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Environmental Data Package for ORNL Waste Area Grouping 3 (WAG 3), Solid Waste Storage Area 3 (SWSA 3)

R. R. Shoun

#109

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ORNL/RAP-21

Chemical Technology Division

ENVIRONMENTAL DATA PACKAGE FOR ORNL WASTE AREA GROUPING 3 (WAG 3), SOLID WASTE STORAGE AREA 3 (SWSA 3)

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ABSTRACT

Oak Ridge National Laboratory (ORNL), as a U.S. Department of Energy facility, must be in compliance with federal and state regulations. The Environmental Protection Agency now enforces its regulatory requirements for remedial action in areas containing residual contamination through Section 3004(u) of the Resource Conservation and Recovery Act as amended in 1984.

As a part of ORNL's Remedial Action Program, the area has been divided into 20 Waste Area Groupings (WAGs). One of these, WAG 3, is addressed in this document. This environmental data package provides background information on geology, hydrology, soils, and ecology of the Solid Waste Storage Area 3, including the adjacent scrap metal area and the Contractor's Landfill nearby. Information concerning known releases and remedial actions or experimental programs is presented, and additional information needed to properly complete the Section 3004(u) requirements is noted.

1. INTRODUCTION

U.S. Department of Energy (DOE) facilities are required to be in full compliance with all federal and state regulations. In response to these requirements, the Oak Ridge National Laboratory (ORNL) has established a Remedial Action Program (RAP) to provide comprehensive management of areas where research, development, and waste management activities have resulted in residual contamination of facilities or the environment. The primary objective of the RAP is to clean up hazardous waste or hazardous constituents that threaten human health or the environment (Trabalka and Myrick in press; Boegly et al. 1987).

The initial ORNL remedial action strategy was based on the guidance of DOE Orders 5820.2 (Surplus Facilities Management) and 5480.14 [Comprehensive Environmental Restoration, Compensation, and Liability Act (CERCLA)]; the Resource Conservation and Recovery Act

(RCRA) was believed to apply to only a limited number of sites. As a part of this strategy, individual sites were investigated according to estimated priorities for site characterization, remedial actions, and decommissioning/closure planning. In 1984, the RCRA was amended to establish broad new authorities within the Environmental Protection Agency (EPA) RCRA programs. One of these new authorities was Section 3004(u), which requires that any hazardous waste management permit issued after November 8, 1984, require corrective action for all releases from solid waste management units at the facility. In a memorandum to DOE in April 1986, EPA expressed concern about the length of time required to implement DOE orders and elected to enforce regulatory requirements for remedial actions through its amended RCRA authority (Scarbrough 1986).

Before the Hazardous Solid Waste Amendments (HSWA) to RCRA, EPA's authority to require corrective action for releases of hazardous constituents was limited to groundwater releases from units that were covered by RCRA permits (Part 264, Subpart F). Since passage of the HSWA, EPA's authority has been extended to include releases to all media and all units at a RCRA facility regardless of when they were used or whether they are covered by an RCRA permit (EPA 1986).

Waste Area Grouping 3 (WAG 3) consists of only three Solid Waste Management Units (SWMUs): (1) the inactive Solid Waste Storage Area 3 (SWSA 3), (2) the active Contractor's Landfill, and (3) the closed scrap metal area now enclosed within the SWSA 3 fence.

2. GENERAL SITE DESCRIPTION OF WAG 3

2.1 HISTORY, PURPOSE, AND GEOGRAPHIC LOCATION OF WAG 3

Since 1943, solid, low-level radioactive wastes generated by ORNL (and in some cases other sources) have been deposited in shallow land burials at ORNL. SWSA-3 was the third of these successively larger disposal areas and the last one located in Bethel Valley (Fig. 1). The useful life of SWSA-3 extended from 1946 to 1951 for routine burial operations; however, aboveground storage of large items of contaminated equipment continued until 1979. Figures 2 and 3 show "before" and after" pictures of SWSA 3. Figure 1 shows the components of WAG 3 in relation to the ORNL area: SWSA-3 approximately 1 km west

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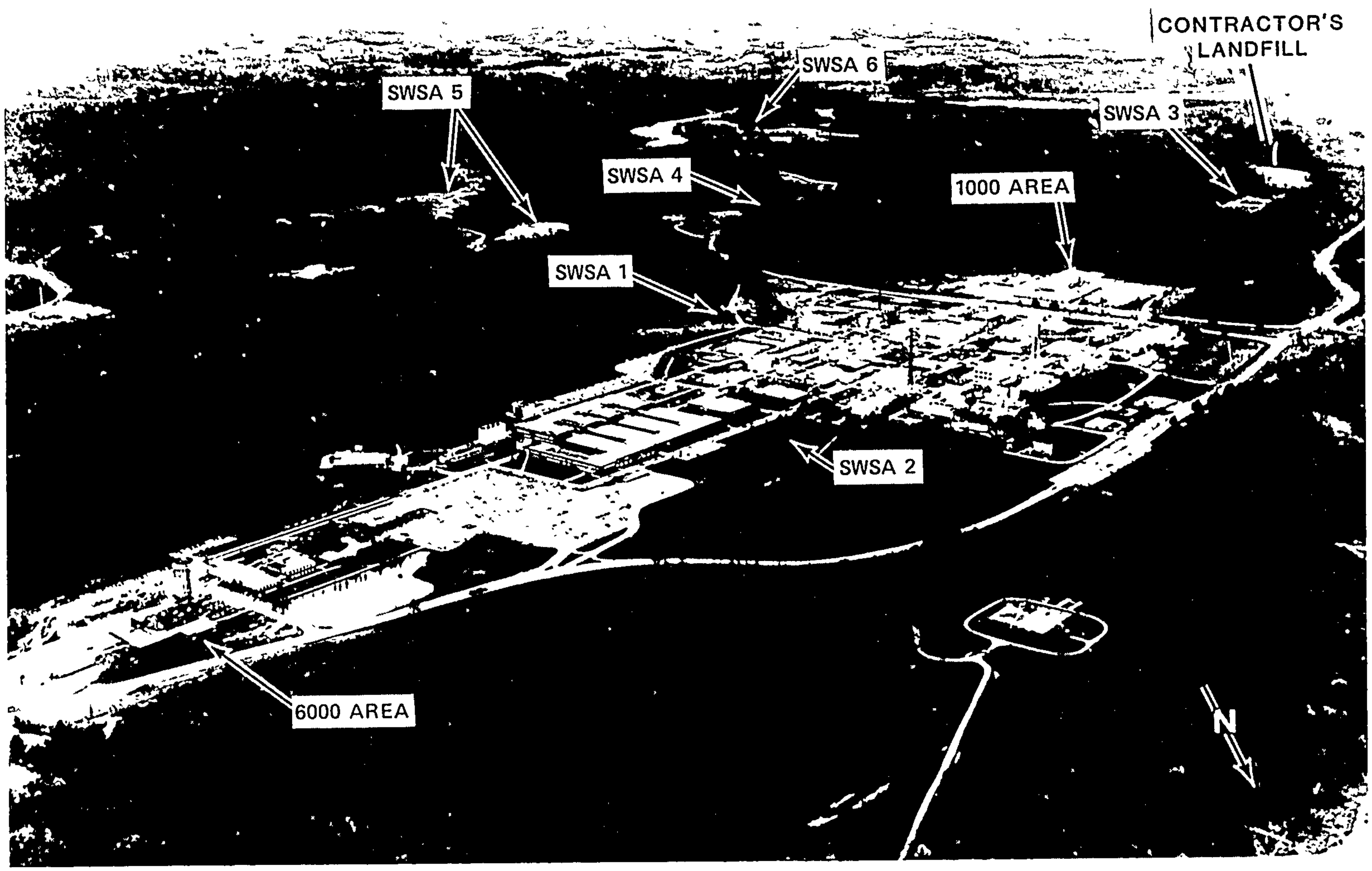

Fig. 1. Aerial view of Oak Ridge National Laboratory showing approximate locations of solid waste storage areas. SWSA 3 and the Contractor's Landfill are in the upper righthand corner.

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Fig. 2. SWSA 3 before 1978-1979 surface cleanup.

ORNL-PHOTO 5064-80

Fig. 3. SWSA 3 after 1978-1979 surface cleanup.

of the main ORNL complex, the closed scrap metal area adjoining the south boundary of SWSA 3 (Fig. 4), and the Contractor's Landfill southwest of SWSA 3.

The second component of the WAG 3 is the closed scrap metal area, which is a small, triangular-shaped section adjoining the south boundary of SWSA 3 for about 80 m. This area was found to contain buried contaminated metal in 1982 (Grizzard 1986), so a fence was constructed to enclose the area. The portion of the fence adjoining SWSA 3 was later removed, and the scrap metal area is now an integral part of SWSA 3. This area is grassed and is maintained with the rest of SWSA 3. A fill area to the south of this area contains uncharacterized construction materials.

The remaining component of WAG 3 is the Contractor's Landfill, which, as seen in Fig. 5, is just southwest of SWSA 3. This landfill (clay spoil area) receives earth materials from construction activities at the ORNL site. Two small areas (Fig. B-2) within this site have been identified as having some ^{137}Cs and ^{90}Sr contamination (Stueber et al. 1981).

2.2 GEOLOGY

The components of WAG 3, including SWSA 3, are located in Bethel Valley at the foot of Haw Ridge, and thus SWSA 3 is underlain by Chickamauga limestone of the Ordovician age.

Stockdale (1951) subdivided the Chickamauga limestone of Bethel Valley into eight distinct units based on variations in types of rock. Three of these units (E, F, and G) underlie SWSA 3, and their relationship is shown in Figs. 6 and 7. Units E and G are nondescript gray limestones 116 and 91 m thick, respectively. Unit F is 7.6-m-thick maroon calcareous siltstone and shale.

The limestones of units E and G are compact and have very little primary porosity. However, secondary openings, which developed from groundwater dissolution, have been identified from drill cores and are reported to be as large as 30 cm in diameter (Steuber et al. 1981).

Soils in the ORNL area (and thus SWSA 3) are silty, contain clay, and exhibit a pH of 4.5 to 5.7 (Cowser 1961). The weathered zone is thin (usually less than 3 m) in the area underlain by Chickamauga

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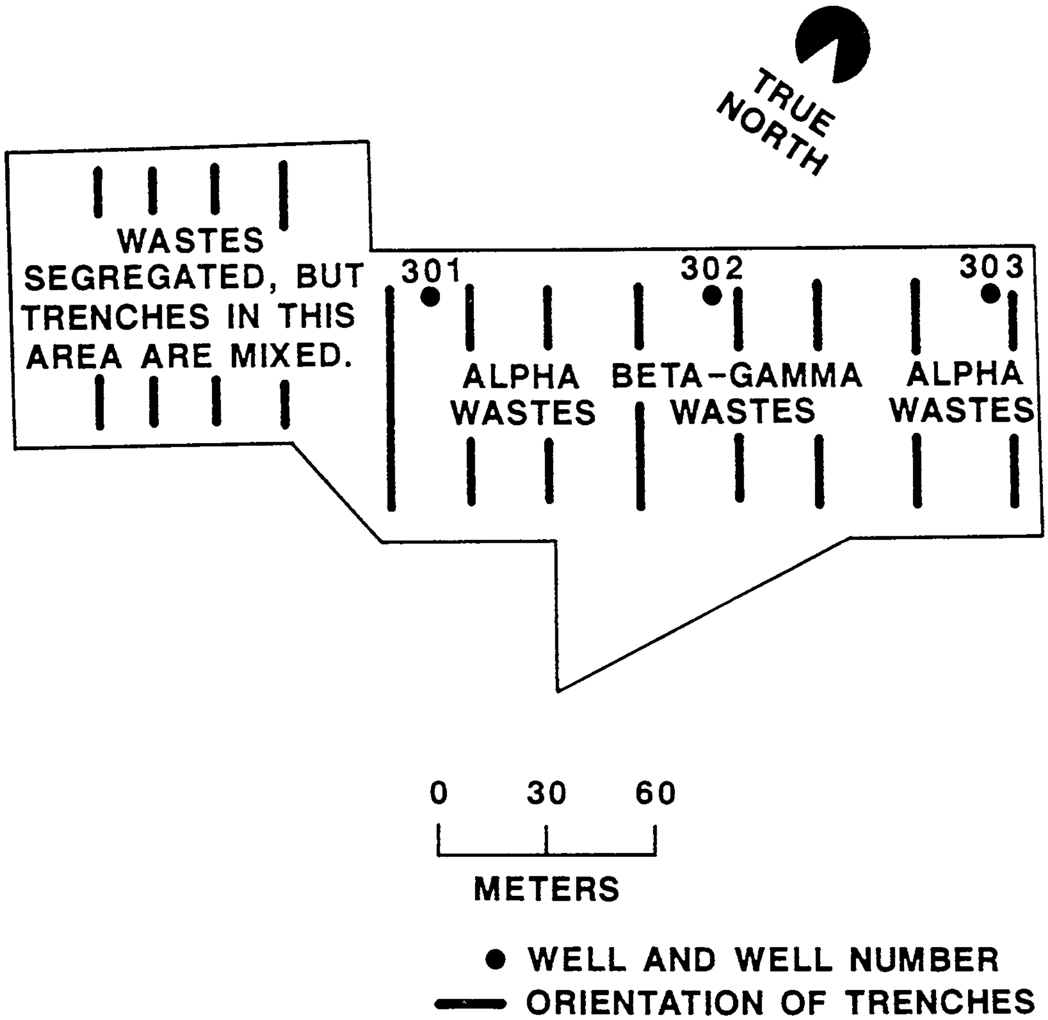

Fig. 4. SWSA 3 with the appended scrap metal area to the south.

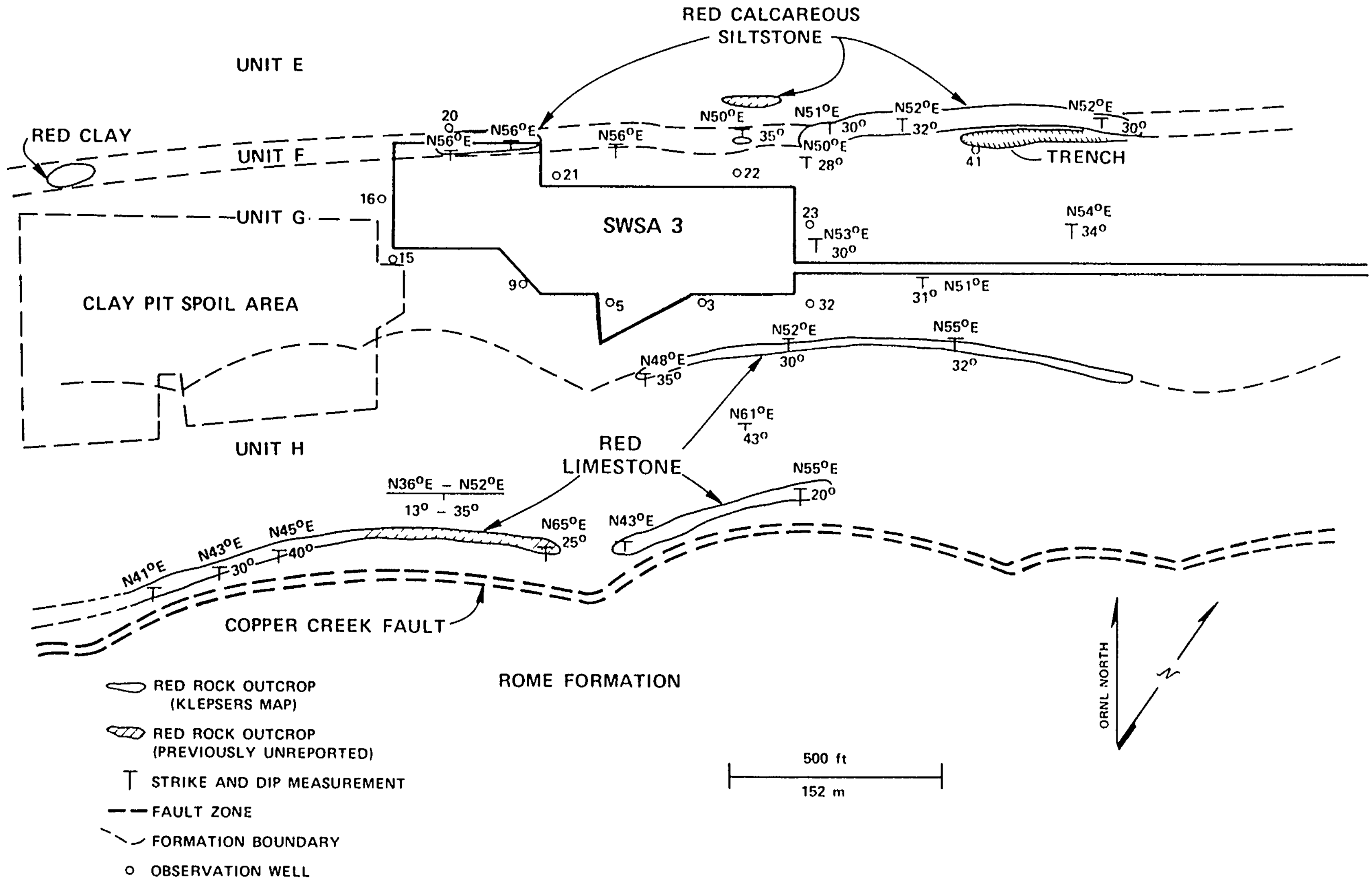

Fig. 5. Contractor's Landfill in relation to SWSA 3.

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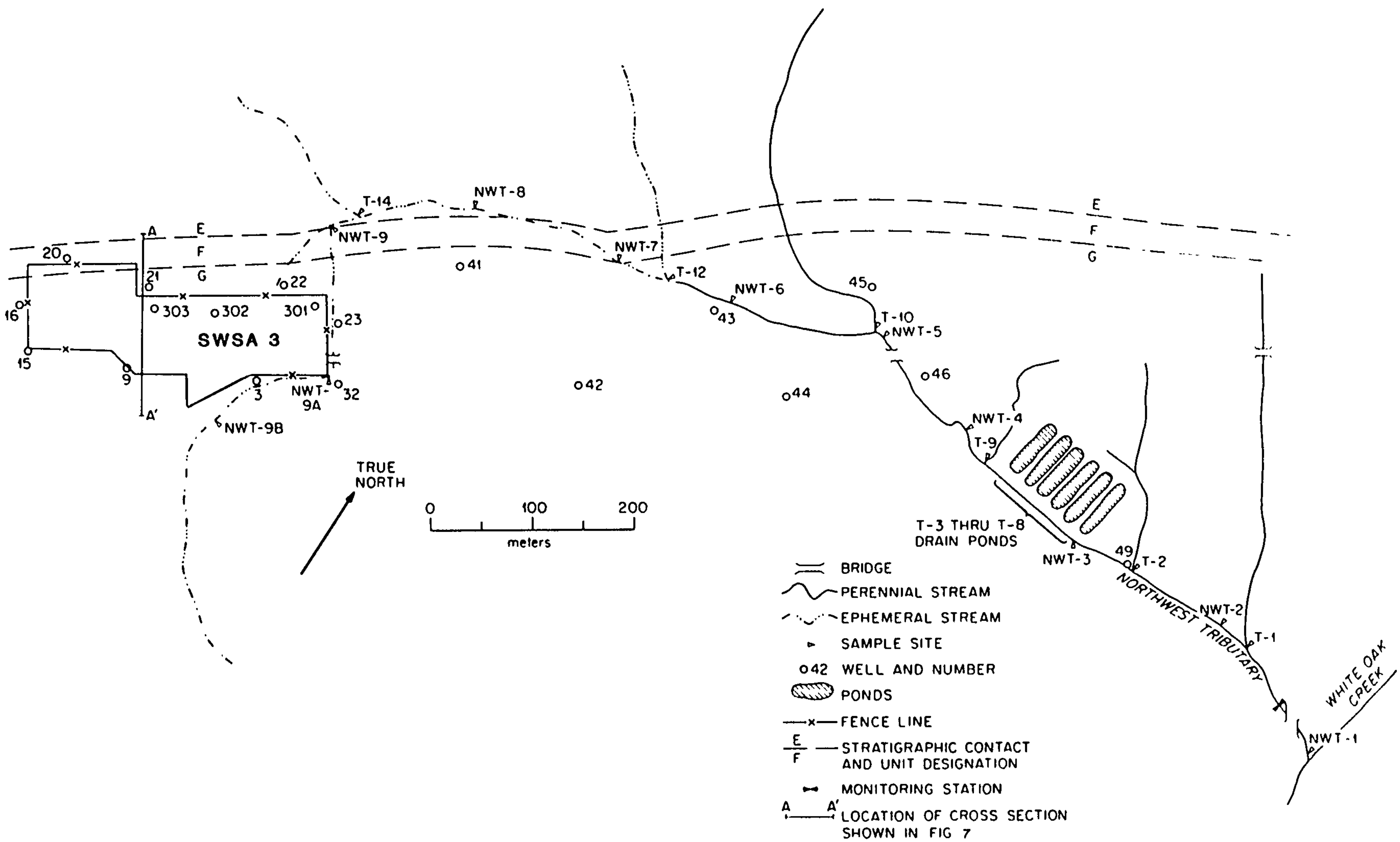

Fig. 6. The Northwest Tributary drainage basin, including surface water sampling sites, wells, and contacts of Chickamauga limestone bedrock units.

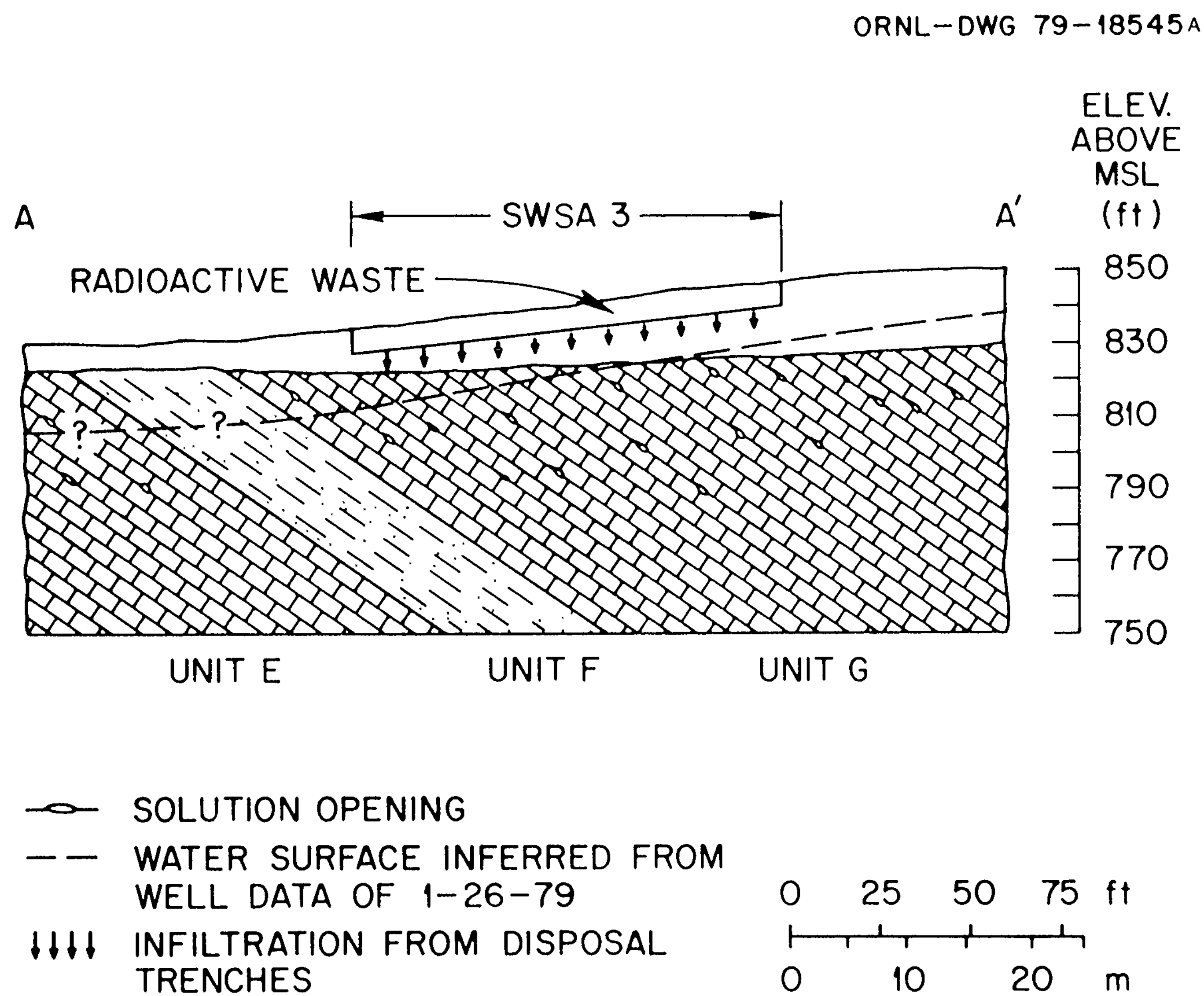

Fig. 7. Schematic cross section through SWSA 3 along line A-A' (Fig. 6) showing significant geologic and hydrologic features.

limestone. The sorptive properties of the various clay minerals have been shown to vary for specific radionuclides (Webster 1976).

2.3 HYDROLOGY

The groundwater hydrology of SWSA 3, as inferred from a 1950 water contour map, first indicates the presence of a groundwater divide in the west end of SWSA 3 (Stockdale 1951; Duguid 1975; Stueber et al. 1981). These data infer that groundwater east of the divide flows east to discharge in the White Oak Creek drainage system (Figs. 8,9). Groundwater west of the divide flows west to discharge in the Raccoon Creek drainage system. The surface water divide appears to occur just west of the disposal site (SWSA 3), so all surface water from SWSA 3 drains to White Oak Creek through the Northwest Tributary (Stueber et al. 1981).

The Northwest Tributary originates on the northwest flanks of Haw Ridge; runoff from this area is now diverted around the northeastern end of SWSA 3. The stream is ephemeral in the vicinity of SWSA 3, but becomes perennial about 400 m downstream from the disposal area (Fig. 6).

A 1979 water-level contour map (Fig. 9) suggests that the direction of groundwater flow below the northeastern portion of SWSA 3 is toward the northwest, and that beyond the northeastern boundary, the flow is generally to the north. Below the southwestern portion of SWSA 3, the hydraulic gradient slopes in two directions, indicating flow toward the northeast and toward the west (Stueber et al. 1981).

Hydrologic information for the Contractor's Landfill is sparse, and data indicate only that surface runoff from this area flows toward the headwaters of Raccoon Creek.

2.4 ECOLOGY

As with other SWSAs at ORNL, the primary vegetation surrounding the WAG-3 components is the oak-hickory association, which consists of extensive stands of mixed yellow pine and hardwoods, as well as oaks and hickories. After clearing the forest from the SWSA 3, completing the waste burial process, and covering the area with approximately 1 m of soil, SWSA 3 was seeded to prevent erosion. For several years,

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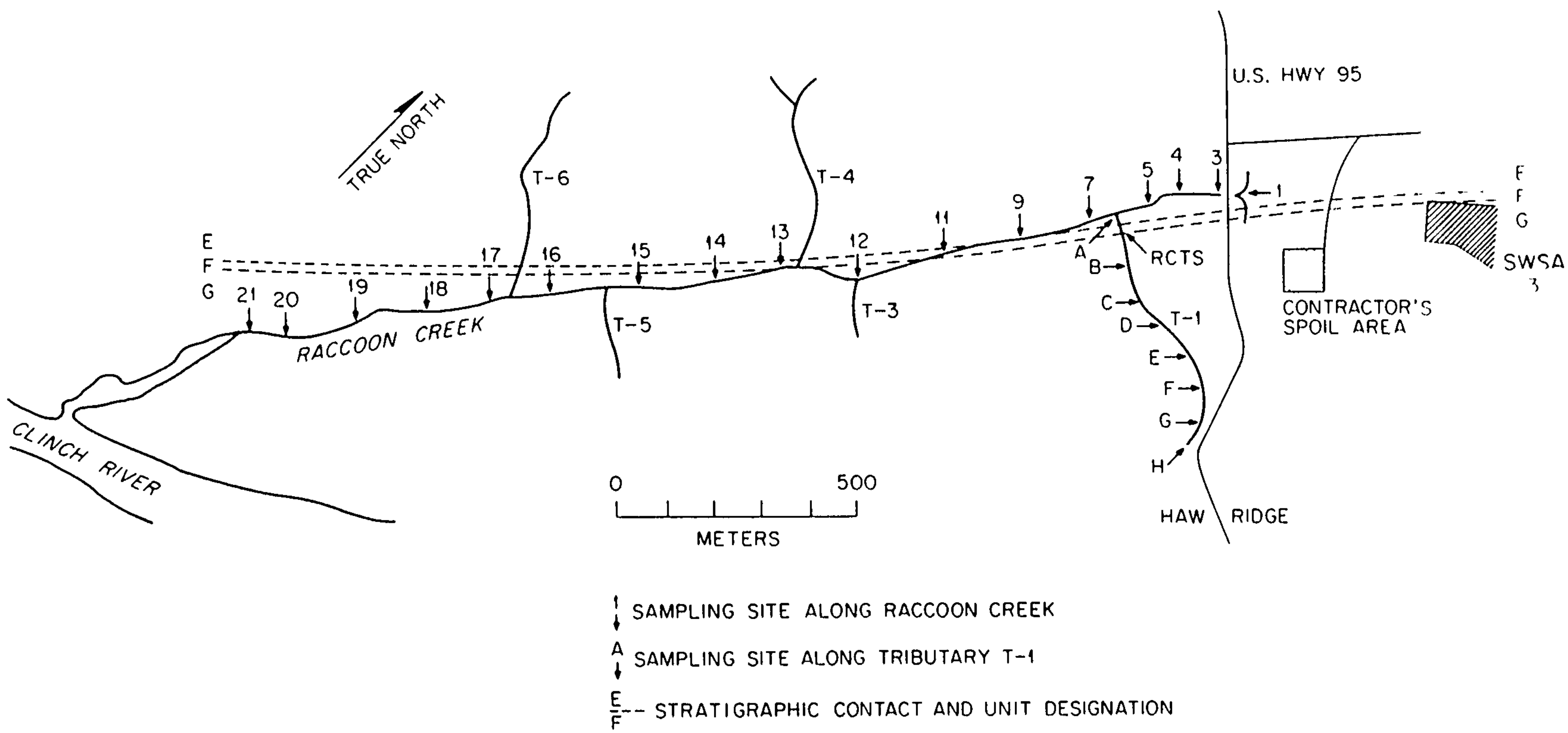

Fig. 8. The Raccoon Creek drainage basin, including surface water sampling sites and contacts of Chickamauga limestone bedrock units.

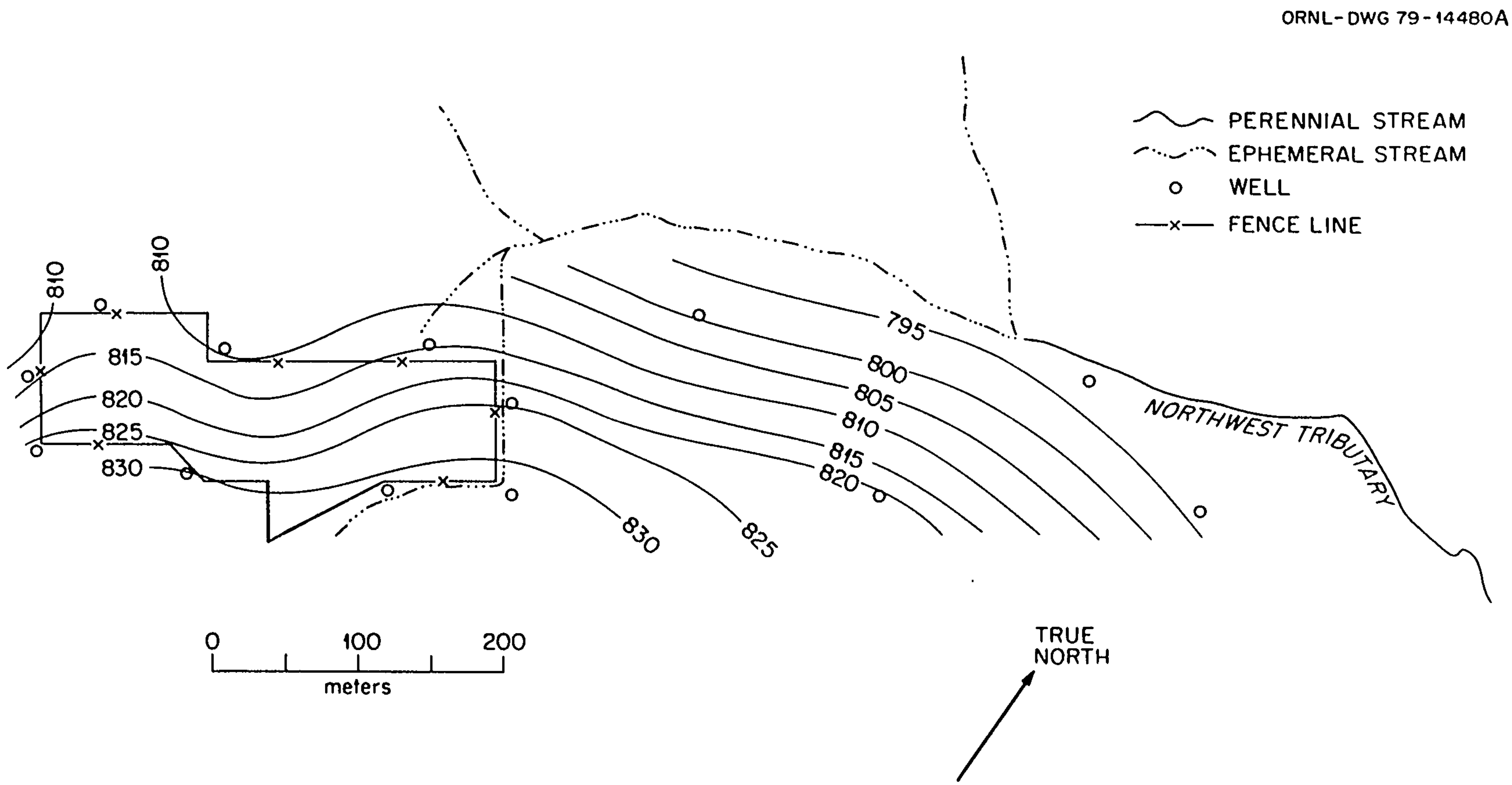

Fig. 9. Water level contour map based on January 1979 water levels.

trees and shrubs were allowed to revegetate SWSA 3, but the area was cleared during 1978-1979 cleanup operations. This area is now periodically mowed during the summer.

Small animals indigenous to the area would be expected to frequent SWSA 3 and the surrounding area. Such mammals as mice, chipmunks, land shrews, squirrels, opossums, rats, groundhogs, muskrats, foxes, and perhaps deer may inhabit portions of the SWSA. Groundhogs are particularly fond of using the old waste trenches for their dens.

2.5 LAND USE

2.5.1 Trench Burial in SWSA 3

SWSA 3 is a completely fenced area of approximately 2.8 ha located about 1 km west of the main ORNL complex at the foot of Haw Ridge (Fig. 1). Parallel trenches were excavated across the width of the area and are generally 4.4 m or less in depth (Fig. 4). During the early operation of the burial ground, alpha-contaminated wastes in drums were placed in concrete-lined trenches in the northeastern end of the area, but later they were placed in unlined trenches and covered with concrete (Webster 1976). Beta-gamma-contaminated wastes were buried in separate, unlined trenches and were backfilled with native soil (Webster 1976; Grizzard 1986).

As the site was extended westward, hard rock was encountered, making excavation difficult (Webster 1976; Myrick et al. 1984; Grizzard 1986). The area was covered with an average of 1 m of soil and grass is maintained to prevent surface erosion.

While no burial records are available, as many were destroyed in a 1958 fire at SWSA 5, an estimated 1.85 PBq (Bates 1983) of radioactivity was buried in a volume of approximately 2 x 10^4 m^3 of refuse. Alpha and beta-gamma wastes were generally segregated; however, the physical forms were varied and probably included some chemical wastes which may well have been reactive, corrosive, or toxic.

2.5.2 Construction Refuse in Contractor's Landfill

The Contractor's Landfill, southwest of SWSA-3, is an active storage area for construction materials removed during construction activities at the ORNL site. According to Dvon Brogan, the maximum amount of fill material in this area is 6 m (Stueber et al. 1981).

While this area is now fenced and secured and material to be dumped must be "green tagged," previous operations deposited some radioactive materials in landfill. Stueber et al. (1981) identified two areas in the northernmost and southwestern portions of the landfill that contain ^{137}Cs, ^{90}Sr, and ^{60}Co. The maximum estimated inventory of ^{90}Sr is 7.4 TBq. Data from this study are presented in Appendix B.

2.6 REMEDIAL ACTIONS, INVESTIGATIONS, AND EXPERIMENTAL PROJECTS

2.6.1 Radionuclide Release

Radionuclide release from SWSA 3 and the Contractor's Landfill was studied by Stueber et al. (1981) through the analysis of surface water and groundwater from local drainage areas. Water from SWSA 3 drains to the Northwest Tributary, which in turn flows to White Oak Creek. During a seven-month monitoring program, it was determined that ^{90}Sr was being discharged in the main stream in amounts varying from 7.8 to 41 mBq per month, with an average discharge of 24 mBq per month. The ^{90}Sr enters the tributary through base flow about 350 m from the disposal area.

The suggested groundwater divide moves water (and ^{90}Sr) from the southwestern end of SWSA 3 toward the Raccoon Creek drainage system. In this watershed, ^{90}Sr is detected as it discharges from a seep adjacent to a Raccoon Creek tributary about 640 m southwest of SWSA 3 and averages 1.8 mBq per month. An additional source of ^{90}Sr may be the Contractor's Landfill, 250 m southwest of SWSA 3, in which two small areas of contaminated fill material have been found.

The ^{90}Sr appears to be moving through groundwater flow to the northeast and southwest of SWSA 3 in a direction related to bedrock structure. A line passing through the two seeps also passes through the SWSA and is parallel to bedrock strike (Fig. 10). Core-hole logs and televiewer logs suggest that ^{90}Sr in groundwater may be moving through solution channels near the contact between Chickamauga limestone units F (calcareous siltstone and shale) and G (shaly limestone).

Data from these studies may be found in Appendix B, and more detailed discussion is in Stueber et al. (1981).

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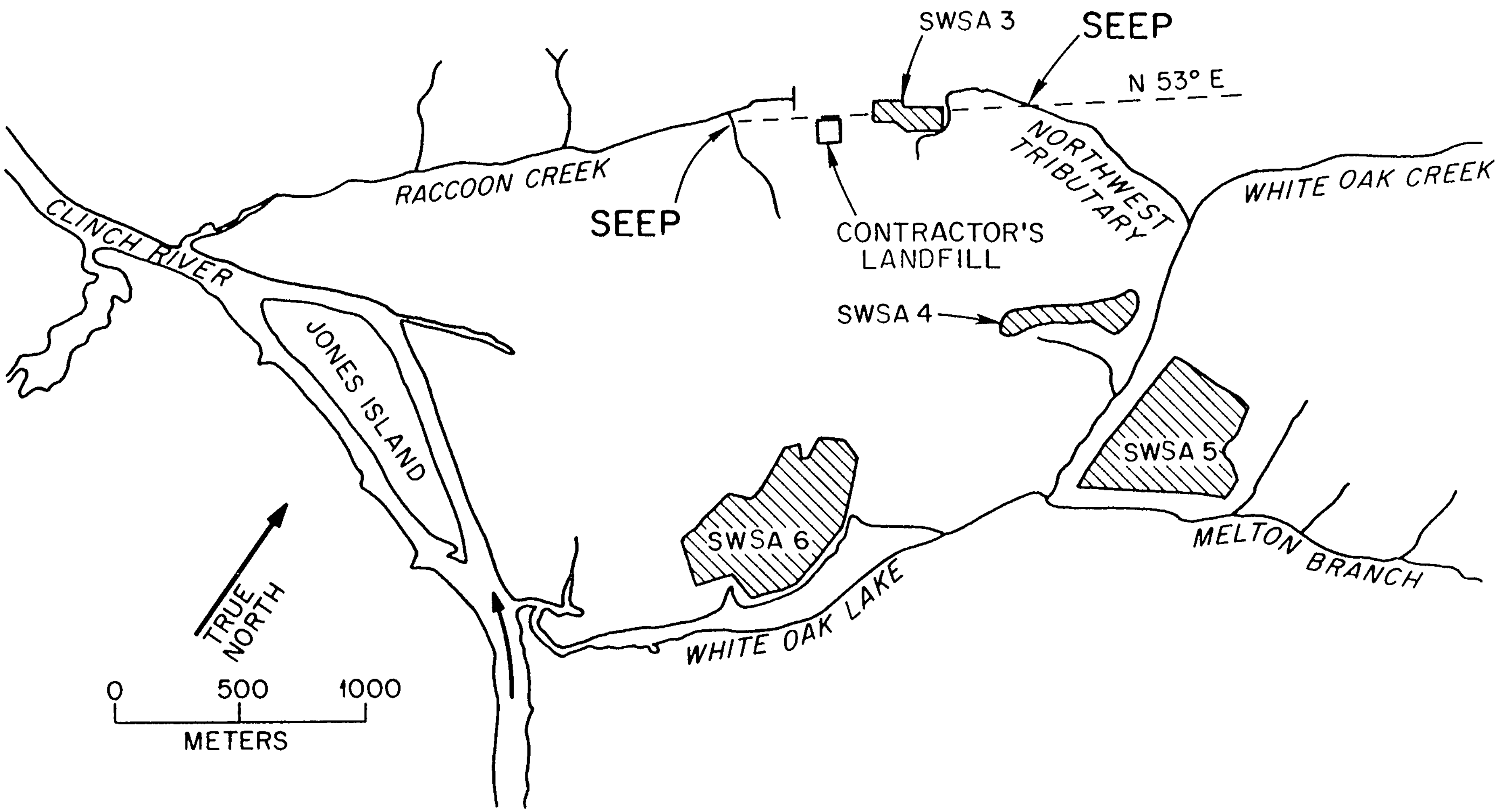

Fig. 10. Drainage systems in the vicinity of SWSA 3, including the two ^{90}Sr seeps and the trend of a line connecting them.

2.6.2 Geophysical Investigations

The desire for additional information about the geologic structure beneath SWSA 3 led to surveys utilizing very-low-frequency electromagnetic resistivity, electrical resistivity, and seismic refraction. Basic geophysical rock properties were measured as well as the depth of weathering and the configuration of the bedrock surface.

A number of geophysical anomalies were noted in the shallow subsurface, especially a linear feature running across the geologic strike in the western half of SWSA 3. Such a feature may conduct water in the subsurface.

None of the geophysical tests performed definitely confirm the presence of voids or fractures in the SWSA 3 area, but with complementary data from other studies, they may yield information necessary for confirmation of such structures. A more thorough discussion of the study may be found in Rothschild et al. (1985).

2.6.3 Dye Injections

In 1981 and 1982, J. Switek of the Environmental Sciences Division injected water, water-soluble fluorescein dye, and water-soluble rhodamine dye into wells near SWSA 3 in order to determine flow rates to various monitoring wells (Fig. 11). Water injected at well 21 was detected by the water level change at well 41 in 1.5 h, a distance of approximately 300 m to the east. A rhodamine dye injection at well 41 required only 21 min to reach the monitoring well approximately 200 m to the east. A fluorescein dye injection at well 493 was detected at a well approximately 550 m to the east in 7 d and also at a well approximately 900 m to the west in 21 d. The rates of movement for the water injection and the rhodamine are comparable to those expected for open channel flow.

2.6.4 Radionuclide Distribution to Streambed Gravel

Cerling and Spalding (1981) studied the association of ^{90}Sr, ^{60}Cs, and ^{137}Cs with streambed sediments as a method of identifying sources of radionuclides in waterways. High nuclide concentrations in sediments reveal locations where contamination begins. The ^{90}Sr, and,

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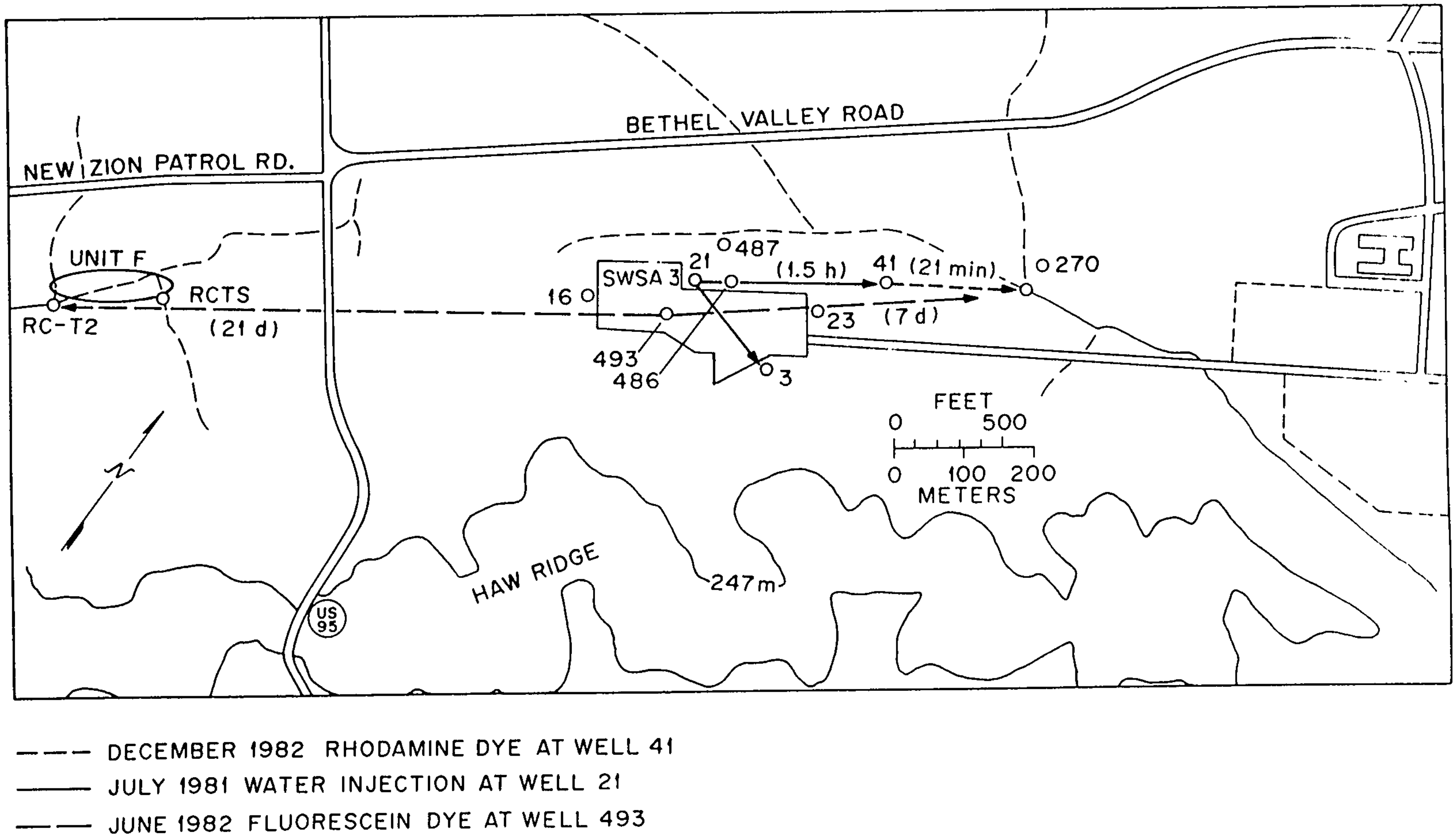

Fig. 11. Results of dye trace and water injection tests done in and near SWSA 3.

to a lesser degree, ^{60}Co associate by ion exchange with the solid phase sediments, but the ^{137}Cs forms a complex with a mineral constituent that is stable until the compound is destroyed. Because of this, the ^{90}Sr and ^{60}Co concentrations in the sediments are roughly proportional to those in the water (distribution coefficient), but the ^{137}Cs may only be used as a flag for a source of contamination. From their studies, Cerling and Spalding (1981) estimated that, in 1978-1979, SWSA 3 contributed about 3% of the ^{90}Sr discharged from ORNL.

Figures representing the areal distribution of ^{90}Sr, ^{60}Co, and ^{137}Cs in White Oak Creek watershed gravel are found in Appendix C.

3. INFORMATION NEEDED

A review of information in this report indicates that, while the components of WAG-3 are not major contributors of radioactivity, there are several areas in which additional data and information are needed to complete the Remedial Investigation/Feasibility Study planning stages.

Source Term and Waste Inventory

- Precise location of waste trenches and transuranic waste
- Trench wall permeability characteristics
- Better definition of the existence of radionuclides and potentially contaminated material in the area south of SWSA 3 through more extensive surveys

Hydrology

- Better definition of groundwater divide (through additional wells)
- Definition of solution channeling (through additional pump tests or dye tests)

Geology and Geochemistry

- Location of voids and underground channels
- Soils map for SWSA 3 and Contractor's Landfill
- Soil sorption-desorption studies

This is not an exhaustive list, but it should indicate possible additions to the WAG 3 data that are needed.

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APPENDIX A. U.S. GEOLOGICAL SURVEY SWSA 3 MONITORING WELL DATA

Table A-1. Data of observation wells in and near Solid Waste Storage Area 3, Oak Ridge National Laboratory, Roane County, Tennessee

Well number	Location: Latitude (deg., m, s)	Location: Longitude (deg., m, s)	Location: ORNL Grid (ft) (ft)	Depth of well (ft)	Year completed	Casing: Diameter (in)	Casing: Type	Finish: Character	Finish: Depth interval (ft)	Altitude of land surface (ft above NGVD)	Measuring Point: Distance above land surface (ft)	Measuring Point: Date determined (m/d/yr)	Depth to Water below land surface: Period of record (yrs)	Depth to Water below land surface: Minimum (ft)	Depth to Water below land surface: Maximum (ft)	Status of well
3[a]	35 55 07	84 19 42	N21630 E26428	251	1950	3 3/16	S	Opn	(?)	839.44	0.56	6/20/79	1975-79	4.51	10.58	A
9	35 55 03	84 19 49	N21671 E26010	99	1950	3 3/16	S	Opn	(?)	848.95	0.75	4/21/75	1975-79	16.95	21.23	A
15	35 55 03	84 19 52	N21726 E25698	100	1950	3 3/16	S	Opn	(?)	848.20	1.00	4/21/75	1975-79	19.34	32.82	A
16	35 55 04	84 19 54	N21871 E25668	100	1950	3 3/16	S	Opn	12-100	840.80	1.00	4/21/75	1975-79	18.98	28.75	A
20	35 55 07	84 19 53	N22013 E25821	99	1950	3 3/16	S	Opn	12-99	836.20	1.40	4/21/75	1975-79	20.63	21.01	A
21	35 55 08	84 19 49	N21925 E26076	100	1950	3 3/16	S	Opn	12-100	834.85	0.95	4/21/75	1975-79	24.30	25.59	A
22	35 55 10	84 19 44	N21934 E26510	100	1950	3 3/16	S	Opn	11-100	826.80	0.40	4/21/75	1975-79	8.05	16.04	A
23	35 55 10	84 19 43	N21807 E26679	100	1950	3 3/16	S	Opn	10-100	828.30	0.70	4/21/75	1975-79	0.04	6.40	A
32	35 55 09	84 19 40	N21621 E26682	99	1950	3 3/16	S	Opn	9-99	840.70	0.70	4/21/75	1975-79	4.99	11.54	A
41	35 55 13	84 19 39	N21900 E27070	33	1950	3 3/16	S	Opn	11-33	833.35	0.25	4/21/75	1975-79	31.39	32.47	A
42	35 55 12	84 19 32	N21613 E27449	49	1950	3 3/16	S	Opn	7-49	834.00	0.40	4/21/75	1975-79	10.90	20.90	A
43	35 55 16	84 19 30	N21849 E27885	46	1950	3 3/16	S	Opn	9-46	799.40	0.90	4/21/75	1975-79	1.21	5.92	A
44	35 55 15	84 19 26	N21575 E28113	49	1950	3 3/16	S	Opn	9-49	813.40	0.90	4/21/75	1975-79	17.66	19.46	A
45	35 55 19	84 19 24	N21841 E28475	24	1950	3 3/16	S	Opn	12-24	794.40	1.10	4/16/75	1975-79	0.53	4.08	A
46	35 55 18	84 19 22	N21634 E28552	50	1950	3 3/16	S	Opn	6-50	788.50	0.60	4/21/75	1975-79	1.04	3.88	A
49	35 55 17	84 19 12	N21079 E29188	47	1950	3 3/16	S	Opn	20-47	778.70	1.40	4/21/75	1975-79	0.77	2.72	A
301	35 55 07	84 19 50	N21856 E26106	14	1964	6 7/8	S	Prf	0-14	841.08	2.62	8/24/76	1975-79	4.81	12.58	A
302	35 55 08	84 19 47	N21837 E26293	6	1964	6 7/8	S	Prf	0-6	836.33	2.77	8/24/76	1976-79	0.57	6.20	A
303	35 55 10	84 19 45	N21855 E26612	6	1964	6 7/8	S	Prf	0-6	831.53	2.37	8/24/76	1976-79	0.75	5.73	B

[a]Casing had been removed to a point several inches below land surface prior to the initial inventory. During the period of record, the measuring point for this well was land surface, and the measuring point distance was 0.0 ft. In May 1979, the damaged casing stub was removed and a second of 4-in. I.D. plastic pipe was emplaced over the upper end of the steel casing. The new measuring point is 0.56 ft above land surface. 1 ft = 0.3048 m.

Source: Webster et al. (1981).

Table A-2. Monitoring well locations and elevations for SWSA 3 area

Well nos.	Location Coordinates		Elevation[a]
M481 (SN-1)	N21,646.6	E26,538.1	836.6 T.C.
M492	N21,767.9	E26,253.8	839.7 T.C.
M493 (SN-3)	N21,816.2	E26,001.7	845.0 T.C.
M494 (SN-4)	N21,868.1	E25,782.0	844.5 T.C.
M495	N21,855.0	E25,384.4	846.0 T.C.
M496	N21,968.1	E26,826.7	831.7 T.C.
M497	N21,778.1	E24,702.7	843.2 GRND.
M498	N21,798.9	E24,701.4	845.1 T.C.
M499	N21,954.7	E26,809.3	829.7 T.C.
M491 (SN-2)	N21,768.3	E26,512.8	834.0 T.C.
M482	N21,638.5	E26,201.6	846.4 T.C.
M483	N21,738.6	E25,829.4	849.7 T.C.
M484	N21,995.5	E25,703.8	838.9 T.C.
M485	N21,990.2	E26,054.7	835.0 T.C.
M486	N21,896.1	E26,302.5	838.6 T.C.
M487	N22,107.0	E26,218.0	833.3 T.C.
JS-1	N21,950.6	E26,172.2	835.5 T.C.
JS-2	N22,129.5	E25,182.1	839.5 T.C.
JS-3	N21,825.6	E24,601.6	842.7 T.C.

[a]T.C. indicates top of casing.

APPENDIX B. RADIONUCLIDE RELEASE DATA

Table B-1. Information regarding wells in the vicinity of SWSA 3

All measurements in feet[a] below land surface

Well	Bedrock units penetrated	Overburden thickness	Well depth	Depth to water 7-12-78	Depth to water 1-26-79
3	G, F	12.0	250.7	8.70	5.87
9	G	22.0	98.7	20.47	18.04
15	G	25.0	99.6	28.04	22.19
16	G, F, E	12.0	99.9	28.75	26.02
20	F, E	12.5	99.0	21.01	20.63
21	G, F, E	12.0	99.8	25.50	24.49
22	G, F, E	10.5	100.5	14.78	10.45
23	G	10.0	100.0	5.25	1.01
32	G	8.7	99.3	10.31	6.44
41	G, F	10.0	33.5	32.22	32.22
42	G	1.0	49.2	19.65	11.95
43	G	9.5	46.5	5.62	4.69
44	G	9.0	49.4	19.05	18.58
45	G	6.5	24.2	3.05	0.98
46	G	3.0	50.3	2.99	1.63
49	H	8.0	46.6	2.43	1.15
301			14.1	6.37	2.18
302			6.3	3.53	2.62
303			6.2	3.23	1.43

[a]1 ft = 0.3048 m.

Source: Stueber et al. (1981).

Table B-2. Strontium-90 concentrations in groundwater samples from wells in the vicinity of SWSA-3

For well locations see Fig. 6. All measurements in pCi/ml.

Well	11-13-73[a]	7-10-78	1-79
3	≤0.05	0.14[b]	0.01
9	1.49	0.05[c]	0.01
15	≤0.05	1.08	0.63
16	0.50	0.21	0.14
20	≤0.05	<0.01	<0.01
21	0.27	0.05	0.06
22	≤0.05	<0.01	0.01
23	≤0.09	<0.01	<0.01
32	≤0.05	≤0.01	0.01
41		1.98	0.77
42		<0.01	0.01
43		0.02	0.05
44		<0.01	<0.01
45		<0.01	<0.01
46		<0.01	0.02
49		0.01	0.01
301	0.14	0.07	<0.01
302	0.45	0.42	0.16
303	0.27	0.18	0.13

[a]Duguid 1975.
[b]Concentration of ^{137}Cs = 0.18 pCi/ml; ^{60}Co = 0.05 pCi/ml.
[c]Concentration of ^{137}Cs = 0.08 pCi/ml.

Source: Steuber et al. (1981).

Table B-3. Strontium-90 concentrations in water samples from the Raccoon Creek Tributary Stream

For sample locations, see Fig. 8. All measurements in pCi/ml.

Sample	^{90}Sr	Distance upstream (m)
T-1A	0.03	
TCTS	0.06	29
T-1B	<0.01	75
T-1C	<0.01	150
T-1D	<0.01	225
T-1E	<0.01	300
T-1F	<0.01	375
T-1G	0.01	450
T-1H	<0.01	468

Source: Steuber et al. (1981).

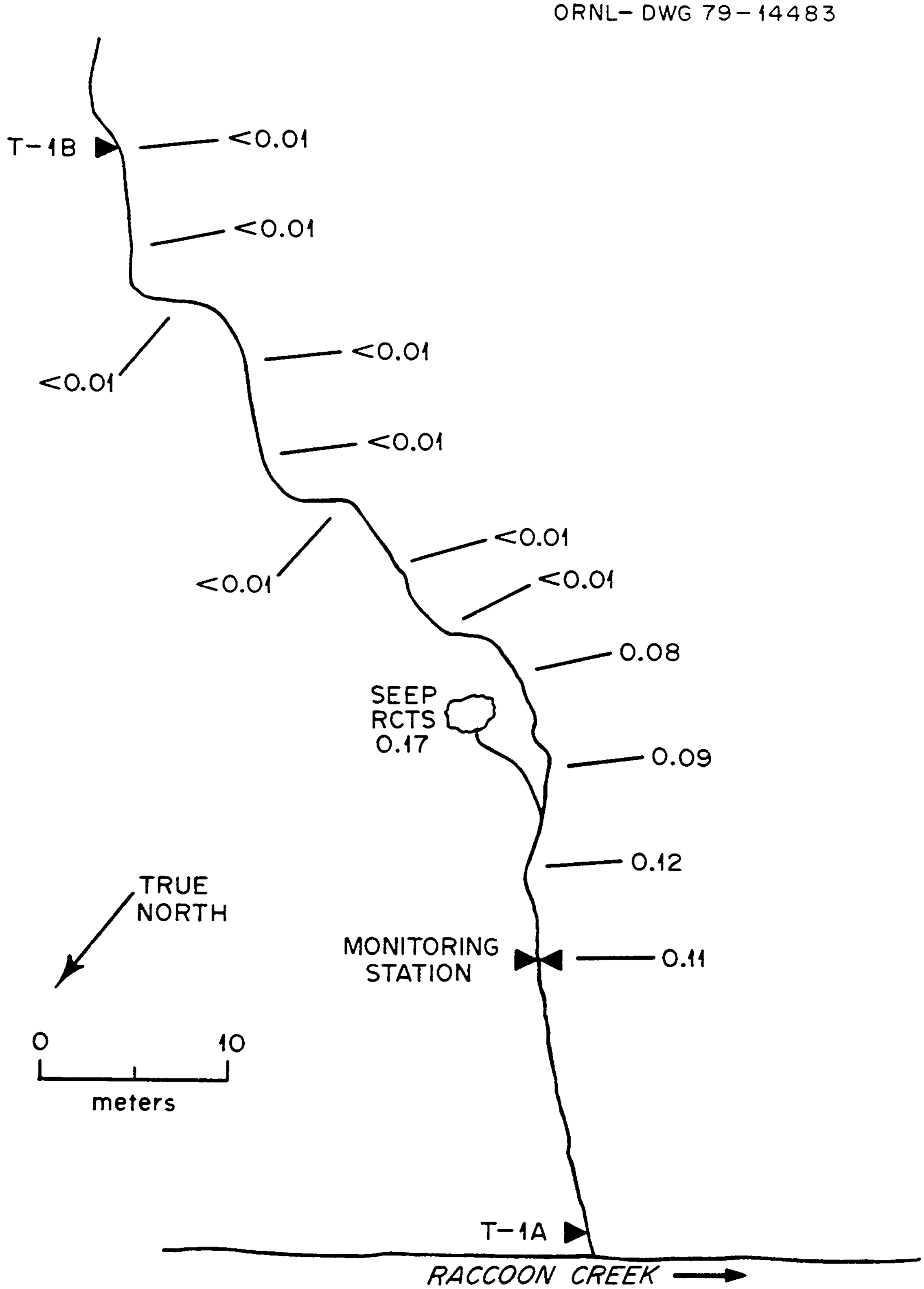

Fig. B-1. ^{90}Sr concentrations (pCi/ml) in the Raccoon Creek Tributary Stream at 5-m intervals near seep RCTS.

ORNL-DWG 79-14485A

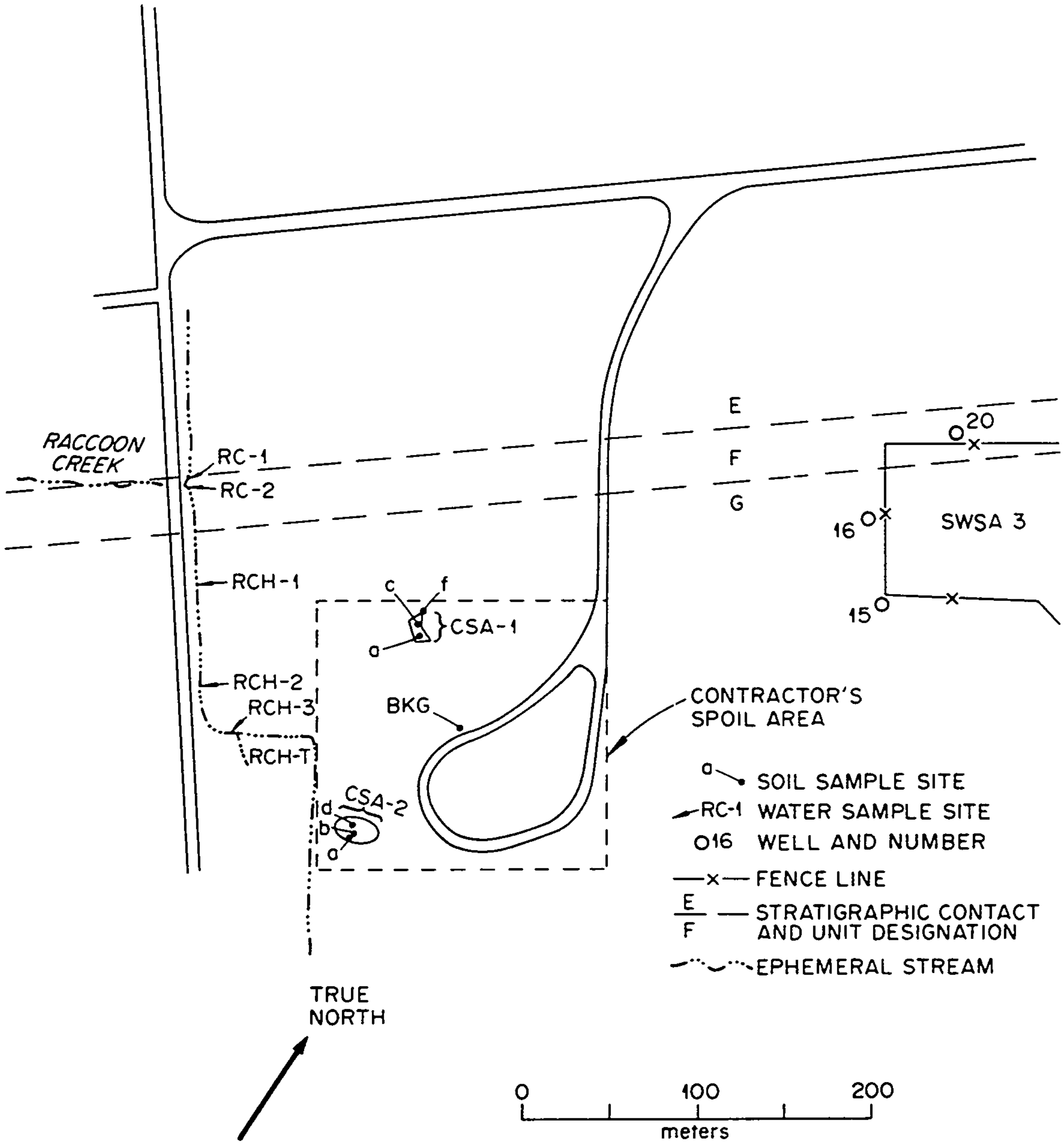

Fig. B-2. Soil sample locations and surface water sampling sites (or Contractor's Landfill) (see Table B-4).

Table B-4. Concentrations of ^{137}Cs, ^{60}Co, and ^{90}Sr in surface samples from the Contractor's Landfill

For sample locations, see Fig. B-2. All measurements in pCi/g.

Sample	^{137}Cs	^{60}Co	^{90}Sr
CSA-1-a			
Soil	1450	$\leq$0.20	257.0 ($\pm$27)
Gravel	2680	$\leq$0.17	
CS-1-c			
Soil	959	$\leq$0.17	14 ($\pm$8)
Gravel	1080	$\leq$0.10	
CSA-1-f			
Soil	9.5	$\leq$0.14	17 ($\pm$4)
Gravel	8650	$\leq$0.19	
CSA-2-a			
Soil	323	2.3	6.3 ($\pm$4)
CSA-2-b			
Soil	649	4.8	20 ($\pm$11)
CSA-2-d			
Soil	550	3.2	8.6 ($\pm$8)
CSA-BKG			
Soil	3.6	$\leq$0.16	1 ($\pm$0.9)

Source: Steuber et al. (1981).

Table B-5. Strontium-90 concentrations in surface runoff water samples collected near the Contractor's Landfill on February 23, 1979

For sample locations, see Fig. 8.

Sample	^{90}Sr (pCi/ml)
RC-1	0.01
RC-2	0.02
RCH-1	<0.01
RCH-2	<0.01
RCH-3	0.01
RCH-T	<0.01

Source: Steuber et al. (1981).

Table B-6. Strontium-90 analyses of surfacewater samples collected from the Northwest Tributary (NWT) and its tributary streams (T) in June 1978

For sample locations,[a] see Fig. 6.
All measurements in pCi/ml.

Sample	June 6, 1978	June 9, 1978
NWT-1	0.05	0.05
NWT-2	0.05	0.06
NWT-3		
NWT-4	0.35	0.09
NWT-5	0.40	0.10
NWT-6	2.93	0.12
NWT-7	0.03	0.09
NWT-7A	0.03	–
NWT-8	0.03	0.03
NWT-8A	0.03	
NWT-8B	0.05	
NWT-9		0.04
NWT-9-1	0.01	
NWT-9A	0.07	0.02
NWT-9A-1	0.01	
NWT-9B	0.01	<0.01
T-1	0.02	<0.01
T-2	<0.01	<0.01
T-3	<0.01	<0.01
T-4		0.03
T-5		0.01
T-6		0.02
T-8	<0.01	0.02
T-9	<0.01	<0.01
T-10		0.05
T-12		<0.01
T-14		<0.01

[a]The locations of most sampling sites designated with the suffix A, B, or 1 are not shown on Fig. 6. These samples were taken from pools of water in the streambed at points upstream from the 150-m site indicated by the sample number. For example, sample NWT-7A was collected at a point between sites NWT-7 and NWT-8; sample NWT-9-1 was taken at a point between sites NWT-9 and NWT-9A.

Source: Steuber et al. (1981).

Table B-7. Strontium-90 analyses of surface water samples collected from the Northwest Tributary (NWT) and its tributary streams (T) in January 1979

For sample locations, see Fig. 6 and footnote following Table B-6. All measurements in pCi/ml.

Sample	June 6, 1978	June 9, 1978
NWT-1	0.06	0.05
NWT-2	0.09	0.10
NWT-3	0.09	0.11
NWT-4	0.12	0.20
NWT-5	0.10	0.19
NWT-5A	0.29	1.13
NWT-5B	0.33	1.13
NWT-5C	0.33	1.13
NWT-5D	0.36	1.08
NWT-6	0.34	1.04
NWT-6A	0.37	1.04
NWT-6B	0.35	1.08
NWT-6C	<0.01	0.01
NWT-6D	<0.01	0.01
NWT-7	<0.01	0.01
NWT-7A	<0.01	0.02
NWT-7B	0.01	0.02
NWT-7C	0.02	0.01
NWT-7D	<0.01	0.01
NWT-8	<0.01	0.01
NWT-9	0.03	0.03
NWT-9A	<0.01	<0.01
NWT-9B	<0.01	0.01
T-1	0.01	0.01
T-2	<0.01	<0.01
T-9	<0.01	<0.01
T-10	<0.01	<0.01
T-12	<0.01	0.05
T-14	<0.01	0.05

Source: Stueber et al. (1981).

Table B-8. Strontium-90 analyses of surface water samples collected from Raccoon Creek (RC) and its tributary streams (T) on January 17, 1979

For sample locations, see Fig. 8.

Sample	^{90}Sr (pCi/ml)
RC-1	<0.01
RC-3	<0.01
RC-4	<0.01
RC-5	<0.01
RC-7	0.07
RC-9	0.05
RC-11	0.05
RC-12	0.03
RC-13	0.02
RC-14	0.02
RC-15	0.02
RC-16	0.02
RC-17	0.01
RC-18	0.01
RC-19	0.01
RC-20	0.01
RC-21	<0.01
T-1	0.09
T-3	<0.01
T-4	<0.01
T-5	<0.01
T-6	<0.01

Source: Stueber et al. (1981).

APPENDIX C. AREAL DISTRIBUTION OF ^{137}Cs, ^{60}Co, AND ^{90}Sr IN STREAMBED GRAVELS OF WHITE OAK CREEK WATERSHED

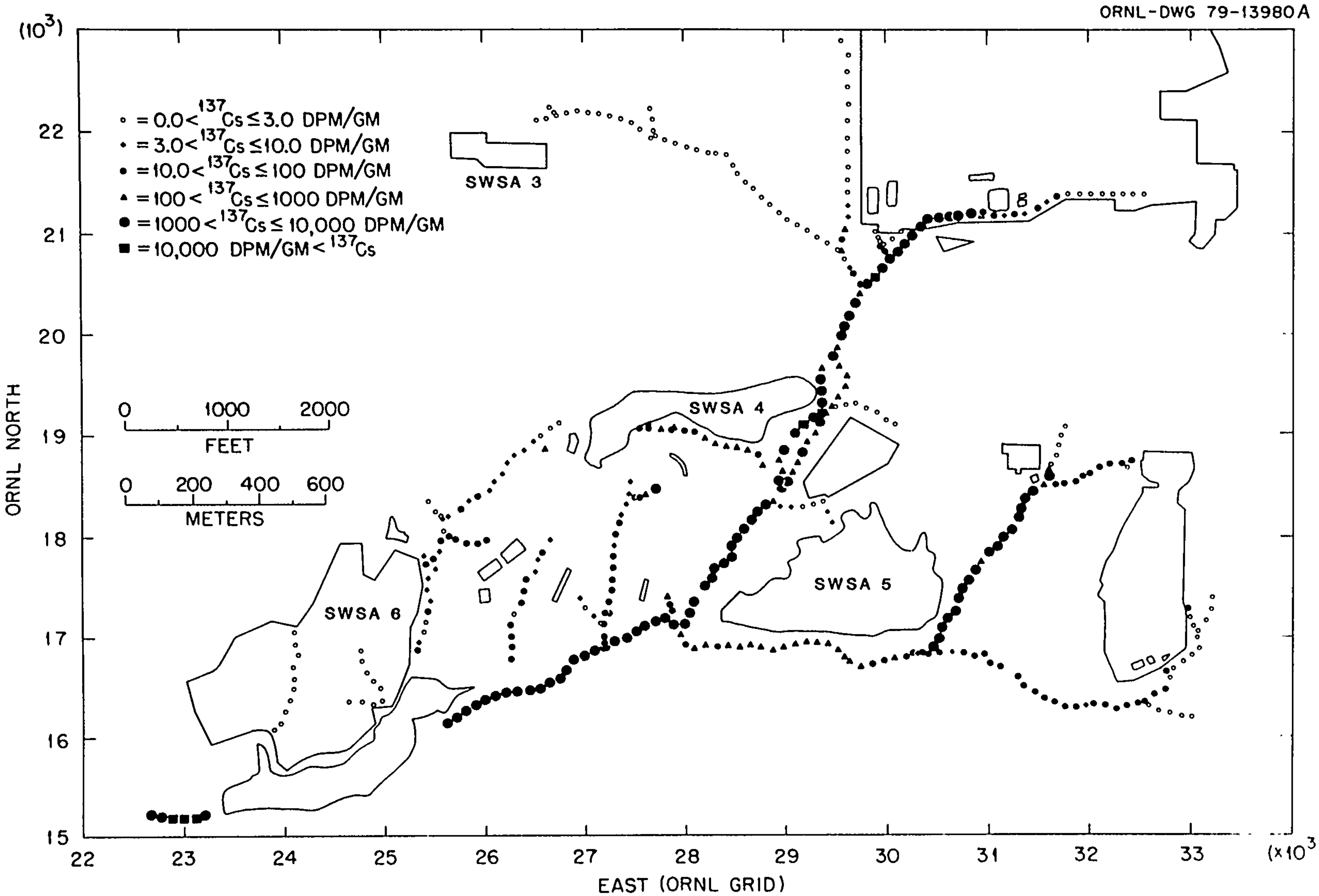

Fig. C-1. Areal distribution of ^{137}Cs activity in streambed gravels of the White Oak Creek watershed, expressed in disintegrations per minute per gram.

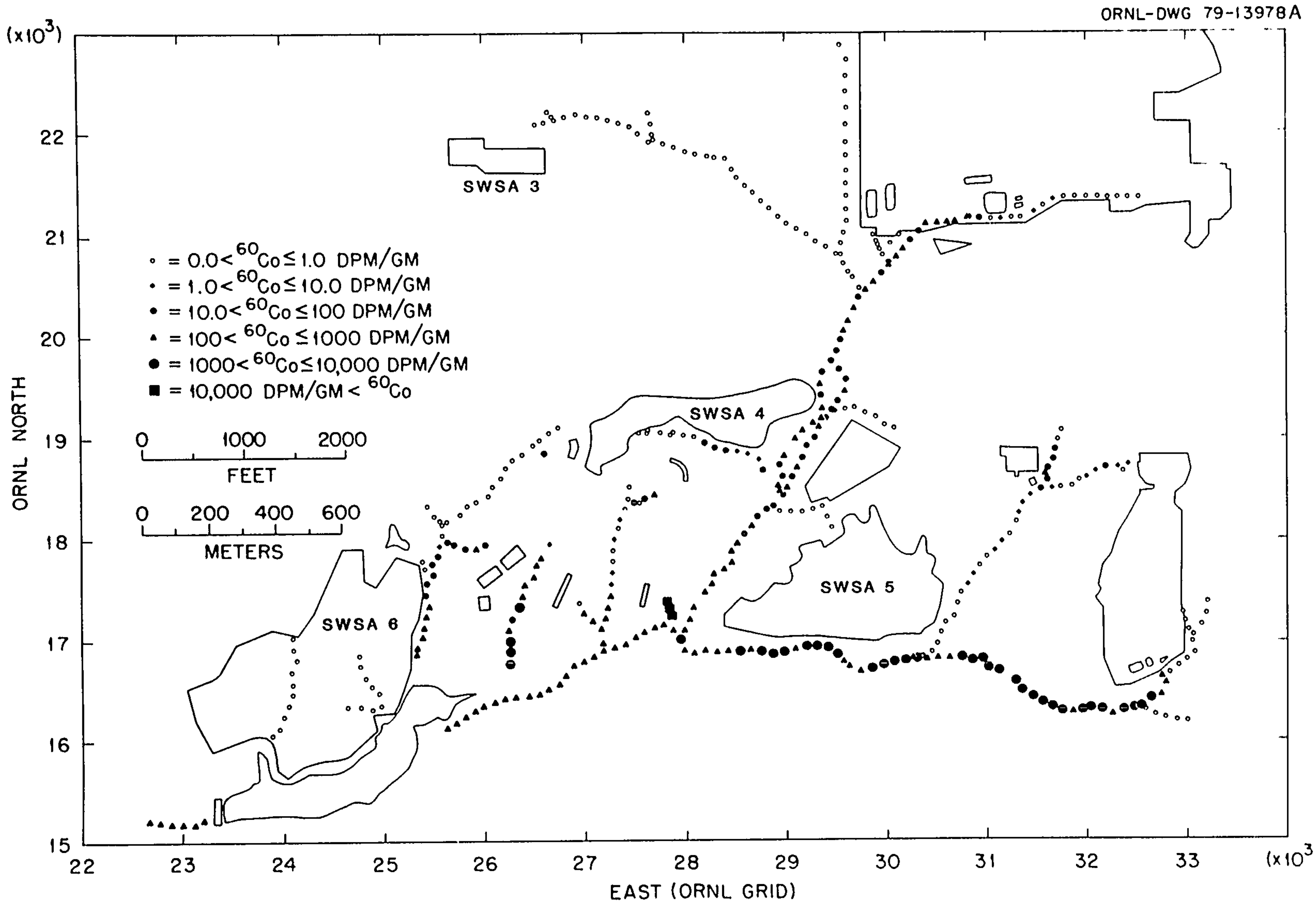

Fig. C-2. Areal distribution of ^{60}Co activity in streambed gravels of the White Oak Creek watershed, expressed in disintegrations per minute per gram.

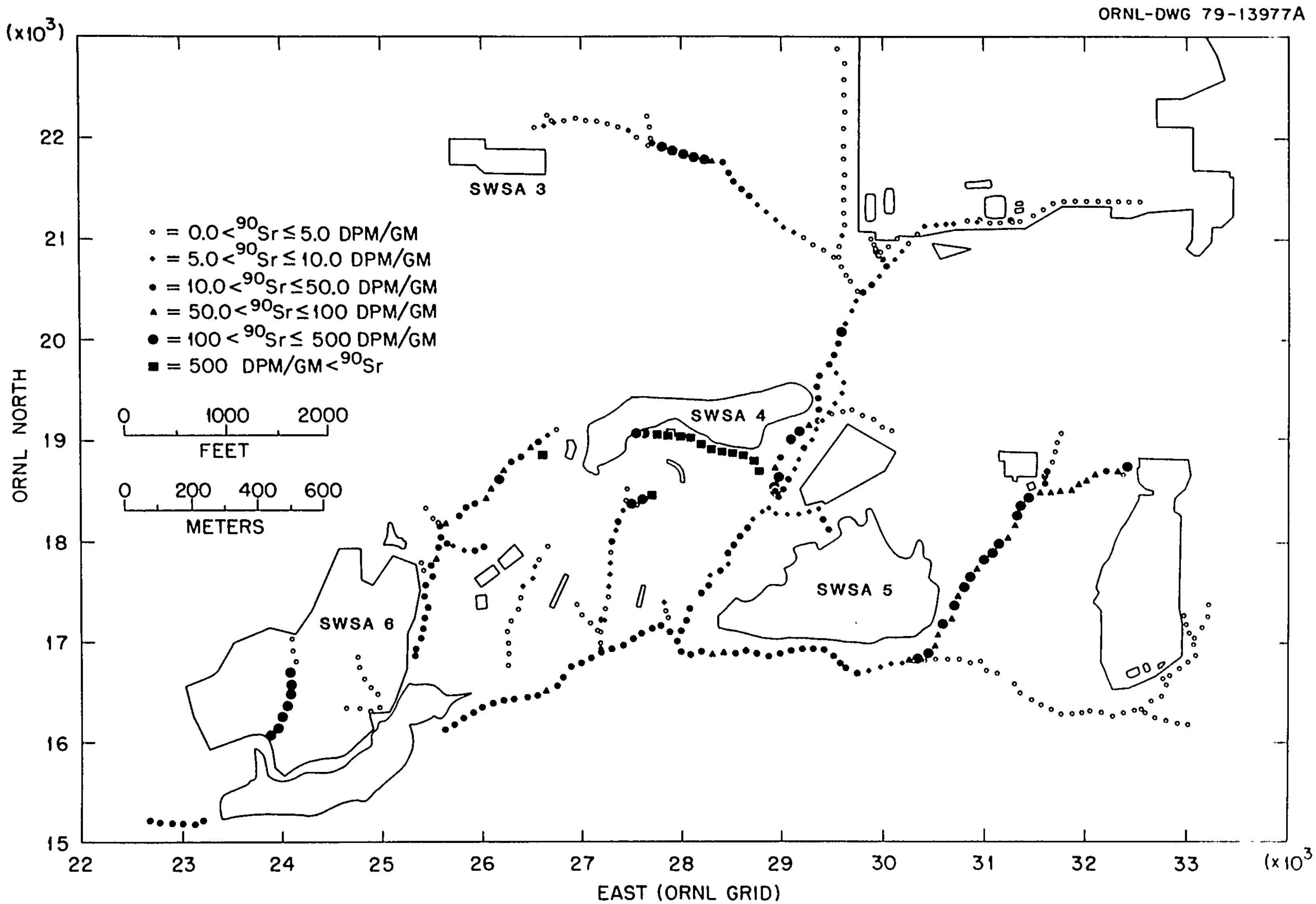

Fig. C-3. Areal distribution of ^{90}Sr activity in streambed gravels of the White Oak Creek watershed, expressed in disintegrations per minute per gram.

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Environmental Data Package for the Main Plant Area (WAG 1)

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H. C. Claiborne

Environmental Sciences Division

Publication No. 2898

ENVIRONMENTAL SCIENCES DIVISION · OAK RIDGE NATIONAL LABORATORY

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DEPARTMENT OF ENERGY

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* Energy Division
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NUCLEAR AND CHEMICAL WASTE PROGRAMS
(Activity No. KG 02 00 00 0; ONLKG02)

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ABSTRACT

BOEGLY, JR., W. J., R. H. Ketelle, R. R. Lee, and H. C. Claiborne. 1987. Environmental data package for the Main Plant Area (WAG 1). ORNL/RAP-13. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 97 pages.

U.S. Department of Energy facilities are required to be in full compliance with all federal and state regulations. In response to these requirements, the Oak Ridge National Laboratory (ORNL) has established a Remedial Action Program to provide comprehensive management of areas where research, development, and waste management activities have resulted in residual contamination of facilities or the environment. In 1986, the Environmental Protection Agency elected to enforce its regulatory requirements for remedial action through Sect. 3004(u) of the amended Resource Conservation and Recovery Act (RCRA) of 1984.

As the first step in identifying compliance requirements under RCRA Sect. 3004(u) for ORNL, a list of all known active and inactive solid waste management units, contaminated facilities, and other potential sources of continuing releases to the environment was prepared. Included in this list were waste collection and storage tanks, solid waste storage areas, waste treatment units, impoundments, spill sites, pipeline leak sites, underground injection wells, and areas of known contamination in order to maintain a comprehensive inventory of all ORNL sites that might require some form of remedial action.

The listing compiled for ORNL includes about 250 sites that might be considered for Sect. 3004(u) remedial action. Because of the complex hydrogeology of ORNL and the large number of sites involved, the ORNL sites have been grouped into 20 geographically contiguous and hydrologically defined Waste Area Groupings (WAGs). This report covers only the Main Plant Area (WAG 1) and the 99 Solid Waste Management Units (SWMUs) identified within its boundary.

The purpose of this environmental data package is to provide background information on the geology, hydrology, soils, and geochemistry of the WAG 1 area, as well as information on releases and inventories of hazardous materials for individual sites (SWMUs) within WAG 1, that will be required for additional remedial action evaluations. Areas where additional site information will be required are identified.

1. INTRODUCTION

U.S. Department of Energy (DOE) facilities are required to be in full compliance with all federal and state regulations. In response to these requirements, the Oak Ridge National Laboratory (ORNL) has established a Remedial Action Program (RAP) to provide comprehensive management of areas where research, development, and waste management activities have resulted in residual contamination of facilities or the environment. The primary objective of the RAP is to clean up releases of hazardous waste or hazardous constituents that threaten human health or the environment (Trabalka and Myrick, in press).

The initial ORNL remedial action strategy was based on the guidance of DOE Orders 5820.2 (Surplus Facilities Management) and 5480.14 [Comprehensive Environmental Restoration, Compensation, and Liability Act (CERCLA)]; the Resource Conservation and Recovery Act (RCRA) was believed to apply to only a limited number of sites. As a part of this strategy, individual sites were investigated according to estimated priorities for site characterization, remedial actions, and decommissioning/closure planning. In 1984, the RCRA was amended to establish broad new authorities within the Environmental Protection Agency (EPA) RCRA programs. One of these new authorities was Sect. 3004(u), which requires that any hazardous waste management permit issued after November 8, 1984, require corrective action for all releases from solid waste management units at the facility. In a memorandum to DOE in April 1986, EPA expressed concern about the length of time required to implement DOE orders and elected to enforce regulatory requirements for remedial actions through its amended RCRA authority (Scarbrough 1986).

Before the Hazardous Solid Waste Amendments (HSWA) to RCRA, EPA's authority to require corrective action for releases of hazardous constituents was limited to groundwater releases from units that were covered by RCRA permits (Part 264, Subpart F). Since passage of the HSWA, EPA's authority has been extended to include releases to all media and all units at a RCRA facility regardless of when they were used or whether they are covered by an RCRA permit (EPA 1986).

1.1. ORNL'S APPROACH TO COMPLIANCE WITH RCRA SECTION 3004(u)

The ORNL area is characterized by complex hydrogeologic conditions, and previous studies have shown that a strong coupling generally exists between the shallow groundwater and surface drainage systems (Trabalka and Myrick, in press). Reliance on groundwater monitoring as prescribed by RCRA regulations would probably not be adequate or effective under ORNL site conditions and that a combination of surface and groundwater monitoring should be more effective in meeting the principal performance objective of RCRA regulations -- the protection of human health and the environment (Trabalka and Myrick, in press).

According to RCRA Facility Assessment Guidance (EPA 1986), a Solid Waste Management Unit (SWMU) is defined as:

> . . . any discernable waste management unit at an RCRA facility from which hazardous constituents might migrate, irrespective of whether the unit was intended for the management of solid and/or hazardous waste. This definition includes containers, tanks, surface impoundments, waste piles, land treatment units, landfills, incinerators, and underground injection wells, including those units defined as 'regulated units' under RCRA. Also included are recycling units, wastewater treatment units and other units which EPA has generally exempted from standards applicable to hazardous waste management units, and areas contaminated by 'routine, systematic, and deliberate discharges' from process areas.

The definition does not include accidental spills from production areas and units (e.g., product storage areas) in which wastes have not been managed (EPA 1986).

As the first step in identifying compliance requirements under RCRA Sect. 3004(u) for ORNL, a list of all known active and inactive waste management units, contaminated facilities, and other potential sources of continuing releases to the environment was prepared. Included in this list were waste collection and storage tanks, solid waste storage areas (SWSAs), waste treatment units, impoundments, spill sites, pipeline leak sites, underground injection wells, and areas of known contamination within buildings. Although some of the identified sites might not be regulated under RCRA Sect. 3004(u), they were included in the site listing in order to maintain a comprehensive inventory of all ORNL sites that might require some form of remedial action.

The listing compiled for ORNL includes about 250 sites that might be considered for RCRA Sect. 3004(u) remedial action (Oak Ridge National Laboratory 1987). Because of the complex hydrogeology of ORNL and the large number of sites involved, the ORNL sites have been grouped into 20 geographically contiguous and hydrologically defined Waste Area Groupings (WAGs).

Trabalka and Myrick (in press) contains a detailed discussion of the rationale used to develop and define the WAG concept. Figure 1 shows the locations of the 20 WAGs. This environmental data package covers only the Main Plant Area (WAG 1) and its 99 identified sites (Table 1).

1.2. PURPOSE OF THE ENVIRONMENTAL DATA PACKAGE

As currently implemented, the RCRA Sect. 3004(u) corrective action program consists of three phases: (1) an RCRA Facility Assessment (RFA) to identify releases or potential releases requiring further investigation, (2) an RCRA Facility Investigation (RFI) to fully characterize the extent of releases, and (3) Corrective Measures (CM) to determine the need for and extent of remedial measures (EPA 1986).

Information developed by ORNL as input to the RFA indicates that the Main Plant Area (WAG 1) represents a source of continuing release under RCRA Sect. 3004(u) and that an RFI will be required (Oak Ridge National Laboratory 1987). The purpose of the environmental data package is to provide background information on the geology, hydrology, soils, and geochemistry of WAG 1, as well as information on releases and inventories of hazardous materials for individual sites [Solid Waste Management Units (SWMUs)] within WAG 1, that will be required in the preparation of the RFI. Areas where it appears that additional information will be required are identified.

This data package does not include all the numerical data and information currently available on WAG 1. Only selected material that the authors feel would be pertinent to the preparation of an RFI has been included. Additional details can be obtained from the references cited.

