ORNL/TM-2001/183

OAK RIDGE
NATIONAL LABORATORY
MANAGED BY UT-BATTELLE
FOR THE DEPARTMENT OF ENERGY

ORNL Groundwater Protection Plan Description

December 2001

Prepared by
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Environmental Protection and Waste Services
Oak Ridge National Laboratory

R. H. Ketelle
Engineering
Bechtel Jacobs Company

UT-BATTELLE
ORNL-27 (4-00)

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OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
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ABBREVIATIONS AND ACRONYMS

AEC	Atomic Energy Commission
ASER	Annual Site Environmental Report for the Oak Ridge Reservation
BJC	Bechtel Jacobs Corporation
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CWA	Clean Water Act
DOE	U.S. Department of Energy
DQO	data quality objectives
DQODMP	Data Quality Objectives and Data Management Plan
EPWSD	Environmental Protection and Waste Services Division
ES&H	environmental, health, and safety
ESDEG	Environmental Sampling and Data Evaluation Group
EM	Environmental Management
EMP	Environmental Monitoring Plan for the Oak Ridge Reservation
EMS	Environmental Management System
EPA	U. S. Environmental Protection Agency
ES	Environmental Surveillance
ETTP	East Tennessee Technology Park
FFA	Federal Facilities Agreement
FFCA	Federal Facilities Compliance Agreement
FUA	Facility Use Agreement
FEVA	Facility Environmental Vulnerability Assessment
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
GWCP	Groundwater Contingency Plan
GWDB	groundwater monitoring database
GWIP	Groundwater Implementation Plan
GWPPD	Groundwater Protection Program Plan Description
GAAT	Gunite and Associated Tanks
HFIR	High Flux Isotope Reactor
HRE	Homogeneous Reactor Experiment
ISMS	Integrated Safety Management System
IWQP	Integrated Water Quality Program
LQAP	laboratory quality assurance plan
LLLW	liquid low-level waste
LLW	low-level waste
MSRE	Molten Salt Reactor Experiment
MWPAP	Monitoring Well Plugging and Abandonment Plan
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
ORR	Oak Ridge Reservation
OREIS	Oak Ridge Environmental Information System
ORNL	Oak Ridge National Laboratory
ORR-PCB-FFCA	Oak Ridge Reservation PCB Federal Facilities Compliance Agreement
P&A	plugging and abandonment
PCBs	polychlorinated biphenyls
PWD	process waste drain
QA	quality assurance
QC	quality control

QPP	Quality Program Plan
QFAPP	Quantitative Facility Assessment and Prioritization Plan
R&D	research and development
RFA	RCRA Facility Assessment
RCRA	Resource Conservation and Recovery Act
RA	remedial action
RI	remedial investigation
RER	Remediation Effectiveness Report for the U.S. Department of Energy Oak Ridge Reservation, Oak Ridge, Tennessee
ROD	Record of Decision
RPSC	Robotics and Process Systems Complex
SAP	Sampling and Analysis Plan
SDWA	Safe Drinking Water Act
S/I	sanitary/industrial
SLLW	Solid low-level waste
SWMU	solid waste management unit
SWSA	Solid Waste Storage Area
SPCC	Spill prevention, control, and countermeasures
SBMS	Standards Based Management System
SWP3	Storm Water Pollution Prevention Plan
TEGD	Technical Enforcement Guidance Document
TDEC	Tennessee Department of Environment and Conservation
TSCA	Toxic Substances Control Act
TSDF	treatment, storage, and disposal facility
WSS	Work Smart Standards
UIC	Underground Injection Control
UST	underground storage tank
VOC	volatile organic compound
WAG	waste area grouping
WOC	White Oak Creek
WRRP	Water Resources Restoration Program
XWQP	X-10 Water Quality Program

1. PURPOSE

This document presents the Groundwater Protection Program Plan Description (GWPPD) for activities at the U.S. Department of Energy (DOE) Oak Ridge National Laboratory (ORNL). The primary goal of ORNL's GWPPD is to ensure that plans for groundwater protection, management, monitoring, and restoration are fully defined, integrated, and managed in a cost-effective manner that is consistent with federal and state regulations. Management of groundwater resources at ORNL are the co-responsibility of UT-Battelle, LLC (UT-Battelle), the contractor responsible for the operation of ORNL, and Bechtel Jacobs Company LLC (BJC), the contractor responsible for cleanup of legacy contamination at ORNL. As such, UT-Battelle is responsible for groundwater surveillance monitoring under applicable sections of DOE Order 5400.1, and BJC is responsible for remediation of ORNL's groundwater.

This document outlines current and proposed activities related to protection of groundwater underlying ORNL. The GWPPD includes policy, goals, strategy, requirements and regulations applicable to groundwater protection, an overview of ORNL site hydrogeology, and outlines programs to prevent groundwater pollution. The GWPPD also outlines potential sources of groundwater pollution, summarizes the current groundwater monitoring activities at ORNL, and discusses the integration of sitewide groundwater programs and improvement of communications between internal and external stakeholders.

The GWPPD will be reviewed annually and updated at least every three years. This will be done as part of ORNL's Environmental Management System (EMS) to ensure that the groundwater program is effective and reflects current operational practices at ORNL.

Section 2 of the GWPPD describes the ORNL environmental protection policy, groundwater protection goals, applicable requirements, and groundwater protection strategy for ORNL. Section 3 provides a brief description of the ORNL site, including site geology and hydrogeology. Section 4 describes current known or potential sources of groundwater contamination at ORNL. Section 5 describes EMS programs that are designed to prevent the release of hazardous and radioactive materials to the environment (including groundwater). Monitoring activities are described in Sect. 6. Section 7 presents an overview of Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) remediation activities at ORNL. Section 8 outlines groundwater program integration between UT-Battelle and BJC. Section 9 outlines avenues of communication between internal and external stakeholders.

2. APPROACH

2.1 ORNL ENVIRONMENTAL PROTECTION POLICY

ORNL is committed to adhering to applicable federal, state, and local environmental, health, and safety (ES&H) laws, regulations, and requirements, as defined by the required compliance documents. ORNL is committed to providing a safe and healthy working environment for all staff, guest scientists and engineers, and visitors. ORNL is also committed to protecting the general public and the environment from unacceptable environmental, safety and health risks, and to operating in a manner that protects and restores the environment. Finally, ORNL is committed to objectively and fully communicate environmental protection, safety, and health information to ORNL staff, subcontractor personnel, DOE , applicable stakeholders, and the public. With respect to groundwater resources, ORNL is committed to protecting groundwater resources that exist beneath and downgradient of ORNL from further chemical and radionuclide releases.

2.2 GROUNDWATER PROTECTION MANAGEMENT PROGRAM OBJECTIVES

The objectives of the ORNL GWPPD are to

1. Comply with all applicable groundwater protection requirements;

2. Employ best management practices (including pollution prevention) to ensure that ORNL facilities and operations are designed, constructed, operated, and maintained in a manner that is protective of groundwater and surface water quality;

3. Conduct waste management practices in a manner that is protective of groundwater and surface water resources, including implementing comprehensive waste minimization practices and safe waste storage and disposal practices;

4. Analyze the hydrogeologic regime to support groundwater protection and management initiatives;

5. Conduct groundwater monitoring in a cost effective manner, based upon a technically sound sampling and analysis strategy;

6. Conduct effluent monitoring at ORNL facilities to provide timely information regarding ORNL operations that could potentially adversely affect groundwater resources;

7. Conduct well construction, maintenance, and abandonment practices in a technically sound and cost-effective manner; and

8. Inform and cooperate with stakeholders (federal, state, and local authorities and the public) on groundwater protection and remediation issues.

2.3 APPLICABLE REQUIREMENTS

The requirements for the protection, preservation, and restoration of groundwater resources are addressed in a number of federal, Tennessee State, and local laws and regulations. Performance standards for groundwater monitoring at these facilities are specified in regulations promulgated under the Resource Conservation and Recovery Act (RCRA), CERCLA, the Safe Drinking Water Act (SDWA), Clean Water Act (CWA), DOE orders, and state regulations. BJC is responsible for RCRA monitoring of Solid Waste Storage Area (SWSA) 6 and remediation of groundwater. UT-Battelle is responsible for surveillance monitoring of groundwater under DOE Order 5400.1 requirements spelled out in the DOE/UT-Battelle contract. The goal of both UT-Battelle and BJC is to comply with applicable requirements, and the following strategies are designed to ensure that this goal is achieved.

2.4 GROUNDWATER PROTECTION STRATEGY

The groundwater protection strategy for implementing this policy and achieving these goals is based on three elements:

1. Preventing contaminants from entering the groundwater flow system,
2. Monitoring groundwater as well as other environmental media, and
3. Improving internal and external communication.

Prevention. To protect groundwater resources from further contamination, ORNL has implemented a two-phased project to (1) identify current activities that have the potential to impact groundwater and (2) conduct a ORNL-wide review of all research and development activities and industrial-type operations. This review will determine the potential impacts of those activities on groundwater and will facilitate integration of pollution prevention/waste minimization, resource conservation, and compliance into planning, decision making, and implementation.

