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Remedial Investigation Plan for Waste Area Grouping 2 at Oak Ridge National Laboratory, Oak Ridge, Tennessee

ChemRisk Document No. 304

TA ENERGY SYSTEMS, INC.
STATES
ENERGY

#304

ES/ER-14&D1

Remedial Investigation Plan for Waste Area Grouping 2 at Oak Ridge National Laboratory, Oak Ridge, Tennessee

Environmental Restoration Division
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MARTIN MARIETTA ENERGY SYSTEMS, INC.
managing the
Oak Ridge National Laboratory
Oak Ridge K-25 Site
Oak Ridge Y-12 Plant
Paducah Gaseous Diffusion Plant
under contract DE-AC05-84OR21400
and the
Portsmouth Gaseous Diffusion Plant
under contract DE-AC05-76OR00001
for the
U.S. DEPARTMENT OF ENERGY

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ACRONYMS

AA	Alternative Assessments
ACL	alternate concentration limits
AEA	Atomic Energy Act
ALARA	as low as reasonably achievable
APR	average or mean percent recovery
ARAR	Applicable or Relevant and Appropriate Requirements
ASC	Analytical Services Coordinator
BNI	Bechtel National Inc.
BMAP	Biological Monitoring and Abatement Program
C_v	coefficient of variation
CAA	Clean Air Act
CARS	Corrective Action Report and Status
CC	Copper Creek
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Ci	curies
CLP	Contract Laboratory Program
CM	Corrective Measures
CMI	Corrective Measures Implementation
CMS	Corrective Measures Study
CPF	Carcinogen Potency Factors
CRK	Clinch River kilometer
CRM	Clinch River mile
CRRFI	Clinch River RCRA Facility Investigation
CWA	Clean Water Act
DEM	Department of Environmental Monitoring
DMC	Document Management Center
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy

DOT	U.S. Department of Transportation
DWPC	Division of Water Pollution Control
EFPC	East Fork Poplar Creek
EMC	Environmental Monitoring and Compliance
EPA	U.S. Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, and Tricoptera
ERD	Environmental Restoration Division
ERP	Environmental Restoration Program
ESD	Environmental Sciences Division
FDA	Federal Drug Administration
FFA	Federal Facility Agreement
FFK	Fifth Creek kilometer
FS	Feasibility Study
GIS	Geographic Information System
GPM	gallons per minute
H&S	Health and Safety
HA	Health Advisories
HFIR	High Flux Isotope Reactor
HHMS	Hydrostatic Head Monitoring Stations
HP	Health Physics
HRE	Homogeneous Reactor Experiment
HRT	Homogeneous Reactor Test
HSWA	Hazardous and Solid Waste Amendments
IRIS	Integrated Risk Information System
LCS	Laboratory Control Sample
LLW	Low Level Waste
m	meter
MB	Melton Branch
MBK	Melton Branch kilometer (MBK=MEK)
MCL	Maximum Contaminant Levels

MCLG	Maximum Contaminant Level Goals
MDL	Method Detection Limit
MEK	Melton Branch kilometer
MMES	Martin Marietta Energy Systems
mrem	millirem
MSDS	Material Safety Data Sheets
MSL	mean sea level
NA	natural area
NARM	naturally occurring and accelorator-produced radioactive material
NBS	National Bureau of Standards
NCP	National Contingency Plan
NCR	NonConformance Report
NDB	Numeric Data Base
NEPA	National Environmental Policy Act
NERP	National Environmental Research Park
NFPA	National Fire Protection Association
NHF	New Hydrofracture Facility
NPL	National Priority List
NPDES	National Pollution Discharge Elimination System
NPRM	Notice of Proposed Rule Making
NRC	Nuclear Regulatory Commission
NSDWS	National Secondary Drinking Water Standards
ODW	Office of Drinking Water
OHF	Old Hydrofracture Facility
ORGDP	Oak Ridge Gaseous Diffusion Plant (K-25)
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations
ORR	Oak Ridge Reservation
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Environmental Response

PA	Preliminary Assessment
PA/SI	Preliminary Assessment and Site Investigation
PAH	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated biphenyls
PCE	Poplar Creek Embayment
PFD	Personal Flotation Devices
PE	Performance Evaluation
PEL	Permissible Exposure Limits
PMF	Probable Maximum Flood
ppm	parts per million
QA	Quality Assurance
QAS	Quality Assurance Specialist
QC	Quality Control
QER	Quality Event Report
QIR	Quality Investigation Report
RA	Reference Area
RAP	Remedial Action Program
RCDB	Records Control Data Base
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RDEC	Radiochemical Development Engineering Center
REL	Recommended Exposure Limits
RFA	RCRA Facility Assessment
RfD	Reference Dose
RFI	RCRA Facility Investigation
RI	Remedial Investigation
ROD	Record of Decision
RPD	relative percent difference
S	slope
S&A	Sampling and Analysis

SARA	Superfund Amendments and Reauthorization Act of 1986
SAS	Statistical Analysis System
SD	standard deviation
SDWA	Safe Drinking Water Act
SI	Site Investigation
SIs	Screening Indices
SOP	Standard Operating Procedures
SOW	Statement of Work
SWMU	Solid Waste Management Unit
SWSA	Solid Waste Storage Area
TBC	to be considered
TCL	target compound list
TCLP	target compound list program
TCMP	Toxicity Control Monitoring Program
TDHE	Tennessee Department of Health and Environment
TLD	thermo-luminescent dosimeter
TLV	Threshold Limit Values
TRE	total rare earths
TRU	Transuranium Processing Facility
TSCA	Toxic Substances Control Act
TSD	Treatment, Storage or Disposal
TVA	Tennessee Valley Authority
USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
V	water velocity
VOC	Volatile Organic Compounds
WAG	Waste Area Grouping
WCK	White Oak Creek kilometer
WOC	White Oak Creek
WOCC	Waste Operations Control Center

WOCE	White Oak Creek Embayment
WOL	White Oak Lake
WQC	water quality criteria

EXECUTIVE SUMMARY

Background:

The White Oak Creek (WOC) system, consisting of WOC, its tributaries, White Oak Lake (WOL), and the White Oak Creek Embayment (WOCE) on the Clinch River, is the primary surface drainage for the Oak Ridge National Laboratory (ORNL) on the Department of Energy's (DOE's) Oak Ridge Reservation (ORR) in eastern Tennessee. The drainage system has been exposed to a diversity of contaminants as a result of operations and waste disposal activities at ORNL during the past 47 years.

Because of the large number of sites in need of remediation and the hydrologic complexity at ORNL, the strategy of Waste Area Groupings (WAGs) has been developed. WAGs are defined by hydrologic units that contain contiguous remedial action sites. ORNL WAG 2 consists of the WOC drainage downstream of ORNL discharge points and includes the associated floodplain and subsurface environment.

A Federal Facility Agreement (FFA) [under Section 120 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA) and Section 6001 of the Resource Conservation and Recovery Act (RCRA)] between DOE, the Environmental Protection Agency (EPA) Region IV, and the Tennessee Department of Health and Environment (TDHE) is under negotiation. These parties intend to coordinate DOE's CERCLA/RCRA response obligations with the corrective measures required and conducted by DOE under its current permit under the Hazardous and Solid Waste Amendments (HSWA) of 1984 to RCRA of 1976, and they expect that the response actions under the FFA, together with corrective measures, will achieve comprehensive remediation of releases and threatened releases of contaminants from ORNL. The WAG 2 Remedial Investigation (RI) is being initiated in compliance with Section 3004(u) of the HSWA of RCRA.

The WAG 2 RI is not a prototypic RI. Remedial investigations are underway or planned for contaminated areas (WAGs) upgradient of WAG 2; therefore, contaminant inputs to WAG 2 will change as individual upgradient areas are remediated. Corrective measures in WAG 2 taken in the short-term could be negated by future contaminant input, therefore implementation of corrective measures in WAG 2 should follow the completion of remediation of upgradient WAGs. Because the WOC system acts as a conduit for contaminants from upgradient areas, and because the WOC system has accumulated contaminants that represent near-term hazards, it is necessary that the WAG 2 RI begin as soon as possible. Therefore, the WAG 2 RI Plan is structured and staged with short-term and long-term objectives in response to the needs and limitations outlined above.

Considerable data exist for the WOC system as a result of numerous research efforts and environmental monitoring programs. Although the data are fairly complete for some components (e.g., aquatic biota), few data are available for other major components (e.g., floodplain soils). Data for bioaccumulation by aquatic biota have identified mercury, PCBs,

chlordane, ^{137}Cs, ^{60}Co, and ^{90}Sr as the primary long-lived contaminants known to accumulate above background levels in biota in the WOC system. Floodplain soils may be a significant repository for contaminants that have been released to the WOC system and also a potential source for the release of these contaminants to the Clinch River. Floodplain soils have not been characterized, with the exception of the Intermediate Pond Site adjacent to WAG 4, and the floodplain of upper WOL, which are known to be contaminated with radionuclides.

Existing data suggest significant but not widespread contamination of groundwater with radionuclides. Additional data for groundwater are needed, especially for nonradiological contaminants.

There are several ongoing surface water monitoring programs in the WOC system. Data from these efforts show that surface water in the WOC system generally meets EPA water quality criteria for freshwater aquatic life. With the exception of ^{90}Sr, ^{3}H, and ^{99}Tc, most contaminants of potential concern are particle-reactive (i.e., readily become associated with particulates) and so are not expected to be found in filtered water samples.

Input and movement of most contaminants are strongly linked to storm events and sediment transport. Sediments are a significant repository for most contaminants of concern in WAG 2. Substantial sediment contamination has been found in WOL and WOCE; however, additional data are needed. Stream sediments are more dynamic and less well characterized. Resuspension and transport of sediments has been a major pathway of contaminant release to off-site areas, and information for this process is needed.

A preliminary contaminant screening based on data from sediments and water collected from WOCE [conducted as part of the Clinch River RCRA Facility Investigation (RFI)] suggested that mercury, chromium, arsenic, PCBs, transuranics, ^{137}Cs, ^{60}Co, ^{3}H, and ^{90}Sr are the primary contaminants that have been released from the WOC system. Tritium is a significant contaminant that is not found in the sediment record.

The construction of a riprap dam at the mouth of WOCE has been initiated as a time-critical CERCLA response action to substantially reduce the resuspension and transport of highly contaminated sediments downstream in the Clinch River. It is important to recognize that hot spots (discrete areas of significant contamination) are usually areas where contaminants from other areas have accumulated. Thus, remediating a contaminated area will do little good if the upgradient source of the contamination is not located and remediated also (i.e., contaminants will simply accumulate again). Therefore, when a hot spot is found, the source of the contamination must be determined and also remediated, if necessary. As the WAG 2 RI progresses, other interim measures may be identified and implemented to protect public health and the environment.

General Plan and Strategy:

A full scale RI and implementation of corrective measures for WAG 2 should not occur until remediation of upgradient WAGs that release or may release contaminants to WAG 2 are completed. However, because hydrologic fluxes through WAG 2 link contaminant sources

in the WOC watershed with off-site areas, there is an obvious need to have a quantitative understanding of where fluxes enter WAG 2, what contaminants are in the fluxes, what contaminants are resident in the system and how contaminants are moving or may move out of the system. Because such information does not exist nor is it likely to become available from efforts in other WAGs, a plan is proposed that addresses the need to (1) take immediate steps to protect the public and the environment, (2) monitor contaminant releases from ORNL WAGs, and (3) form a foundation for eventual remedial actions in WAG 2. The RI Plan calls for a staged effort for characterization, monitoring, risk assessment, and identification of remedial needs and alternatives. Specifically, a risk-driven iterative approach is proposed where human-health and environmental risk analyses will be updated as additional data become available, and the results will be used to focus future monitoring and more extensive sampling and analysis.

The WAG 2 RI Plan is structured with a short-term component to be conducted while upgradient WAGs are investigated and remediated, and a long-term component that will complete the RI process following the remediation of upgradient WAGs. The following figure, *WAG 2 RI Task Structure*, shows the relationship of the short-term and long-term components of the work plan. The objectives of the interim-period plan are:

1. preliminary surveys and sampling to determine hot spots (discrete areas of significant contamination that may need interim corrective measures to protect the public or environment), identify areas where additional data are needed, fill data gaps for the first round of risk assessment, and clearly delineate the boundary of WAG 2; and

2. implementation of a multimedia environmental monitoring and characterization program to (a) define and monitor the input of contaminants from adjacent WAGs, (b) characterize the hydrology of the WOC system and support a mass-balance approach to determining sources, sinks and transport of contaminants in WAG 2, and (c) establish the basis for determining long-term trends in contaminant levels.

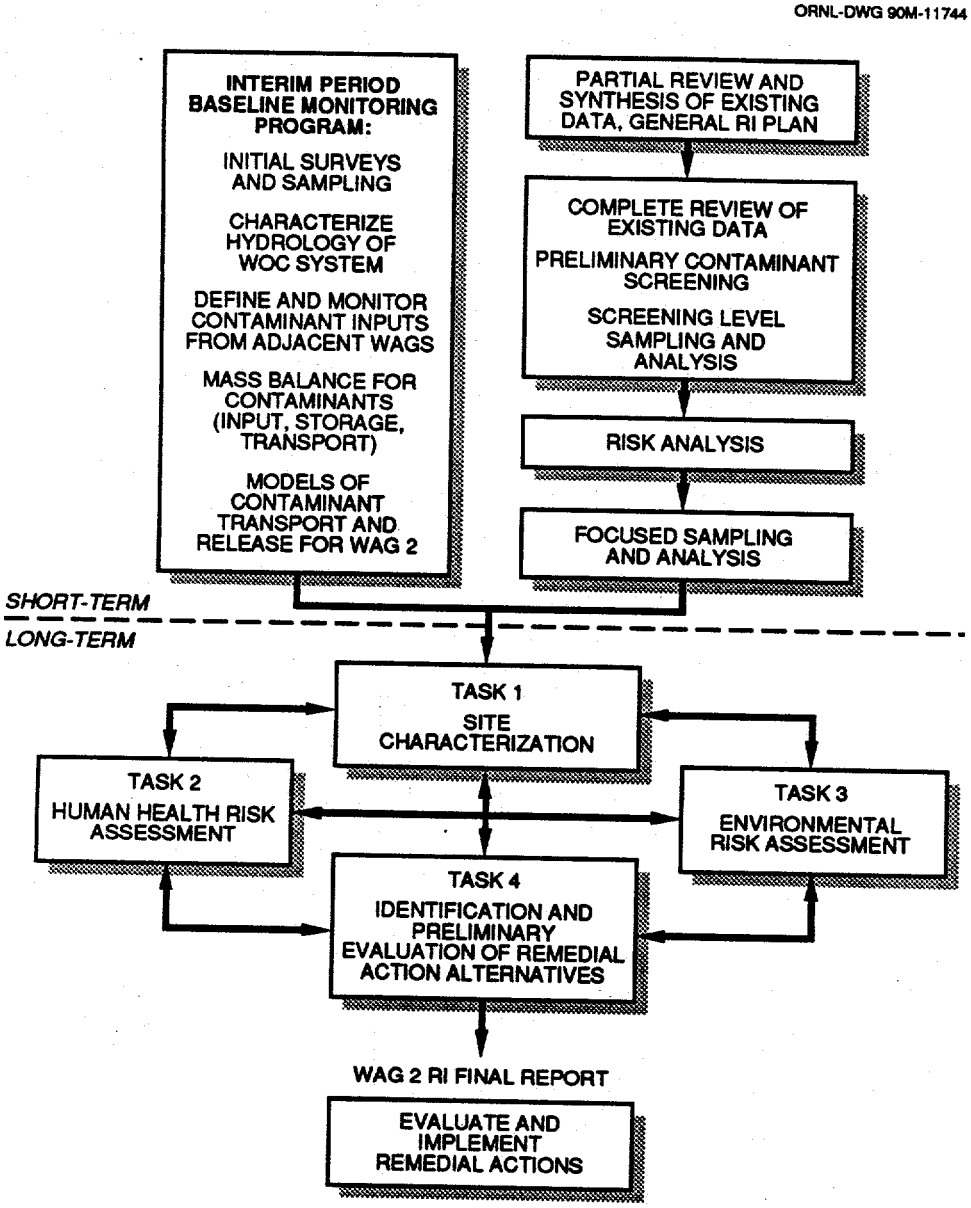
The interim-period baseline monitoring program addresses short-term needs to protect the public and forms a basis for future conponents of the RI. Furthermore, with an accurate understanding of how WAG 2 is connected to adjacent WAGs, it will be possible to evaluate potential effects of remedial actions in those WAGs on WAG 2 and to plan effective mitigating measures to minimize additional contaminant fluxes while clean-up activities are performed.

Long-term objectives of the WAG 2 RI include:

1. definition of the nature and extent of contamination in WAG 2,

2. quantification of any risk to human-health and the environment resulting from the contamination, and

3. preliminary evaluations of potential corrective measures and remedial action alternatives for the operable units in WAG 2.



The WAG 2 RI task structure

Results of human-health and environmental risk assessments will be used to focus monitoring, sampling, and analytical efforts, and ultimately to determine the need for corrective measures to reduce risks. The risk-driven monitoring, sampling, and analysis will proceed while adjacent WAGs are undergoing remediation. The system has been divided into several reaches for the preliminary risk analysis. The monitoring program will deal with the WOC system on a reach-by-reach basis and will support a mass-balance approach for determining contaminant dynamics (input, storage, and release). These reaches will be subdivided as required on the basis of contaminant input and inventory. This approach translates to the identification of operable units to be considered for corrective measures or eliminated from further efforts.

Ongoing monitoring programs provide a necessary base of information that will be enhanced through increased monitoring mandated by DOE orders. In addition, remedial investigations in adjacent WAGs will provide short-term information on contaminant releases and potential releases from those WAGs. Incorporation of this information into the WAG 2 RI is essential. This work will be conducted in conjunction with ongoing monitoring programs and other RI/Feasibility Study (FS)/Corrective Measures Study (CMS) to obtain information useful for determining contaminant dynamics in the WOC system.

Preliminary Work Plan:

The complexity of the WAG 2 area and the mass and diversity of existing information will require significant effort in the initial stages of executing this plan. At this time, the existing information has not been synthesized sufficiently to conduct a preliminary contaminant screening; thus, the initial phases of the risk-driven monitoring, sampling, and analysis program cannot be planned effectively. Currently, the pathways and contaminants of concern are being identified, and this information is being used to conduct a risk-based screening study that will serve as the basis to develop a monitoring, sampling, and analysis plan. In the interim, basic scoping activities will be required to provide information for risk assessment and to support a mass-balance approach in determining sources and sinks for contaminants. This first iteration of the WAG 2 RI Plan presents a summary of the information reviewed to date and the rationale and approach for the RI work plan, with the understanding that more specific addenda to the plan will follow.

Work to be conducted in the initial stage of the WAG 2 RI includes:

1. Continued synthesis of existing information and the preliminary contaminant screening. Two approaches (conservative and nonconservative screening) will be used in the preliminary contaminant screening exercise to identify contaminants that can be assigned low priority for further consideration based on sufficiently small risk and to rapidly identify contaminants of high priority that may establish the need for interim corrective measures.

2. Formulation of the initial screening-level risk-driven monitoring, sampling, and analysis plan to be presented in the future addenda of the RI Plan.

3. Scoping-level sampling of areas suspected to be contaminated but for which no data are available (e.g., sampling of new groundwater wells and floodplain soils) to identify hot spots and operable units and to update the risk analysis as new information becomes available.

4. Discharge monitoring facilities (e.g., weirs) will be upgraded to improve the hydrologic budget for the system and to help identify contaminant input points.

5. Because sediments are of paramount concern for contaminant accumulation and transport, (a) scoping-level surveys of WOC sediments and floodplain soils, (b) preliminary work on sediment transport models, and (c) sampling of WOL sediments are planned.

All efforts on the WAG 2 RI will be coordinated with RI/FS/CMS for upgradient WAGs, the Clinch River RFI, existing monitoring programs, and through the ORNL Technical Integration Committee and the Environmental Restoration Program. In addition, data will be entered in a consolidated database with those from other efforts as required by the FFA. All proposed activities and schedules in this RI Plan are subject to the availability of funds and the negotiation of schedules under the FFA.

The WAG 2 RI plan is organized as follows:

- Sections 1 through 3 include an introduction, site-specific problems, objectives, a preliminary schedule and remedial action alternatives; a brief history of the site; and a characterization of the environmental setting.

- Section 4 describes the existing monitoring programs at ORNL and in the WOC system that can contribute to the WAG 2 RI.

- Sections 5 through 7 list existing information for contaminant inputs into the WOC system, a summary of information for contaminants in WAG 2, and information for contaminant releases from WAG 2.

- Section 8 presents the methodology for identifying contaminants of concern, including ARARs, environmental pathways of contaminant transport and potential exposure, and the methodology for risk assessment.

- Section 9 presents the WAG 2 RI work plan.

- Section 10 provides the first stage of the field sampling and analysis plan.

- Section 11 presents the project organization and management plan.

- Section 12 outlines the quality assurance/quality control procedures.

- Section 13 describes the data management plan.

- Section 14 presents the health and safety procedures.

Supporting materials are appended to the plan.

1. INTRODUCTION

1.1 REGULATORY INITIATIVE

The U.S. Department of Energy (DOE) Oak Ridge Reservation (ORR) was added to the National Priorities List (NPL) in December 1989. A Federal Facility Agreement (FFA) [under Sect. 120 of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) and Sect. 6001 of RCRA] between DOE, the U.S. Environmental Protection Agency (EPA) Region IV, and the Tennessee Department of Health and Environment (TDHE) is under negotiation. These parties intend to coordinate DOE's CERCLA/RCRA response obligations with the corrective measures required and conducted by DOE under its current Hazardous and Solid Waste Amendments (HSWA) permit, and they expect the response actions under the FFA, together with the corrective measures under the permit, to achieve comprehensive remediation of releases and threatened releases of hazardous substances, hazardous wastes, pollutants, or contaminants at or from the Oak Ridge National Laboratory (ORNL).

It is important to note that the Remedial Investigation Plan for ORNL Waste Area Grouping 2 (WAG 2 RI Plan), is not be a prototypic RI plan. ORNL WAG 2 consists of White Oak Creek (WOC) and its tributaries downstream of the ORNL Main Plant area, White Oak Lake (WOL), the White Oak Creek Embayment (WOCE) of the Clinch River, and the associated floodplains and subsurface environment. The WOC system is located on the DOE ORR (Fig. 1.1 and pockets) and drains an area of ~16.8 km^2 that includes ORNL and associated WAGs. The WOC system has been exposed to contaminants released from ORNL and associated operations for 47 years and continues to receive input from adjacent WAGs (Sect. 5). Recognizing that full implementation of an RI is inappropriate while contaminants are continuing to enter the system, a phased effort has been adopted in response to the need to take initial steps to protect the public and the environment and to characterize and assess risks associated with WAG 2 and the limitations imposed by changing contaminant input (see Sects. 2.2 and 9).

The RCRA Corrective Action Process and the CERCLA Remedial Action Process are similar and operate in a parallel manner, as shown in Fig. 1.2. In addition, the requirements of the National Environmental Policy Act (NEPA) will be integrated into the RCRA Corrective Action and CERCLA Remedial Action processes (see Fig. 1.2). On August 2, 1988, the DOE Office of the Assistant Secretary for Environment, Safety, and Health issued DOE Notice 5400.4, which established DOE's policy of integrating the statutory requirements of NEPA and CERCLA. Such integration is intended to (1) avoid duplicative effort and the associated larger commitment of resources that would be needed to implement both NEPA and the CERCLA Remedial Investigation/Feasibility Study (RI/FS) separately; (2) avoid conflicts in analysis and the choice of a remedial alternative; and (3) minimize the risk of delaying remedial actions on procedural grounds. Levine et al. (in press) have provided specific guidance for the integration of NEPA and CERCLA requirements during corrective action/remedial action responses at DOE facilities.

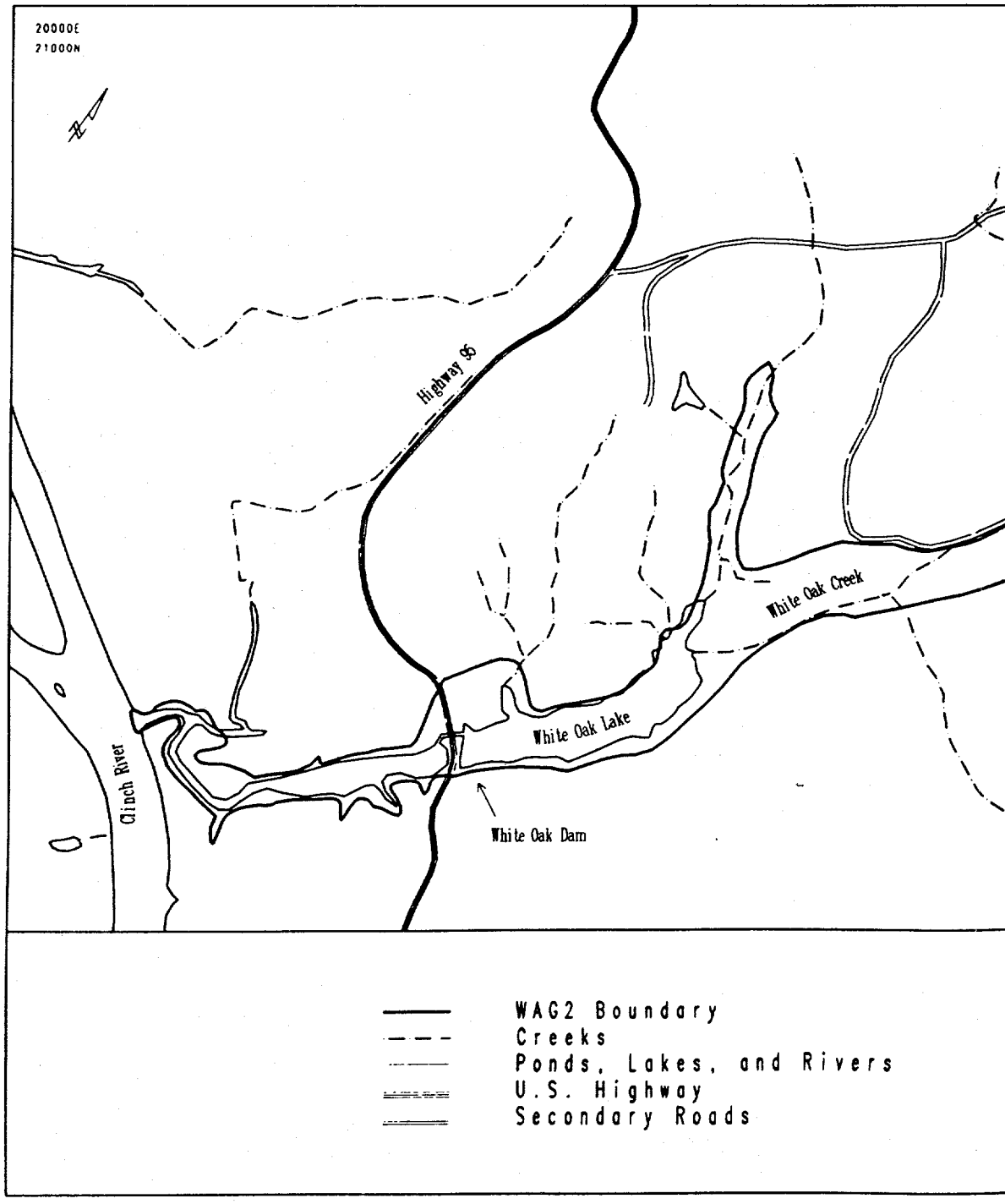


Fig. 1.1. Map showing ORNL W

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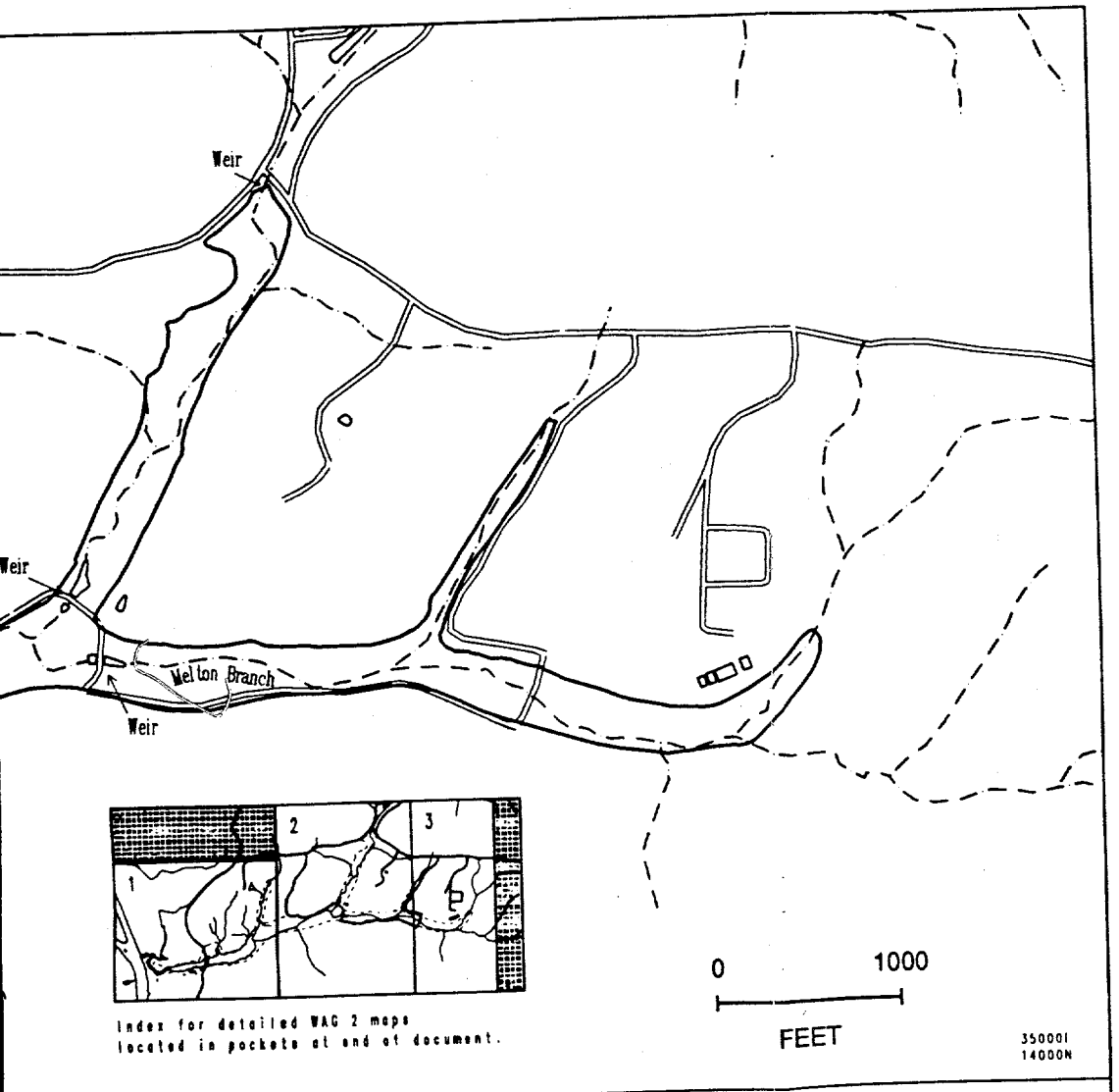

Map Scale: 1 inch = 1000 feet
Grid: ORNL Coordinates (feet)
Source: S-16A (White Oak Lake Update)
Date: November 1990

AG 2 (White Oak Creek system).

ORNL-DWG 90M-11745

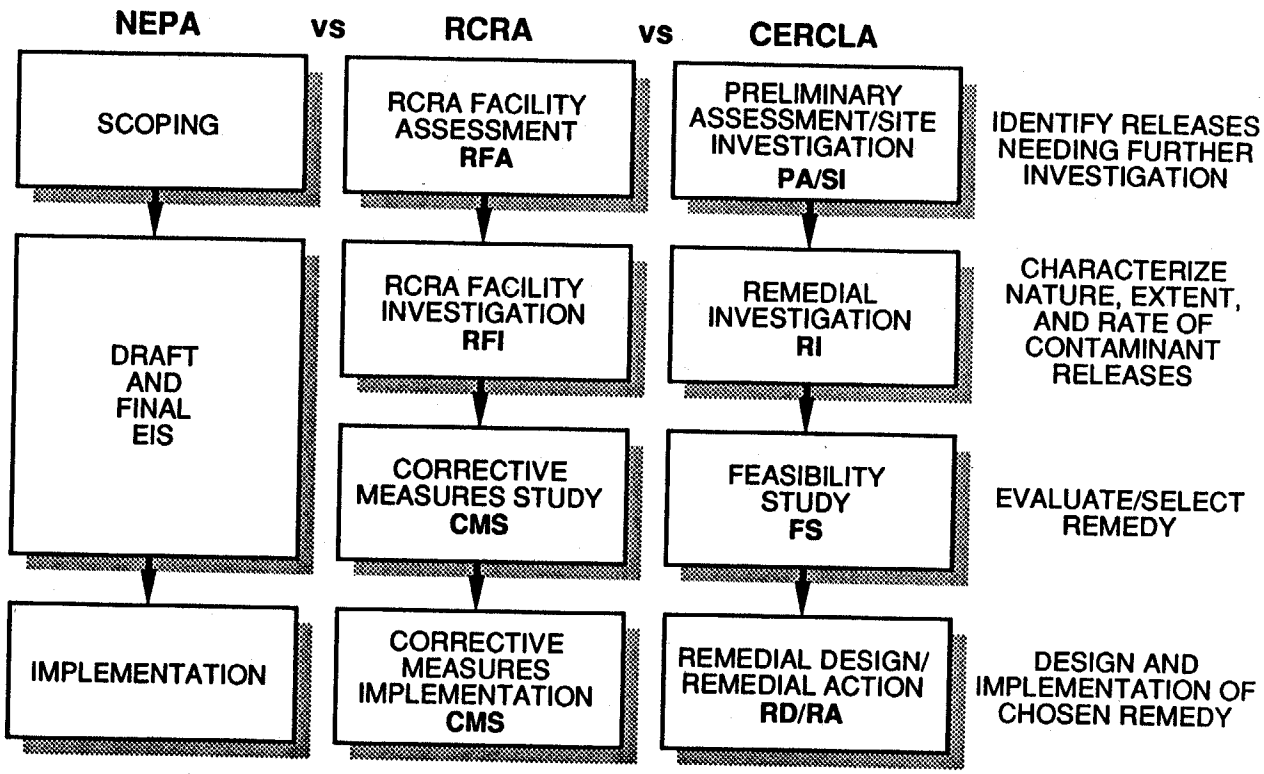

Fig. 1.2. Comparison of the NEPA Process, the RCRA Corrective Action Process and the CERCLA Remedial Action Process. Interim corrective measures or remedial actions may be performed at any point in both processes.

1.2 SITE-SPECIFIC ENVIRONMENTAL RESTORATION PROGRAM

A site-specific plan has been developed for ORR that addresses corrective activities, environmental restoration, and waste management operations (Jones et al. 1990). ORNL is managed for DOE by Martin Marietta Energy Systems, Inc. (Energy Systems). Energy Systems manages the environmental, safety, and health programs at ORNL and supports the DOE Oak Ridge Operations (DOE/ORO) organization in the management of the overall environmental, safety, and health program. The responsibility for all environmental restoration and waste management activities has been placed with the Energy Systems Assistant Manager for Environmental Restoration and Waste Management. A series of corrective activities have been identified and prioritized at ORNL to bring the facilities into compliance with applicable federal, state, and local requirements (Jones et al. 1990). DOE Corrective Activities, Environmental Restoration, and Waste Management Operations programs must comply with the Atomic Energy Act (AEA); other federal and state statutes and regulations; and DOE orders (Sect. 1.2.3 of DOE Environmental Restorations and Waste Management Five-Year Plan, August 11, 1989). The major federal and state statutes applicable to corrective activities, environmental restoration, and waste operations, and other applicable agreements and orders are summarized in the *Site-Specific Plan for the Oak Ridge Reservation Environmental Restoration and Waste Management* (Jones et al. 1990).

The state of Tennessee administers its own RCRA program under the Tennessee Hazardous Waste Management Act through TDHE. Region IV of EPA administers the federal RCRA program, including the HSWA provisions.

The ORNL site was established in 1943, and 47 years of operations have produced a diverse legacy of contaminated inactive facilities, research areas, and waste disposal areas that are potential candidates for remedial action. ORNL initially developed a site specific Remedial Action Program (RAP) that represents a comprehensive effort to meet new regulatory requirements at about 250 sites (Trabalka and Myrick 1987). RAP has been superseded by the Environmental Restoration (ER) Program through Energy Systems (Jones et al. 1990).

Because of the large number of sites and the hydrologic complexity at ORNL, the strategy developed in response to regulatory requirements has been oriented toward Waste Area Groupings (WAGs) rather than individual sites. The WAGs are generally defined by watersheds that contain contiguous and similar remedial action sites. In some cases there has been hydrologic interaction among the sites within a WAG, making individual sites hydrologically inseparable. The use of groupings provides perimeter monitoring of both groundwater and surface water and the development of a response that is protective of human health and environment. Twenty WAGs have been identified at ORNL, of which 13 are definite candidates for further action.

The ER Program follows a structured path of site characterization, site maintenance and surveillance, interim corrective action, alternative assessment, technology development, engineering design, and eventual site closure or remediations. Information gathered by the ER Program will support the efforts described herein.

1.3 SCOPE OF THE WAG 2 RI

The WAG 2 RI addresses WOC downstream of ORNL discharges and the ORNL Waste Area Grouping 1 (WAG 1) area; Melton Branch (MB) downstream of reactor facilities in the Melton Valley; WOL; and WOCE prior to its confluence with the Clinch River at mile 20.8 (CRK 33.5). This area (WAG 2) consists of two solid waste management units (SWMUs): (1) SWMU 2.1, WOL and WOE, and (2) SWMU 2.2, the stream channels of WOC and MB (Fig. 1.1). WAG 2 also includes the floodplain and subsurface environment associated with these areas that may have been adversely affected by contaminants released from the mid-1940s to present from ORNL activities.

The WOC system has received treated and untreated effluents from ORNL activities since 1943 (see Sects. 3 and 5). Controlled releases include the ORNL Sewage Treatment Plant, Process Waste Treatment Plant, and release from a variety of holding ponds. WOC and MB also receive discharge from subsurface flow and surface drainage from numerous nonpoint sources in the ORNL Main Plant area (WAG 1), from solid waste storage areas (WAGs 3, 4, 5 and 6), the liquid waste seepage pits and trenches (WAG 7), and the experimental reactor facilities (WAGs 8 and 9). Any contaminated water ultimately drains into the Clinch River.

Sediments within the watershed (creeks, lake, and embayment) have sorbed chemical and radioactive contaminants. Creek sediments have been transported and subsequently accumulated in the floodplain and in low-velocity areas (e.g., in WOL and WOCE sediments). Under high-flow conditions, these sediments can be carried to the Clinch River. Data (Olsen et al. 1990) show that sediments from the WOC system have historically been a major source of off-site radiological contamination. Contaminated sediments that have accumulated in the WOCE may also be mixed and transported downstream during water level changes resulting from hydropower and other operations of the Tennessee Valley Authority's Melton Hill and Watts Bar dams at the upper and lower end of the Watts Bar Reservoir of the Clinch River, respectively. This finding has resulted in an interim corrective action for WOCE that is currently underway (Sect. 3.2.1.2).

The WAG 2 RI work plan is presented in Sect. 9. The WAG 2 RI will address the potential human-health and environmental risks associated with (1) current and recent contaminant releases to the WOC system (WAG 2) from the operations and facilities at ORNL and (2) long-term contaminant accumulations in aquatic sediments and floodplain soil. In cooperation with the Clinch River RFI, potential human-health and environmental risks associated with the movement of contaminants out of WAG 2 will be addressed. Initial scoping surveys will identify hot spots and determine the need for further interim corrective actions. These surveys contribute to site characterization goals of identifying operable units for future corrective actions. A baseline monitoring of contaminant input, accumulation, and transport in the WOC system will provide a database for guiding and assessing remedial activities at upgradient contaminated areas, as well as assessing the need to remediate WAG 2 following remediation of the upgradient WAGs.

Remediation of existing contamination problems and continuing releases is the ultimate goal of the RCRA/CERCLA/NEPA Corrective Action processes of which the RI, site characterization, and risk assessment components (Fig. 1.2), is a preliminary stage. During the WAG 2 RI, data will be collected for site characterization, identification of operable units, risk assessment, and preliminary identification and evaluation of potential remedial alternatives (see Fig. 9.4). To ensure that the combination of existing data and new data to be collected will be adequate for these purposes, the potential pathways leading to human-health and environmental risks, potential off-site problem areas that could require remediation, and categories of potential remediation alternatives have been preliminarily identified. Existing data relevant to contamination of the surface water, floodplain, sediments, biota, air, and groundwater in the WOC system and off-site contamination are being evaluated and will be used in designing the WAG 2 RI Work Plan (Sect. 9) and the Sampling and Analysis Plan (Sect. 10).

1.4 SITE-SPECIFIC PROBLEMS

The WOC system (WAG 2) is a contaminated *natural system* that links discharges and releases from ORNL and other contaminant source areas with off-site areas. Remedial investigations are underway or planned for WAGs upgradient of WAG 2; therefore, contaminant inputs will change as individual upgradient areas are remediated. Contaminant releases from most of these areas have not been well characterized; thus, it is impossible to predict future contaminant concentrations in WAG 2 resulting from releases or remedial activities upgradient. Because corrective measures in WAG 2 taken in the short-term could be negated by future contaminant input, implementation of corrective measures in WAG 2 should not begin until upgradient WAGs are remediated.

Contaminant releases from the WOC system (releases over the WOL Dam and remobilization of contaminated sediments from WOCE) have historically been a major source of contaminants to off-site areas (CRRFI 1990). Resuspension and downstream transport of highly contaminated sediment from WOCE have necessitated CERCLA time-critical corrective measures. Additional interim measures may be required for other areas of WAG 2 as well (see Sect. 9.4.6).

Although full implementation of the RI is not feasible at this time, there is clearly a need to protect the public and the environment and to evaluate contaminant input, transport, and release for WAG 2.

2. OBJECTIVES, APPROACH, AND SCHEDULE OF THE WAG 2 RI PLAN

2.1 OBJECTIVES OF THE WAG 2 RI

2.1.1 Objectives

At this time information does not exist to determine if the WOC system is exclusively a source, a sink, or a conduit (and how this varies with location) for contaminants from upgradient areas to the Clinch River. Remediation is planned or underway for upgradient WAGs. Remediation of WAG 2 should not begin until remediation of upgradient areas has been completed. However, because the WOC system can act as a conduit for contaminants from upgradient areas, and because the WOC system has accumulated contaminants that represent near-term hazards, it is necessary that initial stages of the WAG 2 RI begin as soon as possible. The RI Plan calls for characterization, monitoring, risk assessment, and identification of remedial needs and alternatives that have been structured and staged with short-term and long-term objectives.

The WAG 2 RI includes two short-term objectives as part of an interim-period work plan to be carried out while the remedial activities are underway at upgradient WAGs. The objectives of the interim-period plan are:

1. preliminary surveys and sampling to (a) determine hot spots (discrete areas of significant contamination that may need interim corrective measures to protect the public or environment), (b) identify areas where additional data are needed, (c) fill data gaps for the first round of risk assessment, and (d) clearly delineate the boundary of WAG 2; and

2. implementation of a multimedia environmental monitoring and characterization program to (a) define and monitor the input of contaminants from adjacent WAGs, (b) characterize the hydrology of the WOC system and support a mass-balance approach to determining sources, sinks, and transport of contaminants in WAG 2, and (c) establish the basis for determining long-term trends in contaminant levels.

Long-term objectives of the WAG 2 RI include:

1. definition of the nature and extent of contamination in WAG 2,

2. quantification of any risk to human-health and the environment resulting from the contamination, and

3. preliminary evaluations of potential corrective measures and remedial action alternatives for the operable units in WAG 2.

These objectives are expanded and incorporated into the WAG 2 RI Work Plan in Sect. 9.

2.1.2 Purpose Of The WAG 2 RI Plan

The purpose of the WAG 2 RI Plan is to provide a rationale for the type (media), location, frequency, and analytical parameters for the proposed sampling. This goal is achieved by:

- providing both historical and current operations information about the site;
- detailing the physical, chemical, and biological characteristics of the site;
- providing a list of potential contaminants of concern;
- identifying potential pathways of contaminant movement and the potential receptors, and identifying potential treatment technologies; and
- providing the methods by which sampling and analyses will be conducted, including all associated QA/QC and health and safety procedures.

2.2 APPROACH FOR THE WAG 2 RI PLAN

The RI Plan calls for a staged effort for characterization, monitoring, risk assessment, and identification of remedial needs and alternatives.

A full scale RI and implementation of corrective measures for WAG 2 should not occur until remediation of upgradient WAGs that release or may release contaminants to WAG 2 are completed. However, because hydrologic fluxes through WAG 2 link contaminant sources in the WOC watershed with off-site areas, there is an obvious need to have a quantitative understanding of where fluxes enter WAG 2, what contaminants are in the fluxes, what contaminants are resident in the system and how contaminants are moving or may move out of the system. Because such information does not exist nor is it likely to become available from efforts in other WAGs, a plan is proposed that addresses the need to (1) take immediate steps to ensure that the public and the environment are protected, (2) form a foundation for eventual corrective measures evaluation, and (3) provide a mechanism to monitor contaminant releases from ORNL WAGs and the movement of contaminants off-site that could also contribute to the formulation and assessment of corrective measures for upgradient WAGs. The proposed strategy calls for an interim-period work plan to be carried out while the remedial activities are underway at upgradient WAGs.

The interim-period plan will include:

- completion of the review and synthesis of extant data for a screening-level risk analysis to identify areas in which additional data collection is necessary for purposes of site characterization and risk assessment;

- preliminary sampling to determine hot spots (areas that may need interim corrective measures to protect the public or the environment);

- implementation of a multimedia environmental monitoring and characterization program to support a mass-balance approach to determining sources, sinks and transport of contaminants (e.g., to characterize the hydrology of the WOC system, identify operable units for corrective actions), define and monitor input of wastes from adjacent WAGs, and establish the basis for determining long-term trends in contaminant levels;

- iterative risk assessment, as additional data become available, to focus additional sampling and analysis and determine the need for interim corrective actions; and

- risk-driven screening-level sampling and analysis efforts for preliminary site characterization.

These activities include the short-term objectives listed in Sect. 2.1 and the initial stages of a traditional RI plan. These activities will be conducted simultaneously while upgradient WAGs are undergoing remediation. The relationship of the short-term and long-term components (to be conducted following the remediation of upgradient areas) is shown diagrammatically in Fig. 2.1. The approach meets short-term needs (described above) and positions the WAG 2 RI for implementation of the more focused efforts needed to meet the long-term objectives of the complete RI listed in Sect. 2.1; more detail is provided in Sects. 9 and 10.

The approach for the long-term objectives of the RI involves iterative human-health and environmental risk assessment, as additional data become available, to quantitatively estimate potential risks to human-health and to the environment, to focus additional sampling and analysis efforts, and to determine the need for corrective measures.

The system has been divided into several reaches for the preliminary risk analysis. These reaches will be subdivided on the basis of contaminant input and inventory. This approach translates to the identification of operable units to be considered for corrective measures or eliminated from further efforts.

The WAG 2 RI will be coordinated with environmental monitoring and environmental restoration programs now being conducted at ORNL and off-site in the Clinch River in compliance with the provisions of RCRA, CERCLA, NEPA, and state of Tennessee environmental protection regulations. On-site monitoring programs and remedial action investigations can provide data relevant to the WAG 2 RI. Coordination with those programs is discussed in Sects. 4, 5, and 10. A further description of the approach is presented in Sect. 9 as part of the RI Work Plan.

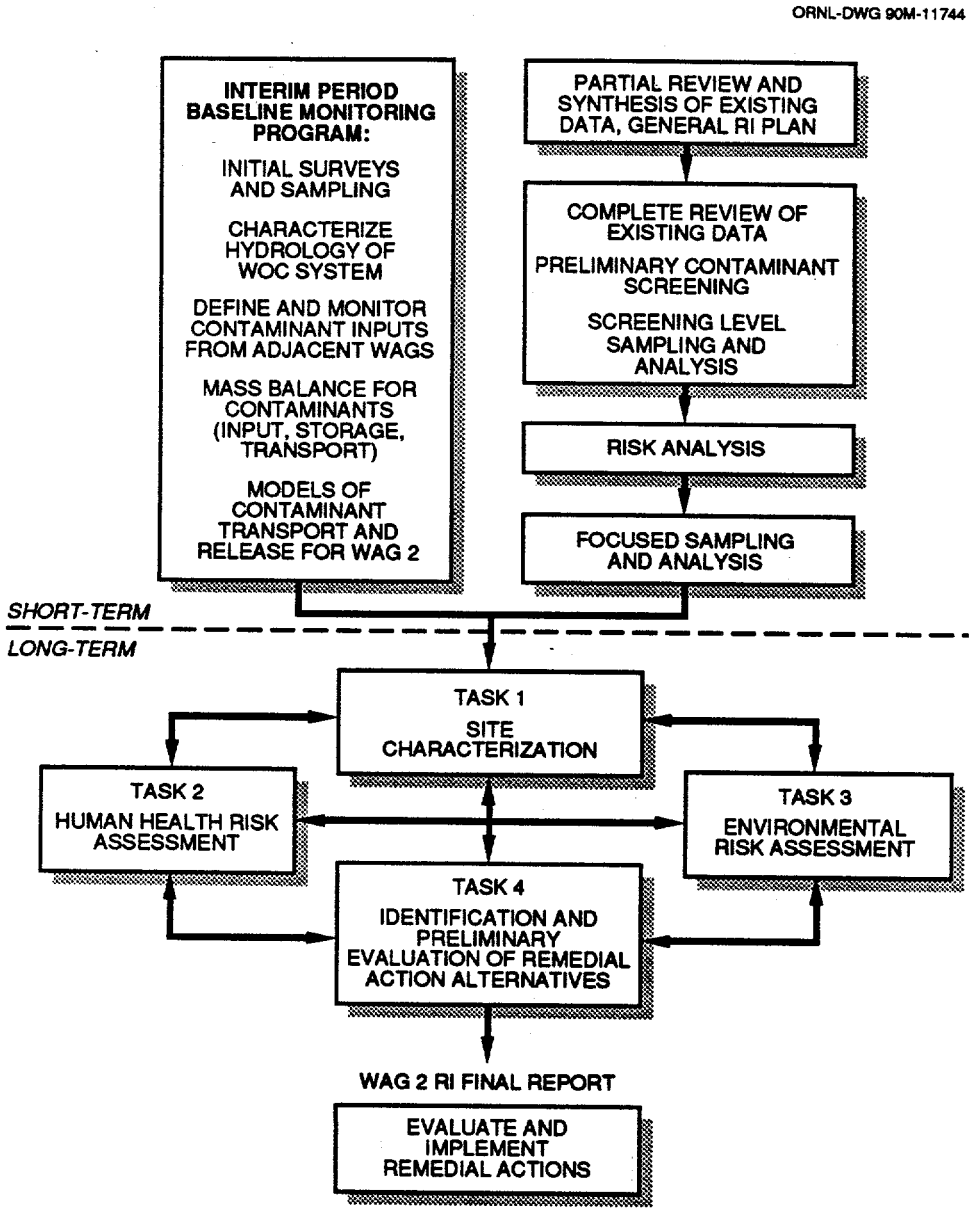

Fig. 2.1. WAG 2 RI Work Plan task structure.

2.3 ORGANIZATION OF THE WAG 2 RI PLAN

The WAG 2 RI plan has been developed in accordance with EPA (1987a, 1988a) guidance. The organization of the WAG 2 RI Plan reflects the complexity and unique characteristics of the WOC system and the resulting requirements for information and considerations not included in prototypic RI plans.

The WAG 2 RI Plan is organized as follows:

- Sections 1 through 3 include an introduction; a description of RI objectives, approach, preliminary schedule, and remedial action alternatives; a brief history of the site; and a characterization of the environmental setting.

- Section 4 describes the existing monitoring programs at ORNL and in the WOC system. These ongoing efforts have provided significant information for site characterization and contaminant movement and will be an important component of the WAG 2 RI.

- Sections 5 through 7 list existing information for known and potential contaminant inputs to WAG 2, provide a summary of the information on the nature and extent of contaminants in WAG 2 that has been reviewed to date, and discusses releases of contaminants from WAG 2.

- Section 8 presents the methodology for identifying contaminants of concern. This section presents ARARs for known contaminants, identifies important environmental pathways of contaminant transport and potential exposure, outlines the methodology and rationale to be used in human-health and environmental risk assessment, and notes special considerations for ecological risk end points of concern.

- Section 9 presents the WAG 2 RI work plan. It includes the integration of short-term and long-term objectives and the task structure. Details are presented for the interim period activities (while adjacent WAGs are being remediated) and the major tasks of the WAG 2 RI:

  Task 1: Site characterization
  Task 2: Human-health risk assessment
  Task 3: Environmental risk assessment
  Task 4: Preliminary identification and evaluation of remedial action alternatives

- Section 10 presents the initial stage of the field sampling and analysis plan.

- Section 11 presents the project organization and management plan, detailing responsibilities and lines of communication.

- Section 12 outlines the quality assurance/quality control procedures to be followed during the project.

- Section 13 describes the data management plan to be instituted for the project.
- Section 14 presents the health and safety procedures to be implemented as part of the project.

Supporting materials and exhibits are appended to the plan. Additional plans that may be required by EPA or TDHE will be prepared as needed.

2.3.1 The General WAG 2 RI Plan

The complexity of the WAG 2 area and the mass and diversity of existing information will require significant effort in the initial stages of executing this plan. At this time, the existing information has not been synthesized sufficiently to conduct a preliminary contaminant screening; thus, the initial phases of the risk-driven monitoring, sampling and analysis program cannot be planned effectively. Currently, the pathways and contaminants of concern are being identified, and this information is being used to conduct a risk-based screening study that will serve as the basis to develop a monitoring and sampling and analysis plan. In the interim, basic scoping activities will be required to provide information for risk assessment and to support a mass-balance approach in determining sources and sinks for contaminants. This first iteration of the WAG 2 RI Plan presents a summary of the information reviewed to date and the rationale and approach for the RI Work Plan (i.e., it is the general plan for the WAG 2 RI). **This plan is presented with the understanding that more specific addenda to the plan will follow.**

Work to be conducted in the initial stages of the WAG 2 RI includes: (1) continued synthesis of existing information and the preliminary contaminant screening; (2) formulation of the initial screening-level risk-driven monitoring, and sampling and analysis plan; (3) scoping-level sampling of areas suggested in aerial radiological surveys, or areas where no data are available (e.g., sampling of new groundwater wells and floodplain soils) to identify hot spots and operable units and to update the risk analysis as new information becomes available; (4) upgrades in the discharge monitoring facilities to determine the hydrologic budget for the system and to identify contaminant input points; and (5) because aquatic sediments are of paramount concern for contaminant accumulation and transport, (a) scoping-level surveys of WOC sediments and floodplain soils, (b) preliminary work on sediment transport models, and (c) sampling of WOL sediments.

2.4 SCHEDULE FOR SPECIFIC ACTIVITIES

Uncertainties surrounding the extent of existing contamination, contaminant inputs, and contaminant transport in WAG 2 make it difficult to provide a firm schedule for any stage of the WAG 2 RI. Short-term objectives (Sect. 2.1), for the purposes of this plan, are assumed to occur over 10 to 15 years or more. This reflects a strategy of dealing with upgradient contaminant source areas prior to focused activities of the long-term objectives (intensive sampling analysis, for site characterization, human-health and environmental risk

assessment, and identification and evaluation of remedial activities) are undertaken for WAG 2. All activities and schedules in this RI Plan are subject to the availability of funds and negotiation of schedules under the FFA.

However, work will begin as soon as possible to identify hot spots in need of corrective action. Efforts to implement a baseline monitoring program to monitor, characterize, and model contaminant input, accumulation, transport, and release, and other components of the short-term objectives of the WAG 2 RI will also begin as funding allows.

Preliminary synthesis of existing data and preliminary contaminant screening will be completed early in the study as budget and funding uncertainties identified above allow. A more focused sampling and analysis plan will be presented as an addendum to the RI plan.

DATE	MILESTONES
TBD*	Submit general WAG 2 RI Plan and documents
TBD	Submit specific addenda to the WAG 2 RI Plan
TBD	Initiate baseline monitoring program and initial stages of site characterization and risk assessment
TBD	Complete screening-level sampling and analyses
TBD	Complete screening-level human-health and environmental risk assessment
TBD	Submit interim period site characterization summary (as remediation of upgradient WAGs is completed)
TBD	Initiate focused sampling and analysis
TBD	Submit final site characterization summary, human-health and environmental risk assessment

* to be determined based on FFA priority negotiations.

Interim corrective measures/remedial alternatives will be initiated at any time in the course of the project that sampling, analysis, and risk assessment activities indicate a significant potential risk to the environment or to public health and welfare.

An overall project schedule, organized by major components, is provided in Fig. 2.2. This schedule is designed in accordance with the specific requirements of the Oak Ridge FFA being negotiated between DOE, EPA-Region IV, and TDHE. The schedule reflects an interim period monitoring program for WAG 2, while upgradient WAGs are being remediated. To expedite the progress of the WAG 2 RI, sampling to fill data gaps, screening-level human-health and environmental risk assessment activities, and some preliminary site characterization activities will begin as soon as possible and continue during the interim period in parallel to the baseline monitoring program (see Sect. 9).

2.5 REMEDIAL ACTION ALTERNATIVES

The RI Plan is designed to obtain information necessary to support corrective measures/feasibility studies. The remedial action alternatives to be evaluated will include those addressed in the EPA Handbook, *Remedial Action at Waste Disposal Sites (Revised)* (EPA 1985). Evaluation of feasible alternatives for remediation of contaminated areas within WAG 2 should include:

- methods for elimination of the contaminant source(s) within WAG 2;
- methods for control of migration and redeposition of floodplain soils and creek sediments;
- methods for isolation and/or treatment of contaminated soils and sediments;
- potential environmental impacts of proposed alternatives; and
- engineering, administrative, and institutional controls to ensure protection of public health and worker health and safety during all phases of site characterization and remediation.

Currently, WOC receives tributary and groundwater inflows that originate in several WAGs which have been, or may be, sources for a variety of contaminants. In addition, various radioisotopes (especially ^{60}Co, ^{90}Sr, and ^{137}Cs) exist in water, sediments, and floodplain soils along WOC (Sherwood and Loar 1987). Although data are limited, it is likely that various hazardous organic compounds and toxic metals are also present in the sediments and floodplain soils. Under existing site conditions, significant amounts of contaminated sediments and floodplain soils will remain in WOC and its floodplain for many years and may continue to serve as a source of contaminants to downstream waters.

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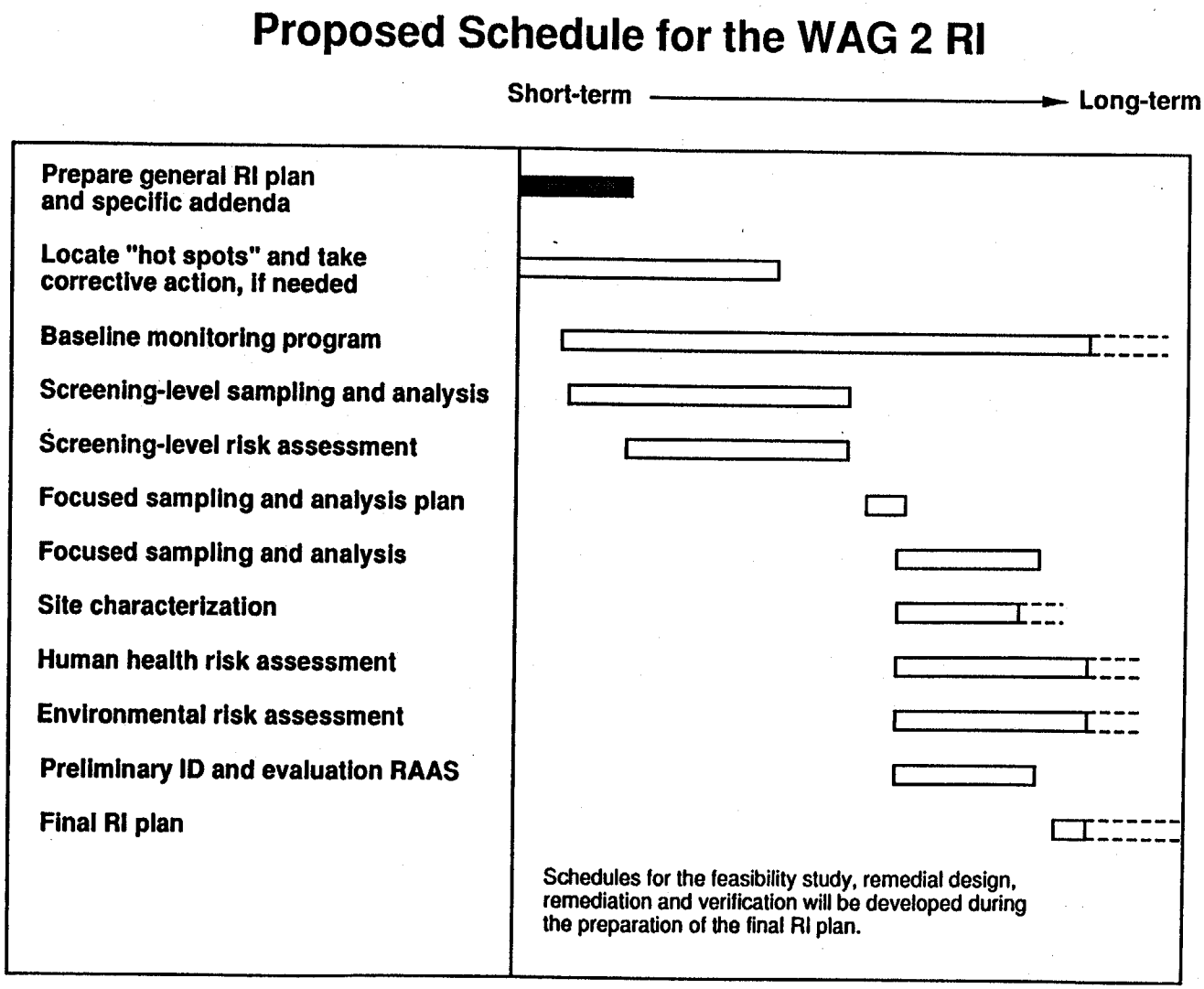

Fig. 2.2. WAG 2 RI project schedule showing primary project phases and deliverables.

Four general types of response actions exist for WOC remediation:

1. institutional controls (e.g., fencing, signs, etc.),
2. source removal,
3. application of in situ corrective measures, and
4. no action.

Different actions or combinations of actions may be appropriate at varying locations within WOC and its floodplain. However, guidance for selection of specific actions is not provided in this document. Instead, knowledge of feasible response actions was used during preparation of this RI Plan. These response actions will be reevaluated following completion of the RI.

2.5.1 Interim Corrective Measures

A major goal of the preliminary work plan (see Sect. 9) is the identification and evaluation of areas of high contamination (i.e., hot spots) where it may be necessary to implement interim corrective measures in accordance with applicable provisions of RCRA (40 CFR 265), CERCLA (40 CFR 300.410-415), or Tennessee Rule 1200-1-11-05. One example of such interim action is the Time-Critical CERCLA Removal Action currently being implemented to reduce the potential for off-site transport of contaminants from WOCE (see Sect. 9.4.6). This process of identifying and evaluating hot spots will continue throughout the RI, but the most intensive effort will take place in the first two years of the project (Fig. 2.1).

2.5.2 Source Removal

The current primary sources of contaminant contribution are the upstream SWMUs, while the WOC floodplain serves as a secondary contaminant source. For WOC, source removal would include partial or complete removal and appropriate treatment/disposal of contaminated soil and sediment. However, removal of contaminated soil/sediment in WOC and its floodplain will not be effective unless the current sources of contaminant contribution are also eliminated. Therefore, source removal would either follow or have to include closure of the contributing SWMUs.

2.5.3 Application of In Situ Corrective Measures

For WOC, corrective measures that minimize erosion of source constituents (soil/sediment) or incidental direct contact include the use of stabilizing technologies, protective covers, lateral erosion barriers, and hydrologic isolation (e.g., stream diversion) at selected locations.

Stabilizing technologies include the following:

- cementitious grout,
- chemical treatment, and
- in situ vitrification.

Protective covers can include the following:

- bituminous compounds,
- vegetation,
- clay, and
- polyethylene or polyvinyl chloride sheeting.

Lateral erosion barriers can include the following:

- riprap,
- sheet piling, and
- concrete.

2.5.4 No Action

For WOC, the no-action alternative can be enacted in areas where the source effect is minimal when compared to the effect on human-health and the environment if removal or corrective action were employed. For example, certain regions of contaminated soil/sediment may not be removed from WOC or the floodplain if dredging would result in resuspension and redistribution of contaminants when none are currently being released from the area or when risk to workers undertaking removal is greater than the risk reduction achieved.

2.5.5 Alternatives Risk Assessment

The environmental and public health risks resulting from the remedial action alternatives presented in Sect. 2.5 will be evaluated by characterizing contaminant sources, the associated environmental setting, the magnitude of the release, and pathways to human exposures. Risk assessment will begin early in the RI process since it will be useful for determining data requirements and may influence site sampling plans.

3. SITE DESCRIPTION

3.1 GENERAL DESCRIPTION

ORNL is located in the Roane County portion of ORR. ORR comprises 150 km^2 of forested land entirely within the city limits of Oak Ridge (Fig. 3.1). Most ORNL facilities occupy the southwest portion of ORR, bounded on the south and west by the Clinch River. ORNL also operates facilities located within the fenced boundaries of the Oak Ridge Y-12 Plant and is responsible for the White Wing Scrapyard near the intersection of State Highways 58 and 95. Access to ORNL is via Bethel Valley Road or White Wing Road (State Highway 95).

3.2 HISTORICAL BACKGROUND

Operations at ORNL began in 1943, with construction of a reactor pilot model for the Hanford, Washington, production plant. The Graphite Reactor, a chemical separations plant, and a number of large underground concrete (gunite) tanks for waste storage were constructed initially. The tanks were intended to store all of the radioactive liquid chemical waste and the liquid uranium waste accumulated during the life of ORNL (estimated to be 1 year) (Browder 1959). Expansion of the scope of work undertaken at ORNL increased the amount of waste produced, and alternatives to tank storage were required.

ORNL's major efforts since 1943 have included research and development activities related to the reprocessing of nuclear reactor fuels, production of isotopes for medical and industrial applications, and significant basic and applied research efforts in both nuclear and non-nuclear areas. The liquid and solid wastes generated as a result of these efforts (both radioactive and nonradioactive) have been treated, disposed of, or stored as part of routine laboratory operations. Over time, the required waste management operations have resulted in the installation of a number of underground storage tanks, waste treatment facilities, waste impoundments, and solid waste storage (disposal) facilities within the ORNL plant area and in the area surrounding the plant. Also, as a result of routine waste management operations, a number of spills and leaks have occurred that contaminated the soil with radioactive and nonradioactive contaminants.

3.2.1 History of White Oak Creek System

3.2.1.1 White Oak Lake/White Oak Creek

White Oak Lake (WOL) has served as a final settling basin for radioactive effluents from ORNL for almost five decades. As a result, radionuclides and other pollutants have accumulated in the sediment and biota. The history and a detailed description of WOL can be found in Oakes et al. (1982a) and Setter and Kochtitzky (1950).

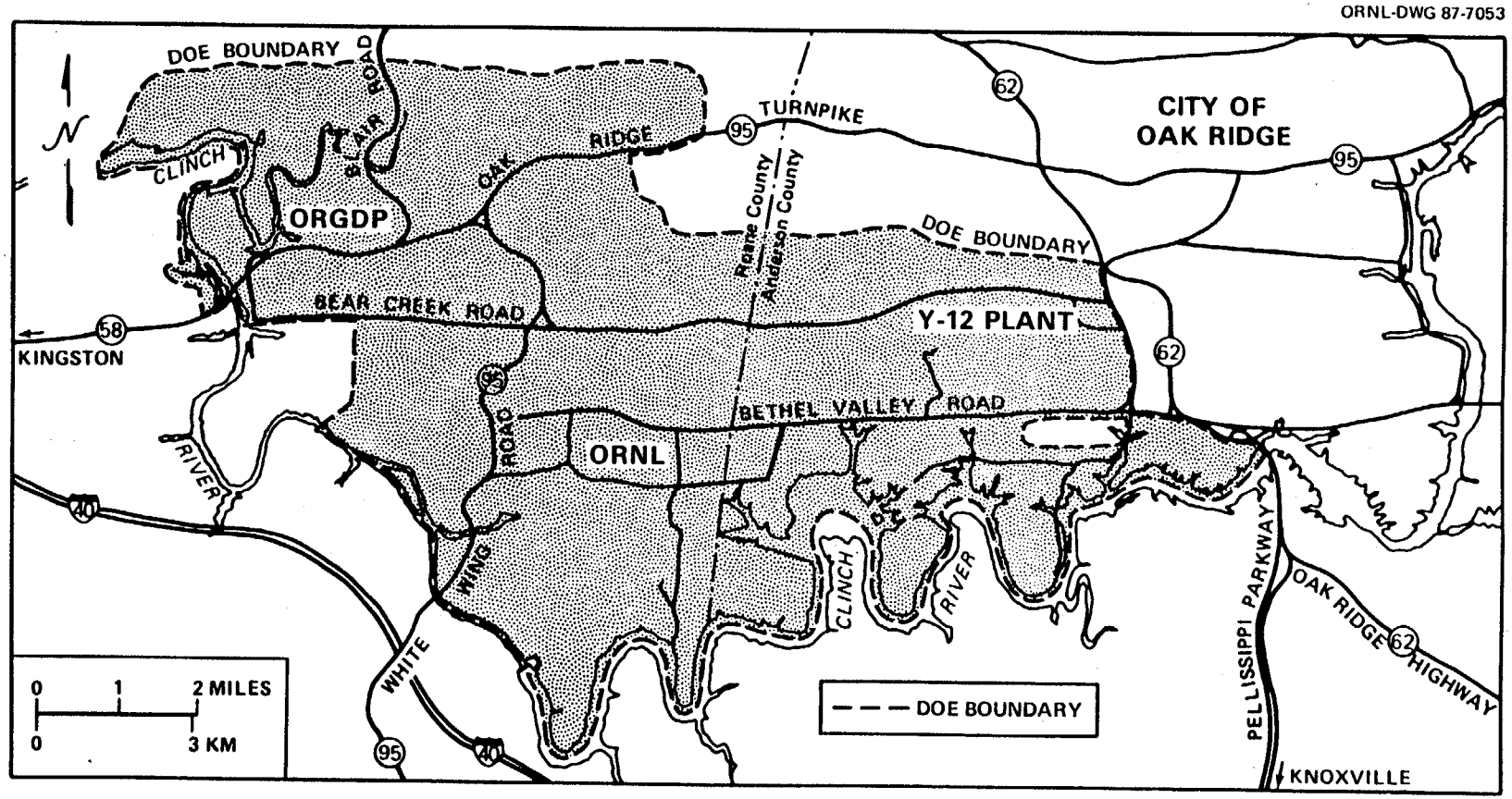

Fig. 3.1. Map showing the Oak Ridge Reservation.

WOC flows into the Clinch River 33.5 km [Clinch River mile (CRM) 20.8] above its confluence with the Tennessee River (Fig. 3.2). In 1941, TVA placed a culvert and an earthen fill at WOC km 1.0 (mile 0.6) for a highway crossing. WOL was created in 1943, when interlocking steel pilings and a sluice gate were placed on the upstream side of the culvert. The overflow elevation was set at 750 ft (msl). At this level the volume of the impoundment was approximately 3.15×10^5 m^3 (10.5×10^6 ft^3 with a surface area of 17.9 ha (44.2 acres).

The gate on the spillway could be raised to increase the water retention time of WOL and permit the settling of suspended solids and the decay of short-lived radionuclides. The normal operating level of the WOL Dam until 1949 ranged from 747 to 749 ft (msl), which resulted in an impoundment of 12 to 16 ha (30 to 40 acres). At a flow rate of 7.5 cfs into the lake, the storage capacity for an elevation of 747 ft was 13.6 d. For an elevation of 750 ft the storage capacity was 23 d; however, periodic rains could flush out the lake in a few hours. Rapid purging of the lake following an intense localized rainfall may have resulted in slugs of radioactivity entering the Clinch River.

By 1954 it was thought that WOL was no longer effective in terms of its ability to dilute and otherwise hold up radioactive materials. The lake was drained in 1955, leaving a standing pond behind the dam of approximately 2.8 ha (6.1 acres) (Kolehmainen and Nelson 1969). In addition to being an emergency holdup basin for radioactive effluents, the upper lake bed served for a time as a terrestrial radioecology research site (Lee and Auerbach 1960). The air dose rate 1 m above the lake bed ranged from 0 to 60 mrem/h and could be related to the pattern of sediment deposition.

In 1953 it was estimated that the lake bed contained 29,170 m^3 of sediment and that the annual rate of sedimentation prior to 1953 was 2830 m^3 (100,000 ft^3) or about 2 cm/year (Oakes et al. 1982b). In 1961 an investigation was made to determine the extent of deposition or loss of sediment that had occurred since the drainage of the lake in 1955. Results of this study indicated that the creek bed, which had been filled with sediment prior to the drawdown, for the most part had eroded to its pre-impoundment depth. The depth of the sediment over the lower one-third of the lake bed, with the exception of the stream channel, had not changed; however, an estimated 4250 m^3 of silt had been lost from the upper two-thirds of the lake bed and the stream channels. In 1956, as discussed below, a significant release of particle-reactive contaminants occurred, probably in association with erosion of freshly exposed sediments during the spring runoff season.

From 1955 to 1969 the size of WOL varied with changes in gate elevations that gradually increased the size of the lake. In 1960 the lake area was increased to 3.2 ha (8 acres) and in 1963, as a result of the construction of Melton Hill Dam on the Clinch River at 37.2 km (CRM 20.8), the gate was reworked and the size of the lake was increased to 6.0 ha (15 acres). By 1969 the surface area of the lake was 10.5 ha (26.3 acres) (Kolehmainen and Nelson 1969), and it remained approximately that size until late November of 1979 when the elevation was reduced to 742 ft, which produced a standing pond of 5.2 ha (13 acres) (Loar et al. 1981).

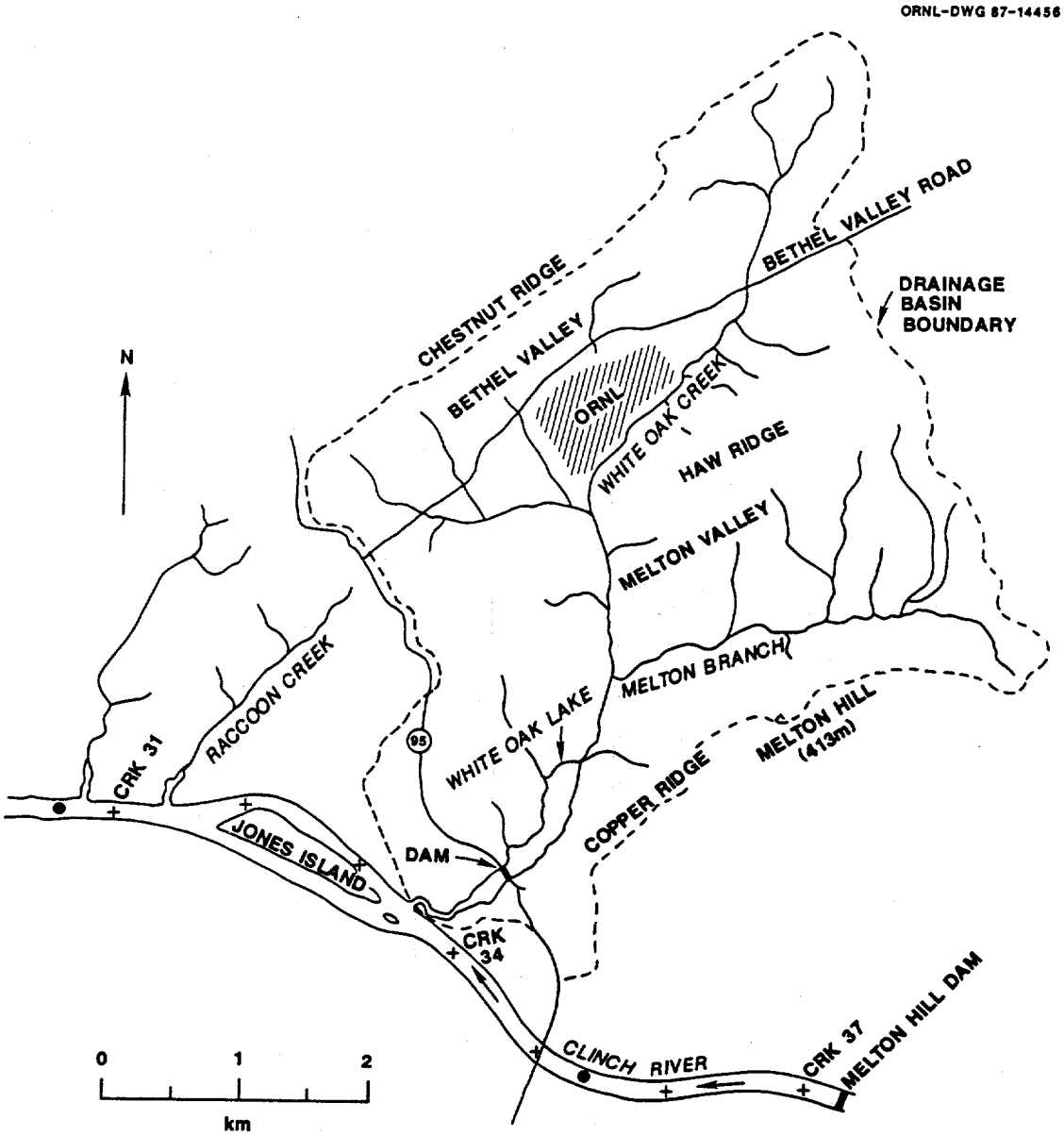

Fig. 3.2. Map showing the WOC watershed boundaries.

In 1979, WOL was drawn down when an evaluation of the integrity of the dam indicated the possibility of internal erosion that could lead to subsidence. Plans were made for improving the structure of the dam and providing a new discharge structure on the northwest side that would accommodate a 100-year flood (Oakes et al. 1982a; Boyle et al. 1982). In 1980 the dam was stabilized by adding a rock berm over a crushed rock and sand fill on the downstream side of the dam. The new discharge channel and weir system was completed in 1983, and the lake is currently maintained at an elevation of 745 ft (msl), which creates a standing pond of approximately 6.9 ha (17 acres). Historical changes in the surface area of the lake and the major events associated with significant changes in the lake are summarized in Table 3.1.

Prior to September 1944 two earthen dikes located at WOC km 3.3 and 3.9 caused the creek to overflow the pond into two marshy areas (Setter and Kochtitzky 1950). Operations associated with the Manhattan Project produced treated wastes containing plutonium, americium, and curium (Dahlman et al. 1980). After treatment with soda ash to precipitate various ions, the liquid effluents were released to the WOC drainage system. Trace quantities of ^{238}Pu, ^{239}Pu, ^{241}Am, and ^{244}Cm were deposited along the water course, in the intermediate retention pond, and eventually in WOL. These elements were deposited in sediments of the retention pond over a 6-month period in 1944, and apparently no additional transuranic radioactivity is believed to have been deposited. The dikes were washed out in September 1944, when 7.75 in. of rainfall fell on the WOC drainage area between 4 p.m., September 28, and 4 p.m., September 29, 1944. The former retention ponds are now a 3-ha contaminated floodplain covered by second growth forest, which is estimated to contain 0.5 Ci of $^{239,240}Pu$ in the top 20 cm of soil in the 3-ha area.

3.2.1.2 WOCE

The WOCE extends 1 km (0.6 mile) downstream from WOL Dam to its mouth at Clinch River km 33.5.(CRM 20.8) (Fig. 3.2). The depth of the water in the embayment is influenced by the summer and winter water levels of Watts Bar Reservoir. The summer pool at the mouth of the embayment is 741 ft (msl). At this elevation the depths of water at the upper end of the embayment range from 0.3 to 1.0 m (1 to 3 ft). The width of the embayment ranges from approximately 65 m (216 ft) at the upper end to approximately 15 m (40 ft) at the lower end where the embayment narrows and reaches a depth of approximately 10 ft. At summer pool level the mouth of WOCE is approximately 36 m (120 ft) wide. The area of the embayment at the summer pool level is approximately 3.4 ha (8.5 acres).

Low levels of radioactivity are released over WOL Dam and deposited in the embayment or transported to the Clinch River. Current levels of radioactivity released over the dam are usually <1 Ci/year of ^{137}Cs. However, in the past larger amounts have been released. For example, in 1956 approximately 170 Ci of ^{137}Cs (DOE 1988) were released over WOL Dam after the lake had been drained in 1955 (Oakes et al. 1981).

Table 3.1 Historical Changes in the Surface of White Oak Lake and major events associated with significant changes in lake size.

Date	Surface area (ha)	Events	References
1941		Highway fill and culvert installed by TVA	Smith (1945) as in Krumholz (1954)
1943	14.5	Sheet piling dam installed with spillway with vertical sliding gate	Krumholz (1954)
1943		Generation of radioactive waste at ORNL began and lake served as final settling basin (750 ft msl)	Clinch River Study Steering Committee (1967)
1944	NA	Dikes at WOC km 3.3 and 3.9 washed out (7.75 in., 26 h, 3.5 in. runoff)	Setter and Kochtitsky (1950)
1945	12.2	Investigation of structural strength of dam (746.5 ft)	Oakes et al. 1982a
1948	10.3	Lake lowered to 7455.5 ft to facilitate sediment sampling, normal operation from 1948 to 1955 was from 747 to 749 ft.	Oakes et al. 1982a
1953	NA	Lake partially drained during rotenone survey of fish population	Oakes et al. 1982a
1955	2.8	Lake drained: radionuclides in lake sediment and water believed to be in equilibrium so lake served no useful function in retaining radioactivity but could function as an emergency storage basin.	Clinch River Study Steering Committee (1967)
1956	0.4	Significant releases of ^{137}Cs probably from erosion of freshly exposed sediment after lake was drained	Lackey (1957)
1959	NA	Gate structure renovated to prevent inflow of backwaters from Clinch River	Clinch River Study Steering Committee (1967)
1960	3.2	Dam closed surface level raised	Kolehmainen and Nelson (1969)
1963	6.0	Completion of Melton Hill Dam	Kolehmainen and Nelson (1969)
1967	8.1	None reported	McMaster (1967)
1969	10.5	None reported	Kolehmainen and Nelson (1967)
1979	4.6	Lake level gradually dropped from 745 to 742 ft due to potential instability of the dam	Oakes et al. 1982a
1980	6.9	Construction of a berm to stabilize dam was completed	Broyle et al. 1982
1983	6.9	Discharge channel and weir constructed, roadbed rerouted	
1988		Estimate of surface area and volume (43,900 m^3) at lake elevation of 745 ft	Cox et al. ORNL (In review)

WOCE is located on ORR (Fig. 3.2) and is part of the WAG 2 RI; however, because the last point of control for effluents from ORNL is WOL Dam, the embayment was included in the Clinch River RFI preliminary screening analysis (Hoffman et al. 1990). The results indicated that WOCE was an area of concern because of the potential for external exposure to ^{137}Cs. The conclusion from this analysis was also in agreement with the 1986 aerial survey, which indicated that in the lower portion of WOCE dose rate from ^{137}Cs ranged from 42 to 64 μR/h (Fritzche 1987). As part of the Clinch River RFI sampling plan, a sediment core was taken approximately 50 yards upstream from the mouth of WOCE in August 1990 and analyzed for radioactivity. The surface sediments of this sample contained 45,000 pCi/g dry wt of ^{137}Cs. As a result of this finding, additional samples were taken and analyzed for radioactivity. Results of these analyses confirmed that concentrations of ^{137}Cs greater than 10^4 pCi/g dry wt existed near the mouth of WOCE. A preliminary estimate of the inventory of ^{137}Cs indicated that between 3 and 4 curies of ^{137}Cs were contained in the surface sediments (depth ~5 cm) of WOCE. Concentrations of ^{137}Cs at the mouth of the embayment were much higher than had been anticipated and were of immediate concern because surface sediments in WOCE are uncontrolled. That is, sediments can be readily eroded from the embayment under some conditions and transported downstream in the Clinch River (either from storm events or from current reversals caused by the generation of electricity at TVA's Melton Hill hydroelectric dam).

TVA's Melton Hill Dam, which was completed in 1963, is located at CRM 23, upstream from the mouth of WOCE. This dam is used as a peaking unit and usually generates electricity twice a day. When the generators are operating, the release of water from the dam reverses the flow of current in WOCE and increases the depth of water at the mouth of the embayment by more than 2 ft in a few minutes time. The surging of the water upstream caused by the operation of Melton Hill Dam, and storm events during the winter months, are believed to erode sediment from the embayment.

As a result of these findings, remedial actions are in the process of being formulated with the aid of the U. S. Army Corps of Engineers. A proposed action to be completed by April 1991 is the construction of a riprap dam at the mouth of the embayment to prevent sediments from being transported downstream.

3.2.2 Sources of Contamination

The RCRA Facilities Assessment (RFA) identified all sites considered to be potential RCRA 3004(u) SWMUs. These sites have been grouped into 20 WAGs on the basis of hydrogeological and functional parameters. Eleven of these WAGs (Table 3.2) are within the WOC watershed (Fig. 3.3) and are potential sources of contamination to WOC. Detailed descriptions of each WAG and its associated SWMUs were developed in the RFA; brief summaries are presented in the following paragraphs.

Table 3.2. Waste area groupings (WAGs) in the WOC watershed.

WAG No.	Name	WAG No.	Name
1	Main Plant Area	8	Melton Valley Area
3	Solid Waste Storage Area 3	9	Homogeneous Reactor Experiment (HRE)
4	Solid Waste Storage Area 4	10	Hydrofracture Injection Wells and Grout Sheets
5	Solid Waste Storage Area 5	13	Environmental Research Areas
6	Solid Waste Storage Area 6	17	ORNL Services Area
7	LLW Pits and Trenches Area		

WAG 1, the ORNL main plant area, includes all the operating research and development facilities located within the main security fence at ORNL (Fig. 3.3). Historically, ORNL has been involved in the development, testing, and operation of various reactor concepts, the development and operation of fuel reprocessing technologies, the large-scale production of radioactive and stable isotopes, and the management of wastes from these activities. These activities have been primarily focused in WAG 1, although several other WAGs have also been involved. Approximately 100 sites in WAG 1 are currently considered to be SWMUs, including radioactive waste collection pipelines and tanks, solid waste storage areas (SWSAs), waste treatment facilities and impoundments, leak and spill sites, and miscellaneous waste handling and storage units. WAG 1 drains into WOC directly, through storm drains, and through two small tributaries—First Creek and Fifth Creek. Conceptual modeling studies have demonstrated the potential for rapid transport of contaminants along the massive array of subsurface pipeline trenches directly to WOC and its WAG 1 tributaries.

WAG 3 (which includes SWSA 3, the closed scrap metal area, and the current operating contractors' landfill) is located in Bethel Valley about 1 km (0.6 mi) west of the west entrance to the main plant area (Fig. 3.3). SWSA 3 and the closed scrap metal area are inactive landfills known to contain radioactive solid wastes and surplus materials generated at ORNL from 1946 to 1979. The contractors' landfill was opened in 1975 and is used to dispose of various uncontaminated construction materials and fly ash from the ORNL steam plant. WAG 3 is drained by Northwest Tributary of WOC. Although Northwest Tributary enters WOC outside the boundary of WAG 2, WAG 3 represents a potential source of contamination to the reach of WOC within WAG 1 and ultimately to WAG 2.

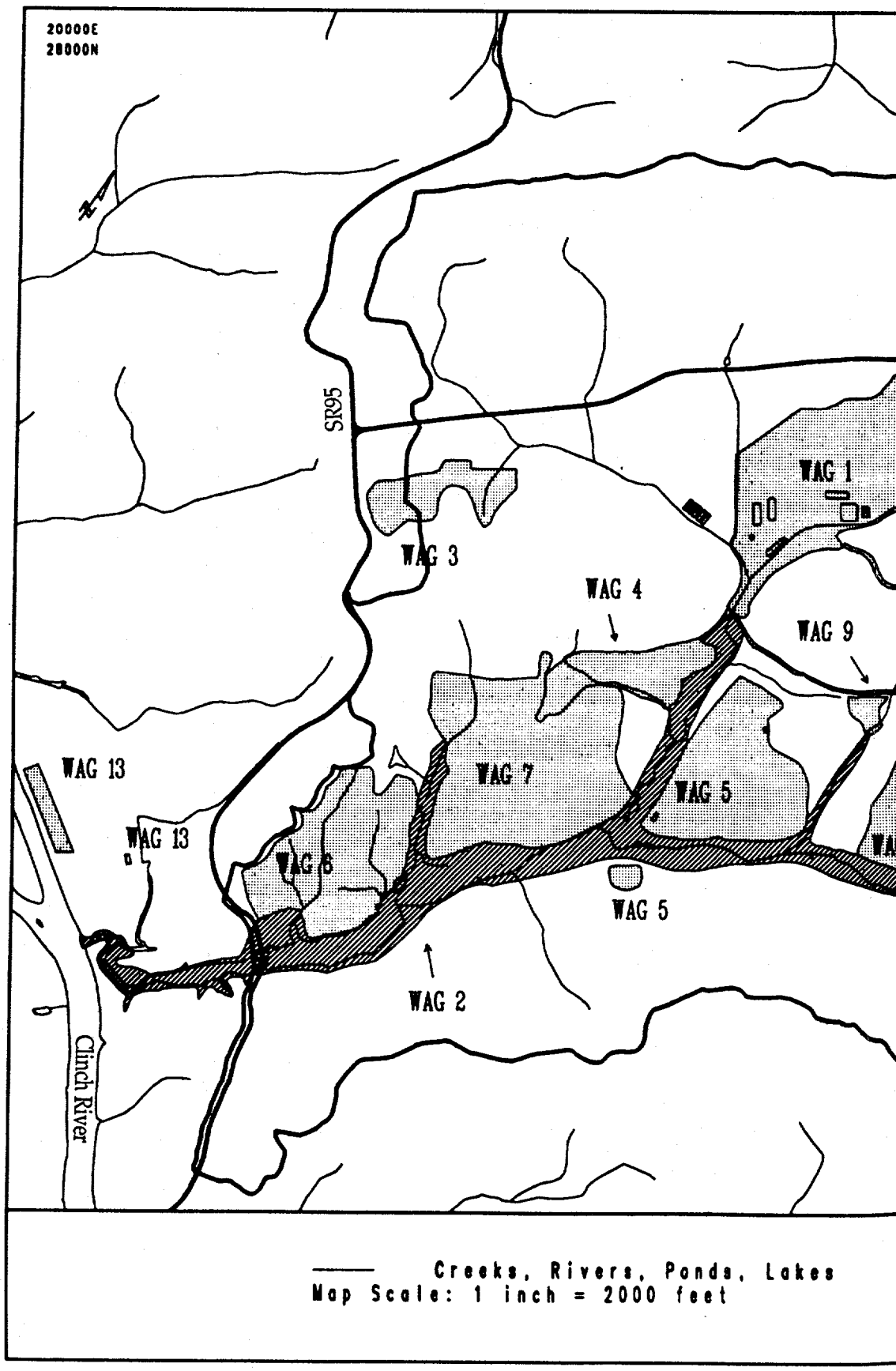

Fig. 3.3. Waste Area Groupings w

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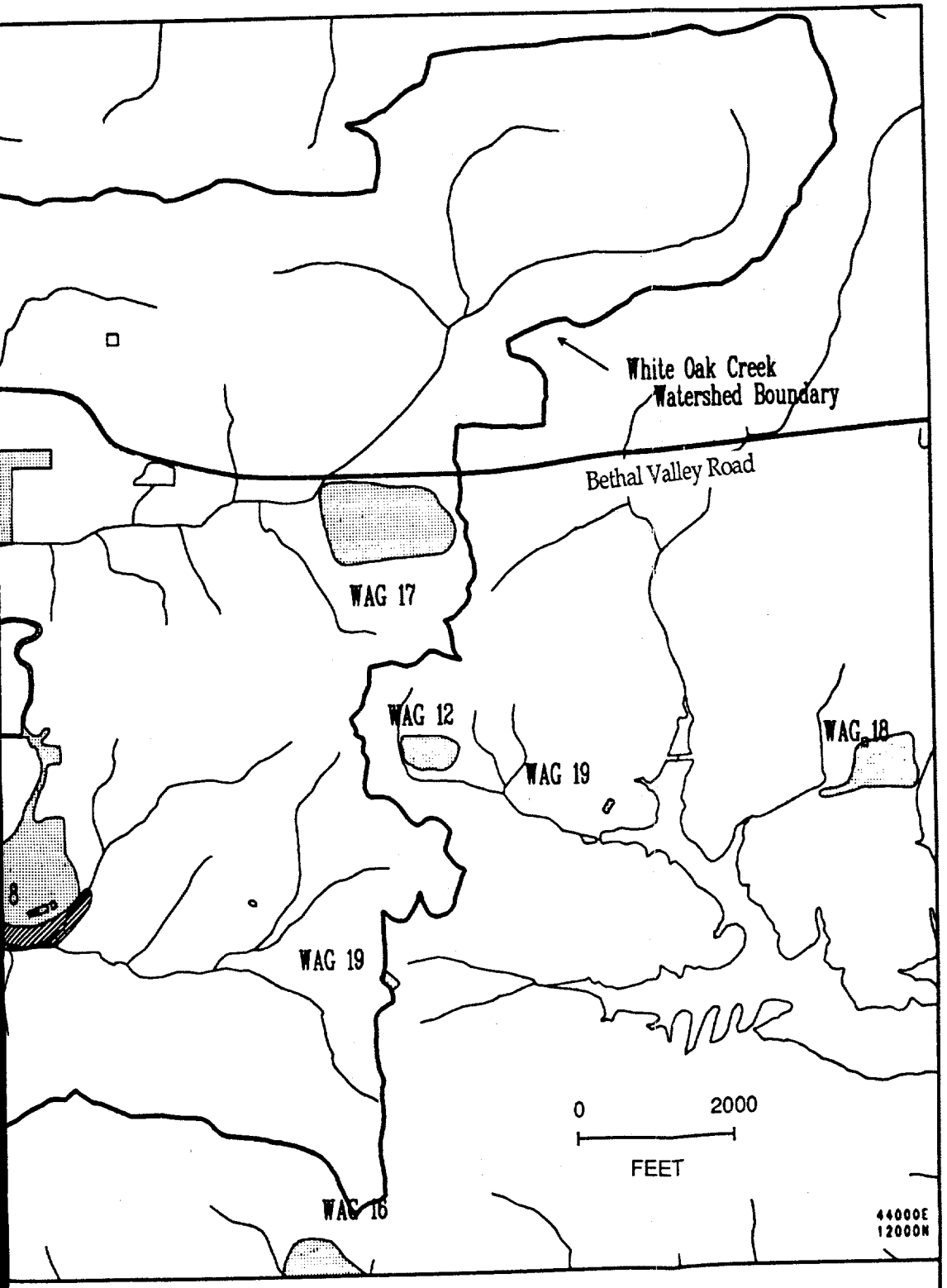

Source: S-16A (White Oak Lake Update)
Grid: ORNL Coordinates (feet)
Date: November 1990

thin the boundaries of the WOC system.

WAG 4, located southwest of the main plant area (Fig. 3.3), consists of three SWMUs: the low-level waste (LLW) line north of Lagoon Road, pilot pits 1 and 2, and SWSA 4. From 1954 to 1975, liquid radioactive wastes were transferred to the waste pits and trenches (WAG 7) through the LLW line north of Lagoon Road. Two known leak sites were covered with bentonite and asphalt caps in 1983. The pilot pit area (Building 7811) was constructed in late 1955 for use in pilot-scale radioactive waste disposal studies. Currently, three large concrete cylinders embedded in the ground, a control building that is now used to store field and laboratory equipment, and four large concrete cylinders that were used in a municipal waste leaching experiment are all that remain at the site. SWSA 4, covering 9.3 ha (23 acres), was opened for routine solid waste burials from 1951 through 1959, but remained open as a disposal area for uncontaminated fill until 1973. Waste from sources outside ORNL accounts for about half of the waste buried in SWSA 4. WAG 4 drains directly to WOC.

WAG 5 is located about 2 km (1.2 mi) south of the main plant area in Melton Valley (Fig. 3.3). This WAG consists of SWSA 5 and SWSA 5 North, two line leak sites, an old landfill, the 7835 process waste sludge basin, and the surface facilities constructed in support of both Old and New Hydrofracture facilities (including several LLW storage tanks and two impoundments). Melton Branch separates the New Hydrofracture Facility from the remainder of WAG 5 (Fig. 3.3). SWSA 5, covering 32.3 ha (80 acres) received radioactive wastes from 1959 through 1973. The area known as SWSA 5 North covers 4 ha (10 acres) and has been used for retrievable storage of transuranic wastes since 1970. WAG 5 drains directly into WOC and into MB and two unnamed tributaries of WOC.

WAG 6 consists of three SWMUs: SWSA 6, the emergency waste basin, and the explosives detonation trench. All three facilities are located in Melton Valley, 2 km (1.2 mi) southwest of the main plant area along Lagoon Road (Fig. 3.3). SWSA 6, covering 28 ha (68 acres), is currently the only operating LLW disposal site at ORNL. Portions of this site have been closed under RCRA regulations because of the disposal of RCRA-regulated waste after 1980. The emergency waste basin was constructed in 1962 to provide storage if wastes could not be released from ORNL to WOC. To date, the basin has not been used, although the water may be contaminated from atmospheric deposition and wildlife inputs. The explosives detonation trench was used for destruction of explosive and shock-sensitive chemicals. A closure plan has been filed for the detonation trench. WAG 6 drains to WOL through four unnamed surface drainages.

WAG 7 is located in Melton Valley about 1.6 km (1 mi) southwest of the main plant area (Fig. 3.3). The primary SWMUs in this WAG are seven pits and trenches used for disposal of liquid LLW from 1951 through 1966. WAG 7 also includes a decontamination facility, three leak sites, a storage area containing shielded transfer tanks and other equipment, and seven fuel wells containing the acid solutions of enriched uranium from Homogeneous Reactor Experiment (HRE) fuel. WAG 7 drains through three unnamed drainage channels into WOL.

WAG 8, located in Melton Valley south of the main plant area (Fig. 3.3), consists of reactor facilities and associated tank and piping systems, 6 leak sites and an old transfer line,

5 surface impoundments, a contractor spoils area, and RCRA-permitted hazardous waste storage facilities. Liquid LLW and process wastes from the reactors and associated facilities are collected on site in tanks and then pumped to the main plant area for storage and treatment. Wastes from the HRE (WAG 9) were pumped using the same transfer system. WAG 8 drains into MB.

WAG 9 is located in Melton Valley about 1 km (0.6 mi) southeast of the main plant area (Fig. 3.3). This WAG includes the HRE, HRE pond, LLW collection and storage tanks, a septic tank, waste evaporator and associated pit, and several miscellaneous sites. The HRE pond was constructed in 1955 as a waste storage impoundment for condensate from the HRE waste evaporator. In 1970 the pond was filled with soil and capped with asphalt. WAG 9 drains to upper MB.

WAG 10 consists of the injection wells and grout sheets from four SWMUs, two of which were experimental sites used in the development of the hydrofracturing process at ORNL. The other two sites were operating facilities (now inactive) used to dispose of ORNL's liquid LLW. All four SWMUs are located in Melton Valley; however, they are not adjacent to one another (Fig. 3.3). WAG 10 is significantly different from the other WAGs in that the grout sheets are located at depths of 90 to 300 m (300 to 1,000 ft) below the ground surface.

WAG 13 is part of what is now called the 0800 Area and is located west of State Highway 95 (White Wing Road) near the Clinch River (Fig. 3.3). There are two SWMUs within WAG 13, both associated with research on transport of ^{137}Cs through the environment. The larger SWMU drains into the Clinch River downstream from the mouth of WOC. However, portions of the smaller SWMU (a 20-m^2 site where 0.015 Ci of ^{137}Cs was sprayed over the surface) may drain to an unnamed tributary of WOC below WOL Dam.

WAG 17 is located about 1.6 km (1 .0 mi) east of the main plant area (Fig. 3.3). This area is the major craft and machine shop area for ORNL and includes the shipping, receiving, shops, and garage operations. The WAG includes 9 SWMUs, all tanks. WAG 17 drains to the easternmost reach of upper WOC. Although WAG 17 does not drain directly into the portion of WOC included in WAG 2, discharges from WAG 17 may ultimately reach WAG 2 after passing through WAG 1.

3.2.3 Contaminant Receptors

3.2.3.1 Human Populations

The human populations in the vicinity of WAG 2 would serve to act as potential receptors to contaminants carried downstream from the WAG. The potential pathways for contaminant migration are discussed in later sections of the RI plan. Identification of potential human receptors is essential to perform the human health risk assessment, which would then drive the selection of cleanup goals and the remedial alternatives for the site. The following sections outline the regional demography, the different water uses, and the potential receptors at these locations.

Regional Demography. According to 1980 census data, except for the city of Oak Ridge (pop. 28,000), the land within 8 km (5 mi) of the ORR is predominantly rural and is used largely for residences, small farms, and pasture land. The ORR, itself, is within the Oak Ridge city limits.

Figure 3.4 shows the location of population centers in the vicinity of ORR. The approximate (1980) populations of cities and towns within an 80-km (50 mi) radius of ORR are listed in Table 3.3, and directional population-distribution maps are shown in Figs. 3.5 and 3.6. Fewer than 5000 persons live within a 10-km (6.2 mi) radius of the center of ORR; however, it should be noted that most of the area within a 10-km radius is encompassed by the 14,260-ha (55 mi^2) ORR.

Knoxville, the largest metropolitan center near Oak Ridge, is located about 40 km (25 mi) east of ORR and has a population of about 183,000 (Petrich et al. 1984, Baumgardner and Chance 1984). Knoxville draws its water supply from the Tennessee River upstream from Watts Bar Reservoir. A number of small towns are located near ORR; their approximate populations and distances from ORR are: Oliver Springs (pop. 3600), 11 km (6.8 mi) to the northwest; Clinton (pop. 5300), 16 km (10 mi) to the northeast; Lenoir City (pop. 5400), 11 km (6.8 mi) to the southeast; Kingston (pop. 4400), 11 km (6.8 mi) to the southwest; and Harriman (pop. 8300), 13 km (8 mi) to the west.

3.2.3.2 Water Use

Water use classifications. Streams in the Clinch River basin are classified by use by the Tennessee Department of Public Health (TDPH) (1978) based on water quality. Water use classifications for streams on or near ORR are presented in Table 3.4. Surface waters in the Clinch and Tennessee rivers are used for multiple purposes, including domestic water supply, industrial processes,fishing and other water-based recreation, growth and propagation of fish and aquatic life, irrigation, hydroelectric power generation, and navigation.

Municipal Water Supplies. Twelve water supplies, serving an estimated population of 200,000 persons, use water potentially influenced by materials released to the Clinch River via WOC. Principal domestic water supply users are the Oak Ridge K-25 Site and the TVA Kingston Steam Plant on the Clinch River, and the communities of Kingston, Rockwood, Spring City, Soddy-Daisy, Falling, Waldens Ridge, Chattanooga, and South Pittsburg, Tennessee, on the Tennessee River. Additionally, stratified conditions in the upper portion of Watts Bar Reservoir during the summer months create the possibility that the cooler Clinch River water released during hydropower generation cycles at Melton Hill Dam may underflow upstream in the Emory River to water supply intakes at Harriman.

Industrial Water Supplies. Industrial water withdrawals from the Clinch-Tennessee river system below WOC are listed in Table 3.5. All point discharges are described in detail by TDPH (1978).

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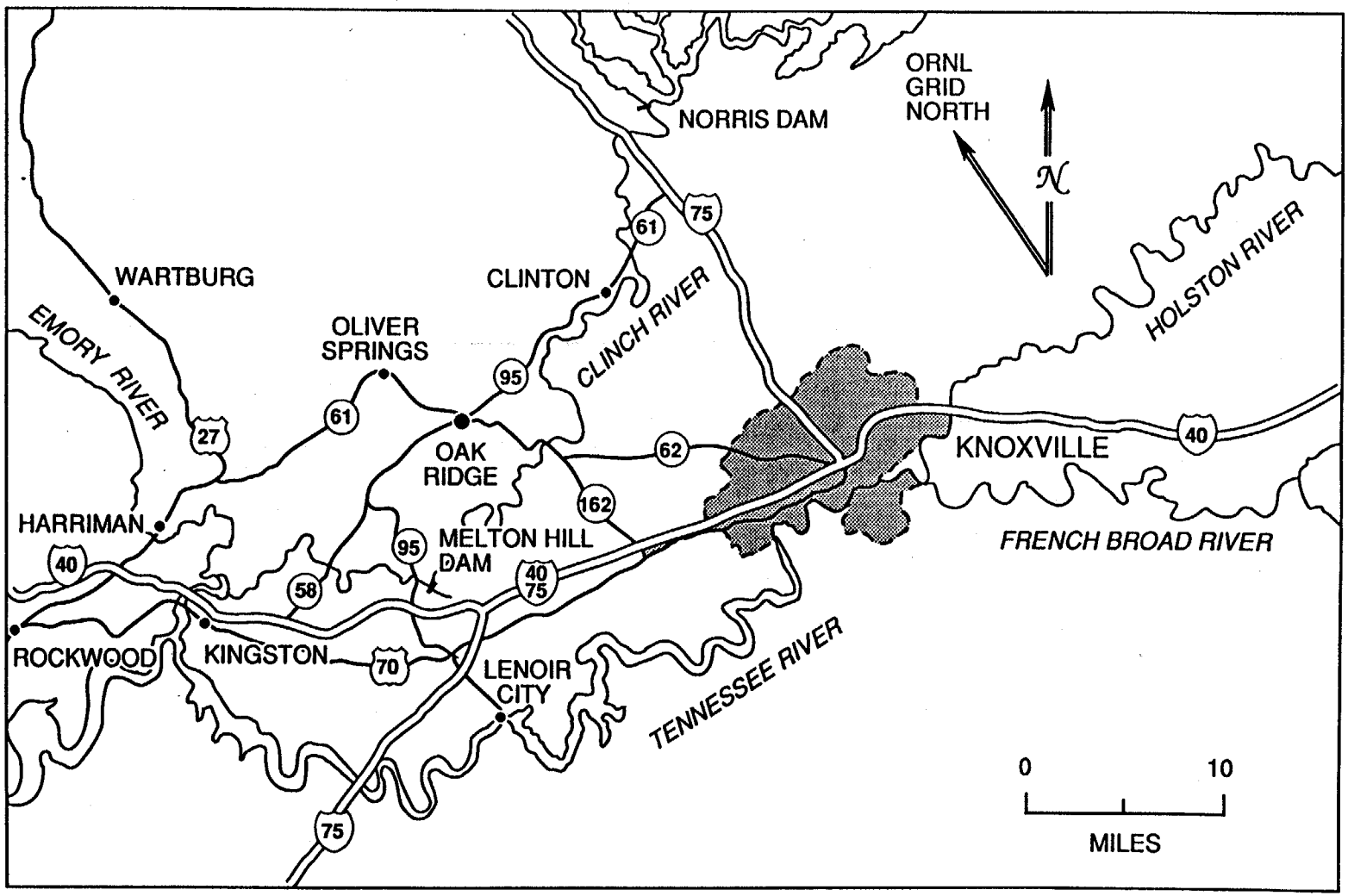

Fig. 3.4. Human population centers and major surface water features in the vicinity of the Oak Ridge Reservation, eastern Tennessee.

Table 3.3. Populations of central East Tennessee towns.

Town/city	Population
Anderson County	
Clinton	5,245
Lake City	2,335
Norris	1,374
Oak Ridge	27,662
Oliver Springs	3,600
Blount County	
Friendsville	694
Alcoa	6,870
Maryville	17,478
Knox county	
Knoxville	183,139
Loudon County	
Greenback	546
Lenior City	5,446
Loudon	3,940
Morgan County	
Wartburg	761
Roane County	
Harriman	8,303
Kingston	4,441
Rockwood	5,767
Sevier County	
Sevierville	4,566
Union County	
Luttrell	962
Maynardville	924
Campbell County	
Caryville	2,039
Jellico	2,769
Jacksboro	1,620
LaFollette	8,176

Source: Energy Systems (1986).

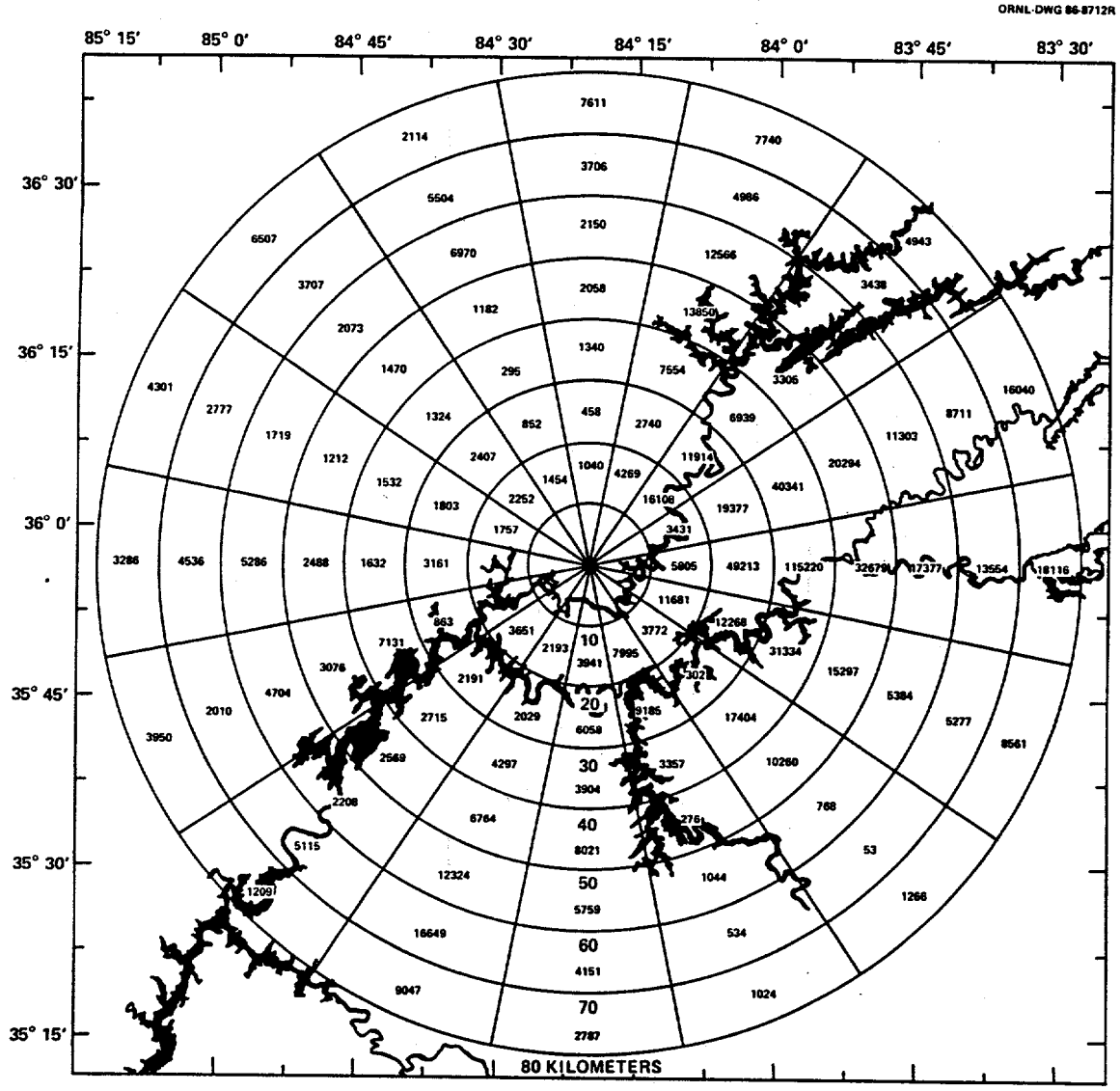

Fig. 3.5. Human population density indicated by sector from the center of the Oak Ridge Reservation and in relation to major surface water features.