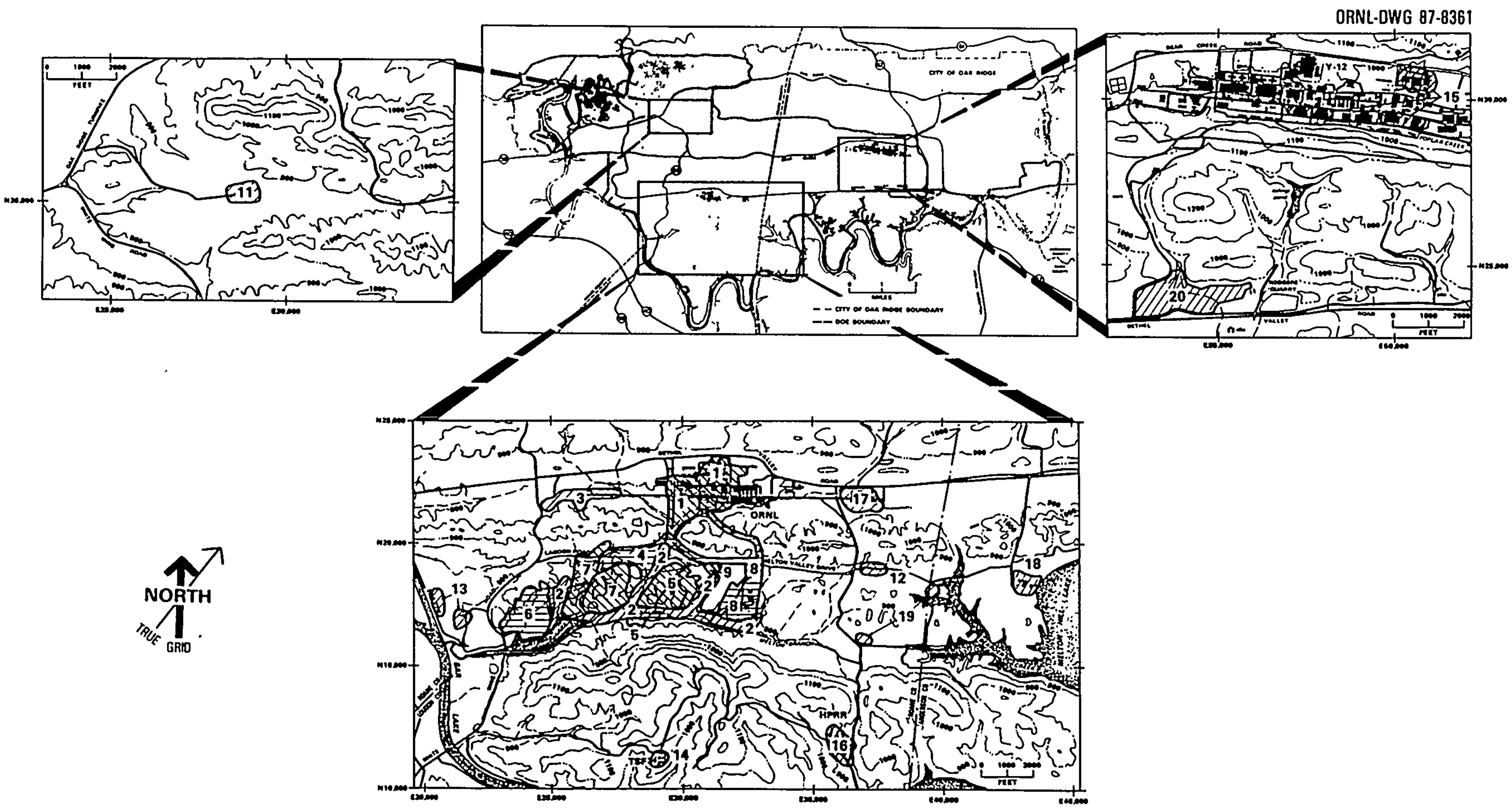

Fig. 1. Waste Area Groupings at the ORNL Site. Area No. 1 delineates the Main Plant Area (WAG 1)

TABLE 1. SOLID WASTE MANAGEMENT SITES IN WAG 1

1.1 Mercury Contaminated Soil - (3503)
1.2 Mercury Contaminated Soil - (3592)
1.3 Mercury Contaminated Soil - (4501)
1.4 Mercury Contaminated Soil - (4508)
1.5a-w LLW Lines and Leak Sites
- a = Bldg. 3020, South
- b = Bldg. 3020, East
- c = Bldg. 3082, West
- d = Bldg. 3019, North
- e = Bldg. 3019, Southwest
- f = Bldg. 3110, Between W-5 and WC-19
- g = Bldg. 3047, Underneath
- h = General Isotopes Area (3037, 3033, etc.)
- i = Bldg. 3092 Area
- j = Bldg. 3026, Underneath
- k = Bldg. 3024, Between WC-1 and WC-5
- l = Bldg. 3085, ORR Pumphouse
- m = Bldg. 3028
- n = Bldg. 2531, East
- o = Bldg. 3515, Underneath
- p = Bldg. 3525, To a Sump
- q = Bldg. 3550, Underneath
- r = Bldg. 3500, Sewer
- s = Abandoned line, Central Avenue
- t = Bldg. 4508, North
- u = Bldg. 3518, West
- v = Northwest of SWSA-1
- w = Bldg. 3503, Ground Contamination

1.6 Contaminated Surfaces and Soil from 1959 Explosion in Bldg. 3019 Cell
1.7 Contamination at Base of 3019 Stack
1.8 Graphite Reactor Storage Canal Overflow - (3001/3019)
1.9 Oak Ridge Research Reactor Decay Tank Rupture Site - (3087)
1.10 Storage pads - (3503, 3504)
1.11 Decommissioned Waste Holding Basin - (3512)
1.12 Waste Holding Basin - (3513)
1.13 Equalization Basin - (3524)
1.14 Process Waste Pond - (3539)
1.15 Process Waste Pond - (3540)
1.16 Sewage Aeration Pond (East) - (2543)
1.17 Sewage Aeration Pond (West) - (2544)
1.18 Coal Pile Settling Basin - (2545)

1.19 Low Intensity Test Reactor (LITR) Pond - (3085W)
1.20 3517 Filter Pit (Fission Product Development Laboratory) - (3517)
1.21 FPDL LLW Transfer Line
1.22 Isotopes Ductwork/3110 Filter House
1.23 Inactive LLW Waste Collection/Storage Tanks - (W-1, W-2)
a = W-1
b = W-2
1.24 Inactive LLW Waste Collection/Storage Tanks - (W-3, W-4)
a = W-3
b = W-4
1.25 Inactive LLW Waste Collection/Storage Tanks - (W-13, W-14, W-15)
a = W-13
b = W-14
c = W-15
1.26 Inactive LLW Waste Collection/Storage Tanks - (W-5, W-6, W-7, W-8, W-9, W-10)
a = W-5
b = W-6
c = W-7
d = W-8
e = W-9
f = W-10
1.27 Inactive LLW Waste Collection/Storage Tank - (W-11)
1.28 Inactive LLW Waste Collection/Storage Tank - (W1-A)
1.29 Inactive LLW Waste Collection/Storage Tank - (WC-1)
1.30 Inactive LLW Waste Collection/Storage Tanks - (WC-15, WC-17)
a = WC-15
b = WC-17
1.31 Inactive LLW Waste Collection/Storage Tanks - (TH-1, TH-2, TH-3)
a = TH-1
b = TH-2
c = TH-3
1.32 Inactive LLW Waste Collection/Storage Tank - (TH-4)
1.33 Active LLW Waste Collection Tank - (2026)
1.34 Active LLW Waste Collection Tank - (WC-2)
1.35 Active LLW Waste Collection Tank - (WC-3)
1.36 Active LLW Waste Collection Tank - (WC-4)
1.37 Active LLW Waste Collection Tanks - (WC-5, WC-6, WC-8, WC-9)
a = WC-5
b = WC-6
c = WC-8
d = WC-9
1.38 Active LLW Waste Collection Tank - (WC-7)

1.39 Active LLW Waste Collection Tanks - (WC-10, WC-11, WC-12, WC-13, WC-14)
a = WC-10
b = WC-11
c = WC-12
d = WC-13
e = WC-14

1.40 Active LLW Waste Collection Tank - (WC-19)

1.41 Active LLW Waste Collection Tank - (W-12)

1.42 Active LLW Waste Collection Tanks - (W-16, W-17, W-18)
a = W-16
b = W-17
c = W-18

1.43 Active LLW Waste Collection/Storage Tanks - (W-21, W-22)
a = W-21
b = W-22

1.44 Active LLW Waste Concentrate Tank - (W-23)

1.45 Active LLW Waste Concentrate Storage Tanks - (C-1, C-2)
a = C-1
b = C-2

1.46 SWSA-1 (2624)

1.47 SWSA-2 (4003)

1.48 Low-Level Waste Evaporator - (2531)

1.49 Neutralization Facility - (3518)

1.50 PCB Storage Area - (2018N)

1.51 Process Waste Treatment Plant - (3544)

1.52 Sewage Treatment Plant - (2521)

1.53 Septic Tank for Building 3000 - (3078)

1.54 Waste Oil Storage Tanks - (2525)

NON-SWMU (SOLID WASTE MANAGEMENT UNIT) REMEDIAL ACTION SITES

1A.1 Graphite Reactor - (3001)

1A.2 Low Intensity Test Reactor - (3005)

1A.3 Oak Ridge Research Reactor Experimental Facilities - (3042)

1A.4 Cobalt-60 Storage Garden - (3029)

1A.5 Fission Product Development Laboratory - (3517)

1A.6 Fission Product Pilot Plant - (3515)

1A.7 Metal Recovery Facility - (3505)

1A.8 Storage Garden - (3033)

1A.9 Strontium-90 Power Generators - (3028)

1A.10 Waste Evaporator Facility - (3506)

1A.11 Ceramic Processing Laboratory - (4508)

1A.12 High-Level Chemical Development Laboratory - (4507)

1A.13 Remote Coating Furnace Loop - (4508)

1A.14 Transuranium Research Laboratory 45 - (5505)

1A.15 High Level Radiochemical Analytical Laboratory (3019B)

1A.16 Oak Ridge Research Reactor Heat Exchanger (3087)

1.3. DESCRIPTION OF WAG 1

WAG 1 includes all the operating research and development facilities located within the main security fence at ORNL (Fig. 2). As shown in Table 1, 99 sites in WAG 1 may be subject to RCRA Sect. 3004(u) evaluation. Also included in Table 1 are 16 Surplus Facility Management Program (SFMP) sites are not subject to 3004(u), but they have been listed to provide an indication of the total remedial action package being undertaken at ORNL for WAG 1. The sites in Table 1 include radioactive waste collection pipelines and tanks, SWSAs, waste treatment facilities and impoundments (for both radioactive and nonradioactive liquid wastes), and miscellaneous waste handling and storage units. A number of areas have also been identified where radioactive or nonradioactive spills or leaks may have resulted in contaminated soils.

Table 2 lists the 99 sites by generic type. Of these, 46% represent waste collection or storage tanks, and 35% represent line leaks or spills. The remaining sites (19%) are solid and liquid waste treatment and disposal units or sewage treatment facilities.

1.4 DESCRIPTION OF SOLID WASTE MANAGEMENT UNITS IN WAG 1

1.4.1 WASTE COLLECTION AND STORAGE TANKS

Since operations at the Laboratory were initiated, 46 radioactive waste collection and storage tanks have been installed, with capacities ranging from 500 gal (1893 L) to 170,000 gal (643,520 L) (Table 3). The large tanks were designed for long-term storage of wastes; however, as tank capacity was depleted, wastes were treated in the large tanks and disposed of. In addition, buildings at ORNL known to generate radioactive wastes were provided with waste collection tanks to allow for sampling before a decision was made regarding disposition of the waste (i.e., storage in the main tanks or release to the process waste system for treatment before disposal). Since the initiation of Laboratory operations, a number of tanks have been removed from service because of leaks in either the tank or the piping used to transfer wastes into or

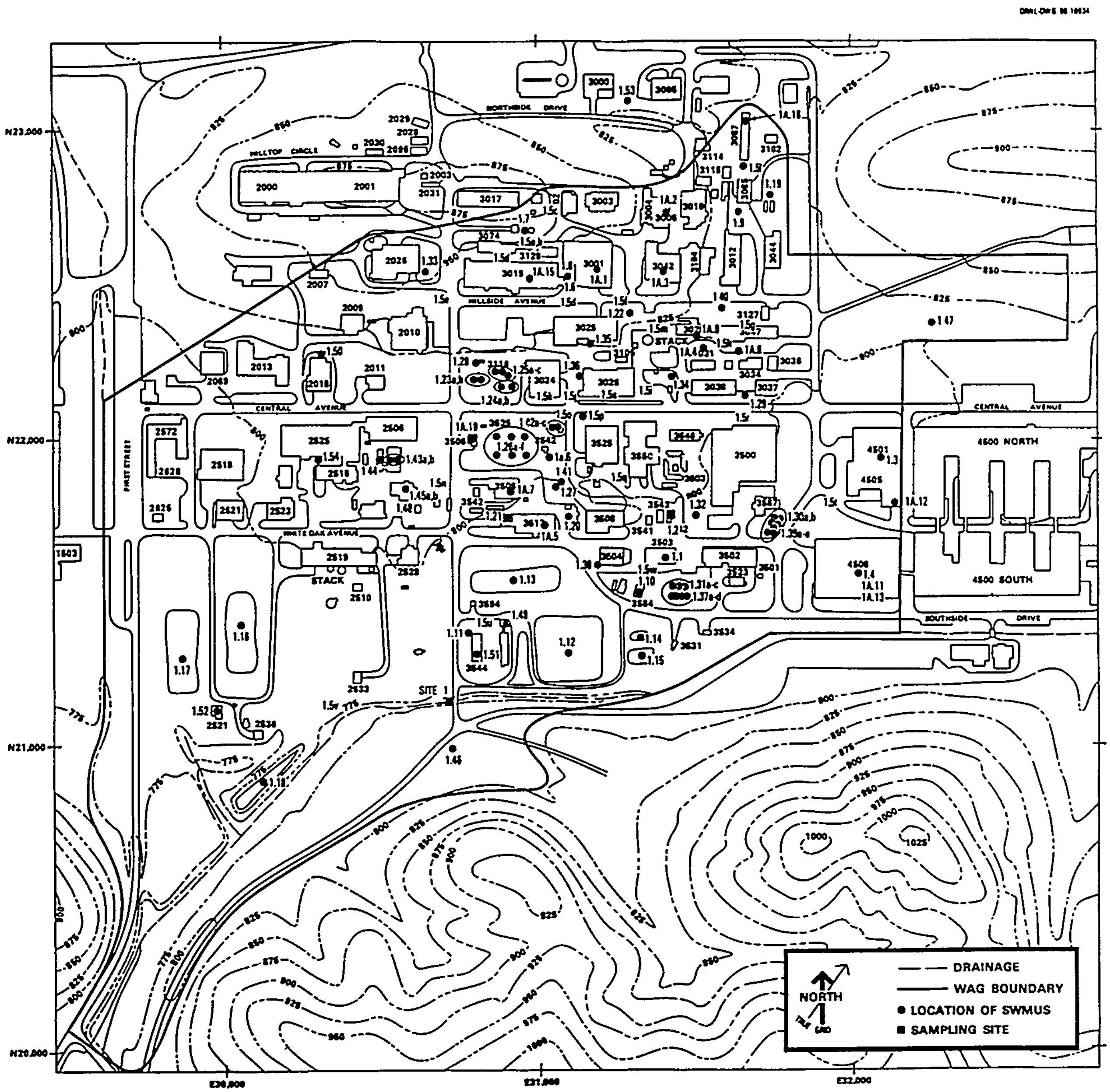

Fig. 2. Map of WAG 1 showing locations of SWMUs

TABLE 2. WAG 1 - LISTING OF SITES BY TYPE

Type of Site	Number of Sites
Collection and Storage Tanks (LLW)	
Inactive	22
Active	24
Leak/Spill Sites and Contaminated Soils	
Radioactive	30
Chemical	4
Ponds and Impoundments	
Radioactive Waste	6
Chemical Waste	3
Waste Treatment Facilities	
Radioactive Waste	2
Chemical and Sewage Waste	2
Solid Waste Storage Areas	
Radioactive Waste	3
Chemical Waste	1
Miscellaneous Facilities	
Chemical and Sewage Waste	2
Total Sites	99

Table 3. Radioactive waste collection and storage tanks at ORNL

Solid Waste Mgmt Units	Tank number	Type[a]	Diameter (ft)	Length (ft)	Construction	Capacity (gal)
1.23a	W-1	VSC	12.0	8.0	Gunite	4,800
1.23b	W-2	VSC	12.0	8.0	Gunite	4,800
1.24a	W-3	VSC	25.0	12.0	Gunite	42,500
1.24b	W-4	VSC	25.0	12.0	Gunite	42,500
1.25a	W-13	HSC	6.0	11.0	Stainless	2,000
1.25b	W-14	HSC	6.0	11.0	Stainless	2,000
1.25c	W-15	VSC	8.0	6.0	Stainless	2,000
1.26a	W-5	VSC	50.0	12.0	Gunite	170,000
1.26b	W-6	VSC	50.0	12.0	Gunite	170,000
1.26c	W-7	VSC	50.0	12.0	Gunite	170,000
1.26d	W-8	VSC	50.0	12.0	Gunite	170,000
1.26e	W-9	VSC	50.0	12.0	Gunite	170,000
1.26f	W-10	VSC	50.0	12.0	Gunite	170,000
1.27	W-11	VSC	8.0	4.5	Gunite	1,500
1.28	W-1A	HSC	7.5	13.5	Stainless	4,000
1.29	WC-1	VSC	8.66	6.0	Stainless	2,000
1.30a	WC-15	VSC	5.5	7.33	Stainless	1,000
1.30b	WC-17	VSC	5.5	7.33	Stainless	1,000
1.31a	TH-1	VSC	7.0	9.89	Stainless	2,500
1.31b	TH-2	VSC	7.0	10.0	Stainless	2,400
1.31c	TH-3	VSC	7.67	10.0	Stainless	3,300
1.32	TH-4	VSC	20.0	6.6	Gunite	14,000
1.33	2026	VDC	4.0	6.5	Stainless	500
1.34	WC-2	VSC	5.5	7.33	Stainless	1,000
1.35	WC-3	VSC	5.5	7.33	Stainless	1,000
1.36	WC-4	VSC	7.0	7.0	Stainless	1,700
1.37a	WC-5	VSC	5.5	7.33	Stainless	1,000
1.37b	WC-6	VSC	4.5	5.67	Stainless	500
1.37c	WC-8	VSC	5.5	7.33	Stainless	1,000
1.37d	WC-9	VSC	7.0	10.75	Stainless	2,140
1.38	WC-7	VSC	5.33	7.5	Stainless	1,100

Table 3. Continued.

Solid Waste Mgmt Units	Tank Number	Type[a]	Diameter (ft)	Length (ft)	Construction	Capacity (gal)
1.39a	WC-10	HSC	6.33	10.33	Stainless	2,300
1.39b	WC-11	HSC	7.67	13.67	Stainless	4,600
1.39c	WC-12	VSC	5.5	7.33	Stainless	1,000
1.39d	WC-13	VSC	5.5	7.33	Stainless	1,000
1.39e	WC-14	VSC	5.5	7.33	Stainless	1,000
1.40	WC-19	HSC	6.08	9.67	Stainless	2,100
1.41	W-12	VSC	4.0	5.33	Stainless	700
1.42a	W-16	VSC	5.5	7.33	Stainless	1,000
1.42b	W-17	VSC	5.5	7.33	Stainless	1,000
1.42c	W-18	VSC	5.5	7.33	Stainless	1,000
1.43a	W-21	HDC	12.0	60.0	Stainless	50,000
1.43b	W-22	HDC	12.0	60.0	Stainless	50,000
1.44	W-23	HDC	12.0	60.0	Stainless	50,000
1.45a	C-1	HDC	12.0	60.0	Stainless	50,000
1.45b	C-2	HDC	12.0	60.0	Stainless	50,000

[a] Tank types are

VSC, Vertical Single-Contained Tank;
VDC, Vertical Double-Contained Tank in Concrete Vault;
HSC, Horizontal Single-Contained Tank; and
HDC, Horizontal Double-Contained Tank in Concrete Vault

SOURCES:

Huang et al. 1984.
Peretz et al. 1986.
Coobs and Myrick, 1983.
Binford and Onfi, 1979.
Horton, J. R., 1984.
Huang et al. 1984.
MCI and H and R. 1985.

out of the tanks. In addition, some tanks are no longer in service because the programs they served have ceased operation. Twenty-two of the existing tanks are now considered inactive, and the remaining 24 continue to be used in support of waste management operations (Table 4). Although the 24 inactive tanks are no longer used, they still contain some liquid wastes and sludges and, in general, are contaminated with radionuclides. More detailed information on the ORNL waste collection and storage tanks can be found in Huang et al. (1984a and 1984b), Taylor (1986a), Horton (1984), Peretz et al. (1986), Binford and Orfi (1979), MCI (1985), and Coobs and Myrick (1983). A brief description of each of the tanks is provided in Sect. 1.4.1.1.

1.4.1.1 Active tank sites

Waste Tank 2026 (SWMU 1.33). Tank 2026 is an underground tank located east of Bldg. 2026 to collect low-level waste (LLW) streams from Bldg. 2026 and discharge to tank W-1A. Waste transfer lines are Hastalloy.

Waste Tank WC-2 (SWMU 1.34). Tank WC-2 is located northeast of Bldg. 3092. Only LLW streams contaminated with I-131 from Bldgs. 3028, 3038, and 3110 are routed to this tank. Waste transfer lines into and out of the tank are stainless steel.

Waste Tank WC-3 (SWMU 1.35). Tank WC-3 is located south of Bldg. 3025 to collect LLW streams from Bldgs. 3025 and 3110. Waste transfer lines are stainless steel.

Waste Tank WC-4 (SWMU 1.36). Tank WC-4 is located west of Bldg. 3026 and serves this building only. Waste transfer lines are stainless steel.

Waste Tanks WC-5, WC-6, WC-8, and WC-9 (SWMU 1.37a-d). This group of tanks is located south of Bldg. 3503 and adjacent to Tank TH-2 (inactive). Tank WC-6 collects LLW from Bldgs. 3508, 3541, and 3592. Tank WC-9 collects LLW from Bldg. 3503 and the central off-gas condensate system. Tanks WC-5 and WC-8 receive waste from Bldgs. 3503 and 3508 respectively. Waste tansfer lines are stainless steel.

Waste Tank WC-7 (SWMU 1.38). Tank WC-7 is located west of Bldg. 3504 and serves this building only. Waste transfer lines are stainless steel.

Table 4. LLW tank data for ORNL

Solid Waste Mgmt Units	Tank number	location	ORNL coordinates		Status	Normal[a] operating volume (gal)	Current contents	
			Northing	Easting			Sludge (gal)	Liquid (gal)
1.23a	W-1	N. Tank Farm	22,210	30,809	Inactive		---[b]	1,000
1.23b	W-2	N. Tank Farm	22,210	30,830	Inactive		500	800
1.24a	W-3	N. Tank Farm	22,180	30,885	Inactive		4,200	22,200
1.24b	W-4	N. Tank Farm	22,180	30,920	Inactive		5,800	11,600
1.25a	W-13	N. Tank Farm	22,230	30,865	Inactive		---	450
1.25b	W-14	N. Tank Farm	22,230	30,872	Inactive		---	120
1.25c	W-15	N. Tank Farm	22,222	30,880	Inactive		NA[c]	NA
1.26a	W-5	S. Tank Farm	22,000	30,850	Inactive		6,000	---
1.26b	W-6	S. Tank Farm	21,940	30,850	Inactive		15,000	---
1.26c	W-7	S. Tank Farm	22,000	30,910	Inactive		Minimal	---
1.26d	W-8	S. Tank Farm	21,940	30,910	Inactive		1,000	---
1.26e	W-9	S. Tank Farm	22,000	30,970	Inactive		3,000	---
1.26f	W-10	S. Tank Farm	21,940	30,970	Inactive		40,000	---
1.27	W-11	S. Bldg. 3536	21,865	31,050	Inactive		45	260
1.28	W-1A	N. Tank Farm	22,255	30,810	Inactive			
1.29	WC-1	S. Bldg. 3587	22,144	31,676	Inactive		NA	NA
1.30a	WC-15	S. Bldg. 3587	21,730	31,771	Inactive		NA	NA
1.30b	WC-17	S. Bldg. 3587	21,736	31,771	Inactive		80 Oil	950
1.31a	TH-1	S. Bldg. 3503	21,520	31,400	Inactive		---	475
1.31b	TH-2	S. Bldg. 3503	21,524	31,420	Inactive		NA	NA
1.31c	TH-3	S. Bldg. 3503	21,524	31,436	Inactive		---	700
1.32	TH-4	S. Bldg. 3500	21,760	31,515	Inactive		5,500	9,800
1.33	2026	E. Bldg. 3026	22,550	30,655	Active	350		
1.34	WC-2	W. Bldg. 3030	22,210	31,445	Active	700		
1.35	WC-3	S. Bldg. 3025	22,310	31,175	Active	700		
1.36	WC-4	W. Bldg. 3026C	22,210	31,145	Active			

Table 4. Continued.

Solid Waste Mgmt Units	Tank number	Location	ORNL coordinates Northing	ORNL coordinates Easting	Status	Normal operating volume (gal)	Current contents Sludge (gal)	Current contents Liquid (gal)
1.37a	WC-5	S. Bldg. 3503	21,515	31,425	Active	750		
1.37b	WC-6	S. Bldg. 3503	21,510	31,425	Active	350		
1.37c	WC-8	S. Bldg. 3503	21,505	31,425	Active	750		
1.37d	WC-9	S. Bldg. 3503	21,500	31,400	Active	1,550		
1.38	WC-7	S. Bldg. 3504	21,600	31,200	Active	750		
1.39a	WC-10	S. Bldg. 3587	21,715	31,765	Active	1,650		
1.39b	WC-11	S. Bldg. 3587	21,730	31,765	Active	2,900		
1.39c	WC-12	S. Bldg. 3587	21,710	31,770	Active	700		
1.39d	WC-13	S. Bldg. 3587	21,725	31,770	Active	700		
1.39e	WC-14	S. Bldg. 3587	21,720	31,770	Active	700		
1.40	WC-19	SW Bldg. 3012	22,430	31,595	Active	1,500		
1.41	W-12	S. Tank Farm	21,875	31,060	Active	400		
1.42a	W-16	S. Tank Farm	22,035	31,065	Active	700		
1.42b	W-17	S. Tank Farm	22,030	31,065	Active	700		
1.42c	W-18	S. Tank Farm	22,030	31,700	Active	700		
1.43a	W-21	NW Bldg. 2531	21,935	30,550	Active	40,000		
1.43b	W-22	NW Bldg. 2531	21,935	30,570	Active	40,000		
1.44	W-23	NW Bldg. 2531	21,935	30,510	Active	40,000		
1.45a	C-1	N. Bldg. 2531	21,820	30,600	Active	40,000		
1.45b	C-2	N. Bldg. 2531	21,820	30,600	Active	40,000		

a Operating volume equals 70% capacity (see Table 3).
b --- (not measured)
c NA (no access to tank contents)

SOURCES:

Huang et al. 1984.
Peretz et al. 1986.
Coobs and Myrick, 1983.
Binford and Onfi, 1979.
Horton, J. R., 1984.
Huang et al. 1984.

Waste Tanks WC-10, WC-11, WC-12, WC-13, and WC-14 (SWMU 1.39). This group of tanks is located south of Bldg. 3587, and inactive tanks WC-15 and WC-17 are associated with the group. Tank WC-10 collects LLW from the radioisotope processing area, 3039 stack drain, and the 3092 scrubber. Tank WC-11 receives waste from Bldgs. 4500N (Wing 1), 4505, 4507, and 4556. Tank WC-12 collects wastes from Bldg. 4505. The WC-13 tank collects LLW from Bldgs. 4500S, 4500N, 4507, and 4508. Tank WC-14 receives wastes from Bldg. 4501 and 4507. All collection and transfer lines are stainless steel.

Waste Tank WC-19 (SWMU 1.40). Tank WC-19 is located northwest of Bldg. 3028. This tank collects waste from Bldgs. 3001, 3002, 3003, 3004, 3005, 3008, 3104, 3010, and 3042. Waste transfer lines are stainless steel.

Waste Tank W-12 (SWMU 1.41). Tank W-12 is located in the South Tank Farm. The tank collects LLW streams from Bldg. 3525 and the tank farm pit (Bldg. 3517). Waste transfer lines are stainless steel.

Waste Tanks W-16, W-17, and W-18 (SWMU 1.42a-c). This group of tanks is located east of the South Tank Farm. The tanks collect LLW from the 3500 area cell ventilation duct. Waste transfer lines are stainless steel.

Waste Tanks W-21 and W-22 (SWMU 1.43a,b). Located at Bldg. 2537, tanks W-21 and W-22 are contained in a concrete vault and are associated with waste evaporator operations. These tanks receive the LLW streams from Valve Box No. 1 and 2 at the South Tank Farm and store them as feed to the waste evaporator. Transfer lines are stainless steel.

Waste Tank W-23 (SWMU 1.44). Tank W-23 is located at Bldg. 2537 in a concrete vault and receives concentrate from the waste evaporator. Transfer lines are stainless steel.

Waste Tanks C-1 and C-2 (SWMU 1.45a,b). Tanks C-1 and C-2 are located in a concrete vault at Bldg. 2531 (north of the waste evaporator) and are used (along with tank W-23) to store concentrate from the waste evaporator before transfer to waste tanks W-24 to W-31 at the Hydrofracture site in Melton Valley. Most of the transfer lines associated with these tanks are doubly contained stainless steel.

1.4.1.2 Inactive tank sites

Waste Tanks W-1 and W-2 (SWMU 1.23a,b). Tanks W-1 and W-2 are located in the North Tank Farm (north of Central Avenue and east of Third Street). These two tanks received LLW from Bldg. 3019 and other facilities. Normally, tank W-2 received the overflow from W-1. Constructed of gunite (a sprayed concrete mix), they have no metallic lining.

Waste Tanks W-3 and W-4 (SWMU 1.24a,b). Tanks W-3 and W-4 are also located in the North Tank Farm. Both tanks received LLW from Bldg. 3019. Tank W-3 collected plutonium waste, and W-4 was used for uranium wastes. These tanks are also constructed of gunite. Wastes in these tanks were neutralized to prevent corrosion attack on the concrete. The tanks were removed from service because groundwater was reported to be entering the tanks.

Waste Tanks W-13, W-14, and W-15 (SWMU 1.25a-c). Tanks W-13, W-14, and W-15 are located in the North Tank Farm. Tanks received LLW from the metal waste drains in Bldg. 3019 and chemical waste for fission product recovery. Tank W-13 served the Chemistry Division's Hot Laboratory, and Tanks W-14 and W-15 served the Operations Division's Radioisotope Department. Tanks W-13 and W-14 are horizontal tanks, and W-15 is a vertical tank. All of these tanks were encased in concrete for containment and shielding. Tanks were taken out of service in 1958 because they were no longer needed.

Waste Tanks W-5, W-6, W-7, W-8, W-9, W-10 (SWMU 1.26a-f). This group of tanks is located in the South Tank Farm. The tanks are constructed of gunite and are the largest capacity gunite tanks at ORNL. They were mainly used for storage of LLW before treatment/disposal. The tanks are arranged in a 60-ft center-to-center grid of two rows of three tanks each. Tanks have been removed from service because of concerns regarding the deterioration of the gunite.

Waste Tank W-11 (SWMU 1.27). Tank W-11, contructed of gunite, is located in the southeast corner of the South Tank Farm; it received LLW from laboratories in Bldg. 3550. It was removed from service because of leaks.

Waste Tank W-1A (SWMU 1.28). Tank W-1A is located south of Bldg. 3019 and east of Third Street in the North Tank Farm. Tank W-1A received various waste streams from Bldg. 3019 and served as a collection tank for wastes from Tank 2026. Waste transfer lines are stainless steel except for the discharge line from Bldg. 2026 which is Hastalloy. The tank was removed from service as a part of LLW system modifications.

Waste Tank WC-1 (SWMU 1.29). Tank WC-1 is located just east of Bldgs. 3038 and 3037. Tank WC-1 collected LLW from Bldgs. 3038, 3029, 3030, 3031, 3032, 3033, 3047, filter Bldg. 3110, stack 3039, and scrubber 3092. The tank is constructed of stainless steel; it was removed from service in 1968 because of a leaking discharge line.

Waste Tanks WC-15 and WC-17 (SWMU 1.30a,b). Tanks WC-15 and WC-17 are located south of Bldg. 3587 and west of Bldg. 4508. Also installed at this location are tanks WC-10 to WC-14 (see Sect. 1.4.1.1). Tanks WC-15 and WC-17 collected waste from various laboratories in the Bldg. 4500 complex. The tanks were removed from service because of leaks.

Waste Tanks TH-1, TH-2, and TH-3 (SWMU 1.31a-c). Tanks TH-1, TH-2, and TH-3 (constructed of 347 stainless steel) are located south of Bldg. 3503. These tanks collected thorium-containing wastes from the Thorium Pilot Plant in Bldg. 3503. The tanks are no longer required and have been removed from service.

Waste Tank TH-4 (SWMU 1.32). Tank TH-4 is located about 50 ft southwest of Bldg. 3500. There are no adjacent waste tanks. This tank collected waste from thorium and uranium pilot plant development studies conducted in Bldg. 3550. The tank is constructed of gunite and is currently filled with alkaline thorium and uranium sludge.

1.4.2 Leak and Spill Sites

Thirty-four leak/spill sites have been identified in WAG 1. Of these, 23 are sites of spills or leaks that have occurred in the LLW collection and transfer lines, 7 are sites where radionuclide contamination has resulted from past and ongoing Laboratory operations, and 4 are sites contaminated with hazardous chemicals (mercury). In general, most of the radionuclide leak/spill sites and contaminated areas are in the vicinity of the North and South Tank Farms and the isotopes production areas (Fig. 2), whereas the chemical spill sites are in the vicinity of the 4500 and 3500 areas of the plant (eastern and southern portions of WAG 1). In many instances, specific information on individual leak sites is not available; the volume of leakage and the extent of the leak being the major data deficiencies. Grimsby (1986a,b) has compiled existing data on the ORNL LLW leak and spill sites, and Saylor (1986) has done the same for the chemical leak and spill sites.

1.4.2.1 Radioactive

LLW Leak and Spill Site - Bldg. 3020, South (SWMU 1.5a). This leak site is located due south of Bldg. 3020. The collection line which was reported to leak served Bldg. 3108, and leaks occurred at the vent stack and in the valve pit areas. The initial leak occurred in the mid 1970s when a sight glass in the header froze and broke. Later a restriction downline caused a backup of waste to occur, with a resulting overflow at both locations. Leakage from this site has contaminated the storm drainage system north of Bldg. 3074 from east to west. Major radionuclides involved were reported to be isotopes of Pu, Sr, and Cs.

LLW Leak and Spill Site - Bldg. 3020, East (SWMU 1.5b). This leak (east of the Bldg. 3020 stack) is believed to have occurred some 25 years ago, possibly from exhaust gas duct leakage. A 1970 contamination survey of the area showed 20 mR/h on top soil and alpha readings of 10 mR/h. Most of the contamination is reported to be in the soil and the concrete pad.

LLW Leak and Spill Site - Bldg. 3082, West (SWMU 1.5c). This leak is thought to have occurred over 25 years ago. Readings in the area ran 1-2 mR/h in the 1970s surveys. The contamination was most likely caused by off-gas duct leakage or a LLW line leak; however, no documentation exists regarding the source. This site is also close to the location of an old plutonium facility that was housed in a wooden frame building. This building was destroyed early in the history of ORNL and is not listed on current maps. The area contamination may or may not be affected by the past presence of this building.

LLW Leak and Spill Site - Bldg. 3019, North (SWMU 1.5d). This LLW line leak occurred in a concrete encased chemware line that served the manipulator shop upstream of the leak site and the Bldg. 3020 stack. There is no real estimate of the period of leakage; however, the leak was discovered in February 1985 after Sr-90 was found in the sewer system at higher-than-normal levels. The leak occurred at the T in the line. Excavation was conducted only to provide access to the leak; no attempt was made to remove all of the contaminated soil in the area. Upon excavation, a cavern was found in the area. Contaminated soil removed (radiation levels of 100 mR/h maximum) was removed and disposed of, and the excavation was backfilled with clean earth after the north and south lines to the T were capped.

LLW Leak and Spill Site - Bldg. 3019, Southwest (SWMU 1.5e). This leak site at the southwest corner of Bldg. 3019 is located in the LLW line draining the analytical cells. The leaks occurred in the 1970s, with the last leak apparently occurring in 1978. After the last occurrence, the leak was corrected, with soil being removed during the repair only to gain access to the line. Samples of the soil removed measured 100 mR/h. The line was known to contain Sr-90, Co-60, mixed fission products, and alpha emitters.

LLW Leak and Spill Site - Bldg. 3110, Between W-5 and WC-19 (SWMU 1.5f). A leak was reported in the LLW transfer line between tanks W-5 and WC-19 in the North Tank Farm on October 16, 1972. The leak occurred at a point 30 feet east of the northeast corner of Bldg. 3025 and 45 feet from the south edge of Hillside Avenue; it contaminated an area with Cd-115, Ce-141, Ba-140, and Nb-95 (all known contaminants in the ORR coolant). Cutie Pie readings of 700 mR/h were noted in the earth around the leak area, and readings of 20-600 mR/h were found in mud in a half-round drain tile extending eastward to a storm sewer catch basin.

LLW Leak and Spill Site - Bldg. 3047, Underneath (SWMU 1.5g). It is suspected that this site has underground contamination due to its history of operations. Few documented cases were found in records; however, certain existing documents indicate the presence of contamination, particularly Sr-90, in this area.

LLW Leak and Spill Site - General Isotopes Area (SWMU 1.5h). This area, located around Bldgs. 3034, 3037, and 3038, is known to be contaminated with Cs-137, Co-60, Ru-106, and Sr-90 radioisotopes and possibly mercury. Various accounts indicate that Pm-147 may also have been involved in some of the spills or leaks. It appears that a number of spills or leaks have occcurred over a twenty-to-thirty-year period, since the 1950s and 1960s.

LLW Leak and Spill Site - Bldg. 3092 Area (SWMU 1.5i). Little information exists for this leak site (included in a tabulation of contaminated areas in January 1972). Based on available information, it appears that a spill occurred along the side of Bldg. 3092; the site was dug up and contaminated dirt was replaced with clean dirt.

LLW Leak and Spill Site - Bldg. 3026, Underneath (SWMU 1.5j). Because of the long use of Bldg. 3026 in isotope production, the ground beneath and around it is likely contaminated from spills and leaks that occurred during the 1950s and 1960s. Few quantitative data exist; however, due to the nature of the operations conducted in 3026 it is possible that the contamination could include isotopes of uranium, fission products, and transuranics. Numerous leaks and spills are referenced in Operations Division reports.

LLW Leak and Spill Site - Bldg. 3024, Between WC-1 and W-5 (SWMU 1.5k). This site is reported to be the location of a leak in the waste transfer line between WC-1 and W-5; however, based on reported information it is possible that a number of leaks from other sources may be contributing to the same problem. Contaminants of concern are probably Sr-90, Cs-137, Ru-106, Co-60, and various rare earths.

LLW Leak and Spill Site - Bldg. 3085, ORR Pumphouse (SWMU 1.5l). This leak occurred in the ORR 24-in. (61-cm) primary coolant water line. The primary coolant water mainly contains neutron activation products. Following repair of the leak, a 6-in. (15-cm) concrete wall was poured on each side of the pipeline and covered with an aluminum plate. Radiation levels encountered during excavation were up to 100 R/h, with transferable contamination to 100 mR/h. Contaminated soil was removed and buried in SWSA-6. Contamination was reported to be primarily Cd-115, with traces of Na-24, Sc-45, Cr-51, Zr-95, Cs-137, and Cs-141.

LLW Leak and Spill Site - Bldg. 3028 (SWMU 1.5m). The leak in the LLW line underneath Bldg. 3028 and leading from it was discovered during excavation for the construction of a drain trap in the LLW line serving Bldgs. 3028 and 3047. After the 6-in.-diameter stainless steel pipe was uncovered, radiation levels of over 200 R/h were observed in contaminated soil at the contact with the pipe. Analysis of the contaminated soil revealed that certain short-lived isotopes that could have originated from the gadolinium process in Bldg. 3047. However, dye tests conducted in an attempt to identify the source of the contamination appeared to rule out Bldg. 3047 as the possible source. The leaking section of pipe was abandoned in place, and new lines were installed to bypass the contaminated area. Contaminated soil from the excavation was removed, and the hole was backfilled with clean soil. No attempt was made to remove all the contaminated soil.

LLW Leak and Spill Site - Bldg. 2531, East (SWMU 1.5n). Release of contamination was reported in the early 1970s due to a leak in an underground crossover between the process waste line from the evaporator and a storm sewer. Sr-90 was the major contaminant of concern. In a later event in the same general area, an abandoned 2-in. (5-cm) cast iron waste transfer line leading to the LLW evaporator (Bldg. 2531) was broken by a communications construction group during trenching operations. Information does not exist to indicate if the abandoned line that was broken was the same one involved in the earlier leak.

LLW Leak and Spill Site - Bldg. 3515, Underneath (SWMU 1.5o). The area under Bldg. 3515 is contaminated as the result of its past use as a radiochemical processing plant. Radioactive material leaking into the condensate line was carried to the concrete drain pipe leading to White Oak Creek. A leaking joint in the concrete pipe about 100 ft south of Bldg. 3515 resulted in the spread of contamination to a ditch and surrounding areas. The contaminated earth in and near the ditch was removed. Cell floor and pan drains were diverted to tank W-12. The concrete gallery floor was decontaminated by chipping and then painted before operations were resumed.

In another reported leak in the same general area, a pipe trench being dug at the southeast corner of the South Tank Farm became highly contaminated when a weld in a process tank jacket failed in Bldg. 3515; the water from the jacket was piped to the storm sewer located in this area. The area has been cleaned up by removing the contaminated soil.

LLW Leak and Spill Site - Bldg. 3525, To a Sump (SWMU 1.5p). In this approximate area, severe contamination results from leaking LLW lines discharging contaminated water into a ventilation duct, which in turn drains into a sump located in the area.

LLW Leak and Spill Site - Bldg. 3550, Underneath (SWMU 1.5q). The ground beneath the former semi-works parts of Bldg. 3550 may be contaminated. This part of the building was demolished, and all materials were taken to the burial ground for disposal.

LLW Leak and Spill Site - Bldg. 3500, Sewer (SWMU 1.5r). Contamination of the 3500 Block area of the sanitary sewer system is the result of inleakage from various LLW sources in Bldg. 3026 and other radioisotope processing areas. The leaks were of active solutions of radioisotopes; waste composition data and the dates of the leaks were not reported. A number of different leaks may have occurred in this area since operations at the Laboratory were initiated. There are indications that SWMUs 1.5s and 1.5t may be related to the contamination at this site.

LLW Leak and Spill Site - Abandoned Line, Central Avenue (SWMU 1.5s). The activity in the sanitary sewer resulted mainly from inleakage under Central Avenue in front of Bldg. 3026, although some traces of activity have also been found in the sewer running east to west on the north side of Bldg. 4508. The leak into the sewer in front of Bldg. 3026 probably originated from earth contaminated by an old intermediate-level waste line that leaked and was taken out of service years ago.

LLW Leak and Spill Site - Bldg. 4508, North (SWMU 1.5t). This site north of Bldg. 4508 is described as ground contaminated with Sr-90. It was reported that attempts to locate the source of the contamination were unsuccessful. The area has since been paved.

LLW Leak and Spill Site - Bldg. 3518, West (SWMU 1.5u). A radioactive leak of less than 100 gal (378L) was discovered in May 1978 along Third Street opposite the Equalization Basin (Bldg. 3524). The material involved in the leak was concentrated strip solution from the Process Waste Treatment Plant (Bldg. 3544) that was contaminated with low-level amounts of Sr-90 and Cs-137. The line was punctured by an air hammer during the installation of a waste transfer line from Bldg. 1504. The spill required the removal of about 5 yd^3 of contaminated dirt.

LLW Leak and Spill Site - Northwest of SWSA-1 (SWMU 1.5v). A break occurred in the LLW transfer line to Melton Valley northwest of SWSA-1, permitting leakage to occur into White Oak Creek. No information is reported on the volume of waste or its activity level.

LLW Leak and Spill Site - Bldg. 3503, Ground Contamination (SWMU 1.5w). Much of the contamination reported was the result of a series of operating accidents at the Solvent Column Pilot Plant (Bldg. 3503). One accident involved the leaking of a discharge line from a waste tank. In another incident, the thorium waste tank overflowed and contaminated the surrounding soil and groundwater. The groundwater surrounding these tanks was pumped to the settling basin.

Contamination of Surfaces and Soil from a 1959 explosion in Bldg. 3019 Cell (SWMU 1.6). On November 20, 1959, a nonnuclear explosion involving an evaporator occurred in a shielded cell in Bldg. 3019. Plutonium released from the cell contaminated areas in Bldg. 3019 and nearby streets and structures. Fallout of the radioactivity was reported as rapid, and the contaminated area was only a small fraction of the Laboratory area. Decontamination actions included multi-layer painting, paving streets, reroofing buildings, and removing and replacing contaminated soils. The estimated release of plutonium was 600 mg of Pu-239 and Pu240. It is reported that most of the contamination was removed during the decontamination operation.

Contamination at Base of Bldg. 3019 Stack (SWMU 1.7). The nature and source of the contamination at this site, also called the "3019 Hot Bank," is not well defined. Sources of contamination may be LLW line leaks or stack emission leakage. Contamination measured at the site includes Co-60, Cs-137, Cm-244, Am-241, Pu-238, and Pu-239. Gross alpha and beta concentrations observed in soil samples at the site range up to 1.7×10^5 and 4.1×10^5 Bq/kg, respectively.

Graphite Reactor Storage Canal Overflow (SWMU 1.8). This canal was used to store and transfer irradiated fuel slugs and targets from the Graphite Reactor to the 3019 fuel reprocessing pilot plant. Although no data or written reports exist regarding an overflow from the canal, notes accompanying an ORNL drawing mention that an overflow may have occurred. It would be anticipated that if a leak occurred, contaminants present would be fission activation products leaking from the fuel slugs and irradiation targets.

Oak Ridge Research Reactor Decay Tank Rupture Site (SWMU 1.9). In 1974 a leak was reported in the 11,000 gal underground decay tank for the Oak Ridge Research Reactor. Primary coolant water was being released at a rate of 1.5 gal/min. The tank was removed, repaired, and replaced during April 1974. During the excavation and repair, radiation levels up to 2 R/h and transferable contamination up to 35 mR/h at 1-in. were reported. There are no records of residual radioactivity remaining at the site after repairs were completed.

3517 Filter Pit (Fission Product Development Laboratory - Bldg. 3517) (SWMU 1.20). The filter pit east of Bldg. 3517 was put in service in 1958 to filter building air exhaust from the Fission Product Development Laboratory (FPDL). The stainless steel roughing filters were acid-backwashed, and the leakage from this operation has contaminated the filter pit. During recent excavations at the site, large quantities of contaminated soil were removed. The principal contaminants are Cs-137 and Sr-90.

FPDL LLW Transfer Line (SWMU 1.21). This line runs from the FPDL to waste tanks W-5 and W-6 in the South Tank Farm (area 3507). The line was installed in 1958 and taken out of service in 1978. Wastes are currently transferred to a collection header on the west side of the South Tank Farm. No leaks have been reported. The inactive line is reported to be contaminated with Cs-137 and Sr-90; no inventory information is available.

Isotopes Ductwork/Bldg. 3110 Filter House (SWMU 1.22). This filter house serves the cell ventilation air exhaust in the isotopes area. A floor drain in Bldg. 3110 collects groundwater and transports it to Tank WC-10. Groundwater leakage into the underground air duct system also accumulates and is collected in a sump for transfer to the Process Waste System. This site has been removed from service.

1.4.2.2 Chemical

Mercury-Contaminated Soil - Bldg. 3503 (SWMU 1.1). During the 1950s and early 1960s, substantial quantities of mercury were used in the spent fuel reprocessing program known as PUREX. No information exists on the quantity of possible losses. Analysis of soil samples collected from various locations around Bldg. 3503 indicated quantities of mercury ranging from 0.8-25 ppm.

Mercury-Contaminated Soil - Bldg. 3592 (SWMU 1.2). During 1956, supporting equipment development work was performed in Bldg. 3592 in conjunction with the research activity on lithium separation. Over a period of about two months, more than 60,000 lb of mercury was used. No estimate of the amounts lost through spills is available; however, operating personnel have estimated that a total of 2,000-3,000 lb was lost due to spills and leaks. The facility was used as a coal conversion pilot plant. Analysis of soil samples taken in 1983 from various locations around 3592 showed mercury concentrations ranging from 4.1-320 ppm.

Mercury-Contaminated Soil - Bldg. 4501 (SWMU 1.3). At Bldg. 4501, ton quantities of mercury were used for about six months during 1954 for the operation of a small pilot plant for lithium separation (OREX process). Spills did occur. During a spill the visible mercury was cleaned up, but the mercury was able to escape into cracks in the concrete floor. The building is currently used as a high-level radiochemistry laboratory. Analyses of soil samples collected in 1983 from various locations indicated that soils around Bldg. 4501 had concentrations of mercury ranging from 0.05-465 ppm.

Mercury-Contaminated Soil - Bldg. 4508 (SWMU 1.4). Although research activities in Bldg. 4508 are reported to have used inventories of less than 100 lb of mercury, there is no information available to indicate that a mercury spill has occurred. No soil sampling has been conducted around Bldg. 4508.

1.4.3 Ponds and Impoundments

Nine ponds or impoundments identified in WAG 1 represent potential 3004(u) sites. Of these sites, four contain process wastes and two represent ponds that have been taken out of service and backfilled. The remaining sites are the two aerated lagoons formerly used for treatment of Laboratory sewage and the coal pile runoff collection basin. More detailed information on the ORNL ponds can be obtained from Taylor (1986b), Francis (1986), Stansfield and Francis (1986a and 1986b), Kitchings and Owenby (1986), and Braunstein et al. (1984).

1.4.3.1 Radioactive waste

Waste Holding Basin (SWMU 1.12). This basin (3513) was constructed during the 1940s as a part of an early waste treatment scheme that involved neutralizing and precipitating sludges in the gunite tanks, then decanting the supernatant. The basin was used for dilution with process wastewater and additional settling of the supernatant prior to release to White Oak Creek. The capacity of the basin is about 1,600,000 gal. After construction of the process wastewater treatment plant in 1957, the basin was used as a secondary settling basin following treatment and before release of the treated process waste to White Oak Creek. The basin was removed from service in 1976 when the new Process Waste Treatment Plant (3544) was completed.

Equalization Basin (SWMU 1.13). This basin (3524) serves to equalize flow for the Process Waste Treatment Plant. As originally constructed in the 1940s, the two ponds (300,000 gal each) were to be used if it was necessary to provide emergency holdup of LLW. When the original Process Wastewater Treatment Plant (3518) was completed in 1957, the earthen dike between the two ponds was removed, creating a 600,000 gal flow-equalization basin. The facility is still in use; however, in 1961 the capacity of the basin was increased to 1,000,000 gal.

Process Waste Pond 3539 (SWMU 1.14). This pond (3539) and the adjacent one (3540) were constructed to hold process waste generated at the 4500 complex before treatment or discharge. Pond contents were sampled before the decision was made to treat the waste or discharge it directly to the Creek. The ponds are located north of White Oak Creek and adjacent to the Waste Holding and Equalization Basins in the southern portion of the main plant area. The capacity of each pond is 150,000 gal.

Process Waste Pond 3540 (SWMU 1.15). See previous description.

Decommissioned Waste Holding Basin (SWMU 1.11). This basin (3512) was constructed in the 1940s as part of the emergency holdup and settling basin for process waste. The basin was adjacent to the 3513 basin (SWMU 1.13), approximately where the current Process Wastewater Treatment Plant is now located. The reported capacity of the basin, which has been filled in, was 30,000 gal.

Low Intensity Test Reactor (LITR) Pond (SWMU 1.19). Two retention ponds were constructed at the LITR to retain the primary coolant (water) when the reactor pool was drained. Little information is available on the characteristics of the waste; however it was reported to mainly be due to Na-24 (half-life of 15h). Each pond was 40 ft by 8 ft and had a capacity of 18,000 gal. Following radioactive decay, the supernatant from the pond was discharged to Fifth Creek. A radiological study of the site in 1985 showed average activities of Sr-90, Pu-238, and Pu-239 in the soil higher than background; there was some contamination due to Cs-137 and Co-60. The radionuclide inventory was estimated at 20 mCi of Cs-137, 1 mCi of Sr-90, and 100 uCi of Pu-239. The ponds have been filled in and grassed.

1.4.3.2 Nonradioactive Waste

Sewage Aeration Pond 2543 (SWMU 1.16). The East Pond (2543) and the adjacent pond (West Pond, 2544, SWMU 1.17) were operated in series as aeration lagoons for treating the sanitary sewage generated within the Laboratory. Each lagoon has a capacity of about 1,000,000 gal. The ponds, constructed in 1974, were used until the new sewage treatment plant was completed. The ponds are now used as an equalization basin for the package sewage treatment plant and are available for holdup and temporary treatment of sewage if the main sewage treatment plant is out of service.

Sewage Aeration Pond 2544 (SWMU 1.17). See previous description.

Coal Pile Settling Basin (SWMU 1.18). The basin (2545) was constructed in 1978 as a part of the ORNL Steam Plant conversion project in which the steam plant was converted to coal buring from oil and gas. The basin is located southwest of the coal pile. Following neutralization of the runoff and sedimentation in the basin, the clarified effluent is released to White Oak Creek. Capacity of the basin is about 300,000 gal.

1.4.4 Waste Treatment Facilities

Four sites can be categorized as waste treatment units: the LLW evaporator (Taylor 1986a, Binford and Orfi 1979), the Process Waste Treatment Plant (Bratz and Robinson 1976), the neutralization facility, and the new sewage treatment plant. Of these sites, two can be considered radioactive waste facilties, and the other two are nonradioactive (chemical or sewage) waste treatment units.

1.4.4.1 Radioactive waste

Low-Level Waste Evaporator (SWMU 1.48). This facility (2531), constructed in 1965, is located in the southwest center of the main plant area just west of the South Tank Farm. The evaporator is used to concentrate LLW before transferring it to the hydrofracture facility. Since the hydrofracture facility has been shut down, the concentrated LLW is being stored. Condensate from the evaporator is directed to the Process Waste Treatment Plant for treatment prior to discharge.

Process Waste Treatment Plant (SWMU 1.51). The existing Process Waste Treatment Plant (3544) is located in the southwestern part of the main plant area. The previous plant (now used as the neutralization facility, SWMU 1.49) is located east of the new plant. Process waste is chemically treated, filtered, and ion-exchanged prior to discharge. The capacity of the plant is 300,000 gal/day.

1.4.4.2 Chemical and sewage waste

Neutralization Facility (SWMU 1.49). This facility (3518) neutralizes process wastes, such as blowdown from the ORNL steam plant. During the period 1957 to 1976, this facility served as the Process Waste Treatment Plant.

Sewage Treatment Plant (SWMU 1.52). This facility (2521) was installed in 1986 to treat the sanitary sewage produced within the main plant area. It is located at the west end of the plant. The unit currently in operation is an extended aeration package sewage treatment plant. The capacity of the plant is 300,000 gal/day.

1.4.5 Solid Waste Storage Areas

During early operations at the Laboratory (1943-1946) radioactive solid wastes were buried at two sites within the WAG 1 boundary: SWSA-1 and SWSA-2. The general location of these sites is shown in Fig. 2. In addition, two storage pads were constructed south of Bldg. 3503 to store radioactively contaminated materials. These materials have been removed and the pads decontaminated; however, radionuclide contamination has been detected adjacent to the pads. In 1985, a storage shed was constructed north of Bldg. 2018 to store PCB-contaminated waste. This waste is placed in drums for periodic disposal by a subcontracted disposal service. Operation of the two SWSAs is described in Webster (1976), Grizzard (1986), and Coobs and Gissel (1986).

1.4.5.1 Radioactive waste

Solid Waste Storage Area (SWSA) - 1 (SWMU 1.46). Solid Waste Storage Area 1 (SWSA-1) is located southwest of the main plant area on the south side of White Oak Creek. Although it is just outside the fence surrounding the main plant area, it is included in WAG 1 for hydrologic site conditions. SWSA-1 was operated for a short time in 1944 to dispose of contaminated solid wastes produced during routine laboratory operations. Disposal was conducted in trenches using a technique similar to a sanitary landfill operation. No records exist of the amount or composition of waste buried.

Solid Waste Storage Area (SWSA) - 2 (SWMU 1.47). Solid Waste Storage Area 2 (SWSA-2) is located in the northeast part of the Laboratory, north of Bldg. 4500N. Disposal operations began in 1944 and were discontinued in 1946. When it was later determined that the presence of SWSA-2 was not compatible with long-range land-use planning at the Laboratory, the waste and some of the surrounding soil were removed and reburied in SWSA-3. The site was backfilled with clean soil and contoured to be compatible with the general area. No records of the amount of waste buried or its composition exist.

Storage Pads 3503, 3504 (SWMU 1.10). The storage pads are located southwest of Bldg. 3503. The concrete pad is approximately 40 ft by 30 ft (15 m by 12 m). A portion of the pad has a covering over two areas used for storage of barrels, surplus equipment, and crates. These two areas have a metal tray flooring. The major radionuclides present are believed to be associated with the storage of U-233 and Pu-239. Due to measurable contamination of the concrete pad, a 4-in. (10-cm) layer of concrete was added to the top of the pad. No measurable alpha activity is now detected. However, the soil around the pad is contaminated and because the pad is located just north of White Oak Creek, there is a possibility that migration of contaminants in surface runoff may occur.

1.4.5.2 Chemical waste

PCB Storage Area (SWMU 1.50). This facility (2018N) is located next to Bldg. 2018, an equipment repair shop. As a part of the operations conducted in 2018, PCB-contaminated waste is generated. This waste is placed in drums and is stored at 2018N until a sufficient quantity is accumulated for pickup and off-site disposal by an outside disposal firm.

1.4.6 Miscellaneous Facilities

Septic Tank for Bldg. 3000 (SWMU 1.53). Because of the topography of the ORNL site and the expense of providing sewage collection systems, a number of ORNL facilities are served by individual septic tanks. A small (580-gal) septic tank (3078) has been provided for Bldg. 3000. The tank is located outside the WAG 1 boundary.

Waste Oil Storage Tanks (SWMU 1.54). Two steel waste oil storage tanks are located on the southeast side of Bldg. 2325. Each tank has a capacity of 500 gal (1,893L) and is used to store waste oil and soluble oil (one tank for each purpose). The tanks are contained in a diked area; no releases from the tanks have been reported.

1.4.7 Surplus Facilities Management Program

Sixteen facilities in WAG 1 have also been identified as surplus facilties that will require some form of remedial action (see Table 1). Although these sites are not 3004(u) sites, they have been included in the list of sites at ORNL in order to present a complete overview of the remedial actions contemplated for WAG 1. Some of these sites are associated with, or proximate to, SWMUs that are on the list; however, the remedial actions for these facilities will be performed under existing DOE Remedial Action Programs.

1.5 KNOWN OR POTENTIAL RELEASES FROM WAG 1

All drainage and treated effluents from WAG 1 ultimately discharges to WOC. As a result, there is a significant amount of historical information on radionuclide and chemical waste releases from WAG 1. However, monitoring information for individual SWMUs within WAG 1 is essentially nonexistent. Other than the Stockdale wells drilled in 1951 (Stockdale 1951), no additional monitoring wells have been installed within WAG 1 before 1985, when the ORNL RAP was initiated.

Historically, tanks in the ORNL liquid waste system have been monitored for water levels and external radiation; however, the contents have not been routinely sampled and analyzed. Only in the past few years have samples been taken from some of the active and inactive tanks and analyzed for radionuclide content. Where recent information on the radionuclide inventory exists, this information has been included in the SWMU summary sheets which have been submitted to EPA as a part of the RCRA Facility Assessment (Oak Ridge National Laboratory 1987). Unfortunately, the radiation levels in the samples analyzed have restricted analysts' ability to measure hazardous constituents at the detection levels required by RCRA hazardous waste definitions. There is no question, however, that based on radionuclide content alone, the wastes should be considered "hazardous."

The relatively large number of release points identified in the ORNL National Pollutant Discharge Elimination System (NPDES) permit provide some indication of the magnitude of releases that are occurring from WAG 1 (Department of Environmental Management 1986). Measurements at these release points do not allow ORNL to identify which contaminants are being released from individual SWMUs, but rather provide some indication of what is being released from generalized areas of the plant. Because of hydrologic interactions between individual SWMUs and the complex geology and hydrology of the main plant area, it appears that identifying the releases from individual SWMUs will be a difficult, if not impossible, task.

Stream gravel surveys were conducted in the drainage areas surrounding WAG 1 in the fall of 1986 (Morrison and Cerling 1987). Samples were taken at many of the stations used in the previous studies (Cerling and Spalding 1981, Cerling 1986). Samples taken from seven sampling sites showed that most of the sites are contaminated with a variety of metals, including Cr, Cu, Mo, and Zn, which may result from cooling towers, unknown sources along First Creek and the Northwest Tributary, or from sources that have not yet been identified. Several sources of Cs-137 were identified, the most significant of which is the effluent from the Process Waste Treatment Plant. Strontium-90 and Co-60 were also identified in the Process Waste Treatment Plant effluent. Strontium-90 was actively being discharged into First Creek from two culverts on the east side of the creek, and Sr-90 contamination in the Northwest Tributary appeared to result from First Creek and SWSA 3 (WAG 3). Hydrocarbons (source unknown) were detected in one of the samples (Site 12, see Fig. 1); no other important contamination by organic compounds was detected.

The results obtained for radionuclides in the stream gravel survey were essentially consistent with those obtained in the 1985 survey; however, the presence of Sr-90 as an active contaminant in First Creek (initially observed in the 1985 survey) was verified.

2. CURRENT STATUS OF INFORMATION ON WAG 1

2.1 SOURCE TERM

Information on the chemical and radionuclide content of most of the SWMUs in WAG 1 is limited or nonexistent. A review of past waste management operations indicates that chemical and radiochemical analyses were not routinely performed to assay the contents of the many tanks and ponds included in the system. Only recently have more detailed analyses of the contents of the ORNL waste tanks and ponds been initiated; these analyses have principally been directed at the inactive waste management units that are no longer accepting wastes.

Because the active tanks and ponds are continually receiving and discharging wastes, it has not appeared to be necessary to sample individual units to analyze for chemical or radioactive constituents on a predetermined basis. The major sampling and analysis effort has been directed at the point of discharge. As a result, there is little information on the inventory of contaminants within components of the ORNL waste system.

Many (34%) of the SWMUs in WAG 1 are spill or leak sites for which detailed information on the composition or volume of the waste involved does not exist. In many cases, only the approximate location and/or the date the leak was detected have been documented. Although these leaks or spills were corrected by repairs to the lines and/or the removal of contaminated soils, the existing documentation of the event does not indicate the level of decontamination achieved. As a result, although the leak was repaired, some of the contaminants may remain at the site.

Using currently existing information regarding the content of the waste systems at ORNL, an attempt was made to compile an inventory of the contaminants in WAG 1 (Table 5). Where existing data were incomplete or fragmentary, an estimate was made of the contaminants present (Trabalka and Myrick in press). These estimates are believed to be generally quite conservative (i.e., overestimates). It can be seen in Table 5 that there is very little definitive information on the hazardous chemicals

Table 5. Inventories of major contaminants.

Site	Contaminant	Inventory[a] [Ci (kg)]
1.0 Main Plant Area		
1.1 Mercury Contaminated Soil (3503)	Hg	(<1.0 est.)
1.2 (3592)	Hg	(<1.4 × 10^{3})
1.3 (4501)	Hg	(<10 est.)
1.4 (4508)	Hg	Presence unconfirmed
1.5a-w LLW Lines and Leak Sites	Sr-90, Cs-137, TRU, Hg	Unknown
1.6 Contaminated Surfaces and Soil from 1959 Explosion in Bldg 3019 Cell	Pu-239	<4.7 × 10^{2}
1.7 Contamination at Base of 3019 Stack	Unidentified	Presence unconfirmed
1.8 Graphite Reactor Storage Canal Overflow (3001/3019)	Unidentified	Presence unconfirmed
1.9 ORR Decay Tank Rupture Site (3087)	Neutron activation products	Presence unconfirmed
1.10 Storage Pads (3503, 3504)	U-233, Pu-239	<1.0 × 10^{-1} est.
1.11 Decommissioned Waste Holding Basin (3512)	Unidentifed	<1.0 × 10^{1} est
1.12 Waste Holding Basin (3513)	Sr-90	3.4 × 10^{1}
	Cs-137	2.0 × 10^{2}
	Pu-239	5.0
1.13 Equalization Basin (3524)	Sr-90	3.0 × 10^{1}
	Cs-137	1.0 × 10^{2}
	Th, U, TRU	1.1 × 10^{1}
1.14 Process Waste Pond (3539)	Unidentified	<1.0 × 10^{1} est
1.15 Process Waste Pond (3540)	Unidentified	<1.0 × 10^{1} est
1.16 Sewage Aeration Pond (East)—(2543)	Unidentified	<1.0 × 10^{1} est
1.17 West Sewage Pond (2544)		
1.18 Coal Pile Settling Basin (2545)		
1.19 LITR Pond (3085W)		
1.20 3517 Filter Pit	Sr-90, Cs-137	Unknown
1.21 LLW Transfer Line	Unidentified	<1.0 × 10^{3} est
1.22 Isotopes Ductwork/ 3110 Filter House	Unidentified	Unknown
1.23 Inactive Tanks (W-1)	Sr-90	9.0 × 10^{-2}
	Cs-137	2.0 × 10^{-2}
	TRU	7.0 × 10^{-4}
W-2	Sr-90	1.0 × 10^{1}
	Cs-137	1.0 × 10^{1}
	TRU	7.0
1.24 Inactive Tanks (W-3)	Sr-90	<1.0 × 10^{2} est
	Cs-137	<1.0 × 10^{3} est.
	TRU	<1.0 × 10^{2} est
(W-4)	Sr-90	1.0 × 10^{2}
	Cs-137	1.0 × 10^{2}
	TRU	4.2
1.25 Inactive Tanks (W-13)	Sr-90	3.0 × 10^{2}
	Cs-137	3.0 × 10^{1}
	TRU	4.3 × 10^{-2}
(W-14)	Sr-90	8.0
	Cs-137	6.0
	TRU	6.0 × 10^{-4}
(W-15)	Unidentified	Unknown
1.26 Inactive Tanks (W-5, W-6, W-7, W-8, W-9, W-10)	Sr-90	1.9 × 10^{4}
	Cs-137	2.5 × 10^{3}
	Th-232	(<1.0 × 10^{4} est.)
	U-238	(<1.0 × 10^{4} est.)
	TRU	1.0 × 10^{2} est.
1.27 Inactive Tank (W-11)	Sr-90	<1.0 × 10^{-3} est
	Cs-137	<1.0 × 10^{-3} est.
	TRU	<1.0 × 10^{-3} est.
1.28 Inactive Tank (W-1A)	Sr-90, Cs-137, U-233, TRU	Unknown
1.29 Inactive Tank (WC-1)	Sr-90	<1.0 × 10^{1} est
	Cs-137	<1.0 × 10^{1} est.
	TRU	<1.0 × 10^{-1} est.
1.30 Inactive Tanks (WC-15)	Sr-90, Cs-137, TRU	<1.0 × 10^{-1} est.
(WC-17)	Sr-90	2.2 × 10^{-3}
	Cs-137	5.2 × 10^{-4}
	TRU	1.2 × 10^{-3}
1.31 Inactive Tanks (TH-1)	Sr-90	6.0 × 10^{-1}
	Cs-137	5.0 × 10^{-1}
	TRU	2.0 × 10^{-4}
(TH-2)	Sr-90, Cs-137, TRU	Unknown
(TH-3)	Sr-90	6.0 × 10^{-1}
	Cs-137	6.0 × 10^{-1}
	TRU	2.0 × 10^{-4}
1.32 Inactive Tank (TH-4)	Sr-90	6.0 × 10^{-2}
	Cs-137	5.0 × 10^{-1}
	TRU	8.5 × 10^{-2}
1.33 Active Tank (2026)		
1.34 Active Tank (WC-2)		
1.35 Active Tank (WC-3)		
1.36 Inactive Tank (WC-4)		
1.37 Active Tanks (WC-5, WC-6, WC-8, WC-9)		
1.38 Active Tank (WC-7)		
1.39 Active Tanks (WC-10, WC-11, WC-12, WC-13, WC-14)		
1.40 Active Tank (WC-19)		
1.41 Active Tank (W-12)		
1.42 Active Tanks (W-16, W-17, W-18)		
1.43 Active Tanks (W-21, W-22)		
1.44 Active Tank (W-23)		
1.45 Active Tanks (C-1, C-2)		
1.46 SWSA-1 (2624)	Sr-90, unidentified	<4.0 × 10^{3}
	Hg	Unknown
1.47 SWSA-2 (4003)	Unidentified	Presence unconfirmed Contents moved to SWSA-3 before 1950
1.48 LLW Evaporator (2531)		
1.49 Neutralization Facility (3518)		
1.50 PCB Storage Area (2018N)		
1.51 PWTP (3544)		
1.52 Sewage Treatment Plant (2521)		
1.53 Bldg 3000 Septic Tank (3078)		
1.54 Waste Oil Storage Tanks (2525)		

[a] Inactive refers to tanks no longer in service; active refers to operating tanks.

[b] Numbers in parenthesis are measured in kilograms.

and radionuclides present in WAG 1. Table 5 does indicate that Cs-137, Sr-90, Co-60, transuranics (TRU), U, and Pu are the major radionuclides in WAG 1.

2.2 GEOLOGY AND SOILS

2.2.1 Regional Geology

The Oak Ridge Reservation is located in the Valley and Ridge Physiographic Province of the Appalachian Highlands. The Valley and Ridge Province is characterized by essentially parallel and elongate, alternating valleys and ridges formed following folding and thrust faulting during the Appalachian Orogeny. Regional strike in the Oak Ridge area is N 45° to 60° E, and dip is typically about 30° southeast but can vary locally from <20 to 40°. A typical northwest to southeast cross section showing the geologic structure of the Oak Ridge Reservation is shown in Fig. 3. A generalized stratigraphic section of the bedrock formations in the Oak Ridge Area is shown in Fig. 4.

2.2.2 Geology in the Plant Area

The bedrock units that underlie the Main Plant Area consist of the limestone, siltstone, and calcareous shale facies of the Ordovician Chickamauga Group. A geologic map of the Oak Ridge Reservation is shown in Fig. 5. Stockdale (1951) summarized the mappable rock units of the Chickamauga in descending order (Table 6).

2.2.2.1 Past Geologic Studies

For evaluations related to on-site liquid radioactive waste disposal, Stockdale (1951) conducted a geological and hydrological study of the Main Plant Area. Fifty-one exploratory borings were completed in and around the area to depths of from 50 to 250 feet with most holes drilled to 50 or 100 feet (Table 7). Most of the holes were drilled into upper Chickamauga Units H-E. Borehole locations are shown in Fig. 5, and core descriptions accompany the Stockdale report. The precise locations of the borings, as well as current borehole conditions, is not known.

ORNL—DWG 82-13318

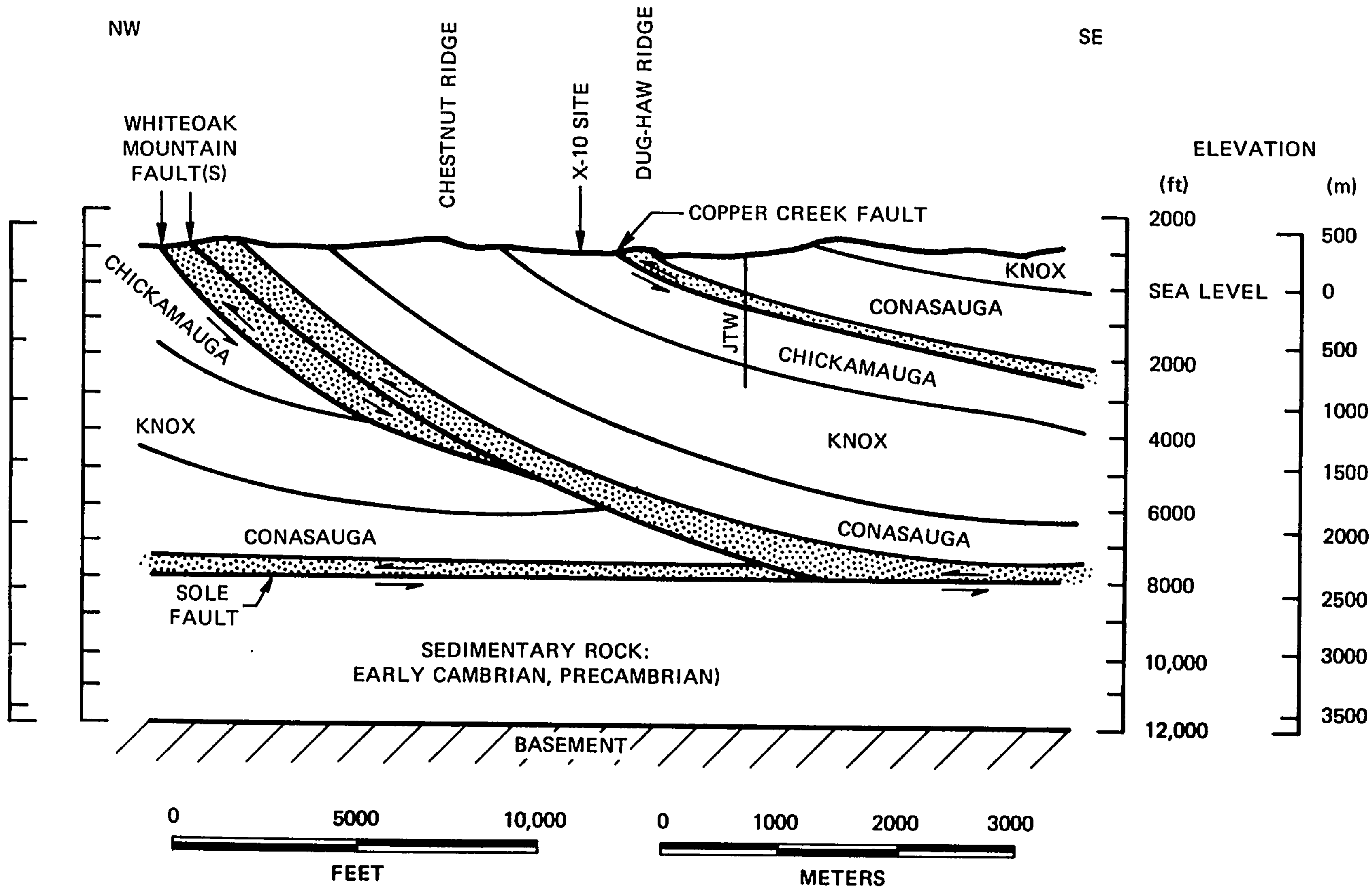

Fig. 3. Geologic cross section through the Oak Ridge Reservation

Generalized Geologic Section of the Bedrock Formations
in the Oak Ridge Area

System	Group	Formation	"Member" or Unit	Thickness (feet)	Characteristics of Rocks
Mississippian		Ft. Payne "chart"			Impure limestone and calcareous siltstone, with much chert
	?	Chattanooga shale			Shale, black, fissile
Devonian					
Silurian					
	Rockwood group	Brassfield		1000+	Shale, sandy shale, sandstone; calcareous; red, drab, brown
		Sequatchie			
Ordovician	Chickamauga group		? H	300+	Limestone, shaly limestone, calcareous siltstone, and shale; mostly gray, partly maroon; with cherty zones in basal portions
			G	300	
			F	25	
			E	380	
			D	160	
			C	115	
			B	215	
			A	240	
	Knox group			2600	Dolomitic limestone; light to dark gray; with prominent chert zones
Cambrian	Conasauga group	Maynardsville limestone		1500	Shale; gray, olive, drab, brown; with beds of limestone in upper part
		Conasauga shale	Pumpkin valley		
		Rome formation		1000+	Sandstone and shale; variegated with brilliant yellow, brown, red, maroon, olive-green; with dolomitic limestone lenses

Fig. 4. Generalized geologic section of the bedrock formations in the Oak Ridge area

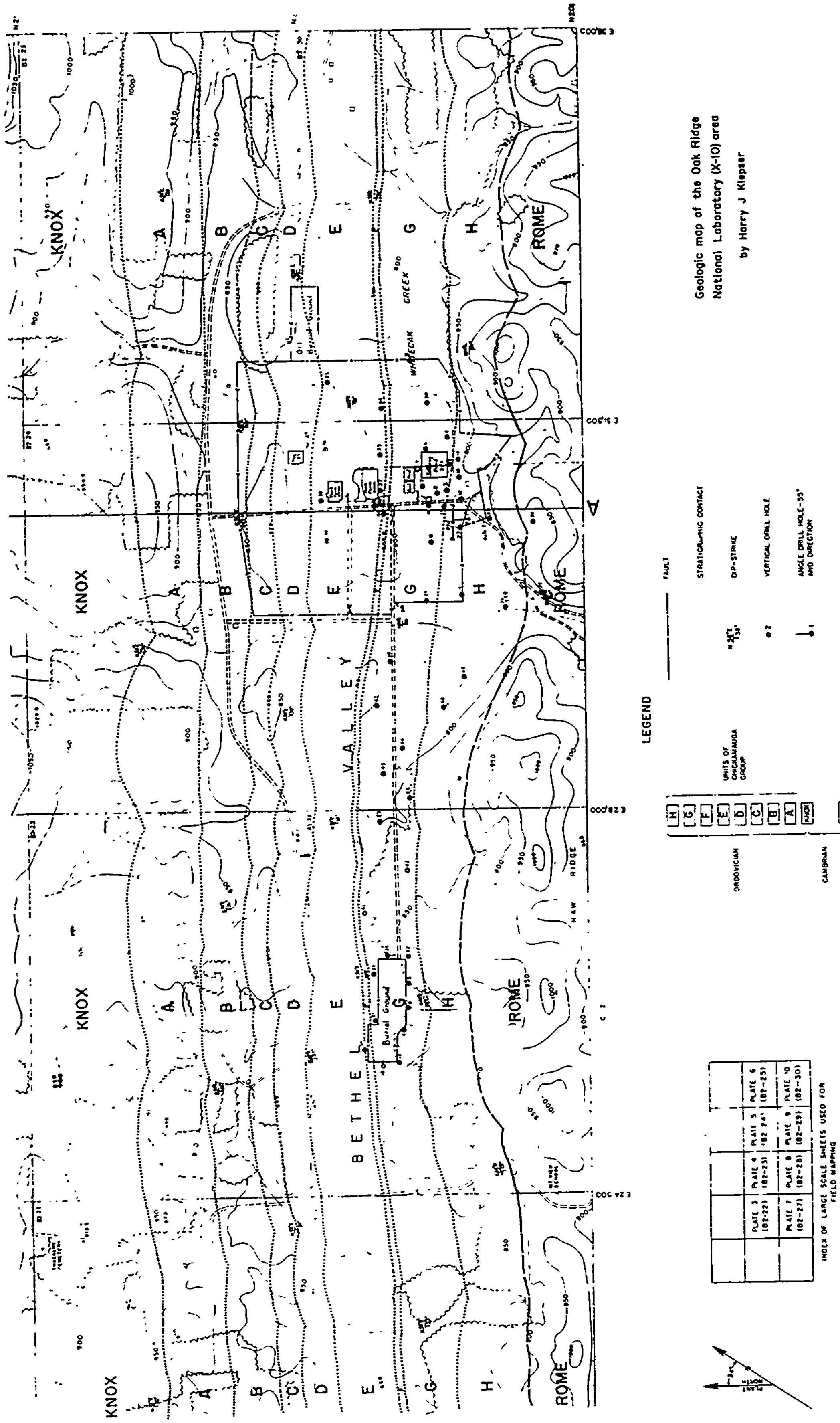

Fig. 5. Geologic map of the Oak Ridge National Laboratory area

Table 6. Stratigraphic description of the ORNL area

Unit	Rock description	Thickness (m)
H	Siltstone; calcareous; gray, olive, maroon; with shaly partings and thin limestone lenses	25.91
	Limestone of varied types; gray, olive-gray, buff, drab; mostly thin-bedded; with argillaceous partings; weathers to shaly appearance; with fossiliferous zones	54.86
	Limestone; argillaceous (calcareous siltstone); gray, olive-gray, "pinkish" maroon; even-bedded, with shale partings . . .	10.67
G	Limestone of varied types; dark gray to brownish gray; mostly nodular with abundant black irregular clay partings; dense to medium-grained; mostly thin-bedded, partly massive, with shale partings; weathers to a lighter-colored shaly or "nodular" appearance; with some fossiliferous horizons; mostly covered in lowlands	91.44
F	Siltstone; calcareous, alternating with shale; olive-gray to maroon; even-bedded; laminated; weathers to a red shaly appearance; produces a slight rise in topography; a very distinctive unit	7.62
E	Limestone; mostly gray to drab, partly pinkish maroon, mottled; brittle, thin-bedded to massive; with shaly partings	18.29
	Limestone, similar to "G" above; mostly covered in lowlands	67.06
	Calcareous shale and argillaceous limestone; gray to buff; in alternating thin even beds; yielding small roundish slabs upon weathering, with yellow-buff color	13.72
	Limestone of varied types; gray, mostly argillaceous and nodular; in thin irregular beds with shale partings; abundant fossils . .	16.76

Table 6. Continued.

Unit	Rock description	Thickness (m)
D	Limestone and chert; limestone is gray to olive-gray; in part nodular, shaly, and thin-bedded; in part massive; with abundant chert in thin, even bands, breaking into angular fragments upon weathering; produces a chain of low hills	48.77
C	Shale; calcareous; olive-gray to light maroon; fissile; even-laminated	3.05
	Limestone of varied types; gray; fine to coarse-grained, partly crystalline, partly nodular; mostly massive; with occasional patches of chert; partly fossiliferous; "quarry beds"	32.00
B	Siltstone, in even beds up to 2 ft thick, laminated, alternating with calcareous shale; olive-gray, buff, maroon; some limestone, non-resistant; more shale at base	65.53
A	Limestone of varied types; dark gray to buff; with shale partings; with gray to black chert in nodules and lenses	24.38
	Chert; thin-bedded, with shaly partings . . .	4.57
	Siltstone; calcareous; olive-gray to maroon; weathers to shaly appearance	9.14
	Siltstone and chert, in alternating beds; siltstone is calcareous, gray, olive, maroon; weathers to shaly appearance; with abundant granular chert in even beds up to 6 in. thick, breaking into angular blocks upon weathering	27.43
	Limestone; mostly covered	7.62
	Total thickness	528.82

<u>Source</u>: Stockdale 1951

Table 7. Exploratory borehole data

Borehole number	Date drilled [a]	Drilling angle (degrees)	Drilling depth (feet)	Overburden thickness (feet)	Elevation, top of casing (feet)	Elevation, water table, June 20, 1950 (feet)	Geologic units encountered[b]
1	12/19 - 1/10	55	300.0	13.0	784.46	776.48	G,F
2	12/16 - 1/22	90	100.0	9.2	779.52	772.12	G
3	12/21 - 1/6	90	250.7	12.0	888.58	825.38	G,F
4	12/27 - 1/5	90	100.2	7.7	787.98	777.24	G
5	1/9 - 1/11	90	100.0	10.5	842.77	825.75	G
6	1/4 - 1/9	90	100.0	11.3	790.62	778.72	G
7	1/10 - 1/15	90	100.0	9.0	780.20	777.31	G
8	1/11 - 1/13	90	100.0	8.0	778.52	776.49	G
9	1/12 - 1/16	90	100.0	22.0	848.28	825.69	G
10	1/16 - 1/20	90	100.0	10.0	780.05	776.45	G
11	1/16 - 1/18	90	100.0	9.0	778.59	775.66	G
12	1/19 - 1/25	90	100.0	9.0	778.53	772.15	H,G
13	1/20 - 1/26	90	100.0	10.0	787.87	774.93	H,G
14	1/26 - 1/31	90	100.0	10.2	788.83	775.73	H,G
15	1/17 - 1/20	90	100.0	25.0	848.89	814.94	G
16	1/23 - 1/26	90	100.0	12.0	840.28	810.52	G,F
17	1/26 - 1/30	90	100.0	9.0	782.16	779.97	G
18	1/31 - 2/2	90	100.0	13.0	778.36	776.27	G
19	2/2 - 2/7	90	100.3	13.5	783.35	771.63	H
20	1/27 - 2/3	90	100.0	12.5	836.22	819.20	F,E
21	2/7 - 2/10	90	100.0	12.0	834.30	807.75	G,F
22	2/13 - 2/18	90	100.0	10.5	825.69	810.60	G,F
23	2/17 - 2/21	90	100.0	10.0	827.50	818.57	G
24	2/4 - 2/8	90	100.0	5.0	779.26	777.84	G
25	2/8 - 2/10	90	50.0	6.0	790.12	784.73	G
26	2/10 - 2/14	90	50.0	20.0	779.62	770.76	H
27	2/9 - 2/10	90	50.0	8.5	778.88	771.68	H
28	2/13 - 2/15	90	100.0	23.0	790.47	776.14	H

Table 7. Continued.

Borehole number	Date drilled [a]	Drilling angle (degrees)	Drilling depth (feet)	Overburden thickness (feet)	Elevation, top of casing (feet)	Elevation, water table, June 20, 1950 (feet)	Geologic units encountered[b]
29	2/17 - 2/29	90	198.0	8.0	797.06	769.48	Rome,H
30	2/15 - 2/16	90	50.0	6.7	782.78	777.01	G
31	2/16 - 2/17	90	50.0	3.0	786.82	781.96	G
32	2/22 - 2/24	90	100.0	8.7	839.59	824.78	G
33	2/20 - 2/21	90	50.0	4.0	799.40	796.53	E
34	2/22 - 2/23	90	50.0	5.8	794.30	788.04	E
35	2/23 - 2/26	90	50.0	15.0	801.90	786.48	E
36	2/28 - 3/1	90	50.0	7.0	818.47	802.14	E
37	3/1 - 3/2	90	50.0	6.2	800.63	781.04	E
38	3/2 - 3/3	90	50.0	20.6	831.38	803.28	E
39	3/7 - 3/8	90	50.0	6.5	820.62	dry	E
40	3/9 - 3/10	90	50.0	4.0	808.07	781.90	F,E
41	2/24 - 2/27	90	50.0	10.0	831.88	799.42	G,F
42	2/28 - 3/2	90	50.0	1.0	833.26	811.79	G
43	3/2 - 3/3	90	50.0	9.5	798.80	792.66	G
44	3/7 - 3/8	90	50.0	9.0	813.10	788.82	G
45	3/3 - 3/8	90	50.0	6.5	791.48	788.57	G
46	3/9 - 3/10	90	50.0	3.0	787.62	783.87	G
47	3/11 - 3/13	90	50.0	9.0	796.45	786.45	G
48	3/9 - 3/10	90	50.0	11.0	784.90	778.51	H
49	3/7 - 3/8	90	50.0	8.0	778.94	774.90	H
50	3/1 - 3/6	90	90.0	6.0	829.11	813.28	Rome,H
51	3/16 - 3/22	90	161.0	3.0			Conasauga

a All dates are late 1949 or early 1950.
b See Fig. 4 and Table 6.
<u>Source</u>: Stockdale 1951.

The location of the recovered core is not known and is presumed to have been discarded.

Stockdale (1951) summarized the descriptions of upper Chickamauga limestones as being tightly cemented and compact with the exception of several small (roughly 1-in.-diam) solution channels.

2.2.2.2 Recent Geologic Studies

In the winter of 1985, five core holes were completed in a north-south line across the plant area, providing an incomplete stratigraphic section from Units B through G. Borehole locations are shown in Fig. 6, and boring depths are shown in Table 8. A series of geophysical logs was obtained from each hole. Logs include acoustic borehole televiewer, variable density, gamma ray, caliper, density, porosity, spontaneous potential, long/short normal resistivity, temperature, single point resistance, and borehole deviation. The core and logs are currently being examined, and preliminary results are expected in FY 87. Initial core observations indicate that the rock is tightly cemented and competent. Fractures often appear to be remineralized with calcite, but some exhibit signs of motion (i.e., bedding plane or fracture slickensides) that could provide pathways for groundwater movement.

A borehole packer testing program began in late November 1986 to test the groundwater transport potential of selected fractured intervals compared with unfractured rock. In addition, selected groundwater geochemistry tests will be performed (i.e., Eh, pH, conductance, and radiological analyses) to determine if specific stratigraphic intervals are geochemically distinct. The testing program will provide quantitative measures of secondary permeability in the Chickamauga.

