Bioavailability

The fate and transport of metals, aromatic hydrocarbons, and radionuclides is influenced by several controlling factors which ultimately affect their respective toxicities to

aquatic macroinvertebrates. These factors include water hardness, pH, total organic or humic acid concentrations, calcium and potassium concentrations (for strontium-90 and cesium-137), adsorption/desorption, and biodegradation.

In addition to the physical and chemical factors of the transporting medium (e.g., water or sediment), biological parameters such as the presence of metal-binding proteins also influence bioavailability and toxicity. Metallothioneins are present in a wide variety of organisms, from yeasts to mammals, but were only recently confirmed in freshwater invertebrates by Everard and Swain (1983). Metallothioneins bind selectively to Group II metals, particularly cadmium and zinc, allowing organisms to store metals in a nontoxic form.

### 7D.3.2 Sensitive Populations

The relative intraspecfic susceptibility of aquatic macroinvertebrates to the toxic effects of contaminants depends upon the organism's lifestage or body size. In general, smaller organisms are more sensitive to metals and monocyclic aromatics than larger ones, and early instars are more sensitive than older instars. The difference in sensitivity of early and late instars can be significant (Williams et al. 1986; Gauss et al. 1985; McCahon, Whiles, and Pascoe 1989). Scott and Guthrie (1972) presented data showing that the first instar of mosquito larvae accumulated more radiophosphorus than later instars, while the fourth instar concentrated more cesium-137, strontium-90, and tritium-90 than the earlier instars. Thus, the total radiation dose may be related to the biological processes ongoing in different instars as well as the radionuclide concentration in the water. Also, exposure duration is a major factor with respect to all radiation sources, so the length of the life stage must be considered.

Microhabitat may also be an important factor influencing the sensitivity of benthic macroinvertebrates to contaminants. McCahon, Whiles, and Pascoe (1989) reported that cased caddisflies, Agapetus fuscipes, were more vulnerable to cadmium as they grew and left their cases to build bigger ones. Cased and uncased larvae would also differ in their vulnerability to external radiation sources.

Interspecific susceptibility of benthic macroinvertebrates to organic and metal contamination has been described by several investigators. In flowing streams and rivers the macroinvertebrate community structure frequently exhibits a predictable graded response to point source pollution. The transition of dominant groups from unimpacted to impacted to recovery zones corresponds closely with the relative tolerance of different taxonomic groups to the metal or organic contaminants. Woodward and Riley (1983) observed the near complete elimination of stoneflies and caddisflies (Plecoptera and Trichoptera) in a stream contaminated by oil field discharge, and a corresponding increase in Diptera. Crustaceans, cladocerans, mayflies, and some species of Diptera (e.g., Tanytarsiini) are more sensitive to metal contamination than stoneflies, caddisflies, tubificid worms, and several Diptera species (e.g., Orthocladiini) (Clements, Cherry, and Cairns 1988, Winner et al. 1980, Anderson 1979). Within some invertebrate groups, such as mayflies and midges, there is a wide range of sensitivities between species. Therefore, the transition from tolerant to

sensitive invertebrates along an impacted stream depends to some extent on which species of mayflies and midges dominate the populations.

There is very little information on susceptibility of different species of benthic macroinvertebrates to radionuclides. King (1964) reported that Daphnia pulex bioconcentrated more cesium-137 than D. magna, apparently due to different capabilities to assimilate this radionuclide from the tagged food source, Chlamydomonas. However, both species may be equally sensitive to the effects of ionizing radiation itself. In general, the less complex benthic organisms and those with short life cycles are more resistant to ionizing radiation.

## 7D.4 TOXICITY ASSESSMENT—AQUATIC INVERTEBRATES

### 7D.4.1 Mode of Action

As with fish, elevated concentrations of metals, organics, and radionuclides can cause both direct and indirect effects on aquatic macroinvertebrates. Exposure to these contaminants may adversely affect biochemical and physiological processes. Since numerous metabolic (biochemical) processes are the same in fish and invertebrates, the cellular level effects of toxicants are frequently the same. For example, the inhibition of oxidative phosphorylation by high copper levels is common to many types of living organisms. In many cases, the toxicological endpoint, such as behavior or decreased growth, has been described for invertebrates, but the actual cause of toxicity at the cellular level is unknown.

Copper is generally more toxic than cadmium to freshwater macroinvertebrates (Khangarot and Ray 1989). Acute and chronic effects of copper exposure to aquatic insect larvae include reproductive effects such as teratogenicity (Kosalwat and Knight 1987b) and reduced larval growth (Hatakeyama 1989). Clements et al. (1989a,b) describe the indirect toxic effects of copper exposure to aquatic insect communities. They reported that two species of net-spinning caddisflies, Chimarra sp. and Hydropsyche morosa, were increasingly vulnerable to predation by the stonefly, Paragnetina media. It was hypothesized that copper exposure caused behavioral changes which made the caddisflies more vulnerable to predation. Peterson and Peterson (1983, as cited in Clements et al. 1989) introduced evidence showing that heavy metal exposure altered silk-spinning in Hydropsychidae caddisflies causing structural anomalies to the web. These alterations may have caused Hydropsyche to spend more time in the open repairing nets, thus, exposing them to increased predation pressure.

The chronic or sublethal effects of cadmium on freshwater invertebrates have been studied by numerous investigators and include reductions in percent emergence, abnormal behavior, reduced ability to construct cases (by caddisflies), and various effects on reproduction (Hatakeyama 1987; Gerhardt 1990; Spehar, Anderson, and Fiandt 1978; McCahon, Whiles, and Pascoe 1989; Williams et al. 1987).

Extensive data concerning the mode of action and general toxicities for xylene and toluene to macroinvertebrates were not encountered; however, some information is available. The total mode of action of xylene is not completely understood but increased cellular

permeability has been noted by Berry et al. [1978, as cited in Jori et al. (1986)]. Simpson [1980, as cited in Woodward and Riley (1983)] reported that Plecoptera and Trichoptera exposed to oil (xylene and toluene are major constituents) resulted in abnormalities in tracheal gills, which probably resulted in respiratory interference.

Exposure of aquatic macroinvertebrates to radiation sources has been reported to cause genetic anomalies, chromosomal aberrations, development abnormalities, depressed reproduction, decreased swimming activity, and sterilization (Klechkovshkii, Polikarpov, and Aleksakhin 1973; King 1964; Scott and Guthrie 1972). The specific mode of action of ionizing radiation in aquatic macroinvertebrates is the same effect that radiation has on all living organisms.

### 7D.4.2 Toxicity of Contaminants

In the following discussion, the toxicity of copper, cadmium, xylene, toluene, cesium-137, and strontium-90 to freshwater invertebrates is assessed based on the ambient water quality criteria and the acute and chronic toxicity values reported in the literature. Acute toxicity is most frequently expressed as the 96-hour $LC_{50}$. Chronic toxicity values for freshwater invertebrates are not reported in terms of the NOEL and LOEL as much as for fish, probably because of the shorter life spans and more numerous lifestages. The lowest observable end points may be changes in growth, egg production, emergence success, behavior, mortality, or other measurable signs of stress.

#### 7D.4.2.1 Ambient water quality criteria

Ambient water quality criteria for cadmium, copper, benzene, and toluene are depicted in Appendix 7B. Criteria for xylene, cesium-137, and strontium-90 are not available.

#### 7D.4.2.2 Acute and chronic toxicity of cadmium

The acute toxicity values for cadmium are given in Appendix 7B. Values are for 96-hour $LC_{50}$ where possible to avoid the confusion of comparing different duration tests. Eisler (1985), Mance (1987), Williams et al. (1986) and others present $LC_{50}$ values for test durations between 24 hours and a month or more. The stoneflies (Plecoptera) and caddisflies (Trichoptera) are among the more tolerant groups of invertebrates. The cladocerans, freshwater shrimp, and crustaceans such as Asellus aquaticus are the least tolerant, with $LC_{50}$s frequently less than 1 mg/L. Mayflies and midges (Chironomidae) both exhibit a wide range of sensitivities among the species within these groups (Appendix 7B). The sensitivities of the different life stages of the crustacean reflect the higher tolerance of the embryos and adults seen in many benthic invertebrates.

The chronic or sublethal effects of cadmium on freshwater invertebrates have been studied by numerous investigators and include reductions in percent emergence, abnormal behavior, reduced ability to construct cases (by caddisflies), and various effects on reproduction (Appendix 7B). Although the 96-hour $LC_{50}$ for the fourth instar of the midge

larvae Polypedilum nubifer was 372 mg/L, reproductive impairment was observed at concentrations as low as 0.02 mg/L. Sublethal exposures in the range of 46 to 186 mg/L reduced case building activities in the caddisfly Agapetus fuscipes, and at the highest end of this range the strength of the cases deteriorated. The net spinning capabilities of another caddisfly, Hydropsyche angustipennis, were reduced by cadmium concentrations as low as 0.3 mg/L (Appendix 7B).

In summary, the Plecoptera and Trichoptera are generally tolerant of cadmium concentrations below 10 mg/L, and older larva of chironomids may be nearly as tolerant (Appendix 7B). Cadmium concentrations less than 1 mg/L may have chronic effects on other invertebrate groups such as mayflies, some species of chironomids, cladocerans, and snails. The emergence of some species of mayflies, Leptophlebia marginata and Baetis rhodani, and midge larvae, Polypedilum nubifer and Chironomus yoshimatsui, may be adversely affected by cadmium concentrations between 0.02 and 0.2 mg/L. Within the literature reviewed, the lowest concentration of cadmium reported to affect aquatic invertebrates was 3 $\mu$g/L, which represented an $LC_{50}$ for a mayfly, Ephemerella sp. over a 28-day exposure period.

### 7D.4.2.3 Acute and chronic toxicity of copper

As with cadmium, the range of acute and chronic toxicities of copper is broad for aquatic macroinvertebrates as depicted in Appendix 7B. Acute 96-hour toxicities range from 16.7 $\mu$g/L for the first instar of the chironomid Chironomus tentans to 8300 $\mu$g/L for the Plecopteran Acroneria lycorlas under similar water hardness conditions. The range of acute toxicities within the midge family Chironomidae (16.7 to 1690 $\mu$g/L) is as broad as the range of toxicities among the different types of aquatic invertebrates presented in Appendix 7B. Similar to cadmium, the stoneflies and caddisflies are relatively tolerant of copper. The different sensitivities of the four instars of Chironomus tentans illustrates that the youngest larval stage is the most sensitive. This has also been observed in other insect larvae.

Copper is chronically toxic to mayflies and midges at concentrations between 10 and 25 $\mu$g/L. Midge larvae in the taxonomic tribe Tanytarsiini represent some of the more sensitive groups of midges. Caddisflies and stoneflies are very tolerant of copper, especially the older instars. Exposure to copper via ingestion of food is apparently less detrimental and may be insignificant in comparison to exposure to copper in water (Kosalwat and Knight 1987a).

### 7D.4.2.4 Acute and chronic exposure to benzene, toluene, and xylene

Data regarding the acute and chronic toxicities of organic compounds to aquatic invertebrates are limited (Appendix 7B). Benville and Korn (1977) reported acute 96-hour $LC_{50}$s for bay shrimp as 20 and 4.3 $\mu$g/L for benzene and toluene, respectively. $LC_{50}$s for xylenes were broken down into their meta, ortho, and para isomers; these values were 3.7, 1.3, and 2.0 $\mu$g/L, respectively. Twenty-four hour $LC_{50}$s for xylene were reported by Jari et al. (1986) who reviewed the work of several investigators. The 24-hour $LC_{50}$ for Daphnia magna was between 100 and 1000 mg/L (Dowden and Bennett 1965, as cited in Jori 1986). Mosquito larvae, Aedes aegipti, appear to be more sensitive with a reported 24-hour $LC_{50}$

of 14 mg/L (Berry and Brammer 1977, as cited in Jori 1986). Woodward and Riley (1983) studied changes in macroinvertebrate populations downstream of oil field discharges and stated that oil-in-water concentrations above 24 $\mu$g/L were biologically unsuitable. They noted that Plecoptera and Trichoptera were nearly eliminated by oil field contaminants, while one species of mayfly and two species of Diptera became relatively dominant at stations downgradient of the discharge area. Other investigators have also noted the sensitivity of Trichoptera and Plecoptera to oil contaminants (Snow and Rosenberg 1975 and Simpson 1980; as cited by Woodward and Riley 1983).

### 7D.4.2.5 Harmful effects of cesium-137 and strontium-90

There is very little information regarding the harmful effects of cesium-137 and strontium-90 on aquatic organisms. King (1964) reviewed available literature and found a few estimates of roentgen dosages harmful to aquatic organisms, and reported $LD_{50}$ values for crustaceans and fish ranged from 500 to 90,000r and 600 to 3,000r, respectively. A radiation dosage of 70r/hour reduced swimming activity in the cladoceran, Daphnia magna within 16 days, and an accumulated dose of 10,500r caused permanent sterility (King 1964). Sterility in the adult mosquito was apparently caused by lower levels; Guthrie and Brust (1971, cited by Scott and Guthrie 1972) estimated that mosquitos were sterilized by a total beta radiation of about 90 rad from the media in which they were reared. Depressed reproduction was observed in D. magna populations exposed to $10^{-5}$ Ci/L radiation for 80 days, and slightly higher levels of strontium-90 + yttrium-90 ($10^{-4}$ to $10^{-3}$ Ci/L) disrupted development in molluscs (Klechkovskii, Polikarpov, and Aleksakhin 1973). A search of available literature did not produce any radiological effect levels for stoneflies, caddisflies, mayflies, or chironomids.

Aquatic macroinvertebrates are less susceptible to cesium-137 and strontium-90 than fish because of their shorter life cycle and other aspects of their life history and morphology. The exoskeleton of most macroinvertebrates, except molluscs, has a low mineral content and, therefore, does not accumulate strontium-90 as much as fish bone and scales. Also, more than 50% of the radioactivity in macroinvertebrate larvae may be lost during molting and emergence, and considerable radioactivity may also be lost by elimination (Wilhm 1970; Harvey 1971). Since up to half of the body burden of radioactive material is lost at each molting, the total accumulation of both adsorbed and absorbed radionuclides over the entire life cycle is significantly reduced. Also, the harmful effects of radiation on a single generation can be offset by the high reproductive potential of many aquatic macroinvertebrates.

# APPENDIX 8A. POTENTIAL ARARS[a]

Section 121 of CERCLA specifies that remedial actions for cleanup of hazardous substances comply with requirements or standards under federal or more stringent state environmental laws that are applicable or relevant and appropriate requirements (ARARs) for hazardous substances or particular circumstances at a site. This appendix defines ARARs and discusses ARARs potentially applicable to WAG 6.

## 8A.1 DEFINITIONS

Applicable requirements are "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically addresses a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site" (52 FR 32496, August 27, 1987).

Relevant and appropriate requirements are "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site" (52 FR 32496).

In the absence of federal- or state-promulgated regulations, there are many criteria, advisories, guidance values, and proposed standards that are not legally binding but that may serve as useful guidance for setting protective cleanup levels. These are not potential ARARs, but are "to be considered" (TBC) guidance.

Only substantive requirements of ARARs need to be followed. Under Section 121(e) of CERCLA and the NCP [40 CFR 300.68(a)(3)], federal, state, and local permits are not required for the portions of CERCLA cleanups conducted entirely on-site as long as the actions are selected and carried out in compliance with Section 121.

OSWER Directive No. 9234.0-05 identifies three types of ARARs:

- Contaminant-specific
- Location-specific
- Action-specific

Contaminant-specific ARARs set limits on concentrations of specific hazardous substances, pollutants, and contaminants in the designated media. Examples include drinking water standards and ambient air quality standards. Location-specific ARARs set restrictions

[a]ARARs were researched and complied, and this section was written, by Elizabeth L. Etnier, ORNL, [Applicable or Relevant and Appropriate Requirements (ARARs) for WAG 6, Oak Ridge National Laboratory, prepared for the ORR ER Program, April 1991.) Ms. Etnier's work has been slightly edited for inclusion in this Wag 6 RFI Report.

on activities in certain types of areas such as wetlands, floodplains, or historic sites. Action-specific ARARs set controls or restrictions on particular kinds of activities that are triggered by the specific type of remedial action under consideration. For example, the Clean Water Act (CWA) includes regulations for treated water discharge to navigable waters.

Contaminant-specific (chemicals and radionuclides) and location-specific ARARs for WAG 6 are described in Sections 8A.3 and 8A.4, below. Action-specific ARARs for WAG 6 related to the site-wide alternatives are presented in Section 8A.5. These ARARs will be discussed in more detail in the FS/CMS/EA.

## 8A.2 ARAR WAIVERS

In some circumstances, ARARs can be waived. Six general conditions for waivers are stated in CERCLA Section 121(d) and are paraphrased below.

1. The remedial action is an interim measure and is part of a final remedy that will attain the ARARs upon completion.

2. Compliance with ARARs will result in greater risk to human health and the environment than other options that do not comply with ARARs.

3. Compliance with ARARs is technically impracticable from an engineering perspective.

4. The remedial action will not meet ARARs, but will attain an equivalent standard of performance through use of another method or approach.

5. The state has not consistently applied the state ARAR or demonstrated the intent to apply such an ARAR to similar remedial action sites.

6. Superfund money spent at this site will not provide a balance between the need to protect human health and the environment and the availability of fund money for response at other facilities. (Because fund money is not being used at WAG 6, this is not appropriate for consideration.)

## 8A.3 CONTAMINANT-SPECIFIC ARARS

### 8A.3.1 Radiation Protection Standards

Very few applicable standards are available for the cleanup of radioactively contaminated CERCLA sites. The Atomic Energy Act (AEA) of 1959 and its amendments have delegated authority for control of nuclear energy to EPA, NRC, and DOE. In addition, Tennessee has regulatory authority and programs for radioactive waste.

Radioactive waste contained in the trenches and auger holes of WAG 6 is thought to be composed of both high- and low-activity LLW. The proper definition of "mixed low-level

radioactive and hazardous waste" has caused considerable debate with regard to dual jurisdiction by EPA and the NRC. However, EPA has published a clarification of the problem (53 FR 37045, September 23, 1988), as did DOE previously [52 FR 15937, May 1, 1987, and DOE Order 5400.3 (Hazardous and Radioactive Mixed Waste Program, dated February 22, 1989)]. In effect, mixed wastes are those containing a RCRA hazardous waste as defined in 40 CFR 261 and a radioactive waste subject to the AEA. RCRA regulations apply to the hazardous component of the waste, and AEA regulations apply to the radioactive component. When the application of both standards is conflicting or inconsistent, RCRA yields to the AEA. Tennessee received final authorization to regulate mixed waste on July 3, 1986 (53 FR 37045, September 23, 1988); however, the state has not yet implemented any related regulations or guidance (West 1989).

DOE is authorized to control all types of nuclear materials at sites under its jurisdiction, and is exempt from NRC licensing and regulatory requirements. Therefore, NRC regulations are not considered to be ARARs for CERCLA cleanup at DOE facilities. DOE regulations for handling and cleanup of radioactive materials are outlined in a series of internal DOE Orders that are legally binding to DOE contractors, but are not considered by EPA to be ARARs. Therefore, for the purposes of development of ARARs, DOE Orders will be treated, along with NRC regulations, as TBC guidance. In general, the EPA and NRC regulations and the DOE Orders set dose limits for exposures of the general public to various sources of radionuclide emissions.

### 8A.3.1.1 EPA, NRC, and DOE regulations and orders

EPA has promulgated MCLs for radionuclides in community water systems (see Table 8A.1). These MCLs appear in two forms: concentration limits for certain alpha-emitting radionuclides (40 CFR 141.15); and an annual dose limit for the ingestion of certain beta- and gamma-emitting radionuclides (40 CFR 141.16). MCLs and MCLGs will be proposed for radon and uranium and reproposed for radium-226 and radium-228, beta, and photon emitters (NPRM expected August 1991, with a Final Rule in December 1992). As with the chemical-specific MCLs, these may be relevant and appropriate for cleanup of contaminated groundwater at WAG 6.

Table 8A.2 summarizes the dose limits set by the various EPA and NRC regulations and DOE Orders. Subpart H of 40 CFR 61 addresses atmospheric radionuclide emissions from DOE facilities and may be applicable to airborne emissions during cleanup of WAG 6. EPA has issued a final NESHAP rule (54 FR 51654, December 15, 1989) that limits emissions of radionuclides to the ambient air from DOE facilities to amounts that would not cause any member of the public to receive an effective dose equivalent of 10 mrem/year (40 CFR 61.92).

Environmental protection standards for the management, storage, and disposal of spent nuclear fuel, high-level wastes, and TRU wastes are found in 40 CFR 191. Management and storage shall be conducted so as to provide a reasonable assurance that no member of the public in the general environment shall receive a combined annual dose equivalent of greater than 25 mrem to the whole body and 75 mrem to any organ (40 CFR 191.03). All potential

pathways must be considered (40 CFR 191.15). 40 CFR 191.04 establishes alternative standards for DOE facilities if EPA determines that such standards prevent any member of the public from receiving a continuous exposure of more than 100 mrem/year effective dose equivalent or an infrequent exposure of more than 500 mrem/year effective dose equivalent from all sources, excluding natural background and medical exposures. EPA intends to revise these standards and promulgate generally acceptable environmental standards to establish limits on radionuclide releases (NPRM December 1991).

EPA intends to develop environmental radiation protection standards for the disposal of LLW under 40 CFR 193 and 764. The intent of these standards will be to protect the public health and general environment from potential adverse effects from LLW disposal. These proposed regulations may provide TBC guidance for cleanup of WAG 6 (NPRM, intended September 1991; Final Rule, December 1992).

### 8A.3.1.2 TBC radiation guidance

TBC guidance includes certain NRC regulations, DOE orders, and TBD guidance, as described below.

- **NRC Regulations.** As mentioned previously, DOE is not regulated by the NRC; however, NRC regulations provide TBC guidance for cleanup of radioactive waste at WAG 6. Thus, the regulations are summarized here. The standards for protection against radiation (10 CFR 20) are designed to limit radiation exposures from NRC-licensed activities. They provide permissible worker exposure limits for restricted areas of 1.25 rem/quarter (10 CFR 20.101) and radiation exposure limits to the general public in unrestricted areas of 500 mrem/year (10 CFR 20.105) (Table 8A.2). The 10 CFR 20 regulations are being revised by the NRC, with a final rule expected in 1991.

  The NRC has promulgated licensing requirements for land disposal of radioactive waste (10 CFR 61). Part 61 contains procedural requirements and performance standards applicable to any method of land disposal, with specific technical requirements for near-surface disposal of radioactive waste. Table 8A.3 summarizes the substantive requirements of 10 CFR 61 as they apply to remedial actions at WAG 6. Although not an ARAR, the substantive requirements found in this regulation might provide TBC guidance for remedial options selected at WAG 6. 10 CFR 61.41 states that concentrations of radioactive materials released to the environment in all media must not result in an annual dose exceeding 75 mrem to the thyroid and 25 mrem to total body or all other organs of any member of the public (Table 8A.1). In addition, reasonable effort must be made to maintain releases of radioactive materials to "as low as reasonably achievable" (ALARA).

- **DOE Orders.** DOE orders are not promulgated regulations and thus are not considered by EPA to be ARARs. They are, however, legally binding between DOE and Energy Systems because of contractual agreements. In particular, DOE Order 5400.5 (Radiation Protection of the Public and the Environment, February 8, 1990) establishes radiation exposure limits for the general public, as well as derived concentration guides for

discharges of radioactively contaminated liquids to surface waters. These may provide guidance for the discharge of contaminated groundwater and wastewater effluents into WOC.

The radiation exposure limits defined in DOE Order 5400.5 are an effective dose equivalent of 100 mrem/year from all exposure pathways and all DOE sources of radiation, and a dose of less than 5 mrem/year for a single acute exposure (see Table 8A.1). In addition, effluent release to surface water must not result in exposures to aquatic organisms exceeding an absorbed dose of 1 rad/day. The overriding principle of DOE Order 5400.5 is that all releases of radioactive material shall be as low as reasonably achievable (ALARA). Table 8A.4 summarizes the contents of DOE Order 5400.5 with regard to remedial actions.

DOE Order 5820.2A (Radioactive Waste Management, September 9, 1988) states that the management of LLW must ensure that the waste and concentrations of radioactive material that may be released into surface water and soil do not result in external exposures that exceed 25 mrem/year to any member of the public. Releases to the atmosphere shall not exceed 10 mrem/year. Reasonable effort should be made to maintain releases to the environment to ALARA levels. The order pertains to the management of radioactive waste that is not mixed with RCRA hazardous waste; Table 8A.5 summarizes the substantive requirements of this order.

- **TBC Guidance for Radiological Risk Assessment.** The EPA Office of Radiation Programs has derived slope factors for radionuclides of concern at remedial sites for each of three major exposure pathways (inhalation, ingestion, and ground and surface irradiation) (EPA 1990b). These are listed in Table 8A.6 for the radionuclides detected at WAG 6.

### 8A.3.2 Chemical-Specific ARARS

"Chemical-specific requirements set health or risk-based concentration limits or discharge limitations in various environmental media for specific hazardous substances, pollutants, or contaminants" (52 FR 32496). These requirements generally set protective cleanup levels for the chemicals of concern in the designated media or indicate a safe level of discharge that may be incorporated when considering a specific remedial activity.