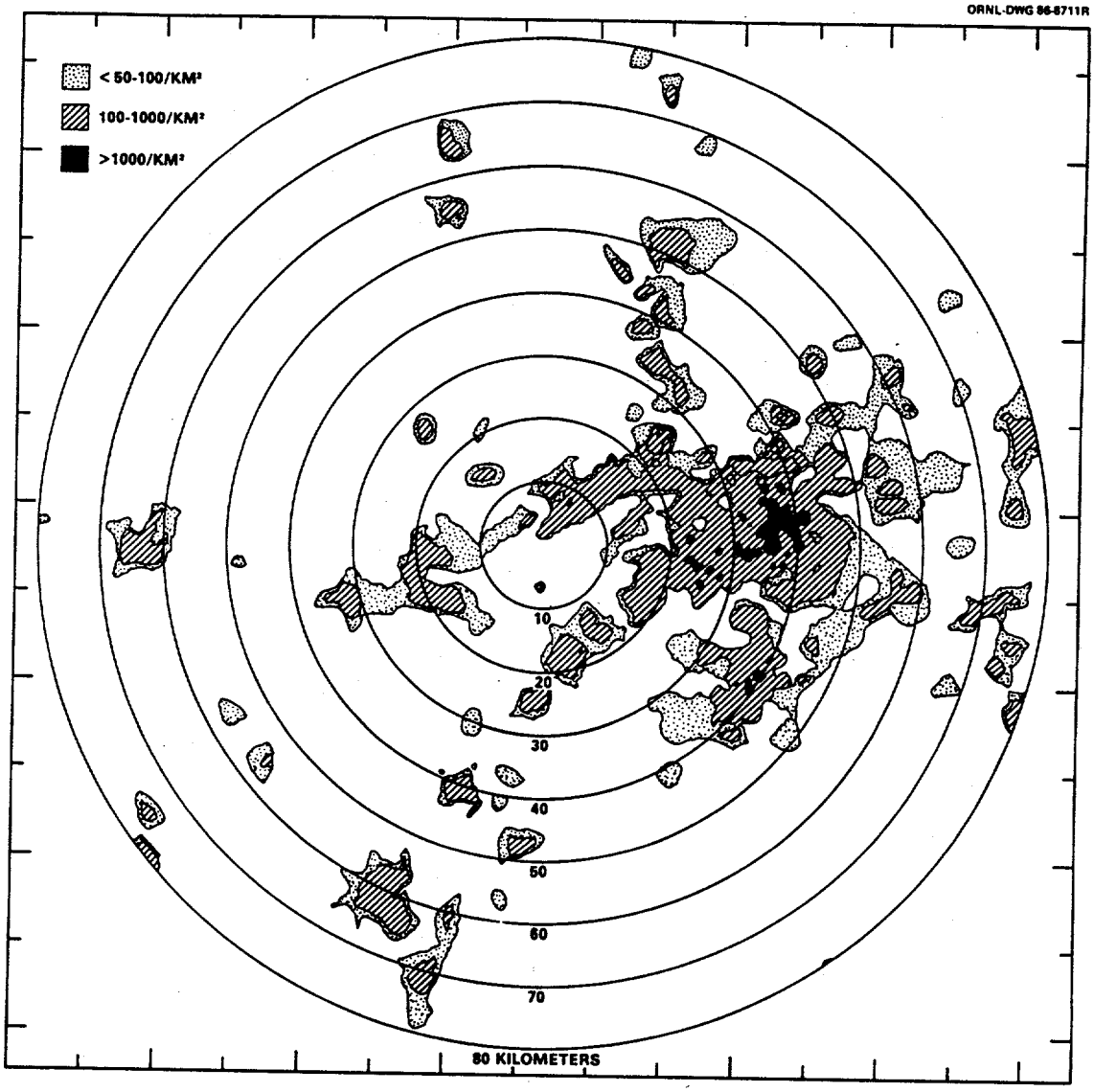

Fig. 3.6. Human population density mapped from the center of the Oak Ridge Reservation. Fewer than 5000 persons live within the 10 km radius of the Center of the Oak Ridge Reservation. Population estimates based on a 1980 census data.

Table 3.4. Use classifications for the Clinch River and its tributaries on the ORR.

Stream	Description	DOM[a]	IND[b]	FISH[c]	REC[d]	IRR[e]	LW&W[f]	NAV[g]
Clinch River	km 7.0-19.2 (Poplar Creek)	X	X	X	X	X	X	X
Poplar Creek	km 0.8-0.8		X	X	X	X	X	
Poplar Creek	km 0.8-2.1			X		X	X	
Poplar Creek	km 2.1-8.8			X	X	X	X	
East Fork Poplar Creek	km 0.0-7.7			X	X	X	X	
Bear Creek	km 0.0-origin			X	X	X	X	
East Fork Poplar Creek	km 7.7-13.3			X		X	X	
East Fork Poplar Creek	km 13.3-dam at Y-12 Plant			X	X	X	X	
Poplar Creek	km 8.8-19.8			X	X	X	X	
Poplar Creek	km 19.8-23.0			X		X	X	
Indian Creek	At Poplar Creek (km 22.9); km 0.0-origin			X	X	X	X	
Poplar Creek	km 23.0-origin			X	X	X	X	
Clinch River	km 19.2-32.0	X	X	X	X	X	X	
White Oak Creek	km 0.0-origin			X			X	
Melton Branch	km 0.0-origin			X			X	
Clinch River	km 32.0-63.4	X	X	X	X	X	X	X
Clinch River	km 63.4-65.8	X	X	X	X	X	X	X
Scarboro Creek	km 0.0-1.6			X	X	X	X	
Scarboro Creek	km 1.6-2.1			X		X	X	
Scarboro Creek	km 2.1-origin			X	X	X	X	
Clinch River	km 65.8-74.7	X	X	X	X	X	X	X

[a]DOM = Domestic water supply.
[b]IND = Industrial water supply.
[c]FISH = Fish and aquatic life.
[d]REC = Recreation.
[e]IRR = Irrigation.
[f]LW&W = Livestock watering and wildlife.
[g]NAV = Navigation.

Source: Tennessee Department of Public Health 1978. Water Management Plant - Clinch River Basin.

Table 3.5. Industrial water withdrawals from the Clinch-Tennessee River System below White Oak Creek

Industrial water use	Average withdrawal rate (m^3/s)	Withdrawal source and location		River distance from mouth of White Oak Creek (km)
Withdrawals below White Oak Creek (mouth of CRK[a] 33.5)				
ORGDP	0.13[b]	CRK	23.3	10.2
ORGDP	0.54[c]	CRK	18.5	15.0
Tennessee Valley Authority, Kingston Steam Plant	61.3	ERK[d]	2.9	29.6
Watts Bar Hydro plant, lock, and steam plant	0.02	TRK[e]	851.5	94.5

[a]CRK = Clinch River Kilometer.
[b]Process and potable water.
[c]Cooling water makeup only.
[d]Emory River Kilometer.
[e]Tennessee River Kilometer.

Source: F. C. Fitzpatrick, *Oak Ridge National Site Data for Safety Analysis Reports*, ORNL/ENG/TM-19, Oak Ridge National Laboratory, Oak Ridge, TN, 1982, updated.

Recreational Use of Surface Waters. The surface waters adjacent to and downstream from WOC (i.e., the lower Clinch River and Watts Bar Reservoir) are popular, heavily used areas for water-based recreational activities (including fishing, waterfowl hunting, boating, water skiing, swimming, and sunbathing).

Sport fishing for game fish such as striped bass, largemouth bass, white bass, sauger, walleye, crappie, and catfish is particularly popular in Watts Bar Reservoir, which is a location of choice for fishing tournaments.

Some fish collected from WOCE and the Clinch River and Tennessee River arms of Watts Bar Reservoir have been determined to contain tissue concentrations of PCBs that exceed the Food and Drug Administration (FDA) tolerance limit of 2 ppm. Accordingly, the TDHE has recently issued public advisories related to the consumption of fish taken from surface waters in the Tennessee River system that may be contaminated. In the Tennessee River arm of Watts Bar Reservoir (Kingston to Lenoir City), catfish, striped bass, and striped bass and white bass hybrids are banned from human consumption. Also, consumption of largemouth bass, white bass, sauger, carp, and smallmouth buffalo has been limited to no more than 545 g/month from this area. In the Clinch River arm of Watts Bar Reservoir (Kingston to Melton Hill Dam), catfish consumption is limited to no more than 545 g/month.

3.2.3.3 The Off-site Aquatic Environment

The Clinch River forms the southern and western boundary of ORR for a distance of approximately 63 km, extending from CRK 79 (CRM 49) on Melton Hill Reservoir to CRK 16 (CRM 10), approximately 3.2 km (2 mi) downstream from the mouth of Poplar Creek. The surface water environments potentially affected by contaminant releases from the ORNL include the lower Clinch River between Melton Hill Dam and Kingston (where the Clinch River enters the Tennessee River) and Watts Bar Reservoir.

The sediments, limnology, and the biotic communities of the lower Clinch River have been surveyed extensively over the years in connection with contaminant releases from ORR (e.g., Loar 1981, Loar et al. 1981, Loar 1984) and development of additional proposed facilities (Project Management Corp. 1975; Exxon Nuclear Co., Inc. 1976). The planktonic, benthic, and fish communities of the river-reservoir system are diverse and productive, as is typical of upper Tennessee Valley reservoirs.

Both Melton Hill and Watts Bar reservoirs are short water-residence time, phosphorus-limited, but moderately productive systems (Elser and Kimmel 1984, 1985). Because Watts Bar Reservoir receives inflow from both the Clinch River and Tennessee River drainages and is thoroughly mixed vertically, it is a considerably productive system (i.e., with regard to phytoplankton photosynthetic production of organic matter) (Elser and Kimmel 1984, 1985). Watts Bar reservoir supports a large standing crop and a high diversity of native and introduced fish species.

The fisheries in Watts Bar Reservoir are classified as cool-warm water communities, since species of both water types are present. A total of 53 species and 2 hybrids represented by

14 families has been reported. Of these species, 16 species and the 2 hybrids (walleye/sauger and white bass/striped bass) are considered game fish, 16 species are forage fish, and 21 species are considered rough or commercial fish. The principal predators and most prized game fish are largemouth bass, striped bass, white bass, sauger, and channel catfish.

Threadfin shad and gizzard shad are the dominant forage fish species, and they play a pivotal role in linking lower trophic-level production to the higher consumers (Fig. 3.7). The threadfin shad populations undergo dramatic seasonal fluctuations in abundance as a result of naturally occurring cold shock mortality in the winter (McLean et al. 1980).

Many of these fish species, including those taken by sport fishermen, do not have well-defined home ranges. These fish often move into embayments and creeks seasonally to spawn or to use these highly fertile areas as feeding and nursery grounds. Based primarily on observations of high densities of ichthyoplankton and larval fish, Loar (1981) and Loar et al. (1981) noted the ecological importance of WOCE as a productive nursery for the Clinch River - Watts Bar Reservoir fish community. This embayment is the primary discharge point for the release of contaminants from ORNL WAGs located in the WOC watershed to the Clinch River.

The two most important forage fishes in the river-reservoir system, the gizzard shad and the threadfin shad, exhibit seasonal migration into the mouths of creeks and embayments. The great winter abundance of threadfin shad in WOCE suggests that this species, which is stressed by low temperatures (Griffith 1978, McLean et al. 1980), moves into the warmer waters found near the mouths of creeks in late winter (Loar 1981).

The smallmouth buffalo, a rough/commercial fish, has been shown to migrate extensively in and out of contaminated areas (Martin et al. 1964). Conventional tagging methods showed that individuals of this species are quite mobile, with one recapture occurring 450 miles downstream from the Clinch River tagging site. Autoradiographic analysis of ^{90}Sr deposited in the fish scales demonstrated that smallmouth buffalo move between WOCE (an area of significant contamination and ^{90}Sr exposure) and uncontaminated areas. An individual fish, known to have resided in WOCE, was recaptured 47 miles downstream in Watts Bar Reservoir. Even though the area of WOCE is relatively small, 8% of all smallmouth buffalo captured in Watts Bar Reservoir had detectable ^{90}Sr in their scales and thus showed autoradiographic evidence of some period of residency in the embayment.

Mobile fish species not only concentrate and accumulate toxic substances from their environment, but also provide a pathway for the transfer of toxic or radioactive substances from areas of contamination to uncontaminated areas. Because several highly mobile game fish species (i.e., striped bass, sauger, white bass) are frequently taken for human consumption, they constitute a potential avenue of contaminant transport and exposure.

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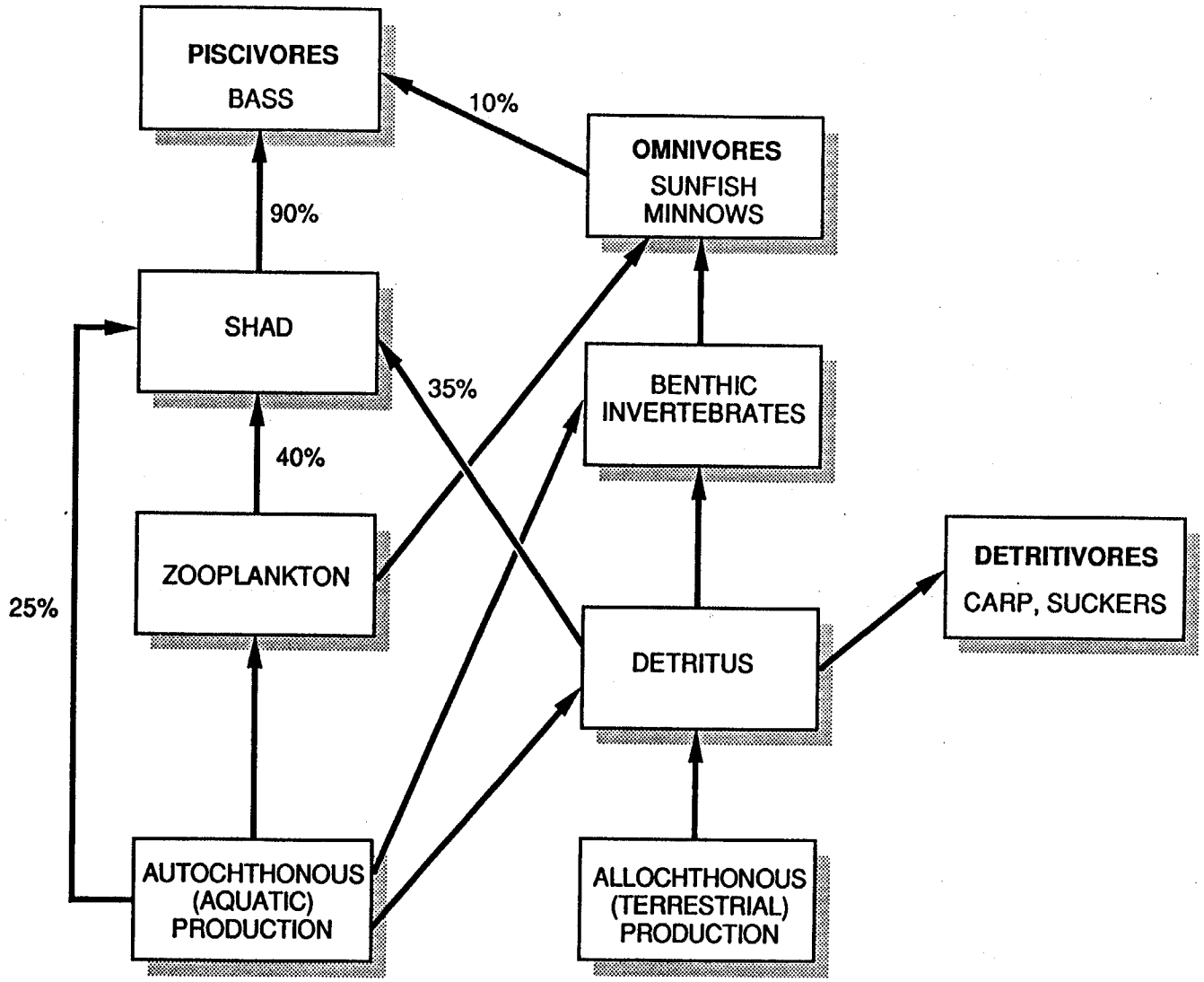

Fig. 3.7. Generalized food web diagram for the fish community of Watts Bar Reservoir.

3.2.3.4 Additional Receptors

In addition to fish species as potential environmental receptors to contaminants from WAG 2, waterfowl and deer have the potential to act as avenues of contaminant transport and exposure to humans. Waterfowl and deer populations in the ORNL area who ingest contaminated fish, vegetation, water, and sediments from the WAG 2 waste unit and migrate off-site are often taken by local hunters for direct consumption. Mean concentrations of ^{137}Cs and ^{60}Co in whole-body and various tissues of either have the potential to be above acceptable limits for human consumption.

3.3 ENVIRONMENTAL SETTING

3.3.1 Climate

The Oak Ridge area has a temperate climate with warm, humid summers and cool winters. The Blue Ridge Mountains to the east and the Cumberland Plateau to the west have a protective and moderating influence on the region's climate. As a result, the climate is milder than the more continental climate found just to the west on the Cumberland Plateau or on the eastern side of the Smoky Mountains. The prevailing winds in the Oak Ridge area follow the general topography of the surrounding ridges: daytime, up-valley winds come from the southwest and nighttime, down-valley winds come from the northeast (Fig. 3.8). The Cumberland Plateau to the west and the Smoky Mountains to the southeast divert severe storms, and tornados and high-velocity windstorms are rare. The mountains similarly divert hot, southerly winds which develop along the south Atlantic Coast. Slow-moving high-pressure cells suppress rain in the fall, remain nearly stationary for days, and provide for mild weather. Year-round mean temperatures are about 15°C (58°F) with a January mean of about 3.5°C (38°F) and a July mean of about 25°C (77°F).

Precipitation in this area of the Tennessee Valley is seasonally distributed (McMaster 1967). Peaks in precipitation usually occur in late winter-early spring and in mid- to late-summer. Winter storms are generally of low intensity and long duration; brief, heavy rains associated with thunderstorms are common in the summer. The annual minimum in precipitation usually occurs in the fall. The mean annual rainfall in the Oak Ridge area is about 136 cm (Fig. 3.9); however, during the recent drought of 1981—1988, the annual precipitation was about 30 to 35 cm less than the annual average.

An isohyetal map of the Oak Ridge area (Fig. 3.10) shows that mean annual precipitation ranges from more than 150 cm in the west to about 115 cm in the east.

Loss of water to the atmosphere by evapotranspiration is about 76 cm annually in the Oak Ridge area, or about 55% of the total annual precipitation. Evapotranspiration is at a maximum from July to September during the vegetation growing season. Runoff is greatest in the winter when evapotranspiration is low and precipitation is high. Precipitation not lost as evapotranspiration or as quick surface and shallow-groundwater runoff to streams percolates through the soil and eventually recharges the groundwater system.

ORNL–DWG 87-8700

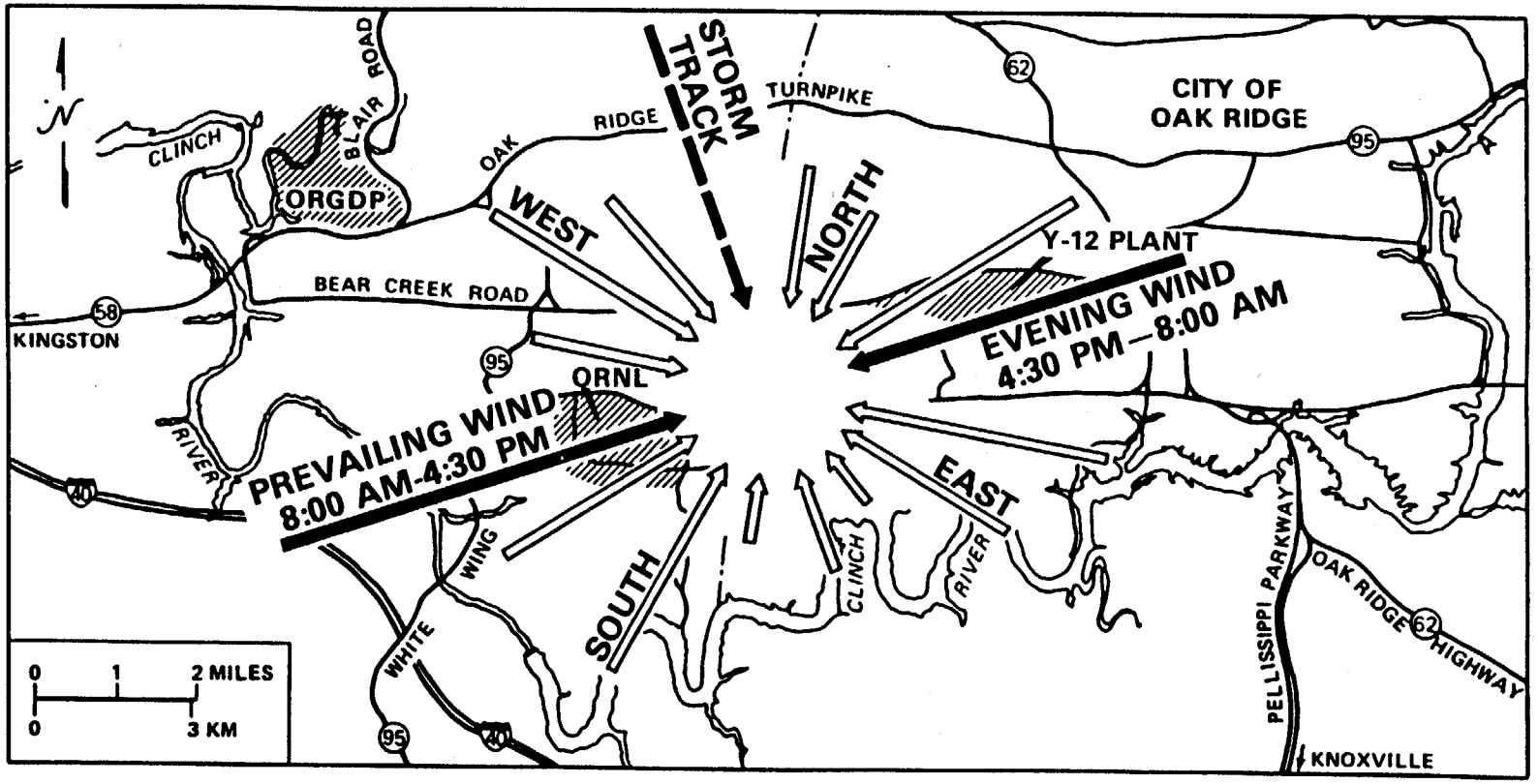

Fig. 3.8. Average wind frequency and direction for the Oak Ridge Reservation and vicinity.

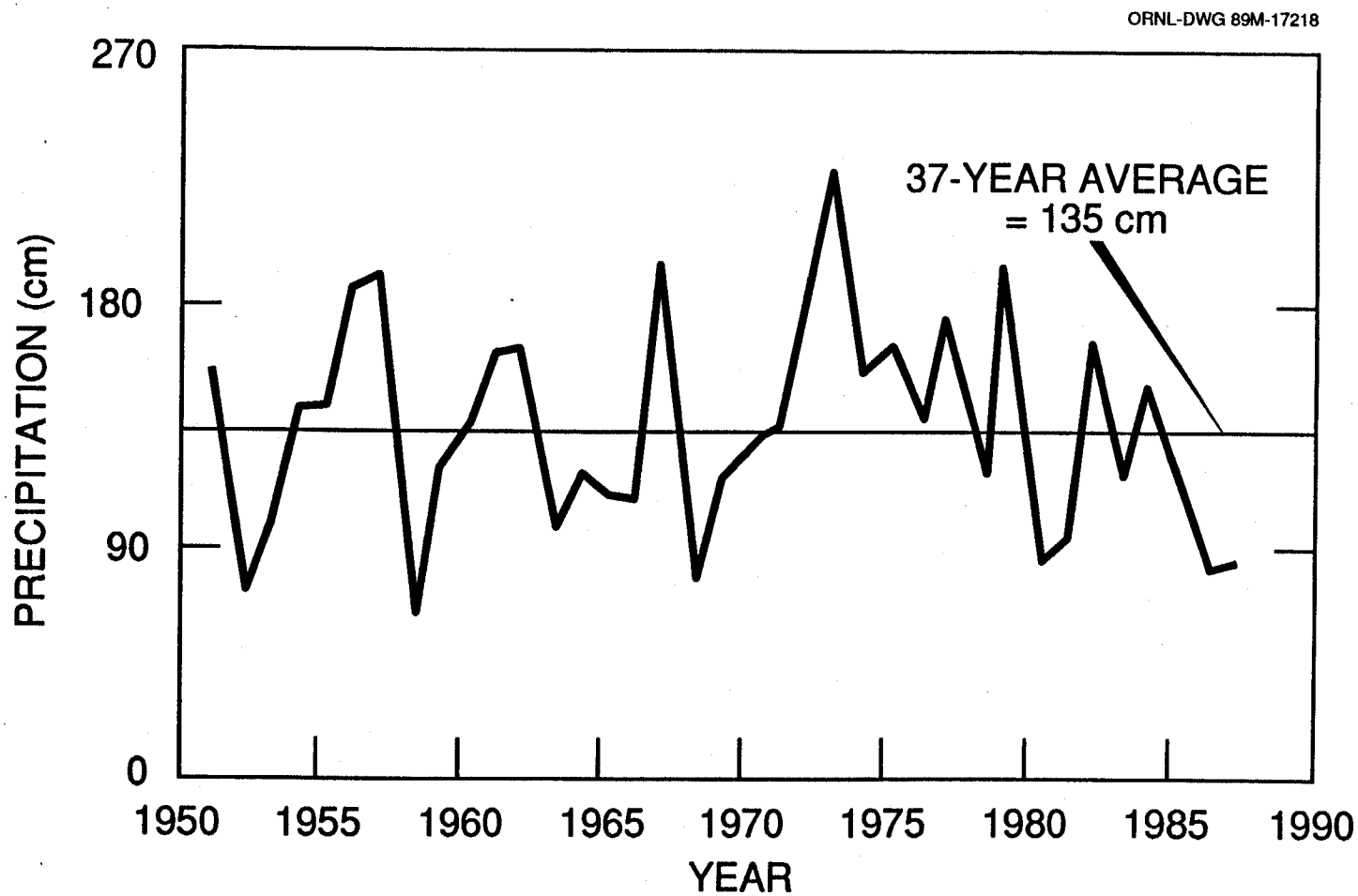

Fig. 3.9. The annual precipitation history of the Oak Ridge, Tennessee area.

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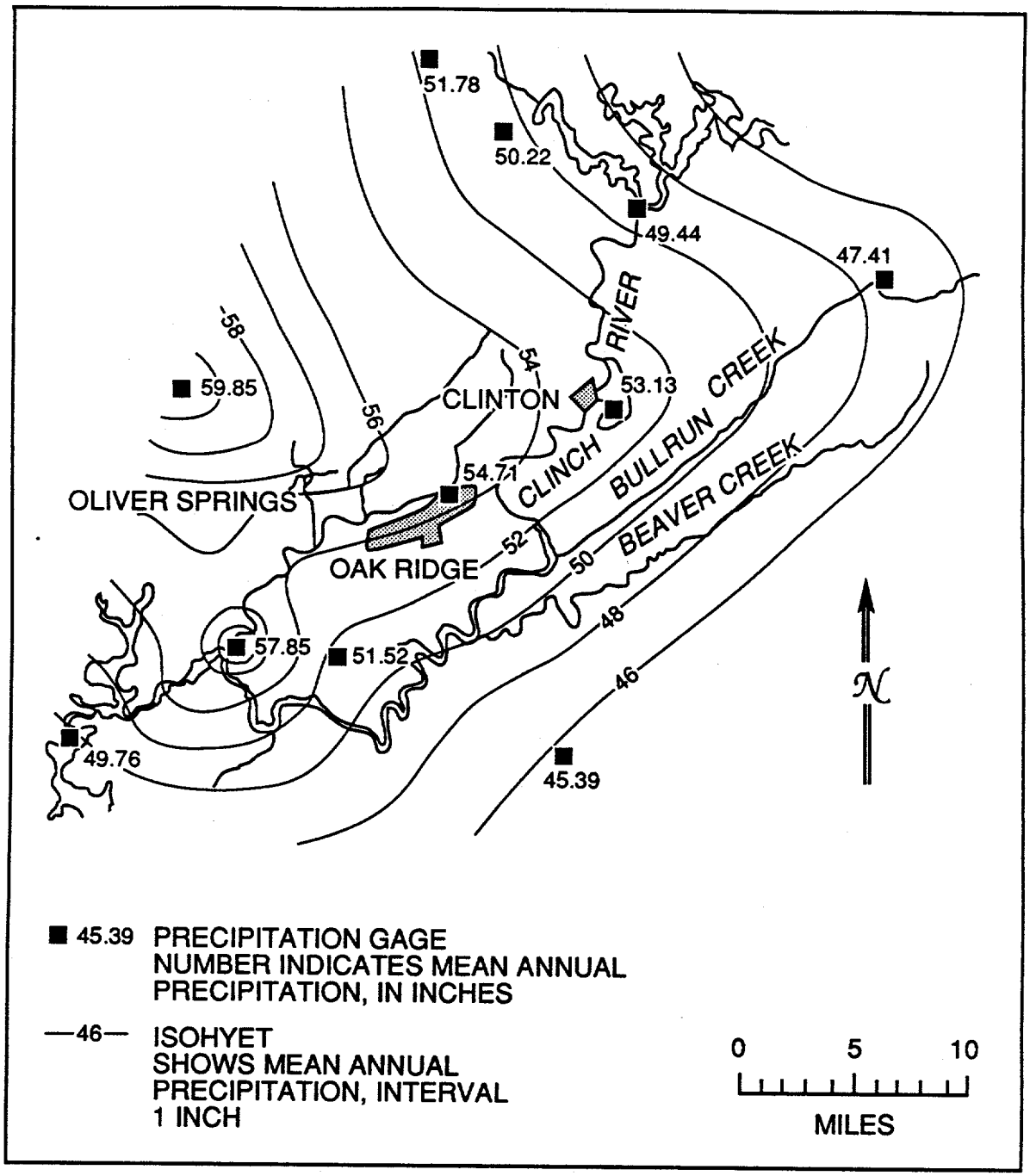

Fig. 3.10. **Isohyetal map of the Oak Ridge, Tennessee area showing a northwest-to-southeast decline in average precipitation. Map based on mean annual precipitation data for 1936-1960.**

3.3.2 Geology, Topography, and Soils

3.3.2.1 General geology

The DOE ORR, which includes WOC and WOL (WAG 2), is located in the Valley and Ridge physiographic province, part of the Appalachian fold and thrust belt. The area is characterized by a succession of northeast-trending ridges and valleys, which formed as a result of differential erosion of the clastic and carbonate lithologies that make up the individual thrust sheets.

WAG 2 is located in Melton Valley, which is bounded to the north and south by Haw Ridge and Copper Ridge, respectively. Maximum relief of the ridges is approximately 200 ft. These ridges and valley are part of the Copper Creek (CC) thrust sheet, which exposes Lower Cambrian to Ordovician rock units in the immediate area. The stratigraphy of the area, from oldest to youngest (and exposed from grid-north to grid-south), includes the Lower Cambrian Rome Formation (exposed on Haw Ridge), the Cambrian Conasauga Group (exposed in Melton Valley), and the Knox Group (exposed on Copper Ridge). The Conasauga Group is further divided into six formations of alternating shale and carbonate-rich lithologies. From oldest to youngest these are: the Pumpkin Valley Shale, the Rutledge Limestone, the Rogersville Shale, the Maryville Limestone, the Nolichucky Shale, and the Maynardville Limestone. Because geologic strike is approximately grid-east, the north-northeast trending streams in the WAG cut across the stratigraphy. Specifically, the northern section of WOC lies in the Pumpkin Valley Shale, Rutledge Limestone, and the Rogersville Shale. The southern section of WOC and the other streams in the WAG lie in the Maryville Limestone and the Nolichucky Shale. Abbreviated descriptions of the Consauga Group that underlies WAG 2 are included in Appendix A, and a geologic cross-section is presented in Fig. 3.11.

Geologic factors that influence contaminant transport in WAG 2 include those that define the flow paths of the shallow groundwater system (geologic structure, detailed weathering characteristics of various lithologies) as well as characteristics that influence retardation of contaminants (stratigraphy/petrology). For example, the location of the seeps presented in Fig. 3.12 are geologically controlled, and these seeps are potential connectors between the shallow groundwater and surface water systems. No specific studies have been directed toward collecting this type of geologic information for WAG 2. However, geologic investigations have been conducted in Melton Valley and a brief discussion of Melton Valley geology is presented in Appendix A.

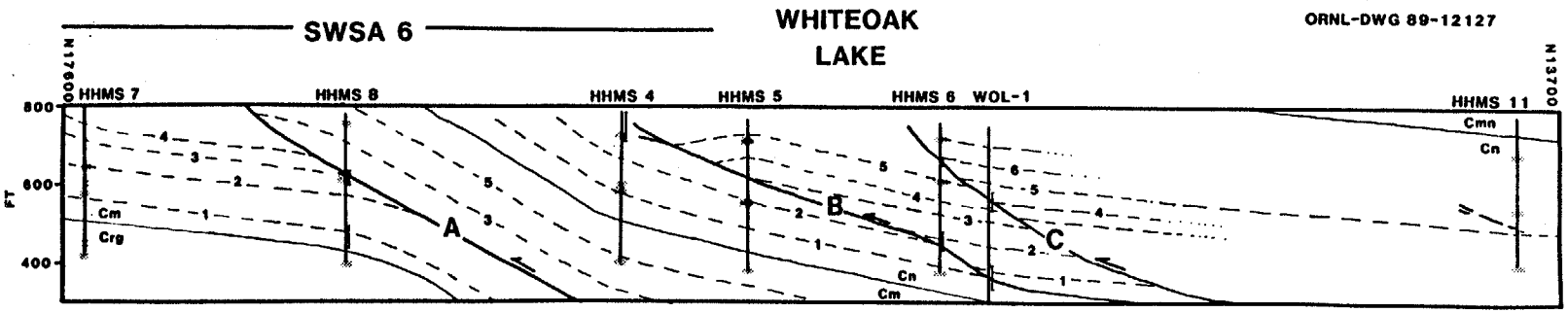

Fig. 3.11. Strike-perpendicular geologic cross-section through SWSA 6 and White Oak Lake. Stratigraphic and structural data from HHMS A borcholes from site 4 through 8, WOL - 1, and HHMS 11A are projected along a grid-east direction to the line of section. Crg = Rogersville Shale, Cm = Maryville Limestone, Cn = Nolichucky Shale. Numbered horizons represent informal stratigraphic divisions within a formation. A, B, and C are thrust faults.

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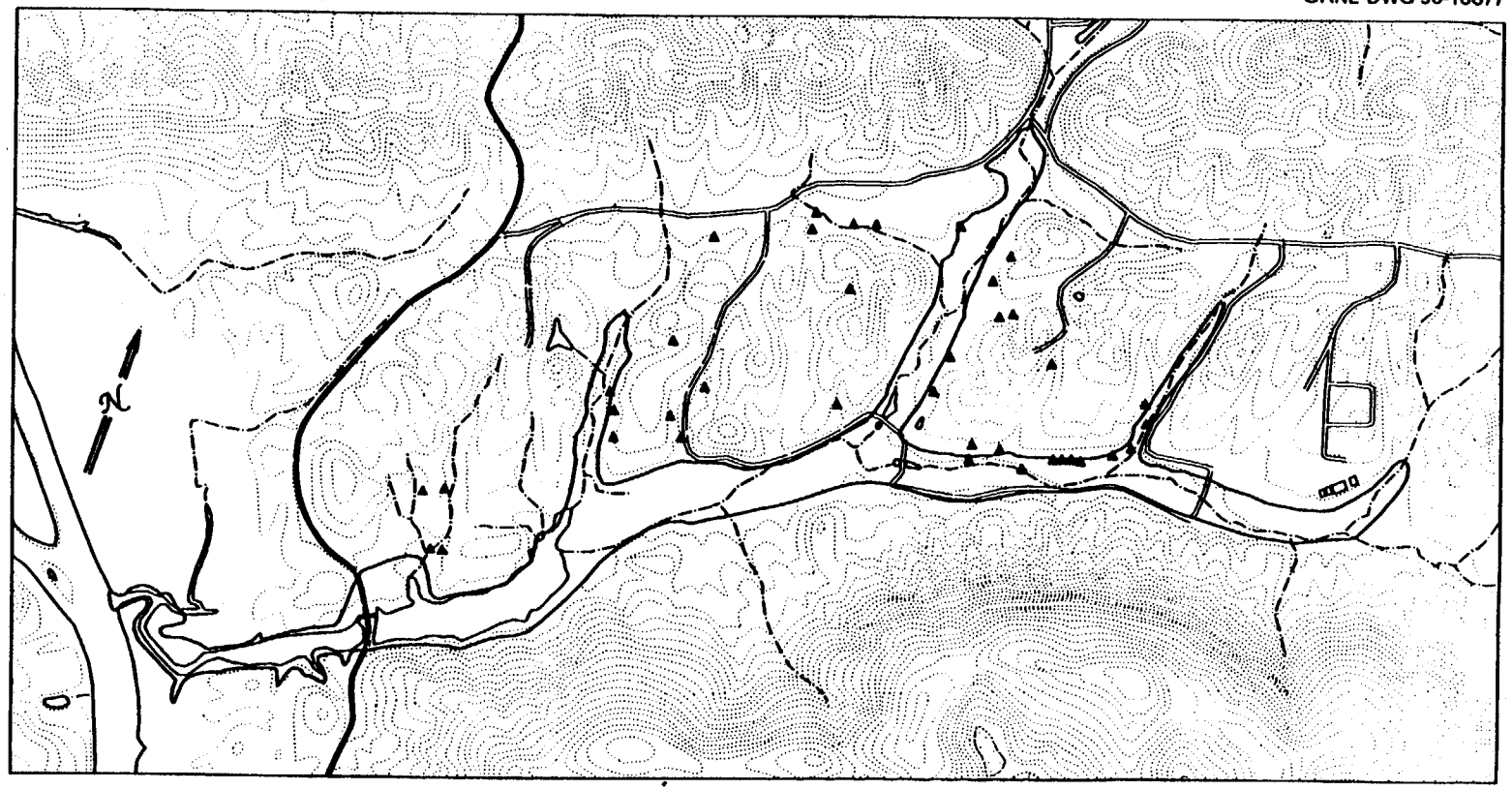

1 inch = 1647.1 feet

Fig. 3.12. Location of seeps (▲) identified in the regions bordering WAG 2. This map is incomplete because only specific areas in WAGs 4 through 7 have been investigated for seeps. Data collected from Zondlo (personal communication); Duguid and Sealand 1975; Duguid 1975; Moore personal communication; Wickliff et al. 1989; Melroy et al. 1986; Wickliff (personal communication); and Solomon et al. 1989.

3.3.2.2 Structure

Faults. WAG 2 is located on the Copper Creek (CC) thrust sheet, which is floored by the Copper Creek thrust fault. The CC is a regional thrust fault of the Valley and Ridge, which shows at least several kilometers of displacement. The fault formed during the Permian-Pennsylvanian Alleghanian Orogeny and has not been historically active. In the vicinity of WAG 2, the fault trends parallel to regional strike (N55E) and dips shallowly (15-5°) to the southeast. Bedding planes dip values measured in outcrop are similar to the dip of the fault (Dreier et al. 1987), but locally may steepen to vertical as a result of local small-scale folding or faulting.

Melton Valley is characterized by numerous cross-strike streams with a consistent northward trend, the largest of these being WOC. Such a consistent orientation suggests that the location of these creek beds is controlled by a geological structural feature, either a minor tear fault or a prominent fracture trend. If these structures are faults, they show minor displacement but should have an associated fracture zone. The fracture zone may be more (or less) permeable to fluids than the surrounding rocks, depending on local lithologic characteristics, fault history, and depth of investigation. Because WOC shows a prominent topographic expression and there is offset of minor ridges on opposing sides of the creek, a fault—the WOC Tear Fault—has been proposed to underlie the north-trending portions of WOC (personal communication, R. B. Dreier - ORNL).

3.3.2.3 Fractures

Because of the large-scale faulting, all geologic units in ORR are highly fractured. Detailed investigations of saprolite in the Conasauga Group show that three fracture sets occur consistently. One set is parallel to bedding; the other two sets are perpendicular to bedding and are either strike-parallel or strike-perpendicular. The bedding-parallel fractures are interpreted to be predominantly release joints. The other sets may also have formed by a release mechanism. Recent studies elsewhere in the Appalachians suggest that release joints can form at depths up to a kilometer (Engelder 1985). All fractures measured in the saprolite are open and conductive to fluids.

Fracture density varies considerably with depth. The greatest densities are measured in the shallow saprolite, averaging ~60 ft. Fracture densities decrease with an increase in depth and are much lower in competent rock; however, specific fracture densities have not been quantified below the saprolite horizon.

Topography. Because WAG 2 is a floodplain, there is very little topographic variation. The slope of WOL and the embayment is negligible for most purposes. WOC above the weir has an average slope of less than 1%, and above the weir at MB the slope is about 1.5%. The average slope in West Seep Tributary is about 1.9%.

The topography for the entire watershed is shown in Fig. 3.13. In this figure, contour intervals are 5 ft, and they are not labeled for clarity. The typical valley-ridge pattern of relief is evident across the watershed. Compared to a nominal level for WOL of 455 ft, the maximum elevation of Copper Ridge to the south is 1355 ft. In the middle of the watershed there is the series of knolls or hills underlain by the Maryville formation, and the maximum elevation of that formation in the Pits and Trenches area (approximately E27,000; N18,000) is 866 ft. This set of hills tends to increase in elevation toward the headwaters of MB. Haw Ridge, underlain by the Rome formation, has a maximum elevation of 1047 ft, and Chestnut Ridge to the north has a maximum elevation of 1188 ft.

3.3.2.4 Soils

The differentiation between soils and sediments in WAG 2 is somewhat arbitrary in that the soils are depositional, i.e., they were deposited as sediments and, like the sediments in thechannels, are subject to resuspension and movement under certain hydrological conditions. For this report the soils are considered to be all the unconsolidated surface material not found in the channels or in the normal range of the lake level. For characterization of soils the main issues are what are the distributions of contaminants within the WAG and what are the conditions for future translocation and discharge under stream discharge conditions of varying frequency. Factors affecting mobility, such as grain size and sorption properties, are important. Macroscale parameters, such as topographic slope and erodibility, are also important. It is also important to establish the rates of transport of both uncontaminated and contaminated soil from surrounding areas. Inflow of uncontaminated soils might cover existing contaminated areas and so be beneficial; however, deposition of clean sediment in contaminated areas can add to the total amount of soil to be removed if a removal option is selected.

There is no modern survey or map of the soils for the entire WOC basin or for WAG 2 in particular. The soils of Roane County, which include all of WOC basin except for a small area at the northeast edge of the basin, were mapped in the 1930s, and the results were published in 1942 at a scale of 1:48000 (Swann et al. 1942). (See Fig. 3.14 and the list of soil series symbols in Table 3.6) The soils from this survey have been classified according to hydrologic group for purposes of watershed hydrologic modeling (Tschantz and Rghebi 1989).

According to the county survey, above the WOC-MB confluence and for a short section below the West Seep Tributary outfall to WOC, WAG 2 is mapped as Pope gravelly fine sandy loam. The lower part of WAG 2, including the areas now covered by WOL and lake sediments, is mapped as Pope fine sandy loam. Because of refined methods of soil mapping and the many changes in the basin, that Roane County soil map is outdated.

There are other pertinent descriptions of the soils found on ORR. Lietzke et al. (1988) describe the soils in the Bear Creek area near State Highway 95, which, because of repetition of geological lithology, is similar to Melton Valley. According to Lietzke (personal

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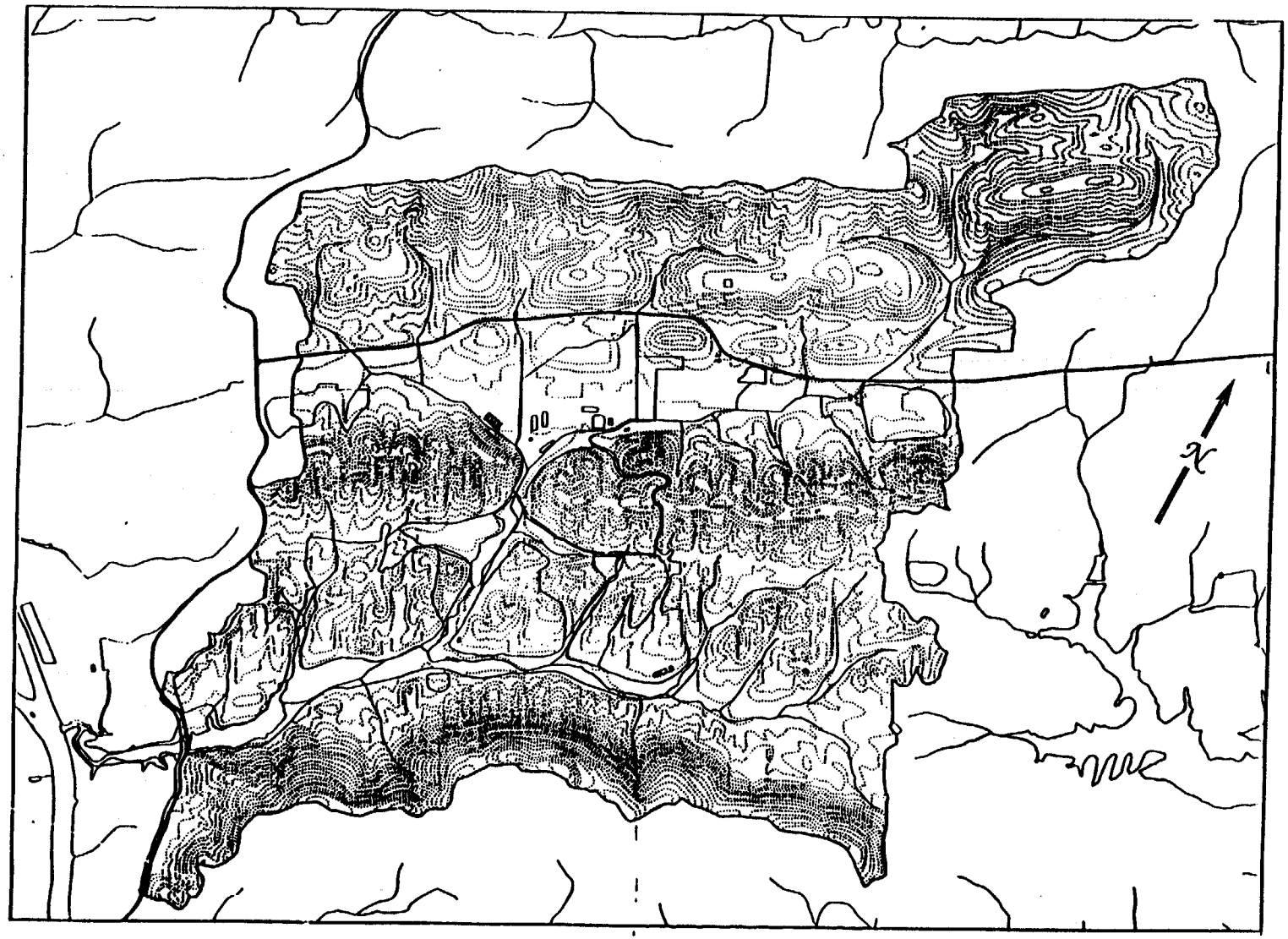

Fig. 3.13. Topography of the White Oak Creek watershed. Contour intervals are 5 ft. Boundary of WAG 2 is also shown.

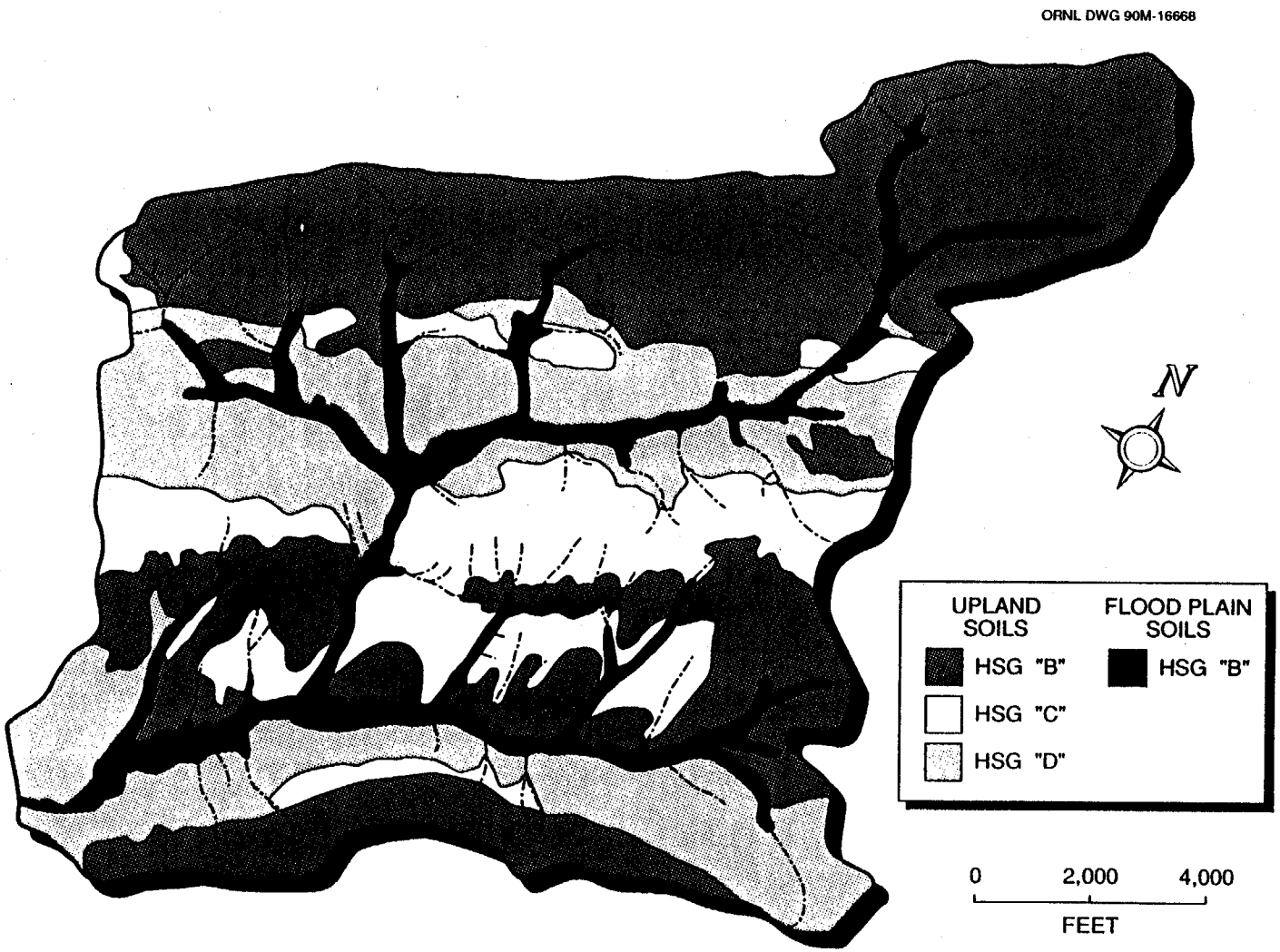

Fig. 3.14. White Oak Creek watershed soils classified according to hydrologic groups (HGs). See Table 3.6 for soil series and HSGs. The HSG *B* soils class has been separated into upland and floodplain soils.

Table 3.6. White Oak Watershed Hydrologic Soil Groups.

County	Symbol	Soil group description	HSG
Roane	As	Armuchee silt loam	D
	Pv	Pope v.f. sandy loam	B
	Ps	Philo v.f. sandy loam	B
	Cs	Colbert silty clay loam	D
	Avk	Apison v.f. sandy loam	B
	Pg	Pope grav f. sandy loam	B
	Ls	Lehew stony f. sandy loam	C
	RgA	Gullied land-Apison soil	B
	Cl	Colbert silt loam	D
	Cc	Clarksville chrty slt loam	B
	Fc	Fullerton cherty silt loam	B
	Fcl	Fullerton cherty silt loam	B
	Fcz	Fullerton cherty silt loam	B
	Us	Upshur silty clay loam	C
	Rsc	Stony land-Colbert/Talbot	D/C
	Ts	Talbott silty clay loam	C
	Ccz	Clarksville cherty silt loam	B
	Ccl	Clarksville cherty slt loam	B
	Avr	Apison v.f. sandy loam	B
	Ll	Lindside silt loam	C
	Clx	Colbert silt loam	D
	Fcr	Fullerton cherty silt loam	B
	Ml	Melvin silt loam	D
	Fct	Fullerton cherty silt loam	B
	Tsl	Talbott silty clay loam	C
	Rst	Talbott stony material	C
	Rgf	Fullerton-rough gullied	B
	Rg	Roane gravelly loam	B
	Dsl	Dewey silty clay loam	B
	Dm	Dewey silt loam	B
	Ds	Dewey silty clay loam	B
	Fck	Fullerton cherty silt loam	B
	Dsz	Dewey silty clay loam	B
Anderson	Fud	Fullerton cherty silt loam	B
	McC	Minvale cherty silt loam	B
	BoD	Bodine cherty silt loam	B
	Fue	Fullerton cherty silt loam	B
	Geb	Greendale silt loam	B
	Fuc	Fullerton cherty silt loam	B

communication) much of the deposited soils in Melton Valley will be very similar to four soil units that are lumped as Maryville and Nolichucky alluvium. The Maryville Limestone within the Conasauga Group forms the discontinuous knolls and hills to the north side of WOL and MB, and the Nolichucky Shale is a more eroded lithological unit at the toe slope of the Maryville formation. The soils are described in Table 3.7, and all of them are characterized as buried soils, where older horizons have been covered by newer material, probably in modern times (since the Holocene). The soil units range from well drained (unit 98A,-B) and moderately drained (unit 100A) to poorly drained (units 99 and 101A). The local characterization and distribution of these soils in WAG 2 have not been determined. Other generalized descriptions of soils and soil-forming processes applicable to the WOC basin and WAG 2 are reported by Lee and Ketelle (1987).

Soils in the WOC basin. Detailed soil maps have been developed for relatively small portions of the basin (SWSA 6 and proposed SWSA-7), as shown in Fig. 3.15. In addition, soils have been mapped but not yet reported for a small portion of the watershed in the central Chestnut Ridge area.

The reports associated with these maps describe the parent materials that have been transported to the floodplain and the soil-forming processes, mineralogy, physicochemical characteristics, and geomorphology of the soils in the uplands and gullies of contributing tributaries.

Most of the soils are either residual soils formed in place or colluvial/alluvial material derived from the residuum (Lietzke and Lee 1986). Residual soils, which often have a thicklayer of saprolite above the coherent bedrock, result from the chemical weathering by the downward percolation of water, which removes the soluble constituents, including calciumcarbonate. Soils are usually acidic, often having a large pH gradient from the surface to the underlying rock. The colluvium was formed as soil was washed down hillsides during extreme variations in climate in the late Pleistocene or Holocene.

The map of soils for SWSA 6 (Lietzke and Lee 1986) is shown in Appendix B. Soil from trenches dug in the Maryville regolith is highly fragmented and subject to erosion whereas colluvial soils, which are formed of sorted material washed or carried down hill slopes, have reduced clay content and are more permeable and less subject to erosion. The soils map for proposed SWSA 7 (Rothschild et al. 1984) is also shown in Appendix B. Soils in comparable map units in the two areas tend to have lesser clay content in SWSA 7 than in SWSA 6 (Lietzke and Lee 1986); therefore, the floodplain soils in upper MB can be expected to be coarser than those closer to WOL. A detailed map of soils is needed in the WAG.

3.3.3 Groundwater

Hydrogeologic studies of ORR (Moore 1988, 1989; Webster and Bradley 1987) have shown that subsurface materials in vegetated areas, like WAG 2, consist of a surficial stormflow zone, a vadose zone, and a groundwater zone. The stormflow zone approximately corresponds with the root zone of vegetation and is much more permeable than the

Table 3.7. Maryville and Nolichucky alluvial soils in Bear Creek Valley similar to WAG-2 Soils.

The soils in these map units classify as Typic and Aquic Udifluvents; coarse or fine-silty, mixed, thermic. These soils have much higher silt content than either the Rome or Pumpkin Valley alluvial soils. They are in narrow drainageways in larger areas of Rogersville, Maryville, and Nolichucky soils. These well-drained and moderately well drained soils are undifferentiated with respect to degree of wetness. Most areas of these soils have a well-defined and entrenched channel. The largest areas of these soils occur on the floodplain and low terraces of Bear Creek. Nearly all areas of these soils have a buried soil at a depth between 50 and 100 cm. Narrow areas of these soils were probably never cultivated and currently support hardwood trees, but larger areas adjacent to Bear Creek were cultivated and now support cane, walnut, planted pines, and other species associates with old field succession.

These soils in this map unit classify as Typic and Aeric fluvaquents; fine or coarse-silty, mixed, thermic. These somewhat poorly drained soils occur in nearly level drainageways within areas of Rogersville, Maryville, and Nolichucky soils that contribute high-silt-content sediments to these drainageways. Most areas of these soils have a buried soil at a depth between 50 to 100 cm. Most areas of these soils either contain springs or seepage zones or have no defined channel and thus remain in wet most of the year. Present vegetation consists of hardwoods with a ground cover of water-tolerant plants.

The soils in this map unit classify as Typic and Aquic Udifluevents; coarse or fine-loamy, mixed, thermic. These soils are moderately well drained to somewhat poorly drained; they formed in a thin veneer of Modern alluvium <50-cm thick over a wet soil (Typic Ochraqualf; fine, mixed or montmorillonitic, thermic) derived from the Maynardville Limestone. Most areas of these soils occur within the present-day floodplain of Bear Creek before the creek turns northerly and cuts through Pine Ridge. In some areas, remnants of an old, cherty paleosol commonly occur just above the bedrock, especially close to the lowermost floodplain.

The soils in this map unit classify as Aeric Ochraqualfs; fine-silty, mixed, thermic. These soils formed in alluvium of the same ages as the No. 951 alluvial soils, but they have a surficial capping of loess overlain by younger Modern alluvium that is <50-cm thick. These somewhat poorly drained soils occupy the nearly level abandoned paleo floodplain and wider channels of Bear Creek. Presentday vegetation is a dense stand of hardwoods and abundant ground cover of poison ivy.

Source: *Lietzke et al. 1988.*

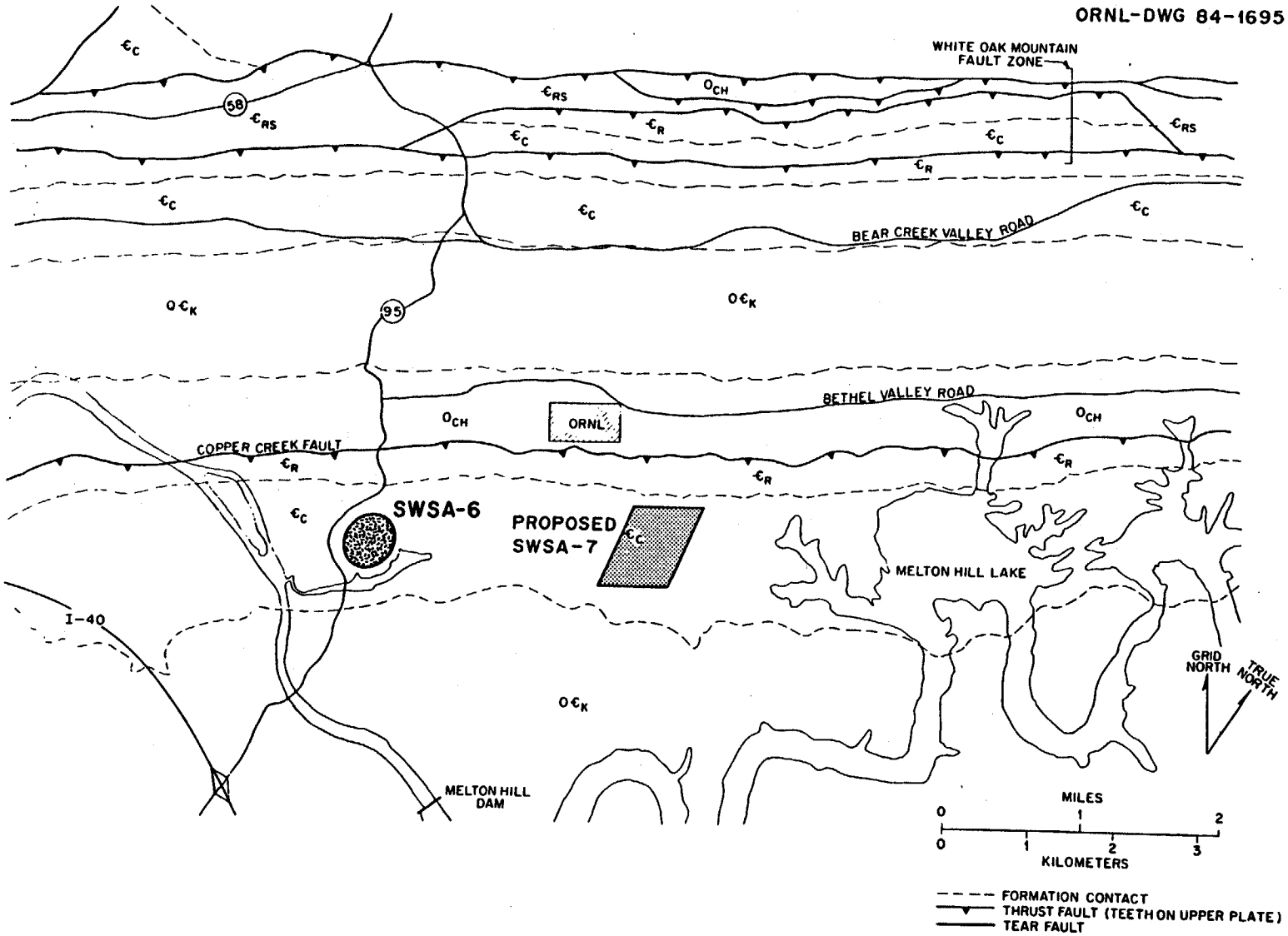

Fig. 3.15. Map showing location of SWSA 6 and proposed SWSA 7.

underlying vadose zone. Many precipitation events produce a transient, perched water table in the stormflow zone, and water is then transmitted downslope to nearby streams (Fig. 3.16). The permanent water table occurs near the regolith and bedrock contact at a depth of <3 m in most of the WAG 2 area. Recharge to the water table occurs at the higher elevations in WAG 2 by slow downward seepage of water after precipitation events. All groundwater is discharged to nearby streams along lateral and upward flow paths (Webster and Bradley 1987; personal communication, G. K. Moore - ORNL). The stormflow and groundwater zones are connected near the streams and may also be connected on steep hillsides above WAG 2. Most groundwater thus follows flow paths that extend into and through the stormflow zone to reach the streams.

Stormflow monitoring tubes were recently installed from land surface to a depth of 79 cm at 17 locations (Fig. 3.17) in the headwaters of MB, upstream from WAG 2. All monitoring tubes had some water inflows, indicating a perched water table, during precipitation events, but tubes on steep slopes and in gullies generally had water inflows during small events, whereas larger or more intense events were required to produce inflows to tubes near a drainage divide and on smooth and shallow slopes. During periods of intense precipitation, overland runoff was observed near some monitoring tubes in gullies and swales, but overland run-off apparently occurs only after the stormflow zone fills to overflowing. The overflow creates source areas and wet weather springs; the resulting run-off and erosion apparently explain the gullies. The recession rates of water levels in the stormflow monitoring tubes and in observation wells can be used to calculate streamflow components after precipitation events. During the period February 15 through 25, 1990, for example, measured streamflow was 71% of precipitation and consisted of 41% overland flow, 48% subsurface stormflow, and 11% groundwater discharge (Fig. 3.18). Calculations based on a chemical mass balance for streamflow and on groundwater flow rates show that stormflow constitutes 80 to 90% of all subsurface water flow to the streams.

Water storage is intergranular in the stormflow zone, but macropores and mesopores (>0.2 mm diam), formed by root channels, worm tubes, and other processes, are the dominant openings for lateral flows and drainage. The effective porosity of the stormflow zone is about 0.015—0.020 in the headwaters area of MB. Lateral flow paths for water generally follow the slope of land surface in this zone, and the average hydraulic gradient in the WOC basin is about 0.075 (Moore 1989). In WAG 2, which has many flatter areas, the average cross-valley hydraulic gradient is 0.016, and the average down-valley hydraulic gradient is about 0.007. The hydraulic conductivity of the stormflow zone in areas near WAG 2 has been measured by infiltration tests under saturated conditions. These data are lognormally distributed and have a large range (Fig. 3.19). The geometric mean of infiltration rate is 8.8 m/d, and the range from the mean minus one to the mean plus one standard deviation is 3.2 to 23 m/d (Moore 1989). One-hour precipitation intensity in this area does not exceed 1.9 m/d (McMaster 1967). Virtually all of the precipitation is therefore absorbed by vegetated soils, and overland run-off occurs mainly on saturated soils.

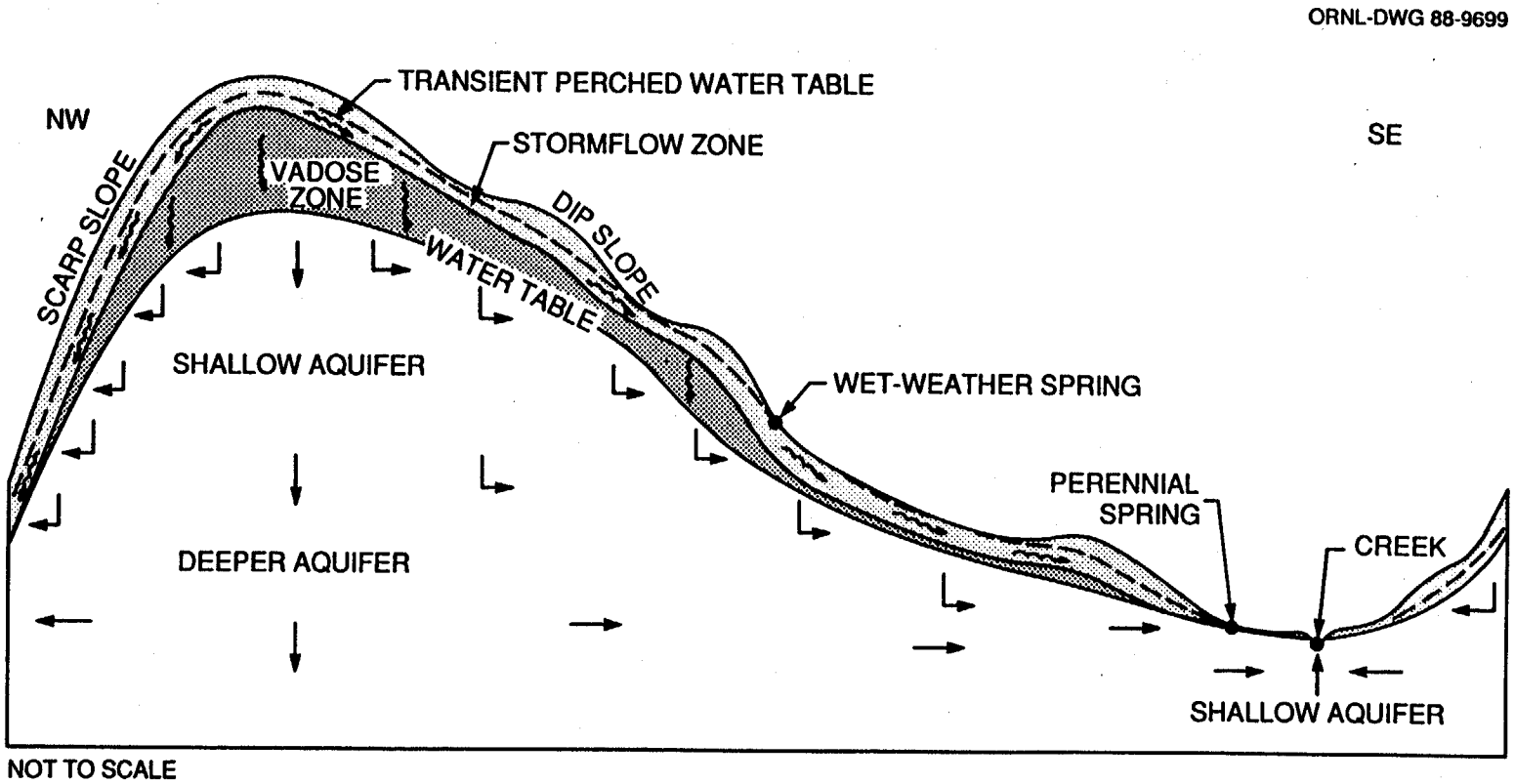

Fig. 3.16. Section showing subsurface zones and direction of groundwater flow.

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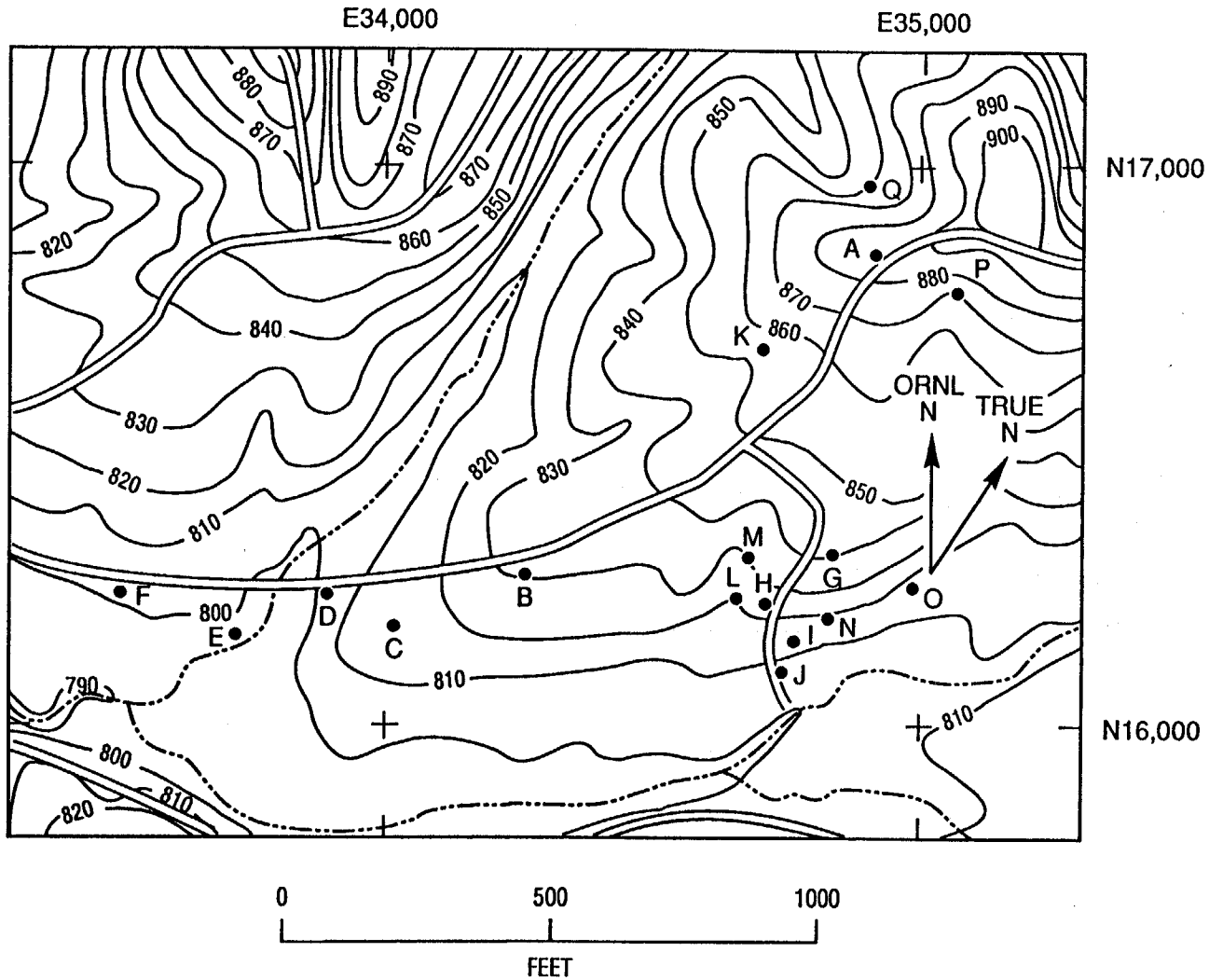

Fig. 3.17. Map showing locations of stormflow monitoring tubes in the headwaters area of Melton Branch.

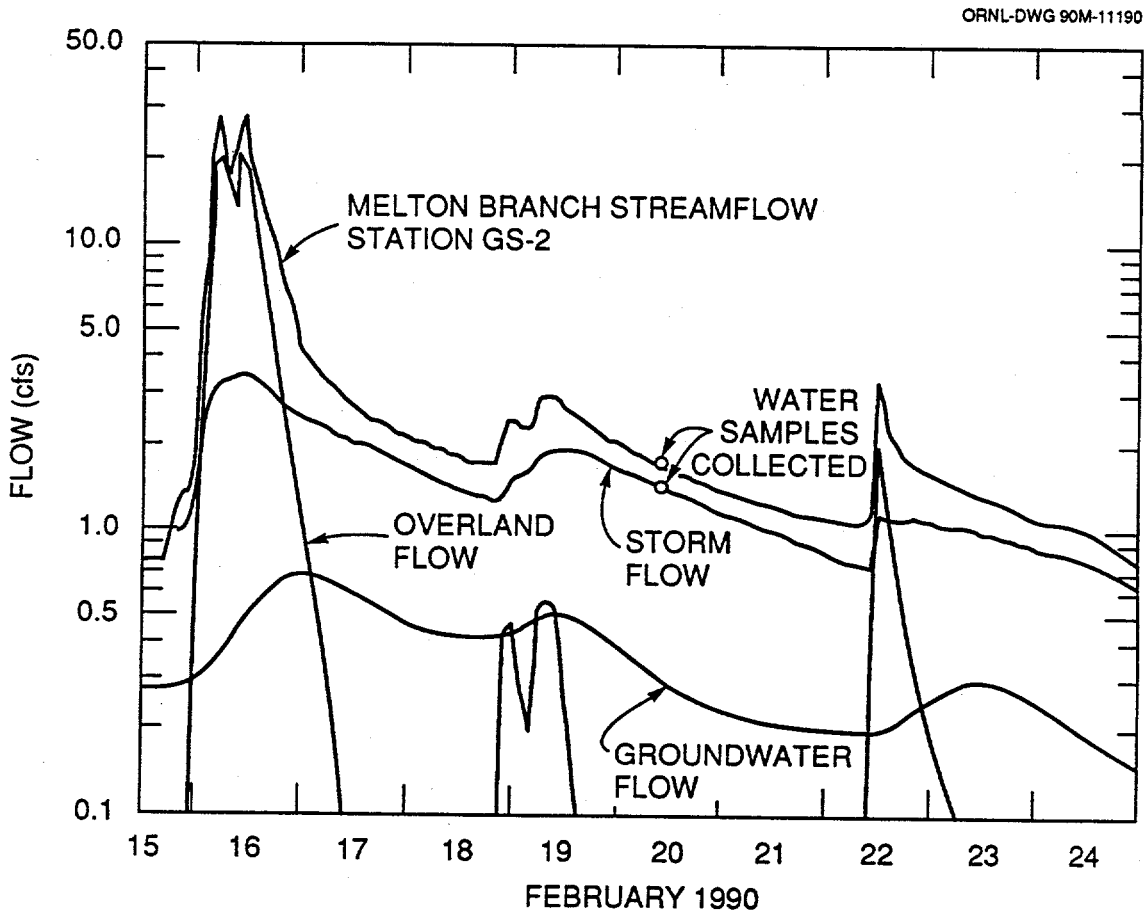

Fig. 3.18. Hydrograph separations for Melton Branch during February 15-25, 1990.

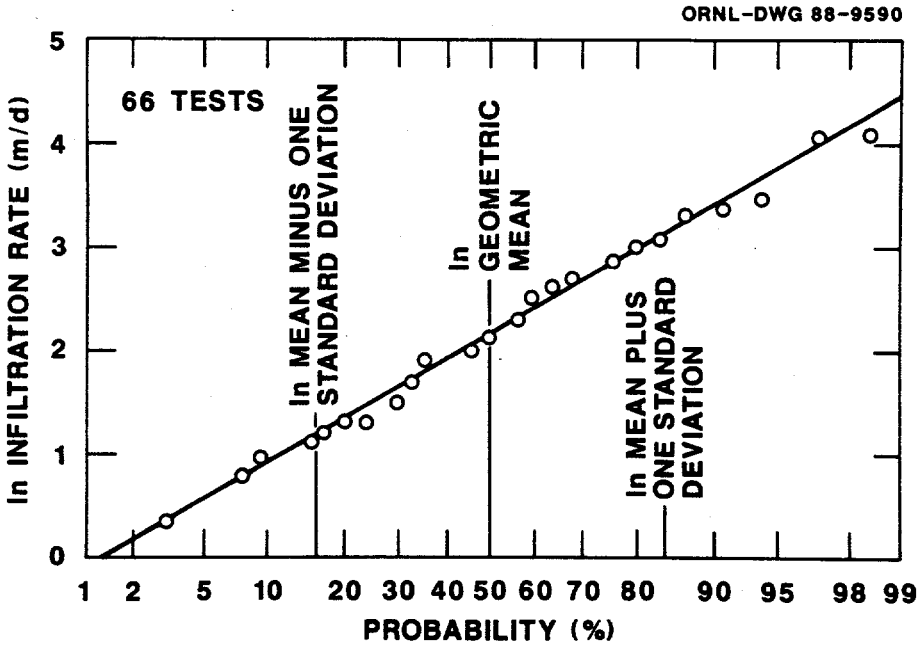

Fig. 3.19. Lognormally distributed hydraulic conductivity data of the stormflow zone in areas near WAG 2.

Water in the stormflow zone is slightly acidic. The arithmetic mean of pH for 150 measurements is 5.8, and the range from the mean minus one to the mean plus one standard deviation is 5.2 to 6.5. This water is a calcium bicarbonate type and has smaller concentrations of magnesium, sodium, and (probably) sulfate. Data for about 200 water samples show that the concentrations of the chemical constituents are lognormally distributed. The geometric mean of total hardness, as $CaCO_3$, is 41 mg/L; the geometric mean of total alkalinity, as $CaCO_3$, is 48 mg/L; and the geometric mean of specific conductance is 109 μmhos/cm at 25°C. All water samples from the stormflow monitoring tubes were cloudy to muddy, and nearly all of the suspended sediment was colloidal in size. The concentration of suspended sediment was not measured and probably was small. Nevertheless, the discharge of colloidal material from the stormflow zone may explain turbid streamflows after small precipitation events, and some pollutants could be sorbed by these colloids in contaminated areas and thereby transported to the streams.

In WAG 2, the vadose zone is 0 to 2 m thick and consists of fractured clayey regolith and weathered bedrock. The vadose zone is unsaturated except in the capillary fringe and except within wetting fronts during periods of vertical percolation from the stormflow zone to the water table. The geometric mean of hydraulic conductivity for 38 infiltration tests in the vadose zone near WAG 2 is 0.0019 m/d, and the 10 to 90% probability range is about 5×10^{-4} to 0.3 m/d (Moore 1989). The effective porosity, as calculated from the times and lengths of recharge periods, is about 0.004 (Moore 1989).

The groundwater zone consists of relatively permeable fracture intervals in a relatively impermeable matrix. About 20 tests with a sensitive electromagnetic borehole flowmeter in the WOC basin showed that the average thickness (vertical dimension) of the permeable intervals is about 60 cm and that the range is about 30 to 150 cm. Five of these tests were in WAG 2. The vertical spacing between permeable intervals increases from about 7 m near the water table to >35 m below a depth of 60 m. A cumulative probability graph (Fig. 3.20) of transmissivity data from slug tests, packer tests, and pumping tests shows two lognormal populations. The upper population on the graph represents permeable intervals; the geometric mean of transmissivity is 0.19 m^2/d, and the range from the mean minus one to the mean plus one standard deviation is 0.020 to 1.8 m^2/d. The lower population represents matrix intervals, and the geometric mean of transmissivity is 0.0018 m^2/d. The average effective porosity of the groundwater zone, as determined from tracer tests and pumping tests, is about 0.001 (Moore 1989), and storativity is about 5×10^{-4}. The average hydraulic gradient in the WOC basin is about 0.050 (Moore 1989); in WAG 2, the average hydraulic gradient in the groundwater zone is the same as in the stormflow zone.

Flow paths in the groundwater zone are determined by fracture orientations. Bedding planes constitute one set of fractures; the other two common fracture sets in Melton Valley (Dreier et al. 1987) are steeply dipping and trend approximately parallel to geologic strike (along-valley parallel) and parallel to dip (cross-valley parallel). Hydrogeologic studies in the WOC basin, as summarized by Webster (1976), agree that fracture permeability is larger in the along-valley direction than in the cross-valley direction and that, if other factors are equal, more groundwater is discharged to cross-cutting, tributary streams than to a stream along the

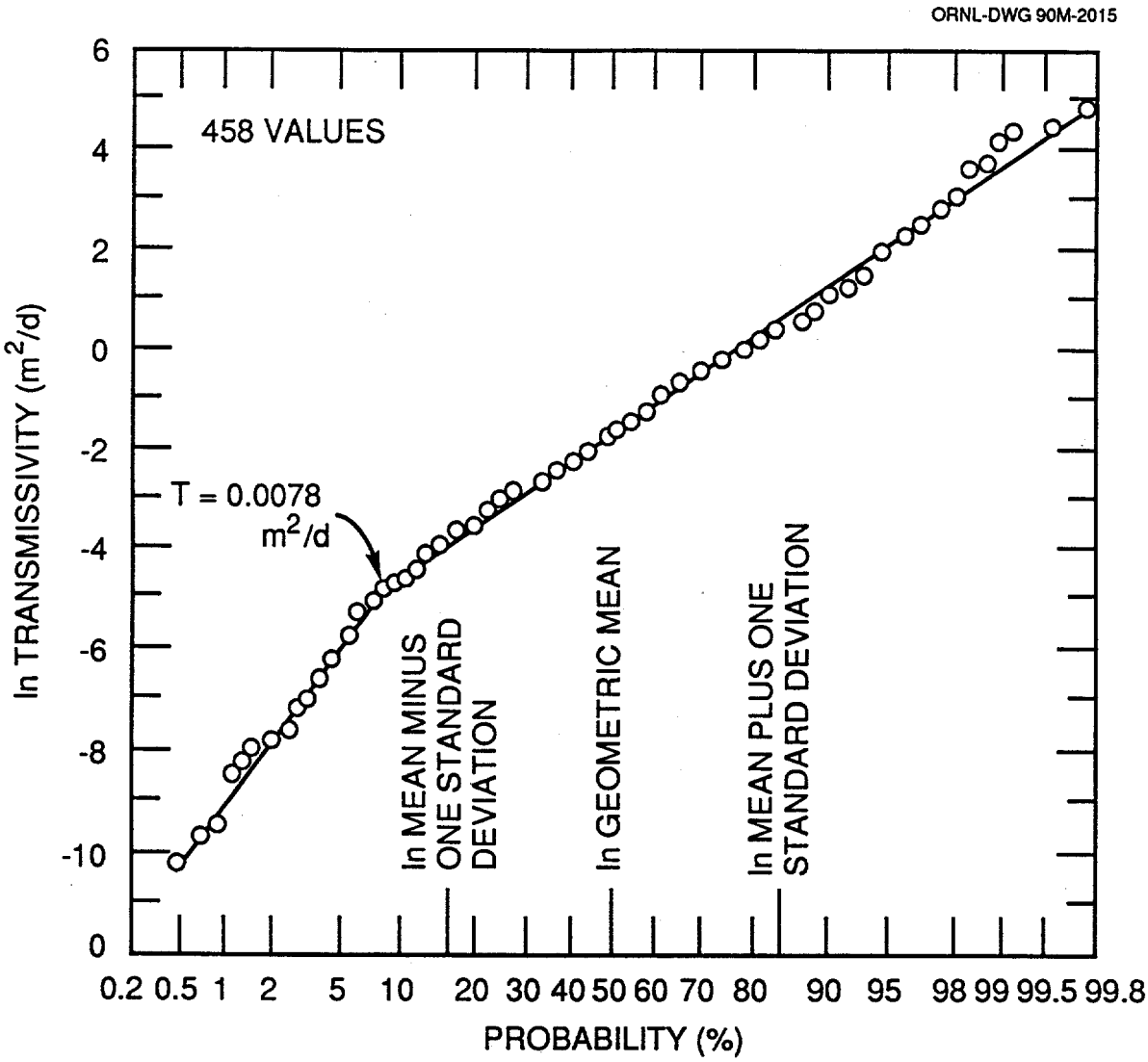

Fig. 3.20. Cumulative probability graph of transmissivity data from aquifer tests in the ORNL area.

valley axis (Webster and Bradley 1987). A conceptual model (Fig. 3.21) shows that if the orientations of permeable intervals are mainly controlled by bedding planes, along-valley flows of groundwater occur within permeable intervals whereas cross-valley flows move through both permeable and matrix intervals. This model is hypothetical but explains the observed anisotropy in the groundwater zone. In WAG 2, the main channel of WOC through Haw Ridge and the tributary streams in Melton Valley would thus be expected to have larger inflows of groundwater per unit channel length than would MB and the channel of WOC below its junction with MB.

Progressively less groundwater follows deeper flow paths because of longer path lengths and because more matrix intervals occur along the flow paths. The base of active groundwater circulation is irregular to gradational and is not determined by stratigraphy. However, several other criteria can be used for an estimate of this depth. First, shallow groundwater, as shown below, is a slightly alkaline, calcium bicarbonate water type. However, wells deeper than 30 to 40 m commonly produce a sodium bicarbonate water with a pH in the range of 8.3 to 11.5, and wells deeper than about 150 m have a slightly acidic, sodium chloride water type with a dissolved solids content as large as 300,000 mg/L. Secondly, the transmissivities of permeable fracture intervals generally decrease with depth. The geometric mean of transmissivity for wells deeper than 30 m is only 0.1 times as large as for shallower wells. The occurrence of cavities in limestone units of the Conasauga Group also decreases with depth; only 16% of the solution cavities are deeper than 16 m, and only one cavity is as deep as 71 m. Finally, only one of eight wells, which are 60 to 90 m deep, has tritium in the water, and this well is atop Haw Ridge.

The composition of groundwater is determined by the chemical content of recharge water; the availability of soluble minerals along fracture flow paths; matrix diffusion, sorption, and ion exchange along flow paths; and mixings with water from other flow paths. These factors result in nearly unique chemical characteristics at each location and depth in the groundwater zone, and there commonly are large differences in the concentration of dissolved constituents in nearby wells. Near the center of WAG 2, for example, there are no apparent relationships between the specific conductance of groundwater and the directions of flow paths or the locations and depths of the wells (Fig. 3.22). A statistical analysis of available data (Table 3.6) in and near WAG 2 shows that shallow groundwater is typically a nearly neutral to moderately alkaline, calcium bicarbonate type. Total dissolved solids is generally <500 mg/L and is almost always <1000 mg/L. A few wells in an uncontaminated area of Melton Valley, upstream of WAG 2, produce water with >250 mg/L of sulfate, apparently from gypsum in shale units of the Conasauga Group. Other wells in the shale units have water with unusually large, natural concentrations of iron and manganese; atypical, natural contents of other metals also are possible. Nitrate concentrations, as nitrogen, in the groundwater zone of WAG 2 typically are <5 mg/L. A few deep wells in limestone units have unusually large, natural concentrations of fluoride.

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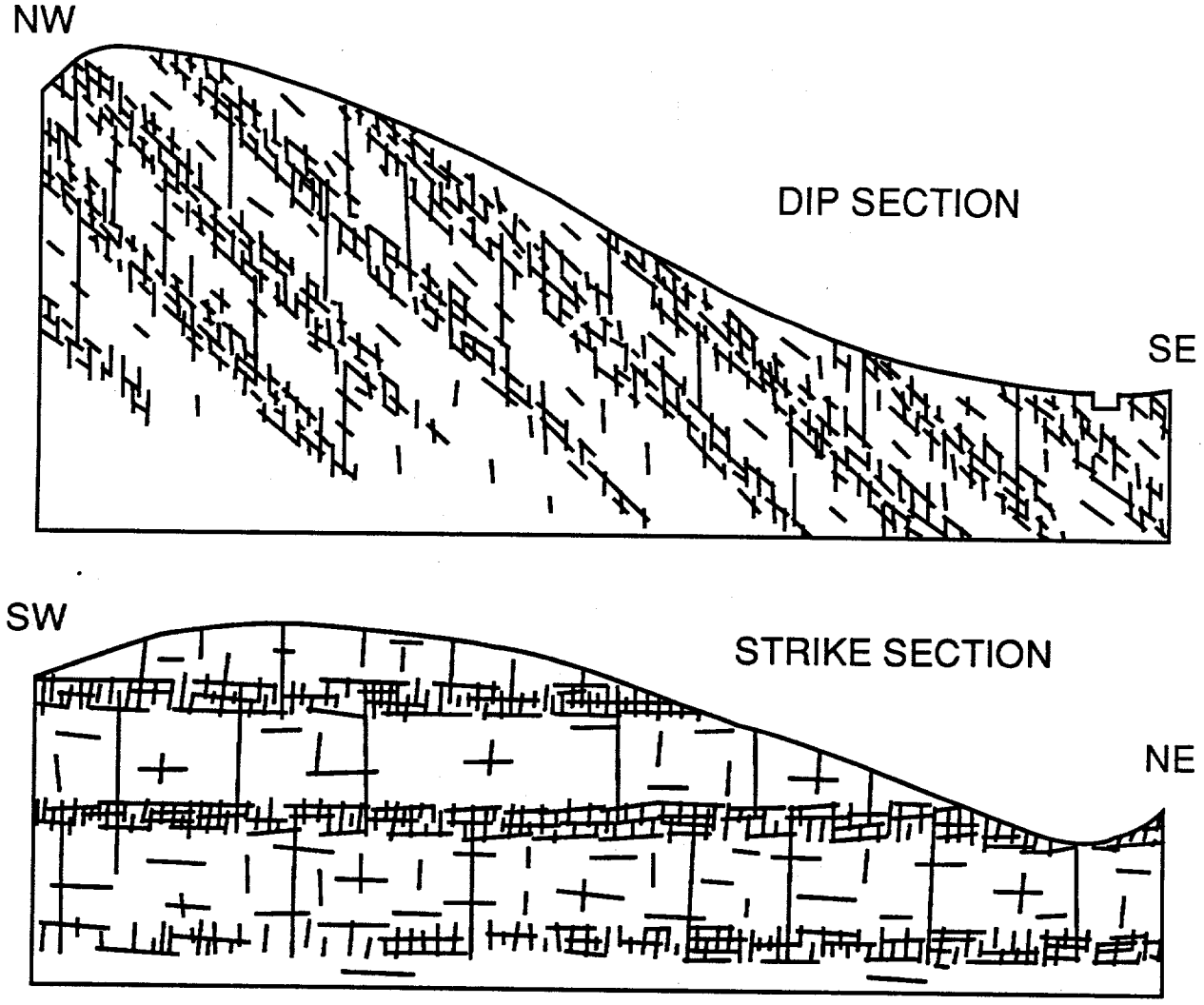

Fig. 3.21. A conceptual model showing differences in the trends and densities of open fractures to explain anisotrophy in the groundwater zone of Melton Valley. A third fracture in each section is represented by the plane of this paper.

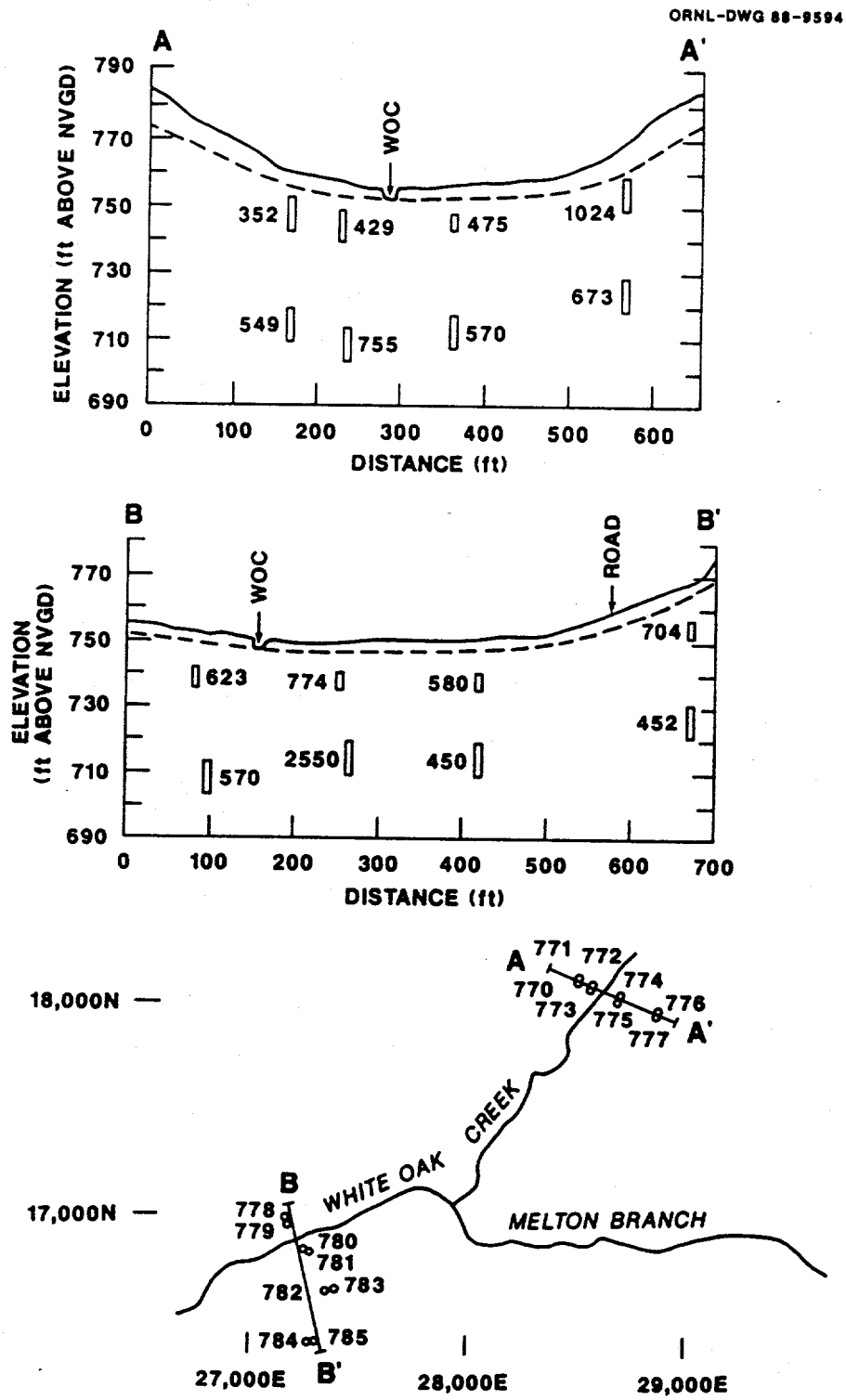

Fig. 3.22. Location map and sections showing specific conductance (umhos/cm at 25°C) of water and screened intervals in paired shallow and deeper wells near the junction of White Oak Creek and Melton Branch.

3.3.4 Surface Water Hydrology

3.3.4.1 WOC Watershed

The stream network on the WOC watershed consists of small perennial and intermittent, first- to third-order streams. Typically, these streams are less than 1 m in depth and consist of alternating series of riffles and pools (Loar 1981, Loar et al. 1981). Springs that occur along the base of Chestnut Ridge and in its valleys are the chief sources of base flow of upper WOC. Upper WOC is underlain by a more productive water-bearing formation than upper MB which has typically low base-flow discharge. Upper MB experiences periods of no flow at times during the summer and fall. In addition, some first order tributaries to WOC in Melton Valley also experience periods of no flow at times.

Numerous seeps have been identified in the WOC watershed. Those on the perimeter of WAG 2 and adjacent to streams draining into WAG 2 (Fig. 3.12) are of interest here. At least 19 seeps lie along the perimeter of Solid Waste Storage Area 5 (SWSA 5), and several of these are inside the WAG 2 boundary. These seeps drain to WOC, MB, and the unnamed tributary to MB (sometimes referred to as HRT or HRE) bordering SWSA 5 to the east. Five seeps lie on the southern boundary of SWSA 4 and drain to WOC. At least ten seeps are scattered throughout WAG 7 (Pits and Trenches), several of which are close to the WAG2 boundary. The WAG 7 seeps drain to WOC, the East Seep Tributary and an unnamed tributary to WOC between the mouth of MB and the East Seep Tributary. Four seeps lie in WAG 6 and drain to the two western tributaries to WOL in this area.

The seeps mentioned above have been identified and located by various studies and individual discoveries over a period of years. In the WOC watershed, SWSA 5 is probably the area most extensively investigated for location of seeps. In addition, seeps have been observed in other areas as well. Wet weather seeps are known to exist on the southern boundary of WAG 7 and have been observed on the hill slopes above MB to the south. Many areas in the vicinity of WAG 2 are suspected to contain numerous seeps, but these have not been identified by specific studies. These areas include the southern banks of WOL and WOC, the eastern banks of WAG 6, and the HFIR area near MB. The distribution of seep locations gives an indication of the highly localized and heterogeneous nature of subsurface discharges to streams in WAG 2.

In addition to natural run-off and groundwater discharge, WOC and its tributaries receive the treated and untreated process wastewater, treated sanitary sewage effluent, and reactor cooling water from the ORNL facilities. This water is imported from outside the watershed, and it represents a significant fraction of the annual streamflow, over 50% of in-stream flow at the WOC and MB National Pollution Discharge Elimination System (NPDES) monitoring stations during some summer dry periods.

The waters of WOC are impounded by WOL Dam, which serves as a holding pond for ORNL waste effluents. The drainage areas upstream from the confluence with the Clinch River and from WOL Dam are approximately 16.8 km^2 (6.5 mi^2) and 16.0 km^2 (6.15 mi^2), respectively (Energy Systems 1985). Elevations in the watershed range from 226 m (741 ft) at the mouth of WOC to 413 m (1355 ft) at the top of Melton Hill, the highest point on ORR.

WOL Dam is a low-head structure with a normal lake elevation of 745 ft. The reservoir is only 1.2 m (4 ft) above normal summer pool elevation in the Clinch River, which is 226 m (741 ft) above mean sea level. A recent survey of WOL by Cox et al. (in review) indicates that the volume of WOL at normal pool level is approximately 43,780 m^3 (1,546,330 ft^3). Flow from WOL discharges through a weir and concrete box culvert to the embayment below WOL Dam. In 1983, modifications were made to the flow system at the dam to increase the flood discharge capacity to 2000 ft^3/s. Tschantz (1987) estimated the 100-year flood peak inflow to be approximately 2453 ft^3/s with a peak outflow of 1574 ft^3/s at the dam. See ORNL Engineering Drawings (Pocket) for 100-year, 500-year, and PMF (probable maximum flood) floodplain maps of the WOC watershed. A history of WOL is presented in Sect. 3.2.1.

WOL is a small, shallow impoundment that functions as a settling basin for waste effluents discharged to the lake via WOC, MB, and other smaller streams. WOL extends approximately 0.7 km upstream from the WOL dam and has a surface area of about 17 acres (7 ha). The accumulation of sediments over the years has altered the environment of WOL. The lake bottom consists primarily of silt, clay, and organic matter. The average annual rate of sediment accumulation prior to 1953 was estimated to be 2832 m^3 (100,000 ft^3), or about 2 cm/year.

Because the lake is small and shallow, the water retention time is very short. Based on the average annual inflow, the retention time has been estimated to be approximately 2 d under normal conditions when the gate elevation is 226 m (745 ft).

3.3.4.2 WOCE

Reservoir embayments are the hydrologic links between the streams draining ORR and the Clinch River system. Along the southern boundary of ORR, WOCE flows directly from ORR into the Clinch River downstream from Melton Hill Dam. Water levels and flow in the WOCE are largely controlled by the operation of Melton Hill Dam (tailwater) and Watts Bar Dam (headwater). Melton Hill Dam is located 3.7 km (2.3 mi) upstream on the Clinch River; Watts Bar Dam, which forms Watts Bar reservoir, is about 94 km (58.8 mi) downstream on the Tennessee River. In addition to constituting an area of potential high contamination as a result of influx of materials from the ORNL, the WOCE has been reported to be an important habitat and productive nursery area for the Clinch River - Watts Bar Reservoir fish community (Loar 1981, Loar et al. 1981).

3.3.4.3 The Clinch River

As described above, water-borne contaminants from ORNL enter the Clinch River primarily via WOC at a point located downstream from the Melton Hill Dam and are transported further downstream into Watts Bar Reservoir. The transport, distribution, and fate of those contaminants are influenced by (1) their chemical characteristics and solubilities and (2) water and sediment dynamics in the river-reservoir system.

The flow regime of the Clinch River is controlled primarily by flood control and hydropower operations at Melton Hill Dam. Peaking power is generated at the Melton Hill Dam, so water flow in the lower Clinch River is pulsed. Periods of zero discharge are followed by 4 to 6 h of discharge up to about 500 m^3/s (20,000 cfs). Discharge rates also vary seasonally as a result of flood-control operations. Typical water releases for winter and summer are shown in Fig. 3.23. The average discharge at the Melton Hill Dam between 1963 and 1979 was 150 m^3/s (5280 cfs). The average summer (June to September) discharge was 134 m^3/s (4720 cfs). The maximum reported discharge for the dam is 1215 m^3/s (42,900 cfs).

Pulsation of flow in the lower Clinch River affects the tributaries on the reservation. During periods of power generation, backflow may occur into WOC and other embayments (Loar 1981, Loar et al. 1981). Periods of no flow from the Melton Hill Dam have lasted as long as 29 d, but the average number of days of no flow per year is 13.

3.3.4.4 Surface water monitoring

Flow has been monitored in the WOC watershed by the USGS since 1950. Early discharge data collected by the USGS at WOL Dam, WOC (above the confluence with MB), and MB (above the confluence with WOC) (Fig. 3.24) indicate average annual discharges of 13.5, 9.62, and 2.50 cfs respectively. Surface water quality monitoring in the WOC watershed of the current ORNL operations and environmental monitoring network, flow is monitored has been performed by the USGS and several divisions of ORNL for over 40 years. As part for radioactivity and chemical constituents at WOL Dam and at a number of sites in WOC and its tributaries. Thirty surface-water monitoring stations have been identified on the WOC watershed and WAG 2 vicinity (Table 3.8). Several of these stations are no longer operating and some have been operated intermittently over a period of years.

Sediments within the WOC flow system have sorbed chemical and radioactive contaminants. Consequently, these contaminants have accumulated in the WOC floodplain and WOL sediments. Oakes et al. (1982) estimated that approximately 1.4 X 10^5 m^3 (5 X 10^6 ft^3) of contaminated sediments have collected in the lake bed since 1943.

3.3.5 Subsurface Gas

There are no data for subsurface gas in WAG 2. The production of contaminated subsurface gas is a problem associated with landfills. Because there are no landfills in WAG 2, this issue will not be pursued.

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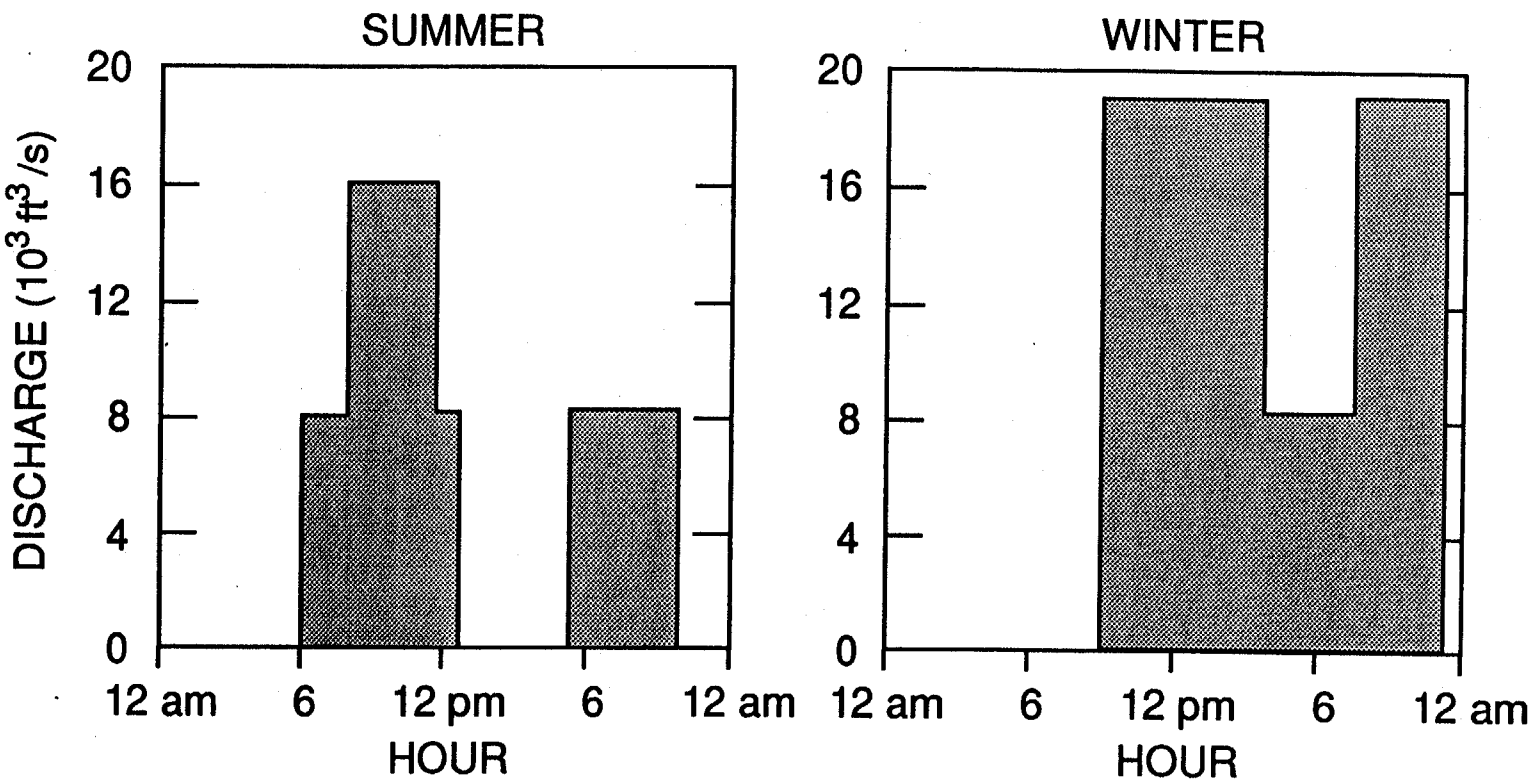

Fig. 3.23. Estimated daily peaking-power discharges from the Melton Hill Reservoir hydropower dam for summer and winter operating conditions.

ORNL-DWG 90-16976

SURFACE WATER MONITORING STATIONS

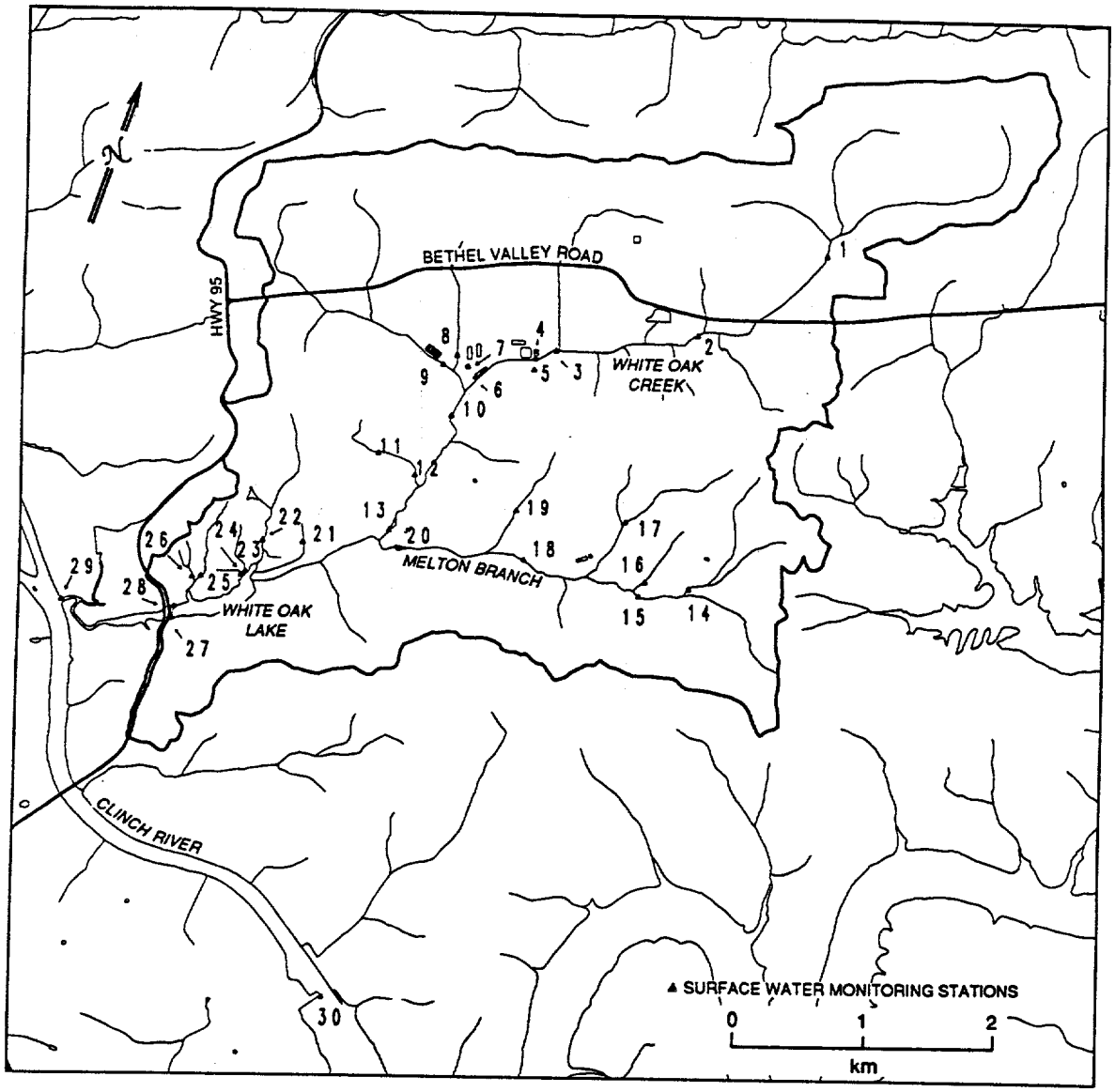

Fig. 3.24. Surface water monitoring stations on the White Oak Creek watershed and WAG 2 vicinity.

Table 3.8. Streamflow Monitoring Stations

Station Number	Station Name	Approx. ORNL Grid Location Northing	Approx. ORNL Grid Location Easting	Period of Record	Source of Info. Agency[b]	Source of Info. Contact	Type of Data[a]
1	White Oak Creek Headwaters (WOCHW)	23,652	37,758	10/89 - Present 1/89 - Present	ESD ESP	6-2766 4-9192, 6-8021	Q Q
2	White Oak Creek near Melton Hill, TN USGS ID: 03536320	21,807	34,928	4/87 - Present	USGS	FTS 854-8909	Q
3	White Oak Creek at Oak Ridge National Laboratory near Oak Ridge TN USGS ID: 03536500	21,413	31,795	1950-55	USGS	FTS 852-5424	Q
4	White Oak Creek near Wheat, TN USGS ID: 03536380	21,227	31,331	12/86 - Present	USGS	FTS 854-8909	Q
5	Nonradiological Wastewater Treatment Plant (X12)	20,972	31,308	1/90 - Present	ESP	4-9192, 6-8021	Q, W
6	Coalyard Runoff (X02)	20,833	30,044	4/86 - Present	ESP	4-9192, 6-8021	Q, W
7	Sewage Treatment Plant (X01)	21,018	29,846	4/86 - Present	ESP	4-9192, 6-8021	Q, W
8	First Creek near Oak Ridge, TN USGS ID: 03536450	21,274	29,638	2/87 - Present	USGS	FTS 854-8909	Q
9	Northwest Tributary near Oak Ridge, TN USGS ID: 03536440	21,007	29,220	5/87 - Present	USGS	FTS 854-8909	Q
10	White Oak Creek below Melton Valley Drive near Oak Ridge, TN USGS ID: 03536550	19,905	29,498	1950-55 4/85 - Present	USGS USGS	FTS 852-5424 FTS 854-8909	Q Q
11	WAG4-2	19,045	27,909	6/83 - Present	ESD	6-2766	Q
12	WAG4-2A	18,559	28,721	10/83 - 1/89	ESD	6-2766, 4-7419	Q
13	White Oak Creek below ORNL near Oak Ridge, TN USGS ID: 03537000 (X14, MS3)	17,306	28,141	1950-53, 1955-64, 1978-81 1/84 - Present 10/89 - Present	USGS ESP ESD	FTS 852-5424 4-9192, 6-8021 6-2766, 4-6079	Q Q, W Q

Table 3.8. (continued).