2.2.3 Site Soils

2.2.3.1 Description of site soils with soils map

McMaster and Waller (1965) conducted a geologic and soils study of the White Oak Creek Basin. The soils belong to the red-yellow Podzolic and the reddish-brown laterite and lithosol groups. The residuum is commonly 1 to 10 ft thick. McMaster and Waller (1965) describe Chickamauga soils as follows:

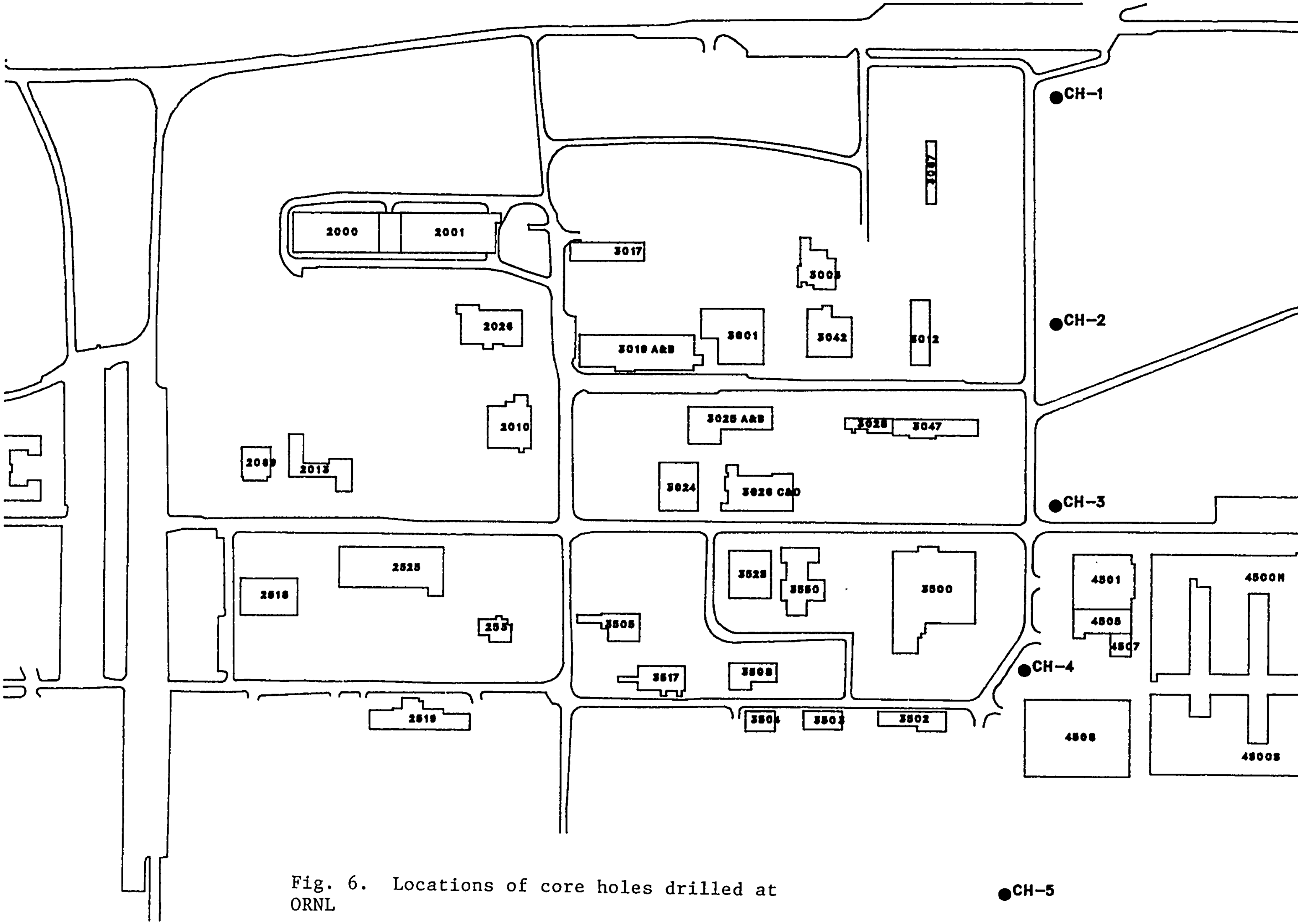

Fig. 6. Locations of core holes drilled at ORNL

Table 8. Drilling depths of five recent boreholes in Main Plant Area

Borehole number	Top of core (ft)	Coring depth (ft)
CH 1	21.5	385.2
CH 2	7.9	472.8
CH 3	11.1	400.6
CH 4	14.2	380.6
CH 5	13.5	446.4

> . . . residuum on Chickamauga typically heavy yellow or yellow-brown montmorillonite-like clay generally containing small chips of white or yellow chert, fragments of porous brown siltstone, and small blocks of limestone. Unit Ocha [UnitA], however, has thick overburden of extremely cherty red clay, the chert occurring as loose rectangular blocks or in beds inter-layered with residual clay. Also, unit Ochb [Unit B] has only a very thin veneer of overburden in most places and in relatively large areas none is present. A series of 50 core holes drilled into units Oche, Ochf, Ochg, and Ochh [Units E through H] by Stockdale showed depths to bedrock ranging from 1 ft to 25 ft. This range of thickness is probably typical of all units except units Ocha and Ochb [Units A and B].

Soils developed over Chickmauga Unit A are considered to be 100% Upland soils and those developed over Units B through G are 80% Upland soil and 20% colluvial soils or alluvial-colluvial deposits. A soil association map of the plant area is shown in Fig. 7. It should be noted that the soil in the Main Plant Area is a heterogeneous mixture of various soil types because of extensive construction and spill clean-up activities since 1965.

2.2.3.2 Soil geochemistry and mineralogy

Most of the soils present in the Oak Ridge Reservation soil survey are confined to certain geologic groups, each of which contains several formations. Each formation weathers chemically to form the distinctive parent materials of each kind of soil. Soil parent materials (regolith) are grouped into two major categories: residuum (the chemical weathering of in-place rock) and transported soil materials. The latter is further subdivided into colluvium (mostly preweathered soil materials identified from the source geologic group, transported downslope under the influence of gravity and water) and alluvium (soil materials transported and deposited by running water in floodplains and low stream terraces, even further separated into two classes based on their geologic age) (Lietzke et al. 1986). The principal underlying rock formations include (from the oldest to the youngest) the Rome formation, the Conasauga group, the Knox group, and the Chickamauga limestone, which underlies Bethel Valley where the ORNL complex lies.

Surveys of the soils of Anderson County (USDA 1981) and of Roane County (USDA 1942) and additional data from the National Cooperative

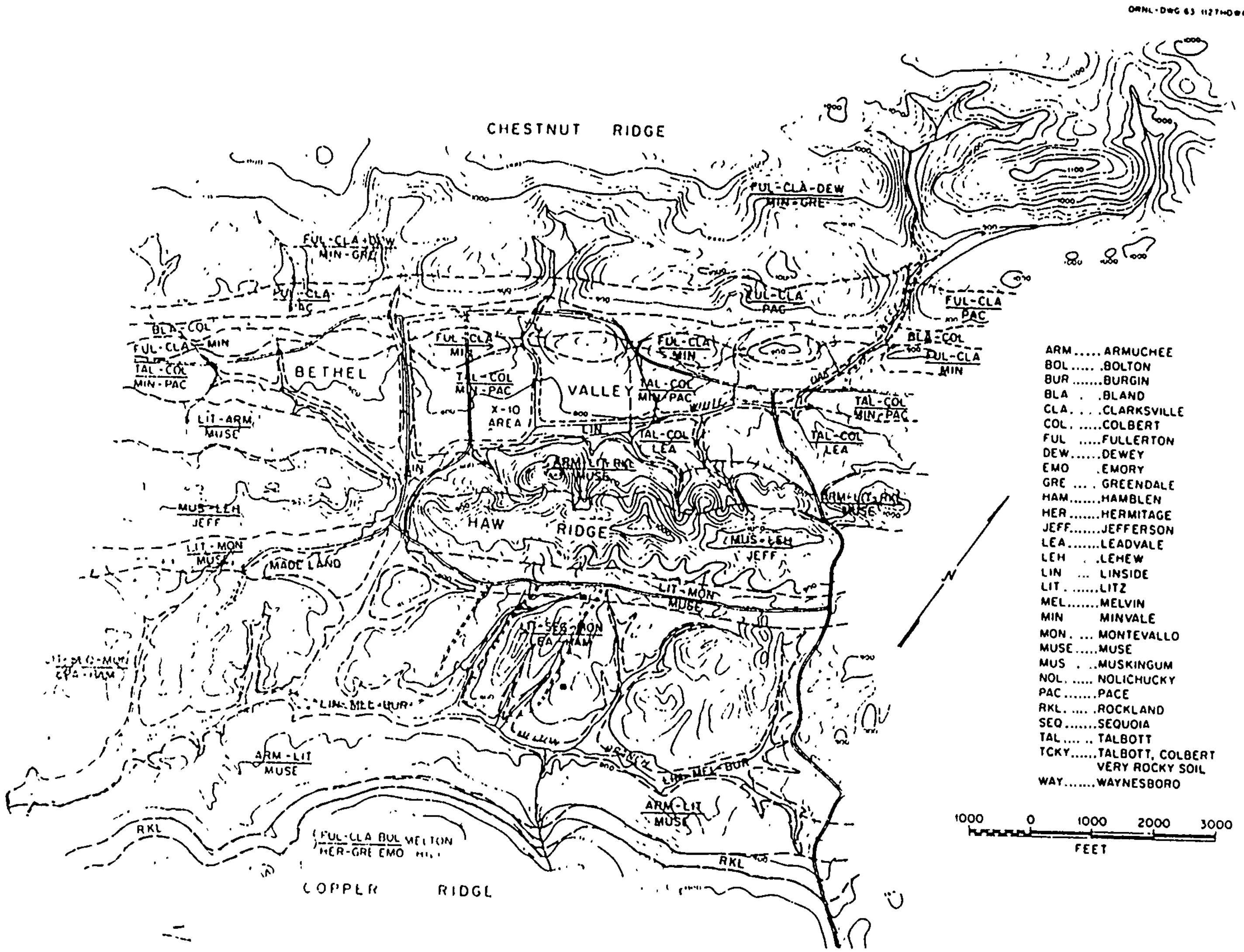

Fig. 7. Soil Association Map of White Oak Creek Drainage Basin.

Soil Survey Program (USDA 1967) were used to develop a soil map for the ORR that was limited in detail (Lietzke 1986). Though some generalizations may be made about the nature of the soils in the Reservation as the results of these surveys, the characteristics of soils are highly localized, and soil properties vary widely even within identical soil types. Soils are intimately related to the underlying rock, degree of weathering, hydrological conditions, slope, vegetation, and other factors. Residual soils also exhibit different characteristics after being disturbed by excavation and recompaction, a condition that exists in a large fraction of the main ORNL complex that comprises the WAG 1 area.

Most Chickamauga rocks are limestone, but the group also includes claystone and siltstone beds. Each Chickamauga rock type has distinct weathering patterns that are expressed in the soils of Bethel Valley. An important difference between Knox and Chickamauga carbonate rocks is the higher purity of the Chickamauga limestones. Another important difference between the two geologic groups is the bentonite contained in some formations in the Chickamauga Group. Little residue remains when these high-purity limestone rocks chemically weather. As a consequence, the soils are shallow to hard rock and typically have a very high clay content. Shale and siltstone members weather similarly, like their equivalents in the Conasauga soil group. The residual clays also contain bentonite, which is lacking in Knox or Conasauga soil clays (and which changes the clay mineralogy). Because of the high clay content and bentonite (which imparts high shrink-swell properties), these soils are less permeable and have a higher erosion potential. In general, Chickamauga soils contain less-weathered clay minerals of higher cation exchange capacity and also have higher shrink-swell characteristics than other soils on the ORR (Lietzke et al. 1986).

The soil produced by weathering of Chickamauga rocks typically consists of yellow, light reddish orange, or red clay containing variable amounts of chert. Chert is abundant enough in the lower layers to cause the development of a line of low hills on the northwestern sides of the valleys. This tendency is more pronounced in Bethel Valley, where the basal materials are composed of alternating siltstone beds and beds of blocky chert. The residuum soils derived from Chickamauga limestone contain a mixture of kaolinitic and illitic minerals, with some units having a significant amount of montmorillonitic clay minerals. The clay minerals are undersaturated with bases, leaving H^+ in the exchange positions of the clay. Base saturation varies from less than 10% to more than 60%. Generally illitic and vermiculitic clay minerals are more efficient in fixation of potassium and other comparable ions into less available positions than are the kaolinitic minerals. The total amount of fixation will depend on such factors as available surface area (as opposed to area available only through solid state diffusion) and the thickness of the soil column (Boyle et al. 1982).

The chemical properties of soils are important in engineering applications, in understanding processes of soil formation, in soil-plant relationships, and in waste disposal. Soil pH heavily influences corrosion of steel and the deterioration of concrete, and it conveys information about associated soil characteristics such as percent base saturation, phosphorous availability, and micronutrient availability or toxicity. Other properties that influence corrosion are soil drainage, clay content, specific ions, and conductivity of the soil solution. The corrosion hazard increases when soil boundaries are crossed, where the soil drainage changes, where pipe goes from one soil horizon to another, or where pipe goes through a disturbed zone in the soil. Deterioration of concrete pipes is related to soil texture and pH, the presence of sodium or magnesium sulfates, or the presence of sodium chloride (Lietzke et al. 1986).

Cation exchange capacity (CEC) is also a significant chemical property of soils; it is a measure of the soil's total capacity to retain positively charged ions, such as Cs^+ and Sr^{++}, on available sorption centers. The other important property related to nuclide holdup is the sorptive distribution coefficient (commonly referred to as k_D) that governs the ratio of nuclides sorbed on solid particles to that in solution and the subsequent holdup time. This property is necessary in determining a retardation coefficient for nuclide migration through geologic media. A considerable amount of information regarding these properties and others is available on the subject of soil characterization in Melton Valley because of the site characterization activities for SWSA 6 (Boegly 1984) and the proposed SWSA 7

(Rothschild et al. 1984). However, such information is not generally applicable to the main ORNL complex because the Melton Valley is underlain by the Conasauga Group, which produced a different residuum compared to the Chickamauga Group. Additional difficulties accrue in developing a localized soil map for the ORNL Complex because of the extensive excavation, filling, and recompaction over the years.

Based on a USDA (1967) survey, Lietzke et al. (1986) have determined ranges in the values of pH and the CEC corrosivity for the two principal clay series (the Gladeville and the Collegedale) that occur in the ORNL Complex. These values are tabulated in Table 9. Other geochemical properties are not available.

2.3 HYDROLOGY

2.3.1 Meteorology

2.3.1.1 Precipitation

The following precipitation data are derived from the Atmospheric Turbulence and Diffusion Division of the National Oceanic and Atmospheric Administration, located about 8 miles (12.9 km) northeast of the main plant area in the city of Oak Ridge. Additional data from on-site weather monitoring stations are available through the Department of Environmental Management.

The average annual precipitation (water equivalent) is 54.76 in. (139.09 cm) over the 29-year period from 1956 to 1985. For the year 1985 precipitation was less than average, with a total water equivalent value of 46.52 in. A period of drought extending through July 1986 is believed to have affected recharge to groundwater throughout much of East Tennessee. This drought is of note because a significant portion of the groundwater level data currently available for WAG 1 was collected during 1985-1986 and probably reflects diminished recharge. The impact of the normal precipitation pattern has on the ORR was described by D. A. Webster (1976). A high drainage density has developed, reducing the distance between points of groundwater recharge and discharge. Seasonally large stream flows are common, and groundwater occurs at

Table 9. Soil chemical properties.

	Corrosivity			Estimated CEC, (meq/100 g)	
	Steel	Concrete	pH range	Surface	Subsoil
Gladeville	high	low	6.6-8.2	20-40	40-80
Collegedale	high	mod-high	4.5-5.5	10-15	20-40

relatively shallow depths. Webster also noted that the amount of rainfall affects soil pH and the development of clay minerals.

2.3.1.2 Evapotranspiration

Insufficient information is available at this time to calculate evaporation and transpiration within WAG 1 accurately. Nevertheless, evapotranspiration estimates do exist for the reservation as a whole and for discrete study sites within the reservation. Webster (1976) estimated annual pan-evaporation losses to range from 41 to 43 inches. Other reports (Rothschild et al. 1984a; Martin Marietta Energy Systems, Inc. 1986) estimate annual evapotranspiration losses of 30 inches. In another study the Thornwaite-Mather technique was used to arrive at a figure of 5.7 in. for the months of November through April when evapotranspiration should be the least because of cooler temperatures and dormant vegetation (Ketelle and Huff 1984).

2.3.2 Surface Water

2.3.2.1 Drainage basin

WAG 1 lies within the Bethel Valley portion of the White Oak Creek drainage basin. The WAG boundary stops at the water gap in Haw Ridge, and for the purposes of this summary the drainage basin will be considered to end there as well. The boundaries of the basin extend to the southeast and northeast along Chestnut Ridge and Haw Ridge. The total area encompassed by the basin is about 2040 acres. White Oak Creek, its headwaters and northwest tributary, as well as First and Fifth Creeks are included in the basin.

White Oak, First and Fifth Creeks, and the proximal end of the Northwest Tributary pass through WAG 1. The Bethel Valley quadrangle (130-NE) shows a spring as the source for First Creek. The spring, located near the foot of Chestnut Ridge, has a potentially large recharge area. At the time this document was prepared no information was available regarding the discharge of the spring, and no field work was carried out in an effort to locate additional springs. First and Fifth Creeks collect runoff from the slopes of Chestnut Ridge and then course southeast through the plant area to their respective confluences with the Northwest Tributary and White Oak Creek. Both have similar gradients of about 4-5% at their headwaters and about 1-2% on their reaches within the plant (Fifth Creek is routed underground by means of concrete culverts at lower elevations in the plant area). White Oak Creek also originates on Chestnut Ridge, then flows southwest along the floor of Bethel Valley through the water gap in Haw Ridge. A review of maps made before plant construction indicates that minor modifications have been made to the stream beds of all three creeks. This fact is of note because the buried stream channels may influence the occurrence of groundwater.

2.3.2.2 Plant contribution to stream flow

The plant area has several major discharges to First, Fifth, and White Oak Creeks. These include (1) treated sanitary waste from the sewage treatment plant, (2) cooling tower blowdown, (3) cooling water, (4) process wastewaters, (5) surface runoff from storm sewers, (6) LLW collection and treatment system waters, and (7) demineralizer regenerant waste (Department of Environmental Management 1986).

An in-depth discussion of each discharge is beyond the scope of this document; however, a summary of the type of information available for the storm sewer system is offered here. The storm sewer system collects area runoff and water from roof drains, storm drains, and parking lot drains. Sampling of the outfalls indicates that there may also be process line leakage, building drain leakage, and seepage from previous spills entering the system, as well as leakage resulting from improper connections with other types of lines (Berry and Yook 1986). Figures 8-10 show the locations of the storm sewer outfalls. The outfalls are numbered as members of the 100, 200, or 300 series. The 100 series drains only rainwater, the 200 series drains building and parking lots but no process effluent, and the 300 series drains buildings and areas where the presence of untreated process wastes is indicated. Flow volumes for the storm sewer system are, of course, dependent on precipitation.

ORNL DWG 86-819

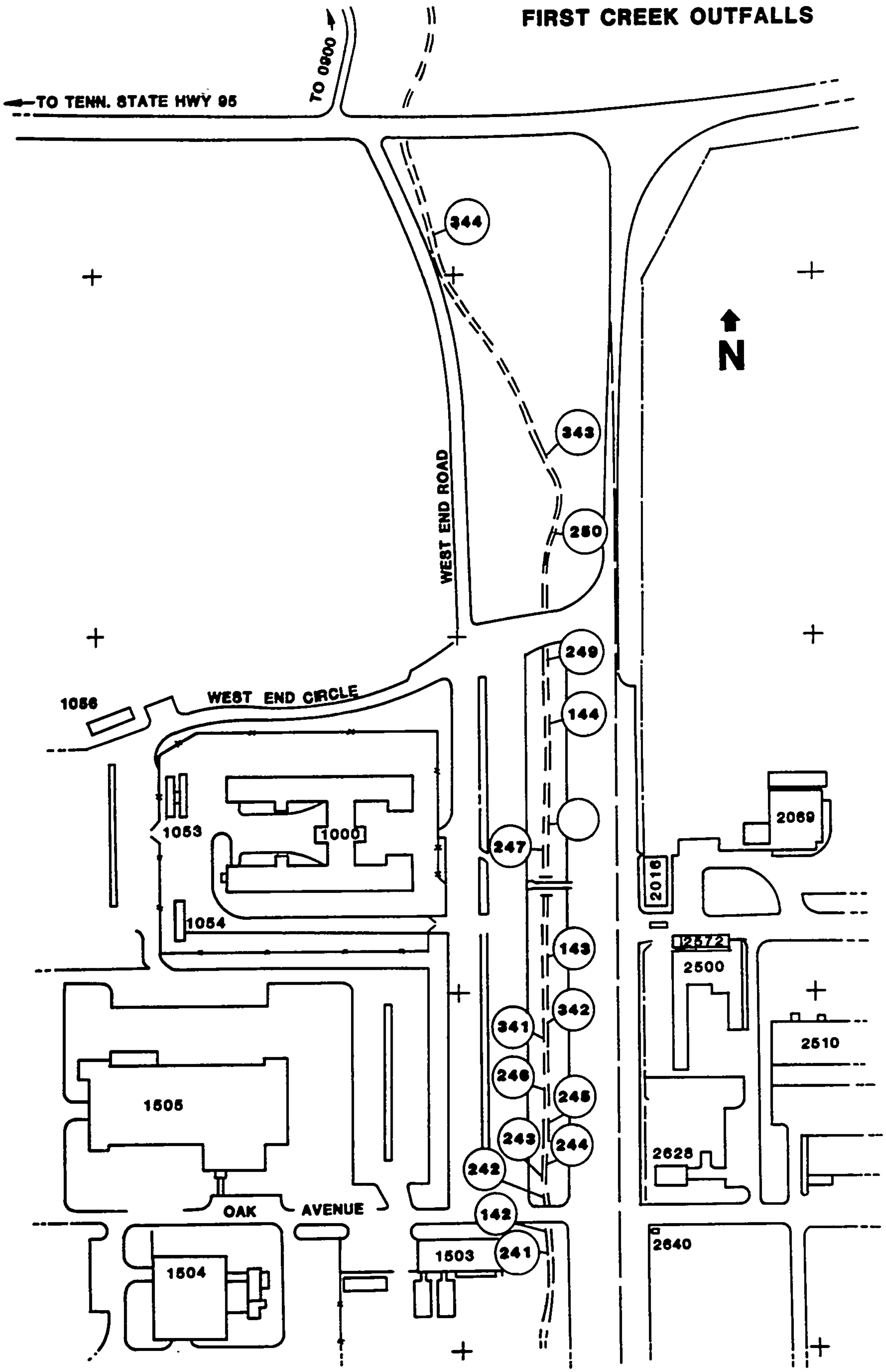

Fig. 8. First Creek storm sewer outfalls, Oak Ridge National Laboratory

ORNL DWG 86-816

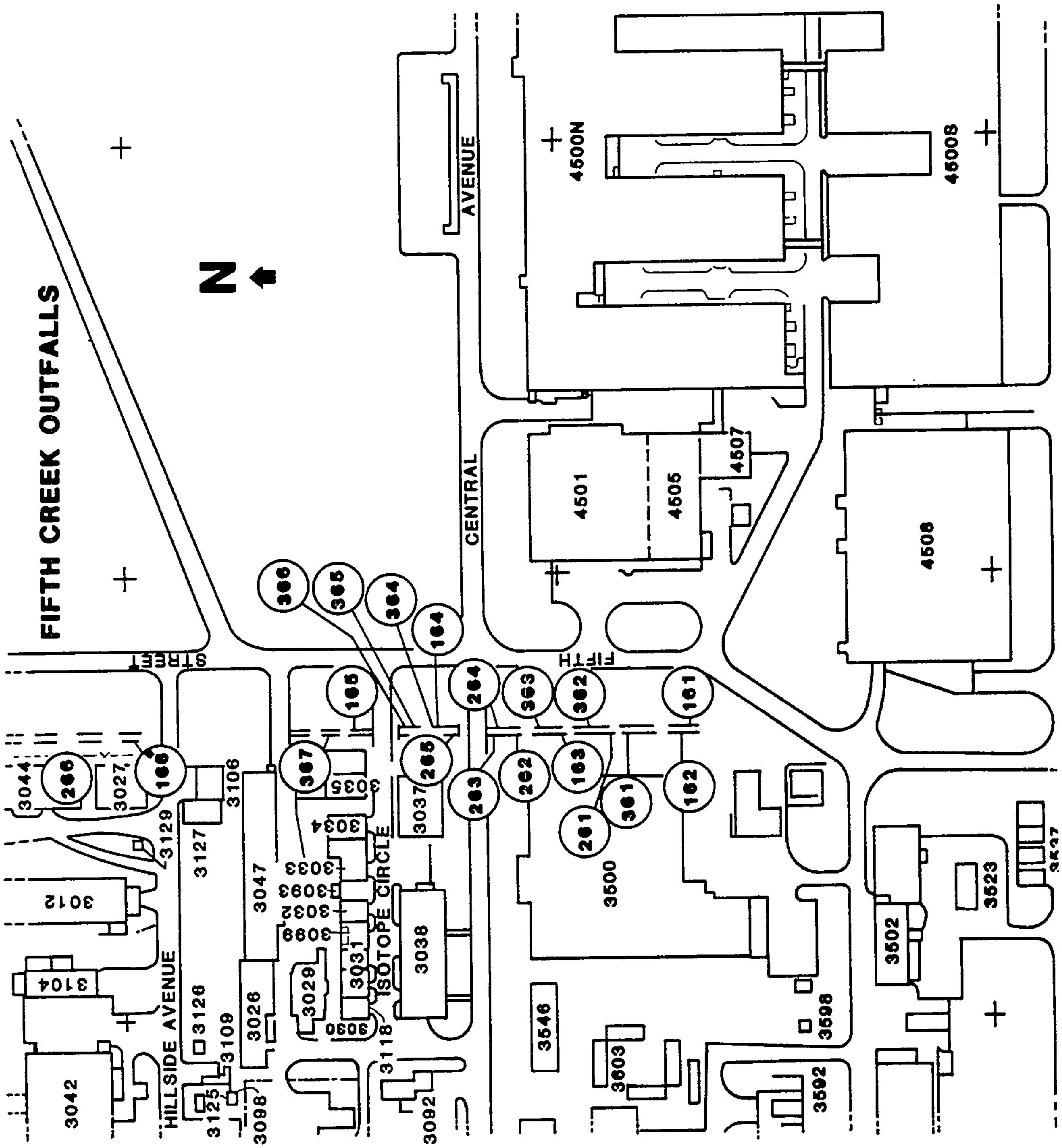

Fig. 9. Fifth Creek storm sewer outfalls, Oak Ridge National Laboratory

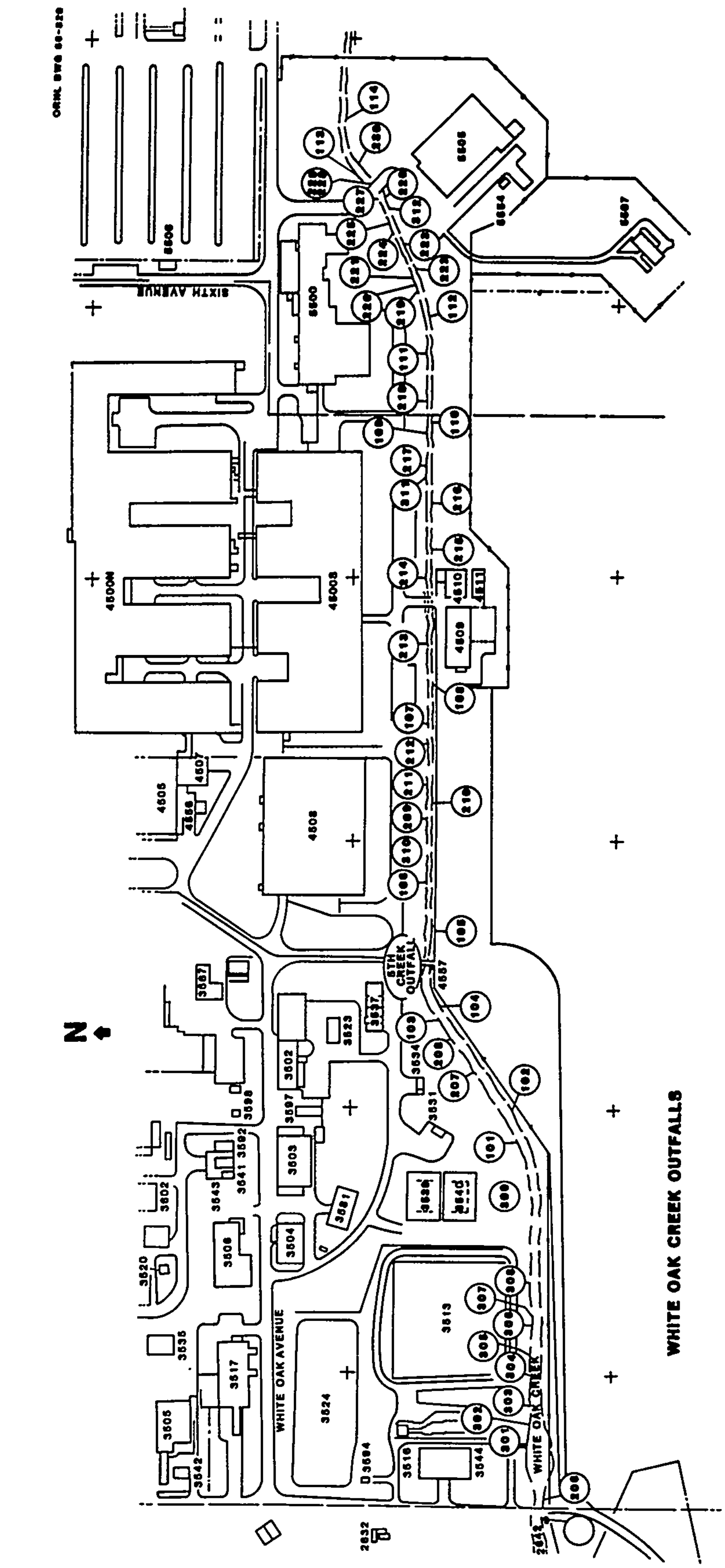

Fig. 10. White Oak Creek storm sewer outfalls, Oak Ridge National Laboratory

2.3.2.3 Stream monitoring and sampling efforts

Waste constituent concentrations and stream flow data are recorded in order to determine the impact of ORNL discharges on receiving creeks (data available through the Department of Environmental Management). In WAG 1 water samples are collected from First and Fifth Creeks and at White Oak Creek at the sewage treatment plant and the 7500 bridge (Fig. 11). The samples from First and Fifth Creeks are grab samples collected weekly, composited and analyzed monthly. The sewage treatment plant samples are flow proportional and are collected weekly, composited and analyzed monthly. The 7500 bridge samples are flow proportional and are collected and analyzed daily for radionuclides. Flow proportional samples from this station are also collected weekly and analyzed monthly for additional parameters (Department of Environmental Management 1986).

In addition to the stream sampling program, seven point source outfalls are monitored within WAG 1 in accordance with NPDES standards (Department of Environmental Management 1986). The following are tabulations of these point sources:

X01 - Sewage Treatment Plant
X02 - Coal Yard Runoff
X04 - 2000 Area
X06 - 3539 and 3540 Ponds
X07 - Process Waste Treatment Plant
X10 - ORR Resin Regeneration Facility
X11 - Acid Neutralization Facility

The parameters monitored at each point source vary according to the type of waste stream. The analyses, summarized monthly, are available through the Department of Environmental Management. An example of the parameters monitored for the 2000 Area is shown in Appendix I.

2.3.2.4 Availability of surface water quality information

Surface water quality measurements are made primarily by the Department of Environmental Management (DEM). Typically the scope of this work includes the entire Oak Ridge Reservation or the ORNL complex as a whole. Information focused on WAG 1 must be gleaned from summary documents of these large scale efforts or from sorting through raw data. The Environmental Sciences Division also has some surface water quality data.

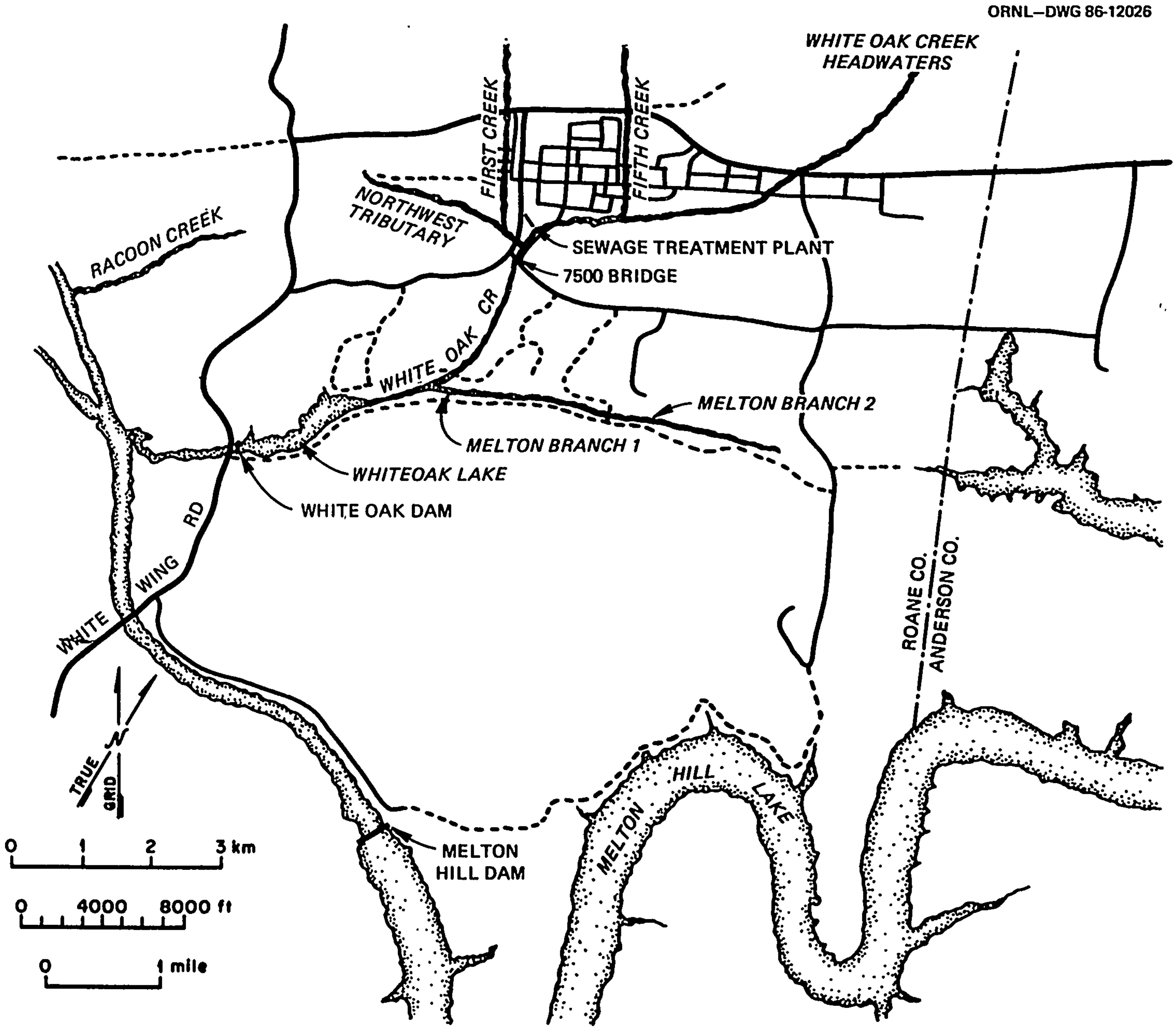

Fig. 11. Location map of ORNL streams

2.3.3 Groundwater

2.3.3.1 Previous investigation

Previous studies (Stockdale 1951; Webster 1976) provide the most comprehensive evaluation of geology and groundwater occurrence in the ORNL area. Stockdale's report characterizes the local stratigraphy with special regard to plant waste disposal practices and groundwater. Of particular interest is the drilling program carried out by Stockdale. On the basis of the drilling and core logs, Stockdale describes a secondary porosity consisting of solution cavities "an inch or so in diameter; the largest ... about 1 foot."[1] Pressure tests on the angle hole beneath the 3513 pond indicated communication between the solution cavities and the pond. The drill hole was tested in 5-ft intervals under 100 lbs of air pressure. Four zones that lost air pressure occurred in the upper 50 ft of the hole, and air bubbles were observed on the surface of the pond. Below the 50 ft level other intervals also lost pressure, but sufficient control of the equipment could not be maintained to determine the exact location of the interval.

Stockdale (1951) also observed that holes that penetrated the Copper Creek fault exhibited a tightly cemented breccia and gouge. On this basis, he judged the fault zone to be an impervious barrier to horizontal groundwater flow. Similarly, he describes Unit F of the Chickamauga limestone to be a "stratigraphic trap" for groundwater and implies that the Rome formation may also serve to retard horizontal groundwater flow. Many of his findings are still relevant to current site conditions. For example, White Oak Creek and its tributaries are believed to be outflow with respect to groundwater; the uppermost aquifer underlying the plant/WAG 1 is unconfined, and recharge to the area occurs primarily through the infiltration of meteoric waters. Stockdale's report also includes a water table map (Appendix II). This map depicts the groundwater surface as a subdued replica of the overlying

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[1] Recently, drilling for the installation of a piezometer network within the plant has revealed similar-sized solution cavities, as well as two larger ones.

surface topography with minor distortions attributed to recharge from the 3500 series ponds.

While it is common practice to plot groundwater movement on the basis of maps such as Stockdale's, Webster (1976) describes pitfalls associated with this type of procedure in the Oak Ridge area. He cautions that the anisotropic qualities of the bedrock aquifer limit the usefulness of phreatic surface maps when applied to movement estimates at depth. Using data from core logs and Stockdale's pressure tests, Webster (1976) concluded that solution cavity size and frequency of occurrence diminished with depth. He inferred that the circulation of groundwater in the Chickamauga group may be restricted to the upper several hundred feet.

2.3.3.2 Summary of current monitoring and data collection efforts

Present study of groundwater occurrence and movement in WAG 1 is focused on the installation of a piezometer network. The piezometers are located on the basis of providing complete areal coverage and investigating areas suspected to have contamination. Most of the piezometers are constructed of 2-in.-diameter, flush-threaded PVC with a screened interval of 5 ft or more (Ketelle et al. 1986). The majority of the piezometers monitor water levels in the upper portion of the saturated zone. This zone typically occurs at or near the soil/bedrock interface on the lower slopes of WAG 1 but may occur well below the top of rock at higher elevations. Eighty-four piezometers have been completed in WAG 1 (Fig. 12). Construction information such as the total depth, screened interval, sandpacked interval, elevation of bentonite seal, and grouted annulus are kept on file and are available through the Remedial Action Program (Voorhees et al. 1987). Drill logs, schematic construction drawings, and piezometer hydrographs are also available. Examples of these materials are shown in Appendix III.

In addition to the piezometer network, 14 RCRA compliance monitoring wells are in place around the 3524, 3539, and 3540 ponds. A detailed report of the well installation procedures and an evaluation of local groundwater occurrence, including a potentiometric map, was prepared by MCI Consulting Engineers, Inc.

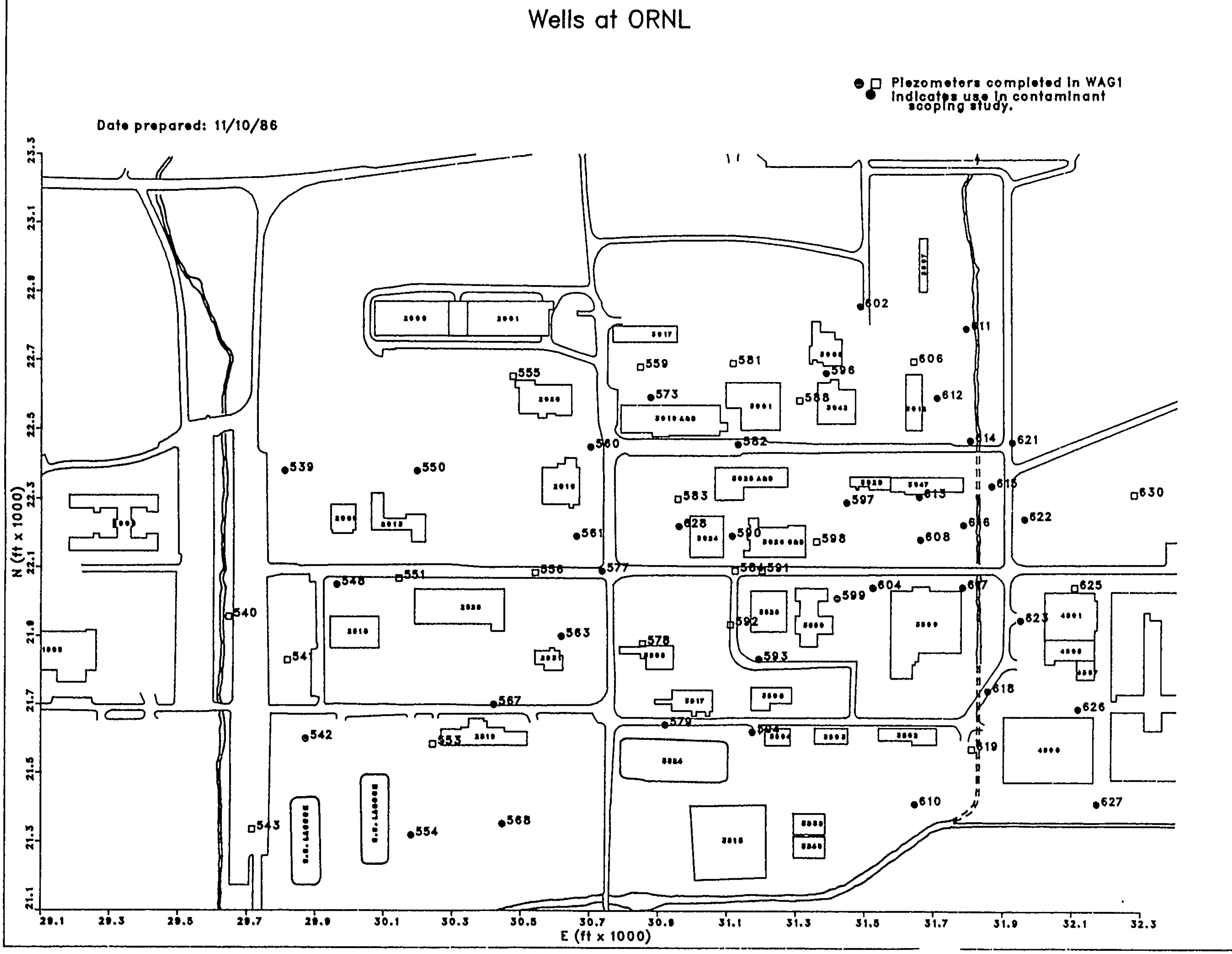

Fig. 12. Wells at the Oak Ridge National Laboratory

2.3.3.3 Mapping Programs

The piezometer drilling program has provided a large data base of depth to bedrock and water level elevations. These data have been used to plot contour maps of both of these surfaces for a large part of WAG 1. The plots are prepared using the CONTUR program (Patterson 1978), which established contours based on linear interpolation between randomly spaced data points. The contours are projected onto digitized maps showing major plant features. The locations of underground tanks, leak/spill sites, contaminated facilities, and solid waste storage areas have been digitized and are optional features on the base map. Selected water quality parameters can also be displayed on these maps (Ketelle et al. 1986). Figure 13 shows an example of the piezometric surface plot.

2.3.3.4 The influence of plant structure and operations on groundwater

The natural groundwater regime of WAG 1 appears to have been affected by the construction of subsurface piping, sumps, and tank farms. A large portion of the plant area is underlain by a complex system of piping, much of which has been abandoned or is of poor integrity (Berry and Yook 1986). For example, it has been estimated that as much as 50% of the water traveling through process wastewater treatment lines every month is attributable to surface water and groundwater input. The lines were reportedly constructed of vitrified clay piping in the 1940s, with expansions to the system in the 1950s and 1960s. In 1986 smoke testing and televiewing of selected sections of the lines revealed poor connections at pipe intersections, offset joints, and crushed segments of pipe (Berry and Yook 1986). These sections are subject to inleakage where they are located below the water table. In some instances the locations of inleakage are known; they are given in Fig. 14.

Groundwater is also believed to enter the LLW system. Suspected inleakage locations are shown in Fig. 15. The storm sewer system may also serve to divert groundwater, as well as leakage from other lines. The above piping systems were typically installed with gravel backfill, which offers ground water yet another artificial flow route. Building sumps (notably in Bldg. 3042), foundations, and building drains further

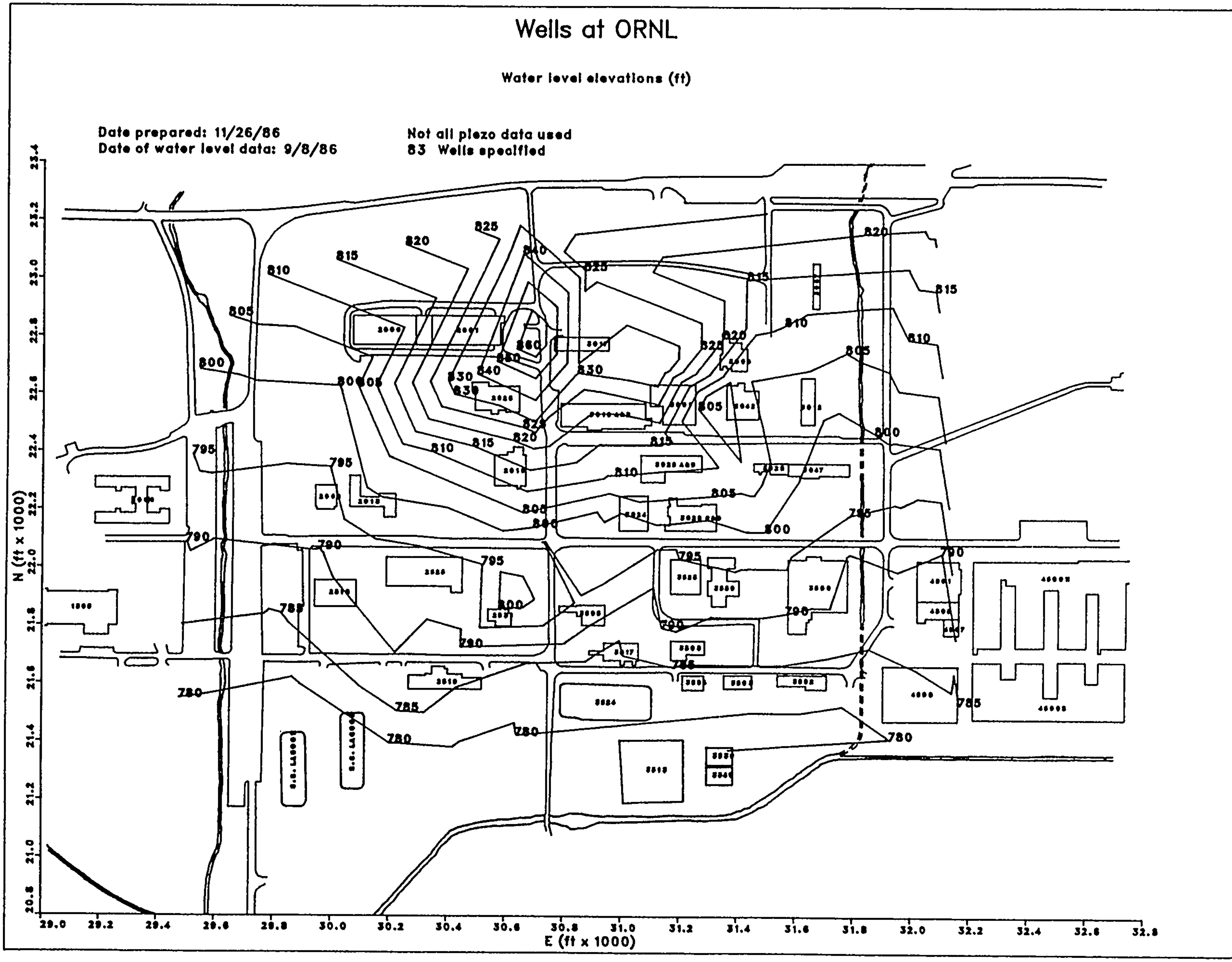

Fig. 13. Wells at ORNL, showing water level elevations in feet

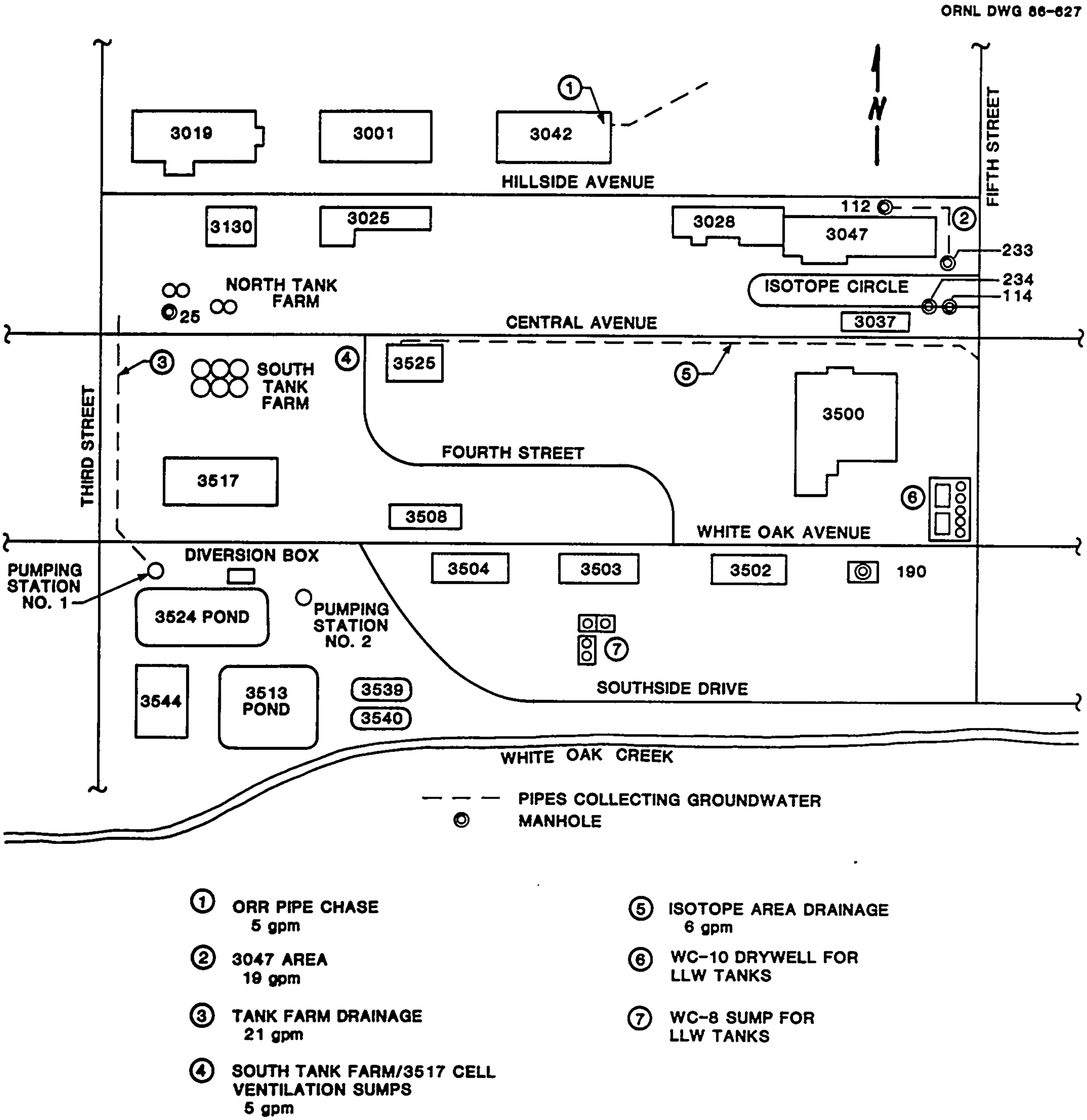

Fig. 14. Locations of inleakage to the process wastewater system in Bethel Valley

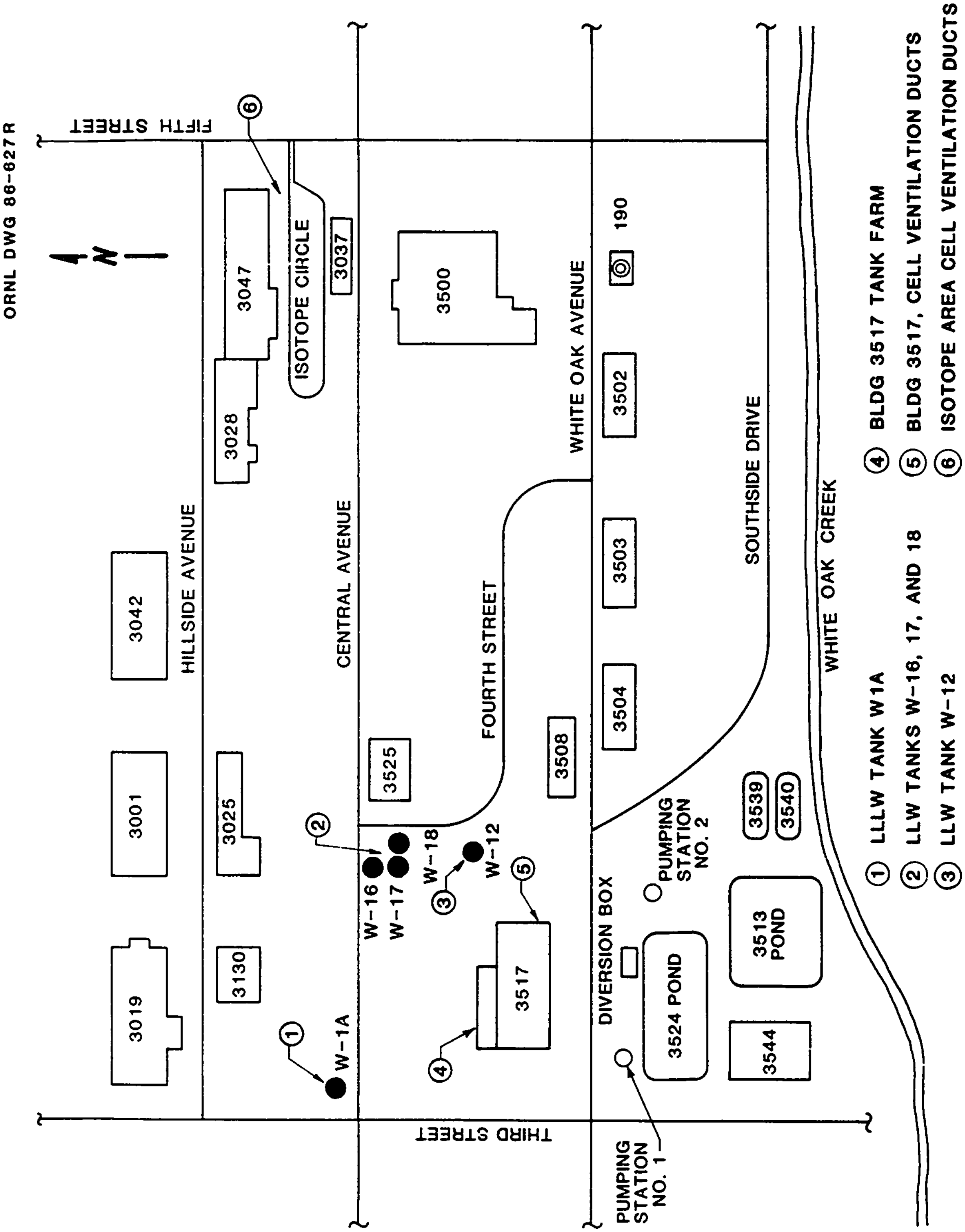

Fig. 15. Groundwater inleakage to the LLW System

complicate local groundwater movement. Studies to investigate these alternate flow routes are being considered, and field work has begun on lining damaged pipeline sections.

Not all plant structures act to collect or divert ground water. The 3500 series ponds are unlined and probably act to recharge groundwater. Similarly, piping of poor integrity located above the water table may provide recharge.

2.3.3.5 Evaluation of groundwater movement

Groundwater movement in WAG 1 may be estimated by constructing flowlines normal to the equipotential isopleths on the plant area water table maps. Flow diagrams of this type indicate that groundwater moves from the potentiometric highs at the crest of the hill in WAG 1 towards potentiometric lows at the base of Bethel Valley, probably providing base flow to White Oak Creek and its tributaries. This description is probably valid for saturated flow in the soils where they are unaffected by buried structures. The bedrock aquifer is believed to be heterogeneous and anisotropic, consisting of fractured siltstone, shale, and solutionally weathered limestone; thus, the applicability of the simple flow diagram analysis described above is restricted. Insight into groundwater movement in the bedrock aquifer may be gained from Stueber and Webster (1981). That document describes a study of groundwater movement and radionuclide migration in the vicinity of SWSA 3; which lies outside of WAG 1 but occurs within the same Chickamauga strike belt. A potentiometric surface map of SWSA 3 indicated that flow should be to the north, directly toward the constant head boundary described by the northwest tributary of White Oak Creek. However, it appears from profiles of radionuclide activity in the creek that groundwater flow was skewed to the northeast along the strike. Furthermore, the location of highest activity is coincident with the contact between Chickamauga units G & F. This observation lends support to both Stockdale's suggestion that unit F plays an important role in groundwater movement and to Webster's caution regarding the use of piezometric maps to predict groundwater flow in bedrock aquifers.

Dye tracing studies (Huff 1985) within WAG 1 also demonstrate preferred groundwater movement along geologic strike. In February

1985, an LLW transfer line leak was identified at the point between Buildings 3074 and 3019. The break was coincident with what was described as an extensive cavity in the underlying bedrock. In an effort to determine LLW migration routes, a permeable riser pipe was placed in the cavity as a dye injection point. Fluorescein dye was introduced into the pipe/cavity and monitored at various locations within the plant by means of adsorbent charcoal packets.

It was discovered that the dominant pathway for groundwater-borne fluorescein was northeast, along strike to a sump in Building 3042. There is a hydraulic gradient from the line break to the sump of about 20 ft over a distance of about 450 ft. The gradient appears to be induced in part by the sump itself but may also reflect a low area in the bedrock surface. Dye was also observed in relatively smaller amounts at other locations along strike to the northeast and downslope.

2.3.3.6 Hydraulic conductivity

Hydraulic conductivity tests have been conducted on the wells monitoring the 3500 series ponds (Fig. 16). The conductivity values were calculated using the Bouwer and Rice method for partially penetrating wells in an unconfined aquifer. Conductivity values for eleven of the wells are summarized in Table 10.

2.3.3.7 Groundwater quality

Groundwater quality in the vicinity of the 3500 series ponds is monitored by 14 RCRA compliance wells (Fig. 16). The wells are designated as upgradient or downgradient with respect to their observed static water levels and their locations relative to the ponds. The upgradient wells (31-001, 31-007 and 31-009) provide background samples that are not significantly affected by the ponds (Department of Environmental Management 1986). The downgradient wells monitor groundwater for waste constituents that may exit the ponds. The wells were sampled for four consecutive quarters in 1985-1986. Analyses were performed for drinking water parameters, water quality parameters, and parameters used as indicators of contamination in accordance with state and federal regulations.

Table 10. Hydraulic conductivity values for wells monitoring 3500 series ponds

Well No.	Map No.	Hydraulic conductivity cm/sec	Hydraulic conductivity m/d
6	31-007	1.6×10^{-4}	0.14
7	31-009	4.4×10^{-4}	0.38
8	31-008	7.0×10^{-4}	0.60
9	31-006	6.9×10^{-5}	0.060
10	31-005	5.4×10^{-4}	0.467
11	31-001	9.6×10^{-5}	0.083
12	31-002	5.9×10^{-5}	0.051
13	31-003	1.3×10^{-4}	0.11
14	31-004	1.7×10^{-5}	0.027
15	31-010	7.6×10^{-5}	0.066
16	31-012	1.4×10^{-4}	0.12

Note: Hydraulic conductivity was calculated by the Bouwer and Rice method, 1976.

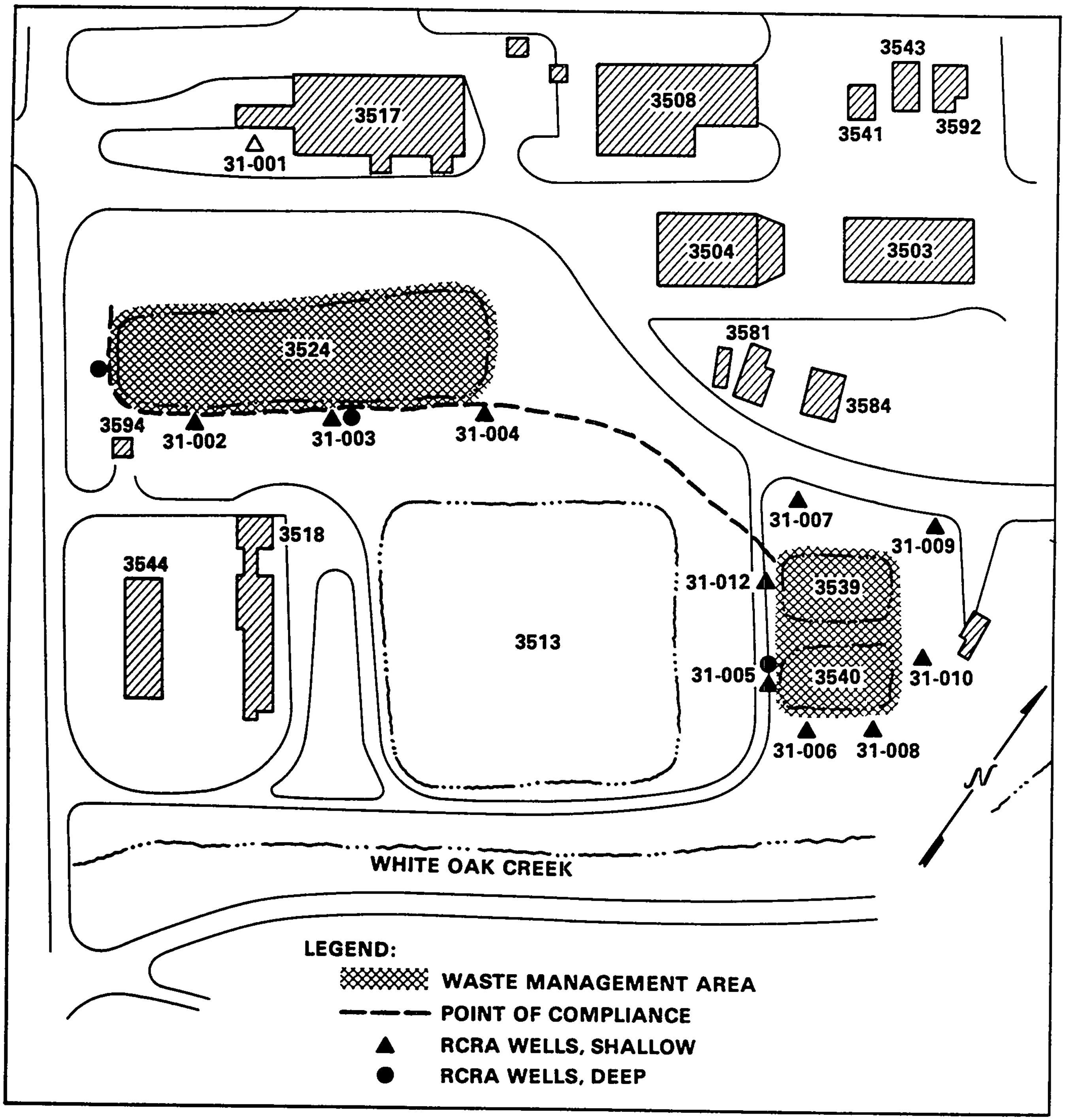

Fig. 16. Locations of sampling wells around ponds 3534, 3539, and 3540

Summary concentrations for each parameter are given in Tables 11 and 12.

In addition to RCRA monitoring, a contaminant scoping survey of selected piezometers was carried out. The survey is a one-time sample collection and analysis to be used along with piezometer water level data in developing an understanding of groundwater movement and contaminant transport (Ketelle et al. 1986). The survey includes analyses for those parameters listed in Table 13. The locations of piezometers within WAG 1 which were used in the survey are shown in Fig. 12.

2.3.3.8 Summary of groundwater quality

The chemical composition of the ambient (uncontaminated) surface waters and groundwaters is needed to characterize the geochemical properties of any site. The chemical composition (concentration of Na^+, K^+, Mg^{++}, Ca^{++}, Cl^-, SO4, HCO3, etc.) and the solution parameters (pH and Eh) play important roles in determining the contaminant leachability from wastes contacted by site water and in establishing the mobility of solubilized contaminants in groundwater. Such data for the groundwaters of the main ORNL complex are lacking, although considerable data are available for the Oak Ridge Reservation.

In general, groundwater quality on the Oak Ridge Reservation is similar to the groundwater quality of the parts of the Valley and Ridge Physiographic Province of which Bethel Valley is a part. The water quality of surface streams in relatively undisturbed water sheds under low flow conditions usually reflects the quality of the groundwater within the watershed. Chemical analyses of samples from eight area streams show some variations in water quality, which may be attributable partly to groundwater quality variations and partly to contaminant sources within some watersheds (Boyle et al. 1982). Other data exist for the SWSA 6 area (Davis et al. 1984; Vaughan et al. 1982) and the SWSA 5 area (Boyle et al. 1982) which are both located in Melton Valley, but the applicability of these data to a Bethel Valley site can be questioned.

Table 11. Concentrations of parameters in wells around 3539-40[a]

Parameter	No. of Samples	Concentration (mg/L) Max	Min	Av	95% cc[b]
2,4,5-TP Silvex	14	<0.01	<0.01	<0.01	0.0
2,4-D	14	0.06	<0.01	<0.014	0.0
Ag	14	<0.005	<0.005	<0.005	0.0
As	14	<0.01	<0.01	<0.01	0.0
Ba	14	<1.0	<1.0	<1.0	0.0
Cd	14	<0.002	<0.002	<0.002	0.0
Cl	14	17	5.2	8.2	1.7
Cr	14	0.032	<0.02	<0.021	0.0017
Endrin	14	<0.0002	<0.0002	<0.0002	0.0
F	14	<1.0	<1.0	<1.0	0.0
Fe	14	5.9	0.052	1.8	0.84
Fecal coliform[c]	14	0.0	0.0	0.0	0.0
Gross alpha[d]	14	0.52	0.03	0.23	0.0023
Gross beta[d]	14	2.0	0.081	0.74	0.01
Hg	14	<0.0001	<0.0001	<0.0001	0.0
Lindane	14	<0.002	<0.002	<0.002	0.0
Methoxychlor	14	<0.008	<0.008	<0.008	0.0
Mn	14	10	0.01	4.4	2.0
Na	14	220	4.8	26	31
NO_3	14	<5.0	<5.0	<5.0	0.0
Pb	14	1.2	0.02	0.10	0.17
pH[e]	98	13	6.5	7.6	0.29
Phenols	14	0.003	<0.001	<0.002	0.0004
Ra (Total)[d]	14	0.17	0.011	0.03	0.0007
Se	14	<0.005	<0.005	<0.005	0.0
SO_4	14	250	<5.0	<6.5	39
Specific conductance[f]	98	1.0	0.01	0.38	0.044
Temperature[g]	98	20	13	16	0.26
Total organic carbon	56	23	1.6	5.1	1.4
Total organic halides	56	0.093	<0.005	<0.005	0.0
Toxaphene	14	<0.005	<0.005	<0.005	0.0

[a] Source: Department of Environmental Management (1986)
[b] 95% confidence coefficient about the average.
[c] Units are colonies per 100 mL.
[d] Units are Bq/L.
[e] Value in pH units.
[f] Units are in mmhos/cm.
[g] Units are in ^{o}C.

Table 12. Concentrations of parameters in wells around 3524[a]

Parameter	No. of Samples	Concentration (mg/L) Max	Min	Av	95% cc[b]
2,4,5-TP Silvex	10	<0.01	<0.01	<0.01	0.0
2,4-D	10	<0.01	<0.01	<0.01	0.0
Ag	10	<0.005	<0.005	<0.005	0.0
As	10	<0.01	<0.01	<0.01	0.0
Ba	10	<1.0	<1.0	<1.0	0.0
Cd	10	<0.002	<0.002	<0.002	0.0
Cl	10	11	4.7	7.0	1.3
Cr	10	0.02	<0.02	<0.02	0.0
Endrin	10	<0.0002	<0.0002	<0.0002	0.0
F	10	<1.0	<1.0	<1.0	0.0
Fe	10	1.5	0.08	0.46	0.3
Fecal coliform[c]	10	14	0.0	1.4	2.8
Gross alpha[d]	10	52	0.011	7.8	0.29
Gross beta[d]	10	220	0.30	52	1.4
Hg	10	<0.0001	<0.0001	<0.0001	0.0
Lindane	10	<0.002	<0.002	<0.002	0.0
Methoxychlor	10	<0.01	<0.01	<0.01	0.0
Mn	10	4.0	0.07	1.3	1.0
Na	10	30	14	20	3.0
NO_3	10	<5.0	<5.0	<5.0	0.0
Pb	10	0.05	<0.02	<0.02	0.01
pH[e]	70	8.2	7.2	7.5	0.05
Phenols	10	0.002	<0.001	<0.0013	0.0
Ra (Total)[d]	10	0.037	<0.011	<0.015	0.0002
Se	10	<0.005	<0.005	<0.005	0.0
SO_4	10	100	19	52	21
Specific conductance[f]	70	0.49	0.03	0.23	0.02
Temperature[g]	70	22	8.8	16	0.78
Total organic carbon	40	3.8	1.1	2.4	0.22
Total organic halides	40	0.07	0.01	0.03	0.0
Toxaphene	10	<0.005	<0.005	<0.005	0.0

[a] Source: Department of Environmental Management (1986)
[b] 95% confidence coefficient about the average.
[c] Units are colonies per 100 mL.
[d] Units are Bq/L.
[e] Value in pH units.
[f] Units are in mmhos/cm.
[g] Units are in °C.

Table 13. Chemical parameters included in the contaminant scoping survey

Cations

Ag	Cu	Pb
Al	Fe	Sb
As	Ga	Se
B	Li	Sn
Ba	Mg	Sr
Be	Mn	Ti
Ca	Mo	V
Cd	Na	Zn
Co	Ni	Zr
Cr	P	

Anions measured by ion chromatography

Br	NO_3
Cl	PO_4
F	SO_4

Anions measured by titration

CO_3	HCO_3

Radiological Parameters

Tritium	Gross beta
Gross alpha	Gamma scan

Organic parameters

Total Organic Carbon (TOC)

Volatile Compounds

acrolein
acrylonitrile
benzene
carbon tetrachloride
chlorobenzene
1,2-dechloroethane
1,1,1-trichloroethane
1,1-dichloroethane
1,1,2-trichloroethane
1,1,2,2-tetrachloroethane
chloroethane
2-chloroehtylvinyl ether
chloroform
1,1-dichloroethene
trans-1,2-dichloroethene
1,2-dichloropropane
trans-1,3-dichloropropene
cis-1,3-dichloropropene
ethylbenzene
methylene chloride
chloromethane
bromomethane
bromoform
bromodichloromethane
fluorotrichloromethane
dichlorodifluoromethane
chlorodibromomethane
tetrachloroethene
toluene
trichloroethene
vinyl chloride

2.4 ENVIRONMENTAL MONITORING

A description of the surface water and groundwater monitoring stations and sampling points for radiological and NPDES requirements are provided in "Environmental Surveillance Data Report of the Second Quarter of 1986" (Department of Environmental Management 1986). For WAG 1, there are 4 monitoring stations (First Creek, 7500 Bridge, Sewage Treatment Plant, and Fifth Creek) for radioactivity discharges, and 7 stations (Sewage treatment Plant, Coal Yard Runoff Treatment Facility, 2000 Area, 190 ponds, Process Waste Treatment Plant, ORR Resin Regeneration Facility, and the Acid Neutralization Facility) for NPDES point source monitoring. In addition, the NPDES permit requires monitoring of storm drains (35 sites), Category II outfalls (61 sites), Category III outfalls (32 sites), miscellaneous sources (35 sites), and ambient monitoring at Melton Branch 1, White Oak Creek, and White Oak Dam. Additional monitoring points are included in the NPDES permit to cover sources outside of WAG 1.

As indicated earlier, the only wells drilled in the WAG 1 area have been installed as a part of the RAP (mainly since 1985). At the present time there are 14 wells drilled in the vicinity of the 3524 (SWMU 1.13), 3539 (SWMU 1.14), and 3540 (SWMU 1.15) ponds; they were installed to meet the requirements of 40 CFR, Part 265, Subpart F (see Fig. 9). These wells are being sampled on a quarterly basis and analyzed for drinking water parameters, water quality parameters, and groundwater contamination parameters (Department of Environmental Management 1986). Studies are currently underway to develop background information for the selection of additional groundwater quality wells.

3. ADDITIONAL INFORMATION REQUIREMENTS FOR WAG 1

3.1 SOURCE TERM

More detailed information on the the source term(s) in WAG 1 will be required before any pathways analyses or performance assesments ar performed for WAG 1.

As indicated in Section 2.1 (Table 5), little is known about the amount of radioactivity present in a large number of SWMUs, and for those for which data are available, most of the inventory figures are based on one set of analyses. Furthermore, essentially no information is available on the hazardous chemical content of the SWMUs.

At the present time many of the samples removed from the LLW collection and storage tanks at ORNL must be diluted so that the samples can be handled in existing analytical facilities. This dilution prevents determination if many of the nonradioactive contaminants are present above the allowed RCRA limits (Peretz et al. 1986). This problem needs to be resolved quickly so that tanks (and other SWMUs) representing potential sources of hazardous waste contaminants can be identified. Based on existing information, it appears that radioactivity is a greater problem than nonradioactive hazardous chemicals in most of the identified SWMUs.

Some of the sites in WAG 1 are known to be hazardous chemical spill sites (SWMU 1.1 to 1.4), and a limited soil sampling program has been performed to evaluate the extent of the contamination (Saylor 1986). Additional soil sampling should be undertaken to provide current information on the extent and amount of mercury contamination remaining at these sites. Also, SWMU 1.4 has been placed on the list (Table 1), even though a soil survey was not performed in the area and only limited mercury usage has been reported.

ORNL does not routinely sample its active tanks (those currently in use) to determine the radionuclide or hazardous chemical content; the reason is that tank contents fluctuate because of the addition and removal of wastes. As a result, there is no available information on sludges or other residual materials that may be present in these tanks

(Table 5). It is suggested that a sampling program be initiated to define the composition of any residuals in active tanks so that estimates can be made of the radioactive and hazardous chemical content of the waste.

Additional "walk-over" surveys and soil sampling should be done to obtain additional information on the areal extent of the leak/spill sites in WAG 1. Some information has been obtained for radionuclides, but little is known about chemically hazardous contaminants. These two techniques offer a relatively simple approach to defining the extent of contamination.

3.2 GEOLOGY AND SOILS

3.2.1 Geophysical Testing and Core Drilling

The extensive set of geophysical logs and rock cores recently obtained from the five new core holes will be analyzed to help determine the nature of Chickamauga lithofacies and secondary lithologic features that may contribute to groundwater movement in both the weathered, near-surface rocks and the unweathered, deeper rock. The extent to which geophysical techniques can adequately describe pertinent lithologic features relevent to groundwater movement in the Chickamauga will also be determined. The results of the analyses of the existing geophysical logs will determine the necessity for additional geophysical testing in the future. Based upon the results obtained from analyzing the existing rock core, further deep drilling may be indicated in the future at other locations in the plant area. A future drilling program would be designed so that data could be correlated with the previous core drilling.

Drilling could also be planned to investigate areas in which known or suspected waste spills or leaks have occurred in the past. Until the existing core is analyzed, however, it is premature to begin further drilling.

3.2.2 Soil Testing

The actual data requirements for the soils located in the ORNL complex (WAG 1 area) will be a function of the type of remedial action that is taken to mitigate any contamination by hazardous material. This could vary from complete removal to entombment in situ of contamination at very localized sites. As previously discussed in Sect. 2.2.3.2, detailed information on the soils of the ORNL complex is essentially non-existent. In characterizing the site, it is necessary to develop a detailed soil map, determining for each soil type (1) the mineralogic analysis and the sorptive properties for various nuclides and (2) the physical and engineering properties. The requirements for characterization are similar to the characterization plan developed for SWSA 6 (Oak Ridge National Laboratory 1985), which is the basis for the following discussion.

3.2.2.1 Soil map

Although soil surveys and limited maps exist for Anderson (USDA 1981) and Roane (USDA 1967) counties, the detail is insufficient for characterizing soils in the ORNL complex, particularly in view of the extensive excavation, filling, and recompaction that have occurred over the existence of the Laboratory. A detailed soil map should be developed, classifying the regolith and residuum, the alluvium and colluvium deposits, and the weathered upper layers containing organics. The fill and recompacted areas, excavations, and other earth-moving construction efforts should be identified and classified.

3.2.2.2 Mineralogy

The mineral composition of clays helps identify the parent rock and influences the physical, chemical, and sorptive properties of the soil. A number of techniques can be used to analyze case samples for their mineral content; petrography and X-ray diffraction are the most widely used. Scanning electron microscopy (SEM), electron microscopy, and transmission electron microscopy (TEM) are also used at ORNL. A detailed mineralogic characterization of the West Chestnut Ridge soils has been made for the proposed site of the Central Waste Disposal

Facility (Lee et al. 1984). The study developed profiles for the site, including morphological, physiochemical, and mineralogical properties. The results are not directly applicable to the WAG 1 area, but they can serve as a guide for a similar study. Some mineralogic analyses were also made for the SWSA 6 (Davis 1984) and the SWSA 7 areas (Rothschild 1984b), but they are limited in extent compared with the West Chestnut Ridge study.

3.2.2.3 **Sorptive properties (retardation)**

Migration of radionuclides or hazardous materials in the dissolved state can be retarded by sorption on the soil particles. The sorption reactions may be ion exchange (usually reversible and rapid), chemisorption (sometimes poorly reversible and slow), and surface adsorption (usually more important for nonionic species) (Boegly et al. 1985). The results of measurements of sorption are usually applied as a simple retardation factor based on the assumption of linearity, which may or may not be the case. The past history of k_D (distribution or partition coefficient that is proportional to the retardation coefficient) determinations have shown the need for great care in controlling the experimental conditions (pH, Eh, temperature, mineralogy, chemical constituents of the water, etc.). The applicability of laboratory results to field conditions can be questionable because the assumptions made (i.e., linear model) are not always valid to a reasonable approximation. However, for a number of materials and conditions, laboratory measurements can be used to make reasonable estimates of the retardation effect of sorption in soils in the field.

Measurements of k_{Ds} were made for a number of radionuclides for the soils of the SWSA 6 area (Davis et al. 1984) and the SWSA-7 area (Rothschild et al. 1984b). A discussion of uncertainty and confidence limits for the results is given by Davis et al. (1984), along with comments on the applicability of the laboratory results to field conditions. The two general laboratory methods for the measurement of soil k_Ds are batch and column elutriation, each having limited usefulness for site characterization. Column elutriation techniques would seem to simulate field conditions more closely than the batch or static "test tube" method, which was used for the SWSA 6 and SWSA 7 measurements.

However, Davis et al. (1984) concluded that laboratory soil columns are impractical because of the large breakthrough volumes and the number of nuclides and soils to be evaluated. Because low water velocities in the field made in situ tests also impractical, Davis et al. (1984) concluded that batch mode k_D determinations were the only feasible alternatives for site characterization.

3.2.2.4 Physical and engineering properties

Mineralogic composition and the size and arrangement of mineral particles in a soil formation determine most of its bulk physical properties. These properties include hydraulic conductivity, porosity, strength, water-retention characteristics, compressibility, and erodibility. Many of these properties are either resultants or causative agents of soil development. Consequently, they influence the classification of soils in the current U.S. Department of Agriculture (USDA) system (USDA 1975), which is based on the degree of development of the soil column (Davis et al. 1984).

Among the physical properties considered most useful for site characerization are texture, bulk density, and structure. These parameters describe the size distribution of the primary soil particles, the degree to which these particles are packed, and the nature of the secondary arrangement of the primary particles, respectively. These properties can sometimes be correlated with hydraulic properties, but the hydraulic properties are usually independent and should be measured in the field. Texture and bulk must be measured in the laboratory using core samples (Davis et al. 1984). Texture refers to the geometric aspects of the component particles of a rock, including size, shape, and arrangement. In practice, the sand, silt, and clay fractions are determined after shaking the soil sample overnight with a dispersing agent.

Geotechnical and engineering properties include compressibility, shear strength, bearing capacity, modulus of rupture, and Atterberg limits (a measure of plasticity). These properties of soil are considered in construction projects and in designing trenches for maximum sidewall stability.

Measurements of bulk density, total porosity, and the percentages of sand, silt, and clay as functions of depth were made in three trenches in the SWSA 6 area (Davis et al. 1984). None of the common geotechnical measurements were made since they were not considered important for the level of site characterization. The percentages of sand, silt, and clay have also been made in the proposed SWSA 7 area, along with grain size distribution for some selected samples (Rothschild et al. 1984b). Measurements of the natural moisture content and the liquid limits were determined as a function of depth in four locations. Davis et al. (1984) and Rothschild et al. (1984b) describe details of the results and the techniques of measurements that were used.

3.3 HYDROLOGY

3.3.1 Planned and Recommended Hydrologic Investigations

3.3.1.1 Water balance

Plans to develop a water balance for the ORNL area are being considered. Two items in particular require additional work before the hydrologic regime in WAG 1 can be defined. A field reconnaissance of the location and flow volumes of springs at the headwaters of First, Fifth, and White Oak Creeks should be conducted. A complete inventory of plant discharges to the creeks should be compiled. A survey of stream elevations along portions of Fifth and White Oak Creeks is presently underway. The survey should help define the relationships of the streams to groundwater.

3.3.1.2 Aquifer tests

Drawdown tests to help define ranges of hydraulic conductivity of the underlying aquifer have been proposed for several piezometers within WAG 1. Because of construction variables, only a limited number of piezometers with certain construction characteristics were selected for testing. The following is a description of the selection criteria:

1. Piezometers with 5 ft screened intervals and sandpacks less than 10 ft were chosen. These criteria are intended to minimize head differentials within the test zone.

2. Piezometers that are screened at or near the soil bedrock interface were selected. This criterion will allow characterization of the uppermost aquifer underlying the plant.

3. Piezometers with water levels 1 ft or more above the 5 ft screened interval were selected for testing. It is hoped that the greater relative heads in these piezometers will slightly increase the recovery time (excluding high well yields). This should allow for more data points to be collected during the test and improve its accuracy.

4. Good areal distribution of the test piezometers was considered in order to characterize as much of the plant area as possible.

The following 10 piezometers meet the preceding criteria and have been recommended for testing:

#542	#570
#551	#602
#554	#604
#560	#618
#563	#622

3.3.1.3 Trench flow characterization

A plan to develop an understanding of groundwater flow along pipe trench backfill is being considered (Ashwood 1986). The plan suggests a review of literature and maps, coupled with piezometer installation, water chemistry analyses, geophysical surveys, and tracer studies.

3.3.1.4 Expanded compliance monitoring system

Locations of compliance monitoring wells are being selected on the basis of existing piezometer water level data and contaminant scoping survey information. These wells will be sampled on a regular basis and will provide reliable water quality data.

3.3.1.5 Mapping

Additional data points for groundwater and top-of-rock elevations are constantly added to the well construction file. These new data points are plotted along with previous data, and the phreatic surface and bedrock maps are revised accordingly. Six cross sections showing the ground surface projected top of rock and projected phreatic surface within WAG 1 are being prepared.

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APPENDIX I

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ADDRESS P.O. Box "E"
Oak Ridge, TN 37830

FACILITY Oak Ridge National Laboratory
LOCATION Oak Ridge, TN 37830

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)
DISCHARGE MONITORING REPORT (DMR)

(2-16) TN0002941 PERMIT NUMBER

(17-19) X04 DISCHARGE NUMBER

2000 Area

Form Approved
OMB No. 2040-0004
Approval expires 9-30-8?

MONITORING PERIOD	YEAR	MO	DAY		YEAR	MO	DAY
FROM	(20-21)	(22-23)	(24-25)	TO	(26-27)	(28-29)	(30-31)

NOTE: Read instructions before completing this form.

PARAMETER (32-37)		QUANTITY OR LOADING (3 Card Only) (46-53) AVERAGE	QUANTITY OR LOADING (54-61) MAXIMUM	UNITS	QUALITY OR CONCENTRATION (4 Card Only) (38-45) MINIMUM	QUALITY OR CONCENTRATION (46-53) AVERAGE	QUALITY OR CONCENTRATION (54-61) MAXIMUM	UNITS	NO. EX (62-63)	FREQUENCY OF ANALYSIS (64-68)	SAMPLE TYPE (69-70)
Flow	SAMPLE MEASUREMENT							MGD			NA
	PERMIT REQUIREMENT									1/30	NA
Temperature	SAMPLE MEASUREMENT							°C			Grab
	PERMIT REQUIREMENT									2/30	Grab
Total Suspended Solids	SAMPLE MEASUREMENT							mg/l			24HC
	PERMIT REQUIREMENT									2/30	24HC
Oil and Grease	SAMPLE MEASUREMENT							mg/l			Grab
	PERMIT REQUIREMENT									2/30	Grab
Total Organic Carbons	SAMPLE MEASUREMENT							mg/l			Grab
	PERMIT REQUIREMENT									2/30	Grab
Total Phosphorus	SAMPLE MEASUREMENT							mg/l			24HC
	PERMIT REQUIREMENT									2/30	24HC
Arsenic	SAMPLE MEASUREMENT							mg/l			24HC
	PERMIT REQUIREMENT									2/30	24HC

NAME/TITLE PRINCIPAL EXECUTIVE OFFICER

J. A. Lenhard, Asst. Manager
Energy Research & Development

TYPED OR PRINTED

I certify under penalty of law that I have personally examined and am familiar with the information submitted herein; and based on my inquiry of those individuals immediately responsible for obtaining the information, I believe the submitted information is true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. See 18 U.S.C. § 1001 and 33 U.S.C. § 1319. (Penalties under these statutes may include fines up to $10,000 and/or maximum imprisonment of between 6 months and 5 years.)

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TELEPHONE		DATE		
615	576-0723			
AREA CODE	NUMBER	YEAR	MO	DAY

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LOCATION Oak Ridge, TN 37830

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DISCHARGE MONITORING REPORT (DMR)

(2-16)	(17-19)	
TN0002941	X04	2000 Area
PERMIT NUMBER	DISCHARGE NUMBER	

Form Approved
OMB No. 2040-0004
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MONITORING PERIOD

	YEAR	MO	DAY		YEAR	MO	DAY
FROM				TO			
	(20-21)	(22-23)	(24-25)		(26-27)	(28-29)	(30-31)

NOTE: Read instructions before completing this form.

PARAMETER (32-37)		Quantity or Loading: Average (3 Card Only) (46-53)	Quantity or Loading: Maximum (54-61)	Quantity or Loading: Units	Quality or Concentration: Minimum (4 Card Only) (38-45)	Quality or Concentration: Average (46-53)	Quality or Concentration: Maximum (54-61)	Quality or Concentration: Units	NO. EX (62-63)	FREQUENCY OF ANALYSIS (64-68)	SAMPLE TYPE (69-70)
Cadmium	SAMPLE MEASUREMENT							mg/l			24HC
	PERMIT REQUIREMENT									2/30	24HC
Chromium	SAMPLE MEASUREMENT							mg/l			24HC
	PERMIT REQUIREMENT									2/30	24HC
Copper	SAMPLE MEASUREMENT							mg/l			24HC
	PERMIT REQUIREMENT									2/30	24HC
Silver	SAMPLE MEASUREMENT							mg/l			24HC
	PERMIT REQUIREMENT									2/30	24HC
Lead	SAMPLE MEASUREMENT							mg/l			24HC
	PERMIT REQUIREMENT									2/30	24HC
Nickel	SAMPLE MEASUREMENT							mg/l			24HC
	PERMIT REQUIREMENT									2/30	24HC
Zinc	SAMPLE MEASUREMENT							mg/l			24HC
	PERMIT REQUIREMENT									2/30	24HC

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DISCHARGE MONITORING REPORT *(DMR)*

(2-16)	(17-19)
TN0002941	X04
PERMIT NUMBER	DISCHARGE NUMBER

2000 Area

Form Approved
OMB No 2040 0004
Approval expires 9-30 85

MONITORING PERIOD

	YEAR	MO	DAY		YEAR	MO	DAY
FROM				TO			
	(20-21)	(22-23)	(24-25)		(26-27)	(28-29)	(30-31)

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PARAMETER (32-37)		QUANTITY OR LOADING (3 Card Only) AVERAGE (46-53)	MAXIMUM (54-61)	UNITS	QUALITY OR CONCENTRATION (4 Card Only) MINIMUM (38-45)	AVERAGE (46-53)	MAXIMUM (54-61)	UNITS	NO. EX (62-63)	FREQUENCY OF ANALYSIS (64-68)	SAMPLE TYPE (69-70)
pH	SAMPLE MEASUREMENT										Grab
	PERMIT REQUIREMENT				6.0		9.0			1/7	Grab
Downstream pH	SAMPLE MEASUREMENT										Grab
	PERMIT REQUIREMENT									1/7	Grab
	SAMPLE MEASUREMENT										
	PERMIT REQUIREMENT										
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	PERMIT REQUIREMENT										

NAME/TITLE PRINCIPAL EXECUTIVE OFFICER	CERTIFICATION	SIGNATURE	TELEPHONE		DATE		
J. A. Lenhard, Asst. Manager Energy Research & Development	I certify under penalty of law that I have personally examined and am familiar with the information submitted herein; and based on my inquiry of those individuals immediately responsible for obtaining the information, I believe the submitted information is true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. See 18 U.S.C. § 1001 and 33 U.S.C. § 1319. *(Penalties under these statutes may include fines up to $10,000 and/or maximum imprisonment of between 6 months and 5 years.)*		615	576-0723			
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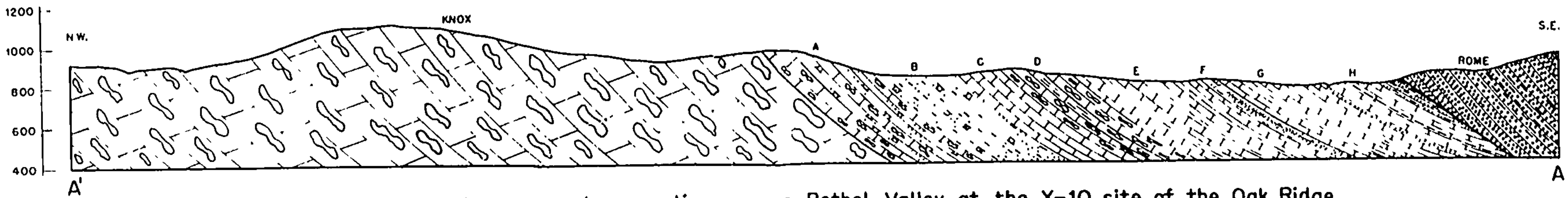
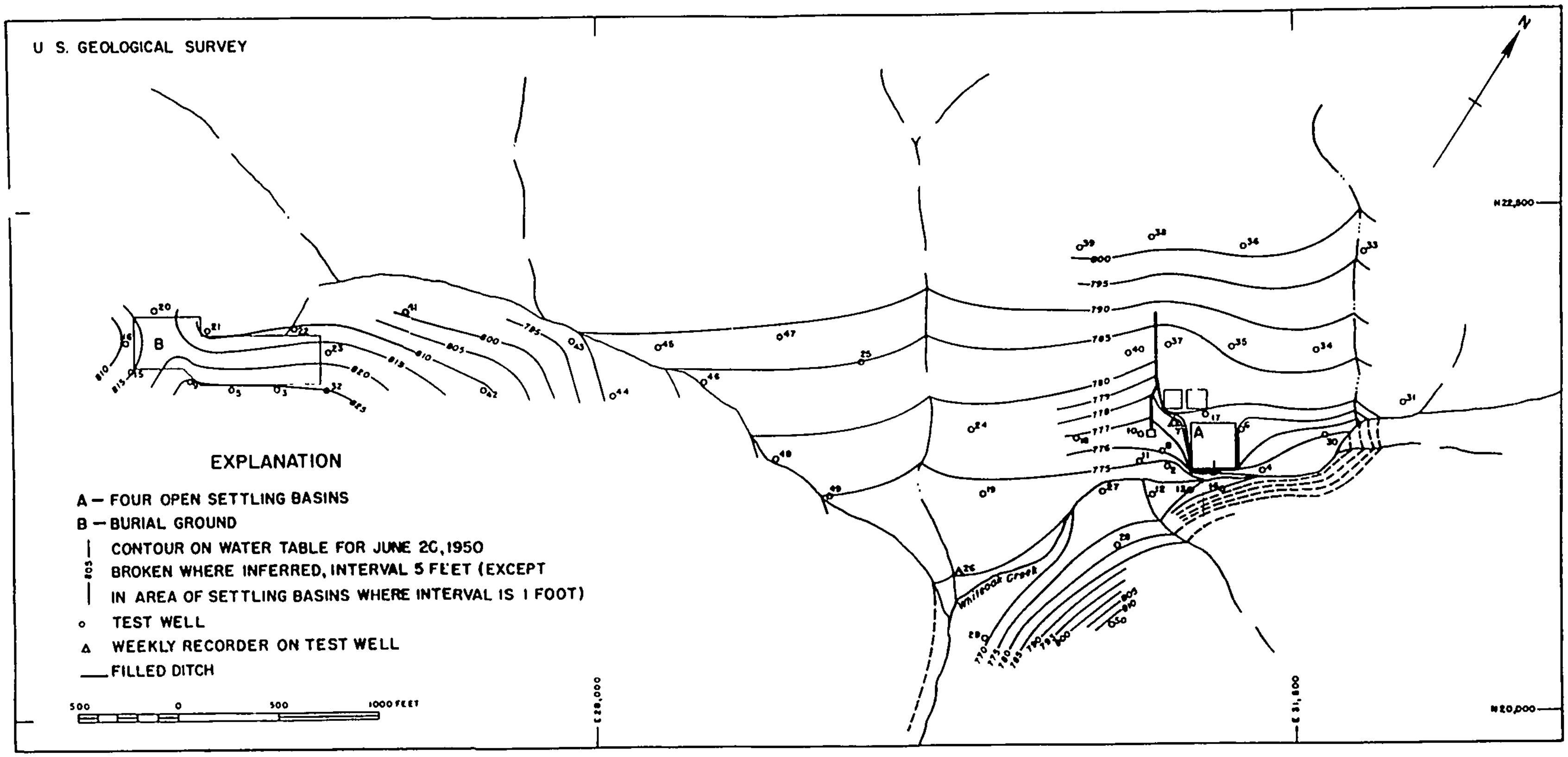
APPENDIX II



Geologic structure section across Bethel Valley at the X-10 site of the Oak Ridge National Laboratory (see plate 2 for location of section line A-A'). By Harry J. Klepser



APPENDIX III

MCI
Consulting Engineers, Inc.