#### 8A.3.2.1 Groundwater and surface water

The following regulations are considered relevant and appropriate only for remedial options in which contaminated groundwater or wastewaters are discharged directly into WOC.

EPA has promulgated primary and secondary drinking water regulations applicable to public water systems that have at least 15 service connections or serve an average of at least 25 people daily at least 60 days of the year. Primary regulations are for the protection of human health, while secondary regulations are for aesthetics. A new category of systems

referred to as non-community, non-transient systems that regularly serve at least 25 people for 6 months of the year was later added (52 FR 25690, July 8, 1987). SDWA National Primary Drinking Water Standards (NPDWS) are established in 40 CFR 141 and include MCLs and MCLGs. Table 8A.7 lists SDWA MCLs and MCLGs for chemicals that have been found above detection limits in groundwater and surface water at WAG 6. Table 8A.8 lists the proposed MCLs/MCLGs for the chemicals detected at WAG 6. When the proposed MCLs are promulgated, they will be considered relevant and appropriate for cleanup at WAG 6 (a Final Rule is expected March 1992). Chapter 1200-5-1 of the Rules of the TDC, as amended effective November 10, 1988, lists MCLs for public water systems that are identical to the federal MCLs. Therefore, they are not repeated here.

MCLs are enforceable standards that take into consideration human health effects, available treatment technologies, and costs of treatment. MCLGs are strictly health-based standards that disregard cost or treatment feasibility and are not legally enforceable. MCLs are legally applicable to water "at the tap," but are not applicable to cleanup of groundwater or surface water at WAG 6 since they are not sources of drinking water. However, they may be considered as relevant and appropriate under certain circumstances.

The CWA federal water quality criteria (WQC) are derived for the protection of freshwater aquatic organisms and for the protection of human health from the consumption of contaminated drinking water and/or aquatic organisms. In determining whether any WQC are relevant and appropriate, one must consider the "designated or potential use of the surface or groundwater, the environmental media affected, the purposes for which the criteria were developed, and the latest information available" [CERCLA §121(d)(2)(B)]. The TDC has classified WOC for fish and aquatic life and livestock watering and wildlife, it is not used for public water supplies. Therefore, only WQC for the protection of freshwater aquatic life are listed in Table 8A.9.

### 8A.3.2.2 Soil

There are no current federal or state ARARs governing cleanup of contaminated soils. The RCRA land disposal restrictions (LDRs) are triggered by movement of RCRA hazardous waste from one unit and placement into another unit. The LDRs are not applicable to waste that is moved from one part of a unit to another in an effort to consolidate waste (55 FR 8759), as may be the case at WAG 6 (see Section 8.5).

### 8A.3.2.3 Other TBC guidance

In the absence of federal- or state-promulgated ARARs, or in the case where ARARs are not adequately protective, other federal or state criteria, advisories, or guidance will be considered. These include EPA RfDs and CPFs. RfDs and CPFs are available from the EPA IRIS and the EPA Health Effects Assessment Summary Tables (EPA 1990b) and will not be presented here.

## 8A.4 LOCATION-SPECIFIC ARARS

Location-specific requirements "set restrictions upon the concentration of hazardous substances or the conduct of activities solely because they are in special locations" (53 FR 51394). Table 8A.10 lists the federal and state location-specific ARARs that might be pertinent to remedial actions at WAG 6.

### 8A.4.1 Caves, Salt-Dome Formations, Salt-Bed Formations, and Underground Mines

WAG 6 is underlain by strata of the Middle to Late Cambrian Conasauga Group in the Copper Creek thrust block, including Upper Maryville Limestone and Nolichucky Shale formations (Phillips 1988). Areas underlain by limestone may be subject to cave formation, sinkhole development, and trends of groundwater movement that could cause problems for site modifications (Lee 1989). However, there is no specific indication of caves or sinkholes, nor of salt-bed formation, salt-dome formations, or underground mines at the site.

### 8A.4.2 Faults

As discussed in Sect. 3.0, WAG 6 is located in Melton Valley within the Valley and Ridge Province, approximately 1.5 km southeast of the southeast dip of the Copper Creek Thrust. White Oak Mountain Fault is located more than 3 miles northwest of ORNL. The latest movement along the fault was during the Late Pennsylvania/ Early Permian Age, 280 to 290 million years ago (Butz 1984). Although minor seismic activity has been recorded in the region, no surface rupturing associated with any of the faults within the ORR has been recorded. The possibility of fault movement is considered extremely unlikely (Chance 1986).

The DOE ORR is exempted from compliance with RCRA seismic requirements of 40 CFR 264.18 because 40 CFR 264.18(a) stipulates that all facilities located within political jurisdictions not listed in Appendix VI are assumed to be in compliance for location of new TSD facilities. Tennessee is not listed in the appendix. However, EPA intends to propose additional floodplain and seismic restrictions for location of TSD facilities (NPRM, December 1991; Final Rule expected April 1993), and these restrictions will be incorporated into the TDC Hazardous Waste Management regulations (Hinch 1989). At that time, the TDC seismic regulations may be ARARs for remedial actions at WAG 6. For now, these regulations are TBC.

### 8A.4.3 Wilderness Areas, Wildlife Refuges, and Scenic Rivers

There are no known designated wilderness areas, wildlife refuges, or natural areas on WAG 6.

### 8A.4.4 Wetlands and Floodplains

Two small areas in the southern portion of SWSA 6 near WOL have elevations lower than this 100-year flood elevation and could possibly become inundated. If remedial

alternatives are selected that would impact the floodplain or wetland areas occurring at WAG 6, the regulations found in Executive Orders 11988 and 11990 and in §404 of the CWA might be ARARs for WAG 6 (Table 8A.10).

### 8A.4.5 Historic Sites and Archaeological Findings

A 1977 historic site reconnaissance and archaeological survey of the ORR found no known registered historical or archaeological sites on or near WAG 6 (Sanders 1984).

### 8A.4.6 Rare, Threatened, or Endangered Species

At present, there are no known threatened or endangered species on WAG 6 (Parr 1989). However, if a site investigation reveals the presence of any rare, threatened, or endangered animals or plants, the Endangered Species Act of 1973, the Tennessee Rare Plant Protection and Conservation Act of 1986, and the Tennessee Non-Game and Endangered or Threatened Wildlife Species Act of 1974 may also be ARARs.

## 8A.5 ACTION-SPECIFIC ARARS

Action-specific ARARs are triggered by the particular remedial activities that are selected to accomplish a remedy. Certain ARARs represent hybrids between contaminant-, location-, and action-specific ARARs. These hybrid ARARs involve an action taken with respect to a specific constituent or location. Effluent discharge limits or air emission standards are considered hybrids between action-specific and contaminant-specific ARARs because an action (i.e., a discharge) is taken with respect to a contaminant.

Seven remedial action alternatives have been selected for WAG 6 including a no-action alternative (see Sect. 8.4 for a discussion of the remedial alternatives under consideration). There are no action-specific ARARs applicable to the no-action alternative. Although WAG 6 is not a RCRA-permitted facility, it contains RCRA-listed hazardous waste which was placed at the site post-1980 as well as radioactive waste. Therefore, the RCRA regulations are applicable for remediation of hazardous wastes at WAG 6. However, since some of the waste is "mixed" waste, EPA and NRC regulations also are pertinent. Guidance for the management of low-level radioactive waste containing no RCRA hazardous waste appears in DOE Order 5820.2A (Radioactive Waste Management, September 26, 1988). Requirements for waste treatment, shipment, disposal, and site closure/post-closure are given (see Table 8A.5).

### 8A.5.1 Alternatives 2-7

All of the alternatives involve preconstruction activities, excavation, consolidation of wastes between areas within the WAG, surface water controls, decontamination of equipment, capping, and post-closure care of waste areas. In addition, structural stabilization of soils via dynamic compaction and in situ grouting may be implemented in certain areas of the WAG for alternatives 4 through 7. Action-specific ARARs common to all of the six remedial alternatives are provided in Table 8A.11 and discussed below.

### 8A.5.1.1 On-site construction/excavation

Certain on-site construction and/or excavation activities may be necessary to prepare the site for remediation. These might include the development of additional roads for vehicular traffic, movement of soils, site grading, or site cleaning activities. Table 8A.11 lists ARARs for these activities.

Airborne pollutants may result from these construction activities. The primary concern is elevation of particulate concentrations resulting from earth-moving and site-grading activities. Nonpoint source contributions to fugitive dust emissions are regulated by the Clean Air Act (40 CFR 50). The National Ambient Air Quality Standard (NAAQS) for particulates is 75 $\mu g/m^3$ (annual geometric mean) and 260 $\mu g/m^3$ as a maximum 24-hour concentration not to be exceeded more than once per year (40 CFR 50.6).

The TDC, Division of Air Pollution Control has also promulgated regulations governing fugitive dust emissions [Tennessee Code Annotated (TCA) 1200-3-8-.01]. These are listed in Table 8A.11 and are applicable to remedial activities at WAG 6.

Consolidation of wastes between areas within the WAG may occur during remediation. The regulations discussed above for control of fugitive dust emissions would be applicable to this activity (see Table 8A.11). Although the RCRA land disposal restrictions (LDR) found in 40 CFR 268 apply to waste consolidation between different units at a CERCLA site, they do not apply to movement of waste within a unit (55 FR 8759).

Dynamic compaction of wastes within the trenches and in situ grouting of selected areas may result in fugitive dust emissions; in that event, the regulations described above for on-site construction would be applicable (see Table 8A.11).

### 8A.5.1.2 Asbestos emissions

NESHAPs for various industrial sources that emit one of several pollutants are established in 40 CFR 61. Most of the NESHAPs are generally neither applicable nor relevant and appropriate to cleanup at CERCLA sites because they regulate particular types of sources that would not be expected to be found at a CERCLA site. However, portions of the NESHAPs relating to waste disposal of asbestos (40 CFR 61.152-153) may be relevant and appropriate for cleanup of the WAG 6 trenches containing asbestos materials (see Table 8A.11). The TDC, Division of Air Pollution Control, also regulates asbestos emissions from particular sources (TCA 1200-3-11-.02); these regulations are similar to the federal regulations, but are listed for completeness (see Table 8A.11).

### 8A.5.1.3 Surface water control

Surface waters in the vicinity of the construction site will need to be monitored to identify potential impacts from nonpoint source (construction) activity. The relevant monitoring parameters for such activities are listed in TCA 1200-4-3-.03 and include total

dissolved solids, dissolved oxygen, pH, and temperature. A run-on and run-off control system must be maintained at the site (40 CFR 264.301, TCA 1200-1-11-.06).

### 8A.5.1.4 Decontamination

Decontamination activities will include hosing of equipment, vehicles, etc., collection of water, and discharge of WOC if the water meets the federal and state standards (see Sect. 8.2.1.2) and the National Pollutant Discharge Elimination System (NPDES) effluent standards for point source discharge (40 CFR 122). Tennessee has an EPA-authorized state program that is equivalent to the federal program (TCA 69-3-108 *et seq.*). NPDES Permit Number TN0002941 regulates point source discharges from WAG 6 to WOC. If the water does not meet the federal or state standards or the NPDES permit standards, it will be piped or transported to the ORNL wastewater treatment plant.

### 8A.5.1.5 Capping

The general requirements for capping are set forth in 40 CFR 264.228 (surface impoundments), 40 CFR 264.258 (waste piles), and 40 CFR 264.310 (landfills). Only the requirements for landfills are listed here, as EPA states that the term "landfill" applies as a general "catchall" regulatory definition for CERCLA land disposal units (55 FR 8760). Design and construction requirements specific to landfills are found at 40 CFR 264.300 et seq., TCA 1200-1-11-.14, and are listed in Table 8A.11. These federal and Tennessee requirements state that the cover must be designed and constructed to provide long-term minimization of migration of liquids through the capped area, function with minimum maintenance, promote drainage and minimize erosion or abrasion of the cover, and accommodate settling and subsidence so that the cover's integrity is maintained. Additionally, to keep water and leachate from collecting in the waste, the cap should have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.

### 8A.5.1.6 Post-closure care

General closure and post-closure care regulations appear at 40 CFR 264.110 et seq. and TCA 1200-1-11-06 and -14 (see Table 8A.11). Post-closure care must begin after closure and continue for 30 years after that date. Long-term maintenance must be provided for the runon diversion system, cover system, cap, groundwater monitoring system, and leachate collection and treatment systems.

### 8A.5.2 Alternatives 3, 6, and 7

Alternatives 3, 6, and 7 involve the use of perimeter groundwater collection drains; if the concentrations of contaminants in the water exceed federal and state standards (see Sect. 8.2.1.2), the water will be piped to the ORNL wastewater treatment plant for treatment. Since the treatment plant is a permitted facility, there are no additional ARARs for this phase of action.

### 8A.5.3 Alternative 7

Alternative 7 involves the in situ vitrification process (ISV). Table 8A.12 lists ARARs for this remedial alternative. ISV involves the use of electrical currents to treat contaminated soils in place and convert them into stable, vitrified materials. Emissions of hazardous constituents and their combustion gases are collected in an off-gas hood placed over the treatment area. An off-gas treatment system is utilized with residual contaminants recycled back to the vitrification process. Quenching, venturi scrubbing, filtration, and carbon adsorption may be used. Quenching and scrubbing solutions are cooled and recycled. Final disposal of residual contaminants will be to a permitted ORNL facility. Disposal of contaminated treatment water will be via pipeline to the ORNL wastewater treatment plant. In the event that the treatment water does not exceed the federal or state standards or the effluent limitations of the NPDES permit, it will be discharged into WOC.

All of the common components for all seven alternatives are listed in Table 8A.11. There are no ARARs pertinent specifically to the ISV process; however, RCRA addresses miscellaneous treatment units in its Subpart X regulations (40 CFR 264.000 et seq.). These regulations, as well as others deemed ARARs for ISV are discussed below and listed in Table 8A.12). In the NCP, EPA emphasizes the need for performing treatability studies for innovative technologies (55 FR 8714). Innovative technologies may be considered for remediation at a site when the technology offers the potential for comparable or superior treatment performance or implementability, fewer or lesser adverse impacts than other available approaches, or lower costs for similar levels of performance than demonstrated technologies (40 CFR 300.430). Treatability studies may be necessary to provide such information for an appropriate analysis of this alternative. However, treatability studies are not considered to be ARAR for the ISV process.

#### 8A.5.3.1 Treatment in a unit

Standards for the operation and maintenance of miscellaneous units are codified in 40 CFR 264.01 (See "Treatment in a Unit," Table 8A.12). These standards require location, design, operation, and closure of the unit in a manner that is protective of human health and the environment. Unlike other RCRA units where the general performance objectives are achieved by specified design standards, only generalized environmental performance standards are applied to miscellaneous units. The general environmental performance standards require that the owner demonstrate prevention of releases to groundwater or subsurface media [40 CFR 601(a)], surface waters or wetlands [40 CFR 601(b)], or air [40 CFR 601(c)] that could have adverse effects on human health and the environment. In demonstrating compliance with these standards, the operator must consider both waste and media characteristics. In the case of ISV, only residual or accidental releases need to be considered as the off-gas hood is expected to collect all gaseous emissions. Post-closure requirements for miscellaneous treatment units are at 40 CFR 264.603 [TCA 1200-1-11-.06(19d)].

### 8A5.3.2 Tank/container storage

Since tanks may be used for the off-gas treatment system, the RCRA 40 CFR 264.190 et seq. tank design and operating requirements are applicable to the activated carbon columns, any holding tanks, and ancillary equipment employed in the treatment system if the contaminated waste is considered to be derived from disposal of RCRA hazardous wastes. If it is not, these RCRA regulations would nonetheless be considered relevant and appropriate. Tank closure and post-closure regulations are found in 40 CFR 264.197 [TCA 1200-1-11-.06(10h)].

During operation, spent activated carbon and spent filter elements may be generated by the treatment unit. Accumulation or on-site storage of this waste will be required. If the spent carbon is considered derived from RCRA hazardous waste and is accumulated for greater than 90 days, the 40 CFR 264 regulations apply ("Container storage" and "Tank storage," Table 8A.11). However, if accumulation is for less than 90 days, the interim status closure requirements of 40 CFR 265.110 et seq. and the unit-specific closure requirements of 40 CFR 265.178 (containers) and 40 CFR 265.197 (tanks) are also considered applicable to the treatment system and storage facility.

### 8A.5.3.3 Tank/container closure

Upon closure of the off-gas treatment facility or the spent carbon/spent filter element accumulation area, the general or interim status closure performance standard of 40 CFR 264.11 or 265.11, respectively, must be met. The general closure requirements require safe handling procedures, mitigation of runon, treatment of runoff, and monitoring during closure. The interim closure requirements of 40 CFR 265.178 for container storage do not exceed the general standards. Interim closure requirements for tank systems are codified by 40 CFR 265.197. For clean closure, these standards are essentially analogous to those for container storage with the added requirements to decontaminate the tank system and secondary containment, remove contaminated soils, and render the tank unfit for further use if it remains on-site. Since the standards of 40 CFR Part 264 are equivalent to, or more stringent than, the Part 265 standards, only the former are listed on the table.

### 8A5.3.4 Post-closure care

The post-closure care regulations for miscellaneous treatment units are meant to ensure protection of human health and the environment (40 CFR 264.603 [TCA 1200-1-11.06(19d)]). The general environmental performance standards for "treatment in a unit" apply to post-closure care (see Table 8A.12).

# Appendix 8A Tables

**Table 8A.1. Radionuclide-specific ARARs for groundwater and surface water contamination at WAG 6**

| Radionuclide | Safe Drinking Water Act MCLs[a] |
|---|---|
| Radium | 5 pCi/L |
| Gross Alpha | 15 pCi/L |
| Gross Beta | 4 mrem/yr |
| Strontium-90 | 8 pCi/L |
| Tritium | 20,000 pCi/L |
| All other man-made radionuclides | 4 mrem/yr[b] |

[a]MCL = maximum contaminant level.
[b]If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 mrem/yr

Table 8A.2. Radiation protection standards that may be ARARs for WAG 6

| Regulation | Applicability | Exposure Conditions | Standard |
|---|---|---|---|
| 40 CFR 61 | NESHAPs for DOE facilities | Public exposure, airborne emissions | 10 mrem/year |
| 40 CFR 141 | Drinking water MCLs | Community water systems, gross beta | 4 mrem/year |
| 40 CFR 191 | Spent nuclear fuel, high-level and TRU wastes | Public exposure, all sources | 25 mrem/year (total body) 75 mrem/year (thyroid) |
| 10 CFR 20 | Radiation from NRC-licensed facilities | Worker exposure limits in unrestricted areas | 5 rem/year (1.25 rem/quarter |
| | | Public exposure, unrestricted areas | 500 mrem/year |
| 10 CFR 61 | Licensing requirements for land disposal of radioactive waste | Public exposure, all sources | 25 mrem/year (total body) 75 mrem/year (thyroid) |
| DOE Order 5400.5 | Radiation Protection of the Public and the Environment | Public exposure, all sources | 100 mrem/year |
| | | Aquatic organism exposure, absorbed dose | 1 rad/day |
| DOE Order 5820.2A | Radioactive Waste Management | Public exposure, all sources, excluding air | 25 mrem/year |
| | | Public exposure, atmospheric releases | 10 mrem/year |

**Table 8A.3. TBC guidance from 10 CFR 61 licensing requirements for land disposal of radioactive waste**

| Action | Requirement | Prerequisites for Applicability | Citation |
|---|---|---|---|
| Closure of land disposal facilities | Closure must ensure protection of inadvertent intruders at any time after active institutional controls are removed. | Closure of NRC-licensed land disposal facility | 10 CFR 61.42 |
| | Closure must achieve long-term stability of the disposal site and eliminate the need for ongoing active maintenance following closure so that only surveillance, monitoring, or minor custodial care is required. | | 10 CFR 61.44 |
| | Wastes designated as Class A pursuant to 10 CFR 61.55 must be segregated from other wastes. | Existence of an NRC-licensed disposal facility designed for near-surface radioactive land disposal. | 10 CFR 61.52a(1) |
| | Wastes designated as Class C pursuant to 10 CFR 61.55 must be disposed of under five (5) meters of cover or with intrusion barrier protection for at least 500 years | | 10 CFR 61.52a(2) |
| | Waste must be placed and covered in a manner that limits the radioactive dose rate at the surface of the cover to levels consistent with an effective dose equivalent of 500 mrem/year | | 10 CFR 61.52a(6) |
| | A buffer zone of land must be maintained between the disposal unit and the disposal site boundary to allow for adequate environmental monitoring and site mitigation, if necessary | | 10 CFR 61.52a(8) |
| | Closure and stabilization measures established in the approved closure plan must be carried out as the disposal unit is filled and covered | | 10 CFR 61.52a(9) |
| | Post-operational surveillance of the disposal site shall maintain a monitoring system capable of providing early warning of releases from the disposal site before they leave the site boundary | | 10 CFR 61.53d |

**Table 8A.4. Summary of DOE Order 5400.5, "Radiation Protection of the Public and the Environment"**

| Action | Requirement | Chapter |
|---|---|---|
| Planning and performance of all DOE activities | DOE will carry out all DOE activities to ensure that radiation doses to individuals will be as low as reasonably achievable (ALARA) | I.4 |
| Routine DOE activities including remedial action | DOE must comply with all legally applicable requirements of 40 CFR 61 (NESHAPS for DOE Facilities), 40 CFR 191 (Spent Nuclear Fuel, High-level, and TRU Wastes), and 40 CFR 192 (Uranium and Mill Tailings), 10 CFR 60 (Disposal of High-level Radioactive Waste) and 10 CFR 72 (Licensing Regulation for the Independent Storage of Spent Nuclear Fuel and High-level Radioactive Waste). | I |
| | Exposures to members of the public from all radiation sources shall not cause an effective dose equivalent to be greater than 100 mrem (1 mSv) per year. | II.1a |
| | Exposures to members of the public from all radiation sources released into the atmosphere shall not cause an effective dose equivalent to be greater than 10 mrem (0.1 mSv) per year | II.1b |
| Management and storage of spent nuclear fuel, high-level or transuranic (TRU) waste at a disposal facility that is not regulated by the NRC | Members of the public shall not receive an effective dose equivalent greater than 25 mrem (0.25 mSv) to the whole body or 75 mrem (0.75 mSv) to a single organ per year. | II.1c |
| | Radioactive materials released into public drinking water supplies shall not cause an effective dose equivalent to be greater than 4 mrem (0.4 mSv) to an individual per year. Combined radium-226 and radium-228 shall not exceed $5X10^{-9}$ $\mu$Ci/ml and gross alpha activity shall not exceed $1.5X10^{-8}$ $\mu$Ci/ml. | II.1d |
| | Liquid effluent shall not cause private or public drinking water systems downstream of the facility to exceed the MCL(s) of 40 CFR 141 | II.1d(3) |
| Discharge of liquid waste containing radionuclides to surface water | Implementation of best available technology (BAT) treatment required if discharge is at an annual average concentration greater than the derived concentration guide (DCG) level. | II.3a(1) |

Table 8A.4. (continued)

| Action | Requirement | Chapter |
|---|---|---|
| | Discharge of liquid waste containing radionuclides to surface water at an annual average concentration less than the DCG level does not require the implementation of BAT treatment. | II.3a(2) |
| | The absorbed dose to native aquatic animal organisms shall not exceed 1 rad/day from exposure to liquid wastes discharged to natural waterways. | II.3a(5) |
| | Liquid wastes containing concentrations of radioactive materials greater than five (5) times the DCG(s) may be discharged to a federal sanitary sewerage system which provides liquid waste treatment prior to discharge to surface water according to II.3a(1). ALARA process considerations are required. | II.3d(3) |
| | If a waste stream contains multiple radionuclides, then the DCG shall be the sum of the fractional DCG values. | II.3a(3) |
| Management of low-level radioactive solid waste containing no RCRA constituents | Design, operational, and monitoring requirements are found in DOE Order 5820.2A (Radioactive Waste Management) | II.4 |
| Demonstration of compliance with the dose limits | DOE shall make appropriate documentation containing information about compliance with dose limits for members of the public in the immediate vicinity and within 80 km of the site. | II.6 |
| Conduct of radiological environmental protection programs | DCG(s) for water ingestion, air inhalation, and immersion in a gaseous cloud are provided as reference values. These DCG(s) are based on a committed effective dose equivalent of 100 mrem for the radionuclide taken into the body by ingestion or inhalation during one year. | III.2 |
| | The DCG values apply to only one mode of exposure, i.e., either ingestion OR inhalation. | III.2a |
| | For known mixtures of radionuclides, the sum of the ratios of the observed concentration of each radionuclides to its corresponding DCG must not exceed 1.0. | III.2c |

Table 8A.4. (continued)

| Action | Requirement | Chapter |
|---|---|---|
| Cleanup of residual radioactive material and management of resulting wastes or residues | DOE facilities shall develop plans and protocols for the implementation of this guidance | IV.1 & 2 |
| | These guidelines are for levels of residual radioactive material that are acceptable for public use of property without restrictions due to radioactive material. | IV.2c |
| | Generic guidelines are taken from existing radiation protection standards. | IV.2c(1) |
| | Authorized limits are levels of residual radioactive material that shall not be exceeded if the remedial action is to be considered completed and the property is to be released without restrictions on use. | IV.2d |
| | Monitoring, cleanup, and control of residual radioactive material are subject to the ALARA policy. | IV.2e |
| | The basic dose limits for exposure to residual radioactive material is 100 mrem (1 mSv) annually. | IV.3a |
| | Under unusual circumstances, the dose limit for exposure to residual radioactive material is increased from 100 (1 mSv) to 500 (mSv) annually. | IV.3b |
| | Residual radioactive material in soil are those concentrations in excess of background concentrations averaged over an area of 100 $m^2$. The derivations are obtained by means of environmental pathway analogies and basic dose limits. | IV.4a |
| | Residual concentrations of radionuclides in the air and water shall not exceed 100 mrem (1 mSv) per year. | IV.4e |