Station Number	Station Name	Approx. ORNL Grid Location Northing	Approx. ORNL Grid Location Easting	Period of Record	Source of Info. Agency[b]	Source of Info. Contact	Type of Data[a]
14	Melton Branch Tributary (East Seven) near Oak Ridge, TN USGS ID: 03537050	15,996	34,858	8/87 - Present	USGS	FTS 854-8909	Q
15	Melton Branch near Melton Hill near Oak Ridge, TN USGS ID: 03537100	15,903	33,605	4/88 - Present	USGS	FTS 854-8909	Q
16	Melton Branch Tributary (Center Seven) near Oak Ridge, TN USGS ID: 03537200	16,204	33,837	8/87 - Present 11/88 - Present	USGS ESD	FTS 854-8909 6-2766	Q Q
17	Melton Branch Tributary (West Seven) near Oak Ridge, TN USGS ID: 03537300	17,504	33,443	8/87 - 9/89	USGS	FTS 854-8909	Q
18	Melton Branch (MB2)	16,668	31,146	NA	ESP	4-9192, 6-8021	?
19	Melton Branch Tributary (HRT, HRE)	17,794	30,972	NA	ESP	4-9192, 6-8021	?
20	Melton Branch near Oak Ridge, TN USGS ID: 03537500 (X13, MS4)	16,877	28,373	1955-64, 1977-80 1/84 - Present 10/89 - Present	USGS ESP ESD	FTS 852-5424 4-9192, 6-8021 6-2766, 4-6079	Q Q, W Q
21	East Seep	17,005	26,262	2/88 - Present	ESD	6-2766	Q
22	West Seep	17,028	25,369	9/88 - Present	ESD	6-2766	Q
23	WAG6-1	16,320	24,997	4/90 - 6/90	ESD	6-2766, 4-6079	Q
24	WAG6-2	16,239	24,905	4/90 - 6/90	ESD	6-2766, 4-6079	Q
25	WAG6-3	16,204	24,023	4/90 - 6/90	ESD	6-2766, 4-6079	Q
26	WAG6-4	16,158	23,756	4/90 - 6/90	ESD	6-2766, 4-6079	Q
27	White Oak Creek at White Oak Dam near Oak Ridge USGS ID: 03538000	15,241	23,397	1953-55, 1960-64, 1977-79	USGS	FTS 852-5424	Q
28	White Oak Dam (X15, MS5)	15,381	23,199	1/84 - Present 10/89 - Present 6/86 - Present	ESP ESD ESD	4-9192, 6-8021 6-2766, 4-6079 6-2766, 4-6079	Q, W Q L

Table 3.8. (continued).

Station Number	Station Name	Approx. ORNL Grid Location Northing	Approx. ORNL Grid Location Easting	Period of Record	Source of Info. Agency[b]	Source of Info. Contact	Type of Data[a]
29	White Oak Creek at Clinch River Confluence (WOCCON)	15,624	20,984	9/88 - Present	ESD	6-2766, 4-6079	L
30	Clinch River at Melton Hill Dam (Tailwater), TN USGS ID: 03535912	6,785	26,900	1936-64, 1967-68, 1978-Present	USGS	FTS 852-5424	L

[a] Q = Flow rate
W = Water quality
L = Water level only

[b] ESP = Environmental Surveillance and Protection Section
ESD = Environmental Sciences Division
USGS = United States Geological Survey

3.3.6 Biological Data

3.3.6.1 Aquatic Biota

The aquatic biota of the WOC watershed, including WOL, were first characterized more than 30 years ago by Krumholz (1954a, 1954b, 1954c). There have been numerous studies since then, among the most extensive of which are Lackey (1957), Kolehmainen and Nelson (1969), Auerbach et al. (1974), Loar et al. (1981), Boyle et al. (1982), Oakes et al. 1982, and Sherwood and Loar (1987). The most comprehensive ecological survey of the watershed was conducted from March 1979 through June 1980. This survey was used to characterize the biological communities (in particular plants, invertebrates, and fish) at selected sites on the WOC system above and below ORNL, in WOL, and in WOCE downstream of WOL (Loar et al. 1981). A synoptic survey was conducted in August and September 1985 to update results obtained in the comprehensive 1979, 1980 survey (Sherwood and Loar 1987). Additional studies of the aquatic biota in the WOC watershed are ongoing as part of ORNL's Biological Monitoring and Abatement Program (BMAP) (Loar et al. 1987; 1988a,b; 1989a; 1990) (for further discussion see Sect. 4). Information used in this report comes largely from the more recent of these studies (Loar et al. 1981; Sherwood and Loar 1987; Loar et al. 1987, 1988a,b, 1989, 1990).

The WOC watershed contains three types of aquatic environments with different biological communities: (1) first- to fourth-order streams (WOC and MB), (2) a small lake fed by these streams (WOL), and (3) an embayment of the Clinch River that receives the discharge from WOL. The embayment includes the former stream channel and floodplain of the lower reach of WOC below the dam (Fig. 3.25). The biota of the embayment are influenced strongly by the Clinch River biological community and are to some degree isolated from the WOC communities by the dam on WOL.

Plants. In WOC and MB, the dominant plants are periphytic (i.e., attached) algae, primarily diatoms (particularly *Achnanthes* sp.), and green algae (particularly *Stigeoclonium* sp.), with somewhat less abundant blue-green algae (particularly *Oscillatoria* sp.) on rock substrata. The density and taxanomic composition of the periphyton taxa is quite variable spatially and seasonally because of changes in physical (light availability, water velocity) and biological characteristics (density of grazing invertebrates). Very little is known concerning the abundance of bryophytes and macrophytes in these streams, although the liverwort *Perella* and watercress (*Radicula nasturtium*) are abundant in other small streams on the ORNL reservation and have been observed in the upper reaches of WOC as well. Macrophytes, primarily *Myriophyllum spicatum* and *Elodea* are locally abundant in the pools behind the weirs that have been established on WOC. The relatively low abundance and spatially patchy distribution of periphyton and the relatively low biomass-adjusted photosynthetic rates at several sites on WOC near discharges from the ORNL complex (WCK 3.9, WCK 3.4, and WCK 2.9) indicate some stress on the periphyton community at those sites, perhaps because of chlorine discharges (Loar 1990).

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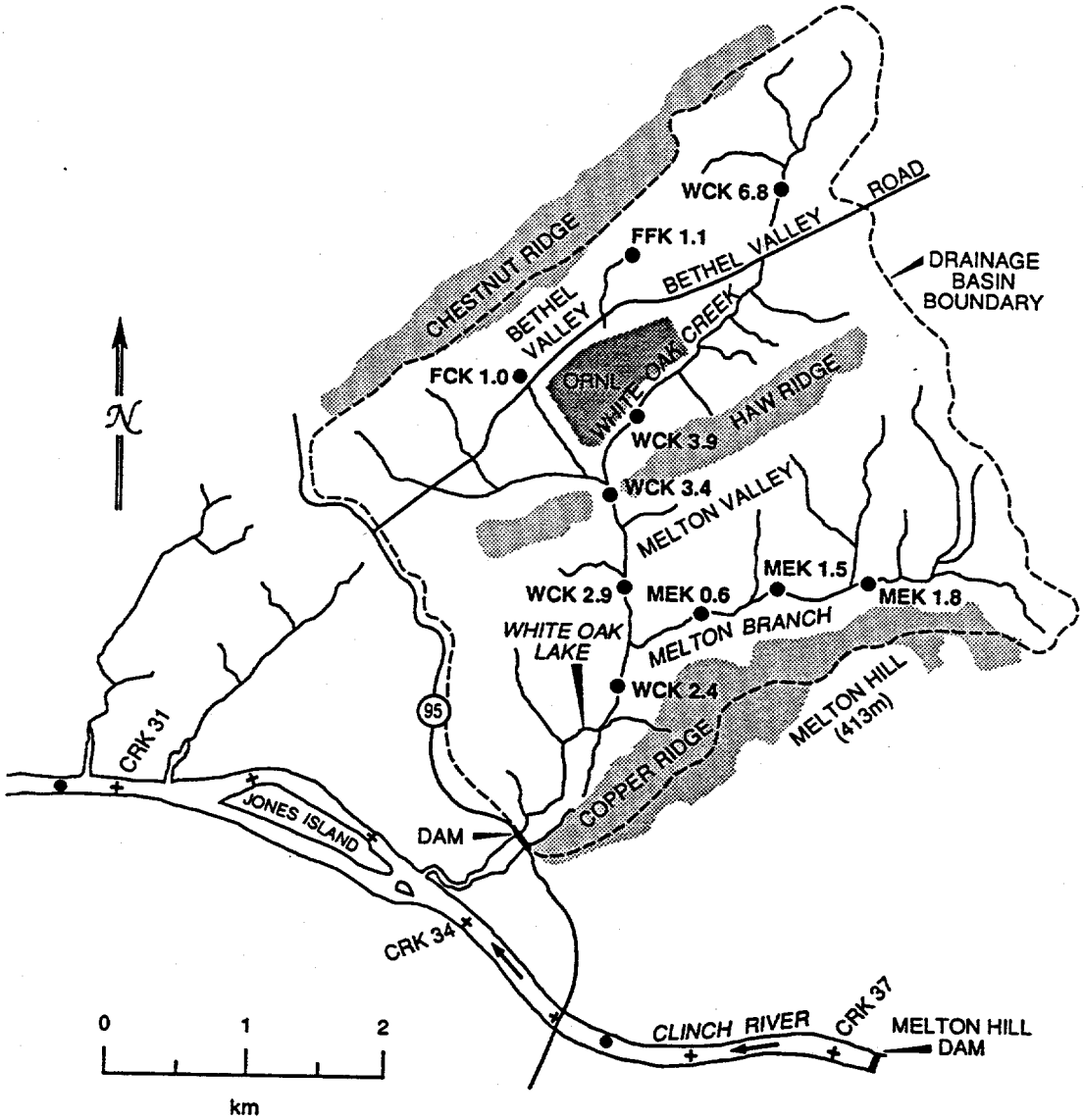

Fig. 3.25. Aquatic environments in the White Oak Creek watershed. Sites where past and ongoing surveys of aquatic biota have been conducted are indicated.

The WOL flora is dominated by phytoplankton, periphyton mats of unicellular and filamentous algae on the lake bottom, and floating and rooted macrophytes, particularly along the lake margins. Thirty-eight of the 68 phytoplankton genera identified were Chlorophyta; these comprise about 90% of the phytoplankton standing crop in the lake. Phytoplankton blooms have been noted in spring (dominated by the chlorophyte *Scenedesmus* sp.), mid-summer (dominated by the chlorophytes *Actinastrum* sp. and *Schroederia* sp. and to a lesser extent the cyanophyte *Merismopedia* sp. and the euglenophytes *Trachelomonas* sp. and *Euglena* sp.), and fall (again dominated by *Scenedesmus* sp.). Peak phytoplankton densities of 10,000 cells/mL have been observed. Temporal variation in phytoplankton abundance is probably influenced largely by changes in flushing rate and suspended sediments associated with periods of high streamflow and by seasonal changes in light and temperature. The periphyton community is dominated by diatoms, particularly *Navicula, Achnanthes*, and *Cymbella*, and the chlorophytes *Stigeoclonium* and *Ankistrodesmus*. Dense mats of the chlorophyte *Spirogyra* sp. and the cyanophyte *Oscillatoria* sp. can also occur on the lake bottom. There is no evidence of stress due to toxic chemicals on the phytoplankton or periphyton communities in the lake.

Submersed and floating macrophytes are abundant during the warmer months in WOL. Milfoil (*Myriophyllum spicatum*) and duckweeds (*Lemna minor, Wolffia*) are the most abundant macrophytes in the lake, covering approximately one-third of the lake surface during the summer months. *Elodea*, pondweed (*Potomogeton foliosus*), and watercress (*Radicula nasturtium-aquaticum* L.) have been observed but are of lesser importance. Cattails (*Typha latifolia*) are abundant along the lake margins.

The flora of the WOCE, downstream from the WOL dam, is dominated by phytoplankton. The 1979, 1980 survey indicated that chlorophyta dominated the phytoplankton community of the embayment, the dominant taxa being *Scenedesmus* sp. and *Chlamydomonas* sp. Peak cell densities were about 12,000 cells/mL. The phytoplankton community of the embayment differs considerably from that in the adjoining Clinch River, which is dominated by diatoms most of the year. Discharge from WOL strongly influences the taxonomy of the embayment community. Macrophytes are absent in the embayment, probably because of water level fluctuations in the Clinch River.

Macroinvertebrates. The most recent survey of benthic macroinvertebrates in the WOC and its tributaries was conducted from May 1987 through April 1988 (Loar 1990). Over 114 taxa were collected in quantitative samples, with the class Insecta represented by the greatest number of taxa (91 taxa). Eight major taxonomic groups were found, including Chironomidae, Diptera other than Chironomidae, Coleoptera, Oligochaeta, Isopoda, Ephemeroptera, Plecoptera, and Tricoptera. Complete taxonomic listings are given in Loar (1990). Chironomids were consistently the most numerically dominant invertebrates, accounting for at least 21% of the total density at all sites. Mean density, taxanomic richness, Ephemeroptera, Plecoptera, and Tricoptera richness (EPT richness), and diversity of benthic macroinvertebrates at various locations in WOC and its tributaries in May and June, 1987, are given in Appendix C (Table C-1). Although considerable differences exist among sites,

relatively low values for these parameters at WCK 3.9 and FFK 0.2, and to some degree at FCK 0.1 and WCK 5.1, indicate negative impacts of discharges to these streams from ORNL. Previous studies have also indicated negative impacts on macroinvertebrate communities at MEK 0.6, MEK 1.2, WCK 2.3 and WCK 3.4 (Loar et al. 1987). Based on results obtained from ambient toxicity tests (Loar et al. 1987, Stewart et al. 1990), chlorine is likely a major toxicant at FFK 0.2 and WCK 3.9. However, results of a toxicity test with water from WCK 3.9 showed that even after removal of chlorine from the sample, there was evidence of toxicity, thus indicating the presence of additional unidentified toxicants (e.g., metals). Other factors such as siltation, elevated temperatures, flow augmentation, and nutrient enrichment) are potential perturbations, particularly in stream reaches in and near the ORNL complex.

The invertebrate fauna of WOL includes both zooplankton and benthic macroinvertebrates. The Rotifera were the dominant group of zooplankton during the 1979, 1980 survey, accounting for 44 of the 70 species identified and >80% of the total zooplankton density. The most abundant rotifers were *Brachionus, Lecane, Monostyla*, and *Keratella*. Crustacean zooplankton in the lake were mostly Copepoda (*Eucyclops agilis* being the abundant species) and Cladocera (*Moina micrura* and *Diaphanosoma leuchtenbergianum* most abundant). Total density of zooplankton fluctuated considerably over time, but was generally highest during the period May—September with maximum densities of about 200 individuals/L. Maximum densities of crustaceans were about 30 individuals/L.

The benthic macroinvertebrates of WOL are dominated by the aquatic insects, which composed 79% of all organisms collected from the lake during the 1979 survey. Taxa from the Mollusca and Annelida composed 14% and 7%, respectively. The composition of the benthic community exhibited a pronounced seasonality, with insects in the order Diptera composing >90% of the community in the spring and increasing relative abundance of Ephemeroptera (mayflies, 20 to 36%) and Odonata (damselflies and dragonflies, 3 to 10%) in the summer and fall months. The relative abundance of the snail *Physa* also gradually increased from July (13%) to October (48%). Populations of the midge *Chaoborus* have apparently declined drastically from densities exceeding 100/0.1 m^2 reported in 1952 (Krumholz 1954b) to only one individual found in the entire 1979 survey.

There is less information on the macroinvertebrate populations in the WOCE. The crustacean zooplankton appear to be similar in composition to that in WOL. In 1974 and 1975, limited sampling of benthic macroinvertebrates in the embayment indicated that total density was relatively low (<300 organisms/m^2). The abundance of *Hexagenia* sp. was relatively high, making up 44% of the total individuals collected. Sampling during 1979 and 1980 indicated densities of up to about 500/m^2, with chironomids, molluscs (*Corbicula manilensis*), and oligochaetes making up 84% of all organisms collected.

Fish. A total of 13 species of fish were collected in the most recent quantitative surveys of WOC and its tributaries in 1989 (Loar 1990). In general, fish densities, biomass, and species richness increased with increasing stream size, or with increasing distance downstream from the headwaters in any one stream (Table C-1, Appendix C). Blacknose dace (*Rhinichthys atratulus*) was the most abundant species and was found at all 16 sites surveyed (Fig. 3.25). Also common were the fathead minnow (*Pimephales promelas*), mosquitofish

(*Gambusia affinis*), and creek chub (*Semotilus atromaculatus*); each of these species was found at 7 of the 16 sites. In 1989, largemouth bass (*Micropterus salmoides*) expanded its distribution relative to previous years to six sites, including all of First Creek and at the middle and lower portions of WOC (WCK 2.3 to WCK 3.9). The fish communities at two sites (FFK 0.2 and WCK 3.9) have consistently been shown to have few or no fish. However, the fish community in MB has recovered substantially in densities and taxa richness since shutdown of the HFIR in November 1986. Application of an index of biotic integrity, a fish community assessment technique that includes measures of species richness and composition, trophic composition, and fish abundance and condition, indicated that all sites had lower-than-expected values reflecting a significant adverse effect of ORNL operations on the entire WOC drainage. The combination of intermittent releases of pollutants (e.g., chlorine) and the isolation of stream segments by water control structures has resulted in a poor rating for WOC fish communities.

In a survey conducted during 1979, seven species of fish were found in WOL, including bluegill (*Lepomis macrochirus*), redear sunfish (*Lepomis microlophus*), largemouth bass (*Micropterus salmoides*), gizzard shad (*Dorosoma cepedianum*), goldfish (*Carassius auratus*), carp (*Cyprinus carpio*), and mosquitofish (*Gambusia affinis*). By far the most abundant species in the lake is the bluegill, composing 78% of the fish collected during the 1979 survey. The composition of the fish community in the lake has changed considerably since the first survey was conducted in 1950 through 1953. Although bluegill was also the most abundant species during the earlier survey, black crappie (*Pomoxis nigromaculatus*) and yellow bullhead (*Ictalurus natalis*), which were relatively abundant during the 1950 through 1953 survey, were not found in 1979.

The fish community of WOCE is similar to that of the adjoining Clinch River, but the relative abundance of cyprinids (e.g., carp) was higher and the relative abundance of percids (e.g., sauger) was lower in the embayment than in the Clinch River proper. The most abundant species is the gizzard shad, but carp and channel catfish (*Ictalurus punctatus*) are also common. Occasionally species that are common in the adjoining section of the Clinch River, such as striped bass (*Morone saxatilis*), yellow bass (*Morone mississipiensis*), white bass (*Morone chrysops*), sauger (*Stizostedion canadense*), and white crappie (*Pomoxis annularis*), are found in WOCE. Although Poplar Creek (14 km downstream from WOCE) has been identified as a major spawning ground for the gizzard shad and white bass, there is no evidence of spawning of these species in WOCE.

Other vertebrates. Numerous waterfowl and wading birds are found in the WOC watershed. The most common waterfowl are Canada geese (*Branta canadensis*), wood ducks (*Aix sponsa*), mallards (*Anas platyrhynchos*), and gadwalls (*Anas strepera*). Waterfowl use WOC and WOL for breeding as well as foraging. WOL also serves as a resting ground and possibly roosting and wintering area for migratory waterfowl. Wading birds are mostly great blue herons and green herons.

No systematic surveys of amphibians and reptiles have been conducted in the WOC system. A checklist of amphibians and reptiles on ORR has been prepared (Klein 1989) and many of these species are probably present in the WOC system. A study of turtles was

recently conducted in WOL to determine whether they could be used as biological monitors of environmental contamination (Schone 1989). This study reported DNA damage in WOL turtles due probably to benthic contaminants. This study identified six species of turtles inhabiting WOL. The most abundant species were the yellow-belied slider (*Trachemys scripta* Agassiz) and the common snapping turtle (*Chelydra serpentina* Linnaeus). Other species in the lake included the painted turtle (*Cyrysemys picta* Schnider), Eastern spiny softshell (*Trionyx spiniferus* Le Sueur), stinkpot (*Sternotherus odoratus* Latreille), and map turtle (*Graptemys geographica* Le Sueur).

Rare and Endangered Species. There are no known aquatic species listed as threatened or rare and endangered in the WOC watershed.

3.3.6.2 Terrestrial Biota

Terrestrial vegetation within WAG 2 is typical of that found in bottomland, hardwood type communities of the Tennessee Ridge and Valley Province. Floodplains along creek bottoms comprise a large percentage of the area. Much of the floodplain forest is mixed hardwood with no single dominant overstory species. Van Voris and Dahlman (1976) characterized the floodplain community east of SWSA 4. Their description is probably representative of much of the floodplain adjacent to WOC and MB. Based on characterizations provided by Van Voris and Dahlman (1976), we expect the principal canopy species in deciduous stands are sycamore (*Plantanus occidentalis*), white ash (*Fraxinus americana*), red maple (*Acer rubrum*), tulip poplar (*Liriodendron tulipifera*), elm (*Ulmus americana*), boxelder (*Acer negundo*), willow (*Salix nigra*), walnut (*Juglans nigra*), and sweet gum (*Liquidambar styraciflua*). Red cedar (*Juniperus virginiana*) and loblolly pine (*Pinus taeda*) are also found scattered throughout the floodplains. Understory tree species include dogwood (*Cornus* spp.), white ash, grape (*Vitis* spp.), plum (*Prunus* spp.), buckeye (*Aesculus octandra*), beech (*Fagus gradifolia*), hackberry (*Celtis occidentalis*), and magnolia (*Magnolia* spp.). Widespread shrub species include wild rose (*Rose setigera*), blackberry (*Rubus* spp.), alder (*Alnus* spp.), and elderberry (*Sambucus canadensis*). In open areas, the ground covers include wild rye grass (*Elymus virginicus*), jewel weed (*Impatiens capenis*), microstegium (*Microstegium vimineum*), aster (*Aster* spp.), golden rod (*Solidago* spp.), trumpet vine (*Campsis radicans*), Japanese honeysuckle (*Lonicera japonica*), vetch (*Vicia* sp.), poison ivy (*Rhus radicans*), sedge (*Carex* spp.), and bulrush (*Scirpus* spp.).

Off the floodplains, vegetation begins to resemble that which is more typical of upland hardwood communities (Boyle et al. 1982). These forests are essentially an oak-hickory forest type that consists primarily of hickory (*Carya glabra* and *C. tomentosa*), oak (*Quercus prinus, Quercus alba, Quercus velutina, Quercus rubra*), yellow poplar, black tupelo (*Nyssa sylvatica*), dogwood, beech, and maple (*Acer rubrum, A. saccharum*). Some forests bordering the floodplain are pine and pine-hardwood associations consisting of oaks, hickories, yellow poplars, loblolly pine, shortleaf pine (*Pinus echinata*), and Virginia pine (*Pinus virginiana*).

Previous sampling has revealed that a variety of small mammal species inhabit terrestrial communities in WAG 2 (Van Voris and Dahlman 1976, Garten and Dahlman 1978), including: raccoon (*Procyon lotor*), possum (*Didelphis marsupialis*), rabbit (*Sylvilagus*

floridanus), shrews (*Blarina brevicauda*), cotton rats (*Sigmodon hispidus*), white footed mice (*Peromyscus leucopus*), and rice rats (*Oryzomys palustris*). Reptiles that have been sampled or observed include the box turtle (*Terrapene carolina*), and the water snake (*Natrix sipedon*). Earthworms (*Lumbricus rubellus*) and crayfish (*Cambraus* spp.) are important soil invertebrates on the floodplain. White-tailed deer (*Odocoileus virginianus*) are also frequently observed within WAG 2, and their attraction to seepage areas and browse areas along the floodplain is thought to contribute to elevated levels of ^{90}Sr that are sometimes observed in animals killed during organized deer hunts on the Oak Ridge Wildlife Management Area (Garten and Lomax 1987).

4. EXISTING MONITORING PROGRAMS

4.1 SURFACE WATER MONITORING

In addition to the extensive surface water discharge monitoring programs (see Sect. 3), two surface water monitoring programs are conducted for regulatory compliance at ORNL. One program supports determinations of compliance with the NPDES, and the other program satisfies the requirements of DOE orders.

The NPDES program (ORNL NPDES permit TN0002941 issued April 1, 1985) consists of five components: effluent monitoring, ambient water monitoring, radiological monitoring, toxicity control and monitoring program (TCMP), and a biological monitoring and abatement program (BMAP). This section presents the ambient water monitoring and radiological monitoring components of the NPDES program only. The TCMP and BMAP programs are discussed separately in the next section (4.2). Effluent monitoring is conducted at numerous locations at ORNL, and a description of this activity is outside the scope of this RI. However, all of the effluent monitoring sites are upstream of one of the ambient stream monitoring sites (7500 Bridge, Fig. 4.1), and the effects of these discharges are integrated and monitored at this point. The surface water program for compliance with DOE orders consists of sampling for radionuclides in ambient surface water locations within the WOC watershed and a variety of water quality and hazardous chemical constituents in reference locations. The description of these two programs is combined and treated as a single program for the purposes of this report and subsequent work plans.

Figure 4.1 shows the locations of the ambient surface water sampling stations in the WOC watershed. Table 4.1 lists the radiological analyses and Table 4.2 the chemical constituents that are routinely monitored at these locations. Note that the chemistry monitoring does not include as many stations as the radiological monitoring. Tables 4.3 and 4.4 list the radiological and chemical analyses routinely performed on water from locations in the Clinch River upstream (Melton Hill Dam) and downstream (Gallaher Bridge, City of Kingston) of the WOC drainage.

Sample collection at most of these locations is conducted monthly. Radiological analyses are performed on flow-proportional or time-proportional samples collected continuously for the sample period. Samples collected in support of the NPDES permit are once-a-month 24-h flow-proportional composite samples, as specified by the permit. Discharges of radionuclides are routinely calculated for WOC at WOL Dam. Monthly flow ratios of WOC to the Clinch River, as measured at Melton Hill Dam, are also computed and reported. Other flow data are used to calculate net contributions to discharge from various reaches of the WOC watershed.

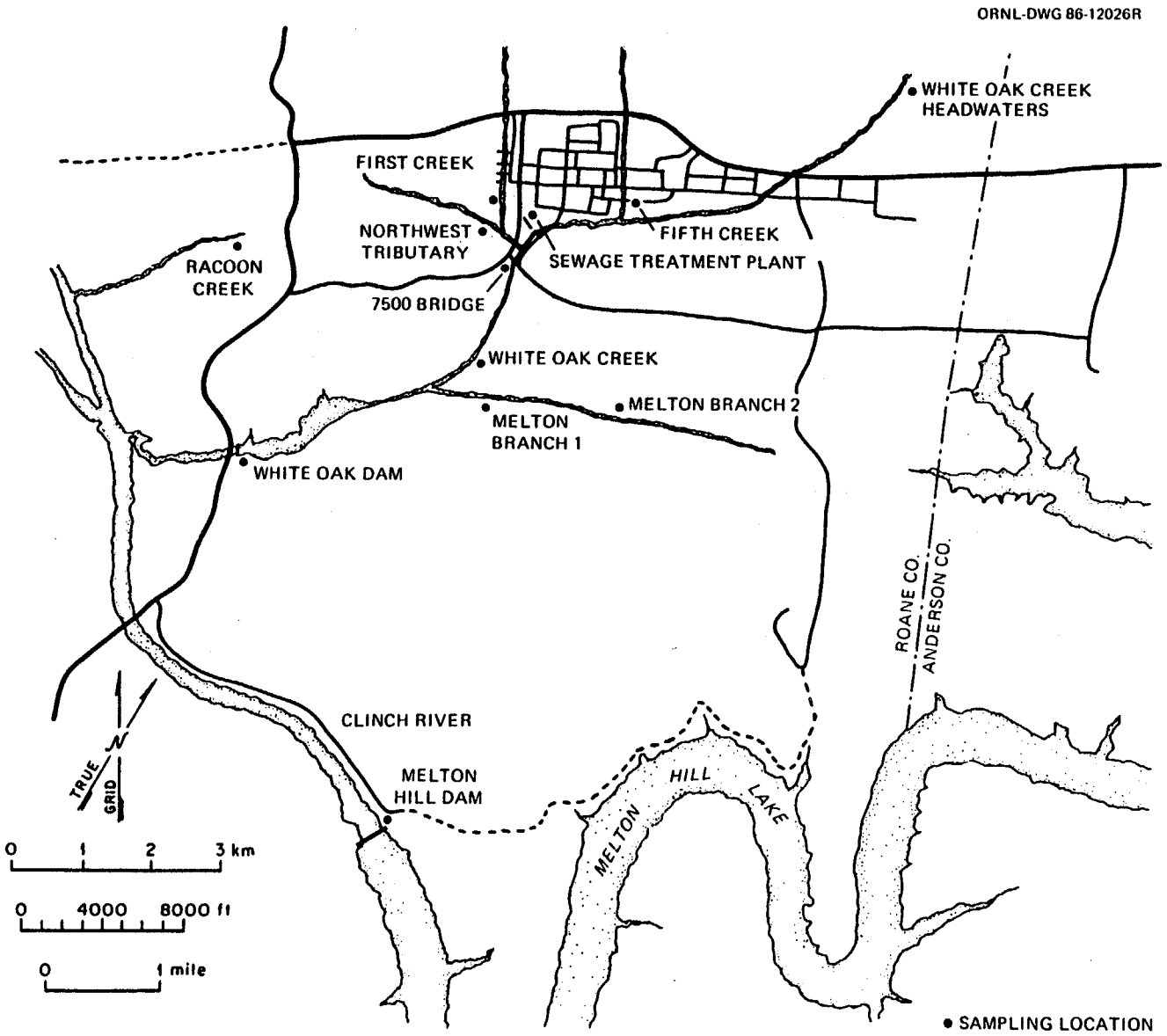

Fig. 4.1. Surface water and reference sampling locations in the ORNL vicinity.

Table 4.1. Radioactivity analyses
White Oak Creek watershed.

Station[a]	Gamma Spec (weekly)	Total Sr (monthly)	Tritium (monthly)	Gross Alpha[b] (weekly)	Gross Beta[c] (weekly)	Flow (weekly sum)
White Oak Dam	X	X	X	X	X	X
White Oak Creek	X	X	X			X
7500 Bridge	X	X	X			X
Northwest Trib.	X	X				X
First Creek	X	X				
Fifth Creek	X	X				
White Oak Creek Headwaters	X			X	X	X
Melton Branch 1	X	X	X			X
Melton Branch 2	X	X	X			X

[a] Station locations are provided in Fig. 4-1.
[b] If gross alpha exceeds 1 Bq/l, isotopic analysis is performed for Am, Cm, Pu, Th, and U.
[c] If gross beta exceeds 30 Bq/l, total radioactive strontium is determined.

Table 4.2. Water quality parameters and hazardous constituents
White Oak Creek watershed (monthly collection).

White Oak Dam, White Oak Creek (above confluence with Melton Branch), Melton Branch 1

Laboratory Analyses
Total suspended solids
Total dissolved solids
Biological oxygen demand (5 days)
Oil and grease
Anions (SO_4, F, NO_3)
Total phosphorus
Ammonium
Metals: ICP - Al, Fe, Cr, Cu, Mg, Ni, Zn
AA - Cd, Pb, Hg, Ag, As, Se, Mn
Total organic carbon
Volatile organics
Polychlroinated biphenyls

Field Measurements
Dissolved oxygen
Chlorine
Temperature
pH
Conductivity
Turbidity

White Oak Creek Headwaters

Laboratory Analyses
Total suspended solids
Total dissolved solids
Oil and grease
Anions (SO_4, F, NO_3
Metals: ICP - Al, Fe, Cr, Cu, Mg, Ni, Zn
AA - Cd, Pb, Hg, Ag, As, Se, Mn

Field Measurements
Dissolved oxygen
Temperature
pH
Conductivity
Turbidity

Table 4.3. Radioactivity Analyses Clinch River (monthly collection).

Station	Gamma spec	Total Strontium	Tritium	Gross alpha	Gross beta	Total Uranium	Plutonium 238, 239	Flow
Melton Hill Dam	X			X	X			X
Gallaher Bridge	X	X	X	X	X	X	X	
Kingston	X	X	X	X	X	X	X	

Table 4.4. Water quality parameters and hazardous constituents Clinch River (monthly collection).

Melton Hill Dam

Laboratory Analyses
Total suspended solids
Total dissolved solids
Oil and grease
Anions (SO_4, F, NO_3)
Metals: ICP - Al, Ba, Be, B, Ca, Cr, Co, Cu, Ga, Fe, Li, Mg, Mg, Na, Ni, Sn, Ti, V, Zn, Zr
AA - As, Se, Mn, Ag, Pb, Cd

Field Measurements
Dissolved oxygen
Temperature
pH
Conductivity
Turbidity

4.2 BIOLOGICAL MONITORING AND ABATEMENT PROGRAM

As a condition of the NPDES permit issued to ORNL, a BMAP was developed for WOC; selected tributaries of WOC, including Fifth Creek, First Creek, MB, and Northwest Tributary; and the Clinch River. The BMAP currently consists of six major tasks that address both radiological and nonradiological contaminants in the aquatic and terrestrial environs at ORNL. These tasks are(1) ambient toxicity monitoring, (2) bioaccumulation monitoring of nonradiological contaminants in aquatic biota, (3) biological indicator studies, (4) instream ecological monitoring, (5) assessment ofcontaminants in the terrestrial environment, and (6) radioecology of WOC and WOL.

The objectives of the ORNL BMAP are to (1) determine if the interim NPDES effluent limits protect the classified uses of WOC and its tributaries; (2) provide an ecological characterization of the WOC watershed that will document ecological impacts and identify contaminant sources that adversely affect stream biota; and (3) monitor ecological recovery during and after implementation of major remedial actions related to both past and present ORNL operations. To meet these objectives, long-term monitoring is conducted at numerous sites in the WOC watershed and the Clinch River (Fig. 4.2) as part of BMAP tasks 1 through 4 above. A brief description of these tasks and their respective monitoring programs follows.

4.2.1 Ambient Toxicity Monitoring

Seven-day toxicity tests are conducted monthly on water samples from 15 sites on five streams near ORNL (Fig. 4.3). The end points for these tests include the survival and fecundity of *Ceriodaphnia dubia* and the survival and growth of fathead minnow (*Pimephales promelas*) larvae.

4.2.2 Contaminant Bioaccumulation Monitoring

Monitoring of metals and pesticides in fish is conducted annually at three sites in the WOC watershed where ambient NPDES water quality monitoring is conducted (WOL, WOC, and MB just upstream from the confluence of the two streams - Fig. 4.2). Nonpesticide semivolatile organics are also monitored at these three sites using caged Asiatic clams (*Corbicula fluminea*) because they are better indicators of phthalate contamination than fish. Polychlorinated biphenyls (PCBs) are monitored semiannually in sunfish from WOL and WOC km (WCK) 2.9 just above the confluence with MB and annually in sunfish from five additional sites, including WOCE, WOC below the confluence of MB (WCK 2.3), WOC at Melton Valley Drive (WCK 3.5), lower MB, and lower Northwest Tributary. Annual monitoring of PCBs and chlordane in channel catfish is also conducted in WOCE (PCBs only) and a nearby reach of the Clinch River.

4.2.3 Biological Indicator Monitoring

The overall health of the redbreast sunfish population in WOC is evaluated using a suite of biochemical and physiological parameters. These parameters can be grouped into five functional categories representing indicators of (1) lipid metabolism, (2) detoxification enzyme

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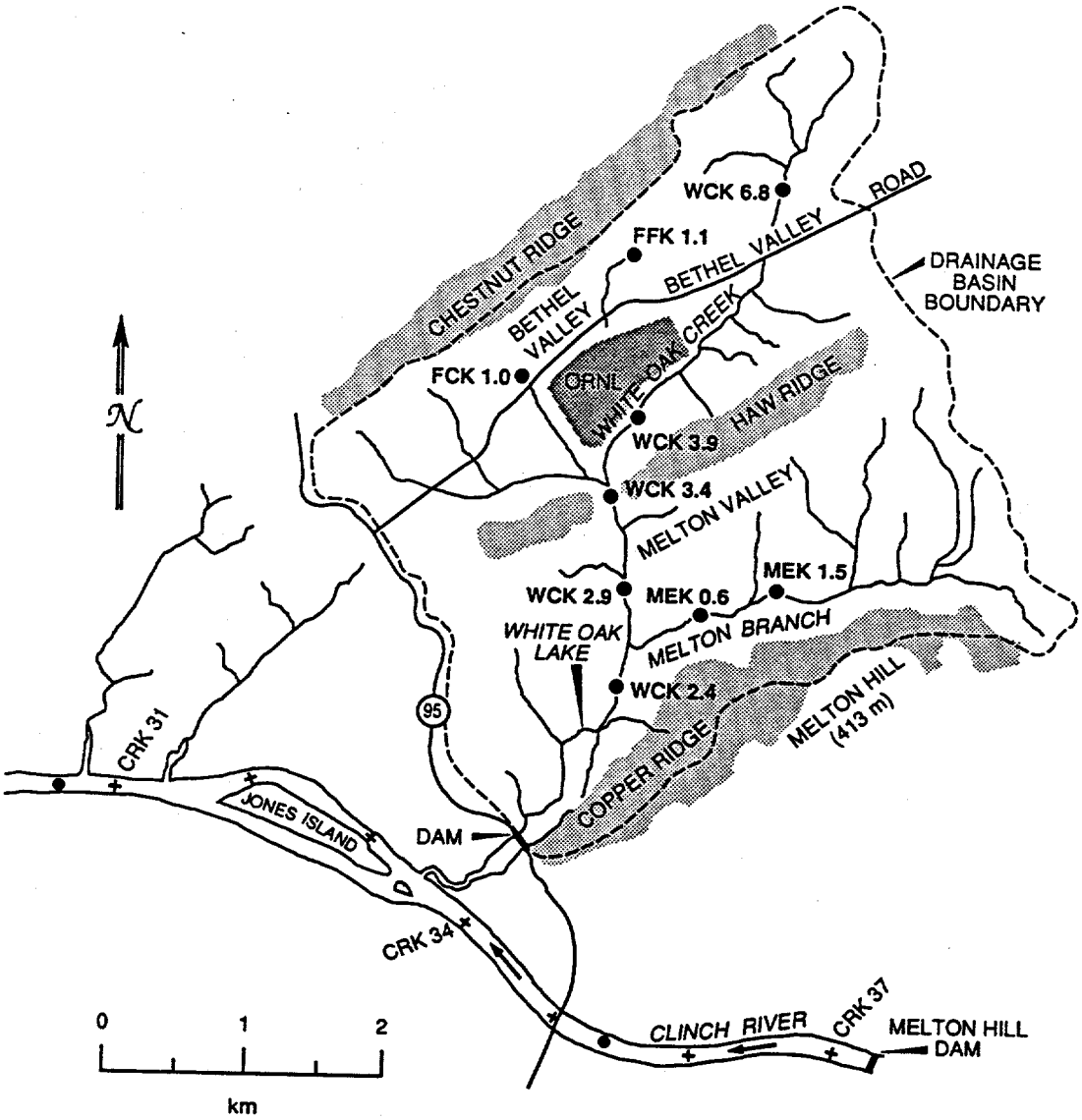

Fig. 4.2. Periphyton monitoring sites in the White Oak Creek watershed.

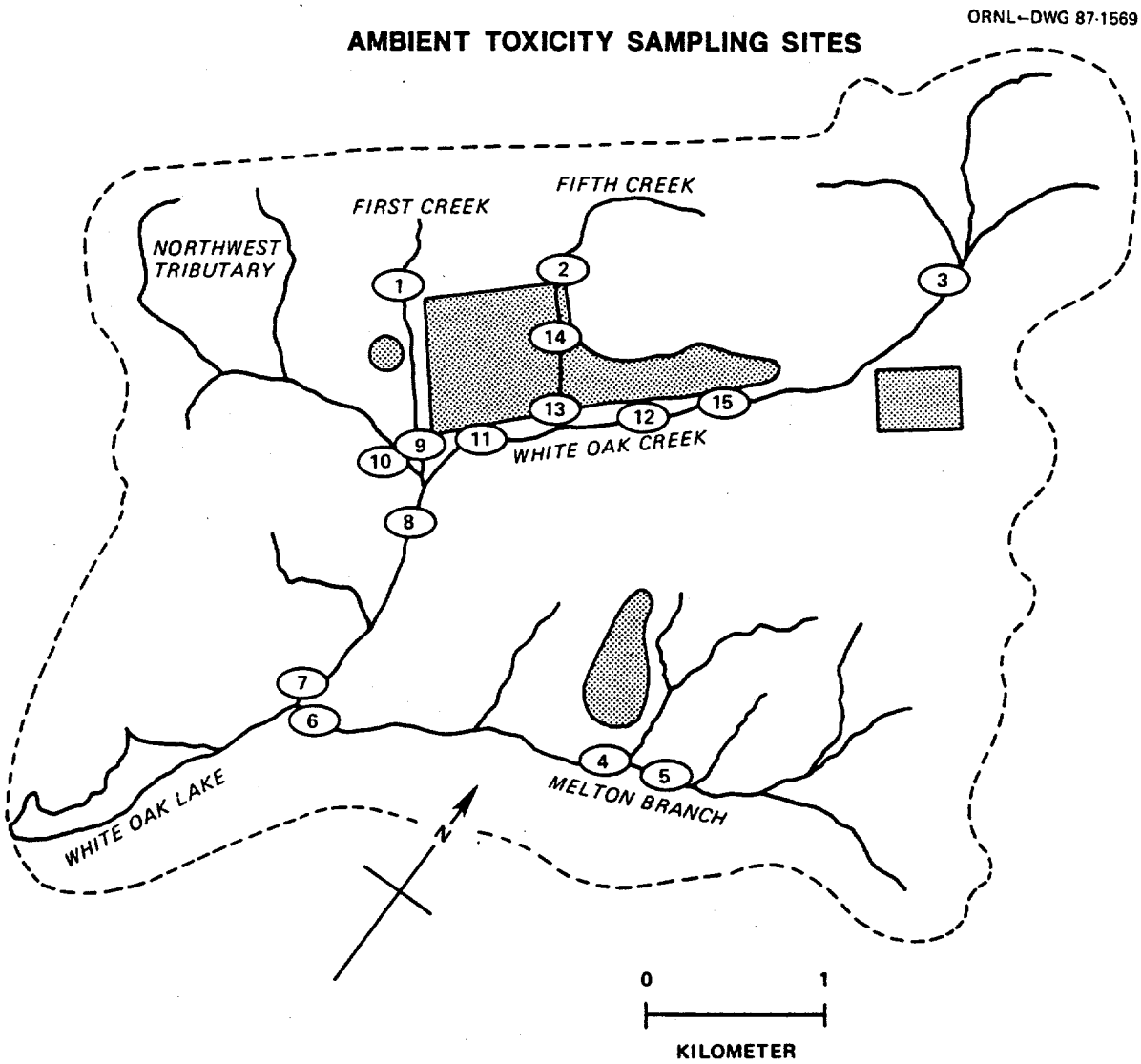

Fig. 4.3. Sampling sites for ambient toxicity tests of water from streams at ORNL.

induction, (3) histopathological condition, (4) organ dysfunction, and (5) overall fish condition. Monitoring of fish health is conducted annually at a site on lower WOC (WCK 2.3) below the confluence with MB.

4.2.4 In-stream Ecological Monitoring

The in-stream ecological monitoring task of the BMAP includes routine sampling of the periphyton, benthic macroinvertebrate, and fish communities in WOC and tributaries. Periphyton (attached algae) communities are sampled monthly at nine sites in the WOC watershed (Fig. 4.2) and analyzed for biomass (as chlorophyll *a*) and primary productivity (carbon incorporation rates). Benthic macroinvertebrates are sampled quarterly (January, April, July, October) at 15 sites in the WOC watershed and 1 site in WOL (Fig. 4.4). Data on macroinvertebrate abundance, as numbers and biomass, and diversity are obtained for each sample. Organisms are identified to the lowest practical taxon, usually genus. Fish are sampled semiannually (spring and fall) at 16 sites in the WOC watershed (Fig. 4.4). A three-pass removal method is employed to obtain an estimate of species population sizes, expressed as numbers and biomass, in standardized stream reaches. Growth is estimated annually from scale and otolith samples collected in the fall. An assessment of the status of the fish community at each site is performed using the Index of Biotic Integrity, which is based on 12 metrics that provide measures of species richness and composition, trophic composition, and fish abundance and condition.

4.3 WASTE DISPOSAL SITES MONITORING PROGRAM

DOE Order 5820.2A requires that LLW disposal sites active on or after September 1988 and all transuranic (TRU) waste storage sites be monitored periodically to ensure that radioactive contamination does not escape from the waste sites and pose a threat to the public or the environment. A monitoring plan has recently been developed for the active LLW disposal sites in SWSA 6 and the TRU waste storage sites in SWSA 5 North (Ashwood et al. 1990a,b). These sites border the WAG 2 (Figs. 4.5 and 4.6) and the monitoring program for them is important because of the potential impact on WAG 2.

Since 1985, ORNL has installed 207 RCRA-quality groundwater monitoring wells. Eighteen of these wells are in WAG 2 and will be sampled beginning in FY 1991 (Fig. 4.7). Parameters to be measured on samples collected from these wells include general water quality indices (specific conductance, pH, and DO), radionuclides (^{60}Co, ^{137}Cs, gross gamma, ^{3}H, ^{14}C, ^{90}Sr, ^{99}Tc, gross beta, gross alpha), metals (ICP analysis), anions (NO^-_3, F^-, SO^{-2}_4, Cl^-, Br^-, and PO^{-3}_4), volatile and semivolatile organics (GCMS analysis), pesticides, and PCBs. Sampling will be conducted during both high- and low-water-table conditions. The groundwater quality data obtained from sampling these wells will directly support the interim monitoring objectives of the WAG 2 RI. In addition to the wells within WAG 2, there are numerous wells in the WAGs upgradient from WAG 2 that also will be sampled for water quality parameters, and results can be used to help define inputs to WAG 2.

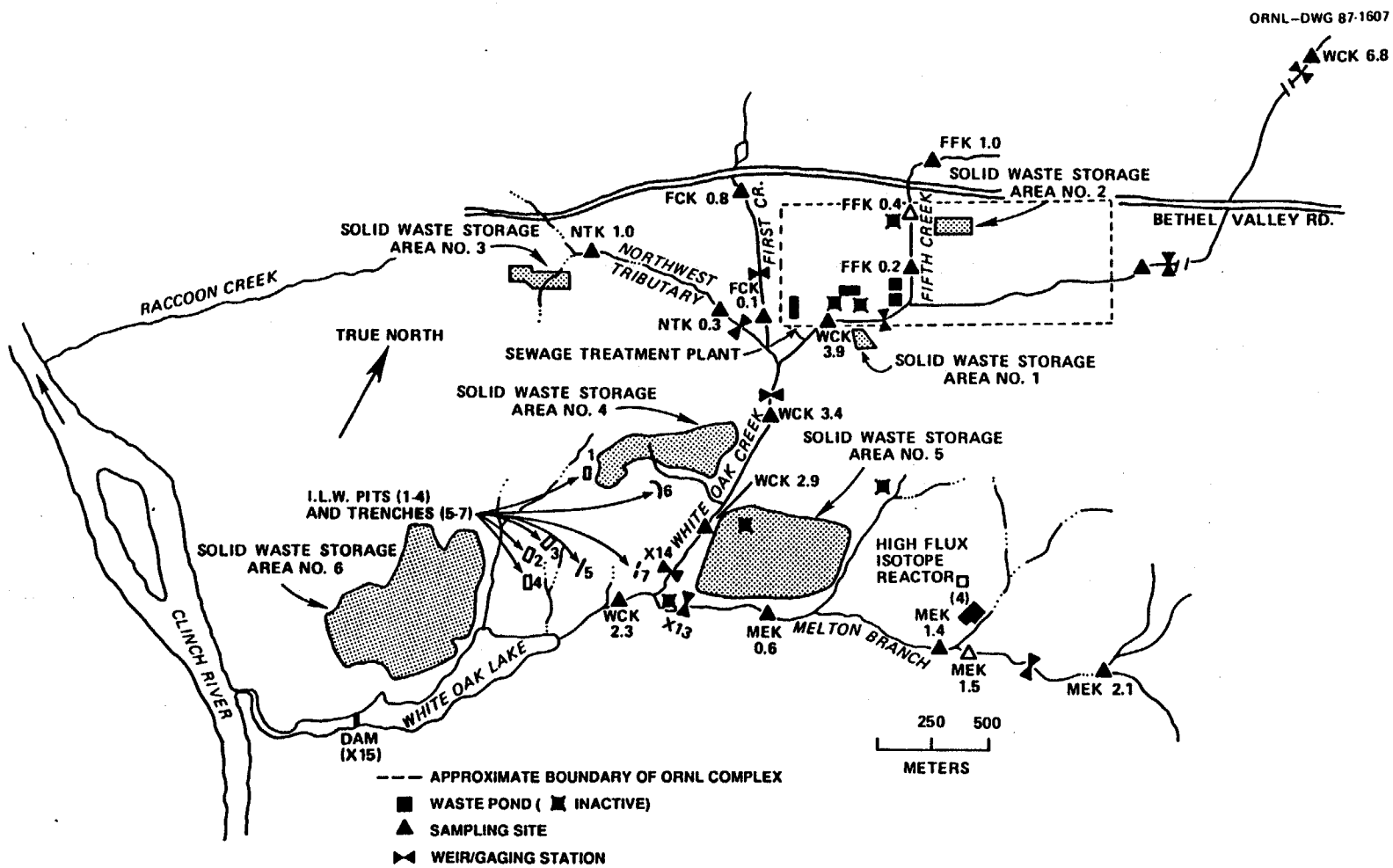

Fig. 4.4. Map showing locations of sampling sites for benthic invertebrates and fish in White Oak watershed (▲ - fish sampling only).

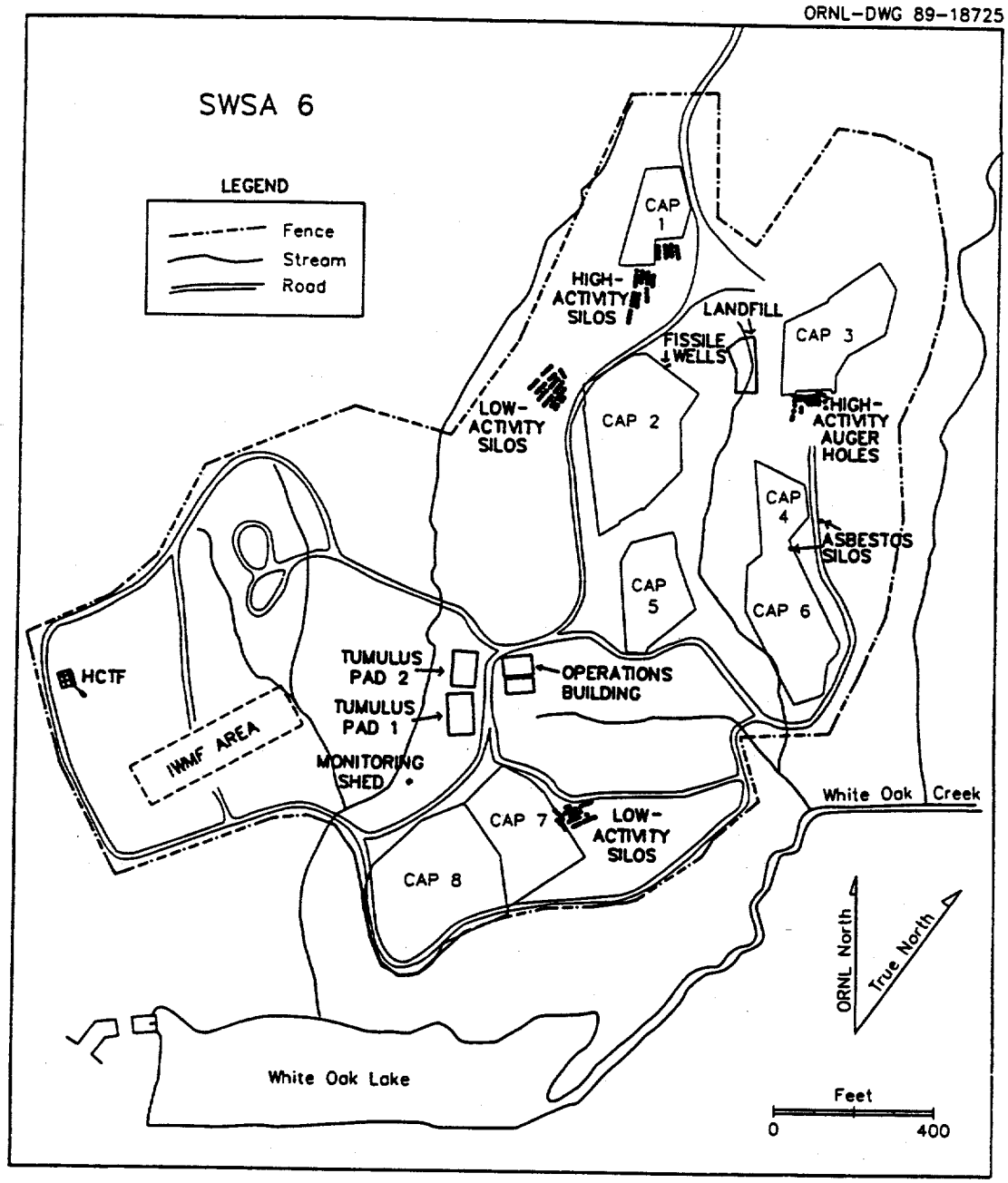

Fig. 4.5. Map showing active LLW disposal sites in SWSA 6 for which monitoring plan has been developed.

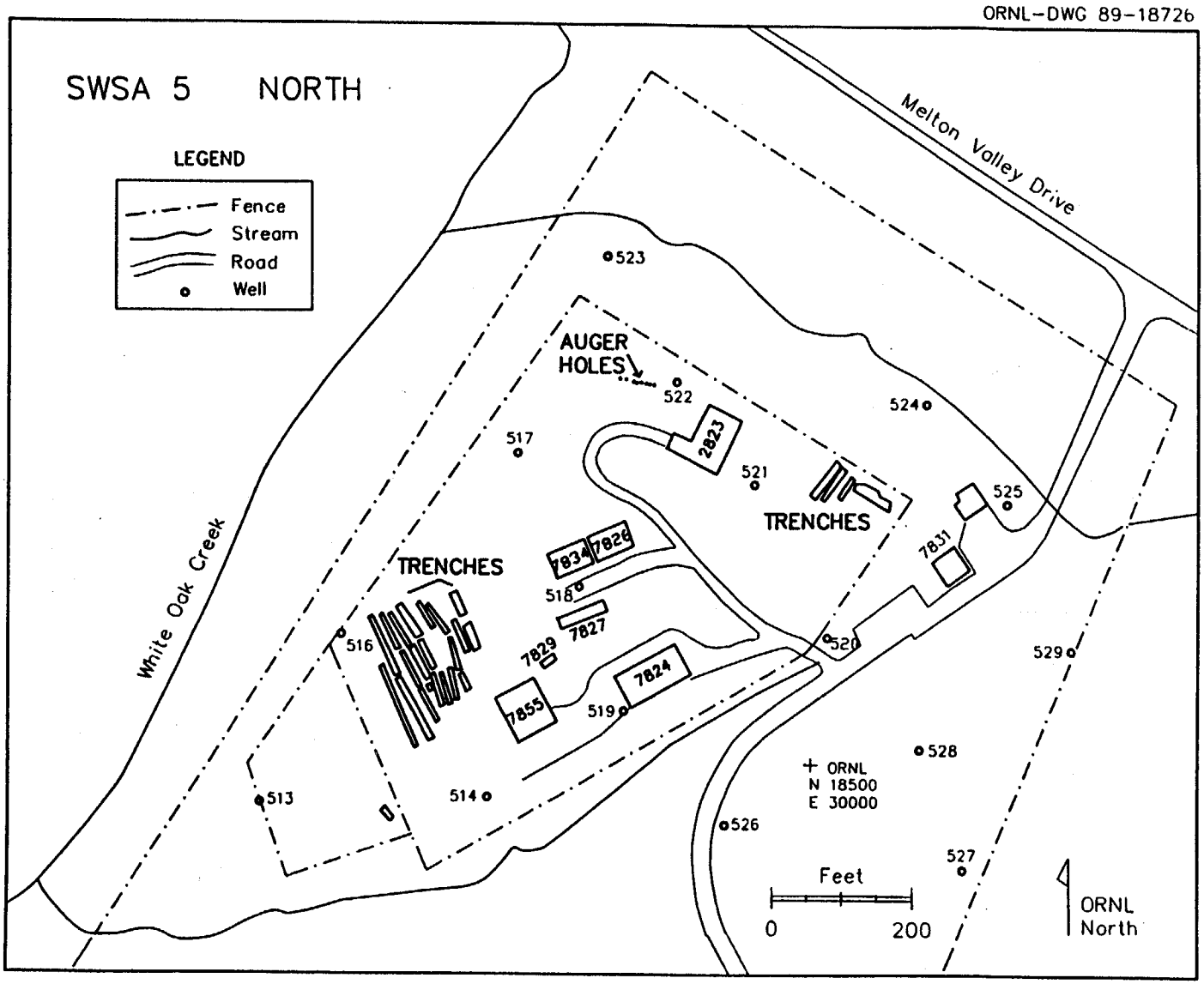

Fig. 4.6. Map showing the TRU waste storage sites in SWSA 5 for which monitoring plan has been developed.

ORNL-DWG 90M-16725

Water Quality Wells in WAG2

STATUS OCTOBER 1990
18 COMPLETED WELLS

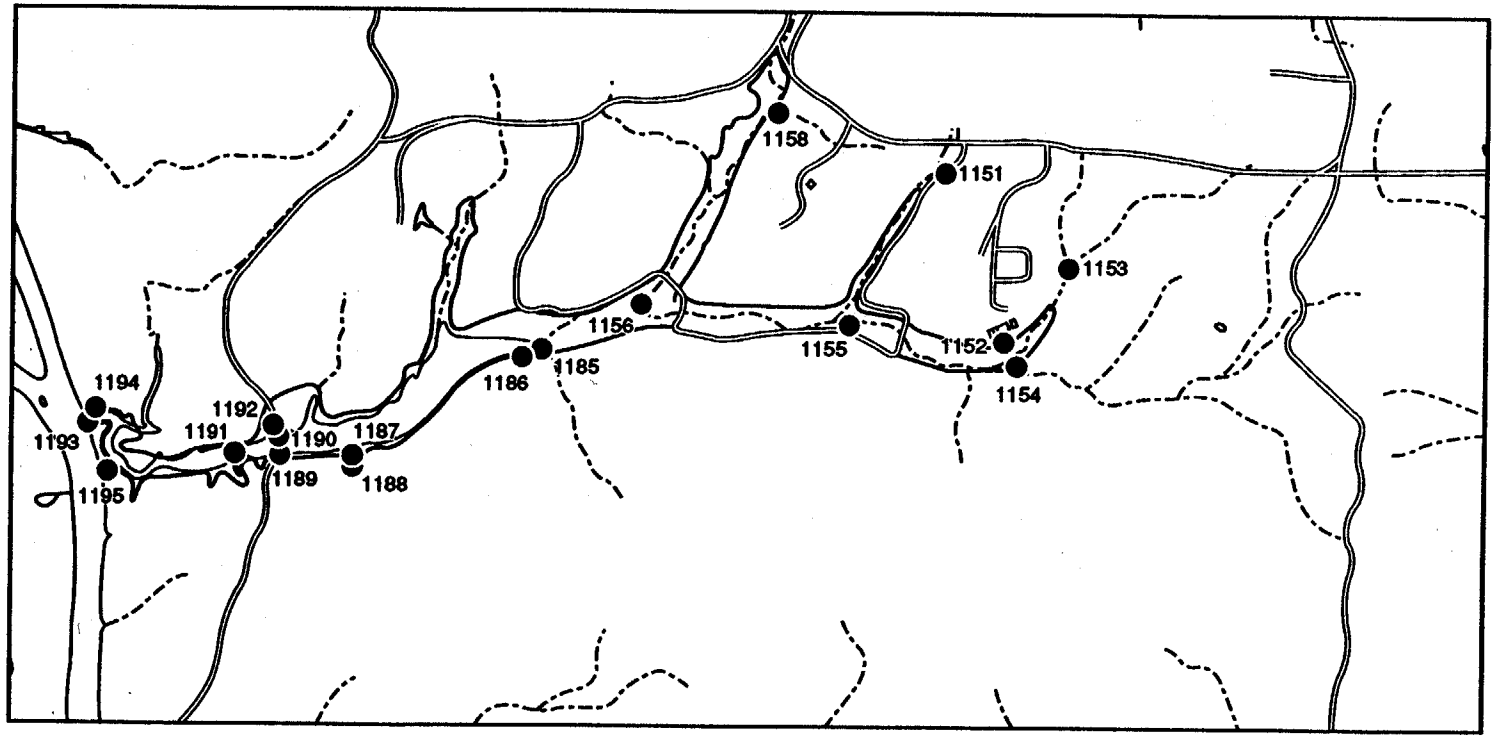

Fig. 4.7. Locations of 18 RCRA-quality groundwater monitoring wells in WAG 2.

5. EXISTING INFORMATION FOR CONTAMINANT SOURCES FOR THE WOC SYSTEM

5.1 CONTAMINANT RELEASES TO THE WOC SYSTEM

With the possible exception of WOCE below White Oak Dam, contamination in the WOC/WOL system is a result of releases from active and inactive sites in eleven WAGs located within the WOC watershed. Sect. 3.2 briefly describes the location and operating history of each of these WAGs. Existing data on releases from each WAG are summarized in this section.

The level of information available on known releases from each WAG to WOC/WOL is highly variable from WAG to WAG, but in no case is there sufficient data to fully characterize either the historical or continuing releases. Primary sources of data for each WAG are listed in Table 5.1. These existing reports typically provide information on waste inventories within the WAG, limited data on known releases, and results of various characterization studies.

Table 5.1. Sources of data for WAGs in the White Oak Creek watershed.

WAG	Name	Environmental data package[a]	RI/RFI[b] Plan
1	Main Plant Area	W. J. Boegly - ORNL	BNI
3	Solid Waste Storage Area 3	R. R. Shoun - ORNL	BNI
4	Solid Waste Storage Area 4	Davis & Shoun 1986	BNI
5	Solid Waste Storage Area 5	R. R. Shoun - ORNL	BNI
6	Solid Waste Storage Area 6	Boegly 1984	BNI
7	LLW Pits and Trenches Area	B. P. Spalding - ORNL	BNI
8	Melton Valley Area	W. J. Boegly - ORNL	BNI
9	Homogeneous Reactor Experiment (HRE) Area	Stansfield & Francis 1986	BNI
10	Hydrofracture Injection Wells and Grout Sheets		BNI
13	Environmental Research Areas	W. J. Boegly - ORNL	
17	ORNL Services Area	W. J. Boegly - ORNL	BNI

[a] Includes site characterization report for some WAGs where no Environmental data package was prepared; entries without dates are personal communications.
[b] RI = Remedial Investigation; RFI = RCRA Facility Investigation, BNI = Bechtel National Inc.

Although available information does not support full characterization of releases from each WAG, the waste inventory and known release data can be used to identify key radioisotopes and (to a lesser extent) elements that may potentially be released from a WAG (Table 5.2). Data on organic contamination is limited to a very few sites. This summary of key potential contaminants can be used to guide further monitoring and characterization efforts.

Table 5.2. Contaminants known or suspected to have been released from each WAG.

WAG	Contaminants[a]
1	^{60}Co, ^{90}Sr, ^{137}Cs, ^{15X}Eu, ^{232}Th, ^{23X}U, ^{23X}Pu, ^{241}Am, ^{244}Cm, other radionuclides, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Zn, TRE, PCBs, chlordane
3	^{3}H, ^{90}Sr, ^{137}Cs, TRE
4	^{3}H, ^{60}Co, ^{90}Sr, ^{106}Ru, ^{137}Cs, ^{23X}Pu, other radionuclides, TRE
5	^{3}H, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{233}U, ^{23X}Pu, ^{241}Am, ^{244}Cm, other radionuclides, Cr, Hg, Ni, Pb, Zn, PCBs
6	^{3}H, ^{14}C, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{15X}Eu, ^{23X}U, Cr, Cu, Hg, Mo, Ni, Pb, Zn, VOCs, nitrates
7	^{3}H, ^{60}Co, ^{90}Sr, ^{99}Tc, ^{106}Ru, ^{137}Cs, ^{233}U, Cr, Ni, Zn, nitrates
8	^{60}Co, ^{90}Sr, ^{137}Cs, Cr, Cu, Zn
9	^{60}Co, ^{90}Sr, ^{137}Cs, Cr, Zn
10	^{90}Sr, ^{137}Cs, ^{244}Cm, TRU isotopes
13	^{137}Cs
17	^{137}Cs, Cd, Cr, Cu, Zn, fuel-derived hydrocarbons, and solvents

[a] Based primarily on data in ORNL RCRA Facility Investigation (unpublished) and environmental data packages for each WAG (see Table 5.1). Ru-106 and TRE have short half-lives (e.g., ~1 year) and should have decayed to trivial levels by this time.

The following sections briefly summarize what is known about historical and continuing releases from each WAG in the WOC watershed. In addition, these sections provide information on what additional data are needed to provide adequate characterization of the sources (both historical and continuing) of contamination to WOC/WOL. Further information will be obtained through programmatic linkages with on-going and planned RI/FS activities in these WAGs (see Sect. 9) and through further review of existing monitoring and characterization data.

5.1.1 Releases from WAG 1, the Main Plant Area

Virtually every radionuclide, element, and organic compound ever used at ORNL has been used at one time in WAG 1. Not surprisingly, historical release data suggest that WAG 1 was a major source for radionuclide and heavy metal contamination to WOC.

Analysis of the 1989 Environmental Monitoring Report for the Oak Ridge Reservation (Energy Systems 1990) suggests that WAG 1 continues to be the primary source of ^{60}Co, ^{137}Cs, and ^{90}Sr to the WOC/WOL system. Recent biological monitoring data suggest that portions of Fifth Creek and WOC just above and below the confluence with 5th Creek are acutely toxic to *Ceriodaphnia* (though not to fathead minnows) and that caged clams accumulate PCBs and chlordane in the reach of WOC affected by WAG 1 (Loar 1990).

An ongoing remedial investigation of WAG 1 is expected to yield data on groundwater contamination and release rates to WOC. Existing surface water monitoring programs provide periodic data on continuing releases of selected radioisotopes from WAG 1. Additional monitoring data are needed, however, to determine the level of continuing releases, if any, of the entire suite of contaminants indicated in Table 5.2.

5.1.2 Releases from WAG 3, SWSA 3

There are no reliable records of what was disposed of in SWSA 3, because the records were lost in a fire. Characterization data suggest that SWSA 3 has historically been a source of ^{90}Sr, and samples of surface soils and gravel in the Contractors Landfill area of WAG 3 revealed ^{90}Sr and ^{137}Cs (^{60}Co was at or near detection levels) (personal communication, R. R. Shoun - ORNL).

Recent monitoring data (Energy Systems 1990) and historical studies (Stueber et al. 1981) suggest that WAG 3 contributes small quantities of ^{90}Sr and ^{137}Cs to Northwest Tributary. However, no data are available on heavy metal or organic contamination.

Additional monitoring and characterization data are needed to determine whether WAG 3 is (or has been) a source of contaminants other than ^{90}Sr and ^{137}Cs.

5.1.3 Releases from WAG 4, SWSA 4

Records of waste disposed of in SWSA 4 during all but its last 2 years of operation were lost in a fire. In addition, over half of the waste buried in SWSA 4 was from sources outside ORNL. For these reasons SWSA 4 must be considered as a potential source for a wide range of radioisotopes including transuranics (Table 5.2). Characterization data have demonstrated that SWSA 4 is a major contributor of ^{90}Sr to the WOC/WOL system. Soil samples have also shown elevated levels of ^{60}Co and ^{137}Cs in SWSA 4. Stream gravel surveys have shown that SWSA 4 has been a source of these isotopes as well as copper, nickel, and zinc to WOC.

Recent monitoring data (Energy Systems 1990) suggests that SWSA 4 is a major source of ^{90}Sr to the WOC/WOL system and the largest contributor of ^{3}H to the reach of WOC above Melton Branch. No data are available on continuing elemental or organic contamination from WAG 4.

Additional data are needed to determine whether and to what extent this WAG is a continuing source of heavy metals and organics.

5.1.4 Releases from WAG 5, SWSA 5

Approximately 200,000 Ci of LLW and TRU wastes are buried at SWSA 5. In addition, more than 62,000 Ci of TRU waste is retrievably stored in SWSA 5 North, much of it buried in concrete casks (Stewart et al. 1989). Eight 190,000-L stainless-steel tanks at the New Hydrofracture Facility (NHF) site hold concentrate from the LLW evaporator. The Old Hydrofracture Facility (OHF) pond contains contaminated water and sediments with almost 500 Ci of activity. The predominant isotopes in all the LLW facilities are ^{60}Co, ^{90}Sr, and ^{137}Cs. TRU wastes are primarily ^{244}Cm, with lesser amounts of several other isotopes. Some lead and mercury were also buried with the TRU wastes (Stewart et al. 1989).

Four separate studies have identified radioactively contaminated groundwater around WAG 5 (ORNL 1987a, Ashwood et al. 1990b, Wickliff et al. 1990). Tritium and ^{90}Sr were measured in groundwater near the OHF pond. Six wells and one seep around SWSA 5 were contaminated with ^{90}Sr, ^{137}Cs, and RCRA-regulated hazardous wastes (e.g., lead). Wells along the southern perimeter of SWSA 5 had measurable levels of ^{90}Sr. A well in SWSA 5 North had measurable levels of ^{244}Cm and ^{24X}Am. Another SWSA 5 North well had elevated levels of ^{3}H. Stream gravel surveys suggest that SWSA 5 has been a source of ^{90}Sr, chromium, nickel, and zinc to Melton Branch. Stream water samples have shown elevated levels of ^{3}H north of SWSA 5 North (personal communication, D. S. Wickliff - ORNL).

Recent monitoring data (Energy Systems 1990), suggests that WAGs 5 and 9 combined contribute about a third of the ^{90}Sr and more than half of the ^{3}H that enters WOC. It is not possible with current monitoring data to separate the contribution of WAG 5 from that of WAG 9. Also, operational monitoring of SWSA 5 North has measured detectable levels

of ^{244}Cm and ^{241}Am in groundwater downgradient of the burial trenches (personal communication, D. S. Wickliff - ORNL).

Additional data are needed to accurately assess the past and continuing releases of radioisotopes, heavy metals, and organic compounds from WAG 5.

5.1.5 Releases from WAG 6, SWSA 6

As the only operating LLW disposal site at ORNL, SWSA 6 continues to receive solid LLW that is buried using greater confinement disposal technologies such as concrete silos, steel-lined auger holes, and concrete vaults on a concrete pad. Through the end of 1984, more than 250,000 Ci of LLW had been disposed of at SWSA 6. RCRA-regulated wastes (e.g., scintillation fluids, oils, cleaning solutions, alcohols, paint thinners, kerosene, jet fuel, acids, and sodium) were disposed of in several trenches and auger holes. These disposal areas have subsequently been covered by high-density polyethylene caps.

Some site characterization data identified in the RI Plan have been collected, and the final RI is expected to be issued in 1991. Tritium, ^{60}Co, ^{90}Sr, and ^{137}Cs were the principle radioactive contaminants found in samples of 35 groundwater wells. These same contaminants were found in surface water and in both surface and subsurface soil samples. Trace levels of TRU isotopes were also found in two wells and two surface samples. Trace levels (generally below health criteria) of several metals and solvents were found in a few wells. Only trace levels of metals or organics were found in surface water or soil samples. Solomon et al. (1988) and Ashwood and Spalding (in press) sampled wells in burial trenches and measured numerous radioisotopes (Table 5.2), heavy metals, volatile organic compounds (VOCs), and nitrates in the leachate.

Stream gravel samples indicate that SWSA 6 has been a source of ^{60}Co, ^{90}Sr, ^{137}Cs, and possibly of copper, molybdemun, and zinc to WOL. No indication of organic contamination was found in the stream gravel samples.

Existing monitoring data do not permit quantification of continuing releases from SWSA 6, primarily becaue of the absence of routine flow monitoring and sampling of the four tributaries that drain the WAG. A monitoring network on these streams is needed to determine the past and continuing contaminant discharges to WOL.

5.1.6 Releases from WAG 7, Pits and Trenches Area

More than 1,100,000 Ci of liquid LLW, primarily ^{90}Sr, ^{106}Ru, and ^{137}Cs, was transferred to the waste pits and trenches; another 2000 Ci of ^{137}Cs was placed in the shielded transfer tanks, and nearly 4 kg of ^{235}U in liquid form was placed in the HRE fuel disposal auger holes. RCRA-regulated contaminants may also be present in this WAG, but data are insufficient to determine which ones.

Characterization studies suggest that WAG 7 has been a source of ^{3}H, ^{60}Co, ^{90}Sr, ^{99}Tc, chromium, and zinc. No organic contamination traceable to WAG 7 has been found.

Existing monitoring data do not allow for characterization of releases from WAG 7. Additional data to determine the extent and nature of past and continuing releases are needed.

5.1.7 Releases from WAG 8, Melton Valley Area

The following summary is derived from the environmental data package for WAG 8. There is no existing inventory on the contents of the LLW collection and storage tanks, which are still in active use. Historical data are insufficient to determine whether or not any contamination remains at the two leak sites in WAG 8. Samples of the sludge in the four impoundments were not hazardous based on the EP-toxicity test. There is probably less than 10 Ci of radioisotopes in these ponds. There is no indication that radioactive or hazardous wastes were ever introduced into the waste treatment facilities that are part of the ORNL sewage treatment system. The solid waste storage facilities are used for storage of hazardous and mixed wastes.

Historical studies have identified WAG 8 as a major source of ^{60}Co to Melton Branch. The WAG has also been a source of ^{137}Cs, copper, chromium, and zinc. No data are available on organic contaminants.

Recent monitoring data suggest that WAG 8 is the source of about half of the ^{60}Co entering the WOC/WOL system. The WAG contributes negligible amounts of other radionuclides.

Additional data are needed to determine the past and continuing WAG 8 contribution of heavy metals (especially chromium and zinc) and organics to WOC.

5.1.8 Releases from WAG 9, Homogeneous Reactor Experiment (HRE) Area

Stansfield and Francis (1986) found approximately 750 Ci of gross beta activity in the sediments of the HRE impoundment. Strontium-90 and ^{137}Cs were the primary isotopes contributing to this activity. The sediments passed the EP-toxicity test. Tritium and ^{90}Sr were found in groundwater downgradient from the HRE impoundment, but only trace levels of metals and organics were found (Stansfield and Francis 1986).

Existing monitoring data are not sufficient to separate the contribution of WAG 9 from that of WAG 5. Moreover, monitoring data are not routinely collected on trace metal or organic contaminants. Additional data are needed to determine the contribution of WAG 9 to past and continuing contamination of WOC.

5.1.9 Releases from WAG 10, Hydrofracture Injection Wells and Grout Sheets

Approximately 12,000,000 L of liquid wastes were injected into the fractured shale at the two major hydrofracture sites. Except for the isotopes listed in Table 5.2, little is known about the contaminants that may have been included in the grout mixtures. Analyses of similar wastes currently in storage reveal only trivial levels of heavy metals and no organics.

Strontium-90 contamination has been found in groundwater wells installed to monitor releases from the grout sheets. No other contaminants have been found, and there is no indication of WAG 10 contamination reaching shallow groundwater or surface water.

There is no existing monitoring data that can be used to determine the input, if any, of WAG 10 contaminants to WOC. Until the RI for WAG 10 is complete, it is unclear whether additional monitoring data will be needed.

5.1.10 Releases from WAG 13, Environmental Research Areas

As noted in Sect. 3.2, only one small (200 m^2) SWMU (13.2) in this WAG drains into WOC. Approximately 15 mCi of ^{137}Cs in liquid form was sprayed on the surface of this SWMU in 1964. Almost one half-life (30 years) of this material has passed since that time.

An aerial radiometric survey of the ORR conducted in 1986 showed the presence of ^{137}Cs at the other SWMU, but the radiometric maps do not show SWMU 13.2 as a separate source of radiation. The ^{137}Cs was applied to study environmental transport. Therefore, it is likely that some portion migrated into the lower reaches of WOC below White Oak Dam. Stream gravel surveys have not detected ^{137}Cs in the reach that drains SWMU 13.2; however, ^{90}Sr levels were about 4 times background.

Existing monitoring data do not provide adequate resolution to ascertain whether or not WAG 13 presents a current source of ^{137}Cs to WOC. An RI plan is currently being prepared for that WAG, and information in that plan should help to determine if WAG 13 is a source of ^{137}Cs to WOCE.

5.1.11 Releases from WAG 17, ORNL Services Area

The SWMUs in WAG 17 are all tanks, of which three are underground. These tanks have the capacity to contain 39,000 gal of domestic sewage, ~13,000 gal of waste oil, and 5000 gal of photographic wastes. In addition to the SWMUs, there are four underground tanks (capacity ~31,000 gal) used for diesel fuel and gasoline, and one 4000-gal, aboveground waste oil tank.

Stream gravel surveys indicate that there may have been a release of ^{137}Cs at some time in the past. The surveys also suggest the presence of cadmium, chromium, copper, and zinc, and semi-volatile organics were present as tar-like grains on the gravels.

Existing monitoring data do not permit separation of WAG 17 inputs from those of WAG 1, and dilution may obscure the contribution of WAG 17. Additional data are needed to determine the continuing contributions, if any, of WAG 17 to contamination in WOC.

5.2 ADDITIONAL DATA NEEDS

The contaminants identified in Table 5.2 represent only those contaminants for which records exist or which have been identified in various characterization and monitoring studies. As discussed in the preceding subsections, there are three types of major data gaps.

1. Systematic identification is needed for all contaminants (especially trace metals and organics) that have been released (or are being released) from each WAG into WAG 2.

2. Routine monitoring data are needed to provide continuous information on the inputs to WAG 2 from ongoing operations and remedial actions in each source WAG. These data are particularly important in identifying hot spots that may require interim corrective measures.

3. A thorough characterization is needed of selected sites (within the source WAGs) that represent possible future sources of contamination through unplanned releases or remedial activities.

To a large extent the first and third type of data gap can be filled through close coordination with planned and ongoing remedial investigations in the source WAGs. To a limited extent the ongoing remedial investigations can provide the basis for the monitoring data needed in the second type of data gap. For example, the RI in WAG 6 upgraded the weirs on three of the four streams that drain SWSA 6. However, the upgraded weirs will not handle more than a 1-year storm; they are not equipped with continuous samplers, and monitoring data was collected for only about 6 weeks. Therefore, the second type of data gap must be addressed through extensions of existing monitoring programs and through specific characterization studies. Steps to address these data gaps are outlined in Sect. 9.

6. EXISTING INFORMATION FOR CONTAMINANTS IN THE WAG 2

Introduction

Considerable environmental monitoring data exist for the WOC system. Thorough summaries of environmental monitoring data prior to 1985 were compiled in ERDA 1975; Loar et al. 1981; Boyle et al. 1982; and Sherwood and Loar 1987. The Oak Ridge Task Force Study conducted in 1984, in response to environmental contamination at the Y-12 Plant, included a substantial amount of sampling in the WOC system (TVA 1985a). More intensive environmental monitoring was initiated with the establishment of a BMAP and specific monitoring programs for PCBs and mercury as part of the NPDES permit issued to ORNL in 1986 (Loar et al. 1987-90). Routine NPDES monitoring continued to provide chemical data for radiological and nonradiological contaminants. Additional environmental monitoring was also initiated as part of the ER Program.

6.1 SOILS

6.1.1 Soil Contamination

Only limited data exist on heavy metal concentrations and organic contaminants measured in soils in WAG 2. Mercury in three samples collected near WCK 2.7 and WCK 2.1 had average concentrations of 0.8 and 2.6 $\pm$ 0.8 μg/g, dry weight, with the highest concentration of 7.0 μg/g (Loar 1988a,b). By comparison, six samples in SWSA 4 had 0.2 $\pm$ 0.1 μg/g, which may be considered a background level. Benzo[a]pyrene concentrations in a single composite sample at WCK 2.1 was 5 ng/g, but at SWSA 4, it was 35 ng/g (Loar 1988a,b).

6.1.2 Intermediate Pond Site

Studies of contamination of the Intermediate Pond site focused on the biomagnification of radionuclides in the ecosystem, and they include concentration data for vegetation and animals. The site is located on WOC between the water gap at Haw Ridge to a location slightly below the unnamed tributary draining the south side of SWSA 4 (Fig. 6.1). In the spring of 1944, several years before the opening of SWSA 4, a small (90-m) earth-fill dam was constructed across WOC at 3.2 km to create the Intermediate Pond. The pond was to serve as a settling basin for radionuclide-contaminated sediments released from ORNL and traveling down WOC toward WOL. On September 29, 1944, the dam was breached by high water, and the pond was greatly diminished in size. A residual pond existed behind the dam until 1951. During the existence of the residual pond, approximately 0.5 m (1.5 ft) of sediment accumulated. The sediment was initially contaminated by radioactivity released from the

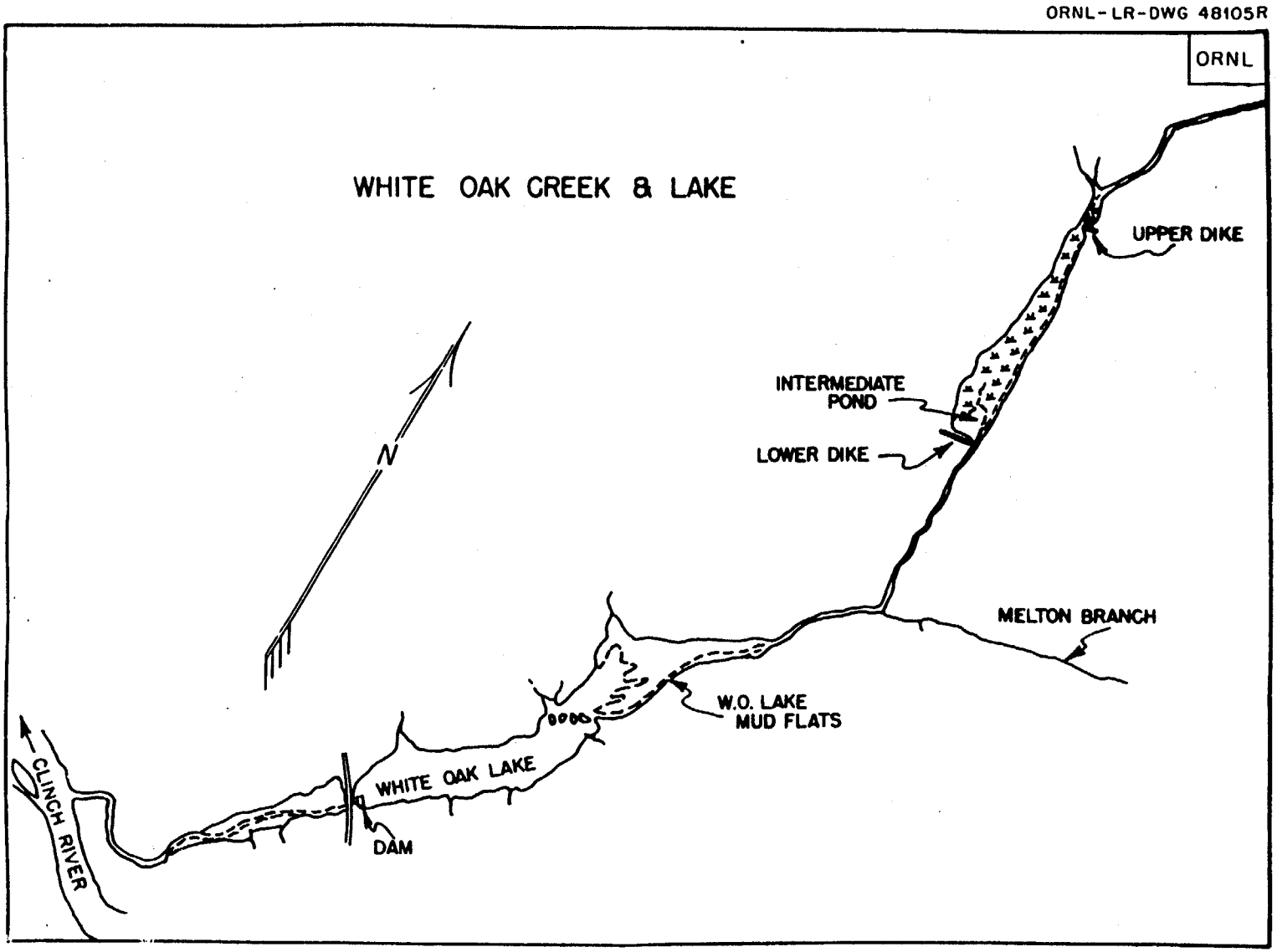

Fig. 6.1. Location of Intermediate Pond in relation to White Oak Lake, ORNL, and the Clinch River.

Laboratory and later contaminated by ^{90}Sr, ^{60}Co, and ^{137}Cs from SWSA 4. The bed of the Intermediate Pond covered an area of about 33,590 m^2 (8.3 acres) (Melroy et al. 1986). The residual pond covered approximately 4850 m^2 (1.2 acres) and was 0.3 to 0.9 m deep. Seven soil samples taken at the area in 1975 contained alpha contamination, ^{90}Sr, ^{60}Co, ^{137}Cs, and minor amounts of ^{125}Sb. Strontium-90 ranged from 59 to 680 pCi/g, ^{60}Co from 15 to 460 pCi/g, ^{137}Cs from 68 to 8.1 X 10^7 pCi/g, and ^{125}Sb from 0.0 to 8.2 pCi/g. Sampling locations are shown in Fig. 6.2; mean concentrations of ^{137}Cs are shown in Fig. 6.3 (Van Voris and Dahlman 1976).

Gross alpha and beta were measured in soil and selected vegetation at 40 locations in the upper and lower ends of the site (personal communication, J. K. Williams - ORNL) (Fig. 6.4). Strontium-90 was analyzed in 15 of the shallow soil samples (0 to 15 cm). Table 6.1 shows significant beta contamination, particularly at the lower end of the site. Strontium-90 appears to be a minor contributor of the gross beta contamination for the surface soils, although the average of 240 pCi/g demonstrates a significant amount of radioactivity. The highest gross alpha (0.35 nCi/g) and gross beta (28 nCi/g) concentrations were found in surface soil samples at location 33.

The treated waste discharged to the Intermediate Pond also contained plutonium, americium, and curium (Dalhman et al. 1980). Plutonium-238, ^{239}Pu, ^{240}Pu, ^{241}Am, and ^{244}Cm were deposited at the pond site and eventually in WOL. Ecological studies focused especially on the bioaccumulation of plutonium in the forest that developed at the pond site. Concentration of $^{239,240}Pu$ in the floodplain soil was found to range from about 10 to 150 pCi/g, and the total inventory was estimated to be 0.5 Ci over a 3-ha area. The highest concentration of plutonium was observed in the 0- to 10-cm zone of the soil profile. Occasionally a higher concentration of plutonium occurred below 10 cm, probably due to deposition of new sediments over the initial plutonium deposit. For samples collected at the pond site, Bondietti and Tamura (1980) investigated the effects of valence state and particle size on the sorption of plutonium to soils.

6.1.3 Former Lake Bed and Floodplain of WOL

When WOL was filled in 1943, the surface area was ~14.5 ha; however, currently the surface area is ~7 ha. The area of the lake has fluctuated as a result of construction and other activities (see Table 3.1). The former lake bed and floodplain areas contain substantial amounts of radionuclides and other contaminants as a result of sediment deposition when the area was covered by lake water or during high water periods. An ecological study area was created on the former lake bed (Lee and Auerbach 1960). Although many studies were conducted in the area in the past, very little information is available on the concentration of contaminants in the floodplain soils and biota during the past decade.

Thirty-one sediment cores were collected in the area between the lake and the weirs on WOC and MB in June and July 1990. The soil samples were analyzed for gamma-emitting

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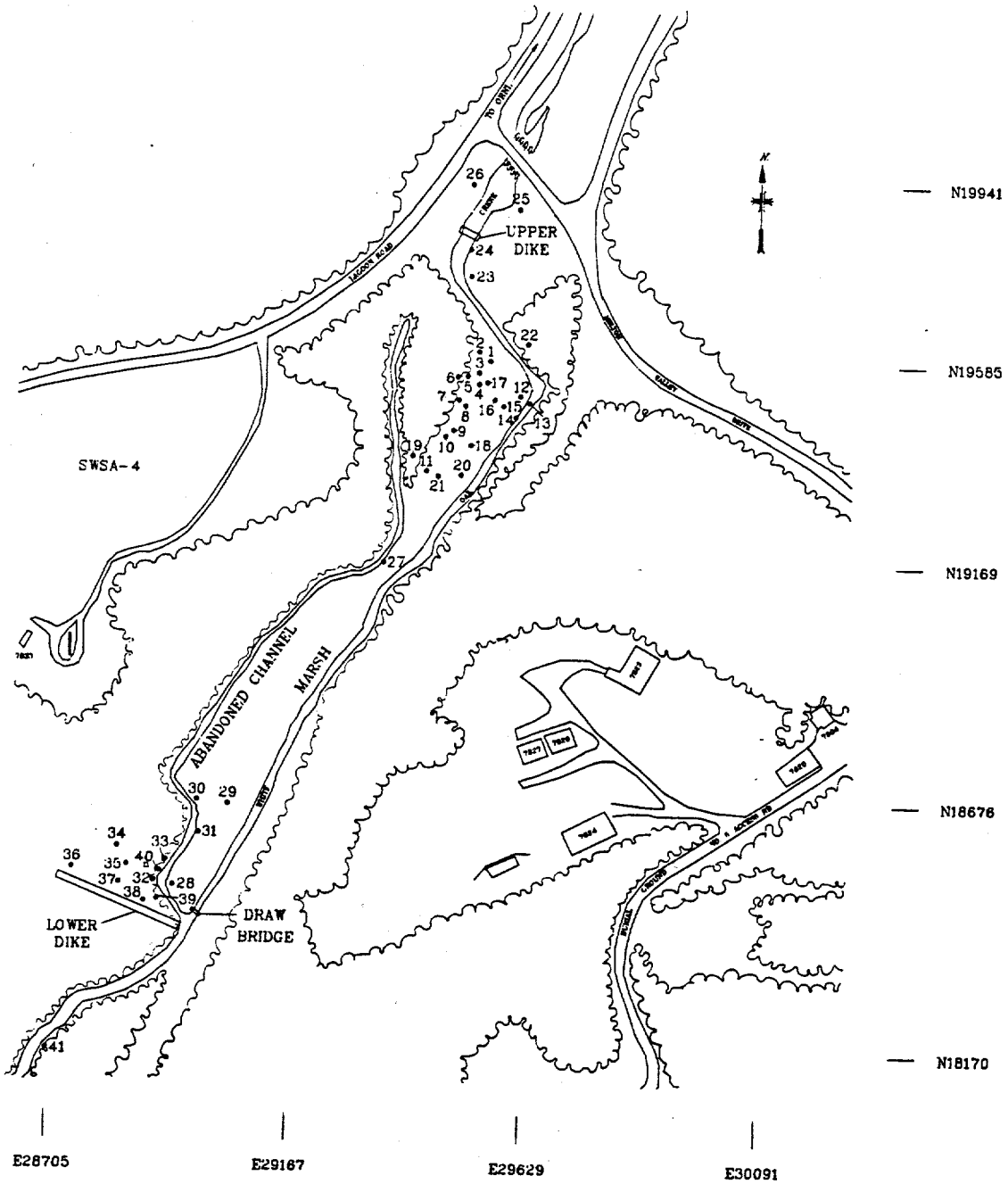

Fig. 6.2. Map showing sampling locations in Intermediate Pond.

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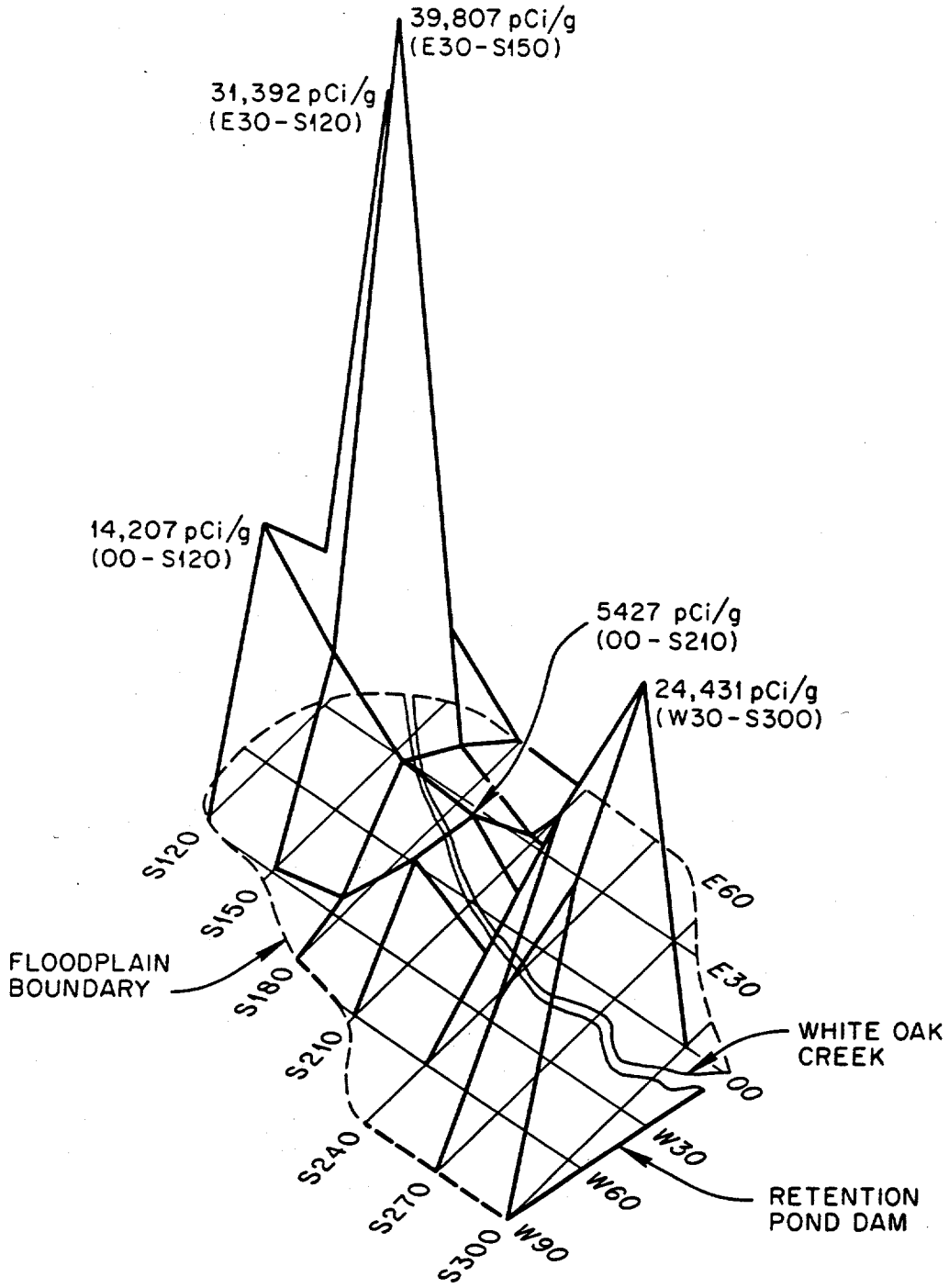
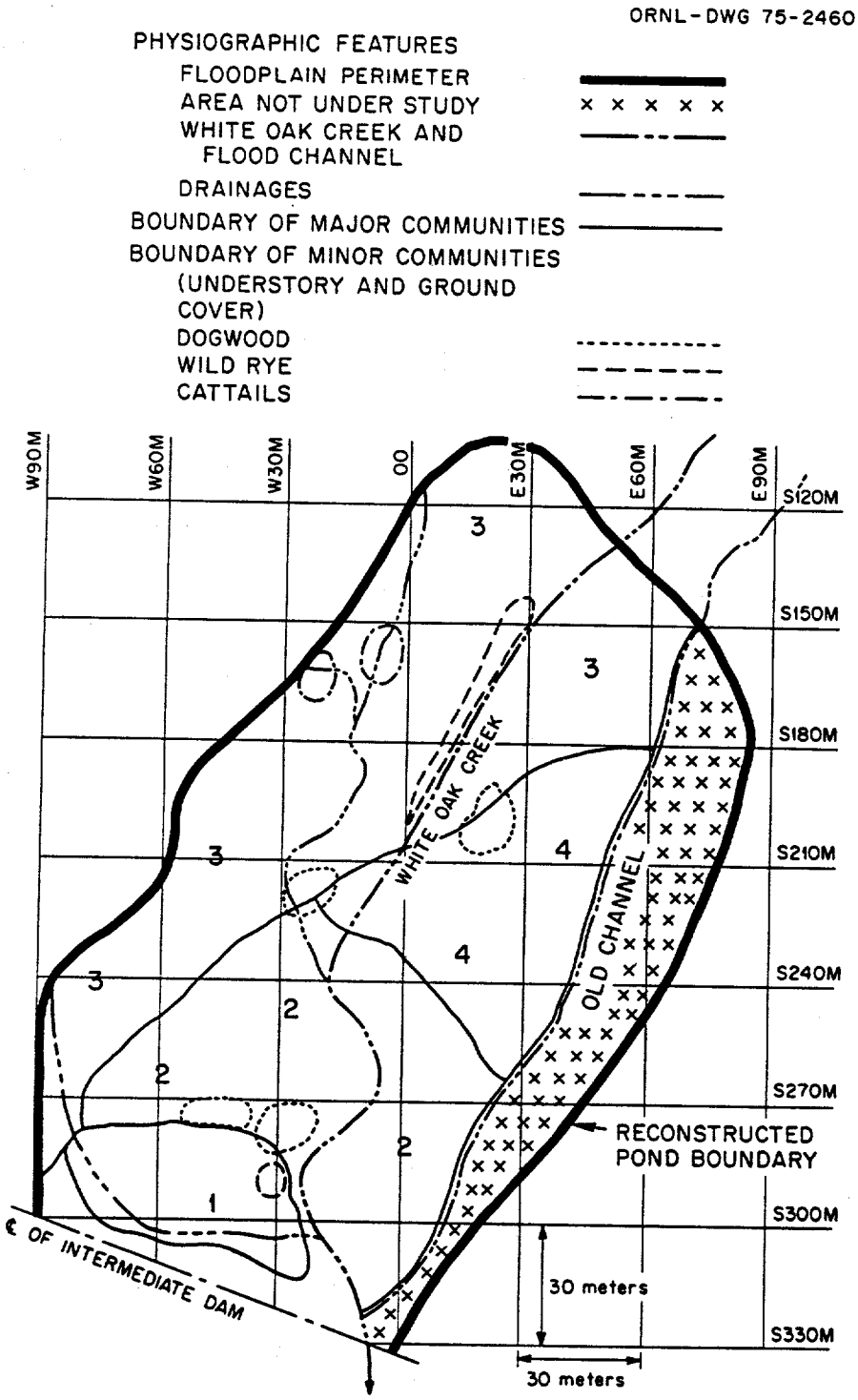


^{137}Cs in Floodplain Soil.

Fig. 6.3. **Mean concentrations of ^{137}Cs in floodplain soils in the Intermediate Pond vicinity.**



Plant Communities of Floodplain Research Facility.

Fig. 6.4. Sampling locations at the grid intersections in the Intermediate Pond area.

Table 6.1. Gross alpha, gross beta, and ^{90}Sr concentrations in soil and selected vegetation samples from the Intermediate Pond Site.

Sample ID[a,b]	Location North	Location East	Soil depth (cm)	Gross alpha (nCi/g DW)	Gross beta (nCi/g DW)	^{90}Sr (nCi/g DW)
1A	19585	29549	0-15	<0.027	1.5	c
1B	19585	29549	15-30	0.054	2.1	c
2A	19601	29528	0-15	0.054	1.8	c
2B	19601	29528	15-30	0.11	6.5	c
3	19563	29527	0-15	<0.027	1.2	c
4	19535	29528	0-15	<0.027	1.6	c
5A	19548	29503	0-15	<0.027	1.3	c
5B	19548	29503	0-15	0.11	4.5	c
6A	19548	29489	15-30	0.054	11	0.10
6B	19548	29489	0-15	0.081	2.9	c
6V	19548	29489	15-30	0.0068	0.30	0.092
7A	19504	29488	-	<0.027	1.3	c
7B	19504	29488	0-15	0.19	5.5	c
8	19489	29502	15-30	0.027	1.6	c
9A	19439	29480	0-15	0.11	7.8	0.15
9B	19439	29480	15-30	0.054	2.6	c
9V	19438	29479	-	0.0057	0.32	0.089
10A	19428	29466	0-15	0.11	10	0.21
10B	19428	29466	15-30	0.14	11	c
11A	19358	29426	0-15	0.081	7.3	0.23
11B	19358	29426	15-30	0.054	4.9	c
11V	19358	29426	-	0.0046	0.15	0.046
12A	19514	29613	0-15	0.30	6.1	0.35
12B	19514	29613	15-30	0.11	8.9	c
13A	19501	29629	0-15	0.054	0.86	c
13B	19501	29629	15-30	0.054	1.1	c
14	19473	29602	0-15	<0.027	0.62	c
15A	19491	29582	0-15	<0.027	1.2	c
15B	19491	29582	15-30	0.19	3.2	c
16	19502	29561	0-15	0.11	4.3	c
17	19541	29545	0-15	<0.027	1.1	c
18	19409	29515	0-15	0.081	2.3	c
19A	19386	29497	0-15	0.081	3.8	c
19B	19386	29497	15-30	0.19	3.9	c
20	19354	29498	0-15	0.054	2.1	c
21A	19346	29452	0-15	0.081	3.0	c
21B	19346	29452	15-30	0.32	4.9	c
22A	19618	29621	0-15	0.16	11	0.19
22B	19618	29621	15-30	0.11	9.7	c
22V	19618	29621	-	0.017	0.65	0.32

radionuclides (^{90}Sr and metals such as mercury, lead, chromium, and selenium). These data are in the process of being evaluated and will be used along with the proposed gamma walkover survey to design a sampling program that will provide data for the ecological and health risk assessment.

6.1.4 Melton Branch Soils

Soils in several locations below the High Flux Isotope Reactor/Transuranic Processing Plant (HFIR/TRU) and the nearby Waste Collection Basins 7905, 7906, 7907 and 7908 have measurable contamination. Recently, a surface radiological investigation was performed (personal communication, Uziel - ORNL). The surface gamma exposure rates generally ranged from 24 to 48 uR/h, compared to background levels for the ORR of 10 to 17 uR/h. Within the plant fences the contamination was confined to nine small isolated spots, whereas below the fence in the direction of MB, contaminated areas of surface soil were widespread, but localized along MB, the floodplain, and waste steams from outfalls 281, 381, 382, and 383 (Fig. 6.5). The maximum measurement was 45,000 uR/h below outfall 381, and for the contaminated section of MB floodplain the gamma exposure rate was generally less than 1700 uR/hr. A few soil, water and vegetation samples were collected from hot spots. The one sample from MB flood plain below the outfalls had 3800 pCi/g of ^{60}Co, 380 pCi of ^{137}Cs, 110 pCi/g gross alpha, and 7500 pCi/g gross beta. (The error for the gross alpha measurement was large, 400 pCi/g.) Two out of three samples of water and the only sample of vegetation showed elevated levels of ^{60}Co and beta activity. Because the facilities were used for processing transuranics, measurements of transuranic concentrations in soils are needed.

6.2 FLOODPLAIN BIOTA

6.2.1 Floodplain Vegetation

There have been numerous studies of radionuclide transport and cycling at contaminated sites within the WOC drainage that can be used to characterize accumulation of radioactive contaminants by floodplain vegetation (Van Voris and Dahlman 1976, Garten and Dahlman 1978, Garten et al. 1978, Dahlman et al. 1980, Garten et al. 1981, Olsen et al., 1983, Garten et al. 1986, Amano et al. 1987, Garten and Lomax 1987, Garten 1987, Garten et al. 1987, Garten and Lomax 1989). Table 6.2 summarizes data on maximum observed levels of ^{90}Sr, ^{99}Tc, ^{137}Cs, ^{239}Pu, ^{233}U, ^{234}U, ^{238}U, ^{241}Am, and ^{244}Cm measured in vegetation from floodplain habitats in or adjacent to WAG 2. For the most part, these concentration data are derived from areas that were selected for field studies of radionuclide behavior in the floodplain ecosystem. They were not derived from representative sampling of WAG 2. Nevertheless, these studies allow some conclusions to be drawn about the relative accumulation of various radionuclides by floodplain vegetation.

Low concentrations (fCi/g to pCi/g levels) of ^{137}Cs, ^{60}Co, uranium isotopes, and transuranic elements are expected in WAG 2 vegetation. Plant/soil concentration ratios, as

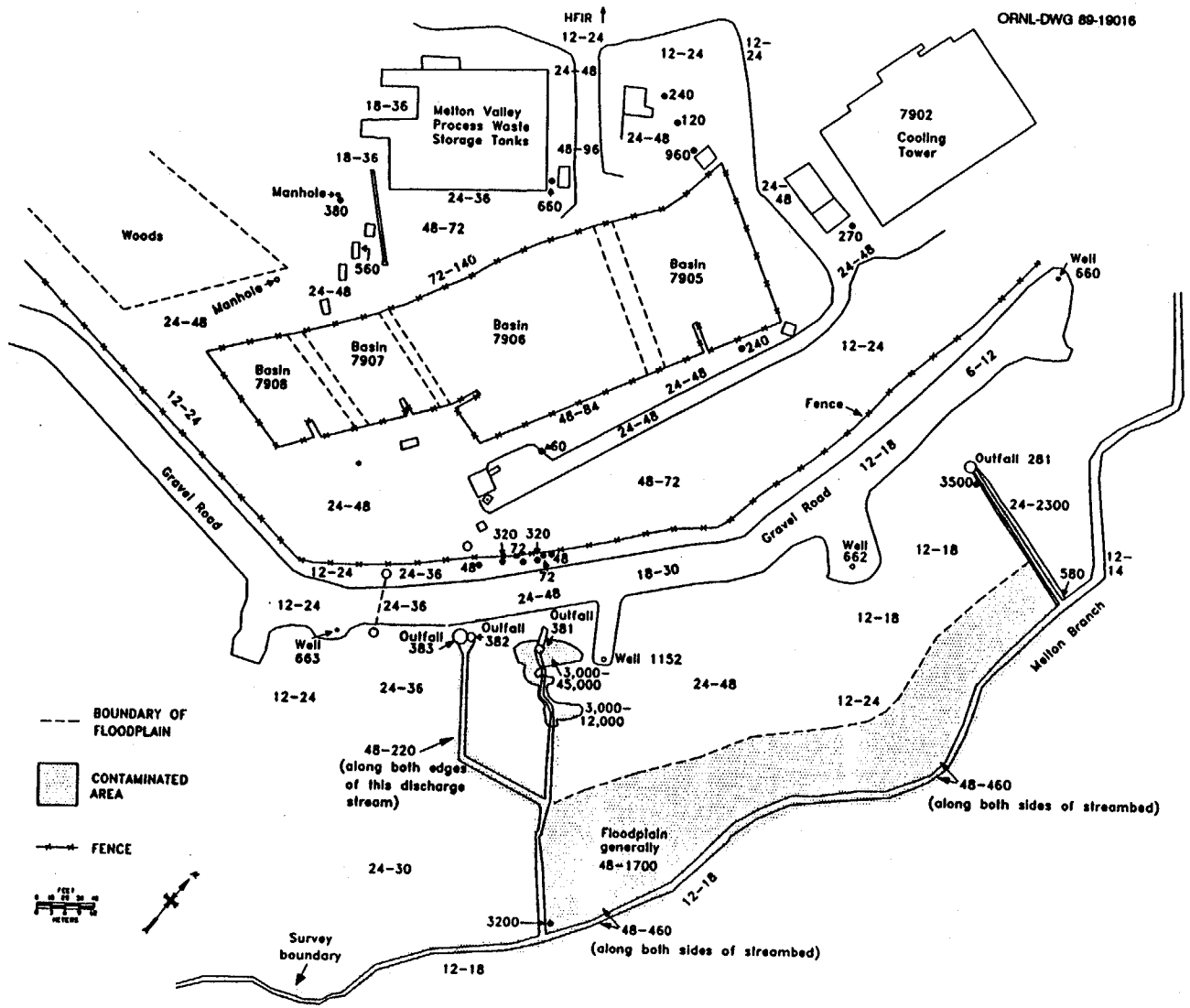


Fig. 6.5. Diagram showing results of surface gamma exposure rate measurements (μR/h) taken at HFIR/TRU Waste Collection Basins 7905, 7906, 7907, and 7908 (Uziel, personal communication).

Table 6.2. Maximum levels of radioactivity measured in vegetation within WAG 2[a].

Radionuclide	Year meas.	Nearest landmark	Concn (pCi/g)	Reference
Strontium-90	1958	WOL	700	Lomenick et al. 1962
	1982	Trench 7	120	Olsen et al. 1983
	1982	Pit 2	4.3	Olsen et al. 1983
	1982	Trench 5	6	Olsen et al. 1983
	1983	SWSA 4	750	Garten and Lomax 1987
	1986	SWSA 4	21000	Garten and Lomax 1987
	1986	SWSA 5	90100	Garten and Lomax 1987
	1987	Trench 7	590000	J. K. Williams (unpublished)
Technetium-99	1982	Trench 7	840	Olsen et al. 1983
	1982	Pit 2	300	Olsen et al. 1983
	1984	Trench 5	1190	Garten et al. 1986
Cesium-137	1974	SWSA 4	180	Van Voris and Dahlman 1976
Uranium-233	1982	Trench 5	<0.03	Olsen et al. 1983
Uranium-234	1978	SWSA 4	0.046	Garten 1980
Uranium-238	1978	SWSA 4	0.034	Garten 1980
Plutonium-239	1975	SWSA 4	0.003	Dahlman et al. 1980
	1978	SWSA 4	0.030	Garten 1980
	1980	SWSA 4	0.400	Adriano et al. 1980
Americium-241	1978	SWSA 4	0.014	Garten 1980
Curium-244	1978	SWSA 4	0.009	Garten 1980

[a]These data are not derived from a representative sampling of WAG 2, but are from field studies that were conducted to characterize radionuclide behavior where contamination by radionuclides was known or suspected to be present in levels that would make reliable measurements possible.

an index of the soil-to-plant transfer of radionuclides, are approximately 10^{-1} for ^{137}Cs (Dahlman and Van Voris 1976) and approximately 10^{-3} for plutonium (Garten et al. 1987,Adriano et al. 1980) and other transuranic elements (Garten 1980a, Trabalka and Garten, 1983). Root/soil concentration ratios are somewhat higher. Comparative studies of plutonium, uranium, and thorium uptake by vegetation show that the order of actinide accumulation by floodplain vegetation from contaminated soil is U > Th ≈ Pu (Bondietti et al. 1979). Environmentally dispersed plutonium tends to behave like naturally occurring ^{232}Th and will not accumulate in terrestrial vegetation to a level exceeding the accumulation of natural ^{238}U (Garten et al. 1981, Garten et al. 1987).

The principal radionuclides of environmental concern (^{90}Sr, ^{99}Tc, and ^{3}H) are mobile radioactive contaminants that exhibit higher levels than ^{137}Cs and transuranic elements in floodplain vegetation (Table 6.2). Based on field studies on or near the floodplain, plant/soil concentration ratios for ^{90}Sr have been determined to range between 0.6 and 3.3 (Garten and Lomax 1987), and those for ^{99}Tc range between 0.5 and 1.1 (Garten et al. 1986). Therefore, both ^{90}Sr and ^{99}Tc exhibit potential for uptake by vegetation and subsequent food chain transfer. In addition, high levels of tritium (up to 50 μCi/L water) have been observed in water extracted from wood cores taken from pine trees growing along the MB floodplain (Amano et al. 1987). Strontium-90, ^{99}Tc, and tritium constitute the radionuclides of greatest concern from the viewpoint of environmental mobility and accumulation by vegetation.

Contaminant inventories and a mathematical model of radionuclide cycling have been developed for some ecological study sites in the WOC drainage. Dahlman and Van Voris (1976) estimated that there was ~100 Ci of ^{137}Cs present in part of the WAG 2 floodplain that was contaminated by Manhattan Project operations in 1944. Estimated inventories and ecosystem models for ^{137}Cs cycling in this forest published by Auerbach (1987), Van Voris et al. (in press), and Garten et al. (1978) described an ecosystem model for plutonium cycling in the same mixed hardwood forest. Plutonium-239 inventories for this ecosystem have been presented by Garten et al. (1978) and Dahlman et al. (1980). Both static inventories and model dynamics support conclusions about the relatively minor role of floodplain vegetation in cycling ^{137}Cs and ^{239}Pu. Vegetation uptake will have little control on the migration of these radionuclides from WAG 2.