10628 Dutchtown Road, P O Box 23010
Knoxville, Tennessee 37933-1010
615 966-9788

Engineering Planning, Landscape Architecture

WELL LOG

WELL NUMBER 37

DATE 2-4-86

DRILLER CLARK, S

MAP NUMBER 567

HELPER KIRK

RIG DRILLTECH

H.P. BLASS

STATIC WATER LEVEL

LOGGED BY CW STANLEY

LOCATION

PLANT COORDINATES N E

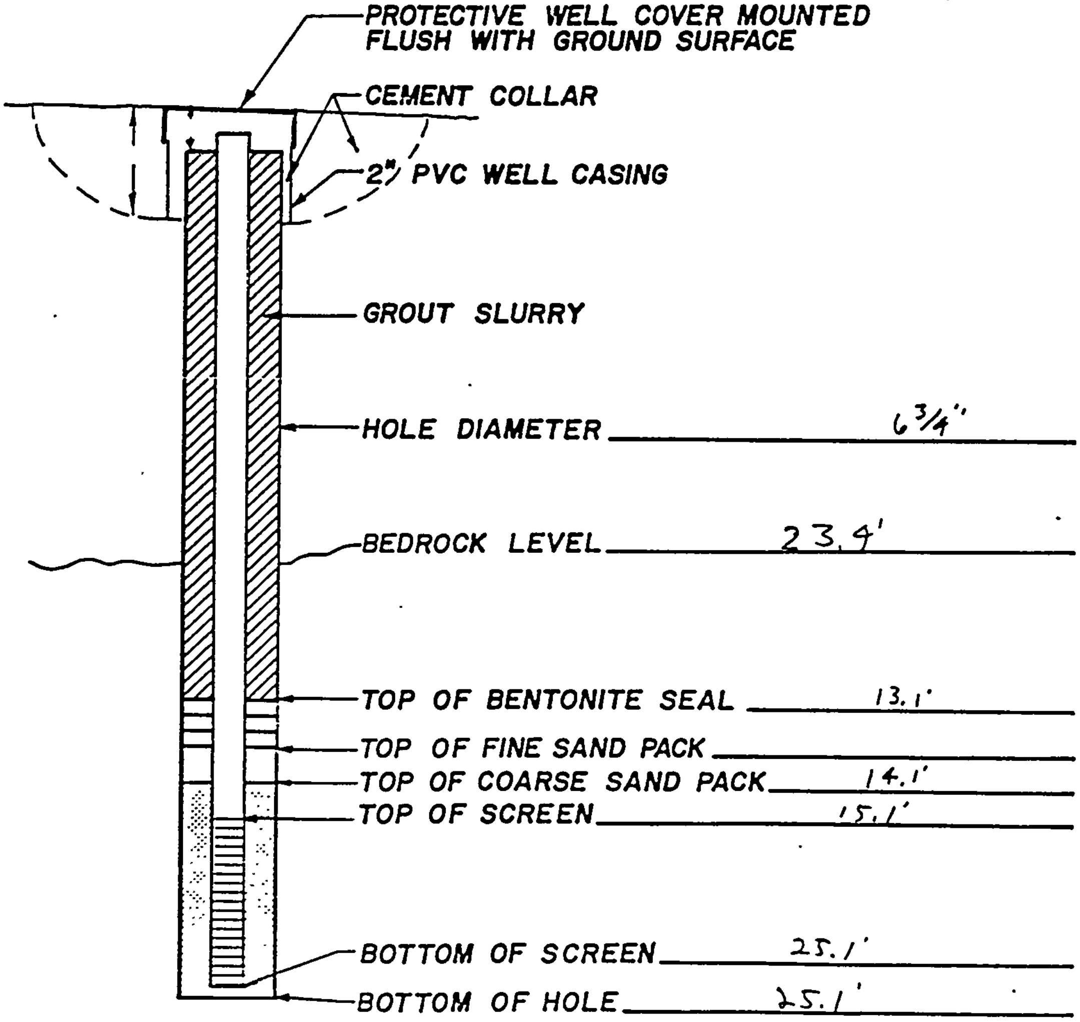
DEPTH (FT)		DESCRIPTION	CONTAMINATION
0	0.5	Asphalt	
0.5	23.4	Subsoil/clay w/gvls - orange	
		to LT Brn, med moist, silty	
		plastic	
23.4	25.1	LS - med gray, hard, calcite	
		xtaline	
		25.1 T.D.	

PIEZOMETER CONSTRUCTION IN ROCK

WELL NO. ____________ DATE INSTALLED: 2-10-86

MAP NO. 567

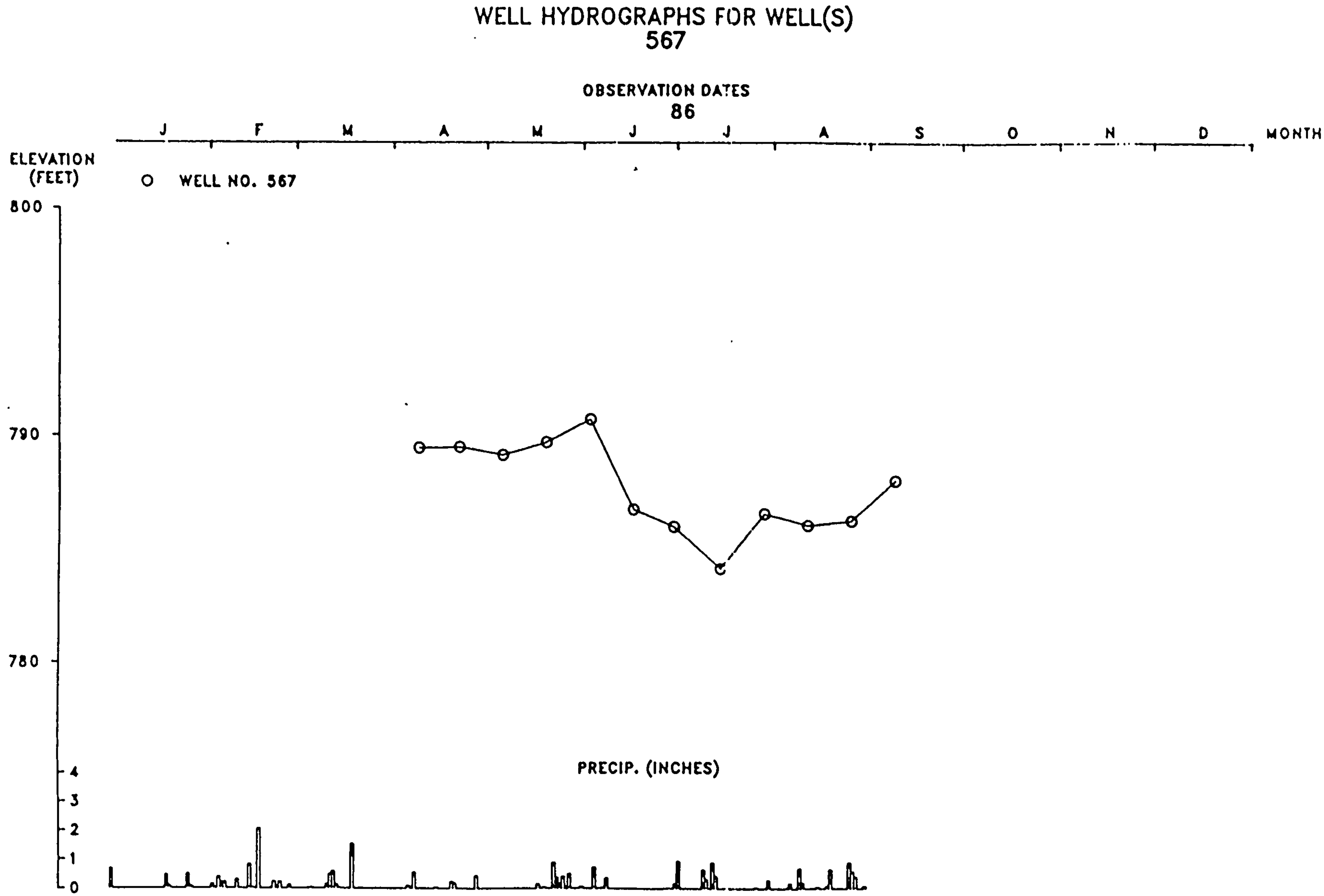
LOCATION NORTH: ____________ EAST: ____________



NOTE: ALL DEPTHS ARE RELATIVE TO TOP OF GROUND.

DRAWING NOT TO SCALE.

MCI/CONSULTING ENGINEERS, INC.
NASHVILLE KNOXVILLE HUNTSVILLE LOUISVILLE



A representative example of a well hydrograph plot used in examination and interpretation of data

ORNL/RAP-13

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OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

Environmental Data Package for ORNL Waste Area Grouping-Five (WAG-5), Solid Waste Storage Area-Five (SWSA-5)

R. R. Shoun

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ORNL/RAP-19

ENVIRONMENTAL DATA PACKAGE FOR ORNL WASTE AREA GROUPING-FIVE (WAG-5), SOLID WASTE STORAGE AREA-FIVE (SWSA-5)

R. R. Shoun

CHEMICAL TECHNOLOGY DIVISION

DATE OF ISSUE — JULY 1987

Prepared for the
Office of Defense Waste and Transportation Management

Nuclear and Chemical Waste Programs
(Activity AR 05 10 05 K; ONLWN17)

Access to the information in this report is limited to those indicated on the distribution list, to the U.S. Department of Energy and its contractors, to other U.S. Government Agencies and their contractors, and to Tennessee Government Agencies.

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

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ABSTRACT

The ORNL Waste Area Grouping-Five (WAG-5) consists of ten subgroupings which include not only the Solid Waste Storage Area-Five (SWSA-5) itself, but nearby low level waste (LLW) line leak sites, the Old Hydrofracture Facility (OHF) surface facilities, tanks, sludge basins, and the New Hydrofracture Site surface facilities. This report describes the site locations, the site history, known waste inventory and release, the hydrology, geology, and ecology, and remedial actions taken in the past. Supporting bibliography, drawings, and pictures are included as considered appropriate.

This document is not intended to be an exhaustive compilation of data, but to be a starting point for the assimilation of information necessary for the decision-making processes mandated by the Resource Conservation and Recovery Act (RCRA).

1. INTRODUCTION

As a Waste Area Grouping (WAG) known to contribute radioactivity to the environment, WAG-5 must be addressed under Section 3004u of the 1984 Resource Conservation and Recovery Act (RCRA) reauthorization. The Remedial Action/Feasibility Study (RI/FS) determines the extent of the problem and provides an assessment of available alternatives for remedial action and recommendations for implementation. This report provides a review and presentation of much of the available information related to WAG-5 with extensive bibliography that should be useful to those responsible for subsequent stages in the RI/FS process.

2. GENERAL SITE DESCRIPTION OF WAG-5

2.1 HISTORY, PURPOSE, AND GEOGRAPHIC LOCATION OF SWSA-5

Since the early operation of the Clinton Laboratories in 1943, solid, low-level radioactive wastes at ORNL have been disposed of by shallow-land burial in six solid waste storage areas (SWSAs). As each of the first four successively larger SWSAs were filled, another was opened to accept waste. SWSA-5 was commissioned in 1959 and the land set aside for this unit was more than double that of the preceding four SWSAs combined (32.3 ha vs 14.1 ha) or 80 acres vs 35 acres. The selection of the site for SWSA-5 was based on experience gained as a result of previous burial operations, as well as studies which addressed radionuclide transport in soil. Criteria that were established for the selection of the SWSA-5 site included depth to groundwater, ease of operation, flood potential, soil erosion by surface runoff, easy excavation, short handling distance, restricted access roads, and underlying geology (Bates, 1983; Grizzard, 1986). However, because of topographic and hydrologic unsuitability of some parts of the SWSA-5 area, only about 20.2 ha (50 acres) has actually been used for trench disposal (Evaluation Research Corporation, 1982).

During the period 1955 to 1963, Oak Ridge was designated by the Atomic Energy Commission as the Southern Regional Burial Ground; both SWSA-4 and SWSA-5 received an estimated 2.83 x 10^4 m^3 of poorly characterized wastes from approximately 50 agencies (Lomenick and Cowser, 1961; Davis and Shoun, 1986; Evaluation Research Corporation 1982; Myrick et al., 1984). SWSA-5 was closed to routine trench burial of waste in 1973.

A section of SWSA-5 (north) was set aside for the retrievable storage of transuranium (TRU) wastes in 1970. Prior to that time, TRU wastes were historically segregated from other radioactive wastes prior to burial in drums, in some concrete capped holes, and in some concrete or asphalt capped trenches. In 1974 the Atomic Energy Commission (AEC) proposed a ban on soil burial of wastes containing more than 10 nCi/g of TRU and required AEC-approved storage for retrievability for 20 years (Evaluation Research Corporation, 1982).

SWSA-5 is located on a hillside east of White Oak Creek, between SWSA-4 and Melton Branch and is south-southwest of the main ORNL complex lying in Melton Valley, which is bounded on the northwest by Haw Ridge and on the southeast by Copper Ridge. Coordinates are: latitude 35.91401, longitude 84.31295. Figure 1 shows SWSA-5 in relation to the ORNL complex and other SWSAs. SWSA-5 actually consists of two distinct geographical areas — the larger southern section on the moderately sloping hillside, and the smaller northern section on a reasonably flat ridge top. The southern section contains most of the buried waste, while the northern section is used for the retrievable storage of TRU waste. A photograph of SWSA-5 (Fig. 2) shows the southern section of SWSA-5 in the foreground, with the northern section near the top center portion of the picture. An aerial view of the TRU waste storage area is shown in Fig. 3 (Oakes and Shank, 1979; Evaluation Research Corporation, 1982; National Research Council, 1985).

2.2 GEOLOGY

The Oak Ridge Reservation lies in the Valley and Ridge portion of the Appalachian Highland Physiographic Province, which extends from Alabama to Virginia. The northeast-southwest trending ridges, in general, are underlain by sandstones, and the more siliceous limestones are dolomites that are relatively resistant to erosion; the valleys are underlain by more easily erodable shales and more soluble carbonate rocks. Principal formations are identified in Fig. 4.

These geologic formations have been subjected to a series of great overthrusts. Fault blocks have resulted, and each of these blocks, or

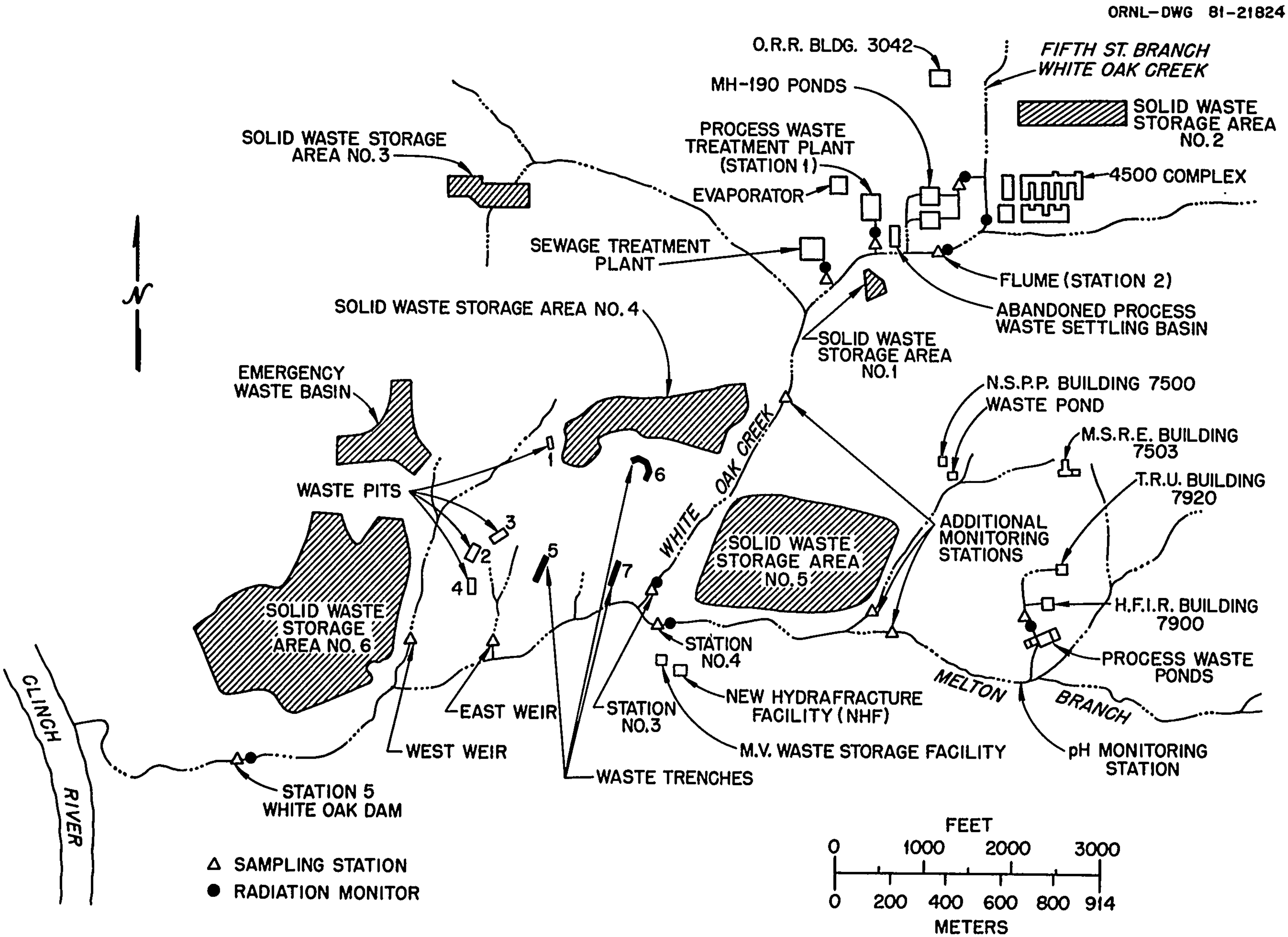

Fig. 1. Bethel and Melton Valley watershed.

ORNL-PHOTO 79-822

Fig. 2. Photograph of SWSA-5.

Fig. 3. Retrievable waste facilities in SWSA-5 north.

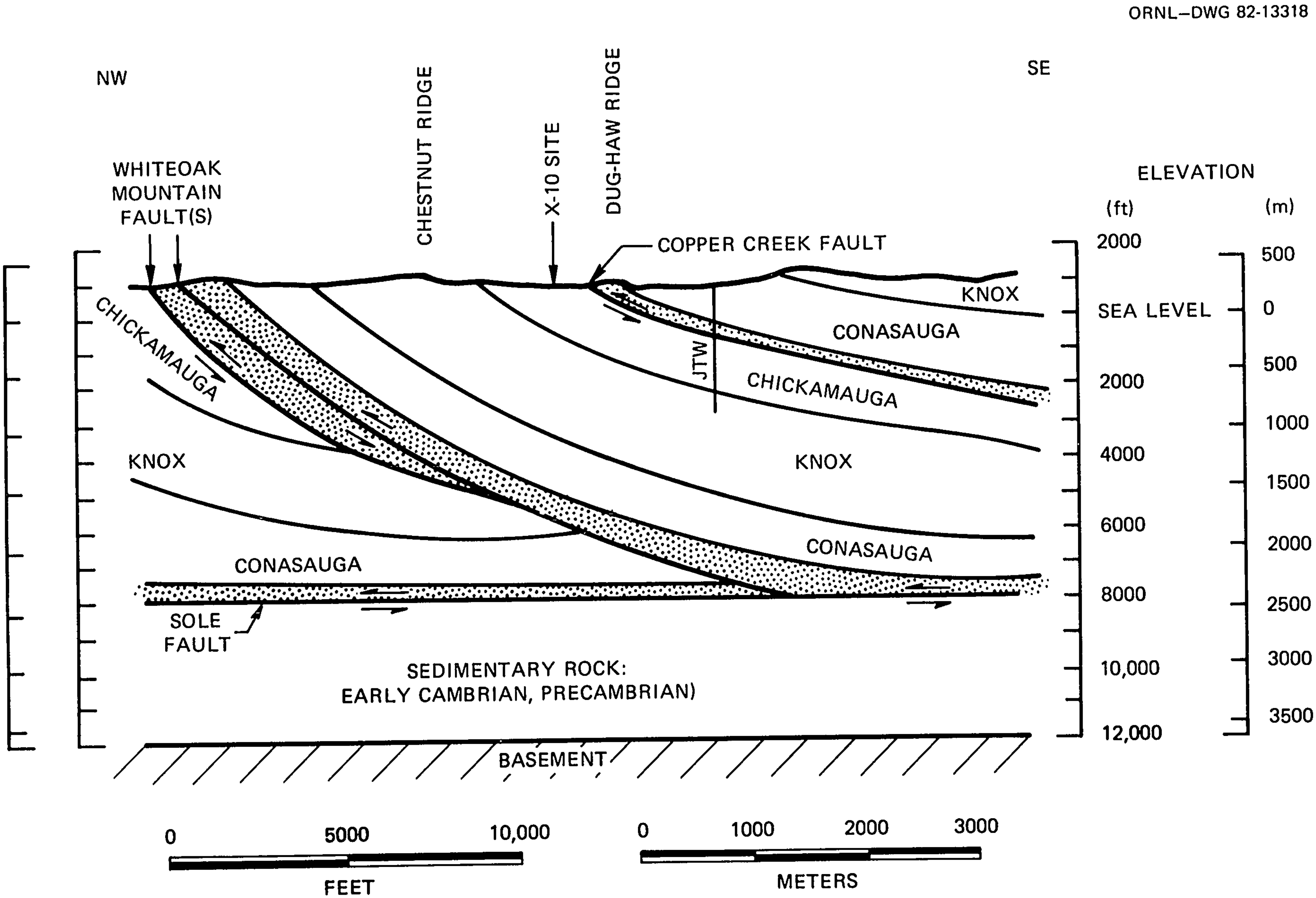

Fig. 4. Basic geological formations in the ORNL vicinity.

layers of rocks roughly 3 km (10,000 ft) thick, have been moved to their present position as much as several tens of miles to the northwest. These blocks have overridden similar layers of rock and, in turn, have been overridden by other layers. Formations on the reservation dip gently to the southeast and become more deeply buried southeastward. As a result of the overthrust faulting, the geology of the area is very complex, and the sequence of formations at Oak Ridge, as shown in Fig. 4, is not always a normal stratigraphic sequence (youngest to oldest).

Four groups of formations are of immediate interest at Oak Ridge. The oldest is the Rome formation, of Lower Cambrian age. The upper part of this formation is composed largely of beds of hard brittle quartzite 2 to 30 cm (1 to 11 in.) thick. The Rome is normally overlain by rocks of the Conasauga group. The Conasauga group of formations and smaller units include, from top to bottom, the Maynardsville limestone, the Nolichucky shale, the Maryville limestone, the Rogersville shale, the Rutledge limestone, and the Pumpkin Valley shale. In aggregate, the Conasauga group is about 600 m (2000 ft) thick. The bottom 100 m (325 ft) of the Conasauga — the Pumpkin Valley member — is a dense argillaceous shale that is thinly bedded and dominantly red. This is the unit into which radioactive waste was injected by hydrofracture. Shales and subordinate interbedded limestones of the Conasauga group underlie the solid waste burial grounds (SWSA 5 is underlain by limestone); the upturned tiled edges of these rocks are commonly concealed and mantled by soil and soft weathered rock to depths ranging from 1 to 12 m (3 to 4 ft). In areas underlain by rocks of the Conasauga group, the depth of weathering ranges with topography, being thicker beneath ridges and thinner in low-lying areas. The thickness of the soil and soft weathered rock varies greatly in low-lying areas.

Dolomites of the Knox group normally overlie the rocks of the Conasauga. The Knox is characterized by broad ridges and incised drainage bordered by steep slopes. In this area there is a deeply weathered blanket of cherty, and somewhat clayey, silt soil; a deep water table; and some karst features (sinkholes, swallow holes) that indicate solutional enlargement of rock fractures.

The Chickamauga group consists of several hundred feet of shales and limestones. These rocks commonly occupy valley bottoms, such as Bethel Valley. The Chickamauga lies in an area of gentle topography whose soils are variable in thickness but, overall, relatively thin — commonly less than 3 m (10 ft).

The coarsely crystalline limestone grades upward into the Reedsville shale, a calcareous, tan to orange-brown, fissile, thin-bedded, fossiliferous shale, which is the uppermost unit of the Chickamauga limestone. This unit is 60 to 75 m (200 to 250 ft) thick.

In Bethel Valley, lithologic differences within the formation are more distinct, and the stratigraphic sequence is more easily defined than in other parts of the area The residual mantle is generally thinner, and outcrops of the beds are more common. Also, the beds are persistent in character along strike, and each unit has more distinguishing features. The Chickamauga in Bethel Valley can be divided into at least eight units. Three of these units consist of redbeds: one about 35 m (120 ft) above the base, another near the middle of the formation, and another at or near the top.

A cross-sectional diagram of the subsurface geology is given in Fig. 4. A test well has been drilled to a depth of 995 m (3263 ft) on a site near Melton Creek on the cross section. The depth of the various geologic formations in this area were determined from the cores of this well.

Most of the soils are silt, with considerable amounts of clay — the weathered residual products of the underlying rocks. They are highly leached, low in organic matter, and acidic; the pH ranges from 4.5 to 5.7 (Cowser et al., 1961).

The weathering characteristics of these rocks are important because they relate to the sorptive qualities of the residual materials. Kaolinite is the principal clay mineral in the soils of the Knox, and both kaolinite and illite are common in the Chickamauga. The chief minerals in the weathered rocks of the Conasauga group are illite, smectite, and vermiculite. The sorptive properties of the clay minerals range considerably (Means et al., 1978); smectite and vermiculite generally have the greatest sorbent capacity (National Research Council, 1985).

The soil produced by weathering of the Chickamauga typically consists of yellow, light reddish orange, or red clay containing variable amounts of chert. Chert is abundant enough in the lower layers to cause development of a line of low hills on the northwestern sides of the valleys. This is more pronounced in Bethel Valley, where the basal material is composed of alternating siltstone beds and beds of block chert.

The surfaces of the valleys underlain by the formation are irregular; the more silty and cherty layers underlie low ridges and hills. Sinkholes are present, but these are not as numerous or as large as those in the Knox group.

Fossils, including brachiopods, bryozoans, gastropods, cephalopods, crinoid stems, corals, and trilobites, are common throughout the formation.

The age of the Chickamauga limestone is Middle and Upper Ordovician. The boundary between Middle and Upper Ordovician rocks in this area is drawn at the base of the Reedsville shale. The thickness of the Chickamauga in Bethel Valley is about 530 m (1750 ft) (Boyle et al, 1982).

2.3 HYDROLOGY

2.3.1 Surface Water

An early study of hydrologic features of the ORNL site was made by DeBuchananne (Stockdale, 1951). He states that the section of Bethel Valley in which the main part of ORNL is located, is drained by White Oak Creek and its tributaries. White Oak Creek flows out of Bethel Valley through Haw Gap at an elevation of 235 m (770 ft). After passing through the gap, it is joined by Melton Branch and then flows south-southwest into the Clinch River, approximately 3.3 km (2.0 miles) away. Flow to the Clinch River is controlled by White Oak Dam, located approximately 1.0 km (0.6 mile) from the mouth of the creek, which forms White Oak Lake.

A later study of the hydrology of the Oak Ridge area provides data on runoff in area streams. The seasonal variation in runoff, averaged for the water years 1961-64 and adjusted to the 1936-60 water years, is as follows in terms of percentage of annual runoff: October-December, 17%; January-March, 49%; April-June, 23%; July-September, 11%. McMaster (1967) states that a large part of the runoff is derived from discharge of stored groundwater. The periods of maximum and minimum runoff correspond to the variations in rainfall. These data represent averages for the Oak Ridge area, but they presumably apply to the burial ground sites (Evaluation Research Corporation, 1982). White Oak Creek is the natural drainage and, as such, is an integral part of the Laboratory's water system, conveying effluents from various parts of the ORNL complex to points beyond the reservation (Webster, 1976). The natural flow of water into the White Oak Creek is augmented by water piped into ORNL from outside the drainage basin and subsequently discharged to White Oak Creek. During prolonged periods of dry weather, the discharge from these sources often makes up a major fraction of the creek flow (Boyle, et al., National Research Council, 1985).

2.3.2 Groundwater

The geology and climate at Oak Ridge significantly affect the groundwater conditions; the distinctive groundwater conditions, in turn, significantly affect waste management practices. Emphasis is placed upon groundwater because it is a carrier of contamination, not because of its potential use a drinking water — there are no water wells subject to contamination by groundwater at ORNL.

The sedimentary rocks in the areas used for waste management, chiefly shale and subordinate amounts of limestone, have a low permeability. The flow that does occur is mainly through fractures rather than through the rock matrix — the greatest porosity is in the upper weathered zone. As a result, these beds of the Conasauga group yield very small quantities of of groundwater to the test wells (less than 38 L/m, or 10 gal/min, average). There are no productive water wells near the waste storage areas. The residual material over the Conasauga is less compact, and the water-bearing openings are larger than in unweathered bedrock. The porosity of the residual material acts as a reservoir feeding water to the fracture system. The rock fractures tend to decrease in size with depth; consequently, the residuum bears most of the groundwater in the Conasauga group outcrop belt, and because the thickness of the residuum in these belts is less than 10 m (30 ft) in most places, the volume of groundwater storage is small and is nearly depleted by September or October (McMaster, 1967).

The Chickamauga group is a poor aquifer because it contains so much shale and siltstone. This formation is practically devoid of any large solution cavities, and the only water derived from it probably permeates along the bedding planes and joint partings. Although numerous small openings may occur within, but rarely beyond, 30 m (100 ft) of the surface, rates and quantity of water transport are small. Recharge is further restricted by the high clay content of the overburden. The residual material is typically less than 3 m (10 ft) thick; therefore, most water input is diverted to surface runoff.

In Bethel Valley, depth to the water table ranges from 0.3 to 11 m (1 to 35 ft), whereas in Melton Valley the range is from 0.3 to 20 m (1 to 67 ft). Seasonal fluctuations tend to be greatest beneath hillsides and near groundwater divides. As much as 4.5-m (15-ft) seasonal variation was reported for Melton Valley.

Water table contour maps are useful, in a general way, for estimating the direction of groundwater movement, especially in the weathered residual soil or unconsolidated materials overlying bedrock. However, direction of movement in the underlying bedrock is influenced more strongly by directional variations in permeability. Groundwater flow in the residual soil is generally toward the individual streams of the surface-drainage network. In Bethel Valley, groundwater in the Chickamauga limestone moves through small solution channels. Although the rate of groundwater flow in the area is not known, the direction and pattern of this flow on the Bethel Valley site is essentially a subdued replica of the topography. Thus, water flows from areas of high elevation to those of low elevation, and the principal movement is in directions normal to the contour lines. The lay of the land is such that drainage at and below the surface of the Bethel Valley site apparently converges to feed WOC and White Oak Lake. An exception to this situation occurs in the western end of the Bethel Valley site where the groundwater west of a groundwater divide flows west into the Racoon Creek drainage basin rather than into WOC (Boyle et al., 1982).

The distinctive, hilly ridge-and-valley topography with closely spaced streams results in a relatively short flow path of the groundwater from recharge to storage to discharge. The water table is a subdued replica of land surface topography; therefore, it is easy to approximate water table contours and to determine the general direction of groundwater flow from ridge tops to the nearest creek. The groundwater flow paths tend to range from as little as 6 m (20 ft) to as much as 300 m (1000 ft), but most range from 60 to 210 m (200 to 700 ft). Some groundwater is not discharged into the nearest creek because it is shunted out to the land surface after periods of heavy precipitation as seeps on lowland slopes. Groundwater travel time may vary from a few months to many hundreds of years.

The groundwater in the drainage basin is neutral to slightly alkaline (pH 7 to 8.5) and is of the calcium bicarbonate type (high contents of calcium, magnesium and bicarbonate), reflecting the influence of the limestone and dolomite through which the water moves. The limestone constituents are only slightly more dilute in local surface streams. The calcium and magnesium in the ground waters and surface waters interfere with sorption of ^{90}Sr on soils and sediments, thereby increasing the mobility and aggravating the management of this important radioactive waste constituent in the ORNL environment (Webster, 1976; Spalding and Cerling, 1979; Boyle et al., 1982; National Research Council, 1985).

The relationship between climate, surface water, groundwater flow, and shallow-land burial of radioactive materials was summarized by Richardson (1963):

> The relatively large amount of rainfall at Oak Ridge has several effects. It causes the water table to occur at shallow depths and is responsible for seasonably large stream flow; it contributes to the development of a high drainage density, thereby reducing the distance between points of ground-water recharge and discharge and the length of time of ground water residence; it lowers soil pH and influences the development of clay minerals that can control or modify the migration of radioactive ions...

Upward movement of contaminated groundwater can occur. Where the water table is shallow, evaporation of water into the atmosphere can be expected; however, as Webster points out, the only radionuclide expected to migrate to any extent by this process is tritium. Studies near the waste pits (Auerbach et al., 1958) showed that ^{106}Ru had been accumulated from ground water by trees and deposited on the ground in fallen leaf litter. Other studies at ORNL (Struxness, 1962) showed that ^{60}Co, ^{137}Cs, and ^{90}Sr can be translocated from ground water by this mechanism.

2.4 ECOLOGY

2.4.1 Flora

The primary vegetation surrounding the SWSA-5 site is the oak-hickory association, which is typified by extensive stands of mixed yellow pine and hardwoods, as well as oak and hickory. Since waste disposal sites were first constructed at ORNL in the 1940s, the existing forest has been cleared, the trenches have been excavated and filled with waste, and the approximate 1 m (3 ft) of soil cover has been seeded to grass to prevent soil erosion. A grass cover has been maintained at SWSA-5, which requires both periodic mowing during the summer and yearly applications of nitrogen-containing fertilizer.

A comprehensive listing of plant species that potentially occur on the Oak Ridge Reservation has been compiled (Mann and Nelson, 1976). There have been no studies on invading species specific to the burial grounds; however, the general pattern of succession of abandoned land is one in which the earliest phase is dominated by annual plants and grasses such as ragweed and crabgrass. The next phase is dominated by biennial and perennial plants such as horseweed, primrose, many species of aster, and other composite. Fescue is dominant at this stage in areas such as power line corridors where it has been planted for erosion control. Areas that are periodically mowed (e.g., SWSA-5), are generally dominated by fescue and other grasses, rapidly growing weedy annuals, and low growing perennials. The grass phase is generally followed by a shrub phase; the grassland is invaded by rapidly growing shrubs, woody vines, and tree seedlings such as sassafras, red cedar, pines, and various hardwoods.

2.4.2 Fauna

The animal population captured or observed on the Oak Ridge Reservation (and likely to inhabit portions of SWSA-5) consists of small mammals (mice, chipmunks, land shrews), and larger mammals (squirrels, opossum, rats, groundhogs, muskrats, foxes, weasels, bobcats, and deer). Groundhogs, in particular, have found old waste trenches to make ideal dens. Wooded and open areas, as well as edge communities, create favorable habitats for a wide variety of bird species.

Mammallian species inhabiting old field or disturbed areas are quite similar, whether the vegetative cover is grass, tree seedlings, or shrubs. In a 1-ha (2.5 acre) study area indicative of these habitats, the dominant vegetation was tall fescue and *sericia lespedeza*. Small mammals trapped were cotton rats, white-footed mice, a golden mouse, a rice rat, short-tail shrews, and western harvest mice (Kitchings and Mann, 1976; Jacobs et al., 1980; Davis and Shoun, 1986).

2.5 LAND USE

2.5.1 Trench Burial

SWSA-5 (including the northern and southern portions) is a fenced area of approximately 32.3 ha (80 acres), of which only approximately 20.2 ha (50 acres) have actually been used for waste disposal (Myrick et al., 1984). The majority of this area is contained in the southern part, known as SWSA-5 (south). SWSA-5 (south) is a moderately sloping hillside with a grass cover (Fig. 5). The area is fenced and contains several unpaved access roads. As was mentioned previously, portions of the area are topographically or hydrologically unsuitable for trench disposal and thus have not been used for burial of waste. The

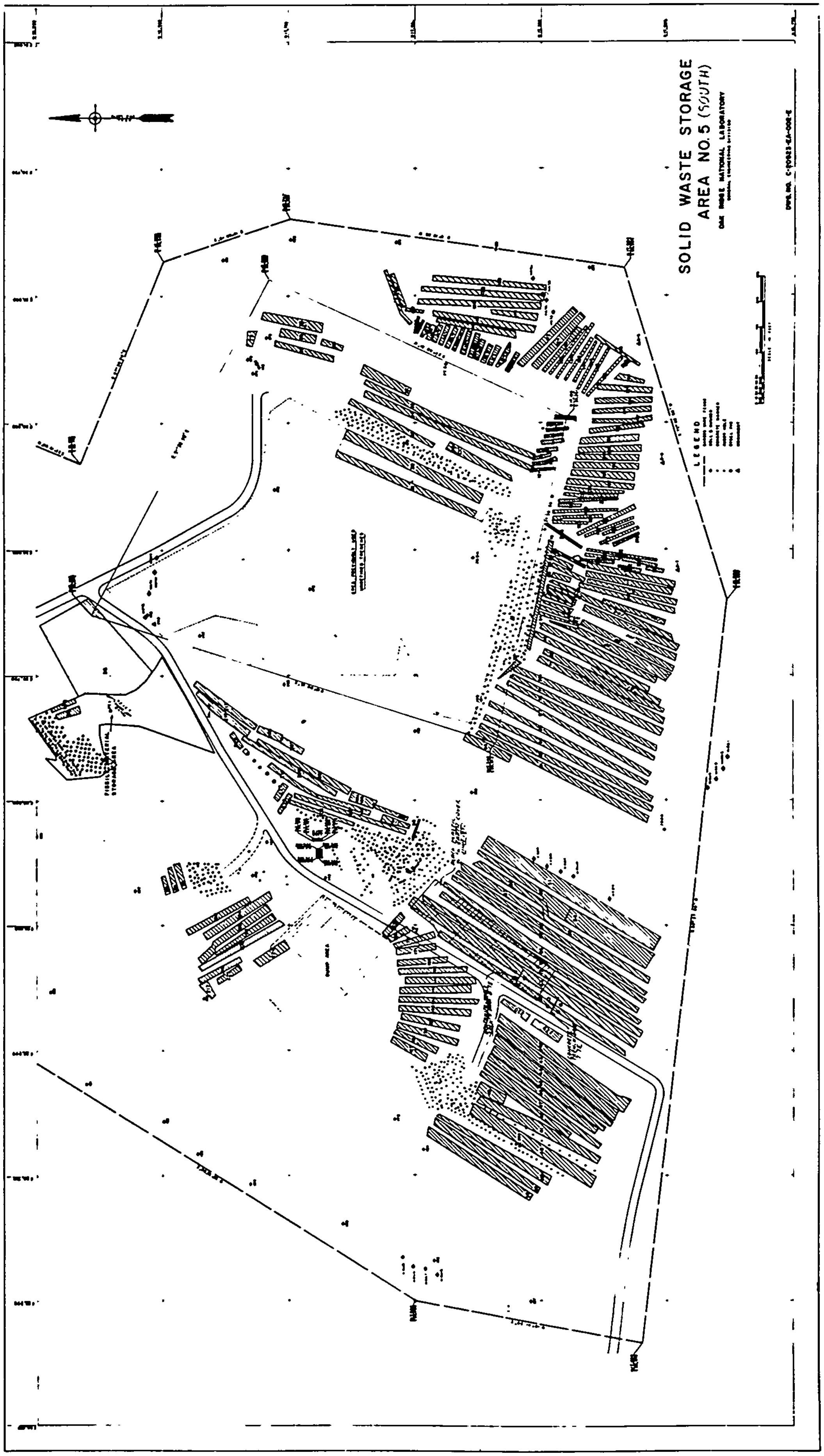

Fig. 5. SWSA-5 (south).

ORNL Old Hydrofracture Facility, utilized for many years for permanent disposal of ORNL generated liquid waste, but now deactivated, is located just inside the southwestern corner of SWSA-5 (south) near coordinates N17,200 and E28,600.

Waste disposal in SWSA-5 (south) was accomplished in a manner similar to that used for SWSA-4 (Davis and Shoun, 1986). Beta-gamma contaminated waste was disposed of by normal trench burial, that is, excavation by backhoe and covered with weathered shale (Bates, 1983). Trenches in the area vary considerably in size from approximately 12 to 150 m (40 to 500 ft) in length, and they are approximately 4.4 m (15 ft) deep and 3.5 (12 ft) wide. The trenches were located at right angles to the strike of the shale to minimize collapse of the trench walls; thus, most trenches are located parallel to the slope. The "undefined area" shown was used primarily for disposal of segregated alpha-contaminated waste which was trench buried and occasionally covered with a slab of concrete. The records for the "undefined area" are missing as are many that were burned in the Building 7803 fire. Auger holes were utilized for disposal of higher-activity and fissile wastes in the areas designated on Fig. 5.

2.5.2 Retrievable Storage

SWSA-5 (north) has been used almost exclusively for the retrievable storage of transuranic (TRU) wastes (Webster, 1976; Myrick et al., 1984; Bates, 1983) (Fig. 6). Since the segregation of TRU waste began in 1970 at ORNL, in response to a DOE order for retrievability, three retrievable storage methods have been used: stored drums, stainless steel-lined wells, and concrete casks. Figure 7 shows the TRU waste storage area and the facilities involved.

Solid TRU wastes with low external gamma exposure rates (<200 mR/hr) were first stored in 114-L or 220-L (30- or 55-gal) stainless steel drums in Building 7823, as shown in Fig. 8. The drums are sealed with a neoprene gasket and a closure ring (Gilbert/Commonwealth, 1981). Building 7823 (now used as a temporary holding area) is 15 m (48 ft) wide, 24 m (78 ft) long, and two-thirds below grade; it has a crushed rock floor, metal roof and walls, and ceiling of chain-link fence fabric. Once a sufficient number of drums have accumulated, a cell of the Retrievable Waste Storage Facility,

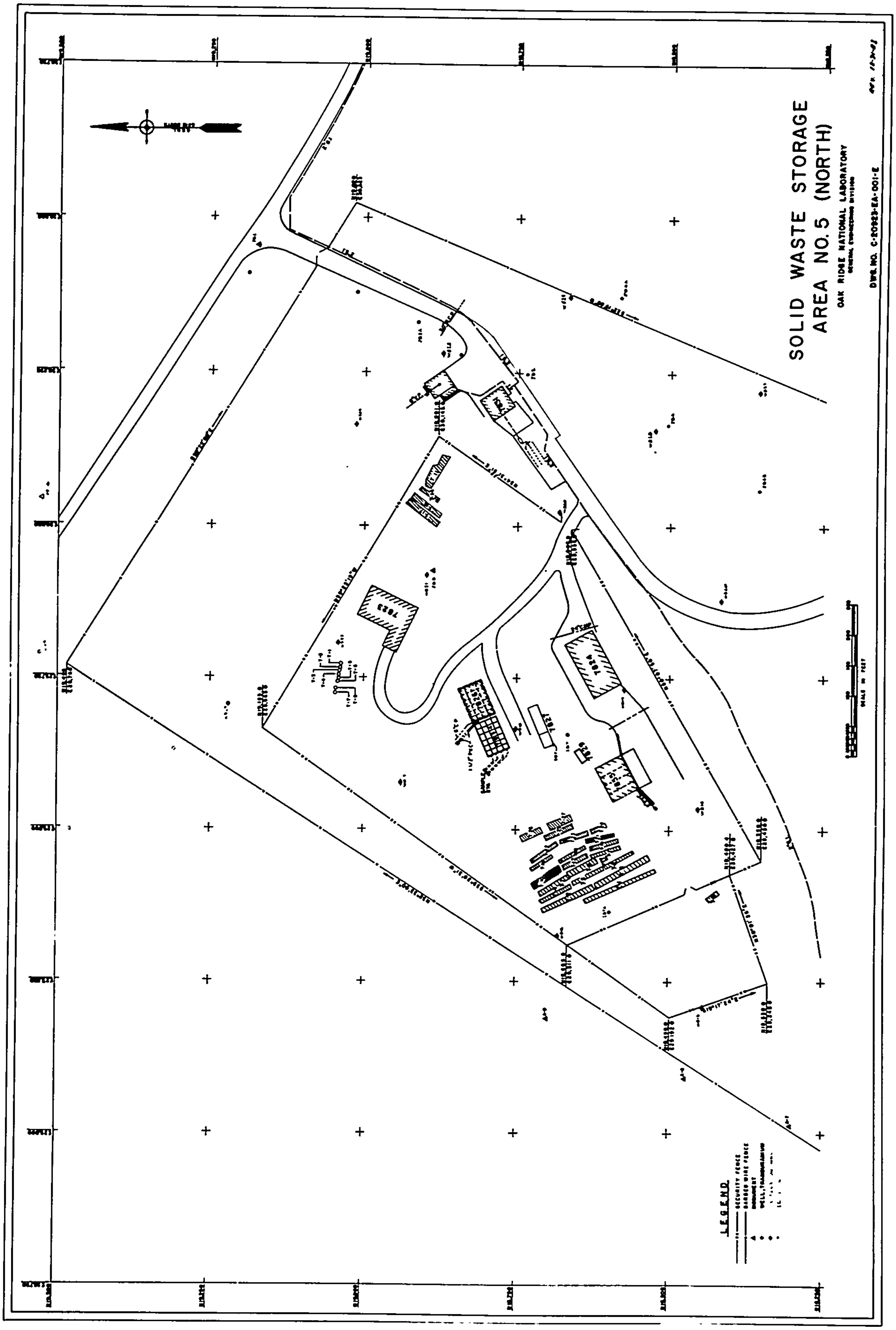

Fig. 6. SWSA-5 (north).

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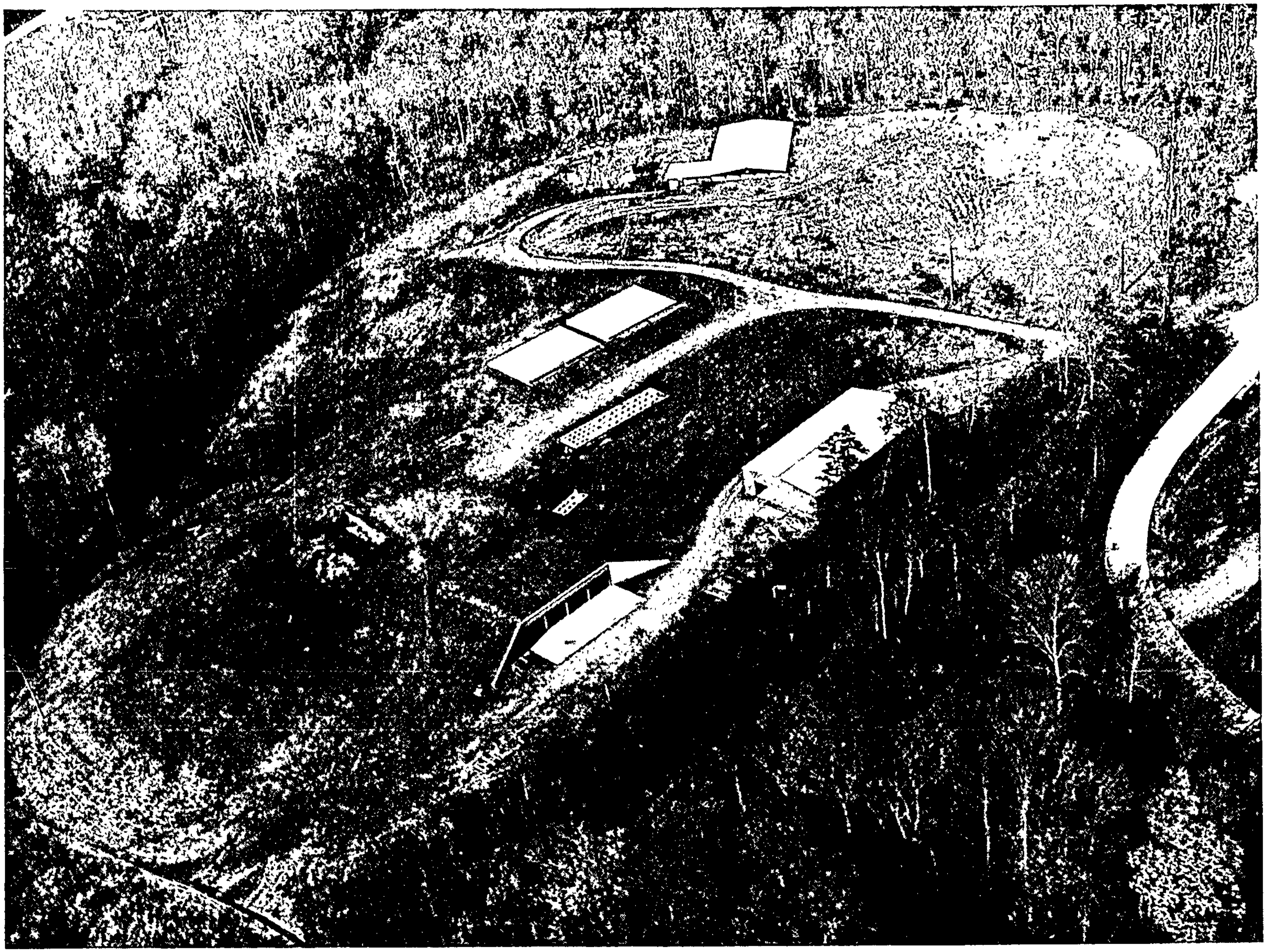

Fig. 7. Aerial view of TRU waste storage area.

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Fig. 8. Inside of TRU drum holding area (Building 7823).

Building 7826, is opened and the waste drums emplaced for storage. Building 7826, which was constructed in 1976, is a one-story reinforced-concrete-and-concrete-block structure measuring 12 m (39 ft) by 17 m (55 ft) and 4 m (13 ft) in height with 85% of the structure below grade. There are 24 cells which hold 220-L drums, with 64 drums/cell, 16 drums/layer, and 4 layers/cell. Figure 9 is a photograph of Building 7826 with the cover removed and drums being loaded into a cell. A second storage facility (Building 7834) with a larger holding capacity was completed in 1980. It has removable concrete plugs rather than metal roofing and has space for an additional layer of drums in each cell (Gilbert/Commonwealth, 1981). About 85% of the structure is below grade.

Prior to completion of Building 7826, the TRU wastes were stored in mild steel boxes, black iron drums, or stainless steel drums in Building 7823 (National Academy of Science, 1976). Use of the black iron drums was discontinued because they were subject to deterioration. The drums are periodically inspected for leakage and are routinely maintained (Gilbert Commonwealth, 1981). Criticality control is maintained by limiting the quantity of fissionable material to 20 g in each 114-L (30-gal) drum. The quantity of fissionable material allowed in each 220-L (55-gal) drum is 36 g (1979 ORNL Radioactive Solid Waste Operations Manual).

The total storage capacity of Buildings 7826 and 7834 is 3456 drums. At the end of 1979, approximately 1600 drums were in storage, 1300 of the stainless steel type and 300 of the black iron type (Gilbert/Commonwealth, 1981).

TRU waste with high external gamma exposure rates (>200 mR/h) or having high neutron emission levels are sealed in reinforced concrete casks at the point of origin. The majority of the waste placed into concrete casks has been generated in Building 7920 (Gilbert/ Commonwealth, 1981). Currently, concrete casks with three different wall thicknesses (thin, intermediate, and thick) are available for waste burial. The internal diameters range from 65 to 100 cm (27 to 42 in.), and the lengths range from 150 to 190 cm (58 to 73 in.) (ORNL Radioactive Solid Waste Operations Manual, 1979). The wall

ORNL-PHOTO 5206-76

Fig. 9. Inside of the TRU waste storage facility (Building 7826).

thicknesses of available casks range from 11 to 30 cm (5 to 12 in.), depending on the shielding requirements, and the casks are 2.5 m (8 ft) in height (Gilbert/ Commonwealth, 1981). Once the casks are filled and sealed, they are transported by tractor-trailer units and unloaded by mobile crane into a 3-m (10-ft)-deep trench, as shown in Fig. 10. The trench is backfilled with soil when loaded to capacity (National Academy of Sciences, 1976). Use of the 11-cm (4.3 in.) casks was discontinued in the late 1970s (Gilbert/ Commonwealth, 1981). Criticality control is maintained by limiting the fissionable material to 200 g per cask (Procedures and Practices for Radiation Protection, Health Physics Manual, Oak Ridge National Laboratory, 1980).

The practice of burial in trenches in the northern section of SWSA-5 (TRU area) was discontinued in 1979, and storage was initiated in a cave-like facility (Building 7855) in the side of a knoll (Fig. 11) (Gilbert/Commonwealth, 1981). Building 7855 is a one-story, four bay concrete block structure with a reinforced-concrete slab base and roof. The casks are loaded into the cave using a forklift. At the end of 1979, 190 casks had been buried in trenches; cave storage began in 1980 (Gilbert/Commonwealth, 1981).

Small TRU-contaminated waste packages with high external gamma exposure rates have been placed in stainless steel (or in some cases, brass) capsules and sealed with a metal-gasket-and-bolt closure assembly for storage. The first capsules were stored in individual auger holes, each lined with stainless steel and closed with a stepped concrete plug (Fig. 12). The auger holes are 2.75 m (9 ft) deep and have a 24-cm (9-in.) outer layer of concrete placed around the stainless steel liner to prevent flotation. The auger hole itself has an internal diameter of 20 to 75 cm (8 to 30 in.), and the concrete plugs are 46 cm (18 in.) thick. One meter spacing was maintained between the eight auger holes.

Buildings 7827 and 7829, built after the first eight auger holes, are an improved extension of ORNL facilities for storing TRU wastes with high external gamma exposure rates. Currently, Building 7827 has 30 wells; 15 of them are 4.6 m (15 ft) deep, and the remaining 15 are 3.1 m (10 ft) deep. Each group is comprised of an equal number of 20-cm

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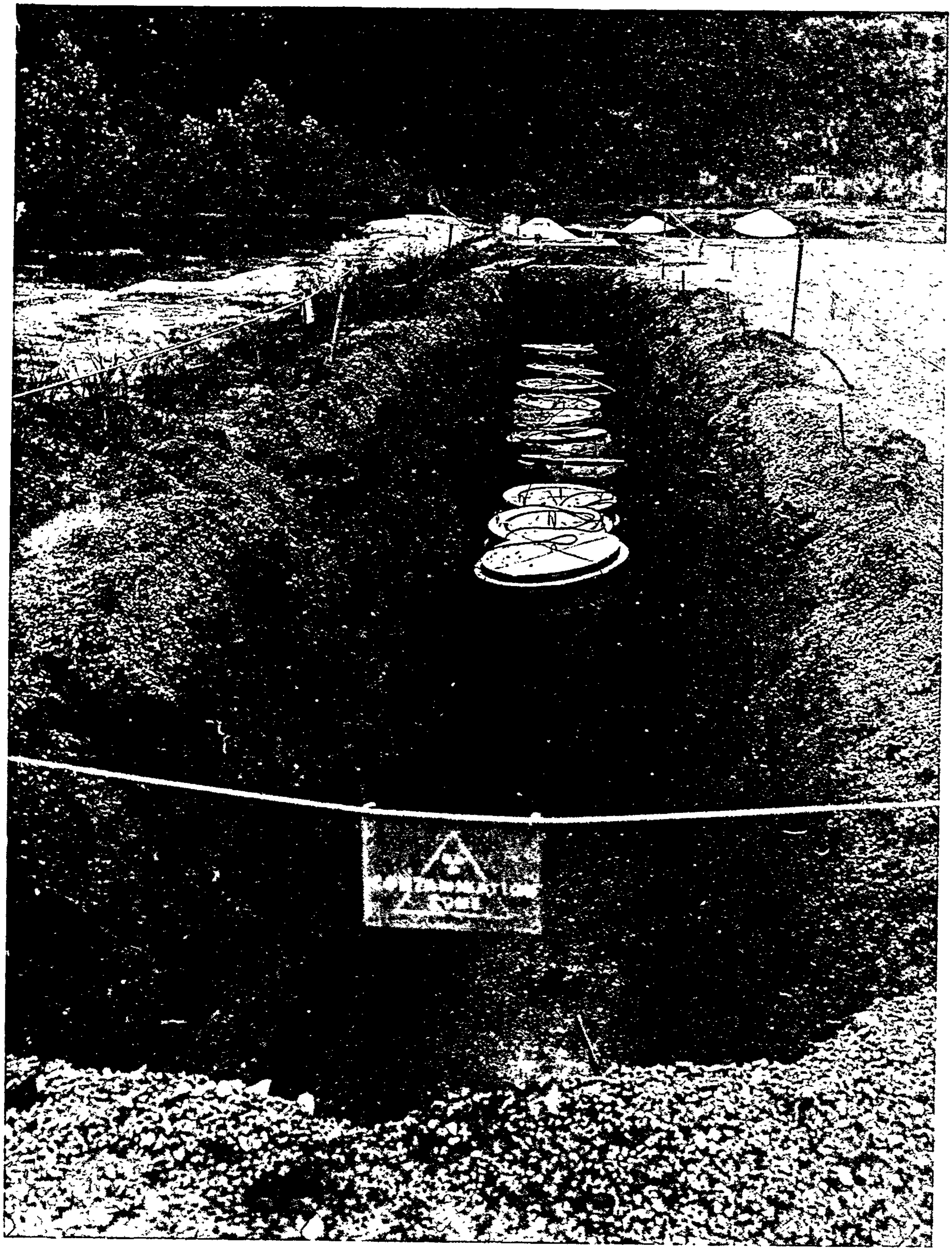

Fig. 10. Concrete casks used for TRU wastes with high external gamma exposure rates.

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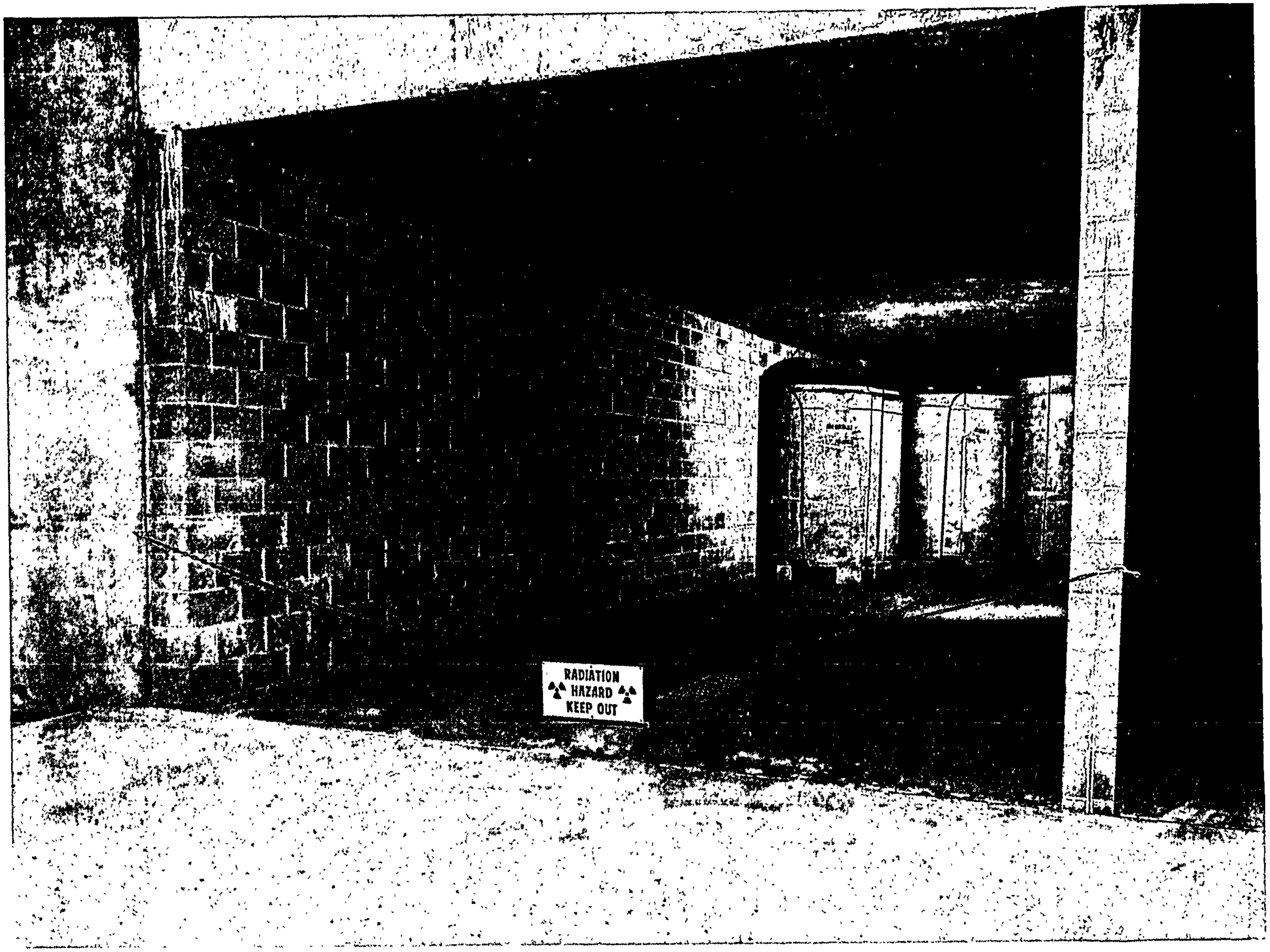

Fig. 11. Cave-like facility for storing TRU waste with high external gamma exposure rates or having high neutron emission levels.

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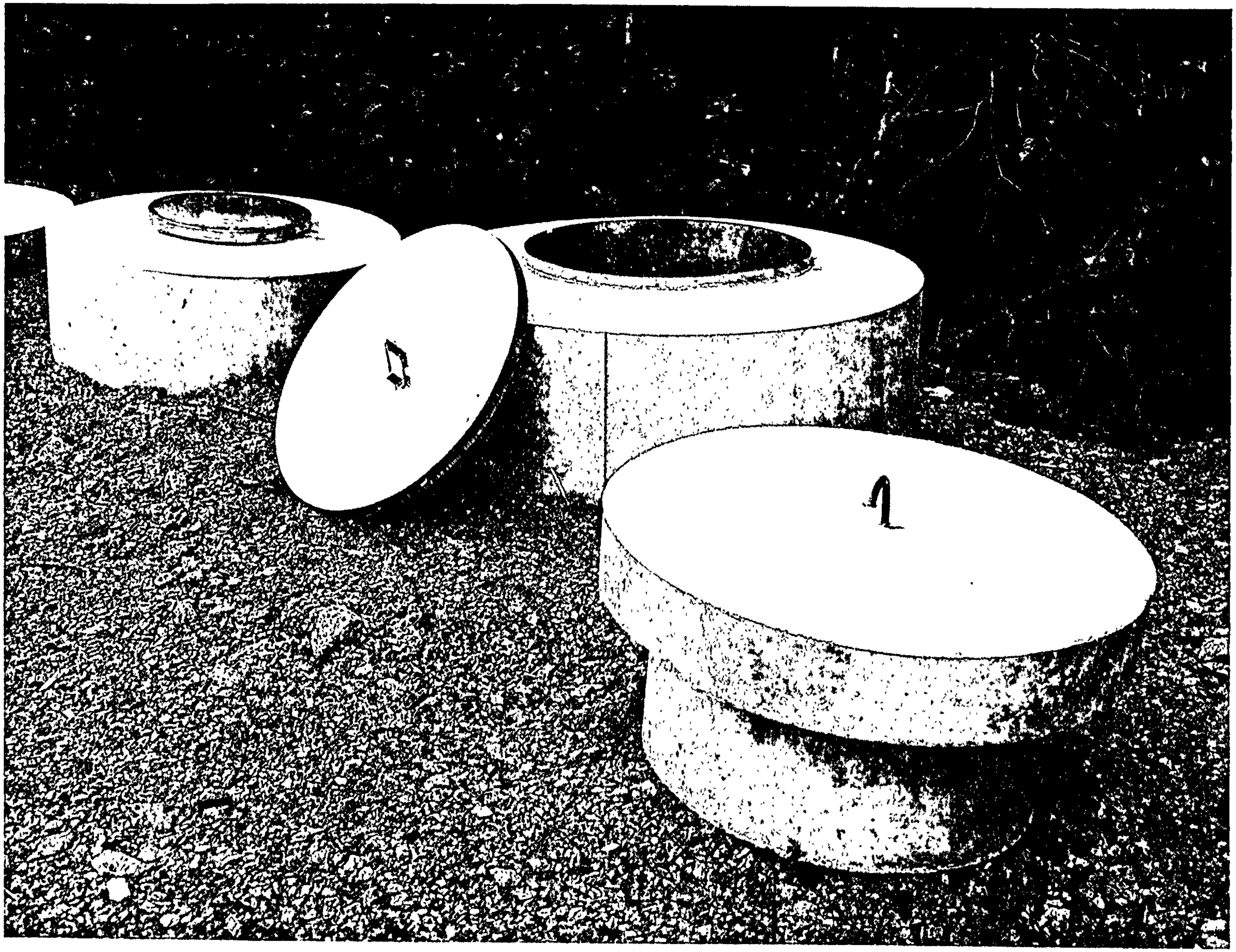

Fig. 12. The above-ground portion of a stainless steel-lined auger hole.

(8-in.), 40-cm (16-in.), and 76-cm (30-in.) diam holes lined with stainless steel and capped with steeped concrete plugs. Building 7829 contains ten wells 30 cm (12 in.) in diameter by 4.6 m (15 ft) deep. The waste containers are held by a cable and lowered into the wells from a shielded carrier (Gilbert Commonwealth, 1981). Spacing between wells is maintained in such a manner that noncriticality is ensured (1979 ORNL Radioactive Solid Waste Operations Manual).

The volumes and quantities of solid radioactive waste retrievably stored at DOE sites are shown in Table 1. ORNL has a relatively small volume of TRU wastes stored in retrievable form in comparison to other DOE sites. The quantity of plutonium stored at ORNL is significantly less than that stored at other DOE sites; yet the quantities of other TRU nuclides stored at ORNL are surpassed only by those at the Idaho National Engineering Laboratory (Evaluation Research Corporation, 1982).

2.6 EXPERIMENTAL PROJECTS AND REMEDIAL ACTIONS

Over a period of time as problems were recognized, a number of remedial actions were undertaken in order to reduce radionuclide release. A discussion of some of these corrective actions and experimental projects follows.

Normal problems caused by infiltration of precipitation were aggravated in SWSA-5 because of poor trench orientation (Webster, 1976; Evaluation Research Corporation, 1982). Trenches in this burial ground were excavated with their long axes in an upslope-downslope direction, paralleling the hydraulic gradient of the water table. The extent of water seepage might have been less if the long axis of the trenches paralleled the hillslope contours and crossed the hydraulic gradient; however, the trenches may have experienced considerably more sidewall collapse (Fig. 13). Some of these trenches filled with water, which seeped out the lower ends of the trenches, a phenomenon known as "bathtubbing."

2.6.1 Trench Cover and Dam

In 1975, corrective actions were taken to reduce the seepage in the southeast corner of SWSA-5 found to have relatively high amounts of ^{90}Sr and measurable mounts of ^{244}Cm and ^{238}Pu (Evaluation Research

Table 1. Solid radioactive wastes buried at DOE sites as of October 1, 1976[a]

Site	Volume (m^3)	Activitity at burial (kCi)	Uranium (kg)	TRU (kg)
Oak Ridge National Laboratory	180,000	100	100	13
Hanford	170,000	2,000	600,000	370
Savannah River Plant	260,000	8,200	84,000	7
Idaho National Engineering Laboratory	150,000	6,100	310,000	360
Los Alamos Scientific Laboratory	240,000	300	200,000	13

[a]From Dieckhoner, 1977.

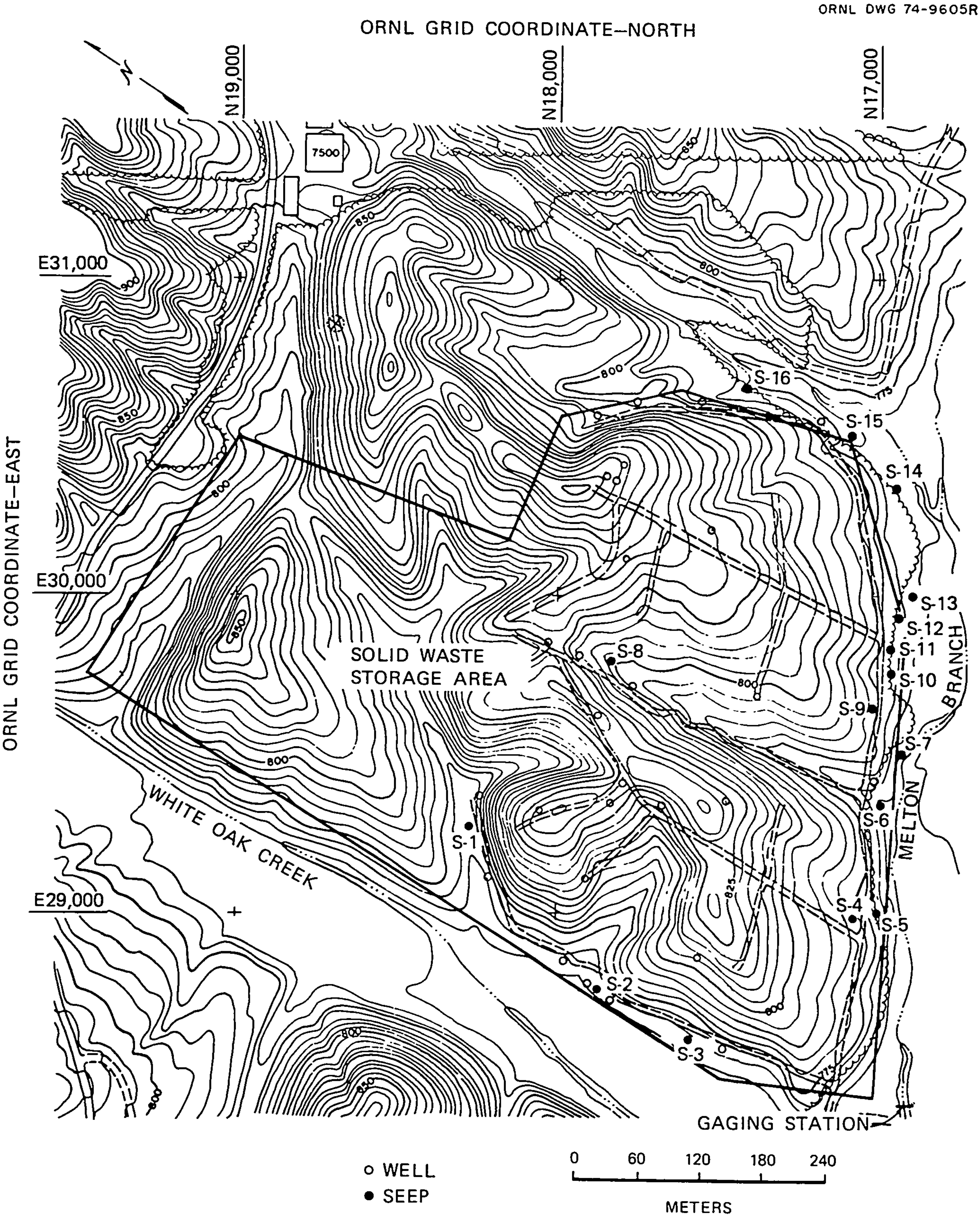

Fig. 13. Location of groundwater seeps on the perimeter of SWSA-5 as identified by Duguid (1975).

Corporation, 1982). Initially, about 0.6 m (2 ft) of overburden was removed from the area overlying four of the burial trenches: 105, 83, 72, and 69. Two underground dams, one of concrete, placed approximately 55 m from the southwestern end of trenches 105 and 83, and one of bentonite-shale, placed approximately 82.5 m (270 ft) from the southwestern end of the same trenches (Figs. 14 and 15) were installed. The stripped area, including the dammed trenches and two parallel trenches (72 and 69) on the southeast, were then covered with 0.254-mm-thick (0.01 in.) PVC membrane with an estimated life of 25 years (Duguid, 1976). The approximately 0.6 m (2 ft) of stripped overburden was replaced, and the area was seeded with grass to prevent erosion.

Duguid (1975a) identified 16 groundwater seeps around SWSA-5 (Fig. 13). The concentration of ^{90}Sr in these seeps, as reported by Duguid, is seen in Table 2. The highest concentration of ^{90}Sr (517.0 kBq/L) found at seep 4 by Duguid in 1974 was not apparent in the study of Spalding and Munro (1984b) since the seep was dry, thus indicating the success of the corrective actions of damming and PVC-covering of the group of trenches in this area as discussed above. The ^{90}Sr concentrations for seep 5 just south of seep 4 are very similar for samples taken in 1974 by Duguid and in 1980 by Spalding and Munro.

While these actions decreased the amount of ^{3}H and ^{90}Sr migrating from SWSA-5 (Tamura et al., 1980) for a time, the annual migration of these radionuclides has apparently recovered to earlier rates. There is a wide fluctuation of these releases; however, apparently the ^{90}Sr release rate was at its lowest level in 1981 (National Research Council, 1985).

2.6.2 Surface Seal

In SWSA-5 (north) a near-surface seal of 14 trenches in the TRU waste area (Fig. 16) was attempted in 1977. The area, consisting of 1765 m^2(0.4 acre) just west of E 29,500 and lying between N 18,500 and N 18,750, was covered with a bentonite shale mixture at the rate of 0.04 kg/m^2 (0.008 lb/ft^2) of bentonite in an attempt to reduce excessive infiltration of precipitation. Results similar to the above actions may be attributed to this remediation project.

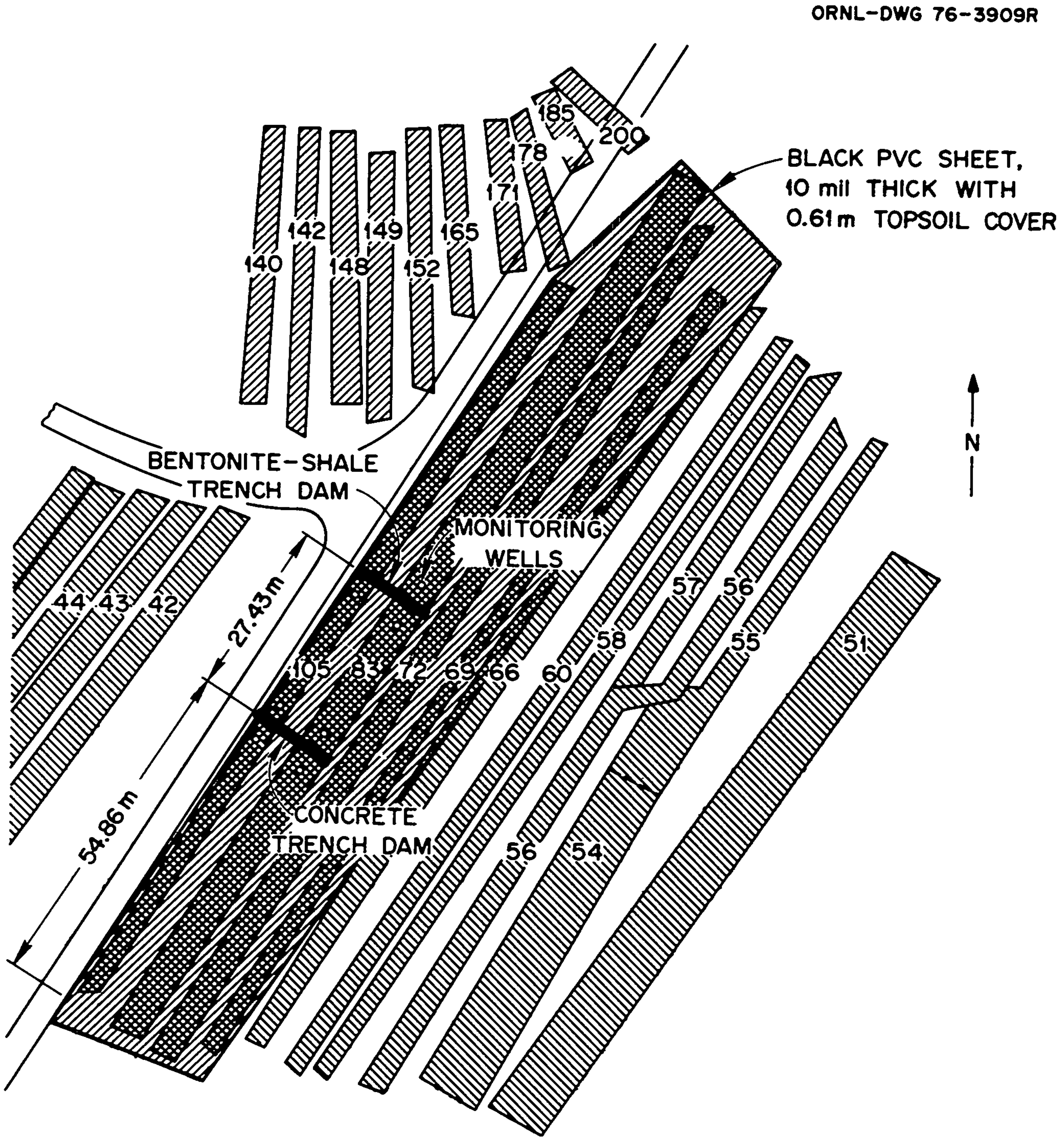

Fig. 14. Near-surface sealing of trenches in SWSA-5.

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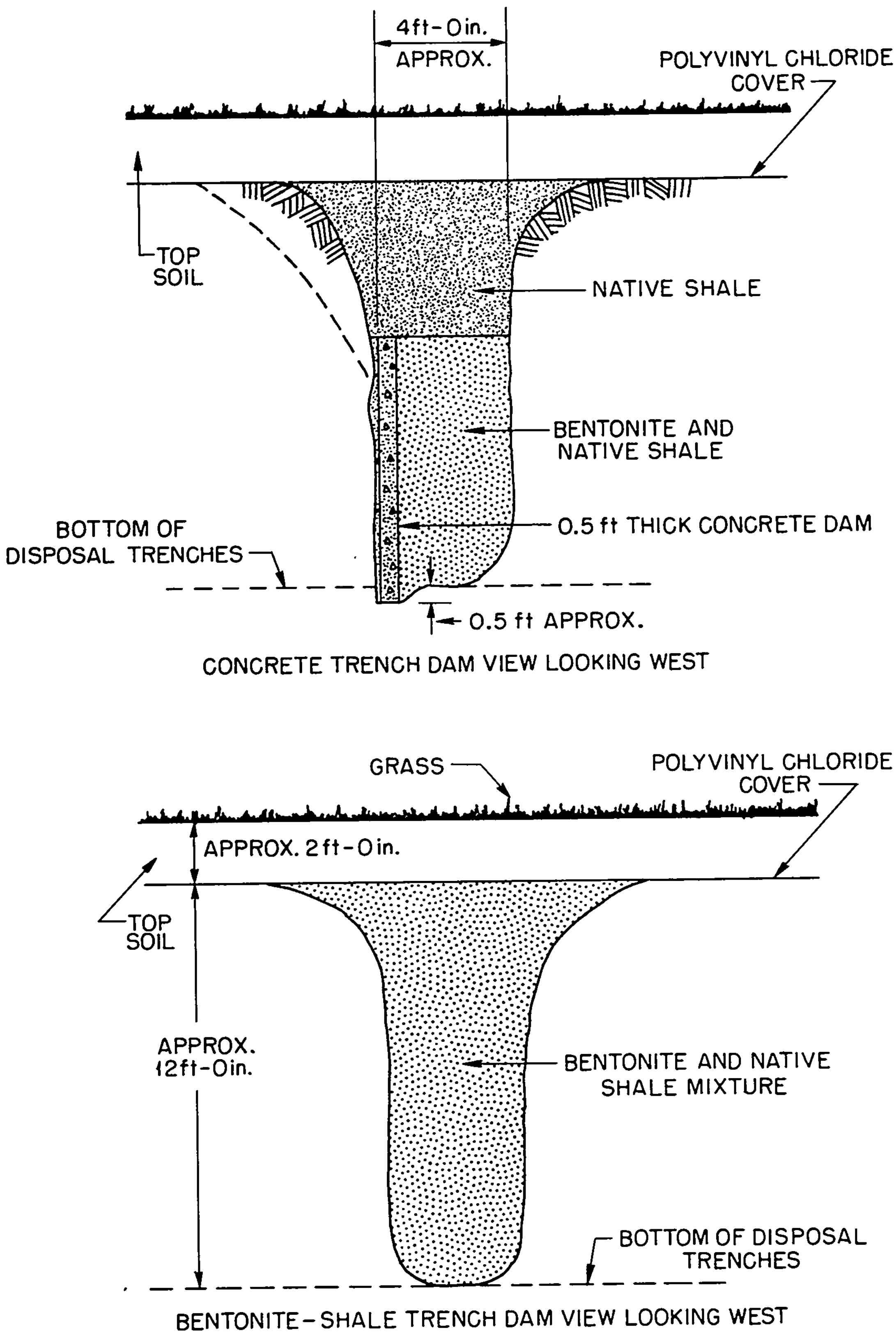

Fig. 15. Cross sections of the concrete and bentonite-shale dams across trenches 105 and 83.

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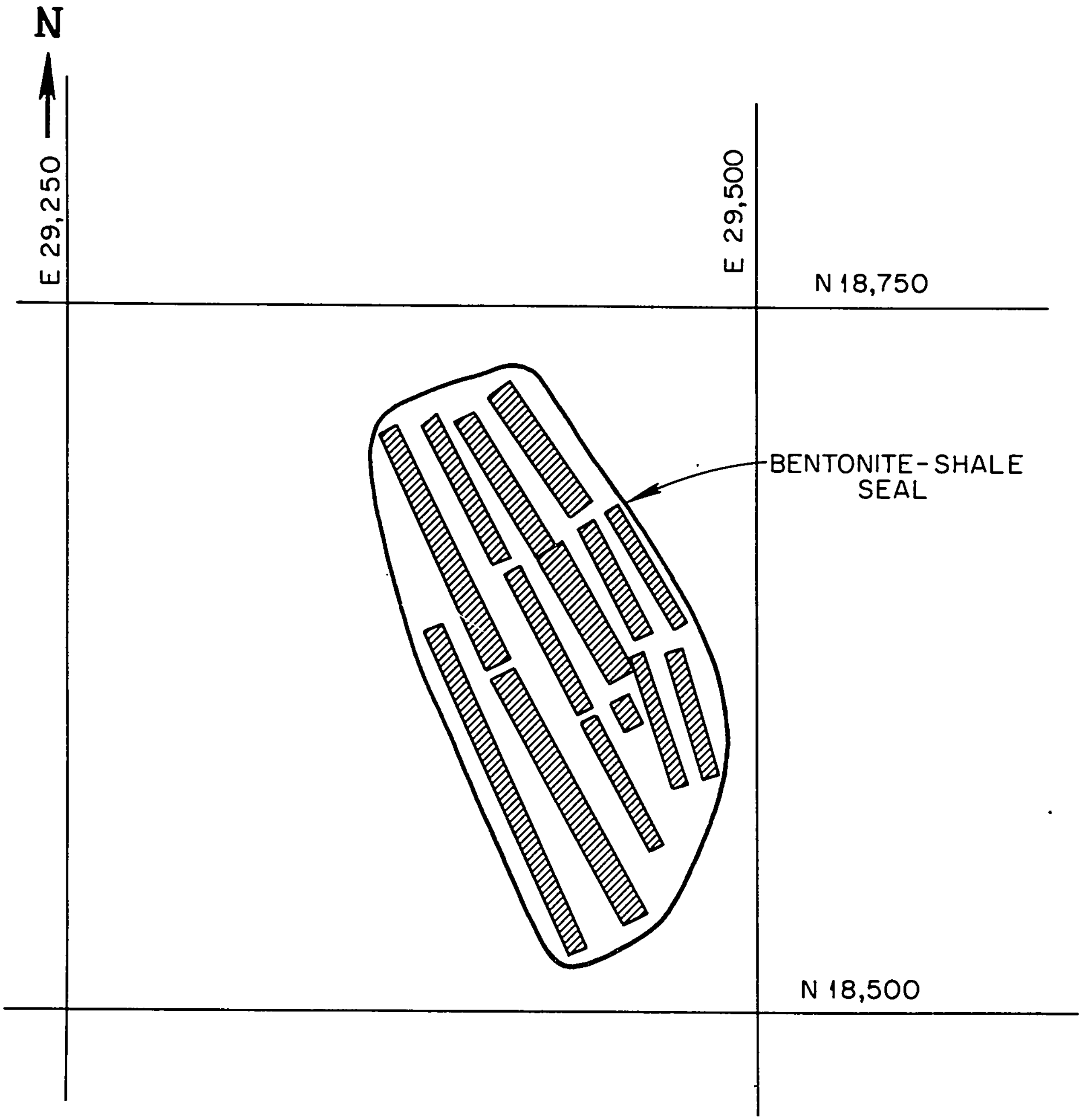

Fig. 16. Bentonite-shale surface seal in SWSA-5.

Table 2. Concentrations of ^{90}Sr in groundwater seep samples on the perimeter of SWSA-5 reported by Duguid (1975)[a]

Seep No.[b]	Date sampled	^{90}Sr (kBq/L)
S1	Nov. 13, 1973	<0.001
S2	Nov. 13, 1973	<0.001
S3	Nov. 13, 1973	<0.001
S4	Mar. 11, 1974	517.0
S5	Mar. 11, 1974	5.8
S6	Mar. 11, 1974	0.13
S7	Mar. 11, 1974	0.088
S8	Mar. 11, 1974	<0.001
S9	Mar. 11, 1974	2.27
S10	Mar. 11, 1974	0.60
S11	Mar. 11, 1974	0.39
S12	Mar. 11, 1974	0.022
S13	Mar. 11, 1974	0.46
S14	Mar. 11, 1974	0.003
S15	Mar. 11, 1974	0.15
S16	Mar. 11, 1974	0.005

[a]From Spalding (1984a).
[b]See Fig. 13.

2.6.3 Miscellaneous Actions and Analyses

Additional corrective measures taken during the same time frame include filling in of collapsed trenches, surface contouring for improved drainage, and installation of concrete-lined drainage ditches (Tamura et al., 1980; Duguid, 1976; Evaluation Research Corp., 1982, Grizzard, 1986; National Research Council, 1985).

Both groundwater and surface water drainage in SWSA-5 are predominantly southeast toward Melton Branch and southwest toward White Oak Creek. The water-table contour map shows that the steepest gradient is in the direction of Melton Branch, which implies that the prevailing movement is to the southeast. Therefore, most of the potential radionuclide transport by surface water is monitored at Station 4 (Fig. 1) on Melton Branch (Myrick, 1984).

In 1964, radiochemical analyses were made on water samples collected from several wells and from the drainage that divides the site into two sections (5 south area and 5 north area). The principal contaminants found were ^{90}Sr, ^{106}Ru, ^{3}H, and trivalent rare earths. Only minor movement of ^{106}Ru, ^{137}Cs, and ^{60}Co from trenches was observed from analyzed core samples of new wells (Webster, 1976; Oakes and Shank, 1979).

Water samples collected from seeps from SWSA-5 in 1974 indicated that ^{90}Sr and ^{3}H were principal contaminants. The average concentration of ^{3}H in the samples was 3.9×10^5 dpm/ml, or 0.2 mCi/ml. Water samples collected at a sampling station about 1.6 km (1 mile) downstream from the confluence of Melton Branch with White Oak Creek have indicated that several thousand curies of ^{3}H had passed that point annually since the mid-1960s. Most of the ^{3}H found at the station is believed to have been discharged to Melton Branch in groundwater from SWSA-5 (Webster, 1976).

Spalding and Munro (1983b) found increased concentrations of ^{90}Sr in groundwater in two major areas along the perimeter of SWSA-5. One area was south of the Old Hydrofracture Facility (OHF) (Building 7860) just outside of and west of the SWSA-5 perimeter fence. Due to the directional flow path of the water in the area, it is assumed that the elevated ^{90}Sr concentrations were related to operations of the OHF. The second area of elevated ^{90}Sr concentrations is in a region downslope from specific trenches in the eastern portion of SWSA-5 that are known to contain high inventories of ^{90}Sr.