Table 8A.4. (continued)

| Action | Requirement | Chapter |
|---|---|---|
| | Limits for hot spots shall be developed in cases where the average concentration in any surface or below surface area equal to or less than 25 $m^2$ exceeds the limit or guidelines by a factor of $(100/A)^{0.5}$. Reasonable effort must be made to remove any radionuclide source that exceeds 30 times the limit. | IV.4a(1) |
| | The generic guidelines for Ra-226, Ra-228, Th-230, and Th-232 are 5 pCi/g averaged over the first 15 cm of soil or 15 pCi/g averaged over 15-cm thick layers of soil below the first 15 cm. | IV.4a(2) |
| Management of residual radioactivity above the guidelines specified in IV.1-4. | Interim storage control and stabilization features shall be planned to have a minimum life of 25 years, and, if reasonably achievable, an effective life of 50 years. | IV.6b(1) |
| | Rn-222 concentrations shall not exceed 100 pCi/L; annual average concentration of 30 pCi/L over the facility site; and annual average concentration of 3 pCi/L at or above any location outside the facility site. | IV.6b(2) |
| | Control features must be designed so that radionuclide concentration in the groundwater shall not exceed applicable Federal and State standards. | IV.6b(3) |
| | If residual radioactive material is in inaccessible locations and would be unreasonably costly to remove, and when residual radioactive material exceeds guideline values, an interim management plan may be arranged to maintain the property. | IV.6c(1) |
| | Administrative controls shall include (but are not limited to):<br>• periodic monitoring as appropriate;<br>• appropriate shielding;<br>• physical barriers to prevent access; and<br>• appropriate radiological safety measures | IV.6c(2) |
| | Control and stabilization for uranium, thorium, and their decay products must be designed to last at a minimum of 200 years and if reasonably achievable have an effective life of 1000 years. | IV.6d(1)(a) |

**Table 8A.4. (continued)**

| Action | Requirement | Chapter |
|---|---|---|
| | Rn-222 emanation to the atmosphere shall be controlled to have an annual release rate of 20 pCi/m$^2$/s. For any location outside the contaminated area, the annual release rate will not exceed 0.5 pCi/L. Field verification shall be in accordance with 40 CFR 61 requirements. | IV.6d(1)(b) |
| | Biodegradable contaminated wastes shall be conditioned before they are placed in a long-term management facility. These wastes will be conditioned so that the generation and escape of biogenic gases will not cause the requirement in IV.6d(1)(b) to be exceeded and cause structural failure in violation of IV.6d(1)(a). | IV:6d(1)(c) |
| | In accordance with legally applicable federal and state standards, DOE facilities shall protect groundwater. | IV.6d(1)(d) |
| | Use of and access to residual radioactive material shall be controlled through appropriate administrative and physical controls. | IV.6d(1)(e) |
| | Long-term management of other radionuclides shall be controlled by applicable requirements in Chapters II, III, and IV of DOE 5820.2A. | IV.6d(2) |

Table 8A.5. Summary of DOE Order 5820.2A, "Radiation Waste Management"

| Action | Requirement | Chapter |
|---|---|---|
| Management of Low-Level Radioactive Waste | Development of site-specific comprehensive closure plans shall address:<br>• Disposal sites' closure after the site has been filled for 5 years<br>• NEPA requirements | III.3j(1) |
| | Residual radioactivity levels for surface soil will comply with DOE decommissioning guidelines (DOE Order 5400.5) | III.3j(2) |
| | DOE must correct problems that could jeopardize the attainment of this order's performance objectives | III.3j(3) |
| | All disposal sites and units shall be maintained to conform with RCRA, CERCLA, SARA standards | III.3j(4) |
| | An appropriate field organization shall review and approve any closure plans for new and existing low-level waste disposal sites | III.3j(5) |
| | An analysis of site performance will be the basis for terminating the monitoring and maintenance activity at closed facilities or sites at the end of the institutional control period | III.3j(6) |
| Management of Buried Transuranic Waste | All disposal sites and units shall be maintained to conform to the CERCLA and SARA standards | II.1 |
| | Transuranic waste shall be managed to protect the health and safety of the public and the workers at the site | II.2 |
| | Each DOE facility will develop a site closure plan which will include:<br>• NEPA requirements<br>• ARARs<br>• Permits required<br>• Selected closure strategy and justification<br>• Post-closure monitoring and control | II.3i(4) |

**Table 8A.6. Radionuclide slope factors and pathway-specific unit risk**

| | Slope Factor | | | Pathway-Specific Unit Risk | | | |
|---|---|---|---|---|---|---|---|
| | Age-averaged lifetime excess total cancer risk per unit intake or exposure | | | Age-averaged lifetime excess total cancer risk per unit intake or exposure daily for 70 years | | | |
| Radionuclide | Inhalation $(pCi)^{-1}$ | Ingestion $(pCi)^{-1}$ | Ground surface $(pCi)^{-1}$ | Air $(pCi)^{-1}$ | Drinking water $(pCi/L)^{-1}$ | External exposure $(pCi/g\ soil)^{-1}$ | Soil ingestion $(pCi/g)^{-1}$ |
| Actinium-225 | 2.4E-09 | 1.7E-11 | 9.4E-13 | 1.2E-03 | 8.7E-07 | 9.4E-06 | 4.6E-08 |
| Americium-241 | 4.0E-08 | 3.1E-10 | 1.6E-12 | 2.1E-02 | 1.6E-05 | 1.6E-05 | 8.4E-07 |
| Barium-137m | 6.0E-16 | 2.4E-15 | 3.4E-11 | 3.0E-10 | 1.2E-10 | 3.4E-04 | 6.5E-12 |
| Bismuth-213 | 3.2E-13 | 2.3E-13 | 8.1E-12 | 1.6E-07 | 1.2E-08 | 8.1E-05 | 6.2E-10 |
| Curium-244 | 2.7E-08 | 2.0E-10 | 5.8E-14 | 1.4E-02 | 1.0E-05 | 5.9E-07 | 5.4E-07 |
| Cobalt-60 | 1.6E-10 | 1.5E-11 | 1.3E-10 | 8.1E-05 | 7.8E-07 | 1.3E-03 | 4.1E-08 |
| Cesium-137 | 1.9E-11 | 2.8E-11 | 0.0E+00 | 9.6E-06 | 1.4E-06 | 0.00E+00 | 7.6E-08 |
| Europium-152 | 1.2E-08 | 2.1E-12 | 6.3E-11 | 6.1E-03 | 1.1E-07 | 6.3E-04 | 5.7E-09 |
| Europium-154 | 1.4E-10 | 3.0E-12 | 6.8E-11 | 7.2E-05 | 1.5E-07 | 6.8E-04 | 8.1E-09 |
| Hydrogen-3 (Tritium) | 7.8E-14 | 5.5E-14 | 0.0E+00 | 4.0E-08 | 2.8E-09 | 0.0E+00 | 1.5E-10 |
| Plutonium-240 | 4.1E-08 | 3.1E-11 | 5.9E-14 | 2.1E-02 | 1.6E-06 | 5.9E-07 | 8.4E-08 |
| Radium-225 | 1.6E-09 | 6.6E-11 | 8.0E-13 | 8.2E-04 | 3.4E-06 | 8.0E-06 | 1.8E-07 |
| Strontium-90 | 5.6E-11 | 3.3E-11 | 0.0E+00 | 2.8E-05 | 1.7E-06 | 0.0E+00 | 8.9E-08 |
| Thorium-229 | 7.7E-08 | 3.9E-11 | 5.8E-12 | 3.9E-02 | 2.0E-06 | 5.8E-05 | 1.1E-07 |
| Thorium-232 | 3.1E-08 | 2.2E-11 | 4.6E-14 | 1.6E-02 | 1.1E-06 | 4.5E-07 | 5.9E-08 |
| Uranium-233 | 2.7E-08 | 1.4E-10 | 3.2E-14 | 1.4E-02 | 7.2E-06 | 3.2E-07 | 3.8E-07 |
| Uranium-238 | 2.4E-08 | 1.3E-10 | 4.6E-14 | 1.2E-02 | 6.6E-06 | 4.5E-07 | 3.5E-07 |
| Yttrium-90 | 5.5E-12 | 3.2E-12 | 0.0E+00 | 2.8E-06 | 1.6E-07 | 0.0E+00 | 8.6E-09 |

*Source:* EPA 1990b.

Table 8A.7. Chemical-specific federal ARARs for protection of human health[a]

| Chemical | Safe Drinking Water Act MCLs[b] (μg/L) | Safe Drinking Water Act MCLGs[c] (μg/L) |
|---|---|---|
| Arsenic[d] | 50 | -- |
| Barium[e] | 1,000 | -- |
| Benzene[d] | 5 | 0 |
| Cadmium[f] | 5 | 5 |
| Carbon Tetrachloride[d] | 5 | 0 |
| Chromium (total)[f] | 100 | 100 |
| 1,2-Dichloroethane[d] | 5 | 0 |
| 1,1-Dichloroethane[d] | 7 | 7 |
| cis-1,2-Dichloroethylene[g] | 70 | 70 |
| trans-1,2-Dichloroethylene[g] | 100 | 100 |
| 2,4-Dichlorophenoxyacetic acid (2,4-D)[f] | 70 | 70 |
| Ethylbenzene[g] | 700 | 700 |
| Lead[d] | 50 | -- |
| Mercury[f] | 2 | 2 |
| Monochlorobenzene[g] | 100 | 100 |
| Polychlorinated biphenyls[g] | 0.5 | 0 |
| Selenium[f] | 50 | 50 |
| Silver[d] | 50 | -- |
| Tetrachloroethylene[g] | 5 | 0 |
| Toluene[g] | 1,000 | 1,000 |
| 1,1,1-Trichloroethane[d] | 200 | 200 |
| Trichloroethylene[d] | 5 | 0 |
| Trihalomethanes (total)[d,h] | 100 | -- |
| 2,4,5-Trichlorophenoxy-propionic acid (2,4,5-TP)[f] | 50 | 50 |
| Vinyl chloride[d] | 2 | 0 |
| Xylenes (total)[g] | 10,000 | 10,000 |

[a]ARAR = applicable or relevant and appropriate requirement.
[b]MCL = maximum contaminant level.
[c]MCLG = maximum contaminant level goal.
[d]52 FR 25690 (July 8, 1987).
[e]The MCL/MCLG has been reproposed for this chemical (56 FR 3526, January 30, 1991); when promulgated the proposed values will become ARARs.
[f]The final MCL/MCLG was reproposed for this chemical (56 FR 3526, January 30, 1991); and supersedes the original SDWA MCL.
[g]56 FR 3526 (January 30, 1991). Effective January 30, 1992.
[h]Total trihalomethanes refers to the sum of the concentration of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.

**Table 8A.8. Proposed Safe Drinking Water Act maximum contaminant level goals (MCLGs) and maximum contaminant levels (MCLs)[a]**

| Chemical | Proposed MCLG (μg/L) | Proposed MCL (μg/L) |
|---|---|---|
| Antimony | 3 | 10/5[c] |
| Barium[b] | 1,000 | 1,000 |
| Beryllium | 0 | 1 |
| Copper[d] | 1,300 | 1,300 |
| Cyanide | 200 | 200 |
| Dichloromethane (methylene chloride) | 0 | 5 |
| Lead (at the source)[d] | 0 | 5 |
| Lead (at the tap)[d] | 0 | TT[e] |
| Nickel | 100 | 100 |
| Phthalates ([di(ethylhexyl)phthalate | 0 | 4 |
| 1,1,2-Trichloroethane | 3 | 5 |

[a]55 FR 30370 (July 25, 1990). A final rule is expected March 1992.
[b]The MCLG and MCL for this chemical have been reproposed (56 FR 3526 January 30, 1991).
[c]EPA proposes two MCLs for public comment based on two practical quantitation limits (PQLs)
[d]53 FR 31516 (August 18, 1988). A final rule is expected May 1991.
[e]TT = treatment technique.

**Table 8A.9. Federal ambient water quality criteria for the protection of freshwater organisms**

| Chemical | Maximum (μg/L)[a] | 24-h (μg/L)[b] |
|---|---|---|
| Aluminum | 750[c] | 87[c] |
| Arsenic (III) | 360 | 190 |
| Cadmium | 1.8[d] | 0.66[d] |
| Chromium (VI) | 16 | 11 |
| (III) | 984[d] | 117[d] |
| Copper | 9.22[d] | 6.54[d] |
| Iron | NA | 1,000 |
| Lead | 33.8[d] | 1.32[d] |
| Mercury | 2.4 | 0.012[e] |
| Nickel | 789[d] | 88[d] |
| Polychlorinated biphenyls (PCBs) | NA | 0.014[f] |
| Selenium (inorganic selenite) | 20 | 5 |
| Silver | 1.23[d] | NA |
| Zinc | 65[d] | 59[d] |

[a]One-hour average concentration not to be exceeded more than once every 3 years.
[b]Four-day average concentration not to be exceeded more than once every 3 years.
[c]pH 6.5-9.0.
[d]Water hardness dependent criteria (100 mg/L as $CaCO_3$).
[e]Based on marketability of fish.
[f]pH dependent criteria.

NA = not available.

*Source:* EPA 1991.

Table 8A.10. Tentative location-specific ARARs for WAG 6

| Location | Requirement | Prerequisite(s) | Citation |
|---|---|---|---|
| Within 100-year floodplain | Facility must be designed, constructed, operated, and maintained to avoid washout by a 100-year flood | RCRA hazardous waste; treatment, storage, or disposal | 40 CFR 264.18(b) |
| Within floodplain | Must take action to avoid adverse effects, minimize potential harm, restore and preserve natural and beneficial values, and minimize impact of floods on human safety, health, and welfare | Action of federal agencies pertaining to: acquiring, managing, and disposing of lands and facilities; construction or improvements; and conducting activities and programs affecting land use in flood-prone areas | Executive Order 11988; Floodplain Management (40 CFR 6, Appendix A); 40 CFR 6.302(b) |
| | Federal agencies must evaluate the potential effects of any action it may take in a floodplain, ensuring that planning programs and budget reflect considerations of flood hazards | | Executive Order 11988 |
| Wetland | Must take action to avoid adverse impact, minimize potential harm, and to preserve and enhance wetlands to the extent possible | Wetland as defined 40 CFR 6, Appendix A §4; action of federal agencies involving construction of facilities or management of property in wetland areas | Executive Order 11990; Protection of Wetlands (40 CFR 6 Appendix A); 40 CFR 6.302(a) |
| | Federal agencies shall incorporate floodplain management goals and wetlands protection considerations in its planning, regulatory, and decision-making process. | | 40 CFR 6, Appendix A |
| | Federal agencies should avoid new construction in wetlands areas | | 40 CFR 6, Appendix A |
| | Prohibits discharge of dredge or fill material into wetlands without permit | Wetlands as defined in 40 CFR 6, Appendix A §4, and U.S. Army Corps of Engineers regulations | Clean Water Act §404; 40 CFR 230.10; 33 CFR 320-330 |

Table 8A.10 (continued)

| Location | Requirement | Prerequisite(s) | Citation |
|---|---|---|---|
| | Provides for the enhancement, restoration, or creation of alternate wetlands | Unavoidable adverse impacts on wetlands | Clean Water Act §404(b)(1) |
| Within area affecting stream or river | Must take action to protect affected fish or wildlife resources; prohibits diversion, channeling, or other activity that modifies a stream or river and affects fish or wildlife | Presence of fish and wildlife resources; action by federal agencies resulting in the control or structural modification of a natural stream or body of water | Fish and Wildlife Coordination Act (16 USC 661 et seq.); 40 CFR 6.302(g); Tennessee Water Quality Control Act of 1977 (Chap.1200-4-3) |
| | Federal agencies should consult with the Fish and Wildlife Service and state personnel to develop protective measures for affected wildlife | Off-site response actions | |

[a]Adapted from EPA (1988).
[b]RCRA = Resource Conservation and Recovery Act; definitions appear at 40 CFR 260.10.
[c]TCA = Tennessee Code Annotated.

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## Table 8A.11. Action-specific ARARs for Alternatives 2-7[a]

| Actions[b] | Requirements | Prerequisites[c] | Federal Citation | Tennessee Code Annotated (TCA) |
|---|---|---|---|---|
| On-site construction/excavation | Total suspended particulates (TSP) must be maintained below National Ambient Air Quality Standards | Nonpoint source contribution to fugitive dust emissions | 40 CFR 50.6 | 1200-3-3 |
| | Must take reasonable precautions to prevent particulate matter from becoming airborne | Handling or transporting of any materials | | 1200-3-8-.01 |
| | Fugitive dust may not be emitted as visible emissions beyond property boundary lines for more than 5 min/hr or 20 min/day | Handling or transporting of any materials | | 1200-3-8-.01 |
| Asbestos emissions | Treat asbestos-containing waste material with water | Applicable for waste disposal for manufacturing, demolition, renovation, spraying, and fabricating operations | 40 CFR 61.152(b)(1) | 1200-3-11.02(k)(3) |
| | Discharge no visible emissions to the outside air from and inactive waste disposal site | Applicable to waste disposal sites for asbestos mills and manufacturing and fabricating operations | 40 CFR 61.153(a)(1) | 1200-3-11.02(1)(1) |
| | Cover the asbestos-containing waste material with at least 15 cm (6 in.) of compacted non-asbestos-containing material, and grow and maintain a cover of vegetation on the area adequate to prevent exposure of the asbestos-containing waste material; or | | 40 CFR 61.153(a)(2) | 1200-3-11.02(1)(5) |
| | Cover the asbestos-containing waste material with at least 60 centimeters (2 feet) of compacted non-asbestos-containing material and maintain it to prevent exposure of the asbestos-containing waste material | | 40 CFR 61.153(a)(3) | 1200-2-11.02(1)(5) |

Table 8A.11. (continued)

| Actions[b] | Requirements | Prerequisites[c] | Federal Citation | Tennessee Code Annotated (TCA) |
|---|---|---|---|---|
| Surface water control | Monitor surface water to ensure compliance with state water quality standards | Wastes discharged into adjacent streams or other surface waters | 40 CFR 122 | 1200-4-3 |
| | Maintain a run-on control system and collect run-off from at least the amount of water volume resulting from a 24-hr. 25-yr storm. | RCRA[d] hazardous waste treated, stored, or disposed at a site after November 19, 1980 | 40 CFR 264.301(f,g) | 1200-1-11-.06(14b) |
| Capping | Placement of a cap over waste (e.g., closing a landfill, or closing a surface impoundment or waste pile as a landfill, or similar action) requires a cover designed and constructed to:<br>• Provide long-term minimization of migration of liquids through the capped area<br>• Function with minimum maintenance<br>• Promote drainage and minimize erosion or abrasion of the cover<br>• Accommodate settling and subsidence so that the cover's integrity is maintained<br>• Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present | Closure of any landfill | 40 CFR 264.310(a) | 1200-1-11-.06(14K) |

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Table 8A.11 (continued)

| Actions[b] | Requirements | Prerequisites[c] | Federal Citation | Tennessee Code Annotated (TCA) |
|---|---|---|---|---|
| Post-closure care | Must begin after closure and continue for 30 years after that date | RCRA hazardous waste management unit | 40 CFR 264.117-120 | 1200-1-11-.06(7h-k) |
| | Prevent run-on and run-off from damaging the final cover | RCRA landfill | 40 CFR 264.310(b) | 1200-1-11-.14(k) |
| | Protect and maintain surveyed benchmarks used to locate waste cells (landfills, waste piles) | RCRA landfill | 40 CFR 264.310(b) | 1200-1-11-.14(k) |
| | Maintain integrity and effectiveness of final cover | RCRA landfill | 40 CFR 264.310(b) | 1200-1-11-.14(k) |
| | Restrict post-closure use of property as necessary to prevent damage to the cover. | RCRA landfill | 40 CFR 264.310(b) | 1200-1-11-.14(k) |

[a]Adapted from EPA (1989).
[b]Action alternatives from ROD keyword index, (EPA 1987c).
[c]Some action-specific requirements listed may be relevant and appropriate even if RCRA definitions of storage, disposal, or hazardous waste are not met (40 CFR 260.10), or if the waste at the site is similar to but not identifiable as a RCRA hazardous waste.
[d]RCRA=Resource Conservation and Recovery Act.

Table 8A.12. Action-specific ARARs for Alternative 7[a]

| Actions[b] | Requirements | Prerequisites[c] | Federal Citation | Tennessee Code Annotated (TCA) |
|---|---|---|---|---|
| On-site construction/excavation | SEE TABLE 8A.11 | | | |
| Surface water control | SEE TABLE 8A.11 | | | |
| Treatment (in a unit) | Design, operating, and closure standards for units in which hazardous waste is treated must ensure protection of human health and the environment | Treatment of RCRA[d] hazardous waste in a unit | 40 CFR 264.601 (Miscellaneous Treatment Units) | 1200-1-11-.06(19b) |
| | Prevention of any releases that may have adverse effects on human health or the environment due to migration of waste constituents | Treatment of RCRA hazardous waste in a unit | 40 CFR 264.601 | 1200-1-11-.06(19b) |
| | Specific considerations must be made to prevent adverse effects in: | Treatment of RCRA hazardous waste in a unit | | 1200-1-11-.06(19b) |
| | • the groundwater or subsurface environment | | 40 CFR 264.601(a) | |
| | • surface water, or wetlands, or the soil surface | | 40 CFR 264.601(b) | 1200-1-11-.06(19b) |
| | • the air | | 40 CFR 264.601(c) | 1200-1-11-.06(19b) |
| Tank storage (on-site) | Existing and new tanks must have sufficient structural strength and compatibility with the waste, to assure that they do not collapse or rupture | Storage of RCRA hazardous waste (listed or characteristic) not meeting small quantity generator criteria held for a temporary period greater than 90 days before treatment, disposal, or storage elsewhere, in a tank (i.e., any portable device in which a material is stored, transported, disposed of, or handled) | | |
| | Waste must not be incompatible with the tank material unless the tank is protected by a liner or by other means | | 40 CFR 264.191 | 1200-1-11-.06(10b) |

Table 8A.12. (continued)

| Actions[b] | Requirements | Prerequisites[c] | Federal Citation | Tennessee Code Annotated (TCA) |
|---|---|---|---|---|
| Tank storage (on-site) (continued) | Tanks must be provided with secondary containments and controls to prevent overfilling, and sufficient freeboard maintained in open tanks to prevent overtopping by wave action or precipitation | | 40 CFR 264.193-194 | 1200-1-11-.06(10d,e) |
| | Inspect the following: overfilling control; control equipment, monitoring data, waste level (for uncovered tanks), tank condition, above-ground portions of tanks (to assess their structural integrity), and the area surrounding the tank (to identify signs of leakage) | | 40 CFR 264.195 | 1200-1-11-.06(10f) |
| | Repair any corrosion, crack, or leak | | 40 CFR 264.196 | 1200-1-11-.06(10g) |
| Capping | SEE TABLE 8A.11 | | | |
| Tank closure | At closure of a tank system, all contaminated residues, system components, soils, and equipment must be removed and handled as hazardous waste | Closure of tank systems containing RCRA hazardous waste | 40 CFR 264.197 | 1200-1-11-.06(10h) |
| Post-closure care (miscellaneous treatment units) | Must meet the general closure requirements of 40 CFR 264.601 which ensure protection of human health and the environment | Presence of residual contaminated soil or groundwater following closure of RCRA hazardous waste treatment unit | 40 CFR 264.603 | 1200-1-11-.06(19d) |

[a]Adapted from EPA (1989).
[b]Action alternatives from ROD keyword index, (EPA 1987c).
[c]Some action-specific requirements listed may be relevant and appropriate even if RCRA definitions of storage, disposal, or hazardous waste are not met (40 CFR 260.10), or if the waste at the site is similar to but not identifiable as a RCRA hazardous waste.
[d]RCRA=Resource Conservation and Recovery Act

# Appendix 8B. SCREENING OF RESPONSE ACTIONS, TECHNOLOGIES, AND PROCESS OPTIONS

This appendix describes the process used to screen response actions and associated technologies that might be applied to the source areas and groundwater at WAG 6.

## 8B.1 DESCRIPTION OF THE SCREENING PROCESS

The first step in the screening process is to identify response actions with the potential for meeting the general objective of protecting human health and the environment. Response actions define a general class of actions that, independently or in combination with other response actions, could be taken on the site to meet the objective. For example, general response actions applied to a site containing contaminated groundwater could include institutional controls, containment, or treatment. Once general response actions that could be used at the site are developed, the technologies associated with each are identified. Process options, which are the different processes that fall within a technology, are also identified for each technology. This general relationship among the different elements is illustrated in Fig. 8B.1.