In the case of ^{90}Sr, ^{99}Tc, and ^{3}H, uptake by vegetation may play a more important role in contaminant retention and redistribution within the ecosystem. A model for the fate of ^{99}Tc cycling in forest ecosystems has been developed based on field studies (Garten 1987) that explains the probable fate of ^{99}Tc entering element cycles in WAG 2. This model indicates under what conditions the forest ecosystem helps to retain ^{99}Tc and prevent its migration from the drainage. Technetium-99 uptake by forest trees is accompanied by metabolism that renders ^{99}Tc less biogeochemically mobile than expected, based on the chemistry of the pertechnetate anion (Garten and Lomax 1989). Organically complexed (reduced) ^{99}Tc is recycled from vegetation to surface soils in autumn leaf fall. Redox conditions in the soil are particularly important in limiting ^{99}Tc migration from contaminated sites. One implication of model simulations (Garten 1987) is that remedial actions that alter floodplain hydrology could result in accelerated losses of ^{99}Tc from the terrestrial ecosystem. Construction activities that dry out or increase aeration of ^{99}Tc-contaminated floodplain soils may convert ^{99}Tc from

insoluble, reduced forms (Tc IV) to soluble, oxidized forms (Tc VII), resulting in increased contaminant losses through migration in surface waters.

Although high concentrations of ^{90}Sr have been observed in vegetation from some areas of WAG 2 (Garten and Lomax 1987), forest inventories and models for the cycling of ^{90}Sr within the floodplain ecosystem are not available. Recycling of ^{90}Sr from vegetation to the surface of the forest soil can be expected where ^{90}Sr is present in soil (personal communication, J. K. Williams - ORNL). The potential impact of remedial actions on the retention of ^{90}Sr by the floodplain forest can not be evaluated until an estimate of ^{90}Sr inventories becomes available for the floodplain forests. Deforestation as a part of remedial action could remove the role of vegetation as an accumulator for ^{90}Sr, alter hydrologic cycles, and increase nitrification (nitrate production) in soils; any or all of these could lead to increased ^{90}Sr migration from the drainage.

6.2.2 Terrestrial Biota

There have been several studies of the accumulation of ^{137}Cs, ^{90}Sr, ^{239}Pu, uranium, and thorium by small mammals inhabiting the WOC floodplain (Van Voris and Dahlman 1976, Garten and Dahlman 1978, Garten 1980b, Garten et al. 1981). Van Voris and Dahlman (1976) reported concentrations of ^{137}Cs ranging from background to 107 pCi/g in small mammals (the highest concentrations were observed in shrews). Concentrations in larger mammals (raccoon, possum, and rabbit) ranged from 20 to 100 pCi ^{137}Cs/g. Radiocesium and plutonium concentrations are correlated in biota from the WOC floodplain (Garten and Dahlman 1978), but ^{239}Pu concentrations are low (1 to 3 fCi/g) in small mammals sampled from areas where ^{239}Pu-contaminated soils are present.

The direct ingestion of soil by small mammals while digging, foraging, or grooming probably shortcuts the trophic transfer of radionuclides like ^{137}Cs and ^{239}Pu in this ecosystem because soil (not vegetation) is the principal reservoir for these contaminants (Garten 1980c). Animal/soil concentration ratios for ^{239}Pu on the floodplain are approximately 10^{-4} to 10^{-5} (Garten and Dahlman 1978). Comparisons of actinide element uptake based on analyses of radionuclide ratios (uranium/plutonium and thorium/plutonium) in soil and small mammal carcasses (shrews, mice, and rats) or bone samples (rabbit, woodchuck, raccoon, and possum) show that plutonium is accumulated to a lesser extent than naturally occurring uranium and to the same extent as naturally occurring thorium (Garten et al. 1981, Trabalka and Garten 1983).

Strontium-90 accumulation by white-tailed deer from seepage areas in WAG 2 has been modeled to determine the effect of amount of browsing and plant ^{90}Sr concentration as determinants of deer body burdens (Garten and Lomax 1987). Model calculations indicate that, based on relatively low usage by deer and measured mean concentrations in browse plants from the floodplain, the calculated ^{90}Sr level in deer bone can exceed 30 pCi/g for a 45-kg buck that visits seepage areas on a regular basis. Because of its higher plant/soil concentration ratio, ^{90}Sr has a theoretically higher potential for food chain transport than ^{137}Cs. However, in field experiments where dairy goats were allowed to graze in contaminated

areas on the WOC floodplain for 7 weeks, milk/vegetation concentration ratios for both ^{137}Cs and ^{90}Sr were both approximately 0.03 (E. A. Bondietti, unpublished data). The uptake and transport of radionuclides from terrestrial communities in WAG 2 by animal migration would appear to be insignificant for all radionuclides, with the exception of ^{90}Sr.

Sampling along the WOC floodplain as part of the ORNL BMAP has revealed detectable (~700 pCi/g bone) levels of ^{90}Sr in small mammals (Loar 1988b). However, aside from radionuclides, there has been limited sampling of small mammals inhabiting WAG 2 for inorganic or organic contaminants. Mercury concentrations were reported to range from 0.04 to 0.55 μg/g fresh kidney in small mammals captured near SWSA 6 during 1985 and 1986 (Loar et al. 1987). These levels were higher than those observed in small mammals captured near the Bull Run Steam Plant (0.05 to 0.08 μg Hg/g fresh kidney). Although trace levels of benzo(a)pyrene (BaP) occur along the WOC floodplain, analysis of blood samples for BaP tetrols, an indicator of exposure, revealed nondetectable levels (<10 pg) of BaP tetrol in small mammals trapped near SWSA 6 (Loar et al. 1987). Analysis of animals for PCBs showed that except for PCB-1260 (2.1 μg/g) in the liver of a white-footed mouse from the WOC floodplain, PCB concentrations in field mice from WAG 2 were similar to those from reference areas (Loar 1988b). Based on experience gained through BMAP studies, the interpretation of contaminant data in field populations of small mammals is difficult and usually equivocal for several reasons, including animal migration (Loar 1990). Therefore, contaminant surveys in soil and vegetation in WAG 2 should have priority over contaminant surveys in small mammals.

6.3 GROUNDWATER CONTAMINATION

A scoping survey of water from 27 piezometer wells in WAG 2 (personal communication, D. W. McCrackin - ORNL) shows serious but not widespread contamination of groundwater by radionuclides, possible contamination by metals at 1 to 8 locations, a possible organics content at one location, and atypical chloride concentrations at five locations. However, the metal contents may be natural, and relatively high concentrations of sulfate in six wells are almost certainly natural. Finally, unusually large contents of aluminum and silicon at four locations are probably caused by colloidal particles in unfiltered water samples.

Ten water samples (37%) exceeded the EPA drinking water standard of 3.7 Bq/L for gross beta, and four samples contained more than 10 times this amount. An EPA drinking water standard is a concentration yielding a risk equal to that from a dose rate of 4 mrem/year. Six samples (22%) exceeded the EPA drinking water standards of 3330 Bq/L for tritium and 3.7 Bq/L for ^{90}Sr; half of these samples in each case contained more than 10 times the drinking water standard. Five water samples (19%) exceeded the 0.55 Bq/L drinking water standard of EPA for gross alpha; the highest concentration was 2.6 Bq/L. Only two samples (7.4%) exceeded the 3.7 Bq/L drinking water standard for ^{137}Cs, and the highest concentration was 12 Bq/L. All samples contained less than the EPA drinking water standard of 7.4 Bq/L for ^{60}Co; the highest concentration was 2.3 Bq/L.

The locations of wells having radioactivity and radionuclide concentrations in excess of EPA drinking water standards (Fig. 6.6) show that the main sources of contamination inWAG 2 are groundwater flows from WAGs 4 and 5. Groundwater from WAG 4 is apparently a major source of gross alpha, gross beta, and ^{90}Sr contamination in adjacent parts of WAG 2 and is also a significant source of tritium. Floodplain and stream channel sediments in this area might also be a source of contamination, but most groundwater flows are upward toward WOC. Groundwater flows from WAG 5 are the source of tritium and gross beta contamination in the adjacent part of WAG 2. In other parts of WAG 2, only 6 of 22 wells (27%) had contamination caused by radionuclides in excess of EPA drinking water standards. Contaminated lake bed and floodplain sediments near WOL may produce some groundwater contamination, but most flow paths are upward, toward the stream and the lake.

Twenty piezometer wells (74%; locations on Fig. 6.7) produced water that exceeds the secondary drinking water standard for iron (0.3 mg/L), and 26 of the water samples (95%) exceeded the secondary drinking water standard for manganese (0.05 mg/L). The highest concentrations were 77 mg/L of iron and 13 mg/L of manganese. Natural concentrations of these constituents in excess of the secondary standards are commonly observed in uncontaminated groundwater of the Conasauga Group, and the large contents in WAG 2 are almost certainly natural. Also, concentrations of dissolved ferrous iron generally do not exceed 60 mg/L in a bicarbonate water, and the highest concentrations of iron and manganese in WAG 2 may occur partly or mostly as colloidal particles in the unfiltered samples. This tentative conclusion is supported by the lack of any correlation between iron and sulfate contents in the water samples. High concentrations of dissolved iron and manganese indicate a low content of dissolved oxygen.

Eight water samples (30%) from the piezometer wells had chromium concentrations that exceed the drinking water limit (0.05 mg/L). The highest concentration was 0.46 mg/L. Some of the wells having water with a large chromium content are near WAGs 4 and 5, but other wells are in areas that should not be contaminated (Fig. 6.7). A low natural content of chromium would be expected in shales of the Conasauga Group, but chromium can also occur as colloidal particles in unfiltered water samples. It may thus be significant that samples with detectable concentrations of chromium also contained relatively large amounts of iron and manganese. The chromium content of groundwater is probably natural in WAG 2, and high concentrations in the samples may not occur in dissolved form. However, new analyses of filtered groundwater samples are needed to evaluate the possibility of chromium contamination in this area.

The water sample from one well (No. 722; location on Fig. 6.7) exceeded the drinking water limit for both barium (1 mg/L) and lead (0.005 mg/L); the concentration of barium was 2.4 mg/L, and the concentration of lead was 0.43 mg/L. The same well had the highest concentrations of beryllium, cadmium, cobalt, and vanadium plus the second highest concentrations of chromium, copper, and nickel among the 27 piezometer wells. These metal contents might be natural. Some metals, notably barium, beryllium, cobalt, copper, and nickel are strongly sorbed on clay, iron oxide, and manganese oxide particles and are commonly found in unfiltered groundwater from shales. The good correlation of barium and manganese contents in the water samples from WAG 2 may thus be significant. Nevertheless, Well 722

ORNL DWG 90-16662

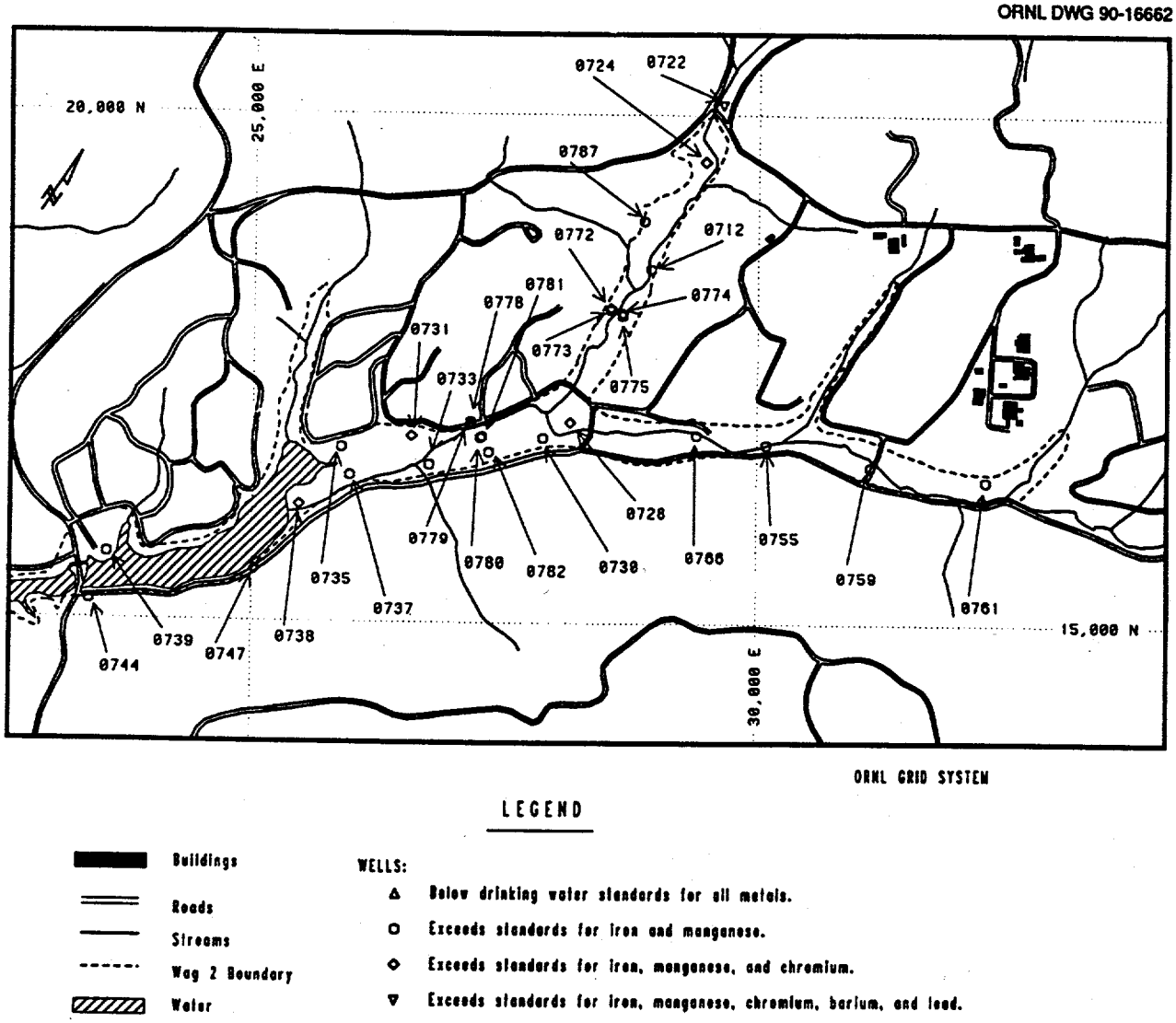
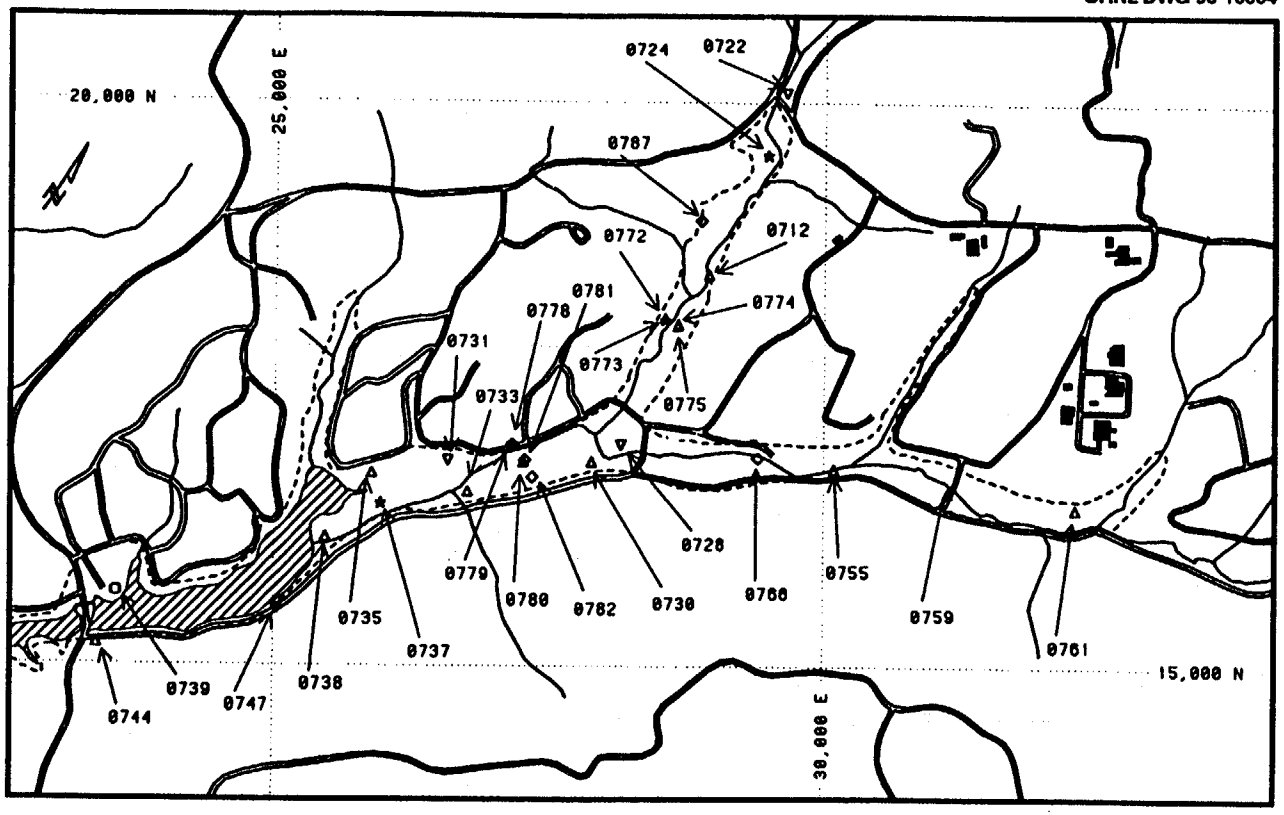


Fig. 6.6. Piezometer wells in WAG 2 where radioactivity and radionuclide contents of groundwater (a) meet drinking water standards, (b) exceed drinking water standards, and (c) are 10 times larger than drinking water standards. (A drinking water standard is a concentration yielding a risk equal to that from a dose rate of 4 mrem/yr).

ORNL DWG 90-16664



LEGEND

- Buildings
- Roads
- Streams
- Wag 2 Boundary
- Water

WELLS:

- △ Typical concentrations of constituents below.
- ○ Positive test for organics scan.
- ◇ Anomalous chloride concentrations.
- ▽ Large contents of aluminum and silicon.
- ★ Anomalous sulfate concentrations.

Fig. 6.7. Piezometer wells in WAG 2 where (a) metal contents of groundwater are below drinking water standards, and (b) the concentration of one or more metals exceeds primary or secondary standards for drinking water.

should be resampled to evaluate the possibility of contamination in this area. It is also important that the detection limit for lead (0.2 mg/L) in the scoping survey was 40 timeslarger than the new drinking water limit; for this reason the concentration of lead in WAG 2 groundwaters has not been adequately evaluated.

Four wells in WAG 2 (Fig. 6.8) had unusually high concentrations of silicon and aluminum in the 1987 water samples. The maximum concentrations were 51 mg/L for aluminum and 47 mg/L for silicon. The aluminum contents greatly exceed the solubility limit for a slightly alkaline water, and silicon concentrations are generally <8 mg/L in this and other areas. These anomalous results were almost certainly caused by acidifying unfiltered samples containing colloidal particles of aluminum and silica. The constituents are natural, but the dissolved concentrations are less than are indicated by these analyses.

The water from five piezometer wells (Fig. 6.8) contained more than 40 mg/L of chloride, and the samples from six other wells contained 10 to 22 mg/L of chloride, whereas concentrations of <10 mg/L are typical of groundwater in uncontaminated areas. The maximum chloride content was 200 mg/L in Well 781, and the sodium content in this well was 250 mg/L. One of the wells having a high chloride content is near WAG 4, and another well is near WAG 5. The other three wells are in a part of WAG 2 that is adjacent to WAG 7 (Pits and Trenches) but is also near WAG 10 (Old and New Hydrofracture facilities). The high chloride concentrations probably represent contamination caused by groundwater flows from other WAGs. It is unlikely that natural brine in the hydrofracture injection zones has migrated upward and contaminated shallow groundwater because all water samples from wells in this area had nitrate concentrations below the detection limit (1 to 5 mg/L). Nevertheless, these wells should be resampled and analyzed for the entire suite of nitrogen ions, including cyanide and cyanate, so as to evaluate this possibility.

The water from six piezometer wells (Fig. 6.8) contained 50 to 130 mg/L of sulfate, whereas 18 other wells contained <30 mg/L. Relatively high sulfate concentrations are not common in groundwater near ORNL but have been observed in uncontaminated areas, including the headwaters area of MB. The high sulfate contents are almost certainly natural and probably represent the solution of gypsum from shale units in the Conasauga Group.

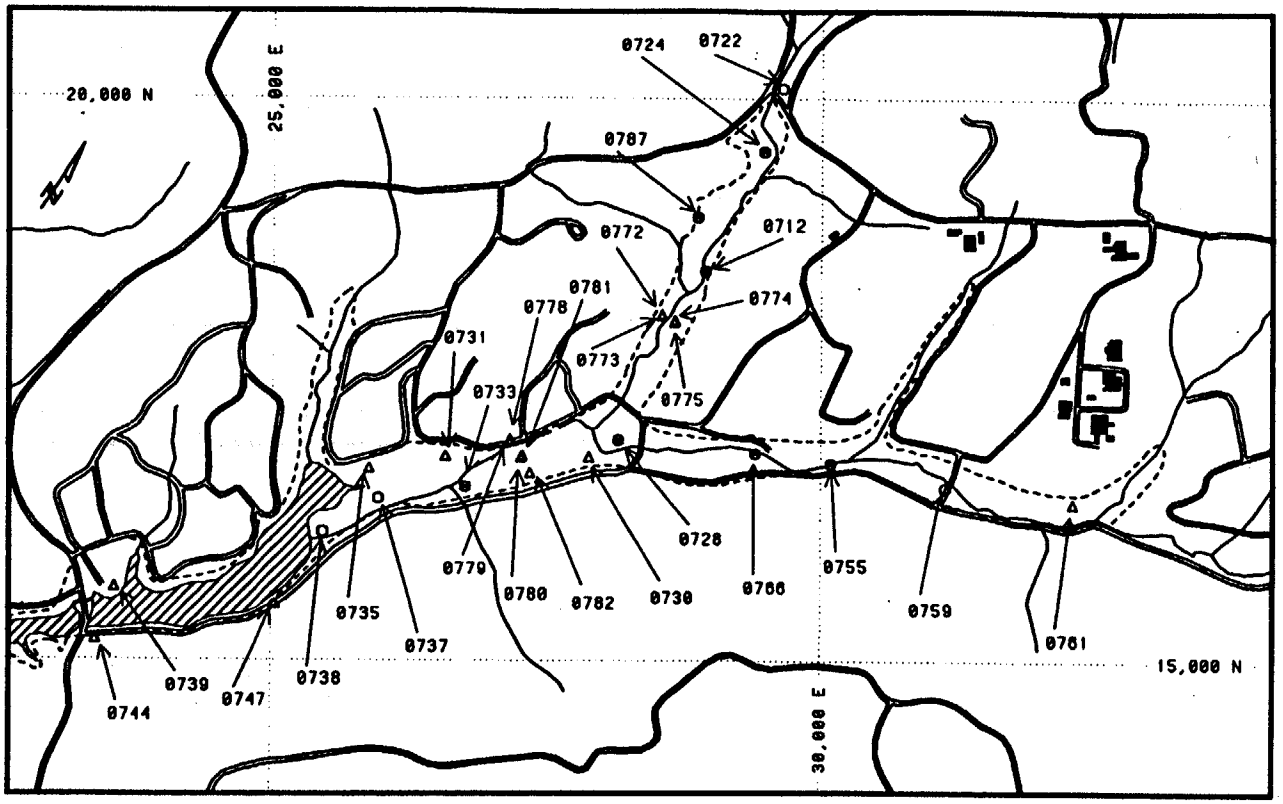
One well (No. 739; location on Fig. 6.8) tested positive on a scan for organic chemicals. This well is near WAG 6, but contamination is unlikely because most groundwater in WAG 6 flows along-valley toward tributary streams. A resampling of this well would be necessary to evaluate the possibility of organic contamination.

6.4 SURFACE WATER CONTAMINANT DATA

6.4.1 Introduction

The chemical quality of WOC upstream from the laboratory (WAG 1) resembles that of groundwater in Bethel Valley (Webster 1976). Water quality in WOC and MB reflects the

ORNL DWG 90-16663



LEGEND

Buildings
Roads
Streams
Weg 2 Boundary
Water

WELLS:
- △ Below drinking water standards for radionuclides.
- ○ Exceeds drinking water standards for radionuclides.
- ● More than 10 times the drinking water standards for radionuclides.

Fig. 6.8. Piezometer wells in WAG 2 that have typical and anomalous concentrations of (a) organics, (b) chloride, (c) aluminum and silicon, and (d) sulfates.

many point-source discharges from ORNL facilities and area-source discharges from waste disposal areas in Bethel and Melton valleys. The effects of plant operations on water quality in the creek and lake have been studied since the early 1940s. Continuous flow-proportional sampling at WOL Dam was initiated in the late 1940s to provide a means of evaluating the amount of radioactivity entering the Clinch River. Measurements of contaminants in the Clinch and Tennessee rivers downstream of the ORR are being made as part of the Clinch River RFI, as well as by ongoing monitoring programs. Calculations of the levels of radionuclides in the Clinch River can be made by use of the concentrations and flow measured at WOL Dam and the dilution provided by the river. The mean annual dilution factor at the junction of WOC and the Clinch River has been estimated as about 400 for the period 1951-60 (Carrigan 1968) and 375 for the period 1962-73 (Webster 1976); in 1988 the average of the monthly dilution factors was 275 (Rodgers et al. 1989).

A characterization of ambient water quality downstream of all point source discharges and most major area sources is presented in Tables 6.3 and 6.4. It is based on routine NPDES monitoring conducted in 1988 at MB weir (MBK 0.16) and at WOL Dam (NPDES Sites X13 and X15, respectively). These data are collected either daily or weekly and are published quarterly by the ORNL Environmental Monitoring and Compliance Section.

Water quality in lower WOC, as characterized by the NPDES monitoring program (Table 6.4), consisted of elevated concentrations of most metals, but very low or nondetectable levels of organic contaminants, and moderate phosphorus and ammonium enrichment. Although concentrations of trace elements in WOC below ORNL exceeded the levels observed in the unimpacted upper reaches of the stream, only mercury and iron exceeded EPA water quality criteria for freshwater aquatic life (EPA 1986a, 1987b). The mean concentration of mercury in WOC exceeded the criterion of 0.012 μg/L (EPA 1986a, 1987b), and concentrations of iron in 1 of 12 samples at Melton Branch (X13) and 2 of 12 samples from WOL Dam (X15) exceeded the criterion of 1000 μg/L (EPA 1986a, 1987b).

6.4.2 Organic Contaminants

Volatile organics are surveyed in WOC and MB as part of the NPDES monitoring program (Rodgers et al. 1989). Samples collected and analyzed for trichloroethene in both MB and WOC were below the limits of detection in 1987 and 1988. Effluent characterization data indicate inputs of numerous halogenated aliphatics to both streams (Murphy 1986, EPA 1986a, 1987b). The volatile organics observed in effluents fall into three groups: trihalomethanes (chloroform, dichlorobromomethane, dibromochloromethane, bromoform) associated with chlorination of water; chlorinated solvents (1,2 dichloroethane, 1,1 dichloroethane, methylene chloride, chlorobenzene, 1,2 dichloroethylene, trichloroethylene, 1,3 dichloropropylene, tetrachloroethylene, 1,1,1 trichloroethylene, and 1,1,2 trichloroethylene); and monocyclic aromatics (benzene and toluene). None of these compounds has significant bioaccumulation potential (Callahan et al. 1979) and all are subject to rapid removal from surface waters by volatilization (Callahan et al. 1979). The trihalomethanes are formed in the chlorination of process water and sewage treatment plant effluents. Their ubiquitous presence in effluent streams suggests that process water may be

Table 6.3. 1989 ORNL NPDES Permit Number TN 0002941 (discharge point X15—White Oak Dam)

Parameter	No. of samples	Concentration (mg/L)			Std. error
		Max	Min	Av	
Aluminum (total)	12	2.8	<0.050	<0.86	0.22
Ammonia (as N)	12	0.16	0.011	0.046	0.012
Arsenic (total)	12	0.090	<0.050	<0.055	0.0034
Biochemical oxygen demand	12	>34	<5.0	<7.4	2.4
Cadmium (total)	12	<0.0020	<0.0020	<0.0020	0
Chlorine (total) residual	52	<0.010	<0.010	<0.010	0
Chloroform	11	<0.025	0.0010[a]	0.0041[a]	0.0021
Chromium (total)	12	0.028	<0.0030	<0.016	0.0025
Conductivity (mS/cm)	12	1.7	0.23	0.87	0.14
Copper (total)	12	0.13	0.0050	0.019	0.010
Dissolved solids (total)	12	240	140	200	9.4
Flow (Mgd)	249	150	4.2	14	1.0
Fluoride (total)	12	1.0	<1.0	<1.0	0
Iron (total)	12	2.3	0.20	0.67	0.16
Lead (total)	12	0.0040	<0.0040	<0.0040	0
Manganese (total)	12	0.10	<0.0020	<0.060	0.0081
Mercury (total)	12	0.00011	<0.000050	<0.000063	
Nickel (total)	12	<0.020	<0.0050	<0.010	0.0017
Nitrate	12	<5.0	<5.0	<5.0	0
Oil and grease	52	>200	<2.0	<10	4.3
Organic carbon (total)	12	6.4	1.7	2.9	0.37
Oxygen (dissolved)	52	14	4.0	8.5	0.29
PCBs (total)	11	<0.00050	<0.00050	<0.00050	0
pH (standard units)	12	8.9	6.7	*b*	*b*
Phosphorus (total)	12	0.50	0.10	0.23	0.031
Silver (total)	12	<0.0050	<0.0050	<0.0050	0
Sulfate (as SO_4)	12	48	12	34	2.9
TSS	12	37	<5.0	<13	3.2
Temperature (°C)	64	28	3.9	17	0.80
Trichloroethene	11	<0.025	0.00070[a]	0.0064[a]	0.0019
Turbidity (NTU)	12	240	10	74	23
Zinc (total)	12	0.040	<0.0080	<0.024	0.0036
		Concentration (pCi/L)			
^{241}Am	18	1.6	−0.23	0.40	0.097
^{244}Cm	10	1.7	−1.6	0.48	0.27
^{60}Co	52	27	−14	8.3	0.87
^{137}Cs	52	320	−11	69	9.3
Gross alpha	30	33	−38	9.5	2.3
Gross beta	40	930	210	450	23
^{238}Pu	18	0.51	−0.068	0.077	0.029
^{239}Pu	18	0.76	−0.30	0.11	0.058
Total Sr	26	380	100	180	18
Tritium	26	430,000	76,000	260,000	22,000

[a]Below detection limit, but estimated.
[b]Not applicable.
Source: Rodgers et al. 1989.

Table 6.4. 1989 ORNL NPDES Permit Number TN 0002941 (discharge point X13—Melton Branch)

Parameter	No. of samples	Concentration (mg/L)			Std. error
		Max	Min	Av	
Aluminum (total)	12	7.1	<0.050	<1.1	0.56
Ammonia (as N)	12	0.070	0.0090	0.030	0.0045
Arsenic (total)	12	<0.060	<0.050	<0.052	0.0011
Biochemical oxygen demand	12	<5.0	<5.0	<5.0	0
Cadmium (total)	12	<0.0020	<0.0020	<0.0020	0
Chlorine (total) residual	52	<0.010	<0.010	<0.010	0
Chloroform	11	<0.025	0.00050[a]	0.0056[a]	0.0020
Chromium (total)	12	0.027	<0.0030	<0.012	0.0022
Conductivity (mS/cm)	12	1.4	0.10	0.61	0.14
Copper (total)	12	0.23	<0.0040	<0.029	0.018
Dissolved solids (total)	12	280	120	190	14
Flow (Mgd)	249	73	0.40	3.5	0.57
Fluoride (total)	12	1.0	<1.0	<1.0	0
Iron (total)	12	10	0.12	1.1	0.81
Lead (total)	12	0.010	<0.0040	<0.0046	0.00050
Manganese (total)	12	2.1	<0.0020	<0.27	0.17
Mercury (total)	12	0.00010	<0.000050	<0.000056	
Nickel (total)	12	<0.020	<0.0060	<0.0094	0.0015
Nitrate	12	<5.0	<5.0	<5.0	0
Oil and grease	52	88	<2.0	<7.0	2.3
Organic carbon (total)	12	5.1	1.6	2.9	0.29
Oxygen dissolved	52	15	5.1	9.3	0.30
PCBs (total)	11	<0.00050	<0.00050	<0.00050	0
pH (standard units)	12	8.0	6.5	[b]	[b]
Phosphorus (total)	12	0.60	0.10	0.19	0.043
Recoverable phenolics (total)	12	0.0030	<0.0010	<0.0015	0.00026
Silver (total)	12	<0.0050	<0.0050	<0.0050	0
Sulfate (as SO_4)	12	27	12	21	1.3
TSS	12	390	<5.0	<45	32
Temperature (°C)	64	27	1.6	15	0.78
Trichloroethene	11	<0.025	0.00030[a]	0.0046[a]	0.0021
Turbidity (NTU)	12	220	10	92	17
Zinc (total)	12	0.16	<0.0080	<0.028	0.012
		Concentration (pCi/L)			
^{60}CO	12	86	−2.7	25	6.9
^{137}CS	12	27	−16	−0.36	4.1
Total Sr	12	650	190	410	45
Tritium	12	1,800,000	350,000	1,300,000	120,000

[a]Below detection limit, but estimated.
[b]Not applicable.
Source: Rodgers et al. 1989.

a major source. Methylene chloride, tetrachloroethylene, trichloroethylene, and chloroform are commonly used in ORNL activities (Boyle et al. 1982) and are also relatively ubiquitous in effluents. If dilution factors are applied to the maximum observed effluent concentrations of volatile organics (Murphy 1986), concentrations as high as 70 μg/L methylene chloride and 25 μg/L tetrachloroethylene could be attained. Such levels are likely to diminish rapidly below an effluent source and are unlikely to be acutely toxic to biota (EPA 1986a, 1987b)

PCB sample collection and analysis in the aqueous phase were conducted in 1979-80 along with the sediment phase monitoring (Oakes et al. 1982a). PCB concentrations were below detection limits (less then 0.5 μg/L) at all sampling sites in WOC and MB (Rodgers et al. 1989).

Aqueous phase monitoring for PCBs in effluents from the ORNL complex was conducted by ORNL staff in 1981 and 1984 (Murphy 1986). In the 1981 sampling, all effluent streams contained less than 0.5 μg/L PCBs except the effluent from the Process Waste Basin, in which PCB concentrations averaging 0.9 μg/L were detected on 3 of 13 sampling dates. Water sampling in July 1984 detected high (more than 1.0 μg/L) levels of PCBs in effluents from the Building 1505 area, the Building 2000 area, the coal pile runoff, and the Building 3544 area, with the highest concentration (4.1 μg/L) found in the Building 1505 area. PCBs are highly insoluble and generally are not detected with detection limits as high as 0.5 μg/L even in systems known to be contaminated, such as East Fork Poplar Creek (EFPC) (TVA 1985d). The observation of high levels of aqueous PCBs in numerous effluents suggests either spurious analytical results or a relatively severe and widespread contamination problem within the ORNL complex. Aqueous phase samples collected in August/September 1984 did not exhibit the high levels seen 1 month earlier. Surprisingly, the Radiochemical Development Engineering Center (RDEC) effluent contained 1.2 μg/L PCBs in the August/September sampling, but was below detection limits in the July sampling. Maximum concentrations observed in August/September in the sites having less than 1 μg/L in July were 0.25 μg/L. The most significant possible sources of PCBs are areas where large amounts of material containing more than 500 ppm PCBs are stored, including Buildings 2026, 2018, 3012, 4500S, 4509, 6000, and 6010 (Dailey and Puett 1988). The lack of correlation between observed high levels of aqueous PCBs and the presence of PCB sources raises doubts about the effectiveness of aqueous phase measurements of very low solubility materials as monitoring procedures. Characterization of PCBs in sediments is required to determine the extent of PCB contamination in WOC.

Hydrophilic organic contaminants are used in large quantities at ORNL. The most significant compounds in terms of quantities used are ethylene glycol, acetone, ethanol, methanol, propanol, methylethyl ketone, oxalic acid, and acetic acid (Boyle et al. 1982). Such compounds have not been monitored in ORNL effluents or WOC basin surface waters. Most are relatively low in toxicity to aquatic life and likely to be readily biodegraded. A large spill or intentional release of any of these compounds could adversely affect aquatic biota, but chronic discharges would be unlikely to have toxic effects or persist in biota or sediments.

6.4.3 Inorganic Contaminants

Monitoring of mercury concentrations in WOC at WOL Dam since 1975 has occasionally detected mercury levels as high as 2 μg/L, but most values have been below detection limits, which varied from less than 1 μg/L to less than 0.05 μg/L (UCC-ND 1976-83, Energy Systems 1984, 1985). Most recent monitoring used relatively insensitive methods (detection limit less than 1 μg/L). However, in 1984 a change to more sensitive methods was made (Energy Systems 1985). The maximum aqueous phase concentration observed in WOC using the more sensitive procedure was 0.2 μg/L, while minimum values of less than 0.05 μg/L were commonly observed (Energy Systems 1985). Similar levels were seen in two water samples from WOCE analyzed by TVA in 1984 (TVA 1985d). The observed levels are consistent with the low but elevated levels of mercury seen in WOL in the 1984 fish survey (TVA 1985c).

An intensive investigation of aqueous mercury levels in the WOC system was carried out in 1979-80 as part of the WOC water quality study (Boyle et al. 1982). A comparison of aqueous concentrations in WOC and MB above and below the ORNL complex clearly depicts the role of ORNL, especially the central ORNL complex, in contributing mercury to the stream in 1979-80. Aqueous mercury levels were highest in WOC between ORNL and the confluence with MB, with mean concentrations of about 0.3 μg/L in this reach (Boyle et al. 1982). Mercury levels at the WOL Dam spillway averaged about one-fourth that measured in the reach of WOC between ORNL and WOL, indicating that substantial removal of mercury from the water column occurred in WOL. MB facilities were much less significant contributors of mercury to the WOC system than WOC.

The 1974-80 water quality survey identified the central ORNL WAG 1 as the most significant source of mercury contamination in the WOC basin. The recent effluent monitoring suggests that the 3539/3940 process waste treatment facility is the most significant NPDES permitted discharge (Murphy 1986, Patton 1985, EPA 1986b). Estimated mercury concentrations in WOC resulting from this discharge approximate 0.1 μg/L, lower but similar in magnitude to levels observed in WOC in the 1979-80 study. Several areas of mercury-contaminated soil are found in the vicinity of Buildings 4501, 4508, 3503, and 3592. These sites may contribute mercury during periods of heavy precipitation, but are unlikely to be major sources of chronic mercury inputs to WOC.

Copper sampling and analysis in WOC, MB, and WOL in 1970 and 1971 found what appeared to be moderately elevated levels in the WOC system (ERDA 1975). Studies carried out in 1974-75 included upstream control sites. Much lower levels were observed in that study, with WOC having a mean concentration of 7 μg/L while the upstream control site exhibited a mean of less than 5 μg/L (ERDA 1975). The 1979 study of water quality in WOC and MB observed levels of copper similar to those seen in the 1974-75 study in MB and WOC, but was able to measure the very low levels in the upstream control sites with greater sensitivity, thus reducing levels observed at those sites to 0.9 μg/L (Boyle et al. 1982). The 1979-80 study indicated a three- to sixfold enrichment of copper in the WOC system due to ORNL activities. Mean levels were low (approximately 5 μg/L) but were similar to the EPA water quality criteria of 5.6 μg/L (Boyle et al. 1982). Water quality measurements conducted by TVA in WOL in 1984 indicated less than 5 μg/L copper (TVA 1985d), while preliminary

results from 1985 ORNL water quality survey indicated levels of less than 20 μg/L. Like zinc, copper appears to have numerous sources within the ORNL complex. Effluents from coal pile runoff, the 3518 Acid Neutralization Facility, the Building 3544 Process Waste Treatment Plant, and the 3539/3540 ponds were significant sources of copper to WOC (based on 1981 data) (Boyle et al. 1982), while more recent data suggests that the Bldg. 3544 facilities are not a major source (Patton 1985). In MB, the HFIR and RDEC process waste basins appear to be major sources (Boyle et al. 1982, Patton 1985, EPA 1986b). Recent data collected by T. E. Cerling (ORNL) indicate that cooling tower blowdown at the central ORNL and HFIR sites is a major contributor of copper to both creeks. The streambed gravel survey identifies the central ORNL site and HFIR/REDC discharges as the sources of elevated copper in sediments.

Water quality monitoring for zinc has shown levels that typically range from less than 0.02 to 0.08 mg/L in WOC and MB in the period from 1970 to the present (ERDA 1975, UCC-ND 1976-83; Energy Systems 1984, 1985). Intercomparisons among years are difficult due to varied analytical sensitivity. The 1979-1980 water quality survey clearly indicated that ORNL activities raise dissolved zinc concentrations by a factor of 7 to 8 in WOC and MB; however, average levels in those streams below ORNL were still low (approximately 0.02 mg/L). Preliminary data from the 1985 survey indicate a similar pattern - <0.02 mg/L at reference sites and <0.02 to 0.08 mg/L below ORNL and HFIR (personal communication, T. E. Cerling - ORNL).

Zinc appears to have numerous sources within the ORNL complex. Effluents from the Sewage Treatment Plant, the Process Waste Treatment Plant (Building 3544), the Acid Neutralization Facility (Building 3518), and the 3539/3540 ponds could contribute much of the excess zinc observed in WOC in the vicinity of the central ORNL complex (Patton 1985, EPA 1986b, Boyle et al. 1982). Cooling towers in the central ORNL complex are also significant sources, contributing an amount of zinc roughly equal to other sources to WOC (Boyle et al. 1982). Cooling towers also appear to be the major contributor of zinc to MB, although the predicted concentrations (based on effluent characteristics) far exceeded observed concentrations in MB (Boyle et al. 1982). The more recent effluent characterizations (Patton 1985) suggest that effluents from the HFIR and REDC process waste basins may contribute a significant fraction of the zinc discharged to MB.

The 1985 survey by Cerling revealed elevated levels of zinc in streambed gravels below HFIR and the central ORNL complex. Aqueous phase analyses and studies of the uptake of zinc by previously uncontaminated gravel indicate the presence of active discharges of zinc to WOC.

Virtually all analyses for cadmium conducted before the 1979-80 water quality survey had insufficient sensitivity to detect cadmium at the levels present in the WOC system (detection limits approximately 0.02 mg/L). The 1979—80 survey indicated a slight (two- to threefold) increase in cadmium below the central ORNL complex (average concentrations from 0.13 to 0.30 μg/L) (Boyle et al. 1982). Occasionally, reference sites contained higher cadmium concentrations than downstream sites, while high values at specific sites typically were not

corroborated by the presence of similar levels of cadmium at downstream sites. The 1985 survey did not analyze aqueous cadmium at sensitivities adequate to discern any pattern.

Effluent data suggest a significant input of cadmium to WOC from the 3539/3540 ponds, based on the maximum observed cadmium level in the input (EPA 1986b, Murphy 1986, Patton 1985). However, this input was not corroborated by aqueous phase monitoring in WOC and MB in 1979 (Boyle et al. 1982) and 1985 (personal communication, T. E. Cerling - ORNL), or by sediment monitoring in 1985, which indicated slight enrichment over relatively high background levels due to carbonaceous bedrock.

Chromium is a contaminant of concern in the WOC system because of the past use of corrosion inhibitors containing chromate in cooling towers at ORNL. The practice was discontinued in 1976 (Boyle et al. 1982). Elevated levels of total chromium were observed in water at WOL Dam between 1969 and 1976 (Elwood et al. 1980; UCC-ND 1976-77), and lower levels observed after 1976 (UCC-ND 1978-83; Energy Systems 1984, 1985). Chromium in current discharges at WOL Dam generally average approximately 0.02 mg/L total chromium. Much higher levels of chromium were observed in MB close to cooling tower discharge from the HFIR in a study conducted in 1973 (Gaswick 1971). In that study, total chromium (which was virtually all chromium VI) was approximately 1.5 mg/L in the reach between HFIR and SWSA 5 in October and approximately 0.8 mg/L in December. Levels of chromium in sediment from MB were not highly enriched relative to reference sites.

The low concentrations of chromium observed in WOC and MB are roughly consistent with chromium levels observed in effluents from HFIR, TRU, and the 3539/3540 ponds (Patton 1985, EPA 1986b). Chromium discharges published in 1981 (Boyle et al. 1982) do not account for observed aqueous concentrations. The streambed gravel survey traces elevated chromium in sediments back to WAG 1 and HFIR. The Cerling study attempted to distinguish whether elevated chromium levels in gravel are residual contamination from past use of chromates in cooling towers or reflects current releases of chromium. Aqueous phase chromium was clearly enriched in WOC and MB downstream of WAG 1 and HFIR in the 1979-80 water quality study (Boyle et al. 1982), but the levels found in WOC averaged about a factor of 2 above levels in MB. Since streambed gravels in MB currently contain levels of easily extractable chromium higher than WOC, it appears as though effluents were probably the major source of observed aqueous phase chromium in 1981, rather than release of chromium from previously contaminated sediments. The tributary draining the watershed of LLW seepage trenches 2, 3, 4, and 5 (WAG 7) contained consistently high levels of chromium (10 to 20 mg/L) in the 1979 water quality survey (Oakes et al. 1982a), but the flux was too small to impact chromium levels in WOL.

Little historical information exists on levels of arsenic in WOC/MB. The 1984 TVA survey found less than 1 mg/L total arsenic at the outfall of WOL Dam (TVA 1985a,b).

Little data exist to characterize levels of silver in the WOC system. In 1984, TVA analyzed for silver in water from WOCE downstream from WOL Dam and found less than 0.2 mg/L (TVA 1985d). However, sediments from WOCE averaged 6 ppm silver in the 1984 TVA survey (TVA 1985d), well above background levels of less than 1.0 ppm noted from

Melton Hill and Norris Reservoirs. Silver concentrations in fish from WOL and WOCE were similar to levels in fish from reference streams, generally averaging less than 0.2 ppm (TVA 1985d). However, the 1985 streambed gravel survey revealed no evidence of elevated silver levels in the WOC basin, with sediment levels below detection limits of 0.5 ppm and aqueous concentrations below detection limits of 0.5 μg/L.

Lead and nickel were also elevated in WOC/MB in the 1979-80 water quality survey (Oakes 1984a,b,c). For nickel and lead, the increase over upstream reference sites was slight in both MB and WOC, with some evidence for nickel release from SWSA 4 (personal communication, T. E. Cerling - ORNL). Concentrations of lead and nickel were well below EPA criteria for the protection of aquatic life (Boyle et al. 1982, EPA 1986a).

Biocides are used at ORNL facilities to treat cooling towers/heat exchangers, to treat the effluent from the sanitary sewage treatment plant, and as a sterilant in process and drinking water. Residual chlorine is monitored daily in the effluent from the ORNL sewage treatment plant and occasionally exceeds NPDES limits of 0.5 ppm (Rodgers et al. 1989). Drinking and process water contain residual chlorine, which could possibly affect aquatic organisms in streams receiving inputs of untreated process water. ORNL contains approximately 25 cooling towers, which are treated with a mixture of commercial bleach (sodium hypochlorite) and a polymeric organic biocide, poly(oxyethylene dimethyl-iminio) ethylene dichloride (Owenby 1986). Approximately 80% of the cooling tower blowdown discharged to WOC comes from the Building 3103 towers, which discharge 175 gpm to Fifth Creek, and from the Building 4510 towers, which discharge 90 gpm to WOC. The Building 7902 tower at HFIR discharges 130 gpm to a tributary of MB. Estimated concentrations of biocides in cooling tower blowdown are 20 ppm for the organic biocide and 1 ppm for reactive chlorine species (Owenby 1986).

Environmental Sciences Division (ESD) staff conducted toxicity tests and reactive halogen measurements in WOC and tributaries within the central ORNL complex in 1985. Toxic levels of total chlorine (0.40 to 0.63 ppm) were observed in WOC and Fifth Creek below blowdown discharges from the 3103 and 4510 cooling towers (Giddings 1985). Residual halogen was also observed in First Creek and WOC above 4510 blowdown, indicating contributions from smaller cooling towers and/or process water. Toxicity tests on stream water correlated well with the observed levels of residual halogen in water samples, but residual halogen did not appear to account for all the observed toxicity (Giddings 1985).

Studies were conducted in 1989 to evaluate the toxicological significance of total residual chlorine (TRC) in receiving streams (Loar 1990). Toxicity tests were used to determine if toxicants other than chlorine were present in some wastewaters where residual chlorine was toxic to test organisms. Three of the five outfalls tested were found to contain evidence of other toxicants. Additional tests on one of these outfalls indicated that metals (possibly zinc or copper) probably accounted for the toxicity remaining after dechlorination (Loar 1990).

ORNL has contributed plant nutrients (NH_4^+, NO_3^-, total PO_4) to WOC/MB for many years. Nitrate and phosphate levels were elevated in WOC in 1961-70 (ERDA 1975). Analyses conducted in 1974 clearly indicate the role of ORNL facilities in elevating nitrate

in MB and WOC, with concentrations rising from less than 1 ppm in upstream sites to 4 to 5 ppm downstream of ORNL (ERDA 1975). The 1979-80 water quality survey revealed the same pattern of low nitrate levels upstream of ORNL (less than 0.5 ppm) and elevated levels downstream (3 to 5 ppm) (Boyle et al. 1982) that was seen in previous years. Monitoring data from the NPDES station at the discharge of WOL Dam indicate that nitrate discharges have continued to follow that pattern up to the present time (UCC-ND 1976-83; Energy Systems 1984, 1985).

Data from the 1974-75 survey (ERDA 1975) and earlier studies (McMaster 1967) indicated some enrichment in PO_4 in WOC due to ORNL, but did not clearly establish the magnitude of the effect. The 1979 survey provided clear evidence of the importance of WAG 1 as a source of phosphate enrichment to WOC and MB. Average levels of total phosphate in WOC above ORNL (0.02 mg/L) were increased by more than a factor of 10 below WAG 1 (0.27 mg/L)(Boyle et al. 1982), while higher background levels (0.2 mg/L) and similar enrichment (to 0.5 mg/L) was observed in MB. While such levels of enrichment are not examples of gross eutrophication, these phosphate levels are undoubtedly supportive of stimulated growth of periphyton and macrophytes in the presence of high levels of nitrate.

The 1979-80 water quality survey established that major inputs of nitrates occur to both WOC and MB in the vicinity of ORNL facilities (Boyle et al. 1982). The major effluent source in WAG 1 appears to be the discharge from the Building 3544 Process Waste Treatment Facility (Murphy 1986, EPA 1986b, Patton 1985). The nitrate levels and volume of this single effluent stream can account for the roughly 5-ppm enrichment of nitrate observed in WOC. Similarly, a single effluent, the HFIR process waste basin, contributes enough nitrate to account for the levels observed in MB. The highest nitrate concentrations observed in the 1979-80 study occurred in two tributaries draining into the northeast corner of WOL, one draining the east part of SWSA 6, the other draining low-level waste pits 2, 3, 4 and 5. Nitrate concentrations in these latter two tributaries are typically about 20 and 80 ppm respectively, (Oakes 1984a-c); their contribution of nitrate to WOL in 1979-80 was about 25% of the loading coming from WOC (calculated using contribution index procedure of Cerling and Spalding 1982). In 1985 nitrates increased from 13 to 60 ppm in WOC between ORNL and monitoring station 3 (above the confluence with MB), suggesting inputs from SWSA 4 and/or SWSA 5 (personal communication, T. E. Cerling - ORNL).

Ammonia is both a plant nutrient and a potential toxicant. It is routinely monitored in the effluent from the ORNL sewage treatment plant, where a high percentage of measurements have indicated noncompliance with statutory effluent limits (UCC-ND 1976-83, Energy Systems 1984-85). Installation of an upgraded sewage treatment system in August 1985 has improved this situation substantially, with ammonia releases now being within effluent limits more than 95% of the time (Murphy 1986). The 1979-80 water quality survey revealed elevated levels of ammonia in WOC only at the station nearest the sewage treatment plant effluent and background levels (less than 0.2 mg/L) at all other stations. The environmental analysis of ORNL (Boyle et al. 1982) estimates that potentially toxic levels of ammonia were released to WOC in early 1979 as a result of sewage plant operations (based on monitoring of the sewage treatment plant effluent); however, the weekly measurements made in the 1979-80 water quality study (Oakes 1984a,b,c) did not corroborate these

calculations. The predicted low flow concentration of ammonia calculated in Boyle et al. 1982 was 0.63 mg/L, which could result in levels of un-ionized ammonia slightly in excess of the EPA criteria (0.02 mg/L) under conditions of high temperature (>5°C) and pH (<7.8). Since the criterion is set at one-tenth of the lowest concentration observed to be toxic to some forms of aquatic life, it is questionable that ammonia was a significant toxicant in WOC.

The sewage plant effluent was the major source of ammonia inputs to WOC prior to upgrading the wastewater treatment plant in 1985. It is likely to remain the major source of ammonia, but at levels lower than in the past. Nitrates are a quantitatively much more significant source, accounting for approximately 95% of the nitrogenous nutrient input to WOC/WOL. Other sources include Building 3544 process waste stream and the 3539/3540 ponds (Boyle et al. 1982).

Major effluent sources of phosphorus in WOC include the coal pile runoff, sewage treatment plant, Building 2000 area, Building 3518, and the 3539/3940 ponds (Murphy 1986, EPA 1986b). In MB, the REDC process waste basin appears to be a major contributor of observed aqueous phosphorus levels (EPA 1986b, Murphy 1986). In addition to effluents, cooling tower blowdown is a major contributor of total phosphorus (Boyle et al. 1982, Owenby 1986) in both WOC and MB. If corrosion inhibitors used in cooling towers contain 5 to 10% total P, cooling tower blowdown alone could account for the excess P observed in WOC and MB. Preliminary uptake experiments using streambed gravel suggest that cooling towers may in fact be the primary source of phosphorus enrichment of the WOL/WOC system.

6.4.4 Radionuclide Contaminants

Major variations in the long-term levels and types of radionuclides discharged through WOL Dam were caused by changes in the source of the radioactivity as well as improvement in plant operations. Much of the radioactivity measured in the early 1960s (particularly ^{106}Ru) came from the seepage pits into which intermediate-level liquid wastes were discharged. A much smaller amount of activity originated at the wastewater treatment plant and from accidental releases of activity discharged into that system. Whereas some of the activity may have come from the SWSAs, the concentrations are thought to have been sufficiently small that they could not be differentiated from the larger concentrations already in the stream (Lomenick and Cowser 1961). During the 1960s and 1970s a significant decrease in contaminant release was accomplished largely by discontinuance of the pits and trenches and by improvement in the treatment of Laboratory effluent. In recent years ^{3}H (tritium) and ^{90}Sr (strontium) have been the principal contaminants in the discharge. These two nuclides are of interest because nearly all of the tritium and a part of the strontium are believed to emanate from the SWSAs.

Trends in discharges of ^{90}Sr and ^{3}H to the Clinch River are presented in Fig. 6.9. These are the principal contributors of radioactivity in terms of total curies discharged. Total curie amounts for the two radionuclides appeared to increase in 1984 compared with 1983—about 14% for ^{3}H and 20% for ^{90}Sr. The annual variations in the discharges from WOL are

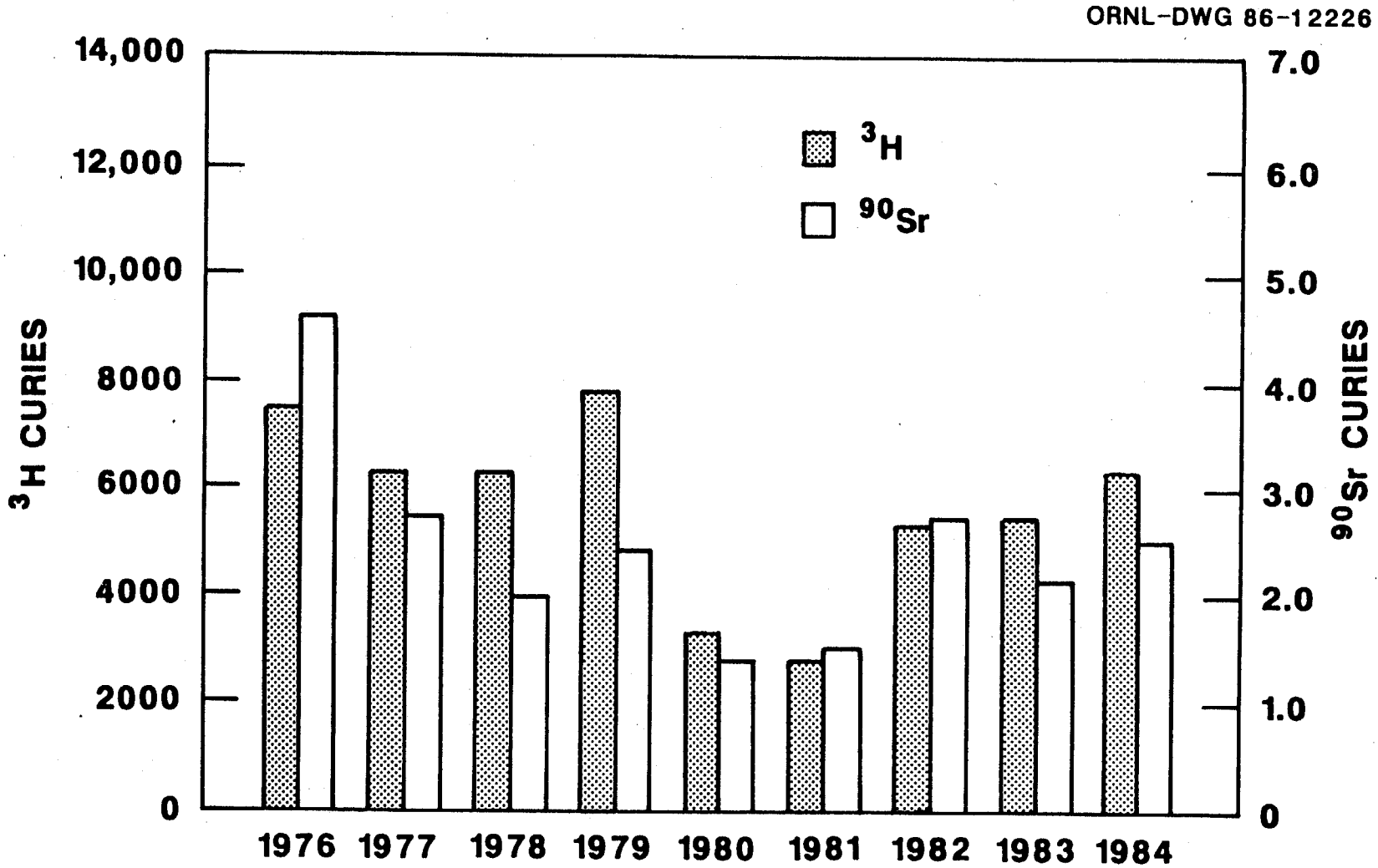


Fig. 6.9. Curies of ^{90}Sr and ^{3}H discharged over White Oak Dam. NOTE: Multiplying the concentration by 3.7×10^{10} will convert curies (Ci) to becquerels (Bq). (Source: Sherwood and Loar 1987).

generally a function of the variability in annual precipitation patterns. The 1984 discharge continues to reflect an increase in the total curies discharge over WOL Dam, beginning in1980 after a significant decrease from 1979 levels. Some of the apparent increase in 1984 mayresult from improved accuracy in high-flow readings. New weirs and associated flow instrumentation were made operational in early 1984 (Energy Systems 1985).

Analysis of water samples collected at the confluence of WOC and the Clinch River showed that ^{90}Sr and ^{3}H concentrations were significantly less than those measured at WOL Dam, ^{60}Co was the same, and ^{137}Cs was higher (Energy Systems 1985). Concentrations at this confluence point are dependent on the relative levels and flows of the creek and river, in addition to the quantity of activity being discharged from WOL Dam. Concentrations determined at the Clinch River sampling stations downstream from the confluence of WOC and the river showed a marked decrease for all measured radionuclides, many of which were below analytical detection limits (Energy Systems 1985).

Samples from MB and WOC were collected in 1988 as part of BMAP (Loar 1989). Discharges at the MB and WOC weirs differed in the concentration of ^{137}Cs, ^{60}Co, and ^{90}Sr. Water in WOC contained greater concentrations of ^{137}Cs, while MB contained greater concentrations of ^{60}Co and ^{90}Sr (Table 6.5). Concentrations of ^{137}Cs, ^{60}Co, and ^{90}Sr in WOC are similar to the concentrations found in WOL. These concentration differences reflect the difference in radionuclide releases to MB and WOC.

6.5 AQUATIC SEDIMENT

6.5.1 Introduction

Stream and lake sediments can be significant repositories for a wide variety of contaminants but especially for contaminants that are "particle-reactive," i.e., those that are adsorbed to particles. Streams and lakes in the WOC basin drain large areas of industrialized land and many chemical laboratory buildings and as a result have received inputs of many types of contaminants. In addition to the radioactive contaminants, the classes of nonradioactive contaminants released to the WOC system include organic chemicals, inorganic chemicals, biocides, and plant nutrients. This subsection summarizes previous investigations of contaminants in sediments in WOC, its tributaries (e.g., MB), WOL and the WOCE. In general, studies conducted prior to about 1970 are not summarized but are referenced as appropriate.

6.5.2 Sources of Data

A variety of data sources for contaminants in sediments of WOC, WOL and WOCE have been reviewed. These sources span nearly the entire period of federal occupancy of the WOC watershed, but results of recent studies are emphasized. Over the years sediment analyses have been performed using different sample preparation and chemistry procedures with varied detection limits and susceptibilities to interferences. Variability also exists in

Table 6.5. Mean radionuclide concentrations in the water column and sediments of Melton Branch weir, White Oak Creek weir, and White Oak Lake.

Location	Radionuclide	Water (Bq/L)	Sediment (Bq/kg, dry wt.)
White Oak Lake	^{137}Cs	1.52×10^{0}	1.32×10^{5}
	^{60}Co	7.40×10^{-2}	8.60×10^{1}
	^{90}Sr	4.96×10^{0}	1.16×10^{2}
White Oak Creek Weir	^{137}Cs	1.52×10^{0}	1.32×10^{5}
	^{60}Co	3.70×10^{-2}	2.26×10^{3}
	^{90}Sr	4.14×10^{0}	8.1×10^{2}
Melton Branch Weir	^{137}Cs	7.40×10^{-2}	1.85×10^{3}
	^{60}Co	1.04×10^{0}	3.86×10^{4}
	^{90}Sr	1.23×10^{1}	6.29×10^{2}

Source: Loar 1989

sampling procedures (sediment cores vs surface samples, size fractionation, etc.) and in the degree to which data have been verified and reviewed—rangingfrom peer-reviewed publications to unpublished data only recently received from one or more of the service analytical laboratories. Minimal effort has been made to sort data by quality or reliability or to compensate or adjust for differences in procedures and methods. For these reasons, care must be taken in extrapolating apparent historical trends or making judgments based on a relatively small number of samples. In general, the most that can be hoped for in comparing such data is a consistency over time, i.e., the absence of elevated chromium levels in fish despite elevated levels in sediments in data collected in different studies over a 10-year period. The available data are adequate for identifying some of the contaminants of concern and, in some cases, assessing the extent of current contamination.

6.5.3 Review of Sampling and Analysis Campaigns

Although the sediments of WOC watershed have been studied extensively since the early 1940s, only relatively recently has attention been given to constituents other than radionuclides. There have been numerous sampling and analysis campaigns for radionuclides (Cheka and Morgan 1947; Abee 1953; Lomenick et al. 1961, 1962, 1963; McMaster and Richardson 1969; Lomenick and Gardiner 1965; Tamura et al. 1970; Blaylock and Frank 1979; Cerling and Spalding 1981; Oakes et al. 1982a). Oakes et al. (1982a) and later Sherwood and Loar (1987) have adequately reviewed and summarized these early investigations, and pertinent findings are included herein.

Significant sediment investigations that have occurred since the historical review by Oakes et al. (1982a) are given in Table 6.6. In December 1979 Oakes et al. (1982b) obtained 12 sediment cores in WOL (Fig. 6.10) and 26 cores in WOCE (Fig. 6.11). These cores were collected using a Swedish foil sampler, a piston-type coring device that collects a 2 1/2-in. (6.4-cm) diam undisturbed core. The cores were subdivided into 1-in. (2.54-cm) depth intervals and analyzed whole for ^{137}Cs, ^{60}Co, ^{90}Sr, $^{152,154}Eu$ and transuranics (top 6 in. only).

Cerling and Spalding (1981) performed a comprehensive survey of the activities of ^{90}Sr, ^{137}Cs and ^{60}Co in 412 streambed gravels (6 to 20 mesh, 0.85 to 3.35 mm) collected from all major streams and their significant tributaries in the WOC basin. As shown in Fig. 6.12 some samples were also obtained from WOCE. The gravels were collected from the upper 10 cm of streambed sediment and were wet-sieved directly in their streamwater. Aliquots of the gravels were also analyzed for extractable iron and manganese.

Three cores were collected in the central portion of WOL (Fig. 6.13) in 1986 (personal communication, T. W. Doyle - ORNL). The cores were taken by forcing a 3-in. (7.62-cm) diam aluminum tube into the lake bottom to refusal (>40 cm in all cases). The cores were frozen, extruded, and divided into 2-cm depth intervals. Each subsection was analyzed for ^{90}Sr, ^{137}Cs, ^{60}Co, and other alpha, beta and gamma emitters, as well as for metals (available by ICP) and organic contaminants (EPA Priority Pollutants).

Table 6.6. Summary of recent (post-1978) investigations of contaminants in sediments of WOC, WOL, and WOCE.

Date	Area (WOC, WOL, WOCE)	Whole sediment or fraction	Analyses			Figure No.	Reference
			Organic	Inorganic	Radionuclide		
December 1979	WOL, WOCE	Whole	No	No	Yes	6.10 6.11	Oakes et al. 1982b
Oct-Nov. 1978	WOC, WOCE	Fraction	No	No	Yes	6.12	Cerling and Spalding 1981
1986	WOL	Whole	Yes	Yes	Yes	6.13	T. W. Doyle (unpublished)
1985	WOC	Fraction	Yes	Yes	Yes	6.14	T. E. Cerling (unpublished)
Aug-Oct. 1990	WOCE	Whole	Yes	Yes	Yes	6.16	Blaylock, unpublished
November 1983	WOL	Whole	Yes	Yes	No	-	Hoffman et al. 1984
May-Aug. 1984	WOCE	Whole	Yes	Yes	Yes	6.15	TVA 1986

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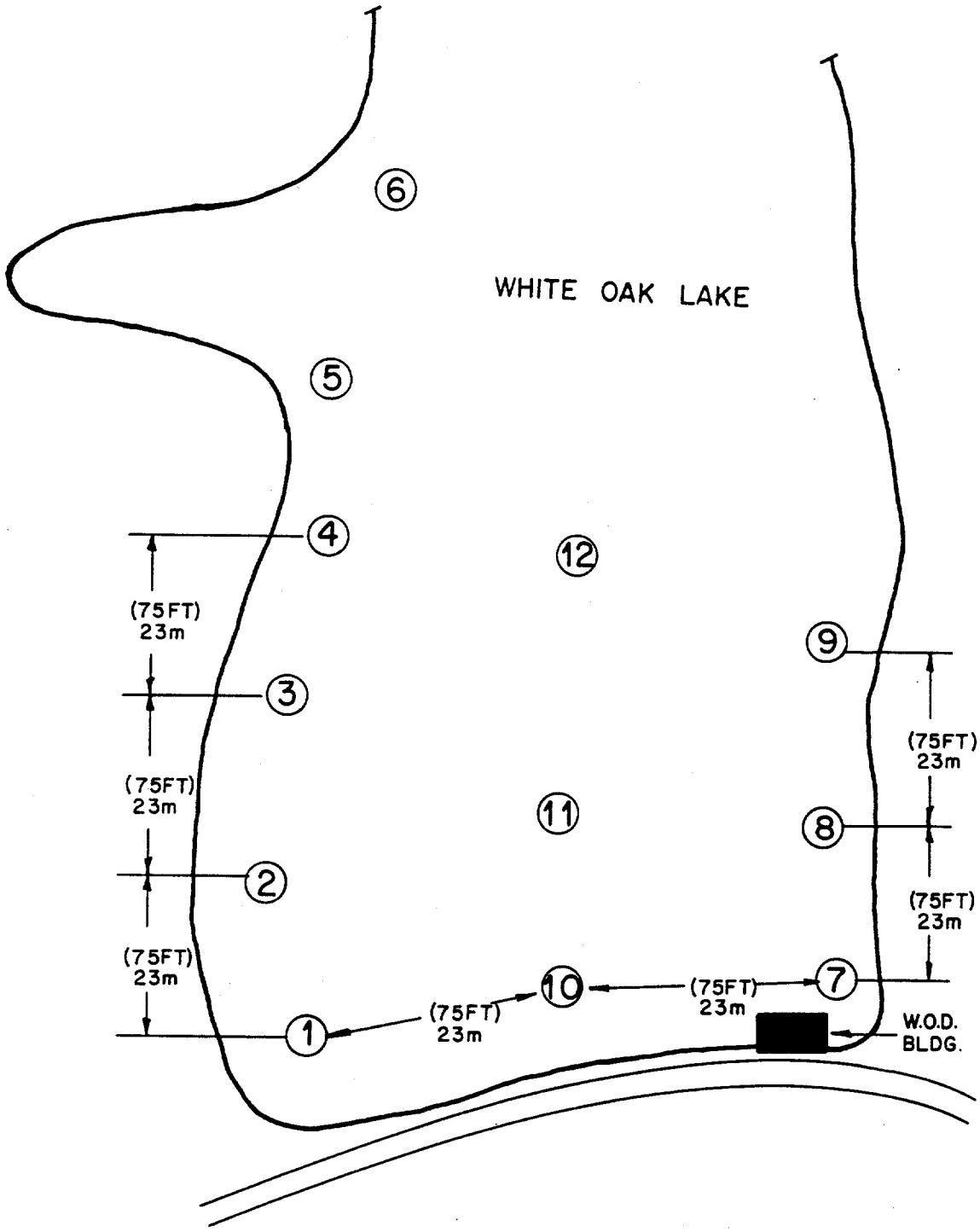

Fig. 6.10. Map of White Oak Lake showing sampling locations, 1979 (Source: Oakes et al. 1982a).

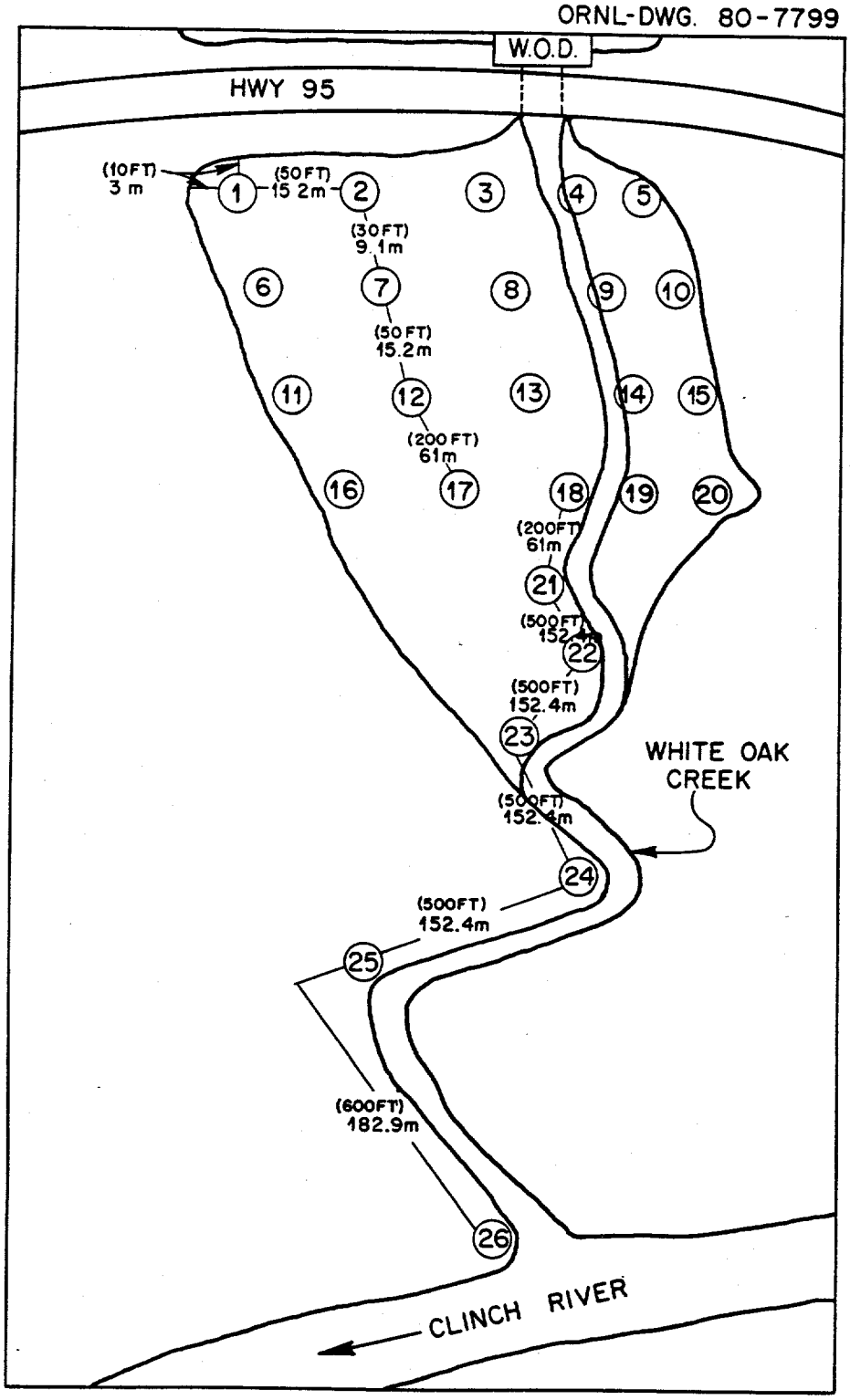

Fig. 6.11. Sediment sampling locations in White Oak Creek, December 1979. (Source: Oakes et al. 1982a).

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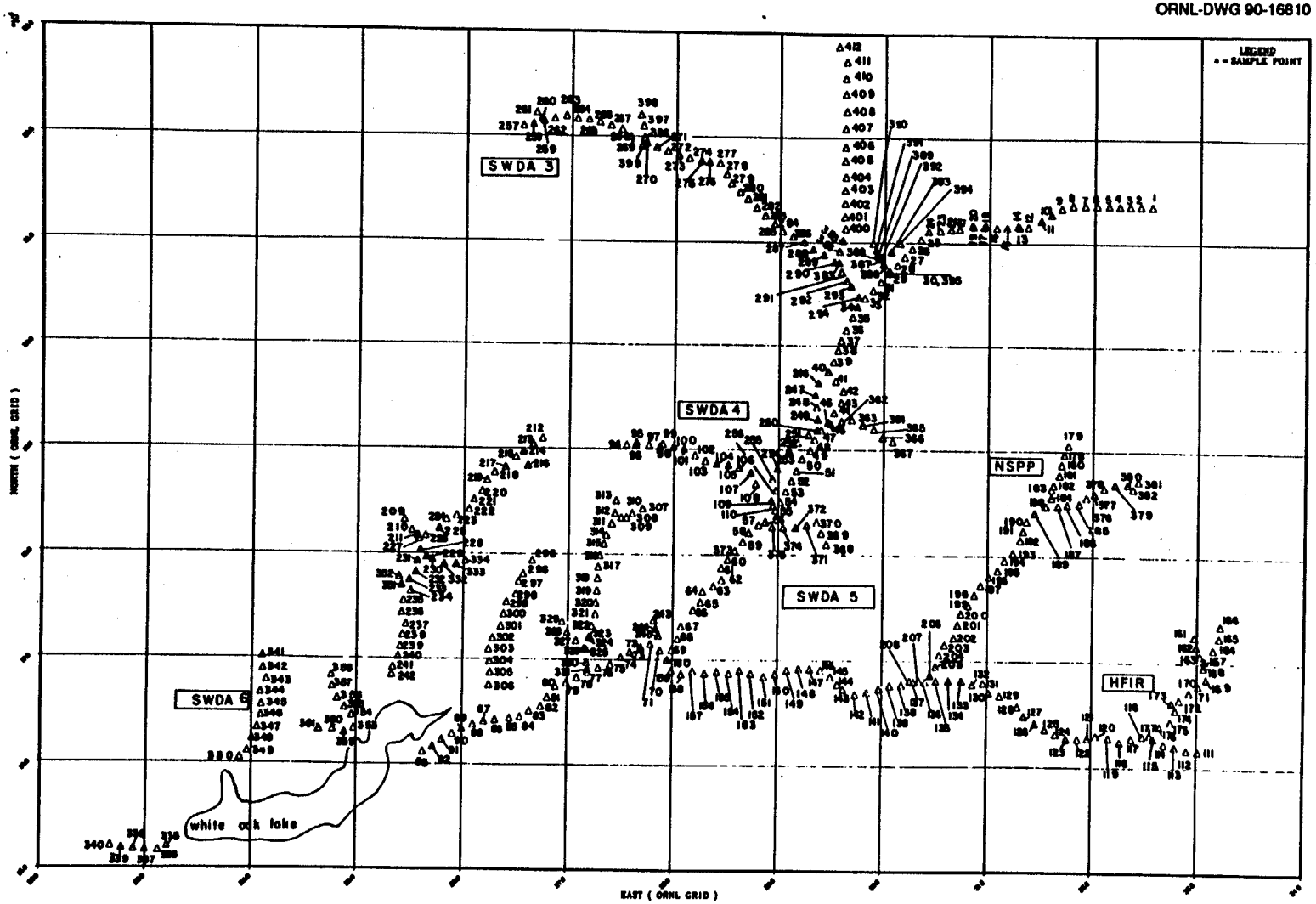

Fig. 6.12. Sampling locations in White Oak Creek watershed (Source: Cerling and Spalding 1981).

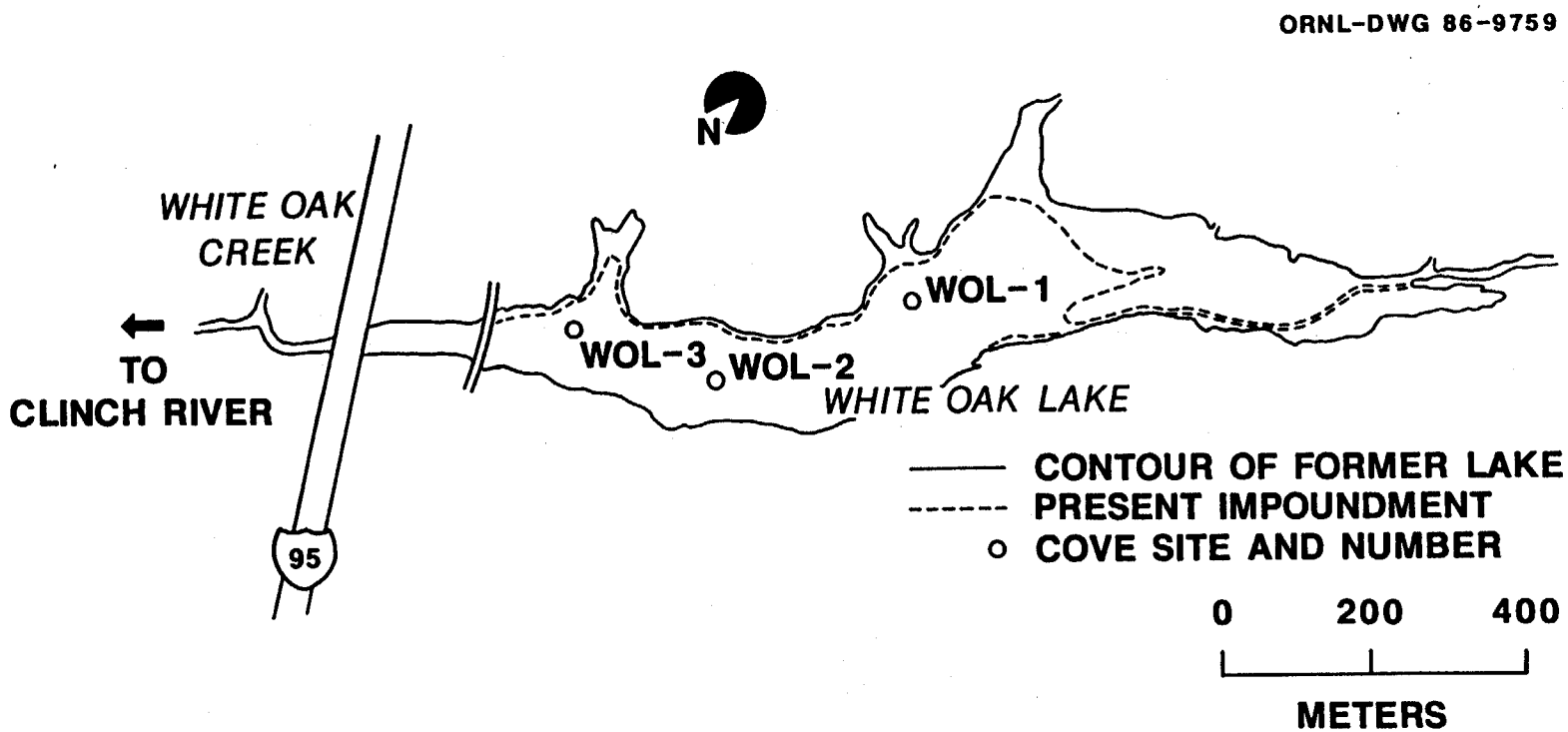

Fig. 6.13. Map of White Oak Lake indicating the approximate locations of core sampling (Source: T. W. Doyle - ORNL).

Thirty-seven streambed gravels (2- to 3.3-mm size fraction) were collected and, where available, fine-grained organic-rich sediments representing all important branch points within the WOC basin (personal communication, T. E. Cerling - ORNL). These included junctions of major tributaries and possible plant effluent contributions, as well as several sites that were thought to have no contamination (Fig. 6.14). The gravels were analyzed for gamma emitters (e.g., ^{60}Co, ^{137}Cs, ^{75}Se, ^{154}Eu and ^{134}Cs), ^{90}Sr, and metals (available by ICP). The 14 fine-grained sediment samples were analyzed for metals (available by ICP) and organic contaminants (semivolatiles available by Method 3540, EPA 1984a).

Hoffman et al. (1984) reported results of analyses of two sediment cores collected in WOL in November 1983. The samples were collected by R. R. Turner of ORNL and consisted of depth-composited cores (5 X 95 cm and 5 X 80 cm) collected in the western and eastern ends, respectively, of the lake. The two samples were analyzed by a TVA analytical laboratory for organic compounds (priority pollutants), metals, and cyanides. Although radionuclides were analyzed in other samples collected elsewhere on ORR, no such analyses were performed on the two samples from WOL.

As part of Oak Ridge Interagency Task Force activities, the TVA collected four sediment cores in WOCE (Fig. 6.15) in 1984 (TVA 1986). The cores were collected by pushing polycarbonate tubes (2-in I.D.) into the sediment to refusal. Each core was divided into four depth intervals for analysis. Analyses included radionuclides (gamma emitters, ^{90}Sr, and transuranics), metals (available by ICP and AAS), and priority pollutant organics.

As part of the Clinch River RFI (CRRFI 1990) sediment sampling was begun in WOCE in the summer of 1990. Results of initial core sampling (vibracoring) and analysis near the mouth to the embayment revealed unexpectedly high activities for ^{137}Cs at the sediment-water interface. This finding prompted additional extensive surface sediment and core sampling in the embayment (Fig. 6.16) which was ongoing at the time this document was prepared. As part of this program, sediment samples are being analyzed selectively for a wide range of contaminants, including radionuclides, metals, and organics.

6.5.4 Organic Contaminants

Polychlorinated biphenyls (PCBs) were detected in sediments in WOC, WOL, and WOCE of the Clinch River/Watts Bar Reservoir in monitoring conducted in 1974-75 (ERDA 1975). The highest level observed was 3.4 $\mu g/g$ in one of three samples from a site 200 m downstream from ORNL. The mean level of PCBs at that site was 1.9 $\mu g/g$ ($\underline{n}$ = 3). An average of 1.2 $\mu g/g$ PCBs was observed in WOL sediments ($\underline{n}$ = 4) and 0.5 $\mu g/g$ in the embayment downstream. Another series of sediment samples analyzed for PCBs in 1974 found 2 $\mu g/g$ in a sample from WOC 2000 m above the mouth, but less than 0.1 $\mu g/g$ in the Clinch River 1 to 2 km downstream (Morrow 1974).

In 1979—80, a survey of sediments in the WOC/MB drainage system by ORNL personnel detected PCBs at a number of sites (Boyle et al. 1982, Oakes et al. 1982b). The highest levels of contamination were observed in the reach of WOC between the mouth of the Northwest Tributary and WOL. Mean PCB levels at sites in that reach ranged from 5.3 $\mu g/g$ at the

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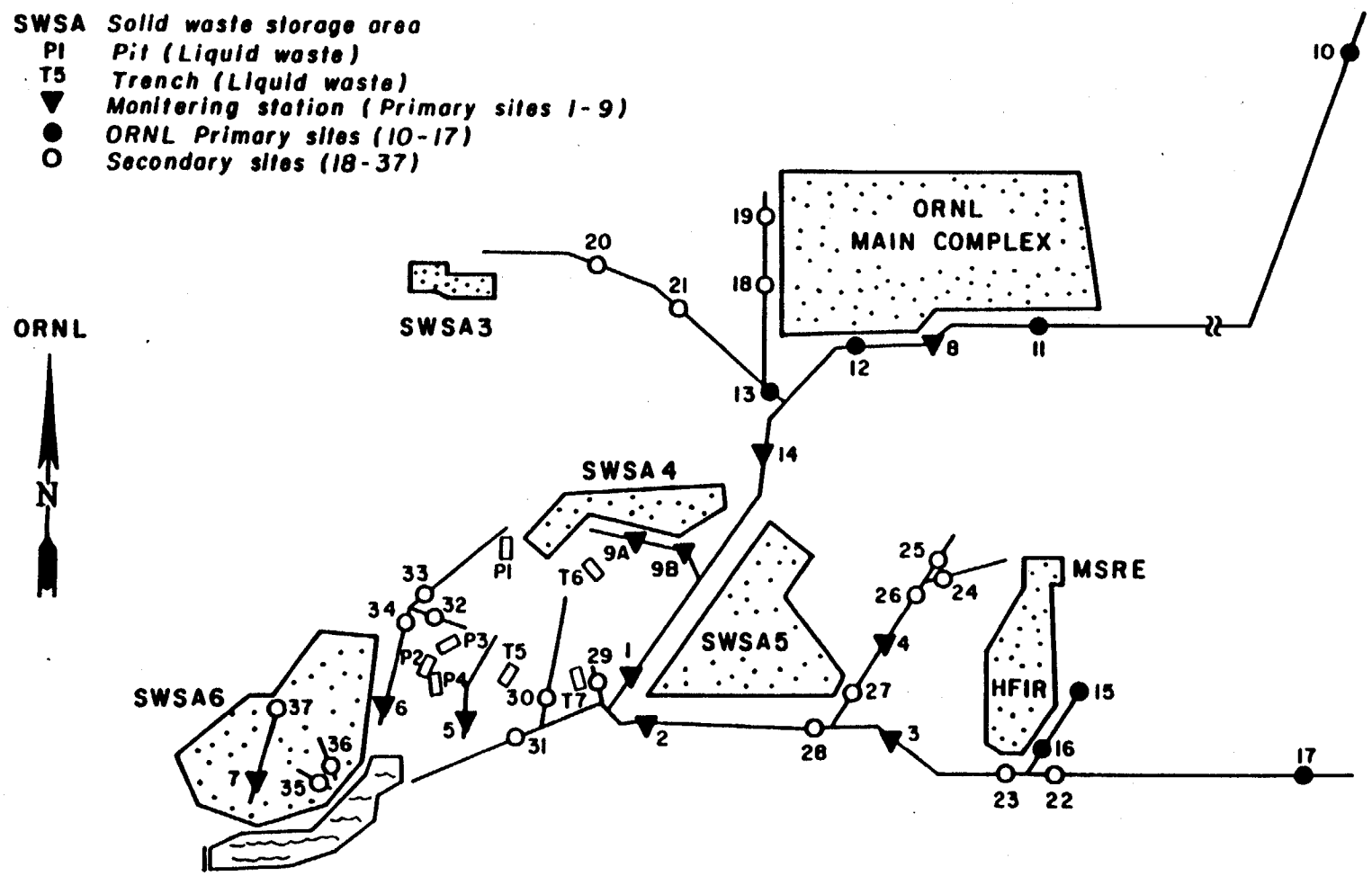

Fig. 6.14. Schematic location map showing sampling sites in White Oak Creek basin (Source: T. E. Cerling - ORNL).

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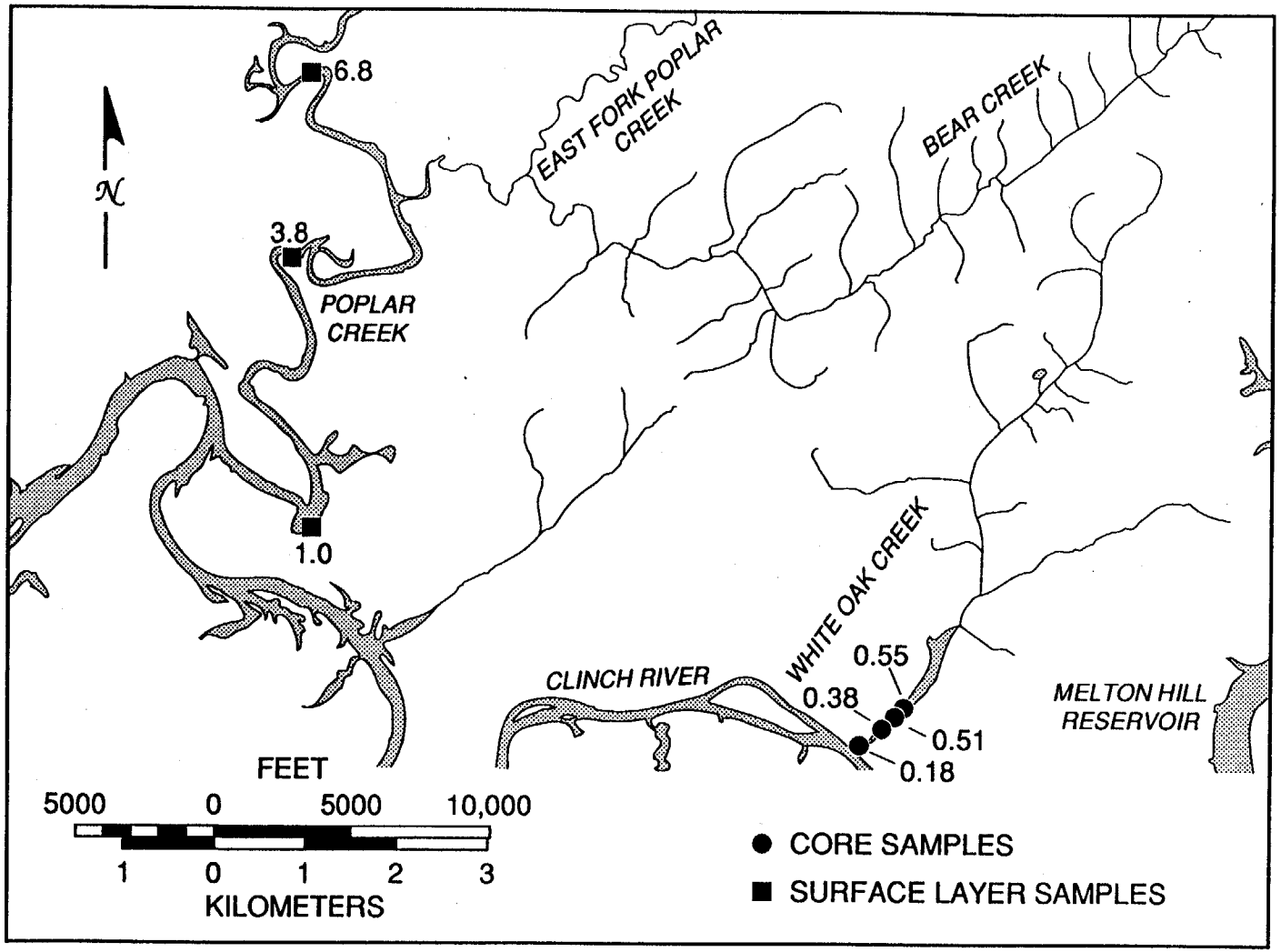

Fig. 6.15. Sediment sampling locations in Poplar Creek and White Oak Creek (Source: TVA 1986).

ORNL-DWG 90M-16785

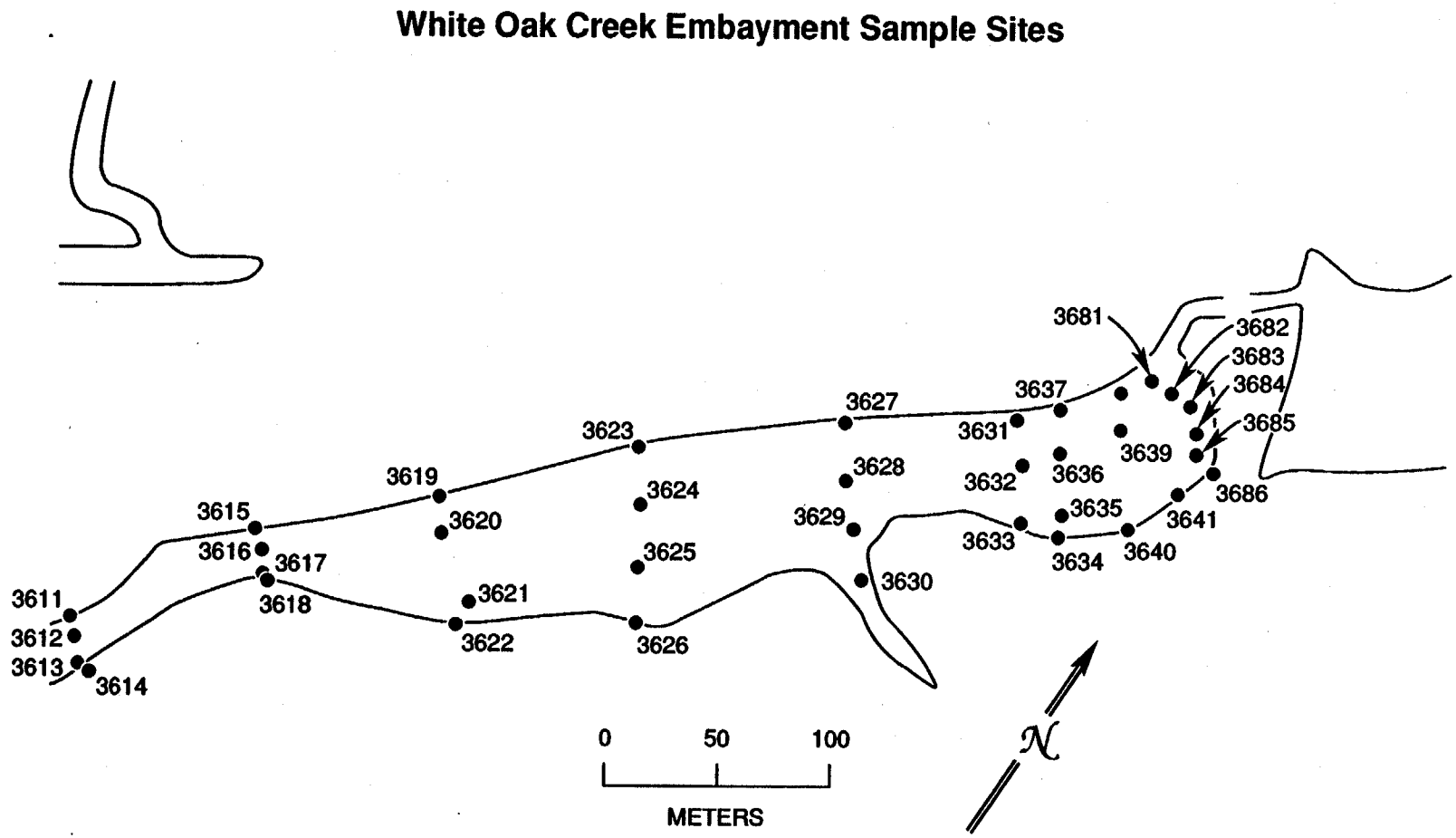

Fig. 6.16. Locations of surface sediment and core sampling sites in the White Oak Creek embayment.

ORNL-DWG 90M-16786

White Oak Creek Embayment Sample Sites

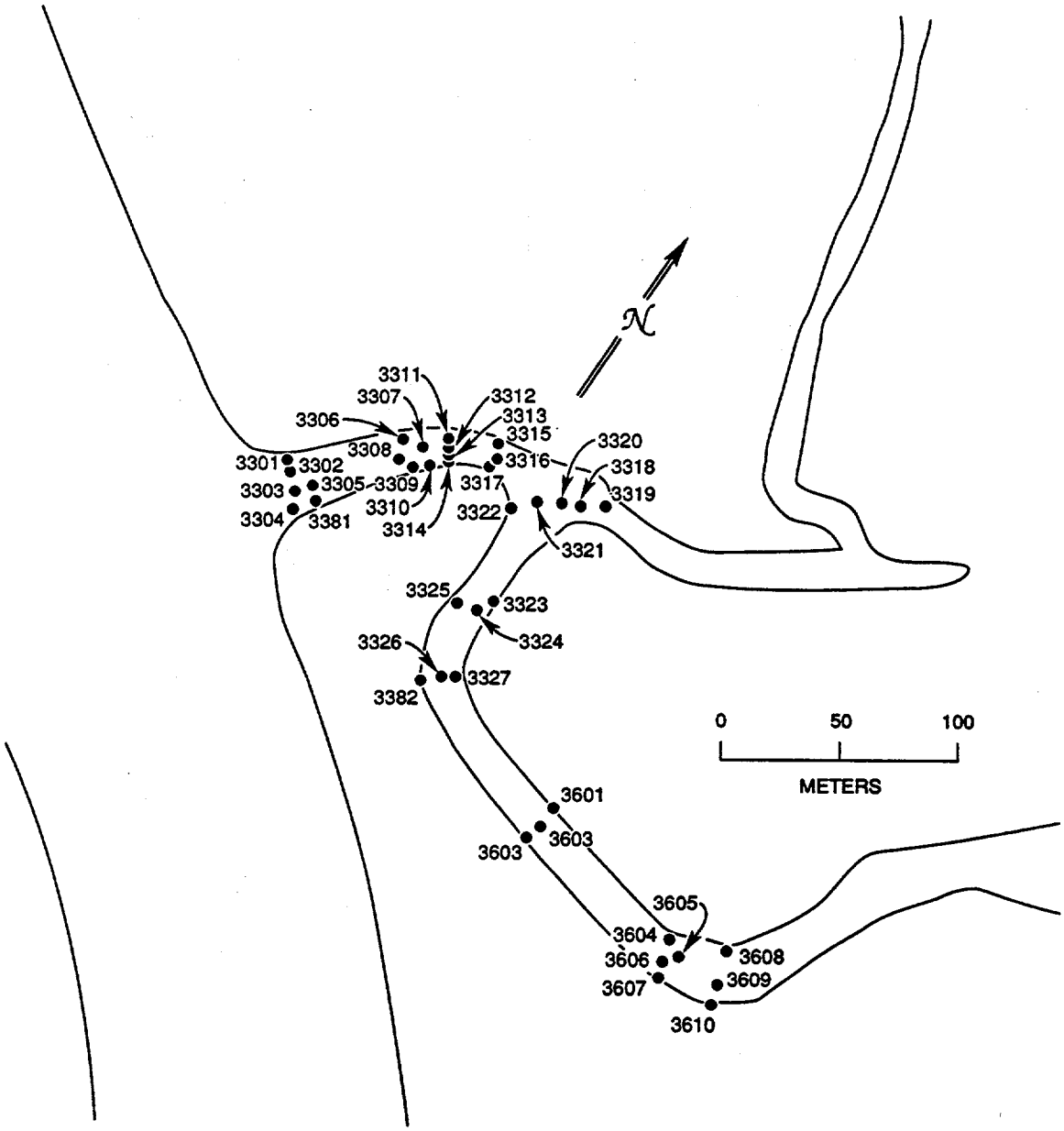

Fig. 6.16. Continued.

mouth of Northwest Tributary to 0.9 μg/g above the confluence with MB. Levels of PCBs in sediments from MB, WOL, and WOCE did not differ from those of upstream reference sites on WOC and MB.

In 1984 TVA sampled sediments in the WOCE as part of the Oak Ridge Task Force Study. PCBs were not detected in three of four samples; the other, taken 200 m above the mouth of WOC, contained 2.8 μg/g PCBs (TVA 1985a,b).

The record of past contamination of sediments clearly indicates that the WOC/MB system has been contaminated with PCBs and that PCBs in the system are still available for uptake by aquatic organisms at some sites (See Sect. 6.6). The data suggest that the facilities in the WOC portion of the system have been the primary contributor of PCB contamination and that facilities in the MB drainage have been less significant contributors of PCB contamination. Sediment sampling in the embayment suggests a very patchy distribution of PCB contamination, with hot spots surrounded by areas of little contamination.

Very little historical data exist on levels of hydrophobic organics other than PCBs in WOC and MB. One of four sediment cores taken by TVA in 1984 from WOCE contained 1.6 μg/g bis 2-ethylhexylphthalate; it was not detected in the other cores. Polycyclic aromatic hydrocarbons (PAHs) were not detected in any of the four cores. In addition to 13 gravel samples that were analyzed for organics by T. E. Cerling (ORNL), fine-grained organic-rich surface sediment (14 samples) were also analyzed for hydrophobic organic compounds. Only high molecular weight PAHs and phthalate esters were detected in WOC sediments. The highest levels of phthalates (di-N-butylphthalate, benzylbutylphthalate, and bis 2-ethylhexyl-phthalate) were found at the WOC reference site, suggesting possible sample contamination or the presence of interfering substances. PAHs, including benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene benz(a)anthracene, chrysene, anthracene, phenanthrene, dibenzanthracene, indenopyrene, fluoranthene, and pyrene, were tentatively identified in sediments from one site only, near the Third Street Bridge in the central ORNL complex. The PAHs were not detected at two sites farther downstream. No lower molecular weight PAHs, such as naphthalene, acenaphthylene, acenaphthene, and fluorene were detected. The sum of PAHs in the Third Street sample was less than 1 μg/g. The composition of the PAH mixture indicates the presence of a highly weathered aromatic oil, creosote, or an asphaltic solid such as coal fines, blacktop, or roofing tar. The low levels, localized detection, and absence of more soluble, low molecular weight PAH suggest the absence of a chronic source of bioavailable PAH input to WOC.

Volatile organics have not been surveyed in sediments from WOC, MB, or WOL embayment. T. W. Doyle (ORNL) submitted sediment samples from the three cores collected in WOL for "priority pollutant analysis" which included volatiles. No volatiles or any other organic compound on the priority list were detected (personal communication, T. W. Doyle - ORNL).

6.5.5 Inorganic Contaminants

Mercury contamination has occurred in the WOC drainage system as a result of spills associated mainly with research on lithium isotope separation at ORNL in the early 1950s. Sediment sampling conducted in 1974—75 (ERDA 1975) revealed elevated (6 to 60 μg/g) levels of mercury in sediments immediately downstream from ORNL (current monitoring station 2A). Elevated mercury levels were also found in WOL sediments (6 to 21 μg/g) and lower levels in WOCE (0.3 to 1.9 μg/g). Sediment cores collected by TVA in 1984 from WOCE had elevated mercury levels several centimeters deep in the cores, with a maximum level of 44 μg/g observed in a section of one core. Levels of mercury in fine-particle surface sediments in WOCE in 1984 ranged from 2 to 6 μg/g, with a mean of 3.3 μg/g (TVA 1985a,b). This is somewhat above levels observed in the 1974—75 study at that site. The levels found in WOCE were comparable to those found in lower Poplar Creek in the same study (Fig. 6.15). Surface sediments and cores taken in 1984 from the Clinch River immediately downstream from the mouth of WOC (CRM 19.7, 20.1, 20.5) all contained less than detectable levels of mercury (TVA 1985a,b).

Copper was slightly elevated (approximately 70 μg/g vs ~37 μg/g) in WOC and WOL sediments relative to reference sites in the 1974—75 survey (ERDA 1975). Copper levels in MB sediments approximated levels at reference sites in 1975. Using a more moderate extraction procedure (hydroxylamine hydrochloride) designed to distinguish available, anthropogenic contamination from mineralogic background levels, the 1985 survey of contaminants in streambed gravels indicated that copper was elevated three- to tenfold downstream of ORNL facilities (personal communciation, T. E. Cerling - ORNL).

In 1974-75, sediments from WOC, WOL, and WOCE averaged 100 to 200 μg/g zinc, compared with 50 μg/g at the reference site. The single sample taken from MB (below ORNL facilities) contained 778 μg/g (ERDA 1975). Similar levels of zinc were observed in the 1985 streambed gravel survey (personal communication, T. E. Cerling - ORNL). The highest levels (approximately 300 μg/g) were observed in MB below HFIR. Uncontaminated gravel left in streams for 30 d took up ~50 μg/g zinc at sites downstream from ORNL facilities (personal communication, T. E. Cerling - ORNL), indicating that ORNL is an active site of zinc contamination in the WOC system and that ambient levels in streambed gravels reflect a relatively short-term exposure history (i.e., zinc in streambed gravels probably equilibrates with aqueous concentrations within a period of a year or so).

No pattern of cadmium contamination in sediments was obvious in the 1974—75 survey (ERDA 1975); a mean level of 3 μg/g was observed in WOL (range less than 2 to 6 μg/g) compared with <2 μg/g at reference sites. Sediments from WOCE were not enriched above background levels in cadmium in 1984 (TVA 1985a,b), and no pattern of anthropogenic contamination is obvious in data from the 1985 streambed gravel survey.

Chromium is a contaminant of concern in the WOC system because of the past use of corrosion inhibitors containing chromate in cooling towers at ORNL. The practice was discontinued in 1976 (Boyle et al. 1982). Levels of chromium in sediment from MB were not highly enriched in chromium relative to reference sites. Total chromium in mud and gravel

sediments (unsieved) averaged 81 μg/g (n = 2) at reference sites and 267 μg/g (n = 6) at sites within the reach below HFIR. Chromium leached by 1N H_2SO_4 (i.e., easily leached) averaged about 120 μg/g at sites below HFIR; results from reference sites were not reported. Data from the 1974—75 survey (ERDA 1975) showed very high levels in WOL sediments relative to reference sites, which averaged 8 μg/g. Chromium levels in fine surface sediments (less than 53 μm) from WOL averaged 672 ± 168 μg/g in 1976, while similar sediments from Melton Hill Dam averaged 44 ± 30 μg/g (Elwood et al. 1980). Data from the 1985 stream survey indicate approximately 20 μg/g easily extractable (with hydroxylamine hydrochloride) chromium in streambed gravel downstream from HFIR and the central ORNL complex and less than 5 μg/g at upstream sites. Elevated chromium levels were evident in fine-particle surface layer sediments from WOCE analyzed by TVA in 1984 (TVA 1985a,b) with four samples having an average of 163 μg/g chromium (range 66 to 290 μg/g), while reference sites (n = 4) ranged from 21 to 25 μg/g. Levels at this site were similar in 1974-75, averaging 149 μg/g (range 13 to 497 μg/g) (ERDA 1975). T. W. Doyle (ORNL - personal communication) found maximum concentrations (up to 4900 μg/g) of chromium in subsurface sediment in WOL with lower, but still elevated, concentrations (250 to 700 μg/g) in surface sediments.

Very little historical information exists on levels of arsenic in WOC/MB. Levels in sediments of WOCE have been well below those found in reference sites (TVA 1985a,b), although detection limits differed (TVA 1985c). The 1985 streambed gravel survey found arsenic to be less than 6 μg/g throughout the WOC basin, and sediments indicated no enrichment due to ORNL discharges. T. W. Doyle found elevated arsenic concentrations in the three sediment cores from WOL. Natural background concentrations are expected to be in the range of 5 to 10 μg/g, whereas surface sediment concentrations in WOL approached 100 μg/g. Peak concentrations of arsenic of 830 and 670 μg/g occurred at depth in one core. If real, these elevated concentrations could have been derived from a variety of sources at ORNL including coal ash disposal, arsenate-treated lumber, herbicides, pesticides, and doping agents for solid state devices.

Little data exist to characterize levels of silver in the WOC system. In 1984 TVA analyzed for silver in sediments from WOCE downstream from WOL Dam. Sediments from WOCE averaged 6 μg/g silver in the 1984 TVA survey (TVA 1985a,b), well above background levels of less than 1.0 μg/g noted from Melton Hill and Norris reservoirs. However, the 1985 streambed gravel survey revealed no evidence of elevated silver levels in the WOC basin, with sediment levels below the detection limit of 0.5 μg/g. Cores collected by T. W. Doyle (ORNL) showed elevated concentrations (approaching 50 μg/g) of silver in the subsurface sediment of WOL. Two of the three cores collected showed a decreasing trend in more recently deposited sediments. The recent decline in silver was due to a cessation or reduction in silver releases from ORNL (personal communication, T. W. Doyle - ORNL).

Sediment data from 1974 (ERDA 1975) gives no evidence of accumulation of iron or nickel in sediments below ORNL, while lead levels were about three-fold higher (68 μg/g vs 21 μg/g) in sediments from WOC and WOL. No increases of levels of those three metals was seen in MB sediments in 1974 (ERDA 1975). The 1985 streambed gravel survey showed no major enrichment of nickel, lead, or iron downstream of ORNL facilities, although nickel was

enriched in the tributary draining SWSA 4 (personal communication, T. E. Cerling - ORNL). T. W. Doyle (ORNL) found concentrations of lead up to 170 $\mu g/g$ in subsurface sediments of WOL. All three cores showed declining, but still elevated, lead concentrations in the more recently deposited sediments. Nickel generally increased slightly from older to younger sediments and, in one core from the lower (western) lake, showed a recent decrease in concentration.

Manganese levels were often relatively high in waters of WOC and MB, occasionally exceeding EPA secondary drinking water standards (Boyle 1982), and it shows substantial enrichment downstream of ORNL sites in both stream valleys. Manganese is often naturally supersaturated in water in both streams, with MnO_2 coatings being in evidence on streambed surfaces (Cerling and Turner 1982). Whether manganese is enriched in waters below ORNL facilities because of its presence in effluents or because of its mobilization from naturally occurring deposits is not known; however, data on ORNL effluent characteristics (Murphy, unpublished; Patten, unpublished) suggest that the latter is the case, since effluent manganese levels are not higher than ambient stream levels. Core data (personal communication, T. W. Doyle - ORNL) for WOL showed no evidence that manganese is elevated above natural levels in the lake.

6.5.6 Radioactive Contaminants

Radioactive contamination of the sediments of WOC, WOL, and WOCE is well-documented beginning within a few years of the first operations at ORNL. In view of the long and diverse history of nuclear research and development at ORNL the nature and extent of radioactive contamination is expected to be complex. ORNL has hosted an array of nuclear and other research programs involving radioactive materials, reactor operations, reactor-related research, isotope production and environmental research. The activities have involved the use of primary fission products, ^{90}Sr and ^{137}Cs, the activation product, ^{60}Co, as well as many heavy, long-lived isotopes known as transuranics. The later group includes isotopes of plutonium, americium, neptunium and curium.

Oakes et al. (1982a) and Sherwood and Loar (1987) have provided a thorough review of the early (pre-1978) radiological investigations of creek and lake sediments in the White Oak basin; thus results of these earlier studies will not be reviewed here.

Results of sediment coring in 1979 (see Figs. 6.10 and 6.11) reported by Oakes et al. (1982b) showed that the dominant gamma emitter in WOL and WOCE was ^{137}Cs. Surficial (0-6 inches, 0-15 cm) sediment in the lake ranged from 133 to 725 pCi/g, wet weight, as ^{137}Cs. Surficial sediment from the embayment exhibited considerable variability in ^{137}Cs activity, ranging from 309 to 4949 pCi/g, wet weight. Considerably higher activities of ^{137}Cs were observed in the subsurface layers of certain cores, especially Core 23 from the embayment (Fig. 6.11). The peak activity in this core was 60,700 pCi/g, wet weight, and occurred 26 in. (66 cm) below the sediment water interface. The average activity of ^{137}Cs in the top 4 cm of the three cores collected in WOL (Fig. 6.13) was 945 pCi/g, dry wt (personal communication, T. W. Doyle - ORNL). The highest activity of this nuclide among the three cores was 20,520 pCi/g, dry weight, and occurred 32-36 cm below the sediment-water interface in

Core 2. Cesium-137 activity in the 4 cores collected in the embayment (Fig. 6.15) by TVA in 1984 ranged from 188 to 46,948 pCi/g, dry weight, with the highest activities located in subsurface layers.