2.6.4 Caustic Soda—Soda Ash Experiments

The more recent work of Spalding and Munro (1984b) investigated the ^{90}Sr concentrations found in grab samples from the main drainage tributary and the small tributary in SWSA-5 and in boreholes placed at 3-m (10 ft) intervals along the perimeter of SWSA-5. Additional water quality parameters from these perimeter boreholes were documented, including hardness, electrical conductivity, and pH.

The applicability of a short-term corrective action for ^{90}Sr release from SWSA-5 was studied by Spalding and Munro (1983). In this experiment, fourteen 22.5-kg bags of anhydrous light soda ash (>98% Na_2CO_3) were buried two bags to a 50-60 cm deep hole in the groundwater flow path leading to the seep. In addition, 45 kg of soda ash was placed on the surface. This treatment was found to effectively reduce the ^{90}Sr concentration from 7000 Bq/L to 900 Bq/L for 90 days after burial followed by a gradual rise to pretreatment levels over the next 100 d as the soda ash was consumed in the precipitation of Ca, Mg, and Sr from the groundwater.

In a similar experiment, Spalding (1984a) injected trench 117 in SWSA-5 (Fig. 17) with caustic soda, soda ash, caustic soda, and lime/soda ash, respectively, over a 1-year period. Much of the ^{90}Sr was found to be coprecipitated with calcium carbonate, and the ^{90}Sr concentration of one well at the foot of the trench decreased from over 100 kBq/L to less than 10 kBq/L. As in the earlier experiment, several additional water quality parameters were correlated, soil analyses were made, and a generic assessment is presented.

3. ADDITIONAL WAG COMPONENTS

3.1 OHF FACILITIES

3.1.1 Process Waste Sludge Basin (Bldg. 7835)

The process waste sludge basin is an approximately 24 x 24 x 2.4 m (78 x 78 x 8 ft) deep pond designed for storage of sludge generated by the Process Waste Treatment Plant. The pond has a compacted clay bottom and is lined with PVC. It is located in SWSA-5 (north), on a bluff southeast of the TRU Waste Storage area approximately 90 m (300

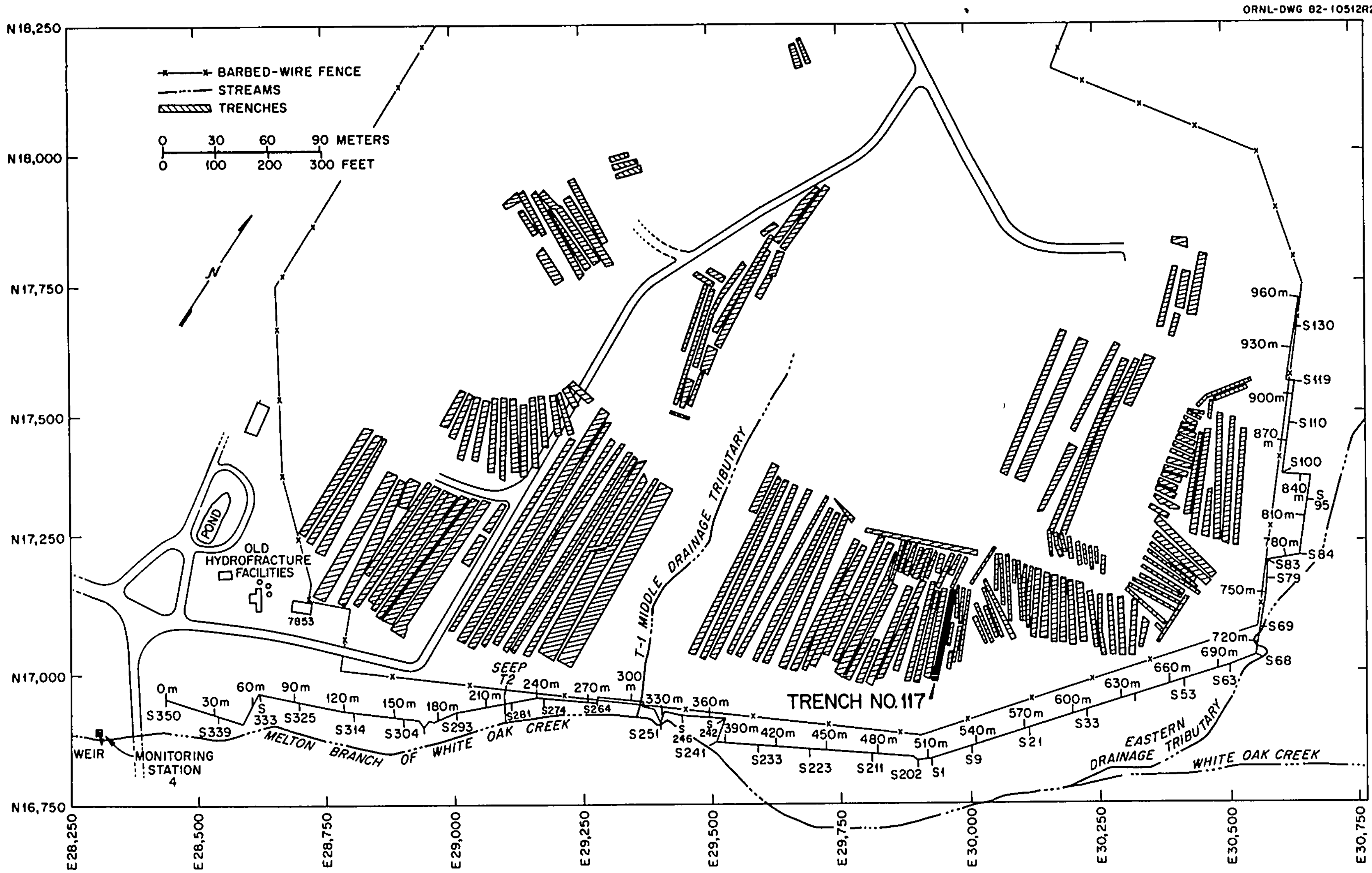

Fig. 17. Groundwater sampling perimeter line on the southern and eastern sides of SWSA-5. Cumulative distance along this perimeter is indicated in meters with every tenth sample identification number indicated. From Spalding and Mauro (1984).

ft) from Bldg. 7824 (see Fig. 6 for reference). Prior to use of this facility being discontinued in 1981, sludge was pumped from the treatment plant to this basin, the sludge was allowed to settle, and the supernate was pumped back to the Equalization Basin. There is an approximately 1.2 m (4-ft) layer of sediment in the open pond consisting of ferrous sulfate, ferric hydroxide, and an estimated 1857 Bq (50 Ci) of mixed fission products (Myrick, et al., 1984).

3.1.2 OHF Impoundment (Area 7852A)

The OHF impoundment is located in Melton Valley, slightly more than 1 mile south of the main ORNL complex (Fig. 18). The facility is situated on the west edge of SWSA-5 at ORNL grid coordinates N17,400, E 28,500. The impoundment is situated at the base of a north-trending valley wall at an elevation below the OHF main plant facilities (see Figs. 17, 18, and 19). White Oak Creek flows southward through Melton Valley, approximately 120 m (400 ft) west of the impoundment, and westward-flowing Melton Branch lies approximately the same distance to the south. Three partially buried concrete waste vaults lie less than 15 m (50 ft) to the east of the south end of the impoundment at a slightly higher elevation. In addition, five steel tanks are buried approximately 20 m (70 ft) south of the impoundment. The vaults and tanks contain radioactive wastes from the hydrofracture operation.

The impoundment was constructed as part of the hydrofracture operation in 1963, essentially by excavating a rectangular basin in the base of the valley wall. Construction dimensions of the bottom of the basin are 6 m (20 ft) in width by 30 m (100 ft) in length, with sides sloping at 1 vertical on 1.5 horizontal pitch. The depth of the pond is slightly greater than 1.5 m (5 ft) at the low (west) side. The sides are lined with limestone riprap. Design capacity was 379,000 L (100,000 gal). Inflow was to the south end of the impoundment via a buried 46-cm (18-in.) line from the injection well cell. A 20.3-cm (8-in.) line from a waste pit, which was part of the injection operation, is also shown on drawings as entering the impoundment at the same location. Construction drawings specified that the pond bottom be sprayed with liquid asphalt to control erosion, and a plastic liner was placed in the pond prior to experimental injections. However, no evidence of either of these treatments was observed while

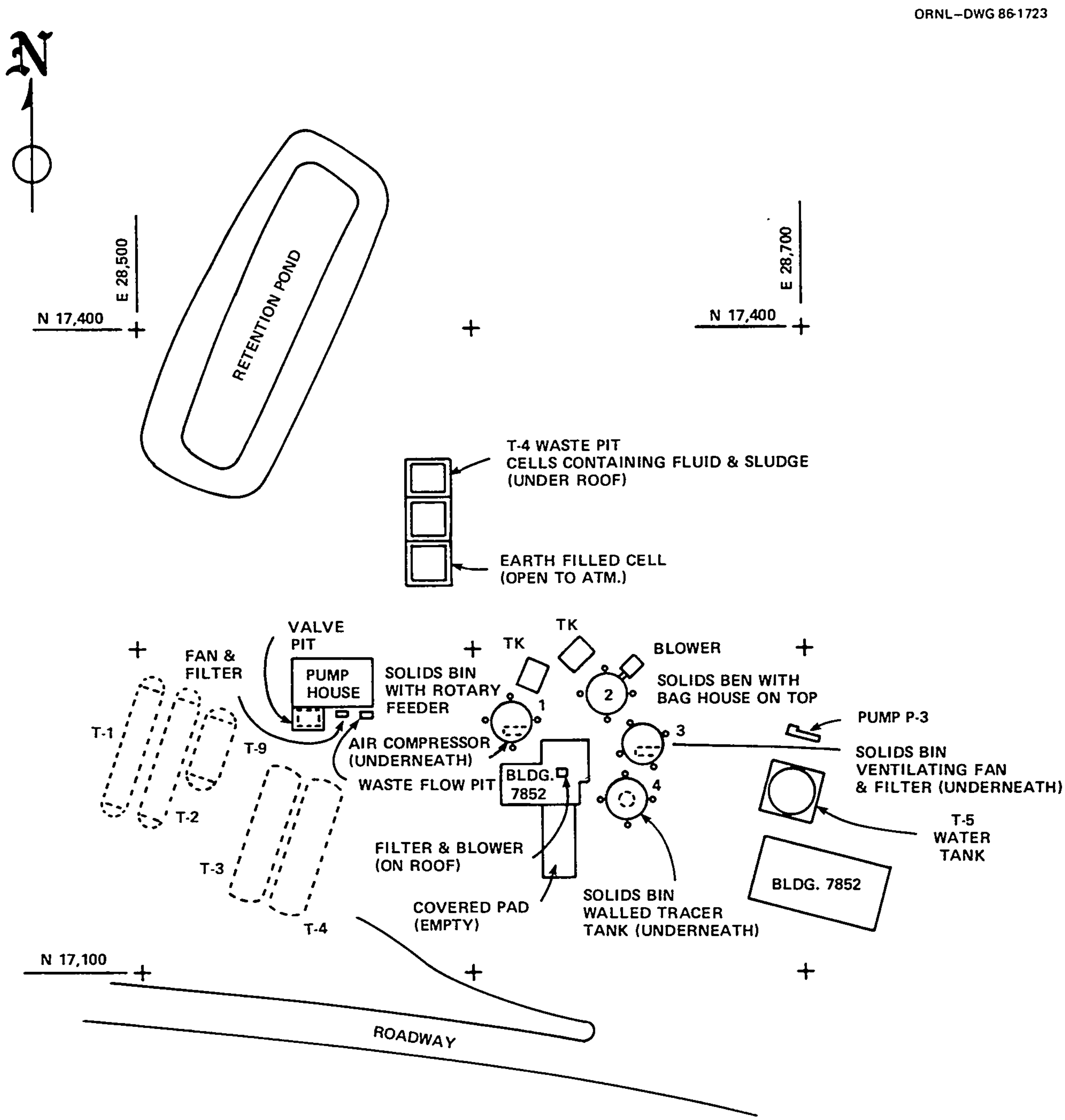

Fig. 18. Site plan of the Old Hydrofracture Facility.

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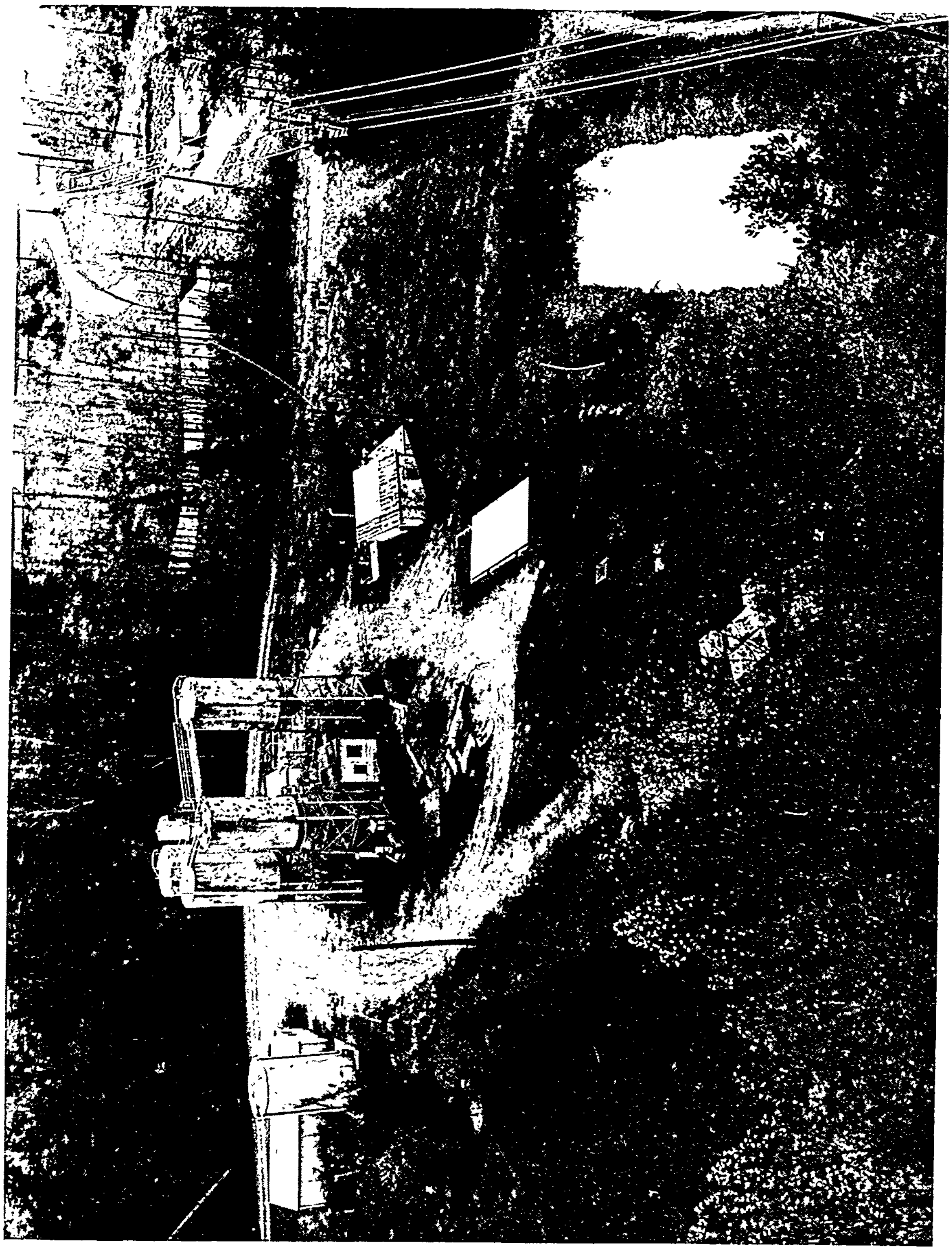

Fig. 19. Aerial photograph of the Old Hydrofracture Facility with the impoundment visible at lower right.

sampling the sediment for this study (Stansfield and Francis, 1986). A concrete standpipe, 1.5 m (5 ft) high, was provided as an emergency outflow at the north end of the impoundment. ORNL Drawing S-10916 EA 001D shows this vertical standpipe connected to 20-cm (8-in.) vitrified clay pipeline. The drawing shows this line extending to the west approximately 15 m (50 ft), where it empties into a shallow natural swale at approximate elevation 233 m (763 ft). Probings made during a recent study indicate that the bottom of the impoundment is at an approximate elevation of 233.1 m (764.6 ft). A geologic section is seen in Fig. 20, and a water table map of the impoundment is seen in Fig. 21.

The impoundment was constructed to serve as an emergency containment basin in the event of a spill from the radioactive grout injections, for example, caused by the backflow of grout. Due to malfunction of pumping equipment or piping, the impoundment did receive radioactive grout from injections made in 1965 (deLaguna et al., 1971) and 1977. Prior to a grout injection at the facility, the water level in the pond was required to be low enough that there would be sufficient freeboard capacity in the impoundment to hold the radioactive grout should an emergency arise that required such action during the operation. Prior to some injections, depending on the water level, this necessitated decanting the water from the pond. Before contamination of the impoundment by radioactive waste, the pond water was siphoned to the White Oak Creek flood plain. Subsequent to contamination of the impoundment, the water was pumped to the low-level waste system for processing.

Operation of the OHF ceased by 1980 (Myrick, 1984). In the winter of 1984-85, the pond received drilling fluid and drill cuttings from an exploratory core boring (5.7-cm core diam and 8.6-cm hole diam) through the radioactive grout sheets underlying the OHF site.

Probings made during a recent study indicate that the thickness of the sediment in the impoundment averages 27 cm (0.9 ft). This amounts to approximately 55,000 L (14,500 gal) of sediment. From the size and length (165 m or 542 ft) of the exploratory core, approximately 900 L (230 gal), or less than 2% of the total sediment volume, is sediment from the 1985 core-drilling operation (Stansfield and Francis, 1986).

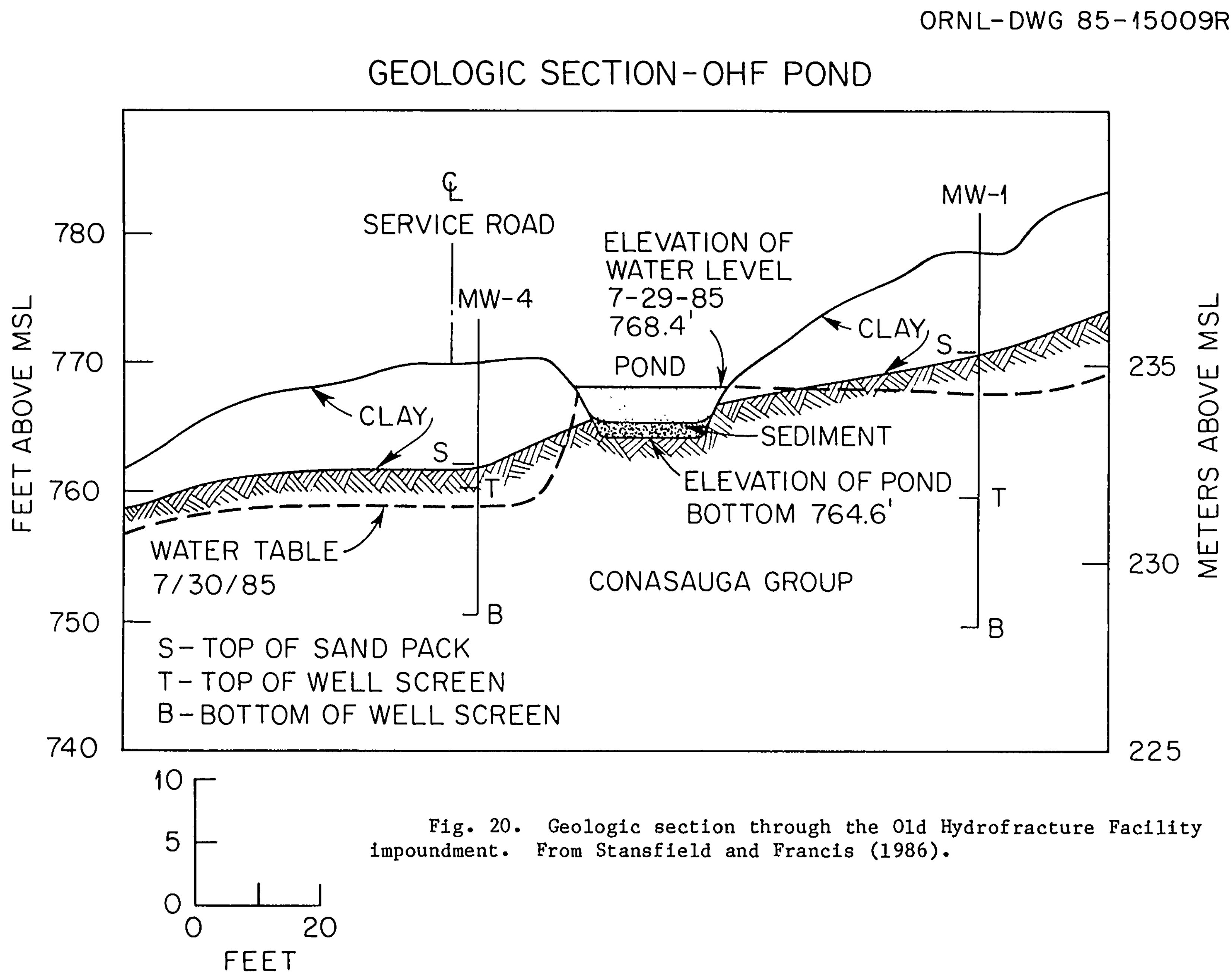

Fig. 20. Geologic section through the Old Hydrofracture Facility impoundment. From Stansfield and Francis (1986).

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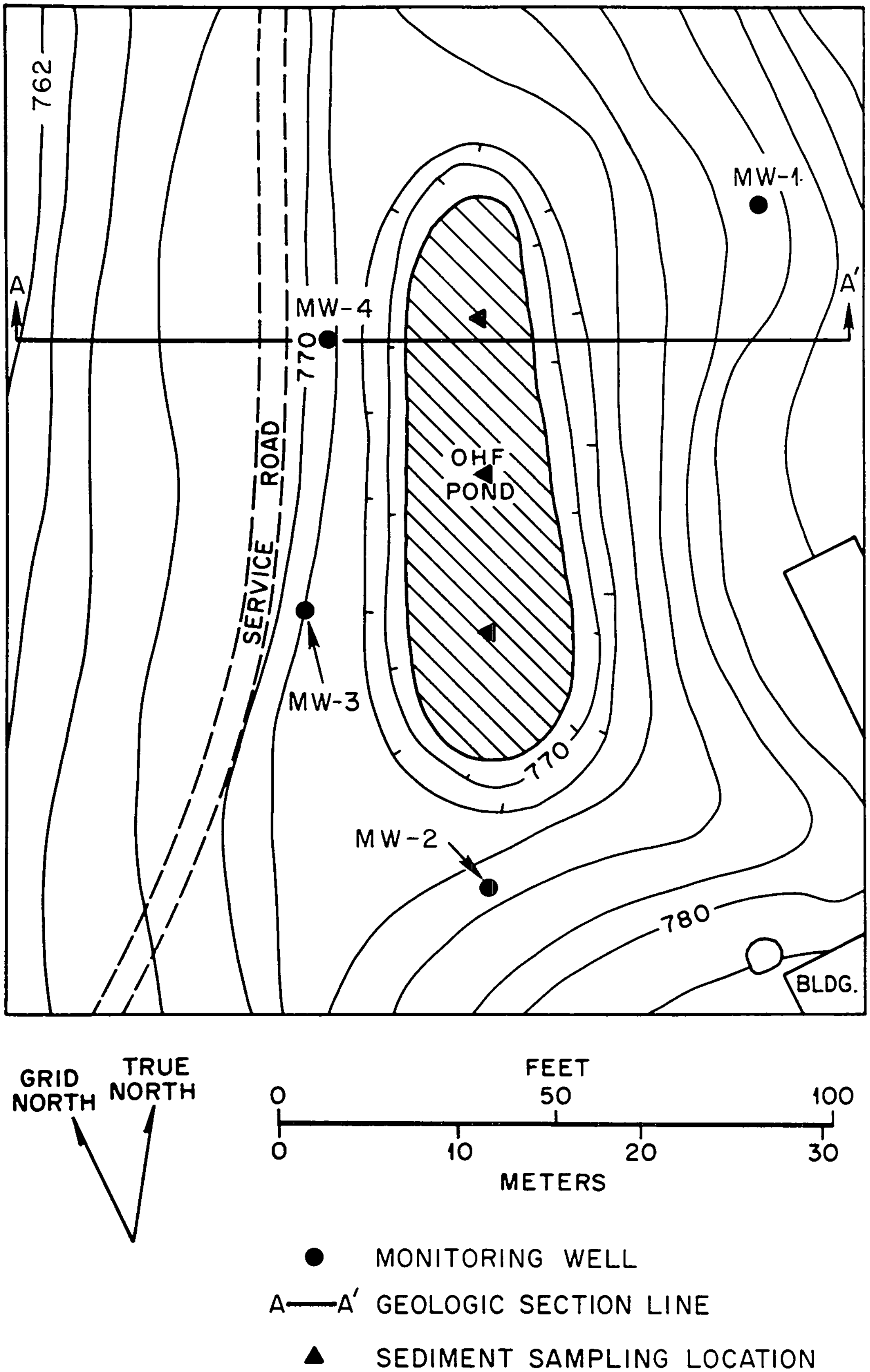

Fig. 21. Water-table map of the Old Hydrofracture Facility impoundment. From Stansfield and Francis (1986).

To determine the constituents of the waste sediment, samples were taken from the north, center, and south sections of the impoundment. Two sets of samples were obtained: the first in November 1984 and the second in February 1985.

The purpose of sampling was to determine whether the sediment in the bottom of the OHF pond would be classified as a hazardous waste under CERCLA or RCRA regulations; EP toxicity is of primary concern.

The major contaminants in groundwater at the OHF impoundment appear to be radionuclides; gross alpha and gross beta concentrations exceed NIPDWS concentrations in upgradient and downgradient wells. With the exception of one possibly contaminated sample, concentrations of metals, herbicides, and pesticides were below NIPDWS maximum limits. The main contaminants include ^{137}Cs, ^{90}Sr, and ^{60}Co. The maximum dose rates are 100 and 300 mrad/h at a height of 10 cm (4 in.) above the pond water. The total estimated activities of the water, sediment, and clay are 71,404, and 12 Ci, respectively. Extensive survey information has been presented by Stansfield and Francis (1986) and Francis and Stansfield (1986b).

Four monitoring wells were installed in March 1985 around the perimeter of the OHF impoundment (see Fig. 21). Monitoring well 1 was located to sample groundwater upgradient from the impoundment. This well is located at the northeast corner of the impoundment ~15 m from the edge of the standing water contained in the impoundment. However, it is located ~30 m downgradient from a disposal trench in a low-level solid waste storage area (SWSA-5), which is a potential source of contamination. Monitoring wells 2, 3, and 4 were located to collect groundwater downgradient from the impoundment.

The depth from ground surface of monitoring well 1 is ~10 m as compared with ~7 m for monitoring wells 2, 3, and 4. The grid coordinates and elevations to specific parts of each of the monitoring wells are presented in Table 3. A geologic cross section of the impoundment, illustrating the relative position of the water table and the monitoring wells, is presented in Fig. 20.

Recent groundwater measurements (Francis and Stansfield, 1986b) indicate that except for radioactivity and coliform bacteria, NIPDWS contaminants were below RCRA maximum limits. The major contaminants in

Table 3. Grid coordinates and elevations for Old Hydrofracture Facility monitoring wells

	Monitoring well			
	1	2	3	4
ORNL grid coordinates, m				
North	280.7	875.6	5272.7	5285.0
East	8717.4	8688.3	8685.8	8692.6
Elevations, m				
Top of well casing	238.4	236.8	235.8	235.8
Ground surface	237.5	236.0	234.9	234.9
Top of well screen	231.7	232.0	231.8	231.8
Bottom of well screen	228.6	229.2	228.7	228.8
Top of sand pack	234.6	234.1	233.1	232.4
Bottom of well hole	226.9	228.7	227.6	227.6

downgradient wells appear to be ^{90}Sr and tritium (mean concentrations of 460 and 80,000 Bq/L, respectively, over four quarters of sampling). The tritium concentrations appear to be derived from a source other than the impoundment, as the mean concentration of tritium in the upgradient wells over the same four quarters of sampling was slightly higher (91,000 Bq/L) than the mean for the downgradient wells. The most likely source of tritium in these groundwater samples is the low-level radiological waste disposed of in the burial ground (SWSA-5) northeast of the OHF. Tritium has been observed in groundwater sampled immediately below this waste burial ground. For example, in 1974 water samples from seeps at the bottom of the hill on the south side of the burial grounds contained 10^9 Bq/L of tritium (Duguid, 1976).

Other than the radiological measurements and coliform counts, there were instances where the concentrations of barium, chromium, and lead in the downgradient wells exceeded the RCRA maximum limits (see Appendix D). The degree to which these concentrations exceeded the limit was generally very small: for example, the concentration of barium was 1.09 mg/L and the limit was 1; the concentration of chromium was 0.08 mg/L (limit, 0.05); and the concentration of lead was 0.09 mg/L (limit, 0.05). Lead concentrations in monitoring well 3 were 0.08, 0.08, and 0.09 mg/L, respectively, in the last three quarters sampled.

3.1.3 Old Hydrofracture Site Surface Facilities

3.1.3.1 Description of the Facility

The OHF was used for the permanent disposal of liquid radioactive waste in impermeable shale formations at depths ranging from approximately 229 to 300 m (750 to 1000 ft) from 1964 to 1979 (Weeren, 1976 and 1980). The liquid waste was formed into a pumpable grout by blending with cement and special clays used to immobilize radionuclides against groundwater transport. The grout was injected through a slotted well casing into the shale where it solidified into nearly horizontally thin sheets, depending on the orientation of the shale formation, around the injection well in a generally elliptical pattern. The average concentrations of radionuclides in the grout mixture prior to injection were approximately 10 MBq/mL (2.6 Ci/L) or less for beta-gamma-emitting radionuclides and 370 Bq/g (10 nCi/g) or less for transuranic alpha-emitting radionuclides. As much as 7.6 x 10^6 L (2 x 10^6 gal) of waste grout containing as much as 2.2 x 10^4 GBq (6.0 x 10^5 Ci) was disposed of in a single injection.

The OHF is lcoated approximately 2 m (1.1 miles) southwest of the main complex of the Oak Ridge National Laboratory at the confluence of Melton Branch and White Oak Creeks (see Fig. 22). Immediately to the east of the OHF is the western fenced boundary of SWSA-5, where low-level radioactive solid wastes were buried between 1958 and 1973. The facility is approximately 120 m (400 ft) east of White Oak Creek and approximately the same distance north of the Melton Branch. White Oak Creek flows into White Oak Lake and hence into the Clinch River.

The OHF site consists of three buildings (Buildings 7852, 7853, and a pump house) and some waste-related containment facilities (waste

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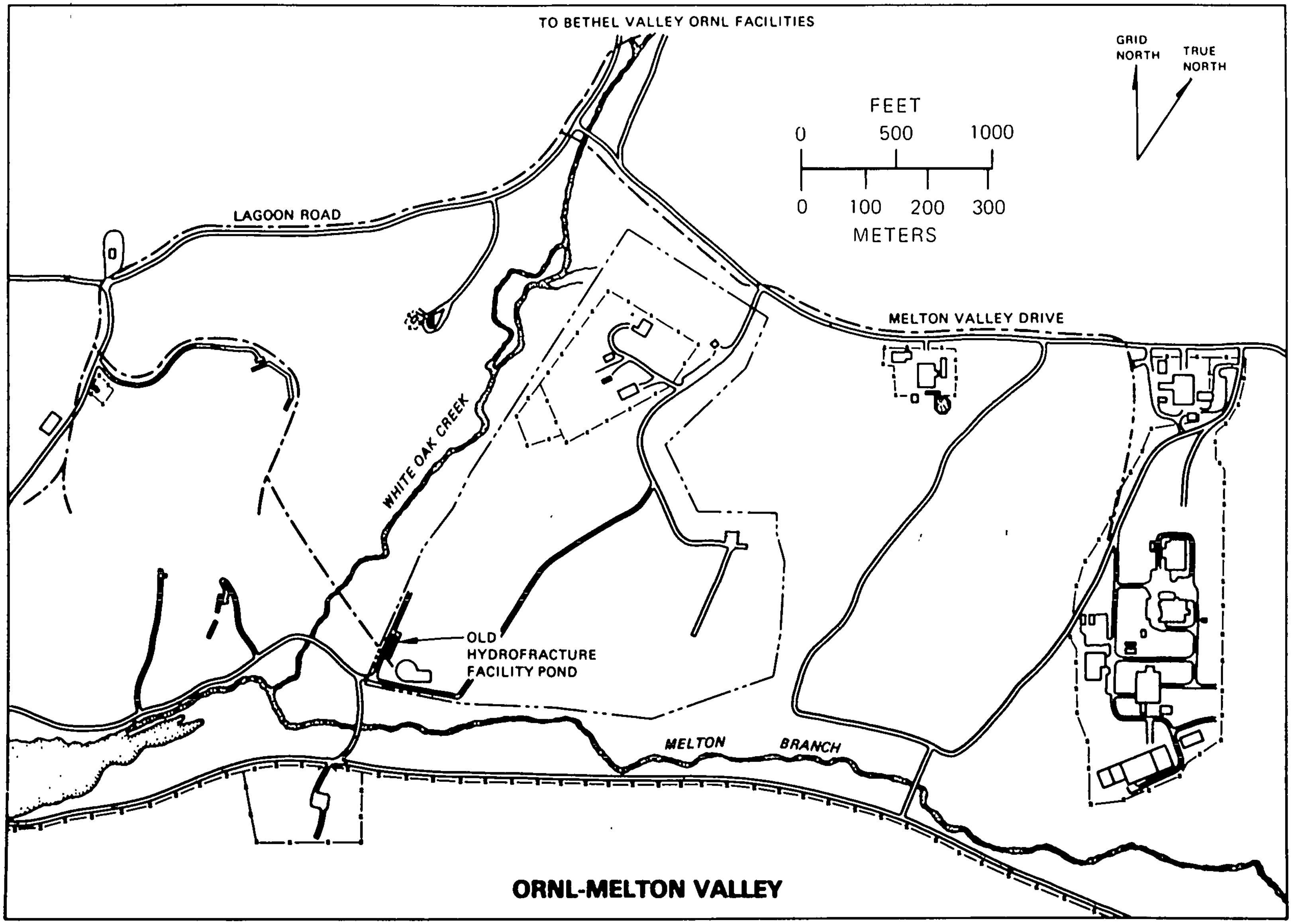

Fig. 22. Location of the Old Hydrofracture Facility at the Oak Ridge National Laboratory.

pits, tanks, and an impoundment discussed previously that was constructed to serve as an emergency containment basin in the event of a spill from the radioactive grout injections. The site plan and a photograph of the OHF are presented in Figs. 23 and 24, respectively.

3.1.3.2 Buildings

3.1.3.2.1 Building 7852

Building 7852 contains a mixing cell, a pump cell for the head end of the injection pump, a well cell, a transit-roof-covered engine pad (at the south end), and a control room (at the north end). The three cells, which were used for the mixing, pumping, and injection of the grout, have 30-cm (12-in.)-thick concrete walls and are covered with a metal roof [triple-layered steel, two 0.63-m (1/4-in.) plates on either side of a steel grating]. The walls, however, are only painted and are not lined with metal as is the ceiling. The hot cells have windows constructed of bulletproof glass. The roof of the mixing cell is fixed in place, but the roofs of the pump cell and the well cell can be removed. The control-room roof is metal decking. On the roof of Building 7852 are a hoist, an air filter and blower, and three disconnected solids conveyers used to transport solids from the adjacent bulk storage bins. Table 4 lists the dimensions for rooms in Building 7852.

Within the mixing cell are located a mixer assembly and a grout mix "tub." The mixer assembly is approximately 2.7 m (8 ft) high and has the shape of a cone that is 1.5 m (5 ft) in diameter at the top. The grout tub is approximately 1 m (3 ft) in diameter and 2 m (6.5 ft) high. The tops of both of these vessels and the motor for the agitation of the grout mix extend through the roof of the mixing cell. The cell also contains valves and piping.

The well cell contains a small drum-sized tank, piping, valves, and the top of the injection well. The pump cell also contains some equipment, namely, hoses, piping, and valves.

Around Building 7852 are located four cylindrical bulk storage bins, with conical bottoms (see Fig. 23), which are elevated to permit

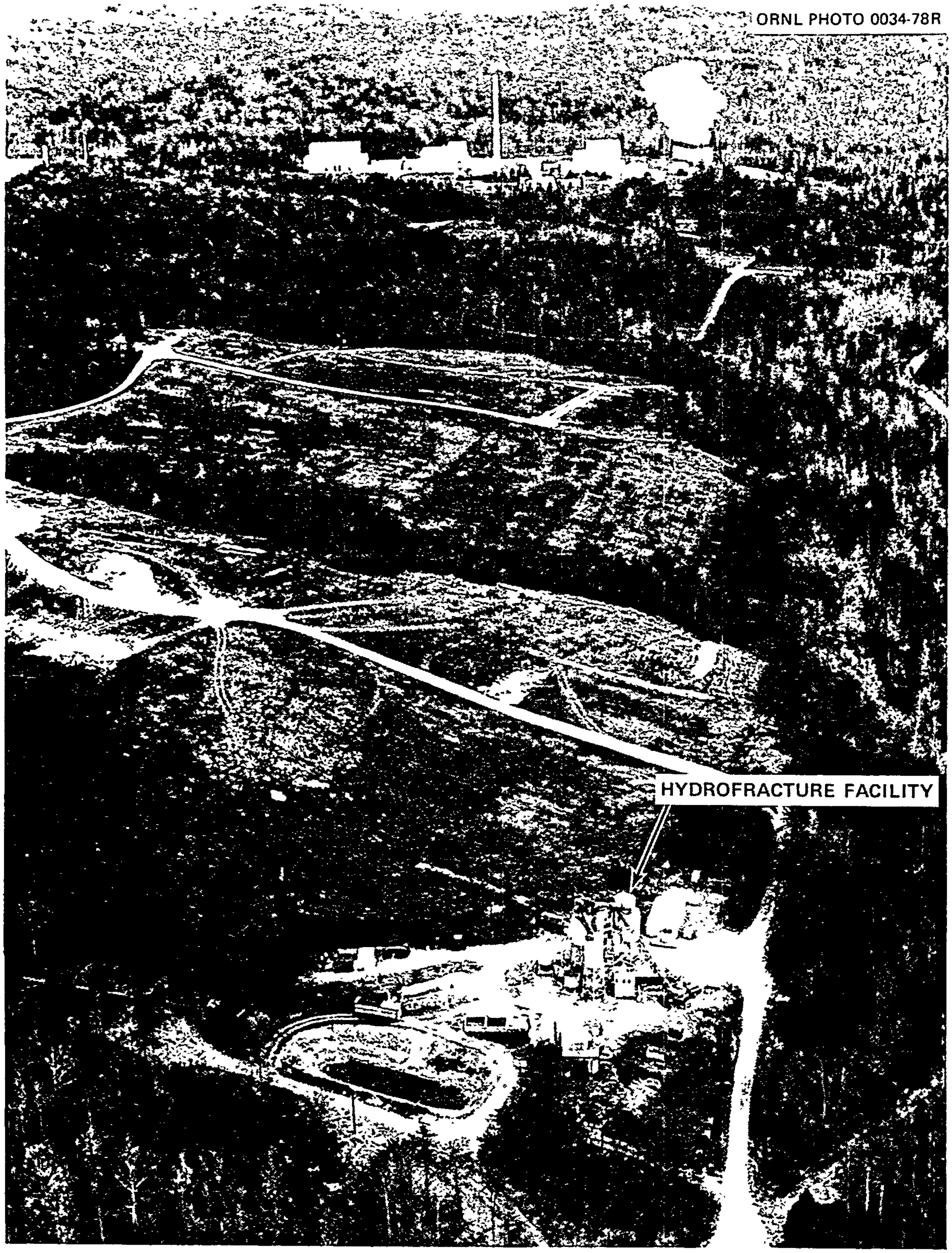

Fig. 23. Aerial photograph of the Old Hydrofracture Facility, SWSA-5, HFIR, TRU, and TURF facilities.

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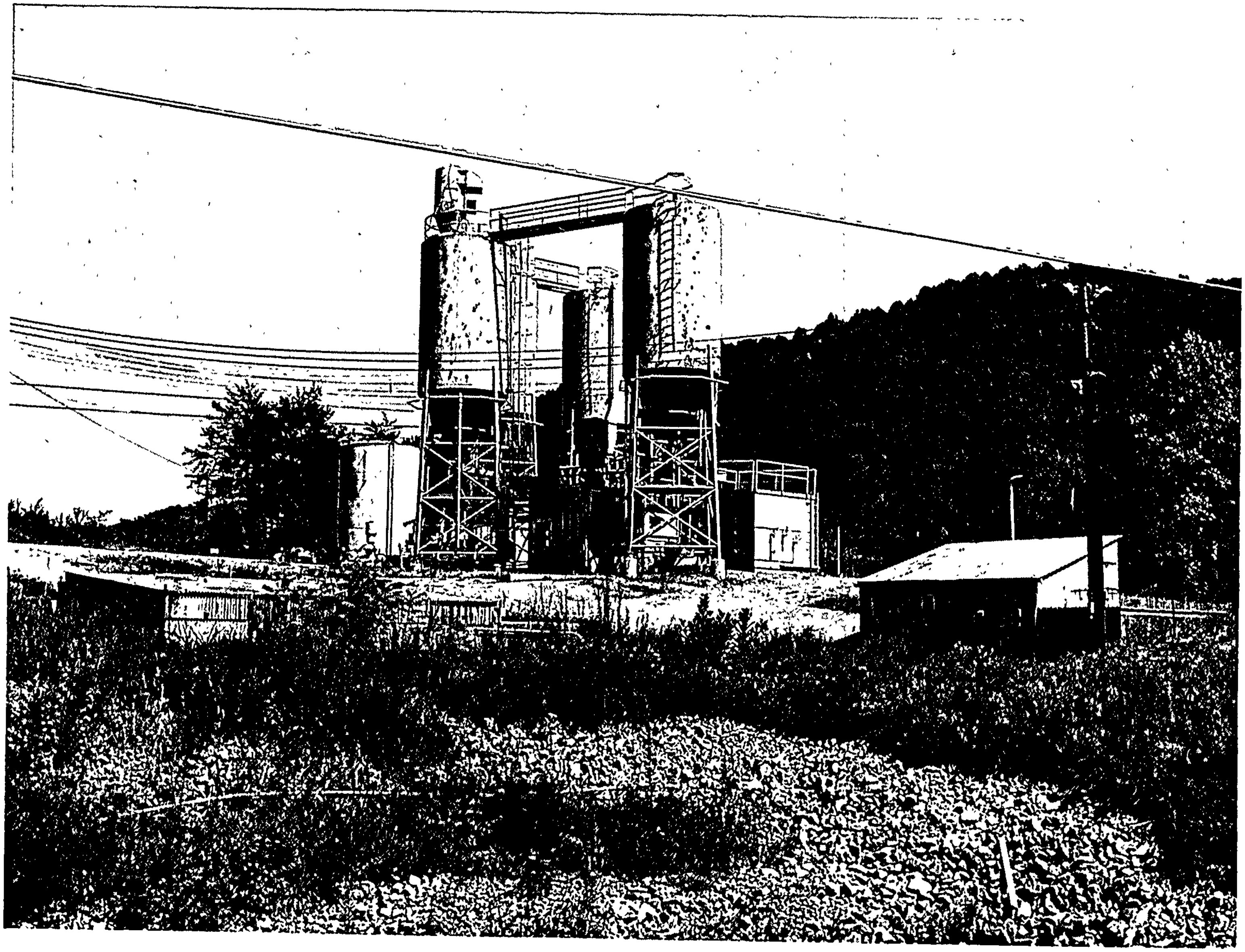

Fig. 24. Photograph of the Old Hydrofracture Facility.

Table 4. Dimensions for rooms in Building 7852[a]

Room	Length (m)	Width (m)	Height (m)
Mixing cell	3.8	3.5	2.4
Pump cell	3.0	2.3	2.4
Well cell	3.3	3.4	3.0
Control room	4.4	3.3	3.1
Engine pad	9.1	3.0	2.7-3.0

[a]From Francis and Stansfield (1986a).

gravity flow of the solids (cement, fly ash, clay, and other additives used during the process) through air slides to Building 7852. Each of the bins is now connected to the mix hopper in Building 7852; all of them are interconnected by piping and by a catwalk. Under bin 4 is a small vessel once used to contain a short-lived radioactive tracer fluid; concrete shielding blocks surround this vessel. Directly to the east of Building 7852 is a 97,000-L (25,000-gal) water tank and pump for delivering water to the facility during mixing and injection.

3.1.3.2.2 Building 7853

This building was used as a change room for operators of the OHF during grout injections. At present, it is used for storage.

3.1.3.2.3 Pump House

The pump house, located to the northwest of Building 7852, contains two 30-hp progressive-cavity-type pumps that were used to feed waste from the nearby buried storage tanks, via underground piping, to Building 7852. This 33-m^2 (360-ft^2) concrete block house was built in an excavation with only the roof and southeast corner (at the door) being fully exposed. A valve pit [6 ft 4 in. by 21 ft (1.9 by 6.4 m)] is located at the southwest corner of the pump house. This pit is covered with metal plates through which valve handles extend for opening and closing valves.

3.1.4 Waste Pits

The waste pits, which are composed of three separate concrete-walled cells [12 x 12 ft wide and approximately 9 ft deep (3.7 x 3.7 x 2.7 m)], are located approximately 6.2 m (20 ft) to the northeast of the pump house. These pits were used to allow maximum recycle of contaminated water during slotting and washup, minimizing the need to inject waste water. The original pit, the southern cell, was filled with grout during an experimental injection, and two additional cells were built to the north. These two pits now contain water-covered sludge. The two northern cells are covered with a corrugated plastic roof, while the south cell remains uncovered.

3.1.5 Waste Tanks

Five buried carbon-steel tanks, placed horizontally, were used for storing liquid radioactive waste prior to injection by the OHF. These tanks, which are located about 18 m (60 ft) directly west of Building 7852, are still connected to the Intermediate-Level Waste (ILW) transfer line; thus, they can serve as a possible emergency storage site. There remains in each of the tanks approximately 1 ft (30 cm) of residual ILW, amounting to less than 10% of the total volume. The tanks were installed on concrete pads in open pits that were equipped with concrete dividing walls to serve as a means of separation and allow for monitoring of possible leakage. They are covered with approximately 1.2 m (4 ft) of soil, are under cathodic protection, and are vented through a HEPA filter to the atmosphere. The voltage/amperage applied to the cathodic protection system and the general radiation background of the storage tank dry well systems (monitoring wells located within the concrete enclosure built to contain each of the tanks) are monitored daily. The ventilation system is also checked daily, and any accumulated liquids in the storage tank dry well systems are sampled and analyzed for radioactivity (Francis and Stansfield, 1986).

3.1.6 OHF Status

A preliminary radiological survey was completed on the buildings by S. F. Huang (EOSD, personal communication, September 1984) in Francis and Stansfield, 1986a). Standard ORNL radiation survey instruments were used for all surveys. Beta-gamma readings were made with a GM meter, a Victoreen 440 (a low-range air ionization chamber), or a Cutie Pie (Gupton, 1961). Smear samples were taken over areas of approximately 100 cm^2 (15.5 $in.^2$) and surveyed in alpha and beta-gamma sample counters or with a portable survey instrument when high levels of contamination were present.

3.1.6.1 Building 7852

Radiation and contamination levels in the interiors of the control room, mixing cell, pump cell, well cell, and pump room were measured. To determine the high levels of transferable contamination on the rough surfaces of the interior walls, wet paper towel smears were used. These smears were surveyed with a portable instrument, rather than with smear counters, to prevent contamination of the smear counters.

In the control room, the absorbed dose rates ranged from 0.75 to 6 mGy/h (75 to 600 mrad/h). Smearable activity per 100 cm^2 varied from 330 to 820 Bq (8.9 to 22.3 nCi) of beta-gamma and from 0.3 to 0.7 Bq (8 to 22 pCi) of alpha. High levels of direct beta-gamma readings ranging from 1.5 to 40 mGy/h (150 to 4000 mrad/h) were observed in the mixing, pump, and well cells. Removable beta-gamma activity measured from 0.05 to 0.35 mGy (5 to 35 mrad). For the most part, removable alpha activity was less than 1.7 Bq/100 cm^2 (<50 pCi/100 cm^2) in these rooms. At 10 cm above the engine pad, the dose rates ranged from 0.2 to 3 mGy/h (20 to 300 mrad/h). Removable beta-gamma activity on the engine pad, using the wet towel smear technique previously described, varied from 5 to 10 μGy/h (0.5 to 1 mrad/h) per 100 cm^2 (15.5 $in.^2$). Alpha activity, using the same smear technique, was usually less than 0.5 Bq (14 pCi) per 100 cm^2 (15.5 $in.^2$).

3.1.6.2 <u>Building 7853</u>

This building, which was used as a change room during OHF operations, was also "considered to be relatively uncontaminated, with no serious radiological impacts expected."

3.1.6.3 <u>Pump House</u>

The interior surfaces of the pump house were contaminated with fixed and removable activity from 0.2 to 80 mGy/h (20 to 8000 mrad/h) and 5 to 150 μGy/h (0.5 to 15 mrad/h), respectively. A radiation reading of 50 μGy/h (5 mrad/h) was measured directly above the sheet metal covering the concrete blocks of the valve pit. The interior of the pit was considered likely to be contaminated with fixed and removable activity.

3.1.6.4 <u>Soils</u>

S. F. Huang made direct beta-gamma readings on 6-by 6-m (20-by 20-m) grids covering a 96-by 60-m (345-by 197-ft) area that encompassed the OHF. Also illustrated in Fig. 25 are the locations

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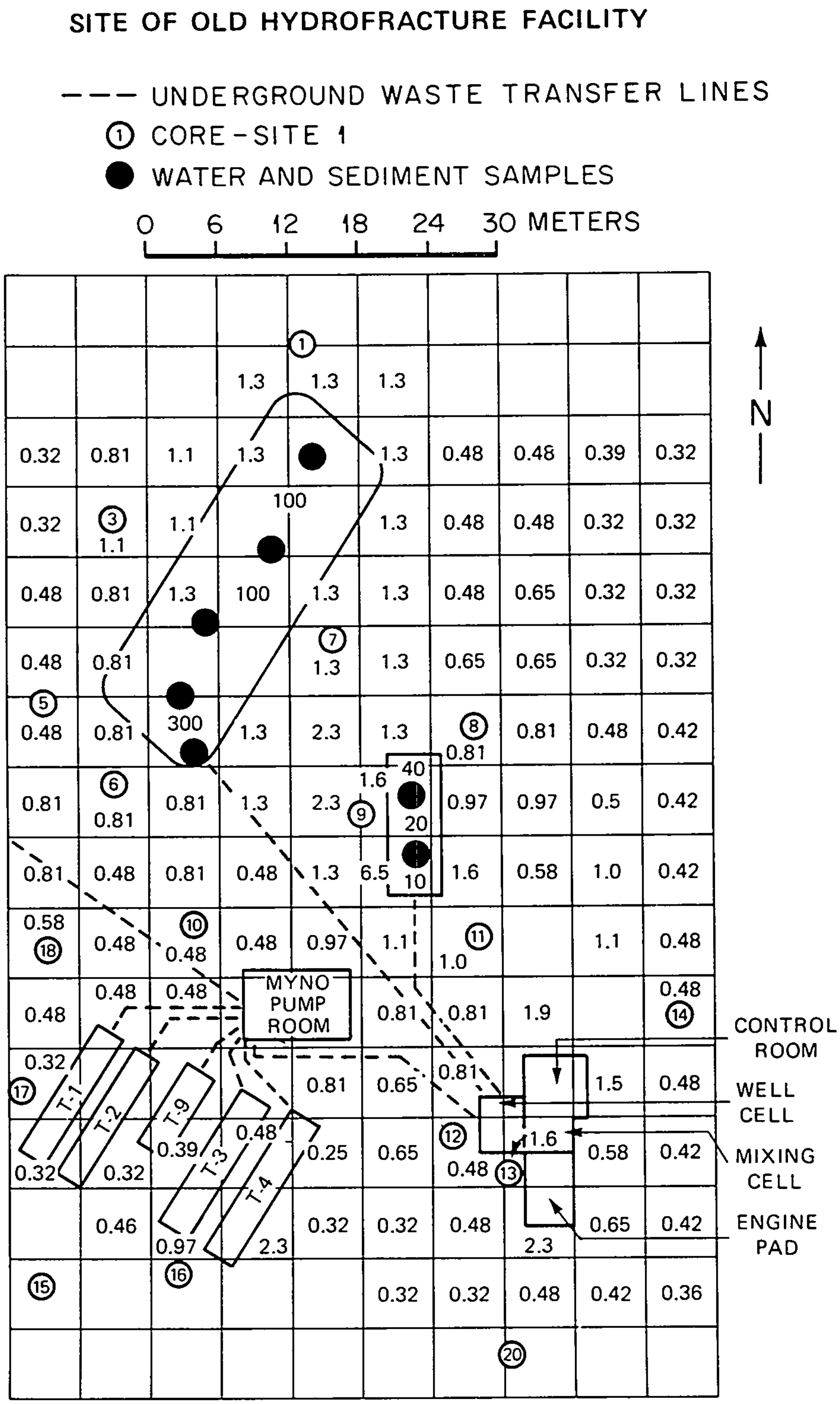


Fig. 25. Beta-gamma direct readings exceeding 0.3 mrad/h (1 mrad = 10 μGy) at 1 to 3 cm (0.4 to 1.2 in.) above the surface at the OHF. From Francis and Stansfield (1986a).

in Fig. 25 are the locations of 17 deep soil cores taken near potential radiation hazards. Sections of these soil cores, of varying soil depths, were counted on a 15 by 15-cm NaI(Tl) detector for 5 min. The gamma-ray spectrum (and total integral counts) over the energy range of 100 to 1500 keV was obtained from the results.

3.1.6.5 Waste Pits

In January of 1984, S. F. Huang measured absorbed dose rates ranging from 0.1 to 0.4 mGy/h (10 to 40 mrad/h) under the roof of the waste pit. In the south pit, 45 cm of water covered a 10-cm (4-in.) layer of sediment. In the north pit, approximately twice as much water (90 cm or 3 ft) covered a 10-cm (4 in) layer of sediment. The total radioactivity in the water and sediment was estimated to be 5 GBq (0.1 Ci) and 10 GBq (0.3 Ci), respectively. The concentrations and inventories of the various radionuclides measured in the water and sediment taken from these pits are listed in Appendix D.

3.1.6.6 Waste Tanks

S. F. Huang estimated the radioactivity in each tank to be between 22 and 37 TBq (600 to 1000 Ci). The total quantity of sludge in the tanks was estimated to be 2 x 10^6 L (5.3 x 10^5 gal), containing on the order of 170 TBq (4.6 kCi). An estimate of the activity in each of the tanks and the assumptions used in making these estimates are presented in Appendix D. Water taken from the "dry wells" (monitoring wells located within the concrete enclosure built to contain each of the tanks) have shown slightly elevated levels of beta activity (maximum of 1.2 Bq/mL). Also, the soil core taken directly to the southwest of tank T-4 (soil core 16) showed some elevated levels of gamma activity at soil depths of approximately 5 m (16.5 ft). The possibility (or likelihood) has to be taken into consideration that the carbon steel tanks, which are inclined to rust (although cathodically protected), may have developed leaks over the years.

3.2 LLW WASTE CONCENTRATED STORAGE TANKS (MELTON VALLEY STORAGE TANKS)

The LLW waste concentrate storage tanks W-24 through W-31, 3.7 m (12 ft) in diameter by 18.3 m (60 ft) long are horizontally mounted stainless steel tanks in stainless steel-lined vaults (Fig. 26). The eight 190,000-L (50,000-gal) stainless steel tanks installed in 1976 are located at Building 7830 near the hydrofracture facility in Melton Valley. The vaults are equipped with appropriate HEPA-filtered off-gas systems.

These tanks were previously used for storage of concentrated LLW from the evaporator by way of tanks W-23, C-1, and C-2, until their contents were disposed by hydrofracture. Since the hydrofracture process is not currently in use, these tanks serve as the primary storage facility for ORNL's liquid LLW until an alternate disposal technology is placed in operation.

Two samping campaigns were initiated, in July and November 1985, to attempt to characterize the contents of each tank. During the July sampling, liquid samples were taken through the plummet level device penetration (a 5-cm- or 2-in.-diam hole in the top of the tank) (Fig. 27). The samples, which were collected through a hose inserted through this opening, were drawn from near the top, the middle, and the bottom of the liquid layer in each tank. Liquid was also drawn from the sludge region of each tank. Only tanks W-24 through W-28 were sampled at this time. Aeration and circulation were used to mix the contents during sampling.

A second sampling was undertaken in November 1985 of all eight tanks. A liquid sample was taken from the middle of the liquid phase, and solid samples were taken from the sludge layer. No mixing of the tank was occurring at this time; however, aeration allowed liquid-phase mixing. Estimates of the amount of sludge, its character, and volume are given in Table 5.

Extensive radiochemical analyses, physical properties, ICP and anion analyses, and spark-source spectrometry data for these tanks are presented in Appendix E. These data should be considered as indicative of the inventory and conditions only at the time of sampling.

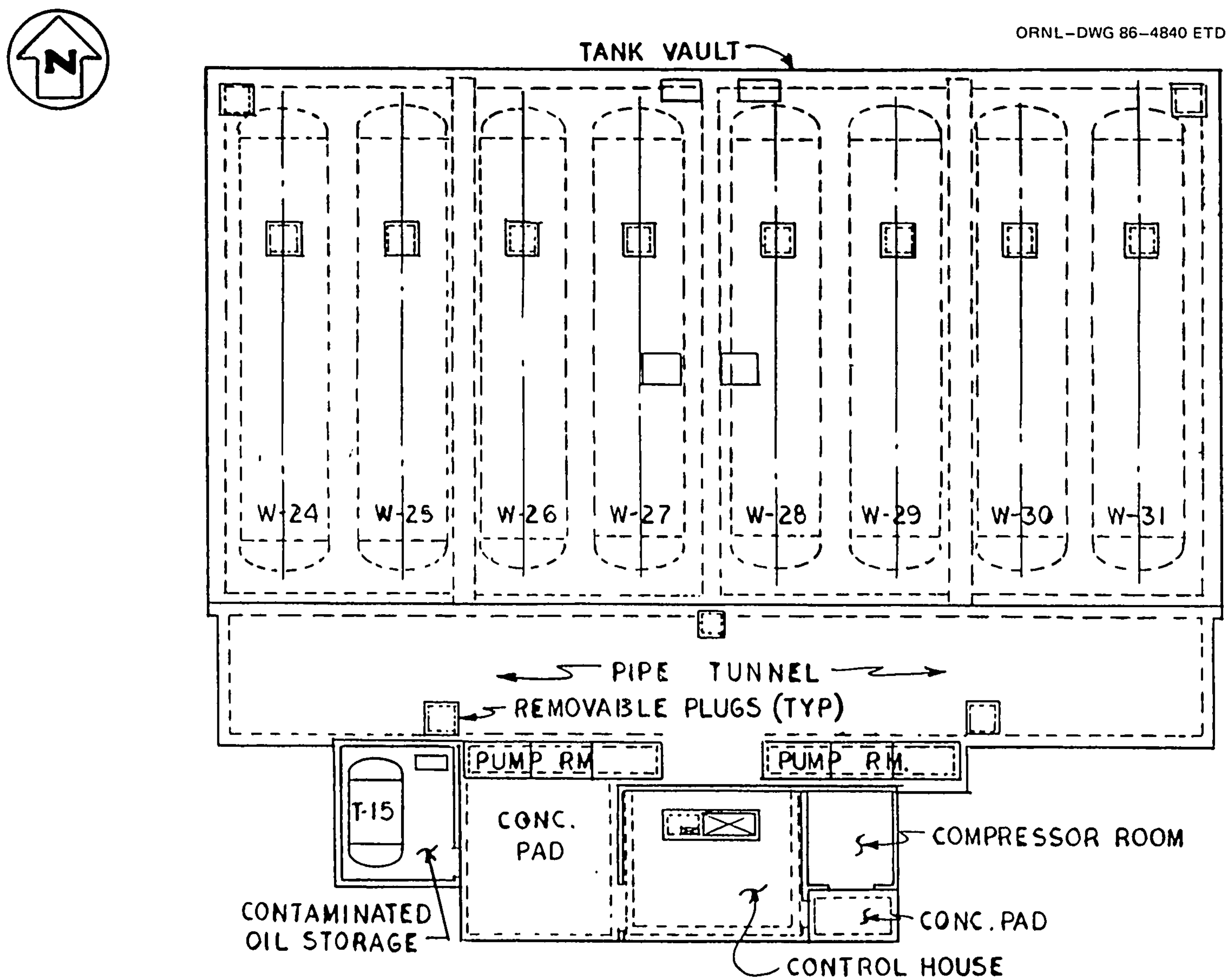
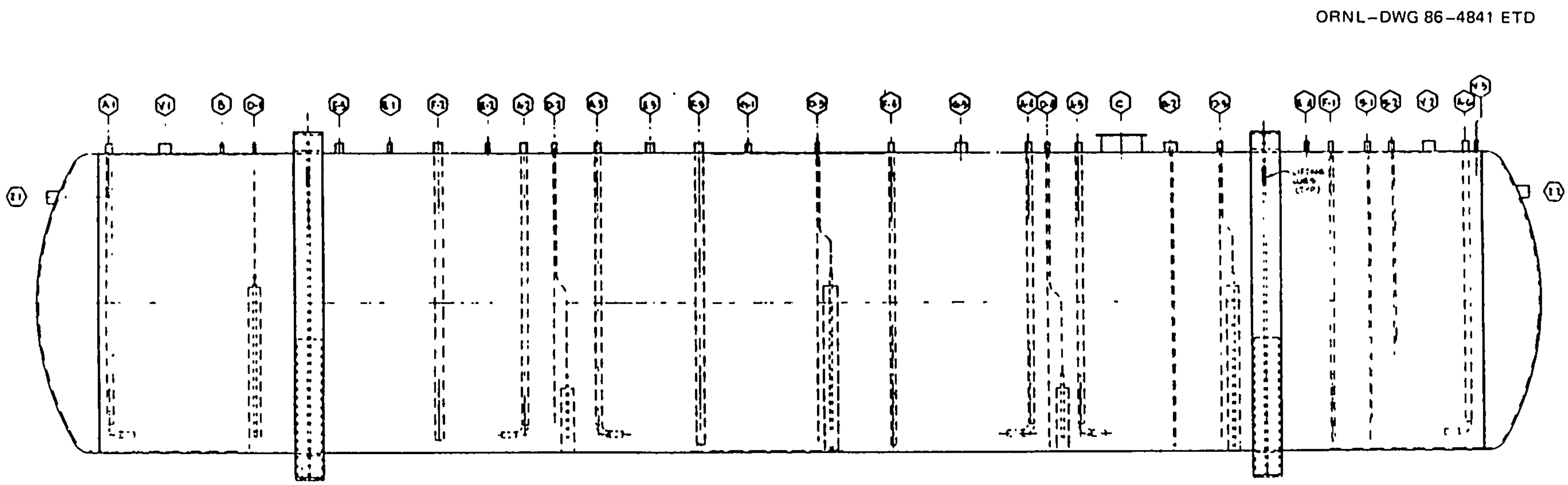


Fig. 26. Layout of the Melton Valley Storage Tanks. From Peretz et al. (1986).



Nozzle Schedule:

ID	Size	Usage	ID	Size	Usage
A-1	3" Sch. 40	Sludge jet	F-1	6" Sch. 40	Pump suction
A-2	3" Sch. 40	Sludge jet	F-2	6" Sch. 40	Spare
A-3	3" Sch. 40	Sludge jet	F-3	4" Sch. 40	Spare
A-4	3" Sch. 40	Sludge jet	F-4	4" Sch. 40	Sludge suction spare
A-5	3" Sch. 40	Sludge jet	G-1	2" Sch. 40	Plummet level device
A-6	3" Sch. 40	Sludge jet	G-2	6" Sch. 40	Density and level probe
B	2" Sch. 40	Chemical addition	G-3	6" Sch. 40	Sludge level detector
C		Flanged manhole	S-1	4" Sch. 40	Low point sample suction
D-1	2" Sch. 40	Tall air sparger	S-2	4" Sch. 40	25% full sample suction
D-2	2" Sch. 40	Short air sparger & temp. sensor well	V-1	6" Sch. 40	Vent inlet
D-3	2" Sch. 40	Short air sparger & temp. sensor well	V-2	6" Sch. 40	Vent outlet
D-4	2" Sch. 40	Short air sparger & temp. sensor well	V-3	1" Sch. 40	Demister drain
D-5	2" Sch. 40	Tall air sparger & temp. sensor well	Z-1	6" Sch. 40	Overflow (W-25 and W-30 only)
E-1	2" Sch. 40	Sample return	Z-2	6" Sch. 40	Overflow
E-2	2" Sch. 40	Spare			
E-3	4" Sch. 40	Spare			
E-4	2" Sch. 40	Sump discharge (pump room)			
E-5	4" Sch. 40	Pump discharge			

Nozzle configuration shown for W-25, W-27, W-28 and W-31.

Nozzles E-5 and F-1 reversed on W-24, W-26, W-29 and W-31.

Fig. 27. Description and nozzle schedule for a typical 50,000 gal storage tank. From Peretz et al. (1986).

Table 5. Descriptions and volume estimates of sludges in the Melton Valley Storage Tanks[a]

Tank	Sludge description[b]	Radiation level	Estimated volume (gal)	(m^3)
W-24	Approximately 0.45 (1.5 ft) of a soft, fluid sludge	200 mR/h at 6 in.	3,600	13.6
W-25	About 1.2 m (4 ft) of sludge similar to that in W-24 but containing noticeable amounts of sand (possibly from hydro-fracture slotting); higher radiation levels than W-24	About 1 R/h at 1 ft	14,600	55.3
W-26	About 0.8 m (2.5 ft) of soft sludge containing more sand than found in W-25; radiation levels similar to W-24	200 mR/h at 6 in.	7,500	28.2
W-27	A hard, crusty layer about 8 cm (3 in.) thick was found 2.5 ft from the bottom of the tank; sludge under the crust was similar to that in W-24; a somewhat thicker consistency may have ben due to the crust breaking off into the sample	Not reported	7,500	28.2
W-28	About 20 cm (8 in.) of sludge similar to that found in W-24	Not reported	1,100	4.2
W-28	About 0.45 m (1.5 ft of soft sludge a little thicker than in W-24 but with similar radiation levels	200 mR/hr at 6 in.	3,600	13.6
W-30	Same as W-29	200 mR/h at 6 in.	3,600	13.6
W-31	About 1 m (3 ft)of extremely thick sludge; the sampler rod had to be hammered through the sludge to reach the tank bottom; the sludge was not at all fluid and was much "hotter" than the other tanks	4 R/h at 4 in.	9,800	37.1

[a]From Peretz et al. (1986).

[b]It is generally believed that there is more sludge on the discharge side of the tanks than on the suction side, relative to the depth at the center. The tank contents were not circulated during sampling, but the aerators were left on. A liquid sample was not taken from W-31 because the contents consisted mainly of sludge.

3.3 RADIOACTIVELY CONTAMINATED WASTE-OIL STORAGE TANK

This tank, used for the storage of low-level contaminated oil, is an approximately 18,900 L stainless steel vessel located in a vault near Building 7860 at the New Hydrofracture Site. The vault is equipped with a HEPA-filtered off-gas system. The present inventory of this tank consists of a few thousand liters of mixed waste which may qualify for disposal by the TSCA incinerator at ORGDP (L. Lasher, personal communication, 1987).

3.4 NEW HYDROFRACTURE SITE SURFACE FACILITIES

The New Hydrofracture Site is within the boundaries of SWSA-5 just southwest of the OHF across Melton Branch. Access is restricted to the approximately 180-m (600-ft) by 120-m (400-ft) fenced area. This site was placed in operation in 1982 to replace the OHF for the disposal of concentrated low-level waste from LLW evaporator bottoms and sludges sluiced from the South Tank Farm gunite tanks. The new facility was last used for the injection of wastes in January 1984; performance problems and regulations now probably relegate it to a permanently inactive status.

Building 7860 consists of three hot cells (the well cell, mixing cell, and pump cell), an operating area, compressor room, change houses for men and women, an office, storage space, an equipment room, a waste tank in a pit, a roof area supporting solids transfer equipment, and a contaminated storage area (penthouse).

The hot cell known as the well cell contains the well head used in the injection process and a high-pressure pipe manifold. Ventilation is through a HEPA filter system. The general background radiation in this cell is approximately 200 mR/hr; the well reading is about 2 R/hr. A system is under design for constant surveillance of well pressure and for sampling the liquid in the well.

The hot cell known as the mixing cell contains the mixing hopper and the mixing tub. Ventilation is through a HEPA filter. The general background radiation in this cell is comparable to that of the well cell; however, the interior of the mixing tub is approximately an order of magnitude higher.

The hot cell known as the pump cell contains the pump suction and discharge manifold. This cell is also ventilated through a HEPA filter.

The general background radiation in the pump cell which varies with the distance from the pump manifold ranges from 400 mR/hr to 50 mR/hr.

The slotting waste pit is the central collection point for all Building 7860 cells and contains the slotting waste tanks and two transfer pumps. One pump, located in the pit sump, pumps any liquid collected in the sump back to the slotting waste tank. The second pump transfers liquid from the slotting waste tank through the Melton Valley Waste Storage Facility (Bldg. 7830) to the Liquid Low-Level Waste Evaporator for concentration and storage for ultimate storage. Radioactive contamination levels in the slotting waste pit and slotting waste tank are comparable to these levels in the mixing cell. The tank contains about 3.8 m^3 (1000 gal) of contaminated sand and shale cuttings from slotting and well recovery operations.

The interiors of the cells and slotting pits are contaminated primarily with mixed fission and activation products (^{137}Cs, ^{90}Sr, ^{60}Co, etc.) and small amounts of transuranic isotopes.

The penthouse contains a large amount of well tubing and drilling equipment that is radioactively contaminated to varying degrees. The general background radiation level in the penthouse is 5 to 10 mR/h.

The roof area supports the system for feeding solids to the mixing cell. Some of the internals of this system are radioactively contaminated, and others contain cement residues. All contaminated internals are vented through the mixing tub.

The compressor room houses three air compressors, a hot water heater, and two air dryers.

The office, operating area, storage room, and change rooms are noncontaminated areas typical of any operating facility. A normal building HVAC system is in operation.

The building is routinely checked at least one time per shift for abnormal conditions and to ensure security (C. B. Scott, personal communication, May 1987).

3.5 LOW-LEVEL WASTE (LLW) LINES AND LEAK SITES

3.5.1 OHF Observation Well Leak

The first of two leak sites associated with WAG-5 is located at ORNL coordinates N17,050, E28,620 (see Fig. 18) and is the result of water leakage from an observation well (S220a) at the southern part of the site.

Hydraulic testing at the site left water under pressure that had been pumped into the formation. Upon drilling the observation well, the pressure was relieved through the well. The spill (contaminated water flow) first happened in 1964; however, the volume of the ^{90}Sr contaminated water released is not known. It was determined that, from Station No. 4 monitoring data, approximately 0.7 Ci of ^{90}Sr was released to Melton Branch.

3.5.2 OHF Grout Release

The second WAG-5 associated leak is located at ORNL grid coordinates N17,200, E28,500 (see Fig. 18) and is the result of a contaminated grout leak at the OHF.

This leak occurred on June 30, 1977 and was caused by valve failure requiring LLW-grout slurry to be directed to the OHF waste pit. Approximately 8700L (2300 gal) of slurry was released. Such a slurry, containing evaporator concentrated LLW, would be expected to contain ^{90}Sr, ^{137}Cs, ^{106}Ru, ^{60}Co, rare earths, plutonium, uranium, and transuranium isotopes.

Upon release of the slurry, the injection was terminated. After the facility was placed on standby, valves were inspected and repaired and the contents of the waste pit were included in the next injection on July 2, 1977 (Lasher, 1987).

4. ADDITIONAL INFORMATION NEEDED

An initial evaluation of the information presented in the previous sections indicates that data gaps exist that will require further investigation in order to complete the RI/FS planning stages. Although more detailed evaluations will be required to determine the need and extent of remedial actions in WAG5, it is apparent that data gaps exist in the areas of waste inventories and source terms, hydrology, and geology and geochemistry.

Source Term and Wsate Inventory

- o Precise locations of waste trenches in "undefined areas."
- o Trench water analyses (as suggested in Davis and Shoun, 1986).
- o Additional contamination surveys in and around the OHF.
- o Characterization of solidified grout in OHF waste pit.
- o Characterization of OHF waste tank sludge.
- o Determine trench wall characteristics such as permeability.

Hydrology

- o Install at least two additional water quality wells on northwest boundary of SWSA-5 and one well on northwest side of the TRU Waste Storage Areas.
- o Determine the geologic permeability on southeast side of SWSA-5.
- o Reversible pump test(s) in SWSA-5 to better determine hydraulic conductivity.
- o Additional monitoring wells near OHF impoundment to define plume shape of contamination.
- o Determine leakage around 30-cm (8-in.) OHF impoundment drain line.
- o Additional shallow (10 m or 32 ft) groundwater monitoring wells on the west side of the OHF impoundment.

Geology and Geochemistry

- o Soils map for SWSA-5.
- o Subsurface soil sampling near OHF impoundment and characterization of sediment.
- o Soil sorption-desorption studies with known contaminants.
- o Deep coring [40 m (130 ft)] in the OHF area.

The above are not an exhaustive list, but should serve as an indication of possible needed data and information in the WAG5 area.

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Appendix A. PRIORITY WAG-5 REFERENCES

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Appendix B. HYDROLOGY

Table B-1. Data of observation wells in Burial Ground 5, Oak Ridge National Laboratory, Roane County, Tennessee

Well number	Location: Latitude (deg., m, s)	Location: Longitude (deg., m, s)	Location: ORNL Grid (ft) (ft)	Depth of well (ft)	Year completed	Casing: Diameter (in)	Casing: Type	Finish: Character	Finish: Depth interval (ft)	Altitude of land surface (ft above NGVD)	Measuring Point: Distance above land surface (ft)	Measuring Point: Date determined (m/d/yr)	Depth to Water below land surface: Period of record (yrs)	Depth to Water below land surface: Minimum (ft)	Depth to Water below land surface: Maximum (ft)	Status of well 12/79
130	35 54 54	84 18 52	N18248 E29136	5	1958	6 5/8	S	Prf	0-5	764.68	1.92	8/23/76	1975-79	1.65	4.47	A
132	35 54 50	84 18 54	N18030 E28872	9	1958	6 5/8	S	Prf	0-9	763.43	1.67	8/23/76	1975-79	0.50	6.00	B
133	35 54 49	84 18 54	N17934 E28795	7	1958	6 5/8	S	Prf	0-7	761.40	1.80	4/08/75	1975-76	+0.04	3.69	D
134	35 54 48	84 18 54	N17827 E28733	8	1958	6 5/8	S	Prf	0-8	760.73	1.27	8/23/76	1975-76	0.84	4.49	D
136	35 54 49	84 18 53	N17464 E28578	10	1958	6 5/8	S	Prf	0-10	768.00	2.40	4/08/75	1975-76	1.97	8.45	D
143	35 54 50	84 18 46	N17686 E29350	25	1958	6 5/8	S	Prf	0-25	823.49	1.51	8/23/76	1975-79	18.82	DRY	B
144	35 54 42	84 18 46	M17794 E29420	3	1958	6 5/8	S	Prf	0-7	838.42	2.00	4/08/75	1975-75	-	-	B
145	35 54 43	84 18 45	N17879 E29644	11	1958	6 5/8	S	Prf	0-11	837.50	3.30	8/23/76	1975-79	5.61	DRY	A
146	35 54 56	84 18 43	N18029 E29872	17	1958	6 5/8	S	Prf	0-17	825.40	2.00	4/08/75	1975-75	-	-	D
147	35 54 55	84 18 43	N17931 E29843	20	1958	6 5/8	S	Prf	0-20	817.61	3.29	4/08/75	1975-79	4.35	10.58	A
149	35 54 51	84 18 43	N17561 E29641	4	1958	6 5/8	S	Prf	0-4	790.07	2.43	4/08/75	1975-79	+0.07	1.57	A
157	35 54 53	84 18 31	N17151 E30555	6	1958	6 5/8	S	Prf	0-6	778.53	0.77	8/23/76	1975-79	1.46	4.85	A
159	35 54 56	84 18 33	N17535 E30610	6	1958	6 5/8	S	Prf	0-6	794.46	0.84	8/23/76	1975-79	2.80	DRY	A
160	35 54 58	84 18 34	N17744 E30617	9	1958	6 5/8	S	Prf	0-9	803.41	1.29	8/23/76	1975-79	0.77	DRY	A
161	35 54 59	84 18 35	N17873 E30578	8	1958	6 5/8	S	Prf	0-8	810.88	1.02	8/23/76	1975-79	0.42	6.28	A
162	35 54 57	84 18 37	N17809 E30360	9	1958	6 5/8	S	Prf	0-9	869.03	2.00	4/08/75	1975-75	-	-	A
165	35 54 51	84 18 51	N17939 E29112	17	1958	6 5/8	S	Prf	0-17	811.76	2.44	8/23/76	1975-79	11.05	DRY	B
167	35 54 53	84 18 49	N18074 E29334	12	1958	6 5/8	S	Prf	0-12	838.81	2.40	4/08/75	1975-79	8.86	DRY	B
169	35 54 50	84 18 41	N17371 E29699	16	1958	6 5/8	S	Prf	0-16	809.42	2.28	8/23/76	1975-79	11.09	DRY	B
172	35 54 57	84 18 36	N17795 E30418	7	1958	6 5/8	S	Prf	0-7	867.63	3.70	4/08/75	1975-75	-	-	A
173	35 54 55	84 18 39	N17779 E30123	17	1958	6 5/8	S	Prf	0-17	847.44	2.26	8/23/76	1975-79	14.81	DRY	A
174	35 54 57	84 18 37	N17829 E30382	125	1958	8 1/8	S	Opn	14-125	870.40	1.60	8/23/76	1975-79	42.17	60.74	A
175	35 54 54	84 18 37	N17521 E30214	148	1958	6 1/8	S	Opn	36-148	831.50	0.10	8/23/76	1975-79	12.67	25.80	B
176	35 54 51	84 18 48	N17829 E29329	143	1958	6 1/8	S	Opn	36-143	827.53	2.77	8/23/76	1975-79	0.36	35.25	A
177	35 54 49	84 18 45	N17529 E29358	149	1958	6 1/8	S	Opn	44-149	827.93	1.77	8/23/76	1975-79	32.68	38.23	A
178	35 54 47	84 18 51	N17572 E28864	153	1958	6 1/8	S	Opn	42-153	804.77	0.83	8/23/76	1975-79	28.54	34.79	A
419	35 54 44	84 18 43	N17008 E29218	17	1975	6 5/8	S	Prf	0-17	779.57	0.03	12/05/75	1975-79	9.36	14.19	A
420	35 54 55	84 18 50	N18258 E29371	10	1975	6 5/8	S	Prf	0-10	774.20	0.20	12/05/75	1975-79	1.37	3.99	A
421	35 54 52	84 18 54	N18197 E28991	9	1975	6 5/8	S	Prf	0-9	763.60	0.00	12/05/75	1975-79	1.41	8.60	A
422	35 54 41	84 18 52	N17166 E28450	12	1975	6 5/8	S	Prf	0-12	769.48	0.72	12/05/75	1975-79	7.00	DRY	A
423	35 54 43	84 18 45	N17038 E29056	18	1975	6 5/8	S	Prf	0-18	782.41	1.09	12/05/75	1975-79	7.92	13.46	A
424	35 54 50	84 18 46	N17683 E29348	39	1976	3	S	Prf	29-39	823.50	0.80	3/01/76	1976-79	18.03	31.41	C
425	35 54 51	84 18 43	N17576 E29620	8	1975	6 5/8	S	Prf	0-8	796.35	2.25	12/05/75	1975-79	4.11	DRY	A
426	35 54 49	84 18 43	N17383 E29497	4	1975	6 5/8	S	Prf	0-4	785.80	2.20	12/05/75	1975-79	1.83	4.01	A
427	35 54 45	84 18 41	N16989 E29425	10	1975	6 5/8	S	Prf	0-10	768.27	0.03	12/05/75	1975-79	1.75	4.70	A

Table B-1 (Continued)

Well number	Location			Depth of well	Year completed	Casing		Finish		Altitude of land surface (ft above NGVD)	Measuring Point		Depth to Water below land surface			Status of well 12/79
	Latitude (deg., m, s)	Longitude (deg., m, s)	ORNL Grid (ft) (ft)	(ft)		Diameter (in)	Type	Character	Depth interval (ft)		Distance above land surface (ft)	Date determined (m/d/yr)	Period of record (yrs)	Minimum (ft)	Maximum (ft)	
428	35 54 47	84 18 36	N16934 E29892	4	1975	6 5/8	S	Prf	0-4	772.90	0.40	11/20/75	1975-79	0.10	2.94	A
429	35 54 52	84 18 34	N17251 E30291	22	1975	6 5/8	S	Prf	0-22	812.68	3.82	8/23/76	1975-79	5.43	14.30	B
430	35 54 57	84 18 43	N18083 E29962	29	1976	3	P	Slt	19-29	824.75	3.15	4/02/76	1976-79	0.96	20.96	B
431	35 54 55	84 18 46	N18059 E29675	35	1976	3	P	Slt	25-35	833.30	0.30	8/23/76	1976-79	17.91	31.06	A
432	35 54 51	84 18 51	N17958 E29101	27	1976	3	P	Slt	17-27	808.92	2.78	4/02/76	1976-79	17.12	DRY	A
433	35 54 47	84 18 48	N17488 E29071	44	1976	3	P	Slt	34-44	829.12	1.88	6/09/76	1976-79	36.20	43.01	A
434	35 54 47	84 18 47	N17393 E29119	32	1976	3	P	Slt	22-32	816.13	2.97	6/24/76	1976-79	20.45	27.47	A
435	35 54 45	84 18 47	N17232 E28990	30	1976	3	P	Slt	20-30	799.47	2.73	6/24/76	1976-79	9.42	16.51	A
436	35 54 44	84 18 45	N17081 E29080	31	1976	3	P	Slt	21-31	785.66	2.74	6/24/76	1976-79	5.96	15.52	A
437	35 54 46	84 18 45	N17270 E29209	36	1976	3	P	Slt	26-36	804.40	2.80	6/24/76	1976-79	13.94	18.79	A
438	35 54 48	84 18 45	N17418 E29317	37	1976	3	P	Slt	27-37	819.62	2.68	6/24/76	1976-79	28.14	32.59	A
439	35 54 45	84 18 43	N17134 E29297	34	1976	3	P	Slt	24-34	795.19	2.71	6/24/76	1976-79	15.64	23.23	A
440	35 54 47	84 18 43	N17280 E29382	36	1976	3	P	Slt	26-36	804.97	4.13	7/09/76	1976-79	19.17	26.12	A
441	35 54 53	84 18 45	N17822 E29604	42	1976	3	P	Slt	32-42	836.55	2.35	7/29/76	1976-79	22.93	33.58	A
442	35 54 45	84 18 51	N17433 E28747	48	1976	3	P	Slt	38-48	808.60	2.70	10/27/76	1976-79	28.02	37.53	A
443	35 54 43	84 18 49	N17185 E28723	47	1976	3	P	Slt	37-47	791.81	2.69	10/27/76	1976-79	19.49	29.45	A
444	35 54 50	84 18 36	N17149 E30017	21	1976	3	P	Slt	11-21	796.50	1.90	10/27/76	1976-79	5.85	10.07	A
445	35 54 55	84 18 37	N17652 E30286	64	1976	3	P	Slt	54-64	845.72	2.08	1/31/77	1976-79	22.00	35.30	A
446	35 54 47	84 18 41	N17184 E29520	29	1976	3	P	Slt	19-29	786.70	2.50	1/31/77	1976-79	12.13	14.06	A
447	35 54 49	84 18 51	N17778 E28992	8	1976	3	P	Slt	3-8	777.95	2.75	1/31/77	1976-79	0.25	2.35	A
448	35 54 53	84 18 49	N18056 E29325	60	1976	3	P	Slt	50-60	839.45	3.40	1/31/77	1976-79	36.31	49.88	B
449	35 54 57	84 18 47	N18285 E29658	40	1976	3	P	Slt	30-40	814.12	3.28	1/31/77	1976-79	27.41	39.37	A
450	35 54 56	84 18 40	N17850 E30073	34	1976	3	P	Slt	24-34	838.70	2.50	1/31/77	1976-79	17.22	24.36	A
451	35 54 53	84 18 40	N17581 E29962	34	1976	3	P	Slt	24-34	829.04	2.46	1/31/77	1976-79	15.96	27.97	A
452	35 54 50	84 18 39	N17341 E29827	30	1977	3	P	Slt	20-30	818.80	3.00	1/31/77	1977-79	14.21	23.80	A
453	35 54 52	84 18 34	N17223 E30290	29	1977	3	P	Slt	19-29	810.74	3.03	1/19/81	1977-79	9.07	24.66	A
454	35 54 54	84 18 32	N17344 E30554	22	1977	3	P	Slt	12-22	801.50	0.70	2/16/77	1977-79	13.43	20.29	A
455	35 54 58	84 18 40	N18007 E30198	36	1977	3	P	Slt	26-36	839.54	3.86	3/14/77	1977-79	13.25	25.29	A
456	35 54 44	84 18 53	N17498 E28577	11	1977	3	P	Slt	1-11	768.53	3.37	5/10/77	1977-79	3.66	9.28	B
457	35 54 48	84 18 54	N17850 E28719	10	1977	3	P	Slt	1-10	759.71	2.59	5/10/77	1977-79	0.49	3.13	A
501	35 54 43	84 18 48	N17176 E28867	19	1964	6 7/8	S	Prf	0-19	799.08	0.82	8/23/76	1975-79	7.15	DRY	B
502	35 54 45	84 18 48	N17301 E28895	18	1964	6 7/8	S	Prf	0-18	807.01	1.99	8/23/76	1975-79	14.54	DRY	A
504	35 54 54	84 18 41	N17806 E29936	16	1964	6 7/8	S	Prf	0-16	827.20	0.00	4/08/75	1975-79	10.89	DRY	C
505	35 54 54*	84 18 40*	N17700 E30000*	18	1964	6 7/8	S	Prf	0-18	--	0.00	4/08/75	1975-75	-	-	D
506	35 54 50	84 18 41	N17410 E29697	18	1964	6 7/8	S	Prf	0-18	811.08	1.62	4/08/75	1975-79	13.06	DRY	B

* Approximate

Table B-1 (Continued)

Well number	Location			Depth of well	Year completed	Casing		Finish		Altitude of land surface (ft above NGVD)	Measuring Point		Depth to Water below land surface			Status of well 12/79
	Latitude (deg., m, s)	Longitude (deg., m, s)	ORNL Grid (ft) (ft)	(ft)		Diameter (in)	Type	Character	Depth interval (ft)		Distance above land surface (ft)	Date determined (m/d/yr)	Period of record (yrs)	Minimum (ft)	Maximum (ft)	
507	35 54 51	84 18 37	N17316 E30064	19	1964	6 7/8	S	Prf	0-19	819.70	0.10	4/08/75	1975-78	5.52	DRY	D
508	35 54 53	84 18 37	N17506 E30138	19	1964	6 7/8	S	Prf	0-19	834.16	0.64	4/08/75	1975-78	17.54	DRY	D
510	35 54 53	84 18 42	N17730 E29766	13	1964	6 7/8	S	Prf	0-13	802.00	2.60	4/02/76	1976-79	0.58	5.53	A
511	35 54 51	84 18 41	N17500 E29801	16	1964	6 7/8	S	Prf	0-16	804.28	3.92	4/08/75	1975-79	8.30	12.01	A
512	35 54 54	84 18 42	N17828 E29850	13	1964	6 5/8	S	Prf	0-13	809.05	2.45	4/02/76	1975-79	2.93	7.64	A
T29-1	35 54 56	84 18 36	N17695 E30419	12	1959	6 5/8	S	Prf	0-12	858.01	2.59	4/08/75	1975-79	3.67	9.44	A
T30-1	35 54 56	84 18 35	N17640 E30403	11	1959	6 5/8	S	Prf	0-11	847.86	3.84	4/08/75	1975-79	4.06	DRY	A
T31-1	35 54 52	84 18 37	N17389 E30078	14	1977	3	P	Slt	4-14	826.46	2.60	2/16/77	1977-79	13.43	DRY	A
T60-1	35 54 44	84 18 45	N17075 E29094	14	1976	3	P	Slt	4-14	784.87	3.53	7/05/76	1976-79	4.58	DRY	A
T64-1	35 54 47	84 18 42	N17061 E29511	15	1977	3	P	Slt	5-15	779.12	2.08	3/14/77	1977-79	3.84	10.29	A
T66-1	35 54 44	84 18 45	N17095 E29073	17	1976	3	P	Slt	7-17	788.47	2.73	7/05/76	1976-79	5.57	DRY	A
T83-1	35 54 46	84 18 46	N17323 E29153	16	1975	4	S	Prf	1-16	807.90	0.00	11/05/75	1975-79	15.09	DRY	A
T83-2	35 54 46	84 18 46	N17306 E29140	10	1975	4	S	Prf	1-10	805.90	0.00	11/05/75	1975-79	DRY	DRY	A
T83-3	35 54 45	84 18 46	N17253 E29096	14	1975	4	S	Prf	1-14	799.10	0.00	11/05/75	1975-79	7.79	DRY	A
T83-4	35 54 45	84 18 46	N17235 E29085	14	1975	4	S	Prf	1-14	798.16	2.54	11/05/75	1975-79	10.45	DRY	A
T83-5	35 54 44	84 18 46	N17138 E29026	11	1975	4	S	Prf	1-11	790.78	3.02	3/01/76	1975-79	6.96	DRY	A
T105-1	35 54 46	84 18 46	N17333 E29138	14	1975	4	S	Prf	1-14	808.60	0.00	11/05/75	1975-79	9.49	DRY	A
T105-2	35 54 46	84 18 46	N17316 E29125	15	1975	4	S	Prf	1-15	806.60	0.00	11/05/75	1975-79	12.87	DRY	A
T105-3	35 54 45	84 18 46	N17259 E29083	14	1975	4	S	Prf	1-14	798.80	0.00	11/05/75	1975-79	7.17	DRY	A
T105-4	35 54 45	84 18 46	N17242 E29070	13	1975	4	S	Prf	1-13	797.75	2.45	11/05/75	1975-79	2.10	7.10	A
T105-5	35 54 44	84 18 46	N17149 E29010	14	1975	4	S	Prf	1-17	790.29	2.91	3/01/76	1975-79	6.27	14.30	A
T105-6	35 54 44	84 18 46	N17119 E28997	16	1975	4	S	Prf	1-19	788.62	2.98	3/01/76	1975-79	4.80	14.52	A
T117-1	35 54 48	84 18 36	N16987 E29933	7	1975	3	P	Slt	0-7	778.36	2.24	3/01/77	1977-79	+0.45	DRY	A

Table B-2. Summary of annual precipitation at Burial Grounds 5 and 6, Oak Ridge National Laboratory, Roane County, Tennessee[a]

Year	Burial Ground 5 (in.)	Burial Ground 6 (in.)
1976	46.17	44.13[b]
1977	54.62	54.68
1978	47.91[b]	51.78
1979	63.26[b]	57.19[b]
1980	37.90[b]	37.02
Mean[c]	51.96	49.60

[a]From Webster et al. (1982).
[b]Incomplete record.
[c]This value is the summation of the monthly means calculated for each gage.