Monitoring. ORNL has a groundwater-monitoring network designed to evaluate groundwater contamination from historical and active operations. Groundwater monitoring is being conducted under two programs: (1) the Environmental Management (EM) Program conducted by BJC for the DOE EM Program and (2) the Environmental Surveillance (ES) Program conducted by UT-Battelle. The EM Program conducts groundwater monitoring related to ORNL's obligations under CERCLA and RCRA (e.g., remedial investigation, landfill closure, and remediation system monitoring). The ES Program is designed to satisfy DOE monitoring requirements for active research and support facilities. Data quality objectives, well installation procedures, sampling and analysis, data management, and well maintenance and abandonment programs will be properly integrated to optimize the groundwater monitoring system. Combined, UT-Battelle and BJC groundwater monitoring efforts are effective in monitoring off-site releases from actively managed and legacy contamination sites located at ORNL.

Communication. ORNL has a public affairs program to ensure that ORNL communicates with and involves the community in a consistent, timely, and accurate manner. In addition, a number of communication mechanisms are in place, such as web pages, briefings, and meetings, that enable ORNL to communicate groundwater issues with internal and external stakeholders.

3. ORNL SITE AND HYDROGEOLOGICAL DESCRIPTION

3.1 ORNL MISSION

ORNL was the smallest of three facilities built in 1942 and 1943 on the newly acquired 58,575-acre federal reservation (now 34,424 acres) in Oak Ridge, Tennessee. From its modest beginning as a wartime pilot plant, ORNL has grown to become one of the world's premier scientific research centers and DOE's largest and most diversified multiprogram national laboratory. ORNL is located on DOE's Oak Ridge Reservation (ORR), which also includes the Y-12 National Security Complex and the East Tennessee Technology Park (ETTP). These three facilities are located in the vicinity of the city of Oak Ridge. Activities at ORNL include active research and development managed by UT-Battelle as well as remedial actions associated with CERCLA cleanup activities currently carried out by BJC.

ORNL's mission is to conceive, design, construct, and operate facilities to conduct complex fundamental science studies. There facilities are the basis of a multiprogram national laboratory in which ORNL carries out R&D in support of all four of DOE's major missions: science and technology, energy resources, environmental quality, and national security. Current ORNL programs include research and technology transfer in areas of

- Materials research and neutron science,
- Nuclear physics,
- Life and environmental sciences, and
- Chemical sciences.

The management of ORNL includes the management and planning for ORNL facilities and for most of the ORR's undeveloped land area. This responsibility includes planning for the Oak Ridge National Environmental Research Park which is an approximately 20,000-acre outdoor laboratory with relatively undisturbed ecosystems. The Research Park provides a protected, biologically diverse land area for environmental research and education. It represents the eastern deciduous forest, with more than 1,100 species of vascular plants, some of which are state-listed rare plants, and 315 wildlife species, some of which are state-listed or federally listed rare wildlife species. The park is a biosphere reserve; an ORNL user facility; a site that contains seven registered state natural areas; an area that plays a significant role in the nesting and migration of breeding birds; and the location of two National Historic Landmarks, Freel's Cabin and the Graphite Reactor.

3.2 HYDROGEOLOGIC FRAMEWORK

3.2.1 ORNL Location

ORNL lies between the Cumberland and Blue Ridge Mountain ranges and is bordered on two sides by the City of Oak Ridge and the Clinch River. The Cumberland Mountains are 16 km (10 miles) to the northwest; the Blue Ridge Mountains, which include the Great Smoky Mountains National Park, are 51 km (32 miles) to the southeast (Fig. 3.1).

3.2.2 Climate and Physiography

The climate of the region may be broadly classified as humid continental. The Cumberland Mountains to the northwest help to shield the region from cold air masses that frequently penetrate far south over the plains and prairies in the central United States during the winter months. During the summer, tropical air masses from the south provide warm and humid conditions that often produce thunderstorms; however, anticyclonic circulation around high-pressure systems centered in the western Gulf of Mexico can bring dry air from the southwestern United States into the region, leading to occasional periods of drought.

The mean annual temperature for the Oak Ridge area is 14.7°C (57.7°F). The coldest month is usually January, with temperatures averaging about 2.9°C (37.2°F) but once dipping as low as –31°C (–24°F). July is typically the hottest month of the year, with temperatures averaging 25.4°C (77.2°F) but occasionally peaking at over 37.8°C (100°F). In the course of a year, the difference between maximum and minimum daily temperatures averages 12.5°C (22.5°F).

The 30-year annual average precipitation is 137.4 cm (54.1 in.), including about 24.4 cm (9.6 in.) of snowfall. Average rainfall in the Oak Ridge area in 2000 was 135.3 cm (53.3 in.). Precipitation in the region is greatest in the winter months (December through February). Precipitation in the spring exceeds the summer rainfall, but the summer rainfall may be locally heavy because of thunderstorm activity. The driest periods generally occur during the fall months when high-pressure systems are most frequent.

Regionally, annual evapotranspiration has been estimated to range from 81 to 89 cm (32 to 35 in.), or 60 to 65% of rainfall (Farnsworth et al. 1982). Evapotranspiration in the Oak Ridge area is 74 to 76 cm (29 to 30 in.), or 55 to 56% of annual precipitation (TVA 1972, Moore 1988, and Hatcher et al. 1989). Evapotranspiration is greatest in association with the growing season, which in the Oak Ridge area is 220 days, from mid-March through mid-October. During this period, evapotranspiration often exceeds the rate of precipitation, resulting in soil moisture deficits.

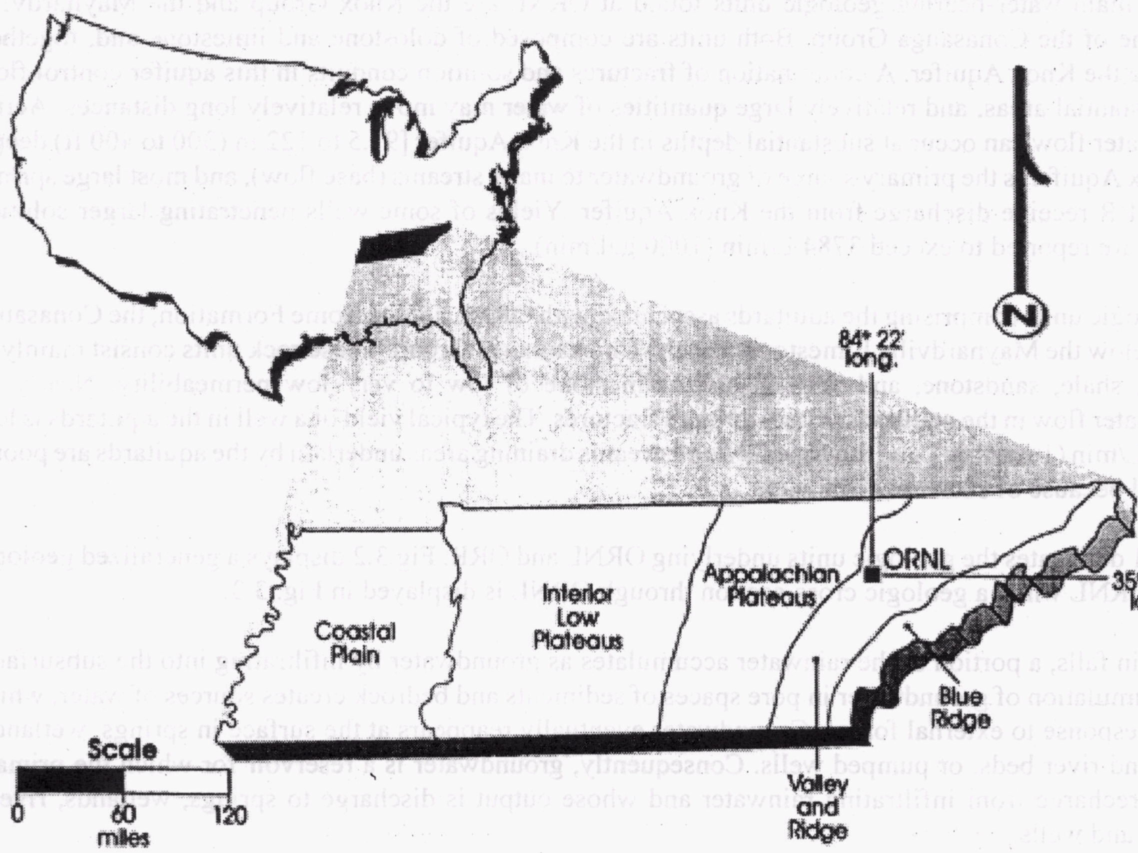

Fig. 3.1. Location map showing the relationship of ORNL to the physiographic provinces of Tennessee.

ORNL sits within the Valley and Ridge Physiographic Province which is part of the southern Appalachian fold-and-thrust belt. Thick, folded beds of sedimentary rock deposited during the Paleozoic era comprise the bedrock of the Valley and Ridge at ORNL. As a result of thrust faulting and differential erosion rates, a series of parallel valleys and ridges have formed that trend southwest-northeast. The long axes of the folded beds control the shapes and orientations of a series of long, narrow parallel ridges and intervening valleys. The differing degrees of resistance to erosion of the shales, sandstones, and carbonate rocks comprising the lithology determine local relief.