Cerling and Spalding (1981) conducted the most comprehensive investigation of ^{137}Cs in WOC sediments. However, they used a specific size fraction (fine gravel, 0.85 to 3.35 mm) of the whole sediment for analysis. Their results were reported in dpm/g, dry weight, but have been converted here to pCi/g for consistency by dividing the values by 2.2 (1 pCi = 2.2 dpm). The stream gravels ranged from <0.1 to 10,545 pCi/g, dry weight. Average activities for upper WOC (upstream of MS 2A) was 1572 pCi/g, for lower WOC (immediately above lake) was 2611 pCi/g, for upper WOC (upstream of MS 3) was 895 pCi/g, and in WOCE was 3950 pCi/g. Analysis of the gravels showed conclusively that ORNL plant effluents accounted for almost all of the ^{137}Cs discharge from the WOC basin. Subsequent analysis of gravel collected in 1985 and the use of uncontaminated gravels used as in situ monitors of ^{137}Cs releases confirmed this conclusion (personal communication, T. E. Cerling - ORNL).

Distribution and activities of ^{60}Co in the WOC watershed are very similar to distribution and activities of ^{137}Cs. Activities are often but not always somewhat lower for ^{60}Co. In addition, ongoing releases of ^{60}Co from HFIR are evident in stream gravels below this facility (Cerling and Spalding 1981). Activities of ^{60}Co in cores collected by TVA (TVA 1986) in the embayment (Fig. 6.15) averaged 116 pCi/g and ranged from 12 to 437 pCi/g.

Oakes et al. (1982a) reported partial ^{90}Sr data for the 12 cores collected in WOL in 1979 (Fig. 6.10) but no data for the 26 cores collected in the embayment. Surface sediment activities for ^{90}Sr in the lake ranged from 22 to 69 pCi/g, wet wt. Subsurface sediment (12.5-15 cm) showed generally similar activities. Surface (0-2 cm) activities for the three cores (Fig. 6.15) collected in WOL ranged from 38 to 92 pCi/g (personal communication, T. W. Doyle - ORNL) and thus are similar to values reported by Oakes et al. (1982b). Activities in the four cores collected by TVA (TVA 1986) in the embayment (Fig. 6.15) averaged 24 pCi/g and ranged from 2 to 100 pCi/g. Gravel showed that the major sources of ^{90}Sr, in decreasing order of concern, were direct ORNL plant effluents, SWSA 4 with its associated contaminated floodplain of WOC, and SWSA 5 from its south side draining into MB. Stream gravels, and presumably whole sediment, below these facilities are elevated in ^{90}Sr (personal communication, T. E. Cerling and T. W. Doyle - ORNL). Uncontaminated gravels placed in the tributary adjacent to SWSA 4 accumulated up to 324 pCi/g in 1 month.

There are very few data for transuranics in sediments of the WOC watershed. Oakes et al. (1982b) refer to transuranic data for the upper 6 in. (15 cm) of WOL but only give the estimated inventory. The total inventory in this layer was estimated at 0.87 Ci, with 0.096 Ci of ^{238}Pu, 0.250 Ci of ^{239}Pu, 0.024 Ci of ^{241}Am, and 0.498 Ci of ^{244}Cm. TVA measured these same isotopes in the four cores (Fig. 6.15) collected in WOCE (TVA 1986). Plutonium-239 activities averaged 9.1 pCi/g and ranged from 0.4 to 69 pCi/g. Plutonium-238 activities averaged 0.62 pCi/g and ranged from 0.007 to 4.1 pCi/g. Americium-241 activities averaged 11 pCi/g and ranged from 0.43 to 73 pCi/g. Curium-244 activities averaged 3.3 pCi/g and

ranged from 0.014 to 12 pCi/g. Other data for transuranics in sediments in the WOC watershed may exist and will be sought as a part of the WAG 2 RI.

6.5.7 Significance of Sediment Contamination

This section uses the available aquatic sediment data to address three questions: (1) On the basis of the available data, what are the contaminants of concern? (2) Have sufficient comprehensive chemical analyses been performed to identify all contaminants of concern? and (3) Have all sediment depositional areas been adequately sampled to determine the nature and approximate extent of sediment contamination?

Preliminary assessments of the human and ecological risk posed off-site releases of contaminants from the WOC watershed have been performed (Hoffman et al. 1984; Travis et al. 1989, Suter et al. 1990a, Hoffman et al. 1990) and may be used to identify contaminants of concern. Some but not all of the sediment data reviewed above was employed in these assessments. For example, the data for the two cores collected in WOL in November 1983 were employed by Hoffman et al. (1984) to identify and rank contaminants according to relative risk via transfer to man from fish consumption. Among the inorganic contaminants reported, arsenic, beryllium, chromium, lead and silver yielded the highest risk screening factors. In all cases the preliminary assessments were performed to identify contaminants requiring further investigation and employed conservative assumptions. Additional discussion of these assessments can be found in other sections of this document.

Although further risk assessments will be performed specifically for the aquatic sediments of the WOC system, it is appropriate at this time to attempt to use the available data to identify contaminants of concern in sediments. Comparison of measured values to local background concentrations or crustal averages is a convenient and conservative means to identify contaminants that may need further study or corrective action. Local background concentrations have often been obtained as part of the sampling and analysis programs by sampling sediments upstream of all sources of contamination. Background concentrations are also obtained by coring completely through deposits of contaminated sediments in lakes and streams. Lastly, the National Uranium Resource Evaluation (NURE) Program included sampling and analysis of sediment in 18 streams on the on the Oak Ridge S-16A Map. Only two of these sites are located downstream of known sources of contamination by the federal facilities. In addition to uranium, a wide range of other metals and elements were analyzed (Sargent et al. 1982). All of these sources of background concentration data were used in arriving at a preliminary list of contaminants of concern.

The nonradioactive contaminants in stream and lake sediments that are most clearly elevated over local background in the WOC system are chromium, silver, lead, mercury, zinc, copper, arsenic, and PCBs. Some other inorganic contaminants, such as nickel, may also be elevated. Some inorganics, such as antimony, which have been identified through the preliminary risk assessments, should probably not be listed until more positive identification of elevated levels is achieved by application of appropriate analytical methods. Antimony is often grossly overestimated in sediment using the commonly applied ICP method. Surprisingly, other than a few semivolatile organic compounds (chiefly phthalates and some

polynuclear aromatics), organic contamination of sediments appears to be restricted to PCBs. However, sampling and analysis for volatile organic compounds has been very limited. While these compounds are not expected to persist very long in sediments, they are often detected in sediment downstream of continuing releases. There is also sufficient uncertainty about the extensiveness and quality of previous sampling and analysis of sediment for organic contamination that some compounds may have been missed.

Among radiological contaminants it is clear that ^{137}Cs, ^{60}Co and ^{90}Sr are major contaminants of concern in sediment. Previous investigations have adequately documented the extent of sediment contamination with these nuclides for risk assessment purposes, but the results may be inadequate for the purpose of identifying alternative corrective measures. Characterization of other radiological constituents has been far less thorough, especially for the transuranics and actinides. In addition, in spite of the use of ^{14}C and a variety of other relatively longlived isotopes as experimental tracers at ORNL, there appear to be no data for most of these nuclides in the sediments of the WOC watershed.

The focus of most previous sediment sampling has generally been on the obvious depositional areas for sediment accumulation in the watershed. Recent (post-1978) sampling, which entailed more comprehensive chemical analysis, has not been extensive. For example, the 1986 coring effort employed only three cores from the central portion of WOL. The gravel study analyzed only 13 samples of whole fine-grained sediment for radionuclides, metals, and organics. The latter samples did come from depositional areas such as behind the hydrological monitoring weirs but represent the only such near-comprehensive analysis of aquatic sediments in WOC.

Transuranics have apparently only been measured in the surficial sediments of WOL and four cores from the embayment. Maximum concentrations from historic releases that may occur in subsurface layers in WOL and in the embayment are currently unknown. Ongoing investigations related to the Clinch River RFI (CRRFI 1990) in the embayment will fill some of this void of information.

Sufficient information exists on contaminants in sediments of the WOC watershed to conclude that corrective measures may be required. The available data would support some preliminary risk assessment, but it is clear that insufficient data exist to support a detailed assessment. The concentrations of a variety of radiological and nonradiological contaminants have not been determined and will be needed to complete this kind of assessment.

As part of the Clinch River RFI sampling plan, a sediment core was taken approximately 50 yd upstream from the mouth of WOCE and analyzed for radioactivity in August 1990. The surface sediments of this sample contained 45,000 pCi/g, dry wt, of ^{137}Cs. As a result of this finding, seventy-two sediment grab samples were collected in the embayment in August and September 1990 and analyzed for radioactivity (Fig. 6.16). Preliminary results confirmed that concentrations of ^{137}Cs greater than 10^4 pCi/g, dry wt, existed near the mouth of WOCE. An inventory of ^{137}Cs indicated that between 3 and 4 Ci of ^{137}Cs were contained in the surface sediments (depth ~5 cm) of WOCE. Concentrations of ^{137}Cs at the mouth of the embayment were much higher than had been anticipated and were of immediate concern,

because surface sediments in WOCE are uncontrolled, i.e., sediments can be readily eroded from the embayment and transported downstream into the Clinch River. Work is now proceeding in collaboration with the U.S. Corps of Engineers to design and install a sediment-retention structure at the mouth of WOCE (Sect 9.4.6).

6.6 AQUATIC BIOTA

6.6.1 Introduction

The accumulation of contaminants in aquatic biota in the WOC watershed has been investigated in a number of recent studies. Prior to 1984, most emphasis was on the accumulation of radionuclides. Beginning with studies in support of a proposed ORR-wide environmental impact statement in 1979/1980, increased emphasis has been placed on monitoring the accumulation of nonradiological contaminants. Sites where much of the recent monitoring was conducted are depicted in Table 3.1.

6.6.2 Nonradiological Contaminants

6.6.2.1 Metals

Concentrations of trace metals were measured in fish from WOC, MB, WOL, and/or WOCE in 1979 (Loar et al. 1981), 1984 (TVA 1985c), and 1986-89 (Loar 1987; 1988a,b; 1989a,b; 1990). Concentrations of antimony, arsenic, beryllium, cadmium, copper, chromium, lead, lithium, nickel, selenium, silver, thallium, and zinc measured in fish from these sites did not differ substantially from concentrations in fish from reference sites (Tables D.1, D.2, and D.3). Mercury, however, was consistently elevated in fish from all sites within the WOC system (Tables D.1-D.3) except MB and WOCE. Mercury contamination in fish in the WOC system is not severe. No individual fish has contained mercury in excess of the 1-μg/g FDA action level (FDA 1984a) (Table D.4). Mercury concentrations in WOC fish are substantially lower than those found in nearby upper EFPC, a severely mercury-contaminated site, and are similar to those found in fish from the lower reaches of Poplar Creek and EFPC on ORR (Loar 1989a, 1990).

Concentrations are generally highest in the reaches of WOC nearest the main ORNL complex and decrease with distance downstream. The primary sources of mercury contamination to the creek appear to be various storm sewers and process water drains in the vicinity of areas where large amounts of elemental mercury were used and spilled in the 1950s (Rodgers et al. 1989). The situation at ORNL is therefore similar, on a much smaller scale, to that at the Y-12 Plant, where the primary determinant of mercury concentrations in fish is most likely chronic inputs from sources upstream, with mobilization of mercury from contaminated sediments acting as a secondary source.

Mercury concentrations were also elevated in turtles collected from WOL in 1987/1988, but the levels in muscle were not high relative to the FDA action level and, in general, were comparable to those measured in fish at that site (Loar 1989a).

Metal concentrations were determined in a number of aquatic plant species from the WOC system as part of the BMAP (Table D.5). Concentrations of cadmium, copper, and lead were substantially higher in moss from MB than in moss from WOC; however, concentrations of trace metals in filamentous algae were similar at the two sites with the exception of lead, which was higher in WOC.

Concentrations of several trace metals were measured in breast and liver tissue from domesticated mallards released on WOL and on transitory waterfowl (Loar 1990). No metals were found to be excessive.

6.6.2.2 Organic Contaminants

PCBs. Fish from the WOC system were first analyzed for organic contaminants in 1984 as part of the Oak Ridge Task Force Study (TVA 1985a-d). Low concentrations of PCBs were detected in 2 of 12 carp from WOL; however, channel catfish from WOCE were found to be highly contaminated with PCBs in that study, ranging from 2.2 to 5.6 μg/g, with a mean ($\underline{n}$ = 9) of 3.2 μg/g. PCBs have been consistently detected in sunfish collected in the WOC system since annual monitoring was initiated in 1986 as a component of the ORNL BMAP (Loar et al. 1987). Mean concentrations of PCBs have commonly exceeded 0.5 μg/g in sunfish at sites in WOL and WOC upstream from the lake (Tables D.6—D.8). Although the highest PCB concentrations have generally been observed in fish in the creek upstream from WOL, a clear pattern of decreasing PCB concentrations with increasing distance below the main ORNL complex is not evident. The concentrations of PCBs measured in sunfish at WCK 3.5, upstream from any inputs from SWSAs 4, 5, and 6 are similar to those observed in fish farther downstream. Largemouth bass and carp from WOL were analyzed for PCBs to estimate maximum concentrations likely in species that have greater affinity for PCB accumulation than sunfish. Bass accumulated higher concentrations of PCBs than sunfish or carp in WOL, averaging 1.6 μg/g (Table D.8).

PCB contamination was also evident in sunfish collected in WOCE, although the concentrations were lower than those measured upstream (Tables D.6-D.8). PCB concentrations in channel catfish from WOCE have been monitored annually since 1986. Catfish have generally averaged about 1.5 μg/g PCBs at that site from 1986 to 1989 (Table D.9), with 30 to 40% of the fish exceeding the 2-μg/g FDA limit (FDA 1984b). Catfish in WOCE have free access to and from the Clinch River, and it appears that the interchange of fish between the two systems is enough that fish in the river near WOCE and fish in the embayment can be considered part of the same population (Loar et al. 1987). Because upstream and downstream sources of PCB contamination in the Clinch River may contribute to PCB contamination of catfish populations in WOCE, it is difficult to ascertain how much of the PCB burden in catfish from this site originates in the WOC system.

PCB contamination was also evident in sunfish from MB (Tables D.6-D.8). However, this site typically produces a mixture of fish with background levels of PCBs and others with substantial PCB contamination, suggesting exchange between contaminated and uncontaminated populations.

Caged clams have also been used to monitor PCB contamination in the WOC system. These studies have consistently detected PCBs at WOL and WOCE (Tables D.10-D.12); however, the concentrations measured at WCK 3.5 (closest to the presumed source in the ORNL main plant area) have generally been much lower than those observed downstream. Sublethal toxic conditions at this site may interfere with the clams' ability to accumulate contaminants at that site. Clam studies have not substantiated the presence of PCB contamination in MB.

PCBs were also detected in two species of turtles from WOL (Loar 1988a,b).

Chlordane: High concentrations of chlordane (~20 μg/g) were detected in clams placed in upper WOC in 1988 (Table D.12). Subsequent sampling found lower but detectable concentrations (~0.1 μg/g) in clams at WCK2.6 and WOL in the WOC system below the ORNL main plant area (WAG 13) (Table D.12). Chlordane contamination has not been detected in fish collected from the WOC system despite the apparent spill or episodic release sometime before March 1988 (Tables D.7 and D.8).

Other organics: No substances other than PCBs and chloroform were found to be elevated in the analysis of fish from WOL and WOCE by TVA for organic priority pollutants in 1984 (TVA 1985c). Given the low bioaccumulation potential of chloroform (Callahan et al. 1979), this observation is almost certainly spurious. Subsequent analyses of fish from sites throughout the WOC system for pesticide/semi-volatile organic priority pollutants did not detect organic contaminants other than PCBs. Caged clams, which accumulate some organic contaminants that are rapidly metabolized and therefore not accumulated by fish, were used to monitor the accumulation of organic priority pollutants in 1990. Preliminary results of that study indicate the presence of PCBs and chlordane, as expected, but also trace amounts of DDT and DDT metabolites in some samples (Southworth, unpublished data, 1990). The highest levels, 0.09 μg/g, were observed in clams from MB. It is unlikely that a substance with as high a bioaccumulation potential as DDT could have been present in WOC prior to 1990 and not have been detected in biological monitoring. These observations probably represent either analytical interferences or a recent release. The inconsistent nature of the DDT results (presence in samples from widely different sites in both MB and WOC but not at sites in between or downstream) suggests the former explanation.

6.6.3 Radiological Contaminants

Numerous studies were conducted on the accumulation of radionuclides by WOL fish in the late 1960s and early 1970s. Results of these studies are summarized in Oakes et al. 1982a. Three isotopes were found to dominate the body burden of radionuclides accumulated by WOL fish — ^{137}Cs, ^{60}Co, and ^{90}Sr (Kevern and Griffith 1966, Kolehmainen and Nelson 1969,

and Nelson et al. 1970). Ruthenium-106, ^{125}Sb, and ^{65}Zr occurred in small quantities in fish in the late 1960s, but the contribution of these three radionuclides to the overall body burden was insignificant (Nelson et al. 1970), and radioactive decay has subsequently eliminated these from consideration.

Eyman and Trabalka (1980) determined that the concentrations of $^{239,240}Pu$ in fish ranged from 0.2 to 1 x 10^{-4} pCi/g fresh weight. The concentrations of tritium in algae, aquatic plants, benthic invertebrates, and fish were usually less than the concentration in water, which ranged from 403 to 646 pCi/mL in 1978 (Blaylock and Frank 1979).

Monitoring conducted as part of the ORNL BMAP was initiated in 1986. It affirmed that ^{137}Cs, ^{60}Co, and ^{90}Sr were the radiologically significant isotopes accumulated in biota in WOL, and it expanded the inventory of biota monitored to include aquatic plants, turtles, invertebrates, and waterfowl as well as fish (Loar et al. 1987; Loar 1988a,b; 1989a; 1990).

A survey of radiological contamination in seven species of fish collected from WOL in May 1987 found ^{137}Cs and ^{90}Sr to average about 400 Bq/kg (wet weight) and found ^{60}Co to be about a factor of 10 lower (Table D.13). Concentrations of ^{137}Cs in sunfish from sites in WOC upstream from WOL, closer to the PWTP discharge in WAG 1, were generally 5 to 10 times higher than in sunfish from the lake (Tables D.14-D.16); ^{137}Cs in MB fish was similar to that in WOL fish. Concentrations of ^{137}Cs and ^{60}Co in invertebrates (midges and worms) from WOL were similar to those in fish if compared on a dry weight basis (Loar 1988a,b).

Aquatic plants in WOL and WOC accumulated somewhat higher concentrations of ^{137}Cs, ^{60}Co, and ^{90}Sr than fish (Tables D.17-D.19). Concentrations in plants from WOC differed little from those in plants from WOL (Table D.20). The relative importance of MB as a source of ^{60}Co, and WOC as a source of ^{137}Cs, are clear from these data (Table D.21). Rooted aquatic plants were demonstrated to play an important role in the exchange of radionuclides between sediments and the water column (Loar 1990). Plants were found to both accumulate radionuclides from water and transport them to sediments and to mobilize radionuclides from sediments and release them to the water in dissolved and particulate form upon senescence of the plant community.

Migratory waterfowl provide a vector for transport of radionuclides from WOC/WOL into the human food chain. Migratory American coots that had resided for 3 months on WOL accumulated ^{137}Cs concentrations of about 600 Bq/kg, wet weight, in edible tissues (Table D.22); however, resident juvenile wood ducks that had been reared on WOL averaged only 131 Bq/kg. Migratory waterfowl collected on WOL averaged 234 Bq/kg (Loar 1990). Domesticated mallards were released on WOL in 1989 in an effort to determine the rate at which migratory waterfowl would accumulate radionuclides while wintering on WOL. The birds were found to accumulate about 300 Bq/kg ^{137}Cs in breast tissue in 2 months on WOL.

A waterfowl census of wetlands on the ORR was conducted from 1987 through 1990, as part of the ORNL BMAP. Substantial numbers of migratory ducks were found to winter on

WOL. Local nonmigratory Canada geese were also found to use the lake for feeding and nesting, as did wood ducks.

In 1987, measurements were made to estimate the inventory of the principal radionuclides in the biotic and abiotic components of WOL (Table D.23). Sediments were found to contain more than 99.99% of the radioactivity, with water containing most of the remainder. Contaminated biota contained less than 1% of the amount of radionuclides in the water column, with plants containing most of the biotic inventory.

6.6.4 Conclusions and Recommendations

Mercury, PCBs, chlordane, ^{137}Cs, ^{60}Co, and ^{90}Sr are the primary contaminants known to accumulate to above-background levels in aquatic biota in WAG 2. Other metals that may be elevated in water or sediments, including chromium, copper, lead, and zinc, do not exceed background levels in fish from WAG 2. The low bioconcentration potentials of ^{3}H, ^{99}Tc, and transuranics indicate that measurements of aqueous phase concentrations can be used to adequately assess contamination of biota. Upstream sources appear to be the major contributors of contamination, but the significance of residual contamination in soils and sediments of WAG 2 as sources to aquatic biota needs to be more clearly delineated though additional investigations.

6.7 AIR

Seven ambient air sampling stations are operated in and around Wag 2 (Fig. 6.17), and the seven major airborne effluent point sources in the two valleys are sampled (Fig. 6.18). Analyses consist of gross alpha, gross beta, adsorbable radioactive gases, and isotopic analyses of composited particulate filters. Tritium is analyzed at the point sources that handle tritium and at two of the ambient air sampling stations. Additionally, ambient air sampling stations are operated in remote locations in order to determine reference concentrations of radionuclides in air. These data are used to estimate the net impact of the facilities upon the local air quality.

In the spring of 1986, special studies were undertaken on tritium in terrestrial environments adjacent to the ORNL solid waste storage areas (Amano et al. 1987). These studies included a survey of ^{3}H in atmospheric moisture and its relationship to soil tritium levels at several sites in WAG 2.

Results: Annual data summaries for these ambient air stations and stacks are provided in the Environmental Monitoring Reports (e.g., Energy Systems 1990). Ambient air results for H-3, I-131, Co-60, Cs-137, plutonium isotopes, thorium isotopes, total radioactive strontium, and uranium isotopes for the last 2 years are all below 0.2% of the derived concentration guides for these analytes. None of these local radionuclide concentrations are significantly different from the remote air station radionuclide concentrations. Radioactive airborne emissions from the major point sources at ORNL resulted in estimated effective dose equivalents of

ORNL-DWG 90M-16724

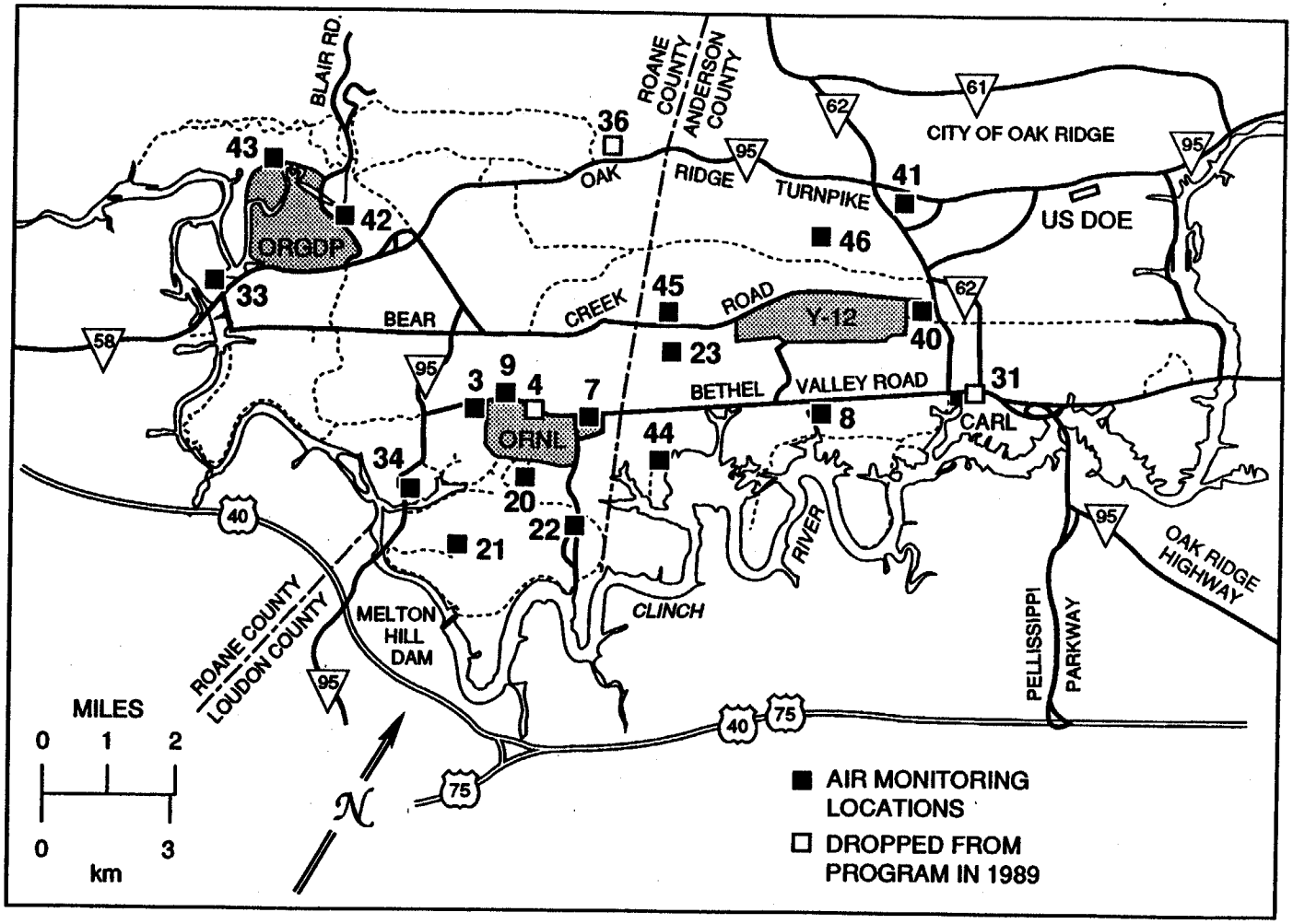

Fig. 6.17. Oak Ridge Reservation and ORNL perimeter monitoring locations.

ORNL-DWG 90M-16787

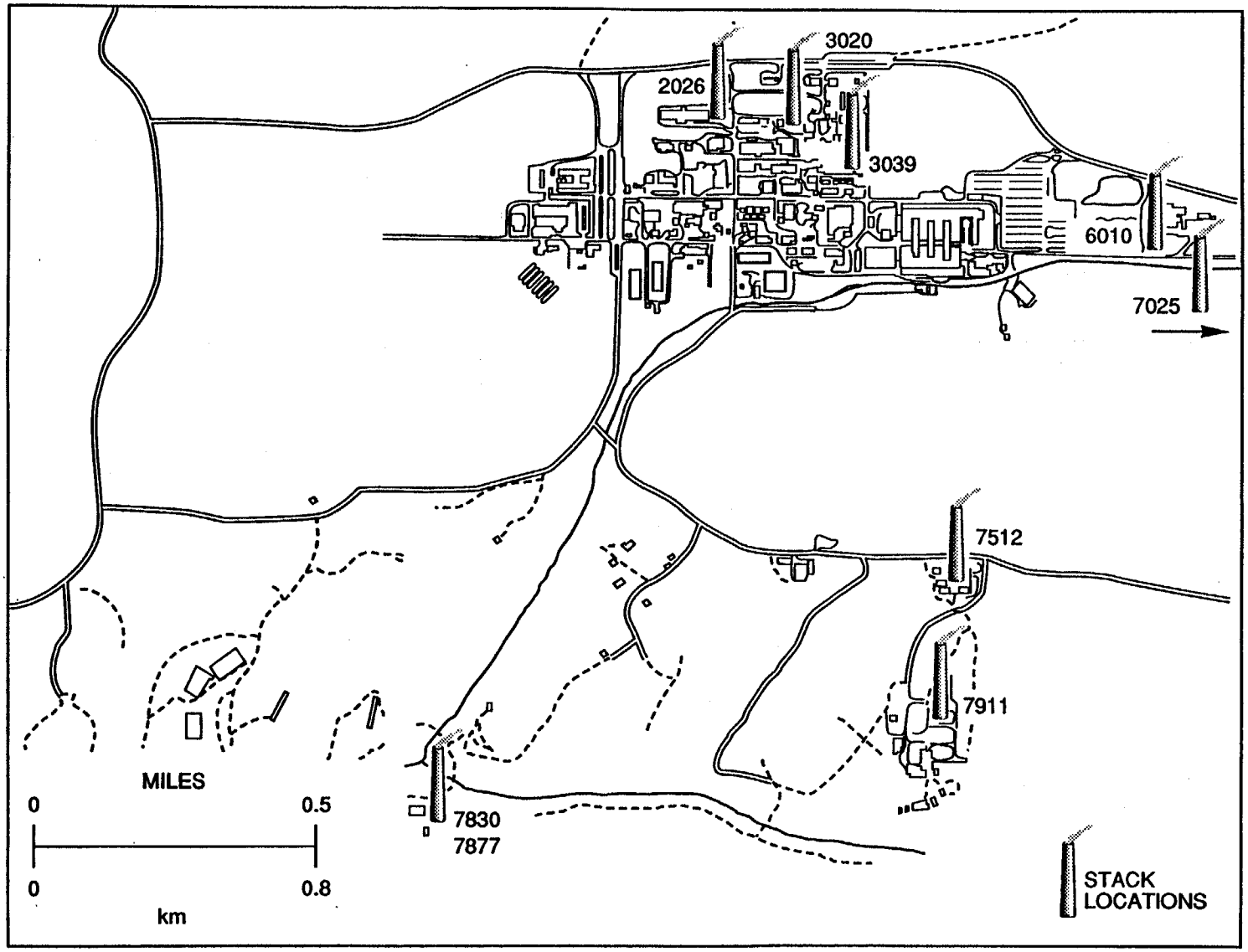

Fig. 6.18. Locations of major emissions points at ORNL.

0.3 mrem to the maximally exposed off-site individual for 1988 and 1989. Tables 6.7 and 6.8 present the ambient air data and the radioactive airborne emissions data for 1989, respectively. The chemical airborne emissions from ORNL are considered to be low. Table 6.9 is the chemical release information for 1989, based upon inventories, and engineering estimates.

Tritium concentrations in air moisture collected immediately south of SWSA 5 along MB floodplain were ~1000 times greater than concentrations measured in air moisture collected at a background location (0.001 μCi ^{3}H/L water in air). Tritium concentrations in air moisture immediately south of SWSA 4 and on the floodplain north of WOL were also elevated 10 to 100 times above background levels (Amano et al. 1987). As expected, ^{3}H concentrations in air moisture close to the ground (25 cm height) were higher than those measured 80 cm above the ground. There was a strong positive correlation between ^{3}H concentrations in surface air moisture and concentrations in surface soil water across the sites surveyed. Tritium concentrations in air at sampling sites with the highest measured concentrations were more than an order of magnitude below levels that would deliver a dose of 5 rem/yr to soft tissue (based on a 40-h work week and a 50-week year) (Loar et al. 1987).

<u>Conclusions and Recommendations</u>: It is unlikely that air is an important pathway for contaminant input to WAG 2 from the major air emission point sources or that WAG 2 provides an important source of contaminants to ambient air. Information regarding flux of tritium from WAG 5 is being collected and will be evaluated to estimate the potential of this WAG being a diffuse source for tritium input to WAG 2. Current releases of contaminants to WAG 2 will be evaluated via sampling of the water. If volatile contaminants are present in elevated concentrations, air sampling will reevaluated. Based upon the information available, general air sampling is not recommended at this time. However, additional monitoring of ^{3}H levels in air at sites within WAG 2 is needed to ensure that air concentrations have not changed such that dose limits would be exceeded.

Table 6.7. ORNL Perimeter Air Sampling Stations Summary Results 1989

Analyte	No. of samples	Max	Min	Av	Std. error	DCG (%)
Gross alpha	153	2.1	-1.6	0.60	0.070	
Gross beta	153	45	13	24	0.52	
H-3	3			35000	0.035	
I-131	153	13	-19	0.36	0.26	<0.01
Co-60	1				0.0041	<0.01
Cs-137	1				0.038	<0.01
Pu-238	1				0.0013	<0.01
Pu-239	1				0.00042	<0.01
Th-228	1				0.0096	0.024
Th-230	1				0.0056	0.014
Th-232	1				0.0059	0.084
TOTALSr	1				0.059	<0.01
U-234	1				0.062	0.069
U-235	1				0.0039	<0.01
U-238	1				0.015	0.015

Table 6.8. 1989 ORNL annual airborne radionuclide emissions[a]

Isotope	Stack number 2026	3020	3039	7025	7830	7911	7512	Total (uCi)
241Am	33	0.25	61		0.003	5.6		0.19
194Au			100					380
140Ba						100		0.83
7Be	0.23	0.094	95		0.13	4.0		82
82Br			100					110
244Cm	88	0.91	2.3		<0.0001	7.8		1.6
60Co	0.026	0.005	99		0.011	0.13		400
137Cs	6.2	0.32	92		0.000	0.95	0.038	650
152Eu						100		1.1
154Eu			21		0.68	78		1.4
155Eu	20					79		1.1
Gross Alpha	67	7.0	23		0.060	1.1	1.1	59
Gross Beta	3.0	3.1	92		0.003	1.5	0.054	3000
125I	23	72					3.9	0.69
129I	0.41	0.74	98		0.001	0.27	0.15	1900
131I	0.006	0.017	27		<0.0001	72	<0.0001	29000
132I						100		750
133I	0.002	<0.0001	0.075		<0.0001	99	0.000	27000
134I						100		210
135I	0.020	0.002	<0.0001		<0.0001	100	0.004	20000
140La						100		0.28
191Os			100					1200000
212Pb	23	5.2	57		0.029	13	0.011	87000
238Pu	8.4	<0.0001	91		<0.0001	0.32		1.4
239Pu	77	0.048	19		<0.0001	2.7		0.49
228Ra	20	28	51		<0.0001	<0.0001		0.44
Total Radium	48	15	31		0.13	4.3		0.25
106Ru			100					34
125Sb			100					8.8
75Se			99			0.14		990
Total Sr	6.6	0.15	90		0.006	3.1		35
228Th	60	3.3	33		0.10	2.9		0.27
230Th	6.6	3.0	85		0.20	4.9		0.041
232Th	2.0	4.5	88		0.18	4.4		0.037
234U	16	1.1	79		0.027	3.2		1.1
235U	11	2.1	81		0.072	4.9		0.10
238U	7.0	4.3	80		0.16	7.4		0.076
Total Uranium			95			4.6		0.66
65Zn			100					0.92
Noble Gas			94			5.2		95000[b]
Tritium			89	10		0.002		28000[b]

[a]Percent contribution to emissions, by stack.
[b]Units are curies, not microcuries.

Table 6.9. ORNL Chemical Release Information, 1989.

Chemical name	Type of release	Quantity released (lb/kg)	Major release sources	Basis of estimate
		SARA 313		
Ethylene glycol	Water: White Oak Creek Soil: lead	3,400/1,500 29,000/13,000	Chilled water system Chilled water	Other[a]
Nitric Acid	Air: point	65/29	Nitric acid tank vents	Engineering calculations
Sulfuric acid	Air: point	<1/<1	Sulfuric acid tank vents	Engineering calculations
Lead	Air: stack	14/6	Lead furnace lead shop	Engineering calculations
		Other large inventory chemicals		
Freon 11	Air: fugitive emissions	8,800/4,000	Refrigeration systems	Other[a]
Freon 12	Air: fugitive emissions	2,900/1,300	Refrigeration systems	Other[a]
Freon 22	Air: fugitive emissions	6,700/3,100	Refrigeration systems	Other[a]
Freon 113	Air: fugitive emissions	3,000/1,400	Refrigeration systems	Other[a]
Sulfur hexafluoride	Air: fugitive emissions	7,400/3,300	Accelerator cooling	Other[a]
		Steam plant emissions		
Sulfur dioxide	Air: stack emissions	2,400,000/1,100,000	Fossil fuels combustion	Emission factors[b]
Nitrogen oxide	Air: stack emissions	300,000/140,000	Fossil fuels combustion	Emission factors
Carbon monoxide	Air: stack emissions	162,000/74,000	Fossil fuels combustion	Emission factors
Particulates	Air: stack emissions	18,000/8,000	Fossil fuels combustion	Stack test[c]

[a]Best engineering judgement
[b]Based on AP-42 emission factors and 1989 ORNL steam plant coal usage/analysis records.
[c]Based on stack test conducted in 1981 in accordance with applicable EPA methods.

7. EXISTING INFORMATION FOR CONTAMINANT RELEASES FROM THE WOC SYSTEM

7.1 INTRODUCTION

The potential pathways for off-site release of contaminants from WAG 2 include surface water leaving the WOCE, groundwater, and pathways associated with plant and animal life. Information on the release of contaminants in surface water are readily available for recent years. The available information for known releases in groundwater or by plant and animal life are limited, although recent investigations have provided an improved understanding of the extent of contamination in these systems (see Sects. 4, 5, and 6 of this report). The remainder of this section deals exclusively with existing information on releases through surface water discharged from the WOL Dam.

7.2 DIRECT MEASUREMENTS OF RELEASES

The specific contaminants and water quality parameters included in the routine surface water monitoring program at WOL Dam are described in Sect. 4 of this report and are listed in Tables 4.1 and 4.2.

The 1989 summary data for this station (NPDES station X15) are listed in Table 7.1. The 1989 maximum concentrations for arsenic exceeded the Tennessee Draft Water Quality Criterion for protection of domestic water supply, and occasionally the biochemical oxygen demand exceeded the Tennessee Draft Criterion for Protection of Fish and Aquatic Life. Because WOC flow is diluted approximately 300 times upon entering the Clinch River, the potential for water quality impairment is considered negligible (Energy Systems 1990). The 1988 summary data for this station are given in Table 6.4 of this report. Similar data from prior years are published annually in the series *Oak Ridge Reservation Environmental Report*.

A summary of annual discharge of radionuclides from WOL Dam to the Clinch River between 1944 and 1984 is given in Table 7.2. These data indicate that, in general, the release of radioactive contamination from WAG 2 by surface water has decreased dramatically from the peak levels in the mid-1960s.

7.3 INDIRECT EVIDENCE OF RELEASES

In addition to the direct measurements of releases from the monitoring station at WOL Dam, indirect evidence of contaminant releases is available from surface water quality and biological monitoring in the Clinch River. Observed changes in water quality or biological indicators in the Clinch River upstream and downstream of the WOCE, along with historic records of waste disposal at ORNL, can be used to infer a historic contaminant release from WOC that was not measured directly. In Sects. 4 and 6 of this report, studies have been

Table 7.1. 1989 ORNL NPDES Permit Number TN 0002941 (discharge point X15 — White Oak Dam).

Parameter	No. of samples	Concentration (mg/L) Max	Min	Av	Std. error
Aluminum (total)	12	2.8	<0.050	<0.86	0.22
Ammonia (as N)	12	0.16	0.011	0.046	0.012
Arsenic (total)	12	0.090	<0.050	<0.055	0.0034
Biochemical oxygen demand	12	>34	<5.0	<7.4	2.4
Cadmium (total)	12	<0.0020	<0.0020	<0.0020	0
Chlorine (total) residual	52	<0.010	<0.010	<0.010	0
Chloroform	11	<0.025	0.0010[a]	0.0041[a]	0.0021
Chromium (total)	12	0.028	<0.0030	<0.016	0.0025
Conductivity (mS/cm)	12	1.7	0.23	0.87	0.14
Copper (total)	12	0.13	0.0050	0.019	0.010
Dissolved solids (total)	12	240	140	200	9.4
Flow (Mgd)	249	150	4.2	14	1.0
Fluoride (total)	12	1.0	<1.0	<1.0	0
Iron (total)	12	2.3	0.20	0.67	0.16
Lead (total)	12	0.0040	<0.0040	<0.0040	0
Manganese (total)	12	0.10	<0.0020	<0.060	0.0081
Mercury (total)	12	0.00011	<0.000050	<0.000063	
Nickel (total)	12	<0.020	<0.0050	<0.010	0.0017
Nitrate	12	<5.0	<5.0	<5.0	0
Oil and grease	52	>200	<2.0	<10	4.3
Organic carbon (total)	12	6.4	1.7	2.9	0.37
Oxygen (dissolved)	52	14	4.0	8.5	0.29
PCBs (total)	11	<0.00050	<0.00050	<0.00050	0
pH (standard units)	12	8.9	6.7	*b*	*b*
Phosphorus (total)	12	0.50	0.10	0.23	0.031
Silver (total)	12	<0.0050	<0.0050	<0.0050	0
Sulfate (as SO_4)	12	48	12	34	2.9
TSS	12	37	<5.0	<13	3.2
Temperature (°C)	64	28	3.9	17	0.80
Trichloroethene	11	<0.025	0.00070[a]	0.0064[a]	0.0019
Turbidity (NTU)	12	240	10	74	23
Zinc (total)	12	0.040	<0.0080	<0.024	0.0036
		Concentration (pCi/L)			
^{241}Am	18	1.6	−0.23	0.40	0.097
^{244}Cm	10	1.7	−1.6	0.48	0.27
^{60}Co	52	27	−14	8.3	0.87
^{137}Cs	52	320	−11	69	9.3
Gross alpha	30	33	−38	9.5	2.3
Gross beta	40	930	210	450	23
^{238}Pu	18	0.51	−0.068	0.077	0.029
^{239}Pu	18	0.76	−0.30	0.11	0.058
Total Sr	26	380	100	180	18
Tritium	26	430,000	76,000	260,000	22,000

[a]Below detection limit, but estimated.
[b]Not applicable.

Table 7.2. Annual discharges of radionuclides from White Oak Creek to the Clinch River, 1944 to 1984[a] (Curies).

Year	Beta	^{137}Cs	^{106}Ru	^{89}Sr	^{90}Sr	TRE(-Ce)[b]	^{144}Ce	^{95}Zr	^{95}Nb	^{131}I	^{60}Co	^{3}H	TRU
1944[c]	600												
1945[c]	500												
1946[c]	900												
1947[c]	200												
1948[c]	494												
1949		77	110		150	77	18	180	22	77		NA[d]	0.04[d]
1950		19	23		38	30	NA	15	42	19			0.04
1951		20	18		29	11	NA	5	2	18			0.08
1952		10	15		72	26	23	19	18	20			0.03
1953		6	26		130	110	7	8	4	2			0.08
1954		22	11		140	160	24	14	9	4	NA		0.07
1955		63	31		93	150	85	5	6	7	7		0.25
1956		170	29		100	140	59	12	15	4	46		0.28
1957		89	60		83	110	13	23	7	1	5		0.15
1958		55	42	NA	150	240	30	6	6	8	9		0.08
1959		76	520	0.3	60	94	48	27	30	1	77		0.68
1960		31	1900	1.9	28	48	27	38	45	5	72		0.19
1961		15	2000	2.0	22	24	4	20	70	4	31		0.07
1962		6	1400	1.7	9	11	1	2	8	0.4	14		0.06
1963		4	430	1.0	8	9	2	0.3	0.7	0.4	14		0.17
1964		6	190	0.8	7	13	0.3	0.2	0.1	0.3	15	1,900	0.08
1965		2	69	0.6	3	6	0.1	0.3	0.3	0.2	12	1,200	0.50
1966		2	29	0.9	3	5	0.1	0.7	0.7	0.2	7	3,100	0.16
1967		3	17	0.7	5	9	0.2	0.5	0.5	0.9	3	13,300	1.03
1968		1	5	0.6	3	4	0.03	0.3	0.3	0.3	1	9,700	0.04
1969		1	2	0.3	3	5	0.02	0.2	0.2	0.5	1	12,200	0.20
1970		2	1	0.3	4	5	0.06	0.02	0.02	0.3	1	9,500	0.40
1971		1	0.5	0.2	3	3	0.05	0.01	0.01	0.2	1	8,900	0.05
1972		2	0.5	NA	6	5	0.03	0.01	0.01	0.3	1	10,600	0.07
1973		2	0.7		7	NA	0.02	0.05	0.05	0.5	1	15,000	0.08
1974		1	0.2		6		0.02	0.02	0.02	0.2	0.6	8,600	0.02
1975		0.6	0.3		7		NA	NA	NA	0.3	0.5	11,000	0.02
1976		0.2	0.2		5					0.03	0.9	7,400	0.01
1977		0.2	0.2		3					0.03	0.4	6,200	0.03
1978		0.3	0.2		2					0.04	0.4	6,300	0.03
1979		0.2	0.1		2.4					0.04	0.4	7,700	0.03
1980		0.6	0		1.5					0.04	0.4	4,600	0.04
1981		0.2	0.1		1.5					0.04	0.7	2,900	0.04
1982		1.5	0.2		2.7					0.06	1.0	5,400	0.03
1983		1.2	0.2		2.1					0.004	0.3	5,600	0.05
1984		0.6	0.2		2.6					0.05	0.2	6,400	0.03

[a]Data from Ohnesorge (1986).
[b]Total rare earths minus cerium.
[c]Individual radionuclide data not available.
[d]No analysis performed
[e]Transuranic

described which have used this approach (Loar et al. 1987; Loar 1988a,b; 1989a; 1990; Sherwood and Loar 1987; CRRFI 1990). Ongoing and additional investigations will improve the ability to infer contaminant releases from off-site environmental monitoring and information on contaminants released to the WOC system.

7.4 CONTAMINANT TRANSPORT FROM WOC

Based on the existing information for contaminant releases from WOC, a tentative description can be established for the transport mechanisms involved.

In general, WOC acts as a conduit for certain contaminants that are transported by streamflow from discharge points within the WOL watershed into the Clinch River in a relatively short period of time. Other contaminants are deposited in WOC or WOL and may reside in the watershed for extended periods of time. Measurements of sediment and water discharge at WOL Dam have indicated that the concentration of suspended sediment in the water leaving WOL Dam can increase sharply during rainfall runoff events. It is known that many of the contaminants in WOC are sorbed in sediments and that the increase in suspended sediment discharge from WOL during floods is a major pathway for contaminants leaving the system. The available information on sediment dynamics in WOC is limited, however. An accurate prediction of the amount of contaminant transport associated with a given flood event is not possible with the existing data base. In Sects. 9 and 10 of this report, an approach will be developed to adequately define the relationship between the discharge of streamflow, sediment, and contamination leaving WOL.

8. METHODOLOGY FOR IDENTIFYING KEY CONTAMINANTS

To develop a plan for field sampling and analysis, it is necessary to identify which contaminants need to be measured in each of the physical and biological media of each segment of the WAG 2. As part of the ongoing RI planning process, existing data concerning the levels of contaminants in WAG 2 will be used to screen the set of potential contaminants of concern into sets of chemicals that will be measured in each medium and section of the WAG. Significant data exist for the environmental compartments of the WOC system (Sect. 6 and Table 8.1). Where data are not available for preliminary analyses, concentrations can be estimated (Sect. 8.2.1). This screening will be performed using three criteria: compliance with applicable or relevant and appropriate requirements (ARARs), levels of risk to humans, and levels of risk to the nonhuman environment. Consideration of ARARs provides a means of ensuring that the RI/FS for WAG 2 will proceed in such a way as to a comply with regulatory standards. However, consideration of ARARs is not sufficient because ARARs are not available for all contaminants and because ARARs do not provide a consistent level of protection for humans or the environment. Therefore, screening will be performed on the basis of the estimated risks to humans and the environment. This risk-based screening will not constitute baseline risk assessments but rather is intended to identify and prioritize potential contaminants of concern for further evaluation and investigation. This section discusses the ARARs (Sect. 8.1 describes how the risk-based screening will be performed for human health (Sect. 8.2) and the nonhuman environment (Sect. 8.3). Contaminants that potentially exceed ARARs or potentially pose unacceptable risks to humans or nonhuman populations will be included in the field sampling and analysis program (Sect. 10).

8.1 ARARS

Sect. 121 of CERCLA specifies that remedial actions for cleanup of hazardous substances must comply with requirements or standards under federal or more stringent state environmental laws that are applicable or relevant and appropriate to the hazardous substances or particular circumstances at a site. This section supplies a preliminary list of available federal and state chemical- and location-specific ARARs for contaminants of concern at WAG 2. This list of ARARs will be expanded as site-specific contamination at WAG 2 is characterized. No attempt will be made in this report to determine whether the regulations will be either applicable or relevant and appropriate. This will be done as the RI progresses. The tables for this section appear in **Appendix E**.

It is understood that DOE will comply with the requirements of NEPA as specified in DOE order 5440.1C "Implementation of the National Environmental Policy Act." Further, DOE order 5400.4 "Comprehensive Environmental Response, Compensation, and Liability Act Requirements" calls for integration of NEPA and CERCLA requirements for DOE

Table 8.1 Existing sources of data applicable for WOCRFI contaminant screening and preliminary risk assessment tasks. All data are available from either the ORNL/ERP (Hook et al. 1990) or CRRFI (CRRFI 1990) Numeric Data Bases.

Environmental media	Description of data
Groundwater	
Scoping Surveys[a]	
T. W. Doyle - ORNL (unpublished data)	Sampled wells and seeps in the solid waste storage and pits and trenches areas.
D. W. McCrackin - ORNL (unpublished data)	Sampled piezometer wells in the WOC floodplain.
Characterization Studies	
ORNL Groundwater Monitoring Program	Routine sampling of monitoring wells at the perimeters of ORNL WAGs.
ORNL RI/FS Groundwater Sampling	Sampling of monitoring wells for the characterization of study areas.
Surface Water	
Scoping Surveys	
T. E. Cerling - ORNL (unpublished data)	Sampling of WOC drainage.
Characterization Studies	
ORNL NPDES Monitoring	Routine monitoring of surface water quality at several stations within the WOC watershed.
ORNL Surface Water Radiation Monitoring	Routine monitoring of radiological concentration at several stations within the WOC watershed.
ORNL RI/FS Surface Water Sampling	Sampling of surface water to characterize study areas.
ORNL BMAP	Sampling of surface water as part of on going ecological monitoring efforts.

Table 8.1. (continued)

Environmental Media	Description of Data
Sediment and Soil	
Scoping Surveys	
T. W. Doyle - ORNL (unpublished data)	Sampled sediment in White Oak Lake.
Cerling and Spalding (1981, 1982), Cerling 1986	Sampled streambed materials in WOC drainage.
Oakes et al. (1982b)	Analyzed sediment from WOCE for concentrations of radiological constituents.
ORNL Water Quality Well Drilling	Analysis of drill cuttings from wells installed adjacent to WOC
Characterization Studies	
ORNL RI/FS Soil and Sediment Sampling	Soil and sediment analyses of numerous borehole samples in study areas.
Clinch River RFI Sediment Sampling	Sediment sampling in WOCE.
TVA - Oak Ridge Task Force Sediment Sampling	Sediment sample from WOCE.
Biota	
Characterization Studies	
ORNL BMAP	Contaminant concentrations in biological samples including: fish, clams, turtles, small mammals, waterfowl, aquatic macrophytes, and periphyton.
Clinch River RFI	Analyses of fish collected from WOCE.
TVA - Oak Ridge Task Force Fish Sampling	Analyses of fish collected from WOCE and WOL.

[a] Scoping surveys are generally less rigorous than characterization studies with regard to (1) QA for sample handling, (2) field and laboratory QA sample submission, and (3) use of standard analytical extraction and analysis techniques.

remedial actions at CERCLA sites. This issue has been reaffirmed in the Federal Facility Agreement (FFA) §I(A)(3) and §I(C) and Secretary of Energy Notice of February 5, 1990 (SEN-15-90), which was issued to ensure that DOE's NEPA activities are carried out in a centralized and uniform manner. Therefore, the regulations found in NEPA will not be addressed in this report as ARARs.

8.1.1 Chemical- and Radionuclide-Specific ARARs

Although limited in number, chemical-specific standards have been established under several statutes, including RCRA, the Safe Drinking Water Act (SDWA), the Clean Water Act (CWA), and the Clean Air Act (CAA). CAA regulations will be addressed as action-specific ARARs when remedial alternative selection is made.

8.1.1.1 Groundwater and Surface Water

Table E.1 lists available chemical-specific ARARs that have been promulgated under federal law for chemicals and radionuclides that are thought to occur in groundwater and surface water at WAG 2 (See Sects. 6.3 and 6.4). Since heavy metals have been detected in soils and sediments at WAG 2 (Sect. 3.2), they are included in the table. This table will be revised if monitoring data indicate the presence or absence of contaminants in groundwater or surface water.

As stated in the National Contingency Plan (NCP) (55 *FR* 8666, March 8, 1990), the goal of EPA's approach to cleanup of contaminated groundwater is to return usable groundwater to its beneficial use within a given time frame that is reasonable for the particular circumstances at a CERCLA site. Groundwater at WAG 2 has not been given an EPA classification. However, WAG 2 is underlain by Conasauga Group formations, which store relatively minor amounts of water (effective porosity, <1%), with very slow yield capabilities (geometric mean hydraulic conductivity is 0.05 m/d) (See Sect. 3.3.3). Given this description, and since the formation yield of groundwater is insufficient for drinking water sources, groundwater at WAG 2 should properly be classified as Class IIB or III.

In the NCP, EPA states the preference for SDWA maximum contaminant levels (MCLs) and nonzero maximum contaminant level goals (MCLGs) or other health-based standards, criteria, or guidance for cleanup of Class I and II groundwater at CERCLA sites (55 *FR* 8732). Alternate concentration limits (ACLs) may also be used when active restoration of the groundwater to MCLs or non-zero MCLGs is not practicable (55 *FR* 8754). For Class III groundwaters, EPA establishes remediation levels based on specific site conditions, the beneficial use of the groundwater, and environmental receptors (55 *FR* 8732). Final determination of ARARs for site-specific cleanup of groundwater at WAG 2 will depend on the chosen groundwater classification.

8.1.1.2 Resource Conservation and Recovery Act

Subtitle C of RCRA lists maximum concentration levels for 14 chemicals; the concentration of these chemicals in groundwater at the plant boundary of a RCRA-permitted treatment, storage, or disposal (TSD) facility may not exceed the stated maximum concentration level [Title 40, Code of Federal Regulations, Part 264, §94 (40 CFR 264.94)]. In addition, background concentrations or ACLs are established in 40 CFR 264.94 as groundwater protection standards. Table E.1 lists RCRA MCLs; the proposed RCRA corrective action regulations (*55 FR* 30798, July 27, 1990) adopt all SDWA MCLs for "potentially drinkable" groundwater, with cleanup throughout the contaminated plume. When promulgated, these RCRA groundwater protection standards will also be potential ARARs.

8.1.1.3 Safe Drinking Water Act

Table E.1 lists SDWA MCLs and MCLGs. At present, EPA is planning to use the SDWA MCLs for remedial action compliance for carcinogens that have an MCLG of zero and any nonzero MCLG for systemic toxicants (55 *FR* 8752). Chapter 1200-5-1 of the Rules of the TDHE, 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.

EPA has promulgated MCLs for radionuclides in community water systems (see Table E.2). These MCLs appear in two forms — concentration limits for certain radionuclides (40 CFR 141.15) and an annual dose limit for the ingestion of certain beta- and gamma-emitting radionuclides (40 CFR 141.16).

Proposed MCLs/MCLGs have appeared in 54 *FR* 22062 (May 22, 1989) and in 55 *FR* 30370 (July 25, 1990). Table E.1 lists the proposed MCLs/MCLGs. When the proposed MCLs/MCLGs are promulgated, they will be considered relevant and appropriate for cleanup at WAG 2 (a final rule is expected January 1991 and March 1992, respectively). However, until that time, the current MCLs will be considered as ARARs.

National Secondary Drinking Water Standards (NSDWS) regulate contaminants that affect the aesthetic qualities related to public acceptance of drinking water and are implemented in 40 CFR 143.3 as secondary MCLs. Tennessee has promulgated secondary drinking water regulations in Chap. 1200-5-1.12 of the Rules of the TDHE (see Table E.1). These regulations are designed to provide water to the consumer that is aesthetically pleasing, and they apply to all community water systems and to those noncommunity water systems "as may be deemed necessary" by the Department of Health and Environment. In that context, they would not be legally applicable to cleanup of groundwater or surface water, but may be considered as relevant and appropriate in instances where these media may provide private drinking water sources. EPA has proposed NSDWS for nine additional contaminants (54 *FR* 22062, May 22, 1989), and, when these are promulgated, they will be incorporated into the TDHE secondary drinking water regulations. Therefore, they are included in Table E.1 for completeness.

8.1.1.4 Clean Water Act

The National Pollutant Discharge Elimination System (NPDES) permit program includes applicable effluent standards, monitoring requirements, and conditions for discharge. Tennessee has an EPA-authorized state program that is equivalent to the federal program. Although NPDES permits are not necessary for on-site discharges from CERCLA sites, the substantive CWA NPDES requirements must be complied with. NPDES Permit Number TN0002941 regulates discharges from ORNL to the Clinch River, WOC, MB, and other tributaries. Surface water at the three ambient NPDES stations at WAG 2 is in compliance with the NPDES permit (See Sect. 6.4).

CERCLA §121(d)(2)(A) specifically states that remedial actions shall at least attain federal ambient water quality criteria (WQC) established under the CWA if they are relevant and appropriate. 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)]. Federal 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 (see Table E.2).

As part of the federal requirement for a triennial review of state water quality standards, the TDHE Division of Water Pollution Control (DWPC) has proposed amendments to Chaps. 1200-4-3 and 1200-4-4 of the Rules of the TDHE. Included in this change are criteria for protection of recreational uses. These criteria are human health criteria derived to protect the consumer from consumption of contaminated fish; these criteria are similar to the federal WQC for the protection of human health from consumption of fish alone. However, the DWPC is proposing a criterion for carcinogens based on a 10^{-5} risk, whereas the federal WQC for carcinogens correspond to a risk of 10^{-6}. When promulgated, these criteria will be ARARs for cleanup of surface waters at WAG 2 that are designated for recreational use.

Chapter 1200-4-3 of the Rules of the TDHE lists seven use designation categories for Tennessee's surface waters and groundwaters. Specific water quality standards are promulgated for each use category. Under the Tennessee Water Quality Control Act, the Tennessee Water Quality Control Board has classified WOC and MB of the Clinch River for fish and aquatic life, and livestock watering and wildlife uses (Chap. 1200-4-4 of the Rules of the TDHE). The TDHE has proposed a change in the use classification that will add recreation as a category for all segments of rivers and streams that are not currently classified as such. When this change is promulgated, the water quality standard for recreational use will be considered as an ARAR for cleanup of surface water at WAG 2.

Table E.3 lists federal WQC for the protection of freshwater aquatic life. When the designated use classification requires protection of aquatic life or when environmental factors are being considered at a remedial action site, a WQC for the protection of aquatic life that is more stringent than the SDWA MCL may be relevant and appropriate (55 *FR* 8754) for CERCLA cleanup. TDHE has proposed WQC for the protection of aquatic organisms and, when promulgated, these will become applicable for cleanup of surface water at WAG 2.

8.1.1.5 Soil

Very little legislation or guidance is available governing cleanup criteria for contaminated soils at CERCLA sites. RCRA has addressed land disposal of treated hazardous wastes in its land disposal restrictions (40 CFR 268), and these will addressed as "hybrid" ARARs for remedial action alternative selection during the RI. Since the RCRA treatment standards are deemed generally inappropriate or infeasible when applied to contaminated soil or debris, EPA is proposing a separate rulemaking to establish treatment standards for disposal of such contaminated soil and debris (NPRM, June 1991; Final Rule expected June 1992). These will be analyzed as ARARs or TBC when available.

The regulations found in the Toxic Substances Control Act (TSCA) limit concentrations of polychlorinated biphenyls (PCBs) in soil to 50 ppm and require that any soils containing concentrations of PCBs greater than 50 ppm (40 CFR 761.60) be incinerated (40 CFR 761.70) or stored in a chemical waste landfill (40 CFR 761.75). TSCA also specifies requirements that must be achieved for PCBs disposed of by incineration (40 CFR 761.70), in a chemical waste landfill (40 CFR 761.75) or by other disposal methods [40 CFR 761.60(a)(5)(iii)]. For alternative methods of disposal, if chemical destruction or separation of PCBs from the soil is carried out, the resulting concentration of PCBs must be less than 2 ppm [40 CFR 761.60(e)]. These regulations will be addressed as "action-specific" ARARs.

8.1.1.6 Other "To-Be-Considered" (TBC) Guidance

In the absence of federally or state-promulgated ARARs, or in the case where ARARs are not adequately protective, EPA states a preference for Office of Drinking Water (ODW) Health Advisories (HAs), RfDs for systemic toxicants and carcinogen potency factors (CPFs) for carcinogens (EPA 1989a).

The EPA ODW has developed nonregulatory HAs for concentrations of noncarcinogenic contaminants in drinking water at which no adverse health effects would be expected to occur. Table E.4 lists 1-d, 10-d, and longer-term (several months to several years) HAs for a child weighing 10 kg. Longer-term and lifetime advisory levels for a 70-kg adult are also listed in Table E.4. The EPA ODW has also determined the concentration of specific carcinogens in drinking water that will result in one excess cancer in one million people (a risk of 10^{-6}) following a lifetime exposure. Although not HAs, which are only developed for noncarcinogens, the carcinogenic values are listed in Table E.4 as they were developed by the ODW.

EPA has also developed other TBC guidance values in the form of RfDs and CPFs, which are available through the EPA *Integrated Risk Information System (IRIS)* (EPA 1989b) and the EPA *Health Effects Assessment Summary Tables* (EPA 1990a). Table E.5 lists RfDs and slope factors.

EPA has suggested cleanup values for lead in soils based on studies of blood lead levels in exposed children. The EPA Office of Solid Waste and Emergency Response (OSWER) Directive 9355.4-02 (dated September 7, 1989) recommends a cleanup level for soils of 500 to 1000 ppm lead.

8.1.2 Radiation Protection Standards

Very few applicable standards are available for the cleanup of radioactively contaminated CERCLA sites. The Atomic Energy Act (AEA) of 1954 and its amendments delegated authority for control of nuclear energy to DOE, the U.S. Nuclear Regulatory Commission (NRC), and EPA. DOE is authorized to control all types of nuclear materials at sites under its jurisdiction and is exempt in most cases from the NRC licensing and regulatory requirements. Therefore, NRC regulations are not considered to be ARARs for CERCLA cleanup at DOE facilities; however, a summary of the general content of NRC regulations will be presented here. 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 the NRC regulations, as TBC guidance, but will not be addressed in this report.

Since a complete characterization of the source and identity of radioactive waste at WAG 2 has not been completed, all of the available EPA regulations will be presented here, as well as the numerical NRC values.

8.1.2.1 EPA Regulations

Subpart H of 40 CFR 61 addresses atmospheric radionuclide emissions from DOE facilities and may be applicable to airborne emissions during cleanup of WAG 2. EPA has issued a final National Emission Standards for Hazardous Air Pollutants (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). Originally, 40 CFR 61.97 allowed for DOE to apply for an alternative emission standard in cases where a facility exceeded the NESHAP; however, this section has been deleted in the current rulemaking (See Table E.6).

Environmental protection standards for nuclear power operations; the management, storage, and disposal of spent nuclear fuel, high-level wastes, and transuranic (TRU) wastes; and uranium mill tailings may be relevant and appropriate for the storage or disposal of radioactive materials at WAG 2 (Table E.6).

EPA intends to develop environmental radiation protection standards for the disposal of low-level waste (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 2 and, when promulgated, will be considered as ARARs (NPRM intended September 1991; Final Rule, December 1992).

In addition, EPA is developing public health and environmental radiation protection criteria for cleanup of residual radioactive materials at decommissioned DOE, Department of Defense (DOD), and NRC-licensed sites, as well as others (NPRM, Summer 1991). These criteria may provide useful TBC guidance for remedial response at WAG 2.

8.1.2.2 NRC Regulations

As mentioned previously, DOE ORR is not regulated by the NRC; however, NRC regulations might provide some TBC guidance for cleanup of radioactive waste at WAG 2. 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). These regulations are being revised by the NRC, with a final rule expected December 1990.

Appendix B of 10 CFR 20.106 sets annual average concentration limits for radionuclides in airborne and liquid effluents. However, these concentration limits are less protective than those derived in various EPA regulations and probably should not be considered for use as TBC cleanup standards at WAG 2.

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. Although not an ARAR, the substantive requirements found in this regulation might provide TBC guidance for disposal options selected at WAG 2. 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. In addition, reasonable effort must be made to maintain releases of radioactive materials to as low as reasonably achievable (ALARA). 10 CFR 61.42 states that inadvertent intruders must be protected following cessation of active institutional controls, and 10 CFR 61.41 provides that operations at land disposal facilities must be carried out in compliance with 10 CFR 20.

8.1.2.3 DOE Orders

DOE orders are not promulgated regulations and thus are not considered to be ARARs by EPA. They are, however, legally binding between DOE and Energy Systems because of contractual agreements. In particular, the derived maximum radionuclide concentration guidelines for discharges of radioactively contaminated liquids to surface waters, aquifers, and soil that appear in the final DOE order 5400.5 (Radiation Protection of the Public and the Environment) may be useful as TBC guidance. These guidelines are based on an annual effective dose equivalent of 100 mrem from all sources. However, the overriding premise of

the DOE order is that all exposures of the public shall be ALARA. In the event that DOE orders are more stringent or cover remedial action activities not addressed by existing ARARs, they should be used as TBC guidance for developing protective remedies at WAG 2. However, the content of the DOE orders will not be addressed in this report.

8.1.2.4 TBC Guidance for Radiological Risk Assessment

The EPA Office of Radiation Programs has derived slope and unit risk factors for radionuclides of concern at remedial sites for each of three major exposure pathways (inhalation, ingestion, and external exposure to contaminated soil). These slope factors are listed in Table E.7.

8.1.3 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 E.8 lists the major federal and state location-specific ARARs that might be pertinent to remedial actions at WAG 2.

8.1.3.1 Caves, Salt-Dome Formations, Salt-Bed Formations, and Underground Mines

There is no indication of salt-bed formations, salt-dome formations, or underground mines at the site (Lee 1989). If any caves are located in areas where remedial activities may occur, the regulations found in RCRA [40 CFR 264.18(c)] that prohibit the placement of noncontainerized or bulk liquid hazardous waste in caves may be ARARs (Table E.8).

8.1.3.2 Faults

Although minor seismic activity has been recorded in the region, no surface rupturing associated with any of the faults within ORR has been recorded. Two regionally extensive thrust faults transect ORR (Sect. 3.3.2.2). The possibility of fault movement is considered extremely unlikely (Chance 1986).

WAG 2 is exempted from compliance with the RCRA seismic requirements of 40 CFR 264.18 since 40 CFR 264.18(a) stipulates that all facilities that are located within the political jurisdictions other than those listed in Appendix VI are assumed to be in compliance for location of new treatment, storage, or disposal facilities. Tennessee is not listed in the Appendix. However, EPA intends to propose additional floodplain and seismic restrictions for location of TSD facilities (Notice of Proposed Rule-making [NPRM] December 1990; Final Rule expected December 1992), and these restrictions will be incorporated into the TDHE Hazardous Waste Management regulations (personal communication, T. Hinch - ORNL). At that time, the TDHE seismic regulations may be ARARs for remedial actions at WAG 2.

8.1.3.3 Wilderness Areas, Wildlife Refuges, and Scenic Rivers

There are no designated wilderness areas, wildlife refuges, or scenic rivers at WAG 2. Certain portions of ORR have been designated as Tennessee and DOE National Environmental Research Park (NERP) Natural Areas (NAs) and Reference Areas (RAs) (Parr and Pounds 1987), and as such are protected by state law. However, there are no known NAs or RAs within WAG 2.

Seasonal streams and tributaries flow into WOC before discharge into the Clinch River, which has been classified by TDHE for a variety of uses, including domestic and industrial water supply, navigation, livestock watering, wildlife, recreation, irrigation, and fish and aquatic life (Chap. 1200-4-4 of the Rules of the TDHE). MB and WOC have been classified for fish and aquatic life and wildlife uses.

If remedial actions are contemplated that would impact those creeks and lakes designated for fish and aquatic life, recreation, irrigation, livestock watering, etc., the Fish and Wildlife Coordination Act and the TDHE Water Quality Control Act (Chap. 1200-4-3 of the Rules of the TDHE) may be ARARs (see Table E.8).

8.1.3.4 Wetlands and Floodplains

Most of WAG 2 is located in the 100- and 500-year floodplains. TVA has conducted studies to evaluate flood hazards associated with land use and construction within ORR; a regional flood on the Clinch River would inundate 454 ha (1123 acres) of DOE land located adjacent to Melton Hill Lake (TVA 1980). There are wetlands located in the WOL watershed.

If any remedial alternatives are selected that would impact floodplains or wetland areas, the requirements found in Executive Order (EO) 11988 and EO 11990, 40 CFR 264.18(b), and §404 of CWA might be applicable for WAG 2 (Table E.8).

8.1.3.5 Historic Sites and Archaeological Findings

There has not been an archaeological survey or historic site reconnaissance of WAG 2. However, an archaeological survey of ORR was conducted in 1974 by the Department of Anthropology, The University of Tennessee, Knoxville (Fielder 1975). Sites of aboriginal occupation that might be affected by future activities on the reservation were located and evaluated. Reconnaissance and testing were done in several different physiographic zones, including the Clinch River and its larger tributary-stream terraces, the interior valleys, selected forested ridges, and specific facility areas. According to the study, 45 sites of prehistoric aboriginal occupations and several historic Euro-American homestead sites were examined. The sites were distributed along the drainage system of the Clinch River, with the majority on the main river (Fielder 1975).

If any remedial action is taken that would cause irreparable harm, loss, or destruction of any prehistoric or historic archaeological sites, regulations found in the Archaeological and Historic Preservation Act and the Archaeological Resources Protection Act may be ARARs (See Table E.8).

8.1.3.6 Rare, Threatened, or Endangered Species

At present, there are no known federally listed threatened or endangered plant or animal species located at ORR (Kroodsma 1990). WAG 2 has not been surveyed for the presence of endangered plants. ORR lies within the range of several state and/or federally listed plants (Kroodsma 1990). A survey for the presence of these species will be included in the WAG 2 RI.

If a site investigation reveals the presence of any rare, threatened, or endangered animals or plants at WAG 2, the Endangered Species Act of 1973, the Tennessee Rare Plant Protection and Conservation Act of 1985, and the Tennessee Non-Game and Endangered or Threatened Wildlife Species Act of 1974 may be ARARs (Table E.8). Habitat modifications impacting any species designated by the state as "in need of management" may also trigger the state endangered species act.

8.2 SCREENING OF HUMAN HEALTH RISKS

The purpose of human-health risk screening is to quantitatively bound the estimate of the risk to a maximally exposed individual using existing data collected from WAG 2. Two approaches will be taken in this screening exercise (Table 8.2). The first approach is the use of conservatively biased calculations to identify contaminants and exposure pathways that should have a low priority for further analyses and data acquisition. Conservative calculations are unlikely to underestimate potential maximum exposures and thus may substantially overestimate the majority of actual exposures received by persons residing in the vicinity of WAG 2. The second approach uses nonconservative calculations and assumptions to identify contaminants that should have highest priority for further evaluation and/or interim corrective actions. Nonconservative calculations provide a more realistic estimate and should not substantially overestimate maximum exposures to local population subgroups. These two screening approaches are intended to rapidly identify contaminants of concern and to guide the acquisition of more extensive data relevant to these contaminants. Contaminants not identified as definitely low- or high-priority substances during the first iteration of screening are likely to be reclassified as additional data and information are obtained. These screening approaches will be similar to those employed in ORNL-ER/9 (Hoffman et al. 1990).

8.2.1 Conservative Screening

The justification for a conservative screening approach is that contaminant concentrations can be assigned a definite low priority for further study if a conservative estimate of health and environmental risk is sufficiently small. The conservative approach is based on the

Table 8.2. A comparison of conservative and nonconservative screening approaches

Approaches to Screening	
Conservative screening	**Nonconservative screening**
Maximum concentration reported for a given reach used	Average of detected values reported for a given reach used
Models used to estimate concentrations in media that are not sampled or detected	Only measured concentrations in specific media (e.g. sediment, water, fish) are considered
Reasonable estimate of maximum diet and occupancy times assumed	Estimates of diet and occupancy times are generally a factor of 10 less than assumed for reasonable maximum
Human receptor exposed for 70 years	Probability of exposure period being less than 70 years considered in estimates of diet and occupancy times
Multiple pathway exposure considered	Multiple pathway exposure not considered
Exposure to dredged sediment considered separately from the consumption of water, fish, and irrigated agricultural produce	Dredging of sediment no considered Use of water for irrigation not considered
Calculated exposure should not underestimate actual maximum exposures	Calculated exposure should not overestimate potential maximum exposures
Screening approach most useful for identifying definitely low priority contaminants.	Screening approach most useful for identifying definitly and potentially high priority contaminants.

maximum reported concentration for a given contaminant and medium within a given reach of the WAG 2 environment. This extreme value is employed in accordance with recent EPA risk assessment guidance (EPA 1989b) because existing data are not adequate for estimating an average concentration representative of possible lifetime exposure of a human receptor. The conservative approach also assumes, unrealistically, that individuals are exposed continuously to this maximum concentration for 70 years to existing levels of contamination despite the fact that WAG 2 is currently a restricted zone with no public access.

Substantial data exist for contaminants in some environmental compartments (see Sect. 6 and Table 8.1). Concentrations of contaminants in environmental media for which data are unavailable are estimated using pathway models that employ conservative assumptions and transfer coefficients appropriate for screening calculations. When the concentration of a contaminant in a specific environmental medium is below the limits of analytical detection, models are used to conservatively estimate a concentration in that medium from concentrations reported in other media at or near the location of interest. In this case, concentrations are equal to the detection limits only when calculated concentrations exceed the reported limits. However, contaminants that are below the limits of detection *in all samples taken from all environmental media at a given location* are not included in these analyses. In these special cases, the limits of detection are evaluated separately by setting concentrations equal to both the lowest and highest reported limits of detection.

The models and parameter values employed in this analysis will be obtained primarily from references that specifically propose methodologies for contaminant screening (Hoffman et al. 1984, Travis et al. 1989, IAEA 1982, NCRP 1989). Where available screening procedures do not include recommended default values for a given contaminant, additional literature (Baes et al. 1984, Baes et al. 1989, Lappenbush 1988, Lyman et al. 1982) and site-specific data will be evaluated, along with the use of professional judgment, to select values that would lead to a conservative estimate of exposure.

8.2.1.1 Exposure Pathways for Conservative Screening

In WAG 2, the components of the environment that are assumed to be potentially contaminated are groundwater, surface water, sediment, aquatic biota, air, and floodplain soil, vegetation, flesh of wild game, and possible agricultural products derived from this region in the future. The exposure pathways to be considered for conservative screening are:

- ingestion of drinking water;
- inadvertent ingestion of surface soil or sediment;
- direct dermal contact with soil or sediment;
- inhalation of contaminated air (via either dust resuspension, volatilization, or vaporization);
- ingestion of agricultural products (milk, meat, vegetables);

- ingestion of aquatic biota, water fowl, and wild game; and
- external exposure to gamma-emitting radionuclides deposited in soil or sediment.

These exposure pathways (Fig. 8.1) will be considered for the following scenarios: (1) the system remains as it is currently, with the exception that complete public access is allowed and all exposure pathways will contribute to the exposure of a hypothetical maximally exposed individual; (2) WOL/WOCE is drained and used for the production of agricultural products, and all exposure pathways contribute to the exposure of a hypothetical maximally exposed individual; (3) the water in WOL/WOCE is used for agricultural irrigation and agricultural products are produced from the land adjacent to the lake, and all exposure pathways contribute to the exposure of a hypothetically maximally exposed individual; and (4) the sediment in WOL/WOCE is dredged and the dredged material placed on land; agricultural products are produced from this material, and all exposure pathways contribute to the exposure of a hypothetical maximally exposed individual. All exposures will be assumed to be of a chronic nature (70-year lifetime). The evaluation of potential subchronic exposures will be assessed during the more detailed risk assessments that are planned for the later phases of this study (see Sect. 9.4).

For the screening assessment, WAG 2 will be divided into the segments given in Fig. 8.2. Additional subdivision may be appropriate as additional data become available. For example, a contaminated area of the floodplain near the old Intermediate Pond site will likely be separated as an operable unit (Sect. 6.1.2).

For screening analyses of multiple pathway exposures, reasonable, maximum estimates of dietary habits and occupancy factors are used instead of absolute maximum values. These practices are made given that the maximum estimate for the use of a specific pathway is not likely to apply to a single individual exposed to all pathways simultaneously. The assumed dietary habits and occupancy times (usage factors) are given in Table 8.3. A partial listing of existing sources of data applicable for screening analyses is given in Table 8.1.

8.2.1.2 Criteria for Conservative Screening

Noncarcinogens with total screening indices <0.1, or carcinogens with total screening indices $<10^{-6}$, are designated through conservative screening as *definitely low priority contaminants* for further sampling and modeling efforts (Table 8.4). All contaminants not designated as definitely low priority substances are considered contaminants of concern subject to further evaluation.

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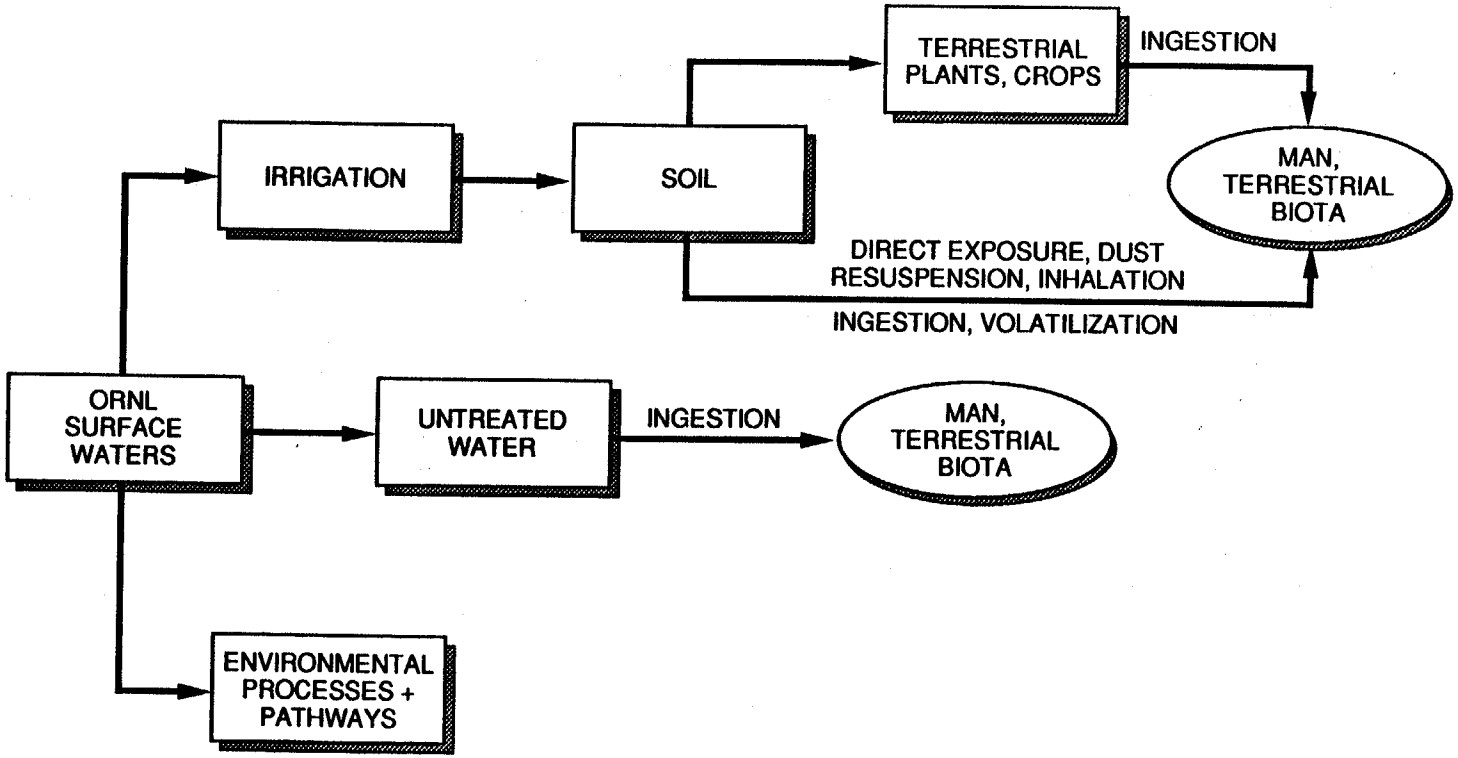

Fig. 8.1. Exposure pathways considered for the WAG 2 screening analysis.

ORNL-DWG 90M-16788

LOCATIONS OF CONCERN:

1. UPPER WHITE OAK CREEK (UWOC)
2. MELTON BRANCH (MB)
3. WHITE OAK CREEK (WOC)
4. WHITE OAK LAKE (WOL)
5. WHITE OAK CREEK EMBAYMENT (WOCE)
6. OFF WAG-2 EXPOSURES:
   CLINCH RIVER, HUNTERS, ETC.

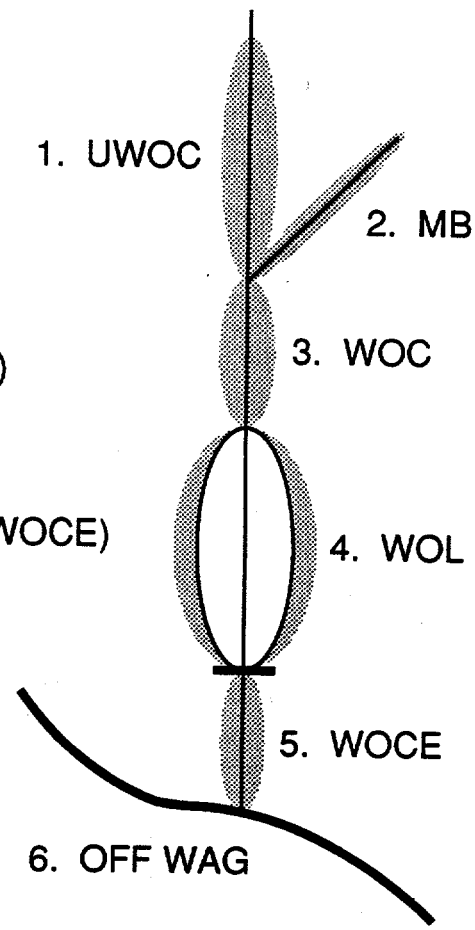

Fig. 8.2. WAG 2 segments for the screening assessments.

Table 8.3. Usage factors for conservative and nonconservative screening.

Exposure Route	Conservative Screening	Nonconservative Screening
Ingestion		
Aquatic biota	20 g D^{-1}	3 g D^{-1}
Drinking water	2 L d	0.25 L D^{-1}
Terrestrial foods	0.5 L d^{-1}	NA[a]
Milk	200 g d^{-1}	NA
Meat	200 g d^{-1}	NA
Vegetables		
Soil ingestion	0.1 g d^{-1}	0.01 g d^{-1}
Inhalation	23 m^3 d	NA
External exposure		
Irrigated soil	1000 h y^{-1}	100 h y^{-1}
Dredged sediment	1000 h y^{-1}	NA

[a]NA = not applicable for scenario considered.

NOTE: These values have been selected to produce upper- and lower-bound estimates of exposure to the maximally exposed individual; as such, they may differ from standard assumptions recommended in EPA guidance manuals (EPA 1989b). The references consulted for the selection of these usage factors are NCRP (1984), Yang and Nelson (1984), Rupp (1980), Rupp et al. (1980), and EPA (1989c).

Table 8.4. Criteria for conservative and nonconservative screening of carcinogens and noncarcinogens.

Screening Criteria	
Noncarcinogens	**Carcinogens**
Screening index (SI) = exposure divided by an RfD	Screening index (SI) = exposure multiplied by a lifetime cancer slope factor
Conservative Estimtate of Exposure	
SI < 0.1 **definitely low priority**	SI < 10^{-6} **definitely low priority**
Nonconservative Estimate of Exposure	
SI ≥ 1.0 **definitely high priority**	SI ≥ 10^{-3} **definitely high priority warranting possible interium decisions**
SI ≥ moderately high priority	SI ≥ 10^{-4} high priority warranting further evaluation

8.2.1.3 Screening Indices for Carcinogens and Noncarcinogens

Screening indices (SIs) for carcinogens and noncarcinogens are calculated for contaminants of potential concern to human health. The screening index for carcinogens is a conservative estimate of exposure of the contaminant via ingestion or inhalation multiplied by an EPA-approved or -suggested *slope factor* for nonradioactive substances to indicate the potential lifetime risk of excess cancer (EPA 1989c, 1990a). The slope factor provides an estimate of the lifetime risk of additional cancer incidence per unit exposure.

The screening index for noncarcinogens is a ratio that is composed of a conservatively biased estimate of ingestion or inhalation of the contaminant divided by a *reference dose (RfD) factor* (EPA 1989c, 1990a). The reference dose is an EPA-approved noncarcinogenic contaminant exposure level below which adverse effects should not occur. To be consistent with EPA recommendations for risk assessment (EPA 1989b), screening indices for each contaminant are summed over all contaminants in a given pathway. For estimation of potential exposure to multiple pathways, screening indices are summed across pathways for each contaminant. Summation is conducted separately for carcinogens and noncarcinogens.

8.2.2 Nonconservative Screening

The objective of nonconservative screening calculations is to rapidly identify contaminants and exposure pathways having the highest priority for further evaluation and/or consideration for interim corrective action. Once a contaminant is assigned a definite high priority, an immediate review of the source data base and health advisory criteria should be conducted, including a review of the data used to derive EPA RfDs and carcinogen slope factors. *These reviews may establish the need for immediate implementation of an interim remediation effort.*

For nonconservative screening, average values of concentrations of contaminants in environmental media are used. These concentrations are averaged only among values reported above the limits of detection. Dietary habits and occupancy factors for potential receptors are based on assumed casual use of the medium of concern (Table 8.3). Multiple exposures to different contaminated media by the same individual are not considered; thus calculated screening indices for carcinogens and noncarcinogens are not summed across pathways, although they will still be summed within a pathyway. This approach is not likely to produce a large overestimate of potential maximum exposure, provided that the environmental media are actually utilized at the location of interest. For current exposures, this assumption will only be realistic for individuals residing off the DOE reservation and for hunters using the reservation during controlled periods of hunting.

8.2.2.1 Exposure Pathways for Nonconservative Screening

The exposure pathways considered for nonconservative screening are only those for which concentrations above the limits of detection have been measured and reported. Models will not be used to estimate concentrations in media that were not sampled, and models will not be used to estimate concentrations of contaminants analyzed for but not detected.

8.2.2.2 Criteria for Nonconservative Screening

For nonconservative screening, contaminants that have noncarcinogen screening indices exceeding 1.0 or carcinogen screening indices exceeding 10^{-3} are designated as *definitely high priority* for remedial action consideration. Contaminants that have noncarcinogen screening indices exceeding 0.1 or carcinogen screening indices exceeding 10^{-4} are designated as high priority substances warranting further investigation.

8.2.2.3 Screening Indices for Carcinogens and Noncarcinogens

The screening indices for nonconservative screening are similar to those for conservative screening. For carcinogens, an estimate of exposure is multiplied by an EPA slope factor to indicate the risk of excess cancer incidence during a 70-year lifetime. For noncarcinogens, an estimate of exposure is divided by an EPA-approved RfD (EPA 1990a). These slope factors and RfDs may themselves contain a large amount of conservatism in their derivation; therefore, detailed reevaluation of their derivation is warranted when nonconservative screening designates a contaminant as a high-priority substance.

8.2.3 Contaminants of Concern Identified Through Previous Screening Exercises

A previous screening has been conducted by Hoffman et al. (1990) for Reach No. 2 of the Clinch River RCRA Facility Investigation, which included the WOCE of WAG 2. The results of this analysis are summarized in Tables 8.5 through 8.7. This study indicated that potential risk to human health will be dominated by external gamma radiation from ^{137}Cs and ^{60}Co in the sediment of WAG 2.

From these studies, the risk from potential exposure to gamma radiation from ^{137}Cs in sediment appears to be sufficiently high ($>10^{-3}$) as to warrant interim decisions for remedial action if the public were permitted access to WAG 2. Interim decisions have already led to action to prevent further migration of contaminated sediment from the WOCE of WAG 2 into the Clinch River. Analysis of surface water indicates that the dominant carcinogenic risks may come from the potential ingestion of arsenic, ^{3}H, and ^{90}Sr. However, it is unlikely that arsenic was released from ORNL. Analysis of aquatic biota indicate that the primary risk contributors are the PCBs 1254 and 1260 in fish.

Table 8.5 Summary of non-conservative screening indices for carcinogens and non-carcinogens present in sediment, fish, and water of Reach 2 of the Clinch River RCRA Facility Investigation (Hoffman et al. 1990).

Carcinogen Screening Indices	Exposure Pathways			
Contaminant type	Sediment ingestion	Fish ingestion	Water ingestion	Sediment external
Inorganics	2.2E-06	2.2E-05	1.4E-04*	
Organics	3.1E-06	3.5E-04*		
Radionuclides	5.8E-06	4.4E-05	1.3E-04*	1.3E-03**
Pathway total	**1.1E-05**	**4.1E-04***	**2.8E-04***	**1.3E-03****
Inorganics				
ARSENIC	2.2E-06	1.7E-05	1.3E-04*	
BERYLLIUM		4.6E-06	1.4E-05	
URANIUM	1.8E-12			
Pathway total	**2.2E-06**	**2.2E-05**	**1.4E-04***	
Organics				
PCB-1260 (AROCLOR 1260)	1.8E-06	2.1E-04*		
PCB-1254 (AROCLOR 1254)	1.3E-06	1.2E-04*		
CHLORDANE		1.4E-05		
P,P'DDT		1.3E-06		
BIS (2-ETHYLHEXYL) PHTHALATE	3.5E-09			
Pathway total	**3.1E-06**	**3.5E-04***		
Radionuclides				
Cs-137	1.3E-06	1.6E-06	8.6E-06	9.6E-04**
Co-60	3.2E-08	3.7E-08	9.4E-07	1.7E-04*
Sr-90	5.9E-08	4.2E-05	6.8E-05*	2.7E-06
Eu-154	8.2E-09			6.7E-05*
Eu-152	5.7E-09			6.3E-05*
H-3			5.4E-05*	
Pa-234	4.1E-10			2.4E-05
U-238	4.3E-07	9.3E-09	5.2E-08	1.2E-05
Cs-134	8.8E-09			1.2E-05
Am-241	3.3E-06		1.7E-06	2.9E-06
Sr-89	6.8E-09	6.5E-07		2.7E-06
Cm-244	5.3E-07		1.1E-06	2.6E-08
U-235	3.4E-08	1.6E-09	4.8E-08	1.5E-06
Pu-239	1.6E-08	5.0E-08	8.4E-08	9.0E-10
Th-234	2.4E-09			1.1E-07
U-234		1.7E-08	8.2E-08	
Pu-238	1.5E-09	1.9E-09	3.7E-08	2.1E-10
U-236			1.4E-10	
Pathway total	**5.8E-06**	**4.4E-05**	**1.3E-04***	**1.3E-03****

Table 8.5 (continued)

Non-carcinogen Screening Indices — Exposure Pathways

Contaminant type	Sediment ingestion	Fish ingestion	Water ingestion
Inorganics	7.7E-03	7.5E-01*	9.3E-02
Organics	1.3E-05	1.9E-01*	
Pathway total	**7.7E-03**	**9.4E-01***	**9.3E-02**
Inorganics			
THALLIUM		6.12E-01*	
ANTIMONY		1.07E-01*	
ARSENIC	1.27E-03	9.70E-03	7.24E-02
MERCURY, TOTAL	9.32E-04	1.19E-02	1.79E-03
CHROMIUM	1.48E-03	7.71E-04	1.07E-02
NICKEL	1.29E-04	2.14E-03	5.01E-03
SELENIUM	3.55E-03	3.73E-03	
SILVER	2.00E-04	5.36E-03	1.19E-03
ZINC	3.75E-05	1.57E-03	5.72E-04
CYANIDE			9.82E-04
BERYLLIUM		2.14E-04	6.57E-04
URANIUM	1.06E-04		
CADMIUM	2.64E-06	3.45E-06	8.85E-05
Pathway total	**7.7E-03**	**7.5E-01***	**9.3E-02**
Organics			
CHLORDANE		1.8E-01*	
P,P'DDT		7.7E-03	
BIS (2-ETHYLHEXYL) PHTHALATE	1.3E-05		
Pathway total	**1.3E-05**	**1.9E-01***	

**= definitely high priority (interim remedial action decision to be considered); carcinogen screening index ≥1E-3; non-carcinogen screening index ≥1.0

* = high priority for further investigation; carcinogen screening index ≥1E-4; non-carcinogen screening index ≥ 0.1.

Table 8.6 Summary of conservative screening indices for carcinogens and non-carcenogens of Reach 2 of the Clinch River RCRA Facility Investigation (Hoffman et al. 1990).

Carcinogen Screening Indices — Exposure Pathways

Contaminant type	Fish ingestion	Water ingestion	Meat ingestion	Milk ingestion	Vegetable ingestion	Soil ingestion	Dust inhalation	External soil exposure	Multiple pathway total
Inorganics	2.5E-04	2.3E-02	6.0E-05	3.2E-06	3.4E-02	1.8E-03	6.4E-04		6.0E-02
Organics	1.2E-02	6.8E-05	4.4E-05	4.6E-05	2.4E-04	5.4E-06			1.3E-02
Radionuclides	4.9E-04	3.1E-03	9.9E-04	1.3E-03	2.2E-03	7.7E-05	7.8E-05	8.7E-04	9.1E-03
Pathway total	**1.3E-02**	**2.6E-02**	**1.1E-03**	**1.4E-03**	**3.7E-02**	**1.9E-03**	**7.2E-04**	**8.7E-04**	**8.2E-02**
Inorganics									
ARSENIC	2.0E-04	2.3E-02	4.7E-05	3.1E-06	3.4E-02	1.8E-03	5.9E-04		6.0E-02
BERYLLIUM	4.9E-05	2.5E-05	1.3E-05	1.7E-08*	3.8E-05	1.9E-06	4.4E-08*		1.3E-04
CHROMIUM							5.0E-05		5.0E-05
NICKEL							1.2E-06		1.2E-06
CADMIUM							2.4E-07*		2.4E-07*
URANIUM	2.9E-10*	1.4E-09*	1.5E-09*	3.0E-10*	2.2E-09*	1.1E-10*			5.9E-09*
Pathway total	**2.5E-04**	**2.3E-02**	**6.0E-05**	**3.2E-06**	**3.4E-02**	**1.8E-03**	**6.4E-04**		**6.0E-02**
Organics									
PCB-1260 (AROCLOR 1260)	7.9E-03	7.3E-07*	2.6E-05	2.8E-05	1.1E-06	5.8E-08*			8.0E-03
PCB-1254 (AROCLOR 1254)	4.4E-03	6.0E-06	1.7E-05	1.8E-05	9.3E-06	4.8E-07*			4.5E-03
CHLORDANE	9.3E-05	6.1E-05	2.0E-07*	2.1E-07*	2.3E-04	4.8E-06			3.9E-04
P,P'DDT	8.7E-06	1.1E-08*	6.7E-08*	7.0E-08*	1.6E-08*	8.3E-10*			8.9E-06
BIS (2-ETHYLHEXYL) PHTHALATE	2.7E-06	2.0E-07*	4.4E-08*	4.6E-08*	3.3E-07*	1.6E-08*			3.3E-06
Pathway total	**1.2E-02**	**6.8E-05**	**4.4E-05**	**4.6E-05**	**2.4E-04**	**5.4E-06**			**1.3E-02**

Table 8.6 (continued)

Carcinogen Screening Indices

Exposure Pathways

Contaminant type	Fish ingestion	Water ingestion	Meat ingestion	Milk ingestion	Vegetable ingestion	Soil ingestion	Dust inhalation	External soil exposure	Multiple pathway total
Radionuclides									
Sr-90	5.4E-05	8.4E-04	8.8E-05	2.9E-04	1.3E-03	4.8E-05	5.0E-06	1.3E-04	2.7E-03
Cs-137	2.6E-04	2.2E-04	6.8E-04	6.0E-04	3.3E-04	1.3E-05	9.2E-08*	5.6E-04	2.7E-03
H-3	3.5E-05	1.8E-03	1.8E-04	4.4E-04	1.8E-04				2.6E-03
Am-241	6.7E-05	1.1E-04	2.3E-07*	1.6E-08*	1.7E-04	8.7E-06	2.4E-05	4.5E-07*	3.8E-04
Cm-244	6.1E-05	1.0E-04	2.1E-07*	1.4E-08*	1.5E-04	4.8E-06	1.4E-05	1.4E-08*	3.3E-04
Co-60	7.2E-07*	1.5E-05	4.6E-05	1.0E-05	2.2E-05	3.1E-07*	2.9E-08*	1.0E-04	2.0E-04
Pu-238	8.7E-08*	3.1E-05	3.3E-08*	1.1E-09*	4.7E-05	2.2E-06	3.0E-05	1.9E-08*	1.1E-04
Eu-154	3.0E-06	3.0E-06	6.2E-07*	6.2E-08*	4.5E-06	8.8E-08*	3.0E-08*	4.3E-05	5.4E-05
Eu-152	1.3E-06	1.3E-06	2.7E-07*	2.7E-08*	2.0E-06	5.1E-08*	2.0E-08*	3.3E-05	3.8E-05
Pu-239	6.6E-06	4.9E-06	5.1E-09*	1.7E-10*	7.4E-06	3.8E-07*	5.2E-06	1.3E-09*	2.4E-05
Cs-134	2.4E-06	6.0E-08*	1.9E-07*	1.7E-07*	9.1E-08*	5.3E-10*	3.9E-12*	4.4E-08*	3.0E-06
U-234	4.2E-07*	4.1E-07*	4.3E-07*	8.6E-08*	6.3E-07*	3.3E-08*	1.8E-07*	7.9E-10*	2.2E-06
U-238	2.5E-07*	2.5E-07*	2.6E-07*	5.3E-08*	3.8E-07*	2.0E-08*	1.1E-07*	3.2E-08*	1.4E-06
U-235	3.4E-08*	1.9E-07*	2.0E-07*	4.0E-08*	2.9E-07*	1.5E-08*	8.2E-08*	4.2E-08*	9.0E-07*
Th-234	4.8E-09*	8.0E-09*	6.1E-11*	1.0E-11*	8.0E-09*	2.3E-12*	6.8E-14*	6.5E-12*	2.1E-08*
Pa-234	3.3E-09*	1.6E-08*	2.2E-13*	7.2E-13*	5.1E-10*	5.5E-14*	2.4E-16*	1.9E-10*	2.0E-08*
U-236	2.7E-10*	1.4E-09*	1.4E-09*	2.9E-10*	2.1E-09*	1.1E-10*	5.8E-10*	1.2E-12*	6.1E-09*
Pathway total	**4.9E-04**	**3.1E-03**	**9.9E-04**	**1.3E-03**	**2.2E-03**	**7.7E-05**	**7.8E-05**	**8.7E-04**	**9.1E-03**

Table 8.6 (continued)

Non-carcinogen Screening Indices

Exposure Pathways

Contaminant type	Fish ingestion	Water ingestion	Meat ingestion	Milk ingestion	Vegetable ingestion	Soil ingestion	Dust inhalation	External soil exposure	Multiple pathway total
Inorganics	5.6E+00	1.4E+01	2.3E+00	9.0E-01	2.2E+01	1.1E+00	1.4E-04*		4.5E+01
Organics	1.3E+00	7.8E-01	3.1E-03*	3.2E-03*	3.0E+00	6.2E-02*			5.1E+00
Pathway total	**6.9E+00**	**1.5E+01**	**2.3E+00**	**9.1E-01**	**2.5E+01**	**1.2E+00**	**1.4E-04***		**5.0E+01**
Inorganics									
ARSENIC	1.1E-01	1.3E+01	2.7E-02*	1.8E-03*	2.0E+01	1.0E+00			3.4E+01
THALLIUM	4.1E+00	2.0E-02*	7.1E-02*	3.5E-02*	7.0E-02*	1.6E-03*			4.3E+00
CHROMIUM	2.1E-02*	2.7E-01	8.7E-01	1.9E-01	4.3E-01	2.1E-02*			1.8E+00
ANTIMONY	7.1E-01	3.6E-01	3.9E-02*	1.3E-02*	5.8E-01	2.8E-02*			1.7E+00
SELENIUM	3.9E-02*	5.2E-02*	8.5E-01	2.8E-01	1.3E-01	4.2E-03*	1.4E-04*		1.4E+00
MERCURY, TOTAL	5.3E-01	1.9E-02*	4.2E-02*	6.9E-03*	8.3E-02*	1.5E-03*			6.9E-01
ZINC	1.6E-02*	1.3E-02*	2.8E-01	9.4E-02*	6.8E-02*	1.0E-03*			4.7E-01
CADMIUM	1.1E-02*	4.3E-02*	9.4E-03*	6.2E-02*	2.7E-01	3.4E-03*			4.0E-01
SILVER	4.8E-02*	2.4E-02*	2.6E-02*	1.7E-01	8.2E-02*	1.9E-03*			3.5E-01
URANIUM	1.7E-02*	8.6E-02*	9.0E-02*	1.8E-02*	1.3E-01	6.8E-03*			3.5E-01
NICKEL	1.4E-02*	5.5E-02*	1.4E-02*	2.3E-02*	1.1E-01	4.4E-03*			2.2E-01
CYANIDE	3.7E-04*	1.9E-02*	3.9E-04*	6.5E-04*	2.8E-02*	1.5E-03*			5.0E-02*
BERYLLIUM	2.3E-03*	1.1E-03*	6.1E-04*	8.1E-07*	1.8E-03*	9.1E-05*			5.9E-03*
Pathway total	**5.6E+00**	**1.4E+01**	**2.3E+00**	**9.0E-01**	**2.2E+01**	**1.1E+00**	**1.4E-04***		**4.5E+01**
Organics									
CHLORDANE	1.2E+00	7.8E-01	2.5E-03*	2.7E-03*	3.0E+00	6.2E-02*			5.0E+00
P,P'DDT	5.1E-02*	6.2E-05*	3.9E-04*	4.1E-04*	9.5E-05*	4.9E-06*			5.2E-02*
BIS (2-ETHYLHEXYL) PHTHALATE	9.6E-03*	7.2E-04*	1.6E-04*	1.6E-04*	1.2E-03*	5.7E-05*			1.2E-02*
Pathway total	**1.3E+00**	**7.8E-01**	**3.1E-03***	**3.2E-03***	**3.0E+00**	**6.2E-02***			**5.1E+00**

*=low priority for further consideration; carcinogen screening index <1E-6; non-carcinogen screening index < 0.1

Table 8.7 Summary of conservative screening indices for carcinogens and non-carcinogens of Reach 2 of the Clinch River RCRA Facility Investigation assuming that sediment is dredged and used as agricultural soil (Hoffman et al. 1990).

Carcinogen Screening Indices

Contaminant type	Vegetable ingestion	Sediment ingestion	Dust inhalation	Milk ingestion	Meat ingestion	External sediment	Multiple pathway total
				Exposure Pathways			
Inorganics	5.8E-03	5.5E-05	2.1E-04	1.5E-06	9.2E-04		7.0E-03
Organics	3.3E-03	3.1E-05		4.8E-02	4.6E-02		9.7E-02
Radionuclides	7.0E-01	3.9E-03	1.4E-03	9.1E-01	9.8E-01	2.7E+00	5.3E+00
Pathway total	**7.1E-01**	**4.0E-03**	**1.6E-03**	**9.6E-01**	**1.0E+00**	**2.7E+00**	**5.4E+00**
Inorganics							
BERYLLIUM	2.7E-03	2.5E-05	5.5E-07*	1.2E-06	9.1E-04		3.6E-03
ARSENIC	3.1E-03	3.0E-05	9.9E-06	2.8E-07*	4.2E-06		3.1E-03
CHROMIUM			2.0E-04				2.0E-04
NICKEL			5.9E-07*				5.9E-07*
CADMIUM			4.2E-07*				4.2E-07*
URANIUM	1.5E-08*	1.4E-10*		2.1E-09*	1.0E-08*		2.8E-08*
Pathway total	**5.8E-03**	**5.5E-05**	**2.1E-04**	**1.5E-06**	**9.2E-04**		**7.0E-03**
Organics							
PCB-1260 (AROCLOR 1260)	1.8E-03	1.8E-05		4.5E-02	4.3E-02		9.0E-02
PCB-1254 (AROCLOR 1254)	1.4E-03	1.3E-05		2.7E-03	2.6E-03		6.7E-03
CHLORDANE	7.0E-05	1.2E-07*		5.8E-08*	5.5E-08*		7.0E-05
P,P'DDT	5.2E-06	4.9E-08*		2.2E-05	2.1E-05		4.9E-05
BIS (2-ETHYLHEXYL) PHTHALATE	4.9E-06	3.8E-08*		6.5E-07*	6.2E-07*		6.3E-06
Pathway total	**3.3E-03**	**3.1E-05**		**4.8E-02**	**4.6E-02**		**9.7E-02**

Table 8.7 (continued)

Carcinogen Screening Indices

Exposure Pathways

Contaminant type	Vegetable ingestion	Sediment ingestion	Dust inhalation	Milk ingestion	Meat ingestion	External sediment	Multiple pathway total
Radionuclides							
Cs-137	5.5E-01	3.4E-03	2.5E-05	8.5E-01	9.6E-01	2.5E+00	**4.9E+00**
Sr-90	1.2E-01	1.7E-04	1.7E-05	5.7E-02	1.7E-02	7.8E-03	**2.0E-01**
Co-60	2.8E-03	1.7E-05	1.6E-06	1.9E-03	8.5E-03	9.2E-02	**1.1E-01**
Am-241	2.4E-02	2.3E-04	6.5E-04	2.2E-06	3.3E-05	2.0E-04	**2.5E-02**
Pu-239	4.5E-03	4.4E-05	6.0E-04	1.0E-07*	3.1E-06	2.6E-06	**5.2E-03**
Cm-244	2.1E-03	2.0E-05	5.7E-05	1.9E-07*	2.9E-06	9.8E-07*	**2.2E-03**
U-238	9.6E-04	9.1E-06	4.9E-05	1.3E-04	6.5E-04	2.4E-04	**2.0E-03**
Eu-154	2.0E-05	1.9E-07*	6.7E-08*	3.2E-07*	3.2E-06	1.6E-03	**1.6E-03**
Eu-152	8.8E-06	8.4E-08*	3.3E-08*	1.4E-07*	1.4E-06	9.2E-04	**9.3E-04**
Cs-134	2.9E-05	1.8E-07*	1.3E-09*	4.5E-05	5.1E-05	2.5E-04	**3.7E-04**
Pu-238	2.4E-04	2.4E-06	3.2E-05	5.5E-09*	1.7E-07*	3.5E-07*	**2.8E-04**
Pa-234	9.0E-08*	4.1E-09*	1.8E-11*	9.4E-11*	2.8E-11*	2.4E-04	**2.4E-04**
U-235	8.6E-05	8.1E-07*	4.3E-06	1.2E-05	5.9E-05	3.7E-05	**2.0E-04**
Th-234	5.4E-06	8.0E-08*	2.3E-09*	6.9E-09*	4.1E-08*	3.7E-06	**9.3E-06**
U-234	4.3E-06	4.1E-08*	2.2E-07*	5.9E-07*	3.0E-06	1.7E-08*	**8.2E-06**
U-236	1.4E-08*	1.4E-10*	7.4E-10*	2.0E-09*	9.9E-09*	2.5E-11*	**2.7E-08***
Pathway total	**7.0E-01**	**3.9E-03**	**1.4E-03**	**9.1E-01**	**9.8E-01**	**2.7E+00**	**5.3E+00**

Table 8.7 (continued)

Non-carcinogen Screening Indices

Exposure Pathways

Contaminant type	Vegetable ingestion	Sediment ingestion	Dust inhalation	Milk ingestion	Meat ingestion	Multiple pathway total
Inorganics	4.9E+01	2.0E-01	1.8E-03*	4.9E+01	1.3E+02	2.3E+02
Organics	9.5E-01	2.0E-03*		1.3E-01	1.3E-01	1.2E+00
Pathway total	**5.0E+01**	**2.0E-01**	**1.8E-03***	**4.9E+01**	**1.3E+02**	**2.3E+02**
Inorganics						
SELENIUM	1.6E+01	5.2E-02*	1.8E-03*	3.3E+01	9.9E+01	1.5E+02
CHROMIUM	1.0E+01	8.3E-02*		4.4E+00	2.0E+01	3.4E+01
THALLIUM	1.0E+01	2.0E-02*		4.4E+00	8.7E+00	2.3E+01
SILVER	2.4E+00	4.8E-03*		4.9E+00	7.4E-01	8.0E+00
CADMIUM	6.6E+00	6.0E-03*		1.2E+00	1.9E-01	8.0E+00
ZINC	5.9E-01	6.6E-04*		6.8E-01	2.0E+00	3.3E+00
ARSENIC	1.8E+00	1.7E-02*		1.6E-04*	2.4E-03*	1.8E+00
URANIUM	9.0E-01	8.6E-03*		1.2E-01	6.2E-01	1.7E+00
NICKEL	4.3E-01	2.1E-03*		8.4E-02*	5.0E-02*	5.7E-01
ANTIMONY	4.3E-01	3.6E-03*		9.7E-03*	2.9E-02*	4.8E-01
BERYLLIUM	1.2E-01	1.1E-03*		5.7E-05*	4.3E-02*	1.7E-01
Pathway total	**4.9E+01**	**2.0E-01**	**1.8E-03***	**4.9E+01**	**1.3E+02**	**2.3E+02**
Organics						
CHLORDANE	9.0E-01	1.5E-03*		7.4E-04*	7.0E-04*	9.0E-01
P,P'DDT	3.1E-02*	2.9E-04*		1.3E-01	1.2E-01	2.9E-01
BIS (2-ETHYLHEXYL) PHTHALATE	1.8E-02*	1.4E-04*		2.3E-03*	2.2E-03*	2.2E-02*
Pathway total	**9.5E-01**	**2.0E-03***		**1.3E-01**	**1.3E-01**	**1.2E+00**

*=low priority for further consideration; carcinogen screening index < 1E-06; non-carcinogen screening index < 0.1

The high-priority noncarcinogens were thallium, antimony, and chlordane in fish. Of these, the concentrations reported for thallium and antimony may be the result of relatively insensitive detection techniques and the presence of false positive concentrations.

8.3 SCREENING OF ECOLOGICAL RISKS

8.3.1 End points

Assessment end points are expressions of the environmental values that are to be protected. The EPA's manual for ecological assessment of hazardous waste sites (Suter 1989) indicates that assessment end points should be (1) socially relevant, (2) biologically relevant, (3) operationally definable, (4) measurable or predictable, (5) susceptible to the hazard, and (6) logically related to the decision. For both the screening assessment and the ecological portion of the risk assessments (Sect. 9.4.4), the following end points were chosen as meeting those criteria: (1) a 10% or greater reduction in the abundance or production of the local populations of any fish species, (2) a 10% or greater reduction in the abundance or production of the local populations of any bird species, (3) a 10% or greater reduction in the abundance or production of the local populations of any wild mammal species other than small rodents, (4) a 10% or greater reduction in the production of any local plant population, and (5) any toxic effect on individuals of an endangered species sufficient to impair survival or reproduction. It should be noted that effects on species that are not included explicitly in the end points are none-the-less included in the assessment. For example, the only end point species in the aquatic community are fish, but effects on all food-chain species must be included in the assessment of risks to fish.

Except for endangered species, the end points are effects at the population level of biological organization. Unlike human health assessments, ecological risk assessments are not concerned with effects on individual organisms (the exception is endangered species). Higher levels of biological organization (i.e., communities and ecosystems) are not used because there is little information on toxic effects at these levels, the toxicity data that are available are highly inconsistent, and effects at higher levels are nearly always less sensitive than those at the population level. The 10% level of population effects was chosen as approximately the limit of detection of field measurement techniques and is probably below the detection limits of the public (i.e., fishermen would probably not notice a 10% reduction in the abundance of fish). The end point is defined at the individual level for endangered species because of the greater legal and societal concern for these species.

8.3.2 Ecological Receptors and Routes of Exposure

WAG 2 includes streams and a lake supporting fish and terrestrial habitats supporting diverse plants, birds, and mammals (Sect. 3.3.7). Unlike the human health risks, all potential ecological receptors and routes of exposure occur on the site now (a possible exception is the reintroduction of species that have become extinct in the region). Therefore, the screening and risk assessments will be based on the current fauna and flora of WAG 2.

Fish are exposed to contaminants in the water primarily through the respiratory pathway and to contaminants in sediments primarily through the food chain, although benthic fish come in direct contact with the sediment and with water that is in equilibrium with the sediment. Toxicity of water and sediment to algae and invertebrates can affect fish by diminishing the food supply. Plants are exposed to contaminated soils in the flood plain. Birds and mammals may drink contaminated water, feed from contaminated terrestrial and aquatic food chains, and ingest soil. Plants, birds, and mammals are exposed to contaminants in the air primarily through respiratory uptake.

8.3.3 Screening Criteria for Ecological Risks

Screening of contaminants will be performed by comparing contaminant concentrations in media from WAG 2 to benchmark values that are concentrations in media that would not cause effects exceeding the ecological end points discussed above. The national ambient water quality criteria have been used for this purpose but they are not really applicable to soil contamination, they do not consistently consider effects on piscivorous wildlife, and they do not correspond to a consistent level of risk on aquatic organisms. In fact, they may correspond to very large effects on fish reproduction and on fish populations (Suter et al. 1987, Barnthouse et al. 1987, 1990). Therefore, the Environmental Sciences Division at ORNL is beginning the process of developing risk-based screening benchmarks for fish (concentrations in water and body burdens), wildlife (concentrations in food and doses), and terrestrial plants (concentrations in soil) to be used in the screening.