Table B-3. Release of ^{90}Sr from operations and buried waste at ORNL from 1964 to 1983

[^{90}Sr releases are for calendar year; rainfall is for water year]

Water year[a]	Precipitation (cm)	Total ^{90}Sr discharge (Ci)	Discharge of ^{90}Sr (mCi/cm)
1967	153.8	0.89	5.8
1968	114.3	2.84	24.8
1969	101.8	0.88	8.7
1970	121.7	0.93	7.6
1971	122.6	0.58	4.7
1972	120.4	0.81	6.7
1973	181.0	1.43	7.9
1974	174.7	1.39	7.9
1975	146.6	2.07	14.1
1976	123.9	0.75	5.8
1977	129.1	0.43	3.4

[a]Water year is September 1 through August 31.
From Tamura et al. (1980).

Table B-4. Release of ^{90}Sr from operations and buried waste at ORNL from 1964 through 1983[a]

[^{90}Sr releases are for calendar year; rainfall is for water year]

Year	Precipitation (cm/y)	White Oak Dam (Ci/y)	Burial Grounds 1, 3, and 4 and 7500 floodplains[b] (Ci/yr)	Burial Ground 5 (Ci/y)[c]
1964		7	3.3	0.7
1965		3	3.4	0.3
1966		3	2.0	0.5
1967	154	5	2.7	1.0
1968	115	3	1.7	2.8[d]
1969	103	3.1	1.3	0.9
1970	122	3.9	1.4	0.7
1971	123	3.4	1.7	0.6
1972	120	6.5	2.2	0.9
1973	180	6.7	2.0	1.3
1974	175	6.0	5.4	1.3
1975	148	7.2	3.6	2.1
1976	125	4.5	4.3	0.7
1977	130	2.7	2.6	0.5
1978	156	2.0	1.2	0.5
1979	170	2.4	1.7	0.7
1980	97	1.5	0.9	0.6
1981	110	1.5	0.8	0.2
1982	155	2.7	1.5	0.5
1983	105	2.5	1.6	0.9
20-year total		77.6	45.3	17.7
Average Ci/y		3.9	2.3	0.9
Contribution, % of White Oak Dam total			58	23

[a]From National Research Council (1985).
[b]Calculated by difference, monitoring station 3-ORNL operations.
[c]As measured at monitoring station 4-Melton Branch.
[d]The result of an accident.

Appendix C. SOLID WASTE

Table C-1. Land used for solid waste disposal

	Total (all SWSA)		SWSA-5		SWSA-6	
	m^2	Acres	m^2	Acres	m^2	Acres
Prior to FY 1982	356,744[a]	(88.17)[a]	202,452[a]	(50.04)[a]	30,466[a]	(7.53)[a]
FY 1981	1,875	(0.46)	63	(0.02)	1,510	(0.38)
FY 1980	2,840	(0.70)	8	(0.002)	2,832	(0.70)
FY 1979	3,277	(0.81)	81	(0.02)	3,196	(0.79)
FY 1978	3,237	(0.80)	81	(0.02)	3,156	(0.78)
FY 1977	3,196	(0.79)	202	(0.05)	2,994	(0.74)
TQ 1976[b]	1,052	(0.26)	41	(0.01)	1,012	(0.25)
FY 1976	4,046	(1.00)	364	(0.09)	3,682	(0.91)
FY 1975	4,248	(1.05)	41	(0.01)	4,208	(1.04)

[a]Corrected to most recent civil engineering data.
[b]Third quarter, FY 1976.

Table C-2. Estimates of total annual activity, volume, and weight of solid waste buried or stored at ORNL[a]

Fiscal year	Activity (Ci)	Volume (m^3)	Weight (kg)	SWSA
1943	2,000	700	1.4×10^5	1
1944	2,000	700	1.4×10^5	1,2
1945	2,000	700	1.4×10^5	2
1946	2,000	700	1.4×10^5	2,3
1947	10,000	3,960	1.4×10^5	3
1948	10,000	3,960	1.4×10^5	3
1949	10,000	3,960	1.4×10^5	3
1950	10,000	3,960	1.4×10^5	3
1951	10,000	3,960	1.4×10^5	3,4
1952	10,000	5,660	1.4×10^5	4
1953	10,000	5,660	1.4×10^5	4
1954	10,000	5,660	1.4×10^5	4
1955	10,000	5,660	1.4×10^5	4
1956	10,000	5,660	1.4×10^5	4
1957	20,000	9,060	1.8×10^6	4
1958	20,000	9,060	1.8×10^6	4
1959	20,000	9,060	1.8×10^6	4,5
1960	20,000	9,060	1.8×10^6	5
1961	20,000	15,000	2.7×10^6	5
1962	30,000	12,000	2.3×10^6	5
1963	20,000	9,430	1.8×10^6	5
1964	20,000	9,090	1.8×10^6	5
1965	10,000	5,350	9.1×10^5	5
1966	10,000	4,500	9.1×10^5	5
1967	10,000	5,640	9.1×10^5	5
1968	20,000	6,850	1.4×10^6	5
1969	10,000	5,440	9.1×10^5	5
1970	10,000	3,630	4.5×10^5	5
1971	10,000	4,730	1.0×10^6	5
1972	9,000	3,650	8.6×10^5	5,6
1973	8,000	3,030	7.1×10^5	5,6
1974	8,000	3,400	7.0×10^5	5,6
1975	1,200	3,170	6.4×10^5	5,6
1976[b]	7,000	3,540	6.8×10^5	5,6
1977	4,046	2,200	1.7×10^5	5,6
1978	3,810	2,360	4.2×10^5	5,6
1979	5,398	2,110	6.1×10^5	5,6
1980	58,400	2,350	6.0×10^5	5,6
1981	113,700	1,800	7.6×10^5	5,6
1982	7,905	1,491	3.7×10^5	5,6
1983	6,299	2,238	7.6×10^5	5,6
1984	11,500	2,444	7.0×10^5	5,6
Total	602,258	202,583	3.233×10^7	

[a]From Grizzard (1986).

[b]July 1, 1975 through September 30, 1976 reflects change in fiscal year to begin in October.

Table C-3. High-radiation-level alpha wastes in retrievable below-grade storage — Buildings 7827 and 7865 and trenches[a]

	Total volume		Transuranium isotopes and ^{233}U (g)	Volume in SS liners[d]		Number of casks
	m^3	ft^3		m^3	ft^3	
Prior to FY 1982	586.6	(20,716)	4,049[b]	3.7	130	202
FY 1981	25.5	(900)	0	0	(0)	9
FY 1980	25.5	(900)	0	0	(0)	7
FY 1979	42.5	(1,502)	9	0.01	(2)	15
FY 1978	40.9	(1,443)	151	0.8	(27)	14
FY 1977	69.0	(2,438)	565	1.1	(38)	24
TQ FY 1976	22.9	(808)	34	0.2	(8)	8
FY 1976	45.3	(1,601)	168	0.9	(31)	15
FY 1975	70.8	(2,500)	15	NA	NA	25
FY 1974	82.2	(2,905)	140	NA	NA	29
FY 1973	124.6	(4,400)	889[b]	NA	NA	44
FY 1972	34.0	(1,200)	2,066[b]	NA	NA	12[b]
FY 1971	2.8	(100)	12[b]	NA	NA	a[c]

[a]From Grizzard (1986).

[b]Quantities of isotopes present were most often given as less than the maximum quantity approved for the specific container used; best estimates are now required.

[c]Forty-three casks for FY 1971 and 44 casks for FY 1972 are buried nonretrievably.

[d]An additional 2.0 m^3 (70 ft^3) in FY 1976 and 0.45 m^3 (16 ft^3) in FY 1978 are retrievably stored.

Table C-4. Low-level alpha wates in retrievable storage in Buildings 7826 and 7834 at Solid Waste Storage Area 5[a]

Period	Volume (m^3)	Transuranium isotopes and ^{233}U (g)	Number of stainless steel drums
Prior to FY 1974	124.7	2,138	282[b]
FY 1974	30.7[c]	1,176	137
FY 1975	42.1	1,761	190
FY 1976	46.3	2,352	205
Adj. Quar. FY 1976	12.9	1,053	57
FY 1977	15.5	1,294	69
FY 1978	34.1	585	151
FY 1979	32.7	818	145
FY 1980	30.0	335	133
FY 1981	35.4	814	129
FY 1982	20.3	103.4	86
FY 1983	25.0	480.6	106
FY 1984	53.3[d]	795.1	85
Total	503.0	13,705.4	1,775

[a]From Grizzard (1986).

[b]An additional 277 black iron drums were stored prior to FY 1974.

[c]Volumes correctd for blue boxes of low-level alpha waste buried in previous years.

[d]This includes 23 metal boxes stored retrievably.

Table C-5. High-radiation level alpha wastes in retrievable below-grade storage in Buildings 7827 and 7833, and trenches in Solid Waste Storage Area 5[a]

Period	Total volume (m^3)	Transuranium isotopes and ^{233}U (g)	Volume in stainless steel liners (m^3)	Number of casks
FY 1971	2.8	12[b]	NA	–[2]
FY 1972	34.0	2066[b]	NA	12[2]
FY 1973	124.6	889[b]	NA	44
FY 1974	82.2	140	NA	29
FY 1975	70.8	15	NA	25
FY 1976	45.3	168	0.9	15
Adj. Quar. FY 1976	22.9	34	0.2	8
FY 1977	69.0	565	1.1	24
FY 1978	40.9	151	0.8	14
FY 1979	42.5	9	0.01	15
FY 1980	25.5	9	0	7
FY 1981	25.5	2	0	9
FY 1982	31.1	1	0	11
FY 1983	25.5	13	0	13
FY 1984	37.1	27	0.33	9
Total	448.6	4101	3.34	235

[a]From Grizzard (1986).

[b]Quantities of isotopes present were most often given as less than the maximum quantity approved for the specific container used; best estimates are now required.

[c]Forty-three casks for FY 1971 and 44 casks for FY 1972 are buried nonretrievably.

Table C-6. Fissile waste in SWSAs[a]

	Volume		Fissile isotopes (g)	Number of	
	m^3	ft^3		Auger holes	Trenches
Prior to FY 1982	325.4	(11,494)	22,833	222	8
FY 1981	0.4	(12)	210	3	0
FY 1980	2.7	(60)	958	3	0
FY 1979	0.4	(13)	39	2	0
FY 1978	2.5	(87)	1,261	14	0
FY 1977	5.7	(200)	1,728	8	0
FY 1976	3.5	(123)	1,225	6	1
FY 1975	50.5	(1,784)	1,992	7	4
FY 1974	58.9	(2,082)	1,915	9	1
FY 1973	33.8	(1,195)	2,128	40	0
FY 1972	101.2	(3,576)	7,289	76	1
FY 1971[b]	48.3	(1,705)	2,784	36	1
FY 1970[c]	17.4	(613)	1,302	16	0

[a]From Grizzard (1986).

[b]Transuranium Waste Storage Facility initiated October 1970.

[c]First year of separation of transuranic from nontransuranic waste. Prior to this, wastes containing isotopes ^{233}U, ^{235}U, and ^{239}Pu were placed below grade in the same section, SWSA-5.

Appendix D. OLD HYDROFRACTURE IMPOUNDMENT AND SURFACE FACILITIES

Table D-1. Waste pit inventories of radionuclides[a]

	Average depth and volume	Radionuclide	Concentration (Bq/mL or BQ/g)	Inventory GBq	Inventory mCi
South cell water	45 cm 6.3×10^3 L	^{135}Cs	1.2×10^2	0.8	20.0
		^{239}Pu	1.1	0.007	0.2
		^{238}Pu	2.2	0.01	0.4
		^{241}Am	1.0	0.006	0.2
		^{244}Cm	1.0	0.006	0.2
		^{90}Sr	15.0	0.09	3.0
South cell sediment	10 cm 1.4×10^3 L	^{137}Cs	4.0×10^3	6.0	200.0
		^{60}Co	31.0	0.04	1.0
		^{239}Pu	97.0	0.1	4.0
		^{238}Pu	30.0	0.04	1.0
		^{241}Am	17.0	0.02	0.6
		^{244}Cm	54.0	0.08	2.0
		^{90}Sr	7.8×10^2	1.0	30.0
North cell water	90 cm 1.3×10^4 L	^{137}Cs	2.1×10^2	3.0	80.0
		^{239}Pu	1.0	0.01	0.4
		^{238}Pu	1.5	0.02	0.5
		^{241}Am	1.0	0.01	0.4
		^{244}Cm	1.0	0.01	0.4
		^{90}Sr	16.0	0.2	6.0
North cell sediment	10 cm 1.4×10^3 L	^{137}Cs	3.1×10^3	4.0	100.0
		^{60}Co	14.0	0.02	0.6
		^{239}Pu	42.0	0.06	2.0
		^{238}Pu	17.0	0.02	0.6
		^{241}Am	13.0	0.02	0.6
		^{244}Cm	6.0×10^2	0.8	20.0
		^{90}Sr	4.0×10^2	0.6	20.0

[a]Taken from S. F. Huang [EDSD, personal communication, September 1984, in Francis and Stansfield (1986a)].

[b]Inventory in the sediment was estimated by assuming that the total volume was equal to the total dry weight.

Table D-2. Radiation levels in Building 7852 and in Pump House[a]

Location	Direct β-γ (mrad/h)	Radiation level Smearable (per 100 cm^2 α (dpm)	β-γ (mrad/hr)[b]
		Building 7852	
Mixing cell	Avg. 2500 Max. 4000	Generally <20 Max. 102 (1 location)	Avg. 16 Max. 30
Pump cell	Avg. 625 Max. 2000	<20	Avg. 2.4 Max. 5
Well cell	Avg. 1320 Max. 3000	<20	Avg. 23 Max. 36
Engine pad	Avg. 130 Max. 300	Generally <20 Max. 27 (1 location)	Avg. 0.85 Max. 1
Control room	Avg. 75-80 except max. 600 (at stored items)	21-36	21,000-49,000 dpm
		Pump House	
Pump room	Avg. 1340 except for max. 8000 (under lead shield)	<20	0.5-16 mrad/h
Valve pit	5	Not given	Not given

[a]From Reed, 1984 in Francis and Stansfield (1986a).
[b]Except as noted.

Table D-3. Estimate of residual radioactivity in waste tanks at the Old Hydrofracture Facility[a]

Tank	Tank capacity (L)	Tank diameter (m)	Tank length (m)	Sludge volume (L)	Sludge activities	
					TBq	kCi
T-1	5.9×10^4	2.4	13.0	4.2×10^3	40	1.0
T-2	5.9×10^4	2.4	13.0	4.2×10^3	40	1.0
T-9	4.4×10^4	3.1	5.9	2.2×10^3	30	0.6
T-3	1.1×10^5	3.2	13.0	4.9×10^3	40	1.0
T-4	1.1×10^5	3.2	13.0	$4.9. \times 10^3$	40	1.0

[a]From S. F. Huang (EOSD, personal communication, September 1984) in Francis and Stansfield (1986a). The estimate was based on the assumption of 30-cm thickness of residual sludge (a rough estimate from operational experience) at a concentration of 0.26 Ci/L.

Table D-4. Concentrations and inventory of nonradioactive contaminants in OHF pond water[a]

Constituent	Concentration (mg/L) Pond	NIPDWS	Inventory[b] (g)
		Metals	
Antimony	<0.3	ND[c]	<74
Arsenic	<0.001	0.05	<1
Barium	0.539	1	132
Beryllium	0.0021	ND	1
Boron	<0.1	ND	<25
Cadmium	0.0015	0.01	<1
Calcium	26.3	ND	6664
Chromium	0.0219	0.05	5
Cobalt	<0.02	ND	<5
Copper	<0.02	ND	<5
Iron	9.25	ND	2266
Lead	<0.001	0.05	<1
Lithium	<0.2	ND	<49
Magnesium	8.99	ND	2203
Manganese	0.2	ND	49
Mercury	0.0001	0.002	<1
Molybdenum	<0.02	ND	<5
Nickel	<0.06	ND	<15
Potassium	6.5	ND	1593
Selenium	0.016	0.01	4
Silver	<0.07	0.05	<17
Sodium	<0.5	ND	<123
Strontium	0.316	ND	77
Titanium	<0.02	ND	<5
Vanadium	<0.03	ND	<7
Zinc	0.134	ND	33
		Anions	
Chloride	64	ND	15,680
Fluoride	1	1.2-2.4	245
Nitrate-N	<1	10	<245
Phosphate	<0.93	ND	<228
Sulfate	19	ND	4655

[a]Data taken from R. G. Stansfield and C. W. Francis (1986a).
[b]Based on a total volume of 2.4×10^5 L.
[c]ND = level not defined by NIPDWS (National Interim Primary Drinking Water Standards).

Table D-5. Concentrations and inventory of organic chemicals in OHF pond water[a]

Constituent	Concentration (mg/L) Pond	NIPDWS	Inventory[b] (g)
	Herbicides/pesticides		
Endrin	<0.0001	0.002	<0.1
Lindane	<0.0001	0.004	<0.1
Methoxychlor	<0.0002	0.1	<0.1
Toxaphene	<0.002	ND[c]	<0.5
	Organic Compounds[d]		
PCBs	0.0001	ND	<0.1
Phenols	<0.0001	ND	<0.1
TOC	16.5	ND	4043
TOX	0.132	ND	32

[a]Data taken from R. G. Stansfield and C. W. Francis (1986).
[b]Inventory based on pond water volume of 2.45×10^5 L.
[c]ND = limit not defined by NIPDWS (Naional Interim Primary Drinking Water Standards).
[d]PCBS = polychlorinated biphenyls; TOC = total organic carbon; TSX = total organic halides.

Table D-6. Concentrations and inventory of radionuclides in OHF pond water[a]

Radionuclide	Stansfield and Francis (1986)[b]			S. F. Huang[c]		
	Concentration (Bq/L)	Inventory (MBq)	Inventory (mCi)	Concentration (Bq/L)	Inventory (MBq)	Inventory (mCi)
Gross alpha	11	2.7	0.07	NC[d]	NR	NR
Gross beta	9400	2303	63	NR	NR	NR
Americium-241	0.24	0.1	<0.01	NR	NR	NR
Cesium-137	3900	956	26	29,000	2100	57
Cobalt-60	27	6.6	0.18	27	2	0.05
Curium-244	6.8	1.7	0.05	NR	NR	NR
Plutonium-238	0.17	<0.1	<0.1	NR	NR	NR
Plutonium-239	0.052	<0.1	<0.1	NR	NR	NR
Radium-226	0.015	<0.1	1080	NR	NR	NR
Strontium-90	4400	1080	29	7100	514	14
Uranium-234	1.5	0.4	0.01	NR	NR	NR
Uranium-238	0.375	0.1	<0.1	NR	NR	NR

[a]Taken from Francis and Stansfield (1986a).

[b]Value used for pond volume, 2.45 x 10^5 L (R. G. Stansfield and C. W. Francis (1986).

[c]Value used for pond volume, 7.24 x 10^4 L (S. F. Huang, EOSD, personal communication, September 1984, in Stansfield annd Francis (1986).

[d]NR = not reported.

Table D-7. Concentrations of RCRA-regulated constituents in EP extracts of sediment from the OHF impoundment

Constituent	Maximum allowable concentration (mg/L)	Measured concentration[a] (mg/L)
Arsenic	5	<0.60
Barium	100	0.307
Cadmium	1	0.0092
Chromium	5	0.0492
Lead	5	<0.0232
Mercury	0.2	0.065
Selenium	1	<1.2
Silver	5	<0.2
Endrin	0.02	<0.0001
Lindane	0.04	0.0001
Methoxychlor	10	<0.0002
Toxaphene	0.5	<0.002
2,4-D	10	<0.005
2,4,5-DTP	1	<0.005)

[a]Taken from R. G. Stansfield and C. W. Francis, in Francis and Stansfield (1986a). Mean concentrations from six replicated PE extracts for metals (sediment from three sample locations at two dates). For the herbicides/pesticides, the concentrations are mean concentrations from three replicated EP extracts (sediment from three sample locations at a single date).

Table D-8. Concentrations and inventory of nonradioactive contaminants in sediment from the OHF impoundment

Contaminant	Stansfield and Francis (1986)[a] Concentration (mg/kg)	Stansfield and Francis (1986)[a] Inventory (kg)	S. F. Huang[b] Concentration (mg/kg)	S. F. Huang[b] Inventory (kg)
Antimony	<194	<3.69	<1.0	<0.08
Arsenic	>120	<2.28	1.1	0.09
Barium	320	6.07	NR[c]	NR
Boron	132	25	NR	NR
Cadmium	>6.1	<0.12	NR	NR
Chromium	342	6.50	17.0	1.30
Cobalt	22.4	0.43	NR	NR
Copper	140	2.66	18.0	1.40
Iron	11,200	403	NR	NR
Lead	<156	<2.97	6.0	0.48
Manganese	370	7.03	NR	NR
Mercury	NR	NR	<2.3	<0.18
Molybdenum	<15.5	<0.29	NR	NR
Nickel	149	2.84	NR	NR
PCB	2.9	0.05	3.5	2.80
Selenium	<240	<4.55	<0.8	<0.06
Silver	<40.9	<0.78	NR	NR
Vanadium	79.1	1.50	NR	NR
Zinc	162	3.07	16.0	1.20

[a]Sediment concentrations by R. G. Stansfield and C. W. Francis, in Francis and Stansfield (1986a).

[b]Sediment concentrations by S. F. Huang (EOSD, personal communication, September 1984) are on dry-weight basis and represent a mean of three sediment samples taken from the north, center, and south sections of the impoundment. Inventory calculated by Stansfield and Francis was based on a total volume of sediment equal to 5.5×10^4 L, a wet bulk density of 1.2 kg/L, and a moisture content of 71%.

[b]Sediment concentrations by Huang et al. are on a wet-weight basis and represent a mean of five sediment samples taken from the center of the pond from a southwest to northeast direction. Inventory calculated by Huang et al. was based on a total volume of sediment equal to 3.7×10^4 L and a wet bulk density of 2.16 kg/L.

[c]NR = not reported.

Table D-9. Concentrations and inventory of radionuclides in sediment from the OHF impoundment

	Stansfield and Francis (1986)[a]			S. F. Huang[b]		
	Concentration	Inventory		Concentration	Inventory	
	(Bq/g)	(GBq)	(Ci)	(Bq/g)	(GBq)	(Ci)
Gross alpha	102	1.93	0.05	NR[c]	NR	NR
Gross beta	92,700	1761	48	NR	NR	NR
Cesium-134	<20	<0.38	0.01	100	8.1	0.22
Cesium-137	125,000	2370	64	180,000	14,000	388
Europium-154	<22.7	<0.43	<0.01	390	31	1
Uranium-234	<33.3	<0.63	<0.01	NR	NR	NR
Uranium-238	<612	<11.6	<1	0.23	0.0055	<0.01
Americium-241	<20.0	<0.38	<0.01	2.8	0.22	<0.01
Cobalt-60	608	11.6	0.31	740	60	1.6
Strontium-90	38,800	737	20	9700	770	21

[a]Sediment concentrations by R. G. Stansfield and C. W. Francis, in Francis and Stansfield (1986a), are on dry-weight basis and represent a mean of three sediment samples taken from the north, center, and south sections of the impoundment. Inventory calculated by Stansfield and Francis was based on a total volume of sediment equal to 5.5×10^4 L, a wet bulk density of 1.2 kg/L, and a moisture content of 71%.

[b]Sediment concentrations by S. F. Huang (EOSD, personal communication, September 1984) are on a wet-weight basis and represent a mean of five sediment samples (except the Europium-154 analysis, which is from a single sediment sample) taken from the center of the pond from a southwest to northeast direction. Inventory calculated by Huang was based on a total volume of sediment equal to 3.7×10^4 L and a wet bulk density of 2.16 kg/L.

[c]NR = not reported.

Table D-10. Summary of monitoring well location, construction data, and water levels at the OHF impoundment[a]

	MW-1	MW-2	MW-3	MW-4
North grid coordinate, ft	17,325.24	17,236.06	17,298.86	17,339.13
East grid coordinate, ft	28,600.38	28,504.80	28,496.78	28,519.01
Top of well casing elevation, ft	782.11	776.89	773.46	773.50
Height of casing above ground, ft	2.80	2.70	2.90	2.90
Ground surface elevation, ft	779.30	774.20	770.60	770.60
Top of well screen elevation, ft	760.10	761.20	760.40	760.50
Bottom of well screen elevation, ft	750.10	751.90	750.40	750.50
Top of sand pack elevation, ft	769.80	768.20	764.70	762.60
Bottom of well hole elevation, ft	744.30	750.20	746.60	746.60
Diameter of well pipe/ screen, in.	3.00	3.00	3.00	3.00
Type material of pipe/screen	————Fiberglass————			
Width of screen opening, in.	0.20	0.20	0.20	0.20
Water level elevation, 4/8/85, ft	770.92	756.58	757.38	760.87
Water level elevation, 6/4/85, ft	768.92	755.37	756.14	759.36
Water level elevation, 7/1/86, ft	768.23	755.34	756.30	759.46
Water level elevation, 7/30/85, ft	768.04	755.47	756.50	759.66

[a]Taken from R. G. Stansfield and C. W. Francis, in Francis and Stansfield (1986a).

Table D-11. Mean groundwater concentrations measured in monitoring wells at the Old Hydrofracture Facility impoundment[a]

Parameter	Maximum allowed[b,c]	Measured[b] Upgradient	Measured[b] Downgradient
National Interim Primary Drinking Water Stndards (NIPDWS)			
Arsenic	0.05	<0.0028	<0.0033
Barium	1	0.45	0.57
Cadmium	0.01	<0.0011	<0.0020
Chromium	0.05	<0.027	<0.031
Coliform bacteria, count/100 mL	1	5.2	<6.4
Endrin	0.0002	<0.0001	<0.0002
Fluoride	1.4-2.4	<1.0	<1.0
Gross alpha, bq/L	0.556	<1.2	<58
Gross beta, bq/L	0.13[d]	4.8	710
Lead	0.05	<0.01	<0.0420
Lindane	0.004	<0.0009	<0.0011
Mercury	0.002	<0.0001	<0.0011
Methoxychlor	0.1	<0.0033	<0.0041
Nitrate-N	10	2.7	<3.8
^{226}Ra, Bq/L	0.19	<0.11	<0.19
Selenium	0.01	0.0033	<0.0037
Silver	0.05	<0.042	<0.036
Toxaphene	0.005	<0.0032	<0.0035
2,4,5-TP Silvex	0.01	<0.0070	<0.0075
2,4-D	0.1	<0.0070	<0.0075
Parameters Establishing Groundwater Quality			
Chloride	ND	12	19
Iron	ND	2.7	17
Manganese	ND	0.20	2.9
Phenols	ND	<0.0012	<0.0012
Sodium	ND	13	24
Sulfate	ND	20	16
Parameters Used as Indicators of Groundwater Contamination			
pH	ND	6.5	6.3
Specific conductannce, μS/cm	ND	710	450
Total organic carbon	ND	4.5	5.7
Total organic halides	ND	0.11	0.13

Table D-11 (Continued)

Parameter	Maximum allowed[b,c]	Measured[b] Upgradient	Downgradient
		Upgradient	Downgradient
	Nonregulated Parameters		
Copper[e]	1	<0.0200	<0.0261
^{137}Cs, Bq/L	ND	1.2	1.7
Dissolved oxygen	ND	6.9	7.4
Nickel[e]	5	<0.06	<0.06
Polychlorinated biphenyls (PCBs)	ND	0.0001	0.0001
^{90}Sr, Bq/L	0.13[d]	1.9	460
Temperature, °C	ND	16	16
Tritium, Bq/L	670[d]	91,000	80,000
Zinc[e]	5	<0.06	<0.1476

[a]From Francis and Stansfield (986b).

[b]Concentrations are in mg/L unless otherwise stated.

[c]ND = maximum level for that parameter not defined.

[d]Level of activity necesary to give a total body dose of 4 mR/y to a prson drinking 2.2 L of water per day for a year.

[e]Hazardous substance guidelines issued by the State of Tennessee (L. W. Gregory, Division of Solid Waste Management, Department of Health and Environment, State of Tennessee, personel communication, 1985).

Table D-13. Water levels (m) in monitoring wells[a]

Date	Monitoring well 1A	1	2	3	4
4/8/85		235.0	230.6	230.8	231.9
5/23/85		234.5	230.3	230.7	231.6
6/4/85		234.4	230.2	230.5	231.5
7/1/85		234.2	230.2	230.5	231.5
7/30/85		234.1	230.3	230.6	231.5
9/17/85		234.2	230.4	230.6	231.6
1/6/86		234.2	230.2	230.6	231.6

[a]From Francis and Stansfield (1986b).

Table D-14. List of samples whose detection levels exceeded Resource Conservation and Recovery Act (RCRA) limits[a]

Parameter	Unit	RCRA limit	Well No.	Sampling quarter	Detection level
Gross alpha	Bq/L	0.55	2	2	2.0
Gross alpha	Bq/L	0.55	4	2	3.0
^{226}Ra	Bq/L	0.19	1	3	0.40
^{226}Ra	Bq/L	0.19	2	1	0.20
^{226}Ra	Bq/L	0.19	3	1	0.20
^{226}Ra	Bq/L	0.19	3	3	0.60
^{226}Ra	Bq/L	0.19	3	4	0.20
^{226}Ra	Bq/L	0.19	4	1	0.20
^{226}Ra	Bq/L	0.19	4	3	0.60
Silver	mg/L	0.05	1	1	0.07
Silver	mg/L	0.05	1	2	0.07
Silver	mg/L	0.05	2	1	0.07
Silver	mg/L	0.05	2	2	0.07
Silver	mg/L	0.05	3	1	0.07
Silver	mg/L	0.05	3	2	0.07
Silver	mg/L	0.05	4	1	0.07
Silver	mg/L	0.05	4	2	0.07

[a]From Francis and Stansfield (1986b).

Appendix E. WASTE CONCENTRATE STORAGE TANKS (MELTON VALLEY STORAGE TANKS)

Table E-1. Spark-source spectrometry and anion data on samples from the Melton Valley Storage Tanks[a]
(From Peretz et al. (1986).)

Anion[b]	Sample				
	W-24 T	W-24 M	W-24 B	W-24 S	W-25 T
		(mg/mL)			
Nitrate	260	260	260	270	210
Chloride	4.2	3.5	3.4	3.5	2.1
Sulfate	<1	<1	<1	<1	1.2
Element[d]		(μg/mL)			
Sodium	Major	Major	Major	Major	Major
Potassium	5000	5000	<1%	9000	7000
Calcium	500	2000	4000	1%	700
Boron	300	500	3000	<1%	100
Aluminum	40	40	7000	2000	100
Iron	200	50	3000	3000	200
Phosphorus	30	20	3000	2000	100
Barium	70	40	6000	100	30
Magnesium	200	300	1000	700	50
Sulfur	200	200	1000	300	200
Zinc	20	20	300	30	10
Silicon	20	30	100	100	50
Manganese	5	5	50	100	5
Chromium	5	5	50	100	10
Uranium	200	300			
Thorium	50	100			
Nickel	50	10	5	200	10
Bismuth	5	10	200	100	<3
Lead	<10	10	200	100	10
Titanium	10	5	10	50	5
Strontium	10	5	50	50	10
Copper	<10	<10	40	30	5
Zirconium	<3	<3	500	5	<1
Vanadium	3	3	3	5	3
Tungsten			<30	30	30
Cobalt	<3	<3	5	1	1
Molybdenum	<3	<3	<5	<5	<5
Lanthanum	<1	<1	<10	10	<10
Cerium	5	<3	<3	3	<3

Table E-1 (continued)

Anion[b]	W-25 M	W-25 B	W-25 S	W-26 T	W-26 M
	Sample				
		(mg/mL)			
Nitrate	210	230	180	320	330
Chloride	2.2	2	2.1	2.4	2.4
Sulfate	1.2	1.2	1.2	<1	<1
Element[d]		(μg/mL)			
Sodium	Major	Major	Major	Major	Major
Potassium	5000	9000	9000	Major	Major
Calcium	500	2000	2000	Major	Major
Boron	100	Major	Major	700	700
Aluminum	200	700	600	600	600
Iron	50	1000	1000	100	100
Phosphorus	100	1000	1000	100	100
Barium	30	50	50	200	100
Magnesium	100	600	1000	600	700
Sulfur	200	600	600	100	100
Zinc	10	50	100	30	30
Silicon	50	200	100	10	10
Manganese	5	50	100	10	10
Chromium	10	50	50	10	10
Uranium				<1100	<=1000
Thorium				100	200
Nickel	5	500	500	10	20
Bismuth	<3	40	50	5	<5
Lead	<10	50	100	5	<5
Titanium	10	100	100	10	30
Strontium	5	50	50	40	30
Copper	5	20	30	<3	<3
Zirconium	<1	<1	3	3	<3
Vanadium	5	10	10	3	5
Tungsten	<30				
Cobalt	3	10	10	1	1
Molybdenum	<5	<3	<3	<3	<3
Lanthanum	<10	5	5	<1	<1
Cerium		5	<5	10	<3

Table E-1 (continued)

Anion[b]	Sample W-26 B	W-26 S	W-27 T	W-27 M	W-27 B
		(mg/mL)			
Nitrate	330	340	140	130	130
Chloride	2.4	2.5	c		
Sulfate	<1	<1	2.2	2	1.9
Element[d]		(μg/mL)			
Sodium	Major	Major	Major	Major	Major
Potassium	Major	6000	5000	5000	5000
Calcium	Major	Major	2000	2000	3000
Boron	50	<10,000	200	500	500
Aluminum	500	2000	300	600	800
Iron	200	1000	200	200	300
Phosphorus	500	2000	300	600	1000
Barium	20	70	200	100	100
Magnesium	1000	1000	500	600	1000
Sulfur	200	300	600	500	600
Zinc	30	50	100	50	100
Silicon	40	1000	100	20	20
Manganese	10	50	20	10	20
Chromium	20	100	20	20	40
Uranium	>2000	>6000	>2000	>2000	<5000
Thorium	500	>3000	200	300	500
Nickel	10	100	30	20	30
Bismuth	10	10	<10	<5	10
Lead	10	10	<10	<10	10
Titanium	20	10	20	10	20
Strontium	30	30	10	5	10
Copper	<3	<3	<10	<10	<10
Zirconium	<3	10	<3	<3	<3
Vanadium					
Tungsten					
Cobalt	1	1	<3	10	<3
Molybdenum	<3	<3	<3	<3	<3
Lanthanum	1	<1	<1	<1	<1
Cerium	<3	<3	<3	<3	<3

Table E-1 (continued)

Anion[b]	Sample W-27 S	W-28 T	W-28 M	W-28 B	W-28 S
		(mg/mL)			
Nitrate	130	330	320	330	330
Chloride					
Sulfate	1.8	<1	<1	<1	<1
Element[d]		(μg/mL)			
Sodium	Major	Major	Major	Major	Major
Potassium	5000	8000	9000	5000	5000
Calcium	4000	2000	3000	8000	5000
Boron	400	10	10	30	30
Aluminum	300	20	10	200	200
Iron	400	20	20	300	300
Phosphorus	400	5	5	50	50
Barium	100	3	10	30	20
Magnesium	1000	100	100	2000	2000
Sulfur	800	200	100	200	200
Zinc	100	10	10	100	50
Silicon	100	10	10	50	100
Manganese	30	1	<1	30	30
Chromium	30	3	3	20	20
Uranium	>6000	<30	<30	5000	7000
Thorium	600	<10	<10	500	500
Nickel	30	30	30	100	200
Bismuth	10	<3	<3	<10	<10
Lead	20	<3	<3	<10	50
Titanium	20	<10	<10	30	<10
Strontium	10	30	20	30	20
Copper	<10	20	10	20	20
Zirconium	<3	<3	<3	<3	<3
Vanadium	10	1	3	5	3
Tungsten					
Cobalt	<3	<1	<3	<3	<3
Molybdenum	<3	<3	<3	<3	<3
Lanthanum	<1	<1	<1	<1	<1
Cerium	<3	<3	<3	<3	<3

[a]July sampling.

[b]Anion data: Request Nos. 52879 and 52900; sample received 7/17/85, analyses complete 8/9/85.

[c]A blank space means no data available.

[d]Elemental data: Request Nos. 33312 (7/29/85), 33314 (8/2/85), and 33318 (8/8/85).

Table E-2. Physical properties of samples from the Melton Valley Storage Tanks[a] (From Peretz et al. (1986).)

Tank	Sample date[b]	Sample location	Specific gravity	Total dissolved Solids	Total dissolved Solids	OH-	Total alkalinity
(Liquid sample units):			(none)	(g/L)	(g/L)	(normal)	(ppm)
(Solids sample units):				(mg/g)		(meq/g)	
W-24	July 85	Top	1.2755	469	576	1.15	6.10E+04
	July 85	Middle	1.2714	539	493	1.18	6.20E+04
	July 85	Bottom	1.3016	697	565	1.23	7.25E+04
	July 85	Sludge	1.3850	469	502	0.91	1.28E+05
	Nov. 85	Liquid	1.2775	487	427	0.92	
	Nov. 85	Solids		454		0.65	
W-25	July 85	Top	0.9714	517	278	0.67	3.70E+04
	July 85	Middle	0.9912	499	279	0.65	3.85E+04
	July 85	Bottom	1.0814	430	290	1.00	6.40E+04
	July 85	Sludge	1.0512	515	297	1.14	8.40E+04
	Nov. 85	Liquid	1.2314	469	362	0.61	
	Nov. 85	Solids		580		0.26	
W-26	July 85	Top	1.2994	618	547	0.01	2.70E+03
	July 85	Middle	1.3036	655	488	0.01	3.20E+03
	July 85	Bottom	1.2986	653	485	<0.01	5.00E+03
	July 85	Sludge	1.3404	742	485	<0.01	5.20E+03
	Nov. 85	Liquid	1.2450	429	383	0.01	
	Nov. 85	Solids		413		<0.01	
W-27	July 85	Top	1.1438	287	255	0.24	3.30E+04
	July 85	Middle	1.1541	310	241	0.25	3.20E+04
	July 85	Bottom	1.1558	326	240	0.26	4.40E+04
	July 85	Sludge	1.1662	323	241	0.28	4.50E+04
	Nov. 85	Liquid	1.2182	405	337	<0.01	
	Nov. 85	Solids		408		0.11	
W-28	July 85	Top	1.2403	434	467	0.02	2.00E+03
	July 85	Middle	1.2521	438	445	0.02	2.00E+03
	July 85	Bottom	1.2703	490	470	0.40	5.15E+04
	July 85	Sludge	1.2357	494	450	0.50	6.65E+04
	Nov. 85	Liquid	1.3250	597	509	0.04	
	Nov. 85	Solids		450		0.56	
W-29	Nov. 85	Liquid	1.2688	442	415	0.80	
	Nov. 85	Solids		428		0.01	
W-30	Nov. 85	Liquid	1.2577	492	386	1.00	
	Nov. 85	Solids		342		0.04	
W-31	Nov. 85	Solids		344		0.03	

[a]All data from the Radioactive Materials Analytical Laboratory (RMAL).
[b]July data: Request No. 34380, received 7/1/85, completed 2/5/86.
Nov. data: Request NNo. 34523, received 11/7/85, completed 11/26/85.

Table E-3. ICP and anion analyses of liquid in the Melton Valley Storage Tanks[a,b] (From Peretz et al. (1986).)

Element or anion	Sample (μg/mL) W-24 M	W-25 M	W-26 M	W-27 M	W-28 M
Sodium	120,000	83,000	79,000	53,000	82,000
Calcium	<30	<30	14,000	<30	5,100
Magnesium	<75	<75	1,200	<75	220
Silicon	160	90	<30	68	<30
Lithium	150	61	75	60	90
Zinc	55	50	31	13	6.2
Phosphorus	<45	<45	<45	52	<45
Aluminum	<30	41	<30	<30	<30
Strontium	<0.75	<0.75	35	<0.75	22
Copper	14	11	23	10	3.4
Barium (100)[c]	<3.0	<3.0	8	<3.0	8.5
Chromium (5)c	<6.0	<6.0	<6.0	6.3	<6.0
Cadmium (1)[c]	<0.75	<0.75	<0.75	1.4	<0.75
Silver (5)[c]	<7.5	<7.5	<7.5	<7.5	<7.5
Arsenic (5)[c]	<15	<15	<15	<15	<15
Boron	<12	<12	<12	<12	<12
Beryllium	<0.30	<0.30	<0.30	<0.30	<0.30
Cobalt	<1.5	<1.5	<1.5	<1.5	<1.5
Iron	<4.5	<4.5	<4.5	<4.5	<4.5
Gallium	<45	<45	<45	<45	<45
Hafnium	<6.0	<6.0	<6.0	<6.0	<6.0
Manganese	<0.75	<0.75	<0.75	<0.75	<0.75
Molybdenum	<6.0	<6.0	<6.0	<6.0	<6.0
Nickel	<9.0	<9.0	<9.0	<9.0	<9.0
Lead (5)[c]	<30	<30	<30	<30	<30
Antimony	<30	<30	<30	<30	<30
Selenium (1)[c]	<30	<30	<30	<30	<30
Titanium	<3.0	<3.0	<3.0	<3.0	<3.0
Vanadium	<1.5	<1.5	<1.5	<1.5	<1.5
Zirconium	<3.0	<3.0	<3.0	<3.0	<3.0
Nitrate	240,000	180,000	260,000	89,000	200,000
Chloride	4,100	2,900	2,900	2,700	2,900
Sulfate[d]					
Fluoride[d]					
Bromide[d]					
Phosphate[d]					

[a]July sampling.
[b]Request No. 53607, received 1/14/86, completed 1/21/86.
[c]EP Toxicity levels follow constituent names in parentheses.
[d]Could not analyze in presence of nitrates.

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Environmental Data Package for the Melton Valley Area (WAG 8)

W. J. Boegly, Jr.
A. F. Iglar

Environmental Sciences Division
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ENVIRONMENTAL SCIENCES DIVISION

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* ORAU Faculty Research Participant, East Tennessee State University.

Date of Issue - September 1987

NUCLEAR AND CHEMICAL WASTE PROGRAMS
(Activity No. KG 02 00 00 0; ONLKG02)

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ABSTRACT

This environmental data package was prepared as part of the effort to meet regulatory requirements for remedial action under Section 3004(u) of the Resource Conservation and Recovery Act. The report considers the 21 Solid Waste Management Units (SWMUs) in Waste Area Grouping (WAG) 8 in Melton Valley. ORNL has recommended that a remedial investigation be conducted to identify the nature of remedial actions in WAG 8.

The purpose of this data package is to provide background information on the geology, hydrology, and soils for the WAG 8 area, as well as information on releases and inventories of radionuclides and hazardous materials for individual sites within WAG 8 that will be required for additional remedial action evaluations. Areas where additional site information will be required are also identified.

The data package indicates that limited information exists on inventories of radioactive and hazardous waste constituents at most of the identified sites. Although there is information on geology, soils, and hydrology for nearby areas, additional evaluations will be required to ensure that the available data can be applied to WAG 8.

1. INTRODUCTION

U.S. Department of Energy (DOE) facilities are required to be in full compliance with all federal and state regulations. In response to these requirements, the Oak Ridge National Laboratory (ORNL) has established a Remedial Action Program (RAP) to provide comprehensive management of areas where past and current research and development and waste management activities have resulted in residual contamination of facilities or the environment. The primary objective of the RAP is to clean up releases of hazardous waste or hazardous constituents that threaten human health or the environment (Trabalka and Myrick, in press).

The initial ORNL remedial action strategy was based on the guidance of DOE Orders 5820.2 (Surplus Facilities Management) and 5480.14 (Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA]); the Resource Conservation and Recovery Act (RCRA) was believed to apply only to a limited number of sites. As a part of this strategy, individual sites were being addressed according to estimated priorities for site characterization, remedial actions, and decommissioning and closure planning. In 1984, the RCRA was amended to establish broad new authorities within the Environmental Protection Agency (EPA) RCRA programs. One of these new authorities was in Section 3004(u), which requires that any hazardous waste management permit issued after November 8, 1984, require corrective action for all releases from solid waste management units (SWMUs) at the facility. In a memorandum to DOE on May 2, 1986, EPA expressed concern about the length of time required to implement DOE Orders and elected to enforce regulatory requirements for remedial actions through its amended RCRA authority (Scarborough 1986).

Prior to the Hazardous and Solid Waste Amendments (HSWA), EPA's authority to require corrective action for releases of hazardous constituents was limited to groundwater releases from units that were covered by RCRA permits (Part 264, Subpart F). Since passage of the HSWA, EPA's authority has been extended to all groundwater releases at a RCRA facility regardless of when they were used and whether or not they are covered by a RCRA permit (USEPA 1986).

1.1 DESCRIPTION OF ORNL'S APPROACH TO COMPLIANCE WITH 3004(u)

The ORNL area is characterized by complex hydrogeologic conditions, and previous studies have shown a close relationship between shallow groundwater flow systems and surface drainage systems (Trabalka and Myrick, in press). It is felt that reliance on groundwater monitoring as prescribed by RCRA regulations would not be adequate or effective under ORNL site conditions; a combination of surface and groundwater monitoring should be more effective in meeting the principal performance objective of RCRA regulations; the protection of human health and the environment (Trabalka and Myrick, in press).

According to RCRA facility assessment guidance an SWMU is defined as:

> any discernible waste management unit at a RCRA facility from which hazardous constituents might migrate, irrespective of whether the unit was intended for the management of solid and/or hazardous waste. This definition includes containers, tanks, surface impoundments, waste piles, land treatment units, landfills, incinerators, and underground injection wells, including those units defined as 'regulated units' under RCRA. Also included are recycling units, wastewater treatment units and other units which EPA has generally exempted from standards applicable to hazardous waste management units, and areas contaminated by 'routine, systematic, and deliberate discharges' from process areas.

The definition does not include accidental spills from production areas and units in which wastes have not been managed (e.g., product storage areas) (EPA 1986).

As the first step in identifying compliance requirements under RCRA 3004(u) for ORNL, a listing of all known active and inactive waste management areas, contaminated facilities, and potential sources of continuing releases to the environment was prepared. Included in this list were waste collection and storage tanks, solid waste storage areas (SWSAs), waste treatment units, impoundments, spill sites, pipeline leak sites, underground injection wells, and areas of known contamination within buildings. Although some of the identified sites might not be regulated under 3004(u), they were included in the site listing in order to maintain a comprehensive inventory of all ORNL sites that might require some form of remedial action.

The listing compiled for ORNL includes about 250 sites that might be considered for 3004(u) remedial action (ORNL 1987b). Because of the complex hydrogeology of ORNL and the large number of sites involved, the ORNL sites were grouped into 20 geographically contiguous and hydrologically defined Waste Area Groupings or WAGs (see Trabalka and Myrick [in press] for a detailed discussion of the rationale used in developing and defining the WAG concept). Fig. 1 shows the locations of the 20 WAGs. This Environmental Data Package covers only the Melton Valley Area (WAG 8) and its 21 sites (Table 1).

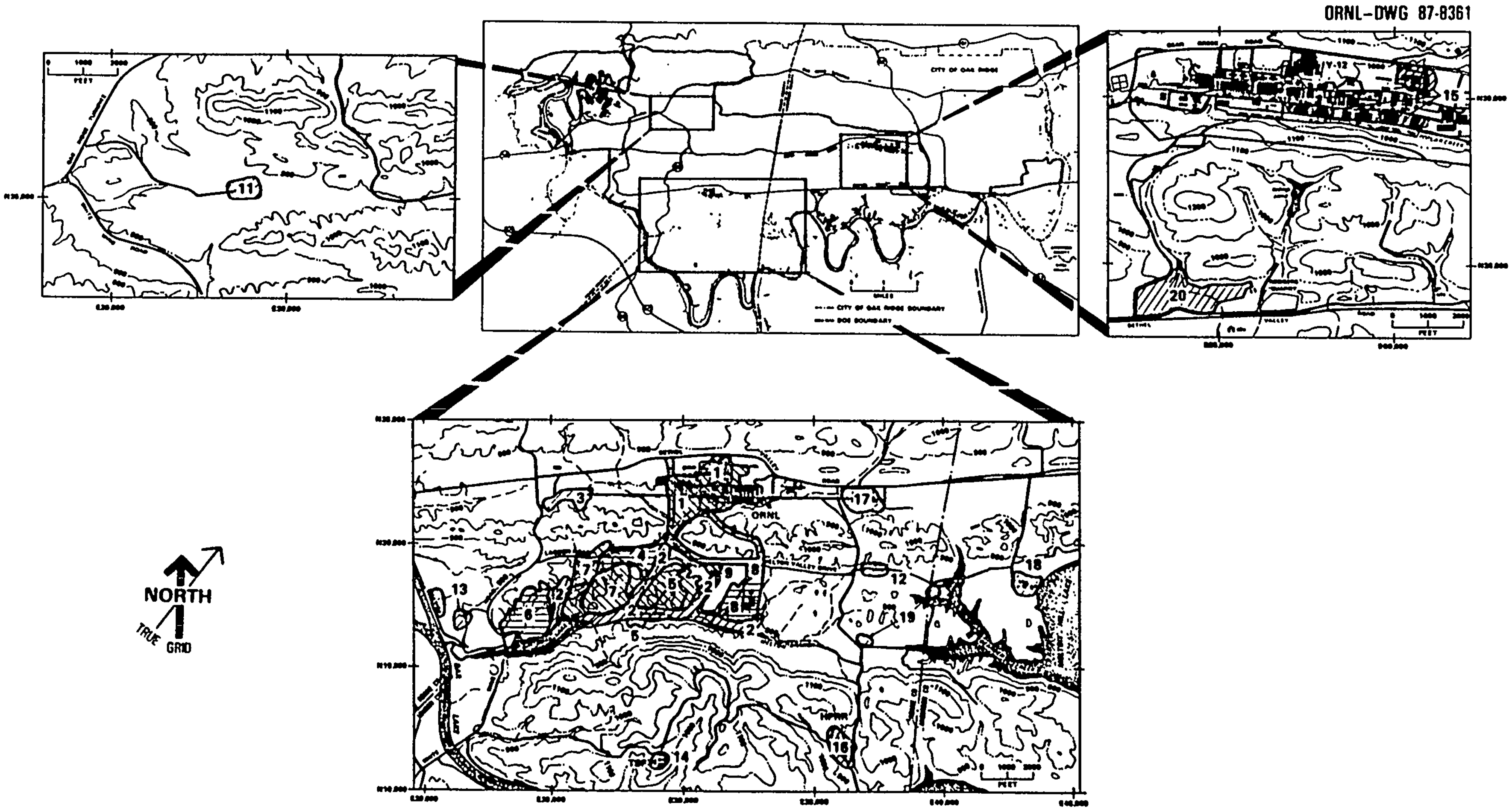

Fig. 1. Locations of the 20 Waste Area Groupings.

Table 1. SWMUs Included in WAG 8

8.1a-d	HIFR/TRU Waste Collection Basins - (7905, 7906, 7907, 7908)
8.2	Hydrofracture Experimental Site 2, Soil Contamination (HF-S2A)
8.3a-g	LLW Line and Leak Sites - Melton Valley Drive Area (7 leak sites)
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	b - Melton Valley Drive and SWSA-5 Access Road
	c - 7500 Area
	d - West of Melton Valley Pumping Station
	e - Bldg. 7920 and MV Pumping Station Area
	f - Bldg. 7920 ditch line
	g - The Melton Valley Transfer Line
8.4	Hazardous Waste Storage Facility (7507)
8.5	Active LLW Collection and Storage Tank - (WC-20)
8.6	Active LLW Collection/Storage Tank - (HFIR)
8.7a,b	Active LLW Collection/Storage Tanks - (T-1, T-2)
8.8	Mixed Waste Storage Pad - (7507W)
8.9	Sewage Treatment Plant (7904)
8.10	Silver Recovery Process (7934)
8.11	Septic Tank (7503)

1.2 PURPOSE OF THE ENVIRONMENTAL DATA PACKAGE

As currently implemented, the 3004(u) corrective action program consists of four phases: (1) a RCRA Facilities Assessment (RFA) to identify releases or potential releases requiring further investigation, (2) a RCRA Facilities Investigation (RFI) to fully characterize the extent of releases, (3) Corrective Measures Study (CMS) to determine the need for and extent of remedial measures (this step includes the selection of appropriate remedies for all problems identified), and (4) Corrective Measures Implementation to design, construct, operate, maintain, and monitor the performance of the measure(s) selected (EPA 1986).

Based on information developed by ORNL as input to the RFA, it appears that the Melton Valley Area (WAG 8) represents a source of continuing release under 3004(u) and that an RFI will be required (ORNL 1987b). The purpose of this environmental data package is to provide background information on the geology, hydrology, soils, and geochemistry of the WAG 8 area, as well as information on releases and inventories of hazardous materials for individual sites (SWMUs) within WAG 8 that will be required in the preparation of the RFI. Also identified are areas where it appears that additional information will be required.

This data package does not include all of the numerical data and information currently available on WAG 8. Only selected material which the authors feel would be pertinent to the preparation of an RFI has been included. Additional details can be obtained from the references cited.

1.3 DESCRIPTION OF WAG 8

The location of WAG 8 and its SWMUs is shown in Fig. 2. Most of the reactor facilities other than those in the main ORNL plant area (WAG 1) are located in Melton Valley. WAG 8 includes the Molten Salt Reactor Experiment (MSRE) facility (formerly used as the Aircraft Reactor Experiment) and the High Flux Isotope Reactor (HFIR). Also included in this WAG are radioisotope separation and processing facilities (Transuranium Processing Plant [TRU] and the Thorium-Uranium Recycle Facility [TURF]). Radioactive wastes from these facilities are collected in on-site, low-level waste (LLW) tanks and periodically pumped to WAG 1 for storage and treatment (Berry et al. 1984). The waste transfer pipeline from WAG 8 to WAG 1 originally followed the route of Melton Valley Drive to its intersection with the LLW line from WAG 1 to the waste pits and trenches; in 1976 this pipeline was replaced with a new stainless steel line which was routed directly over Haw Ridge to the waste collection tanks in WAG 1 (Fig. 3).

Berry et al. (1984) describe operating procedures for the LLW and process waste systems in WAG 8. LLW includes demineralizer backwash, regeneration effluents, decontamination fluids, experimental coolant, drainage from the compartmental areas of filter pits, etc. The normal flow of LLW from all facilities in Melton Valley is about 3,300 gal/week (12,000 L/week), although this flow could be much higher if the process waste should become contaminated. Chemical and radiochemical analyses are not routinely conducted on the LLW; however, the major nuclides are probably ^{90}Sr, ^{137}Cs, ^{106}Ru, ^{60}Co, and various rare earths (Binford and Orfi 1979). LLWs from the Melton Valley facilities are treated with

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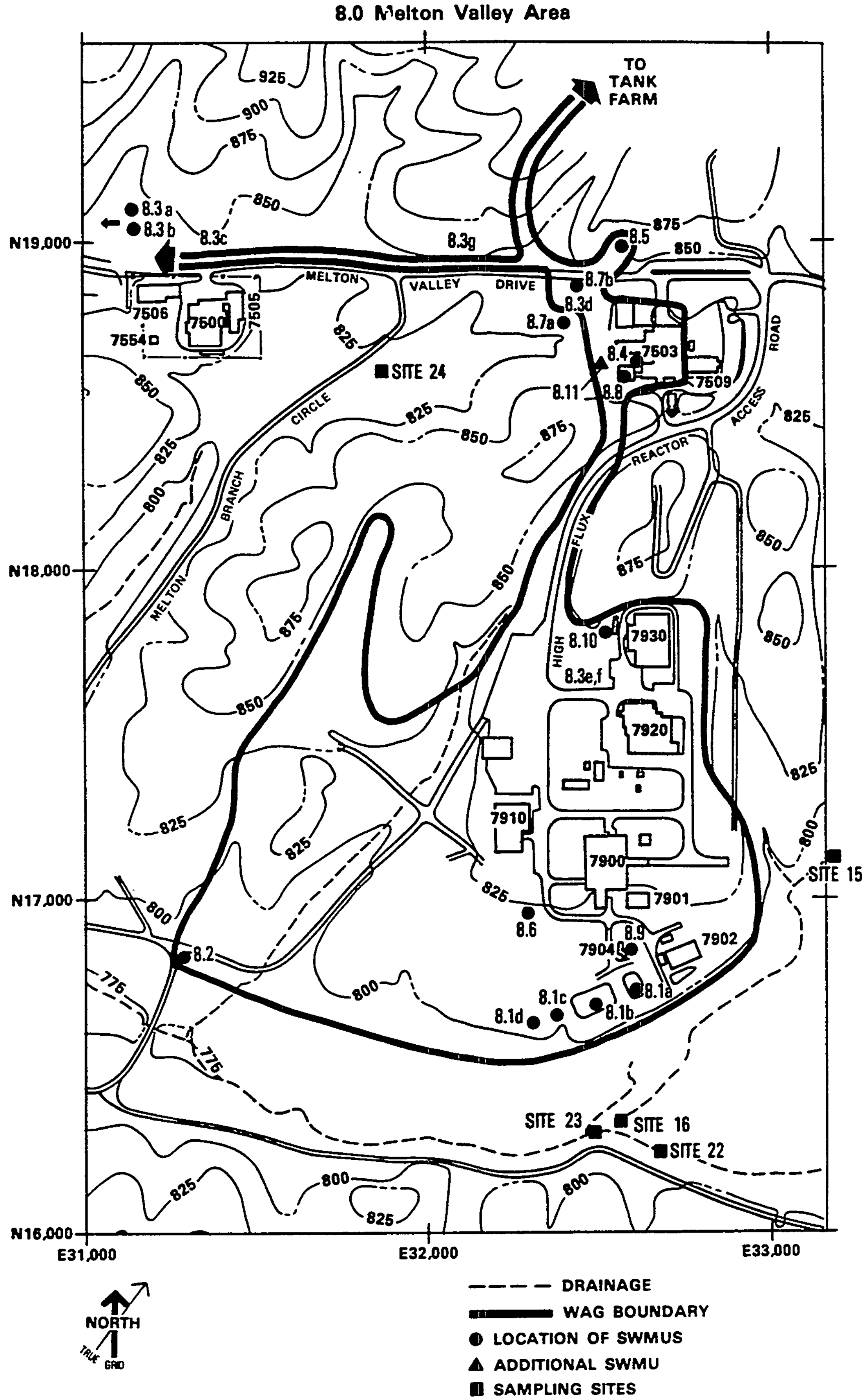

Fig. 2. WAG 8, Melton Valley area, showing locations of SWMUs.

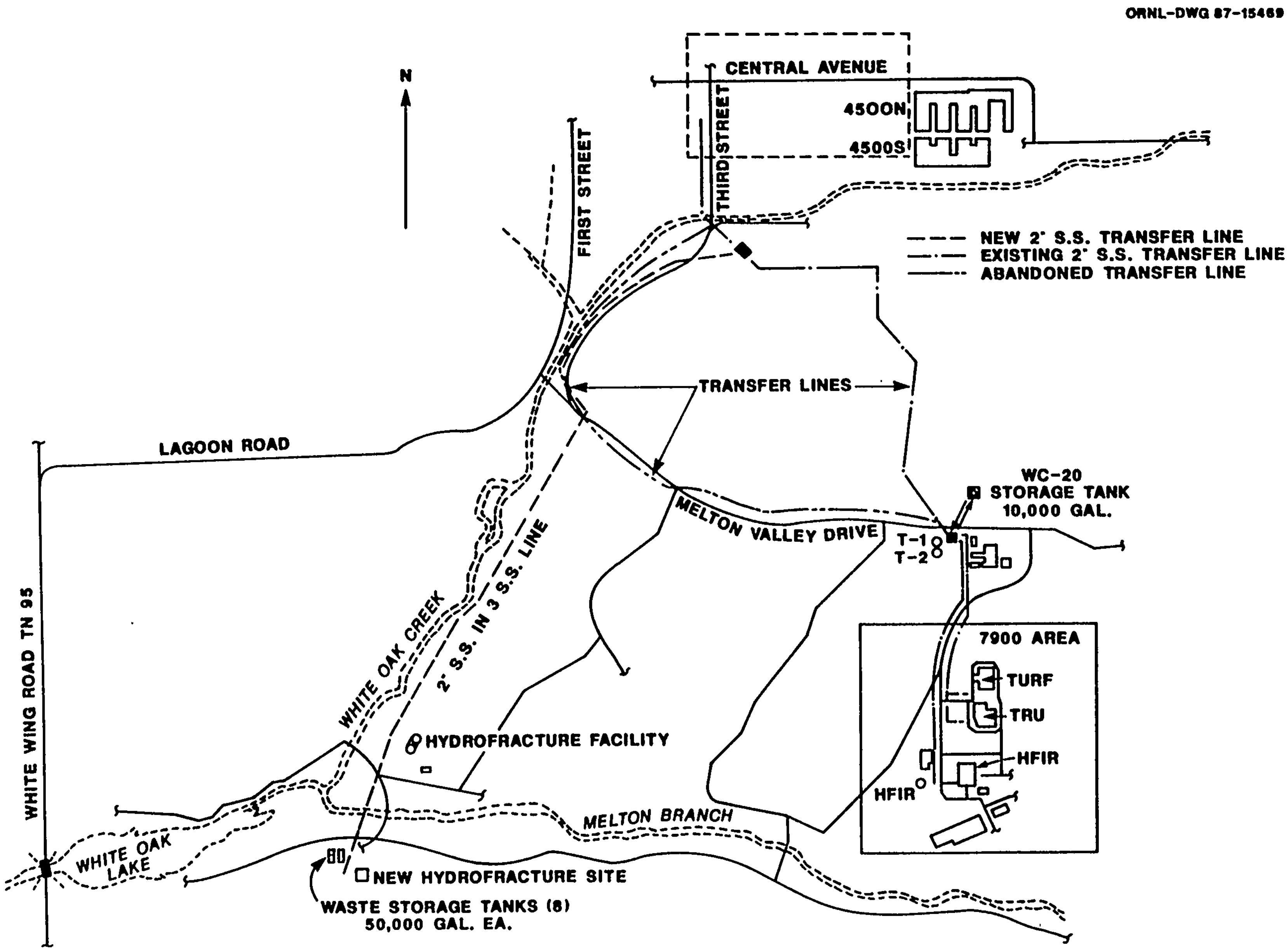

Fig. 3. WAG 8: schematic of waste transfer lines to WAG 1.

caustic, transferred to tanks T-1, T-2, and WC-20 for interim storage, and pumped to the main ORNL complex (Berry et al. 1984).

In addition to the LLW collection and storage system, two additional systems are installed to handle the process wastes and domestic sewage generated in WAG 8 facilities. Process wastes originate from sources such as equipment, experiment, and floor drains in the reactor building; filter pit; and cooling tower areas that normally do not contain radionuclides, but may contain, because of leaks, spills, etc., very low levels of radioactivity (Berry et al. 1984).

Sewage treatment for Bldg. 7503 (MSRE) is provided by a septic tank; facilities in the rest of the Melton Valley area (HFIR, TRU, TURF, etc.), are connected to a sewage holding tank (the holding tank was formerly a small sewage treatment plant) prior to transfer to the main ORNL sewage treatment plant by tank truck (ORNL 1987b,c).

Water from the HFIR cooling tower normally discharges directly into a tributary of Melton Branch but can be diverted to Pond No. 1 if radioactivity above background is found. Cooling tower blowdown from the HFIR is approximately 1.1 gpm (6.9 L/s) (Boyle et al. 1982).

Table 2 lists the 21 SWMUs that are located in WAG 8 by functional description (i.e., ponds, leak sites, storage areas). A more detailed description of each of the 21 SWMUs follows.

1.3.1 LLW Collection and Storage Tanks

Four LLW collection and storage tanks are located in WAG 8 (SWMUs 8.5, 8.6, 8.7a and 8.7b) (ORNL 1987b). Only tank WC-20 (SWMU 8.5) is contained in a concrete vault (double containment); the other three tanks are directly buried. Leaks occurring in the three buried tanks can be detected by observation of the liquid level in the tank and by monthly checks of dry wells installed next to the tanks (Binford and

Table 2. WAG 8 - Listing of sites by type.

Type of Site	Number of Sites
Collection and Storage Tanks (LLW)	
Inactive	0
Active	4
Leak/Spill Sites and Contaminated Soils	
Radioactive	8
Chemical	0
Ponds and Impoundments	
Radioactive Waste	4
Chemical Waste	0
Waste Treatment Facilities	
Radioactive Waste	0
Chemical and Sewage Waste	3
Solid Waste Storage Areas	
Radioactive Waste	0
Chemical Waste	1
Mixed Waste	1
Total Sites	21

Orfi 1979). Additional details on the construction and operation of these tanks can be found in Binford and Orfi (1979), MCI (1985), and Taylor (1986a).

Active LLW Collection and Storage Tank WC-20 (SWMU 8.5) - This is a doubly contained LLW tank with capacity of 10,000 gal (38,000 L) (operating volume 7,000 gal or 26,000 L) located north of Melton Valley Drive. This horizontal tank has a diameter of 10 ft (3 m) and length of 19 ft 6 in. (5.9 m). The tank is fabricated of 304L stainless steel and is located in a concrete vault lined with 304L stainless steel. WC-20 receives wastes from Buildings 7920 (TRU) and 7930 (TURF).

Active LLW Collection and Storage Tank HFIR (SWMU 8.6) - Located southeast of Building 7910, this tank serves HFIR. It is a horizontal tank with capacity of 13,000 gal or 49,000 L (operating volume: 9,100 gal or 34,000 L). Dimensions are 8 ft (2.4 m) in diameter and 35 ft (10.7 m) long. The tank is fabricated of 772-R-2 high-chrome iron and installed on concrete saucer with monitoring access.

Active LLW Collection and Storage Tank - T-1 (SWMU 8.7a) - Located west of the Melton Valley Pumping Station (Bldg. 7567), this tank has a volume of 15,000 gal or 57,000 L (operating capacity: 10,500 gal or 40,000 L). It is a horizontal tank with a diameter of 10 ft (3 m) and length of 27 ft 6 in. (8.4 m). This is an all-welded vessel fabricated of type 304L stainless steel, built in accordance with requirements for primary nuclear vessels. It is buried on a concrete saucer provided with monitoring access. This tank (and T-2) receives wastes from Buildings 7500, 7502, and 7503, and the HFIR tank.

Active LLW Collection and Storage Tank T-2 (SWMU 8.7b) - This tank is similar to T-1 in capacity and construction. Tanks T-1 and T-2 both serve as storage tanks for waste pumped from buildings 7500, 7502, 7503, and the HFIR tank.

1.3.2 Leak and Spill Sites and Contaminated Soils

Grimsby (1986) summarized available information on 35 LLW line leak sites at ORNL, including 8 sites in WAG 8. In many instances, specific information on individual leak sites is not documented; the volume of leakage and the extent of the leak are the major data deficiencies. According to Grimsby:

> Estimates of the extent of contamination at a given site are virtually impossible given current information. For most of the sites, uncertainty exists as to when and where a leak began, how long it lasted and how extensive was the resulting contamination, making it difficult to arrive at any accurate estimate of contaminant inventory and volume. Remedial actions would, therefore, have to locate the boundaries of these sites, and then to estimate the extent of contamination in each of these areas.

The original Melton Valley transfer line was constructed of mechanical joint steel pipe, resulting in the potential for leaks to occur at each of the gasketed joints. With time these gasketed joints failed and the only indication that a leak had occurred was a visual sighting of liquid or a discrepancy in the volumetric material balances. In addition, given the large number of modifications and corrections to the LLW system, it is probable that other leak sites may be discovered in the older waste lines during remedial investigation. The transfer line passing over Haw Ridge is welded stainless steel pipe, some portions of which consist of a pipe within a pipe (i.e., double containment) and no leaks have been reported in this system (Binford and Orfi 1979).

Hydrofracture Experimental Site 2, Soil Contamination (SWMU 8.2) - This site represents the location of the second series of experimental injections conducted to establish the viability of the application of hydrofracturing to low-level radioactive waste disposal. All that remains at the site is the injection well (ORNL Grid coordinates N 16,817 and E 31,260). Two injections of grout additives and water were conducted. Each injection included 25 Ci of ^{137}Cs to allow monitoring of the grout sheets. No spills or surface contamination have been reported. However, the subsequent drilling of observation wells could have provided a possible route for contaminants to reach the surface. The injection well is currently capped and covered by a road (ORNL 1987a).

LLW Line Leak and Spill Site, Melton Valley Drive (SWMU 8.3a) - This is a leak that occurred April-June 1960, where the Melton Valley transfer line crosses White Oak Creek at the intersection of Lagoon Road and Melton Valley Drive. The break was reported to be due to heavy equipment operation. The radiation hazard was not serious, but the creek could have been seriously contaminated if the break had occurred during a waste transfer. Repairs were made, during which the possibility of other line leaks was noted.

LLW Line Leak and Spill Site, Melton Valley Drive and SWSA 5 Access Road (SWMU 8.3b) - This SWMU refers to two leaks (July 9 and 31, 1970) in the Melton Valley transfer line near Melton Valley drive at the intersection with the SWSA 5 Access Road. The first leak was reported to be south of the Drive and just west of the SWSA 5 access road. The second site is about 300 feet east of the first, on the north side of

Melton Valley drive. Both were due to failures at mechanical pipe joints with neoprene gaskets. Contamination was removed and the line repaired.

LLW Line Leak and Spill Site, 7500 Area (SWMU 8.3c) - This leak occurred in the Melton Valley transfer line in July 1969 when a coupling failed in the line north of Building 7500. Although some 2100 gal (7950 L) was released, the contamination (^{244}Cm and fission products) was removed and the line repaired. It is reported that some low-level contamination still remains in a swampy area on the south side of Melton Valley Drive.

LLW Line Leak and Spill Site, West of Melton Valley Pumping Station (SWMU 8.3d) - On January 15, 1971, an area of 100 ft^2 (9 m^2) was contaminated west of the Melton Valley Pumping Station as waste was being transferred from Melton Valley. Subsequently the area was excavated.

LLW Line Leak and Spill Site, Bldg. 7920 and MV Pumping Station Area (SWMU 8.3e) - In July 1970, a leak occurred in a line from the Transuranium Processing Plant to the Melton Valley Pumping Station. The leak occurred at a mechanical joint (with neoprene gasket) in the line. The contamination was removed and the line repaired; however, pressure tests of the line were unsatisfactory and the line was abandoned.

LLW Line Leak and Spill Site, Bldg. 7920 Ditch Line (SWMU 8.3f) - This was a leak reported on January 31, 1972, in the line from the Transuranium Processing Plant (along the HFIR Access Road) to the Melton Valley Pumping Station. Released liquid flowed under the road through culverts and then south along natural drainage parallel to Melton Branch Circle.

LLW Line Leak and Spill Site, Melton Valley Transfer Line (SWMU 8.3g)- This SWMU represents the LLW transfer lines for the original line installed along Melton Valley Drive and the replacement line over Haw Ridge.

1.3.3 Ponds and Impoundments

Four ponds have been constructed in the southeast corner of WAG 8 to retain process wastes before they are released to Melton Branch (Fig. 2) (Taylor 1986b). Pond No. 1 (SWMU 8.1a), with a capacity of 240,000 gal (910,000 L), receives all process wastes from the HFIR building, providing a minimum detention of 12 hrs under normal conditions. Pond No. 2 (SWMU 8.1b) receives waste of higher activity than would normally be discharged to the No. 1 Pond, but not as high in activity as that processed by the LLW system. Also, the large capacity (500,000 gal or 1,900,000 L) of this pond would allow it to contain flows from use of the sprinkler system or fire-fighting equipment in contaminated areas. Waste from both ponds can be pumped into the LLW waste collection system if activity levels are too high to allow direct release to Melton Branch.

The final two ponds (SWMUs 8.1c and 8.1d) were installed to handle process waste from the TRU facility. The two ponds are filled and emptied alternately. Piping is arranged so that the contents of the ponds can be pumped to the waste equalization basin (3524, SWMU 1.13) in the Main Plant Area (WAG 1).

<u>HFIR/TRU Waste Collection Basin, 7905 (SWMU 8.1a)</u> - This basin is referred to as the Cold Pond and is used as an intermediate collection and storage basin for process wastes from the HFIR facility. The unlined pond (240,000 gal or 900,000 L capacity) has dimensions of 86 X 116 ft (26 X 35 m) at the top of the berm and 40 X 70 ft (12 X 21 m) at the bottom of the pond; and the maximum liquid depth is 7.0 ft (2.1 m). The reported sediment depth is about 12 in. (30 cm). The basin also serves as emergency storage for radioactively contaminated blowdown water from the HFIR cooling tower. Effluent from the basin is released to a tributary of Melton Branch or pumped to the equalization basin (3524) in the Main Plant Area for treatment.

<u>HFIR-TRU Waste Collection Basin, 7906 (SWMU 8.1b)</u> - This basin is called the Hot Pond because it receives wastes that are thought to contain radionuclides from the HFIR, or wastes diverted from the TURF or TRU facilities. The unlined pond (500,000 gal or 1,890,000 L capacity) has dimensions of 167 X 116 ft (51 X 35 m) at the top and 121 X 70 ft (37 X 21 m) at the bottom. The reported sediment depth is about 8 in. (20 cm).

<u>HFIR-TRU Waste Collection Basin, 7907 (SWMU 8.1c)</u> - This basin is located south of the HFIR building (7900) and is designed to receive the process waste streams from the TRU facility. During operation the basin is filled and emptied alternately with basin 7908 (SWMU 8.1d). The unlined pond (50,000 gal or 190,000 L capacity) has dimensions of 60 X 80 ft (18 X 24 m) at the top and is about 11 ft (3.4 m) deep. The reported sediment depth in the basin is 2.4 in. (6.0 cm). This basin is also called the No. 3 Pond or the TRU A Pond.

HFIR-TRU Waste Collection Basin, 7908 (SWMU 8.1d) - This basin is also located south of the HFIR building and is adjacent to the 7907 pond (SWMU 8.1c). Its function is the same as the 7907 pond in that it handles process wastes from the TRU facility. This pond (50,000 gal or 180,000 L capacity) is 60 X 80 ft (18 X 24 m) at the top and 11 ft (3.4 m) deep. Sediment depth is reported to be the same as the 7907 pond (2.4 in. or 6.0 cm). Basin is also called the No. 4 Pond or the TRU B Pond.

1.3.4 Waste Treatment Facilities

There are three waste treatment units in WAG 8; two of these (SWMU 8.9 and SWMU 8.11) are part of the domestic sewage collection and treatment systems for the buildings in WAG 8. The third SWMU (8.10) is a facility (not operational at this time) to treat photographic waste water for silver removal and recovery) (ORNL 1987b).

Sewage Treatment Plant, Bldg. 7904 (SWMU 8.9) - Although installed as an extended aeration plant, the entire capacity of this is used as storage. The sewage is transferred to the main sewage treatment plant in Bethel Valley (Bldg. 2521), typically 13 to 15 times per month using a 4,000-gal (15,000-L) tank truck.

Silver Recovery Process, Bldg. 7934 (SWMU 8.10) - This facility was to open April 1987 to separate silver from photographic fixer and developer waste solutions using a chemical precipitation process. Process chemicals that are used include sodium hydroxide, sodium hydrosulfite, and sulfuric acid. Location is just west of TURF. Although facilities for the silver recovery process are essentially complete, operation depends on meeting certain regulatory requirements and issuance of a permit.

Septic Tank, Bldg. 7503 (SWMU 8.11) - This is a concrete tank with a capacity of 1500 gal (5900 L). It collects and disposes of domestic sewage from the MSRE Building and is located west of Bldg. 7503.

1.3.5 Solid Waste Storage Areas

Two interim permitted storage facilities for hazardous solid wastes are located in WAG 8. These facilities are utilized for storage of "lab packs" of chemical wastes, bulk quantities of hazardous wastes, and liquids and solids contaminated with polychlorinated biphenyls. One of these facilities (SWMU 8.4) is a metal building, and the other is a concrete storage pad (SWMU 8.5). Utilization of both of these facilities will cease when the Hazardous Waste Storage Facility (7652) becomes operational (ORNL 1987b).

Hazardous Waste Storage Facility, Bldg. 7507 (SWMU 8.4) - Adjacent to the MSRE, this is a building of 1467 ft^2 (136 m^2) restricted to a maximum of 200 drums/containers (normally holding 130 drums/containers) registered as an interim hazardous waste storage facility. Various hazardous wastes and PCB materials have been stored pending shipment to an approved facility for treatment/disposal. Operation will be terminated when the Hazardous Waste Storage Facility (7652) is operable.

Mixed Waste Storage Pad, Bldg. 7507W (SWMU 8.8) - This is a 40-ft X 40-ft (12-m X 12-m) concrete pad provided with dikes and a sump. Mixed radioactive and hazardous waste are stored here until disposal is resolved, or until the Long-Term Hazardous Waste Storage Facility (Bldg. 7652) is in operation.

1.4 KNOWN OR POTENTIAL RELEASES FROM WAG 8

The initial stream gravel studies of Cerling and Spalding (1981) identified WAG 8 as a major source of ^{60}Co contamination, with measurable releases of ^{137}Cs also being detected. In general, the source of this contamination appeared to be the cooling water effluent from the HFIR. ^{90}Sr was not detected above background concentrations. In the 1985 survey, essentially the same findings for radionuclides were reported; in addition, there was clear evidence that WAG 8 was also a potential source of Zn and Cr releases (Cerling and Huff 1986).

Four sampling sites were used by Morrison and Cerling (1987) in evaluating WAG 8. Two of the sites (15 and 22 in Fig. 2) are located above most of the HFIR discharges and are used as indicators of background contamination. No contamination by radionuclides or metals was detected at either site. Site 16 is below the cooling effluents from HFIR. The site is mainly contaminated by ^{60}Co, with lesser amounts of ^{137}Cs and ^{90}Sr (Table 3). The ^{137}Cs and ^{90}Sr concentrations observed were reported to have declined from those observed in previous surveys (Cerling and Spalding 1981). Based on the results of this survey, Morrison and Cerling (1987) concluded that the cooling water effluent from HFIR was the dominant discharge source of ^{60}Co from ORNL facilities. Sampling at

Table 3. Preliminary survey results for WAG 8, Site 16.

Year	n	*Gravels (radionuclides)*[a] ^{60}Co	*Gravels (radionuclides)*[a] ^{90}Sr	*Gravels (radionuclides)*[a] ^{137}Cs
		(Bq/kg)	(Bq/kg)	(Bq/kg)
BKGD[b]		<2	<10	3
1978	3	29,200 ± 13,300	48 ± 15	232 ± 70
1985	1	41,000	360	130
1986	1	56,000 ± 3,000	5.6 ± 3.3	150 ± 40

Year	n	*Gravels (metals)*[a] Cd	Cr	Ni	Cu	Zn
		(μg/g)	(μg/g)	(μg/g)	(μg/g)	(μg/g)
BKGD[c]		0.05	0.9	5.6	2.4	9
1986	2	<0.1–0.4	9.8–11	7.3–7.9	15	340–400

[a]Concentrations reported on basis of dry weight of gravel sample.
[b]Backgrounds estimated for counting procedure used in this study.
[c]Backgrounds estimated from several uncontaminated samples.
Note: No measurements of metals were made for 1978 and 1985.
Source: Morrison and Cerling 1987.

Site 23 also indicated that ^{60}Co and ^{137}Cs were present in the stream gravels of Melton Branch, but ^{90}Sr was at background level. Sampling Site 24 (Table 4) indicates that ^{90}Sr and ^{137}Cs are being released from the MSRE area. (Although this sampling point is located outside the WAG 8 boundary, it receives drainage from a portion of WAG 8.) The source of these contaminants cannot be identified at this time.

Stream gravel samples from sites 16 and 23 verified contamination by Cr, Cu, and Zn (Tables 3 and 5). The presence of these metals probably results from the discharge of HFIR cooling water. Water samples were not taken at any of the sampling sites in WAG 8, and no organic analyses were conducted.

Changes in water quality in Melton Branch are related to the composition, frequency, and volume of the discharges from the TRU and HFIR process waste basins. The batch discharges from these units have high content of total dissolved solids, composed primarily of sulfates (Loar et al. 1987). The two TRU basins are emptied an average of once every 5 days. The HFIR basin is emptied when two-thirds full, or about three times per month. The batch discharge pattern of operation also apparently contributes to the variability observed for conductivity, pH, and dissolved oxygen. However, more than 90% of the loading of total dissolved solids is from the much larger discharge of cooling tower blowdown, which has an average flow more than ten times that from all the waste basins in WAG 8 (Loar et al. 1987).

The HFIR-TRU ponds were included as a part of the ORNL Part B RCRA permit application submitted to the Tennessee Department of Health and Environment (TDHE) in August 1985. On January 7, 1986, TDHE requested that additional waste analyses be submitted to demonstrate that the ponds were not receiving or accumulating hazardous waste materials. To

Table 4. Preliminary survey results for WAG 8, Site 24

Year	n	Gravels (radionuclides)[a]			n	Gravels (metals)[a]				
		^{60}Co	^{90}Sr	^{137}Cs		Cd	Cr	Ni	Cu	Zn
		(Bq/kg)				(μg/g)				
BKGD[b]		<2	<10	3		0.05[c]	0.9[c]	5.6[c]	2.4[c]	9[c]
1978	3	11±18	1,090±194	294±66						
1985	3	20+-8	363±42	137±31						
1986	1	13	290	120	3	<0.05–<0.3	7–10	3.6–5	1.9–3.5	16–17

[a]Concentrations reported on basis of dry weight of gravel sample.
[b]Backgrounds estimated for counting procedure used in this study.
[c]Backgrounds estimated from several uncontaminated samples.
Note: No samples for water or organics were taken. Blank spaces indicate no samples taken.
Source: Morrison and Cerling 1987.

Table 5. Preliminary survey results for WAG 8, Site 23.

Year	n	Gravels (radionuclides)[a] ^{60}Co	^{90}Sr	^{137}Cs
		(Bq/kg)		
BKGD[b]		<2	<10	3
1978	3	25,500 ± 12,000	<10	360 ± 170
1985	3	25,300 ± 5,100	<10	140 ± 100
1986	1	21,000	4.7	75

Year	n	Gravels (metals)[a] Cd	Cr	Ni	Cu	Zn
		(μg/g)				
BKGD[c]		0.05	0.9	5.6	2.4	9
1986	4	nd[d]–0.05	nd–18.0	4.8–5.7	4.2–8.8	170–260

[a]Concentrations reported on basis of dry weight of gravel sample.
[b]Backgrounds estimated for counting procedure used in this study.
[c]Backgrounds estimated from several uncontaminated samples.
[d]Not detected.

Note: No measurements of metals were made for 1978 and 1985.
Source: Morrison and Cerling 1987.

comply with this request, influent liquid and sludge samples were taken and analyzed for hazardous constituents (sludge samples were extracted using the EP-toxicity procedures). The results of these analyses, including determinations of organic constituents, indicated that neither the influent waste nor the sludge would not be classified as toxic (hazardous) under RCRA guidelines. In addition, the samples were tested for ignitability, reactivity, and corrosivity, and these results were also negative (Kitchings and Owenby 1986). Results of the EP-toxicity extractions of the sludge (metals and pesticides only) from each of the basins are given in Table 6. In general, only a few organics were detected, none of which approached allowable concentration limits.

Loar et al. (1987) present considerable information on chemical contaminant levels in Melton Branch. They found impacts on benthic invertebrate and fish communities in Melton Branch to be downstream of the tributary that receives discharges from the HFIR area; however, some recovery could be seen in lower reaches of Melton Branch. It was also reported that possible toxic effects on periphyton biomass could be observed in the middle reaches of Melton Branch.

Table 6. Maximum concentrations (μg/L) in EP-toxicity extracts of sludge from HIFR/TRU waste basins.

Constituent	Basin 7905	Basin 7906	Basin 7907	Basin 7908	EP-toxicity limit
			(Concentrations in μg/L)		
Ag	<0.0500	<0.0500	<0.0500	<0.0500	5.0
As	<0.1000	<0.1000	0.7400	<0.1000	5.0
Ba	0.7300	1.6000	1.7000	0.5000	100.0
Cd	0.3600	0.1000	0.0240	<0.0050	1.0
Cr	<0.0400	0.0970	<0.0400	<0.0400	5.0
Hg	<0.0001	<0.0001	<0.0001	<0.0001	0.2
Pb	<0.2000	<0.2000	0.5000	<0.2000	5.0
Se	<0.2000	<0.2000	<0.2000	<0.2000	1.0
Endrin	<0.20	<0.20	<0.20	<0.20	20
Lindane	<2.0	<2.0	<2.0	<2.0	400
Methyoxychlor	<8.0	<8.0	<8.0	<8.0	10,000
2,4,D	<10.0	<10.0	<10.0	<10.0	10,000
2,4,5-TP Silvex	23.0	<10.0	11.0	18.0	1,000
Toxaphene	<5.0	<5.0	<5.0	<5.0	500

2. CURRENT STATUS OF INFORMATION ON WAG 8

2.1 SOURCE TERMS (INVENTORIES)

In the fall of 1986 an aerial radiological survey of the White Oak Creek floodplain was conducted by EG&G Data Measurements (Fritzsche 1987). Similar surveys of the same general area were conducted in 1973, 1974, and 1980. Measurements were taken from a helicopter at an elevation of 150 ft (46 m) and used to plot count rate isopleth maps for total gamma exposure, ^{137}Cs, ^{60}Co, and ^{208}Tl. Results indicate that there is a source of ^{137}Cs contamination (elevated count rate) in the vicinity of the MSRE (approximately the area of the off-gas filter house). Another area of increased ^{137}Cs count rate was observed in the vicinity of the Hydrofracture 2 site (SWMU 8.2). The rest of WAG 8 showed essentially background count rates. The highest count rates for ^{60}Co were recorded in the vicinity of the HFIR Ponds; no evidence of contamination was observed in the MSRE, TRU, or TURF areas. There was no evidence of ^{208}Tl in WAG 8 (Fritzsche 1987). Although this type of survey does not accurately measure the amount of radioactivity present, it does provide some indication of the location of sources of gamma radioactivity.

2.1.1 LLW Collection and Storage Tanks

The four LLW tanks in WAG 8 are classified by ORNL as active (i.e., they are currently receiving, storing, or discharging waste). The liquid content of the tanks are changes constantly, and as a result, detailed sampling and analysis has not been conducted routinely. Thus, there is essentially no information on the inventory of radionuclides or hazardous chemicals in these tanks. Binford and Orfi (1979) suggest that ORNL's LLW contains an average of 30 mCi/gal (8 mCi/L). Because the total operating volume of the four tanks is 53,000 gal (201,000 L), the radionuclide content could be as high as 1,600 Ci when the tanks are full. No information exists on the volume of sludge, if any, in the tanks. Other than one reported leak in the transfer system near the Melton Valley Pumping Station, there is no reported leakage from any of the tanks.

2.1.2 Leak Sites

As noted earlier, in most cases there is little information available to estimate the amount of radioactivity (and hazardous materials) that may remain at the identified leak and spill sites. In general, some degree of remedial action was undertaken when each of the leaks was detected and repaired; however, the existing documentation does not establish the amount (if any) of radioactivity remaining at the sites.

2.1.3 Ponds and Impoundments

Samples were taken of the sludges in the bottom of the four impoundments in WAG 8 for RCRA EP toxicity testing (Kitchings and Owenby 1986). The results of these analyses (Table 6) indicate that the sludges would not be classified as RCRA toxic. Although no analyses for radionuclides in the sludges were conducted, it has been estimated that the radionuclide content of the four ponds is less than 10 Ci (Myrick et al. 1984).

2.1.4 Waste Treatment Facilities

Two of the waste treatment facilities in WAG 8 are a part of the ORNL sewage treatment system. There are no reports that indicate that radioactivity or hazardous materials were discharged to either of these units. Sludge from the septic tank (SWMU 8.11) is pumped from the tank and treated in the main ORNL sewage treatment plant. All of the sewage from the holding tank is also transported and treated in the ORNL plant. No analysis of the sludge in either system has been reported. The silver recovery facility is not in operation, and as a result does not produce waste. The photographic wastes are currently stored in SWMUs 17.4a and 17.4b in WAG 17 (ORNL Services Area) awaiting issuance of a permit for operation of the facility.

2.1.5 Solid Waste Storage Facilities

According to the Closure Plan for Bldg. 7507, the normal amount of hazardous waste stored in Bldg. 7507 is 130 drums; the maximum inventory is 200 drums or containers of waste. Types of stored hazardous waste include: laboratory chemical wastes in "lab packs"; bulk quantities of ignitable, corrosive, and/or EP-toxic wastes; and polychlorinated biphenyl contaminated liquid and solids (Oakes 1984). These wastes do not contain radioactivity.

The mixed waste storage pad, an interim facility located west of Bldg. 7507, is used to store 55-gal drums of hazardous chemical wastes that are contaminated with radionuclides (mainly scintillation vials). The drums are stored until arrangements can be made for disposal (ORNL 1987b).

2.2 GEOLOGY, SOILS, AND GEOCHEMISTRY

2.2.1 Geology

From north to south, WAG 8 includes three major geologic units: the Chickamauga Limestone, the Rome Formation, and the Conasauga Group. The new LLW transfer line from the Melton Valley Pumping Station (Conasauga Group) crosses Haw Ridge (Rome Formation) and terminates in WAG 1 (Chickamauga Limestone) (Figs. 1 and 2). The original LLW transfer line along Melton Valley Drive is located in the Pumpkin Valley Shale of the Conasauga Group. From Melton Valley Drive southward, WAG 8 overlies the geologic formations in the Conasauga Group.