3.2.3 Geology and Hydrogeology

The two main water-bearing geologic units found at ORNL are the Knox Group and the Maynardville Limestone of the Conasauga Group. Both units are composed of dolostone and limestone and, together, constitute the Knox Aquifer. A combination of fractures and solution conduits in this aquifer control flow over substantial areas, and relatively large quantities of water may move relatively long distances. Active groundwater flow can occur at substantial depths in the Knox Aquifer [91.5 to 122 m (300 to 400 ft) deep]. The Knox Aquifer is the primary source of groundwater to many streams (base flow), and most large springs on the ORR receive discharge from the Knox Aquifer. Yields of some wells penetrating larger solution conduits are reported to exceed 3784 L/min (1000 gal/min).

The geologic units comprising the aquitards associated with ORNL are the Rome Formation, the Conasauga Group below the Maynardville Limestone, and the Chickamauga Group. These rock units consist mainly of siltstone, shale, sandstone, and thinly bedded limestone of low to very low permeability. Nearly all groundwater flow in the aquitards occurs through fractures. The typical yield of a well in the aquitards is less than 3.8 L/min (1 gal/min), and the base flows of streams draining areas underlain by the aquitards are poorly sustained because of such low flow rates.

Table 3.1 delineates the geologic units underlying ORNL and ORR. Fig.3.2 displays a generalized geologic map of ORNL while a geologic cross-section through ORNL is displayed in Fig. 3.3.

When rain falls, a portion of the rainwater accumulates as groundwater by infiltrating into the subsurface. The accumulation of groundwater in pore spaces of sediments and bedrock creates sources of water, which flow in response to external forces. Groundwater eventually reappears at the surface in springs, wetlands, stream and river beds, or pumped wells. Consequently, groundwater is a reservoir for which the primary input is recharge from infiltrating rainwater and whose output is discharge to springs, wetlands, rivers, streams, and wells.

Groundwater at ORNL occurs both in the unsaturated zone as transient, shallow subsurface stormflow and within the deeper saturated zone. An unsaturated zone of variable thickness separates the stormflow zone and water table. Adjacent to surface water features or in valley floors, the water table is found at shallow depths and the unsaturated zone is thin. Along the ridge tops or near other high topographic areas, the unsaturated zone is thick, and the water table often lies at considerable depth [15 to 50 m (50 to 175 ft) deep]. In low-lying areas where the water table occurs near the surface, the stormflow zone and saturated zone are indistinguishable.

In undisturbed, naturally vegetated areas, about 90% of the infiltrating precipitation does not reach the water table but travels through the 1 to 2 m (3 to 7 ft) deep stormflow zone, which approximately corresponds to the root zone. Because of the permeability contrast between the stormflow zone and the underlying unsaturated zone, the stormflow zone partially or completely saturates during rainfall events, and then water flows laterally, following very short flow paths to adjacent streams. When the stormflow zone becomes

Table 3. l. Geologic units of the ORR[a]

Unit	Age	Thickness (m)	Lithology
Rockwood Formation	Silurian	120	Sandstone, shale
Sequatchie Formation	Upper Ordovician	60	Argillaceous limestone
Reedsville Shale	Upper Ordovician	60	Calcareous shale
Chickamauga Group	Middle Ordovician	400-700	Limestone, argillaceous Limestone, shale, siltstone
Blackford Formation		50-80	Siltstone, limestone
Lincolnshire Formation		70-100	Limestone, siltstone
Rockdell Formation		80-85	Limestone
Benbolt Formation		110-116	Limestone, siltstone
Bowen Formation		5-10	Siltstone, limestone
Witten Formation		90-110	Limestone, calcarenite, siltstone
Mocassin Formation		100-170	Calcareous siltstone, limestone
Knox Group			
Mascot Dolomite		75-120	
Kingsport Formation		90-150	
Longview Dolomite	Lower Ordovician, Upper Cambrian	46-60	Massive dolomite, siliceous dolomite, bedded chert, limestone, some clastics
Chepultepec Dolomite		150-215	
Copper Ridge Dolomite		245-335	
Conasauga Group			
Maynardville Limestone		125-145	
Nolichucky Shale		100-150	
Dismal Gap Formation (formerly Maryville Limestone)	Middle, Upper Cambrian	95-120	Dolomitic limestone, limestone Shale, siltstone, calcareous siltstone and shale, shaly limestone, limestone
Rogersville Shale		20-35	
Rutledge Limestone		30-40	
Pumpkin Valley Shale		90-100	
Rome Formation	Lower Cambrian	90-125	Shale, siltstone, sandstone, local dolomite lenses

[a]Names in italic are units that make up the Knox aquifer. Other units form the ORR aquitards.

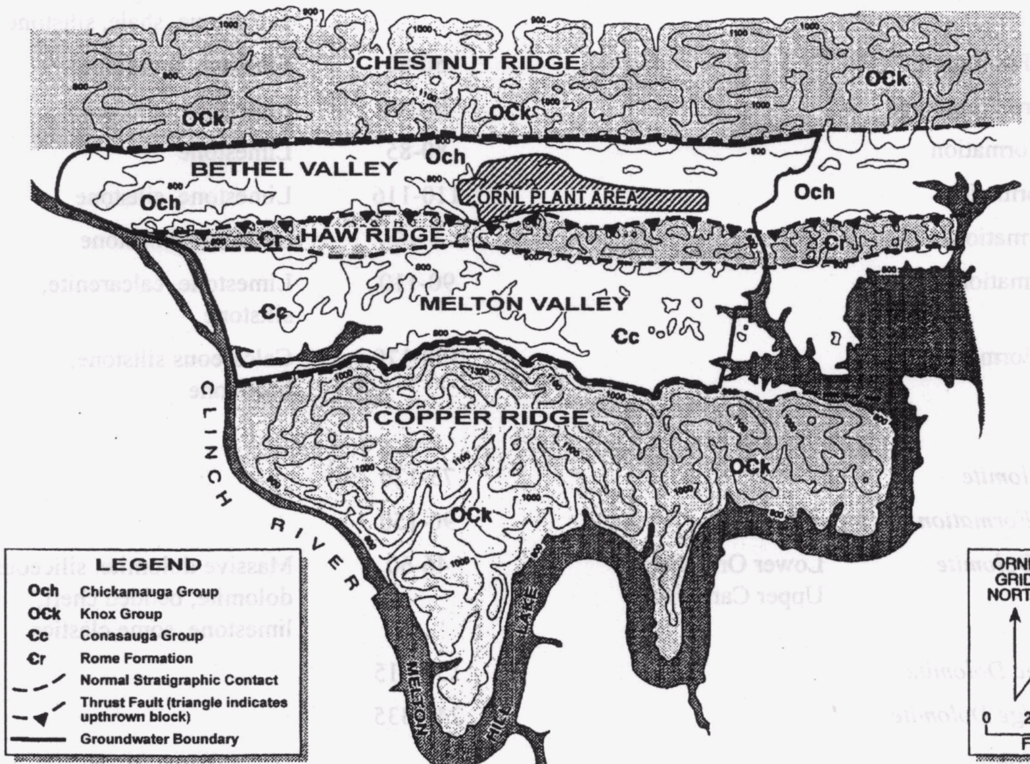

Fig. 3.2. Generalized geologic map of the vicinity around ORNL.

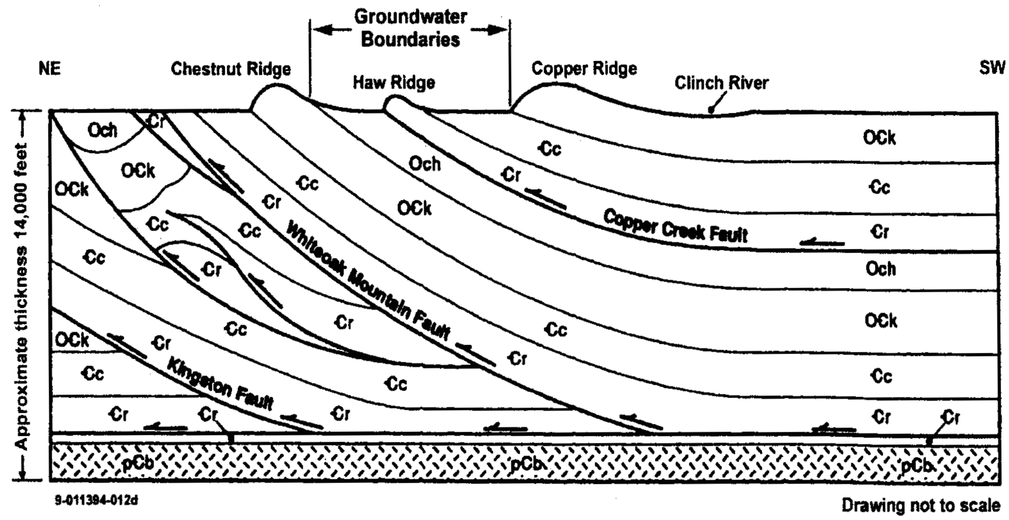

Fig. 3.3. Schematic geologic cross section in the vicinity of ORNL.

completely saturated, flow of water over the land occurs. Between rainfall events, as the stormflow zone drains, flow rates decrease dramatically, and water movement becomes nearly vertical toward the underlying water table.