The media concentrations used will be adjusted as necessary and possible to reflect the forms to which organisms are actually exposed. The greatest problem is sediments and soils. Concentrations are reported for whole soils and sediments that contain both available dissolved forms of chemicals and unavailable sorbed forms. For all organic chemicals and for as many inorganic chemicals as possible, concentrations of available dissolved forms will be estimated. Concentrations of metals and inorganic ions will be adjusted for water chemistry as recommended in the national ambient water quality criteria. Concentrations in fish fillets will be adjusted to estimate whole body concentrations. Bioaccumulation for mercury and PCBs, the two contaminants that are known to occur in significant amounts in WAG 2 and which bioaccumulate, will be estimated using food chain models for mink and great blue heron.

8.3.4 Known Contaminants of Concern for Ecological Effects

As part of the RI for the off-site environment, existing information was used to screen the contaminants in the Clinch River and associated embayments of tributary streams (Suter 1990a). The results for Reach 2, which included the WOCE, can be used to define a preliminary list of key contaminants. Both mercury and PCBs were identified as key contaminants in water, sediments, and fish tissues. Copper was identified in both water and fish tissues, and sediment concentrations could not be evaluated. In addition, aluminum, arsenic, chromium, cyanide, iron, lead, and zinc were identified as key contaminants in water.

Selenium, silver, thallium, and DDT were reported to occur in fish tissues at concentrations that may pose risks to piscivorous wildlife or to the fish themselves. In addition, many chemicals were reported to occur at concentrations less than limits of detection, but the limits of detection were greater than the screening benchmarks. New contaminant data are becoming available for the WOCE, and these will be used with the improved benchmark values to rescreen contaminants in the embayment. However, it is clear that mercury and PCBs will continue to be key contaminants, and it is likely that most of the other contaminants identified by the off-site ecological screening will continue to be key contaminants.

9. WAG 2 RI WORK PLAN

9.1 BACKGROUND AND OBJECTIVES OF THE WAG 2 RI

During its 47-year history, the ORNL site has generated a variety of radioactive, hazardous, and mixed wastes. These wastes and wastes generated elsewhere have been disposed of on-site. The WOC system consisting of WOC, its tributaries, WOL, and WOCE on the Clinch River, is the primary surface drainage for the ORNL. The aquatic system and the associated floodplain have been exposed to a diversity of contaminants as a result of operations and waste disposal activities at ORNL during the past 47 years.

At this time, there are about 250 sites at ORNL being considered for remediation. Remediation sites have been grouped into WAGs, based on common remediation needs and hydrogeological connections. ORNL WAG 2 consists of the WOC drainage downstream of the main ORNL plant area, WOL, WOCE on the Clinch River, and the associated floodplains (Fig. 9.1).

Discharges and releases (seeps and surface runoff) from existing operations and contaminated areas (including previous waste disposal sites) are a continuing source of contaminants to the WOC system (Sects. 5 and 6). Releases (surface water discharge) from the WOC system have been a significant source of contaminants to off-site areas via the Clinch River (Sect. 7).

Considerable data exist for the WOC system as a result of numerous research efforts and environmental monitoring programs. Contaminants have been found in almost every media in WAG 2 (Sect. 6). Although the data are fairly complete for some components (e.g., aquatic biota), few data are available for other major components (e.g., floodplain soils). Data for bioaccumulation by aquatic biota have identified mercury, PCBs, chlordane, ^{137}Cs, ^{60}Co, and ^{90}Sr as the primary long-lived contaminants known to accumulate above background levels in biota in the WOC system. Floodplain soils may be a significant repository for contaminants that have been released to the WOC system and are also a potential source for the release of these contaminants into the Clinch River. Floodplain soils have not been characterized, with the exception of the Intermediate Pond site adjacent to WAG 4 and the floodplain of upper WOL, which are known to be contaminated with radionuclides.

Existing data suggest significant but not widespread contamination of groundwater with radionuclides. Additional data for groundwater are needed, especially for nonradiological contaminants.

There are several ongoing surface water monitoring programs in the WOC system. Data from these efforts show that surface water in the WOC system generally meets EPA water quality criteria for freshwater aquatic life. With the exception of ^{90}Sr, ^{3}H, and ^{99}Tc, most contaminants of potential concern are particle-reactive (i.e., they readily become associated with particulates) and so are not expected to be found in filtered water samples.

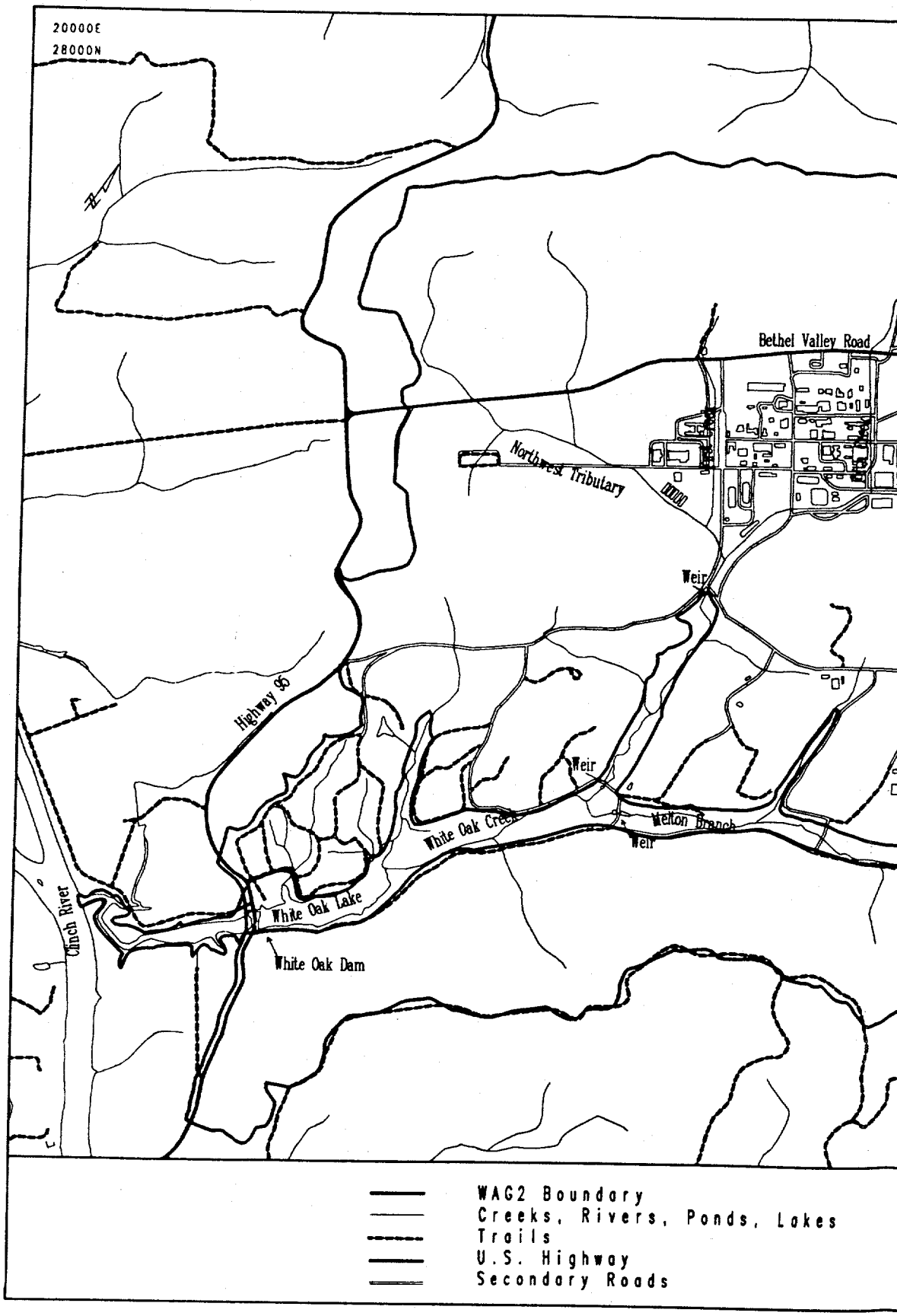

Fig. 9.1. Map of White Oak Creek watershed showing

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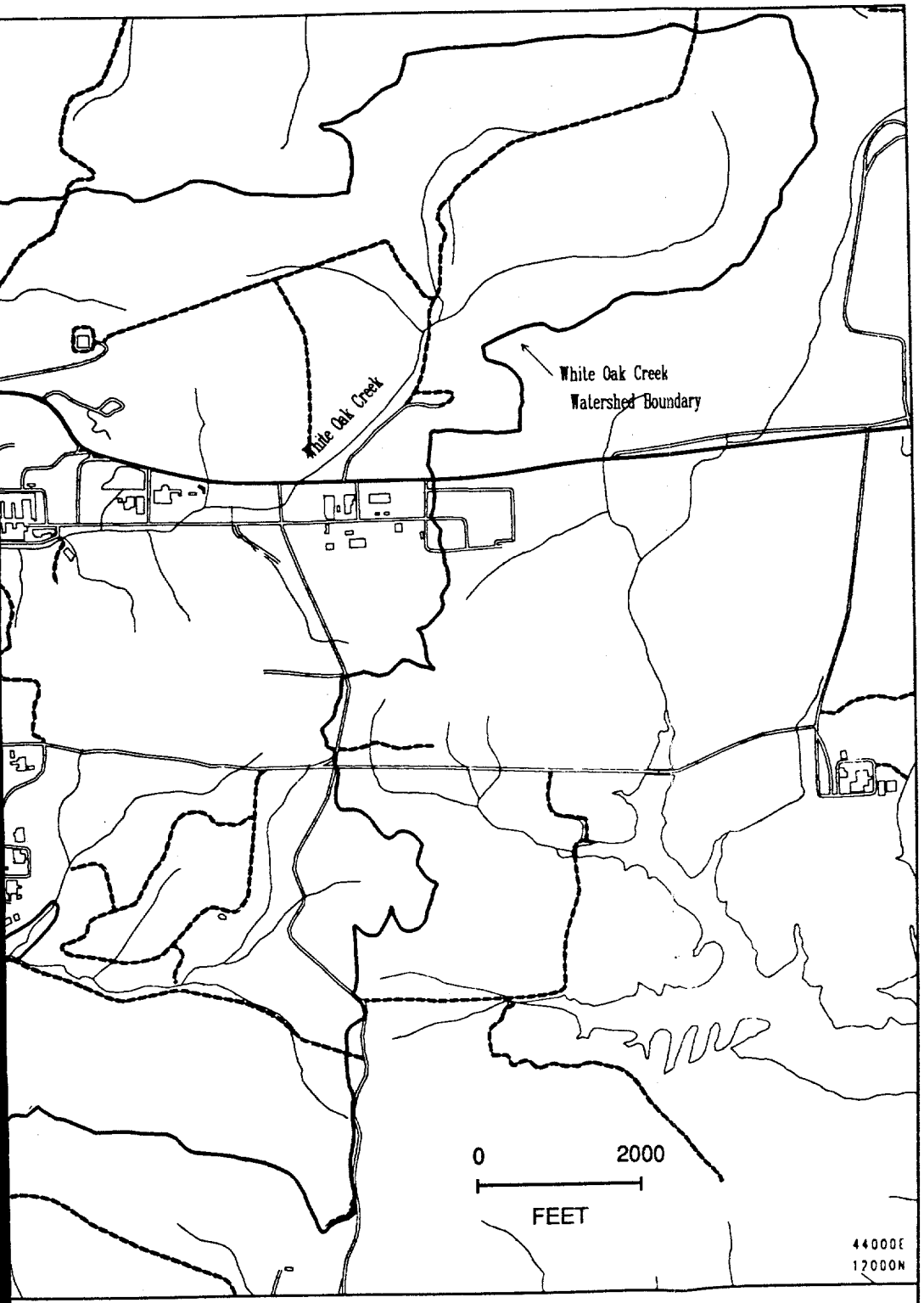

Map Scale: 1 inch = 2000 feet
Source: S-16A (White Oak Lake Update)
Grid: ORNL Coordinates (feet)
Date: November 1990

the location of the ORNL and associated features.

Input and movement of most contaminants are strongly linked to storm events and sediment transport. Aquatic sediments are a significant repository for most contaminants of concern in the WOC system. Substantial sediment contamination has been found in WOL and WOCE; however, additional data are needed. Stream sediments are more dynamic and less well characterized. Resuspension and transport of aquatic sediments have been a major vector of contaminant release to off-site areas, and information for this process is needed.

A preliminary contaminant screening based on data from sediments and water collected from WOCE (conducted as part of the Clinch River RFI) suggests that mercury, chromium, arsenic, PCBs, transuranics, ^{137}Cs, ^{60}Co, ^{3}H, and ^{90}Sr are the primary contaminants that have been released from the WOC system. Tritium is a significant contaminant that is not found in the sediment record.

The construction of a riprap dam at the mouth of WOCE has been initiated as a time-critical CERCLA response action to substantially reduce the resuspension and transport of highly contaminated sediments downstream in the Clinch River. It is important to recognize that hot spots (discrete areas of significant contamination) are usually areas where contaminants from other areas have accumulated. Thus, remediating a contaminated area will do little good if the upgradient source of the contamination is not located and remediated also (i.e., contaminants will simply accumulate again). Therefore, when a hot spot is found, the source of the contamination must be determined and also remediated, if necessary. As the WAG 2 RI progresses, other interim measures may be identified and implemented to protect public health and the environment.

A full scale RI and implementation of corrective measures for WAG 2 should not occur until remediation of upgradient WAGs that release or may release contaminants to WAG 2 are completed. However, because hydrologic fluxes through WAG 2 link contaminant sources in the WOC watershed with off-site areas, there is an obvious need to have a quantitative understanding of where fluxes enter WAG 2, what contaminants are in the fluxes, what contaminants are resident in the system and how contaminants are moving or may move out of the system. Because such information does not exist nor is it likely to become available from efforts in other WAGs, a plan is proposed that addresses the need to (1) take immediate steps to protect the public and the environment, (2) monitor contaminant releases from ORNL WAGs, and (3) form a foundation for eventual remedial actions in WAG 2.

The WAG 2 RI Plan is structured with a short-term component to be conducted while upgradient WAGs are investigated and remediated, and a long-term component that will complete the RI process following the remediation of upgradient WAGs. The objectives of the interim-period plan are:

1. preliminary surveys and sampling to determine hot spots (discrete areas of significant contamination that may need interim corrective measures to protect the public or environment), identify areas where additional data are needed, fill data gaps for the first round of risk assessment, and clearly delineate the boundary of WAG 2; and

2. implementation of a multimedia environmental monitoring and characterization program to (a) define and monitor the input of contaminants from adjacent WAGs, (b) characterize the hydrology of the WOC system and support a mass-balance approach to determining sources, sinks and transport of contaminants in WAG 2, and (c) establish the basis for determining long-term trends in contaminant levels.

The interim-period baseline monitoring program addresses short-term needs to protect the public and forms a basis for future conponents of the RI. Furthermore, with an accurate understanding of how WAG 2 is connected to adjacent WAGs, it will be possible to evaluate potential effects of remedial actions in those WAGs on WAG 2 and to plan effective mitigating measures to minimize additional contaminant fluxes while clean-up activities are performed.

Long-term objectives of the WAG 2 RI include:

1. definition of the nature and extent of contamination in WAG 2,

2. quantification of any risk to human health and the environment resulting from the contamination, and

3. preliminary evaluations of potential corrective measures and remedial action alternatives for the operable units in WAG 2.

Results of human-health and environmental risk assessments will be used to focus monitoring, sampling, and analytical efforts, and ultimately to determine the need for corrective measures to reduce risks. The risk-driven monitoring, sampling, and analysis will proceed while adjacent WAGs are undergoing remediation. The system has been divided into several reaches for the preliminary risk analysis. The monitoring program will deal with the WOC system on a reach-by-reach basis and will support a mass-balance approach for determining contaminant dynamics (input, storage, and release). These reaches will be subdivided as required on the basis of contaminant input and inventory. This approach translates to the identification of operable units to be considered for corrective measures or eliminated from further efforts.

The WAG 2 RI will be coordinated with ongoing environmental monitoring and environmental restoration programs at ORNL (see Sect. 9.3.1) in compliance with the provisions of RCRA, CERCLA, NEPA, and Tennessee hazardous waste management regulations and environmental standards. On-site monitoring programs and remedial investigations can provide data relevant to determining the concentrations and fluxes of contaminants of concern, the nature and extent of contaminant release off-site, and contribute data for the evaluation of potential human health and environmental risks. Extant data for contamination in WAG 2, derived from an initial review and synthesis of available information, have been used in the design of the WAG 2 RI Work Plan, described in this section.

Remediation of existing contamination problems is the ultimate goal of the RI process. Data collected during the WAG 2 RI will be used for site characterization, human health and environmental risk assessment, and identification and evaluation of potential remedial action alternatives. To ensure that the combination of existing data and new data to be collected will be adequate for these purposes, methods for determining the potential pathways leading to human health and environmental risks (Sect. 8) and categories of corrective measures or remedial action alternatives (Sect. 9.4.5) have been preliminarily identified. Further, the sampling and analysis program will be dictated by results of risk assessment in an iterative fashion such that risk analysis drives data collection that is used to update the risk analysis and direct more focused sampling and analysis.

9.2 CONCEPTUAL MODEL

As described in Sects. 5 through 7, essentially all components (biotic and abiotic) of the WOC system have been exposed to heavy metals, hazardous organic chemicals, radionuclides, or some combination of these. The WAG 2 RI will characterize the nature and extent of contamination and the potential human health and environmental risks; it will also identify and evaluate potential corrective measures and/or needs or interim corrective actions. These tasks are complicated because the WOC system is unlike the prototypic SWMU. The contaminants that have accumulated in the WOC system have resulted from releases from other areas and redistribution within the WAG 2 area (Sect. 5). Continued input of contaminants from unregulated sources further complicates evaluation. Fate and transport of contaminants in the WOC system are influenced by the physical, chemical, and biological processes that interact in natural systems. The WOC system has been a significant source of contaminants to off-site areas. However, whether the WOC system acts as a source, a sink, or simply a conduit for contaminants depends on the contaminant in question and the temporal scale of interest. Both biotic and abiotic media in WAG 2 have been contaminated. Soils and sediments have clearly accumulated contaminants and act as a temporary sink for the bulk of the contaminants in the system. Particle-reactive contaminants (e.g., PCBs, ^{137}Cs, ^{60}Co, lead, chromium) that have accumulated in soils and in sediment depositional areas can be resuspended and transported downstream (off-site) during high discharge events or as a result of changes in hydrology due to construction activities. For less particle-reactive contaminants (e.g., ^{90}Sr, ^{3}H, VOCs) the WOC system may serve largely as a conduit, with biota and physical characteristics influencing transport time.

The conceptual model for WAG 2 (Fig 9.2A) is a flow chart of the potential contaminant sources, transport and exposure pathways, and potential human andenvironmental receptors for contaminants. More detailed versions of the conceptual model (Figs. 9.2B and 9.2C) include hydrological phenomena, such as floodplain erosion, sediment scouring and transport, and subsurface flow and groundwater discharge, and biological and chemical phenomena such as sorption-desorption, biotic uptake, particle ingestion, direct exposure, and inhalation. The conceptual models are important because they identify or acknowledge the pools and the pathways of contaminant movement for site characterization and risk analysis; that is, they summarize our current knowledge of contaminant dynamics (sources, pathways, pools, and receptors) and so influence our approach to the WAG 2 RI. Other models (empirical and

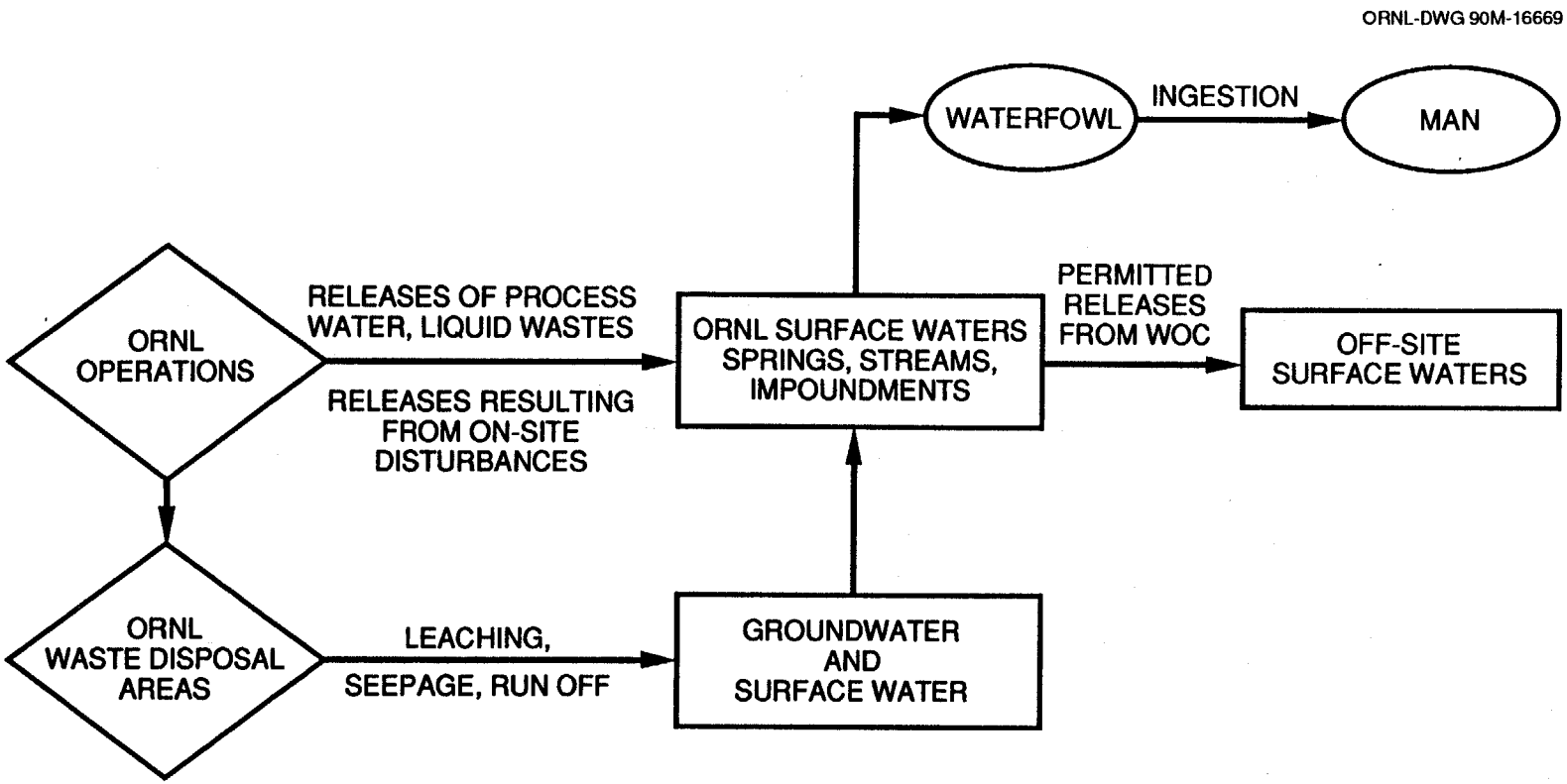

Fig. 9.2A. The Conceptual Site Model. This flow-chart represents the contaminant sources, potential transport and exposure pathways, and potential human and non-human receptors for contaminants released from ORNL WAGs.

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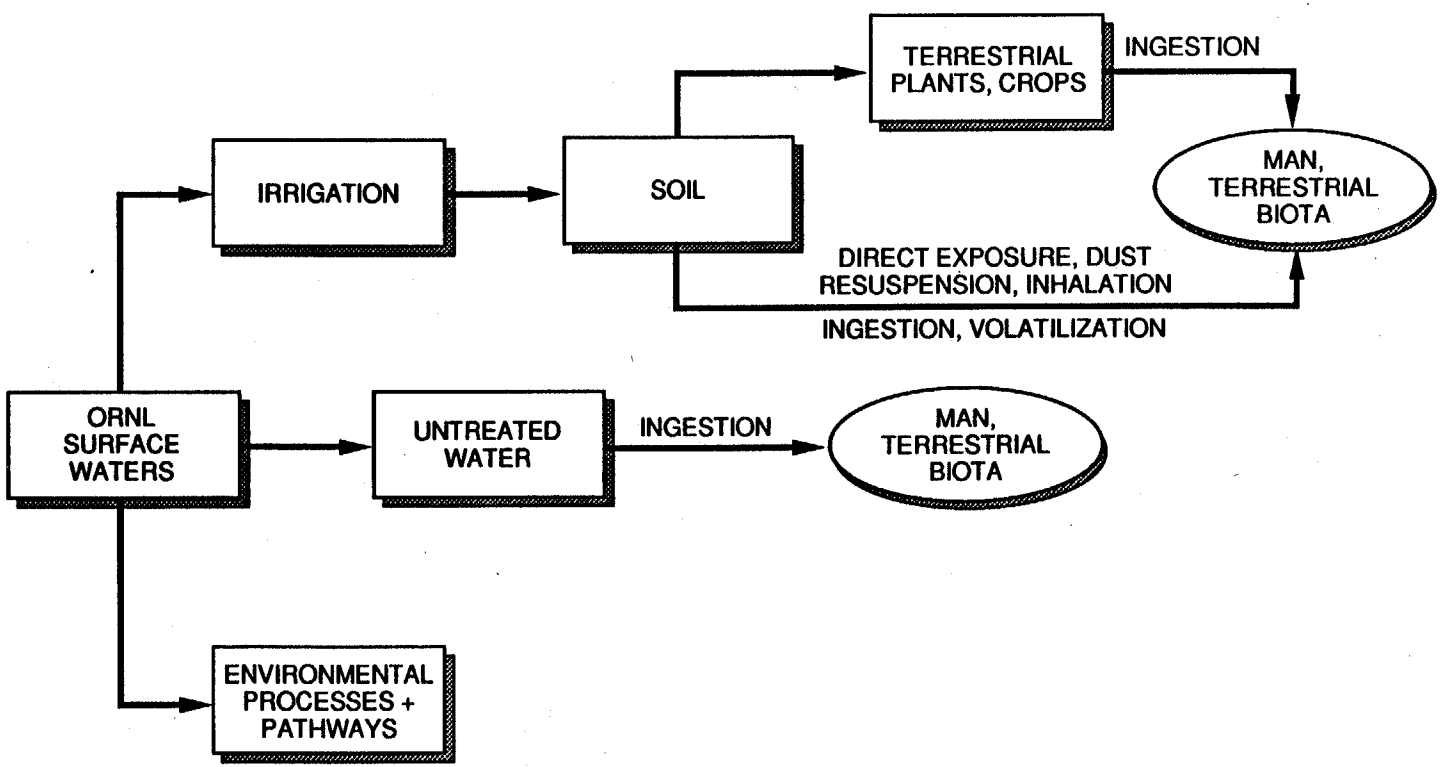

Fig. 9.2B. The Conceptual Site Model continued.

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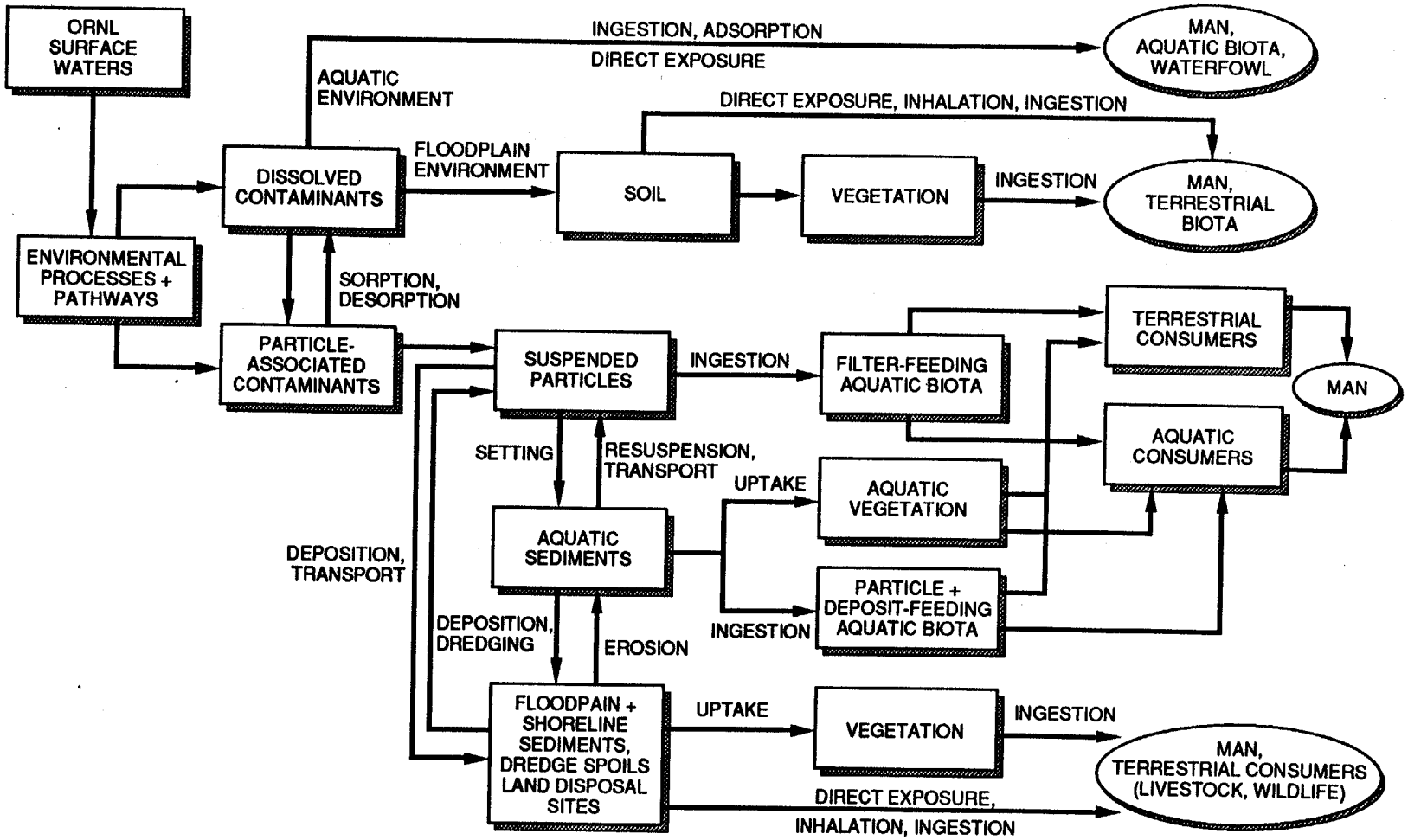

Fig. 9.2C. The Conceptual Site Model continued.

mechanistic models) will be developed for other aspects of system characterization needed for specific RI tasks (Sects. 8, 9.4.3, 9.4.4, 9.4.5 and 10). For example, contaminant accumulation and transport with sediments is clearly important for contaminant dynamics in WAG 2. Efforts are already underway to describe and predict the movement of sediments and the associated contaminants.

9.3 APPROACH FOR THE WAG 2 RI WORK PLAN

9.3.1 WAG 2 RI Approach

The WAG 2 RI Plan has been developed in accordance with both the *RCRA Facility Investigation (RFI) Guidance* (OSWER Directive 9502.00-6C, July 1987) and the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA/540/G-89/004) OSWER Directive 9355.3-01, October 1988), issued by EPA (1987a and 1988a, respectively).

The approach calls for a staged effort for characterization, risk assessment, and identification of remedial needs and alternatives. We propose a risk-driven iterative process where human health and environmental risk analyses will be updated as additional data become available, and the results will be used to focus more extensive sampling and analysis. A logic diagram illustrating the decision pathway to be employed in the WAG 2 RI staged approach is presented in Fig. 9.3.

Recognizing that full implementation of an RI is inappropriate at this time, a plan has been developed for a staged effort that addresses the need to (1) take immediate steps to ensure that the public and environment are protected, (2) form a foundation for eventual corrective measure evaluation, and (3) provide a mechanism to monitor contaminant releases from ORNL WAGs and the movement of contaminants off-site, which could contribute to the formulation and assessment of corrective measures for upgradient WAGs.

The WAG 2 RI Work Plan, therefore, is structured and staged in response to the needs and limitations outlined above and includes tasks to be conducted in the short-term (while upgradient WAGs are being remediated) and in the long-term (following remediation of upgradient contaminant source areas).

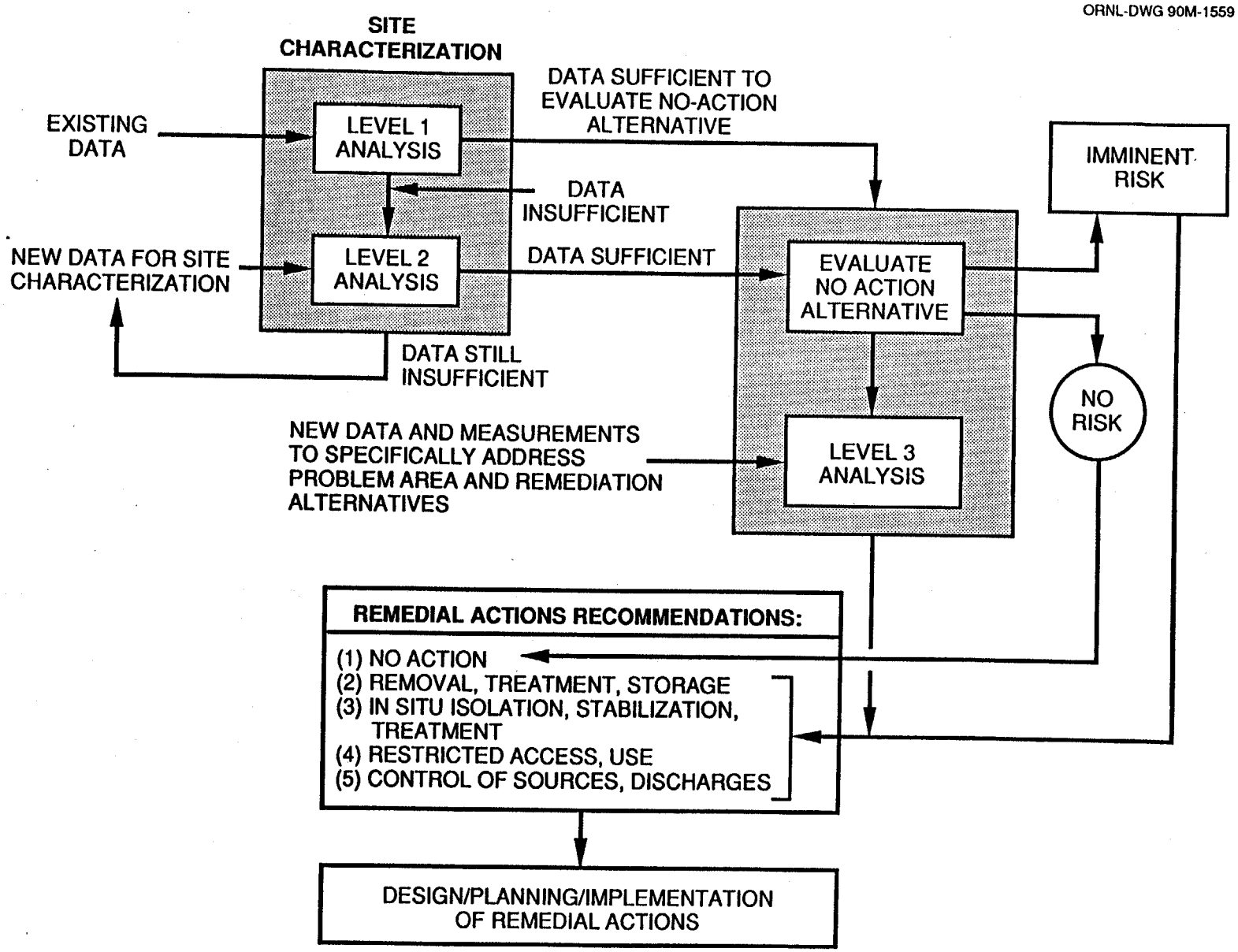

Fig. 9.3. Diagram of the risk-driven decision pathway that will be followed in the WAG 2 RI phased approach.

Short-term tasks include the initial components of a standard RI plan and components of an interim period baseline monitoring program:

- **Completion of the review and synthesis of extant data for a preliminary contaminant screening.** This exercise will identify areas in which additional data collection is necessary for purposes of site characterization and risk assessment and will allow the preparation of the first iteration of a risk-driven sampling and analysis (S&A) plan. Two approaches (conservative and nonconservative screening) will be used in the contaminant screening exercise to identify contaminants that can be assigned low priorty for further evaluation, based on sufficiently small risk and to rapidly identify contaminants of high priority, that may establish the need for interim corrective measures.

- **Initial scoping surveys to determine hot spots.** These surveys and sampling will identify discrete areas of significant contamination that may need interim corrective measures to protect the public or environment, help to fill data gaps for the first round of risk assessment, and clearly delineate the boundary of WAG 2.

- **Implementation of a multimedia environmental monitoring and characterization program.** This program will support a mass-balance approach to determining sources, sinks, and pathways for contaminants (e.g., to characterize the hydrology of the WOC system, and identify operable units for corrective actions), define and monitor input of wastes from adjacent WAGs, and establish the basis for determining long-term trends in contaminant levels.

- **Iterative risk assessment.** As new information becomes available, risk assessments will be updated to focus additional sampling and analysis and determine the need for interim corrective actions.

- **Risk-driven screening-level sampling and analysis.** As risk assessments are updated, more focused iterations of the S&A program can be developed to allow a preliminary site characterization. The program will include sampling and analysis of water, sediments, soil, and biota from selected sites that are representative of differing levels of contamination (including reference sites located upgradient from WAG 2) to determine the range of contaminant concentrations present, to establish background (reference) concentrations for those contaminants, and to identify specific contaminants of concern by the screening level risk analyses. This additional sampling and analysis will largely feed into the baseline monitoring program, recognizing that contaminant inputs and the nature and extent of contamination in WAG 2 are subject to change until upgradient WAGS are remediated.

These activities include the short-term objectives listed in Sect. 9.1 and the initial stages of a traditional RI Plan. These activities will be conducted simultaneously while upgradient WAGs are undergoing remediation as shown in Fig. 9.4. The approach meets short-term needs (described above) and positions the WAG 2 RI for implementation of the more focused efforts needed to meet the long-term objectives of the complete RI listed in Sect. 9.1.

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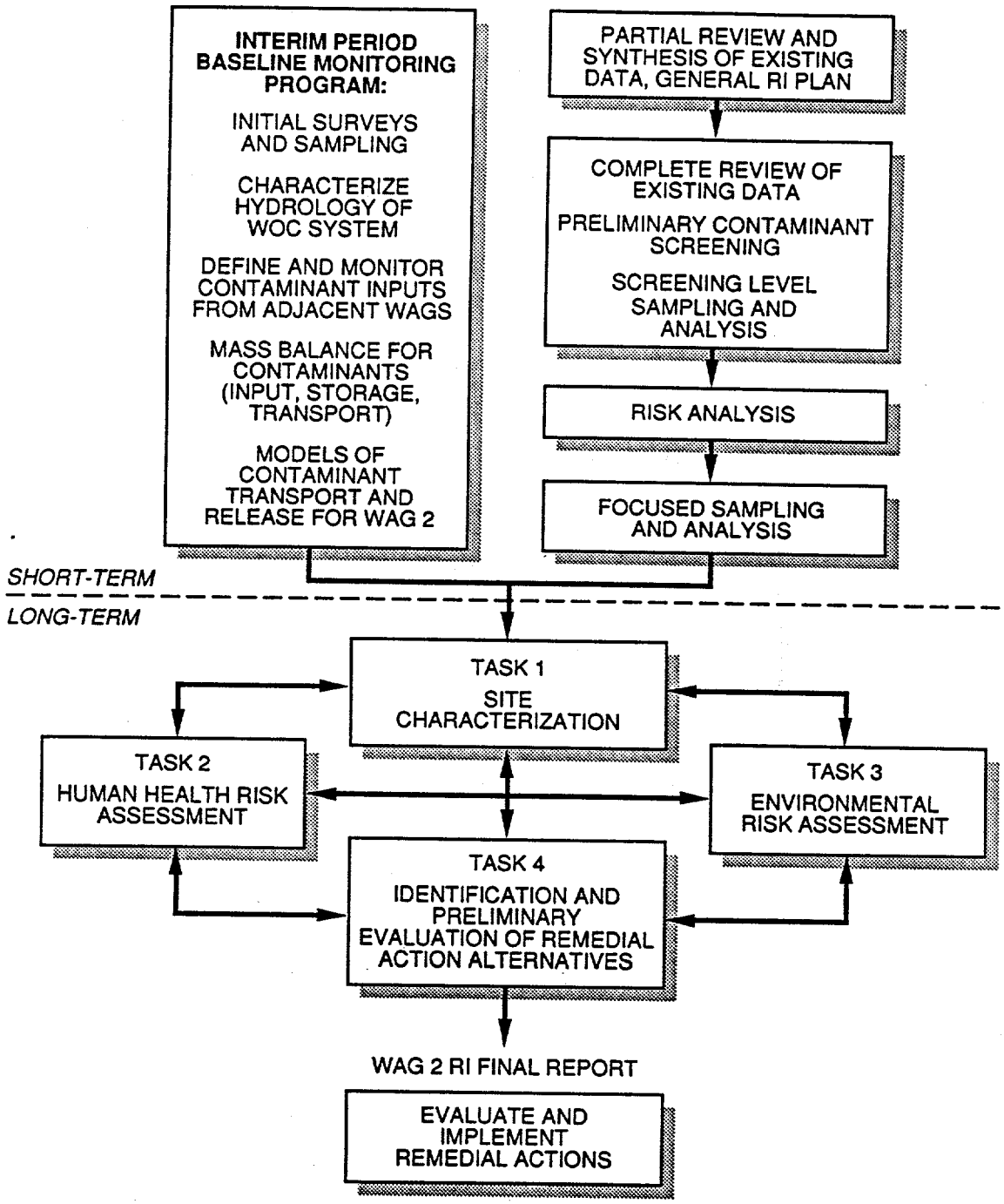

Fig. 9.4. **Interrelationship of the WAG 2 RI phased approach and the Work Plan task structure.**

The approach for the long-term objectives of the RI and specifically a final report identifying and evaluating remedial action alternatives involves four tasks:

- **Final site characterization.** Determining the nature and extent of contamination in WAG 2 following the remediation of upgradient WAGs.

- **Human-health risk assessment.** A quantification of risk for adverse human health effects resulting from current and future exposure to hazardous substances released to the environment from WAG 2.

- **Environmental risk assessment.** A quantification of risk to biota from current and future exposure to hazardous substances released to the environment from WAG 2.

- **Identification and Preliminary Evaluation of Potential Corrective Measures/Remedial Action Alternatives.** Identification and preliminary evaluation of potentially applicable remediation alternatives for off-site contamination problems. If needed, implementation of corrective measures/remedial actions will be accomplished through the RCRA Corrective Measures Study/Implementation process and the FS/ROD/RA components under CERCLA.

The system has been divided into several reaches for the preliminary risk analysis. These reaches will be subdivided based on contaminant input and inventory. This approach translates to the identification of operable units to be considered for corrective measures or eliminated from further efforts.

The four long-term tasks (Fig. 9.4), in conjunction with ongoing on-site remedial action activities, conform to EPA's recommended strategy for:

1. characterization of contaminant sources and contaminant releases to surface waters (Task 1 and Sects. 5 and 7);

2. characterization of the environmental setting and current conditions (Task 1 and Sect. 6);

3. identification of contaminants of concern and the extent of downstream migration of those contaminants (Task 2 and 3, and Sects. 6, 7, and 8);

4. identification of potential receptors and quantitative assessment of risks to the public health and welfare and to the environment (Task 2 and 3, and Sects. 5, 6, 7, and 8); and

5. preliminary identification and evaluation of potential corrective measures/remedial action alternatives and, if necessary, implementation of interim corrective actions (Task 4 and Sects. 9.4.5 and 9.4.6).

The WAG 2 RI will be coordinated with environmental monitoring and environmental restoration programs now being conducted at ORNL, and off-site in the Clinch River in compliance with the provisions of RCRA, CERCLA, NEPA, and state of Tennessee

environmental protection regulations. On-site monitoring programs and remedial action investigations can provide data relevant to the WAG 2 RI.

The tentative schedule for these tasks is presented in Sect. 2.4; however, all activities and schedules in the RI Plan are subject to the availability of funds and the negotiation of schedules under the FFA.

9.3.2 Integration with Other RFI/CMS/CMIs and Ongoing Monitoring Programs

Because the WOC system receives contaminants from upgradient WAGs (Sect. 5) and releases of contaminants to downgradient off-site areas (Sect. 7), the exchange of information and coordination of efforts are essential. Several ongoing environmental monitoring programs (Sect. 4) can provide a great deal of information needed for site characterization and risk assessment. Data from the WAG 2 RI and the environmental monitoring programs are or will be available through the ORNL Environmental Restoration (ER) Consolidated Database. The ORNL ER Program (Sect. 1.2) will act to further coordinate the ongoing remedial investigations. The WAG 2 RI management has established and will maintain a link with the Clinch River RFI and ORNL environmental monitoring programs. The combined database, shared staff, regular communication among program managers, and coordinating role of the ER Program and the ORNL Technical Advisory Committee will ensure communication and foster cooperation.

9.4 WAG 2 RI WORK PLAN ELEMENT DESCRIPTIONS

9.4.1 Interim Period Tasks

Interim period tasks have largely been described in the work plan approach (Sect. 9.3.1) and in the initial field sampling and analysis plan (Sect. 10). Details of additional subtasks will be provided as they are developed, as addenda to the WAG 2 RI Plan. In the following sections, elements not described elsewhere are presented.

9.4.1.1 Review and Synthesis of Existing Data

Operations and waste disposal activities at ORNL have introduced contaminants into the WOC system and ultimately into the Clinch River. The purpose of this subtask is to review and integrate extant data on contaminant releases and on contaminant concentrations in the water, sediments, soils, and biota. These data are being used to focus screening-level human health and environmental risk analyses toward (1) preliminary identification of likely contaminants of concern and possible interim corrective measures, (2) identification of additional data needs, and (3) prioritization and focusing of additional tasks.

This subtask is ongoing and has partly been completed in preparation of Sects. 5, 6, and 7. Existing data on contaminant releases from the ORNL WAGs, water quality and

contaminant data on the WOC system, environmental surveillance monitoring data, and data from other ongoing studies are being incorporated into the ORNL ER Program numeric database (see the WAG 2 RI Data Management Plan) as they become available.

Information from the review and integration of existing data will be used to conduct preliminary (screening-level) human health and environmental risk assessments for identifying potential contaminants of concern and prioritizing data needs. A thorough review of existing data helps avoid duplication of previous investigations and, therefore, results in a more focused and efficient site characterization effort.

9.4.1.2 Interim monitoring and characterization of the hydrologic and hydrogeologic systems

With respect to surface water and groundwater, the goals of the interim monitoring and characterization activities are:

1. to provide baseline data on contaminant fluxes into and out of WAG 2 and at key points within WAG 2 (i.e., the weirs on WOC and MB);

2. to identify large scale and long-term trends in contaminant fluxes; and

3. to assess the performance of remediated sites and ICMs, both for sites within WAG 2 and for sites that are upgradient.

The goals of the hydrologic characterization activities are:

1. to quantify, or to at least reduce the uncertainty in, the source terms for contaminants leaching from buried waste in adjacent WAGs, and

2. to identify and quantify the main hydrologic and geohydrologic mechanisms of contaminant transport, including shallow subsurface stormflow, groundwater fracture flow and diffusion of contaminants into and out of the rock matrix, and sediment transport in surface water.

These same goals are identified, along with others, in the strategic plan for the site investigation (SI) component within the ER Program (Clapp et al. 1990). This plan has provided the basis for the integration for site investigation activities that have been pursued in a fragmented manner in the past several years. Many activities identified here and in Sect. 10 are currently being implemented as part of the ER Program SIs component. With the initiation of the WAG 2 RI, it is appropriate to move these monitoring functions into the RI project. From an administrative viewpoint, surface water and groundwater monitoring at the key sites in WAG 2 is performed by Environmental Surveillance and Protection (ESP) staff in accordance with regulations. Actual monitoring work should not be duplicated; therefore, coordination among staff and programs is essential.

9.4.1.3 Hydrologic and Geohydrologic Monitoring

To support ORNL monitoring and RIs/RFIs at other WAGs, sampling of groundwater at 118 monitoring wells will be conducted in FY 1991. The ER Program will sponsor the sample collection, analysis, and data interpretation at all groundwater monitoring wells including 18 wells located in the WOC floodplain. Furthermore, it is strongly recommended that both surface water and groundwater monitoring be well coordinated because these systems are tightly interrelated at and near ORNL.

For surface water monitoring, the monitoring network itself will be evaluated, including the performance of the weirs, the water-level sensors, and data processing. Deficiencies will be corrected. Upgrades to weirs in WAG 2, discussed in Sect. 10.4.3, is essential and will be implemented. A system to monitor suspended sediment and associated particulate-bound contamination will be developed and implemented at the main weirs. This information is essential for the assessment of ^{137}Cs, PCBs, and heavy metal movement within the watershed.

Inputs to WAGs must be characterized. Where ongoing RIs/RFIs are in place, those studies will supply flux data; however, monitoring on some tributaries must be initiated. Where continuous monitoring is not feasible, intensive stormflow monitoring may be sufficient. Past studies have indicated that contaminant loading can be estimated from discharge measurements alone; therefore, annual loadings from tributaries can be estimated from direct discharge measurements or from models coupled with empirical discharge-contaminant relationships or sediment loading functions. A hydrologic summary will be produced, which will include water balances and fluxes of major contaminants for the major reaches above the WOL Dam, and will be provided annually as needed.

9.4.1.4 Characterization studies

Within the domain of hydrology and hydrogeology, several special studies within the SI component of the ER Program are in progress or being initiated that are critical to evaluating and understanding contamination transport and evaluating risk in WAG 2.

The primary goals related to the source term identification studies are to:

1. develop a system of monitoring and modeling that will provide a reliable indication of whether the rate of mobilization of the leachable fraction in the SWSAs is increasing or decreasing,

2. demonstrate, via models, the degree to which possible catastrophic releases from containerized wastes will be buffered,

3. provide a three-dimensional inventory of the secondary source (the plume that has developed downgradient), and

4. for streams and tributaries below WAGs, map locations of contamination seeps and calculate mass flow rates for contaminants, which will serve as source-term information for area-wide risk models, as well as identification of remediation sites.

The complexity of defining and monitoring the source term requires a multifaceted approach, and although this study is viewed as speculative, it appears to provide the only knowledge of source term behavior short of actual excavation. This study is being initiated on a site below SWSA 5 near MB, and its results will be directly applicable to WAG 2 characterization. If successful, it will be applied to other contaminant sources.

Other relevant studies are the characterization of stormflow, via field investigations, and modeling and investigations of fracture flow. Results from these studies will be incorporated in the hydrologic monitoring activity for WAG 2.

9.4.2 Site Characterization

The primary objectives of the site-characterization task are to:

1. define the nature and extent of the contamination in the environmental compartments of the WOC system;

2. quantify the migration, accumulation, and distribution patterns of contaminants of concern; and

3. provide the data on contaminants of concern required for assessing the potential risks to human health and the environment and for identifying and evaluating potential remedial action alternatives.

Efforts to accomplish the objectives rely upon the review and summary of existing information and the risk-directed acquisition of additional information. The first phase of the WAG 2 RI S&A plan is presented in Sect. 10. More detailed and focused plans will be provided in the future as addenda to the WAG 2 RI plan.

Extant data are being used to focus the screening-level human health and environmental risk analyses for preliminarily identifying likely contaminants of concern, for identifying data needs, and for prioritizing additional work.

On the basis of data needs identified in Sects. 5, 6 and 7, a limited screening/scoping-level sampling will be conducted upon initiation of the RI Plan, while the preliminary contaminant screening is being completed (see Sect. 10). Depending on the results of the initial screening analyses, decisions will be made concerning contaminants, media, sites, and/or species for which preliminary (screening-level) sampling and analyses will be necessary.

Contaminant concentrations and distributions will be mapped and contaminant inventories will be estimated to characterize the nature and extent of contaminant

accumulation in the WOC system. Data obtained will be used to (1) link contaminant concentrations and inventories directly to human health and environmental risk analyses and (2) determine the need for a focused assessment of the mobility and biological availability of contaminants.

9.4.2.1 Screening-level Sampling and Analysis for Contaminants of Concern

The primary objective of this subtask is to provide contaminant concentration data from selected sites for conducting screening-level risk analyses. These initial human health and environmental risk analyses will be directed at determining specific contaminants of concern to be investigated in the more focused (Level 2) sampling and analysis effort. Secondary objectives of this subtask are to (1) characterize concentration levels for a variety of probable contaminants of concern in the water, sediments, soils, and biota of the WOC system, (2) determine background or reference levels of contaminants in selected sites upgradient of ORNL WAG releases, (3) identify potential problem areas with regard to human health or environmental risks, and (4) provide contaminant concentration data useful for evaluating potential remedial action alternatives.

The initial stages of the risk-directed S&A plan will be initiated following better determination of specific contaminants of concern via the preliminary contaminant screening. These samples will be analyzed for a variety of organic compounds, heavy metals, and radionuclides that have been determined to occur in the WOC system at levels warranting further consideration. Sampling operations and analyses will be conducted according to documented environmental surveillance procedures (Kimbrough et al. 1988).

Data obtained from the above contaminant analyses will be used to update the risk analysis to identify specific contaminants of concern and environmental media or processes for which additional information is required to evaluate human health and environmental risk. In this way, contaminant concentration data obtained for site characterization will be linked directly to the human-health and environmental risk analyses. A limited number of water, sediment, soil, and biotic samples will be collected from areas not influenced by the ORNL WAGs.

In this subtask, Geographic Information System (GIS) techniques will be employed to develop maps and estimates of the concentrations and spatial distributions of the contaminants of concern.

9.4.3 Human-Health Risk Assessment

9.4.3.1 Background, Objectives, and Approach

Human-health risk assessment is an analysis of the potential for adverse health effects in human populations resulting from current and future exposure to hazardous substances released into the environment from hazardous waste sites. The baseline risk assessment, which is the major component of the overall risk assessment process, identifies the risks in

the absence of actions designed to control or mitigate releases of hazardous substances from the site. The risk assessment may be both qualitative and quantitative, the extent of either depending on the complexity of and the particular circumstances at the site as well as the availability of regulatory guidance and ARARs.

Both existing data and data gathered during the preliminary scoping and site characterization exercises will be used in the risk assessment process. As the contaminants of concern and migration and exposure pathways are identified, further sampling plans will be initiated and modified as necessary. Risk assessment will be conducted as an iterative process starting with the preliminary risk assessment, which identifies contaminants and pathways of concern; a baseline risk assessment, which evaluates risks for the "no-action" condition; and an alternatives risk assessment, which evaluates risks from any of the possible remedial action alternatives.

The staged risk-based approach to be used in the WAG 2 RI can be divided into the following subtasks and follows Fig. 9.3:

1. A preliminary risk assessment consisting of an initial screening-level risk analysis of existing data that identifies a preliminary list of contaminants, transport pathways, and exposure pathways to identify the need for interim corrective measures (ICMs) (if necessary) and to determine the type and amount of data needed for Level 1 sampling and analysis (see Sect. 8.2).

   A preliminary risk analysis based on the Level 1 sampling and site characterization data that specifically identifies contaminants of concern and information gaps with regard to contaminated media, transport and exposure pathways, and receptors. This risk-based information will be a primary consideration in planning for Level 2 (focused) sampling.

2. A baseline risk assessment which will include detailed risk analyses of Level 2 data focusing on the specific contaminants, media, and pathways addressed in this phase of sampling. These analyses will be performed iteratively as additional pathway-specific data become available.

   A multiple-pathway risk analysis to identify sensitive human subpopulations and to estimate the risk to these receptors in the absence of any remedial action at the site.

3. A detailed risk assessment for each of the proposed remedial alternatives and an analysis of the uncertainty associated with the exposure scenarios.

9.4.3.2 Description of Subtasks

1. Preliminary risk assessment

   A preliminary screening-level risk analysis will be conducted on existing data to identify a preliminary list of contaminants and pathways of concern. The screening analysis not

only serves to delineate the high priority contaminants (if any) that might require interim corrective measures but also serves to delineate low-priority contaminants for further evaluation (see Sect. 8.2 for further details on this approach).

A preliminary risk analysis will be conducted on Level 1 sampling results to further evaluate contaminated media, environmental and exposure pathways, and receptors. Contaminants found to be extremely unlikely to cause significant human-health risk will not be included for further sampling. Detailed, pathway-specific risk analysis will be conducted for those contaminants whose screening indices indicated uncertainty with regard to potential human-health risk or regulatory violations. In this phase, the exposure concentrations will be represented by the 95% upper-bound estimate of the average concentration. Wherever possible, statistically represented data will be used, and exposure assumptions will be based on 95th percentile upper-bound values. In the absence of statistically based values, professional judgement will be used to estimate a reasonable upper-bound value (in such cases, the RPM will be contacted for approval). "Worst-case" (which would assume unrestricted access to the site) and "Best-case" (which would use the prevalent access restrictions to the site) scenarios will be used to estimate the highest and most likely exposures. Critical information gaps will be identified for Level 2 sampling. Level 1 sampling data would be used to assess the potential risk from acute or subchronic exposure resulting from "hot spots" (if any) that may require an ICM. A preliminary analysis of uncertainty will be conducted to identify the parameters and pathways associated with the greatest uncertainty.

2. Baseline risk assessment

A detailed risk analysis will be performed iteratively as data from Level 2 sampling become available. This risk analysis will estimate the risk to potential receptors in the absence of any remedial action at the site. The analysis will be focused on specific contaminants, media, and pathways of concern. The potential pathways that would be covered in this phase of the risk assessment include:

- ingestion of drinking water;
- ingestion of aquatic and/or terrestrial biota;
- external exposure to radiation from sediments in the river, mudflats, and shoreline or floodplain soils;
- inhalation/ingestion of contaminants resuspended from sediment deposits;
- incidental ingestion of contaminants in water, sediments, and soils;
- dermal contact with contaminants in sediment or soil;
- inhalation of vapors of volatile organic compounds or tritium; and
- ingestion of crops and agricultural produce (e.g., meat and milk) assuming future unrestricted utilization of WAG 2 by the public.

The uncertainty analysis will be further refined and focused on specific pathways of concern to identify those parameters causing the greatest uncertainty in the exposure and risk estimation. This identification would identify further data gathering needs (if necessary) to refine the risk assessment.

Another subtask of the baseline risk assessment is the identification of sensitive human subpopulations and multiple pathway risk analysis. This will serve to identify subpopulations within the realm of potential receptors that might be especially sensitive to exposure to contaminants from the site. Sensitive subpopulations in the vicinity of WAG 2 include populations with high fish consumption patterns, populations receiving drinking water from the Clinch River, populations using recreational facilities in the Clinch River—Watts Bar Reservoir system, preschool children with pica, and workers at water treatment plants along the river. Both chronic and subchronic exposure scenarios will be evaluated, and the uncertainties associated with the exposure assumptions will be evaluated. Because individuals can be members of more than one subpopulation, the individual and combined pathways that represent the maximum risk will be used to identify the subpopulation(s) at greatest risk.

3. Risk Assessment for the Selection of Remedial Alternatives

This task will evaluate and determine potential human-health risks for the exposure scenarios associated with each of the remedial alternatives using design and anticipated performance parameters. Criteria have been detailed by the NCP for evaluating remedial alternatives:

- overall protection of human-health and the environment;
- compliance with ARARs (unless waiver-applicable);
- long-term effectiveness and permanence;
- reduction of toxicity, mobility, or volume through the use of treatment;
- short-term effectiveness;
- implementability;
- state acceptance; and
- community acceptance.

The uncertainties associated with the scenarios will also be evaluated. The primary objective of the risk assessment would be to determine whether the proposed remedial alternative would increase or decrease the existing baseline risk. Other considerations that must be addressed include cost associated with treatment options and the technical feasibility of proposed remediation.

9.4.4 Ecological Risk Assessment

Two approaches for ecological risk assessment will be employed. First, data concerning concentrations of chemicals in water, sediments, and fish will be used in iterative screening assessments to refine the lists of chemicals of concern. The refinement will result from use of new contaminant concentration data and refinement of the assumptions and database used to develop the benchmarks.

Second, the results of measurements of the biotic populations and communities will be used along with the contaminant data and toxicity testing in an epidemiological approach to ecological risk assessment. This approach will use the indicators of effects and supporting data to answer the following four questions.

1. **Are real toxicological effects occurring?** That is, is there evidence that the organisms exposed to DOE emissions are injured? Answering this question will require establishing that there are specific injuries or signs of debility in the biota that are not normal for the species and habitat type, or that species of fish that should occur in the habitat are not present or are present in very low numbers relative to their expected abundance. That will require habitat analysis and establishing the "normal" state of the biota. Some data appropriate for this purpose are available from the BMAP, particularly for the upstream portions of WAG 2 (Sect. 4).

2. **What is the cause of the effects?** Proving that the effects (if any) are caused by DOE emissions will require satisfying Koch's postulates, as modified for toxic effects (Suter 1990b). First, a regular association must be established between the effects and the source. This requires that a particular effects syndrome be identified and that syndrome be found regularly in the communities exposed to the DOE emissions and not in reference areas (i.e., those that are clean or at least are exposed to effluents that are not similar to the DOE emissions). Second, the organisms that display the effects must also display evidence of exposure (i.e., body burdens or biomarkers of exposure). Third, the pollutants must be shown to induce effects in controlled exposures (i.e., toxicity tests). To establish the toxicity of existing water, soil, and sediment, the toxicity of these whole media can be tested in the laboratory or field. If toxicity is demonstrated, then it is desirable to determine which components are responsible for the toxicity. This can be done by comparing the concentrations of chemicals in the media to existing toxicity data or by tests of spiked site water, soil, or sediment. Fourth, to establish the relevance of the controlled exposures to the observed effects in the field, it should be shown that the same effects occurred at similar levels of exposure in the laboratory and field. If there is good evidence that the biota is being affected, but this analysis indicates that the effects are not attributable to direct toxic effects, other causes should be considered. Although we will attempt to satisfy all of Koch's postulates, when necessary data are missing causation will be determined on the basis of preponderance of evidence. Data for in-stream biological effects, bioaccumulation, biomarkers, and media toxicity collected

by BMAP (Sect. 4) have been used to identify toxic effects of NPDES effluents and can be used to begin to identify effects of wastes.

3. **What are the magnitude and extent of the effects?** This question might be answered in a variety of ways, depending on the nature of the effects and the data supporting the attribution of effects to pollution. If end point effects are measured in the field, then the problem is to describe the distribution of those effects in space, relative to concentrations of individual pollutants or indices of multiple pollutant exposure. If effects are shown to occur at the organismal or suborganismal levels, then the relationship between the lower-level effects and the population-level end points must be established before the distribution of effects can be described. It may be desirable to use results of water, soil, or sediment toxicity tests, rather than measurements of field collected organisms, to establish the distribution of effects.

4. **What are the ultimate consequences of remedial options?** Ultimately, if significant ecological effects are shown to be occurring, it will be necessary to consider the consequences of alternate remedial actions on the magnitude and extent of effects. This will be done by using the models developed to describe the current effects (i.e., to answer question 3) to extrapolate into the future.

9.4.5 Identification and Evaluation of Potential Corrective Measures

9.4.5.1 Background and Objectives

A detailed evaluation of corrective measures/remedial action (CM/RA) alternatives properly falls within the scope of the RCRA Corrective Measures Study and the CERCLA Feasibility Study. However, identification of potentially appropriate CM/RAs early in the remedial investigation process is essential to (1) ensure that data collected during the course of the RI are relevant and applicable for the CM/RA selection process, and (2) permit an intelligent selection of an interim CM/RA if such is found to be necessary for protection of human-health and/or the environment. Additionally, because certain CM/RA could result in significant environmental impacts, data must be collected in a manner that supports a NEPA assessment (Levine et al. in press).

Some information on contaminant distributions in the WOC system already exists (see Sect. 6), and additional data will be obtained as part of the site characterization activities. Estimates will also be made of the risks to human-health and to the environment associated with contamination derived from past and present contaminant releases from the WOC watershed. Additional focused sampling and analysis efforts and risk analyses will specifically identify the risks associated with specific locations and contaminants within the system. Thus, this RI will be focused progressively on specific problem areas in which significant risk to human-health or welfare or to the environment may exist.

The specific objectives of this task are to (1) preliminarily identify potential problem areas that may require CM/RA; (2) initially identify appropriate CM/RAs applicable to

specific problem areas or area groupings; (3) apply site-characterization data, results of risk analyses, and understanding of the nature and extent of off-site contamination gained during the RI to assess, on an iterative basis, the human-health and ecological consequences of potential CM/RA alternatives (including the No-Action Alternative); and (4) advance a set of recommendations for use in CM/RA selection and implementation.

9.4.5.2 Approach

As previously described, the RI will be a phased investigation. Depending on the results of progressive phases of the investigation (e.g., availability of existing data, risk analyses, acquisition of necessary additional data), the No-Action Alternative will either be evaluated or additional information will be required for its evaluation. Given sufficient information to evaluate the no-action alternative, there are three possible findings:

1. **Imminent risk to human-health or to the environment**—immediate interim CM/RA is required.

2. **Insignificant potential risk to human-health or to the environment**—no CM/RA is necessary or advisable.

3. **Sufficient risk to human-health or to the environment exists to warrant evaluation of CM/RAs**—additional analysis is required to further evaluate the specific problem area(s) for the purpose of identifying the most appropriate (i.e., the most effective, technologically feasible, environmentally acceptable, and cost-efficient) CM/RA alternative. The decision-making process summarized above will be employed for acquiring the information necessary for determining the human-health and environmental risks associated with off-site contamination and identifying and preliminarily evaluating potential CM/RA alternatives.

Remediation of existing contamination problems, if necessary, is the objective of the RI process. Data collected during the RI will be used for site characterization, human-health and environmental risk assessment, and identification of potential CM/RA alternatives. To ensure that the combination of existing data and new data to be collected will be adequate for these purposes, the potential pathways leading to human-health and environmental risks, potential problem areas that could require remediation, and categories of potential remediation alternatives must be identified early in the remedial investigation process.

9.4.5.3 Description of Subtasks

Subtask 4.1 Preliminary Identification of Potential Problem Areas

As site characterization data and results of risk analyses become available, information will be compiled on an iterative basis in Subtask 4.1 to identify specific sites in the WAG 2 that represent potential problem (high or uncertain risk) areas and groupings of specific sites

with similar problems that can be treated as common problem areas with their own candidate CM/RA alternatives.

Sites that have been identified as potentially causing unacceptable health and environmental risks will be evaluated. Sites will then be grouped into problem areas potentially requiring remediation. This approach will limit the scope of the RI investigation to areas where contamination problems actually occur and will help identify candidate CM/RAs that may be appropriate to remediate any significant problems. For example, sites may have different candidate CM/RAs depending on the types of contaminants posing risks, the exposure pathways, the species affected, the contaminated materials, and the site characteristics. Sites that are proximal and have similar conditions may be treated as a single problem area with a common set of CM/RAs.

Subtask 4.2 Preliminary Identification of Potential CM/RA Alternatives

Several general categories of potential CM/RAs (Table 9.1) will be considered for all of the identified problem areas. A specific remedial action for a particular problem area could include combinations of activities in these remediation categories. A variety of potential remedial actions will be considered because of the number of media, contaminants, and locations involved. All remedial actions that provide at least a minimum level of risk reduction will be considered.

Table 9.1. Categories of potential corrective measures/remedial actions.

1. **No Action** - data show that no significant potential risk to human-health or to the environment exists.

2. **Restricted Access, Restricted Use** - no trespassing in contaminated terrestrial areas; no swimming and no fishing, etc., in contaminated aquatic environments; recommend no dredging permits issued in "hot spots."

3. **In-place Isolation or Stabilization of Contaminated Media** - in situ fixation of contaminated sediment, sediment covers, treatment, hydrologic isolation.

4. **Bulk Removal and Storage of Contaminated Media** - bulk removal of contaminated soil and/or sediment, etc.; must consider human-health and environmental consequences of disposal (e.g., dredging of contaminated sediments and land disposal, stripping of contaminated soil from terrestrial areas).

5. **Treatment of Contaminated Media**

6. **Control of Sources, Discharges** - on-site remedial actions will address these controls.

Potential CM/RAs to be assessed will include both on-site and off-site remedial actions and a variety of emergency response strategies and scenarios. Both on-site and off-site CM/RAs must be considered because a selected CM/RA can impact all downgradient areas. Emergency response strategies and scenarios are important because not all CM/RAs involve removing or treating the contaminants. Contaminants that remain are subject to catastrophe events, unauthorized access by humans, and unintended exposure to the environment.

The search for CM/RAs for specific problem areas will be refined and focused as data become available and as quantitative assessments are performed. Candidate CM/RAs that are clearly inappropriate will be eliminated from further consideration.

Subtask 4.3 Preliminary Evaluation of Potential Corrective Measures/Remedial Action Alternatives

The primary benefits associated with a CM/RA are the reductions in risk to human-health, welfare, and the environment. The benefits of each candidate CM/RA for a problem area will be estimated relative to other potential CM/RAs for that area. Specifically, increased risks to human-health or to the environment during the implementation of the CM/RA must be carefully considered.

The factors to be included in the preliminary assessment of potential CM/RA include (1) the effectiveness of the risk reduction to health and the environment associated with the CM/RA, (2) new risks to health or environment that will be posed during implementation of the CM/RA, (3) the public acceptance of the recommended CM/RA, (4) the feasibility and reliability of the remediation, and (5) compliance with ARARs.

For factors that do not already have quantitative measurements, a ranking system will be employed to estimate the relative benefits of the CM/RA alternatives associated with a problem area. Each of these factors will be assigned weights to indicate its relative importance in the decision-making process.

Contaminant transport and fate simulation models, contaminant remobilization models, and the risk assessment models will be used to help evaluate ecological and human-health risks. Risks will be evaluated for existing conditions, for CM/RA alternatives during their implementation stage, and for CM/RAs once they are completed. These risks will be used to rank the relative benefits of each of the alternatives.

Rankings for acceptance of the CM/RAs and the feasibility/reliability of the remediation will be assigned using expert judgments. The feasibility criteria include the availability of technology, the possibility of implementation in the desired location, and whether RCRA-approved facilities exist that can receive generated (removed) wastes. A committee of technical experts will be used to evaluate the objectivity of the ranking process. Technical judgments that a CM/RA is not feasible or is totally unreliable will cause it to be eliminated from further consideration.

9.4.6 Interim Corrective Measures

Following the same rationale and regulatory initiative as presented for potential corrective measures (Sect. 9.4.5), interim corrective measures may be required where an imminent risk to human-health or to the environment is identified. Although characterization of the nature and extent of contaminants in the WOC system is preliminary, indications of significant radioactive contamination warrant the consideration of interim remedial action decisions to be made prior to completion of the RI/FS. At the present time, work is proceeding in collaboration with the U.S. Army Corps of Engineers to design and install a sediment-retention structure at the mouth of WOCE . This action is being undertaken as a CERCLA Removal Action in order to minimize the potential for release of contaminated sediments. The control features are to be implemented as soon as possible. DOE and Energy Systems have notified EPA and TDHE that they are proceeding in characterizing the embayment and developing interim measures.

The presence of significant levels of contamination in portions of WAG 2 is indicated by high concentrations of ^{137}Cs (>1000 pCi/g) in sediment and gamma dose rate measurements from overflight surveys exceeding 0.5 mrem/h (Fritzsche 1987). These concentrations and dose rates warrant assurances that WAG 2 will remain a restricted area for public access until such time as cleanup activities can be completed. In addition, actions should be considered to ensure that the contaminated sediments will be stabilized and that storm events will be ineffective in remobilizing and transporting contaminated sediment to unrestricted areas.

10. FIELD SAMPLING AND ANALYSIS PLAN

10.1 PURPOSE

The field sampling and analysis (S&A) plan supports the DOE WAG 2 RI at ORNL. ORNL WAG 2 (Fig. 9.1) consists of the WOC system and its tributaries downstream of the ORNL main plant area (WAG 1), WOL, WOCE of the Clinch River, and the associated floodplain. WAG 2 is the primary surface drainage for the ORNL. The drainage system has been exposed to a diversity of contaminants as a result of operations and waste disposal activities at ORNL during the past 47 years. A preliminary review of existing data shows that the water, soil, sediment, and biota have been contaminated as a result of releases of metals, radionuclides, and organic chemicals from operations, waste management practices, and inadvertent spills at ORNL (Sect. 6). Current operations at ORNL and releases from waste disposal and contaminated areas continue to contribute contaminants to WAG 2 (Sect. 5). Existing data for releases over the WOL Dam and an initial survey in Watts Bar Reservoir indicate that contaminants released from WAG 2 have accumulated in the sediments downstream (Sect. 7).

The primary purpose of the S&A plan is to provide contaminant concentration data from selected sites for conducting screening level risk analyses. These initial human health and environmental risk analyses will be directed at determining specific contaminants of concern to be investigated in the more focused (Level 2) sampling and analysis effort. Secondary objectives of this subtask are to (1) characterize concentration levels for a variety of probable contaminants of concern in the water, sediments, soils, and biota of WAG 2, (2) determine background or reference levels of contaminants in selected sites upgradient of ORNL WAG releases, (3) identify potential problem areas with regard to human health or environmental risks, and (4) provide contaminant concentration data useful for evaluating potential remedial action alternatives.

The collection and analysis of biotic and abiotic environmental samples support both the long-term objectives of the WAG 2 RI (Sect. 9.1):

1. definition of the nature and extent of contamination in WAG 2,

2. quantification of any risk to human health and the environment resulting from the contamination, and

3. preliminary evaluations of potential corrective measures and remedial action alternatives for the operable units in WAG 2.

and the short-term objectives:

1. initial scoping surveys and sampling;

2. implementation of a multimedia environmental monitoring and characterization program; and

3. initial stages of the RI process, iterative screening-level (Level 1) risk assessment, and risk-driven screening-level sampling and analysis.

Components of the S&A Plan are linked to specific work plan tasks described in Sect. 9.3.1.

10.2 SUMMARY OF EXISTING INFORMATION FOR CONTAMINANTS IN WAG 2

Discharges and releases (seeps and surface runoff) from existing operations and contaminated areas (including previous waste disposal sites) are a continuing source of contaminants to WAG 2 (Sects. 5 and 6). Releases (surface water discharge) from WAG 2 have been a significant source of contaminants to off-site areas in the Clinch River (Sect. 7).

Considerable information is available for contaminants in WAG 2; however, while data for selected radionuclides and metals are available for most media, data for organics and other radionuclides likely to be present (e.g., ^{99}Tc and transuranics) are rare.

10.2.1 Floodplain Soil

The soils in WAG 2 have not been well surveyed, and little information exists for contaminants in floodplain soils. Information for these soils may point to contaminant inputs from other areas and to the potential for contaminant movement via erosion; the soils may also be a pathway for human exposure (Sect. 8.2). Soils have recently been collected from the floodplain at the upper end of WOL (Sect. 6.1.3) and are being analyzed for gamma-emitting radionuclides, ^{90}Sr and metals (including mercury). Soils at the Intermediate Pond site (Sect. 6.1.2) have been fairly well characterized for radionuclides. This area has been identified as an operable unit for remedial assessment. There is evidence of radiological contamination of soil in the Melton Branch area as well (Sect. 6.1.4). An aerial radiological survey of the WOC floodplain (Fritzche 1987) found contamination in several additional areas of the floodplain. Aside from areas known to be contaminated with radionuclides, data for floodplain soil are sparse and need to be improved, especially for nonradiological contaminants.

10.2.2 Floodplain Biota

Vegetation on contaminated soils accumulate radionuclides, especially environmentally mobile elements (^{90}Sr, ^{99}Tc, and ^{3}H). There are fairly good data for the accumulation and cycling of mobile radionuclides by vegetation (Sect. 6.2.1). Data for other contaminants in vegetation are lacking but could be predicted if soil data were available.

Data are available for selected radionuclides and organics in terrestrial biota (Sect. 6.2.2); however, data for many potential contaminants are lacking. Contaminant accumulation by animals using floodplain areas could be adequately predicted were data for contaminants in the soils available.

10.2.3 Groundwater

Groundwater contamination with radionuclides appears to be serious, but not widespread (Sect. 6.3). There is less evidence for contamination with organics or metals; however, it is clear that the groundwater and subsurface environment in WAG 2 has not been adequately evaluated. Because most subsurface flow in WAG 2 apparently discharges into the streams, it has been suggested that widespread deep groundwater contamination is not likely and that surface water is a more likely pathway for contaminant movement out of the system. However, more information for the subsurface environment is needed.

10.2.4 Surface Water

Surface water quality in WAG 2 has been fairly well characterized for radionuclides and metals as a result of several ongoing monitoring efforts (Sects. 4 and 6.4). Data for volatile organics indicate relatively low concentrations. Monitoring for PCBs in the aqueous phase has found low concentrations; however, because PCBs are highly insoluble, analysis of sediments is more appropriate to determine the extent of PCB contamination. Although WOC water generally meets drinking water standards, high concentrations of mercury have been found on occasion, and the concentration of certain metals (copper, zinc, lead, and nickel) is greater than at background sites. Concentrations of radionuclides (^{137}Cs, ^{90}Sr, ^{3}H, and ^{60}Co) in surface water have generally declined substantially since the 1960s, but significant quantities of these radionuclides continue to move off-site in surface water (see Table 7.2). With the exception of ^{3}H, ^{90}Sr, and ^{99}Tc, contaminants of probable concern in WAG 2 are more likely to be associated with the particulated phase (soils and sediments) than with the aqueous phase. This suggests that contaminant transport during high discharge events is likely to be more important for contaminant movement than discharge under baseflow conditions. Stormflow measurements of contaminant movement are needed.

10.2.5 Sediments

Existing data show that the aquatic sediments have accumulated particle-reactive contaminants (Sect. 6.5). The sediments of WOL and WOCE are highly contaminated with radionuclides, and a CERCLA removal action is currently underway in the WOCE as a result of high concentrations of ^{137}Cs in the sediment. Elevated concentrations of mercury have been found in WOL and WOCE sediments. High concentrations of chromium have also been found in WOL sediments. WAG 2 has been contaminated with PCBs in the past, and PCBs are still in the system. Sediment sampling for PCBs in the WOCE suggest very patchy hot spots surrounded by areas of little contamination. Little data for hydrophobic organics exist; however, existing data suggest little contamination.

The sediments of WOCE are currently being characterized by the Clinch River RFI, as part of the CERCLA activities for WOCE. Those data should provide a fairly complete characterization for that area and will be useful in directing sampling and analysis in upgradient areas of WAG 2 (via the preliminary contaminant screening). There are good preliminary data for selected radionuclide and metals in WOL sediments; however, data for transuranics and organics are lacking. There are good historic data for contaminants associated with stream gravels; however, data for contaminants associated with the more mobile smaller size fractions are needed. Thus far, chromium, silver, lead, mercury, zinc, copper, and arsenic have been identify as being above background concentrations in the sediment and ^{137}Cs, ^{60}Co, ^{90}Sr, PCBs are high enough to be of probable concern (see Sects. 6.5 and 8.2.3).

10.2.6 Aquatic Biota

There are good data for contaminants in aquatic biota (Sect. 6.6). In fish, mercury is the only metal with concentrations above background in fish; however, plants may accumulate several metals including cadmium, copper, and lead. Fish have been analyzed for organics and some fish in WOCE exceed the FDA limit for PCB contamination. Chlordane has been found in clams downstream from the ORNL main plant area. Aquatic plants and animals, including waterfowl, have been found to accumulate radionuclides. Mercury, PCBs, chlordane, ^{137}Cs, ^{60}Co, and ^{90}Sr are the primary contaminants known to accumulate to above-background levels in the aquatic biota in WAG 2. Soils and sediments are major pools of contaminants in WAG 2 and need to be evaluated as contaminant sources for the aquatic biota relative to new inputs.

10.2.7 Air

With the possible exception of ^{3}H in atmospheric moisture, airborne contaminants have not been found to be significant for WAG 2 (Sect. 6.7).

10.2.8 Other Considerations

Based on a previous contaminant screening using data for contaminants found in water, fish, and sediment in the WOCE, arsenic, PCBs, chlordane, ^{137}Cs, ^{60}Co, ^{90}Sr, and $^{152,154}Eu$ were designated as being of "definitely high priority" for remedial action considerations, based on a nonconservative screening criteria (Sect. 8.2.2). Of these, ^{137}Cs imparted by far the highest potential risk to human health.

The surrounding WAGs are known or suspected to have released a diversity of contaminants to WAG 2 (Sect. 5). Characterizing the nature and extent of contamination in WAG 2, determining the fate and transport of contaminants in WAG 2, and the eventual evaluation of remedial actions for WAG 2 will depend upon an understanding of the input and fate of contaminants from adjacent source areas.

Input and movement of most contaminants are strongly linked to storm events and sediment transport. Soils and sediments are the primary temporary sinks for contaminants

in WAG 2. Substantial sediment contamination has been found in WOL and WOCE; however, additional data are needed to define the nature and extent of contamination, to allow the estimation of potential contaminant releases, and to evaluate the need for remedial action. Stream sediments are more dynamic and less well characterized. The transport of contaminants associated with soils and sediments during high discharge events needs to be evaluated.

10.3 APPROACH AND STRATEGY

10.3.1 Approach

The S&A plan will be staged where results of a preliminary contaminant screening drive the Level 1 (scoping-level) S&A and the results of the Level 1 S&A are used to update human-health and environmental risk analysis, which in turn are used to focus more extensive S&A (Level 2). A logic diagram illustrating the decision pathway of this risk-driven iterative process is shown in Fig. 9.3.

The WAG 2 RI Work Plan includes tasks to be conducted in the short-term (while upgradient WAGs are being remediated) and in the long-term (following remediation of upgradient contaminant source areas). Short-term tasks include the initial components of a standard RI plan and the components of an interim period baseline monitoring program. These objectives have been presented in Sects. 9.1 and 10.1. The S&A plan follows directly from the Work Plan.

The EPA has established an extensive list of contaminants of concern. However, not all of these pollutants are expected to be present in the sampling area. It is, therefore, reasonable to reduce the list of potential pollutants and concentrate on those contaminants of concern, but still have confidence that no pollutant of concern is overlooked. Because the S&A program is driven by the need to estimate human-health and environmental risk, procedures outlined in Sect. 8 will determine the parameters of interest and the level of analytical resolution needed.

It is impossible to anticipate the concentrations and distributions of contaminants *a priori*; therefore, the S&A plan must be flexible to adjust to needs identified by the risk assessment. That is, we will employ an adaptive sampling process under which suspected hot spots or contaminant sources identified in scoping surveys, and key processes identified in pathway analysis (e.g., aspects of sediment transport), will be the focus of more intensive sampling efforts to minimize variance in the risk estimates.

Appropriate statistical design of sample collection and data analysis is critical for an adequate representation of contaminant concentration, distribution, and movement. It is, therefore, critical for reducing uncertainty in risk analysis. These goals are essential for an appropriate estimate of risk and timely completion of sampling tasks. To this end, the project organization includes a statistical support team consisting of environmental scientists and statisticians who are well versed in sensitivity analysis, uncertainty analysis, and other areas

that relate directly to sampling design (Sect. 11). The team will include statisticians from the Statistics Group of the ORNL Engineering Physics and Mathematics Division.

10.3.2 Initial Stages of the S&A Plan

The complexity of the WAG 2 area and the mass and diversity of existing information will require significant effort in the initial stages of executing this plan. At this time, the existing information has not been synthesized sufficiently to conduct a preliminary contaminant screening, thus the initial phases of the risk-driven monitoring, sampling, and analysis program cannot be planned effectively. Currently, the pathways and contaminants of concern are being identified, and this information is being used to conduct a risk-based screening study that will serve as the basis to develop a monitoring and sampling and analysis plan. In the interim, basic scoping activities will be required to provide information for risk assessment and to support a mass-balance approach in determining sources and sinks for contaminants. This first iteration of the WAG 2 RI S&A plan presents a rationale and approach for the S&A plan and a description of the S&A activities to be conducted while the preliminary contaminant screening is being completed and the risk-driven S&A plan is being prepared. This plan is presented with the understanding that more specific addenda will follow. The schedule for the completion of these tasks is subject to negotiation under the FFA.

The initial stage of the S&A program emphasizes two areas:

1. **Initial Scoping Surveys:**

   Preliminary surveys and sampling to determine hot spots (discrete areas of significant contamination that may need interim corrective measures to protect the public or environment) and to clearly define the boundaries of WAG 2, and scoping level sampling of areas where few data are available (i.e., sampling of new groundwater wells and floodplain soils).

2. **Baseline Monitoring Program:**

   Implementation of a multimedia environmental monitoring program to support a mass-balance approach to determining sources and sinks of contaminants (e.g., to characterize the hydrology of WAG 2 and identify operable units for corrective actions) and to define and monitor input of wastes from adjacent WAGs. Activities for this task include upgrades in the discharge monitoring facilities to improve the hydrologic budget for the system and to identify contaminant input points. Because aquatic sediments are of paramount concern for contaminant accumulation and transport, (a) scoping-level surveys of WOC sediments and floodplain soils, (b) preliminary work on sediment transport models, and (c) sampling of WOL sediments are planned.

10.4 S&A ACTIVITIES FOR INITIAL STAGES OF THE WAG 2 RI

10.4.1 Rationale

Because WAG 2 carries hydrologic fluxes out of the WOC watershed, there is an obvious need to have a quantitative understanding of where fluxes enter WAG 2, what contaminants are in the fluxes, what contaminants are resident in the system, and how these contaminants are moving or may move out of the system. With an accurate understanding of how WAG 2 is connected to surrounding WAGs, it will be possible to evaluate the potential effects of remedial alternatives in adjacent WAGs connected to WAG 2 and to plan effective mitigating measures to minimize additional contaminant fluxes while cleanup activities are performed in adjacent WAGs. The S&A plan presents some of the initial components of this effort.

10.4.2 Groundwater

A 1987 scoping survey of unfiltered water samples from 27 piezometer wells in WAG 2 showed serious but not widespread contamination of groundwater by radionuclides, possible contamination by metals at 1 to 8 locations, a possible organics content at one location, and atypical chloride concentrations at five locations (Sect. 6.3). These results will be incorporated into a detailed sampling plan for WAG 2. However, some additional chemical data from compliance wells near the WAG 2 boundary have not been evaluated, and water samples from other compliance wells will soon be obtained. Eighteen perimeter and interior compliance wells (Table 10.1) in WAG 2 were constructed, developed, and slug tested in FY 1990 but have not yet been sampled. Thirty-eight perimeter compliance wells for other WAGs (Table 10.1) are near the WAG 2 border, and at least one water sample each has been analyzed from 31 of these wells. More than 80 piezometer wells are also located in and near WAG 2 and can be sampled, if necessary.

All available data will be evaluated as part of the iterative risk-driven programs (Sect. 9.3), and a detailed sampling plan, including whether or not sampling or resampling of selected piezometer wells is required; will be provided as an addenda to the WAG 2 RI. The new sampling and analysis of groundwater will include organics, inorganics, and radionuclides. Detection limits will be risk based, as determined by EPA drinking water standards. Organics analyses will include, at least, organic halogens or volatiles. Inorganic analyses will include major constituents, metals, sulfate, chloride, nitrate, and fluoride. Water samples from wells near WAGs 7 and 10 will also be analyzed for cyanide and cyanate. Radioactivity and radionuclide analyses will include at least gross alpha, gross beta, tritium, gamma scan, and total strontium. The list of selected analytical parameters, detection limits, and supporting rationale will be included in the Data Quality Objectives section of the Sampling and Analysis Plan prior to new field sampling.

The initial sampling of the newly completed wells in WAG 2 and resampling of older wells will provide sufficient information for preliminary risk analysis and information for pathways of contaminant movement. This information will then be used to plan additional groundwater sampling, if necessary.

Table 10.1. Compliance wells in and near WAG 2

WAG 1	WAG 2	WAG 4	WAG 5	WAG 6	WAG 7	WAG 8
806*	1150	954	969*	745*	1078*	1094
1087	1151	955	970*	833*	1079*	1095
	1152	956	971*	835*	1080*	
	1153	957	972*	836*	1081*	
	1154	958	973*	837*	1082*	
	1155		974*	838*	1083*	
	1156		975*	839*	1084*	
	1157		976*	840*	1085*	
	1158		977*		1086*	
	1185		978*			
	1186		979*			
	1187		980*			
	1188		981*			
	1189		1150			
	1190					
	1191					
	1192					
	1193					
	1194					
	1195					

*One or more water samples have been analyzed.

10.4.3 Surface Water

Determining a water budget, developing a better understanding of sediment transport, and determining the relative contributions of existing WAGs, including WAG 2, to off-site transport of key contaminants are the primary objectives of a surface water and analysis program. Understanding the surface water hydrology and determining a water budget for WAG 2 are critical for determining contaminant input, dynamics, and releases for WAG 2, as well as for other WAGs located upgradient. Basic questions such as the extent of communication of stream flow with groundwater and subsurface flow (i.e., are there gaining or losing reaches) have not been answered for WAG 2. It is likely that groundwater seeps are a major pathway of contaminant input to surface waters; therefore, seeps need to be located, mapped, and quantified for both discharge and contaminant load. This activity will contribute to identification of contaminant sources and is needed to complete the hydrologic picture of the system. Information for ungaged streams (discharge and contaminant load) is needed, along with a general improvement in existing gaging and monitoring facilities.

Better information for water budgets and improved sampling at existing USGS stations and NPDES monitoring points can begin to identify areas of contaminant input based on differences in mass fluxes. A streamflow sampling program has been proposed as part of the interim monitoring program (Sect. 9.4.1) that addresses contaminant input from adjacent WAGs. This sampling program will be developed during FY 1991 in cooperation with RIs on other WAGS and other stream sampling programs. Many upgradient WAGs (e.g., 4, 5, 8, and 9) will not have sampling programs developed by this time. Therefore, much of the stream sampling will have to be initiated by this task. Because we have little or no information for organics, transuranics, mercury, and other probable contaminants in WOC surface waters, a limited scoping-level sampling will be useful to fill data gaps. In addition to a general screening, information for additional contaminants found in the Clinch River downstream of WOCE and for contaminants in upgradient WAGs will be used to guide the scoping exercise.

Because aquatic sediments are a major sink for contaminants in WAG 2 and resuspended sediments are the major vector for the off-site movement of contaminants, efforts to address sediment transport are needed. Empirical approaches, such as sediment rating curves (sediment load versus discharge), are essential for evaluating contaminant movement. Models of sediment resuspension and transport are being developed for the Clinch River RFI. Working with those investigators, we will extend those models into WAG 2. Preliminary work on sediment transport models and limited stormflow sampling of sediment and contaminant load will begin immediately. An important intermediate goal is assessment of the potential consequences of corrective measures in upgradient WAGs on sediment and associated contaminant transport. These activities are described in Sect. 5.

As a result of DOE Order 5400.1 and reauthorization of ORNL's NPDES permit, surface water monitoring requirements for the ongoing monitoring programs (Sect. 4) will see significant changes. Additional parameters are expected to be required for water quality

monitoring and more emphasis on sediment transport. In the near term, coordination with these monitoring programs will be implemented to improve information for surface water hydrology and contaminant sources, sinks, and transport in WAG 2. The NPDES and environmental surveillance efforts can provide an inventory of discharges from ORNL operations in the main ORNL plant area (WAG 1) that flow into WAG 2. Available discharge records collected by the USGS and ORNL monitoring efforts (see Fig. 3.3) on the network of streams in and around WAG 2 will be used to aid in completion of a hydrologic budget. Water quality data from surface-water monitoring stations at the boundaries of WAG 2 will be obtained, for screening-level assessment, from other monitoring programs (see Sect. 4) where available. NPDES effluent water quality data are available from the Environmental Surveillance and Protection Section for the USGS surface-water monitoring station below Melton Valley Drive on WOC. Screening-level water quality data from work on other WAGs upgradient from WAG 2 will be used as they become available. Additional screening-level measurements of water quality at the boundaries of WAG 2 will be made to cover any deficiencies in available data. Specifically, data from the three USGS surface water monitoring stations in the headwater region of Melton Valley will serve to define background water quality and the contribution of discharge from WAG 8 to MB.

Innovative screening methods include the in-stream placement of packets of manganese-oxide-coated acrylic fibers. These packets can be tested for retention of particle-reactive contaminants that will sorb to the manganese oxide layer. Such packets will initially be placed in WOC between two tributaries draining the WAG 5 area for identification points of contaminant inflow. If successful, this approach will be employed elsewhere. It is recognized that this approach may be of limited use for some contaminants; however, it may be generally useful as a screening tool to pinpoint sources of contaminants to and within WAG 2.

The WAG 4 Environmental Data Package (Davis and Shoun 1986) identified the need for continuous operation of the two discharge monitoring stations (WAG 4-2 and WAG 4-2A) on the SWSA 4 tributary to WOC for water budget calculations. In addition, the most immediate need identified was water quality sampling and analysis to allow investigation of longer-term trends. Continuous discharge records are available from station WAG 4-2; however, discharge monitoring at WAG 4-2A was discontinued in early 1989. Upgrade and reactivation of this station coupled with water quality sampling at both stations on this tributary will help to quantify the contaminant contribution from WAG 4.

As noted in Sect. 5.2, the weirs installed as part of the WAG 6 RI need to be upgraded to handle larger storms and to take continuous samples. In addition, a flow measuring and sampling system needs to be installed in the lower reaches of the stream between WAGs 6 and 7. All of these flow monitoring stations need to be operated continuously to identify the input from these WAGs, which drain directly into WOL. This is particularly important because it is believed that more than 90% of the groundwater in areas like WAG 6 occurs as shallow flow that discharges directly to surface streams.

An upgrade of the control device at the monitoring station (MB2) on MB immediately upstream from the confluence with the HRE tributary may be required to better quantify contaminant contribution from WAG 8. The existing control device is a 6-ft Cipolletti (sharp-

crested trapezoidal) weir. This device is inadequate for measuring base flows at this site. Only storm event flows (above approximately 1.75 ft^3/s) can be measured with an adequate degree of accuracy. The existing weir plate could be replaced with a compound section consisting of a small angle V-notch (for measuring low flows) and a larger trapezoidal section for high flows.

A number of tasks having direct benefit to WAG 2 characterization are proposed for implementation under the site investigation component of the ORNL ER Program. Three projects related to surface-water monitoring are described below.

Weirs and flumes in the WOC watershed have degraded due to sediment buildup in the stilling pools and submergence effects during high flows. There is a critical need to remove the contaminated sediments that have rendered these stations unsatisfactory for discharge measurements. Stage-discharge relationships must be developed for high flows at the NPDES monitoring stations on WOC and MB. The relationships previously used at these stations were established using scale physical models and have never been verified from field measurements. In addition, submergence of the broad-crested weir at the MB station at high flows, due to downstream obstruction, renders the theoretical relationship invalid. The stage-discharge relationship here will be applied for verification of a theoretical extended rating at the low-flow control. Improved discharge measurements at these primary surface water monitoring stations will aid in development of a water budget and quantification of mass flux of contaminants from the two major subbasins contributing to WAG 2. Though interim corrective measures have not been determined at this time, the upgrade of these surface water monitoring weirs is essential for evaluation of the effectiveness of any measures implemented. Work plans for collecting discharge measurements and rating the weirs at high flows will be developed and implemented, and NEPA documentation and work plans for removing contaminated sediments and upgrading weirs will be developed.

Performance of weirs and sampling stations in WAG 2 are being evaluated. Three surface water monitoring stations in the WOC watershed are currently being reviewed for upgrade. All three will directly impact WAG 2 characterization. These stations are the East and West Seep drainages that are tributaries to WOC below the confluence with MB that drain WAG 7 (Pits and Trenches area), and the surface water monitoring station on the unnamed tributary to MB, which lies in WAG 2, near the old HRE site. Discharge and water quality data from the East and West Seep drainages are important for water budget determinations and for quantifying contaminant contributions from WAG 7. The HRE station may serve as a background water quality station to WAG 5 effluents and separate the contaminant contributions from WAG 9 as well.

An annual hydrologic data summary report for the WOC watershed for Water Year 1990 will be produced. For the surface water hydrologic data base, continuous precipitation and surface water discharge will be reported. All monitoring sites will be maintained, and instrumentation will be serviced routinely. The needs of data users within the ER Program will be identified and met. All data will be processed and made available, as appropriate, for the WAG 2 characterization.

Surface water is the primary pathway for the release of contaminants from the WOC system to off-site areas. Flow pulses caused by intermittent releases from Melton Hill Dam provide the scour and transport mechanism for contaminated bottom sediments in WOCE. Discharge measurements coupled with sampling that quantitatively represents suspended sediment loads are needed to quantify contaminant releases from the WOC system at the mouth of WOCE. Discharge from (or into) WOCE will be determined during the rising and falling limbs of the flow pulses volumetrically. Discharge associated with each flow pulse will be obtained by development of stage-area-volume relations by defining bathymetric features of the embayment at a number of cross-sections. However, the sampling program for discharge from the WOC system (at the mouth of WOCE) will be designed as part of the WAG 2 RI following the finalization of plans for interim corrective measures for that area (see Sect. 3.2.1.2). During the next several months, measurements at the WOL Dam and grab samples at the mouth of the WOCE will be used for preliminary scoping where necessary.

10.4.4 Sediment Transport Models

Aquatic sediments are a major sink for contaminants in WAG 2 and resuspended sediments are the major vector for the off-site movement of contaminants. Therefore, accurate and flexible sediment transport models are required along with a database to calibrate and verify these models. The objective of the sediment modeling will be to predict the contaminant transport associated with the movement of sediments during a given stream discharge. The range of events to incorporate in the models will be determined by the results of the risk assessment. As upstream conditions change due to remedial actions on other WAGs, the models will be modified.

The sediment transport models will be developed in two stages. Initially, a conceptual model will be developed to describe the movement of sediment and the associated contaminants in WAG 2. This will require data to identify the sources of sediment and contaminants, the interaction between specific contaminants and sediment particles, and the relationships between grain size, discharge and movement of contaminated sediment. Once this conceptual model has been verified, quantitative models of sediment and contaminant transport will be developed. Grain size distribution vs discharge relationships will be established from measurements of bed load and suspended sediment during a representative range of flow regimes at critical locations in the watershed. Field data will be collected to verify the relationships between mineral composition, grain size, water chemistry, and adsorption/desorption of contaminants. This information will be used to develop several types of models. Hydrodynamic models will be required to simulate the hydraulics of streamflow in WAG 2 upstream of WOL, in WOL, and in WOCE and the Clinch River. Hydrologic models will be developed for the rainfall runoff process and groundwater movement in the WOC watershed as necessary. Models will be used to simulate the erosion, resuspension, transport, and deposition of sediment in the watershed, WOL, and areas downstream of WOL Dam. The ability to model the interaction of contaminants and sediment particles will be established. The sediment transport modeling in WAG 2 will be coordinated with and linked

to modeling on the Clinch River RFI where possible. The ability to provide estimates of uncertainty in the simulated results will be developed along with these models.

Preliminary work on sediment transport models and limited stormflow sampling of sediment and contaminant load will be initiated as soon as funding is available. The design of a sampling program and the development of models to meet the long-term needs of sediment transport modeling during future remedial actions at the ORNL WAGs, including WAG 2, will follow the preliminary investigations. The ultimate complexity of these models will be controlled by the results of the risk assessment, the available field data for calibration and verification, the range of flow regimes to be simulated and the impacts of anticipated upstream remedial actions in the WOC watershed. The limited data currently available indicate that the transport of sediment over WOL Dam increases sharply with increasing discharge. Therefore, it will be essential to establish monitoring stations to collect accurate data at several locations in WAG 2 during flood events for each type of model involved. Backup data collection systems will be included to be certain that information is collected during extreme events since the occurrence of a single infrequent flood (e.g., a 30- to 100-year event) would provide invaluable data.

10.4.5 Sediment Surveys and Sampling

Most contaminants of concern are chemically and biologically reactive and rapidly become associated with particles in freshwater systems. The sediments of WOL and WOCE are a large temporary sink for particle-reactive contaminants in WAG 2, and are known to be contaminated with radionuclides (Sect. 6.5). The transport of contaminated sediments is a major concern for off-site contamination. An extensive sediment sampling program in WOCE is being conducted as part of interim corrective measures for the Clinch River RFI (Sects. 6.5 and 3.2.1.2).

10.4.5.1 Creek sediments

Insufficient information is available for the sediments in WOC and its tributaries (Sect. 6.5). Because sediment movement is expected to be a major concern for risk assessment, a preliminary screening survey of creek sediments in WAG 2 will be conducted as soon as funds permit. Data from the aerial gamma survey (Fritsche 1987) will be used to guide these efforts.

As a prescreening exercise in WOC and its tributaries, we will conduct a walkover survey to locate depositional zones and to scan for gamma emitters. The objectives of this exercise are to locate depositional areas (accumulation zones) and to use gamma hot spots (discrete areas of contamination) to begin to scope the nature and extent of sediment contamination and to point to possible sources of contaminants to the creeks (because stream sediments are transitory, they tend to reflect recent inputs to the system and so may indicate recent sources of contaminants). The gamma survey will be useful for identifying hot spots for non-gamma emitting contaminants if co-contamination has occurred (i.e., if the deposition of particle-

reactive gamma emitters is well correlated with the deposition and accumulation of particle-reactive non-gamma emitters). Samples will be collected from sediment accumulation areas that do not show high gamma activity to determine if gamma emitters are good indicators of other contaminants (i.e., if co-contamination is consistent). Data for sediment particle size distribution will be collected and these data will feed into the sediment transport models for estimation of the potential for downstream transport of contaminants.

10.4.5.2 Sediments sampling for WOL and WOCE

Data for sediment contamination in WOL has been reviewed in Sect. 6.5. A comprehensive sediment core sampling study of WOL reported by Lomenick and Gardner (1965) was used to establish an inventory of the predominant radionuclides in the lake sediments. Since then, there has been sporadic sampling of the sediments in the lake and WOCE (Oakes et al. 1982a; Douple 1972; Loar et al. 1985; TVA 1984; T. W. Doyle, unpublished - ORNL); however, all of these studies were limited either in the number of samples taken or in the analyses conducted on the sample. Most of the samples were analyzed only for radionuclides. The purpose of the initial sediment sampling in WOL will be to verify the presence of contaminants and compare the concentrations with those that have been reported from previous sediment sampling in WOL. The cores will be sectioned and analyzed in order to determine the depth of the contaminants.

For the initial sediment core sampling, WOL will be divided into three sections: upper, middle, and lower. Three sediment cores will be collected from each section of the lake and analyzed for organic and inorganic contaminants and for radionuclides. Locations of the sampling sites will be based on results of recent sediment sampling (Loar 1988), previous studies, (see Sect. 6.5) and known sediment depositional areas. The depth of the core will be sufficient to ensure that the deepest occurrence of contaminants in sediments will be sampled. In the lower section of the lake, where a new spillway and weir system was completed in 1982, additional samples may be required if it appears that surface sediments were disturbed by these activities. Present and historical data (Loar 1988) indicate that the highest concentrations of radioactivity are located in the upper end of WOL. Additional samples may be required in this section of the lake to determine the areas having the highest levels of radioactivity (hot spots) and the areas where relatively high levels of radioactivity are located at some distance (1 to 2 ft) below the sediment surface.

Cesium-137, which is a gamma-emitting, particle-reactive radionuclide, will be used as an indicator of sediment contamination. Sediment core samples will be sectioned according to depth and analyzed for radionuclides and for organic and inorganic contaminants. Results of chemical analyses of core sections will be used to make inferences about the release of various contaminants and also to determine if co-contamination is common (i.e., if the presence of one contaminant reliably predicts the presence of one or several others). If ^{137}Cs reliably co-occurs with other particle reactive contaminants (e.g., PCBs), gamma scans will provide a rapid and inexpensive screening for PCB hot spots. Because there is relatively little information on the transuranic radionuclides in WOL, emphasis will be placed on obtaining measurements on these radionuclides. Results obtained from the analyses of the sediment

cores will also be compared with previous data to verify the existence of contaminants that have been identified in previous studies.

Sediment sampling in WOL will be an iterative process. Ecological and health risk screening will be conducted on existing data while initial sediment core samples are collected and analyzed. The conservative approach to screening will identify contaminants that should have a low priority for further analyses and data acquisition, whereas nonconservative screening will identify contaminants that should have highest priority for further evaluation and/or remediation. Comparison of the results of the screening analyses with data from the sediment cores will help establish a reduced list of contaminants for analyses in subsequent sediment samples. A statistically designed sediment sampling plan will then be implemented to characterize the contamination in WOL and to provide data (e.g., modeling parameters) that can be used in the ecological and human-health risk assessment for WOL and the other aquatic environments associated with the WAG 2 RI.

Sediment data from WOCE were included in the preliminary screening analysis for the Clinch River RFI (Hoffman et al. 1990), and additional sediment samples were recently collected and are now being analyzed (Sect. 6.5). These data will be evaluated to determine whether additional data are needed for the embayment to complete an ecological and health risk assessment for the WAG 2 RI.

10.4.6 Floodplain Soils

Floodplain soils have been contaminated by water and sediment from adjacent creeks and from erosion and deposition from upgradient WAGs; however, little is known of the nature and extent of contamination. The objectives for a prescreening collection and analysis of soil samples are:

1. to identify discrete areas of contamination (hot spots) that may pose a health risk,

2. to identify hot spots in erosion-sensitive locations (i.e., areas subject to erosion in a flood of about 5-year recurrence),

3. to qualitatively identify the contaminant and drainageways below WAGs surrounding WAG 2, and

4. to begin to examine the downgradient movement of contaminated soils from areas where soil contamination is known to exist.

To identify contaminant hot spots, a surface radiological investigation of selected areas will be performed. Emphasis will be placed on increasing the resolution of large-scale information rather than pinpointing small spots of a few square meters. The investigation will consist of a walkover survey of gamma radiation exposure rates and limited direct sampling of soils. Areas will be selected on the basis of available aerial survey data and available information on contaminated tributaries, springs and seeps. The aerial survey of September-

October 1986 (Fritzche 1987) (Fig. 10.1) shows about nine local areas with maximum gamma emissions relative to surrounding areas. These locations are roughly 180 m^2, and it seems reasonable that a fourfold increase in linear resolution should be possible; therefore, the goal is to identify hot spots of about 45 m^2 surface area. Soil sample collection will emphasize the collection of shallow (<10 cm) samples composited over an area of similar size for determination of alpha contamination below known or suspected alpha sources (e.g., HFIR/TRU settling ponds and the Intermediate Pond site). About 5 to 15 samples will be collected and analyzed.

As a prescreening activity, about 5 to 15 samples will be collected for metals and PCBs analysis. Where deemed reasonable, samples collected for radiological analysis will be used. Methods for compositing samples and the scale of investigation will be established on the basis of the needs of the risk assessment component prior to sample collection. Possible correlations among contaminants will be investigated.

Several future objectives have been tentatively identified.

1. Perform mapping and characterization of the WAG 2 soils. Soils of the entire ORR are being mapped, parcel by parcel. Mapping of the WOC floodplain should be scheduled early in order to provide input to subsequent investigations. The effort will also serve to delineate the boundary of WAG 2, which will be essential for site characterization and identification and evaluation of corrective measures.

2. Use a multitiered approach to identify erosion-sensitive areas. Initial emphasis should be placed on areas downgradient of known source areas in surrounding WAGs and in WAG 2. Conduct field inspections of channel and hillside erosion. Communicate with the ORNL Environmental Compliance group to be aware of activities in adjacent areas that may lead to soil erosion. Beginning with Universal Soil Loss Equation applications and USDA Soil Conservation models, map potentially sensitive areas.

3. At contaminated sites (e.g., the Intermediate Pond site near WAG 4), determine total contaminant inventories by sampling, analyzing and mapping the results. Available data will be reviewed and used in order to minimized new sampling. Physical characteristics (grain size, sorption capacity) will be determined concurrently. By means of three-dimensional imaging software, volumes of distributed contaminants will be determined.

4. Employ geostatistics in development of the sampling plan and data analysis.

5. Develop correlations between contaminants so that it may be possible to develop a hierarchical list of analytes for screening studies to reduce analytical costs.

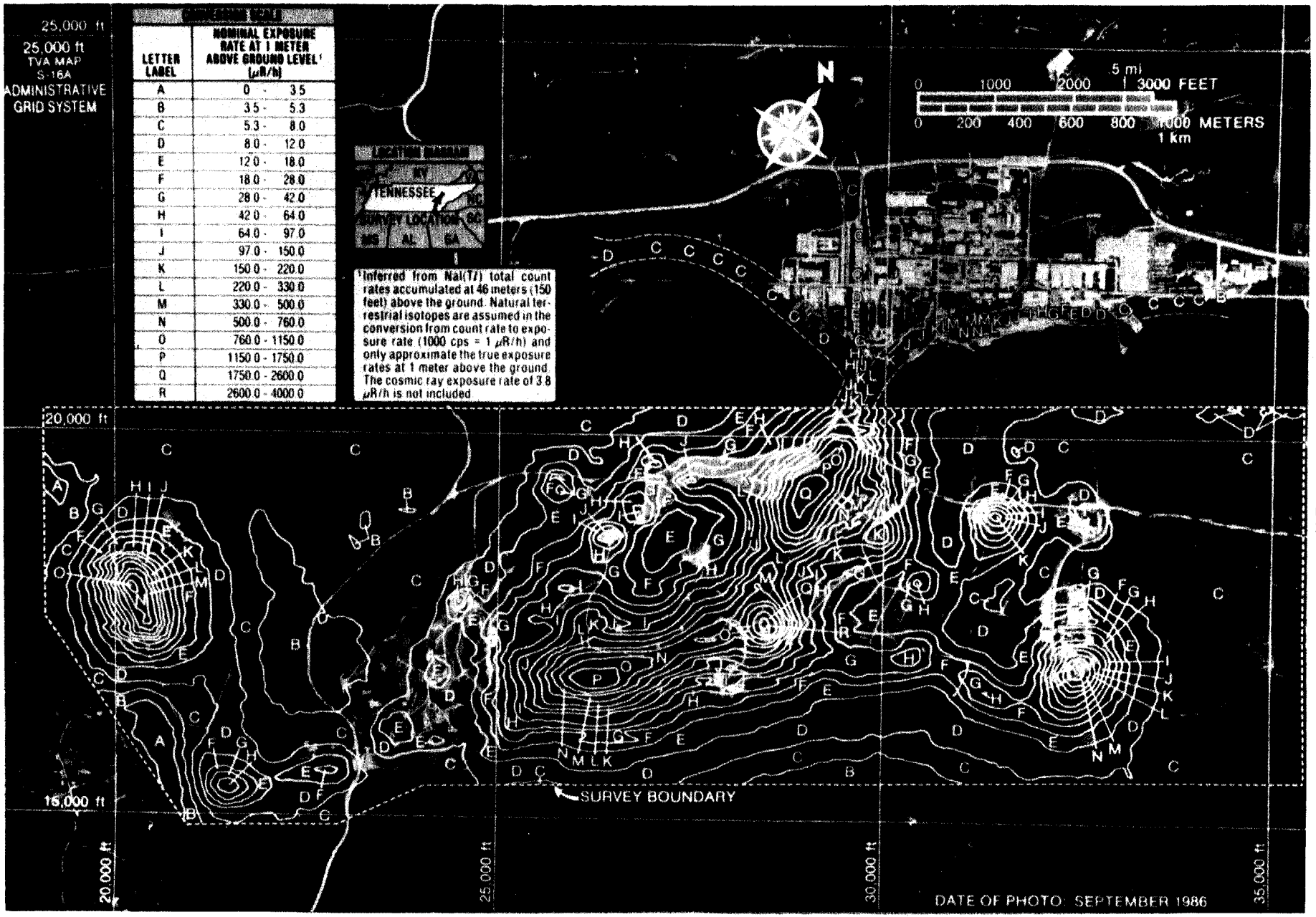

Fig. 10.1. Airborne survey of terrestrial gamma exposure rates derived September- October 1986 of the White Oak Creek floodplain (Source: Fritzche 1987).

10.4.7 Other Compartments

For many other environmental compartments and system properties we either had sufficient information to conduct the preliminary contaminant screening or had not reviewed enough of the existing information to propose interim scoping-level activities. These components will be addressed in the Phase 1 sampling plan to be presented in the next iteration of this plan.

10.5 SAMPLE COLLECTION AND DATA MANAGEMENT

Detailed methods for sample collection, sample tracking, sample analysis, QA/QC, and records management will developed prior to sample collection. The general QA/QC plan (Sect. 12) and the Data Management plan (Sect. 13) have been presented. Other components will be presented in future addenda to the WAG 2 RI Plan.

11. PROJECT ORGANIZATION AND MANAGEMENT PLAN

The DOE and Energy Systems management structure for the Environmental Restoration Program at Oak Ridge and the position of the WAG 2 RI project in that organizational structure is shown diagrammatically in Fig. 11.1.