Two steps then are taken to reduce the list of technologies and process options. First, each process option is evaluated to determine if it can be technically implemented at the site. To determine technical implementability, the capabilities of the process option are compared to the characteristics of the site and the site wastes. Process options that are not technically implementable are eliminated from further consideration. In some cases, none of the process options under a given technology will be considered technically implementable. In this case, the entire technology will be eliminated.

Each technology that passes the first screening step will have one or more process options. As a second step in the screening process, these remaining process options are evaluated more closely to determine which process options and technologies will be developed into remedial alternatives. The purpose of this evaluation is to select a single process option or combination of process options to represent each technology. The process options are compared on the basis of effectiveness, implementability, and cost, and the single process option or combination of options that offer the best combination of effectiveness, implementability, and cost is carried forward for development into remedial alternatives. Process options not carried forward may be considered again during remedial design.

## 8B.2 GENERAL RESPONSE ACTIONS

To protect human health and the environment from the contaminants at WAG 6, general response actions have been developed with respect to the site's source areas and groundwater. The actions are intended to address the environmental and public health impacts of the contaminants, possible migration pathways, and exposure routes for each source area and groundwater. Combinations of response actions may prove to be more effective in meeting the objectives.

The general response actions include the "No Action" category as mandated by the NCP. This No Action response will serve as a baseline comparison against which the other developed actions can be compared. Table 8B.1 summarizes the general response actions for each media/source and its risk type.

## 8B.3 IDENTIFICATION AND SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

The specific technologies and process options that are potentially applicable at WAG 6 are a subset of the universe of remedial technologies. The technologies and process options that have been identified are those that are potentially applicable to the source areas and groundwater present and are not still in laboratory development. As shown in Fig. 8B.2, the remedial technologies are broad categories, each of which addresses a similar problem. For example, the general response action, Containment, includes the remedial technologies capping, vertical barriers, etc. Each of these remedial technologies, in turn, comprises several process options that might be used. For example, capping comprises clay cap, multilayer cap, asphalt cap, etc.

The screening process eliminates technologies from further consideration on the basis of technical implementability. Two general screening criteria are used to eliminate process options or technologies that are not considered applicable for the site:

- Applicability to site physical conditions (and their ranges)
- Applicability to type and combinations of contaminants (and their ranges)

Table 8B.2 identifies site and contaminant characteristics applied in screening potential technologies and process options. These criteria have been applied to the technologies and process options developed for WAG 6, and brief results of the screening are presented in Fig. 8B.2.

## 8B.4 DISCUSSION OF RETAINED TECHNOLOGIES

Each technology retained for further evaluation is described below in terms of relevant aspects of its implementability, effectiveness, and cost. In this discussion, a representative process encompassing several similar process options is often carried forward for further evaluation. This limits the number of options used in alternative development without losing the flexibility of reevaluating these options at a later phase in the FS or during the design. Options that are extremely difficult to implement or that do not offer significantly improved protection, yet are very expensive, have not been carried forward for further consideration (see Fig. 8B.2).

### 8B.4.1 Institutional Controls—Access and Use Restrictions

The objectives of access and use restrictions are to prevent prolonged exposure to contaminants, to control future development or disturbance of the site, and to prevent

installation of water supply wells downgradient of or within the contaminated area. These objectives are accomplished by placing site usage and deed restrictions on property within potentially contaminated areas and fencing the site. DOE already maintains significant access restrictions for security. WAG 6 is fenced and has significant use restrictions, and the effectiveness of the existing access restrictions is high.

This technology would be implemented after DOE control of the facility is released, and its future effectiveness would depend upon its continued implementation. Access restrictions are subject to changes in political jurisdiction, legal interpretations, and regulatory enforcement. If implemented correctly, access restrictions provide moderate protection against direct contact with contaminants at low cost. Access restrictions will be carried forward for further evaluation.

### 8B.4.2 Containment

#### 8B.4.2.1 Capping

Caps are intended to minimize any or all of the following:

- Infiltration of surface water and subsequent leachate generation caused by water percolating through the waste
- Release of contaminants by wind or water erosion
- Surface radiation levels
- Direct contact with surface and subsurface contaminants by site intruders

Capping technologies include single-layer and multilayer systems, both of which may involve clearing, grubbing, and grading before placement of the cap. In general, capping is performed when extensive subsurface contamination at a site precludes excavation and removal of wastes because of the potential hazards or costs, which may be the case at WAG 6.

The main disadvantages of capping are the need for long-term maintenance and uncertain design life. Caps must be periodically inspected for settlement, erosion, and invasion by animals and deep-rooted vegetation. If not stabilized before capping, trenches in WAG 6 might subside significantly as a result of degradation of trench wastes. Dynamic compaction and trench grouting are being demonstrated at ORNL as techniques for stabilizing trenches prior to capping and are discussed later in this section.

The presence of relatively high groundwater levels in the lower areas of WAG 6 might limit a cap's ability to significantly decrease groundwater contamination in these areas. In such cases, other technologies could be necessary to lower the groundwater levels below the trench bottoms (e.g., trench drains). Capping with no or minimal excavation limits worker risk and the difficulty in locating acceptable alternate permanent disposal locations over excavation and off-WAG disposal. Both a clay cap and a multilayer cap were retained after the process option screening based on technical implementability.

**Clay cap.** Although a single-layer clay cap is low cost and easy to implement, it is unreliable and lacks durability. Local freeze-thaw and wet-dry cycles create fractures in the clay, reducing its effectiveness as a low permeability barrier and requiring frequent maintenance. Therefore, a multilayered cap will be considered as a representative process option.

**Multilayer caps.** Multilayer caps combine one or more layers of low-permeability material with other layers serving various design functions. Multilayer caps have three distinct types of layers that can be combined in a number of ways, (1) surface protection layer, (2) drainage layer, and (3) barrier layer.

The topsoil and fill layer separates the low-permeability or barrier layer from the environment, which protects the barrier layer, from factors such as frost damage, maintenance vehicles, and burrowing animals. Topsoil also supports vegetation, which helps minimize erosion.

The drainage layer, which typically consists of clean sand and perforated drain pipes or a geonet, limits water infiltration from the surface and reduces the amount of water that could penetrate the barrier layer. The drainage layer is covered with a geotextile filter, which reduces clogging by fine-grained soil.

The barrier layer minimizes infiltration of water into the waste mass and the release of radioactivity to the atmosphere. Both clay and synthetic membranes are used as low-permeability barriers. There are many different kinds of clay, most of which can be compacted to provide a permeability of $10^{-7}$ cm/s. The performance life of a protected clay barrier is expected to exceed 30 years, unless large differential settlements occur. At WAG 6, settlement would be a concern with wastes that were containerized before burial or that are biodegradable.

When properly installed and protected, synthetic membranes are impermeable. The performance life is uncertain because of limited operational history.

A variety of multilayer caps will be considered for WAG 6 as a whole, with different caps used as appropriate for the different burial areas. In addition, a multilayer cap may be constructed over the Tumulus. The details of the cap(s) and their application will be developed as part of the alternatives. Any caps constructed over biodegradable material may include gas venting or collection to prevent gas buildup. (See Sect. 8B.4.3.5, Vapor/Gas Collection.)

### 8B.4.2.2 Vertical barriers

Vertical barriers control the horizontal flow of groundwater. If the barrier is hydraulically upgradient, groundwater is diverted around the waste. If downgradient or around the waste, the vertical barrier helps to contain or control the movement of contaminated groundwater. Potentially applicable vertical barriers include slurry walls and imposed hydraulic barriers.

**Slurry walls.** Two types of slurry walls—soil-bentonite or diaphragm—are under consideration. Either type would be constructed by excavating a trench that is filled with a bentonite slurry to provide temporary stabilization of the vertical trench walls, especially below the water table. For a soil-bentonite slurry wall, the trench is backfilled with a mixture of bentonite and soil. For a diaphragm wall, concrete is placed into a trench containing a bentonite slurry usually in conjunction with steel reinforcement. The concrete displaces the bentonite slurry and is allowed to harden. Typically the concrete is reinforced to provide additional strength.

Both soil-bentonite and diaphragm walls are effective in controlling the flow of groundwater. When used downgradient of a source area for the purpose of containing contaminated groundwater, they must be keyed into an impervious stratum or confining layer. They also need to be used in combination with an interior groundwater collection system to provide a negative hydraulic gradient to limit leaking through the wall. Because there is no known, confining layer at WAG 6, slurry walls in this application will not be considered.

Another application of slurry walls is the installation of shallow walls upgradient of buried sources to divert groundwater around the sources. The difficulty is that a very carefully designed system of walls is needed to prevent the diverted groundwater from entering other buried sources. Because the diversion of shallow groundwater would more effectively be accomplished if the groundwater were removed instead of just diverted, hydraulic barriers will be considered over shallow slurry walls.

**Hydraulic barriers.** Another applicable process option under the vertical barrier technology is a hydraulic barrier. Well systems and drains may be used to reduce the flow of groundwater through waste and contaminated soil. The drains or wells are positioned upgradient of the sources and through the collection and removal of groundwater a barrier to flow is produced. However, because of hydrogeologic conditions an extraction well system may not be feasible at WAG 6. The site's subsurface is complex and the bedrock is fractured. Collection trenches are appropriate for such site conditions, because, regardless of subsurface conditions, they can intercept groundwater flowing through an area and prevent it from entering a waste disposal area. A French drain at WAG 6 has been successful in collecting groundwater. However, the system performance has diminished over less than 10 years, and this problem would need to be addressed in any trench design. Hydraulic barriers represented by collection drains will be carried forward for alternative development.

### 8B.4.2.3 Surface controls

There are a number of surface controls potentially applicable for WAG 6. These are discussed below.

**Grading and revegetation.** Grading is used to modify the natural topography and surface characteristics of the site to control ponding, runoff, and infiltration. Revegetation stabilizes the site surfaces and decreases wind and water erosion, contributing to the

development of a naturally fertile and stable surface environment. In addition, vegetative cover helps decrease infiltration of surface water by maximizing evapotranspiration. The option involves seeding, fertilizing, and watering the area until a stand of vegetation has been established. Grading and revegetation are easily implemented and are relatively inexpensive, effective options, although maintenance costs (e.g., mowing) will be incurred over the life of the alternative.

**Diversion and collection.** Surface water diversion and collection methods are effective and relatively inexpensive. Dikes and berms (well-compacted earthen ridges or ledges) isolate areas from runoff. Ditches and trenches collect and/or convey water around, through, or from an area. This option could be used as a secondary technology for control of surface runoff during construction or from a cap.

**Dynamic compaction.** Dynamic compaction involves dropping a weight on buried waste to compact it and reduce voids in the SLB waste. Filling in the voids diminishes the likelihood of subsidence, which could result in failure of a cap. This provides control of the surface condition of the buried waste. Dynamic compaction has been tested on WAG 6 trenches and has been shown to be effective in reducing estimated voids. Monitoring of the surface of the trench showed no release of volatiles or radioactivity. However, some dust was produced, which might require control in any site-wide application. This process option is applicable for buried waste materials that, if excavated, might cause unacceptable worker health risks. However, use on containerized waste may result in the rupturing of the containers.

**Surface sealing.** The purpose of surface sealing is similar to that of capping; i.e., to prevent surface water infiltration, isolate waste, and control erosion. However, compared to capping, this process option is temporary and has limited effectiveness. Surface sealing will not be retained for further evaluation.

**In situ grouting.** This process involves injecting grout into voids in SLB waste. If the grouting is successful, the material is solidified with sufficient structural integrity to support a cap, thereby controlling surface conditions of the buried waste. The solidified material may also reduce mobility of contaminants. This process option is applicable for buried waste materials that, if excavated, might cause unacceptable worker health risks.

For fine-grained soil with small pores, chemical grouts are better suited. For coarse-grained materials, particulate grouts are suitable. Although this process option is experimental, in situ grouting has been conducted at WAG 6 on existing trenches. The process appears to be relatively inexpensive compared to excavation and disposal and presents fewer health risks.

Grading, revegetation, and diversion/collection systems will be carried forward for use either with capping (to control SLB wastes/soil and/or the tumulus), or as part of an alternative for control of surface water. Dynamic compaction and in situ grouting will also be retained as methods for structurally stabilizing buried waste before capping. They would be used only with alternatives that involve capping of SLB buried waste/soil.

#### 8B.4.2.4 Dust and vapor suppression

The control of dust and vapors is a secondary activity that requires consideration with every technology that would disturb the waste. Various agents (water, polymer, foam, or hygroscopic salts) can be spread over disturbed areas to reduce the dust and vapor migration. Membranes and tarps can also be used. The process option used would be a design decision, but methods would be selected that would minimize environmental impacts yet be cost-effective. At this stage, water and tarps will be used in any cost estimates of dust- and vapor-control processes.

### 8B.4.3 Removal

#### 8B.4.3.1 Drum and debris removal

Among the buried wastes are casks, pieces of large equipment, old laboratory furniture, and a variety of other contaminated debris. To complete a remedial action, it may be necessary to use specialized equipment to remove this debris or miscellaneous site debris such as trees. Specific alternatives for debris removal or excavation techniques will not be developed, but the various process options under drum and debris removal will be reevaluated when designs for the final alternative require the movement of debris.

#### 8B.4.3.2 Excavation

Excavation of SLB waste and associated contaminated soil or sediments, combined with disposal and/or treatment, is an effective remedial technology that reduces potential risks associated with release of contaminants to groundwater and surface water. Soil and buried waste are removed with ordinary construction equipment such as backhoes. However, the actual excavation and subsequent handling techniques will vary due to the variety of waste materials and site conditions. After removal, wastes would need to be segregated for different handling, treatment, or disposal requirements. Excavated areas would be backfilled to grade consistent with the site area and capped or covered as appropriate.

In some areas of WAG 6, excavation of materials will pose high risk of worker exposure to hazardous or radioactive materials. These risks include accidental rupture of buried containers, release of contaminants, and the potential for elevated radiation exposure. Also, dust, surface water, and groundwater would have to be controlled and monitored during the excavation to avoid or minimize release of contaminants and off-site exposure. Ambient air monitoring and radiological surveys during excavation activities would be required. Because the risks to workers and the environment may be unacceptable, excavation would be limited to buried waste/soil with low radiation levels.

Excavation is an effective and implementable technology. With adequate health and safety controls, and combined with treatment and/or disposal technologies, it can provide a reliable means of protecting human health and the environment. Excavation will be carried forward.

### 8B.4.3.3 Bulk liquid removal

With the proper equipment, liquid can be moved from one place to another with the use of hoses and pumps. There are significant amounts of leachate in some of the trenches, and there is the possibility that waste liquids may be formed in the process of treating the SLB waste or groundwater. Liquid removal minimizes the potential for leachate migration and improves the efficiency of in situ waste treatment processes. This technology also provides for the transfer of process wastewater to further treatment or disposal. The removal of liquids presents the possibility of spills from leaks, hose failures, or splashing; therefore, provisions for spill containment must be made.

Pumping is a reliable, inexpensive way to remove or collect bulk liquid, especially effective for removing water contained in the waste through the surface and for transferring waste water. It will be retained as an option for consideration but will not be developed specifically as an alternative because the need to remove bulk liquid can only be determined during design or construction. Bulk liquids are probably present in some of the SLB waste and may result from other remedial actions, but based on current data, the removal of bulk liquid is not expected to comprise a large part of the remediation. Continuous leachate collection is considered an element of groundwater collection. Any removed bulk liquid would need to be treated and/or disposed as discussed under Groundwater Treatment and Disposal.

### 8B.4.3.4 Groundwater collection

The groundwater collection process options are well systems and drains. Collecting groundwater with wells involves installing and operating extraction wells or well points for removing contaminated groundwater (followed by treatment and/or disposal). If properly designed and constructed, the wells are generally reliable, effective, and durable. However, at WAG 6 an extraction well system may not be feasible because of hydrogeologic conditions (See Section 3.0). It would be difficult to site a well system that could prevent contaminated groundwater from escaping the collection system. Therefore, extraction wells will not be retained as an option for groundwater collection.

A drain collection system would consist of a series of perforated pipes laid in trenches excavated to the bottom of the active flow zone of the upper aquifer. The trenches would be backfilled with a permeable medium such as gravel. Drain systems without perforated pipes can also be used. The groundwater collected in the trenches would flow by gravity to a wet well, from which it would be pumped to a holding tank prior to treatment or discharge. Collection trenches are appropriate for WAG 6 conditions because of the relatively low volume of groundwater to be collected, and because they can intercept groundwater flowing through an area regardless of subsurface conditions. Also, by using the natural contours of the burial areas, trenches can be constructed to intercept and prevent clean groundwater from entering a waste disposal area. As cited earlier, a French drain has already been used successfully at WAG 6. Drains will be carried forward as alternatives associated with groundwater collection.

### 8B.4.3.5 Vapor/gas collection

Collection and venting of gases is an important consideration when capping biodegradable material, such as the wastes in the biological trenches. Without a venting system, gas pressures produced could build up and cause the cap to crack. Gases could also lead to lateral subsurface migration of contaminants. Gases within covered areas can be collected and vented to the atmosphere, with or without treatment, depending on the composition of the gas. Collection systems include passive vents, which are free-venting structures, and active vents, which mechanically draw gases from the capped material.

Passive vent systems require that highly permeable material, typically gravel and a perforated pipe in a trench or a well, be placed in the flow path of gas near the upper part of the capped material. These gas collection trenches are often lined on one side to help channel gas into the collection pipes. Gas collected in the pipes may be monitored, then either discharged to the atmosphere or treated. An active gas system consists of a series of wells or trenches containing perforated pipe. A mechanical blower or compressor applies suction to draw the gas to a central point, where it is monitored and either discharged or treated.

Both process options for collection will be retained for incorporation into capping options. The active system is more costly and requires regular maintenance; however, it is more effective. Also, at WAG 6 the gas would need to be collected and monitored for radioactivity and hazardous constituents before release. Gas collection will be carried forward for further evaluation as part of a capping process option. Gas collection would be used for sources that are still biodegradable. It would not be used in areas that are stabilized/solidified as part of the alternative.

Vapor and/or gas collection may be a consideration if groundwater is collected for treatment and radon gas or organic volatiles are present in sufficient concentration to pose a hazard to treatment plant operators. Because of the potential for gases or vapors, any treatment system would include air monitoring, and, if needed, a gas/vapor collection system would be incorporated.

### 8B.4.3.6 Decontamination

Decontamination, by washing or mechanical operations, is potentially viable at WAG 6. Although only routine health and safety decontamination has been identified as a definite requirement, decontamination will be included as part of all developed alternatives.

## 8B.4.4 Treatment

### 8B.4.4.1 Solids processing

Solids processing either separates material or changes the size of the material. Solids processing usually is required before treatment to create a more homogeneous material. Two processes—crushing/grinding and shredding/chopping—change a material's size. Crushing

and grinding are used on brittle waste; shredding and chopping are used on nonbrittle waste. Both process options would be used as part of alternatives that involve excavation and treatment of SLB waste material that contains large solid objects such as drums or equipment.

The other process options, including magnetic processes, screening, and hydraulic classification, separate wastes by property or size. Magnetic processes separate magnetic from nonmagnetic waste, which is especially useful prior to resource recovery (not under consideration), or incineration, which is under consideration. However, because magnetic and nonmagnetic wastes have been mixed together, are equally contaminated, and equally require remediation, magnetic separation processes will not be useful and will not be retained.

Screening mechanically separates material particles on the basis of size using a uniformly perforated surface. Particles larger than the perforations are retained on the screen while smaller particles pass through. This process can be very effective on coarser particles such as pieces of glass or metal with the use of a slow feed and long screening period. Screening can be performed on very dry or very wet (suspended) material, but not damp material. At WAG 6 the material would be dry. Also, it will be effective only after larger pieces of waste (e.g., equipment, casks) have been removed. This is an inexpensive separation technique and will be retained.

Classification is the separation of particles according to their settling rate in a fluid. With the hydraulic classifier, water or air is introduced so that the direction of flow opposes that of settling particles. The simplest form of a hydraulic separator is the settling-cone. Solids-bearing liquid flows into the settling-cone as if into a funnel. The heavier, solid-laden flow exits the bottom while the liquid flows radially over the lip of the cone. Classifiers have a lengthy history of reliable, continuous operation for finer-sized particles. This could be used on contaminated soils at WAG 6. However, clayey soils are difficult to process.

Screening will be used to represent both separation processes, because it is more applicable to varying conditions. Classification could be reconsidered during the final design, if appropriate. This technology is considered a secondary technology.

### 8B.4.4.2 Solidification and/or stabilization

Solidification produces a monolithic block of waste with high structural integrity and reduced leaching potential. The contaminants do not interact chemically with the solidification agents, but are mechanically bonded. Stabilization usually involves addition of reagents, which limit the solubility or mobility of the waste constituents. The intent of solidification and/or stabilization of contaminated materials would be to limit the spread of radioactive material via leaching, to trap and contain decay products in the densified mass, and to improve the waste's structural integrity.

Contaminated soil and/or sediments would be excavated and mixed with solidifying agents in either a continuous or a batch process. Portland cement, pozzolanic fly ash, or other chemical fixation, sorption, or encapsulation agents could be used. The varying waste types at WAG 6 would require different agents. In addition, much of the waste in the burial units at the site could not be stabilized because it includes materials (desks, casks, etc.), not amendable to the process. The material that could be stabilized would be placed in containers and disposed on-site—most likely in the Tumulus.

As a treatment technology, solidification/stabilization, preceded by excavation and followed by disposal, would be very expensive. It would also have a much higher risk to workers and the environment than in situ solidification/stabilization. Because the variable waste at WAG 6 will contribute to reduced effectiveness, and because of the cost and significant materials-handling issues, stabilization/solidification will not be carried forward for further consideration as a treatment technology.

### 8B.4.4.3 Solids dewatering

The solids dewatering process would be used to dewater excavated waste before treatment or used to dewater sludge produced from treating the groundwater. One such process, sludge drying beds, allows free water in a sludge or waste matrix to drain or evaporate. Because of the hazards associated with any water that has been in contact with the waste, any sludge drying bed would be constructed with a sophisticated leachate collection/detection system. The bed would also need to be covered to protect against rain/humidity. This process could be used for sediments resulting from treatment of groundwater; however, because of the small particle size of sediments, drying beds would not be as effective as dewatering equipment. They would be much more effective for larger-size waste. Sludge drying beds will be carried forward only for alternatives considering excavating and treatment or disposal; it is considered a secondary process option.

### 8B.4.4.4 Physical/chemical water treatment

Any groundwater treatment must be coupled with its extraction, and the treatment system would need to be designed to produce water of suitable quality to meet discharge limits. Bulk liquid removed and/or collected from the disposal units would contain similar contaminants and may also be treated in this plant. Because groundwater is expected to be the most significant contributor to the plant influent waste stream, groundwater characteristics will be used to design the treatment system.

The following groups of contaminants are representative of those that have been detected in the groundwater during RFI activities as exceeding federal or state standards or health-based criteria. While these are the contaminants present, the treatment levels and ultimate treatment required will depend on the discharge point selected and its requirements. More than likely, single process option will not be able to remove all constituents.

- Radionuclides, including strontium-90, tritium, and cobalt-60. Total radium levels were also elevated, but it is naturally occurring at WAG 6. Strontium also belongs to the same chemical series as radium and calcium. Tritium cannot be removed from groundwater and collected for disposal. However it decays fairly rapidly.

- Filtered inorganics such as antimony, barium, beryllium, cadmium, and silver were found at levels exceeding MCLs and above reference values. The extent of contamination appears to be limited.

- VOCs are present in the groundwater at levels exceeding federal standards and human health criteria. Fairly prevalent are 1,2-dichloroethene, 1,1-dichloroethane, and trichloroethene. BTX compounds were found, but the areal extent of contamination is limited.

When groundwater from different areas of the collection system is combined across the site, nonradioactive inorganics will most likely not be of significant concern due to dilution. Therefore, only those inorganic treatment process options that have proven to be effective on radionuclides or that may be necessary pretreatment or posttreatment processes for other options were carried forward.

**Flow and strength equalization.** By using temporary storage, influent water quantity and quality can be regulated to minimize process-disrupting changes. Initial temporary storage will be included as part of any wastewater treatment plant because of the anticipated variations in groundwater quantity and quality. Additionally, waste leachate, or aqueous residual from soils treatment may require periodic treatment.

**Coagulation/flocculation.** If contaminants of concern are associated with suspended particles, this process accelerates the settling of suspended solids through the addition of floc-forming chemicals. While this process option is an effective method for significant removal, it is not effective on dissolved contaminants nor for very low effluent concentration requirements. Because it is anticipated that most of the contaminants of concern are dissolved, coagulation/flocculation will not be retained. If appropriate, it may be reconsidered during the design phase.

**Media filtration.** Filtration separates suspended matter from water. Water is passed through a filter medium, and particulates either accumulate on the surface of the medium or are collected throughout its depth. Filters have been found to be effective for removing a wide range of sizes and types of particulates, including algae, colloidal clay compounds, viruses, asbestos fibers, and colloidal clay particles. Examples of filter media include screens, with openings of 1 to 100 $\mu$m, and granular materials, usually sand, anthracite, or coal with grain sizes varying from 0.1 to 10 mm.

Filters are frequently used as a polishing step in the removal of suspended solids. They are more effective than coagulation/flocculation. However, when used with water containing too many suspended solids, filters may bind on the top and matter cannot be removed deeper in the filter. Filtration will be carried forward.