The rate at which groundwater is transmitted through the stormflow zone is attributed to large pores (root channels, worm bores, and relict bedding planes and fractures). Stormflow is primarily a transport mechanism in undisturbed or vegetated areas, where it intersects shallow waste sources. Most buried wastes in waste area groupings (WAGs) at ORNL are within or below the stormflow zone; however, in some trenches a commonly observed condition known as "bathtubbing" can occur, in which the excavation fills with water and may overflow into the stormflow zone. All stormflow ultimately discharges to streams at ORNL.

The saturated zone at ORNL can be divided conceptually into four flow zones in a vertical cross section: an uppermost water table interval, an intermediate zone, a deep zone, and an aquiclude. The presence and thickness of any zone may vary across ORNL. Available evidence indicates that most water in the saturated zone in the aquitards is transmitted through a 1 to 6 m (3 to 20 ft) thick layer of closely spaced, well connected fractures near the water table (the water table interval).

As in the stormflow zone, the bulk of groundwater in the saturated zone resides within the pore spaces of the rock matrix. The rock matrix typically forms blocks that are bounded by fractures. Contaminants migrating from sources by way of the fractures typically occur in higher concentrations than in the matrix; thus, the contaminants tend to move (diffuse) into the matrix. This process, termed diffusive exchange or matrix diffusion, between water in matrix pores and water in adjacent fractures reduces the overall contaminant migration rates relative to groundwater flow velocities. For example, the leading edge of a geochemically nonreactive contaminant mass such as tritium may migrate along fractures at a typical rate of 1 m/day (3 ft/day); however, the center of mass of a contaminant plume typically migrates at a rate less than 0.66 m/day (0.2 ft/day).

In the aquitards, chemical characteristics of groundwater change from a mixed-cation-HCO_3 water type at shallow depth to a Na-HCO_3 water type at deeper levels [30 m (about 100 ft)]. This transition, not marked by a distinct change in rock properties, serves as a useful marker and can be used to distinguish the more active water table and intermediate groundwater intervals from the sluggish flow of the deep interval. No evidence exists of similar change with depth in the chemical characteristics of water in the Knox Aquifer; virtually all wells are within the monitoring regime of Ca-Mg-HCO_3 type water. Although the mechanism responsible for this change in water types is not quantified, it most likely is related to the amount of time the water is in contact with a specific type of rock.

Most groundwater flow in the saturated zone occurs within the water table interval. Most flow is through weathered, permeable fractures and matrix rock and within solution conduits in the Knox Aquifer. The range of seasonal fluctuations of water table depth and rates of groundwater flow varies significantly across ORNL. In areas underlain by the Knox Aquifer, seasonal fluctuations in water levels average 5.3 m (17 ft), and mean discharge from the active groundwater zone is typically 322 L/min (85 gal/min) per square mile. In the aquitards of Melton Valley and Bethel Valley, seasonal fluctuations in water levels average 1.5 m (5 ft) and typical mean discharge is 98 L/min (26 gal/min) per square mile.

In the intermediate interval, groundwater flow paths are a product of fracture density and orientation. In this interval, groundwater movement occurs primarily in permeable fractures that are poorly connected. In the Knox Aquifer, a few cavity systems and fractures control groundwater movement in this zone, but in the aquitards, the bulk of flow is through fractures, along which permeability may be increased by weathering.

The deep interval of the saturated zone is delineated by a change to a Na-Cl water type. Hydrologically active fractures in the deep interval are significantly fewer in number and shorter in length than in the other intervals, and the spacing is greater. Wells finished in the deep interval of the ORR aquitards typically yield less than 1.1 L/min (0.3 gal/min) and thus are barely adequate for water supply.

In the aquitards, saline water characterized by total dissolved solids ranging up to 275,000 mg/L and chlorides generally in excess of 50,000 mg/L (ranging up to 163,000 mg/L) lies beneath the deep interval of the groundwater zone, delineating an aquiclude. Chemically, this water resembles brines typical of major sedimentary basins, which originated from an evaporating water body. The brines are thought to have been pushed westward and trapped by overthrusting rock during the formation of the Appalachian Mountains (approximately 250 million years ago). The chemistry suggests extremely long residence times (i.e., very low flow rates); however, some mixing with shallow groundwater has been observed (Nativ et al. 1997).

The aquiclude has been encountered at depths of 122 and 244 m (400 and 800 ft) in Melton and Bethel Valleys, respectively. Depth to the aquiclude in areas of the Knox Aquifer is not known but is believed to be greater than 366 m (1200 ft).

Many factors influence groundwater flow at ORNL. Topography, surface cover, geologic structure, and rock type exhibit especially strong influence on the hydrogeology. Variations in these features result in variations of the total amount of groundwater moving through the system (flux). As an example, the overall decrease in open fracture density with depth results in a decreased groundwater flux with depth.

Topographic relief at ORNL is such that most active subsurface groundwater flow occurs at shallow depths. U.S. Geological Survey modeling (Tucci 1992) suggests that 95% of all groundwater flow occurs in the upper 15 to 30 m (50 to 100 ft) of the saturated zone in the aquitards. As a result, flow paths in the active-flow zones (particularly in the aquitards) are relatively short, and nearly all groundwater discharges to local surface water drainages within ORNL. Conversely, in the Knox Aquifer, it is believed that solution conduit flow paths may be considerably longer, perhaps as much as 1.6 km (2 miles) long in the along-strike direction. No evidence at this time substantiates the existence of any deep, regional flow from ORNL or between basins within the ORR in either the Knox Aquifer or the aquitards.

Migration rates of contaminants transported in groundwater are strongly influenced by natural chemical and physical processes in the subsurface (including diffusion and adsorption). Peak concentrations of solutes, including contaminants such as tritium moving from a waste area, for instance, can be delayed for several to many decades in the aquitards, even along flow paths as short as a few hundred feet. The processes that naturally retard contaminant migration and store contaminants in the subsurface are less effective in the Knox Aquifer than in the aquitards because of rapid flow along solution features allowing minimal time for diffusion to occur.

The groundwater monitoring programs at ORNL were designed to gather information to determine the effects of DOE operations on groundwater quality. Because of the complexity of the hydrogeologic framework at ORNL however, groundwater flow and, therefore, contaminant transport are difficult to predict on a local scale. Consequently, individual plume delineation is not always feasible.

Detailed information regarding ORNL's stratigraphy, structural geology, and hydrogeology can be found in Appendix A.

3.3 GROUNDWATER CLASSIFICATION AND USE

3.3.1 Groundwater Classification

Groundwater is not used for human consumption within the boundaries of ORNL. No public or private water supply wells exist within the boundaries of ORNL; however, several private water supply wells are located across the Clinch River from ORNL to the south and west. The Clinch River serves as a major groundwater divide which restricts groundwater discharge from ORNL to private wells located across the Clinch. DOE has not classified the groundwater at ORNL under the Groundwater Classification Rules (1200-4-3-.07). Potable water used at ORNL is supplied by the City of Oak Ridge.

3.3.2 Surface Water Classification

ORNL is near the Clinch River and Melton Hill Reservoir. The White Oak Creek watershed drains the majority of the main plant area of ORNL and discharges into the Clinch River. Surface waters are in hydraulic communication with the upper portion of the aquifer underlying ORNL. Water levels and flow rates in the tributaries to White Oak Creek and other surface water bodies are influenced by the position of the water table. Under natural conditions, flow in the Clinch River, White Oak Creek, and their tributaries is derived from groundwater discharge and surface water runoff. Surface waters at ORNL are classified by the State of Tennessee to support fish, aquatic life, and recreation as well as livestock and wildlife under Use Classification for Surface Water (1200-4-4). Surface water is not used for human consumption within the boundaries of ORNL. Water used at ORNL for drinking and cooling is supplied by the City of Oak Ridge. The City of Oak Ridge's water intake is located on the Clinch River upstream of ORNL at Clinch River kilometer 66. See Fig. 3.4 for the locations of water intake locations for towns and cities located near ORNL.

4. KNOWN OR POTENTIAL SOURCES OF CONTAMINATION

4.1 CERCLA ACTIVITIES

The ORNL site encompasses approximately 2000 acres of land that has been used for industrial development or waste management. The main industrial site lies in Bethel Valley, and most of the waste management sites are in Melton Valley. The DOE CERCLA environmental cleanup activities at Oak Ridge have been organized in several administrative "watershed" projects since 1996. The administrative watersheds loosely follow hydrologic watersheds, and, more importantly, they form a basis for integrated cleanup decisions that address large numbers of contaminated facilities and sites that are geographically grouped. The ORNL site environmental cleanup is being performed under two Records of Decision (ROD) – one each for Bethel and Melton Valleys. The following sections describe groundwater contamination in Bethel and Melton Valleys at ORNL.