The WAG 2 RI staff organization is summarized in Fig. 11.2. The WAG 2 RI staff and summaries of their credentials and specific areas of expertise are listed in Appendix F. Functional responsibilities for project activities are listed below.

11.1 PROJECT MANAGER

The project manager is the principal project contact between the WAG 2 RI project staff, the Energy Systems ER Program, and DOE. This position holds primary responsibility for technical, financial, and scheduling matters. Specific duties of the WAG 2 RI project manager are to:

- ensure excellence in meeting the goals and objectives of the WAG 2 RI in a timely and cost-effective manner;
- provide project planning, coordination, and supervision;
- assign duties to the project staff and orient the staff to the needs and requirements of the project;
- allocate resources to facilitate achievement of project objectives and requirements;
- provide budget and schedule control;
- evaluate project staff training and performance;
- coordinate preparation of the RI General Document and Work Plan;
- obtain DOE, EPA and TDHE approval for proposed variances to any of the support plans, if required;
- obtain Quality Assurance Specialist (QAS) approval for proposed QA variances to the support plans, if required;
- approve Corrective Actions, Nonconformance Reports, Quality Investigations, and Quality Event Reports;
- review subcontract work and approve subcontract invoices;

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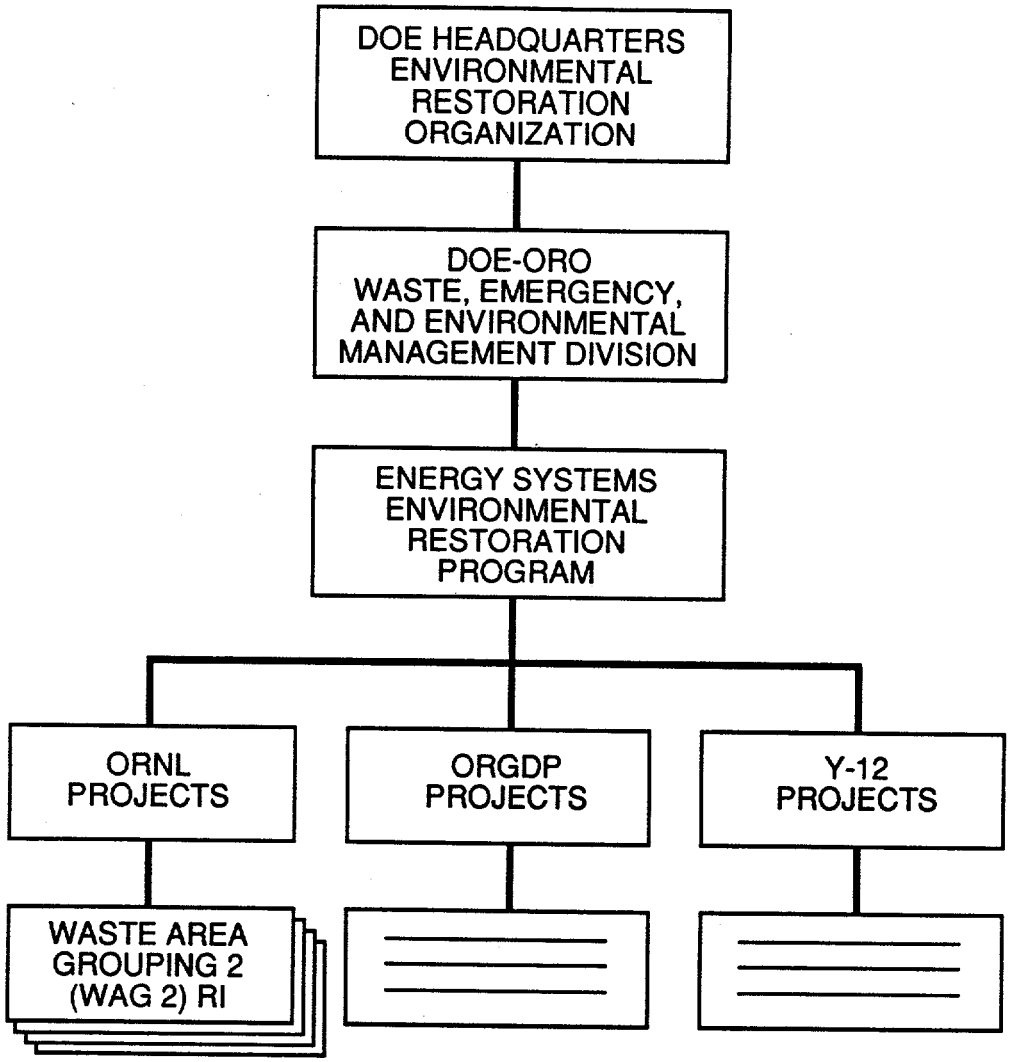

Fig. 11.1. Organizational structure for the WAG 2 RI project.

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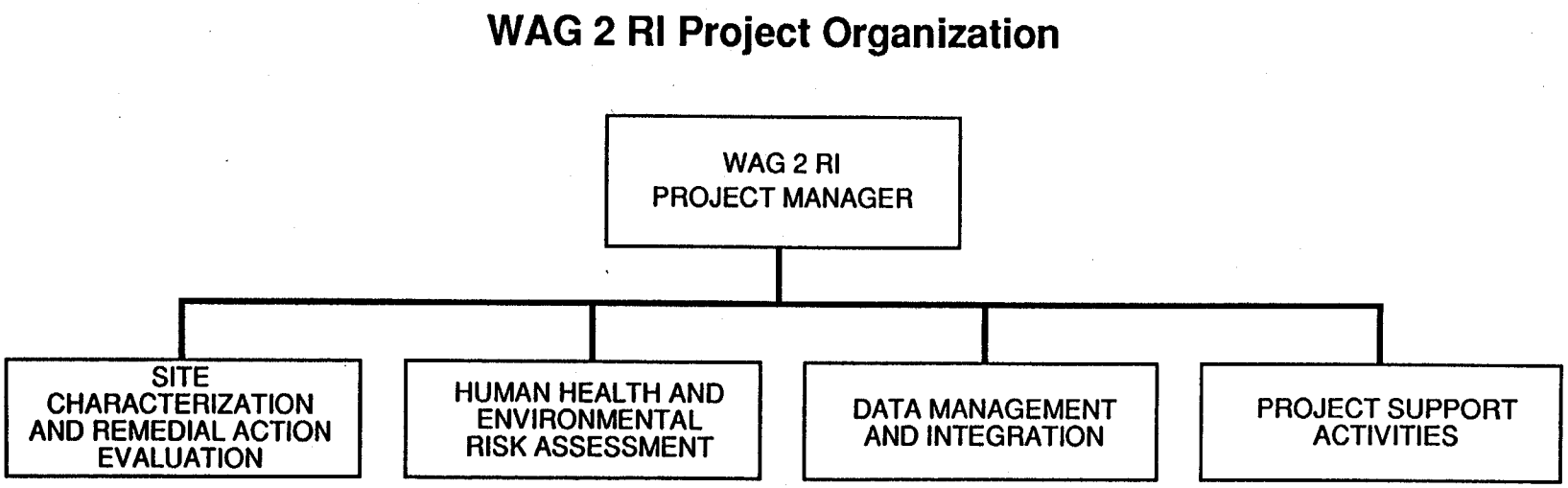

Fig. 11.2. WAG 2 RI staff organization.

- establish and maintain project files and submit materials to the Records Control Database (RCDB);
- identify all record items and forward them to the RCDB;
- ensure that field records and raw data submitted by WAG 2 RI investigators are safeguarded in secure project files and approved for inclusion in the Numeric Data Base (NBD) and the RCDB;
- review the RCDB for completeness;
- approve access to data and information in the NDB and RCDB;
- ensure that project reports and submissions are reviewed for technical accuracy and completeness; and
- ensure that project milestones and deliverables are achieved and submitted according to the project schedule.

11.2 TASK LEADERS

Task leaders are responsible for integrating available information and collected data to meet the objectives and requirements of their specific tasks. Responsibilities of the task leaders include the following:

- assist the project manager in achieving the goals and objectives of the WAG 2 RI project;
- assist in project management and provide the project manager with project progress reports;
- provide input and review for the WAG 2 RI Plan;
- supervise and review subcontractor activities as appropriate;
- maintain records in accordance with the Data Management Plan;
- provide final validation of field and analytical laboratory data, review of data for completeness, documentation, procedures, and consistency with known physical-chemical principles;
- resolve any technical questions concerning the data; and
- implement appropriate staff training and ensure that all project staff comply with project QA/QC, health and safety, waste management, and data management requirements.

Specific responsibilities for individual task leaders are listed below.

Site Characterization Task Leader

The site characterization task leader is responsible for coordinating efforts for site characterization, coordinating the fate and transport modeling efforts, and evaluating CM/RAs. These responsibilities include defining the nature, distribution, and extent of contamination in the WOC system and coordinating monitoring activities and data exchange with programs and investigations for areas (WAGs) contributing contaminants to the WOC system and with the Clinch River RFI. (The Clinch River is the receptor of contaminant releases from the WOC system.) The task leader is also responsible for providing these data in support of the human health and environmental risk analyses.

The site characterization task leader has responsibility for facilitating interactions among the WOC system modeling team, and for modeling efforts in the Clinch River.

The site characterization task leader will cooperate with the risk assessment task leader in the identification and preliminary evaluation of potential CM/RA alternatives.

Risk Assessment Task Leader

The risk assessment task leader has responsibility for quantifying any risks to human health and the environment resulting from off-site contamination and for employing risk analysis to help focus data collection efforts. The responsibility for risk assessment will be divided between coleaders for human-health and environmental risk.

Data Management and Integration Task Leader

The data management and integration task leader has responsibility for management of project data and for input of information into a facility-wide, cross-program data management system (Oak Ridge Consolidated Database). This leader maintains a linkage with data generated by activities related to the WAG 2 RI. Additional responsibilities include providing and maintaining digitized base maps with contours covering the reservation and the surrounding area. Duties specific to the data management and integration task leader are:

- prepare and implement the Data Management and QA/QC plans;
- monitor chain-of-custody forms, Corrective Actions, Nonconformance Reports, and variances;
- ensure proper management of all records, data, and documents generated during the project;
- ensure that submitted data are encoded and entered correctly into the NBD and RCDB; and
- assist with the manipulation, analysis, assessment, display, and output of verified data.

Field Sampling and Analysis Coordinator

The field sampling coordinator is responsible for all field sampling and analysis activities. Designated responsibilities are to:

- organize and coordinate all field sampling and analysis activities through field sampling team leaders so that all required data are available within an acceptable time frame; and

- ensure that all sampling and analytical activities and data collection meet the objectives of the WAG 2 RI staged approach with regard to data requirements for site characterization, risk assessment, and identification and preliminary evaluation of CM/RA alternatives.

Modeling Team Leader

The modeling team leader coordinate modeling activities related to the fate and transport of contaminants in the WOC system. In conjunction with the site characterization task leader, the modeling team leader will interact with personnel involved with the Clinch River RFI to evaluated historic contaminant releases from the WOC system, and to predict future releases and movement under various CM/RA scenarios.

Statistical Support Team

The statistical support team will provide appropriate statistical design for sample collection to ensure an adequate representation of contaminant concentration , distribution, and movement. This team will interact with the risk assessment team to guide data collection towards reducing uncertainty in risk analysis. This team includes environmental scientists who are well versed in statistical methods, sensitivity analysis, uncertainty analysis, and other areas that relate directly to sampling design. These environmental scientists will be supported by statisticians from the Statistical Design Group of the ORNL Mathematics and Engineering Physics Division.

11.3 SAMPLING TEAM LEADERS

Sampling team leaders are responsible for the management and coordination of specific field sampling teams. General responsibilities of the sampling team leaders are to:

- coordinate and supervise field sampling activities, and ensure that all sampling activities have been approved by the statistical support team;

- provide input and review for the WAG 2 RI Plan;

- coordinate activities with project management;

- provide orientation, hazard information, and training to technical staff, based on the requirements of the support plans;
- ensure that field-related activities are performed correctly and documented as required by the support plans;
- review daily entries in the field logbooks and maintain field records management system in accordance with the Data Management Plan;
- perform initial validation of all field and analytical data, prior to data transfer;
- transfer custody of original field notes to the project manager;
- transfer custody of original field data to the Analytical Services Coordinator (ASC);
- initiate procedural variances and maintain a log on particular variances, as necessary;
- ensure sample custody until transferred to the ASC.
- ensure that chain-of-custody and request-for-services forms are properly completed and cross-referenced prior to transfer of sample custody;
- receive custody of sample results from laboratory supervisors;
- submit laboratory results to the K-25 Plant Data Entry and oversee manual entry of data by Data Entry staff;
- transfer results from the K-25 Plant Data Entry to respective task leaders;
- provide field implementation of the health and safety (H&S) plan, including communication of requirements to all personnel and field supervision and ensure that site personnel adhere to the site safety requirements;
- inform the project H&S coordinator of any changes in sampling plans so that they may be appropriately addressed; and
- ensure that Corrective Actions and Nonconformance Reports are initiated, if necessary.

For some task components samples will be collected as part of ongoing programs in the WOC system (Sect. 4). In those cases the team leaders responsibility is data acquisition rather than sample collection. Specific responsibilities for individual sampling team leaders are given below.

11.3.1 Hydrology and Water Chemistry Field Team Leader

The hydrology and water chemistry field team leader is responsible for the acquisition of hydrologic data and acquisition of water chemical data including the collection of samples

where necessary. The leader is also responsible for the quality and technical adequacy of work accomplished in the Water Processing Laboratory. Additional responsibilities include cooperation with the modeling team to develop hydrologic and contaminant transport models for the system.

11.3.2 Floodplain Soil and Groundwater Field Team Leader

The floodplain soil and groundwater field team leader is responsible for collection of soil samples from the WOC system floodplain and the acquisition of groundwater data from the WOC system and adjacent areas. The leader is also responsible for the quality and technical adequacy of work accomplished in the Soil Processing Laboratory.

11.3.3 Sediment Team Leader

The sediment field team leader is responsible for collecting sediment samples from the aquatic environment. The leader is also responsible for the quality and technical adequacy of work accomplished in the Sediment Processing Laboratory.

11.3.4 Biota Field Team Leader

The biota field team leader is responsible for collecting biological samples from the aquatic and terrestrial environment. The leader is responsible for preparation and review of proposed variances to the supporting documents.

11.4 OTHER STAFF

11.4.1 Sample Custodians

The sample custodians will maintain custody of samples. Sample custodians will be required to follow the chain-of-custody procedures given in the WAG 2 RI Plan. General responsibilities are to:

- maintain integrity of samples during collection, transport, processing or storage;
- provide initial tagging, identification, and care of field samples; and
- ensure proper completion and cross-referencing of chain-of-custody and request-for-services forms.

Staff from both the sampling teams and laboratories may assume the role of sample custodian during sample collection, processing, analysis, and storage.

11.4.2 Technical Staff

The technical staff are responsible for conducting field and laboratory activities to achieve the objectives of the WAG 2 RI. Technical staff responsibilities are to:

- collect field samples and perform field and laboratory analyses according to prescribed standard operating procedures at the sampling team leader's direction;
- prepare samples for analysis;
- prepare requests for analytical services and chain-of-custody forms;
- maintain proper sample documentation and sample chain-of-custody;
- safeguard record materials including, but not limited to, field notebooks, raw data sheets, and chain-of-custody forms;
- maintain complete, factual, detailed, and objective program notes;
- retain records of all analyses and procedures used for the WAG 2 RI;
- ensure that proper waste management procedures are followed; and
- ensure that the requirements of the S&A, QA/QC, Data Management and H&S plans are satisfied;

Technical staff will consist of individuals who have the appropriate training and who are qualified to conduct the activities specified in the WAG 2 RI Plan (See Appendix F).

11.4.3 Analytical Services Coordinator

The WAG 2 RI analytical services coordinator (ASC) is responsible for all aspects of custody and transfer of samples and results among the sampling teams and analytical laboratories. The ASC is the main contact for the laboratories concerning chain-of-custody and requests-for-services. ASC duties involve the:

- reviewing of the General RI, QA/QC, and Data Management plans;
- contributing to and reviewing the S&A Plan;
- preparating and reviewing the H&S Plan;
- establishing and maintaining a chain-of-custody and requests for services forms control system. Numbered forms will be used to cross-reference custody and request-for-services and for sample tracking;
- receiving chain-of-custody samples from the field crews and transfering to analytical laboratories;
- ensuring that chain-of-custody and request-for-services forms are properly completed and cross-referenced prior to transfer of sample custody;

- ensuring that corrective actions and nonconformance reports are initiated, if necessary;
- reviewing the variances to any of the support plans, if required;
- overseeing manual entry of field data by the K-25 Plant Data Entry staff; and
- overseeing final disposal of samples.

11.4.4 Analytical Laboratory Supervisors

The analytical laboratory supervisors are responsible for supervising laboratory personnel and maintaining the integrity of samples analyzed and data generated for the WAG 2 RI. Laboratory supervisors responsibilities are to:

- provide orientation, hazard information and necessary training to technical staff, based on the requirements of the S&A, QA/QC, Data Management and H&S plans;
- ensure laboratory implementation of the H&S plan;
- inform the project H&S coordinator of any changes in procedures so that they may be appropriately addressed;
- maintain and execute internal laboratory QA/QC procedures, providing these procedures to WAG 2 RI project management and regulators as requested;
- perform routine QA checks of sample handling procedures, methods of analysis, QA data, and sample analysis results before releasing data reports and the results of QA checks to team leaders;
- maintain copies of data until results are verified;
- transfer custody of data reports to team leaders; and
- report any laboratory deficiencies and subsequent corrective actions to WAG 2 RI management.

11.4.5 Quality Assurance Specialist

The quality assurance specialist (QAS) is the official contact for QA matters relevant to the WAG 2 RI project and is independent of the WAG 2 RI staff. The duties of the QAS are to:

- actively identify and respond to QA/QC needs, resolve problems, and answer requests for guidance or assistance in complying with the QA/QC Plan;

- review, evaluate, and approve quality-related aspects of and variances to the support documents where technically competent;
- ensure that quality aspects of training, field sampling, and chain-of-custody activities meet WAG 2 RI plan requirements;
- schedule and perform internal audits and surveillances to ensure compliance with requirements and procedures specified by the support plans;
- prepare and approve Quality Investigation and Quality Event Reports;
- approve corrective actions and NCR; ensure that Corrective Actions are taken for any nonconformance, as required for all aspects of the WAG 2 RI; and
- prepare and submit project QA/QC reports summarizing audit and surveillance activities to WAG 2 RI project management.

11.4.6 QA/QC Coordinator

The WAG 2 RI QA/QC coordinator is the intermediary between the WAG 2 RI sampling team personnel and the QAS. Responsibilities of the QA/QC coordinator are to:

- review QA/QC, H&S and S&A plans and chain-of-custody procedures;
- instruct WAG 2 RI personnel on the chain-of-custody and sample labeling procedures, as necessary;
- verify that methods specified are appropriate for obtaining data of known quality and integrity;
- conduct field and laboratory evaluations of sampling methods and analytical procedures to ensure that procedures adhere to chain-of-custody requirements;
- review field QC sample results to ensure that field measurement and sampling protocols have been followed;
- report the results of these reviews to the QAS for forwarding to the project manager; and
- ensure that all Corrective Actions, Nonconformance Reports, and variance activities are initiated, if necessary.

11.4.7 Health and Safety Coordinator

The health and safety coordinator is responsible for ensuring that site personnel adhere to the site health and safety requirements. Duties of the H&S coordinator are to:

- review S&A and QA/QC plans;
- develop, coordinate, and implement the H&S plan;
- revise the H&S plan as warranted by changed site conditions;
- approve all variances to support documents or the WAG 2 RI Work Plan that are relevant to H&S, as required; and
- ensure that all WAG 2 RI personnel adhere to H&S requirements.

Agency liaison on matters relating to H&S is handled by the project manager with the assistance of the H&S coordinator. During field work, the sampling team leaders will normally assume the responsibilities of the H&S coordinator.

11.4.8 Subcontractor Activities

The selection of qualified subcontractors will be done according to the ORNL Procurement and Quality Assurance Procedures. Subcontractors, such as analytical services, surveyors, and environmental monitoring specialists, must meet predetermined qualifications developed by the project manager, as defined in the procurement bid packages. Each subcontractor bid submittal is reviewed by technical, purchasing, and QA personnel to ensure that the bidders are qualified and can satisfy bid requirements. Subcontractors involved in environmental measurements will be monitored by the sampling team leaders to ensure compliance with the WAG 2 RI Plan.

11.4.9 Qualifications and Training of Personnel

All ORNL and subcontractor personnel working on the WAG 2 RI will be properly trained and qualified individuals. To ensure this, prior to commencement of work, all sampling team personnel will be given instructions specific to the remedial investigation, covering the following areas:

- organization and lines of communication and authority;
- description of the WOC system;
- overview of the S&A, QA/QC, H&S, and Data Management plans;
- documentation requirements;
- personal protection procedures;
- waste management procedures;
- decontamination procedures; and

- emergency procedures.

Training of field personnel will be provided by a sampling team leader. All training will be documented and certified.

11.4.10 Waste Management

All waste generated as a result of WAG 2 RI activities will be segregated as to type and disposed of following Laboratory procedures in accordance with RCRA requirements and ORNL Environmental Protection requirements. Conventional waste shall be sent to the sanitary waste landfill. Glass items will be cleaned and placed in special containers for disposal. Procedures for the disposal of radioactive and mixed (radioactive plus other hazardous waste) are provided in the *ORNL Environmental Protection Manual.*

12. QUALITY ASSURANCE/QUALITY CONTROL PLAN

12.1 INTRODUCTION AND PROJECT DESCRIPTION

This Plan supports the WAG 2 RI. The QA/QC plan defines procedures to be followed in the collection and analysis of data used in the WAG 2 RI program. These procedures are intended to ensure that results achieve the QA/QC goals established for the WAG 2 RI. They are also intended to minimize field measurement errors, analytical errors, and errors occurring in data transfer and management. The mechanisms employed to ensure quality are:

- prevention of defects in quality through planning and design, documented instructions and procedures, and careful selection of personnel;
- assessment through regular audits and surveillances to supplement continual informal reviewed; and
- permanent correction of conditions adverse to quality.

This plan describes the QA program and the QC procedures to be implemented by the WAG 2 RI.

Data produced by the WAG 2 RI program will be used to meet the RI objectives given above. The methods used to meet these objectives are described in the WAG 2 RI Plan (Sects. 1—11).

This QA/QC plan is designed to comply with QAMS-005/80 and ANSI/ASME NQA-1 guidelines. EPA QAMS-005/80 (EPA 1980a) contains EPA's guidance for project QA/QC plans. ANSI/ASME NQA-1 (ANSI/ASME 1986) has been adopted as the main QA/QC standard. This project falls under both RCRA and CERCLA regulation; therefore, this project QA plan is subject to OSWER Directive 9502.00-6C (EPA 1987a), OSWER directive 9355.0-76 (EPA 1987b), and OSWER Directive 9355.3-01 (EPA 1988b). This plan is structured around the QAMS-005/80 guidelines (EPA 1980a), but Table 12.1 cross-references the NQA-1 requirements with the contents of this plan. This project has a category I QA rating (Roberson and Logsdon 1989) because of the QA programs imposed by regulatory agencies. The NQA-1 Modular Profile (Table 12.1) shows the relationship between the elements of this plan, those of the ORNL QA Program, and the procedures of the Environmental Sciences Division QA Program (Roberson and Logsdon 1989).

12.1.1 Project Requirements

All organizations performing tasks for the WAG 2 RI must have a QA plan that meets project requirements. If there is no approved QA plan for the task, then the organization will be required to develop an acceptable plan. It may be necessary to add project-specific attachments such as organization charts, functional responsibility matrixes, and surveillance plans to otherwise adequate plans. WAG 2 RI tasks, responsible organizations, and QA plans are listed in Table 12.2.

Table 12.1. Modular Profile and cross-reference of EPA QAMS-005/80 and NQA-1 elements[a].

EPA QAMS-005/80 ELEMENT[b]	NQA-1 ELEMENT[c]	ORNL QA PROCEDURES	ORNL-ESD PROCEDURES[d]
1. Title Page	6. Document Control	QA-L-6-100	QA-ES-6-100 QA-ES-6-101
2. Table of Contents	6. Document Control	QA-L-6-100	QA-ES-6-100 QA-ES-6-101
3. Project Description	2. QA Program	QA-L-2-100 QA-L-2-101 QA-L-2-103 QA-L-2-104 QA-L-2-105 QA-L-2-106	QA-ES-2-100 QA-ES-2-101 QA-ES-2-102 QA-ES-2-103
	6. Document Control	QA-L-6-100	QA-ES-6-100
4. Organizational Responsibility	1. Organization	QA-L-1-100	QA-ES-1-100
5. QA Objectives for Measurement of data	3. Design Control	QA-L-3-100 QA-L-3-101 QA-L-3-102	QA-ES-3-100
6. Sampling Procedures	3. Design Control	QA-L-3-100 QA-L-3-101 QA-L-3-102	QA-ES-3-100
	6. Document Control 9. Control of Processes	QA-L-6-100 QA-L-9-100	QA-ES-6-100 QA-ES-9-100
7. Sample Custody	13. Handling Storage & Shipping	QA-L-13-100	QA-ES-13-100
	6. Document Control	QA-L-6-100	QA-ES-6-100
8. Calibration Procedures and Frequency	8. Identification and Control of Items	QA-L-8-100	QA-ES-8-100
	12. Control of Measuring & Test Equipment	QA-L-12-100	QA-ES-12-100
9. Analytical Procedures	9. Control of Processes	QA-L-9-100	QA-ES-9-100
10. Data Reduction Validation and Reporting	3. Design Control	QA-L-3-100 QA-L-3-101 QA-L-3-102	QA-ES-3-100
	8. Identification and Control of Items	QA-L-8-100	QA-ES-8-100

Table 12.1. (continued)

EPA QAMS-005/80 ELEMENT[b]	NQA-1 ELEMENT[c]	ORNL QA PROCEDURES	ORNL-ESD PROCEDURES[d]
11. Internal QC Checks and Frequency	3. Design Control	QA-L-3-100 QA-L-3-101 QA-L-3-102	QA-ES-3-100
12. Performance Audit and Frequency	18. Audits & Surveillances	QA-L-18-100 QA-L-18-101 QA-L-18-102	QA-ES-17-100
13. Preventive Maintenance Procedures	12. Control of Measuring & Test Equipment	QA-L-12-100	QA-ES-12-100
14. Statistical Assessment of Data Quality	3. Design Control	QA-L-3-100 QA-L-3-101 QA-L-3-102	QA-ES-3-100
15. Nonconformances & Corrective Action Procedures	18. Audits & Surveillances	QA-L-18-100 QA-L-18-101 QA-L-18-102	QA-ES-17-100 QA-ES-17-101 QA-ES-17-102
	15. Control of Nonconforming Items	QA-L-15-100	QA-ES-15-100
16. QA Reports to Management	2. QA Program		
	16. Corrective Action	QA-L-16-100	QA-ES-15-100
17. Other QA/QC Measures to Meet NQA-1 Guidelines	4. Procurement Document Control	QA-L-4-100 QA-L-4-101	QA-ES-4-100
	5. Instructions Procedures & Drawings	QA-L-5-100	QA-ES-5-100
	7. Control of Purchased Items and Services	QA-L-7-100 QA-L-7-101 QA-L-7-102	QA-ES-7-100
	10. Inspection	QA-L-10-100	QA-ES-10-100
	11. Test control	QA-L-11-100	QA-ES-11-100
	14. Inspection Test & Operating Status	QA-L-14-100 QA-L-14-101	QA-ES-14-100
	17. Quality Assurance Record	QA-L-17-100	QA-ES-16-100
	19. Software	QA-L-19-100	QA-ES-18-100

[a]Subject to final Approval.
[b]EPA 1980a, number correspond to sections of this plan.
[c]ANSI/ASME 1986.
[d]Reference Roberson and Logdson, 1989.

Table 12.2. WAG 2 RI project quality assurance plan matrix.

Project Description: WAG 2 RI Plan

Task/Activity	Responsible Organization(s)	QA Plan Title/QAP No.
RI of contaminants present in WOC System from DOE Oak Ridge Reservation	WAG 2 RI Project Manager (this plan)	WAG 2 RI QA/QC Plan
Analytical laboratory QA/QC plans will be included later		

12.1.2 Quality Assurance Awareness and Training

All WAG 2 RI personnel will be evaluated in their roles to ensure the quality of the RI, QA awareness will be addressed by information sessions and distribution of the project QA plan. The QA coordinator will be responsible for conducting the sessions and distributing the plans. This plan has been developed to include interpretations and descriptions of how OR facility policies are to be incorporated into the WAG 2 RI QA plan, as well as how this plan addresses the needs and problems of the WAG 2 RI. All WAG 2 RI personnel will attend briefing sessions or otherwise obtain information describing this project's QA plan. Receipt of information shall be documented by attendance and document sign-out sheets.

12.2 QA OBJECTIVES FOR MEASUREMENT OF DATA

This section implements applicable regulatory requirements and provides internal control and review so that the data are scientifically sound and legally defensible.

QA objectives for data are that:

- scientific data generated will withstand scientific scrutiny;
- data will be gathered using appropriate procedures for field sampling, chain-of-custody, laboratory analyses, and data reporting; and
- data will be of known precision and accuracy.

The QA requirements for the WAG 2 RI are defined above. The procedures to be used for assessing the quality of field and analytical laboratory data are described in Sect. 12.6. Analytical laboratories selected for this project must meet criteria for laboratory certification and adherence to regulator QA requirements.

12.2.1 Level of Analysis

The specific QA objectives for all data are to obtain reproducible, precise, and accurate measurements consistent with the intended use of the data and the limitations of the sampling and analytical procedures used. This is accomplished through the assignment of measurement tasks to the appropriate analytical level (I—V), as defined in *Data Quality Objectives for Remedial Response Activities* (EPA 1987c). Table 12.3 gives the analytical level to which WAG 2 RI measurement tasks have been assigned.

12.2.2 Data Quality Parameters

Typical quantitation limits applicable to this project are presented in either the *Test Methods for Evaluating Solid Waste* (SW-846, EPA 1986c) or the EPA Contract Laboratory Program statements of work (EPA 1986d, 1987d), as applicable, as are sample precision, accuracy, and completeness objectives. The QA objectives for QC data are designed to screen out data of unacceptable precision or accuracy and to provide data that will meet the data quality goals for this project.

This project will follow the definitions for precision, accuracy, completeness, comparability, and sensitivity given in the *Handbook for Analytical Quality Control in Water and Wastewater Laboratories* (EPA 1979a).

12.2.2.1 Field activities

Precision among monitoring instruments is determined by comparison of readings during calibration to a standard. Precision in sampling is measured through the use of field duplicates.

Accuracy is addressed by the use of standard criteria for container and equipment cleaning, sample collection, personnel training and performance criteria, uniform sample handling techniques, and blanks to detect contamination.

Representativeness of samples collected is controlled through adherence to the sampling plan and to detailed descriptions of sampling procedures which will be included in the final WAG 2 RI Field Sampling and Analysis Plan (Sect. 10).

The QA completeness objective for this project is to obtain valid, analytical results for at least 95% of the samples collected during the project. This means that completeness of sample collection (number planned versus number collected for which valid data can be

Table 12.3. QA/QC levels to which WAG 2 RI measurement tasks have been assigned[a].

Parameter[b]	Analytical Level[c]	Media
^{3}H	III	water
^{137}Cs	IV	sediment, water
^{90}Sr	IV	sediment
^{99}Tc, $^{239,240}Pu$, ^{241}Am ^{244}Cm, and ^{238}U	IV	biota, sediment, water
Total metals	IV	biota, sediment, water
Dissolved metals	IV	water
Organics	IV	biota, sediment, water
Alkalinity and hardness	IV	water
Temperatures	II	water
pH	II	water
Dissolved oxygen	II	water
Conductivity	II	water
Oxidation-reduction potential	I	water
Water flow rate	II	water
Secchi transparency	I	water
Chlorophyll-a	III	water
Total suspended particles	III	water
Turbidity	III	water

[a] Subject to final review.

[b] For field analyses, all data are collected in situ for real-time site characterization. Number of measurements will depend upon local environmental conditions.

[c] Analysis level from Kimbrough et al. (1988) ESP-700 Sect. IV.

obtained) must be essentially 100% to allow for some laboratory wastage. Accountability of samples collected, from field to final disposal, must be 100% complete.

Objectives for comparability between samples are meet by the following: (1) narrowly defined sampling methodologies; (2) site surveillance and use of standard sampling devices and monitoring devices; (3) training of personnel; (4) documentation of sampling point; (5) stringent control limits for the daily QC checks; and (6) reporting results in appropriate, comparable units.

Procedures to attain sensitivity objectives include (1) uniform training and certification for staff; (2) standard provisions for inspection, maintenance, and repair; (3) provision of standard operating procedures (SOPs) to technical staff; (4) reference of SOPs in the S&A Plan; and (5) field inspections by the QA/QC coordinator to determine compliance with the items specified in the support plans. Procedures regarding measurement and test equipment calibration will be developed and will include appropriate calibration information for each piece of equipment.

Staff responsible for particular instruments must maintain a log of calibration procedures and results that will remain with the instrument as a means of establishing a record of calibration. The sampling team leaders will inspect such logs, which will become part of the project records. Each operator must be trained in the proper use of the instrument, be familiar with the instrument's use, and be able to properly interpret data from the instrument.

12.2.2.2 Laboratory activities

The QA objectives for precision and accuracy in the Laboratory are defined by control limits established by the EPA Contract Laboratory Program (CLP) (EPA 1986d, 1987d). The Laboratory will be required to submit the results of all control sample analyses to the WAG 2 RI ASC to ensure conformance with established control limits and other QA requirements.

The QA completeness objective for this project is to obtain valid analytical results for at least 95% of the samples collected. Laboratory completeness will be determined by the extent to which data are substantiated by hard-copy documentation, which includes chain-of-custody requests for services and instrument calibration forms. Comparability and sensitivity criteria are established by either CLP (EPA 1986d, 1987d) or SOPs for particular analytical laboratories.

Field procedures for the collection of samples are discussed in the S&A Plan (Sect. 10). The equipment and the techniques that will be employed to obtain representative samples will be in accordance with approved Environmental Surveillance Procedures (ESP-300 series, Kimbrough et al. 1988).

12.2.3 Prevention of Cross-Contamination

Sampling equipment will be decontaminated before use and between each sample per ESP-900 (Kimbrough et al. 1988). Each decontamination activity will be recorded in the field log book.

12.2.4 Sample Identification

The identification of samples will be established and maintained as specified by the chain-of-custody procedures described in Sect. 14.3 and will be specifically as described in the final S&A Plan (Sect. 10).

12.2.5 Sample Turnaround Time

Sample analyses will be scheduled according to site investigation needs consistent with the sample holding times. The S&A Plan will be organized to provide a turnaround time that will meet the project schedule and objectives. These requirements shall be included in any contractual agreement between the WAG 2 RI Project and contract laboratories, when possible.

12.2.6 Field Documentation

An integral part of the QA/QC Plan for the field activities will be to maintain accurate and complete field records, including log books and appropriate field data forms. Field log books shall be of hardcover construction with stitched binding and water-resistant pages. Information identified in these records will be obtained from the site exploration and sampling activities and will be reviewed by the sampling team leader. All information pertinent to field activities will be recorded. Entries in the log books or on the data forms will be made in water-resistant ink and will include as a minimum:

- the names and affiliations of field personnel;
- a general description of the day's field activities;
- documentation of weather conditions during the previous 48 hours, as well as current conditions;
- field equipment and instrument number;
- field equipment calibration data;
- field readings from personnel safety instruments; and
- field data measurements such as temperature, secchi depth and turbidity will be recorded on data forms.

Appropriate field-generated data forms will be prepared based on the requirements in the WAG 2 RI Plan. Data to be recorded will include such information as the monitored location (e.g., depth, sampling station, reservoir elevation, and field coordinates) and applicable sample analyses to be conducted.

12.2.7 Shipping and Handling

Handling, shipping, and storage of samples and data resulting from field activities will adhere to custody (Sect. 12.3) and safety procedures (Section 14), and will ensure that sample integrity for analytical purposes is maintained. Specific shipping and handling procedures for each sample medium will be given in the S&A Plan.

12.2.8 Variance System

Procedures that properly anticipate all conditions encountered during a field sampling program cannot be prepared. Variances from approved operating procedures in the WAG 2 RI Plan, the S&A Plan, the QA/QC Plan, or the H&S Plan will be documented in a deviation request form (Fig. 12.1).

The sampling team leaders will initiate and chronologically maintain a variance log. A variance requires the approval of the WAG 2 RI project manager and the QAS before work proceeds. As appropriate, regulatory agencies will be notified of any variances that significantly affect project scope or objectives. Any variances from the H&S Plan must be approved by the H&S Coordinator. Approval by the WAG 2 RI project manager and QAS can be initiated on a verbal basis via the telephone or radio with follow-up sign-off. In no case will non-WAG 2 RI project personnel initiate a variance. Copies of the deviation request forms will be maintained by sampling teams until the fieldwork is complete and will then be forwarded to the WAG 2 RI project manager and sent to the ERD Document Management Center (DMC).

12.2.9 Field Data Management

Field records will be recorded in permanent ink, legible, and sufficiently complete to permit reconstruction of data-gathering activities by a qualified individual (other than the originator) when data are reduced. Field notebook entries should be factual, detailed, and objective. The field records will be the basis for later written reports, and all entries must be free of terminology that might prove inappropriate. The method of data reduction will be identified and recorded. Field-generated data sheets will be collected and reviewed daily for accuracy and completeness by the sampling team leaders before being transferred to the ASC. Manual entry of field data will be coordinated by the ASC. Data entry will enter field data into specified computer systems to facilitate retrieval by WAG 2 RI personnel. Quality will be checked by double entry and verification of entered data. The WAG 2 RI project manager will forward field notebooks to the DMC at the conclusion of field activities.

MARTIN MARIETTA ENERGY SYSTEMS, INC.

DEVIATION REQUEST

DEVIATION NO.
DIVISION

TYPE: ☐ MATERIAL ☐ PART ☐ SYSTEM ☐ ASSEMBLY ☐ OTHER

PROJECT TITLE		PROGRAM
ITEM NAME		SPECIFICATION
DRAWING NO.	SHOP ORDER	WORK/PURCHASE ORDER

DESCRIPTION OF DEVIATION

COST IMPACT

NAME	TITLE	DATE

JUSTIFICATION AND LIMITATIONS

☐ QAA/P REVISION REQUIRED

☐ CHECK IF DRAWING OR DOCUMENT IS TO BE REVISED ☐ DESIGN REQUEST INITIATED

NAME	TITLE	DATE

APPROVED BY:	TASK LEADER	DATE	OTHER	DATE
	LEAD DESIGNER	DATE	OTHER	DATE
	ITEM USER	DATE	QAC	DATE

UCN-5458A
(23 5-86)

Fig. 12.1. Deviation Request Form.

12.2.10 Decontamination of Equipment and Supplies

The guidelines for decontamination of sample containers and sampling devices given in ESP-900 (Kimbrough et al. 1988) will be followed. Specific decontamination procedures are addressed in Sect. 14.9 of the H&S Plan.

12.3 SAMPLE CUSTODY PROCEDURES

Chain-of-custody procedures require documented sample possession from the time of collection to disposal, in accordance with Energy Systems procedure ESP-500 (Kimbrough et al. 1988). Additional details of document control are included in the WAG 2 RI Data Management Plan (Sect. 13). A sample is considered in custody if:

- It is in the sampler's or the transferee's actual possession.
- It is in the sampler's or the transferee's view, after being in his/her physical possession.
- It was in the sampler's or the transferee's physical possession and then he/she secured it to prevent tampering.
- It is placed in a designated secure area.

Sample custody will be initiated at the time of sample collection. Field samples will be identified by sample tags or other appropriate labels with the following information: unique sample identification code, date and time of sampling, sampling location or station, preservation, analysis, and any additional comments that are applicable. Descriptions of sampling activities and sample identification data will also be recorded in a field notebook. Field chain-of-custody forms containing the same information will be completed for each set of samples. A line item on the sample chain-of-custody form will be completed for each sample, and the sampling technician will confirm by signature the completeness of the information on the form. Each individual who assumes responsibility for the samples will sign the chain-of-custody form.

Sample custody will be maintained by WAG 2 RI staff until custody is transferred to the ASC. The ASC delivers samples and transfers custody to particular analytical laboratories where their intra-laboratory chain-of-custody procedures will be in effect. Upon completion of analyses, sample custody will be returned to WAG 2 RI staff. Remaining sample may be archived as directed by the ASC or disposed as prescribed in ESP-1000 (Kimbrough et al. 1988) and the *Environmental Sciences Division Waste Disposal Procedure for Radioactive and Nonradioactive Waste Materials Disposal* (ESD 1986). The chain-of-custody form terminates upon final disposal of the sample. A notation on the form will indicate that the completed form is to be forwarded to the ASC. The WAG 2 RI project manager will be responsible for ensuring that the original chain-of-custody form is submitted to the DMC.

12.3.1 Field Custody Procedures

Field custody procedural activities include the following steps.

- Before sampling begins, the WAG 2 RI QA/QC coordinator will instruct sampling personnel on the chain-of-custody and sample labeling procedures, as necessary.
- A chain-of-custody record will be initiated in the field for each sample, corresponding to the sample identification label.
- Each time sample custody is transferred, the person relinquishing the sample and the new custodian will sign the record, note the date, and indicate the reason for transfer of custody.
- The analyses to be performed for each sample will be recorded on a request-for-analysis form.
- The sampling team leader will confirm that proper custody procedures and report forms were used during the fieldwork and that results were documented in the field log book.
- Samples transferred to analytical laboratories will be recorded in the field log book by the ASC at the end of the collection period.

12.3.2 Sample Labeling

Sample labels or tags will contain sufficient information to identify the sample in the absence of other documentation. The label or tag will be directly affixed to the sample container and will be completed using indelible ink. Labels will include as a minimum:

- project name,
- unique sample number,
- sample location,
- sampling date and time,
- signature of individual collecting the sample,
- preservation method employed, and
- comments regarding sample characteristics.

12.3.3 Laboratory Receipt and Handling of Samples

Upon receipt at the laboratory, each sample identification is compared to the information contained on the included chain-of-custody documents. If discrepancies exist, appropriate notes (signed and dated) will be made on the chain-of-custody document, and the ASC and the contract laboratory programs manager will be notified.

After receipt and initial inspection of samples and accompanying forms, the following items are checked and recorded.

- The seals and tapes on the transportation container are unbroken and uncut.
- The sample containers in the transportation container are intact.
- The identification on the sample bottles corresponds to the entire description on accompanying forms.
- The number of sample containers received is equal to the number of samples listed on the chain-of-custody forms.

In the event that samples arrive damaged or custody seals have been broken, a Nonconformance Report (Sect. 12.11) will be initiated. The project manager and the ASC will be advised, and the ASC will make a decision as to the fate of the nonconforming sample. The WAG 2 RI project manager and WAG 2 RI QAS will sign the Nonconformance Report, noting the reason for sample disposition, and initiate corrective actions if necessary.

Once samples are in the possession of the laboratory, their internal chain-of-custody and sample handling procedures will be in effect. If samples are to be shipped from one laboratory to another, proper chain-of-custody and packaging procedures will be maintained. Preanalysis sample storage procedures used are described in the CLP Statement of Work (EPA 1987d). Anticipation of reanalysis requires proper environmental control of samples following analysis. Samples requiring refrigeration will remain refrigerated for 3 months unless prior arrangements have been made by the WAG 2 RI project manager. Unused sample portions will be archived. If reanalysis is not anticipated, environmental conditions are not observed, and the samples are stored at room temperature. Sample residues will be disposed of by contractor laboratories in accordance with ESP-1000 (Kimbrough et al. 1988), *ESD Waste Disposal Procedure, Radioactive and Non-radioactive Waste Materials Disposal* (ESD 1986), or other EPA-approved procedures.

12.4 CALIBRATION PROCEDURES AND FREQUENCY

12.4.1 Instrument Calibration Procedures and Frequency

A list of all measuring and test equipment to be used, along with a schedule for calibration, will be prepared prior to initiating fieldwork. In general, field calibration methods will be those recommended by the manufacturer. Instrument log books will be established.

Laboratory equipment will be calibrated in accordance with the CLP (EPA 1986d, 1987d) or other contractor laboratory QA manuals when CLP protocol is not established. Calibration frequency will be based on the analytical methods employed, type of equipment, inherent stability, manufacturer's recommendations, values given in national standards, intended use, and experience.

Calibrated equipment will be uniquely identified by using either the manufacturer's serial number or other means. All equipment shall be categorized as one of the of the following.

- Category A: casual devices and systems (e.g., rulers, tape measures, graduated cylinders, pipettes) that are not to be calibrated in service (i.e., not calibrated other than by the manufacturer).

- Category B: routine devices and systems (e.g., balances, spectrophotometers) that are to be included in a calibration recall program on a regular cycle.

- Category C: experimental devices and systems (e.g., fluorometers, pH meters, turbidimeters) that are to be calibrated by, or at the direction of, the user as deemed necessary.

The appropriate category decal with the identification number and the due date of the next calibration will be attached to the equipment. If this identification is not possible, records traceable to the equipment will be readily available for reference.

12.4.2 Calibration Failures

Scheduled periodic calibration of equipment will not relieve field or laboratory personnel of the responsibility of employing properly functioning equipment. If an individual suspects an equipment malfunction, that person should remove the device from service, tag it so it is not inadvertently used, and notify project management. If equipment is found to be out of calibration, the sampling team leader or laboratory supervisor shall evaluate and document (in the instrument log book) the validity of previous inspection or test results and the acceptability of similar equipment previously inspected or tested. The responsible supervisor shall ensure that devices that are out of calibration are tagged or segregated from other equipment and disposed of or not used until they are recalibrated. Any equipment consistently found to be out of calibration shall be repaired or replaced. Any such action should be recorded in the instrument log book.

All standards used for equipment calibration will be traceable to the EPA, National Bureau of Standards, or a commercially available certified standard. The source of the standard used must be documented in a calibration log book.

12.4.3 Calibration Records

Calibration data shall be recorded in the instrument log book. Records will be prepared and maintained for each piece of calibrated equipment to indicate that established calibration

procedures have been followed. The sampling team leader or laboratory supervisor will ensure that records of calibration data are kept current. Records for field equipment used will be maintained by the sampling team leader and kept in the project files.

12.5 ANALYTICAL PROCEDURES

A preliminary Field Sampling and Sample Analysis Plan (Sect. 10) for the WAG 2 RI has been prepared to address the types of analytical procedures to be used in sample analysis.

12.5.1 Field Analyses

All field measurements will be recorded in the field notebooks or on specially designed data forms. All data will be directly entered in the field, signed, and dated. If entry changes are made, one line will be drawn through the error and the change and explanation will be signed and dated in the notebook or on the data form. Changes made to original notes should not obliterate the original information. All field data records will be organized into standard format, when possible. Team leaders are responsible for review of daily entries in the field log books.

12.5.2 Laboratory Analyses

WAG 2 RI samples will be analyzed for potential contaminants of concern using established procedures (EPA 1979b; 1980b,c; 1983; 1984; 1986c,d; 1987d; Kimbrough et al. 1988, ESP, Appendices A.2, A.4).

12.5.3 Analytical Laboratories

At a later date, contracts will be established with analytical laboratories to analyze samples collected during the sampling phase of the WAG 2 RI.

Each contractor laboratory that analyzes samples will provide quantification limits for each constituent analyzed. The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero. The MDL actually achieved in a given analysis will vary depending on instrument sensitivity and interferences. The objectives for precision and accuracy for each chemical are based mainly on the capabilities of the approved EPA analytical method with respect to laboratory QC.

In addition to evaluating each set of data for accuracy and precision, an assessment will also be made of the completeness of the data. This assessment will involve computing the

fraction of the reported values that remain valid after the sampling procedures have been reviewed and the results have been assessed for precision and accuracy.

For those analyses conducted using the EPA CLP protocol, current acceptance criteria established by the EPA will be used.

12.6 DATA SUMMARIZATION, VALIDATION, AND REPORTING

Data validation is a systematic process for reviewing a body of data against a set of criteria to ensure that the data are adequate for their intended use. Data validation consists of data editing, screening, checking, auditing, verification, certification, and review (EPA 1988a,c).

All data for this project will be evaluated by QA/QC methods and internal peer review. Data reduction, verification, and reporting will be in accordance with the ongoing ORNL ER Program Data Base Management activities (Voorhees et al. 1988). Data will be entered into common, standardized formats. In addition to following field sampling documentation and QA/QC procedures, data are verified using a variety of computerized checks for reasonableness. These procedures will ensure that data are entered, encoded, and manipulated in a consistent way and available to WAG 2 RI investigators in a useable format.

12.6.1 Field Data Reduction and Evaluation

Data collected during field activities will be evaluated by checking the procedures used and comparing the data to previous measurements. The QA/QC coordinator and sampling team leaders will be responsible for checking field QC sample results to ensure that field measurement and sampling protocols have been observed. These reviews will check:

- date and time sampled,
- preservation,
- standard operating procedures,
- calibration method and frequency, and
- chain-of-custody documentation.

Reviewers are responsible for ensuring that data reduction calculations are documented and checked by qualified personnel.

Written reports including reduced and summarized data will include the raw data in appendices. Specific calculations used for data reduction will also be included.

12.6.2 Analytical Laboratory Data Reduction and Evaluation

Analytical data generated during the WAG 2 RI will be evaluated for completeness. This will include, but is not limited to, review of completed custody logs, photocopied pages of laboratory notebooks and data forms completed by the technical staff, including sample weights, dilutions, concentrations, data reduction, instrument logs, and all raw data. Reviewers of materials will include the WAG 2 RI QA/QC coordinator and the assigned contract laboratory program manager; however, the WAG 2 RI task leader has primary responsibility for review. In the data review process, the data are compared to information such as the sample history, sample preparation, and QC sample data to evaluate the validity of the results. Data validation includes:

- dated and signed entries by technical staff and supervisors on the worksheets and log books used for samples;
- the use of sample tracking and numbering systems to track the progress of samples through the laboratory;
- the use of quality control criteria to reject or accept specific data in accordance with EPA CLP protocols and laboratory data validation functional guidelines for evaluating organic and inorganic data (EPA 1988, EPA 1984); and
- examination of all data for a sample and site by evaluating ion balance, checking for consistency among replicate samples, sending split samples to other laboratories for analysis, and using frequency distributions and range checks to evaluate outliers.

12.6.3 Data Reporting of Analytical Results

The format and content of hardcopy and electronic data reports will adhere to project needs. These include contract requirements of DOE and regulatory agency reporting formats. The laboratory supervisors are responsible for the preparation of each technical report, including the process of data validation. The preferred hardcopy report format is the complete CLP data package, including case narrative.

- Final data presentation shall be checked according to data validation requirements and approved by the appropriate sampling team leader and laboratory manager.
- Each page of data will be identified with the project number or project name, sample delivery group number, and date of issue.
- Electronic copies of the data must match the hardcopy reports.

Electronic data contents in the report will include:

- sample identification number used by the laboratory and/or the sample identification provided to the laboratory, if different than that used in the laboratory;
- sample delivery group number;
- chemical parameters analyzed, reported values, laboratory data qualifiers,and units of measurement;
- quantification limit of the analytical procedure;
- results of QC sample analysis;
- achieved accuracy, precision, and completeness of data;
- references to specific data if required to explain reported values; and
- analytical methods used.

These methods will be specifically referenced on all laboratory reports. Any method modification will be included in the case narrative. Data for field QC samples will be reported in the same format as actual samples.

12.7 INTERNAL QC CHECKS AND FREQUENCY

The basic elements of QC are listed below, proceeding from general to specific; each element depends on the ones preceding it (adapted from Taylor 1987):

- technical competence of staff,
- appropriate equipment and instruments,
- good sampling practices,
- good measurement practices,
- project procedures,
- field implementing procedures,
- inspection,
- documentation, and
- training.

The staff must have the necessary competence (defined as education, skill, technical judgement, experience, and professional attitude) to reduce variability in executing procedures, taking measurements, and obtaining data in the field.

The QC procedures presented in this section are designed to:

- achieve the QA objectives for precision, accuracy, completeness, representativeness, comparability, and sensitivity;
- document data quality and provide accountability information about data received from each laboratory;
- provide criteria to ensure that analytical results are statistically valid; and
- provide sufficient documentation of analytical procedures to establish that the resulting parameter estimates are defensible and the comparability of estimates from each laboratory is quantifiable.

Internal QC procedures involve review of the documentation of maintenance and operational procedures and inspection of the instruments and equipment by personnel other than instrument users. Inspection entails the spot inspections conducted by the QA specialist in combination with the continuous process of inspection conducted by the sampling team leaders and laboratory supervisors as part of normal procedures.

Achieving the highest level of documentation quality is imperative to QC. Bound notebooks with numbered pages will be used to record all events and activities. Data forms will be used to record selected field and laboratory measurements. All notebooks and data forms will be subject to custody requirements including limited distribution, secure storage, and long-term retention (30 years after completion of sample collection and analysis).

12.7.1 Field QC Procedures

Field QC sampling will be established to check sampling. All QC samples will be shipped according to the chain-of-custody procedures specified in Sect. 10.5. Field QC samples will include blanks and replicates as follows.

Trip Blank. A trip blank, consisting of a sealed container of organic-free water, will travel from the field to the laboratory with the samples to be analyzed for the contaminant of concern. The trip blank identifies contamination that may have been contributed to the field samples during the transport (receives same treatment as sample containers). Trip blanks will be collected no less than once per week during field sampling.

Field Rinsate. A field rinsate consisting of final rinse water from the decontamination of field sampling equipment. Analysis of the field rinsate determines if the decontamination

procedure is adequate to avoid carryover of contamination from one sampling location to another. One field rinsate will be collected between each site sampled on days when multiple sites are to be sampled.

Laboratory Rinsate. A laboratory rinsate consisting of final rinse water from the decontamination of field sampling equipment. Analysis of the laboratory rinsate determines if decontamination procedures are adequate. Laboratory rinsates will be collected prior to each day of field activities.

Field Blank. One field blank consisting of rinse water used for final issue during decontamination will be collected from the source of final rinse water (distilled/deionized water).

Field Duplicate. Field duplicates, which consist of a duplicate sample from one sampling location, indicate whether the field sampling technique is reproducible. Duplicate samples will be obtained for all sample matrices.

Field QC samples will have discrete sample numbers and be submitted as "blind" to the laboratories. The quantities and collection procedures for each field QC sample type will be specified in the S&A Plan (Sect. 10). Results of these samples will be included in the analytical data report. Results for QC samples will not be used to adjust the results obtained for original samples. If contaminants are found in the blanks, attempts will be made to identify the source of contamination, and corrective action will be initiated according to Sect. 12.13.

12.7.2 Laboratory QC Procedures

A number of laboratory QC samples will be used to check sample preparation and analysis and to monitor laboratory performance. The control samples listed below are defined in general terms. Analysis-specific control samples may be required as indicated by EPA CLP procedures. QC samples will consist of blanks, duplicates and spikes. Laboratory standards will also function as QC components. QA procedures for laboratory processing include laboratory duplicates of all field samples to determine the precision of laboratory results. Laboratory QC samples will include the following:

Method Blank. A method blank is a blank sample made up of a pure, noncontaminated substance of the matrix of interest (usually distilled/deionized water or silica sand) that is subjected to all of the sample preparation (e.g., digestion, distillation, extraction) and analytical methodology applied to the samples. The purpose of the method blank is to check for contamination from within the laboratory that might be introduced during sample analysis.

Calibration/Continuing Calibration Blank. A calibration blank is the substance that is used to zero the instrument. The calibration blank comprises the solvent used for the preparation of the calibration standards and samples. The calibration blank accounts for any interferences from the solvent matrix.

Sample Container Cleaning Blanks. If sample containers are cleaned in the laboratory, "sample container cleaning blanks" are taken for each batch of containers that goes through the cleaning process. If contamination is detected, the containers associated with the contaminated blank will be recleaned and another blank taken and analyzed.

Laboratory Duplicates. Laboratory duplicates are prepared by the laboratory analyst for each sample and are obtained by homogenizing a sample as thoroughly as possible and taking two separate aliquots of that sample for analysis. The duplicate sample, however, should never be a method blank, trip blank, or field blank. The purpose of laboratory duplicates is to check the precision of the analyst, the sample preparation methodology, and the analytical methodology.

Matrix Spikes. A matrix spike is a sample to which a known concentration of the compounds of interest has been added. The matrix spike is subjected to the same sample preparation and analytical methodology applied to the samples. The sample to be spiked is selected prior to sample submittal by the ASC; however, the spiked sample cannot be a method blank, trip blank, or field blank. The purpose of the matrix spike is to check for interferences or false readings caused by the sample matrix. The sample matrix effect is measured by calculating the percent recovery (%R, Sect. 12.10.2) of the compounds added to the sample.

Blank Spike/Laboratory Control Sample (LCS). The blank spike, or LCS, is a blank sample (usually distilled/deionized water or silica sand) to which a known concentration of the compounds of interest has been added. The blank spike is subjected to the same sample preparation and analytical methodology applied to the samples. The purpose of the blank spike is to check the accuracy of the analyst, the sample preparation methodology, and the analytical methodology. The level of accuracy is measured by calculating the %R.

The laboratory QA/QC Coordinator is responsible for preparing QC standards and for sending QC samples into the laboratory for analysis. Statistical analyses will then be performed utilizing the results of QC sample analyses. Each laboratory will apply precision and accuracy criteria to each parameter that is analyzed. When analysis of a sample set is completed, the QC data are reviewed and evaluated through the use of control charts to validate the data set. Laboratory QC standards will include the following:

Calibration Standards. Calibration standards are standards comprising the compounds of interest at known concentrations. Calibration standards are prepared from EPA reference material or commercially available, certified reference materials traceable to the National Bureau of Standards (NBS). Calibration standards are prepared using the same solvent used for sample preparation at the same concentration. Calibration standards for each analyte are prepared for at least three concentration levels throughout the calibration range required for the analysis. Calibration standards are not subjected to all of the preparation (e.g., extraction, distillation, digestion) that is applied to the sample. Calibration standards are used to initially calibrate the instrument by providing reference points throughout the calibration range and to establish linearity throughout the calibration range and working range of the instrument. The instrument is then checked continually throughout the analysis with the calibration standards to check for any instrument drift that may have occurred.

Performance Evaluation (PE) Samples. Performance evaluation samples consist of known concentrations of the analytes submitted to the laboratory being audited. These samples are obtained through various EPA-sponsored programs and private vendors to provide an objective evaluation of laboratory performance and comparison with other participating laboratories.

Control charts are statistical representations of the laboratory's performance and are used to monitor laboratory performance and to establish control limits or the acceptance criteria for all compounds of interest. For each analyte, a separate control chart is required for each type of control sample that measures precision or accuracy (blank spike, matrix spike, and duplicate) and for each matrix type and concentration level (high, medium, and low). A minimum of ten measurements of precision and accuracy are required before control limits can be established. Control limits of three standard deviations shall be utilized for all samples.

Once established, control limits are updated as additional precision and accuracy data become available to the lab QC coordinator. Any control sample data point that falls beyond the control limits or any data trend (indicated by seven or more consecutive points on either side of the mean) will require an investigation and corrective action. For all identified contaminants of concern, control limits and corrective actions will be in accordance with EPA protocol. Additional statistics for organics work will be done in accordance with SW-846 (EPA 1986c) or the CLP SOW (EPA 1986d), as applicable.

12.8 PERFORMANCE AND SYSTEMS AUDITS AND FREQUENCY

Audits are performed to review and evaluate the adequacy of field and laboratory performance and to ascertain whether the QA/QC Plan is being completely and uniformly implemented. The following requirements are adapted from basic requirement 18, "Audits," of ANSI/ASME NQA-1 (ANSI/ASME 1986) and ESP.18.1 (Martin Marietta Energy Systems Quality Procedures Manual). Planned and scheduled audits shall be performed to verify compliance with all aspects of the QA program and to determine the program's effectiveness. These audits shall be conducted according to written procedures and checklists and shall be performed by personnel who do not have direct responsibility for performing the activities being audited. Audit results shall be documented and reported to and reviewed by responsible management. Follow-up action shall be taken by the responsible line organization when necessary, and the corrective actions will be monitored by the ORNL manager of quality audits.

The objectives of performance and systems audits are to (1) ensure that the QA program developed for this project is being implemented according to the specified requirements, (2) assess the effectiveness of the QA program, (3) identify nonconformances, and (4) verify that identified deficiencies are corrected. Upon discovery of any significant deviation from the QA program, the project manager shall be informed of the nature and extent of the deviation, and the corrective action taken (Sect. 12.13).

An individual audit plan will be developed to provide a basis for each audit. This plan will identify the audit scope, the activities to be audited, the audit personnel, any applicable documents, and the schedule. Records of audits will be maintained in the project files. Audit files will include, as a minimum, the Surveillance Report (Fig. 12.2), the reply to audit, and any supporting documents. It is the responsibility of the WAG 2 RI project manager to conform to the ORNL QA audit procedures, particularly as to timely replies to audit reports and implementation of such corrective action as indicated.

12.8.1 Frequency of Audits

ESD QA specialist is responsible for internal audits and will perform them according to a schedule that coincides with appropriate activities on the project schedule and sampling plans. Such scheduled audits may be supplemented by additional audits for one or more of the following reasons:

- when significant changes are made in the QA/QC Plan;
- when it is necessary to verify that corrective action has been taken on a nonconformance reported in a previous audit; or
- when requested by the project manager.

In addition to these internal audits, surveillance of selected activities may be performed on a periodic basis, as outlined in Table 12.4.

12.8.2 Performance Audits

A performance audit can be defined as a review of the existing project and QC data to determine the accuracy of a total measurement system(s) or a component part of the system. The analysis of laboratory performance evaluation samples and the participation in scheduled interlaboratory studies may be included as part of the performance audit. Laboratory audits are further described in QA/QC procedures for particular analytical laboratories.

A performance audit will also be made of the laboratory activities during the first sampling phase. The QA specialist or a designee will check on the logging of the samples, proper chain-of-custody and related documentation. Any irregularities in QA procedures that are not immediately corrected will be brought to the attention of the WAG 2 RI project manager.

12.8.3 Systems Audits

A systems audit consists of an evaluation to determine if the components of a measurement system were properly selected and are being used correctly. A systems audit includes a careful evaluation of field and laboratory QC procedures. Systems audits are

SURVEILLANCE REPORT

ORGANIZATION: _____ *REPORT NO.:* _____

PROJECT/ACTIVITY: _____ *SURVEILLANCE DATES(S):* _____

REQUIREMENTS DOCUMENT(S): _____

REQUIREMENTS/ACTIVITIES TO BE VERIFIED	SAT	UNSAT	OBSERVATIONS

CHECKLIST APPROVED: _____ (QA Specalist) _____ (Date)

SURVEILLANCE COMPLETED BY: _____ (Surveillant) _____ (Date)

FAILURE REPORT REQUIRED? (Y/N) _____ *TYPE: NCR* ___, *QIR* ___, *UOR* ___

APPLICABLE REPORT NUMBER(S): _____

ADDITIONAL SURVEILLANCE REQUIRED? (Y/N) ___ *FREQUENCY OR DATE:* _____

APPROVAL:

_____ (Project Manager) _____ (Date) _____ (QA Specialist) _____ (Date)

Fig. 12.2. Surveillance Report Form.

Table 12.4. Surveillance Activities.

Activity	Frequency
Spot-checking technical notebooks	weekly
Tracking water samples through sampling, analysis and report phases	quarterly
Participating in laboratory meetings and discussions	monthly
Verifying statistical computations on final reports	monthly

conducted as deemed necessary by the QA specialist, or on an annual basis. The systems audit is reported in formal audit reports distributed by the laboratory manager.

12.8.4 Field Surveillance

An individual surveillance plan will be developed to provide a basis for each field surveillance. This plan will identify the scope, activities, and personnel to be involved, any applicable documents, and the schedule for each field surveillance. Checklists will be prepared by the auditors and used to conduct all surveillances. They will be developed to accomplish the review of necessary items and to document the results of the surveillance.

Field surveillance may involve an on-site visit by the auditor. Items to be examined may include, but are not limited to, the availability and implementation of approved work procedures; calibration and operation of equipment; packaging, storage, and shipping of samples obtained; documentation procedures and instructions; and nonconformance documentation.

The records of field operations will be reviewed to verify that field-related activities were performed in accordance with standard procedures. Items reviewed may include, but are not limited to, the calibration records of field equipment, daily field activity log books, chain-of-custody records, and data resulting from field operations.

During a surveillance and upon its completion, the auditors will discuss the observations or deviations with the individuals surveyed and discuss and agree on corrective actions to be initiated. A surveillance report will be completed for each surveillance activity (Fig. 12.2).

Minor administrative findings that can be resolved to the satisfaction of the auditors during a surveillance are not required to be cited as items requiring corrective action. Findings that are not resolved during the course of the surveillance and findings affecting the overall quality of the project will be noted on the checklists and included in the surveillance report. In addition to these internal audits, surveillance of selected activities may be performed on a periodic basis, as outlined in Table 12.4.

12.9 PREVENTIVE MAINTENANCE PROCEDURES

Periodic preventive maintenance is required for all measuring and test equipment. Instrument manuals will be kept on file for reference purposes if equipment needs repair. Maintenance frequency will be based upon manufacturer's recommendations, intended use, and experience. The troubleshooting section of factory manuals may be used to assist personnel in performing maintenance tasks. Routine maintenance will be performed on instruments to reduce the incidence of extensive repairs immediately prior to sampling and analysis.

12.9.1 Field Instruments

The frequency of preventive maintenance for field equipment is usually indicated in each operating instruction manual. Maintenance will be documented and maintained in permanent records by the individual responsible for each instrument. Critical spare parts will be identified and stocked to minimize equipment downtime and lost field sampling effort.

12.9.2 Laboratory Instruments

Laboratory equipment requiring routine maintenance have a control system indicating the date of required maintenance, person maintaining the equipment, and the next maintenance date. Information pertaining to life histories of equipment maintenance will be kept in individual logs for each instrument. Preventative maintenance for ESD laboratory equipment will follow the procedures established in QA-ES-12-100 (Roberson and Logsdon 1989).

12.10 STATISTICAL ASSESSMENT OF DATA QUALITY

A statistical evaluation of laboratory analytical results will be performed that will apply precision and accuracy criteria for each parameter that is analyzed. When the analysis of a sample set is completed, the QC data generated will be reviewed and evaluated to validate the data set. All QC data will be reported to the WAG 2 RI project manager along with the sample analysis results. The QC data will be reviewed for precision and accuracy.

The evaluation criteria of the QC sample data for the target compound list (TCL) have been established for the EPA CLP (EPA 1986d, 1987d). The control limits for other compounds are derived from laboratory control charts. These criteria provide a means of categorizing a data set as being quantitative, semiquantitative, or qualitative. Where applicable, contract laboratories will use data qualifiers to clearly identify results as qualitative and semiquantitative. Otherwise, reported data are to be considered quantitative. These results provide information on the relative quality of sampling and analytical procedures. Deviations suggested by these assessments (in combination with other quality parameters) will be utilized in nonconformance and corrective action procedures (Sect. 12.13).

12.10.1 Precision

Precision will be assessed by conducting separate analyses of the duplicate samples. The level of precision is determined by calculating the relative percent difference (RPD) between

the two measurements, as

$$\text{RPD} = \frac{(D_1 - D_2) \times 100}{(D_1 + D_2) / 2}$$

where: D_1 = value of first measurement,
D_2 = value of second measurement.

12.10.2 Accuracy

Accuracy will be assessed by splitting a sample into two portions, spiking (i.e., adding known quantity of the constituents of interest to one of the portions), and then analyzing both portions for these parameters. The difference in the concentration levels of the constituents of interest should be equal to the quantity of the spike added to one of the two portions. The percent recovery is calculated as follows:

$$\%\text{R} = \frac{O_i - O_s}{T_i} \times 100$$

where: O_i = Observed spiked sample concentration,
O_s = Observed sample concentration,

and

T_i = True or actual concentration of the spike.

Recovery of 100% is equivalent to 100% accuracy. Values less that 100% may indicate a sample matrix effect and a false reading. A periodic program of sample spiking is required (e.g., 1 matrix spike and 1 matrix spike duplicate per 20 samples).

Blank spikes or laboratory control samples check the accuracy of the analyst, the sample preparation, and the analytical methodology free of sample matrix effects. Blank samples are spiked with known concentrations of the compounds of interest, then prepared and analyzed as samples. The level of accuracy is measured by calculating the %R as follows:

$$\%\text{R} = (O/T) \times 100$$

where %R = percent recovery,
O = observed or measured concentration,
T = true or known concentration.

The coefficient of variation (C_v) of the percent recovery values is calculated as follows:

$$C_v = (SD/APR) \times 100$$

where SD = standard deviation of the percent recoveries for the various spiked constituents,

APR = average or mean percent recovery.

12.10.3 Determinations of Significance

Statistical tests for determination of significance are to be added.

12.11 DEVIATIONS FROM ESTABLISHED PROCEDURES

This section identifies methods and policies for the documentation, evaluation, corrective action, and verification activities necessary when a deviation from established procedure occurs. Requirements for the documentation and implementation of corrective actions are also included.

Any unplanned deviation or nonconformance will be evaluated with respect to its possible impact on reportable data. All unplanned deviations from standard operating procedures (SOPs), equipment calibrations, or any aspect of the QA plan will be evaluated and documented. Significant deviations identified using the statistical assessment of quality data will also be utilized in Nonconformance and Corrective Action Procedures (Sect. 12.13).

Planned deviations or variance from SOPs may be necessary given that procedures properly addressing the entire range of conditions encountered during a field sampling program cannot be prepared. Requirements for issuance and implementation of variance from SOPs are included.

12.11.1 Responsibilities of Project Participants

WAG 2 RI personnel will ensure the prompt identification, control, and disposition of nonconforming items. Each laboratory participant is responsible for submitting records of all potential nonconformance events to the appropriate sampling team leader and/or the project QA/QC coordinator within a reasonable period of time following the initial identification and documentation of the potential nonconformance. The potential nonconformance will then be evaluated by team leaders, QA specialist, project manager, and others as is deemed relevant. This evaluation will determine if (1) the event has adversely affected results of particular analyses and (2) the event justifies the issuance of a Nonconformance Report (NCR).

12.11.2 Nonconformances and Corrective Action Procedures

Nonconforming equipment, items, activities, conditions, and unusual incidents that could affect compliance with project requirements will be identified, controlled, and reported in a timely manner. A nonconformance is defined as a malfunction, failure, deficiency, or deviation that renders the quality of an item unacceptable or indeterminate. The originator of a NCR will describe the finding on the form provided for this purpose (Fig. 12.3, ESI.15.1, *MMES QPM*) and notify the WAG 2 RI project management, QA specialist and QA/QC coordinator. Each nonconformance will be reviewed and a disposition given for the item, activity, or condition. Evaluations also will determine if the event justifies the issuance of a Corrective Action Report and Status (CARS) (Fig. 12.4). The appropriate report will document the event, the findings of the evaluation, and the required corrective actions. The disposition of a nonconformance will be documented and approved by the WAG 2 RI project manager. The QA specialist will concur with the disposition of the nonconformance.

The QA/QC coordinator for a particular laboratory is responsible for the assessment of laboratory QC sample information. If data fall outside accepted limits, established laboratory procedures for identifying the problem and taking appropriate corrective actions will be employed (ORGDP-ACD TP 2300, R-10 1988d; Weaver 1988). Completion of corrective action should be evidenced by deviations returning to prescribed acceptable limits.

The modification, repair, rework, or replacement of nonconforming equipment, items, or activities will require the reverification of acceptability. In certain instances, as determined by project management (including the project manager, laboratory program manager, or QA specialist), these activities may require that corrective action be completed and verified before site work continues.

If, in the opinion of project management and QA specialist, the nonconformance does not significantly affect the technical quality or use of the work, the work may continue pending resolution of the nonconformance. The basis for such a decision will be documented on the Nonconformance Report and submitted to the QA specialist for review and approval. The documentation will include the statement that the decision was made before continuing with the work. The records of nonconformance and their dispositions will be maintained by the WAG 2 RI project manager and forwarded to the RCDB.

12.11.3 Variance Procedures

Variances from approved operating procedures in any of the plans associated with this project will be documented on a deviation request form. Sampling team leaders will initiate and chronologically maintain deviation request forms. If, in the opinion of project management and QA specialist, the variance does not affect safety or quality of work, the

NONCONFORMANCE REPORT (NCR)

MARTIN MARIETTA

Sheet ____ of ____

This form should be completed when one or more distinct, describable, and measurable properties or characteristics of an item (hardware or software) do not conform to documented technical requirements.

1. NONCONFORMANCE REPORT NO. NCR-

2. OCCURRENCE DATE	3. ORIGINATOR	4. PLANT/ORGANIZATION	5. DIVISION	6. ADDRESS	7. PHONE NUMBER

8. PURCHASE ORDER/WORK ORDER OR CONTRACT/ STORES NO.	9. ITEM NO.	10. REC. REPORT NO.	11. DWG/SPEC/DOC. NO.	12. REV. NO.	13. QTY REC'D. OR PRODUCED	14. QTY. NONCONFORM.

15. DESCRIPTION

15A. SPECIFIED REQUIREMENT(S)	15B. NONCONFORMANCE(S)

16A. NONCONFORMANCE DISPOSITION	16B. REMEDIAL ACTION(S) AND JUSTIFICATION
☐ ACCEPT; USE-AS-IS ☐ REWORK (TO SPEC.) ☐ REPAIR (TO USABLE COND.) ☐ RETURN TO VENDOR/SHOP ☐ REJECT/SCRAP	

17. DISPOSITION APPROVALS

17A. ENGINEER/REQUISITIONER	DATE	17B. CUSTOMER/USER	DATE	17C. QA SPECIALIST	17D. DATE

17 E. REMEDIAL ACTION COMPLETED BY (NAME)	DATE

18. CORRECTIVE ACTION(S) TO PREVENT RECURRENCE

18A. ACTION	18B. TECHNICAL OR SYSTEM	18C. RESPONSIBILITY	18D. SCHEDULED COMPLETION DATE

19. CORRECTIVE ACTION APPROVALS

19 A. ENGINEER/REQUISITIONER	DATE	19B. RESPONSIBLE MGR. OR BUYER	DATE	19C. QA SPECIALIST	19D. DATE

20. COST/SCHEDULE DELAY SUMMARY

COST ITEM	TOTAL
- COST OF REPAIR/REWORK - the cost of correcting failed and defective items to make them fit for intended use.	
- COST OF REPLACEMENT - the cost of procuring and installing a fit substitute for failed and defective items.	
- COST OF DELAY - the cost occurring as a result of delays caused by the nonconformance.	
- COST OF REDESIGN - the cost of revising, deviating, eliminating or approving the design of items due to nonconformance.	
- COST OF CONSEQUENTIAL DAMAGE - the cost of actual, nominal, tangible, or intangible damage.	
- REIMBURSABLE CREDIT - actual dollar amount credited or reimbursed for the nonconformance.	
20A. TOTAL COST IMPACT	

WAS SCHEDULE IMPACTED? ☐ YES ☐ NO 20B. SCHEDULE DELAY (DAYS) ____

ENERGY SYSTEMS QUALITY INFORMATION SYSTEM ATTRIBUTES

21. NCR TITLE ____

22. REF. QER NO. ____

23. OTHER APPLICABLE QIRS, UORS, OR NCRS: ____

24. ☐ HARDWARE ☐ SOFTWARE

25. ITEM

26. DEFECT

27. QUALITY INDICATOR CATEGORY

28. JOB/PROJECT NO.

29. SOURCE OF SUPPLY ☐ VENDOR ☐ SUBCONTRACTOR ☐ AE ☐ MMESI

ACTIVITY TYPE ☐ FABRICATION ☐ DEVELOPMENT ☐ CONSTRUCT. ☐ SERVICE

30. NAME OF VENDOR /SHOP/ORG/CONTRACTOR/AE

31. KEYWORD

32. PRIMARY PROBLEM CAUSE CATEGORY: ☐☐

33. PROBLEM DISCIPLINE CATEGORY: ☐☐

NOTE: SHADED AREAS INDICATE ESQIS BASE ENTRIES

UCN-11457 (12356 5-88)

Fig. 12.3. Nonconformance Report (NCR) Form.

CORRECTIVE ACTION REPORT AND STATUS

CORRECTIVE ACTION SOURCE: Initiation Date: _____

AUDIT# _____ UOR# _____

NCR# _____ QIR# _____

FINDING AND/OR RECOMMENDATION:

CORRECTIVE ACTION:

RESPONSIBLE PERSON: _____

SCHED. COMPLETION DATE: _____ *REVISED COMPLETION DATE:* _____

Commit to Corrective Action: _____ (Division/Program Manager/Director) _____ (Date)

Accept and Understand Task: _____ (Responsible Person) _____ (Date)

Reviewed for Adequacy: _____ (Division/Program QAS) _____ (ESQIS Entry Date)

STATUS:

CORRECTIVE ACTION COMPLETION:

_____ (Responsible Person) _____ (Date Completed)

QAS: _____

Date Verified Completion and Effectiveness: _____

Date Entered in ESQIS: _____

Fig. 12.4. Corrective Action Report and Status (CARS) Form.

work may continue pending resolution of the nonconformance. The basis for such a decision will be documented on the deviation request form. Variances affecting project scope, costs, or schedule must be approved by WAG 2 RI project manager. As appropriate, regulatory agencies will be notified of any variances that significantly affect project scope or objectives. Any variances from the H&S Plan must be approved and acknowledged by the H&S coordinator. Variance approval by the project manager can be initiated on a verbal basis via the telephone or radio with follow-up written acknowledgement.

12.12 QA REPORTS TO MANAGEMENT

The active participation of management in WAG 2 RI is fundamental to the success of this QA/QC Plan. Management will be aware of project activities and will participate in development, review, and operation of the project. Management will be informed of quality assurance status and activities through the receipt, review, and/or approval of:

- regular ESD quality status reports,
- laboratory and project-specific QA/QC plans and procedures,
- post-audit reports and audit closures,
- surveillance reports,
- corrective-action overdue notices, and
- nonconformance reports.

Copies of these reports will be distributed to appropriate Energy Systems and ORO management and regulatory agencies. In addition, periodic assessment of QA/QC activities and data precision, accuracy, representativeness, completeness, and comparability will be conducted and reported by the analytical laboratories.

Project management will inform the QA specialist, as appropriate, of the QA status of the project, especially any significant quality accomplishments. WAG 2 RI personnel are required to inform the project manager or project support staff of all nonconformances or quality failures (QA-ES-15-100, Roberson and Logsdon 1989). The project manager will document and immediately report any nonconformance or quality failure to the QA specialist. It is the responsibility of the ESD QA specialist to report all quality associated activities to the ORNL quality assurance manager.

12.13 OTHER QA/QC MEASURES TO MEET NQA-1 STANDARDS

The ANSI/ASME NQA-1 standards, which are implemented for ORNL projects, contain criteria that are not included in the EPA QAMS-005/80 requirements for QA/QC plans.

Only NQA-1 Criterion 14, "Inspection, Test, and Operating Status," is specifically excluded from this plan. NQA-1 criteria overlapping with the EPA QAM-005/80 criteria or explicit in other relevant documents include "Procurement Document Control" (Criterion 4), "Instructions, Procedures, and Drawings" (Criterion 5), "Development and Control of Procedures" (Criterion 5), "Purchased Items and Services Control" (Criterion 7), "Inspection" (Criterion 10), and "Test Control" (Criterion 11). These NQA-1 elements are invoked for this QA/QC plan by the following rationale.

12.13.1 Procurement Document Control (NQA-1 Criterion 4)

This criterion ensures that purchasing documents such as bid specifications are properly prepared. Purchasing for the WAG 2 RI project will be through normal ORNL procedures, which implement NQA-1 procurement document control requirements (ORNL 1988).

12.13.2 Instructions, Procedures, and Drawings (NQA-1 Criterion 5)

This criterion ensures that activities affecting quality be conducted according to documented instructions and procedures. This criterion is met for WAG 2 RI project through preparation and implementation of WAG 2 RI general document and work plan (Sects. 1—9), project organization and management plan (Sect. 11), field sampling and analysis plan (Sect. 10), QA/QC plan (Sect. 12), data management plan (Sect. 13), and H&S plan (Sect. 14). This criterion is also implemented for ORNL activities through the ORNL Quality Assurance Manual (ORNL 1988).

12.13.3 Document Control (NQA-1 Criterion 5)

This criterion for Development and Control of Procedures (QA-ES-5-101, Roberson and Logsdon 1989) is also met through the preparation and implementation of these WAG 2 RI plans. QA for each of these documents is provided for in the Data Management Plan list of items of record to be included in the RCDB (Section 13). Laboratory operations manuals are available for the analytical laboratories involved in WAG 2 RI work. This criterion is also implemented for ORNL activities through the *ORNL Quality Assurance Manual* (ORNL 1988).

12.13.4 Purchased Items and Services Control (NQA-1 Criterion 7)

This criterion ensures that quality is maintained in purchasing items or services. Purchasing for the WAG 2 RI project will be accomplished through normal ORNL procedures. These procedures implement NQA-1 procurement control requirements, as described in the ORNL Quality Assurance Manual (ORNL 1988).

12.13.5 Inspection (NQA-1 Criterion 10)

This criterion ensures that inspections sufficient to verify conformance with specified requirements are planned and executed. This QA/QC Plan specifically addresses procedures including instrument calibration (Sect. 12.4), review and validation of data (Sect. 12.6), and audits (Sect. 12.7). This criterion is also met for WAG 2 RI by the QA/QC requirements in the Sampling and Analysis and Data Management plans. This criterion is also implemented for ORNL activities through the ORNL Quality Assurance Manual (ORNL 1988).

12.13.6 Test Control (NQA-1 Criterion 11)

This criterion ensures that tests sufficient to verify conformance with specified requirements are planned and executed. This criterion is met for WAG 2 RI by the QA/QC requirements in the Sampling and Analysis and Data Management plans. Sects. 12.4 and 12.6 of this plan ensure that procedures such as instrument calibration and review and validation of data conform to specific requirements. This criterion is also implemented for ORNL activities through the *ORNL Quality Assurance Manual* (ORNL 1988).

12.13.7 Inspection, Test, and Operating Status (NQA-1 Criterion 14)

This criterion ensures that established procedures requiring inspections and tests are performed and that items that have not passed the necessary inspections or tests are not installed, used, or operated. This criterion is met for the WAG 2 RI project by the QA/QC requirements in the Sampling and Analysis and QA/QC plans for procedures such as instrument calibration. This criterion is also implemented for ORNL activities through the *ORNL Quality Assurance Manual* (ORNL 1988).

12.13.8 Nonconforming Items Control (NQA-1 Criterion 15)

This criterion ensures that nonconforming items are controlled to prevent inadvertent installation or use. This criterion is met for WAG 2 RI by the QA/QC requirements in the Sampling and Analysis and QA/QC plans for procedures such as instrument calibration (Sect. 12.4) and nonconformances and corrective action procedures (Sect. 12.13). In addition, ORNL procedures for control of nonconforming items are specified in the *ORNL Quality Assurance Manual* (ORNL 1988).

12.13.9 Quality Assurance Records (NQA-1 Criterion 17)

This criterion ensures that documentary evidence of quality is specified, prepared, and maintained; and that QA records are protected against damage, deterioration, or loss. This criterion is implemented by the *ORNL Quality Assurance Manual* and by the WAG 2 RI

project QA/QC and Data Management plans. The Data Management Plan includes specific procedures for retention of QA/QC records in the project RCDB. QC of all records, their retention period, and other pertinent information is included in Table 12.1. QA reports are implemented by Sect. 12.8.

13. DATA MANAGEMENT PLAN

13.1 INTRODUCTION

The WAG 2 RI will generate data from many sources, including field measurements, laboratory analyses of environmental samples, and output from simulation models. Important records regarding the collection, analysis, and disposition of the samples and data will also be generated. The handling of these data and records along with documents related to project organization, health and safety, employee training, and QA/QC, among others, are described in this section.

13.2 OBJECTIVES

The objectives of the Data Management Plan are to provide organization, protection, retrievability, and accountability of the data and documents generated during the WAG 2 RI. All documents required to provide a complete and accurate history of data collection and analyses will be included in the records management system (EPA 1988a). The procedures in this plan are necessary to ensure that such data and records are documented to the extent necessary to support any future legal or administrative actions. The data management procedures will ensure that data are made available for uses such as statistical analysis and modeling without the introduction of additional uncertainty from data entry and management activities.

This plan identifies the documents, records, and data to be retained and describes the management structure and organization necessary to ensure their integrity and retrievability.

Three general types of information and documents will constitute the necessary WAG 2 RI record.

1. Records – any documentation (printed material) that must be maintained permanently unless directed otherwise by project management; see Tables 13.1 and 13.2.

2. Nonrecord Material – documentary materials that have little or no value from an overall operational standpoint and are used for short-term reference purposes.

3. Data – primarily numerical results obtained from environmental monitoring and sampling activities; see Table 13.3.

Items of record are listed in Table 13.2. Record materials will be maintained in the Environmental Restoration Division (ERD) Document Management Center (DMC) (Sect. 13.4). Controlled documents are considered to be record material and have controlled distribution. Controlled documents are maintained in the DMC and are subject to document control procedures outlined in Sect. 13.5. Numeric data are maintained in the

Table 13.1. Records to be included in the ERD DMC and the originating office.[a] Items of record (duplicate or original) are to be transmitted to the WAG 2 RI project manager for inclusion in the DMC.

Record Origination	Items of Record	Comment
ORNL Medical	Employee physician statements	Duplicates transmitted at the project manager's request through S&H Coordinator
ORNL Industrial Safety	Inspections Reports	Duplicates transmitted Safety Reports at the Project manager's request through S&H Coordinator
ORNL Technical Resources and Training	Training/qualification records OSHA training RCRA training Employee training Category III training	Duplicates transmitted at the Project manager's request through S&H Coordinator
ORNL Industrial Hygiene Division	Personnel monitoring Equipment monitoring Logbooks Routine surveillance reports Respirator fit testing and training	Duplicates transmitted at the Project manager's request through S&H Coordinator
ORNL Radiation Protection Department (Health Physics)	Personnel monitoring Equipment monitoring Decontamination records Unusual occurrence reports Routine Surveillance reports Logbooks	Duplicates transmitted through S&H Coordinator, at project manager's request
Environmental Monitoring and Compliance Division (EMC)	ALARA memoranda Engineering permits Environmental documents (ADM, EAM)	Duplicates transmitted at project manager's request through the S&H Coordinator
Quality Assurance	Audits Readiness review Surveillance reports	Originals transmitted to and maintained by the project manager

Table 13.1. (continued)

Record Origination	Items of Record	Comment
Contract Analytical Laboratories	Chain-of-custody procedures Analytical procedures QA/QC data	Duplicates transmitted by Laboratory Manager, originals are kept by the laboratory
WAG 2 RI Project Manager		plans to be prepared, reviewed and submitted in technical manual format
WAG 2 RI Task Leaders	Field and Laboratory notebooks Personnel training Reports Analysis procedures	Duplicates kept by Task Leaders, originals are transmitted
WAG 2 RI Sampling Team Leaders	Sampling procedures Personnel training Field and Laboratory notebooks	Duplicates kept by Team Leader, originals are transmitted to the DMC
Analytical Services Coordinator	Chain-of-custody forms	Duplicates kept by ASC, originals are transmitted to the DMC
Field and laboratory technical support staff	Field and laboratory notebooks	Duplicates are kept by staff, originals are transmitted to the DMC

*Subject to final approval.

Table 13.2. Items of record to be included in the DMC[a]. All records shall be maintained for the lifetime of the project plus 30 years.

Project Title: WAG 2 REMEDIAL INVESTIGATION

Name of Record	Master File Point[b]	Duplicate File Point[c]
Employee physician Statements	Medical	DMC
Inspections & Reports	Industrial Safety	DMC
Training Qualifications and Records	Technical Resources and Training	DMC
Monitoring records	Health Physics	DMC
Environmental documents	EMC Division	DMC
Audits, Surveillance Reports	project manager (DMC)	Quality Assurance Specialist
Laboratory Chain-of-Custody procedures, Analytical procedures, and QA/QC data	Analytical Laboratories	DMC
Field/Lab notebooks, Personnel training, Reports, and Analysis procedures	DMC	Task Leaders
Sampling procedures, Personnel training, and Field/Lab notebooks	DMC	Team Leaders
Chain-of-custody forms	DMC	Analytical Services Coordinator
Field/Lab notebooks	DMC	Technical Support Staff

[a]Subject to final approval.
[b]Master File Point: Location of master records. See Table 13.1 for details.
EMC: Environmental Monitoring and Compliance; DMC: Document Management Center.
[c]Duplicate File Point: Location of duplicate records. See Table 13.1 for details.

Table 13.3. Data to be included in the Numeric Database (NDB) and the originating office.[a] All data are to be transmitted to the WAG 2 RI project manager for inclusion in the NDB.

Record Origination	Category of Data Record	Comment
Biota Sampling Team	Organism vital statistics ESD laboratory data	Recorded in field notebooks, duplicates transferred to Program Manager
Sediment Sampling Team	Sediment characteristics Water quality data Water flow rate data Sediment core length ESD laboratory data	Recorded in field notebooks, data forms duplicates to Program Manager
Surface Water Sampling Team	Water quality data Field turbidity data Water flow rate data ESD laboratory data	Recorded on standard field data sheets, duplicates to Program Manager
Data Management, Integration, and Remedial Action Evaluation Task	Contaminant fate and transport model data	Retention of model input, output, and calibration data
Contract Analytical Laboratory	Analytical and QA data CLP forms	Electronic transfer to NDB, originals to Program Manager

[a]Subject to final approval.

Numeric Data Base (NDB) (Sect. 13.3.1). The DMC will support the provision of all project documents required for the Administrative Record (see Sect. 13.6).

13.3 DATA MANAGEMENT

Data management for this project will utilize the ORNL ER Program NDB for management and storage of field, analytical, and simulation model data as described in numerous reports (Voorhees et al. 1988, 1989; Hook et al. 1990). Numeric data are manipulated primarily with SAS software and stored as SAS data sets on the ORNL mainframe computers. SAS and various other compatible products (e.g., Lotus 1-2-3 and dBASE III Plus) are utilized with individual personal computers. The ERD DMC will be used for management of record material. The DMC serves as a computerized index for retrieval of information generated by the program (e.g., correspondence, project plans, field notebooks, chain-of-custody records, hard-copy data reports) from serially numbered archived files. All records will be permanently retained. Data management activities will support the preparation of all documents required for the Administrative Record (Sect. 13.6).

13.3.1 Numeric Database

The principal steps for processing data to be included in the NDB are identified in Fig. 13.1. These procedures will be followed for entry and verification of all numeric data generated during the WAG 2 RI. Data are stored on the IBM-3380 disk pool/Automated Data Library complex on the ORNL IBM-3090 system with daily incremental backup and weekly full-volume dumps to magnetic tape by computer operations staff. Access to the files is controlled under the ACF2 security system installed on the ORNL computer system. Data management activities, reference to programs used to manipulate the data, and documentation to the database are recorded in technical notebooks (QA-ES-6-100, Roberson and Logdson, 1989). Changes to the database, initiated by the analytical laboratory, will be provided in writing. Correction to the database initiated by the WAG 2 RI staff will be submitted in writing to the appropriate analytical laboratory. They shall be responsible for subsequent verification, correction, and reissuance of the data in question. All requests for direct "read only" access to WAG 2 RI data or hard-copy and graphical output will require the approval of the WAG 2 RI project manager.

The following sections discuss the various types of numeric data that may be generated during the WAG 2 RI and their processing from entry through verification.

13.3.2 Field Data Measurements and Observations

Field notes are the primary record that will provide sufficient data and observations that enable reconstruction of events that occurred. Field notebook entries should be factual, detailed, and objective.

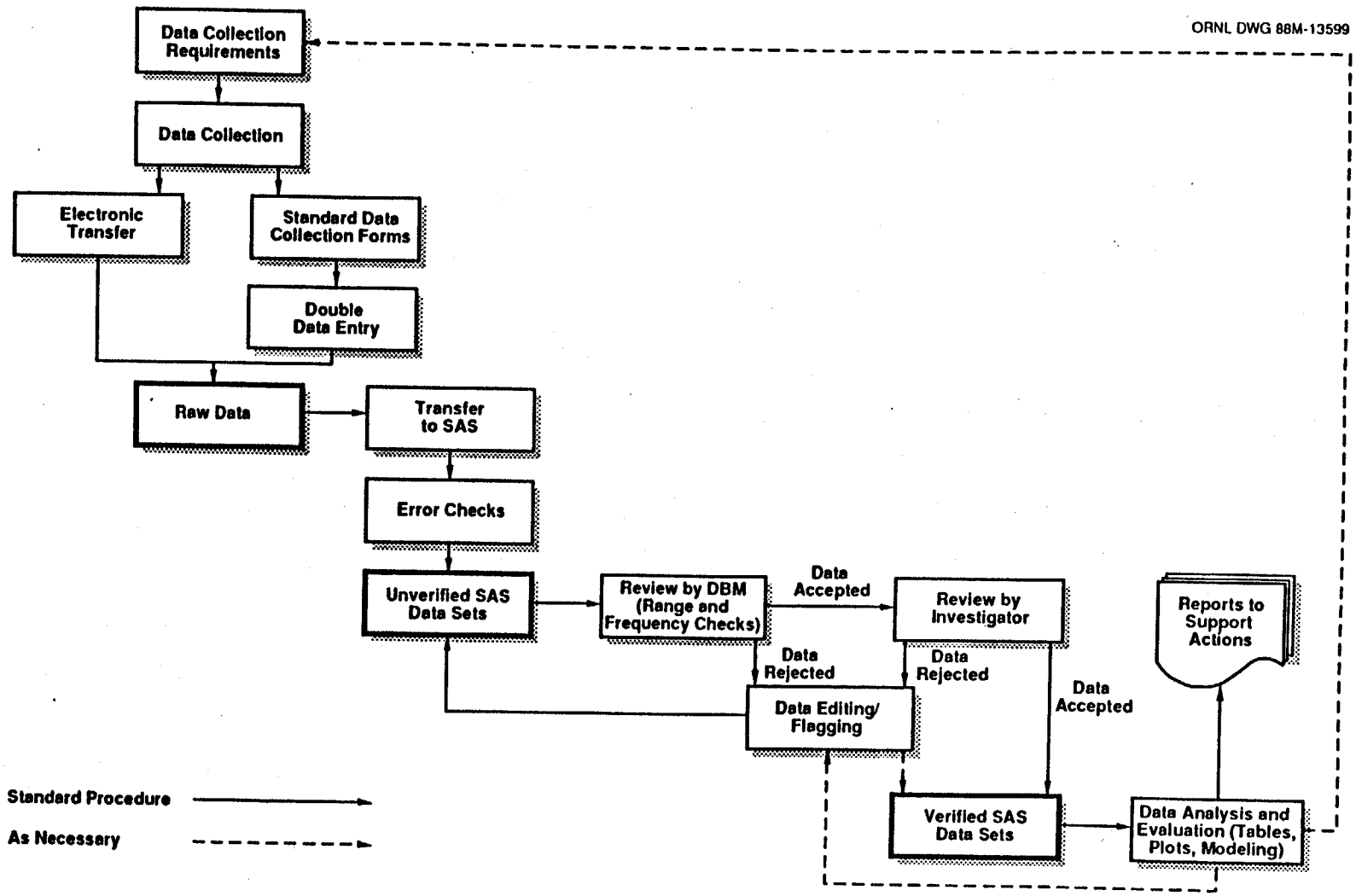

Fig. 13.1. Generalized flow diagram for processing numeric data.

All field measurements, such as pH, temperature, conductivity, water flow, sediment characteristics and instrument calibration data, will be recorded in the field notebooks or on specially designed data forms. All data will be directly entered in the field, signed, and dated. Changes made to original notes should not obliterate the original information. All field data records will be organized into standard format when possible. Team leaders are responsible for review of daily entries in the field logbooks.

It is the responsibility of the individual investigators and the WAG 2 RI project manager to safeguard these records. Manual double entry of field data by K-25 site data entry staff will be coordinated by the ASC. The WAG 2 RI project manager will forward field notebooks to the DMC at the conclusion of field activities.

13.3.3 Analytical Laboratory Data

Contract analytical laboratories will be required to use a computerized laboratory management system to track samples and report analytical results. Completed and approved data files will be electronically copied to ORNL computers. Transfers will be accomplished with software that incorporates accepted error-checking protocols. Data will be included in the NDB only after the hard copy of such data has been submitted by the WAG 2 RI project manager to the DMC.

Results of any water quality analyses performed at the ESD Aquatic Ecology and Radiological Laboratories will be recorded directly on data sheets, reviewed by the analysts, signed, and copies sent to K-25 site data entry where data will be double entered and verified to ensure accurate entry.

13.3.4 Simulation and Risk Assessment Models and Data

Documentation of contaminant fate and transport models will be retained. Documentation includes descriptions of the model equations, assumptions, solution methods, and initial and boundary conditions used. The input data, output, and program files for calibration and for analyses used as bases for important programmatic decisions will be available to outside reviewers. All data input, output, program files, and equations, factors, and assumptions employed in the screening-level risk analyses and in subsequent risk analyses conducted for the WAG 2 RI project will also be retained and available to outside reviewers.

13.3.5 Validation of Existing Data

Data from numerous historical and current sources, which were/are collected for various programs and under varying degrees of QA, will be included in contaminant fate and transport models, risk assessment analyses, and potentially the NDB. The WAG 2 investigations will be closely linked with other environmental monitoring activities at ORNL:

NPDES, surface water radiological, other RIs, the CRRFI of off-site contamination, and various research activities. Before such data can be used for the WAG 2 RI, they must be evaluated for quality (i.e., validated). A procedure will be developed to provide an independent examination of the quality of previously and externally collected environmental data to determine whether they can be used in the WAG 2 RI for purposes such as risk assessment analyses or for reaching a recommended remedial action. The ORNL/ER Program RI/FS procedure (Project Procedure 1502, BNI Team 1988h) will serve as a guide. Quality criteria will include evaluation of sample collection, sample handling, laboratory analysis, and data reduction and storage procedures.

13.3.6 WAG 2 RI Data

Data reduction, verification, and reporting will be in accordance with the ongoing ORNL ER Program database management activities (Voorhees et al. 1989; Hook et al. 1990) QA/QC procedures, data are verified using a variety of computerized checks for reasonableness.

Field data will be reviewed by the appropriate WAG 2 RI task leader, who will be responsible for resolving any questions regarding the data.

Laboratory data will be checked for both internal consistency and transmittal errors by the laboratory supervisor. Errors will be corrected and documented. The analytical data reports will be reviewed using QA/QC procedures outlined in the WAG 2 RI QA/QC plan (Sect. 12).

13.4 ERD DOCUMENT MANAGEMENT CENTER

All information that is required to provide a complete and accurate history of the project organization, sample collection, and analysis activities is designated as "record documents." The database associated with the hard copy repository provides for organization, protection, retrievability, and accountability of such information. All requests for access to WAG 2 RI information from the DMC will require the approval of the WAG 2 RI project manager and the WAG 2 RI database manager.

Protocols for communication of necessary documents and data between the DMC and the administrative record will be implemented as part of the WAG 2 RI database management activities.

13.4.1 Records Control Process

Records to be controlled as well as responsible organizations and personnel are shown in Table 13.1. Those responsible for the preparation, review, and approval of records will transmit the original to the WAG 2 RI project manager and maintain an indexed,

retrievable duplicate file. Major changes to documents must be reviewed and approved by the same organizations that performed the original review and approval. The WAG 2 RI project manager has the responsibility to identify all record items and will forward appropriate information to the DMC. Each submittal will be attached to a submittal cover sheet (Fig. 13.2).

13.4.2 Document Index and Archive

The database associated with the DMC serves as a computerized index for retrieval of record documents generated by the program. All documents submitted will be indexed and permanently retained unless directed otherwise by the WAG 2 RI project manager. Backup files of the document index will be created at the end of each day during which new records were created or existing records edited. A copy of the entire database will be transferred on a monthly basis and stored in another location to minimize the loss of the database in the event of catastrophe.

13.5 DOCUMENT CONTROL

A procedure developed for the ORNL ER Program that defines the management system to control the issuance and distribution of documents will be applied to use with WAG 2 RI documents. The project manager is responsible for ensuring that the document has been fully reviewed, assigned a correct document number, and if appropriate, had document approval forms filed before being sent to the DMC. This procedure ensures that once a reproducible copy of the document has been sent to the DMC, the document will be reproduced in sufficient quantity, distributed with return receipts for numbered copies, updated when necessary with instructions and return receipts, and returned to the DMC when no longer needed. Controlled documents are generally those associated with QA/QC of projects, safety of workers, and construction or engineering plans.

13.6 ADMINISTRATIVE RECORD

DOE will maintain and preserve the complete administrative record, including supporting documents, for a minimum of 10 years following the termination and satisfaction of the project. DOE shall notify EPA and TDHE at least ninety days before the destruction of any such records or documents. DOE will upon request by EPA or TDHE make such documents (or copies) available.

Copies of the current index to the administrative record and selected documents shall be available to the public during normal working hours at the center established by DOE at Lee Wan and Associates, Inc., on Jefferson Circle in the city of Oak Ridge, Tennessee.

COVER SHEET FOR WAG 2 RI SUBMITTALS TO THE DOCUMENT MANAGER CENTER

NAME _____ DATE SUBMITTED _____

PHONE _____ BUILDING _____ ROOM _____ MAIL STOP _____

TITLE/SUBJECT OF ITEM: (if not obvious, please describe briefly)

_____

_____

_____

DATE WHEN DATA/INFORMATION WAS COLLECTED: _____

DATE WHEN ITEM/RECORD ATTACHED WAS PREPARED: _____

SITE NAME: (Include site name or number, if known or a general description of the area addressed by the item attached.)

_____

_____

_____

IF YOU WANTED TO RETRIEVE THIS ITEM FROM THE Database OR IF IT IS A PART OF A PARTICULAR PORTION OF YOUR COLLECTION, LIST SOME TERMS OR DESCRIPTIVE PHRASES THAT WOULD IDENTIFY IT FOR QUICK RETRIEVAL.

_____

_____

_____

Approved for Submittal to the DMC

_____

WAG 2 RI project manager

Fig. 13.2. Cover sheet for submittals to the ERD DMC.

14. GENERAL HEALTH & SAFETY PLAN

14.1. INTRODUCTION

This WAG 2 RI Health and Safety (H&S) plan presents the concepts and methodologies to be used during the WOC system project to protect the health and safety of sampling team personnel.

14.1.1 Policy

The procedures that must be followed while performing site investigations for the WAG 2 RI are prescribed by this H&S plan. Personnel working on the WAG 2 RI project shall be informed of existing and potential hazards associated with the tasks to be performed through presampling briefings. Information disseminated and personnel in attendance shall be recorded in the field log book. This knowledge will allow effective application of required safety precautions. Specific health and safety information (personnel protective equipment, water safety, organizational structure, etc.) is given in the following sections.

This H&S plan complies with all applicable Occupational Safety and Health Administration (OSHA) regulations including 29 CFR 1910.120. The provisions of this plan are mandatory for all personnel and subcontractors assigned to the project, as well as all authorized visitors. As appropriate, written addenda to the plan will be provided by the project health and safety coordinator. No changes to the plan will be implemented without prior approval of the H&S coordinator.

14.1.2 Adherence to Quality Assurance/Quality Control Plan

The philosophy, activities, and procedures which implement requirements of the WAG 2 RI H&S plan comply with and complement the requirements of the WAG 2 RI Quality Assurance/Quality Control (QA/QC) plan (Sect. 12).

14.1.3 WAG 2 Health and Safety Information and Procedures

The principal hazards expected during these activities are related to physical and aquatic activities, heat and cold stress, and potential contact with media (sediment, water, and biota) contaminated with radionuclides.

Most field activities will be conducted at sites located in Radiological Areas, i.e., areas where workers may be exposed to radiation or radioactive materials. Site-specific health and safety information and procedures shall be developed and made available to all site employees. This information shall include the following:

- names of key health and safety personnel;
- health and safety risks or hazard analysis for each site task and operation described in H&S plan Overview (Sect. 14.1.8), Site Characterization and Evaluation (Sect. 14.2), and Safe Sampling Practices (Sect. 14.3);
- medical surveillance requirements (if requirements other than those stated in Sect. 14.5 are necessary); and
- personnel protection requirements (Sect. 14.6).

The H&S coordinator shall make audits and inspections of sampling sites to determine the effectiveness of the site health and safety plan. Deficiencies shall be noted in the site log. Any deficiencies noted shall be corrected immediately, and the corrective action taken shall be noted.

14.1.4 WAG 2 Health and Safety Practices

The following steps will be taken routinely to ensure the safety and well-being of all project personnel:

1. The H&S coordinator will review each task before it begins. The coordinator will determine which, if any, requirements shall be required; changes to the health and safety plan must be documented.

2. Sections of the H&S plan that relate to physical and radiological hazards must be satisfied.

3. All personnel, including contract and other agency employees, must wear a thermoluminescent dosimeter badge (TLD) issued by ORNL while engaged in WAG 2 activities.

14.1.5 Laboratory Health and Safety Practices

Laboratory analysis of samples returned from WAG 2 may involve hazards unrelated to the constituents of a particular sample. It must be documented that all contract program laboratories will be in compliance with relevant DOE, OSHA, and ORNL health and safety requirements. Laboratory-specific H&S requirements will be addressed by the standard operating procedures (SOPs) for each laboratory.

14.1.6 Information Programs

Employees will be informed regularly (Sects. 14.1.5, 14.2, and 14.4.4) of site-specific health and safety hazards and the requirements of 29 CFR 1910.120, Hazardous Waste Operations and Emergency Response; DOE Oak Ridge Operations, "Radioactive Contamination Control Policy" (October 1989); DOE Order 5480.11, Radiation Protection for Occupational Workers; and the *ORNL Health Physics Manual.*

14.1.7 Regulatory Requirements

The environmental, safety, and health protection requirements applicable to the WAG 2 RI are set forth in DOE orders; Energy Systems and ORNL procedures; and applicable federal, state, and local regulations and standards. Certain DOE orders are applicable to site characterization. As most recently revised, these may include, but are not limited to, relevant DOE orders, OSHA regulations, and ORNL manuals.

Concurrently, DOE and its contractors have adopted permissible exposure limit (PEL) guidelines for chemical substances and physical agents, as listed in 29 CFR 1910. Where 29 CFR 1910 is silent for relevant chemical substances or physical agents, the values listed in the following order will be used in the order given:

- American Conference of Governmental Industrial Hygienists threshold limit values (TLV).
- National Institute of Occupational Safety and Health recommended exposure limits (REL).

Where more than one standard exists, the more conservative value will be applied.

Administrative guidelines for occupational exposure to radiation for workers at ORNL have been established at approximately one-third of the limits set by DOE (DOE Order 5480.11). For whole-body exposures, ORNL guidelines limit the effective dose equivalent for workers to 2.0 rem/yr (20 mSv), 100 mrem/wk (1 mSv), and 20 mrem/d (0.2 mSv). Workers who do WAG 2 RI field work shall be required to complete on-site SARA/OSHA training for hazardous site activities and radiation worker training before they are permitted to work in radiological areas.

The packaging and shipment of samples to and from laboratory facilities shall be performed in accordance with federal Department of Transportation (DOT) regulations set forth in 49 CFR and with Tennessee DOT regulations. Other codes applicable to safe operations include National Fire Protection Association (NFPA) codes and federal and local fire codes.

14.1.8 H&S Plan Overview

The health and safety sections of the WAG 2 RI plan, specifically those concerned with organization and responsibility of personnel and with training, are designed to ensure that the safety and health of personnel are not endangered by negligence or inadequate training. Specifically the H&S plan addresses the following:

- Personnel: Discussion of the requirements and responsibilities for personnel involved in this program.

- Training: Discussion of the implementation of the employee informational program, training and certification program, medical surveillance programs, personnel protection, water safety, decontamination, and emergency procedures.

All personnel who are involved in operations and who handle, sample, dispose of, or otherwise have a potential for exposure to site-specific contaminated materials are subject to this H&S plan. Maintaining a safe and healthful work environment is the responsibility of supervisors and each team member. Through the training program (Sect. 14.4), all team members shall be informed of potential hazards, proper use of protective equipment, applicable procedural requirements, and their responsibilities for maintaining safe working environments. Personnel are required to adhere to all safety requirements. All subcontractors will be trained as necessary according to the specifications set forth in Sect. 11.

General responsibilities for WAG 2 RI staff will be expected to:

- safeguard record materials, including, but not limited to, field notebooks, raw data sheets, and chain-of-custody forms;
- maintain complete, factual, detailed, and objective program notes;
- retain records of all analyses and procedures used for the WAG 2 RI;
- ensure that proper waste management procedures are followed; and
- ensure that the requirements of the S&A plan, QA/QC, Data Management, and H&S plans are satisfied.

All WAG 2 RI contractors and subcontractors performing each sampling task at each sampling site shall be informed of the potential hazards associated with these procedures and be required to undergo the same level of training as WAG 2 RI personnel. All plans relevant to the health and safety of any sampling personnel as outlined in this document shall be made available to the contractor and the subcontractor.

14.2 SITE CHARACTERIZATION AND EVALUATION

Each sampling site shall be evaluated to identify specific site hazards and to determine the appropriate health and safety procedures needed to protect employees from the identified hazards.

14.2.1 Site Evaluations

Data from preliminary site evaluations will be used to aid in the selection of appropriate personnel protection methods prior to the initial sampling phase. Methods will be selected according to ORNL-ESD Health and Safety Policy (McConathy 1990). After the initial phase of sampling and after each subsequent phase as data become available, more detailed evaluations of each site shall be performed to aid in the selection of appropriate protective equipment and controls. All potentially hazardous conditions shall be identified during the site evaluations.

14.2.2 General Site Information

The following health and safety information shall be included in the site-specific characterization and evaluations:

- location of the site,
- description of sampling task(s),
- site hydrology or topography (as relevant),
- site accessibility, and
- potential pathways for hazardous substance dispersal and exposure.

Hazardous substances and health hazards involved or expected and their chemical and physical properties shall be included in the form of Material Safety Data Sheets (MSDS). It should be noted that MSDS information relates to pure forms of a chemical. Wastes are often admixtures of greater hazard than encountered from component contaminants. Radiological hazards shall be addressed in the form of specific procedures for working in radiological areas, handling contaminated materials, and monitoring to measure exposure levels and to prevent spread of contamination.

14.2.3 Health and Safety Site Characterization

The principal health hazard for workers engaged in field activities for the WAG 2 RI will be from exposure to or contact with radioactive materials present in the WOC system. One goal of the S&A plan is to identify sites where maximum concentrations of contaminants, including radionuclides, are found.

A physical hazard that is associated with sampling the WOC embayment involves sudden increases in water velocity and depth caused by hydroelectric power generation from the TVA Melton Hill Dam at Clinch River Mile 22.9.

14.3 SAFE SAMPLING PRACTICES

Procedures for obtaining sediment, water samples, and biota for this project will be prepared before sampling gets underway and will be included in the final S&A plan.

14.3.1 General Site Health and Safety Requirements

The following health and safety requirements will be implemented at each sampling site:

- At least one copy of the S&A plan, including specific sampling procedures, shall be available at the sampling site.
- Flotation devices, such as life vests, shall be worn by all personnel, both team members and visitors, under the conditions specified in Water Safety (Sect. 14.8) and in Boat Safety (Sect. 14.3.4).

- Procedures for working in radiological areas and handling contaminated materials shall be enforced.
- Legible and understandable precautionary labels shall be affixed prominently to containers of samples, contaminated scrap, waste, debris, and clothing. Labels shall include date, location, and suspected or known contaminant material.
- Removal of contaminated soil from protective clothing or equipment by blowing, shaking, or any other means that disperses contaminants into the environment is *prohibited*.
- Samples shall be stored in tightly closed containers in well-ventilated areas, as specified by the S&A and QA/QC plans.
- Containers shall be moved only with the proper equipment and shall be secured to prevent dropping or loss of control during transport.
- Emergency equipment shall be readily accessible.
- DOT transportation requirements will be met.

Personnel Safety

Each member of the sampling team shall be informed of the hazards associated with working on a boat along with the site-specific hazards (Sect. 14.3.4). When sampling from a boat, sampling teams shall consist of at least two persons. Crew members must observe each other for signs of temperature or other stresses, as discussed in Medical Surveillance Sect. (Sect. 14.5, 14.6). Also, employees shall inform each other of nonvisual effects of stress.

Other Regulations

All personnel and visitors shall abide by the following at all sampling sites:

- No food or beverages shall be present or consumed while collecting samples.
- No tobacco products shall be present or used, and no cosmetics shall be applied at the sampling site.
- The use of alcohol or drugs is prohibited.
- Workers using prescription medication shall disclose this fact to the WAG 2 RI project manager, the sampling team leader, and (if needed) to the occupational physician so that potential complications can be avoided.
- No personal clothing (except undergarments) or other items (books, magazines, etc.) shall be taken or worn into a radiological area.
- Visitor inspection of the sampling sites will be left to the discretion of the sampling team leader.

14.3.2 Field Communications

Field communication procedures are outlined in Emergency Procedures (Sect. 14.10), in *ESD Radio Use Procedures* (McConathy 1988) and in *ESD Guidelines for Field Work and Safety* (McConathy and Parr 1988).