**Adsorption.** In an adsorption process, contaminated water would flow over a bed of granular activated carbon, using either pressurized or gravity tanks. This existing, conventional treatment process will remove VOCs, BNAEs, and some inorganics from dilute aqueous solutions. The process is effective and applicable for a wide range of contaminants. Carbon adsorption can achieve a high level of organic removal when regularly maintained to monitor for breakthrough and to replace spent carbon. Testing would be required to determine its effectiveness on radionuclides. In addition, spent carbon may be considered a radioactivity source. This process option will be carried forward.

**Membrane processes.** In a membrane process, contaminated groundwater would contact a membrane that separates contaminants from an aqueous stream. Three types of membrane processes are suitable for consideration: reverse osmosis, electrodialysis, and ultrafiltration. Reverse osmosis and ultrafiltration are similar; both remove water from a mixture by passing it through a device that retains the other components. There are significant differences: (1) osmotic pressure has an extremely important role in reverse osmosis and not in ultrafiltration; and (2) ultrafiltration separates mixtures based primarily on size. Many factors affect separation by reverse osmosis.

Electrodialysis uses an electric current to induce partial separation of components in an ionic solution. Separation is accomplished by alternately placing cation- and anion-selective membranes across the electric current path. When current is applied, the electrically attracted cations pass through the cation exchanger in one direction, and the anions pass through the anion exchanger membrane in the other direction.

All membrane processes are fairly developed and would be effective on some of the groups of contaminants at WAG 6. They require rather extensive pretreatment to control fouling and scaling. All processes also produce a contaminant-laden solution or brine requiring disposal. This brine may be a liquid mixed waste as a result of RCRA-metal and radionuclides removal. Further treatment such as solidification would be needed prior to disposal as a mixed solid waste. The processes' high energy demands, pretreatment needs, and brine disposal requirements make them fairly expensive compared to carbon adsorption and ion exchange. However, due to the varied WAG 6 wastes, several primary treatment processes may be necessary. Until more is known about the actual quality of the groundwater treated by the plant, ultrafiltration will be carried forward as representative of the membrane processes since organics and radionuclides (large ions) are of more concern than inorganics.

**Air stripping.** In the process of air stripping, a compound is transferred from a liquid stream to an air stream. The driving force for the transfer is related to the equilibrium partial pressure of the compound in air. The partition constant (Henry's law constant) indicates the volatility of the compound and is the primary parameter for determining air stripper removal efficiency for the compound. Removal efficiencies increase with increasing partition coefficients, temperature, and/or air-to-water ratios. Air stripping is usually conducted in counter-current packed towers. Air is forced through the bottom of the tower and exits at the top with the volatile compounds. If sufficiently low

concentrations are present in the effluent, the gaseous compounds can be discharged directly to the air. Otherwise, air pollution control devices may be necessary.

Air stripping has been proven reliable for removing volatile compounds, including some organics and ammonia and will be carried forward. However, if it is used before removal of volatile radionuclides (radon), vapor phase carbon may be needed to treat the air emissions. This would present health and safety issues for the workers. It also results in disposal/regeneration issues for the carbon, as it would contain radionuclides.

**Neutralization.** The groundwater does not require neutralization prior to discharge; however, a base may be added to reduce the solubility of metals (discussed under Precipitation subsection). Although neutralization will not be considered as a primary treatment, it may be needed as post-treatment to readjust the pH of the water.

**Precipitation.** In a precipitation process, a chemical constituent (such as lime or sodium hydroxide) is added to the aqueous stream. The constituent alters the equilibrium and forms a precipitate with the contaminant. The precipitate is removed by clarification operations.

Precipitation has been used effectively to remove inorganic contaminants, including radionuclides. There are several methods of precipitation, each differing in the precipitation agent and the pH at which precipitation is performed. The precipitation method can be tailored to match the contaminants requiring removal. The process is relatively well developed, and equipment is available from a number of manufacturers and is readily implemented. Precipitation has generally been shown to be both cost- and performance-effective for removing heavy metal contaminants. One disadvantage is that it produces a significant volume of residuals that require additional treatment and disposal. Also, it has no effect on organics. However, it will be carried forward because of its effectiveness for radionuclides.

**Ion exchange.** In an ion exchange process, contaminated groundwater flows over a bed of special resin that removes ions from solution and replaces them with less harmful ions. Ion exchange is a physical-chemical process in which ions are transferred from a liquid to a solid phase or vice versa. Ions held by electrostatic forces to charged functional groups on the surfaces of a solid (an ion exchange resin) are exchanged for ions of similar charge from a solution that flows past the resin. These resins can tolerate a range of temperature and pH conditions, exhibit a high exchange capacity, and can be tailored to show selectivity towards specific ions. Synthetic resins are employed in many applications; however, some natural exchanges are available. For example, clinoptilolite, a sodium-calcium-aluminum silicate, has a very strong affinity for ammonium ions.

Due to its high removal efficiencies, ion exchange may be useful in a polishing operation following treatment by other processes. Ion exchange is relatively well developed and could be readily implemented. However, ion exchange units either must be regenerated, which produces a liquid waste stream requiring treatment, or the ion exchange

resin itself must be disposed when exhausted. Its specific effectiveness would need to be tested because of the potential for competing ions. This option will be carried forward.

### 8B.4.4.5 In situ treatment

**Permeable treatment beds.** Permeable treatment beds are trenches dug to intercept groundwater. Adsorbent chemicals are added so the groundwater is treated in the trench. The contaminants can be adsorbed, biodegraded, neutralized, oxidized, precipitated, or reduced. This process option is experimental, and permeable treatment beds cannot achieve the degree of removal that can be achieved by extraction and treatment. Also, effluent limits are likely to be lower than the bed can achieve, meaning the groundwater would require further treatment. Additionally, the contaminants removed remain in the trench and would most likely require excavation for ultimate disposal since the trench cannot be completely lined and still collect groundwater. The additional treatment requirements and the excavation and reburial of bed materials makes this process option expensive compared to traditional treatment with the potential for significantly less effectiveness. Therefore, this process option will not be carried forward.

**Vitrification.** In the vitrification process, the contaminated material is heated to its melting temperature then allowed to cool and solidify to a glassy mass. Testing to date has indicated that the glassy mass or monolith is structurally stable and resists leaching. Vitrification consumes high amounts of energy. In situ vitrification involves the application of electricity to electrodes placed in the ground over the waste mass. The ground and waste mass both heat and melt, with the melting zone growing downward. A hood is placed over the zone to catch gases, which are treated and removed to eliminate air emissions.

Vitrification destroys organic contaminants during processing via pyrolization in the melt followed by combustion in the offgas hood; however, it will also volatilize tritium and metals such as cesium, mercury, and lead. There is the potential for the production of incomplete combustion byproducts. These contaminants present a secondary (and possibly mixed) waste stream and potential worker exposure problems.

Although available commercially, this process option is still experimental for the type of complex waste matrices (e.g., buried steel and concrete containers) present at WAG 6. However, tests performed by DOE on contaminated soils (at ORNL and Hanford) and on a small-scale (30-cm diameter) steel/concrete tank have been promising. Future tests include a 6000-gal tank melt at Hanford. Because in situ vitrification significantly reduces mobility of inorganics, including radionuclides, it will be carried forward.

**Stabilization/solidification.** The same general principals apply to in situ stabilization/ solidification as to excavation and stabilization/solidification, described alone. Because of the difficulties associated with stabilizing the types of waste at WAG 6, this option will not be carried forward.

#### 8B.4.4.6 Thermal treatment

The only process option remaining for the thermal treatment technology is incineration, which can be used both to minimize waste material volume and to destroy many compounds. Through incineration, materials are thermally destroyed in a controlled, oxygen-sufficient environment. The oxidation products are primarily carbon dioxide, water, and ash. The ash contains various end-products from the incineration of nitrogen- and halogen-containing materials, in addition to noncombustible materials.

The system is reliable and effective for destroying organic contaminants (consisting of combustible material) in the soil and the trenches. However, very little volume reduction is anticipated due to the large amounts of noncombustible material buried in or associated with the WAG 6 SLB units. In addition, other disadvantages include its high capital and operating costs and the fact that radionuclides are not destroyed. In fact, the radionuclides may be volatilized, requiring gas and ash to be collected and controlled. Incineration is expensive and may be useful only for a small portion of the waste. However, because of its high degree of effectiveness on organics and potential for some waste volume reduction, incineration will be carried forward.

### 8B.4.5 Disposal

#### 8B.4.5.1 Temporary storage

Any temporary storage would be needed only during construction. There are no plans to remove waste materials to temporary storage to await technological advancements or development of a mixed waste disposal facility. Temporary waste piles and containers or tanks are the temporary storage options most likely to be used; however, the presence of radioactivity makes it more likely that construction will be scheduled to avoid any temporary storage. Therefore, this technology will no longer be considered. If storage becomes necessary as a secondary component in design, it will be reevaluated at that stage.

#### 8B.4.5.2 Nuclear waste repository

DOE Order 5820.2A, "Radioactive Waste Management," Chapter III, states "DOE low-level waste shall be disposed of on the site at which it is generated, if practical, or if on-site disposal capability is not available, at another DOE disposal facility consistent with the requirements detailed in reference 50." For this reason, and because limited on-site disposal capacity is available and a nuclear waste repository is not available, this option will not be considered for disposal of WAG 6 waste.

#### 8B.4.5.3 Wastewater discharge

After technology screening, discharge to surface water and discharge to an on-site existing treatment plant remain as process options. The only viable surface water discharge point is WOL, which is sufficiently large to handle additional flow from a groundwater treatment plant. Any treatment plant would have to be designed to protect the surface

water environment, which will require meeting discharge standards specified in the plant's NPDES permit.

The other process option is using the existing on-site liquid waste treatment system prior to surface water discharge. The ORNL Process Wastewater Treatment Plant (PWTP) treats water that contains very low concentrations of radionuclides, mostly strontium-90 and cesium-137. About 70 percent of the strontium-90 is removed by softening at a pH of 11.5. Clarified water is then treated by strong acid ion exchange, which removes the rest of the strontium-90. To remove cesium-137, zeolite columns are used, either in series or parallel to the routine PWTP processes. The PWTP has an average flow of 120 gpm. The Nonradiological Wastewater Treatment Plant (NRWTP) usually treats only for organics by filtration, followed by air stripping, followed by carbon columns. The average flow is 250 gpm. This plant does have metals-removal capabilities. In addition, water from the PWTP can be piped to the nonradiological plant for treatment in series. Treatability tests using trench water from WAG 6 showed that the two plants have the processes necessary to remove the contaminants.

Depending on the flow predicted for collection at WAG 6 and the ORNL plants' capacities, discharge to the ORNL liquid waste treatment system could be a cost-effective process option. Most of the treatment process options carried forward during this evaluation are available in the ORNL plants. Therefore, the ORNL liquid waste treatment system will be used in alternatives instead of constructing a new treatment plant. A new plant or the option of treating wastewater at existing Y-12 and K-25 facilities may be reconsidered during the design if appropriate.

### 8B.4.5.4 Solids disposal

After treatment, much of the excavated materials could be replaced in the locations from which they were removed. Material excavated from other areas of the site also could be consolidated within major areas of contamination or placed in the IWMF, providing they are classified as LLW. In addition, solidified brines, carbon, ion exchange resins, and other solid residues from liquid treatment could be disposed on-site if necessary. This solids disposal option could be effective and reliable when combined with a relatively impermeable cap. All treated RCRA waste would need to meet RCRA land ban requirements before disposal in its originating area. This option will be carried forward for further consideration.

### 8B.4.6 Monitoring

Monitoring of groundwater and surface water contamination is used primarily to evaluate over time the effectiveness of the chosen remedial action and/or to determine whether existing and future receptors are threatened. This is a necessary component of a flexible remedial program. Samples would be taken regularly at various locations to determine required adjustments or additions to the implemented actions. Monitoring can be used in conjunction with other technologies or could be considered alone. Capital costs

should be low since many monitoring wells are already in place. This technology will be carried forward.

# Appendix 8B Tables

**Table 8B.1. General response actions, ORNL WAG 6**

| Media/Source | Risk Type | General Response Action |
|---|---|---|
| SLB Solid Waste | Environmental | No action<br>Containment<br>Removal/disposal<br>Treatment |
| | Human Health | No action<br>Institutional control<br>Containment<br>Removal/disposal<br>Treatment |
| Tumulus Solid Waste | Environmental | No action<br>Containment |
| Groundwater | Environmental | No action<br>Containment<br>Removal/disposal<br>Treatment |
| | Human Health | No action<br>Institutional control<br>Monitoring<br>Containment<br>Removal/disposal<br>Treatment |

**Table 8B.2. Site and contaminant characteristics considered in remedial technology screening, ORNL WAG 6**

**Physical Site Characteristics**

**Climate:** Humid, minor freeze/thaw
**Soil Properties:** Clayey, disturbed, varying depth
**Aquifer Properties:** Shallow
**Bedrock Properties:** Fractured, areas of shallow bedrock
**Terrain:** Varied, steep
**Access:** Easy, yet controlled
**Depth** to Aquitard: Unknown

**Contaminant and Waste Characteristics**

**Type:** Mixed, organic, radioactive
**Waste Form:** Varied; mostly solid
**Previous Actions:** Varied; containment, cap, fence
**Quantity:** High volumes of waste
**Persistence:** Varied; most is high
**Biodegradability:** Varied; most is low
**Volatility:** Varied; most is low
**Explosivity:** Varied; most is low
**Solubility:** Varied
**Radioactivity:** Varied
**Corrosivity:** Varied

# Appendix 8B Figures

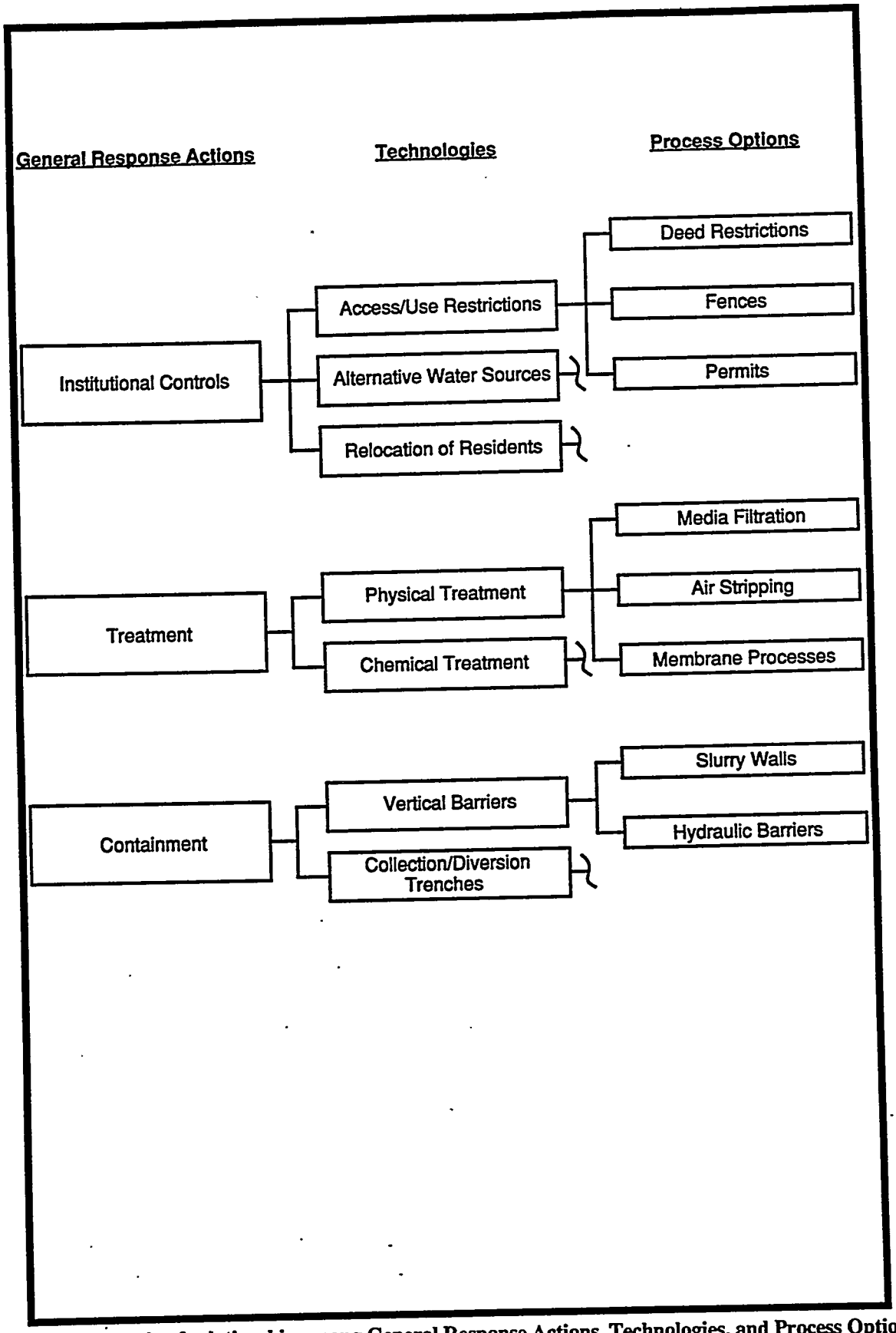


**Fig. 8B.1. Example of relationship among General Response Actions, Technologies, and Process Options.**

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| GENERAL RESPONSE ACTIONS | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | DISCUSSION | RETAINED: GROUNDWATER | RETAINED: SLB WASTE | RETAINED: TUMULUS |
|---|---|---|---|---|---|---|---|
| NO ACTION | NONE | NONE | NO ACTION. | NCP REQUIRES THE NO ACTION ALTERNATIVE TO BE CARRIED THROUGH THE DETAILED ANALYSIS. | ✔ | ✔ | ✔ |
| INSTITUTIONAL CONTROLS | ACCESS AND USE RESTRICTIONS | DEED RESTRICTIONS | DEED RESTRICTIONS ISSUED FOR PROPERTY WITHIN POTENTIALLY CONTAMINATED AREAS TO RESTRICT PROPERTY USE. | POTENTIALLY VIABLE. | ✔ | ✔ | ✔ |
| | | FENCES | SECURITY FENCES INSTALLED AROUND POTENTIALLY CONTAMINATED AREAS TO LIMIT ACCESS. | POTENTIALLY VIABLE. | | ✔ | ✔ |
| | | PERMITS | REGULATIONS PROMULGATED TO REQUIRE A PERMIT FOR DRILLING INTO AQUIFERS. | POTENTIALLY VIABLE. | ✔ | | |
| | ALTERNATIVE DRINKING WATER SOURCE | CISTERNS OR TANKS | DRINKING WATER DISPENSED TO USERS FROM A CENTRALIZED POINT. | NO RESIDENT IS, OR SOON WILL BE, USING CONTAMINATED WATER. | | | |
| | | BOTTLED WATER | DRINKING WATER OBTAINED FROM A COMMERCIAL VENDOR. | NO RESIDENT IS, OR SOON WILL BE, USING CONTAMINATED WATER. | | | |
| | | DEEPER OR UPGRADIENT WELLS | WELLS INSTALLED DEEP OR UPGRADIENT IF THESE AREAS ARE ISOLATED FROM CONTAMINATION. | NO RESIDENT IS, OR SOON WILL BE, USING CONTAMINATED WATER. | | | |
| | | RELOCATION OF INTAKE | RELOCATE INTAKE IN AN UNCONTAMINATED AREA. | NO RESIDENT IS, OR SOON WILL BE, USING CONTAMINATED WATER. | | | |
| | | MUNICIPAL WATER SUPPLY | ESTABLISH ADDITIONAL WATER SOURCES. | NO RESIDENT IS, OR SOON WILL BE, USING CONTAMINATED WATER. | | | |
| | RELOCATION OF RESIDENTS | TEMPORARY | MOVE RESIDENTS TO A MOTEL OR APARTMENT. PAY FOR MOST ADDITIONAL OUT-OF-POCKET EXPENSES FOR A FINITE PERIOD OF TIME. | NO RESIDENTS PRESENT ON WAG 6. | | | |
| | | PERMANENT | MOVE RESIDENTS TO A NEW RESIDENCE. PAY FOR OUT-OF POCKET MOVING COSTS, TEMPORARY HOUSING AND MEALS, UTILITY CONNECTIONS, MORTGAGE PURCHASE, AND CLOSING COSTS. | NO RESIDENTS PRESENT ON WAG 6. | | | |

NOT CARRIED FORWARD

**Fig. 8B.2. Identification of applicable remedial technologies and process options.**

5.18A 4104.72

| GENERAL RESPONSE ACTIONS | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | DISCUSSION | RETAINED: GROUNDWATER | RETAINED: SLB WASTE | RETAINED: TUMULUS |
|---|---|---|---|---|---|---|---|
| (CONTINUED) | | | | | | | |
| CONTAINMENT | CAPPING | NATIVE SOIL | UNCONTAMINATED NATIVE SOIL PLACED OVER CONTAMINATED AREAS. SOIL SHOULD REDUCE INFILTRATION OF PRECIPITATION. | POOR EFFECTIVENESS. NOT RETAINED IN FAVOR OF LESS PERMEABLE, MORE EFFECTIVE CAP. | | | |
| | | CLAY CAP | COMPACTED CLAY PLACED OVER CONTAMINATED AREAS. CLAY SHOULD BE COVERED BY AT LEAST A FOOT OF SILTY SAND OR SANDY SOIL TO MAINTAIN THE INTEGRITY OF THE CLAY CAP. | POTENTIALLY VIABLE. | | ✔ | |
| | | SYNTHETIC MEMBRANES | SYNTHETIC MEMBRANE PLACED OVER PREPARED SOIL OR GEOTEXTILE SURFACE THAT IS OVER A CONTAMINATED AREA. THE MEMBRANE IS SEAMED BY A VARIETY OF METHODS. THE MEMBRANE MUST BE COMPATIBLE WITH THE WASTES PRESENT. | DEGRADATION FROM UV SIGNIFICANT. NOT RETAINED IN FAVOR OF CAP NEEDING LESS MAINTENANCE. | | | |
| | | SPRAYED ASPHALT | SPRAYED ASPHALT IS PLACED OVER CONTAMINATED AREAS AND COVERED WITH SOIL OR OPAQUE REFLECTIVE PAINT TO PROTECT THE ASPHALT FROM ULTRAVIOLET LIGHT AND TO RETARD OXIDATION. | SUSCEPTIBLE TO CRACKING. NOT RETAINED IN FAVOR OF LOWER MAINTENANCE CAP. | | | |
| | | ASPHALTIC CONCRETE | ASPHALT FOR PAVING GRADES OR SPECIAL BLENDS MIXED WITH WELL GRADED, CRUSHED AGGREGATE, PLACED OVER CONTAMINATED AREAS. | NOT RETAINED IN FAVOR OF CAP LESS SUSCEPTIBLE TO CRACKING. | | | |
| | | CONCRETE CAP | CONCRETE PLACED OVER PREPARED CONTAMINATED AREA. FILL SETTLEMENT MUST BE EVALUATED IN CONSIDERING A CONCRETE CAP DESIGN. | NOT RETAINED IN FAVOR OF A LESS PERMEABLE CAP LESS SUSCEPTIBLE TO CRACKING. | | | |
| | | MULTILAYERED CAP | CAP MAY BE COMPOSED OF ROCKS, NATURAL SOILS, SOIL ADMIXTURES, CLAY, SYNTHETIC MEMBRANES, SPRAY-ON ASPHALTS, ASPHALTIC CONCRETE, OR PORTLAND CEMENT CONCRETE AND PLACED OVER CONTAMINATED AREAS. IF PROPERLY DESIGNED, WILL MEET RCRA REQUIREMENTS. INCLUDES RCRA-COMPLIANT CAP. | POTENTIALLY VIABLE. | | ✔ | ✔ |