4.1.1 Nature of Contamination in Bethel Valley

Bethel Valley is the site of ORNL's main plant and support facilities. In addition to the main plant industrial area with its associated buildings, below-ground infrastructure such as buried pipelines and waste holding tanks, Bethel Valley contains three solid waste burial grounds that were used between 1943 and 1951. The main plant area had numerous underground liquid low-level waste (LLLW) holding tanks with an interconnected network of buried liquid waste transfer pipelines, and four liquid waste holding ponds were used. Evaporator facilities have been used to reduce the volume of LLLW. A support facility located approximately 1.2 km (0.75 mile) from the main plant area houses the shipping and receiving facilities as

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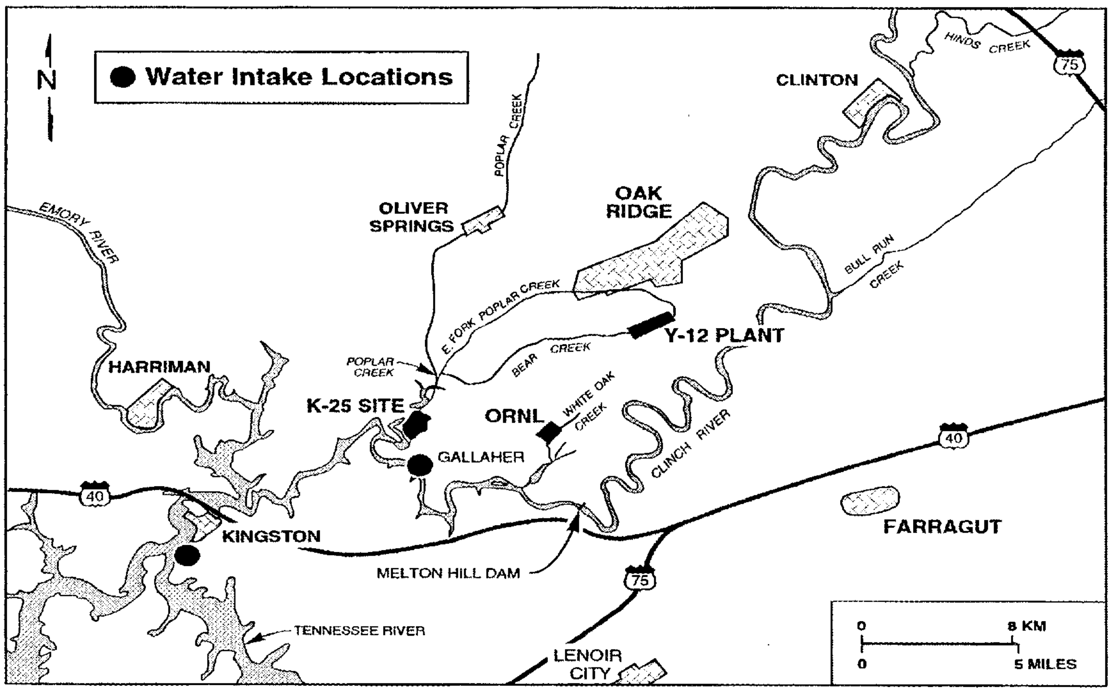

Fig. 3.4. Locations of water intakes for towns located downstream of ORNL.

well as numerous shop facilities and the garage and vehicle fuel storage and pumps. The principal sources of groundwater contamination in Bethel Valley are

- LLLW pipeline leaks and spills of mixed fission products,
- Releases from shallow land burial of solid low-level waste (SLLW) at SWSA 3,
- Release of chlorinated solvents from a spill in the shipping and receiving area, and
- Releases from the wastewater holding ponds.

Figure 4.1 shows the areas of groundwater contamination in Bethel Valley. Groundwater contamination in Bethel Valley occurs in three areas–the main plant area in Central Bethel Valley, in West Bethel Valley at SWSA 3, and in East Bethel Valley at the services area.

Central Bethel Valley. The principal groundwater contaminants in Central Bethel Valley are strontium-90, tritium, uranium-234, and cobalt-60. Additionally, low concentrations of trichloroethylene, beryllium, cadmium, chromium, and lead are present in shallow groundwater in Central Bethel Valley. The sources of groundwater contamination in Central Bethel Valley include numerous LLLW transfer pipeline leak sites and liquid waste spill sites. During routine operations, leaking waste transfer pipelines were repaired, and enough contaminated soil was removed to allow workers to make the repairs within health physics controls. Residual soil contamination remained in place and excavations were backfilled with clean soil. Several key areas of groundwater contamination and known or suspected contamination sources have been identified in Central Bethel Valley. Historic leakage of LLLW in the North Tank Farm have created the Core Hole 8 Plume. The Core Hole 8 Plume contaminants include strontium-90 and uranium-234. Similar LLLW leakage has occurred in the vicinity of Building 3019, in the 3039 stack area, and in the isotopes area near Buildings 3028 and 3047. Although most of the active groundwater flow paths in Bethel Valley are relatively shallow, groundwater contamination beneath some contaminant sources is known to extend to depth greater than 30 m (100 ft) below the water table. Seepage of water from the liquid waste holding impoundments has contaminated groundwater in the vicinity of the impoundments. Strontium-90 and tritium are the principal groundwater contaminants associated with the impoundments area. Elevated tritium concentrations have been detected in groundwater near the low-level waste (LLW) evaporator facility; however, a specific source of the tritium in that area has not been identified.

West Bethel Valley. Waste management units in West Bethel Valley include SWSA 3 and a closed contractor's landfill. SWSA 3 was the ORNL waste burial ground from about 1946 until 1951. The burial ground received radioactive waste from ORNL as well as the Y-12 complex and off-site Atomic Energy Commission (AEC)[1] facilities. The principal groundwater contaminant in West Bethel Valley is strontium-90 that originates from LLW burial trenches. The plume originates from a location near the water table divide between the Northwest Tributary of White Oak Creek (WOC) and Raccoon Creek to the west, and contaminant seepage occurs to both the east and west of the two streams.

East Bethel Valley. The principal groundwater contamination in the East Bethel Valley area is a volatile organic compound (VOC) plume that originates from the shipping and receiving area. Neither the source area nor the plume has been fully characterized.

[1]The Atomic Energy Commission was the predecessor to the DOE.

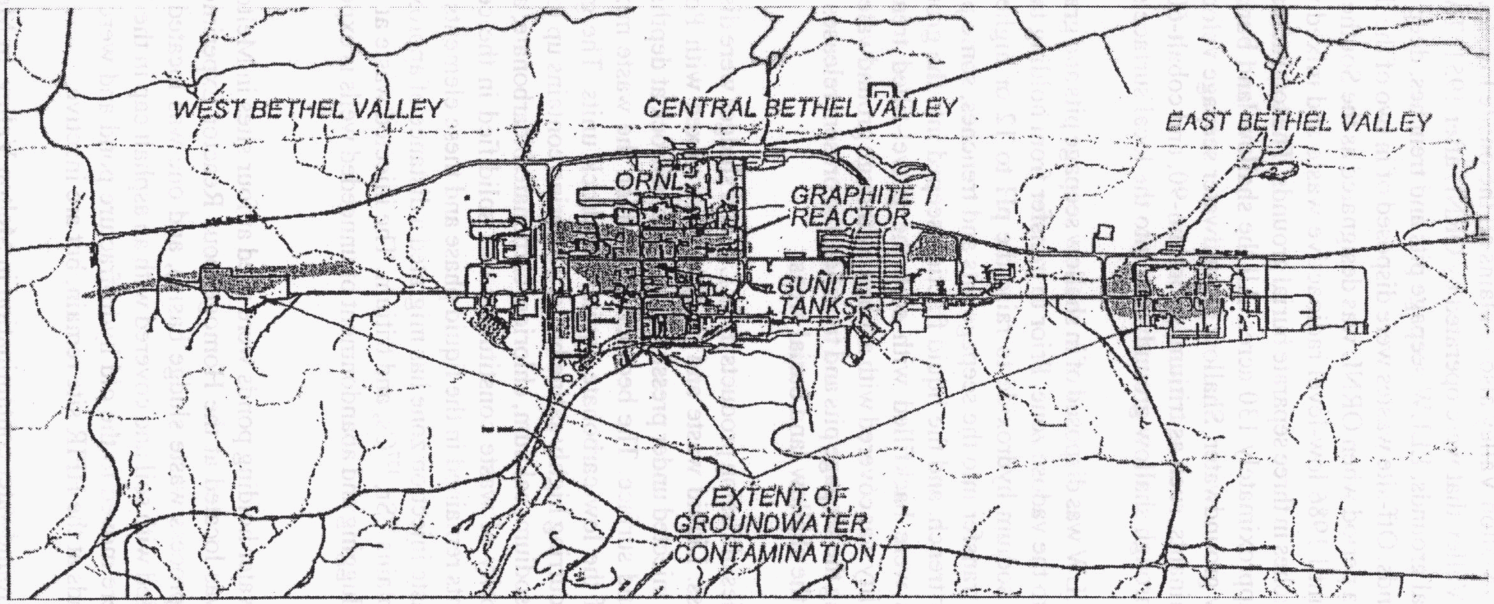

Fig. 4.1 Extent of groundwater contamination in Bethel Valley.