Webster and Bradley (in press) describe the Conasauga Group as a clastic marine shelf deposit of variable lithology, including a complex sequence of carbonate-poor units alternating with carbonate-rich units. The geologic formations in the Conasauga, in descending order, include the Maynardville Limestone, the Nolichucky Shale, the Marysville Limestone, the Rogersville Shale, the Rutledge Limestone, and the Pumpkin Valley Shale. The Maynardville Limestone does not outcrop within the WAG 8 boundary, and the Nolichucky Shale contact is projected to be just north of the southern boundary of the WAG (Dreier et al. 1987).

Thin layers and lenses of limestone are common in the Conasauga Group, but are irregular in distribution. There are no persistent limestone beds in the formations; a very few small solution cavities have been reported in other areas underlain by the Conasauga Group. Per unit drainage area, the Conasauga Group has lower stream flow than do areas underlain by the Chickamauga Limestone.

The Rome formation is lithologically heterogeneous and consists of interbedded sandstones, siltstones, and shales (Dreier et al. 1987, Haase et al. 1985). The Chickamauga formation, underlying Bethel Valley, is composed predominantly of limestone, although shales, siltstones, and bedded chert comprise a significant minor part of the formation (Webster 1976).

Although detailed geologic investigations have not been performed within WAG 8, there have been a number of studies related to the geology of adjacent areas of Melton Valley. During site characterization studies for the proposed SWSA 7 (east of WAG 8), Rothschild et al. (1984a) conducted a detailed geologic investigation. Lithologic and geophysical logs from three rock cores taken onsite at SWSA 7 were used as the basis for preparing a generalized geologic map of the site (Rothschild et al. 1984a).

Dreier et al. (1987) summarized geological data in the vicinity of the four ORNL hydrofracture sites (adjacent to and west of WAG 8). Their report addressed a need to synthesize existing borehole data into a local geologic model that would serve as a database for future hydrofracture characterization studies. A geological map and cross sections were prepared to illustrate the geologic structure of the Copper Creek Thrust Sheet in Melton Valley (Dreier et al. 1987). One of these cross sections is west of WAG 8 (Section D-D′ at ORNL E31,000), and another is in the area of the proposed SWSA 7 (Section E-E′ at ORNL E34,500). Fig. 4 illustrates the geology of the WAG 8 area. Also included in Dreier et al. (1987) is an annotated bibliography of 72 reports containing geologic information related to the Melton Valley area.

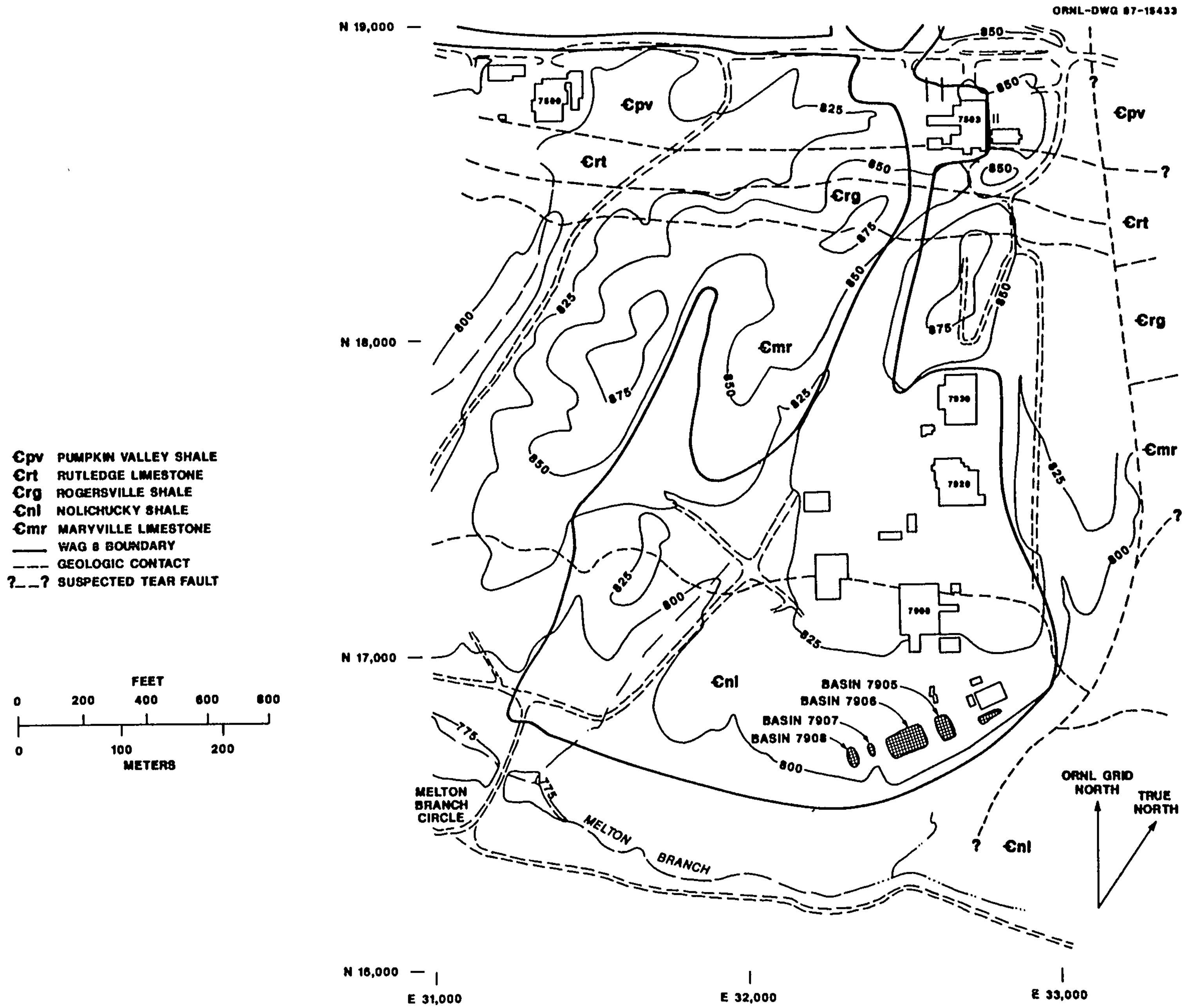

Fig. 4. Geologic map of WAG 8.

2.2.2 Soils in WAG 8

The soil survey map for Roane County (location of WAG 8) was produced during the 1930s (USDA 1942) and was prepared on a scale (1:48,000) suitable only for showing general soil conditions (Lietzke and Lee 1986). In 1986, Lietzke et al. developed a soil management plan for the Oak Ridge Reservation (ORR) which includes general information on the soil types may might be found in WAG 8.

Soils associated with formations of the Conasauga Group predominate in Melton Valley. Illite is the dominant clay mineral. Glauconite and vermiculite are abundant in some of the Conasauga Shales. Weathered illite should possess considerable cation exchange capacity (CEC), and adsorption potential should also be high (Lietzke et al. 1986). Conasauga rocks contain very little sand but have higher silt and clay content than the weathered material and have more calcium carbonate. However, because rocks of the Conasauga group dip steeply and are folded and fractured, there are complexities in relating soils to a particular formation within the group. Leaching and deep oxidation are enhanced by fractures which have greater permeability porosity than interfracture areas or areas of higher calcium carbonate (Lietzke et al. 1986). The soil horizons commonly have about 50% porosity but yield little water to gravity drainage.

Soils associated with the Rome and Chickamauga formations are less significant in WAG 8 than the Conasauga derived soils. Rome Formation soils are located on steep slopes, with a high potential for erosion if vegetation is removed. There is little reported information on the chemical and mineralogical properties of Rome soils. Chickamauga soils typically are shallow, have a high content of clay, are poorly permeable, and have a high erosion potential. These soils may contain montmorillonite and tend to have high CEC and high shrink-swell characteristics compared with other soils on the ORR (Lietzke et al. 1986).

A soil survey was included in the site characterization effort for the proposed SWSA 7 in the area east of WAG 8 (Rothschild et al. 1984b). In general, the upland soils were reported to be well drained and the soils in lower areas poorly drained. Soil profiles were examined, and soil properties and mineralogical composition of the clay fractions determined. The soils were described as well leached and acidic, and were composed of quartz (in the silt size fraction), various clay minerals (illite, kaolinite, and vermiculite) and mica. Engineering properties of the soils were also determined.

Because of the influence of soils on groundwater quality, the chemical characteristics of the soils in SWSA 7 were also investigated (Rothschild et al. 1984b). Eighteen soil and stream sediment samples were collected and evaluated for radionuclide adsorption properties. Cation exchange capacity for all of the soil samples analyzed was found to average 169 meq/kg. In general, the CEC was found to decrease with depth, with calcium found to be the dominant element on the cation exchange complex. Total cations and acidity of cuttings were considerably higher near the surface, whereas calcium was lower.

2.3 HYDROLOGIC DESCRIPTION OF WAG 8

2.3.1 Meteorology

A number of meteorological stations are located in the Oak Ridge area. Long-term precipitation and temperature records (>40 years) exist from the U.S. National Weather Service station in Oak Ridge (USDOC 1987) and Knoxville's McGhee Tyson Airport (ORO 1953).

Supplementing these sources of long-term records are additional rain gages and meteorological stations that have been installed in the vicinity of WAG 8 for area monitoring and research program support. A description of these stations (installation date, measurements recorded, and location) is given in Appendix B of "Characterization Plan for Solid Waste Storage Area 6" (Boegly et al. 1985).

2.3.2 Surface Water

Surface water runoff from WAG 8 flows predominantly southward, in the direction of Melton Branch (Fig. 2). Melton Branch is the largest tributary of White Oak Creek. Most of the Melton Branch watershed (approximately 95%), is underlain by the Rome Formation of Haw Ridge and the Conasauga Group of Melton Valley. The Rome and Conasauga formations are characterized by low base flow in the upper reaches of the stream. Zero flow can sometimes be observed in upstream Melton Branch, especially during long periods of drought (Loar et al. 1987). However, in the lower reaches of Melton Branch, stream flow is augmented by discharges from the HFIR/TRU process waste basins and cooling tower blowdown. Discharges from these sources constitute a significant fraction of the flow in Melton Branch (Loar et al. 1987). Stream flow of Melton Branch (1955-1963), at a point 0.1 mile above White Oak Creek ranged from 0 to 242 cfs (0 to 6.85 m^3/s) with an average flow of 2.50 cfs (0.071 m^3/s).

Webster and Bradley (in press) described the hydrology of the Melton Valley waste burial areas (SWSAs 4, 5, and 6). They reported that stream flow in the White Oak Creek watershed comprises overland runoff from precipitation, groundwater discharge during base flow, and wastewater discharges. It was estimated that 45% of yearly rainfall reaches streams as overland runoff and as base flow discharge from aquifers. They also observed that wastewater was the principal component of flow during dry weather.

2.3.3 Groundwater

Groundwater movement from the main portion of WAG 8 is inferred to follow the same general pathway as surface water drainage: recharge from precipitation and infiltration occurs on unpaved areas throughout the WAG 8 area and groundwater discharge occurs in the southern area along Melton Branch. Recently, several water quality monitoring wells and piezometers have been installed in the vicinity of the HFIR ponds. Data from these wells are being analyzed to develop a more refined description of the local groundwater flow system. For the LLW transfer line portion of the WAG, it is presumed that the permanent water table is below the trench and fill material associated with the line.

No groundwater studies have been performed on the area within the WAG 8 boundary; however, a number of studies related to groundwater in Melton Valley have been conducted that may provide data applicable to WAG 8. Webster and Bradley (in press) described the hydrology of

Melton Valley, with particular reference to SWSAs 4, 5, and 6. Data from 245 wells in Melton Valley have allowed preparation of water level contour maps and depth to water maps, hydrographs showing patterns of fluctuation in water levels, determination of recharge and discharge areas, and a flow net for each disposal site. The water table was observed to follow topography, with groundwater flow being from high elevations to low areas and surface drains, though somewhat skewed in the direction of strike because of remnant folds and fractures in the regolith (decomposed earthen materials constituting the weathered zone above bedrock). Evidence indicated that direction of groundwater flow was influenced by both the hydraulic gradient and by relict structure. Flow through the regolith was inferred to include (1) a zone at the water table and immediately below where the largest flow component is in the direction of the water table gradient, and (2) an underlying transitional zone where various components of flow are parallel to both strike of the beds and the water table gradient. In the bedrock, flow occurs primarily between the beds in the direction of strike to points of lower hydraulic head. This zone extends to depths of more than 200 ft, giving it the greatest thickness of the three zones. However, they suggested that the total flow in the third zone is probably less than that in the first two zones combined (i.e., more than 50% of all groundwater flow occurs in the regolith in the uppermost part of the bedrock; and less than 50% flows through deeper levels in the bedrock) (Webster and Bradley, in press). Migration of radionuclides into the Conasauga bedrock is generally considered unlikely because of the high sorption and ion exchange potential of the upper, weathered strata, and the low permeability of the bedrock. However, Webster and Bradley (in press) indicated that some of the wells drilled into bedrock in SWSAs 5 and 6 and in the Pits and Trenches area showed detectable radionuclides at depths of 100 ft into the bedrock. Information reported to date does not indicate any significant radionuclide movement in the Melton Valley bedrock.

Tucci (1986) reported the results of a preliminary model analysis of groundwater flow in Melton Valley. In the bedrock, flow was thought to be mainly through faults and joints in the upper 200 ft of the system. Tucci applied a computer program to simulate three-dimensional groundwater flow in Melton Valley. Groundwater levels predicted by the model generally compared well with observed or estimated actual conditions in 1978.

Rothschild et al. (1984a) reported that the SWSA 7 area was structurally complex, with small-scale features including several joint systems, small-scale faulting, and folding. Several linear features were reported to cross the SWSA 7 site, appearing to be tear faults or other types of fracture zones. To determine aquifer properties and evaluate the groundwater flow system at the SWSA 7 site, a network of 18 wells was installed (Rothschild et al. 1984a). Slug tests were performed on these wells to measure the hydraulic conductivity of the subsurface materials. Average values for hydraulic conductivity ranged from 1.13×10^{-6} cm/s to 2.98×10^{-4} cm/s, with a geometric mean of 2.57×10^{-5} cm/s. Various other aquifer characteristics were also reported.

A network of RCRA monitoring wells was installed in the vicinity of the four impoundments in WAG 8 (MCI 1986). Fig. 5 shows the general location of the eight wells constructed in WAG 8. Fig. 6 is a

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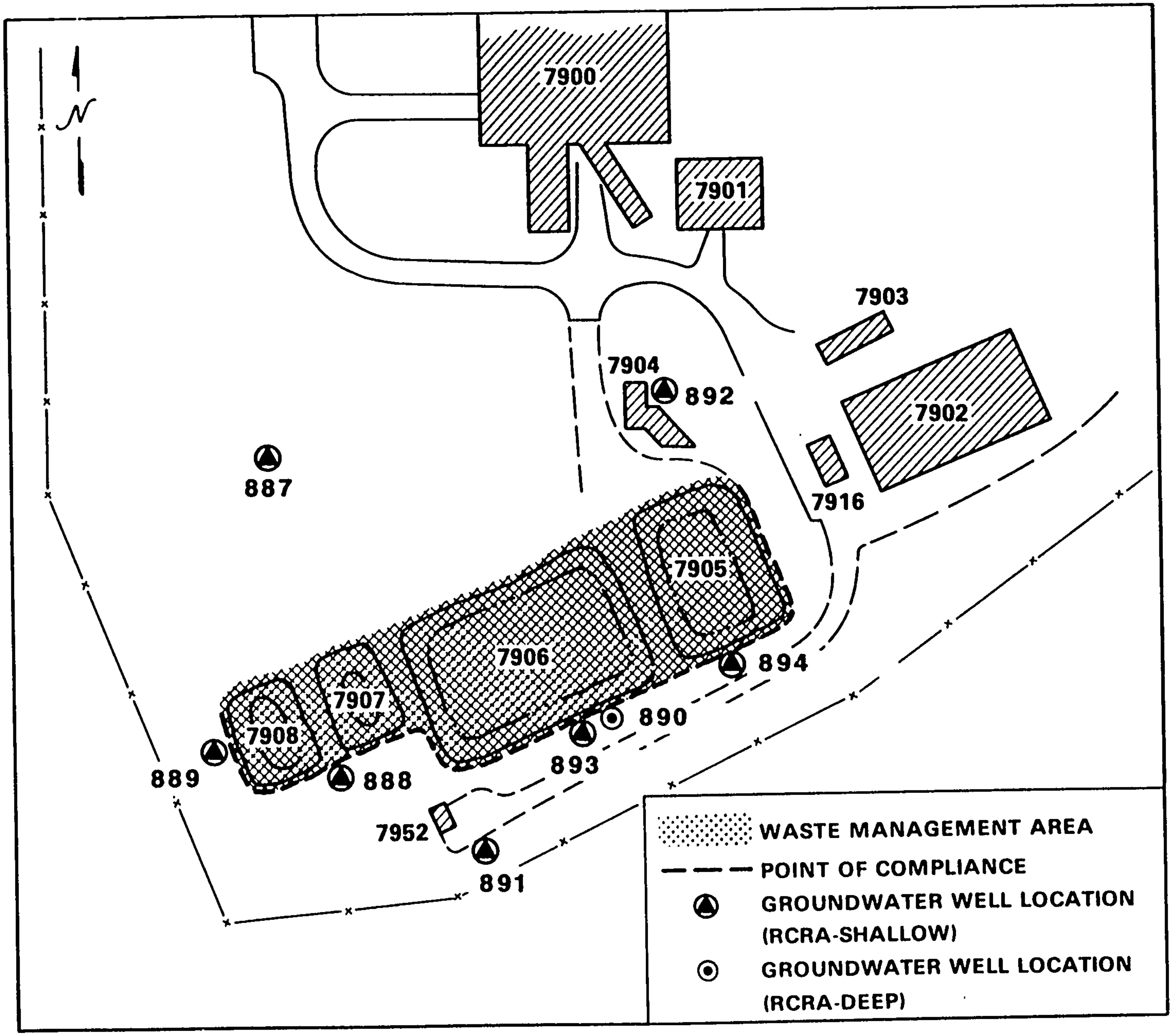

Fig. 5. Locations of monitoring wells around the HFIR-TRU ponds, WAG 8.

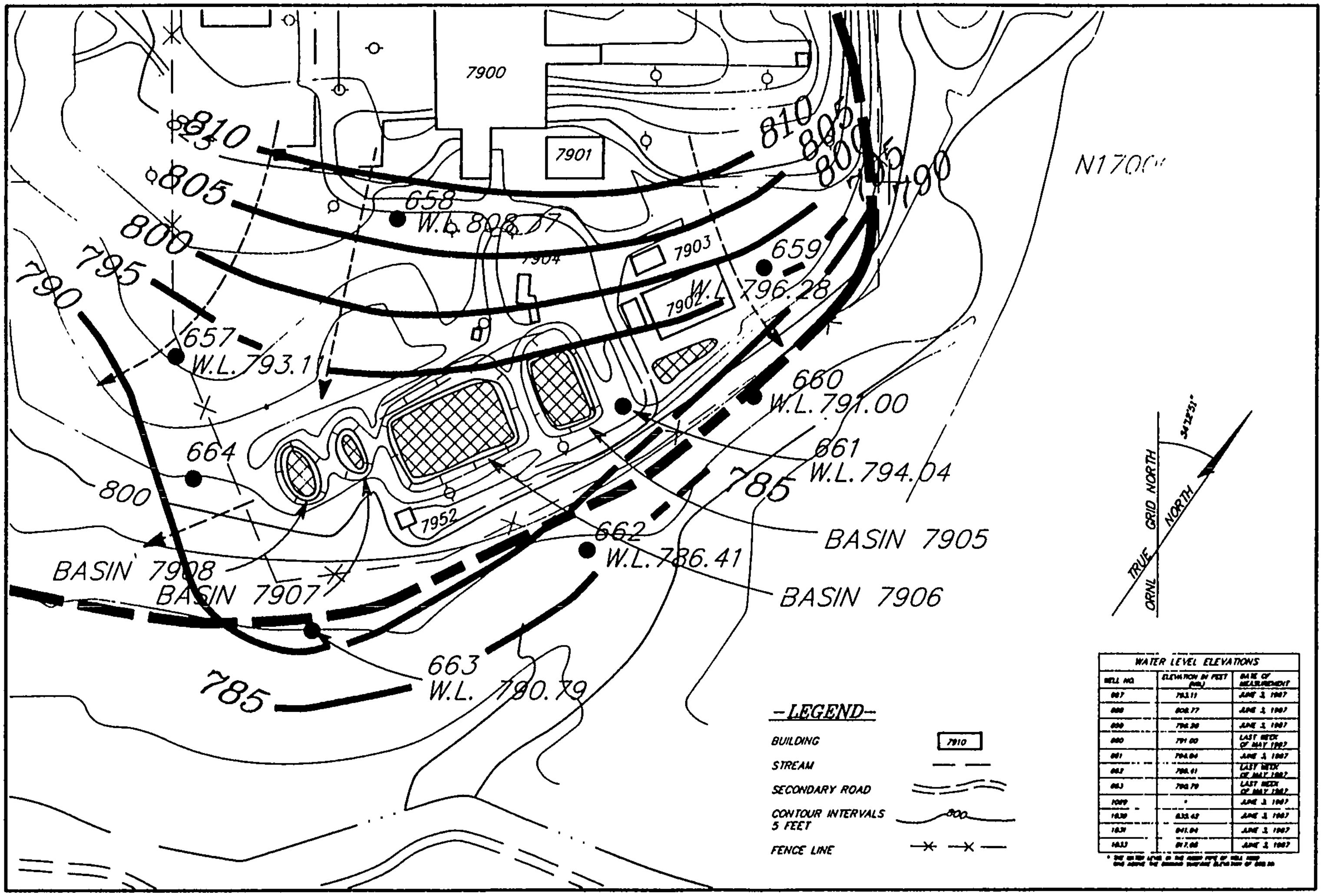

Fig. 6. Potentiometric map of groundwater in the HFIR-TRU pond area, WAG 8.

potentiometric map of groundwater in the 7900 area and indicates that the direction of maximum hydraulic gradient is southeast, following the topographic gradient toward Melton Branch (MCI 1987). Most groundwater flow is along fractures in the directions of lower potentiometric heads.

Recently, 17 piezometer wells have been installed within and around the perimeter of WAG 8. In addition, three piezometers have been installed in the Melton Branch watershed south of WAG 8. To date, only a few sets of water level measurements have been taken from these wells. Slug tests have been conducted on 8 of the 17 piezometer wells (designated 657 to 664) to determine hydraulic conductivity, transmissibility, and aquifer thickness. The results of these tests are given in Table 7. Water level measurements in the piezometers are stored in the RAP computerized database (Voorhees et al. 1986).

2.4 ENVIRONMENTAL MONITORING

2.4.1 Surface Water

A number of monitoring stations provide information on surface water in the vicinity of WAG 8 (Fig. 7). Sherwood and Loar (1987) described the National Pollutant Discharge Elimination System (NPDES) stations in the White Oak Creek (WOC) watershed. One of these stations (NPDES discharge point 002, ORNL station 4) is located on Melton Branch before its confluence with WOC. This station measures any contaminant contributions from WAGs 5, 7, 8, and 9. Other stream flow and water quality monitoring stations in the WAG 8 area are stations 4A (on an unnamed tributary to the east of SWSA 5) and 4B (located upstream of station 4 on Melton Branch) (see Fig. 7). In addition to the stream

Table 7. Results of slug tests for WAG 8 piezometers

Well No.	Hydraulic conductivity (cm/s)	Transmissivity (m^2/day)	Aquifer thickness[a] (m)
657	4.5×10^{-5}	0.25	6.4
658	3.2×10^{-5}	0.10	3.6
659	4.3×10^{-5}	0.59	16.0
660	6.7×10^{-5}	0.45	7.8
661	3.0×10^{-5}	0.41	16.0
662	17.4×10^{-5}	0.40	2.7
663	2.0×10^{-5}	0.067	3.9
664	2.0×10^{-5}	0.07	4.1

[a] Aquifer thickness = transmissivity/hydraulic conductivity

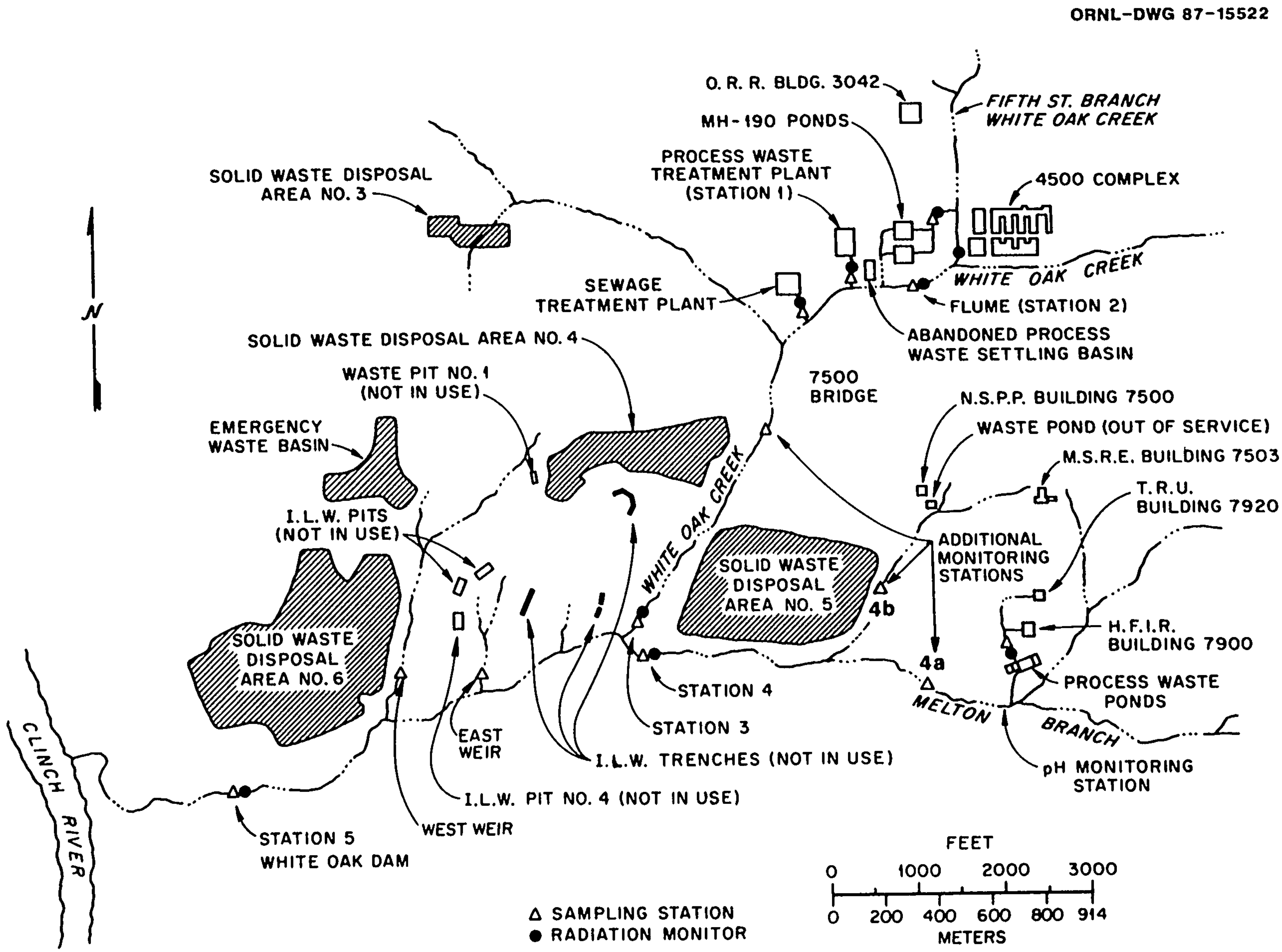

Fig. 7. Surface water monitoring stations in the WOC watershed.

monitoring stations, the NPDES permit designates the HFIR ponds (X09) and the TRU ponds (X09) as point source outfalls and requires sampling and analysis of these discharges at periodic intervals.

Sherwood and Loar (1987) suggested the installation of additional stream flow and water quality stations on three unnamed tributaries that would provide information on discharges from WAG 8; these stations would be in the same general location as the Morrison and Cerling (1987) preliminary sampling sites 16, 22, and 24 (see Fig. 2). To date these stations have not been installed.

Loar et al. (1987) described locations of sampling stations used in the Biological Monitoring and Abatement Program (BMAP) required by the NPDES permit. Locations of these sites are shown in Fig. 8.

2.4.2 Groundwater

As previously discussed (Sect. 2.3.3), eight monitoring wells have been installed in the vicinity of ponds 7905, 7906, 7907, and 7908 (MCI 1986). Sampling of these wells is performed quarterly, with results of analyses available from the Department of Environmental Management (DEM 1987). Table 8 includes sampling results for the eight monitoring wells obtained during the third quarter of 1987.

Suggested locations for nine additional water quality monitoring wells in WAG 8 have been proposed (MCI 1987). Installation of these wells is scheduled to begin in 1987. Analytical data from the proposed water quality wells will be stored in the RAP computerized data base (Voorhees et al. 1987).

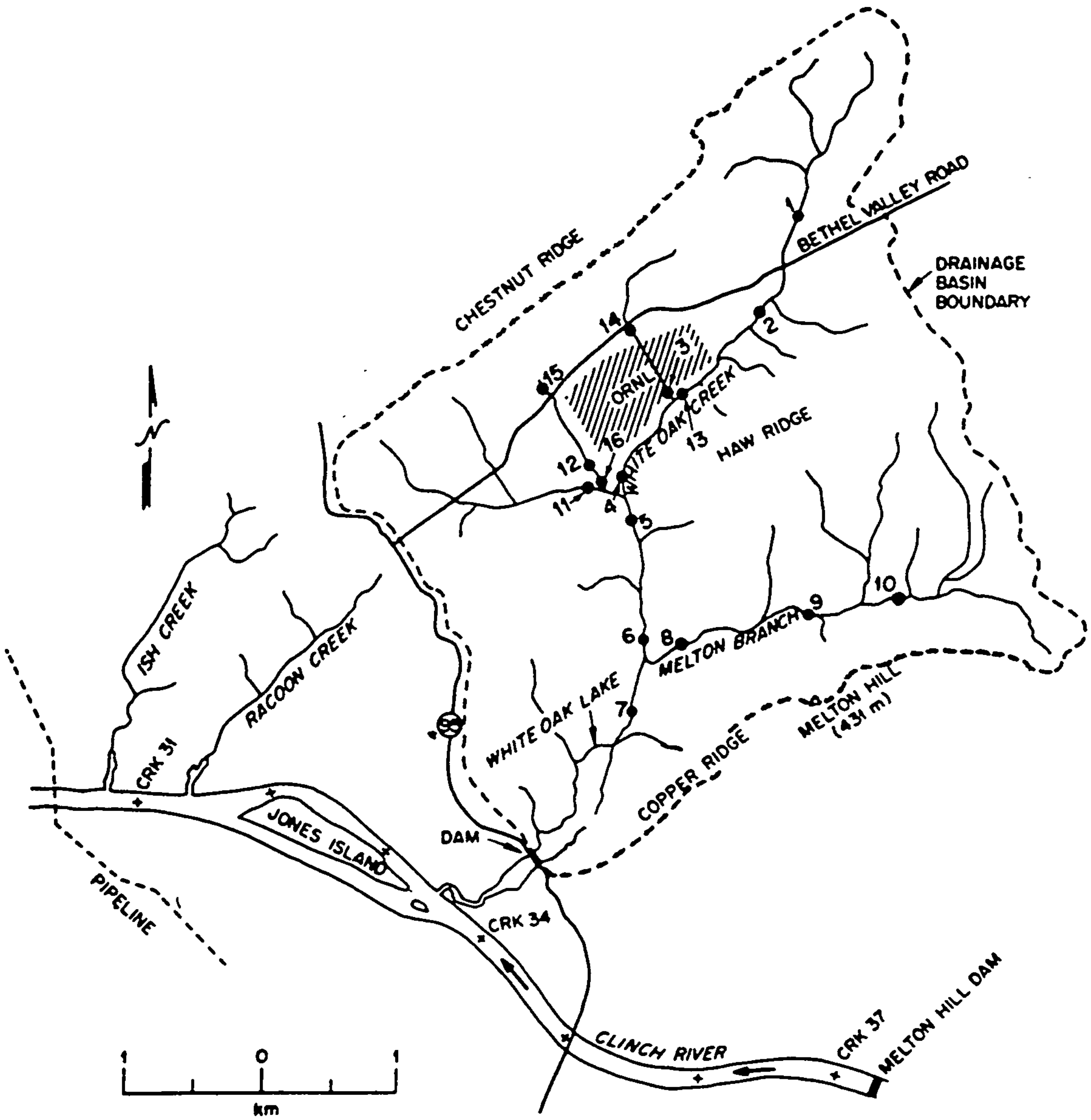

Fig. 8. Biological monitoring stations in the WOC watershed.

Table 8. Water quality data for wells near HFIR-TRU Ponds
(Concentrations in mg/L unless otherwise noted)
(samples taken March 9, 1987)

Constituent	Well Number 887	888	889	890	891	892	893	894
Temperature[a]	14.4	15.3	14.3	15.6	15.6	14.7	13.3	
pH[b]	7.7	7.4	7.4	7.6	7.5	7.4	6.7	7.2
Specific Conductance[c]	0.04	0.17	0.01	0.11	0.16	0.22	0.05	
Ag	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.00
As	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ba	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Cd	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.00
Cl	6	22	2	10	12	57	11	15
Cr	<0.02	<0.02	<0.02	<0.02	<0.02	0.07	<0.02	<0.02
F	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Fe	<0.05	<0.05	<0.05	0.48	0.15	0.62	0.2	<0.05
Hg	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00
Mn	0.03	0.04	0.04	0.13	0.21	0.07	0.32	0.05
Na	5.8	5.8	3.6	8.1	6.3	6.5	23	51
NO_3	< 5	< 5	< 5	< 5	< 5	< 5	23	40
Pb	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Se	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.00
SO_4	23	18	6	42	50	76	84	146
TOC	0.4	0.4	0.6	0.4	0.5	0.4	0.1	0.6
TOX	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endrin	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.00
Lindane	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.00
Methoxychlor	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008	<0.00
Toxaphene	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.00
2,4-D	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,4,5-TPSilvex	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total phenols	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.00
Fecal Coliform[d]	0	0	0	0	0	0	0	0
Gross Alpha[e]	0.22	0.1	0.14	<0.1	<0.1	0.09	1	0.49
Gross Beta[e]	0.44	0.25	<0.2	0.43	0.06	0.29	40	22
Total radium[e]	<0.05	<0.05	0.1	,0.01	0.24	<0.05	0.058	<0.05

[a] in degrees C
[b] in pH units
[c] In mmhos
[d] in colonies per 100 ml
[e] in Bq/L

Source: Data compiled by the Environmental Monitoring and Compliance Department of the Environmental Compliance and Health Protection Division, ORNL.

Data is stored in the ORNL RAP Data Base Management (DBM) System (Voorhees et al. 1987).

3. ADDITIONAL INFORMATION REQUIREMENTS FOR WAG 8

3.1 SOURCE TERMS

More detailed information on the the source term(s) in WAG 8 will be required any pathways analyses or performance assessments are performed. As indicated in Sect. 2.1, little is known about the amount of radioactivity or hazardous chemicals present in most of the SWMUs. The following tabulation suggests areas in which additional source term (inventory) information will probably be required.

1. HFIR/TRU Waste Collection Basins (SWMUs 8.1a-d): Additional information on radionuclide contaminants present in basin sludge should be obtained.

2. LLW Leak and Spill Sites (SWMU 8.3a-g and SWMU 8.2): Generally, information is lacking regarding the identification and quantification of contamination remaining at these sites. Soil sampling and a "walk-over" radiation survey should be conducted to identify the extent, if any, of the reported contamination. Presence and extent of hazardous waste materials should be included in the soil sampling.

3. Active LLW Collection and Storage Tanks (SWMUs 8.5, 8.6, and 8.7a-b): No information is available on residual material (sludge) in the WAG 8 LLW tanks. A program of sampling and analysis is suggested to determine the nature and amount of radioactivity and hazardous chemicals present.

4. <u>Other SWMUs in WAG 8</u>: The remaining SWMUs in WAG 8 are either sewage treatment facilities, solid waste storage facilties, or chemical waste treatment facilities. None of these SWMUs appears to be a source of release of hazardous waste constituents.

3.2 GEOLOGY, SOILS, AND GEOCHEMISTRY

A considerable amount of geologic information has been accumulated for Melton Valley since waste disposal operations were initiated (Webster 1976, De Laguna et al. 1968, Webster and Bradley in press). Recent studies in areas adjacent to WAG 8 by Rothschild et al. (1984a), Haase et al. (1985), and Dreier et al. (1987) have provided more detailed information on the geologic setting of WAG 8; however, specific information on geologic features within the WAG perimeter can only be inferred from these studies. It is suggested that geophysical surveys and field mapping studies similar to those conducted in SWSA 7 by Rothschild et al. (1984a) and proposed for SWSA 6 (Boegly et al. 1985) be conducted. The level of detail required for other types of geologic characterization in WAG 8 will depend on the data requirements of the models selected for pathways analyses and performance assessments. Because current information does not indicate that there were past releases of radioactivity or hazardous chemicals (at sites other than the ponds and leak sites), there are no additional requirements for further geological characterization in WAG 8 at this time.

No studies have been conducted on the soils of WAG 8 although soil information is available for adjacent areas. In order to establish if similar soil types exist in WAG 8, it will be necessary to conduct a soil survey and produce a soil map. Data requirements for soils would include mineralogical analysis, measurement of sorptive properties, and determination of physical and engineering properties.

3.3 Hydrology

A considerable amount of information has been reported regarding the hydrology of Melton Valley; however, most of this information is related to the areas occupied by the SWSAs and pits and trenches east of WAG 8 (Webster 1976, Webster and Bradley in press, Tucci 1986). Recently, drilling has been conducted around WAG 8 for piezometer well installation, and drilling of additional water quality wells is in the planning stages.

Despite this progress, various aspects of the groundwater hydrology of the Melton Valley are incompletely understood. This is due to the complex geology of the area and to the control of groundwater flow directions by fractures and folds. Particular needs include determining the applicability to WAG 8 of information gathered in nearby areas, such as the site of the proposed SWSA 7 and SWSA 6. In addition, there needs to be a study of the potential for contamination of bedrock in the area of WAG 8, as well as the presence of joints, solution channels, and faults that may divert or control groundwater flows.

Plans to develop a water balance for the WAG 8 area should be considered. Two items in particular require additional work before the hydrologic regime in WAG 8 can be defined. A field reconnaissance of springs, seeps, and emergent streams and their location and flow volumes should be conducted. A complete inventory of plant discharges to the Melton Branch and other unnamed tributary creeks should also be compiled.

3.4 MONITORING

The locations for nine new water quality monitoring wells in WAG 8 have been selected (MCI 1987). Because the existing water quality wells in the vicinity of the HFIR-TRU ponds are considered adequate to identify contaminant movement in the pond area of WAG 8, the new wells will provide groundwater quality data for the northern (upper) part of the WAG and the two extensions of the WAG containing the LLW transfer lines.

The existing surface water monitoring stations appear to provide an adequate monitoring network for contaminant releases from WAG 8; however, it appears that contamination from WAG 8 might enter the drainage west of the WAG, and it is suggested that a scoping survey be conducted in this area (near Site 24 in Fig. 2) to determine if an additional monitoring station is warranted. There are also plans to provide a station on the unnamed tributary just east of Station 4A (personal communication, D.D. Huff).

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Environmental Data Package for the Environmental Research Areas (WAG 13)

W. J. Boegly, Jr.
G. K. Moore

Environmental Sciences Division
Publication No. 3153

MANAGED BY
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W. J. Boegly, Jr., and G. K. Moore*

Environmental Sciences Division
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ABSTRACT

This environmental data package covers the Environmental Research Areas which were designated as Waste Area Grouping 13 (WAG 13) in the ORNL RCRA Facilities Assessment. It was prepared as part of the effort to meet regulatory requirements for remedial action under Section 3004(u) of the Resource Conservation and Recovery Act (RCRA).

Based on the available information regarding the absence of RCRA hazardous waste contamination at WAG 13, Oak Ridge National Laboratory has recommended that WAG 13 be deleted from further consideration under RCRA 3004(u) and that future remedial investigation be conducted under Department of Energy Order 5480.14 (Comprehensive Environmental Response, Conpensation, and Liability Act).

The purpose of this data package is to provide background information on the geology and hydrology of the WAG 13 area, as well as information on releases and inventories of radionuclides and hazardous materials for individual sites within WAG 13 that will be required for additional remedial action evaluations. Areas where additional site information will be required are also identified.

The data package indicates that no RCRA-defined hazardous waste constituents were applied at either of the Solid Waste Management Units (SWMUs) in WAG 13; ^{137}Cs was reported to be the only contaminant applied. Although sampling has indicated the presence of ^{137}Cs outside the boundary of SWMU 13.1, there does not appear to have been ^{137}Cs migration from SWMU 13.2. Evaluation of existing geologic and hydrologic information concerning WAG 13 indicates that there is sufficient information available to characterize the site; however, no RCRA-quality wells exist at this time to determine if ^{137}Cs is present in the groundwater at the site.

ENVIRONMENTAL DATA PACKAGE - ENVIRONMENTAL RESEARCH AREAS (WAG 13)

W. J. Boegly, Jr., and G. K. Moore

1. INTRODUCTION

U.S. Department of Energy (DOE) facilities are required to be in full compliance with all federal and state regulations. In response to these requirements, Oak Ridge National Laboratory (ORNL) has established a Remedial Action Program (RAP) to manage areas where past and current research, development, and waste management activities have resulted in residual contamination of facilities or the environment. The primary objective of the RAP is to clean up releases of hazardous waste or hazardous constituents that threaten human health or the environment (Trabalka and Myrick 1987).

The initial ORNL remedial action strategy was based on the guidance of DOE Orders 5820.2 (Surplus Facilities Management) and 5480.14 [Comprehensive Environmental Restoration, Compensation, and Liability Act (CERCLA)]; the Resource Conservation and Recovery Act (RCRA) was believed to apply to only a limited number of sites. As a part of this strategy, individual sites were addressed according to estimated priorities for site characterization, remedial actions, and decommissioning/closure planning. In 1984, the RCRA was amended to establish broad new authorities within the U.S. Environmental Protection Agency (EPA) RCRA programs. One of these new authorities was Section 3004(u), which mandates that any hazardous waste management permit issued after November 8, 1984, require corrective action for all releases from solid waste management units at the facility. In a memorandum to DOE on April 1986, EPA expressed concern about the length of time required to implement DOE orders and elected to enforce regulatory requirements for remedial actions through its amended RCRA authority (Scarbrough 1986).

1.1. DESCRIPTION OF ORNL'S APPROACH TO COMPLIANCE WITH 3004(u)

The ORNL area is characterized by complex hydrogeologic conditions, and previous studies have shown that a strong coupling generally exists between the shallow groundwater and surface drainage systems (Trabalka and Myrick 1987). It is felt that reliance on groundwater monitoring as prescribed by RCRA regulations would not be adequate or effective under ORNL site conditions; a combination of surface and groundwater monitoring should be more effective in meeting the principal performance objective of RCRA regulations: the protection of human health and the environment (Trabalka and Myrick 1987).

According to RCRA Facility Assessment Guidance, a Solid Waste Management Unit (SWMU) is defined as "any discernable waste management unit at a RCRA facility from which hazardous constituents might migrate, irrespective of whether the unit was intended for the management of solid and/or hazardous waste. This definition includes containers, tanks, surface impoundments, waste piles, land treatment units, landfills, incinerators, and underground injection wells, including those units defined as 'regulated units' under RCRA. Also included are recycling units, wastewater treatment units and other units which EPA has generally exempted from standards applicable to hazardous waste management units, and areas contaminated by 'routine, systematic, and deliberate discharges' from process areas." The definition does not include accidental spills from production areas and units in which wastes have not been managed (e.g., product storage areas) (EPA 1986).

As the first step in identifying compliance requirements under RCRA 3004(u) for ORNL, a listing of all known active and inactive waste management areas, contaminated facilities, and potential sources of continuing releases to the environment was prepared. Although some of the identified sites might not be regulated under 3004(u), they were included in the site listing in order to maintain a comprehensive inventory of all ORNL sites that might require some form of remedial action.

The initial listing compiled for ORNL included about 250 sites, which were grouped into 20 geographically contiguous and hydrologically defined Waste Area Groupings or WAGs (ORNL 1987a). A detailed discussion of the rationale used in developing and defining the WAG concept is presented in Trabalka and Myrick (1987). Figure 1 shows the locations of the 20 WAGs.

1.2 ENVIRONMENTAL RESEARCH AREAS (WAG 13)

As part of ORNL's initial remedial action efforts, Taylor (1986) reviewed past environmental research conducted at field locations and identified 37 sites that might require further remedial action. Only 3 of the 37 sites identified by Taylor (1986) were assigned an SWMU designation and included within the proposed 20 WAGs; the remaining 34 sites were excluded from further 3004(u) evaluation because (1) the radioactivity had decayed to undetectable levels, (2) the radionuclides had been removed from the site, or (3) no known hazardous waste constituents were included (ORNL 1987a).

ORNL-DWG 87-9552A

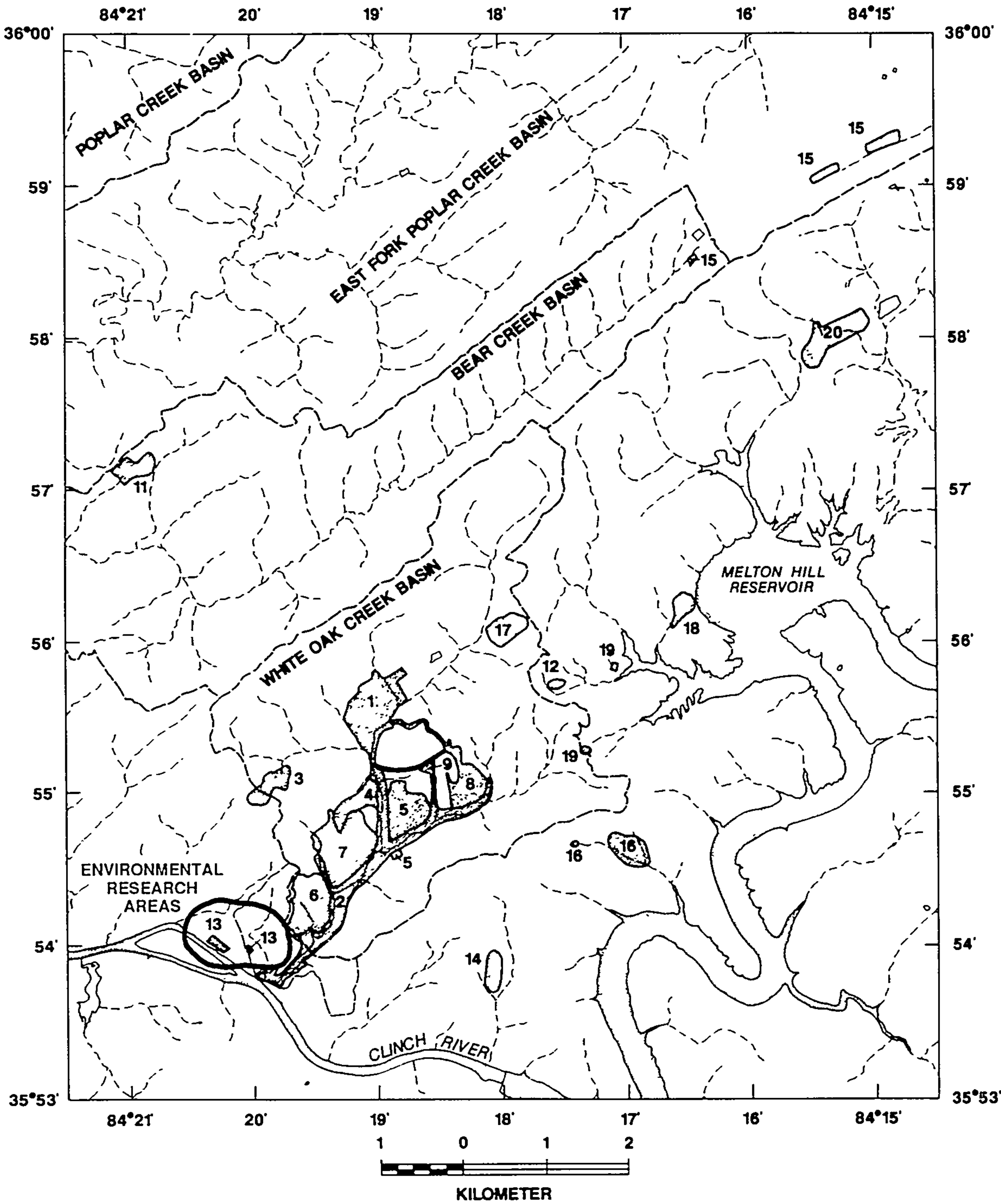

Fig. 1. Locations of the 20 Waste Area Groupings (WAGs).

Of the three sites included in the RCRA Facilities Assessment (RFA), two are southwest of the main ORNL complex near the Clinch River (Fig. 1). These two SWMUs have been combined and identified in the RFA as WAG 13. The remaining environmental research site has been assigned to WAG 16, the Health Physics Research Reactor Area (ORNL 1987a). It is assumed that the excluded sites (the remaining 34) will be treated as DOE Order 5480.14 (CERCLA) sites in future remedial action investigations.

WAG 13 is a part of what is now called the 0800 area (Fig. 2). The two SWMUs in WAG 13 are located about 1300 ft (400 m) apart in separate portions of the WAG (Fig. 2). A part of this area (SWMU 13.1) was the site of a simulated fallout experiment utilizing ^{137}Cs-tagged particles. At the present time, part of the 0800 area is used for field studies related to air pollution and acid rain effects on vegetation.

SWMU 13.1 consisted of a 5-acre (2-ha) fenced area in a fescue grassland community approximately 330 ft (100 m) north of the Clinch River at mile 20.5 (33 km) (Auerbach 1969, Auerbach and Dunaway 1970, Auerbach et al. 1973). The site included eight 33- by 33-ft (10- by 10-m) treatment plots, each of which was enclosed by metal sheeting 18 in. (46 cm) below the surface and 24 in. (61 cm) above the ground (Fig. 2). In August of 1968 four of the plots were contaminated with ^{137}Cs fused to silica particles (88 to 177 m in diameter), and the remaining four plots were used as controls. Each enclosed plot received approximately 2.2 Ci (8.1×10^{10} Bq) of ^{137}Cs, representing a total of 8.8 Ci (3.3×10^{11} Bq) for the entire site. The particle-size distribution was selected to simulate the particle sizes characteristic of weapons fallout. During the period of experimental observation, samples of

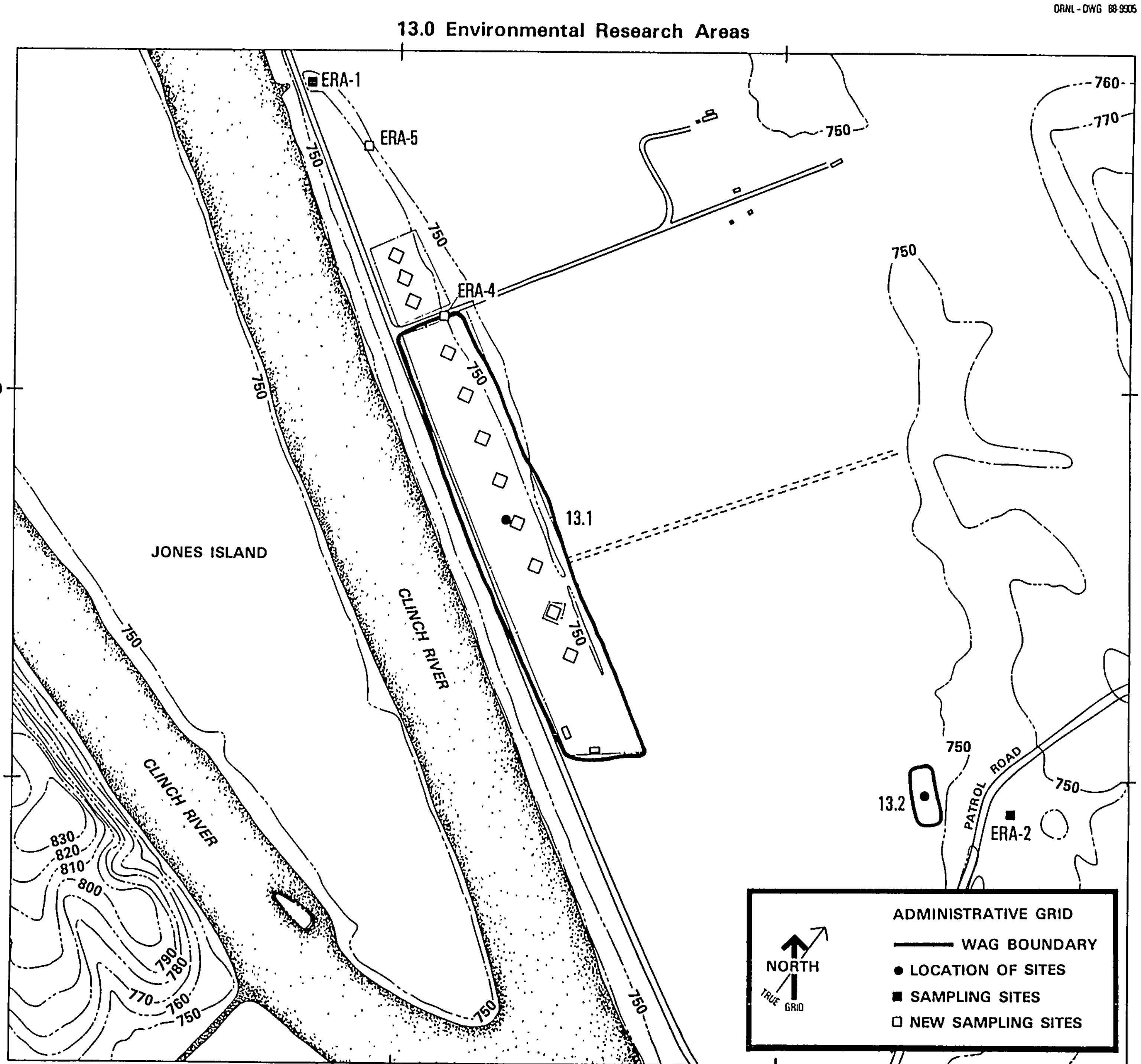

Fig. 2. Location of Solid Waste Management Units (SWMUs) in the Environmental Research Area (WAG 13).

vegetation clippings and soil cores were removed from the enclosures and were analyzed and disposed of elsewhere. Because the ^{137}Cs was applied about 20 years ago, radioactive decay has reduced the remaining radioactivity to less than 5.5 Ci, assuming that no particle losses due to weathering, runoff, or wind transport occurred. The site is presently enclosed by a chain link fence and is not being used.

Numerous experiments with shorter half-life isotopes have also been conducted in the vicinity of the cesium plots; however, due to the radioactive decay process, the isotopes are no longer present in detectable amounts (Taylor 1986).

SWMU 13.2 was an experimental area used to study ^{137}Cs runoff, erosion, and infiltration on a silt-loam soil (Rogowski and Tamura 1965, 1970a, 1970b, Tamura 1967). This study was also related to ORNL's Civil Defense Program. The isotope in this experiment was sprayed as a liquid on soils having varying degrees of ground cover. A total of 15 mCi (5.6 x 108 Bq) of ^{137}Cs was used; the area contaminated was less than 215 ft^2 (20 m^2). The isotope was applied on October 20, 1964, approximately 24 years ago. Correcting for radioactive decay, the maximum amount of radioactivity remaining should be about 8.6 mCi. The site is currently fenced and inactive.

1.3 ENVIRONMENTAL RELEASES FROM WAG 13

Since the basic premise behind the experiments conducted in the two SWMUs was to evaluate the movement of radiocesium resulting from nuclear weapons fallout, it follows that some of the activity applied was released from the sites.

Morrison and Cerling (1987) sampled stream soils in WAG 13 as a part of a scoping survey. At the time of sampling no water flow was occurring at either of the two sites. Only one soil sample was taken at each site. At SWMU 13.1 there was evidence of ^{137}Cs and possibly ^{90}Sr contamination, as well as detectable concentrations of Cd, P, and Zn. At SWMU 13.2, the ^{137}Cs concentration was slightly above detectable levels; however ^{90}Sr was about 4 times the background levels for the Conasauga Group (Table 1).

Prior to implementing further remedial action on the sites included in WAG 13, it was recommended that additional surveys should be undertaken (ORNL 1987a). Additional sampling along the stretch of the dry streambed [the RFA sample (ERA-1) was taken about 300 ft northwest of the plots] should provide some indication of potential movement of ^{137}Cs. In the case of SWMU 13.2, no further sampling was recommended because the stream gravel survey conducted in 1986 did not locate ^{137}Cs contamination. The amount of ^{137}Cs that can be calculated to remain at the site is very small; in fact, most of the remaining isotope may already have been removed or may have migrated from the site.

As recommended in the RFA, samples were taken in June 1987 from two additional sampling sites (ERA-4 and ERA-5) that were located between SWMU 13.1 and the original sampling point (Fig. 2). The results are shown in Table 2 (ORNL 1987b). It is evident that ^{137}Cs has migrated from the site; the concentration in the soil increases in the samples nearer the contaminated plots. Based on the results of the two sampling surveys, it was recommended that WAG 13 be deleted from further consideration as a RCRA Section 3004(u) site, but that SWMU 13.1 should receive continued surveillance and corrective action and be implemented

Table 1. Preliminary survey results for WAG 13[a]

Element	Background	ERA-1[b]	ERA-2[b]
^{60}Co[c]	<2	<7	<5
^{90}Sr[c]	<10	21	41
^{137}Cs[c]	3	390	<6
Cd[d]	0.5	0.3	ND
Cr[d]	0.05	ND	ND
Cu[d]	0.9	ND	ND
Ni[d]	0.6	ND	ND
Zn[d]	9	11	1.3

ND = not detected

[a]Concentrations reported on basis of dry weight of sample. Radionuclides in becquerels per kilogram; metals in micrograms per gram.

[b]Sample Notes: ERA-1 (soil, one sample; no water or mud sample). ERA-2 (soil, one sample; no water or mud samples).

[c]Backgrounds estimated for counting procedure used in this study.

[d]Backgrounds estimated from several uncontaminated samples.

Source: Morrison and Cerling 1987; ORNL 1987a.

Table 2. Soil survey results from WAG 13 in 1987 (becquerels per kilogram)

Element	Background[a]	ERA-4	ERA-5
^{60}Co	<2	<2	2
^{137}Cs	40.7	580 + 10	2300 + 100

[a]Backgrounds estimated from the mean of samples collected at several remote sites (Martin Marietta Energy Systems Environmental Surveillance Report - Oak Ridge 1986). Radionuclide Concentrations in Bq/kg.

Source: Morrison and Cerling 1987; ORNL 1987b.

under CERCLA Superfund Amendments and Reauthorization Act (SARA) and applicable DOE orders (ORNL 1987a, 1987b).

Aerial radiometric surveys of the White Oak Creek watershed area were conducted in 1974 and 1986 (Burson 1976, Fritzsche 1987). In the first survey, exposure rates (from man-made radioisotopes) up to 50-100 μR/h were detected in the area of the cesium fallout plots (SWMU 13.1); however, SWMU 13.2 did not show up as a separate source of radiation on the radiometric maps (Fig. 3). Spectral analysis indicated that ^{137}Cs was the dominant radionuclide present (Burson 1976). The 1986 survey, using improved instrumentation, produced radiometic maps documenting the presence of ^{137}Cs in SWMU 13.1; the results of this survey also showed a distortion of the exposure contours indicating the presence of an above background amount of ^{137}Cs in SWMU 13.2 (see Fig. 4).

As a part of Taylor's survey (1986) of the Environmental Research Areas, a walk-over radiological survey was conducted for SWMUs 13.1 and 13.2. The survey was made with Geiger-Mueller type beta-gamma survey meters and NaI gamma scintillation detectors. The results of the Taylor survey indicated that exposures rates of 8-10 mR/h existed at SWMU 13.1 and that exposure rates up to 1 mR/h could be detected in parts of SWMU 13.2.

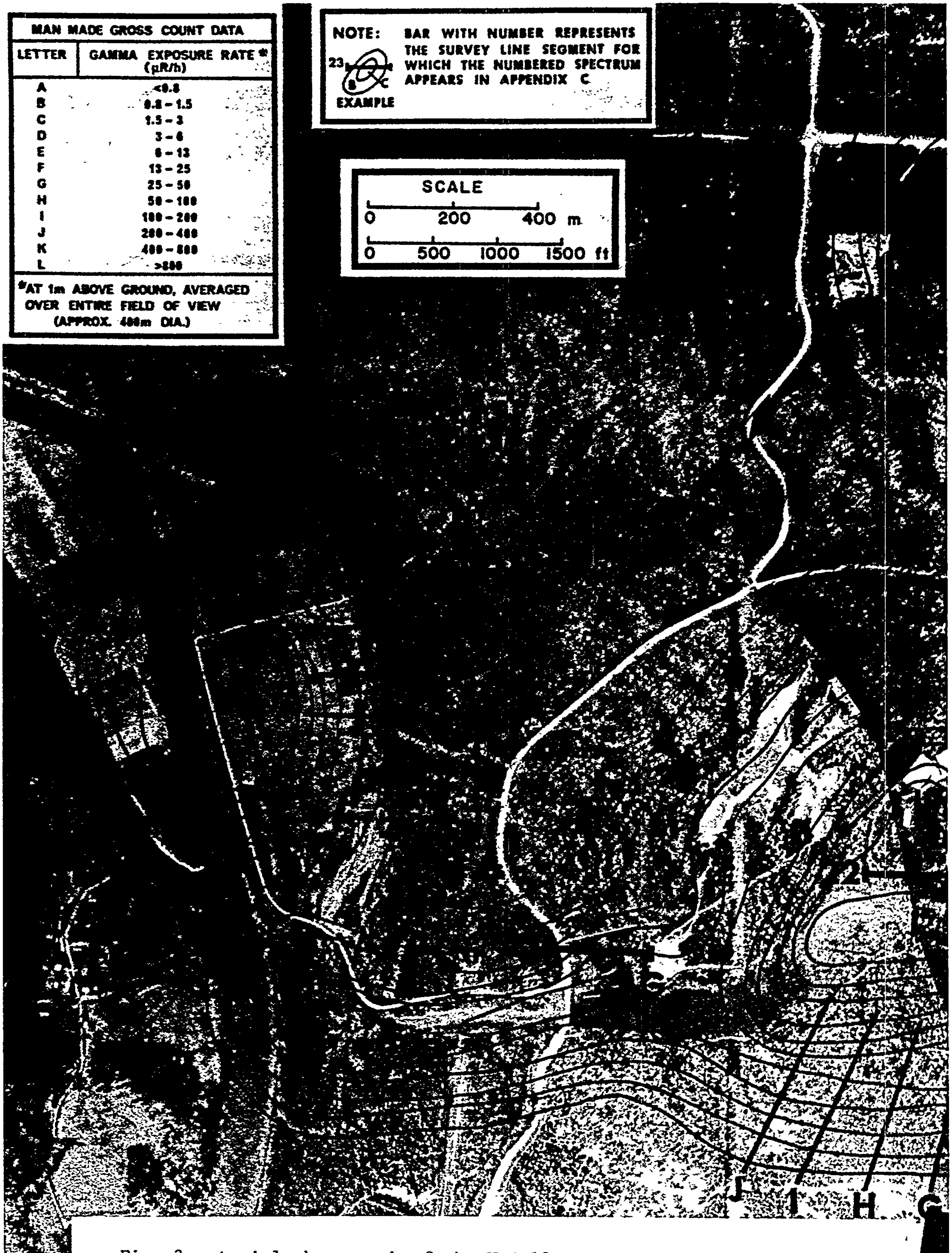

Fig. 3. Aerial photograph of the WAG 13 area taken in 1974 showing manmade radiation isopleths.

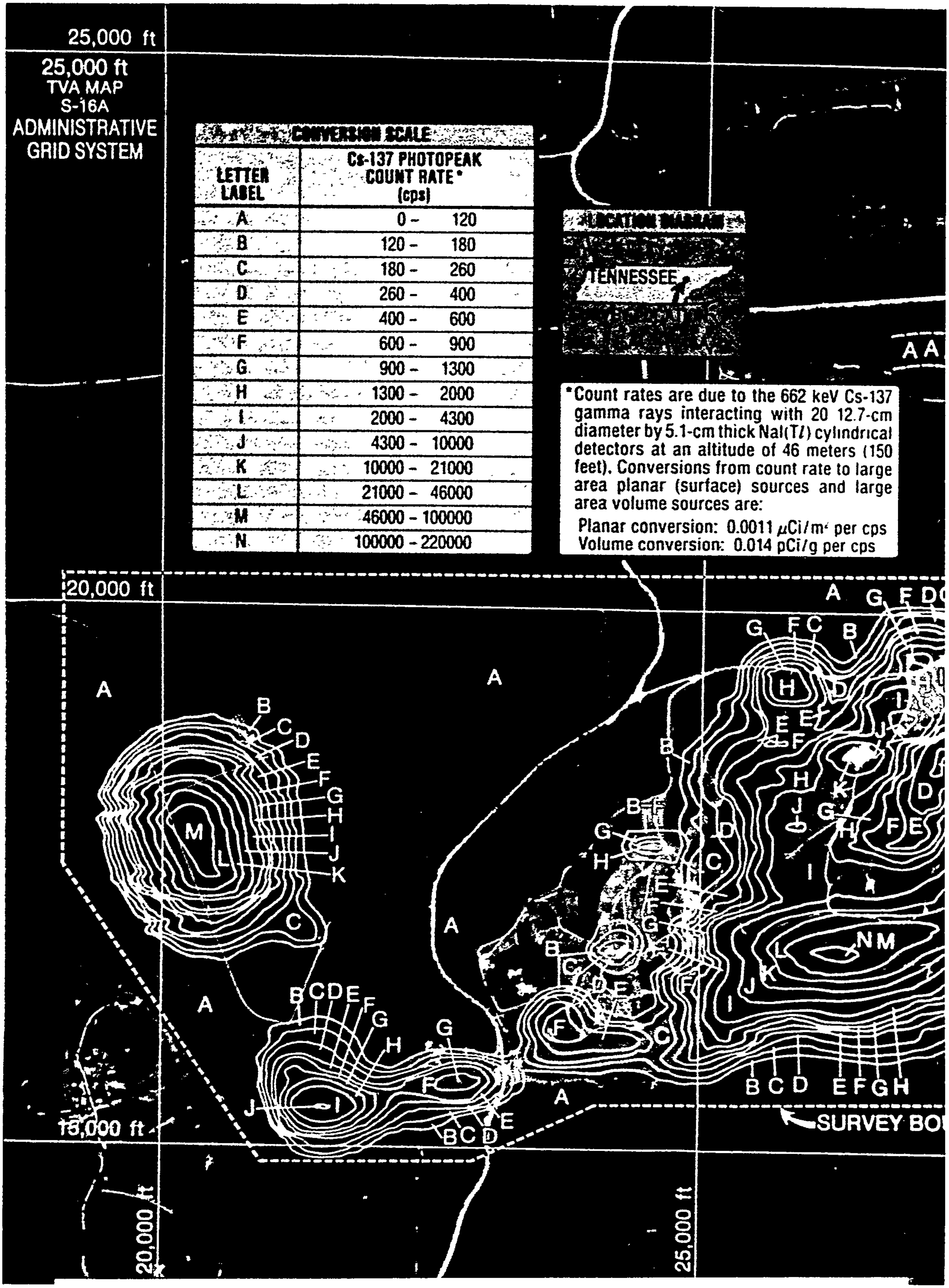

Fig. 4. Aerial photograph of the WAG 13 area taken in 1986 showing 137

2. CURRENT STATUS OF INFORMATION ON WAG 13

2.1 SOURCE TERMS

All literature reports and personal contacts indicate that ^{137}Cs was the main radionuclide used in the WAG 13 experiments. However, the samples taken by Morrison and Cerling (1987) indicated that ^{90}Sr and perhaps ^{60}Co were also above background levels in the stream gravels at sampling sites ERA-1 and ERA-2. Although the event is undocumented, it appears that additional tracer experiments using long-lived radionuclides other than ^{137}Cs may have been conducted in the vicinity of SWMU 13.1.

2.2 GEOLOGY

The WAG 13 area is on the floodplain of Clinch River, and surficial materials are alluvial rather than residual. Logs kept by geologists (MCI Consulting Engineers, Inc.) during the drilling of three piezometer wells (locations on Fig. 5) show that the alluvium consists mainly of brown silt and clayey silt about 25-30 ft thick. Gravel was mixed with the silt in samples from one well, and a layer of gray clay, 10 ft thick, was found in the same well. Drillers' logs of two older and deeper wells in this area show an overburden thickness of 50-55 ft; this interval probably includes soft clayey shale and weathered shale, which might instead be classified as upper bedrock.

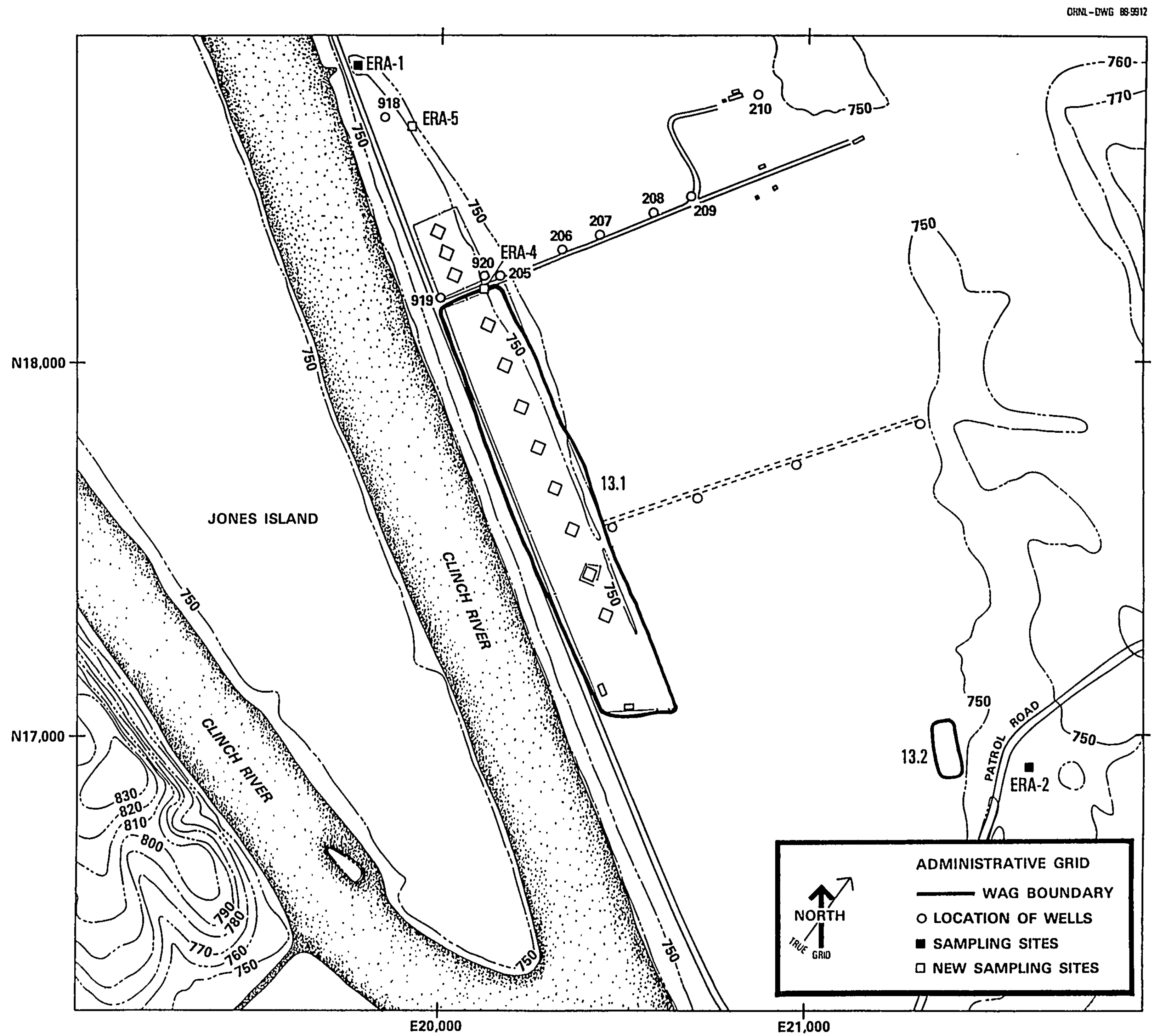

Fig. 5. Locations of new piezometer wells (918-920), older wells (205-210), and unnumbered wells in WAG 13.

WAG 13 is near the center of the outcrop belt of the Conasauga Group (McMaster 1962). The area has not been mapped in detail, but a lateral projection of contacts from a geologic map of Melton Valley (R. B. Dreier, ORNL, personal communication to author, 1987, Fig. 10) shows that the bedrock beneath WAG 13 might be Maryville Limestone. Drillers' logs of the two deeper wells list 230-250 ft of blue or red shale underlain by white, red, or blue limestone. This description might fit a leached lower member of the Maryville Limestone underlain by Rogersville Shale and Rutledge Limestone. A more detailed geologic map of the area or a better description of the subsurface lithology is necessary for a more precise stratigraphic determination.

The rocks strike about N55^{o}E in the WAG 13 area and dip about 20-30^{o}SE (McMaster 1962). Small folds and small faults may occur in the area but have not been mapped.

2.3 HYDROLOGY

2.3.1 General Hydrology

Mean annual precipitation in the period 1954-1983 was 52.2 in. for stations near ORNL; the minimum and maximum amounts in this same period were 35.3 and 74.8 in., respectively (Webster and Bradley 1987, p. 13). The 1986 water year was unusually dry, and only 34.5 in. of precipitation were recorded by the U.S. Geological Survey at a station in WAG 5. The wettest months generally are January through March, and the driest months are August through October; for the wet and dry periods, mean monthly precipitation at the Oak Ridge station of the National Oceanic and Atmospheric Administration is 5.3-6.2 in. and 2.9-3.8 in., respectively. The monthly extremes for the Oak Ridge station are 13.3

in. for January 1954 and 0.5 in. for August 1953 (National Oceanic and Atmospheric Administration 1974, p. 378). In the dry 1986 water year, only 0.9 in. of precipitation was measured in WAG 5 during January, and 3 months (December, April, and June) had less than 2.0 in. of precipitation. The average frequencies of occurrence for various precipitation intensities over periods of 30 min to 24 h are shown by McMaster (1967, Fig. 3).

Droughts lasting 7 d occur about 17% of the time, but droughts lasting 15 d occur, on an average, only 1.8% of the time (McMaster 1967, Fig. 5). In the dry 1986 water year, the longest droughts at the WAG 5 station were 18 days in January, 15 days in April-May, 15 days in June, and 17 days in July.

The mean annual runoff for streams in the ORNL area is 22.3 in. of water (McMaster 1967, p. 9). The remainder of the mean annual precipitation, about 30 in. of water, is consumed by evapotranspiration. Based on pan evaporation measurements at Norris, Tennessee, about 75% (22.5 in. of water) of the evapotranspiration occurs during a 6-month period from April through September (Tennessee Division of Water Resources 1961, p. 18). The growing season, when potential evapotranspiration is highest, averages 220 d, from April 1 to November 5 (National Oceanic and Atmospheric Administration 1974, p. 373). A water-balance graph for Rogersville, Tennessee, shows that potential evapotranspiration exceeds precipitation for 5 months, from May through September, and that the main period for replenishment of the soil moisture deficit is October 1 to November 10 (Tennessee Division of Water Resources 1961, Fig. 4).

Streamflow and runoff depend upon amounts and changes in precipitation, evapotranspiration, and groundwater storage. The ratios of average quarterly runoff to mean annual runoff (percentages) for the Oak Ridge area (McMaster 1967, p. 10) are shown below.

Quarter	Percent of annual runoff
October-December	17
January-March	49
April-June	23
July-September	11

A comparison of seasonal differences in precipitation and runoff shows that about 5 in. of water represents both the increase of evapotranspiration in the summer months over that in the winter months and the decrease in groundwater storage during the summer and fall.

All of the WAG 13 area drains to Clinch River, to WOC, or to other small tributaries near their junctions with Clinch River. Groundwater flows are in the same directions as overland flows. All groundwater is discharged to the nearest flowing stream.

2.3.2 Infiltration and Groundwater Recharge

The processes that produce aquifer recharge are precipitation, infiltration, and percolation. The infiltration capacity of the mixed grass and brush areas in WAG 13 has not been measured. Tests in forested areas under saturated soil conditions (Watson and Luxmoore 1986, Wilson and Luxmoore, in press) have shown a typical infiltration capacity of about 14-16 in./h. Other tests have shown a typical infiltration capacity of about 0.008-0.02 in./h for undisturbed C-horizon soils (Luxmoore et al. 1981, p. 688; Davis et al. 1984, p. 72). The average infiltration capacity of the land surface in WAG 13 is probably about 3-6 in./h.

Very little infiltration and percolation occur as intergranular flow. The porosity of clay soils is generally about 50%. However, Watson and Luxmoore (1986, p. 581) found that macropores and mesopores, which together occupy only 0.2% of the soil volume, account for 96% of the infiltration. Macropores and mesopores are not completely understood; they are connected voids that may have various causes, including biochanneling, cracking, and aggregation of soil particles. One result of macropore flow is that there is less filtering of any contaminants than would be assumed by only a consideration of regolith thickness and depth to water table. A second factor is that effective porosity (as well as water storage capacity) is much smaller than is indicated by total porosity. A third effect is that small changes in the number or size of openings at any level produce large differences in the relative rates and amounts of vertical and lateral percolation.

Percolation occurs through the unsaturated zone above the water table, but changes in the permeability of the flow paths occur at every level. Locally, lateral movement toward land surface may dominate at one level, whereas vertical movement or lateral movement in other directions may dominate at other levels. Local flow directions may also change through time as infiltration ends and as openings drain. Flow paths thus are complex in detail with numerous splits and joins. Some percolating water reaches the water table and recharges the aquifers. The remainder is discharged at wet-weather seeps and springs.

A majority of all aquifer recharge occurs during the nongrowing season and soon thereafter, from about November 5 to April 30. During periods of intense precipitation in the growing season, some recharge reaches the water table, and water levels rise in wells or show a slower rate of decline for a few days. However, the water levels in all wells decline, although at a variable rate, throughout the growing season because most precipitation is captured by vegetation in this period of time.

The geometric mean of October depth to water in wells near ORNL is 14 ft, and the range from the mean ± 1 standard deviation is 6.6-30 ft. The geometric mean amount of seasonal change in water level in wells is 3.9 ft; the range from ± 1 standard deviation is 2.0-8.2 ft. In the WAG 13 area, the mean of October depth to water in three piezometer wells is 13.3 ft, and the mean amount of seasonal change in water level is 4.5 ft.

2.3.3 Groundwater Occurrence

Groundwater in the regolith of the WAG 13 area occurs in intergranular pores, in mesopores and macropores, and probably in fractures that extend upward from bedrock. In bedrock, essentially all groundwater occurs in fractures and in a few larger cavities; the rocks have almost no primary porosity and permeability. The hydrologic importance of all openings increases with size and flow rate because, as shown by infiltration measurements, a very few openings produce nearly all groundwater flow.

The water-bearing characteristics of aquifers below the water table have been examined by the drilling and testing of 14 wells (locations on Fig. 5). Piezometer wells 918-920 were screened in alluvium, just above the top of bedrock. The hydraulic conductivity and transmissivity of the aquifer near these wells, as shown in the table below, were determined by analysis of data from slug tests.

Well	Hydraulic conductivity (ft/d)	Transmissivity (ft^2/d)	Aquifer thickness (ft)
918	0.43	7.6	18
919	0.13	1.6	12
920	0.46	8.6	19

The geometric mean of hydraulic conductivity for these three wells is 0.29 ft/d. In comparison, the geometric mean of hydraulic conductivity for 413 shallow wells within a 5-km radius of ORNL is 0.13 ft/d.

Two deeper wells were drilled in 1979 to develop a water supply for agricultural research plots. Drillers' logs show that the first hole (located near well 209; see Fig. 5) produced only 0.5 gal/min of water at a depth of 270 ft; this hole was filled and abandoned. A second hole (well 210) was drilled to a depth of 310 ft; the drillers' log reports inflows of 10 gal/min of water at a depth of 195 ft and 8 gal/min at a depth of 280 ft. Groundwater flows of this size have not been reported from similar depths elsewhere in the Conasauga Group, and it is likely that total well yield at the indicated depths represents a cumulation of flow from smaller water-producing zones at shallower levels.

In fractured rock, storativity is approximately equal to the porosity of the aquifer (the volume of open fractures in a unit volume of rock). In the ORNL area, storativity probably has a lognormal distribution and a large range. Various studies have estimated the mean value of this parameter. Webster and Bradley (1987, Table 6) estimated storativity of the aquifers at 1×10^{-4} to 1×10^{-5}, based on aquifer test data for several wells. Recent slug tests on 150 piezometer wells near ORNL suggest that the range in storativity is 1 X 10^{-2} to 1 X 10^{-6} but that the median may be about 1 X 10^{-4}. More accurate measurements were made by Smith and Vaughan (1985, pp. 141, 144), using two aquifer tests and the data from six observation wells in each test; they obtained geometric mean values for aquifer storativity of 1 X 10^{-3} and 4 X 10^{-3}.

The average porosity of 0.25% determined by Smith and Vaughan is approximately the same as the 0.21% volume of macropores and mesopores calculated from soil infiltration tests (Watson and Luxmoore 1986, p. 581). If mean effective porosity is 0.0023, then the 4.5 ft of seasonal change in water level in the WAG 13 area represents a change in aquifer water storage of 0.12 in. The total amount of groundwater stored below WAG 13 cannot be determined. However, if nearly all fresh groundwater occurs in the upper 100 ft of the aquifer, active groundwater storage might be about 2-3 in.

2.3.4 Flow Paths and Groundwater Movement

Groundwater flow directions in the WAG 13 area are determined by the orientations of openings in alluvium and bedrock and by the hydraulic gradient within each opening. Although flow paths for water particles may be locally tortuous, a water table map (Fig. 6) shows that groundwater movement is generally toward Clinch River or the nearest tributary stream. Thus, most groundwater flow paths are short and shallow. The hydraulic gradient toward Clinch River is 0.014, and calculations based on Darcy's law show (1) mean groundwater velocity in this area is about 0.049 in./d, (2) about 1400 gal/d of groundwater are discharged from the water table aquifer to Clinch River (along the reach shown in

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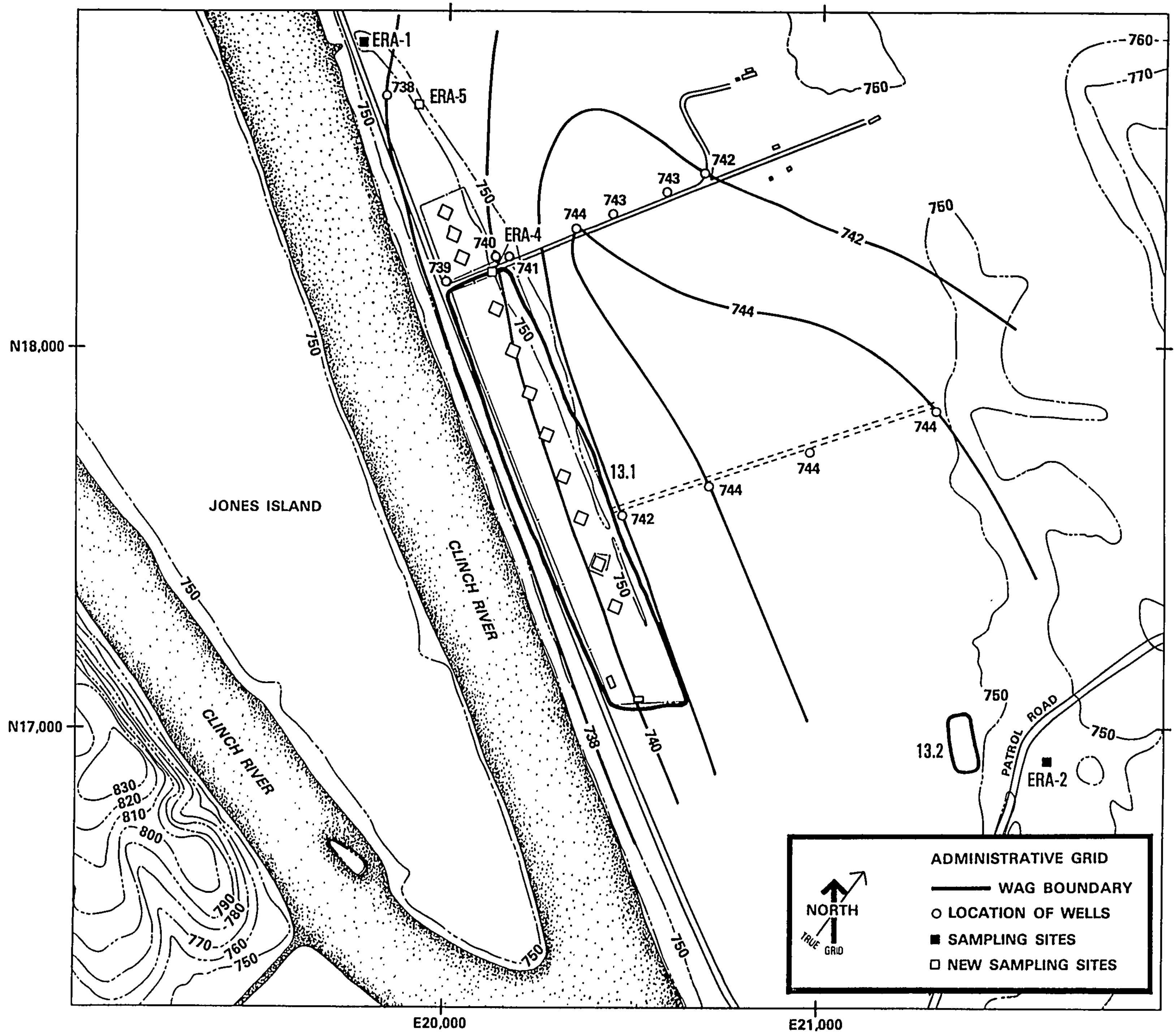

Fig. 6. Configuration of the water table in November, 1987.

Fig. 6), and (3) an estimated 2000-3000 gal/d of groundwater are discharged to tributary streams from the water table aquifer. On this basis, total annual discharge from the water table aquifer is equivalent to about 0.5 in. of water; deeper water-producing zones may discharge another 0.5 in./year of water to these streams.

2.3.5 Water Budget and Contaminant Transport

A water budget for the WAG 13 area can be estimated, as follows, from parameters measured in this and nearby areas.

		Inches
INFLOW		52
Mean annual precipitation	52	
OUTFLOW		52
Evapotranspiration	32	
Streamflow	20	
Stormflow	19	
Base flow	1	

The stormflow component of this budget consists of water that infiltrates the land surface but is discharged laterally at wet-weather seeps and springs before reaching the water table. The base-flow component is water that is discharged at the closest seep, spring, stream, or pumping well from aquifers below the water table.

The magnitude of the stormflow budget component generally has not been recognized in previous hydrologic studies of the ORNL area, partly because it is ephemeral and partly because of uncertainties in the calculation of rates and quantities of flow below the water table. The uncertainties have been caused by the interpretation of water table gradients as large as 0.3-0.4 beneath steep hillsides. A recent revision of groundwater flow concepts attributes hydraulic potential to the nearly vertical movement of groundwater from one aquifer level to another. This revision means that lateral hydraulic gradients in the ORNL area are limited to a range of about 0.005-0.02 and that hydraulic conductivities in the range 0.1-0.3 ft/d transport only about 0.5-2.0 in./year of groundwater below the water table. Any flow paths for larger amounts of groundwater are above the water table.

Contaminant transport by groundwater is more likely to occur at or near land surface in the WAG 13 area than at deeper levels, which may be above or below the water table. As shown by the estimated water budget, nearly 20 times more water follows a path near land surface than follows any deeper flow path. If control of contaminant transport proves necessary in this area, the plans for remedial action should consist of (1) blocking infiltration by precipitation over the entire control area and (2) blocking lateral groundwater flows near land surface. Dewatering of surficial materials will probably be unnecessary because the water table is 8-13 ft below land surface in the WAG area.

2.3.6 Chemical Characteristics of Groundwater

The composition of groundwater is controlled by many factors including the chemical content of recharge waters, interactions with regolith and bedrock, residence times, and mixtures or dilutions with waters from other flow paths. Also, the concentration of many constituents is not constant but varies throughout the year, apparently depending on groundwater flow rates. Chemical analyses are not available for WAG 13, but the characteristics of the major constituents can be estimated from analyses of groundwater in other areas near ORNL.

Most groundwater from shallow wells is a nearly neutral to slightly alkaline (pH 6.5-8.1), calcium bicarbonate type water. Magnesium concentration typically is about the same as sodium and is about half the concentration of calcium (Stockdale 1951, p. 79; Davis et al. 1984, pp. 157-170; Webster and Bradley 1987, Table 10).

A variation in the type of water from shallow wells is shown by samples from five wells 50-100 ft deep (Stockdale 1951, p. 79). This water, like that of the more typical type, above, is neutral to slightly alkaline (pH 6.7-7.8), but sodium content is approximately equal to calcium plus magnesium. These characteristics suggest that soluble sodium salts are more readily available for solution in some areas than in others, especially at levels a little deeper than those of the shallowest wells.

A distinctly different groundwater is reported by Webster and Bradley (1987, Table 10) from six wells 100-200 ft deep. This is a sodium carbonate or sodium bicarbonate type water with a pH of 8.5-10.5, a sodium content of 60-300 mg/L, and a calcium plus magnesium concentration of less than 12 mg/L. These characteristics apparently result from ion exchange (calcium and magnesium for sodium) along deeper flow paths and suggest that much less water moves along these deeper paths than moves through fractures near the top of bedrock. All three of the chemical types that characterize water from wells up to 200 ft deep generally have a dissolved solids content of less than 500 mg/L, and the concentration in water from most wells is 300-400 mg/L.