CONT'D

NOT CARRIED FORWARD

Fig. 8B.2. (continued)

| GENERAL RESPONSE ACTIONS | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | DISCUSSION | RETAINED: GROUNDWATER | RETAINED: SLB WASTE | RETAINED: TUMULUS |
|---|---|---|---|---|---|---|---|
| CONTAINMENT (CONTINUED) | VERTICAL BARRIERS | SOIL-BENTONITE SLURRY WALL | TRENCH AROUND CONTAMINATED AREA EXCAVATED AND FILLED WITH A BENTONITE SLURRY. TRENCH BACKFILLED WITH A SOIL-BENTONITE MIX. | POTENTIALLY VIABLE. | ✔ | ✔ | |
| | | DIAPHRAGM SLURRY WALL | TRENCH EXCAVATED AND FILLED WITH A BENTONITE WATER SLURRY. CONCRETE DISPLACES BENTONITE AND FORMS THE WALL. | POTENTIALLY VIABLE. | ✔ | ✔ | |
| | | VIBRATING BEAM | VIBRATORY FORCE USED TO ADVANCE STEEL BEAM INTO GROUND; INJECTION OF A RELATIVELY THIN WALL OF CEMENT OR BENTONITE INTO VOID AS BEAM IS WITHDRAWN. | DIFFICULT DRIVING CONDITIONS. DIFFICULT TO MONITOR EFFECTIVENESS. | | | |
| | | GROUT CURTAINS | GROUT PRESSURE-INJECTED ALONG CONTAMINATION BOUNDARIES IN A REGULAR OVERLAPPING PATTERN OF DRILLED HOLES. | DIFFICULT TO CONTROL AND INSTALL UNDER TOPOGRAPHIC SITE CONDITIONS. | | | |
| | | SHEET PILING | STEEL SHEET PILING DRIVEN ALONG CONTAMINATION BOUNDARIES. | DIFFICULT DRIVING CONDITIONS. FAIRLY PERMEABLE. | | | |
| | | GROUND FREEZING | COOLANT IS CIRCULATED THROUGH REFRIGERATION PIPES TO FREEZE THE GROUND FOR SEEPAGE CONTROL. | SHORT-TERM. DIFFICULT TO MONITOR EFFECTIVENESS. | | | |
| | | HYDRAULIC BARRIERS | TRENCH DRAINS AND WELLS USED AS GOUNDWATER BARRIERS TO CONTAIN CONTAMINATION | POTENTIALLY VIABLE. | ✔ | ✔ | |
| | OTHER IN SITU BARRIERS | BLOCK DISPLACEMENT | CONTROLLED INJECTION OF SLURRY IN NOTCHED INJECTION HOLES PRODUCES A HORIZONTAL BARRIER BENEATH CONTAMINATION. EXPERIMENTAL PROCESS OPTION. | DIFFICULT TO IMPLEMENT AND MONITOR EFFECTIVENESS. | | | |
| | | GROUND FREEZING | SIMILAR TO VERTICAL BARRIERS BY GROUND FREEZING. EXPERIMENTAL PROCESS OPTION. | SHORT-TERM. DIFFICULT TO MONITOR EFFECTIVENESS. | | | |
| | | LINERS | LINERS PLACED TO RESTRICT VERTICAL FLOW CAN BE CONSTRUCTED OF THE SAME MATERIALS CONSIDERED FOR CAP CONSTRUCTION. | WOULD REQUIRE WASTE REMOVAL AND REPLACEMENT. | | | |

NOT CARRIED FORWARD

Fig. 8B.2. (continued)

5.18A 4104.74

| GENERAL RESPONSE ACTIONS | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | DISCUSSION | RETAINED: GROUNDWATER | RETAINED: SLB WASTE | RETAINED: TUMULUS |
|---|---|---|---|---|---|---|---|
| CONTAINMENT (CONTINUED) | SURFACE CONTROLS | SURFACE SEALING | COVER MATERIALS AND SEAL TECHNIQUES IMPLEMENTED TO STABILIZE WASTE DEPOSITS AND TO PREVENT SURFACE WATER INFILTRATION, CONTROL EROSION, AND ISOLATE AND CONTAIN THE WASTES. SIMILAR TO CAPPING. | POTENTIALLY VIABLE. | | ✔ | |
| | | GRADING | RESHAPING OF TOPOGRAPHY TO MANAGE SURFACE WATER,INFILTRATION AND RUNOFF TO CONTROL EROSION. | POTENTIALLY VIABLE. | | ✔ | |
| | | IN SITU GROUTING | INJECTION OF GROUT INTO BURIED SOURCES TO FILL VOIDS AND PROVIDE STRUCTURAL STABILIZATION. | POTENTIALLY VIABLE. | | ✔ | |
| | | REVEGETATION | A SYSTEMATIC REVEGETATION PLAN INCLUDES SELECTION OF A SUITABLE PLANT SPECIES, SEEDBED PREPARATION, SEEDING/PLANTING, MULCHING AND/OR CHEMICAL STABILIZATION, FERTILIZATION, AND MAINTENANCE. | POTENTIALLY VIABLE. | | ✔ | |
| | | DIVERSION AND COLLECTION SYSTEMS | DIVERSION AND COLLECTION STRUCTURES INSTALLED UPSLOPE OR AT PERIMETER OF THE SITE TO CONTROL DRAINAGE OF STORMWATER RUNOFF. SYSTEM CAN ALSO BE IMPLEMENTED TO COLLECT CONTAMINATED SURFACE WATER FOR REMEDIATION. | POTENTIALLY VIABLE. | | ✔ | |
| | | DYNAMIC COMPACTION | LARGE WEIGHT DROPPED ON WASTE TO COMPACT WASTE TO MINIMIZE FUTURE SUBSIDENCE. | POTENTIALLY VIABLE. | | ✔ | |

NOT CARRIED FORWARD

Fig. 8B.2. (continued)

| GENERAL RESPONSE ACTIONS | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | DISCUSSION | RETAINED: GROUNDWATER | RETAINED: SLB WASTE | RETAINED: TUMULUS |
|---|---|---|---|---|---|---|---|
| CONTAINMENT (CONTINUED) | DUST AND VAPOR SUPPRESSION | WATER | WATER SPRAYED OVER AREA OF CONCERN TO PREVENT DUST GENERATION. | POTENTIALLY VIABLE IN LIMITED APPLICATION. | | ✔ | |
| | | ORGANIC AGENTS/POLYMERS/ FOAMS | ORGANIC AGENTS/POLYMERS/FOAMS SPRAYED OVER AREA OF CONCERN TO PREVENT DUST/VAPOR GENERATION. | POTENTIALLY VIABLE IN LIMITED APPLICATION. | | ✔ | |
| | | MEMBRANES/TARPS | MEMBRANES OR TARPS ARE SPREAD OVER AREA OF CONCERN TO PREVENT DUST/VAPOR GENERATION. | POTENTIALLY VIABLE IN LIMITED APPLICATION. | | ✔ | |
| | | HYDROSCOPIC AGENTS | HYDROSCOPIC SALTS ABSORB MOISTURE INTO THE SOIL IN WHICH THEY ARE MIXED. | POTENTIALLY VIABLE IN LIMITED APPLICATION. | | ✔ | |
| REMOVAL | DRUM AND DEBRIS REMOVAL | HYDRAULIC EXCAVATOR | USED FOR LARGE EXCAVATION AND TRENCHING JOBS, PULLING DOWN STRUCTURES, GRUBBING, AND LOADING DEBRIS WITH ATTACHMENTS; USED TO SHEAR TANKS AND PIPING AND TO REMOVE DRUMS. | NOT NEEDED FOR CONTAMINATED SOURCES/MEDIA ON-SITE. | | | |
| | | FORKLIFTS AND ATTACHMENTS | USED FOR MOVING DRUMS ON PALLETS. | NOT NEEDED FOR CONTAMINATED SOURCES/MEDIA ON-SITE. | | | |
| | | CRANES AND ATTACHMENTS | USED WITH WRECKING BALLS FOR DEMOLITION OF WALL OR CONCRETE PADS, CLAMSHELLS FOR LIFTING OR RIPPING, WIRES OR PLATFORMS FOR LIFTING, AND HOPPERS, BUCKETS, AND OTHER DEVICES FOR CARRYING. | NOT NEEDED FOR CONTAMINATED SOURCES/MEDIA ON-SITE. | | | |
| | | HANDTOOLS | USED FOR LIGHT DEMOLITION AND MOVING DEBRIS. | NOT NEEDED FOR CONTAMINATED SOURCES/MEDIA ON-SITE. | | | |
| | | BACKHOES AND ATTACHMENTS | USED FOR EXCAVATION, TRENCHING, PULLING DOWN STRUCTURES, AND LOADING MATERIAL. | POTENTIALLY VIABLE. | | ✔ | |
| | | BULLDOZERS AND GRADERS | USED FOR LEVELING WORK AREAS, MOVING PILES OF MATERIAL, OR PUSHING OVER TREES AND STRUCTURES. | NOT NEEDED FOR CONTAMINATED SOURCES/MEDIA ON-SITE. | | | |
| | | CUTTING DEVICES | USED TO CUT STEEL--REBAR, BEAMS, DRUMS, TANKS, SIDING, ETC. | NOT NEEDED FOR CONTAMINATED SOURCES/MEDIA ON-SITE. | | | |
| | | EXPLOSIVES | USED TO MAKE BIG THINGS VERY SMALL, VERY RAPIDLY. FIRES MAY RESULT. | NOT NEEDED. LITTLE CONTROL. | | | |

NOT CARRIED FORWARD

Fig. 8B.2. (continued)

5.18A 4104.76

| GENERAL RESPONSE ACTIONS | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | DISCUSSION | GROUNDWATER | SLB WASTE | TUMULUS |
|---|---|---|---|---|---|---|---|
| | | | | | RETAINED | | |
| REMOVAL (CONTINUED) | EXCAVATION | SOLIDS | EXCAVATION OF CONTAMINATED SOLIDS CAN USE ORDINARY CONSTRUCTION EQUIPMENT (BACKHOES, BULLDOZERS, AND FRONT-END LOADERS). | POTENTIALLY VIABLE. | | ✓ | |
| | | SEMI-SOLIDS | EXCAVATION OF CONTAMINATED SEMI-SOLIDS REQUIRES WORKING ON MATS OR FLOATING EQUIPMENT. A TOOTHLESS BUCKET IS RECOMMENDED OVER DRAGLINES OR CLAMSHELLS. TRANSPORTATION AND DISPOSAL METHODS MUST CONSIDER THE WATER ASSOCIATED WITH THE SEMI-SOLIDS. | NO WET AREA LARGE ENOUGH TO REQUIRE FLOATING EQUIPMENT. | | | |
| | | SEDIMENTS | EXCAVATION OF CONTAMINATED SEDIMENTS REQUIRES FLOATING EQUIPMENT OR OPERATION OF EQUIPMENT ON THE BANK. HYDRAULIC DREDGES, BARGE-MOUNTED PUMPS, VACUUM TRUCKS, AND PNEUMATIC DREDGES ARE USED FOR EXCAVATION. GENERALLY BULK LIQUID REMOVAL WILL ALSO BE REQUIRED. | NOT NEEDED FOR CONTAMINATED SOURCES/MEDIA ON-SITE. | | | |
| | BULK LIQUID REMOVAL | PUMPS | USED TO REMOVE LARGE AMOUNTS OF LIQUID. LIQUID MUST BE FREE OF DEBRIS. | POTENTIALLY VIABLE IN LIMITED APPLICATION. | | ✓ | |
| | | DIVERSION | USE OF DIVERSION/COLLECTION SYSTEMS TO REMOVE LARGE SURFACE WATER BODIES. | NOT NEEDED FOR CONTAMINATED SOURCES/MEDIA ON-SITE. | | | |
| | | GRAVITY/SIPHON | USED TO REMOVE LIQUIDS FROM TANKS. | NO TANKS REQUIRE DEWATERING. | | | |
| | | DREDGES | USED TO REMOVE LARGE QUANTITIES OF LIQUID OR SLUDGE. A SYSTEM OF PIPELINES AND CONTAINMENT SYSTEMS IS REQUIRED. | NOT NEEDED FOR CONTAMINATED SOURCES/MEDIA ON-SITE. | | | |
| | | BAILING | USED TO REMOVE SMALL AMOUNTS OF LIQUID OR SLUDGE. | INEFFICIENT. | | | |

NOT CARRIED FORWARD

Fig. 8B.2. (continued)

| GENERAL RESPONSE ACTIONS | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | DISCUSSION | RETAINED: GROUNDWATER | RETAINED: SLB WASTE | RETAINED: TUMULUS |
|---|---|---|---|---|---|---|---|
| REMOVAL (CONTINUED) | GROUNDWATER/ LEACHATE COLLECTION | WELLS | WELLS ARE INSTALLED TO COLLECT CONTAMINATED GROUNDWATER AND LEACHATE. | POTENTIALLY VIABLE. | ✔ | | |
| | | DRAINS | UNDERGROUND GRAVEL-FILLED TRENCHES GENERALLY EQUIPPED WITH TILE OR PERFORATED PIPE INSTALLED TO COLLECT CONTAMINATED GROUNDWATER AND LEACHATE. | POTENTIALLY VIABLE. | ✔ | | |
| | VAPOR/GAS COLLECTION | PASSIVE VENTS | PASSIVE CONTROLS TYPICALLY CONSIST OF FREE VENTING STRUCTURES OR CUT-OFF BARRIER TRENCHES THAT ARE EXCAVATED TO THE DEPTH OF THE LANDFILL. THE TRENCHES ARE FILLED WITH GRAVEL TO INTERCEPT THE LFG AND PROVIDE IT THE PATH OF LEAST RESISTANCE SO IT CAN VENT TO THE ATMOSPHERE. | POTENTIALLY VIABLE (FOR NEW CAPS). | | ✔ | |
| | | ACTIVE GAS COLLECTION SYSTEM | A SERIES OF VERTICAL WELLS OR TRENCH WELLS WITH PERFORATED PIPE INSTALLED AND CONNECTED TO A MAIN HEADER SYSTEM TO DRAW GAS TO A CENTRAL LOCATION FOR TREATMENT OR DISPOSAL. | POTENTIALLY VIABLE. | | ✔ | |
| | DECONTAMINATION | WASHING | CONTAMINATED BUILDINGS OR OTHER STRUCTURES WASHED WITH A SUBSTANCE THAT REMOVES CONTAMINANTS UPON RINSING. OFTEN DECONTAMINATION IS DONE WITH A PRESSURIZED STREAM. | POTENTIALLY VIABLE IN LIMITED APPLICATION. | | ✔ | |
| | | MECHANICAL OPERATIONS | CONTAMINATION IS REMOVED MECHANICALLY BY SANDBLASTING OR SIMILAR MEANS. | POTENTIALLY VIABLE IN LIMITED APPLICATION. | | ✔ | |

▨ NOT CARRIED FORWARD

**Fig. 8B.2. (continued)**

5.18A 4104.78

| GENERAL RESPONSE ACTIONS | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | DISCUSSION | RETAINED: GROUNDWATER | RETAINED: SLB WASTE | RETAINED: TUMULUS |
|---|---|---|---|---|---|---|---|
| TREATMENT | SOLIDS PROCESSING | MAGNETIC PROCESSES | MAGNETIC FINES SEPARATED FROM NON-MAGNETIC SOLID WASTES OR DEBRIS THROUGH THE APPLICATION OF A MAGNETIC FIELD. | POTENTIALLY VIABLE. | | ✔ | |
| | | CRUSHING AND GRINDING | BRITTLE WASTES STRESSED BY IMPACT BEYOND THEIR ELASTIC LIMIT AND BROKEN BY HEAVY, SLOW-MOVING EQUIPMENT. | POTENTIALLY VIABLE. | | ✔ | |
| | | SHREDDING AND CHOPPING | NON-BRITTLE WASTES ARE REDUCED TO UNIFORM SIZE BY MECHANICALLY SHREDDING, CHOPPING, CRUMBLING, ETC. | POTENTIALLY VIABLE. | | ✔ | |
| | | SCREENING | SOLID WASTES, INCLUDING SEDIMENTS, AND DEBRIS ARE SEPARATED ACCORDING TO SIZE BY SCREENS. GENERALLY APPLICABLE TO COARSE MATERIAL (>200 MICRONS). | POTENTIALLY VIABLE. | ✔ | ✔ | |
| | | HYDRAULIC/ CLASSIFICATION | WASTES HYDRAULICALLY SIZED USING SPECIFIC GRAVITY DIFFERENCES. GENERALLY APPLICABLE TO FINER-SIZED PARTICLES (<200 MICRONS). | POTENTIALLY VIABLE. | ✔ | ✔ | |
| | SOLIDS TREATMENT | NEUTRALIZATION | ACID ADDED TO AN ALKALINE WASTE OR BASE ADDED TO AN ACIDIC WASTE TO ADJUST THE PH. | NOT NEEDED FOR CONTAMINATED SOURCES/MEDIA ON-SITE. | | | |
| | | OXIDATION | OXIDIZING AGENTS ADDED TO WASTE FOR OXIDATION OF ORGANIC CONTAMINANTS TO LESS TOXIC OXIDATION STATES. | INSUFFICIENT ORGANIC CONTENT. WASTE TOO VARIED. | | | |
| | | CHEMICAL REDUCTION | REDUCTION AGENTS ADDED TO WASTES TO STABILIZE METALS BY CONVERTING THEM TO A LESS SOLUBLE, MORE STABLE FORM. | NOT NEEDED FOR CONTAMINATED SOURCES/MEDIA ON-SITE. | | | |
| | | WATER LEACHING | WATER INFILTRATES CONTAMINATED SOLID, LEACHING OUT WATER-SOLUBLE CONTAMINATION. | NOT NEEDED FOR CONTAMINATED SOURCES/MEDIA ON-SITE. | | | |
| | | SOLVENT LEACHING | SOLVENT INFILTRATES CONTAMINATED SOLID, LEACHING OUT CONTAMINANTS THAT ARE SOLUBLE IN THE SELECTED SOLVENT. | INSUFFICIENT ORGANIC CONTENT. WASTE TOO VARIED. | | | |
| | | SOLVENT EVAPORATION | CONTAMINATED SLUDGE OR SOIL HEATED IN EQUIPMENT WHICH ALLOWS MIXING. ORGANICS VOLATILIZED FROM SOLIDS INTO THE GAS STREAM. | INSUFFICIENT ORGANIC CONTENT. WASTE TOO VARIED. | | | |

NOT CARRIED FORWARD

Fig. 8B.2. (continued)

| GENERAL RESPONSE ACTIONS | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | DISCUSSION | RETAINED: GROUNDWATER | RETAINED: SLB WASTE | RETAINED: TUMULUS |
|---|---|---|---|---|---|---|---|
| TREATMENT (CONTINUED) | SOLIDIFICATION, STABILIZATION | SORPTION | AN INERT, NONDEGRADABLE, NONREACTIVE SORBENT ADDED TO LIQUID OR SLUDGE TO SOAK UP MOISTURE AND PRODUCE A SOIL-LIKE MATERIAL. | POTENTIALLY VIABLE. | | ✔ | |
| | | POZZOLANIC AGENTS | LIME AND FINE-GRAINED SILICEOUS MATERIAL ADDED TO AQUEOUS WASTE TO PRODUCE A CONCRETE-LIKE SOLID. | POTENTIALLY VIABLE. | | ✔ | |
| | | ENCAPSULATION | MATERIAL IS ENCAPSULATED BY EITHER COATING THE INDIVIDUAL PARTICLES OR ENCLOSING ENTIRE MASS IN A JACKET OF INERT MATERIAL. | POTENTIALLY VIABLE. | | ✔ | |
| | SOLIDS DEWATERING | SEDIMENTATION | SUSPENDED SOLIDS REMOVED FROM LIQUID BY GRAVITY IN A TANK OR LAGOON. SEDIMENTATION OFTEN PRECEDED BY CHEMICAL PRECIPITATION AND/OR BY COAGULATION AND FLOCCULATION. | NOT APPROPRIATE FOR LARGE SOLID MATERIALS. | | | |
| | | GRAVITY THICKENING | WATER REMOVED FROM SLUDGE BY GRAVITY IN THICKENING TANKS. CHEMICALS CAN AID IN SLUDGE DEWATERING. | NOT APPROPRIATE FOR LARGE SOLID MATERIALS. | | | |
| | | CENTRIFUGES | SLUDGE DEWATERED BY CENTRIFUGAL FORCE. CENTRIFUGES ARE USED WHEN SPACE IS LIMITED OR WHERE SLUDGE INCINERATION/DISPOSAL IS REQUIRED. | NOT APPROPRIATE FOR LARGE SOLID MATERIALS. | | | |
| | | FILTER PRESSES | SLUDGE PASSED INTO PRESS UNDER PRESSURE. WATER PASSES THROUGH FILTER CLOTH WHILE SOLIDS FORM A CAKE ON THE FILTER CLOTH SURFACE. | NOT APPROPRIATE FOR LARGE SOLID MATERIALS. | | | |
| | | VACUUM FILTRATION | A PARTIALLY SUBMERGED CYLINDRICAL DRUM ROTATES IN A VAT OR PAN OF CONDITIONED SLUDGE. A VACUUM IS PULLED INSIDE THE DRUM, SOLIDS COLLECT ON OUTSIDE AND ARE CONTINUOUSLY SCRAPED OFF. | NOT APPROPRIATE FOR LARGE SOLID MATERIALS. | | | |
| | | DEWATERING AND DRYING BEDS | WASTE PLACED ON SAND LAYERED OVER GRAVEL. WATER EVAPORATES AND DRAINS. | POTENTIALLY VIABLE. | | ✔ | |
| | | SLUDGE DRYERS | CONTAMINATED SLUDGE OR SOIL HEATED IN EQUIPMENT THAT ALLOWS MIXING. AQUEOUS LIQUIDS EVAPORATED FROM SOLIDS INTO THE GAS STREAM. | NOT APPROPRIATE FOR LARGE SOLID MATERIALS. | | | |

NOT CARRIED FORWARD

Fig. 8B.2. (continued)

| GENERAL RESPONSE ACTIONS | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | DISCUSSION | RETAINED: GROUNDWATER | RETAINED: SLB WASTE | RETAINED: TUMULUS |
|---|---|---|---|---|---|---|---|
| TREATMENT (CONTINUED) | PHYSICAL TREATMENT | FLOW AND STRENGTH EQUALIZATION | EQUALIZATION BASIN REGULATES FLOW THROUGH A TREATMENT FACILITY. MECHANICAL MIXING EQUALIZES CONCENTRATION. | POTENTIALLY VIABLE. | ✔ | | |
| | | COAGULATION/ FLOCCULATION | SUSPENDED PARTICLE AGGREGATION THAT RESULTS FROM CHEMICAL ADDITIONS TO THE WASTEWATER. ONCE PARTICLES HAVE AGGREGATED INTO LARGE PARTICLES, THEY CAN BE REMOVED BY SEDIMENTATION, FLOTATION, OR FILTRATION. | POTENTIALLY VIABLE. | ✔ | | |
| | | OIL-WATER SEPARATION | OIL SEPARATED FROM WATER BY GRAVITY. TREATMENT MAY BE REQUIRED FOR DISSOLVED AND EMULSIFIED OIL PRIOR TO SIMPLE PHYSICAL SEPARATION. | NO OIL TO SEPARATE. | | | |
| | | FLOTATION | GAS BUBBLES RELEASED INTO WASTEWATER ATTACH TO SUSPENDED SOLIDS, FREE AND EMULSIFY OILS, AND GREASE. THESE FLOAT TO THE TOP AND ARE SKIMMED OFF. | INSUFFICIENT SOLIDS, OILS, AND GREASES. | | | |
| | | MEDIA-FILTRATION | FINE SOLID PARTICLES REMOVED FROM LIQUID STREAM BY A FILTER MEDIUM. COMMON MEDIA ARE SAND, DIATOMITE, COAL, NATURAL OR SYNTHETIC FABRIC, AND WIRE CLOTH. | POTENTIALLY VIABLE. | ✔ | ✔ | |
| | | ADSORPTION | CONTAMINATED LIQUID OR GAS STREAM PASSED OVER ADSORBENT THAT REMOVES CONTAMINANTS. | POTENTIALLY VIABLE. | ✔ | ✔ | |
| | | MEMBRANE PROCESSES | BARRIER MEMBRANE PREFERENTIALLY PASSES SOME COMPONENTS OF A FLUID MIXTURE OR SOLUTION. | POTENTIALLY VIABLE. | ✔ | ✔ | |
| | | CRYSTALLIZATION | DISSOLVED SOLIDS REMOVED FROM LOW-VISCOSITY LIQUIDS, SLURRIES, AND SLUDGES WHICH HAVE A COMPONENT THAT FREEZES. | WATER WOULD FREEZE WITH DISSOLVED SOLIDS. NOT EFFECTIVE ON GROUNDWATER. | | | |
| | | AIR STRIPPING | LARGE VOLUMES OF AIR FORCED THROUGH LIQUID IN A PACKED COLUMN OR BY DIFFUSED AERATION TO PROMOTE TRANSFER OF VOCS TO AIR. | POTENTIALLY VIABLE. | ✔ | ✔ | |
| | | STEAM STRIPPING | SIMILAR TO AIR STRIPPING EXCEPT STEAM PUMPED THROUGH STRIPPING COLUMN TO ADD HEAT IN THE PROMOTION OF VOC TRANSFER FROM LIQUID TO AIR. | WILL BE CONSIDERED A SUBSET OF AIR STRIPPING. | | | |