4.1.2 Nature of Contamination in Melton Valley

Melton Valley is the site of two experimental nuclear reactors and the High Flux Isotope Reactor (HFIR), which is an operational reactor. Melton Valley also contains all the onsite low-level radioactive and mixed waste disposal sites in Melton Valley that were operated by ORNL after 1951. The types of waste disposal sites include shallow land burial grounds, LLLW seepage pits and trenches, deep waste injection well, and unlined wastewater holding ponds. Off-site wastes were disposed of in two of the three LLW burial grounds in the 1950s and 1960s during a period when ORNL was designated as the Southeastern Regional Disposal Site by the AEC. From 1951 until 1986 low-level radioactive waste and mixed waste was disposed of in unlined shallow land burial trenches in three separate burial grounds. The total acreage of shallow land burial grounds in Melton Valley is approximately 130 acres. All the shallow land burial grounds have released contamination into the shallow groundwater. Shallow groundwater seepage velocities are relatively rapid, and chemically mobile contaminants, such as tritium, strontium-90, and cobalt-60, have migrated from the contaminant source trenches through shallow groundwater into the local surface streams.

During the 1950s and 1960s, LLLW was disposed of in shallow seepage pits and gravel-filled trenches where the excess liquid percolated into the vadose zone. Prior to transfer from holding tanks in Bethel Valley, the liquid waste was treated with sodium hydroxide to raise the pH to 12 or higher, rendering most of the radionuclides insoluble. Upon transfer into the seepage pits and trenches, some precipitated LLLW solids settled to the floor of the pit or trench, and the liquid fraction seeped into the ground. After use of the pits and trenches ceased, the pits were backfilled with soil, the gravel-filled trenches were covered, and subsequently each seepage facility was covered with asphalt. Although groundwater contamination is known to exist beneath and surrounding the seepage pits and trenches, the present releases to surface water are quite small compared to those from the shallow land burial areas.

Approximately 1.5 million curies of fission products in LLLW and sludges were disposed of in deep bedrock using the hydrofracture process. Liquid waste and sludges were mixed with Portland cement and other additives, and the mixture was injected under pressure into shale bedrock at depths between 240 and 300 m (800 and 1000 ft) below ground surface. The bedrock into which the waste mixture was injected is the Pumpkin Valley Shale--one of the low-carbonate aquitard bedrock units. The groundwater in the waste injection zone is a naturally occurring highly saline brine. The brine contains up to 250,000 to 300,000 m/L of dissolved solids made up of sodium, calcium, chloride, carbonate/bicarbonate, and sulfate. At the time of waste injection, the vast majority of waste constituents was solidified in the cement; however, a small fraction of the waste constituents remained in the liquid phase and these elements are now contained in the brine. The deep brine in the waste injection zone has migrated a distance of approximately 300 m (1,000 ft) from the injection well and contains ^{90}Sr, ^{137}Cs, and tritium. The injected waste at the hydrofracture sites is in a stable configuration, and plugging and abandonment of unneeded wells is expected to ensure long-term containment.

A total of eight unlined wastewater holding ponds were used at four sites in Melton Valley. The HFIR site has four unlined ponds, one was located at the Homogeneous Reactor Experiment (HRE) site, one was located in the SWSA 5 area (process waste sludge basin), and one was located at the old hydrofracture facility. The HRE pond was filled with soil and covered with an asphalt cap in the 1970s. The sludges in the process waste sludge basin were moved to the old hydrofracture pond and were stabilized with lime and cement kiln dust. The four ponds at the HFIR site remain, but are inactive.

Figure 4.2 shows the areas of groundwater contamination in Melton Valley. In Melton Valley, the depth of contaminant plumes beneath the shallow land burial areas, the liquid waste seepage pits and trenches, and the wastewater ponds is generally less than 30 m (100 ft), and most of the contaminant seepage pathways are less than 9 m (30 ft) below ground surface. Seepage pathways from near-surface contaminant sources

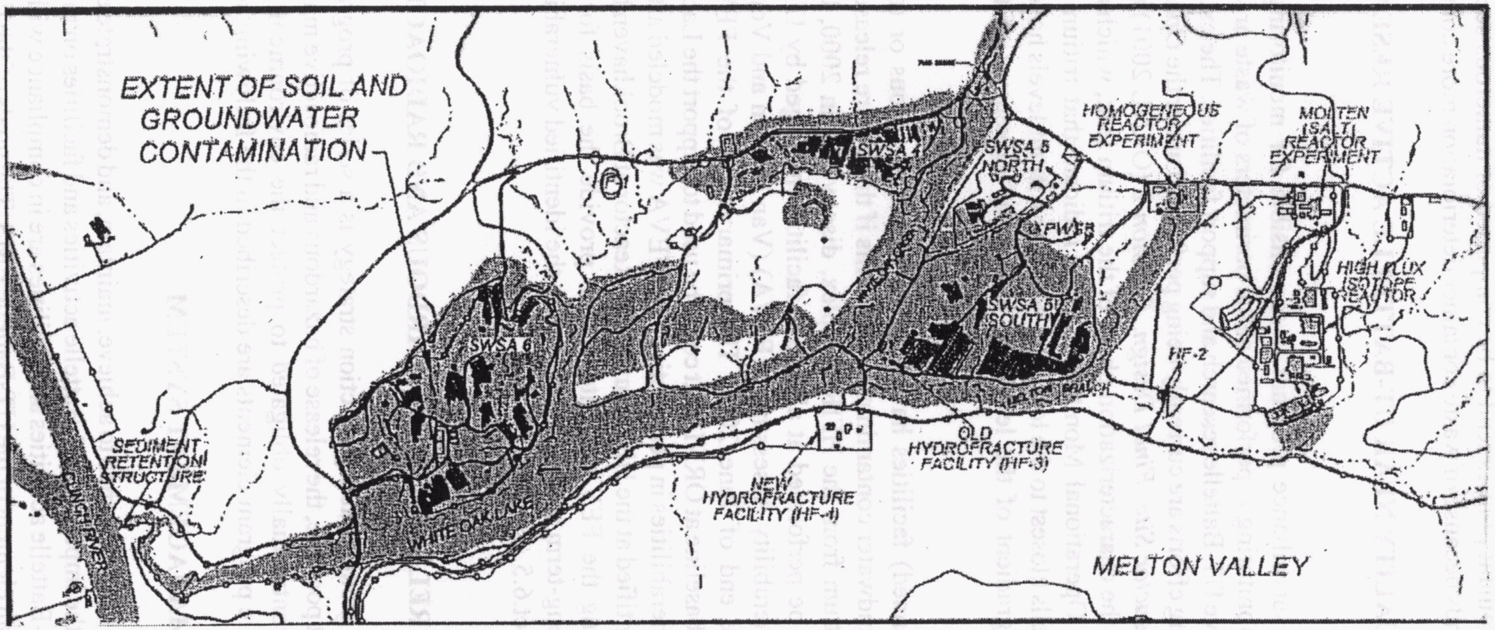

Fig. 4.2 Extent of soil and groundwater contamination in Melton Valley.

discharge into the local surface water drainage system. The orientation and transmissivity of seepage pathways are controlled by the locations and orientations of fractures and weathered zones in bedrock and in the residuum in which the wastes were disposed. Since seepage pathways are largely controlled by discrete geologic features, the contaminant plumes tend to be comprised of numerous seepage fingers. As the area of contaminant release expands because of waste container deterioration more contaminant fingers develop.

4.2 GROUNDWATER QUALITY NEAR UT-BATTELLE ACTIVE RESEARCH AND SUPPORT FACILITIES

UT-Battelle's groundwater surveillance program is responsible for monitoring off-site releases to the environment, and as such, monitoring is performed at the perimeters of waste area groupings (WAGs) and not in close proximity to active UT-Battelle research and support facilities. The exception to this is the HFIR complex where the monitoring efforts are currently being performed under the *Operational Monitoring Plan for the High Flux Isotope Reactor Site, Final Design, Revision 2* (ORNL 2001) (Operational Monitoring Plan). Data collected during the characterization phase of the tritium leak, which occurred in 2000, as well as data collected under the Operational Monitoring Plan, indicate that tritium levels have declined in downgradient monitoring wells closest to the leak site; however tritium levels have increased in monitoring wells located further downgradient of the leak site, indicating movement of the tritium plume in the downgradient direction.

A number of active (or planned) facilities have inventories of hazardous or radioactive materials that potentially could create groundwater contamination problems if there were releases to the environment. As a result of the release of tritium from the HFIR complex, discovered in 2000, UT-Battelle management directed that an assessment be performed at all active facilities managed by UT-Battelle. As a result, a Facility Environmental Vulnerability Assessment (FEVA) (Van Hoesen and Vogel 2001) was performed from mid-April through the end of June 2001. The primary goal of the FEVA was to establish an environmental vulnerability baseline at ORNL that could be used to support the Laboratory planning process and place environmental vulnerabilities in perspective. The FEVA was modeled after the Battelle-supported response to the problems identified at the High Flux Beam Reactor at Brookhaven National Laboratory. The information developed during the FEVA is intended to provide the basis for management to initiate immediate, near-term, and long-term actions to respond to the identified vulnerabilities. Details concerning the FEVA are outlined in Sect.6.5.