A much higher concentration of dissolved salts is found in water from wells 500-1500 ft deep (Haase et al. 1987, and Switek et al. 1987); total dissolved solids contents as high as 300,000 mg/L have been reported. This water is acidic and has (1) a high percentage weight of chloride and an equivalent weight of Na less than that of chloride, (2) enriched Ca, Mg, Sr, and bromide contents, and (3) relatively low concentrations of bicarbonate, sulfate, and N. In terms of membrane-filtration theory, these waters are membrane concentrated and connate. It is very unlikely that these analyses represent circulating groundwater, but there is not yet a preponderance of evidence to support the hypothesis.

3. ADDITIONAL INFORMATION REQUIREMENTS FOR WAG 13

Based on the information developed in this report, it appears that the major radiological concerns with the Environmental Research Areas (WAG 13) are external exposure to radiation from WAG 13 and movement of cesium in surface drainages.

The Environmental Research Areas were used mainly to conduct Civil Defense research activities using radioactive ^{137}Cs; there are no records to indicate that RCRA hazardous waste constituents were applied in any of these experiments. Although there is some indication in the existing sampling data that other radionuclides (^{90}Sr and ^{60}Co) may exist above background values in the site soils, the source of these materials is unknown. Based on the existing information regarding the experiments performed at the sites, additional effort to identify the source of these materials is not warranted.

Because the ^{137}Cs used in the experiment at SWMU 13.1 was fused to silica particles (88 to 177 um) prior to application, the movement of radioactivity should be in conjunction with movement of the particles. The ^{137}Cs should not have been leached from the particles. Sampling of soils has confirmed that ^{137}Cs has moved in the surface drainage from SWMU 13.1. Although no groundwater sampling has been conducted in WAG 13, monitoring experience at other ORNL sites has shown that movement of ^{137}Cs through the local soils is minimal. Installation of water-quality wells between SWMU 13.1 and the Clinch River should be considered. These wells could be used to confirm that ^{137}Cs is not entering the Clinch River through this pathway and to monitor the effectiveness of any remedial actions undertaken.

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ENVIRONMENTAL DATA PACKAGE FOR THE ORNL SERVICES AREA (WAG 17)

W. J. Boegly, Jr. and G. K. Moore

Environmental Sciences Division

Publication No. 3063

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ENVIRONMENTAL SCIENCES DIVISION

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W. J. Boegly, Jr. and G. K. Moore*

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NUCLEAR AND CHEMICAL WASTE PROGRAMS
(Activity No. KG 02 00 00 0; ONLKG02)

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ABSTRACT

This environmental data package was prepared as part of the effort to meet regulatory requirements for remedial action under Section 3004(u) of the Resource Conservation and Recovery Act (RCRA). The report considers the seven Solid Waste Management Units (SWMUs) in Waste Area Grouping (WAG) 17 (also known at the ORNL Services Area) in Bethel Valley. ORNL has recommended that a remedial investigation be conducted to identify the nature of the remedial actions required for WAG 17.

The purpose of the environmental data package is to provide background information on the geology and hydrology of the WAG 17 area, as well as information on releases and inventories of radionuclides and hazardous materials for individual sites within WAG 17 that will be required for additional remedial action evaluations. Areas where additional site information will be required are also identified.

The data package indicates that limited information exists on the inventories of radionuclide and hazardous waste constituents at most of the identified SWMUs (waste oil and photographic waste storage tanks). Although sampling of stream gravels has indicated the presence of organics, the source of this material remains unknown. The only documented leak occurring in WAG 17 is in a non-SWMU gasoline storage tank. This tank is being remediated under Subtitle I of RCRA. Evaluation of existing geologic and hydrologic information on WAG 17 indicates that there is sufficient information available to characterize the site; however, additional information may be required to define the remedial actions required.

ENVIRONMENTAL DATA PACKAGE -- ORNL SERVICES AREA (WAG 17)

W. J. Boegly, Jr. and G. K. Moore

1.0 INTRODUCTION

U.S. Department of Energy (DOE) facilities are required to be in full compliance with all federal and state regulations. In response to these requirements, the Oak Ridge National Laboratory (ORNL) has established a Remedial Action Program (RAP) to provide comprehensive management of areas where past and current research, development, and waste management activities have resulted in residual contamination of facilities or the environment. The primary objective of the RAP is to clean up releases of hazardous waste or hazardous constituents that threaten human health or the environment (Trabalka and Myrick 1987).

The initial ORNL remedial action strategy was based on the guidance of DOE Orders 5820.2 (Surplus Facilities Management) and 5480.14 (Comprehensive Environmental Restoration, Compensation, and Liability Act [CERCLA]); the Resource Conservation and Recovery Act (RCRA) was believed to apply only to a limited number of sites. As a part of this strategy, individual sites were being addressed according to estimated priorities for site characterization, remedial actions, and decommissioning/closure planning. In 1984, the Resource Conservation and Recovery Act (RCRA) was amended to establish broad new authorities within the Environmental Protection Agency (EPA) RCRA Programs. One of these new authorities was Section 3004(u), which specifies that any hazardous waste management permit issued after November 8, 1984, require corrective action for all releases from solid waste management units at the facility. In a memorandum to DOE in April 1986, EPA expressed concern about the length of time required to implement DOE Orders, and elected to enforce regulatory requirements for remedial actions through its amended RCRA authority (Scarborough 1986).

Prior to the Hazardous and Solid Wastes (HSWAs) Amendments of 1984, EPA's authority to require corrective action for releases of hazardous constituents was limited to ground water releases from units that were covered by RCRA permits (Part 264, Subpart F). Since passage of the HSWA, EPA's authority has been extended to releases to all media and all units at a RCRA facility regardless of when they were used or whether they are covered by a RCRA permit (EPA 1986).

1.1. Description of ORNL's Approach to Compliance with 3004(u)

The ORNL area is characterized by complex hydrogeologic conditions, and previous studies have shown that a strong coupling generally exists between the shallow groundwater and surface drainage systems (Trabalka and Myrick 1987). It is felt that reliance on groundwater monitoring as prescribed by RCRA regulations would not be adequate or effective under ORNL site conditions; a combination of surface and groundwater monitoring should be more effective in meeting the principal performance objective of RCRA regulations: the protection of human health and the environment (Trabalka and Myrick 1987).

As the first step in identifying compliance requirements under RCRA 3004(u) for ORNL, a listing of all known active and inactive waste management areas, contaminated facilities, and potential sources of continuing releases to the environment was prepared. Included in this list were waste collection and storage tanks, solid waste storage areas (SWSAs), waste treatment units, impoundments, spill sites, pipeline leak sites, underground injection wells, and areas of known contamination within buildings. Although some of the identified sites might not be regulated under 3004(u), they were included in the site listing in order to maintain a comprehensive inventory of all ORNL sites that might require some form of remedial action.

The listing compiled for ORNL includes about 250 sites which might be considered for 3004(u) remedial action (ORNL 1987). Because of the complex hydrogeology of ORNL and the large number of sites involved, the ORNL sites have been grouped into 20 geographically contiguous and hydrologically defined Waste Area Groupings or WAGs. (See Trabalka and Myrick for a detailed discussion of the rationale used in developing and defining the WAG concept.) Figure 1 shows the locations of the 20 WAGs. This Environmental Data Package covers only the ORNL Services Area (WAG 17) and its eight identified SWMUs (Table 1).

1.2. Purpose of the Environmental Data Package

As currently implemented, the 3004(u) corrective action program consists of four phases: (1) a RCRA Facility Assessment (RFA) to identify releases or potential releases requiring further investigation, (2) a RCRA Facility Investigation (RFI) to fully characterize the extent of releases, (3) a Corrective Measures Study (CMS) to determine the need for and extent of remedial measures (this step includes the selection of appropriate remedies for all problems identified), and (4) Corrective Measures Implementation to design, construct, operate, maintain, and monitor the performance of the measures(s) selected (EPA 1986).

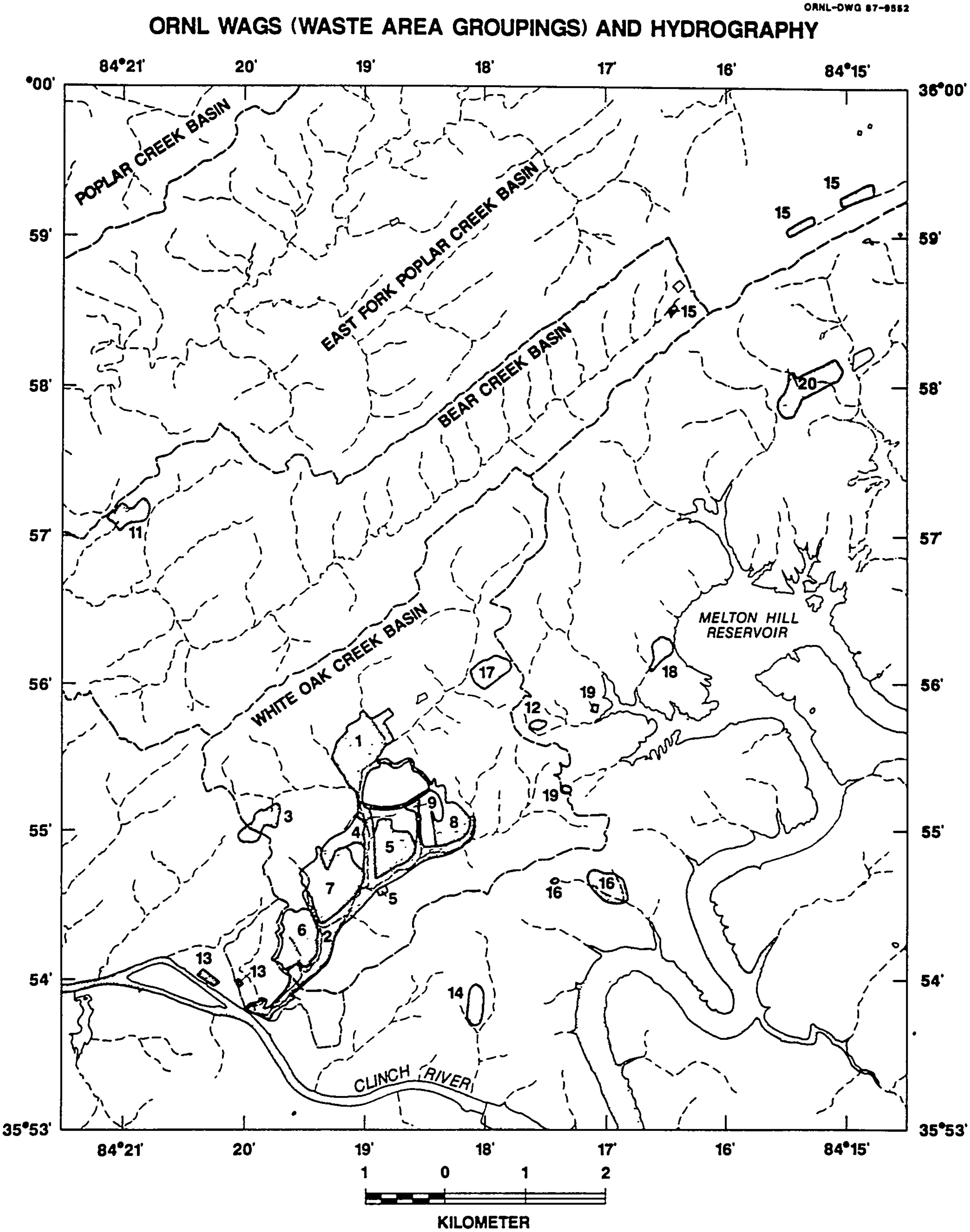

Fig. 1. Locations of the 20 Waste Area Groupings (WAGs).

Table 1. SWMUs located in ORNL services area (WAG 17)

17.1 Septic Tank (7000)

17.2 Waste Oil Storage Tanks

- a = 7002W
- b = 7009E
- c = 7075
- d = 7030E

17.3 Waste Oil Storage - Mobile Junk Truck

17.4 Photographic Reproduction Waste Storage Tanks

- a = 7075a
- b = 7075b

Based on information developed by ORNL as input to the RFA, it appears that the ORNL Services Area (WAG 17) represents a source of continuing release under 3004(u) and that a RFI will be required (ORNL 1987). The purpose of this environmental data package is to provide background information on the geology, hydrology, soils, and geochemistry of the WAG 17 area, as well as information on releases and inventories of hazardous materials for individual sites (SWMUs) within WAG 17 that will be required in the preparation of the RFI. Also identified are areas where it appears that additional information will be required.

1.3 Description of WAG 17

WAG 17, the ORNL Services Area, is located about 1 mile directly east of the ORNL Main Plant Area (Fig. 1). WAG 17 is the major craft and machine shop area for ORNL. The area encompassed by the WAG boundary is 33.9 acres. It includes the receiving and shipping departments, machine shops, carpenter shops, paint shops, lead burning facilities, garage facilities, welding facilities, material storage areas, etc., which are required to support ORNL's routine and experimental operations. These laboratory support facilities were originally located in the southwest corner of the Main Plant Area (WAG 1), but were moved in the late 1940s to their present location.

Eight SWMUs have been identified within the boundary of WAG 17 (Fig. 2 and Table 1). Of these, SWMU 17.1 is a former septic tank now used as a sewage collection/pumping station for the area, five SWMUs (17.2a, 17.2b, 17.2c, 17.2d, and 17.3) are tanks used for waste oil collection and storage (one of these is a tank truck), and the

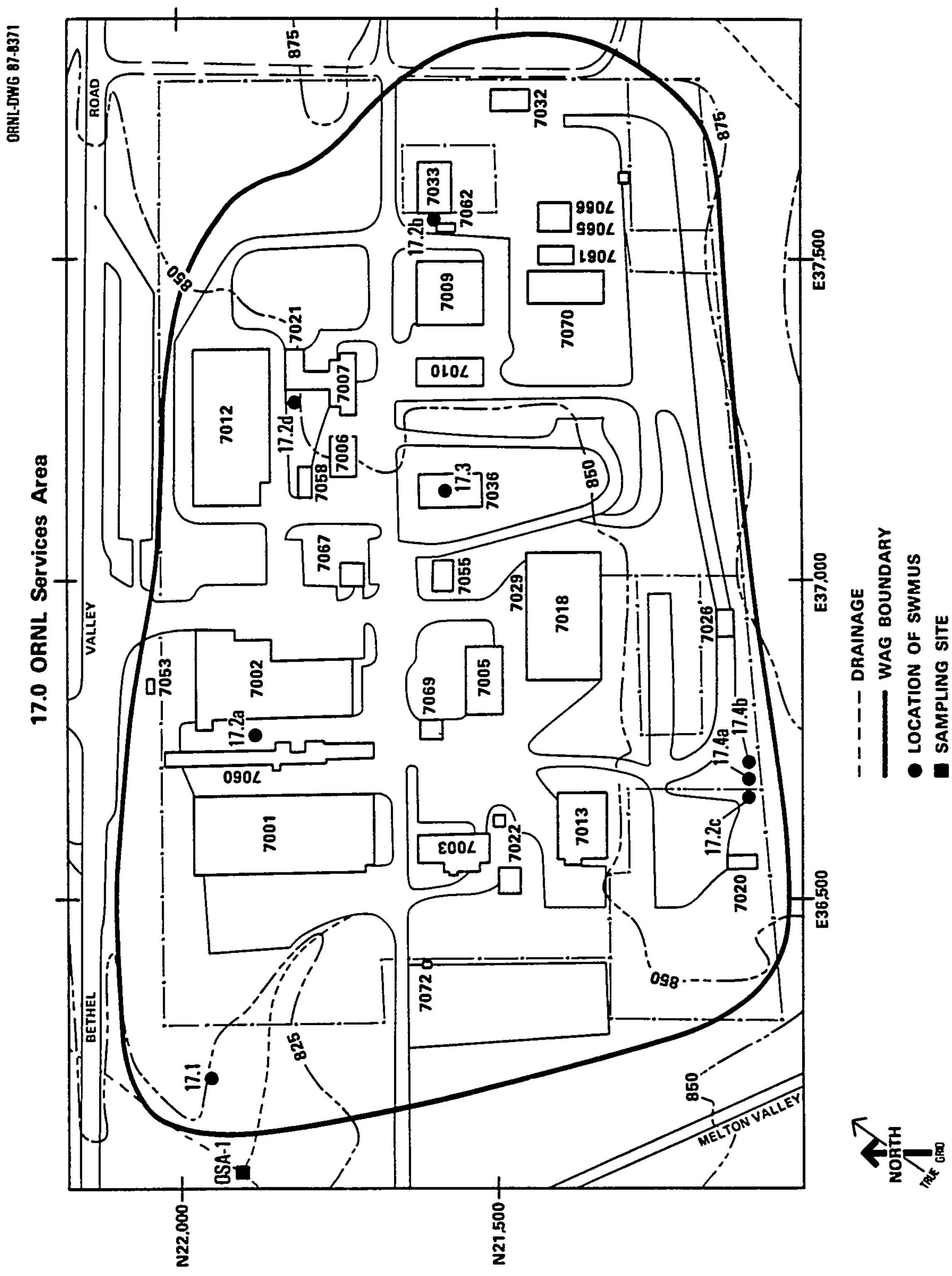

Fig. 2. WAG 17, ORNL Services area, showing locations of SWMUs.

Table 2. Engineering information on tanks in WAG 17

Tank	Contents	Coordinates N	Coordinates E	Capacity (Gal)	Construction	Installation	Secondary containment
SWMUs							
17.1	Domestic Sewage	21950	36230	39,000	Concrete	Underground	None
17.2a	Waste Oil	21800	36800	2,500	Steel	Aboveground	Drip Pan
17.2b	Waste Oil	21580	37560	5,000	Steel	Underground	None
17.2c	Waste Oil	21100	36680	4,200	Steel	Underground	None
17.2d	Waste Oil	21800	37300	480	Steel	Aboveground	Drip Pan
17.3	Waste Oil	21540	37140	1,100	Steel	Tank Truck	None
17.4a	Photographic Waste	21100	36700	3,000	Fiberglass	Aboveground	Diked
17.4b	Photographic Waste	21100	36700	2,000	Fiberglass	Aboveground	Diked
NON-SWMU TANKS[1]							
7012	Waste oil/soluble oil	SE Bldg. 7012		4,000	Steel	Aboveground	None
7069a	Diesel Fuel	E Bldg. 7069		8,500	Steel	Underground	None
7069b	Gasoline (Unleaded)	E Bldg. 7069		10,000	Steel	Underground	None
7069c	Gasoline (Regular)	NE Bldg. 7069		4,000	Steel	Underground	None
7069d[2]	Gasoline (Unleaded)	E Bldg. 7069		8,300	Steel	Underground	None

[1]Coordinates not available.

[2]Tank emptied and out of service.

remaining two SWMUs (17.4a and 17.4b) are tanks used for storage of photographic reproduction wastes.

The sewage pumping station services rest room facilities only, and should not represent a source of radioactive or hazardous chemical constituents. In the case of the oil storage tanks (two are underground and three aboveground), one of the underground tanks (SWMU 17.2c) is known to contain some radioactivity (tritium); the other tanks store waste oil from vehicle maintenance operations and cutting oils from machining operations. The two aboveground photographic waste tanks store wastes prior to transport to the silver recovery unit (SWMU 8.10 in WAG 8). No leaks or spills of oil or hazardous materials from any of the listed tanks have been reported. All of the aboveground tanks are installed on concrete pads with dikes or drip pans to contain leakage or spills; however, testing of these containment systems have indicated that leakage may still occur.

Location and engineering features of the identified SWMUs are given in Table 2. Also included in Table 2 are five storage tanks (four of which are underground) that are located in WAG 17. In preparation of the RFA (ORNL 1987), these five tanks were not considered to be solid waste management units under RCRA 3004(u); it is proposed that these tanks will be remediated (if required) under RCRA Subtitle I. They have been included in this data package in order to identify all potential sources of contaminant release in the WAG.

1.4 Known or Potential Releases from WAG 17

There are no reported releases of hazardous material or radionuclides from WAG 17 (ORNL 1987). However, since this area has been in use since the late 1940s, it can be assumed that some spills/leaks of waste oils or solvents have probably occurred since that time, but have not been documented. Morrison and Cerling (1987) established a sampling station (OSA-1) on the unnamed drainage from WAG 17 about 2 m upstream from its confluence with White Oak Creek (Fig. 2) as a part of the preliminary sampling survey for the RFA. Some of the stream gravel at this sampling site was coated with a black tarlike substance. At the time of sampling, flow in the drainage was about 3 gal/min. Samples of stream gravel, bank mud, and water were taken; also taken was a hand-picked sample of about 100 cc of the tar-covered pebbles from the stream bed.

According to Morrison and Cerling (1987), the stream gravels from WAG 17 had some of the highest Cd values found in the preliminary sampling survey (0.8 μg/g), and the concentrations of Cr, Cu, and Zn were above background levels. Triplicate gravel samples that were analyzed for radionuclides showed that ^{60}Co and ^{90}Sr were at background levels whereas the Cs-137 concentration was elevated in one sample (triplicate samples); however, ^{137}Cs, ^{60}Co, ^{90}Sr, and ^{3}H were below detection limits in the water samples (Table 3). This indicates that the radioactivity detected on the stream gravels probably was released at some time in the past, if indeed a release has occurred.

The mud and gravel samples indicated contamination by semivolatile organic compounds. The organics are visible as tarlike grain coatings in the stream. Elevated concentrations of 11 organic substances were detected in the hand-picked, tarlike coated gravel sample (Table 4).

Morrison and Cerling (1987) summarized their findings by concluding that Cd and organic contamination exists at the site. Cr, Cu, and Zn concentrations were also reported to be above the average values noted

Table 3. Preliminary sampling survey results for WAG 17

Element	BKGD	OSA-1
Gravels[a]		
^{60}Co[b]	<2	<5
^{90}Sr[b]	<10	8.8 ± 7.1
^{137}Cs[b]	3	30.5 ± 38.5
Cd[c]	0.05	0.8 ± 0.1
Cr[c]	0.4	2.6 ± 0.2
Cu[c]	0.2	2.6 ± 1.6
Ni[c]	0.9	d
Zn[c]	3.6	47 ± 11
Water (Bq/L)		
^{60}Co	<0.2	<0.3
^{90}Sr	<0.2	0.1
^{137}Cs	<0.2	<0.3
^{3}H	<30	<30

[a]Concentrations reported on basis of wet weight of gravel sample. Radionuclides in Bq/kg. Metals in μg/g.

[b]Backgrounds estimated for counting procedure used in this study.

[c]Backgrounds estimated from several uncontaminated samples.

[d]Not detected.

Source: Morrison and Cerling 1987.

Table 4. Organics from mud and gravel at WAG 17 in 1986 ($\mu g/kg$)[a]

EPA code	Organic compound	Mud[b]	Gravel[c]
26B	Di-n-butylphthalate	d	d
44B	Phenanthrene	d	120,000
03B	Anthracene	d	12,000
31B	Fluoranthene	d	87,000
45B	Pyrene	d	109,000
05B	Benzo(a)anthracene	d	36,000
18B	Chrysene	d	42,000
07B	Benzo(b)fluoranthene	d	24,000
09B	Benzo(k)fluoranthene	d	30,000
06B	Benzo(a)pyrene	d	21,000
37B	Indeno(1,2,3-cd)pyrene	d	24,000
08B	Benzo(g,h,i)perylene	d	24,000
13B	Bis(2-ethylhexyl)phthalate	d	d
15B	Butylbenzylphthalate	d	d

[a]Wet weight.
[b]Black mud, one sample.
[c]Gravel sample with black tarry coatings, one sample.
[d]Not detected.

Source: Morrison and Cerling 1987.

in the preliminary sampling survey. No radionuclide contamination was observed, with the exception of one anomalous value for ^{137}Cs (75 Bq/kg).

On the basis of the preliminary sampling results, the RFA (ORNL 1987) recommended that an RI plan be developed to determine the extent of remedial action required for WAG 17. This data package provides background information required to develop the RI plan.

In 1986, it was discovered that one of the underground unleaded gasoline storage tanks was leaking (Wiltshire 1986). This tank is designated as non-SWMU tank 7069d in Table 2. The tank has been drained and capped. It is estimated that as much as 800 gallons of gasoline may have leaked. An Assessment Plan was prepared for the leak site and three piezometer wells were installed to measure depth to water at the site. A soil sampling program was also initiated to define the extent of contamination (Wiltshire 1986). Results to date have not identified the presence of total benzene, toluene, and xylene (BTM) in excess of the action level for soils of 10 ppm (Rohwer 1987). Water samples taken from the piezometer wells indicate benzene in excess of the 5 ppb action level.

2.0 CURRENT STATUS OF INFORMATION ON WAG 17

2.1 Source Terms

Information on the capacity and contents of the SWMUs and Non-SWMUs in WAG 17 is given in Table 2. Sampling of tank contents has not been conducted, with the exception of one sample taken from SWMU 17.2c. Radiochemical analysis of this sample showed the presence of ^3H ($5.5 \pm 0.9 \times 10^3$ Bq/L).

2.2 Geology

WAG 17 is located in the outcrop area of the Chickamauga Limestone of Middle Ordovician age (McMaster 1962). This WAG is northeast of the detailed geologic map prepared by H. J. Klepser (Stockdale 1951), but a projection indicates that the outcrops probably include units E, F, and G. These units, from youngest to oldest, were described (Stockdale 1951, p. 22-23) as follows:

Unit	Description	Thickness (ft)
G	Limestone, dark gray to brownish gray, with black clay partings between beds. Weathers to a shaley or nodular appearance.	300
F	Siltstone, calcareous, and shale; olive gray to maroon; laminated. Weathers to a red shaley appearance.	25
E	Limestone to argillaceous limestone and calcareous shale; massively bedded with shale partings; gray to buff or pinkish. Some layers have mottled appearance.	380

The rocks strike about N50°E to N57°E and dip to the southeast at angles of 25-45°. Small faults, small folds, and flexures may occur in the area but have not been mapped.

Logs prepared by geologists with MCI Consulting Engineers, Inc. during the drilling of 25 piezometer wells (Fig. 3) show that the regolith in the WAG 17 area is 4-26 ft thick and generally consists of maroon to brown clay and silty clay. Thin layers of limestone fragments mixed with clay are common in the regolith; the fragments generally are gravel size, but cobble and boulder sizes also occur. Locations where the regolith is more than about 15-ft thick include an interval of weathered shale to highly weathered shale or clay above the top of bedrock. The logs describe bedrock as generally consisting of olive gray, fine-grained limestone in which some layers are greenish gray or medium to dark gray. Locally, the limestone is pyritic or contains calcite-filled fractures and vugs. The limestone beds are massive and generally are separated by shale partings. Some logs describe layers of dark gray shale up to 16 ft thick. The shale beds cannot be traced from well to well and probably are lenses with a limited lateral extent. These shale lenses probably account for saprolite layers in areas where the regolith is thickest.

A probability plot of regolith thickness for 233 piezometer wells near ORNL (Fig. 4) shows that these values represent a single log-normally distributed population in which the geometric mean thickness is 10 ft, the thickness of the mean minus one standard deviation is 5.2 ft, and the thickness of the mean plus one standard deviation is 19 ft (Moore et al. 1987, pp. 38-57). In the WAG 17 area, 65% of the wells have a regolith thickness within one standard deviation of the mean of

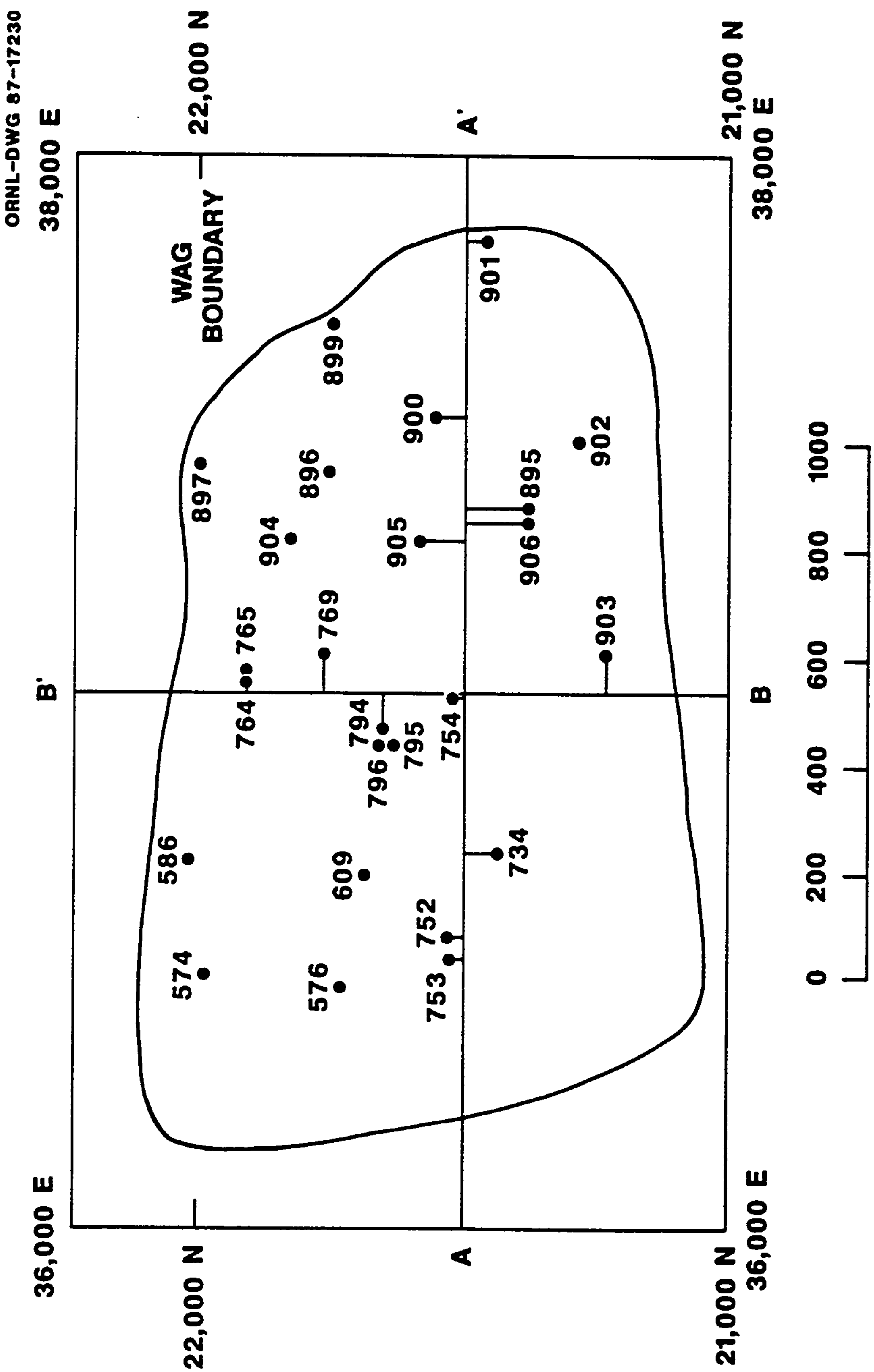

Fig. 3. Locations of piezometer wells and lines of section.

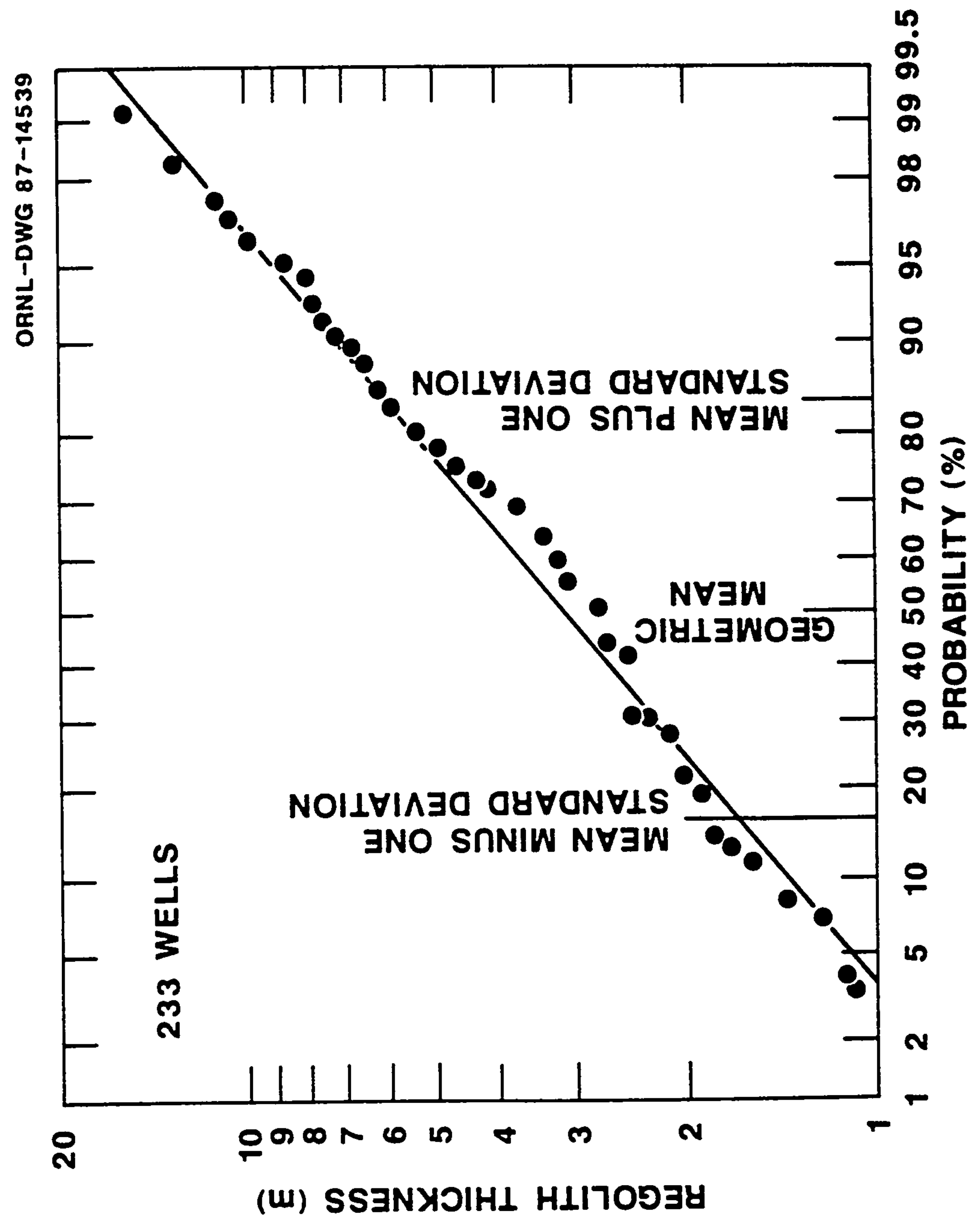

Fig. 4. Cumulative probability graph of regolith thickness in wells.

all wells, 22% have a thinner regolith, and 13% have a thicker regolith. These results are in general agreement with the statistical distribution for the population; the distribution can thus be used to predict the probability of any regolith thickness at other locations in the WAG. Cross sections of the WAG 17 area (Figs. 5 and 6) show that the regolith has a similar thickness in nearby wells and is thicker in some parts of the WAG than in others.

A cavity was reported in one piezometer well (well No. 906) at a depth of 12-26 ft. The driller described the cavity as filled with clay and stated that "drilling was stopped because the ground swelled, and a small blowout was seen 12 ft from the hole." Other cavities may occur in the WAG 17 area, but probably are uncommon.

2.3 Hydrology

2.3.1 General Hydrology

Mean annual precipitation in the period 1954-1983 was 52.2 in. for stations near ORNL; the minimum and maximum amounts in this same period were 35.3 and 74.8 in. of water (Webster and Bradley, in press, p. 14). The 1986 water year was unusually dry, and only 34.5 in. of precipitation were recorded by U.S. Geological Survey at a station in WAG 5. The wettest months generally are January through March, and the driest months are August through October; in these periods, mean monthly precipitation at the Oak Ridge Station of the National Oceanic and Atmospheric Administration is 5.3-6.2 in. and 2.9-3.8 in., respectively. The monthly extremes for the Oak Ridge station are 13.3 in. for January 1954 and 0.5 in. for August 1953 (National Oceanic and Atmospheric Administration, 1974, p. 378). In the dry 1986 water year, only 0.9 in.

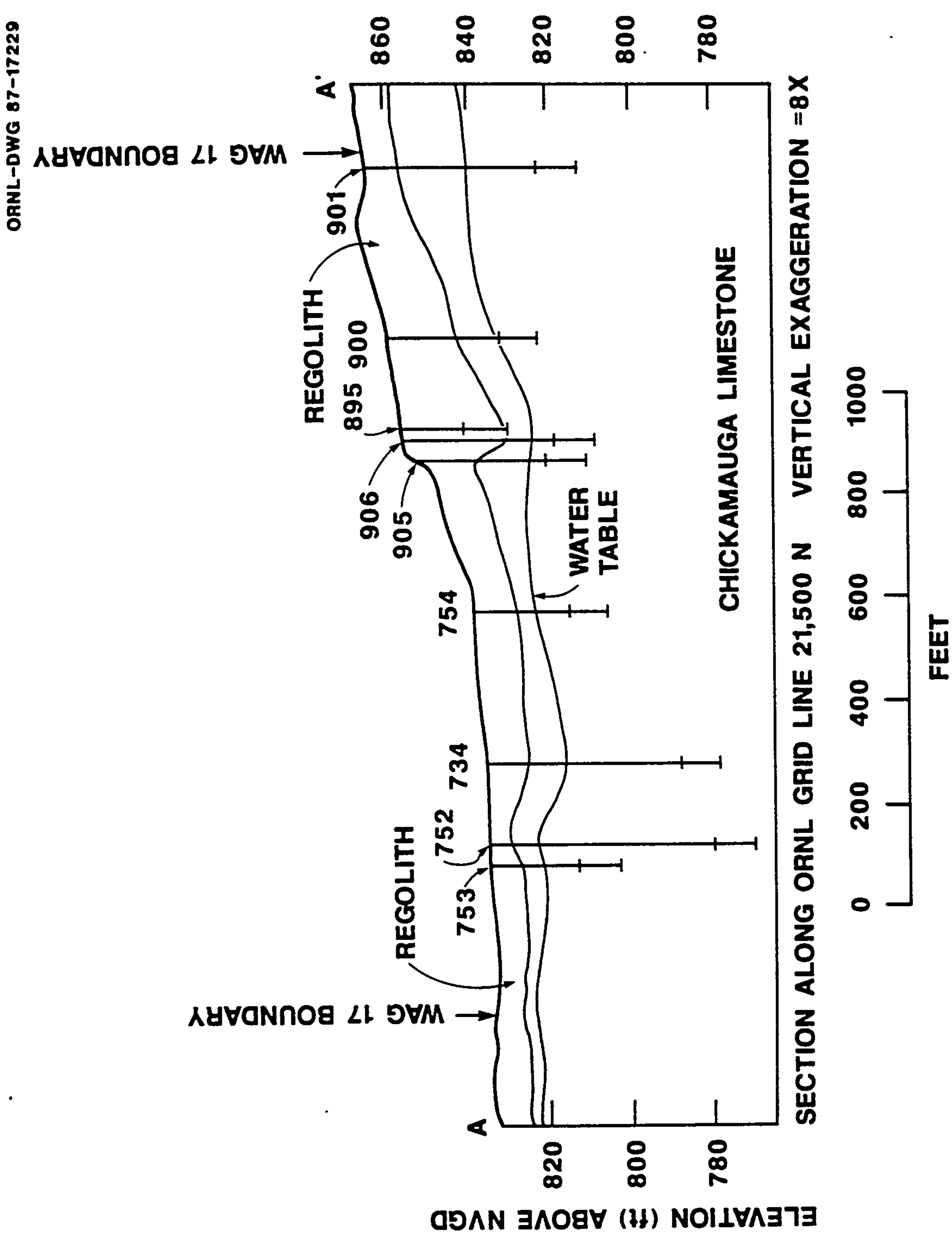

Fig. 5. Section A-A'. WAG 17 sections showing well depths, screen intervals, regolith thickness, and water table depths.

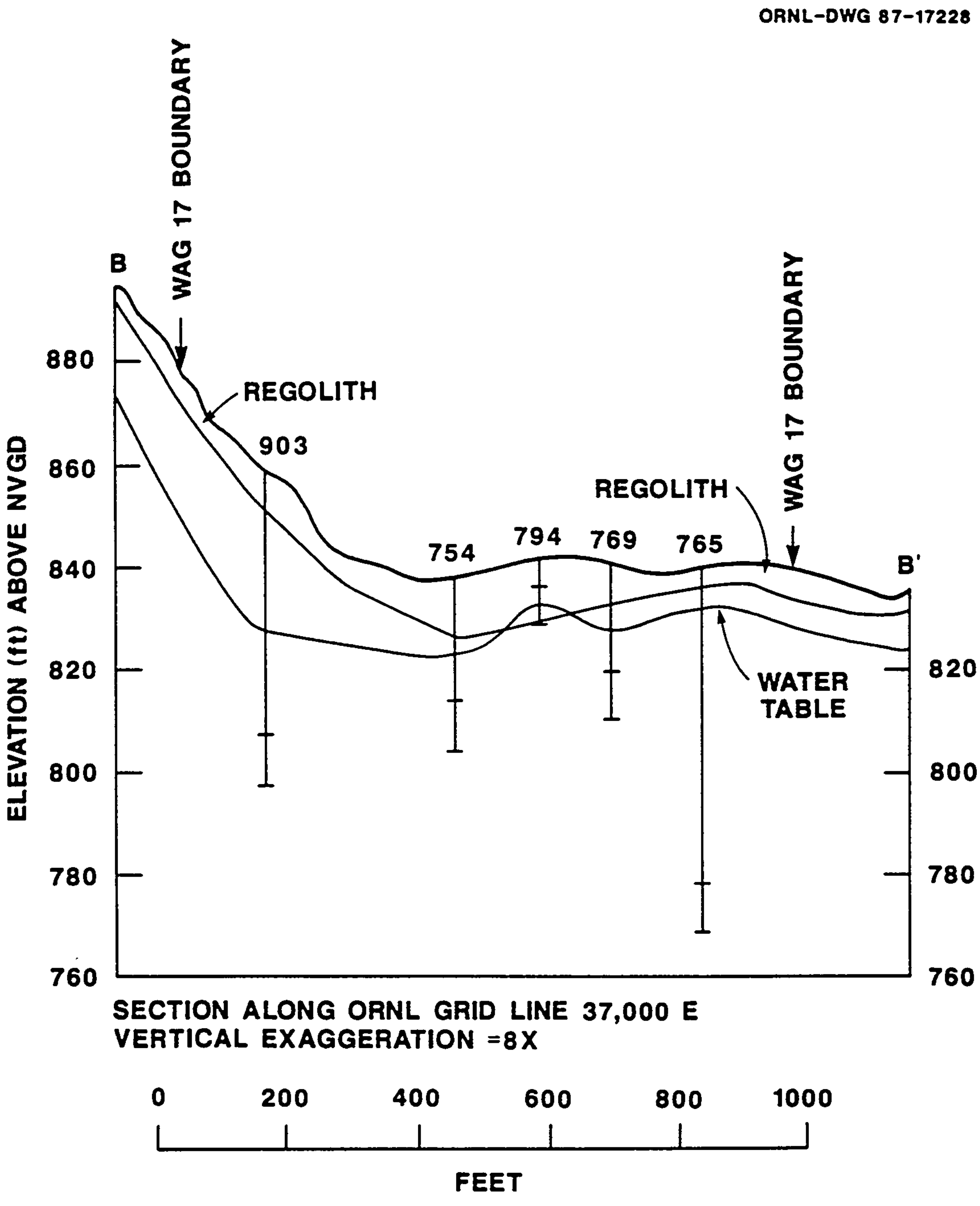

Fig. 6. Section B-B'. WAG 17 sections showing well depths, screen intervals, regolith thickness, and water table depths.

of precipitation was measured in SWSA 5 during January, and 3 months (December, April, and June) had less than 2.0 in. of precipitation. The average frequencies of occurrence for various precipitation intensities over periods of 30 min. to 24 hrs are presented in McMaster (1967, Fig. 5).

Droughts lasting 7 days occur about 17% of the time, but droughts lasting 15 days occur, on an average, only 1.8% of the time (McMaster 1967, Fig. 7). In the dry 1986 water year, the longest droughts at the SWSA 5 station were 18 days in January, 15 days in April-May, 15 days in June, and 17 days in July.

The mean annual runoff for streams in the ORNL area is 22.3 in. of water (McMaster 1967, p. 9). The remainder of the mean annual precipitation, about 30 in. of water, is consumed by evapotranspiration. Based on pan evaporation measurements at Norris, Tennessee, about 75% (22.5 in. of water) of the evapotranspiration occurs during a 6-month period from April through September (Tennessee Division of Water Resources 1961, p. 18). The growing season, when potential evapotranspiration is highest, averages 220 days, from April 1 to November 5 (National Oceanic and Atmospheric Administration 1974, p. 373). A water-balance graph for Rogersville, Tennessee, shows that potential evapotranspiration exceeds precipitation for 5 months, from May through September, and that the main period for replenishment of the soil moisture deficit is October 1 to November 10 (Tennessee Division of Water Resources 1961, Fig. 6).

Streamflow and runoff depend upon amounts and changes in precipitation, evapotranspiration, and groundwater storage. Average quarterly runoff from the Oak Ridge area (McMaster 1967, p. 10), as a percentage of mean annual runoff, is shown below.

Quarter	Percentage of annual runoff
Oct.-Dec.	17
Jan.-March	49
Apr.-June	23
July-Sept.	11

A comparison of seasonal differences in precipitation and runoff shows that about 5 in. of water represent both the increase of evapotranspiration in the summer months over that in the winter months and the decrease in groundwater storage during the summer and fall.

The WAG 17 area is about 50% impervious because of parking lots, roads, and buildings; storm sewers carry runoff from the impervious areas to White Oak Creek. The other 50% of this WAG is covered by grass, which is mowed during the growing season. The grass areas are relatively flat, but some overland flow onto paved areas probably occurs during intense storms. An exact water budget for WAG 17 cannot be determined, but an estimated budget can be based on conditions in the area and on parameters measured in nearby areas, as follows.

		Inches
INFLOW		
Mean annual precipitation		52
Total inflow		52
OUTFLOW		
Streamflow		34
Overland flow (storm sewers)	28	
Base flow (discharge from aquifers)	6	
Evapotranspiration		18
Total outflow		52

This budget assumes no interchange of water between storm sewers and the aquifer, no leakage from other pipes, and no control of water table fluctuations by permeable fill materials.

2.3.2 Infiltration and Groundwater Recharge

The processes that produce aquifer recharge are precipitation, infiltration, and percolation. The infiltration capacity of grass areas like those in WAG 17 has not been measured in the ORNL area. Tests in forested areas under saturated soil conditions (Watson and Luxmoore 1986; Wilson and Luxmoore, in press) have shown a typical infiltration capacity of about 12 in./hr. Other tests have shown typical infiltration capacities of about 0.021 in./hr for undisturbed C-horizon soils and 0.15 in./hr for trench-fill materials (Luxmoore et al. 1981, p. 688; Davis et al. 1984, p. 72). The grass areas in WAG 17 consist partly of fill materials; infiltration capacity is probably in the range 0.2-2 in./hr.

Very little infiltration occurs as intergranular flow. The porosity of clay soils is generally about 50%. However, Watson and Luxmoore (1986, p. 581) found that macropores and mesopores, which together occupy only 0.2% of the soil volume, account for 96% of the infiltration. Macropores and mesopores are not completely understood but are connected voids that may have various causes, including biochanneling, cracking, and aggregation of soil particles. The significance of this effect is that there is much less filtering of any contaminants than would be assumed by only a consideration of regolith thickness and depth to water table.

Percolation is generally vertical from land surface to the water table, but changes in the permeability of the flow tubes occur at every level. Flow paths thus are complex and may be tortuous in detail with numerous splits and joins. Locally, lateral movement in one direction may dominate at one level whereas vertical movement or lateral movement in other directions may dominate at other levels. Local flow directions may also change through time as infiltration ends and as flow conditions slowly change from saturated to unsaturated. Some percolating water reaches the water table and recharges the aquifers. The remainder is discharged at wet-weather seeps and springs.

A majority of all aquifer recharge occurs during the nongrowing season and soon thereafter, from about November 5 to April 30. During periods of intense precipitation in the growing season, some recharge reaches the water table, and water levels in many wells rise or show a slower rate of decline for a few days. However, the water levels in all wells decline, although at a variable rate, throughout the growing season because most precipitation is captured by vegetation in this period of time.

Cumulative probability plots of October depth to water (Fig. 7) and seasonal water level change (Fig. 8) for all wells near ORNL show that these parameters are log-normally distributed populations. The geometric mean depth to water is 14 ft, and the two standard deviation range in water depths is 6.6-30 ft. The geometric mean amount of seasonal change in water level in wells is 3.9 ft; the two standard deviation range is 2.0-8.2 ft. In the WAG 17 area, water level depths and seasonal changes in water level approximately fit the statistical distributions of the populations: 75% of the depths to water in

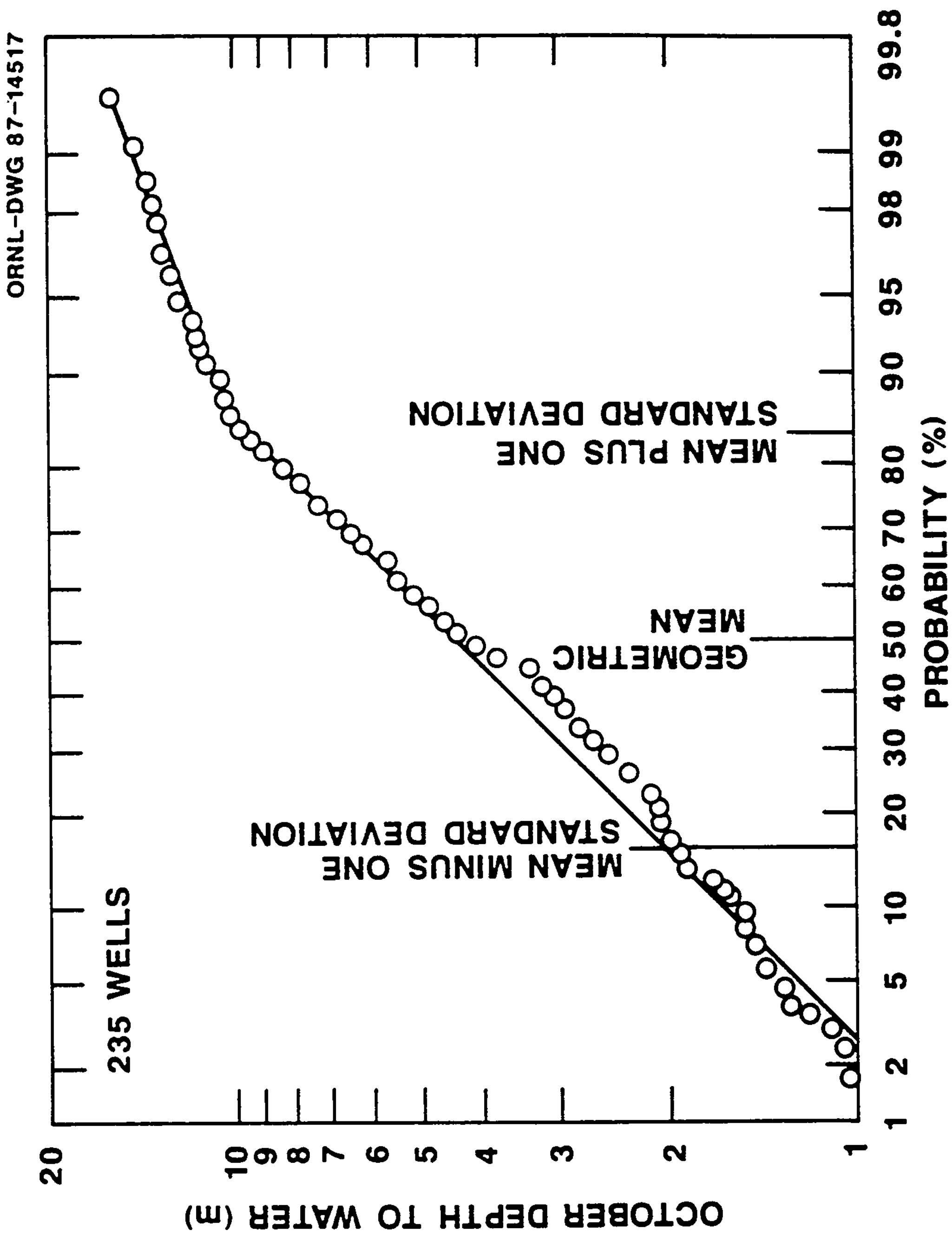

Fig. 7. Cumulative probability graph of depth to water in observation wells during October 1986.

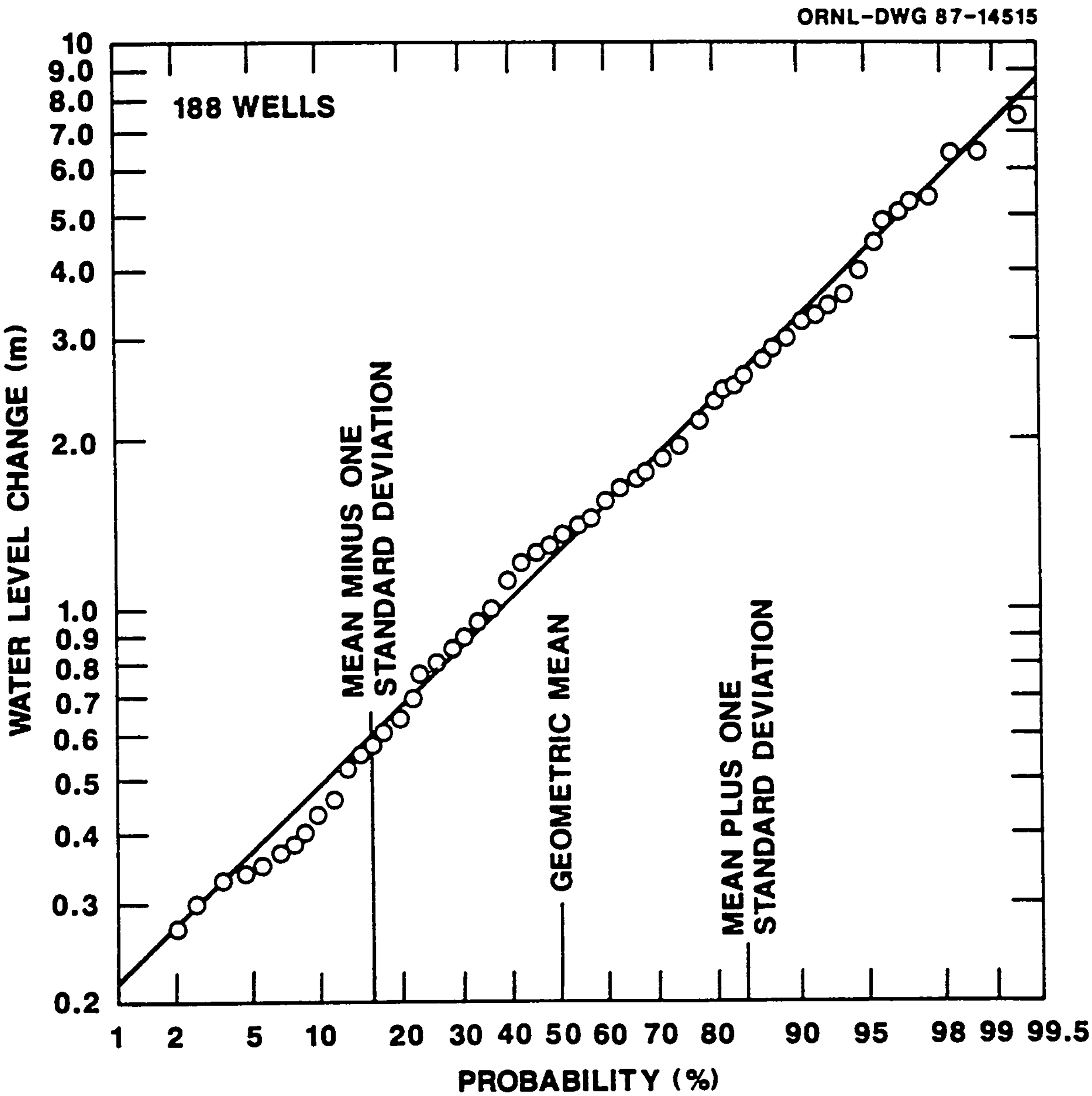

Fig. 8. Cumulative probability graph of seasonal water level changes in wells.

September-October and 74% of the amounts of seasonal water level change are within one standard deviation of the means. The statistical distributions can thus be used to predict the probability of these parameters at other locations in the WAG.

2.3.3 Groundwater Occurrence

The chemical characteristics of groundwater and of the aquifer affect the mobility of many contaminants. Thus, it is important that the water table in WAG 17 (Fig. 9) is generally below the top of bedrock (Figs. 5 and 6). The regolith is acidic (pH 4.0-5.5) and contains little calcium carbonate and other soluble minerals (Davis et al. 1984, p. 45-49); water in contact with only this material would have similar characteristics. Water samples have not been collected from wells in WAG 17, but virtually all groundwater from other shallow wells near ORNL and all water from streams during periods of base flow is a nearly neutral to moderately alkaline (pH 6.5-8.1), calcium-bicarbonate type (Stockdale 1951, p. 79; Webster and Bradley, in press, Table 8). These chemical characteristics show that groundwater from shallow wells and streams has had contact with limy layers in the bedrock.

In bedrock, essentially all groundwater occurs in fractures and in a few larger cavities because the rocks have almost no primary porosity and permeability. The fractures consist of joints and faults that formed in the geologic past by extension, compression, and shear of the rocks. These processes created a large number of both isolated and interconnected fractures with a large range in aperture (gap width). Most individual fractures are short, a few inches to several feet in length, but various joint sets form intersecting systems (Sledz and

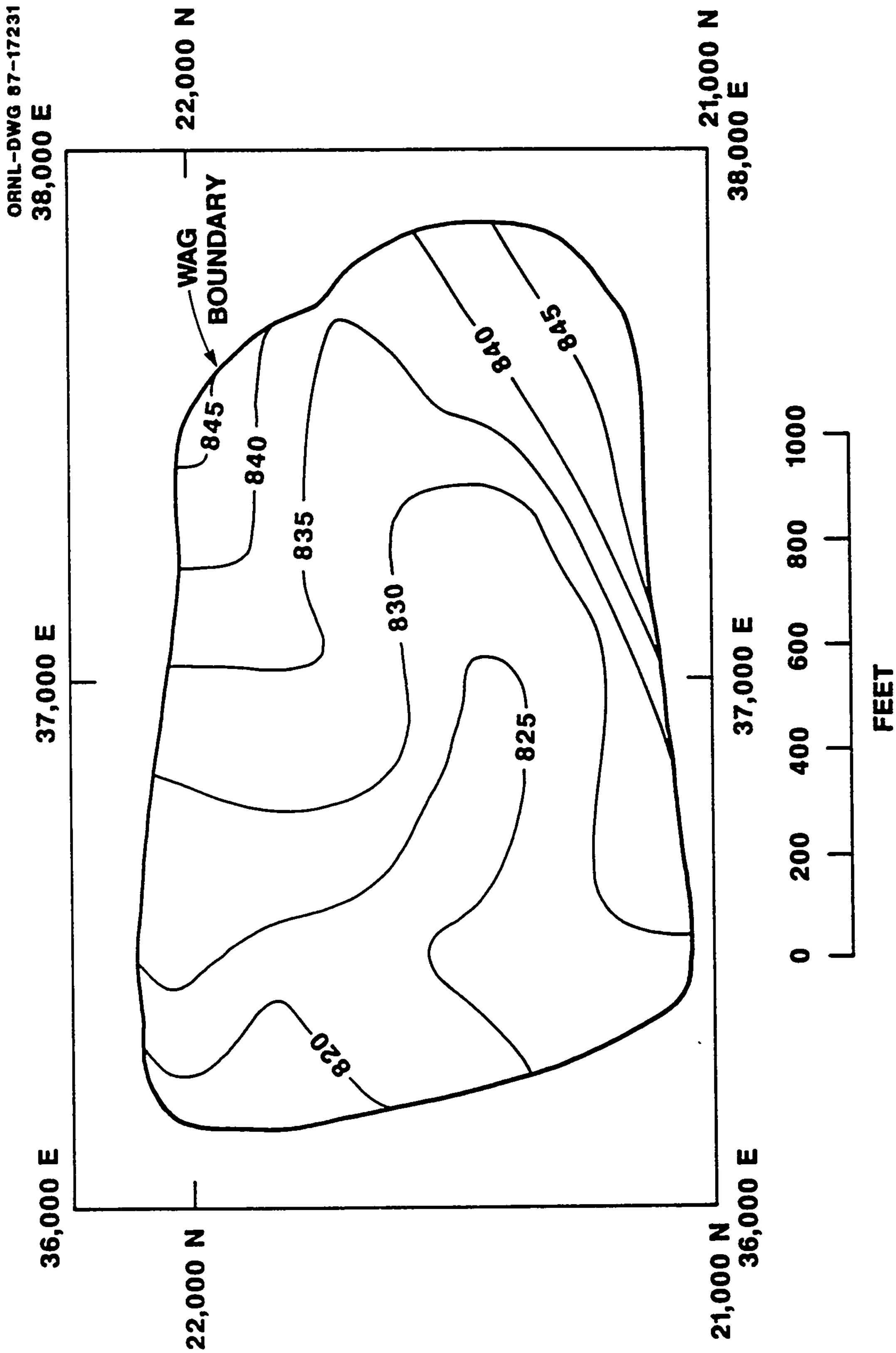

Fig. 9. Configuration of the water table in late September, 1987.

Huff 1981). One pervasive fracture set, noted by many authors, is oriented parallel to the bedding planes. The separate fractures in this set most commonly occur in the partings between rock layers in the Chickamauga Limestone (R. H. Ketelle, personal communication). A less common, orthogonal fracture set is parallel to the dip of the beds. These two fracture sets may be presumed to occur in the WAG 17 area, and other sets may also be present.

Through geologic time, the deposition of minerals dissolved from adjacent rocks sealed some open fractures, but differential earth movements and slow groundwater seepage opened, extended, and enlarged other fractures. Thus, new flow paths were progressively opened at deeper levels while shallow flow paths were removed by erosion, altered by weathering, or captured by the newer routes. The configuration and extent of the fracture flow system in WAG 17 is a result of these processes.

Cavities formed by solution and abrasion may occur wherever there are limy beds in the aquifers. Solution cavities in the Chickamauga Limestone were first described by Stockdale (1951, p. 41). However, only the smallest enlarged openings are true solution cavities; most authors (Moore 1973, for example) agree that larger openings are formed mainly by the more effective process of physical erosion, which accompanies turbulent groundwater flows. In WAG 17, one filled cavity was reported by the driller in well No. 906 at a depth of 12-26 ft. If piezometer well records are representative of subsurface conditions in the WAG, then easily recognized cavities (those larger than about 0.5 ft) are rare. One 14-ft opening in 776 ft of rock drilling is equivalent to a vertical spatial frequency of 0.018; thus, the chance of a 1-ft cavity in any 10 ft of well bore below the top of rock is 18%. Nevertheless, only a few large, open cavities might transmit relatively large quantities of groundwater. The importance of cavities in WAG 17 and in other areas near ORNL is not completely understood at present.

A probability plot of well depths (Fig. 10) shows that this parameter is log-normally distributed near ORNL. The geometric mean depth is 23 ft, and the two standard deviation range is 11-48 ft. In the WAG 17 area, 61% of the wells have depths within one standard deviation of the population mean: 13% are shallower; and 26% are deeper. All wells were drilled to a level that was thought to be water producing. The probability graph thus may adequately represent the distribution of water-producing zones with depth in the WAG area. Another analysis of the well data shows that four piezometer wells in WAG 17 are screened in the regolith, just above the top of bedrock; ten wells obtain water from fractures in the upper 25 ft of the rock; and another ten wells were drilled an average of 57 ft into bedrock before intersecting water-bearing fractures.

Hydraulic conductivity, transmissivity, and aquifer thickness values (Table 5) were obtained by analysis of data from slug tests on piezometer wells in WAG 17. Probability plots of hydraulic conductivity and transmissivity in other areas (Figs. 11 and 12) show that the populations are log-normally distributed. The geometric mean hydraulic conductivity is 0.13 ft/day, and the two standard deviation range is 0.023-0.72 ft/day. The geometric mean transmissivity is 1.6 ft^2/day and the two standard deviation range is 0.27-9.7 ft^2/day. More wells in the WAG 17 area have low values of hydraulic conductivity and transmissivity than in the other populations: 29% of the WAG 17 wells have a hydraulic conductivity and a transmissivity less than the mean minus

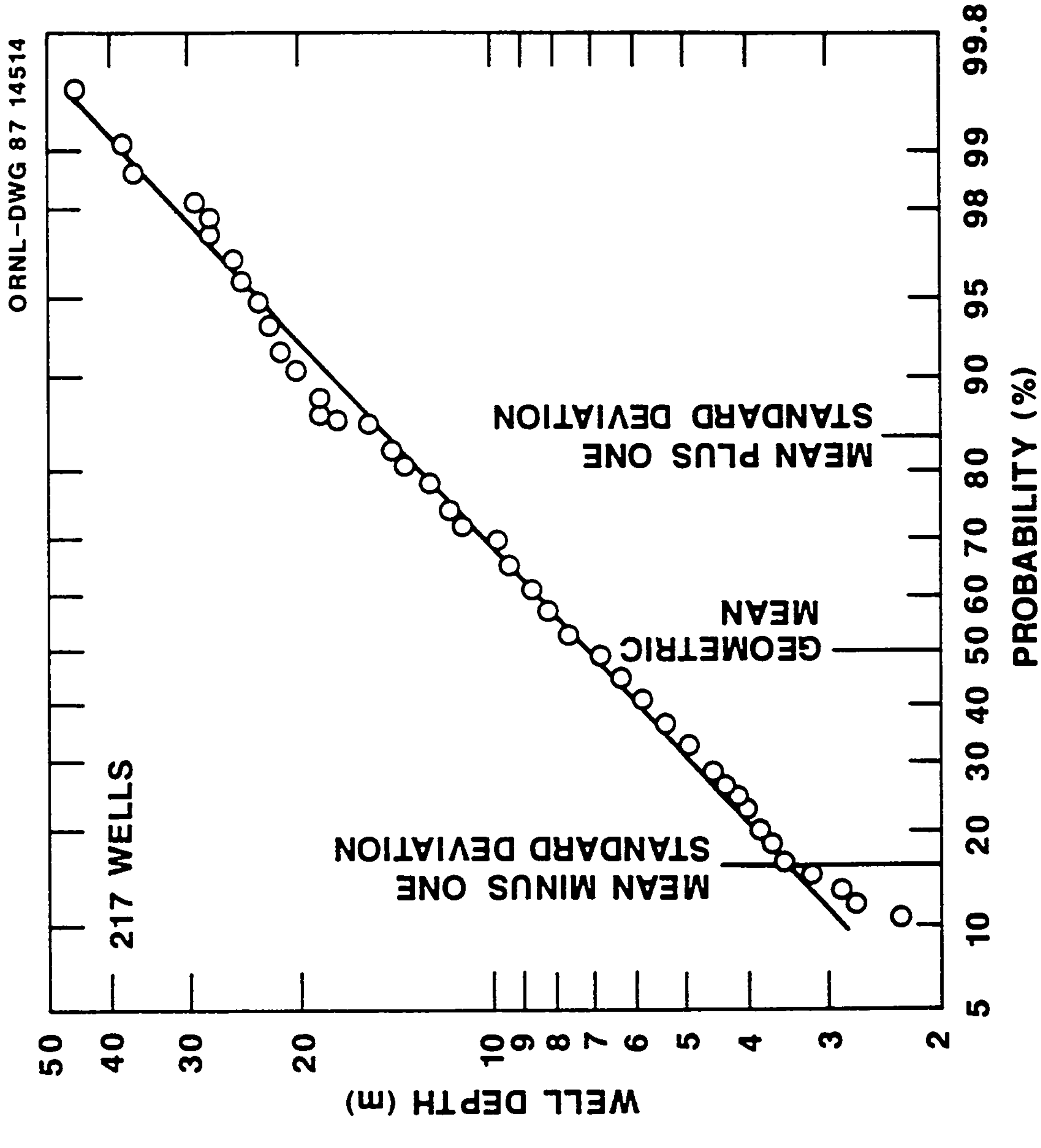

Fig. 10. Cumulative probability graph of piezometer well depths.

Table 5. Results of slug tests on piezometer wells in WAG 17.

Well No.	Hydraulic Conductivity (m/d)	Transmissivity (m^2/d)	Aquifer Thickness (m)
574	0.021	0.16	7.6
586	--	0.019	--
609	0.027	0.12	4.4
734	0.20	0.93	4.6
752	0.57	5.4	9.5
753	0.0013	0.0037	2.8
754	0.049	0.23	4.7
764	0.031	0.24	7.7
765	0.023	0.069	3.0
769	0.037	0.18	4.9
794	0.0001[a]	0.0005[a]	--
795	0.0069	0.011	1.6
796	0.59	1.2	2.0
895	0.0048	0.0055	1.1
896	0.0016	0.0064	4.0
897	0.030	0.17	5.7
899	0.023	0.11	4.8
900	0.036	0.21	5.8
901	0.0093	0.032	3.4
902	0.0029	0.026	9.0
903	0.032	0.19	5.9
904	0.64	3.1	4.8
905	0.22	0.96	4.4
906	0.00056	0.0028	5.0
Geometric mean	0.020	0.081	4.3

[a]Data value near zero and too small for accurate determination.

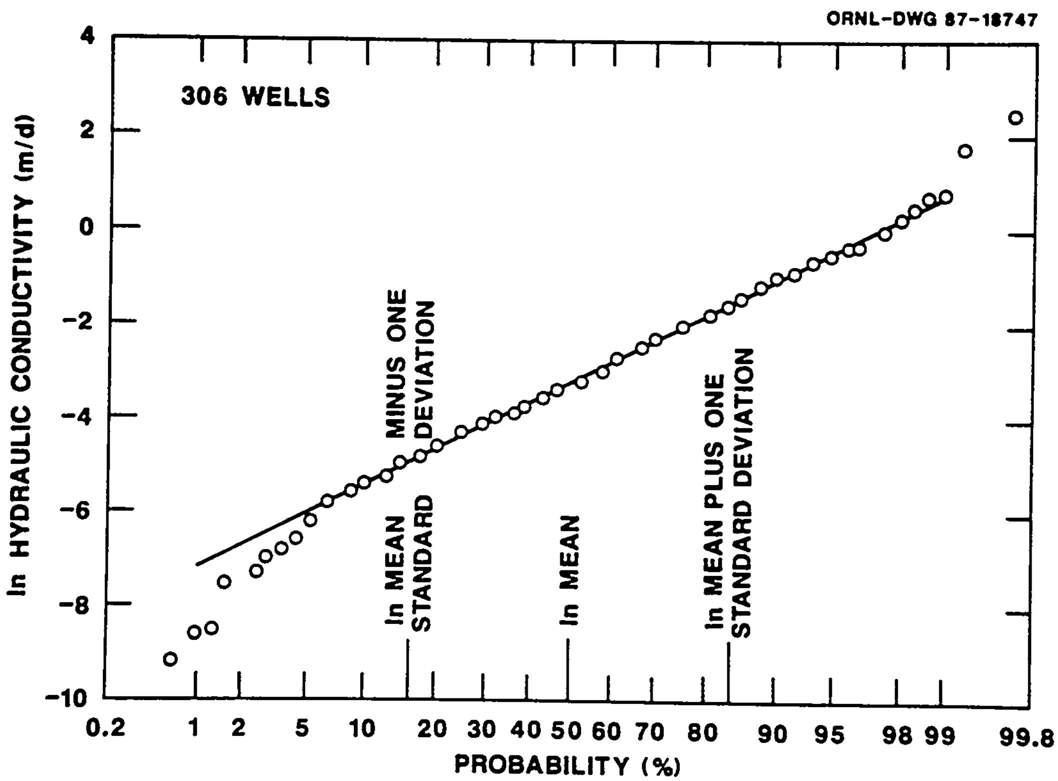

Fig. 11. Cumulative probability graph of hydraulic conductivity values from slug tests.

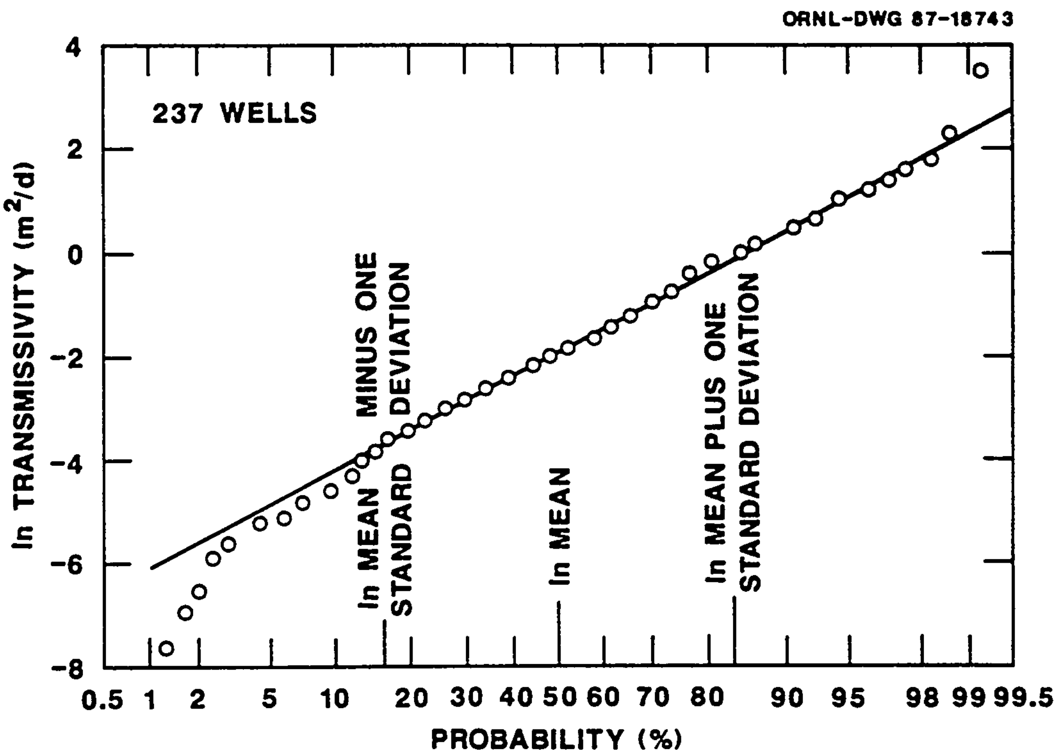

Fig. 12. Cumulative probability graph of transmissivity values from slug tests.

one standard deviation.

The slug test results show that water-producing fractures are very common in WAG 17, as in other areas near ORNL. Only one well (No. 794) did not have a measurable response to the slug after a period of 20 minutes; even this well intercepts a tight water-bearing fracture because the water level elevation is similar to those in nearby wells. Thus, if the piezometer wells are representative of the subsurface distribution of fractures in the WAG, all wells will intercept a water-bearing fracture at a depth of 70 ft or less. Other calculations show that only two wells, or 8%, will produce more than 1 gal/min of water; thus, amounts of water adequate for domestic use are rare in the WAG as in other areas near ORNL.

Piezometer wells generally were drilled to the shallowest level where an inflow of water from the aquifer was detected. Thus, the permeability of deeper levels in the aquifers has not been tested in WAG 17. However, the analysis of hydraulic conductivity values in other areas from packer tests in deep core holes shows a statistically significant decrease in aquifer permeability below a depth of about 65-100 ft. The geometric mean hydraulic conductivity below this level is 0.0021 ft/day, and the two standard deviation range is 0.00011-0.039 ft/day. Conditions in WAG 17 are probably similar.

There is no apparent spatial correlation for values of hydraulic conductivity and transmissivity in WAG 17. Even the closest wells (10-30 ft) commonly have hydraulic conductivities that differ by an order of magnitude or more. This same condition was observed during infiltration studies elsewhere near ORNL; Luxmoore et al. (1981, p. 690) found no spatial correlation for infiltration tests with a 6-ft spacing.

2.3.4 Aquifer Water Storage

Various previous studies have estimated the storativity (coefficient of storage) of aquifers near ORNL. In fractured rock, storativity is approximately equal to the porosity of the aquifer (the volume of open fractures in a unit volume of rock). Webster and Bradley (in press, p. 71, 95-96) estimated storativity of the aquifers at 1×10^{-2} to 1×10^{-5} based on slug test data for about 40 shallow wells and on pumping test data for several deeper wells. Recent slug tests on 150 piezometer wells near ORNL suggest that the range in storativity is 1×10^{-2} to 1×10^{-6}, but that the mean may be about 1×10^{-4}. More accurate measurements were made by Smith and Vaughan (1985, p. 141, 144), using two aquifer tests and the data from six observation wells in each test; they obtained geometric mean values for aquifer storativity of 1×10^{-3} and 4×10^{-3}.

Another approach to the estimation of aquifer storativity can be made by use of a lumped-parameter model. Viscous flow through open fractures is similar to flow between parallel plates in a Hele-Shaw model. The Navier-Stokes equation for laminar flow in a Hele-Shaw model is:

$$T = gb^3/12v,$$

where T is aquifer transmissivity (ft^2/sec), g is acceleration of gravity (32.2 ft/sec^2), b is aperture (ft), and v is kinematic viscosity of water (1.21×10^{-5} ft^2/sec at 60°F). Since the geometric mean transmissivity for aquifers near ORNL is 1.9×10^{-5} ft^2/sec, the aperture of the fracture that supplies water to a hypothetical average well is 4.4×10^{-4} ft or 0.0052 in. The average piezometer well has a well-bore diameter of 0.54 ft and a depth of 23 ft, including 10 ft of regolith; the mean volume of rock represented by the well bore is 3.0 ft^3. One dimension of the fracture volume is aquifer thickness (calculated geometric mean = 13 ft), the second dimension is well-bore diameter, and the third dimension is aperture. Mean fracture volume in the space represented by the well bore thus is 0.0031 ft^3. The ratio of these volumes shows that the average porosity (and aquifer storativity) of the uppermost part of the rock is 0.0010.

The porosity of 0.10% calculated from the lumped-parameter model is reasonably close to the average porosity of 0.25% determined by Smith and Vaughan. It is probably also significant that these values are approximately the same as the 0.21% volume of macropores and mesopores calculated from soil infiltration tests (Watson and Luxmoore 1986, p. 581).

If porosity is 0.0015, then the upper 10 ft of aquifer in the WAG 17 area stores 0.18 in. of water, and the mean seasonal water level change of 3.9 ft represents a change in aquifer storage of 0.07 in. The exact amount of groundwater stored below WAG 17 cannot be determined. However, if nearly all fresh groundwater is stored in the upper 100 ft, total groundwater storage might be about 2 in.

2.3.5 Flow Paths and Groundwater Movement

WAG 17 is within the White Oak Creek drainage basin, but the northeastern edge of the WAG is near the boundary of the Bearden Creek basin. Several previous studies (Webster and Bradley, in press, p. 119, 144, for example) of the ORNL area have concluded that interbasin transport of groundwater is unlikely but not impossible. Elsewhere in the fractured rock aquifers of Tennessee, interbasin groundwater movement has been observed only (1) in the Knox Group, which includes zones with intergranular porosity and permeability (Newcome and Smith 1962), (2) along fault zones as at the campground in Cades Cove, Great Smoky Mountains National Park, and (3) along cavities from one valley with a relatively high land-surface elevation into an adjacent deeper valley (Moore and Wilson 1972, p. 25-27). Rocks in the WAG 17 area do not have a significant intergranular porosity; faults have not been mapped in the area; and the valley of Bearden Creek is not deeper than that of White Oak Creek near the drainage divide. Thus, all groundwater in WAG 17 can be presumed to flow toward White Oak Creek.

In bedrock, groundwater movement in the WAG 17 area, as elsewhere near ORNL, occurs through fractures. As discussed previously, individual fractures are short, but various local fracture sets form an intersecting system; this fracture system permits both vertical and lateral flows. In both plan and section views, groundwater flow paths probably resemble stairsteps. In other words, groundwater may move laterally along an open fracture until it reaches an intersection where it may then move in an orthogonal direction, either laterally or vertically. Changes in aperture, which determines hydraulic conductivity, probably occur at every intersection, and flow paths may split or join at these points. Splits are probably more common near recharge areas whereas joins are more common near discharge areas. These characteristics mean that flow paths are complex. Both vertical flow and lateral flow may occur along any individual fracture as well as at intersections, and lateral flow in different directions (but always along a fracture and down the hydraulic gradient) may occur at different levels in the aquifer.

G. D. DeBuchananne (Stockdale 1951, p. 50-51) first noted that in areas near ORNL "the water table is a subdued replica of the land surface, rising below the hills but occupying positions closer to land surface in the valleys." This same general configuration is shown by the water table map for WAG 17 (Fig. 6); this map also shows that groundwater generally moves toward the southwest, in the same direction as the average slope of the land surface. However, the contour map must be interpreted cautiously. Within the WAG, water table contours are closely spaced in areas where vertical flow is dominant and widely spaced where most groundwater flow is in a lateral direction. Also, the map is only an interpretation of water table elevations between control points (the piezometer wells). Thus, local groundwater flow is not necessarily in the direction of maximum apparent gradient, as shown by the map, and hydraulic gradients at deeper levels in the aquifer are almost certainly different from those near the water table.

Water level information from paired shallow and deep wells in WAG 17 is difficult to interpret. On September 23, 1987, the water level in well No. 765, which is 72 ft deep, was 5.0 ft higher than that in well No. 764, which is 22 ft deep. However, the water level in well No. 752, which is 65 ft deep, was 0.6 ft lower than that in well No. 753, which is 32 ft deep. Similarly, the water level in well No. 796, which is 48 ft deep, was 0.9 ft lower than that in well No. 794 and 1.4 ft lower than that in well No. 795, both of which are 12 ft deep. Water level elevations in the latter paired cluster had the same order on March 3, 1987, but only 0.2 ft of elevation separated the highest and lowest water levels. On April 15, 1987, the deeper well of the pair 752 and 753 had a water level 0.4 ft higher than the shallower well; this difference was exactly reversed in September. A tentative conclusion is that differences of up to 5.0 ft in water level elevation may occur at different levels in the aquifer, but that these differences do not necessarily indicate the vertical movement of groundwater from one aquifer level to another. If water level differences in the paired wells indicated vertical movement at these locations, the hydraulic gradient would not change direction and amount from one time of year to another.

Very little is known about the degree of interconnection between shallow and deep fractures. Webster and Bradley (in press, p. 96) note that aquifer tests on two of the deeper wells near ORNL "influenced water levels in nearby shallow wells, thereby demonstrating that secondary openings in the bedrock are hydraulically connected in the vertical direction." However, flowing wells occur at several locations near ORNL; the water table in these areas is at or below land surface. Also, Webster and Bradley (p. 89) mention that water levels in some of the deeper wells respond to earth tides; this response is indicative of confined conditions and of poor connections at most between land surface and the deeper fractures. The deeper flow paths must be closely interconnected with shallow fractures in recharge and discharge locations. Elsewhere, the degree of interconnection is probably spatially variable, from almost none to a condition where there is a considerable movement of groundwater from one level to another.

Cross-valley hydraulic gradients in the WAG 17 area are in the range 0.031-0.12 whereas along-valley gradients are 0.010-0.022, as shown by contour spacings (Fig. 9). As mentioned above, the larger apparent gradients represent mostly a change in potential resulting from the vertical movement of groundwater from one level in the aquifer to another. The ratio of the least cross-valley gradient (representing mostly or entirely lateral flow) to the least along-valley gradient is 3.1. Similar gradient differences have been measured elsewhere in Bethel and Melton Valleys, and it is probably significant that Tucci (1985, p. 10, 15) used an anisotropy ratio value in the range 1.5-3.0 for calibration of a groundwater flow model of the Melton Valley area. In the WAG 17 area, this gradient difference may indicate that three times as many fractures occur along bedding planes (oriented along-valley) as across bedding planes (oriented cross-valley). Alternatively, the permeability of fractures in the along-valley direction might be three times as large as fractures oriented cross-valley. In either case, three times as much groundwater flows southwesterly across WAG 17 as flows southeasterly and northwesterly, toward valley center.

All groundwater in the WAG 17 area apparently flows across the southwestern boundary of the WAG. The rate of this flow is given by a form of Darcy's Law:

$$Q = 7.48KbIL,$$

where Q is rate of flow (gal/day), K is hydraulic conductivity (ft/day), b is aquifer thickness (ft), I is hydraulic gradient (dimensionless), and L is width of section (ft). The width of the section is 1,050 ft, and mean hydraulic conductivity is 0.13 ft/day. If aquifer thickness is 100 ft, and if the mean hydraulic gradient is 0.010, then an average 1,021 gal/day of water flows across the boundary. This flow rate is equivalent to 4.1 in./yr of water on the 33.9 acre area of WAG 17. The average rate of linear flow of groundwater can be calculated by a different form of Darcy's law:

$$V = IK/S,$$

where V is velocity (ft/day), K is hydraulic conductivity (ft/day), and S is aquifer storativity or effective porosity (dimensionless). If mean aquifer porosity is 0.0015, then the average linear velocity of groundwater flow through the fractures is 0.87 ft/day.

The calculations above do not consider the possibility of groundwater flow through open cavities. If such cavities occur in the WAG 17 area, groundwater velocity within a cavity would be faster, and the groundwater flow rate would be larger, as would the groundwater component of the water budget.

2.3.6 Chemical Characteristics of Groundwater

The composition of groundwater is controlled by many factors including the chemical content of recharge waters, interactions with the regolith and with bedrock, residence times, and mixtures or dilutions with waters from other flow paths. Also, the concentration of many constituents is not constant but varies throughout the year, apparently depending on groundwater quantities and flow rates. Chemical analyses are not available for WAG 17, but the characteristics of the major constituents can be estimated from analyses of groundwater in other areas near ORNL.

As mentioned previously, most groundwater from shallow wells is a nearly neutral to moderately alkaline (pH 6.5-8.1), calcium-bicarbonate type. Magnesium concentration typically is about the same as sodium and is about half the concentration of calcium (Stockdale 1951, p. 79; Davis et al. 1984, p. 157-170; Webster and Bradley, in press, Table 8).

A variation in the type of water from shallow wells is shown by samples from five wells 50-100 ft deep (Stockdale 1951, p. 79). This water, like that of the more typical type, above, is neutral to slightly alkaline (pH 6.7-7.8), but sodium content is approximately equal to calcium plus magnesium. These characteristics suggest that soluble sodium salts are more readily available for solution in some areas than in others, especially at levels a little deeper than those of the shallowest wells.

A distinctly different groundwater is reported by Webster and Bradley (in press, Table 8) from six wells 100-200 ft deep. This is a sodium-carbonate or sodium-bicarbonate type water with a pH of 8.5-10.5, a sodium content of 60-300 mg/L, and a calcium plus magnesium concentration of less than 12 mg/L. These characteristics apparently result from ion exchange along deeper flow paths and suggest that much less water moves along these deeper paths than moves through fractures near the top of bedrock. All three of the chemical types that characterize water from wells up to 200-ft deep generally have a dissolved solids content of less than 500 mg/L and the concentration in water from most wells is 300-400 mg/L.

A much higher concentration of dissolved salts is found in water from wells 500-1,500 ft deep (Haase et al. 1987; Switek et al. 1987); total dissolved solids contents as high as 300,000 mg/L have been reported. This water is acidic and has (1) a high percentage weight of chloride and an equivalent weight of sodium less than that of chloride, (2) enriched calcium, magnesium, strontium, and bromide contents, and (3) relatively low concentrations of bicarbonate, sulfate, and nitrogen. In terms of membrane-filtration theory, these waters are membrane concentrated and connate. It is very unlikely that these analyses represent circulating groundwater, but there is not yet a preponderance of evidence to support the hypothesis.

At shallower levels, the distribution of each water type by location and by range in well depth is poorly known; both lateral and vertical boundaries are apparently irregular and may be gradational. Other water types may also occur because a few analyses of water from wells less than 300-ft deep have shown a relatively high sulfate concentration or a dissolved solids content of up to 3,000 mg/L.

2.4 Environmental Monitoring

Although ORNL has monitored radioactivity discharges to White Oak Creek and the Clinch River for a number of years, no environmental monitoring stations have been installed to identify radionuclide or hazardous waste discharges from the ORNL Services area (WAG 17). Because this area was mainly used for materials storage, machine shops, and general laboratory support facilities, it was not considered to be a potential source of radionuclides. As previously mentioned (Section 2.3.1), surface runoff from WAG 17 does enter the White Oak Creek drainage system upstream of the main plant area; however, the nature and amount of contaminants contributed by WAG 17 cannot be estimated from the existing White Oak Creek sampling station data. The NPDES permit for ORNL does require sampling of certain source discharges in WAG 17 for oil and grease, pH, temperature, total suspended solids, and BOD; however, radionuclides and heavy metals are not routinely determined.

Prior to 1987 no groundwater monitoring wells were installed in the WAG 17 area. In the past year (1987), 25 piezometer wells were installed in WAG 17 in order to provide information on groundwater flow for use in locating new water quality wells (see Sections 2.2 and 2.3.5). A study to locate these wells is currently in progress (D. C. Baughn, personal communication, January 1988).

3.0 ADDITIONAL INFORMATION NEEDS FOR WAG 17

WAG 17 was recommended for an RI plan on the basis of the nature of the operations conducted in past years and the observance of some tar-coated gravels in the stream bed draining the site (ORNL 1987). Specific information on possible leaks/spills occurring in past years has not been located. An evaluation of the information used in preparing the RFA, and additional information obtained for WAG 17 since the RFA, indicates that there is still some doubt regarding the need for remedial action.

As previously discussed, there is little background information on hazardous constituents in the waste oil tanks in WAG 17. Analysis of one tank (SWMU 17.2c) for 3H showed concentrations below allowable limits. All of the aboveground storage tanks in WAG 17 have some sort of leak/spill collection system; the adequacy of these containment systems is currently being evaluated. It is suggested, however, that sampling and analysis of the waste oil tank contents (especially the underground tanks which have no containment systems) should be performed.

It is estimated that as much as 800 gallons of gasoline may have leaked from one of the underground storage tanks in WAG 17. The tank has been drained and capped. AnEnvironmental Assessment Remedial Alternatives Work Plan is currently being prepared for this site under RCRA Subtitle I.

Examination of the geologic and hydrologic data available indicates no major data deficiencies. The recently conducted piezometer and water quality well drilling programs have provided adequate information regarding the geology and hydrology of WAG 17. Although no investigations have been conducted regarding soil properties (such as porosity, distribution coefficients, engineering properties, etc.) in WAG 17, it is not apparent that a need exists for this type of information at this time.

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