NOT CARRIED FORWARD

Fig. 8B.2. (continued)

| GENERAL RESPONSE ACTIONS | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | DISCUSSION | RETAINED: GROUNDWATER | RETAINED: SLB WASTE | RETAINED: TUMULUS |
|---|---|---|---|---|---|---|---|
| TREATMENT (CONTINUED) | PHYSICAL TREATMENT (CONTINUED) | EVAPORATION | WASTEWATER HEATED TO ITS BOILING POINT THEN CONDENSED TO RECOVER WATER AND A BRINE STREAM WHICH CONTAINS VIRTUALLY ALL THE DISSOLVED SOLIDS. | RADIOACTIVE CONTAMINANTS MAY BE VOLATILIZED. LOW VOC CONTENT. | | | |
| | | DISTILLATION | ORGANIC LIQUID WASTES ARE BOILED TO RELEASE VOLATILE COMPOUNDS INTO THE VAPOR PHASE. THE VAPOR PHASE IS CONDENSED, TREATED AND/OR DISPOSED. | USUALLY USED FOR MORE CONCENTRATED ORGANICS. | | | |
| | | LIQUID-LIQUID EXTRACTION | TWO IMMISCIBLE LIQUIDS BROUGHT TOGETHER BY FORCED MIXING OR COUNTERCURRENT FLOW TO PROMOTE THE TRANSFER OF A SOLUTE FROM ONE LIQUID TO THE OTHER. APPLICABLE FOR REMOVAL OF ORGANICS FROM AQUEOUS SOLUTIONS OR RADIONUCLIDES BY AN EXTRACTANT. | TYPES OF CONTAMINANTS TOO VARIED. PROCESS EXPERIMENTAL FOR RADIOACTIVITY. | | | |
| | | CRITICAL FLUID EXTRACTION | A GAS (TYPICALLY $CO_2$) AT ITS CRITICAL POINT IS FED COUNTERCURRENT TO A CONTAMINATED WASTE, EXTRACTING ORGANICS THEN SEPARATE FROM THE GAS AT ATMOSPHERIC CONDITIONS. | USED FOR MORE CONCENTRATED ORGANICS. | | | |
| | CHEMICAL TREATMENT | NEUTRALIZATION | ACID ADDED TO AN ALKALINE WASTE OR BASE ADDED TO AN ACIDIC WASTE TO ADJUST THE STREAM TO A pH NEAR NEUTRALITY. | POTENTIALLY VIABLE. | ✔ | ✔ | |
| | | PRECIPITATION | CHEMICAL EQUILIBRIA OF WASTE ALTERED TO REDUCE THE SOLUBILITY OF HEAVY METALS THROUGH THE ADDITION OF A SUBSTANCE THAT REACTS WITH THE METALS OR CHANGES THE pH OR THROUGH A CHANGE IN TEMPERATURE. | POTENTIALLY VIABLE. | ✔ | ✔ | |
| | | ION EXCHANGE | CONTAMINATED WATER PASSED THROUGH A BED OF RESIN MATERIAL WHERE EXCHANGE OF IONS OCCURS BETWEEN THE BED AND THE WATER. | POTENTIALLY VIABLE. | ✔ | ✔ | |
| | | OXIDATION | OXIDIZING AGENTS ADDED TO WASTES FOR OXIDATION OF CYANIDE, HEAVY METALS, UNSATURATED ORGANICS, SULFIDES, SULFITES, PHENOLICS, PESTICIDES, ALDEHYDES, AND AROMATIC HYDROCARBONS TO LESS TOXIC OXIDATION STATES. | CONTAMINANTS TREATED BY OXIDATION NOT OF CONCERN. | | | |

NOT CARRIED FORWARD

**Fig. 8B.2. (continued)**

| GENERAL RESPONSE ACTIONS | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | DISCUSSION | RETAINED: GROUNDWATER | RETAINED: SLB WASTE | RETAINED: TUMULUS |
|---|---|---|---|---|---|---|---|
| TREATMENT (CONTINUED) | CHEMICAL TREATMENT (CONTINUED) | CHEMICAL REDUCTION | REDUCTION AGENTS ADDED TO WASTES FOR REDUCTION OF HEXAVALENT CHROMIUM, MERCURY, DISSOLVED LEAD, AND SILVER TO LESS SOLUBLE, MORE STABLE FORMS. | CONTAMINANTS TREATED BY REDUCTION NOT OF CONCERN. | | | |
| | | ELECTROCHEMICAL REDUCTION | ELECTROCHEMICAL TREATMENT CHANGES THE OXIDATION STATE OF IONS IN SOLUTION TO A PREFERRED AND TREATABLE STATE THROUGH THE APPLICATION OF A DIRECT CURRENT TO TWO SUBMERGED ELECTRODES IN AN ELECTROLYTE SOLUTION. GENERALLY USED TO PRECIPITATE HEAVY METALS. | CONTAMINANTS TREATED BY REDUCTION NOT OF CONCERN. | | | |
| | | ORGANIC CHEMICAL DECHLORINATION | CHEMICAL REAGENTS OR CATALYSTS ADDED TO WASTES TO REMOVE CHLORINE ATOMS FROM CHLORINATED HYDROCARBONS. NOT APPLICABLE TO AQUEOUS WASTES. EXPERIMENTAL PROCESS OPTION. | INSUFFICIENT ORGANIC CONTENT. | | | |
| | | PHOTOLYSIS | SUNLIGHT, FLUORESCENT LAMPS, OR MERCURY ARCS APPLIED TO LIQUID OR GASEOUS WASTE STREAM TO PROMOTE THE PHOTODEGRADATION OF THE CONTAMINANT. EXPERIMENTAL PROCESS OPTION. | EXPERIMENTAL. MINIMAL EFFECTIVENESS. | | | |
| | BIOLOGICAL TREATMENT | AEROBIC PROCESSES | ORGANIC WASTES OXIDIZED THROUGH THE USE OF A MIXED CULTURE OF ORGANISMS IN AEROBIC CONDITIONS. | TOO LOW OF ORGANIC CONCENTRATION TO SUSTAIN BIOLOGICAL GROWTH. | | | |
| | | ANAEROBIC PROCESSES | ORGANIC COMPOUNDS OXIDIZED THROUGH THE USE OF A MIXED CULTURE OF ORGANISMS IN ANAEROBIC CONDITIONS. | TOO LOW OF ORGANIC CONCENTRATION TO SUSTAIN BIOLOGICAL GROWTH. | | | |
| | | FACULTATIVE PROCESSES | ORGANIC COMPOUNDS REMOVED FROM WASTEWATERS THROUGH THE USE OF A MIXED CULTURE OF ORGANISMS IN BOTH AEROBIC AND ANAEROBIC CONDITIONS. | TOO LOW OF ORGANIC CONCENTRATION TO SUSTAIN BIOLOGICAL GROWTH. | | | |
| | | NEW BIOTECHNOLOGIES | GENETICALLY MODIFIED MICROORGANISMS APPLIED TO WASTEWATER TO OXIDIZE SPECIFIC ORGANIC COMPOUNDS. PURIFIED ENZYME SYSTEMS DETOXIFY ORGANIC CONTAMINANTS. EXPERIMENTAL PROCESS OPTION. | EXPERIMENTAL. | | | |
| | | LAND TREATMENT | ORGANIC LIQUID AND SLUDGE WASTE APPLIED TO OPEN LAND. BIODEGRADABLE ORGANICS OXIDIZE AND CROPS CONSUME NUTRIENTS AND MINERALS (HEAVY METALS). | LAND APPLICATION WILL NOT TREAT RADIOACTIVE CONTAMINANTS. | | | |

NOT CARRIED FORWARD

Fig. 8B.2. (continued)

5.18A 4104.83

| GENERAL RESPONSE ACTIONS | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | DISCUSSION | RETAINED: GROUNDWATER | RETAINED: SLB WASTE | RETAINED: TUMULUS |
|---|---|---|---|---|---|---|---|
| TREATMENT (CONTINUED) | IN SITU TREATMENT | NEUTRALIZATION | SUBSTANCES APPLIED OR INJECTED INTO A CONTAMINATED SITE TO ADJUST THE PH OF THE WASTE. INNOVATIVE PROCESS OPTION FOR CONTAMINATED SOILS OR BURIED WASTES. | TOO DIFFICULT TO CONTROL INJECTION OF CHEMICALS AT SITE. WASTE TOO VARIED. | | | |
| | | OXIDATION | OZONE OR HYDROGEN PEROXIDE APPLIED IN WATER SOLUTIONS TO THE SOIL TO PROMOTE THE OXIDATION OF ORGANICS. CONCEPTUAL PROCESS OPTION. | TOO DIFFICULT TO CONTROL INJECTION OF CHEMICALS AT SITE. WASTE TOO VARIED. | | | |
| | | CHEMICAL REDUCTION | REDUCTION AGENTS APPLIED TO CONTAMINATED SOIL TO REDUCE CHLORINATED ORGANICS, UNSATURATED AROMATICS AND ALIPHATICS, AND HEAVY METALS TO LESS SOLUBLE, MORE STABLE FORMS. CONCEPTUAL PROCESS OPTION. | TOO DIFFICULT TO CONTROL INJECTION OF CHEMICALS AT SITE. WASTE TOO VARIED. | | | |
| | | PRECIPITATION | SUBSTANCES APPLIED TO SOIL OR STREAMS TO PROMOTE THE PRECIPITATION OF METALS AS SULFIDES, PHOSPHATES, AND HYDROXIDES. SUITABLE SOIL PH MUST BE MAINTAINED FOR MAXIMUM INSOLUBILITY OF METAL PRECIPITATES. EXPERIMENTAL PROCESS OPTION FOR SOILS. | TOO DIFFICULT TO CONTROL INJECTION OF CHEMICALS AT SITE. WASTE TOO VARIED. | | | |
| | | BIORECLAMATION | MICROBIOLOGICAL DEGRADATION, DETOXIFICATION, AND MINERALIZATION OF HAZARDOUS SUBSTANCES IS ENHANCED WITH RESPECT TO ELECTRON ACCEPTORS, NUTRIENT LEVELS, MOISTURE CONTENT, PH, AND TEMPERATURE. | TOO DIFFICULT TO CONTROL EFFECTIVENESS. | | | |
| | | THERMAL EVAPORATION | ELECTRODES PLACED OVER SURFACE OF CONTAMINATED SITE OR IN VERTICAL OR HORIZONTAL BORE-HOLES DRILLED THROUGH CONTAMINATED ZONE. ELECTROMAGNETIC ENERGY IN RADIOFREQUENCY BAND IS APPLIED TO ELECTRODES TO CAUSE RAPID HEATING OF THE SOIL BY MOLECULAR EXCITATION. | DIFFICULT TO CONTROL RELEASE OF RADIOACTIVE MATERIALS. | | | |
| | | STEAM STRIPPING | VOC REMOVAL FROM SOIL BY APPLICATION OF STEAM. INJECTION WELLS FORCE STEAM THROUGH CONTAMINATED SUBSURFACE. STEAM CARRYING STRIPPED VOLATILES IS COLLECTED AT SURFACE THROUGH EXTRACTION WELLS. | WILL BE CONSIDERED AS A SUBSET OF SOIL VAPOR EXTRACTION. | | | |
| | | PERMEABLE TREATMENT BEDS | TRENCH EXCAVATED, FILLED WITH APPROPRIATE MATERIAL, AND CAPPED TO INTERCEPT CONTAMINATED GROUNDWATER. DEPENDING UPON BED MATERIAL, GROUNDWATER CAN BE NEUTRALIZED, METALS AND ORGANICS CAN BE REMOVED, AND NUTRIENTS CAN BE ADDED. CONCEPTUAL PROCESS OPTION. | POTENTIALLY VIABLE. | ✓ | | |

NOT CARRIED FORWARD

**Fig. 8B.2. (continued)**

5.18A 4104.84

| GENERAL RESPONSE ACTIONS | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | DISCUSSION | RETAINED: GROUNDWATER | RETAINED: SLB WASTE | RETAINED: TUMULUS |
|---|---|---|---|---|---|---|---|
| TREATMENT (CONTINUED) | IN SITU TREATMENT (CONTINUED) | VITRIFICATION | GRAPHITE ELECTRODES PLACED IN A SQUARE ARRAY. ELECTRIC CURRENT PASSES THROUGH ELECTRODES CREATING HIGH TEMPERATURES THAT MELT THE SOIL OR WASTE SOLIDS INTO A BLOCK OF GLASSLIKE MATERIAL. EXPERIMENTAL PROCESS OPTION. | POTENTIALLY VIABLE. | | ✔ | |
| | | SOIL VAPOR EXTRACTION | LARGE VOLUMES OF AIR PULLED THROUGH THE SOIL TO STRIP VOLATILE CONTAMINANTS FROM THE SOIL IN A MANNER SIMILAR TO AIR STRIPPING. | DIFFICULT TO CONTROL RELEASE OF CONTAMINANTS DUE TO SUBSURFACE CHARACTERISTICS. | | | |
| | | SOIL FLUSHING | CONTAMINATED SOIL IS FLUSHED WITH AN APPROPRIATE FLUSHING SOLUTION AND THE ELUTRIATE IS COLLECTED IN A SERIES OF SHALLOW WELL POINTS OR SUBSURFACE DRAINS. | DIFFICULT TO CONTROL DUE TO CONDITIONS. SUBSURFACE CONDITIONS. | | | |
| | | STABLILIZATION/ SOLIDIFICATION | MINIMIZING MOBILITY BY ADDING SORBENT, SILICOUS MATERIAL, ETC. AND CHEMICALLY BINDING CONTAMINANTS. | POTENTIALLY VIABLE. | | ✔ | |
| | THERMAL TREATMENT | INCINERATION | HAZARDOUS MATERIALS THERMALLY DESTROYED IN A CONTROLLED, OXYGEN-SUFFICIENT ENVIRONMENT. GENERALLY, PRODUCTS INCLUDE CARBON DIOXIDE, WATER, AND ASH. MANY TYPES OF INCINERATORS WITH VARYING CAPABILITIES EXIST. | POTENTIALLY VIABLE. | | ✔ | |
| | | CO-DISPOSAL PROCESS | WASTE MATERIALS MIXED WITH PULVERIZED COAL, NATURAL GAS, WOOD CHIPS, ETC., OR OTHER WASTES AND USED AS A SUPPLEMENTAL FUEL SOURCE TO PRODUCE STEAM FOR A CONVENTIONAL POWER CYCLE. | NOT APPROPRIATE FOR RADIOACTIVE MATERIAL. | | | |
| | | PYROLYSIS | HAZARDOUS MATERIALS THERMALLY DESTROYED IN AN OXYGEN-DEFICIENT ENVIRONMENT. | NOT RETAINED IN FAVOR OF INCINERATION. | | | |
| | | WET AIR OXIDATION | WASTE MIXED WITH AIR AND FED TO A REACTOR WHERE DESTRUCTION TAKES PLACE AT HIGH TEMPERATURES (UP TO 600°) AND PRESSURES (UP TO 200 ATM). | NOT RETAINED IN FAVOR OF INCINERATION. | | | |

NOT CARRIED FORWARD

Fig. 8B.2. (continued)

| GENERAL RESPONSE ACTIONS | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | DISCUSSION | RETAINED: GROUNDWATER | RETAINED: SLB WASTE | RETAINED: TUMULUS |
|---|---|---|---|---|---|---|---|
| DISPOSAL | RESOURCE RECOVERY | MATERIALS REUSE | CERTAIN MINERALS, METALLIC PRODUCTS, AND COMBUSTIBLE MATERIALS CAN BE RECLAIMED. LANDFILL GAS CAN BE CONVERTED TO METHANOL AND HYDROGEN. | NOT APPROPRIATE FOR LOW LEVEL RADIOACTIVE MATERIAL. | | | |
| | | ENERGY RECOVERY | ENERGY IS RECOVERED FROM THERMAL TREATMENT, OR WASTES ARE CONVERTED FOR USE AS FUEL. | NOT APPROPRIATE FOR LOW LEVEL RADIOACTIVE MATERIAL. | | | |
| | TEMPORARY STORAGE | TEMPORARY BURIAL | HAZARDOUS MATERIALS ARE TEMPORARILY BURIED (ONSITE) UNTIL PERMANENT TREATMENT OR DISPOSAL. | POTENTIALLY VIABLE IN LIMITED APPLICATION. | | ✓ | |
| | | SURFACE IMPOUNDMENTS | SURFACE IMPOUNDMENTS ARE USED TO STORE OR TREAT LIQUID AND SLUDGE-TYPE WASTE. ALSO KNOWN AS PONDS, LAGOONS, LIQUID TRENCHES, EVAPORATION PONDS, TREATMENT PONDS, AERATION PITS, AND STABILIZATION BASINS. | DIFFICULT TO CONTROL RELEASES TO AIR AND TO SUBSURFACE. | | | |
| | | WASTE PILES | WASTE PILES ARE USED FOR TEMPORARY STORAGE OF SOLID WASTES. | POTENTIALLY VIABLE IN LIMITED APPLICATION. | | ✓ | |
| | | CONTAINERS/TANKS | CONTAINERS ARE USED TO TEMPORARILY STORE AND TRANSPORT WASTES. TANKS ARE USED TO TEMPORARILY STORE LIQUID WASTES PRIOR TO TREATMENT OR DISPOSAL. | POTENTIALLY VIABLE IN LIMITED APPLICATION. | ✓ | ✓ | |
| | LAND APPLICATION | | LIQUID AND SOLID WASTES THAT ARE PRIMARILY ORGANIC ARE INCORPORATED INTO THE UPPER SOIL HORIZON SO THEY CAN BE DEGRADED, TRANSFORMED, OR IMMOBILIZED. | NOT APPROPRIATE FOR RADIOACTIVE MATERIALS DUE TO BIOACCUMULATION | | | |
| | NUCLEAR WASTE REPOSITORY | | REPOSITORY FOR NUCLEAR WASTE BEING DEVELOPED BY DOE. | POTENTIALLY VIABLE. | | ✓ | ✓ |

NOT CARRIED FORWARD

Fig. 8B.2. (continued)

5.18A 4104.86

| GENERAL RESPONSE ACTIONS | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | DISCUSSION | RETAINED: GROUNDWATER | RETAINED: SLB WASTE | RETAINED: TUMULUS |
|---|---|---|---|---|---|---|---|
| DISPOSAL (CONTINUED) | WASTEWATER DISCHARGE | ON-SITE PLANTS | AQUEOUS STREAMS ARE DISCHARGED TO ORNL TREATMENT PLANTS. | POTENTIALLY VIABLE. | ✔ | | |
| | | POTW | AQUEOUS STREAMS ARE DISCHARGED TO A POTW FOR TREATMENT. | NOT APPROPRIATE FOR RADIOACTIVE MATERIALS. | | | |
| | | SURFACE WATERS | TREATED/UNCONTAMINATED AQUEOUS STREAMS ARE DISCHARGED TO SURFACE RECEIVING STREAMS. | POTENTIALLY VIABLE. | ✔ | | |
| | | REINJECTION | TREATED GROUNDWATER OR SURFACE WATER IS REINJECTED INTO ONSITE WELLS. | NOT RETAINED IN FAVOR OF SURFACE WATER DISCHARGE. | | | |
| | | DEEP WELL INJECTION | AQUEOUS WASTES ARE INJECTED INTO CLASS I WELLS. RECENT GUIDANCE MAY FURTHER REGULATE THIS PRACTICE. | NOT RETAINED IN FAVOR OF SURFACE WATER DISCHARGE. | | | |
| | | EVAPORATION PONDS | SURFACE IMPOUNDMENTS ARE USED TO CONTAIN TREATED OR UNTREATED WASTEWATER OR GROUNDWATER UNTIL IT EVAPORATES. | NOT RETAINED DUE TO LARGE WASTE VOLUME AND HUMID ENVIRONMENT. | | | |
| | SOLIDS DISPOSAL | ONSITE | EXCAVATED MATERIAL REPLACED OR CONSOLIDATED WITH OTHER WASTE OR PUT IN IWMF. | POTENTIALLY VIABLE. | | ✔ | |
| | | OFF-SITE LANDFILL | EXISTING LANDFILL THAT CAN ACCEPT MATERIAL FROM SITE. | NONE AVAILABLE FOR MIXED WASTE. LIMITED CAPACITY FOR LLW. | | | |
| MONITORING | MONITORING | | SHORT- AND/OR LONG-TERM MONITORING IS IMPLEMENTED TO RECORD SITE CONDITIONS AND CONTAMINATION LEVELS. | POTENTIALLY VIABLE. | ✔ | ✔ | ✔ |

NOT CARRIED FORWARD

Fig. 8B.2. (continued)

# APPENDIX 8C. WORKER EXPOSURE ASSESSMENT FOR WAG 6

## 8C.1 INTRODUCTION/PURPOSE

The purpose of this analysis is to evaluate the potential radiation exposure hazards associated with the total or partial excavation of the trenches, silos, and auger holes located at WAG 6. The excavation of these waste units would involve handling radioactive and chemical wastes, since WAG 6 has received wastes from most operational activities conducted at ORNL. In this preliminary analysis, worker exposure to radioactive materials will be assessed. This analysis is a follow-up of the study documented in Attachment A to this Appendix that evaluated shield thicknesses necessary to reduce the worker exposure rates associated with the excavation of worst case and typical inventory trenches and auger holes. The previous study is summarized in Attachment A.

The types of radiological hazards to which workers may potentially be exposed during excavation include:

- Direct external exposure to beta/gamma radiation
- Inhalation of alpha particles from contaminated soil
- Ingestion of soil contaminated with alpha emitters
- Ingestion of soil contaminated with beta/gamma emitters

However, this analysis estimates only the exposure rates due to external gamma radiation; it does not include evaluation of the potential inhalation and ingestion hazards. It is assumed that the dust suppression and personal protective equipment would be used to reduce the impact of the inhalation and ingestion pathways.

The total excavation scenario focuses on the worst and average case inventory for each waste unit — trench, silo, and auger hole. The partial excavation scenario examines the exposures rates to workers from a worst and average case inventory in a solvent auger hole and biological trench. Three types of workers are evaluated -- the observer, the backhoe operator, and the waste hauler. The worker exposure rates are calculated assuming no shielding and with limited shielding.

## 8C.2 WASTE INVENTORY

The waste in WAG 6 is generally classified as low-level solid waste. The waste consists of a variety of material including laboratory equipment, construction debris, animal remains, and contaminated soil. Some of the waste was buried loose and unpackaged, while some was containerized prior to disposal.

The variety of materials disposed in WAG 6 does not lend itself to easy characterization and modeling of the contents of the disposal units. Therefore, for the purposes of this analysis, it was assumed that the radioactivity was uniformly distributed in backfill/soil. The bulk density for the soil used in this analysis was 1.34 g/cc (Davis et al. 1984). The elemental composition of the soil was based on an average dry soil (Jaeger et al. 1975).

The majority of radioactive waste was disposed in several variations of three general types of disposal units:

- Trenches (built before May 1986)
- Auger holes
- Silos (built after May 1986)

The dimensions of waste units used in this analysis are derived from previous estimates (Smith and Amrit, CCN 010664, 1991). The dimensions of the waste units will often vary in depth or diameter; in those cases, average waste unit dimensions are assumed. The trench dimensions used in this analysis are 50 ft long, 10 ft wide, and 15 ft deep. To simplify the analysis, the trenches were assumed to be uncovered and the contents were considered to be homogenous. Silos are double walled and concrete lined. The silo dimensions were assumed to be 8 ft in diameter and 20 ft deep. A concrete pipe surrounding the waste was assumed to be 0.5 ft thick; the corrugated metal pipe was not included in the shielding calculations since it may be corroded. The auger holes were considered to be unlined and the contents homogenous. The auger hole dimensions assumed were 30 in. in diameter and 20 ft deep. The solvent auger hole dimensions assumed were 36 in. diameter and 20 ft deep. A summary of the waste unit dimensions is shown in Table 8C.1.

## 8C.3 EXCAVATION METHODS

Waste excavation may be conducted with a variety of equipment, such as, backhoes and crawl loaders. Hauling may be conducted with vehicles such as dump trucks and scrapers. As an excavating tool, the backhoe was selected because it is often used for trenching and subsurface excavation. A dump truck was selected because it is a typical type of equipment used in hauling debris.

Exposure conditions to an on-site observer, backhoe operator, and hauler are shown in Table 8C.1. Observer exposure was based on the assumption that the observer was 6 ft from the trench, silo, or auger hole. Exposure to the backhoe operator is evaluated based on the bucket contents and the distance from the bucket to the operator. The standard backhoe bucket dimensions are 0.6 cubic yards (3.25 ft x 1.67 ft x 3 ft) and the bucket is assumed to be filled to capacity with waste material. The backhoe is extended in its overall operating position at a distance of 10 ft. The transport-position distance may be 7 ft; however, it was assumed that the backhoe will be at the operating distance the majority of time. The hauler evaluated in this study is filled to its hauling capacity of 12 cubic yards (11 ft x 7.4 ft x 4 ft). The driver is located 2 ft from the front end of the truck bed and is separated from the contents of the truck bed by 1/4 in. of stainless steel.

In the shielded scenario, as shown in Table 8C.2, the backhoe operator is shielded by leaded glass. Its composition is 50% lead and 50% glass; concrete is used to simulate glass. The leaded glass density is 6.825 g/cm$^3$. It is assumed that the leaded glass is on the side with the load. Contribution to the exposure from the open waste unit or secondary radiation (sky shine) is not evaluated. The truck driver is shielded (in addition to the stainless steel) by a 25-mm thick lead plate placed between the dump body and the cab. In the shielded

scenarios, buildup within the shield was taken into account, but the added contribution to the exposure rate due to the open waste unit or sky shine was omitted. As a preliminary evaluation, direct gamma radiation exposure from the contents of the backhoe bucket or truck bed was considered to be of primary concern to each type of worker.

Initially the radionuclide inventory in the backhoe bucket and truck bed were calculated by dividing the waste unit inventory by the ratio of waste unit volume to bucket or truck bed volume. Since, the exposure rate also varied by this ratio, the exposure rates were calculated based on the waste unit inventory, and then the ratio was applied to these results to yield the exposure rate to the backhoe operator and the truck driver.

## 8C.4 SCENARIOS

A number of scenarios were chosen to evaluate the potential of exposure to workers during the total and partial excavation of the waste units at WAG 6 as shown in Table 8C.3 and 8C.4, respectively. The general approach taken was to evaluate the worst case inventory and the average inventory for each type of waste unit. For total excavation, the waste units considered were trenches, silos, or auger holes. The partial excavation scenario evaluates specific types of waste material, specifically biological (animal burial trenches) and solvent auger holes.