5. PREVENTION OF RELEASES OF HAZARDOUS AND RADIOACTIVE MATERIAL

The foundation of ORNL's groundwater protection strategy is a series of programs that are designed to prevent, to the greatest extent possible, the release of hazardous and radioactive material to the environment. UT-Battelle and BJC are contractually obligated to protect the environment and prevent releases to groundwater. The UT-Battelle program elements are described in the following sections.

5.1 ENVIRONMENTAL MANAGEMENT SYSTEM

UT-Battelle has developed an EMS designed to achieve, maintain, and demonstrate environmental excellence by assessing and controlling the impact of UT-Battelle activities and facilities on the environment. The EMS is designed to ensure that UT-Battelle activities and facilities are in compliance with environmental laws and regulations. This GWPPD is an element of the UT-Battelle EMS. The goals of the EMS include ensuring that UT-Battelle conducts its work and manages the Laboratory facilities in a cost-effective and efficient manner, while protecting workers, the public, and the environment. The EMS seeks to integrate environmental protection (including groundwater protection), pollution prevention, and compliance assurance into all aspects of the Laboratory's mission.

5.2 ENVIRONMENT, SAFETY, AND HEALTH STANDARDS

As part of the Standards Based Management System (SBMS), UT-Battelle has a centralized, integrated, requirements management process. This process maintains the current list of applicable requirements contained in UT-Battelle's contract with DOE. This process also facilitates the receipt, distribution, and review of new and modified requirement documents. Applicable ES&H standards are contained in the UT-Battelle Work Smart Standards (WSS). UT-Battelle's EMS translates these requirements into useable procedures and guidelines that enable staff to perform their assigned work safely and efficiently. These procedures contain requirements that hazardous and radioactive materials are managed in a manner that protects groundwater and the environment.

5.3 NEPA AND PERMIT REVIEW

The National Environmental Policy Act (NEPA) review and documentation process is initiated during the preliminary planning phases of a project. Potential groundwater impacts are assessed during the NEPA review process. Applicable permit applications are prepared, and reviews are conducted during the project design phase.

5.4 FACILITY USE AGREEMENTS

It is the intent of UT-Battelle to have a Facility Use Agreement (FUA) for each active facility or building that houses UT-Battelle staff, users and guests, contractor staff, programmatic equipment or other support equipment, and/or hazardous environments or hazardous materials. FUAs will define the capabilities and processes that are in place within a facility and ensure that the identified hazards are controlled within the confines of the facility or the immediate work location. The FUAs will also identify monitoring requirements associated with each facility.

5.5 FACILITY DESIGN REVIEWS

All proposed plans for major construction projects for new facilities or significant improvements to existing facilities are reviewed to ensure that the design elements meet all applicable regulatory and contractual requirements. Potential groundwater issues would be identified and addressed during this review process.

5.6 POLLUTION PREVENTION PROGRAM

The goal of UT-Battelle's pollution prevention program is to prevent the generation of waste (solid, hazardous/mixed, and radioactive), and minimize the generation of waste that cannot be prevented. ORNL's *Pollution Prevention Program Plan* (Ostergaard 1997) establishes the program for the site. The pollution prevention program at UT-Battelle focuses on identifying and using cost-effective opportunities for reducing waste generation. Such opportunities are identified by formal Pollution Prevention Opportunity Assessments, Waste Minimization Working Groups, and employee suggestions. Pollution prevention and waste minimization values are currently used in the operation of all facilities managed by UT-Battelle. Minimizing the waste streams generated reduces the overall mass of wastes that have to be managed, thus reducing the risk to groundwater.

5.7 WASTE MANAGEMENT PROGRAM

5.7.1 RCRA

RCRA established a management system that regulates hazardous waste from generation to final disposition, also known as from "cradle to grave." The objective of UT-Battelle's RCRA compliance program is to ensure that hazardous waste and hazardous waste containing radioactive components (mixed waste) is always handled in a manner that is protective of human health and the environment. ORNL is registered with the Tennessee Department of Environment and Conservation (TDEC) as a large quantity generator and as a treatment, storage, and disposal facility (TSDF) operator under U. S. Environmental Protection Agency (EPA) ID Number, #TN1 89 009 0003.

UT-Battelle generators manage their hazardous and mixed waste in satellite accumulation areas and/or 90-day accumulation areas until the waste is transferred to an on-site permitted storage unit (operated by BJC) or shipped directly off-site from a generator accumulation area. Management of hazardous and mixed wastes in accordance with RCRA is protective of groundwater in that RCRA dictates security requirements for waste areas, requires routine inspection of waste storage areas, requires training of personnel involved in the management of wastes, requires that waste storage areas adhere with location standards, etc. ORNL has an established site-specific contingency plan covering emergency situations and spill response that provides detailed instructions to generators and emergency responders.

5.7.2 Toxic Substances Control Act (TSCA)

TSCA addresses the manufacture, processing, distribution in commerce, use, and disposal of certain chemical substances that pose an unreasonable risk of injury to human health and the environment. The most prevalent of these TSCA substances are polychlorinated biphenyls (PCBs) and asbestos. To address PCB compliance issues at the ORR, EPA Region 4, and DOE entered into the ORR PCB Federal Facilities Compliance Agreement (ORR-PCB-FFCA) that became in effect in 1996.

The objective of UT-Battelle's TSCA program is to ensure compliance with the TSCA regulations and the ORR-PCB-FFCA. UT-Battelle generators manage their PCB waste in TSCA waste accumulation areas until the waste is transferred to an on-site storage unit or shipped directly off-site from a generator accumulation area. UT-Battelle also tracks the disposition of all PCB and PCB-contaminated equipment in use or stored for reuse. UT-Battelle procedures are provided to staff for the decontamination of equipment and cleanup of any PCB spills. Management of toxic articles and wastes in accordance with TSCA is protective of groundwater in that TSCA dictates security requirements for waste areas, requires routine inspection of waste storage areas, requires training of personnel involved in the management of wastes, requires that waste storage areas adhere with storage standards, etc.

5.7.3 Sanitary/Industrial (S/I) Waste

Generation and management of S/I waste at ORNL is governed by a UT-Battelle procedure. The procedure provides waste generators guidance for transferring S/I waste to the receiving facility's landfill in accordance with waste acceptance criteria, including requirements for training, waste characterization, documentation, and other necessary items. Each generator must take steps to provide a reasonable level of assurance that prohibited wastes are segregated from the S/I waste streams. Dumpsters are provided for the collection of S/I wastes prior to disposal in an appropriate landfill. Inspections and self policing of S/I waste dumpsters are performed on a routine basis. The majority of the S/I waste at ORNL is disposed of at the ORR landfill at the Y-12 complex. The ORR landfill is permitted by TDEC. Properly managed S/I waste streams and leachate from S/I wastes are not allowed to enter into ground or surface water at ORNL, thereby protecting these resources.

5.7.4 Training

Waste generators are trained through formal waste management training programs in regulatory compliance and waste management issues as well as on the importance of preventing pollution and minimizing waste generation.

5.8 SPILL AND RELEASE REPORTING AND RESPONSE, SINK AND DRAIN SURVEY, AND UNDERGROUND INJECTION CONTROL

5.8.1 Spill Prevention, Control, and Countermeasures Plan

In accordance with 40 CFR Part 112 "Oil Pollution Prevention," ORNL maintains and applies a site-specific *Spill Prevention, Control, and Countermeasures (SPCC) Plan*. The plan provides instruction on spill response, control, and reporting, and documents ORNL practices designed to prevent spills of oils and other hazardous substances. Included in the plan are instructions for above-ground tank inspections, secondary containment dike inspections and operations, transportation safeguards, and maintenance of a comprehensive database of storage tanks on the ORNL site. Inspection of above ground tanks, secondary containment requirements, etc., aids in the prevention of discharges of oils and other hazardous substances onto the surface and subsurface, thereby protecting groundwater resources at ORNL.

5.8.2 ORNL Sink and Drain Survey Program

In 1997, ORNL completed a comprehensive verification of the routing of all wastewater discharges from points of entry such as building sinks and floor drains. As a result, over 9000 sink and drain records were produced and are stored in a central database. ORNL continued its efforts in 1998 to ensure that sinks and drains discharge to the proper wastewater collection systems by initiating an annual division-by-division recertification of ORNL sinks and drains. An intranet web interface is available for facility personnel to record corrections and updates to sink and drain data. Annual division certification of drain discharges gives ORNL management confidence that no drains discharge to the subsurface, thereby protecting groundwater resources at ORNL.