14.3.3 Hazard Communication

Once hazards associated with either particular sampling sites or with sampling in general have been identified, the risks of these hazards shall be communicated to the site personnel. The methodologies of hazard communication are outlined in Sect. 14.4. MSDS shall be made available to all employees.

14.3.4 Boat Safety

Sampling personnel should inform ESD personnel of the nature of their sampling trip, their destination, and their estimated time of return. They also should carry and monitor a laboratory radio for field communications. Gear should always be loaded into the boats prior to launch, as the water and shoreline surrounding most launch ramps is uneven and steep. General precautions to be when sampling water, biota or sediment from boats include the following:

- Personnel should make as few movements as possible.
- Personnel should maintain a low center of gravity to avoid loss of balance.
- Personnel should be aware of the speed at which water velocity and depth will change, especially when sampling in the WOC embayment.
- Personnel should also be alert to rapidly changing weather conditions, especially if inclement weather has been predicted. Personnel should be prepared to immediately seek shelter on shore if lightening threatens.
- Boat decks should be maintained as free from obstructions as possible.
- Boats and equipment used in radiological areas must be checked for contamination before leaving the area.

Additional water safety requirements are given in Sect. 14.8.

14.3.5 Water Sample Collection

Operation of sampling devices (Kemmerer or Van Dorn style bottles) may present hazards to extremities. This is primarily due to the rapid, forceful spring action required to close these devices. Prior to collecting a sample, the following precautions should be taken:

- The line for lowering and retrieving the device should be free from tangles.
- Sampling devices should be opened (set) immediately before being lowered into the water.
- Sampling personnel should have good footing and should be able to steady themselves if the boat should shift suddenly.
- For particular samplers:
  - Van Dorn style bottles should be held by the side handle, away from the body before being lowered into the water.
  - Kemmerer bottles should be held by the top metal sleeve.

The sampling device will be lowered by hand to the prescribed depth. As the sampling device is retrieved, the personnel responsible should ascertain whether the device failed to

close at depth. If so, the device should be triggered while below the water surface, retrieved, drained, and reset. A "set" sampler should not be brought on board.

Precautions should be taken while filling sample containers and moving them to storage locations. Both sample devices and containers have considerably more mass when filled with sample, and, in the case of sample containers, no handle is present to facilitate carrying the container. Because sampling locations are in areas contaminated with radioactive materials, special precautions must be taken to minimize the spread of contamination when collecting and handling water samples.

14.3.6 Electroshocker Operation

Any general cautions listed above will apply to the collection of fish by electroshocking. Sampling team personnel should wear appropriate insulating clothing (gloves and boots) to prevent inadvertent shock. Hearing protection should be worn. Another hazard is derived from the exhaust noise and fumes produced by small gasoline engines. If fume concentrations reach irritation levels, sampling should be discontinued until sensitive organs have recovered and fumes have dispersed. The cautions concerning center of balance and maintaining an uncluttered work space are critically important to safe sampling with electroshockers.

14.3.7 Sediment Sample Collection

Sediment samples will be collected using ponar grab, vibracorer, or gravity corer. Each of these devices has sharp edges, is heavy, and is not easily manipulated. It is crucial to keep boat decks free from mud and other obstructions. Leather gloves, safety goggles, and reinforced toe boots are required in order to operate this equipment. Whenever devices are being lowered or raised using steel cable, that cable should be handled using leather gloves to protect hands from cuts. Proper rest breaks and sharing of tasks among personnel should alleviate exhaustion.

The ponar grab sampler should only be transported with the device locked open. When preparing to collect sediment, the locking pin should be removed with the jaws of the sampler supported by a photo tray. Whenever the locking pin is removed and the jaws are open, personnel should hold the trigger bar in place and pick up the sampler under the cross arms. If the open sampler is picked up immediately under the cable connection, it may be triggered, causing injury. Closed samplers should be picked up immediately under the cable connection, as specified above.

The vibracorer presents additional hazards, involving exhaust noise and fumes from the engine and vibrating machinery. Hearing protection shall be worn while the vibracorer is in operation. If fume concentrations reach irritation levels, the engine should be turned off and sampling discontinued until sensitive organs have recovered and fumes have dispersed. Special care must be taken to avoid damage to appendages caused by the vibrating head attached to the sample pipe. Sediments of the WOC system contain the highest

concentrations of radionuclide of all the media sampled. Procedures for collecting and handling sediment samples will be prepared and included in the final S&A plan before sampling begins.

14.4 EMPLOYEE TRAINING AND CERTIFICATION PROCEDURES

14.4.1 Duration

All personnel involved in the WAG 2 RI project are subject to training in accordance with 29 CFR Part 1910.120. All personnel will have previous experience in field sampling and will receive a minimum of 3 days of actual field experience under the direct supervision of the appropriate sampling team leader. Personnel engaged in sampling site management and supervision shall receive a minimum of 8 hours of additional training. All employees having the required previous experience and 3 days of field experience and acknowledging their understanding and intent to comply with procedures outlined in these plans will be certified as sampling personnel. It is necessary for each person involved in the WAG 2 RI sampling to receive annual refresher training on the items outlined in this section.

14.4.2 Sample Site Personnel Course Content Outline

Following is a general list of topics to be covered in the training course:

- General sampling operation safety.
- Physical hazards (noise, heat stress).
- Names of personnel responsible for site safety and health.
- The specific nature of the sampling operation relevant to contaminant exposure levels.
- Purpose, proper selection, fitting, use, and limitations of personal protective equipment and clothing applicable to field sampling.
- Medical surveillance requirements.
- Personnel Right-to-Know (Hazard Communication, 29 CFR 1910.1200).
- Information concerning adverse health effects associated with exposure to contaminants.
- Routes of exposure to contaminants.
- Engineering controls and safe sampling practices.
- Components of the sample collection program.
- Boat safety procedures.
- Radio use procedures.
- Decontamination practices for personnel and equipment.
- Emergency response plan.
- Waste disposal procedures.
- Procedures for working in radiological areas, handling contaminated items, and using radiation survey equipment.

Certification procedures for both sediment and water sample collection will be included in the final Sampling and Analysis plan. Training for operation of electroshockers is conducted by the Biota Sampling Team Leader or a qualified designee. Additionally, certification in American Red Cross lifesaving and first aid procedures, specifically procedures such as CPR, are advisable for sampling team personnel.

14.4.3 Radiation Protection

All personnel involved with this project will participate in a training course (e.g., ORNL SARA/OSHA Training for Hazardous Waste Site Activities and Radiation Worker Training) to review the health physics (personnel radiation protection) precautions, to be used to reduce exposures to as-low-as-reasonably-achievable (ALARA). This training will be based on job requirements and training shall be documented. This course will comply with the requirements of ORNL HP Procedure 1.2.

14.4.4 Pre-Sampling Briefings

The following training sessions and informational materials will be provided on site:

- A safety meeting will be conducted at the beginning of each sampling run or whenever new personnel are to be employed at particular sampling sites. The health and safety considerations for the day's activities will be discussed, and the necessary protective equipment will be outlined. All information discussed shall be recorded in log books.
- Material Safety Data Sheets - Completed MSDS for the toxic materials identified as being present at hazardous concentrations at the site shall be available.
- Site Safety plan - All persons entering the site shall be informed of the contents of the site safety and health plan.

14.5 MEDICAL SURVEILLANCE

14.5.1 Physical Examination

As required by OSHA regulation 29 CFR 1910.120, all personnel on site will have successfully completed a replacement or periodic/update physical examination. This examination has been designed to comply with 29 CFR 1910.120 requirements for hazardous waste site operations. Less thorough examinations may be required for sampling team personnel.

All subcontractor personnel who have potential for exposure to hazardous materials must have successfully completed an examination similar to the replacement physical. The cost for medical surveillance will be paid by the subcontractor. All physicals will be approved by a physician who is board-certified in occupational medicine.

14.5.2 Medical Records

Medical and personnel exposure monitoring records will be maintained in accordance with the requirements of 29 CFR 1910.20 and shall be kept for 30 years after employee termination. Employee confidentiality shall be maintained.

14.5.3 Injury and Illness Treatment

A physician familiar with occupational medicine will be identified before job startup. This physician will be familiar with the effects of the chemicals on-site and will be used as a consultant in the event of a job-related illness. If an injury or illness is the result of a chemical exposure, a supervisor shall promptly initiate the steps necessary to identify the chemical(s). Chemical identification shall be accomplished through use of monitoring equipment (photoionization detectors in conjunction with detector tubes and/or conventional industrial hygiene monitoring) and any prior sampling results that are available. Such information shall be made available to the treating physician and the health and safety coordinator.

An injury or illness requires the completion of a "Supervisor's Incident Report" (Fig. 14.1). An injury/illness not limited to a first-aid response requires that the sampling team leader immediately notify the health and safety coordinator. This notification allows the coordination of internal resources to assist the treating physician in rendering appropriate care.

Any employee or subcontractor who is suspected of having an overexposure to the chemicals on-site will be given another complete physical examination. Any employee or contractor who develops a lost-time illness or sustains a lost-time injury will be reexamined. The physician will certify in writing that the employee is fit to return to work by completing the "Request for Pre-placement/Health Evaluation/Medical Restriction" form (Fig. 14.2). If necessary, activity restrictions will be specified on the Fig. 14.2 form.

14.6 PERSONNEL PROTECTION

Protective equipment to be employed at all sites includes U. S. Coast Guard (USCG) approved personal flotation devices (PFDs, worn as specified in Sect. 14.8) and clothing appropriate to season. Protective equipment to guard against contamination of personnel will be specified by an industrial hygienist or health physicist. Personal protective equipment will be specified in sampling procedures for the type of sample being collected and the area being sampled. First aid kits shall be available at all times when sampling.

Field sampling clothing should not interfere with operation of instruments, recording of data, and collection of samples while protecting against thermal extremes. When environmental conditions persist that prevent these requirements from being met practically, then sampling should be postponed until more favorable conditions prevail. Adequate cold weather clothing (as listed in Sect. 14.6.2) shall be made available to all sampling team personnel.

SUPERVISOR'S INCIDENT REPORT

NJURED EMPLOYEE	EMPLOYEE NO.	AGE	SEX ☐ MALE ☐ FEMALE
JOB TITLE	DIVISION	DEPARTMENT	
TYPE OF INJURY	PART OF BODY AFFECTED		

PROPERTY AFFECTED

DESCRIPTION	ESTIMATED LOSS	ESTIMATED COST OF REPAIR

EMPLOYEES INVOLVED

NAME	EMPLOYEE NO.

DATE OF INCIDENT	TIME OF INCIDENT ☐ AM ☐ PM	LOCATION OF INCIDENT	CAUSE CLASS
REPORTED TO *(Name)*	DEPARTMENT	DATE	TIME ☐ AM ☐ PM

DESCRIPTION OF INCIDENT

CAUSE OF INCIDENT

RESPONSIBILITY

ACTION TAKEN TO PREVENT A SIMILAR INCIDENT

ADDITIONAL ACTION THAT SHOULD BE TAKEN

CORRECTIVE ACTIONS AND CAUSE OF THE INCIDENT HAVE BEEN REVIEWED WITH THE EMPLOYEE(S) CONCERNED ☐ YES ☐ NO

SUPERVISORS SIGNATURE	DEPARTMENT	DATE
DIVISION SUPERINTENDENT OR REPRESENTATIVES SIGNATURE		DATE

UCN-103
(1235 4-82)

DISTRIBUTION: (1) Safety (2) Insurance (3) Division (4) Supervisor

Fig. 14.1. Supervisor's Incident Form Report required when an injury or illness results from a chemical exposure.

MARTIN MARIETTA ENERGY SYSTEMS, INC.

☐ ORGDP ☐ ORNL ☐ Y-12 ☐ PGDP ☐ PORTS

REQUEST FOR PRE-PLACEMENT/HEALTH EVALUATION/MEDICAL RESTRICTION

☐ New Applicant ☐ Former Employee ☐ Transfer ☐ Return From Disability/Leave ☐ Health/Restriction Evaluation

NAME | RESIGNATION/LEAVE DATE

BADGE NUMBER | DATE OF BIRTH | JOB TITLE (Please Attach JOB Restriction/Requirements)

SEND REPORT TO (Supervisor/Employment)

TITLE | DEPARTMENT | ADDRESS

TELEPHONE | CITY | STATE

NOTIFIED | DATE/TIME:

MEDICAL RECOMMENDATIONS

☐ Fit For Employment Without Restrictions

☐ Fit For Employment With The Following Restrictions (See Reason Below, Be Specific, Duration of Time, Circumstances, Etc.)

- ☐ Desk work only
- ☐ Sedentary: seated most of the time, minimal physical exertion
- ☐ Light Work: sit or move about, some walking, stair climbing, bending, stooping or squatting. Lifts or handles up to 25 lbs.
- ☐ Moderate Work: Lift up to 50 lbs., capable of all other work.
- ☐ No Lifting over _____ pounds.
- ☐ No excessive walking or standing
- ☐ No repeated squatting or bending
- ☐ No work requiring good hearing
- ☐ No work in area with excessive noise(85dB+)
- ☐ No work requiring good visual acuity
- ☐ No work requiring true color vision
- ☐ Limited respirator use
- ☐ No respirator use
- ☐ No working alone
- ☐ No motor vehicle operation
- ☐ No rotating shifts
- ☐ No work at elevation
- ☐ No rung ladder climbing
- ☐ No work around dangerous machinery
- ☐ No exposure to weather extremes
- ☐ Minimum repetitive motion of _____
- ☐ Re-evaluate prior to Re-assignment
- ☐ Other _____

Reason:

☐ Recommend Employment Be Deferred (See reason below, e.g., acute infection, awaiting medical information; specific diagnoses will NOT be stated.)

Reason: _____

☐ Not Fit for Employment (Specify extent and permanence of health problem.)

Reason: _____

☐ Re-Evaluation May Be Scheduled In (Days, weeks, months, years, specify) _____

Review Dates:

_____ ____ _____ ____ _____ ____ _____ ____

_____ ____ _____ ____ _____ ____ _____ ____

HANDICAP CLASSIFICATION

Is this applicant handicapped? ☐ YES ☐ NO

Date | Signed M.D./P.A./R.N.

UCN-16305 (6 7-87)

DISTRIBUTION:

WHITE - Employment GREEN - Health Services YELLOW - Employee

BLUE - Supervisor Copy PINK - Division

Fig. 14.2. Request for Pre-placement/Health Evaluation/Medical Restriction Form.

14.6.1 Heat Stress

The following measures can be used to monitor and control heat stress:

- Adequate water to replace lost body fluids must be provided.
- All breaks are to be taken in a shaded rest area or in a moving boat.
- Employees shall always decontaminate their hands and face before rest periods.
- Employees shall remove impermeable protective garments during rest periods.
- All employees shall be informed of the importance of adequate rest, acclimatization, and proper diet in the prevention of heat stress.

Because most field work will occur in radiological areas, rest breaks must be taken outside contaminated areas if food or beverages are consumed.

14.6.2 Cold Stress

Aquatic sampling may expose sampling personnel to cold stress during extremely cold weather. Cold stress may also strike inadequately clothed personnel during summer rain storms. One or more of the following measures should be used to help control cold stress:

- Thermal clothing needs to be capable of retaining warmth when wet. Articles manufactured from wool, silk, neoprene, or thinsulate are preferred to articles made of cotton or nylon. Because personal clothing (except undergarments) and shoes are not permitted in radiological areas, arrangements must be made ahead of time to see that all workers are provided with the necessary company-issue clothing.

- Areas of the body with high surface-area-to-volume ratios, such as limbs, feet, hands, the head, and ears are most susceptible to cold stress. Thermal socks, gloves, and hats may be necessary.

- Personnel should dress in layers: Jackets, shirts, and sweaters should be layered over long thermal underwear.

- Personnel should avoid getting wet during any season. Adequate rain gear should be available, and it should be maintained in good condition or replaced periodically.

- If personnel should find themselves in the water, techniques such as keeping the head out of the water and doing the inverted jelly fish float should be used to reduce heat loss.

- Adequate extra clothing should be carried in the boat in a secure, dry location.

- Warm drinks (other than caffeinated coffee) and warm break areas are essential and must be taken outside of radiological areas.

- Emergency equipment should include thermal blankets.

- All employees shall be informed of the importance of adequate rest, acclimatization, and proper diet in the prevention of cold stress.

Cold stress should always be considered a most serious threat to health and safety when conducting aquatic sampling. Problems associated with cold stress include the following:

- Temperature: Ambient temperatures at or below freezing may cause unprotected skin to be frostbitten over time. Extreme cold for a short time may cause sever injury to the surface of the body or result in profound generalized cooling.

- Wind Chill: A second factor influencing the development of a cold injury is wind chill. Wind chill effects may be eliminated by covering exposed skin and seeking a wind block on board.

- Wet conditions.

14.6.3 Protective Equipment for Specific Sites

Sampling tasks may expose sampling team personnel to potentially hazardous concentrations of contaminants, especially radionuclides, in the WOC system.

Existing data indicate that sampling of other sites does not constitute a contamination hazard.

Potential contaminant hazards of sampling PCE results from direct contact with sediment. Protective clothing to be worn by personnel involved in sediment collection and processing shall include anti-contamination gloves, splash gear, and boots. Personnel responsible for recording data and chain-of-custody procedures who do not come in direct contact with the sediments shall not be required to wear protective clothing.

Contaminant hazards to sampling personnel in WAG 2 result mainly from direct contact with sediment contaminated by hazardous concentrations of industrial wastes and radioactive materials. Principal hazards originate from gamma emitters. Protective clothing to be worn by personnel involved in sediment collection and processing shall include contamination-zone coveralls, anti-contamination gloves and boots, and disposable rain pants. Additional protection in the field will be provided by the use of pocket dosimeters. Personnel who are likely to come in direct contact with contaminated material shall not be required to wear contamination-zone clothing, but shall not wear personal clothing or shoes into a radiological area. A beta-gamma survey meter shall be taken on all trips to radiological areas. The meter shall be used to frisk personnel and equipment prior to leaving the areas or entering vehicles. A beta-gamma scan shall be performed in the field on collected cores. If environmental conditions permit, sediment cores should be processed in the field. If radioactivity exposure levels greater than 10 mrem/h are detected, further sampling should be postponed and all personnel moved a safe distance from the contaminated area. Personnel shall contact the area HP supervisor for guidance before sampling is resumed.

14.6.4 Protective Equipment for Specific Tasks

Specific protective equipment requirements are summarized by task. Protective equipment will be provided and must be inspected during use to ensure suitability. The team leader or the user is responsible for equipment inspection.

Boat Electroshocking: Personnel operating electroshockers and those netting fish are required to wear the following protective equipment:

- insulating gloves,
- insulating boots,
- personal flotation devices,
- safety glasses,
- hearing protection, and
- company-issue clothing, shoes, waders, etc.

Sediment Coring: Personnel collecting sediment samples by ponar grab sample, gravity core, or vibracore device are required to wear the following protective clothing:

- protective gloves,
- boots,
- safety glasses,
- hearing protection (only for using vibracorer), and
- company-issue outer clothing and shoes.

14.7 AIRBORNE CONTAMINANTS

Airborne concentrations of chemical and radiological contaminants should not be routes of exposure significant enough to justify air monitoring at most sampling sites. However, elevated concentrations of ^{3}H may be present in certain areas along upper MB. No site monitoring for airborne contaminants is planned in conjunction with the WAG 2 RI. Certain tasks involving the use of internal combustion engines in sampling (specifically, electroshocking and sediment coring) shall be conducted in a manner to minimize exhaust fumes and noise pollution. Adequate ventilation shall be provided, and engine operation times shall be limited to achieve minimal exhaust and noise pollution.

14.8 WATER SAFETY

Primary attention shall be given to USCG and ESD boating safety procedures. These regulations include the following requirements:

- At least one USCG-approved fire extinguisher shall be carried on each boat.
- Decks and other working surfaces shall be maintained in a safe condition.
- One USCG approved throwable personal flotation device (cushio, life-ring) shall be on each boat.
- One USCG-approved life jacket shall be provided for each person on board.

- No smoking, matches or open flames of any sort will be permitted in the boats.
- Daily inspection of all safety equipment and systems shall be documented by team leaders.

Additional requirements and training procedures are found in Sect. 14.3.4, and in the ESD Boating Safety Procedures. An annual training course in water safety and safe boating practices will be required for all ORNL-ESD and subcontractor personnel involved in field sampling on the WAG 2 RI project.

14.9 RADIOACTIVE CONTAMINATION CONTROL

14.9.1 Radiological Areas in Laboratories

14.9.1.1 Delineated Zones

Work areas where surface contamination is likely to be in excess of the guides specified in Attachment 2 to DOE Order 5480.11 (Fig. 14.3) must be designated a Regulated Area. Work areas where surface contamination is in excess of 10 times the guides in Fig. 14.3 must be designated a Contamination Area. Regulations governing the control of radioactive contamination are given in Procedure RP-2.5 of the *ORNL Health Physics Manual.* Before establishing a Radiological Area, WAG 2 RI personnel shall contact area radiation protection personnel for assistance in establishing the appropriate Radiological Area and developing routine monitoring programs for the area and the personnel who work therein.

14.9.1.2 Area Controls

Only persons who are authorized by the supervisor of a Radiological Area and are qualified by training shall be permitted to enter a Regulated Area or a Contamination Area. Entrance to and exit from a Regulated Area or a Contamination Area shall be made through specified area portals where special instrumentation, protective equipment, and radiation protection surveillance are provided. Regulated Areas and Contamination Areas shall be marked with radiation rope (or other appropriate barrier) and shall have signs at the entrances to signify the current contamination levels and the protective measures to be taken. Guidelines concerning the use of radiological signs, tags, labels and other identification markings are provided in Procedure RP-2.3 of the ORNL Health Physics Manual and shall be followed by WAG 2 RI personnel. The exits of Contamination Areas shall be provided with step-off pads and receptacles for the segregation of reusable protective clothing and trash. Persons exiting Regulated Areas or Contamination Areas must perform a whole-body frisk in accordance with requirements and instructions posted at the exit. Careful frisking of the total body requires at least a 3-min scan with the appropriate hand-operated monitoring device.

SUBJECT: Attachment 2 of DOE Order 5480.11

SURFACE RADIOACTIVITY GUIDES

NUCLIDE[1]	REMOVABLE [2/4]	TOTAL [2/3] (FIXED PLUS REMOVABLE)
U-nat, U-235, U-238, and associated decay products	1,000 dpm α/100 cm^2	5,000 dpm α/100 cm^2
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	20 dpm/100 cm^2	300 dpm/100cm^2
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	200 dpm/100 cm^2	1,000 dpm/100 cm^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.[5]	1,000 dpm β-Γ/100 cm^2	5,000 dpm β-Γ/100 cm^2

1. Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should apply independently.

Fig. 14.3. Example of warning signs to be affixed in readily visible locations in or near contaminated work areas.

SUBJECT: Attachment 2 of DOE Order 5480.11

2. As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

3. The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 cm^2 is less than three times the guide values. For purposes of averaging, any square meter of surface shall be considered to be above the activity guide G if: (1) from measurements of a representative number n of sections it is determined that $1/n \ \Sigma n \ S_i \geq G$, where S_i is the dis/min-100 cm^2 determined from measurement of section i; or (2) it is determined that the sum of the activity of all isolated spots or particles in any 100 cm^2 area exceeds 3G.

4. The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. (Note - The use of dry material may not be appropriate for tritium.) When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. Except for transuranics and Ra-226, Ra-228, Ac-227, Th-228, Th-230, and Pa-231 alpha emitters, it is not necessary to use wiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

5. This category of radionuclides includes mixed fission products, including the SR-90 which is present in them. It does not apply to SR-90 which has been separated from the other fission products or mixtures where the SR-90 has been enriched.

Fig. 14.3. Continued.

14.9.2 Radiological Field Areas

Only persons qualified by training (SARA/OSHA Training for Hazardous Site Activities and Radiation Worker Training) shall be permitted to work in Radiological Areas in the WOC system. Protective measures taken by workers engaged in activities in Radiological Areas shall depend in part on the type of work to be performed. Procedures for radiation protection and contamination control shall be included in the final S&A plan. Topics to be covered shall include but not be limited to (1) requirements for personal protection (clothing, gloves, boots, personal radiation monitors, etc.); (2) use of radiation monitors; (3) decontamination of equipment; (4) disposal of waste; (5) handling, labeling, and transporting contaminated samples; (6) requirements for entering and exiting Radiological Areas; and (7) restrictions such as no eating, drinking, smoking, or personal items in Radiological Areas.

14.10 EMERGENCY PROCEDURES

These supplementary emergency response procedures have been developed to cover extraordinary conditions that might possibly occur at the sampling site. All emergencies and injuries, other than minor events, will be reported to the health and safety coordinator.

14.10.1 General

All incidents will be dealt with in a manner to minimize adverse health risks to site workers and spread of contamination. In the event an incident occurs, the following procedure will be followed:

- First aid or other appropriate initial action will be administered by properly trained personnel who are closest to the incidents. This assistance will be conducted in a manner to ensure that those rendering assistance are not placed in a situation of unacceptable risk.

- All incidents will be reported to the sampling team leader. The sampling team leader will decide if off-site assistance and medical treatment are required and will arrange for assistance.

- All sampling team personnel are responsible for conducting themselves in a manner to avoid spreading the danger to themselves and surrounding workers.

The following emergency equipment will be available at the site:

- first-aid kit,
- fire extinguisher and blanket,
- appropriate decontamination equipment and material, and
- portable two-way radio.

The sampling team leader will document all H&S risk incidents.

14.10.2 Responses to Specific Field Situations

Emergency procedures for specific situations are given in the following subsections.

14.10.2.1 Personal Injury

If a sampling team member is physically injured, Red Cross first-aid procedures will be followed. Depending on the severity of the injury, emergency medical response may be sought by calling KIN-294 with a portable radio. Seriously injured personnel shall not be removed from the scene unless imminent hazards exist. Professional medical help should be present before moving victims to prevent additional injury. If the injuries are minor, first aid will be administered as needed. If an injury occurs in a Radiological Area, and the wounded area is contaminated, medical help should be obtained to decontaminate the wound.

If the injury to the worker is chemical in nature (e.g., overexposure), the following first-aid procedures are to be instituted:

- Eye Exposure - If radioactively contaminated soils or liquids get into the eyes, wash eyes for at least 15 min if clean water is available. Obtain medical attention immediately. Safety glasses will be worn when performing specified tasks.

- Skin Exposure - If radioactively contaminated solids or liquids get on the skin, if possible, promptly wash the contaminated skin using soap or mild detergent and water for at least 15 min. Otherwise, use wipes to remove as much contamination as possible. Monitor the activity levels. Obtain medical attention immediately when personnel are exposed to concentrated solids or liquids.

Other potential hazards to personnel include those from animals (snake bite, insect sting, or puncture wounds from fish), poisonous plants and slip/trip/fall hazards. Additionally, there is always the potential for drowning accidents. In the event an injury results from these hazards or accidents, Red Cross first-aid procedures will be followed by certified personnel. If necessary, emergency medical response will be sought.

14.10.2.2 Fires

As a fire prevention measure, no smoking, matches, or open lights will be permitted in any boat. Dry chemical fire extinguishers, rated for class A, B, and C fires, will be provided. If a localized fire breaks out, dry chemical fire extinguishers will be used to bring the fire under control. If necessary and feasible, a fire blanket, soil, or other inert material will be placed on the burning area to extinguish the flames and to minimize the potential for spreading. If appropriate, the ORNL fire department will be contacted by radio (KIN-294) for assistance. All fires and use of fire extinguishers will be reported to the health & safety coordinator.

If an uncontrolled fire develops, releasing potentially toxic gases, all persons in the immediate vicinity will be evacuated. Radio contact with the ORNL fire department will be made immediately to notify them of the materials involved.

14.10.2.3 Spills

In the event of a spill involving contaminated material in a boat, the area will be isolated from traffic by the sampling team leader. Spilled solids will be removed and placed into appropriate containers for subsequent disposal or taken to the original destination. Liquid spills will be contained with absorbent material and then the absorbent will be placed into appropriate containers for disposal.

14.10.3 Notification

Maps showing routes to the hospital, clinic, fire department, and police will be located in the boats along with the emergency phone numbers and radio instructions (McConathy 1988). Emergency telephone numbers are found in Table 14.1.

The sampling team leader will be responsible for contacting these organizations if necessary. If the fire department or paramedic emergency services are required, they will provide transportation to the hospital. For less serious circumstances, the sampling team leader or designated representative will provide transportation to the hospital or on-site medical facilities. Communications will be established prior to conduct of WAG 2 RI sampling activities. Each sampling team shall be equipped with an ORNL laboratory-and radio.

14.10.4 Documentation

In the event of an emergency, or a H&S risk incident, the sampling team leader will produce a report describing the following:

- the incident (including date and time) that necessitated the notification and the basis for that decision;
- date, time, and names of all person/agencies notified and their responses; and
- resolution of the incident (including duration) and the method/corrective action involved.

This report will be submitted to the H&S coordinator within 5 working days of the resolution of the event.

Table 14.1. Emergency telephone and ORNL radio call numbers.[a]

Responder	Radio call	Number Telephone
ORNL Shift Superintendent	KIN-294	4-6606
Fire Department		911
Paramedic/Rescue		911
Emergency Hospital		911
ORNL Industrial Hygiene		4-6164
ORNL Health Physics Field Surveyors		4-6700
National Response Center (for toxic chemicals and oil spills, USCG and EPA will be notified)		(800) 424-8802
CHEMTREC (For information and assistance in the event of a chemical release)		(800) 424-9300

[a]Subject to final review.

14.11 SANITATION

The proximity of the WOC system to ORNL shall enable persons engaged in field activities to return to ORNL for rest breaks. Furthermore, eating, drinking, and smoking are not permitted in Radiological Areas.

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Appendix A

STRATIGRAPHY OF THE CONASAUGA GROUP

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STRATIGRAPHY OF THE CONASAUGA GROUP

For general descriptions of the stratigraphy of the ORR, the reader is referred to Haase et al. 1985 (Conasauga Group and Rome Formation), Hasson and Haase 1988 (Conasauga Group) and Lee and Ketelle, 1987 (Knox Group). The summary of the Conasauga Group, which underlies WAG 2, presented below is taken from King and Haase (1987). All footage measurements refer to measured stratigraphic thicknesses of the units throughout the ORR.

PUMPKIN VALLEY SHALE (260-350 ft)

The Pumpkin Valley Shale consists of massive to thinly-bedded, maroon-brown to gray mudstones and shales interbedded with thinly bedded to laminated glauconitic siltstones. Two members can be identified, with the upper one being more shale- and mudstone-rich than the lower one. The lower member contains abundant zones of mottled, bioturbated shaly siltones interbedded with thinly bedded shales and siltstones.

RUTLEDGE LIMESTONE (90-140 ft)

The Rutledge Limestone consists of light gray to white, medium- to thinly bedded limestones and shaly limestones interbedded with medium to dark gray, thinly bedded to laminated, calcareous mudstones and shales. A persistent, 5 to 10-ft-thick interval of maroon to maroon-gray mudstone occurs toward the base of this formation and serves as a marker bed within the lower Conasauga Group throughout Bear Creek Valley (Law Engineering, 1975).

ROGERSVILLE SHALE (90-140 ft)

The Rogersville Shale is composed predominately of massive to medium-bedded, gray to maroon mudstones interbedded with medium to very thinly bedded, gray to maroon-brown shales. The shales and mudstones contain subordinate amounts of thinly bedded, glauconite-rich, locally calcareous siltstone. Within the middle and upper portion of the shale, a locally stromatolitic (Hasson and Haase 1988) carbonate unit, the Craig Limestone Member, of variable thickness is observed.

MARYVILLE LIMESTONE (340-463 ft)

The Maryville Limestone consists of light to dark gray, fine to coarsely crystalline limestone interbedded with subordinate amounts of dark gray, medium to thinly bedded, calcareous shales and shaly siltstones. The Maryville Limestone can be divided into two members (Haase and Tank, 1985), with zones of limestone-pebble conglomerates and ooid-rich beds being locally abundant in the upper member. The lower member consists of medium to thinly bedded calcareous shales and siltstones with subordinate amounts of crystalline limestones. Limestone-pebble conglomerates and ooid-rich beds are rare to nonexistent in the lower member (Haase and Tank 1985; Haase et al. in prep).

NOLICHUCKY SHALE (420-550 ft)

The Nolichucky Shale can be divided into three members: the Upper Shale, the Bradley Creek, and the Lower Shale members (Hasson and Haase 1988) although identification of these members in Bear Creek Valley is not straightforward. The formation consists of maroon-brown to rare green-gray, massive to very thinly bedded, locally calcareous mudstones and shales interstratified with thinly bedded, medium gray limestones and calcareous siltstones. The maroon-brown color of the shales is characteristic of the Nolichucky Shale (Haase et al. in prep). The interbedded limestone typically contains limestone-pebble conglomerates and ooid-rich beds similar to those ocurring in the underlying Maryville Limestone. Throughout much of the Nolichucky Shale, mudstone/shale and limestone lithologies alternate on a scale of 1 to 3 ft, giving the formation a thickly bedded appearance (Haase et al. in prep).

MAYNARDVILLE LIMESTONE (320-450 ft)

In ORR, the Maynardville Formation shows a gradational lower contact with the Nolichucky Shale (King and Haase 1987). The Maynardville Limestone is composed of light gray to tan, massive to thinly bedded limestone with subordinate amounts of dolostone. This formation can be divided into members on ORR (Haase et al. 1985). The uppermost Chances Branch Member consists of medium- to thinly bedded buff and light-gray dolostones, ribbon-bedded dolostones/limestones, and thinly bedded medium-gray limestones. The lower Low Hollow Member is principally wavy to evenly thinly bedded (oo)microsparite, with alternating horizons of dolomite-bearing, ribbon-bedded microsparite and calcarenite. The Low Hollow Member and the lower portion of the Chances Branch Member are oolitic, and soft sediment deformation fabrics have been observed (Geraghty and Miller 1987). Both members are locally stylolitic.

Appendix B

SOILS SURVEY MAP

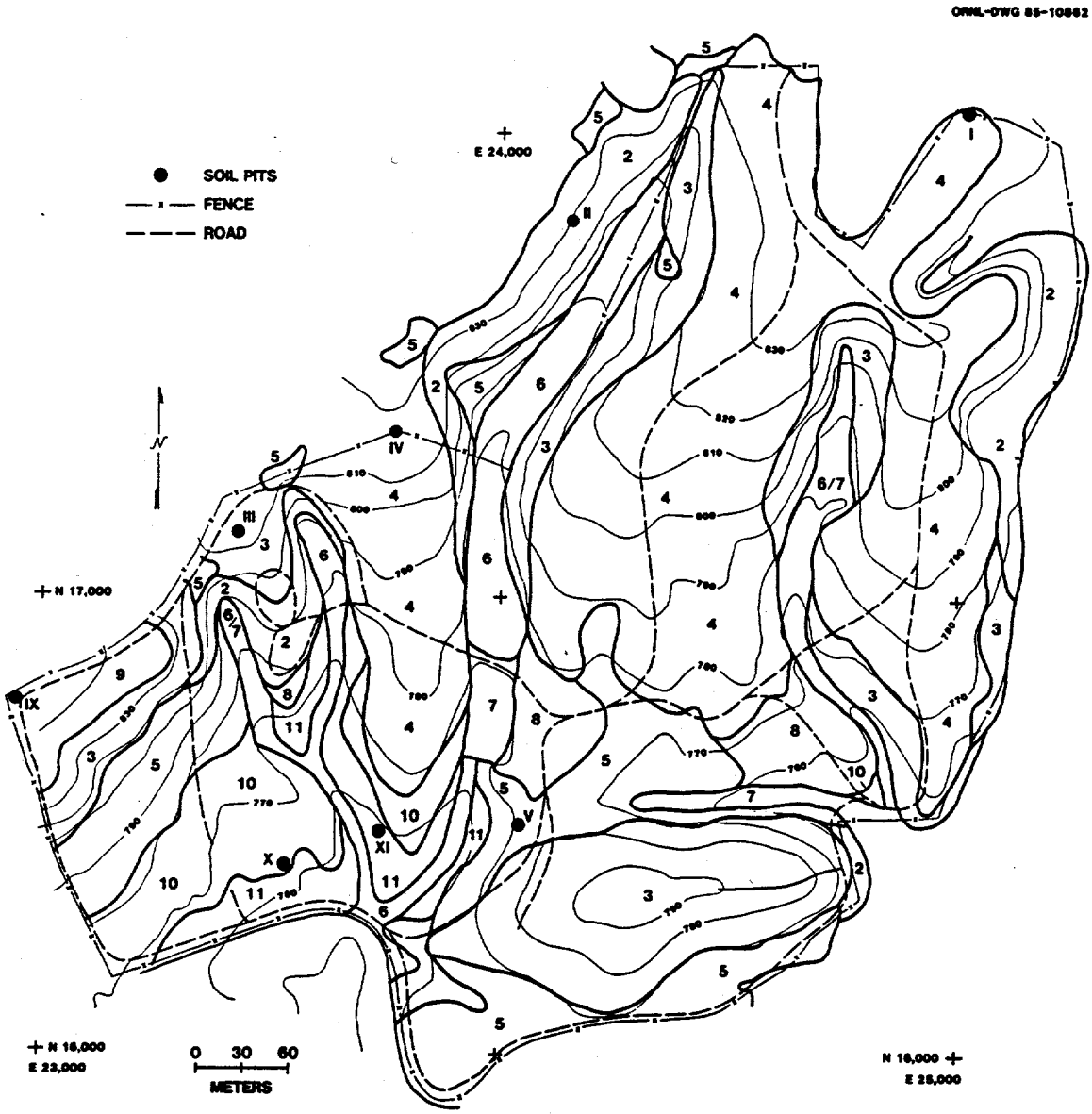

Fig. B.1. Aerial Soil Survey Map of SWSA 6.

Table B.1. Legend for the SWSA 6 soil survey map (Fig. B.1).

Map Unit	Description
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 (Litz 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 Fragiudults; fine-silty, mixed, thermic (Leadvale series) and Typic Hapludults; fine-silty, mixed, thermic (Shelocta series).
6	Drainage-ways with mostly wet alluvial soils that classify as Typic or Aeric Fluvaquents; fine-silty, mixed, thermic (series not designated).
7	Drainage-ways that have been filled with debris from land clearing activitities 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% amd mostly doubly convex slope configuration. Soils are mostly Ruptic-Aquultic Dystrochrepts; 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 Hapludalfs; clayey. mixed, thermic (Tupulo series).

Appendix C

EXISTING MONITORING PROGRAMS AT ORNL

Table C.1. Density (no. individuals/0.1 m^2), taxonomic richness (no. taxa/sample), mean Ephemeroptera, Plecoptera, and Trichoptera (EPT) richness (no. EPT taxa/sample), and taxonomic diversity (H') of benthic macroinvertebrates in White Oak Creek watershed, May and June 1987. Values are means ± 1 SE

	Density		Richness		EPT Richness		Diversity	
Site	May	June	May	June	May	June	May	June
FCK 0.1	1018.3 ± 386.7	237.9 ± 84.5	14 ± 1.8	17 ± 2.6	3 ± 0.3	2 ± 0.3	1.2 ± 0.05	2.6 ± 0.05
FCK 0.8	975.6 ± 217.9	439.9 ± 120.5	23 ± 1.5	21 ± 2.3	8 ± 0.3	6 ± 0.9	3.2 ± 0.05	3.1 ± 0.1
FFK 0.2	241.1 ± 66.0	87.5 ± 24.1	12 ± 2.7	9 ± 1.3	1 ± 1.0	1 ± 0.7	1.2 ± 0.2	1.8 ± 0.07
FFK 1.0	1308.6 ± 106.7	792.6 ± 288.2	31 ± 0.3	27 ± 3.2	18 ± 1.5	14 ± 2.1	3.0 ± 0.11	3.4 ± 0.05
MEK 0.6	1232.9 ± 210.4	289.2 ± 150.1	19 ± 0.3	17 ± 3.8	7 ± 0.3	4 ± 1.2	1.0 ± 0.17	2.4 ± 0.39
MEK 1.2	816.3 ± 146.7	209.9 ± 62.0	14 ± 2.4	13 ± 1.3	4 ± 1.2	4 ± 0.7	0.9 ± 0.2	2.3 ± 0.12
MEK 2.1	302.8 ± 91.5	190.2 ± 23.7	18 ± 0.9	19 ± 3.5	7 ± 1.2	4 ± 1.2	2.7 ± 0.25	2.5 ± 0.5
NTK 0.2	701.1 ± 289.1	455.0 ± 86.1	16 ± 3.2	20 ± 1.8	4 ± 1.7	3 ± 0.0	2.3 ± 0.07	2.9 ± 0.17
NTK 1.0	318.3 ± 89.0	286.3 ± 15.7	24 ± 2.2	23 ± 4.3	11 ± 0.7	6 ± 0.7	3.4 ± 0.09	2.4 ± 0.32
WCK 2.3	1023.0 ± 79.5	628.6 ± 173.8	15 ± 1.5	17 ± 0.3	6 ± 0.7	4 ± 0.6	2.1 ± 0.23	2.3 ± 0.27
WCK 2.9	836.7 ± 225.0	245.4 ± 34.9	17 ± 3.6	14 ± 1.2	4 ± 0.9	3 ± 0.6	1.9 ± 0.05	2.8 ± 0.08
WCK 3.4	1329.0 ± 227.9	985.3 ± 200.8	14 ± 1.2	24 ± 1.9	2 ± 0.3	4 ± 0.9	0.9 ± 0.7	2.7 ± 0.14
WCK 3.9	753.1 ± 272.4	16.1 ± 6.5	7 ± 1.2	3 ± 0.6	0 ± 0.0	0 ± 0.0	1.0 ± 0.05	1.2 ± 0.27
WCK 5.1	837.5 ± 492.2	160.7 ± 37.3	10 ± 3.5	12 ± 2.1	3 ± 1.2	2 ± 0.3	0.7 ± 0.17	2.0 ± 0.39
WCK 6.8	700.0 ± 85.6	979.9 ± 472.0	25 ± 4.8	25 ± 2.4	13 ± 2.4	10 ± 1.9	2.5 ± 0.12	2.2 ± 0.13

Source: Loar et al. 1990

Appendix D

TABLES OF CONTAMINANTS IN AQUATIC BIOTA

Table D.1. Density (no. individuals/0.1 m^2), taxonomic richness (no. taxa/sample), mean Ephemeroptera, Plecoptera, and Trichoptera (EPT) richness (no. EPT taxa/sample), and taxonomic diversity (H') of benthic macroinvertebrates in White Oak Creek watershed, May and June 1987. Values are means ± 1 SE

	Density		Richness		EPT Richness		Diversity	
Site	May	June	May	June	May	June	May	June
FCK 0.1	1018.3 ± 386.7	237.9 ± 84.5	14 ± 1.8	17 ± 2.6	3 ± 0.3	2 ± 0.3	1.2 ± 0.05	2.6 ± 0.05
FCK 0.8	975.6 ± 217.9	439.9 ± 120.5	23 ± 1.5	21 ± 2.3	8 ± 0.3	6 ± 0.9	3.2 ± 0.05	3.1 ± 0.1
FFK 0.2	241.1 ± 66.0	87.5 ± 24.1	12 ± 2.7	9 ± 1.3	1 ± 1.0	1 ± 0.7	1.2 ± 0.2	1.8 ± 0.07
FFK 1.0	1308.6 ± 106.7	792.6 ± 288.2	31 ± 0.3	27 ± 3.2	18 ± 1.5	14 ± 2.1	3.0 ± 0.11	3.4 ± 0.05
MEK 0.6	1232.9 ± 210.4	289.2 ± 150.1	19 ± 0.3	17 ± 3.8	7 ± 0.3	4 ± 1.2	1.0 ± 0.17	2.4 ± 0.39
MEK 1.2	816.3 ± 146.7	209.9 ± 62.0	14 ± 2.4	13 ± 1.3	4 ± 1.2	4 ± 0.7	0.9 ± 0.2	2.3 ± 0.12
MEK 2.1	302.8 ± 91.5	190.2 ± 23.7	18 ± 0.9	19 ± 3.5	7 ± 1.2	4 ± 1.2	2.7 ± 0.25	2.5 ± 0.5
NTK 0.2	701.1 ± 289.1	455.0 ± 86.1	16 ± 3.2	20 ± 1.8	4 ± 1.7	3 ± 0.0	2.3 ± 0.07	2.9 ± 0.17
NTK 1.0	318.3 ± 89.0	286.3 ± 15.7	24 ± 2.2	23 ± 4.3	11 ± 0.7	6 ± 0.7	3.4 ± 0.09	2.4 ± 0.32
WCK 2.3	1023.0 ± 79.5	628.6 ± 173.8	15 ± 1.5	17 ± 0.3	6 ± 0.7	4 ± 0.6	2.1 ± 0.23	2.3 ± 0.27
WCK 2.9	836.7 ± 225.0	245.4 ± 34.9	17 ± 3.6	14 ± 1.2	4 ± 0.9	3 ± 0.6	1.9 ± 0.05	2.8 ± 0.08
WCK 3.4	1329.0 ± 227.9	985.3 ± 200.8	14 ± 1.2	24 ± 1.9	2 ± 0.3	4 ± 0.9	0.9 ± 0.7	2.7 ± 0.14
WCK 3.9	753.1 ± 272.4	16.1 ± 6.5	7 ± 1.2	3 ± 0.6	0 ± 0.0	0 ± 0.0	1.0 ± 0.05	1.2 ± 0.27
WCK 5.1	837.5 ± 492.2	160.7 ± 37.3	10 ± 3.5	12 ± 2.1	3 ± 1.2	2 ± 0.3	0.7 ± 0.17	2.0 ± 0.39
WCK 6.8	700.0 ± 85.6	979.9 ± 472.0	25 ± 4.8	25 ± 2.4	13 ± 2.4	10 ± 1.9	2.5 ± 0.12	2.2 ± 0.13

Source: Loar 1990

Table D.2. Mean metal concentrations in fish (ppm, wet wt) from White Oak Creek and tributaries, White Oak Lake (WOL) and Hinds Creek (reference stream). Fish are bluegill (Lepomis macrochirus) and redbreast sunfish (Lepomis auritus) collected in winter 1986/1987; n = 8 except where noted; ± 1 s.d. in parentheses.

Metal	Site NTK 0.2	WCK 3.5	WCK 2.9	WCK 2.3	MEK 0.2[a]	WOL	WCK 0.9	Hinds Cr[b]	TVA[c]	USFWS[d]	PGV[e]
Antimony	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.3	---	---	5.2
Arsenic	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.10	<0.03	0.16	0.0007
Beryllium	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.05	<1	---	0.004
Cadmium	0.026	0.024	0.008	0.018	0.035	0.031	0.019	0.015	0.007	0.04	1.0
	(0.019)	(0.029)	(0.004)	(0.012)	(0.015)	(0.018)	(0.016)	(0.014)	(0.003)		
Chromium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.06	---	1.8
Copper	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	0.45	0.4	0.86	36
								(0.56)	(0.3)		
Lead	<0.04	0.04	0.03	0.03	<0.04	0.10	0.03	<0.02	0.21	0.19	1.8
		(0.04)	(0.02)	(0.01)		(0.11)	(0.01)		(0.33)		
Lithium	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.5	---	---	---
Mercury	0.26	0.25	0.44	0.49	0.13[f]	0.16	0.07	0.09[g]	<0.1	0.11	0.42[h]
	(0.05)	(0.12)	(0.09)	(0.18)	(0.03)	(0.10)	(0.01)	(0.03)			
Nickel	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	---	5.2
Selenium	0.41	0.36	0.51	0.18	0.34	0.30	0.21	0.55	0.7	0.46	12
	(0.10)	(0.10)	(0.16)	(0.06)	(0.07)	(0.08)	(0.07)	(0.12)	(0.2)		
Silver	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.10	<0.3	---	0.29
Thallium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<1	---	0.66
Zinc	5.2	6.4	6.4	7.2	6.4	5.1	5.6	6.2	8.4	25.6	180
	(1.1)	(1.2)	(1.3)	(2.4)	(0.8)	(0.7)	(0.6)	(1.0)	(2.6)		

[a]n=5.
[b]n=4.
[c]TVA 1985c (n = 13 for Hg, Cd; n=9 for Cr, As, Ni; n=4 for others).
[d]Lowe et al. 1985.
[e]Preliminary Guidance Values (from Hoffman et al. 1984; Travis et al. 1986).
[f]n=11.
[g]Adult redbreast sunfish, n=20.
[h]FDA action level is 1.0 ppm, wet wt.

Source: Loar 1989a

Table D.3. Mean metal concentrations in fish (μg/g, wet wt) from White Oak Lake (WOL), White Oak Creek and tributaries. Fish are bluegill (*Lepomis macrochirus*) and redbreast sunfish (*Lepomis auritus*) collected in winter 1988; n=4 except where noted; ± 1 SD in parentheses. NS = not sampled

Metal	Site NTK 0.2	WCK 3.5	WCK 2.9	WCK 2.3	MEK 0.2[a]	WOL	WCK 0.9	Hinds Cr[b]	TVA[c]	USFWS[d]	PGV[e]
Antimony	NS	NS	<0.50	NS	<0.50	<0.50	NS	<0.50	---	---	5.2
Arsenic	NS	NS	<0.50	NS	<0.50	<0.50	NS	<0.50	<0.03	0.16	0.0007
Beryllium	NS	NS	<0.10	NS	<0.10	<0.10	NS	<0.10	<1	---	0.004
Cadmium	NS	NS	<0.20	NS	<0.20	<0.20	NS	<0.20	0.007 (0.003)	0.04	1.0
Chromium	NS	NS	<0.50	NS	<0.50	<0.50	NS	<0.50	0.06	---	1.8
Copper	NS	NS	<0.50	NS	<0.50	0.52[e] (0.06)	NS	<0.50	0.4 (0.3)	0.86	36
Lead	NS	NS	<0.50	NS	<0.50	<0.50	NS	<0.50	0.21 (0.33)	0.19	1.8
Mercury	0.19[f] (0.10)	0.31[f] (0.07)	0.44[g] (0.15)	0.22[f] (0.13)	0.09[f] (0.04)	0.14[f] (0.07)	0.09[f] (0.03)	0.08[g] (0.04)	--- <0.1	--- 0.11	--- 0.42
Nickel	NS	NS	<0.50	NS	<0.50	<0.50	NS	<0.50	<0.1	---	5.2
Selenium	NS	NS	0.50 (0.04)	NS	<0.50	0.51[e] (0.04)	NS	<0.50	0.7 (0.2)	0.46	12
Silver	NS	NS	<0.20	NS	<0.20	<0.20	NS	<0.20	<0.3 <1	--- ---	0.29 0.66
Zinc	NS	NS	5.2 (0.47)	NS	6.3 (1.2)	6.8 (1.7)	NS	5.6 (1.1)	8.4 (2.6)	25.6	180

[a]Reference stream located in Anderson County, TN; N=2 except for Hg (N=16).
[b]TVA (1985) (N=13 for Hg, Cd; N=9 for Cr, As, Ni; N=4 for others).
[c]Lowe et al. 1985.
[d]Preliminary Guidance Values (from Hoffman et al. 1984; Travis et al. 1986).
[e]Two of four samples exceeded detection limits.
[f]N=8.
[g]N=16.

Source: Loar 1990

Table D.4. Concentrations of Hg (μg/g, wet wt) in bluegill and redbreast sunfish (*Lepomis macrochirus* and *L. auritus*) from White Oak Creek (WCK) and tributaries, 1986-1988. Values are mean ± 1 SE (range in parentheses). N=8 except where noted. WOL = White Oak Lake; MEK = Melton Branch; NTK = Northwest Tributary

Site	Species	Season		
		1986	1987	1988
WCK 3.5	Bluegill	0.25 ± 0.04 (0.14 - 0.52)	0.30 ± 0.02 (0.22 - 0.41)	0.31 ± 0.03 (0.16 - 0.40)
WCK 2.9	Bluegill	0.40 ± 0.05[a] (0.30 - 0.52)	0.39 ± 0.06[b] (0.20 - 0.62)	0.41 ± 0.04 (0.30 - 0.62)
	Redbreast	0.47 ± 0.04[a] (0.37 - 0.58)	0.37 ± 0.03 (0.28 - 0.49)	0.47 ± 0.06 (0.19 - 0.69)
WCK 2.3	Bluegill	0.44 ± 0.11[a] (0.20 - 0.73)	0.18 ± 0.03 (0.05 - 0.28)	0.22 ± 0.05 (0.09 - 0.49)
WOL	Bluegill	0.09 ± 0.01[c] (0.07 - 0.11)	0.25 ± 0.04 (0.10 - 0.41)	0.14 ± 0.03 (0.07 - 0.31)
WCK 0.9	Bluegill	0.07 ± 0.01[d] (0.05 - 0.08)	0.06 ± 0.01 (0.04 - 0.08)	0.09 ± 0.01 (0.03 - 0.12)
MEK 0.2	Bluegill 0.09 ± 0.02	0.10 ± 0.01[e] (0.08 - 0.11)	0.06 ± 0.01 (0.05 - 0.10)	(0.05 - 0.16)
NTK 0.2	Bluegill	0.26 ± 0.02 (0.19 - 0.32)	0.24 ± 0.03 (0.16 - 0.40)	0.19 ± 0.03 (0.04 - 0.37)

[a]N=4.
[b]N=7.
cN=5.
[d]N=6.
[e]N=3.

Source: Loar 1990

Table D.5. Concentrations of selected elements in the above-ground parts of aquatic macrophytes from White Oak Creek and Melton Branch. Values are ppm dry wt for single determinations. Note: values for Cr may not be accurate; compare the certified and analytical value for the reference material.

Elements	MB-PW1	MB-PW2	MB-DW	MB-FA	WOW-MS	WOW-FA	WOW-EL	WCK-MS	MEK-AM	WCK-AM	PNR	PNR-C
Al	4900	4700	4900	5200	7900	5300	8700	14000	27000	21000	420	545
Ca	38000	28000	30000	28000	15000	3700	20000	16000	20000	14000	4800	4100
Cd	31	<0.12	<0.12	<0.12	1.4	<0.12	1.6	1.3	89	<0.12	<0.5	
Co	15	20	6	7.3	7.9	7.8	13	14	26	25	<0.74	
Cr	35	17	20	17	34	32	37	45	61	290	34	2.6
Cu	140	140	58	69	120	74	220	260	480	120	3.5	3
Fe	6000	7100	5200	4900	7000	5500	9800	12000	21000	22000	240	200
Mg	2800	3300	4600	4000	3000	5000	3900	3800	5400	3700	1200	
Mn	35000	43000	6200	6500	5800	3100	11000	6100	13000	27000	740	675
Na	6800	7000	7300	3200	8400	3900	9200	8400	1700	1000	66	
P	7600	8700	7600	12000	4900	7500	12000	4900	5900	3300	1200	1200
Pb	5.1	6.7	<4.9	9.7	34	39	49	160	170	9.8	<15	10
Sr	62	74	46	47	34	46	53	41	54	48	4.6	4.8
Zn	1500	1700	490	410	1000	760	1400	2100	2200	1800	76	

MB = Melton Branch Weir at MEK 0.16
WOW = White Oak Weir at WCK 2.65
WCK = WCK 3.4
MEK = MEK 0.6
PW1 = Pondweed (collected 7/13)
PW2 = Pondweed (collected 7/24)
DW = Duckweed
FA = Filamentous Algae
MS = Milfoil
EL = Elodea
AM = Moss
PNR = Pine Needle Reference Material
PNR-C = Pine Needle Reference - Certified Value

Source: Loar 1988

Table D.6 Concentration of PCBs and other organic priority pollutants (ppm, wet wt) in sunfish (Lepomis macrochirus and L. auritus) from White Oak Creek and tributaries and White Oak Lake (WOL), winter 1986, 1987.

Site	Mean ± s.d.	Range	Occurrence[a]	Other Organics[b]
WCK 3.5	1.0 ± 1.9	<0.2 - 4.8	2/8	BLD[c]
WCK 2.9	1.4 ± 1.3	<0.2 - 3.9	6/8	BLD
WCK 2.3	2.4 ± 1.9	<0.2 - 5.8	8/8	BLD
WOL	0.4 ± 0.7	<0.2 - 1.5	2/8	BLD
WCK 0.9	0.6 ± 0.4	<0.4 - 1.0	7/8	BLD
MEK 0.2	1.1 ± 1.2	<0.2 - 2.8	2/3	BLD
NTK 0.2	<0.2	<0.2 - <0.4	0/8	BLD

[a]Number of samples exceeding detection limit/total number of samples.

[b]Names and detection limits of organics that were screened for but not detected are listed in Appendix D, Table D-4.

[c]Below limit of detection. See Table S.24.

Source: Loar 1988

Table D.7. Concentrations of PCBs and other organic priority pollutants (μg/g, wet wt) in bluegill and redbreast sunfish (*Lepomis macrochirus* and *L. auritus*) from the Clinch River, White Oak Lake (WOL), White Oak Creek and tributaries, and Melton Hill Reservoir (MHR).

Site	Season	Species	PCB Mean ± SD	Range	Exceedences[a]	Other organics[b]
WCK 3.5	Dec87	Bluegill	0.69 ± 0.36	0.34 - 1.19	0/8	BLD[c]
WCK 2.9	Dec87	Bluegill	1.47 ± 1.25	0.50 - 4.2	1/7	BLD
	Dec87	Redbreast	0.88 ± 0.31	0.47 - 1.34	0/8	---
	Jul88	Redbreast	0.89 ± 0.90	0.13 - 2.7	1/8	---
WCK 2.3	Dec87	Bluegill	0.65 ± 0.41	0.31 - 1.6	0/8	BLD
WOL	Dec87	Bluegill	0.91 ± 0.70	0.30 - 2.25	1/8	BLD
	Jul88	Bluegill	1.17 ± 0.68	0.35 - 2.4	1/8	BLD
WCK 0.9	Dec87	Bluegill	0.53 ± 0.62	0.09 - 2.0	1/8	---
MEK 0.2	Dec87	Bluegill	0.06 ± 0.01	0.05 - 0.08	0/8	---
NTK 0.2	Dec87	Bluegill	0.35 ± 0.45	0.03 - 1.29	0/8	BLD
CRK 31.5	Dec87	Bluegill	0.04 ± 0.02	0.02 - 0.08	0/8	---
CRK 35.2	Dec87	Bluegill	0.04 ± 0.02	0.01 - 0.08	0/8	--
MHR	Dec87	Bluegill	0.03 ± 0.01	0.02 - 0.06	0/8	---

[a]Number of samples exceeding the FDA limit for PCBs of 2μg/g (FDA 1984b) divided by the total number of samples.

[b]N=4.

[c]BLD = Below limit of detection. Low concentrations of benzo(a)pyrene (<0.04 μg/g); benzo(b)fluoranthene (<0.25 μg/g); benzo(k)fluoranthene (<0.09 μg/g); and dibenz(a,h)anthracene (<0.36 μg/g) were reported in HPLC analysis of most samples. Benzo(ghi)perylene and indenopyrene were reported in HPLC analysis of most samples and laboratory blank.

Source: Loar 1990

Table D.8. Concentrations of PCBs and other organic priority pollutants (μg/g, wet wt) in bluegill and redbreast sunfish (*Lepomis macrochirus* and *L. auritus*), largemouth bass (*Micropterus salmoides*), and carp (*Cyprinus carpio*) from the Clinch River (CRK), White Oak Lake (WOL), White Oak Creek (WCK), Melton Branch (MEK), Northwest Tributary (NTK), and Melton Hill Reservoir (MHR) and tributaries, fall/winter.

Site	Season	Date	PCB, (μg/g) Mean ± SE	Range	Exceedences[a]	Other organics[b,c]
WCK 3.5	Bluegill	Nov 1988	0.63 ± 0.30	0.14-2.7	1/8	BLD[d]
WCK 2.9	Redbreast	Nov 1988	0.31 ± 0.06	0.13-0.58	0/8	BLD
	Bluegill	Nov 1988	0.54 ± 0.21	0.18-2.01	1/8	---
	Redbreast	Jul 1989	0.28 ± 0.10	0.07-0.78	0/8	---
WCK 2.3	Bluegill	Nov 1988	0.63 ± 0.16	0.18-1.52	0/8	---
WOL	Bluegill	Nov 1988	0.62 ± 0.20	0.09-1.72	0/8	---
	Bluegill	Jul 1989	0.44 ± 0.10	0.02-0.80	0/8	---
	Carp	Nov 1988	0.57 ± 0.09	0.24-0.85	0/7	BLD
	Largemouth bass	Nov 1988	1.62 ± 0.64	0.21-5.0	2/8	---
WCK 0.9	Bluegill	Nov 1988	0.28 ± 0.09	0.08-0.79	0/8	BLD
MEK 0.2	Bluegill	Nov 1988	0.30 ± 0.10	0.09-0.92	0/8	---
NTK 0.2	Bluegill	Nov 1988	0.12 ± 0.04	0.04-0.36	0/8	BLD
CRK 31.5	Bluegill	Nov 1988	0.07 ± 0.02	0.04-0.11	0/8	---
CRK 35.2	Bluegill	Nov 1988	0.15 ± 0.02	0.08-0.30	0/8	---
MHR	Bluegill	Nov 1988	0.15 ± 0.02	0.05-0.28	0/8	---
Hinds Cr	Bluegill	Nov 1988	0.08 ± 0.02	0.02-0.14	0/8	---
	Redbreast	Nov 1988	0.10 ± 0.03	0.01-0.18	0/8	---

[a]Number of samples exceeding the FDA limit for PCBs of 2 μg/g divided by the total number of samples.

[b]N=4.

[c]Low concentrations of benzo(a)pyrene, (<0.10 μg/g); pyrene (<0.03 μg/g); benzo(k) fluoranthene, (<0.10 μg/g); and acenaphthene, (<0.10 μg/g) were reported in HPLC analysis of some samples. Low concetrations of phthalates (<0.6 μg/g) were reported in several samples, blanks, and reference stream fish.

[d]Below limit of detection.

Source: Loar 1990

Table D.9. Changes from 1986 to 1989 in average concentrations of PCBs (μg/g, wet wt) and fraction of fish exceeding the Food and Drug Administration (FDA) limit, for channel catfish from White Oak Creek embayment (WCK), the Clinch River (CRK), lower Poplar Creek (PCK) and Melton Hill Reservoir (MHR). Site locations are depicted in Fig. 6.3.

Site	PCBs				Fraction over FDA limit			
	1986	1987	1988	1989	1986	1987	1988	1989
WCK 0.3	1.30	1.59	0.96	1.54	3/12	2/8	2/8	4/8
CRK 32.2	1.01	1.61	0.58	1.20	0/8	2/8	1/8	1/8
MHR	0.46	0.81	0.52	0.28	0/6	1/7	0/10	0/8
PCK 6.9	----	----	0.71	1.07	----	----	0/8	1/8
CRK 15.0	----	----	0.50	0.79	----	----	0/9	1/8

Source: Loar 1990

Table D.10. Concentrations of PCBs (ppm, wet wt) in composite samples of caged clams (Corbicula fluminea) held in White Oak Creek (WCK), Melton Branch (MEK), White Oak Lake (WOL) and East Fork Poplar Creek (EFK) at the outfall of New Hope Pond near the Y-12 Plant.

Site	Exposure period	Mean ± s.d.	N	Control
WCK 3.5	July 15 - August 17, 1987	0.17 ± 0.02	2	0.05
WCK 2.6	July 15 - August 17, 1987	1.5 ± 0.0	2	0.05
MEK 0.2	July 15 - August 17, 1987	0.11 ± 0.04	2	0.05
WOL	July 15 - August 17, 1987	1.4 ± 0.1	2	0.05
EFK 23.4	July 7 - August 6,1986	0.45 ± 0.07	3	0.07
EFK 23.4	April 28 - May 26,1987	0.57 ± 0.19	3	0.08
EFK 23.4	September 1 - 29, 1987	0.40 ± 0.10	3	0.03

Source: Loar 1988

Table D.11. Concentrations of PCBs and other organics (μg/g, wet wt) in duplicate composite samples of caged clams (*Corbicula fluminea*) held in White Oak Creek (WCK), Melton Branch (MEK), Northwest Tributary (NTK), White Oak Lake (WOL), and two unnamed tributaries of White Oak Creek, March 2 - 31, 1988. NA = Not analyzed; BLD = Below detection limit.

Site	Total PCBs[a]		Other organics
	Mean	Range	
WCK 6.9	0.07	0.07 - 0.07	NA
WCK 5.4	b	b	b
WCK 4.7	0.08	0.08 - 0.08	NA
WCK 3.8	0.08	0.04 - 0.12	NA
WCK 3.5	0.06	0.06 - 0.06	BLD[c]
WCK 2.6	d	d	---
WOL	0.82	0.77 - 0.87	BLD[c]
WCK 0.1	0.37	0.36 - 0.37	BLD[c]
NTK 0.2	0.05	0.04 - 0.05	---
MEK 0.2	0.04	0.03 - 0.05	BLD[c]
East Trib[e]	0.03	0.03	---
SWSA 4 Trib[f]	0.05	0.04 - 0.05	---
Bull Run[g]	0.04	0.03 - 0.04	BLD[c]

[a]PCB-1254 + PCB-1260. PCB-1260 was ≤0.01 μg/g in all samples except WOL (0.06 μg/g in each) and WCK 0.1 (0.04 μg/g in each).

[b]Interference prevented detection of PCBs. GC/MS analysis of samples identified interference as chlordane (estimated concentrations of 18.6 and 19.4 μg/g in duplicate samples).

[c]All clams (including reference site) contained similar concentrations of benzo(a)pyrene, (0.033-0.086 μg/g), dibenz(a,h)anthracene, (0.012-0.030 μg/g) and pyrene (0.024- 0.040 μg/g). Benzo(ghi)perylene and indenopyrene were present in all samples and most laboratory blanks. Other results exceeding detection limits in individual samples were 0.29 μg/g naphthalene and 0.04 μg/g phenanthrene at WOL, 0.04 μg/g anthracene at WCK 3.5, and 0.015 μg/g at WOK 0.9.

[d]Cage lost in high water.

[e]Small tributary on east side of White Oak Creek at WCK 3.4.

[f]Small tributary draining SWSA 4.

[g]Background concentrations in clams before placement in stream.

Source: Loar 1990

Table D.12. Concentrations of chlordane and PCBs (μg/g wet wt) in duplicate composite samples of caged clams (*Corbicula fluminea*) held for four weeks at sites in WOC, WOL, and tributaries; and concentrations of chlordane in sediment (μg/g dry wt, <125 μm fraction) at sites in the White Oak Creek drainage.

	Chlordance (μg/g)			PCBs (μg/g)
	Clams		Sediment	Clams
Site	November 1988	April 1989	October 1989	November 1988
WCK 6.8	<0.025 <0.025	0.007 0.003-0.011	<0.025	0.04 0.03-0.04
WCK 5.6	0.120 0.115-0.125	0.108 0.103-0.113	0.142	0.04 0.03-0.04
WCK 5.45	----	----	0.099	----
Trib WCK 5.4	----	2.54 2.54-2.55	0.143	----
WCK 5.4	1.26 1.12-1.40	0.596 0.489-0.703	0.185	0.05 0.03-0.06
WCK 3.4	----	----	----	0.05 0.04-0.06
WCK 2.6	0.115 0.105-0.124	----	----	0.23 0.20-0.25
WOL	0.084 0.079-0.088	----	----	0.52 0.51-0.52
WCK 0.1	----	----	----	0.32 0.29-0.34
MEK 0.2	----	----	----	0.09 0.07-0.10
Reference[a]	<0.025 <0.025	0.020 0.019-0.020	---- ----	0.05 0.03-0.07

[a]Background concentrations in clams before placement in stream or concentration in reference stream sediment.

Source: Loar 1990

Table D.13. Concentration of ^{137}Cs, ^{60}Co, and ^{90}Sr (Bq/kg, wet wt) in fish collected from White Oak Lake in May 1987. Values are the mean ±1 s.d.; N=10 for ^{137}Cs and ^{60}Co and N=5 for ^{90}Sr. NA = not analyzed.

Species	^{137}Cs	^{60}Co	^{90}Sr
Bluegill (Lepomis macrochirus)	340±80	26±9	520±140
Carp (Cyprinus carpio)	219±130	37±11	NA
Gizzard Shad (Dorosoma cepedianum)	480±90	44±7	370±360
Largemouth Bass (Micropterus salmoides)	960±850	22±15	230±120
Redbreast Sunfish (Lepomis auritus)	600±580	15±7	NA
Redear Sunfish (Lepomis microlophus)	290±46	15±6	NA
Warmouth (Lepomis gulosus)	220±120	11±4	NA

Source: Loar 1988

Table D.14. Levels of ^{137}Cs (Bq/kg, dry wt) in sunfish[a] from the White Oak Creek system, December 1986.

Site	Mean ± 1 s. d.	Range	N
WCK 3.5	21600 ± 2200	18000 - 25000	8
WCK 2.9	29800 ± 9100	21000 - 45000	8
WCK 2.3	13600 ± 8400	7000 - 30000	8
WOL	3011 ± 1200	2100 - 6000	9
WCK 0.9	1500 ± 600	560 - 2700	8
MEK 0.2	2900 ± 600	2300 - 4000	5
NTK 0.2	8400 ± 11400	140 - 25000	8

[a]Includes bluegill (Lepomis macrochirus) and redbreast sunfish (L. auritus).

Source: Loar 1988

Table D.15. Levels of ^{137}Cs (Bq/kg, dry wt) in bluegill (*Lepomis macrochirus*) from the White Oak Creek system, December 1987. N = No. of fish analyzed.

Site	Mean ± 1 SD	Range	N
WCK 3.5	6400 ± 640	5800-7600	6
WCK 2.9	7900 ± 3400	4300-1300	7
WCK 2.9[a]	7600 ± 1300	5600-9300	5
WCK 2.3	4600 ± 752	3900-5600	5
WOL	2000 ± 530	1500-2500	6
WCK 0.9	2500 ± 300	2100-2900	5
MEK 0.2	2800	2800	1
NTK 0.2	2500 ± 3700	<85-8600	6

[a]Redbreast sunfish (*L. auritus*).

Source: Loar 1989

Table D.16. Concentrations of ^{137}Cs (Bq/kg, dry wt) in bluegill (*Lepomis macrochirus*) from the White Oak Creek system, December 1988.
n = 4 at all sites

Site	Mean ± 1 SD	Range
WCK 3.5	18,250 ± 7,805	11,000 - 28,000
WCK 2.9	12,500 ± 1,290	11,000 - 14,000
WCK 2.3	7,425 ± 5,900	2,500 - 16,000
WOL	2,775 ± 770	1,900 - 36,000
WCK 0.9	1,550 ± 545	1,100 - 2,300
MEK 0.2	5,000 ± 2,500	2,600 - 78,001
NTK 0.2	115 ± 143	<40 - 330

Source: Loar 1990

Table D.17. Mean radionuclide concentrations in aquatic macrophytes collected in White Oak Lake in 1989 (Bq/kg dry wt x 1000). nc = not collected; nd = not detected

		March	May	June	July	August	September	October	November	December	Mean	SD
Milfoil	^{137}Cs	14.8	11.3	8.1	5.5	5.9	5.6	4.3	4.5	11.5	8.4	3.7
	^{60}Co	3.9	1.3	1.6	0.71	0.99	1.3	1.3	1.4	1.9	1.6	0.93
Filamentous algae	^{137}Cs	6.9	11.2	6.7	12.9	nc	nc	11	8.2	nc	9.5	2.6
	^{60}Co	1.6	1.7	0.82	1.1	nc	nc	1.6	1.2	nc	1.3	0.35
Lemna and Spirodela	^{137}Cs	nc	nc	3.1	nc	nc	2.22	nc	nc	nc	2.7	0.64
	^{60}Co	nc	nc	0.6	nc	nc	0.41	nc	nc	nc	0.51	0.13
Wolffia	^{137}Cs	nc	nc	1.7	2.3	0.07	5	nc	nc	nc	2.3	1.3
	^{60}Co	nc	nc	0.61	0.56	0.007	0.42	nc	nc	nc	0.4	0.27
Watercress	^{137}Cs	nc	nc	nc	nc	nc	2.4	nc	3.2	nc	2.8	0.57
	^{60}Co	nc	nc	nc	nc	nc	0.11	nc	0.97	nc	0.54	0.61
Cattails	^{137}Cs	nc	nc	nc	nc	nc	0.05	nc	0.35	nc	0.2	0.2
	^{60}Co	nc	nc	nc	nc	nc	0.02	nc	0.04	nc	0.03	0.01

Source: Loar 1990

Table D.18. Radionuclide concentrations in aquatic macrophytes collected in White Oak Creek weir in 1988. Values are the mean ± SD; ND = Not detected; NA = Not analyzed; N = No. of samples analyzed.

Month/species	N	^{137}Cs (Bq/kg, dry wt)	^{60}Co (Bq/kg, dry wt)	^{90}Sr (Bq/kg, dry wt)
April				
pondweed	1	4550	311	1200
filamentous algae	1	5510	1050	629
cattails	2	1830 ± 1610	37 ± 44	3200 ± 2550
May				
filamentous algae	2	12100 ± 1770	377 ± 192	1400[a]
June				
filamentous algae	2	8660 ± 3250	155 ± 218	781[a]
duckweed	2	1590 ± 810	70 ± 15	1200[a]
July				
cattails	2	344± 4	11 ± 0	1380 ± 1170
August				
filamentous algae	3	94700 ± 13400	799 ± 318	529[a]
Elodea	1	3850	ND	NA
September				
filamentous algae	1	162000	555	NA
cattails	1	544	ND	NA
October				
filamentous algae	1	22100	ND	NA
duckweed	1	27900	ND	NA
November				
watercress	1	11600	566	NA
December				
Elodea	1	6880	673	NA
cattails	1	799	ND	NA

[a]N=1.

Source: Loar 1990

Table D.19. Radionuclide concentrations in aquatic macrophytes collected in Melton Branch weir in 1988. Values are the mean ± SD; ND = Not detected; NA = Not analyzed; N = No. of samples analyzed.

Month/species	N	^{60}Co (Bq/kg, dry wt)	^{137}Cs (Bq/kg, dry wt)	^{90}Sr (Bq/kg, dry wt)
May				
pondweed	2	5920 ± 2590	196 ± 89	5810[a]
cattails	2	1010 ± 1090	52 ± 67	2800[a]
June				
filamentous algae	2	13900 ± 1070	303 ± 311	599[a]
pondweed	1	5370	81	NA
July				
filamentous algae	1	8730	1240	NA
pondweed	1	8100	248	2000
duckweed	1	6510	ND	1800
cattails	1	455	4	3400
August				
filamentous algae	1	9510	207	5220
duckweed	1	11500	344	4110
September				
filamentous algae	1	2680	307	NA
duckweed	1	11500	130	NA
cattails	1	52	7	NA
October				
filamentous algae	2	3890 ± 344	104 ± 56	NA
pondweed	1	3380	155	NA
duckweed	1	12300	ND	NA
November				
watercress	1	4440	411	NA
bulrush	1	87	4	NA
December				
cattails	1	116	ND	NA

[a]N=1.

Source: Loar 1990

Table D.20. Mean radionuclide concentrations in aquatic macrophytes collected at the White Oak Creek weir in 1989 (Bq/kg dry wt x 1000). nc = not collected; nd = not detected

		January	April	May	June	July	August	September	October	December	Mean	SD
Milfoil	^{137}Cs	nc	5.1	2.1	4.9	5.1	11.1	10.7	9.7	11.6	7.5	3.6
	^{60}Co	nc	0.5	0.44	1.7	0.6	0.64	0.32	0.81	1.8	0.85	0.57
Elodea	^{137}Cs	7.5	2	0.85	1.9	8.4	3.9	nc	6.8	nc	4.5	3.1
	^{60}Co	1.1	0.48	0.32	0.53	0.56	0.16	nc	0.26	nc	0.49	0.31
Watercress	^{137}Cs	6.4	4.9	nc	5.9	4	5.2	nc	8.6	10.2	6.5	2.2
	^{60}Co	1.6	2	nc	0.45	nd	0.06	nc	0.14	0.93	0.86	0.8
Filamentous algae	^{137}Cs	nc	nc	6.1	8.7	6.8	4.3	7.6	nc	nc	6.7	1.7
	^{60}Co	nc	nc	0.2	nd	0.18	nd	0.2	nc	nc	0.12	0.11
Cattails	^{137}Cs	nc	0.33	nc	0.04	nc	0.4	nc	nc	nc	0.26	0.19
	^{60}Co	nc	0.02	nc	0.004	nc	0.01	nc	nc	nc	0.01	0.01
Bulrush	^{137}Cs	2.8	nc	nc	0.67	nc	0.2	nc	nc	nc	1.2	1.4
	^{60}Co	1	nc	nc	0.009	nc	nd	nc	nc	nc	.34	.57

Source: Loar 1990

Table D.21. Mean radionuclide concentrations in aquatic macrophytes collected at the Melton Branch weir in 1989 (Bq/kg dry wt x 1000). nc = not collected; nd = not detected

		January	April	May	June	July	August	September	October	December	Mean	SD
Elodea	^{137}Cs	0.11	nc	0.11	0.06	0.1	0.06	0.11	nd	0.25	0.1	0.07
	^{60}Co	12.7	nc	1.8	1.9	2.6	3.2	2.9	1.9	9.4	4.6	4.1
Filamentous algae	^{137}Cs	nc	nc	0.72	nc	0.04	0.1	nc	nc	nc	0.29	0.38
	^{60}Co	nc	nc	4.5	nc	1.8	7.8	nc	nc	nc	4.7	3
Milfoil	^{137}Cs	nc	nc	nc	0.13	0.05	0.04	nc	nc	nc	0.07	0.05
	^{60}Co	nc	nc	nc	1.5	1	2.5	nc	nc	nc	1.7	0.77
Pondweed	^{137}Cs	nc	nc	nd	0.05	0.08	nc	nc	nc	nc	0.04	0.04
	^{60}Co	nc	nc	1.5	1.2	2.8	nc	nc	nc	nc	1.8	0.85
Duckweed	^{137}Cs	nc	nc	nc	nc	0.09	0.23	nc	nc	nc	0.16	0.1
	^{60}Co	nc	nc	nc	nc	0.65	1.2	nc	nc	nc	0.93	0.39
Cattails	^{137}Cs	nc	0.02	nc	0.01	nc	nc	nc	nc	nc	0.02	0.01
	^{60}Co	nc	0.21	nc	0.07	nc	nc	nc	nc	nc	0.14	0.1
Bulrush	^{137}Cs	nc	nc	nc	0.02	nc	nd	nc	nc	nc	0.01	0.01
	^{60}Co	nc	nc	nc	0.16	nc	0.05	nc	nc	nc	0.11	0.08

Source: Loar 1990

Table D.22. Estimated inventories of ^{137}Cs, ^{60}Co, and ^{90}Sr (Bq) in the abiotic and biotic compartments of White Oak Lake. NA = Not available.

Compartment	^{137}Cs	^{60}Co	^{90}Sr
Fish	1.1×10^6	9.6×10^4	1.1×10^6
Benthic invertebrates	4.2×10^5	9.7×10^4	NA
Emergent macrophytes	8.4×10^6	1.1×10^6	2.3×10^7
Sediment	1.5×10^{13}	4.2×10^{11}	6.6×10^{11}
Water	1.7×10^8	1.3×10^7	2.2×10^8
Total	1.5×10^{13}	4.2×10^{11}	6.6×10^{11}
	(405)[a]	(11.4)	(17.8)

[a]Ci.

Source: Loar 1989

Table D.23. Mean concentrations (± 1 SD) of ^{137}Cs and ^{60}Co (Bq/kg, wet wt) in American coots collected from White Oak Lake. ND = Not detected.

Type of sample	Number of birds analyzed	^{137}Cs	^{60}Co
Whole-body	3	1457 ± 220	121 ± 30
Breast tissue	3	625 ± 110	ND
Thigh tissue	2	697 ± 50	ND
Liver	3	352 ± 30	55 ± 8.0
GI tract	3	3014 ± 2300	307 ± 230
Crop	3	1085 ± 500	97 ± 70
Crop contents	3	6558 ± 1700	673 ± 160
Bone	3	364 ± 50	ND
Carcass	3	537 ± 150	19 ± 8.0

Source: Loar 1989

Appendix E

ARARs

Table E.1. Federal and state applicable or relevant and appropriate requirements (ARARs) for WAG 2 (μg/L)

Chemical Name	RCRA MCLs[a]	SDWA MCLs[b]	SDWA MCLGs[c]	SDWA Proposed MCLGs[d]	SDWA Proposed MCLs[d]	SDWA Secondary MCLs[e]
RADIONUCLIDES						
Gross alpha	—	15 pCi/L	—	—	—	—
Gross beta	—	4 mrem/year	—	—	—	—
Strontium-90	—	8 pCi/L	—	—	—	—
Tritium	—	20,000 pCi/L	—	—	—	—
All other man-made radionuclides	—	4 mrem/year	—	—	—	—
INORGANIC COMPOUNDS						
Arsenic	50	50	—	—	—	—
Barium	1,000	1,000	—	5,000	5,000	—
Beryllium	—	—	—	0	1	—
Cadmium	10	10	—	5.0	5.0	—
Chromium (total)	50	50	—	100	100	—
Chloride	—	—	—	—	—	250,000
Copper	—	—	—	1300	1300	1000
Cyanide	—	—	—	200	200	—
Iron	—	—	—	—	—	300
Lead (at the tap)	50	50	—	0	TT[g]	—
Lead (at the source)	—	—	—	0	5	—
Manganese	—	—	—	—	—	50
Mercury	2	2	—	2	2	
Nickel	—	—	—	100	100	—
Selenium	10	10	—	50	50	—
Silver	50	50	—	—	—	90
Sulfate	—	—	—	400,000	500,000	250,000
Zinc	—	—	—	—	—	5000
ORGANIC COMPOUNDS						
Chlordane	—	—	—	0	2	—
Polychlorinated biphenyls	—	—	—	0	0.5	—

[a]Resource Conservation and Recovery Act maximum concentration limits (40 CFR 264.94).
[b]Safe Drinking Water Act maximum contaminant level (52 *FR* 25690).
[c]Safe Drinking Water Act maximum contaminant level goal (52 *FR* 25690).
[d]Proposed MCLGs/MCLs are not considered ARARs until promulgated but are listed for reference. Proposed MCLGs/MCLs are found at 54 *FR* 22062 (May 22, 1989, final rule expected January 1991) and 55 *FR* 30370 (July 25, 1990, final rule expected March 1992).
[e]Rules of the Tennessee Department of Health and Environment Chapter 1200.5-1.12.
[f]Proposed secondary drinking water standard (54 *FR* 22062, final rule expected January 1991). When final, TDHE will undoubtedly incorporate the proposed secondary standards into Chapter 1200.5-1.12 of the Rules of the TDHE.
[g]TT = Treatment technique.

Table E.2. Federal ambient water quality criteria (WQC) for the protection of human health (μg/L)

Chemical	WQC for aquatic organisms and drinking water[a]	WQC for aquatic organisms alone[a]
Antimony	14	4,308
Arsenic	0 (0.018)	0 (0.014)
Barium	1,000	—
Beryllium	0 (0.077)	0 (0.13)
Cadmium	10[b]	—
Chlordane	0 (5.8E-04)[c]	0 (5.9E-04)
Chromium (VI)	50[b]	—
Chromium (III)	33,300	673,077
Copper	1,000 (organoleptic)[d]	—
Cyanide	200[b]	—
Iron	300[b]	—
Lead	50[b]	—
Manganese	50[b]	—
Mercury	0.151	0.153
Nickel	607	4584
Polychlorinated biphenyls (PCBs)	0 (4.4E-05)	0 (4.5E-05)
Selenium	10[b]	—
Silver	50[b]	—
Zinc	5,000 (organoleptic)[d]	—

[a]The criterion value of zero for all potential carcinogens is listed in the table. Concentrations in parentheses for potential carcinogens correspond to a risk of 10^{-6}.

[b]The EPA Office of Water Regulations and Standards has adopted these values from criteria developed by the EPA Office of Drinking Water for domestic water supplies (MCLs).

[c]Read as 5.8×10^{-4}.

[d]Criteria designated as organoleptic are based on taste and odor effects, not human health effects. Health-based WQC are not available for these chemicals.

Source: Environmental Protection Agency (EPA). 1990. U. S. Environmental Protection Agency, Region IV. Letter from Larinda T. Gronner, Water Quality Standards Unit.

Table E.3. Federal ambient water quality criteria for the protection of freshwater organisms (μg/L)

Chemical	Maximum[a]	24-h[b]
Aluminum	750	3
Cadmium	1.79[c]	0.66[c]
Chlordane	2.4	0.0043[c]
Chloride	860,000	230,000
Chromium (VI)	16	11
(III)	984[c]	117[c]
Cyanide	22	5.2
Iron	—	1000
Lead	34[c]	1.32[c]
Mercury	2.4	0.12[d]
Nickel	789	88
Polychlorinated biphenyls (PCBs)		0.014[e]
Selenium (inorganic selenite)	20	5
Silver	1.23	—

[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]Water hardness dependent criteria (100 mg/L as $CaCO_3$).
[d]Based on marketability of fish.
[e]Final Residue Value based on wildlife feeding study.
Source: Environmental Protection Agency (EPA). 1990a. U. S. Environmental Protection Agency, Region IV. Letter from Larinda T. Gronner, Water Quality Standards Unit.

Table E.4. EPA drinking water health advisories ($\mu g/L$)[a]

Chemical	Child[b]			Adult[d]			Cancer Group
	1-d	10-d	Longer-term[c]	Longer-term	Lifetime[e]	10^{-6} Cancer risk[f]	
Barium[g]	—	—	—	—	2000		D
Beryllium	30,000	30,000	400	20,000	NA	0.008	B2
Cadmium[g]	40	40	5	20	5		D
Chlordane[h]	60	60	NA	NA	NA	0.03	B2
Chromium (total)[g]	1000	1000	200	800	100		D
Cyanide	200	200	200	800	200		D
Mercury[g]	NA	NA	NA	NA	2		D
Nickel	1000	1000	100	600	100		D
Silver	200	200	200	200	100		D
Zinc	4000	4000	4000	4000	4000		D

[a]Environmental Protection Agency, Office of Drinking Water, Final Health Advisories.
[b]10-kg child consuming 1 L of water per day.
[c]Longer-term health advisories may cover a period of several months to several years.
[d]70-kg adult consuming 2 L of water per day.
[e]Lifetime health advisories are estimated for daily ingestion of contaminated drinking water for a 70-year lifetime. This is the value from which MCLs and MCLGs are derived. This value assumes that 20% of a person's exposure to a compound is via the drinking water pathway. Therefore, if site-specific information indicates that there are no other sources of exposure to a particular compound, the lifetime health advisory may be increased by a factor of 5.
[f]The concentration in drinking water that will result in one excess cancer death in one million people (a 10^{-6} cancer risk).
[g]Compounds for which MCLs have been reproposed (54 *FR* 22062, May 22, 1989).
[h]MCLs and MCLGs have been proposed for this chemical (54 *FR* 22062, May 22, 1989).
NA = Not available.
Source: 52 *FR* 34294 (September 10, 1987); 54 *FR* 7599 (February 22, 1989); 55 *FR* 29893 (July 23, 1990).

Table E.5. "To be considered" (TBC) guidance for compounds detected in environmental media at WAG 2[a]

Compound	Oral RfD[b] (mg/kg/day)	Oral CPF[c] $(mg/kg/day)^{-1}$	Inhalation RfD (mg/kg/day)	Inhalation CPF $(mg/kg/day)^{-1}$
Aroclor 1254	—	7.7E+00	—	—
Aroclor 1260	—	7.7E+00	—	—
Barium	5.0E-02	—	1.0E-04	—
Beryllium	5.0E-03	4.3E+00	—	8.4E+00
Cadmium (food)	1.0E-03	—	—	—
(water)	5.0E-04	—		—
(occupational)	—	—	—	6.1E+00
Chlordane	6.0E-05	1.3E+00	—	—
Chromium VI (total)	5.0E-03	—	—	4.1E+01
Cyanide	2.0E-02	—	—	—
Manganese	2.0E-01	—	3.0E-04	—
Mercury	3.0E-04	—	—	—
Nickel	2.0E-02[d]	—	—	1.7E+00[e]
Selenium	3.0E-03	—	—	—
Zinc	2.0E-01	—	—	—

[a]From USEPA Health Effects Assessment Summary Tables, Third Quarter, FY 1990.
[b]RfD = Reference dose.
[c]CPF = Carcinogen potency factor.
[d]Nickel sulfate.
[e]Nickel subsulfide.

Table E.6. EPA radiation protection standards that may be ARAR for WAG 2

Regulation	Applicability	Exposure conditions	Standard
40 CFR 141	Drinking water MCLs	Community water systems, gross beta	4 mrem/year
40 CFR 190	Nuclear power operations	Public exposure, all sources	75 mrem/year (thyroid) 25 mrem/year (total body, other organs)
40 CFR 191	Spent nuclear fuel, high-level and TRU wastes	Public exposure, all sources	75 mrem/year (any organ) 25 mrem/year (total body)
40 CFR 192	Uranium and mill tailings	Radium-226	5 pCi/gm over background

Table E.7. Radionuclide slope factors and pathway-specific unit risk[a]

Radionuclide	Slope Factor: Age-averaged lifetime excess total cancer risk per unit intake or exposure			Pathway-specific Unit Risk: Age-averaged lifetime excess total cancer risk per unit intake or exposure daily for 70 years			
	Inhalation $(pCi)^{-1}$	Ingestion $(pCi)^{-1}$	Ground surface $(yr/pCi/m^2)^{-1}$	Air $(pCi/m^3)^{-1}$	Drinking water $(pCi/L)^{-1}$	External exposure $(pCi/g)^{-1}$	Soil ingestion $(pCi/g)^{-1}$
Americium-241	4.0E-08	3.1E-10	1.6E-12	2.1E-02	1.6E-05	1.6E-05	8.4E-07
Cesium-137	1.9E-11	2.8E-11	0.0E+00	9.6E-06	1.4E-06	0.0E+00	7.6E-08
Cobalt-60	1.6E-10	1.5E-11	1.3E-10	8.1E-05	7.8E-07	1.3E-03	4.1E-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
Plutonium-238	4.2E-08	2.8E-10	6.1E-14	2.1E-02	1.4E-05	5.9E-07	7.6E-07
Plutonium-239	4.1E-08	3.1E-11	2.6E-14	2.6E-02	1.6E-06	2.6E-07	8.4E-08
Strontium-90	5.6E-11	3.3E-11	0.0E+00	2.8E-05	1.7E-06	0.0E+00	8.9E-08
Technicium-99	8.3E-12	1.3E-12	3.4E-17	4.2E-06	6.6E-08	3.4E-10	3.5E-09

[a]EPA 1990b.

Table E.8. Tentative location-specific applicable or relevant and appropriate requirements for WAG 2[a]

Location	Requirement	Prerequisite(s)	Citation
Within salt dome formation, salt bed formation, underground mine, or cave	Prohibits placement of noncontainerized or bulk liquid hazardous waste	RCRA[b] hazardous waste	40 CFR 264.18(c)
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
Wetlands	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 their planning, regulatory, and decision-making process.		40 CFR 6, Appendix A
	Federal agencies should avoid new construction in wetlands areas		40 CFR 6, Appendix

Table E.8 (continued)

Location	Requirement	Prerequisite(s)	Citation
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	
Critical habitat upon which an endangered or threatened species depends	Must take action to conserve endangered or threatened species; must not destroy or adversely modify critical habitat	Determination of presence of federal or Tennessee listed endangered or threatened species; presence of species listed as "in need of management" in Tennessee	Endangered Species Act of 1973 (16 USC 1531 et seq.); 50 CFR 402; Fish and Wildlife Coordination Act (16 USC 661 et seq.); 33 CFR 320-330.; Tennessee Rare Plant Protection and Conservation Act of 1985 (TCA[c] §11-26-201); Tennessee Non-Game and Endangered or Threatened Wildlife Species Conservation Act of 1974 (TCA §70-8-101 et seq.)
	Must consult with Department of Interior, FWS, and state personnel required to ascertain that proposed actions will not affect any listed species		
Within area where action may cause irreparable harm, loss, or destruction of significant artifacts	Must take action to recover and preserve artifacts	Dam construction or alteration of terrain that threatens significant scientific, prehistorical, historical, or archeological data	Archaeological and Historic Preservation Act (16 USC 469a-1); Archaeological Resources Protection Act (16 USC 470dd)

[a]Adapted from EPA (1988a,c).
[b]RCRA = Resource Conservation and Recovery Act; definitions appear at 40 CFR 260.10.
[c]TCA = Tennessee Code Annotated.

Appendix F

WAG 2 RI STAFF

TOM L. ASHWOOD

M.S., Economics, 1975, Murray State University

PROJECT POSITION: Site Characterization Task Leader; ORNL-ESD

AREAS OF EXPERTISE: Sediment contamination, groundwater pollution and remediation.

B. GORDON BLAYLOCK

Ph.D., Zoology, 1963, University of Tennessee

PROJECT POSITION: Sediment Team Leader and Risk Assessment Staff; ORNL-ESD

AREAS OF EXPERTISE: Radiation effects and toxicity of environmental pollutants, trace elements, and radionuclide cycling in aquatic systems, environmental assessment.

DENNIS BORDERS

M.S., Env. Eng., 1986, The University of Tennessee

PROJECT POSITION: Hydrology and Water Chemistry Field Team Leader

AREAS OF EXPERTISE: Surface-water hydrology, hydraulics, hydrologic and hydraulic modeling

HARRY L. BOSTON

Ph.D., Botany, 1984, University of Wisconsin-Madison

PROJECT POSITION: Project Manager; ORNL-ESD

AREAS OF EXPERTISE: Energy production and nutrient dynamics in aquatic systems; responses of aquatic systems to anthropogenic stress and biological monitoring in aquatic systems; land application of wastes; physiological ecology of aquatic plants.

VENKATESH CHIDAMBARIAH

M.S., Environmental Engineering, 1989, University of Tennessee

PROJECT POSITION: Risk Assessment Team Co-Leader; ORNL-HASRD

AREAS OF EXPERTISE: Risk Assessment, RI/RFI document development, risk assessment methodology

ROGER B. CLAPP

Ph.D., Environmental Sciences, 1982, University of Virginia

PROJECT POSITION: Floodplain Soil and Groundwater Field Team Leader; ORNL-ESD

AREAS OF EXPERTISE: Hydrology, radionuclide transport, ecosystem modeling.

ROBERT B. COOK

Ph.D., Geochemistry, 1981, Columbia University

PROJECT POSITION: Site Characterization Staff-Laision with Clinch River RFI; ORNL-ESD

AREAS OF EXPERTISE: Aqueous geochemistry, chemical limnology, biogeochemistry, mechanisms controlling pH in aquatic ecosystems.

RANAYE B. DREIER

Ph.D., Geology, 1985, University of Texas-Austin

PROJECT POSITION: Site Characterization Staff; ORNL-ESD

AREAS OF EXPERTISE: Structural geology, low-level waste R&D.

E. L. ETNIER

M.A., Zoology, 1965, University of Tennessee

PROJECT POSITION: Risk Assessment Staff; ORNL-HASRD

AREAS OF EXPERTISE: CERCLA sites, ARARs determination.

THOMAS A. FONTAINE

Ph.D., Civil and Environmental Engineering, 1989, University of Wisconsin

PROJECT POSITION: Modeling Team Leader; ORNL-ESD

AREAS OF EXPERTISE: Surface water hydrology, low-level waste R&D, multiphase groundwater contamination.

MARILYN L. FRANK

M.S., Radiation Biology, 1970, University of Tennessee

PROJECT POSITION: QA/QC Coordinator; ORNL-ESD

AREAS OF EXPERTISE: Radiation effects on aquatic organisms, radionuclide cycling in aquatic environments.

ROBERT H. GARDNER

Ph.D., Zoology, 1975, North Carolina State University

PROJECT POSITION: Statistical Support Team Leader

AREAS OF EXPERTISE: Statistical applications and analysis, population dynamics, systems ecology, landscape ecology

CHARLES T. GARTEN Jr

M.S., Zoology, 1974, University of Georgia

PROJECT POSITION: Site Characterization Staff; ORNL-ESD

AREAS OF EXPERTISE: Forest ecology, radioisotope and stable isotope applications in biogeochemical cycling, environmental behavior of hazardous chemicals, atmosphere-biosphere interactions.

F. OWEN HOFFMAN

Ph.D., Ecology, 1981, University of Tennessee

PROJECT POSITION: Risk Assessment Staff; ORNL-ESD

AREAS OF EXPERTISE: Validation of environmental assessment models, food chain bioaccumulation of toxic substances, development and application of methods for environmental risk analysis.

LESLIE A. HOOK

Ph.D., Zoology, 1988, Southern Illinois University

PROJECT POSITION: Data Management Task Leader; SAIC

AREAS OF EXPERTISE: Research data management, assessment of contaminant effects on aquatic ecosystems.

RON K. McCONATHY

M.S., Forestry, 1976, University of Tennessee

PROJECT POSITION: Health & Safety Coordinator; ORNL-ESD

AREAS OF EXPERTISE: Safety, quality assurance, waste management, training, radiation safety, forest ecology, forest physiology.

GERALD K. MOORE

B.S., Geology and Mineralogy, 1956, Pennsylvania State University

PROJECT POSITION: Site Characterization Staff; UT-ESD

AREAS OF EXPERTISE: Groundwater hydrology and chemistry.

PATRICK J. MULHOLLAND

Ph.D., Environmental Biology, 1979, University of North Carolina

PROJECT POSITION: Site Characterization Staff; ORNL-ESD

AREAS OF EXPERTISE: Stream ecology, nutrient cycling and organic carbon processing in aquatic ecosystems and watersheds, interactions between terrestrial and aquatic systems in biogeochemical cycles, watershed hydrology, ecosystem modeling, wetland ecology.

LARRY E. ROBERSON

M.S., Zoology, 1973, University of Tennessee

PROJECT POSITION: Project QA Specialist; ORNL-QA Division

AREAS OF EXPERTISE: Certified quality assurance lead auditor.

GEORGE R. SOUTHWORTH

M.S., Aquatic Ecology, 1974, University of Michigan

PROJECT POSITION: Biota Field Team Leader; ORNL-ESD

AREAS OF EXPERTISE: Environmental transport and transformation of organic contaminants.

GLENN W. SUTER II

Ph.D., Ecology, 1976, University of California, Davis

PROJECT POSITION: Risk Assessment Task Co-Leader; ORNL-ESD

AREAS OF EXPERTISE: Ecological toxicology, environmental risk assessment, soil ecology.

MARK TARDIFF

M.S., Ecology, 1982, SUNY College of Environmental Science and Forestry

PROJECT POSITION: Site Characterization Staff Laision with NPDES and Environmental monitoring data; ORNL-HP Division

AREAS OF EXPERTISE: Statistical analysis and interpretation of environmental surveillance and effluent monitoring data, systems analysis, RI/RFI design.

JULIE A. WATTS

M.S., Mathematics/Statistics, 1968, Tennessee Technological University

PROJECT POSITION: Data Management Team, Statistical Support Team

AREAS OF EXPERTISE: Statistical applications, analyses, and graphic display of numeric data, application of geographic information systems and remotely sensed data to environmental sciences, vegetation analyses.

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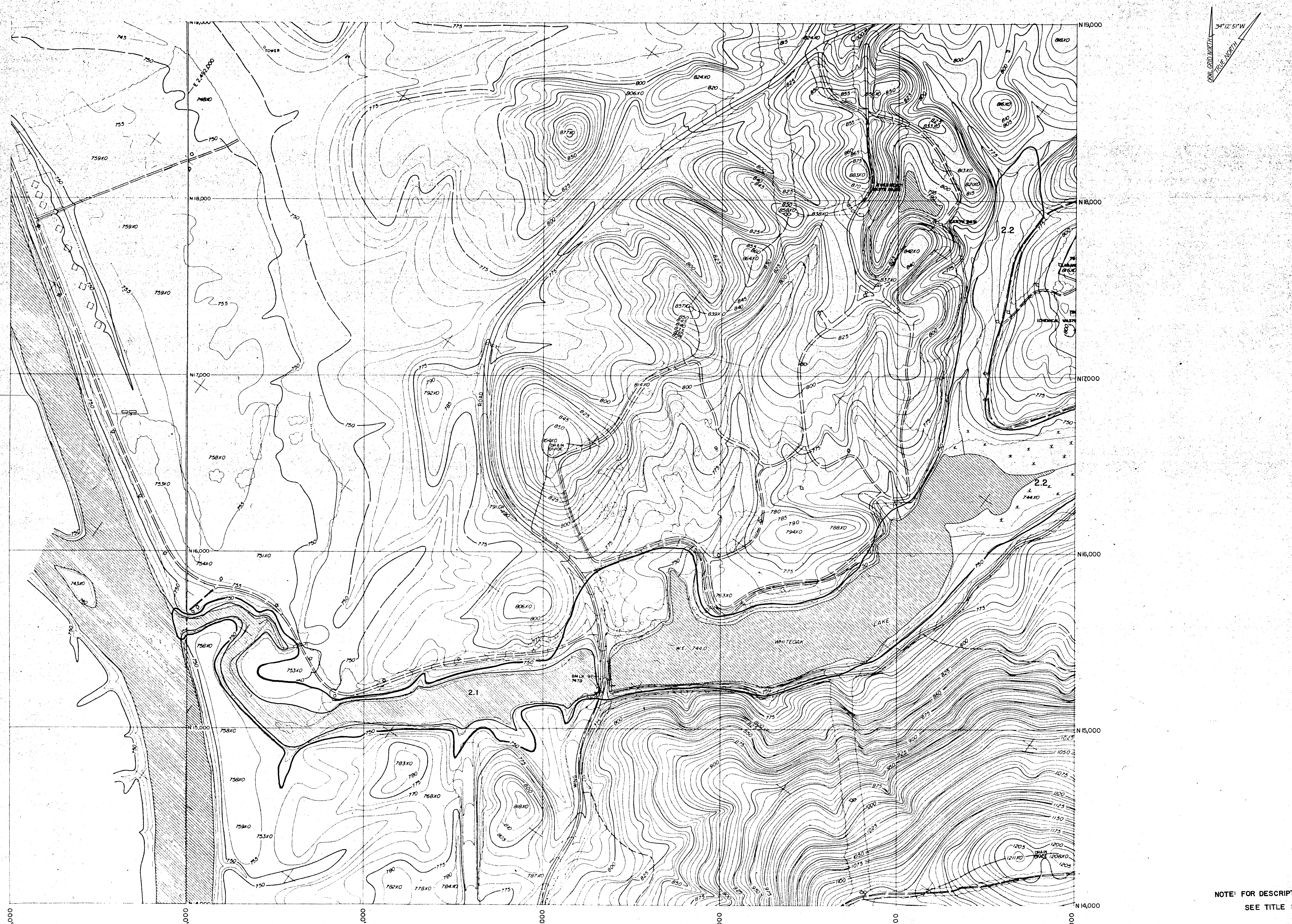

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B	GENERAL REVISION		A.P.	C.F.	anw	WM	9/15/87
A	GENERAL REVISION		C.S.	C.S.			4/7/87
O	ISSUED FOR INFORMATION		C.S.	C.S.	ANW		3/2/87

REVISION OR ISSUE PURPOSE — REVISION APPROVALS — SQUAD CHECK — DRAWING APPROVALS

TOLERANCES UNLESS OTHERWISE SPECIFIED
FRACTIONS
XX DECIMALS ±
XXX DECIMALS ±
ANGLES
BREAK SHARP EDGES MAX
FINISH

DES	C. FOLDEN	9/87
DRW	A. PHILLIPS	9/87
CHK	C. FOLDEN	9/87
SECT	A.N. Wyle	9/87
DEPT & PLANT	[signature]	9/1/87
	[signature]	9/21/87

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REMEDIAL ACTION PROGRAM

WASTE AREA GROUPING (WAG) 2 (1 OF 3)

R A P WAS A G WAG 2 1 OF 3 M — TYPE
3 C P T — PLANT X-10 — BLDG — FL A — SHT — OF — CLASS U
SCALE — A2502J49 C3E 12785 A009 — REV. B

#304

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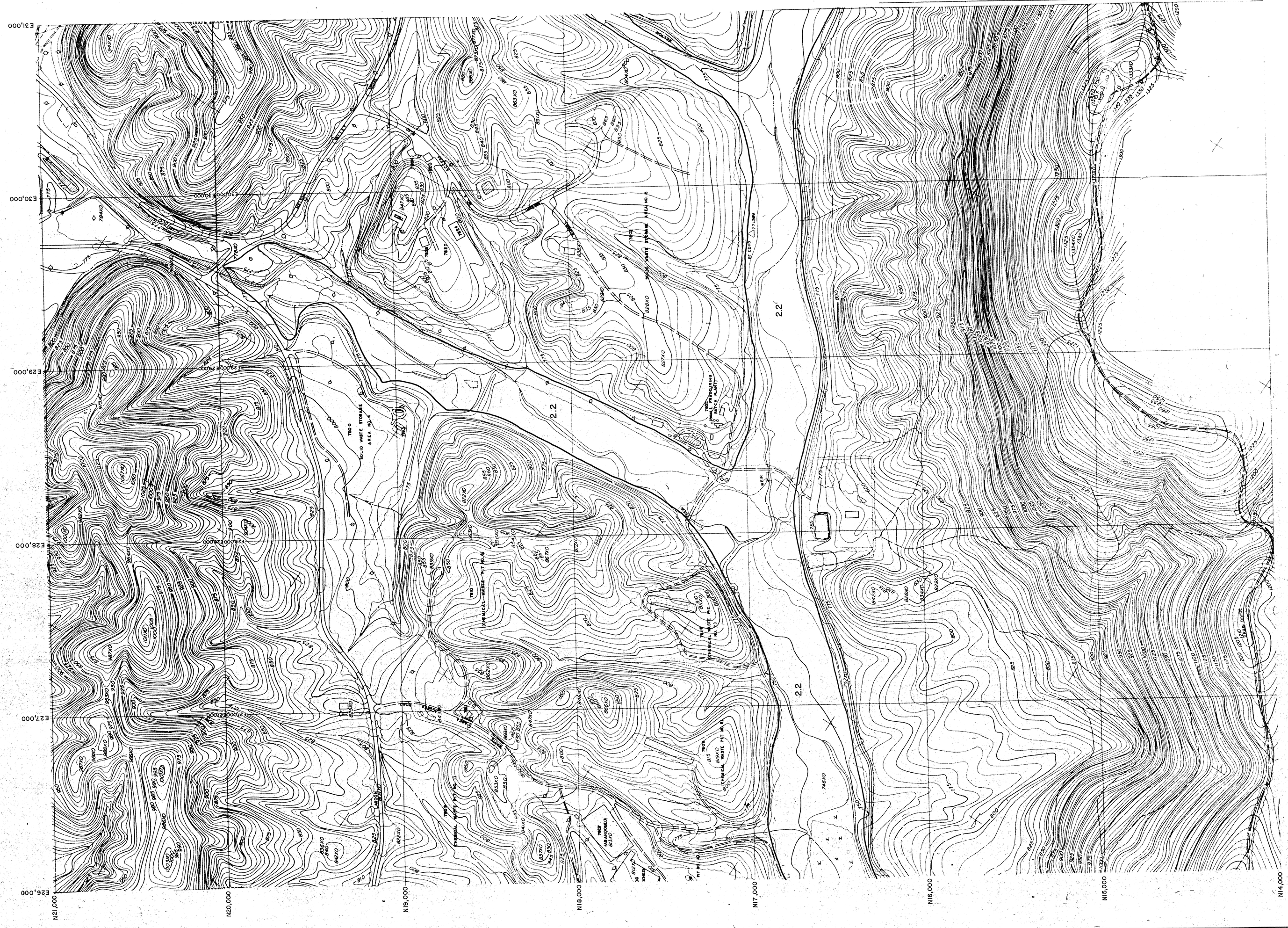

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A	GENERAL REVISION	C.C.	C.C.										
0	ISSUED FOR INFORMATION	C.S.	C.S.	ANW	WM	4/19/82							

REVISION OR ISSUE PURPOSE

REVISION APPROVALS

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SQUAD CHECK

TOLERANCES UNLESS OTHERWISE SPECIFIED			DATE
FRACTIONS ±	DES	C. SHARP	3-87
XX DECIMALS ±	DRW	C. SHARP	3-87
XXX DECIMALS ±	CHK	C. SHARP	3-87
ANGLES ±	SECT	A.N. WYLIE	3-87
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A.E.	
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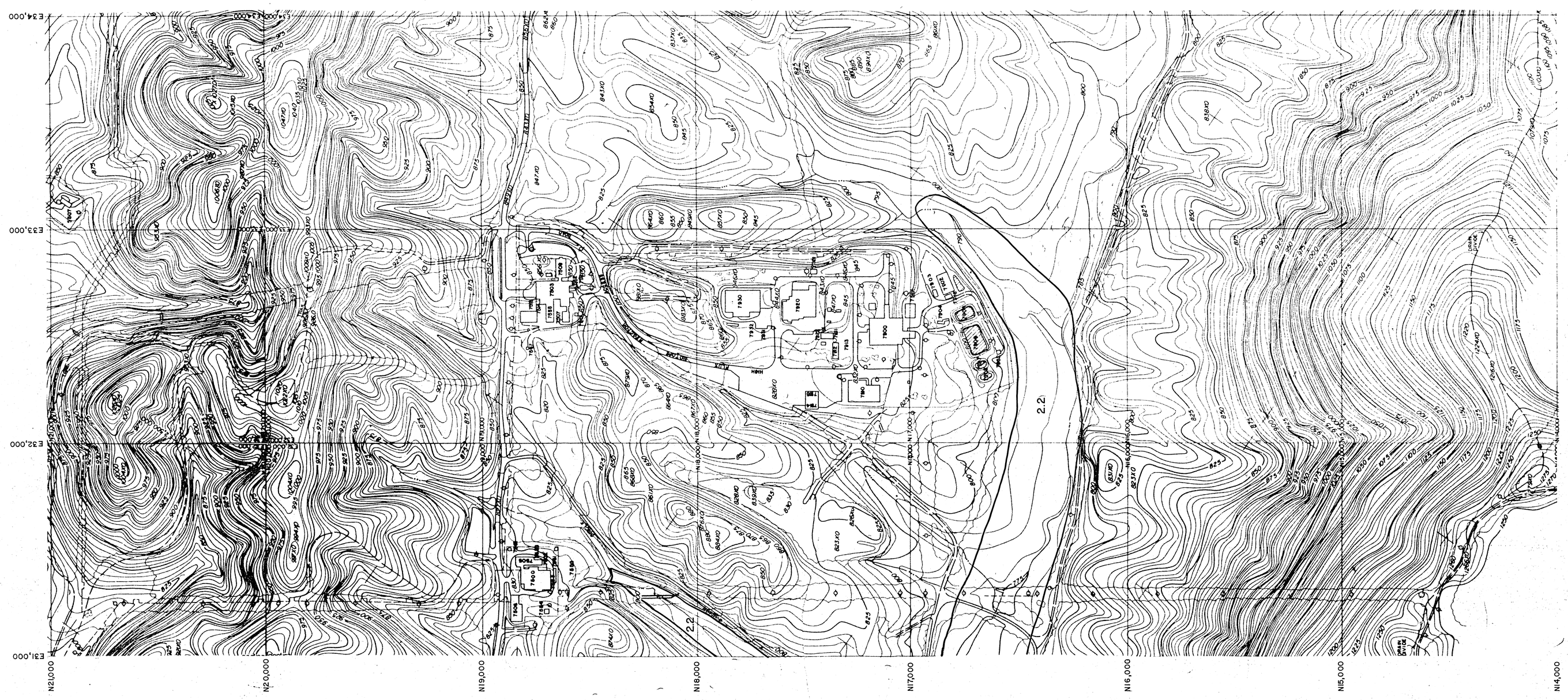
REMEDIAL ACTION PROGRAM

WASTE AREA GROUPING (WAG) 2 (2 OF 3)

SCALE	ID							TYPE
1 3 C	48 49 P	T 50	PLANT —	BLDG —	FL A	SHT —	OF —	R A P W A S A G W A G 2 2 OF 3 M
	A250204 4	C3E	1 2 7 8 5	A 0 1 0				CLASS U REV A

#304



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STEPS
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LIGHT POLES
TELEPHONE POLES
FENCE LINE
PERIMETER
TRAILS
ELECTRICAL TOWERS
SHOT ELEVATIONS
INTERMEDIATE CONTOURS
MONUMENTS
BOUNDARY MARKER
PIPE OR STEAM LINE
DROP INLET

WHITE OAK CREEK WATERSHED
SCALE IN FEET
0 100 200 400 600 800

SCALE IN METERS
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O.R.N.L. COORDINATES GRID
PLANT COORDINATES GRID
PHOTO DATE 2-29-78
SCALE 1"=200
CONTOUR INTERVALS
MEAN SEA LEVEL DATUM OF 1929

GRID NORTH
TRUE NORTH
34°15' W

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REVISION APPROVALS

	CA	EC	EE	EM	JE	M	PD	SE	XAD

SQUAD CHECK

		DATE
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MMES		
A.E		
DEPT & PLANT		
SECT	A. N. WYLIE	3-87
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WASTE AREA GROUPING (WAG) 2 (3 OF 3)

R	A	P	WAS	A	G	WAG	2	3	OF	3	M
1	48	49	50	PLANT		BLDG		FL	SHT	OF	CLASS
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