The worst case conditions for a trench, silo, or auger hole were based on the highest photon activity inventory in the respective waste unit. The average case conditions were based on the calculated averages of the activity inventory for a particular waste unit. For example, pre-1986 trench and auger hole data was tabulated, based on the summary data, which stated that 90% of the activity was in 19 auger holes and 7 trenches (Davis et al. 1987). The average trench inventory is based solely on the Davis et al. (1987) summary data. The average silo inventory was ascertained from the yearly radionuclide activity inventory (1986 to 1990) (Smith, 1991). The average auger hole inventory was calculated using both pre-1986 inventory data and the yearly radionuclide activity inventory (1986 through 1990) (Smith, 1991). For both the average silos and auger hole inventory, the total activity per radionuclide was divided by the total number of silos/auger holes that exhibited specific radionuclide activity data. Silos/auger holes that did have any entry data or had zeros were not counted in the average. This approach is conservative since the activity was distributed only with those waste units that exhibited specific radionuclide data (except for the pre 1986 data).

In the excavation scenarios, three different workers were evaluated: the observer, the backhoe operator, and the dump truck operator. Table 8C.1 shows the assumptions used in these analyses. For example, the hypothetical observer was located 6 ft in front of the trench or auger hole; this was to simulate an observer watching the excavation of the trench or auger hole. The backhoe operator would be exposed to the contents of the backhoe bucket and the truck driver's source of exposure would be from the truck bed contents.

The backhoe operator and the truck driver exposures were further evaluated based on (1) no added shielding and (2) added shielding. As previously described, the shielding used

for the backhoe operator was leaded glass (simulated by 50% lead and 50% concrete). The shielding used for the truck driver was a plate of 25-mm thick lead. The lead plate is in addition to the 1/4" of steel (iron) that simulated the dump body thickness. Twenty-five millimeters (1 in.) of lead was assumed to be the maximum lead that could be used without significantly affecting the operation of these vehicles. It is important to note that both the backhoe and the dump truck can be built to specifications, especially if they are not used off-site.

## 8C.5 EXPOSURE ASSESSMENT METHODOLOGY

A computer model, Microshield (TM), was used to calculate exposure rates to the workers. It is a microcomputer adaptation of the code ISOSHLD. Microshield retains the solution algorithms and physical data from ISOSHLD. This program which uses the point kernel method of integration, allows for the selection of a variety of source and shield geometries. Buildup was accounted for in this analysis. The activities were not decay corrected to be generally conservative and because the waste units' inventory were often averaged over a number of years.

The source-to-receptor geometries used in this study are summarized in Table 8C.5 and illustrated in Attachment B. The geometric form used to simulate trenches was a rectangular volume with slab shields. A cylinder on its end with slab shields was used to calculate this exposure rate to an observer from an auger hole. The geometry chosen for both the backhoe bucket and truck bed was a rectangular volume with slab shields. Two conditions were evaluated for silo excavation: (1) excavation of the silo contents without concrete, and (2) excavation of the silo with the concrete intact and cut into 4-ft segments. Two source geometries were used to simulate excavation of the silo: (1) a cylinder on its end with slab shields for the open silo, and (2) a cylinder on its side with cylinder shields for excavation of the 4-ft segment. For the backhoe operator and truck driver at the excavation of a silo, three geometries were selected: (1) a rectangular volume with slab shields for the excavation of silo contents only; (2) a cylinder on its side with cylinder shields to simulate a 4-ft segment within the backhoe bucket and truck bed without shielding; and (3) a cylinder on its side with cylinder and slab shields to simulate the 4-ft segment in a truck bed and backhoe bucket with shielding.

## 8C.6 EXPOSURE LIMITS

The maximum whole body dose-equivalent allowed for a calendar quarter for the ORNL RI/FS project is 1.25 rem (PP 1280.3). Administrative limits established as an ALARA goal are 75% of the ORNL limits (0.938 rem) for ORNL RI/FS projects. Using the 938 mrem as the maximum individual exposure/quarter means that each individual weekly exposure should not average more than 72 mrem without prior approval.

The 72 mrem/man-week and the hourly permissible exposure rate of 1.8 mR/hr will be used for comparing the potential exposures from the excavation practices. These values are reasonable both from the perspective of compliance with federal regulations and ALARA.

It also falls within the procedural limit of 100 mrem/man-week established for the ORNL RI/FS projects.

## 8C.7 RESULTS AND DISCUSSION

The purpose of this evaluation was to determine potential worker exposure with standard excavation techniques for total excavation. Potential worker exposure for partial excavation was also determined.

### 8C.7.1 Total Excavation

Table 8C.3 shows the estimated exposures that may occur given the total excavation alternative. Assuming that the hourly permissible exposure rate is 1.8 mR/hr (based on the 72 mrem/man-week), some exposure time estimates associated with excavation activities can be made:

- Auger Hole
  - An observer would be prohibited from observing auger hole remediation at the exposure rates calculated for the worst-case (WH 272 and 501) and average conditions.
  - The backhoe operator and truck driver, for both the worst case (WH 272 and 501) and average conditions, would be unable to handle the waste either with or without shielding.

- Trench
  - The observer would be unable to observe the trench excavation under the given worst case or average conditions.
  - The backhoe operator excavating the average trench with the given shielding would only be able to work for less than 1 hour before exceeding the weekly operational limits.
  - The truck driver would not be able to operate without additional shielding.

- Silo 505 - Worst Case
  - The observer would be unable to observe the excavation of Silo 505 under the given conditions.
  - The backhoe operator excavating Silo 505 would be able to work for 3.6 hours without shielding and 6.2 hours with shielding before exceeding the weekly operational limits.
  - The truck driver would be unable to operate without shielding and for less than 1 hour (0.7 hrs) with the additional shielding.

- Silo—Average (Contents without Concrete Liner)
  - The observer would be able to observe the silo excavation at the given conditions for approximately 1.3 hours before exceeding the weekly operational limits.
  - The backhoe operator would be able to work for approximately 13 hours without shielding before the weekly exposure limit was exceeded. The shielded backhoe

operator would be able to work for a greater period of time, approximately 23 hours.
- The truck driver without shielding would not be able to work at the given exposure rate. With shielding the truck driver would be able to work for approximately 3 hours.

- Removal with Concrete Lining Intact (4-ft Segments)
  - The observer would be able to work for approximately 1.3 hours, assuming the exposure was based on the open silo, not the exposed 4-ft segment. Exposed to the 4-ft segment only, the observer would be able to work for 6.5 hours.
  - The backhoe operator would be able to work for 16.3 hours without shielding and 36 hours with shielding before to exceeding the operational limits.
  - The truck driver would be able to work without shielding for approximately 4.4 hours and approximately 27 hours with the 25 mm lead shielding before exceeding the operational limits.

### 8C.7.2 Partial Excavation

Partial excavation was evaluated by determining the potential exposure rates that may occur during the excavation of the biological and solvent auger holes. As shown in Table 8C.4, the exposure rates attributed to the "worst case" and "average" biological trench and solvent auger holes are still generally above permissible exposure rates (with the exception of the average biological trench) but are significantly less than the exposure rates attributed to total site excavation. A summary of the exposure rates to the permissible exposure limits is given below:

- Biological Trenches
  - Observation of the worst case biological trench (468) removal would not be permitted given the estimated exposure rate. Observation of the average biological trench would be permitted for approximately 13 hours.
  - The backhoe operator would be able to operate for approximately 13 hours (worst case, 468) and the entire week (average) without shielding. With the given shielding, the backhoe operator would be able to work for approximately 23 hours with the worst case, Trench 468.
  - The truck driver would not be able to work on Trench 468 without shielding and only for approximately 3 hours with the given shielding. In the case of the average biological trench, the truck driver would be permitted to work for approximately 4 hours without shielding and approximately 33 hours with the given shielding.

- Solvent Auger Holes
  - The observer would be permitted to observe the excavation of the solvent Auger Hole 327 less than 1 hour and approximately 3 hours for the excavation of an average Solvent Auger Hole.
  - The backhoe operator would be able to work for only 2.8 hours at Auger Hole 327 and for approximately 8 hours unshielded at the average solvent auger hole

excavation. Given the shielded scenario, the backhoe operator would be able to operate for approximately 5 hours at Auger Hole 327 and approximately 14 hours at the average solvent auger hole.

- The truck driver would be unable to operate without shielding; with shielding the driver could haul waste from Auger Hole 327 for 1.3 hours and from the average solvent hole for approximately 4 hours.

## 8C.8 CONCLUSION

If excavation is considered to be an alternative, it appears that partial excavation, of at least the biological trenches, would be far more feasible with additional administrative/engineering controls than total excavation. In terms of potential exposure based on these calculations, excavation of the average silos would be less hazardous than removal of the auger holes and the trenches. But due to potential complexity of excavation, the silos may be more difficult to excavate and could lead to greater exposures.

Considering the number of trenches, silos, and auger holes throughout WAG 6 and the complexities in excavation, total excavation of WAG 6 could yield potentially high exposures to workers, based on the aforementioned assumptions.

It is important to note that this study evaluated only the external gamma radiation hazard under the given conditions and scenarios. As these conditions vary, the exposure rates will also change. In addition, this analysis did not evaluate potential inhalation hazards or chemical hazards. These must be considered prior to serious consideration of excavation, partial or total, of the trenches, silos, and auger holes at WAG 6.

# Appendix 8C Tables

**Table 8C.1. Dimensions used in exposure assessment, WAG 6 ORNL**

| Disposal unit | Dimensions (ft) | Observer distance | Backhoe operator distance | Volume ratio waste unit/backhoe | Hauler distance | Volume ratio waste unit/truck |
|---|---|---|---|---|---|---|
| Trench | 50 x 10 x 15 | 6' | – | 460.7 | – | 23 |
| Silo (total) | 8 dia. x 20 | 6' | – | 61.75 | – | 3.09 |
| Silo (4 ft segment) | 8 dia. x 4 | 6' | – | 4.999* | – | 4.999* |
| Auger hole | 2.5 dia. x 20 | 6' | – | 6.03 | – | 0.3 (Assume 1) |
| Solvent auger Hole | 3 dia. x 20 | 6' | – | 8.69 | – | 0.4 (Assume 1) |
| Method<br>Backhoe Bucket | 3.25 x 1.67 x 3(0.6 $yd^3$) | – | 10' | – | – | – |
| Hauler | 11 x 7.4 x 4 (12 $yd^3$) | – | – | – | 2' | – |

*Volume ratio of Silo (20')/Silo(4')

**Table 8C.2. Shielding assumptions**

| Excavation equipment | Type of shield | Thickness (mm) |
|---|---|---|
| Backhoe | Leaded glass ($6.825\ G/cm^3$) | 25 |
| Hauler | Lead plate | 25 |

Table 8C.3. Total excavation alternative, exposure assessment, WAG 6

| | Without Shielding (mR/hr) | | | Shielding (mR/hr) (25 mm) | |
|---|---|---|---|---|---|
| Disposal Type | Observer | Backhoe Operator | Truck Driver* | Backhoe Operator** | Truck Driver*** |
| AUGER HOLE | | | | | |
| Worst Case<br>WH 272 (9.64E4 Ci) | 6', 4.92E5 | 2.54E5 | 2', 2.60E6 | 1.28E5 | 2.63E5 |
| WH 501 (2.57E5 Ci) | 6', 1.56E6 | 8.06E5 | 2', 8.26E6 | 3.99E5 | 8.37E5 |
| Average<br>(6.41E3 Ci) | 6', 3.03E4<br>10', 1.18E4 | 1.57E4 | 2', 1.6E5 | 7.62E3 | 1.62E4 |
| TRENCH | | | | | |
| Worst Case<br>#436 (3816.9 Ci) | 6', 1.72E4 | 3.32E2 | 2', 8.64E3 | 1.94E2 | 1.65E3 |
| Average<br>(2342.5 Ci) | 6', 6.9E3 | 1.28E2 | 2', 4.7E3 | 7.48E1 | 6.39E2 |
| SILO (>1986) | | | | | |
| Worst Case<br>#505 (80 Ci) | 6', 2.03E2 | 2.01E1 | 7.28E2 | 1.17E1 | 9.94E1 |
| Average segments<br>(1.184 Ci) | 6', 5.52E1 (total silo)<br>1.1E1 (4' segment) | 4.42E0 | 1.64E1 | 1.99E0 | 2.64E0 |
| Average contents<br>(1.184 Ci) | 6', 5.52E1 | 5.47E0 | 2', 1.97E2 | 3.14E0 | 2.63E1 |

*Truck driver assume 1/4" iron
**Leaded glass (50% Pb)
***Lead shielding between cab and trailer

Table 8C.4. Partial excavation alternatives exposure assessment, WAG 6

| Disposal Type | Without Shielding (mR/Hr) | | | Shielding (mR/hr) (25 mm) | |
|---|---|---|---|---|---|
| | Observer | Backhoe Operator | Truck Driver* | Backhoe Operator** | Truck Driver*** |
| BIOLOGICAL TRENCH | 6', 2.78E2 | 5.37E0 | 1.96E2 | 3.13E0 | 2.67E1 |
| Worst Case #468 (119 Ci) | | | | | |
| Average (31.2 Ci) | 6', 2.40E1 | 4.47E-1 | 1.62E1 | 2.6E-1 | 2.19E0 |
| SOLVENT AUGER HOLE | 6', 7.87E1 | 2.57E1 | 4.05E2 | 1.5E1 | 5.52E1 |
| Worst Case #327 (572.4 Ci) | | | | | |
| Average (285 Ci) | 6', 2.76E1 | 8.99E0 | 1.42E2 | 5.2E0 | 1.91E1 |

*Assume 1/4"-0.635 cm stainless steel
**Leaded glass (50% Pb)
***Lead shielding between cab and trailer

Table 8C.5. Summary of source geometry

| Waste Unit | Receptor | Source Geometry |
|---|---|---|
| Trench | Observer | Rectangular volume with slab shields |
| | Backhoe operator truck driver | Rectangular volume with slab shields |
| Silos<br>o Contents only | Observer | Cylinder on its end with slab shields |
| | Backhoe operator truck driver | Rectangular volume with slab shields |
| o 4 ft concrete segments | Observer | Cylindrical source from side-cylindrical shields |
| | Backhoe operator truck driver (without shielding) | Cylindrical source from side-cylindrical shields |
| | Backhoe operator truck driver (with shielding) | Cylindrical source from side-combination shields |
| Auger holes | Observer | Cylindrical source on end with slab shields |
| | Backhoe operator truck driver | Rectangular volume with slab shields |

# ATTACHMENT A

## SHIELDING OPTIMIZATION

## EXPOSURE ASSESSMENT - PRELIMINARY EVALUATION

ATTACHMENT A

EXPOSURE ASSESSMENT PRELIMINARY EVALUATION

An initial analysis was conducted that evaluated total excavation of WAG 6. The waste unit inventories selected are as follows:

- Trenches
  - Worst Case, Trench 436 -- Total activity 5100.23 C
    Primary radionuclide Cobalt-60
  - Worst Case, Trench 436 -- Total activity in 1/3 of the trench volume
  - Trench 410 -- Total activity 1001.2 Ci
    -- Primary radionuclide cobalt-60
  - Average, Trench 410--Total activity 72.134 Ci
    --Primary radionuclide cobalt-60
- Auger Holes
  - Worst Case, Auger Hole 272 -- Total activity of 96,400 Ci
    -- Primary radionuclides europium-152, europium-154, europium-155
  - Average Auger Hole (Hypothetical) -- Total activity 57.06 Ci

The exposure scenarios used in this analysis are as follows:

- Estimates of exposure to an observer were calculated based on the source-to-receptor distances of 10 ft, 20 ft, and 30 ft
- Estimates of exposure to a front-end loader operator, with a bucket capacity of 2 $yd^3$
- Estimates of exposure rates to a truck driver with a 12 $yd^3$ capacity

Calculations were conducted to determine the shielding requirements for the operators of the backhoe (front end loader) and truck. Table 8A.1 summarizes the results of these analyses. The lead thicknesses chosen ranged from 0 to 80 mm. It was observed that Trench 436 (5100.23 Ci) required 70 mm of lead so that the exposure rate to the backhoe (front end loader) operator was reduced to 314 mR/hr. If the contents of the Trench 436 were consolidated into one-third the volume, 80 mm of lead would be required to reduce the exposure rate to 232 mR/hr. Trench 410 (1001.2 Ci) required 50 mm of lead to reduce the

exposure rate to 208 mR/hr. Trench 271 (72.13 Ci), used to represent the "average" trench, indicated that no lead shielding was required. Added operators for the backhoe and the truck would allow for the excavation of this trench without added shielding. The worst case auger hole (272) shielding calculations indicated that 40 mm of lead would be required to reduce the exposure rate to 198 mR/hr.

Table A.1. Exposure Assessment - WAG 6

| TRENCH | Without Shielding MR/hr | | | | | | Shielding Optimization |
|---|---|---|---|---|---|---|---|
| | Observer | | Backhoe Operator* | | Truck Driver | | Backhoe |
| Worst Case (436)<br>(5100 2 Ci) | 16' | 9.13E4 | 4' | 9.68E3 | 6'3 | 1.98E4 | Exp distance 20'(Operator @ 10') 20'<br>0mm - 40176 mR/hr<br>20mm - 10,014 mR/hr<br>40mm - 2511 mR/hr to<br>70mm - 314 mR/hr |
| | 20' | 3.26E4 | 10' | 1.13E3 | 10' | 6.5E3 | |
| | 30' | .874E3 | 20' | 189.2 | 20' | 804.7 | |
| | 40' | 3.96E3 | 30' | 73.6 | 30' | 284.4 | |
| Worst Case (436) | 8.5' | 2.03E5 | 4' | 5.69E4 | 6'4" | 8.42E4 | $\frac{5100.23\ Ci}{(17'x10'x75')} \times 12\ yd^3 = 1296.06\ Ci$<br>27 |
| (1/3 area)<br>(7.5 ft deep) | 10' | 1.66E5 | 10' | 6.62E3 | 10' | 3.37E4 | Operator @ 10'<br>0mm-59,307 mR/hr |
| | 20' | 1.90E4 | 20' | 2.22E3 | 20' | 4.23E3 | 20mm-14,827 mR/hr<br>40mm-3,707 mR/hr |
| | 30' | 6.34E3 | 30' | 4.33E2 | 30' | 1.48E3 | |
| Trench #410<br>(1001.2 Ci) | 4' | 5.69E4 | 4' | 1.63E3 | — | — | Operator @ 10'<br>0mm-6,614 mR/hr |
| | 10' | 6.62E3 | 10' | 1.897E2 | — | — | 20mm-1,661 mR/hr<br>40mm-415 mR/hr |
| | 20' | 1.11E3 | 20' | 3.19E1 | — | — | 50mm - 208 mR/hr |
| | 30' | 4.33E2 | 30' | 1.24E1 | — | — | |
| Trench #410 | 8.5' | 3.42E4 | 4' | 9.61E3 | 6.4' | 1.42E4 | |
| (1/3 area)<br>(7.5 ft deep) | 10' | 2.79E4 | 10' | 1.12E3 | 10' | 5.67E3 | |
| | 20' | 3.21E2 | 20' | 1.88E2 | 20' | 7.13E2 | |
| | 30' | 1.07E3 | 30' | 7.31E1 | 30' | 2.5E2 | |
| | 20' | 3.21E3 | 20' | 1.88E2 | 20' | 7.13E2 | |
| | 30' | 1.07E3 | 30' | 7.31E1 | 30' | 2.5E2 | |

Table A.1. (continued)

| TRENCH | Without Shielding MR/hr | | | | | | Shielding Optimization |
|---|---|---|---|---|---|---|---|
| | Observer | | Backhoe Operator* | | Truck Driver | | Backhoe |
| Average | | | | | | | |
| (Trench #271)<br>(7213 Ci) | 16' | 1.52E1 | 4' | 1.476 | 6'.3 | 2.7 | |
| | 20' | 5.46 | 10' | 0.172 | 10'-0 | 1.11 | |
| | 30' | 1.493 | 20' | 0.029 | 20'-0 | 0.134 | |
| | 40' | 0.688 | 30' | 0.0011 | 30'-0 | 0.016 | |
| AUGER HOLE | | | | | | | |
| Worst Case<br>WH 272<br>(96400 Ci) | 18' | 1.7E5 | — | — | — | — | Operator @ 10' but use 20'<br>(8' deep + 10' = 18' ~20')<br>0mm 3172 mR/hr<br>20mm 793 mR/hr<br>40mm 198 mR/hHr |
| | 20' | 1.59E5 | — | — | — | — | |
| | 30' | 1.74E4 | — | — | — | — | |
| | 40' | 6.96E3 | | | | | |
| Average<br>(57.06 Ci) | 9-10' | 296.1 | 4' | 2.56E3 | 6'-3 | 7.08E3 | |
| | 10' | 362.3 | 10' | 297.3 | 10' | 2.86E3 | |
| | 20' | 17.5 | 20' | 50.08 | 20' | 353.5 | |
| | 30' | 6.03 | 30' | 19.52 | 30' | 123.5 | |
| | 18' | 1.7E5 | — | — | — | — | |
| | 20' | 1.59E5 | — | — | — | — | |
| | 30' | 1.74E4 | — | — | — | — | |
| | 40' | 6.96E3 | | | | | |

Volume AH 2.09 cy, 6 holes in truck2

# ATTACHMENT B
# SOURCE-TO-RECEPTOR GEOMETRIES

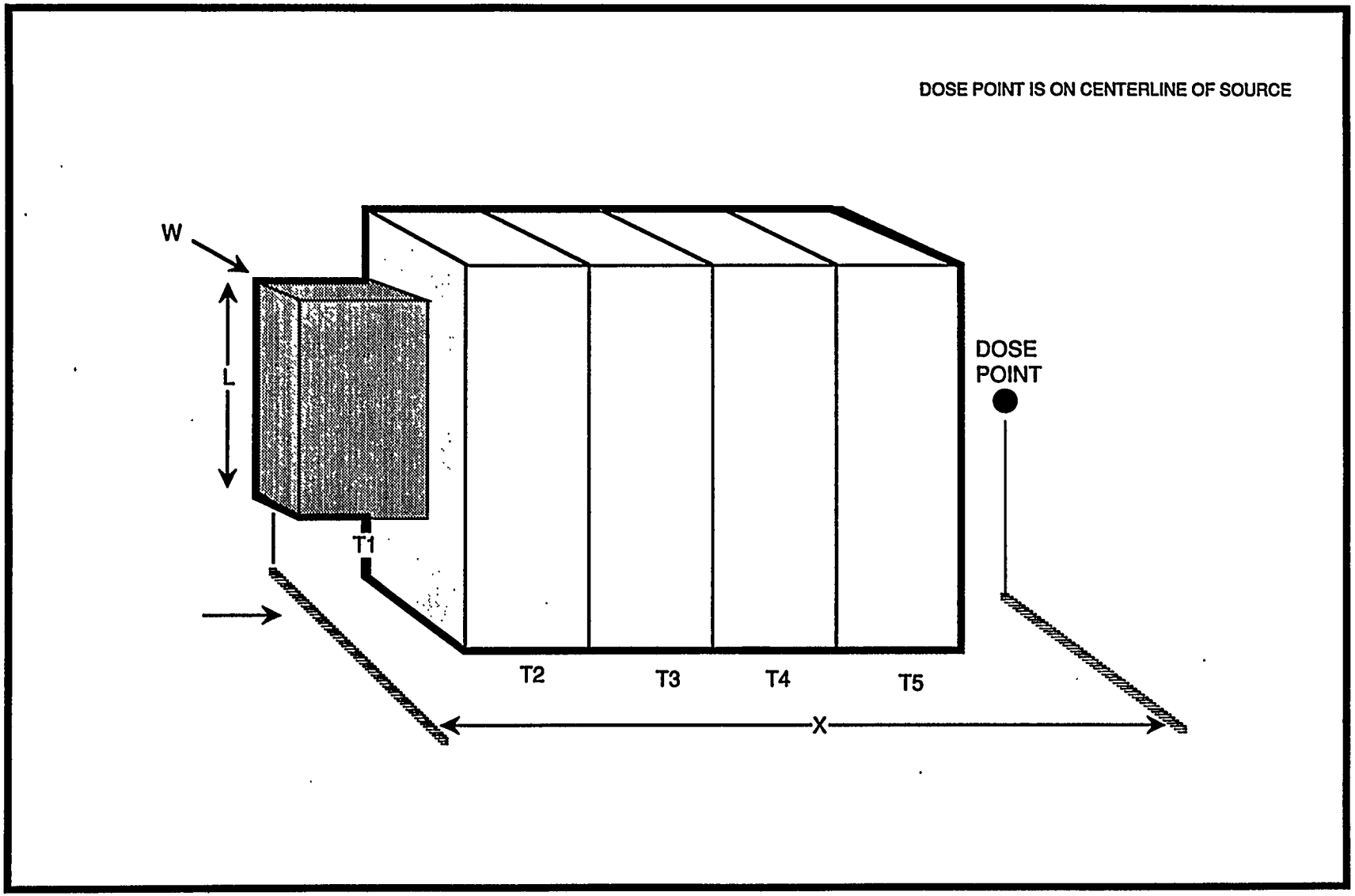


**Fig. B.1. Rectangular volume source.** ***Source:*** Microshield 3 Manual Grove Engineering, Inc.

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