5.8.3 Underground Injection Control (UIC)

The UIC program provides standards, technical assistance, and grants to state governments to regulate injection wells in order to prevent them from contaminating drinking water resources. The EPA defines the five classes of wells according to the type of fluid they inject and where the fluid is injected. The EPA has published regulations related to siting, drilling, constructing, and operating many types of injection wells. ORNL has no active wells for the underground injection of wastes, and, as such, has no UIC permits for such activities. Hydrofracture wells used for past injection of radioactive wastes are regulated by CERCLA because they are part of the overall groundwater remediation program administered by BJC. Periodically, UIC approval is sought from the State of Tennessee for UT-Battelle research activities that may involve the injection of experimental tracers underground (Class V well permitting). The State of Tennessee maintains a program for dye/tracer notifications, which are usually allowed in place of UIC permitting for research activities. Direct injections into groundwater at ORNL are regulated and, therefore, no materials are injected into groundwater without prior permission from the state of Tennessee.

5.9 CONTROLLED USE OF FERTILIZERS AND PESTICIDES

Except for limited and controlled use of fertilizers in selected forestry, experimental biology, and construction applications, fertilizers are not applied on a routine basis at ORNL. Fertilizers may occasionally be used during initial stages of grass growth (e.g., hydroseeding) following new construction projects. Insecticides, herbicides, and pesticides are occasionally used at the ORNL site. In compliance with regulatory requirements under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), ORNL maintains an inventory of all chemicals stored at various facilities and records of all chemical applications. Supervisors of personnel applying chemicals are trained and certified for the safe handling and application of these chemicals. Uncertified applicator personnel perform pesticide application under the direct supervision of those who hold certification.

6. MONITORING

Groundwater monitoring program elements include installation of monitoring wells, planning and scheduling; quality assurance, sample collection, sample analysis, data analysis and interpretation, and reporting. The two main programs involved with groundwater monitoring are the UT-Battelle ES Program and the BJC EM remedial action program. UT-Battelle and BJC groundwater programs coordinate their efforts and discuss areas of mutual interest to prevent duplication of effort in monitoring groundwater resources at ORNL. In the future, these programs be more closely coordinated to prevent duplication of effort in the sampling and analysis of groundwater. The GWPPD will ensure that groundwater data collected from UT-Battelle and BJC monitoring programs undergo periodic reviews by UT-Battelle and BJC hydrogeologists to determine whether an off-site release has occurred. A listing of facilities currently under the jurisdiction of UT-Battelle and BJC is found in Appendix B. Additionally, a map showing the ownership of facilities in the main plant area, HFIR, and the Robotics and Process Systems Complex (RPSC) is found in Appendix C.

6.1 ORNL GROUNDWATER MONITORING PROGRAMS

Ongoing groundwater monitoring activities at ORNL include (1) monitoring in direct support of the groundwater monitoring requirements specified under the DOE - UT-Battelle contract (WSS, DOE Order 5400.1 components), (2) continued RCRA monitoring of SWSA 6 by BJC, and (3) monitoring in support of CERCLA-related environmental remediation activities at ORNL by BJC. UT-Battelle's responsibilities include monitoring active sites currently under control of UT-Battelle; the groundwater monitoring activities performed under the auspices of RCRA and CERCLA are covered in Sect. 6.5.

6.2 DOE ORDER 5400.1 MONITORING

DOE Order 5400.1 (*General Environmental Protection Program*), Chapter IV requires that a groundwater monitoring program be developed and implemented. The goals of the monitoring element of the groundwater monitoring program are to

- Demonstrate compliance with and implementation of all applicable regulations and DOE orders,
- Obtain data for the purpose of determining baseline groundwater quality and quantity conditions,
- Identify existing and potential groundwater contamination sources and maintain surveillance of these sources,

- Provide data to permit the early detection of groundwater contamination,
- Provide a reporting mechanism for communicating the groundwater quality information,
- Provide data upon which decisions can be made regarding management and protection of groundwater resources and the need for remedial actions,
- Evaluate the effectiveness of groundwater remediation systems and provide the data necessary for decisions on the current and future operations of these systems,
- Evaluate groundwater quality in areas where contaminants have the potential to migrate off-site, and
- Support decisions concerning land-use practices and the management of groundwater resources.

Several of these monitoring objectives are achieved through implementation of current BJC RCRA and CERCLA groundwater monitoring programs at ORNL. Other objectives are addressed by groundwater monitoring activities currently performed by UT-Battelle. In accordance with the monitoring strategy presented in the *Environmental Monitoring Plan for the Oak Ridge Reservation* (EMP) (DOE 1998a), current UT-Battelle groundwater monitoring efforts are implemented as either surveillance monitoring or exit-pathway monitoring. The surveillance and exit-pathway monitoring programs conducted by Ut-Battelle have been periodically evaluated to ensure that the current monitoring strategy addresses the potential of off-site migration of contaminants.

The network of 49 monitoring wells that are specifically sampled for surveillance purposes was established in 1996. Surveillance monitoring also encompasses groundwater sampling and analysis activities associated with the recent tritium leak from the process waste drain (PWD) system at the HFIR site. All sampling and analysis activities performed by UT-Battelle are executed in accordance with standardized monitoring protocols, and the results of the monitoring are presented in the *Annual Site Environmental Report for the Oak Ridge Reservation* (ASER) (DOE 2001). Exit-pathway monitoring at ORNL involves collection of groundwater samples from a fixed network of perimeter monitoring wells. The following is a brief description of current surveillance monitoring and exit-pathway monitoring.

The groundwater monitoring program at ORNL consists of a network of wells of two basic types and functions: (1) water-quality monitoring wells built to RCRA specifications and used for site characterization and compliance purposes and (2) piezometer wells used to characterize groundwater flow conditions. Groundwater quality monitoring wells are designated as hydraulically upgradient or downgradient, depending on their location relative to the general direction of groundwater flow. Upgradient wells are located to provide groundwater samples that are not expected to be affected by possible leakage from a facility. Downgradient wells are positioned along the perimeter of a facility or site to detect possible groundwater contaminant migration from the site. Historically, the surveillance and exit-pathway monitoring programs have been based on the concept of the WAG. The concept of the WAG was developed to facilitate evaluation of potential sources of releases to the environment. A WAG is a grouping of multiple sites that are geographically contiguous and/or that occur within hydrologically (geohydrologically) defined areas. Some WAGs share boundaries, but each WAG represents a collection of distinct small drainage areas, within which contaminants have been introduced. Monitoring data from each WAG are used to direct further groundwater studies aimed at addressing individual sites or units within a WAG as well as contaminant plumes that extend beyond the perimeter of a WAG. The monitoring data collected from the surveillance program is used to determine if releases to off-site users of groundwater have occurred.

At ORNL, 20 WAGs were identified by the RCRA Facility Assessment (RFA) conducted in 1987. Fig. 6.1. displays the locations of the WAGs. Thirteen of these have been identified as potential sources of groundwater contamination. Additionally, a few areas exist where potential remedial action sites are located outside the major WAGs. These individual sites have been considered separately (instead of expanding the area of the WAG). Water quality monitoring wells were established around the perimeters of the WAGs that were determined to have a potential for release of contaminants.

In 1996, the DOE EM Program established the Integrated Water Quality Program (IWQP) to conduct long-term environmental monitoring throughout the ORR. The IWQP was the vehicle for the DOE EM to carry out the regulatory requirement from the Federal Facilities Agreement (FFA) to conduct postremedial action monitoring. Under the IWQP Plan (DOE 1998), the use of the WAG concept shifted to a watershed approach to monitoring, which resulted in the assignment of two watersheds to ORNL–Bethel Valley and Melton Valley. The Water Resources Restoration Program (WRRP) succeeded the IWQP in fall 1999. BJC has responsibility for the implementation of the WRRP at ORNL.

The ORNL groundwater program was reviewed in 1996, and modifications included transfer of monitoring responsibility for approximately 120 surveillance wells to the WRRP. UT-Battelle monitors groundwater at 49 well locations as part of its surveillance and exit-pathway monitoring program to determine if releases to off-site users of groundwater are occurring. UT-Battelle has monitoring responsibility for facilities that have the potential for groundwater contamination caused by ongoing UT-Battelle activities. To provide consistency with ASERs and to allow comparison of activities and sampling results, the WAG monitoring concept is used in the following discussions.

6.2.1 Bethel Valley

ORNL's research and development facilities have been located in Bethel Valley for 50 years. Facilities in Bethel Valley include the main ORNL buildings used in current research and development (R&D) activities, reactors, surface impoundments, three inactive low-level radioactive waste burial grounds, several wastewater treatment systems, buried waste tank farms with transfer pipelines, and a general services area that includes a gas station for government vehicles. Many of the facilities and essentially all of the contaminated sites are legacies of past R&D activities at the site and are managed for remedial action (RA) under CERCLA by BJC.

6.2.1.1 ORNL Main Plan Area (WAG 1)

The ORNL main plant area (WAG 1) contains most of the facilities used in current R&D activities at ORNL as well as about one-half of the remedial action sites identified to date by BJC. Many of the WAG 1 sites were used to collect and store LLW in tanks, ponds, and waste treatment facilities; but some sites also include landfills and sites that have been contaminated by spills and leaks that have occurred over the past 50 years. Because of the nature of cleanup and repair, it is not possible to determine which spill or leak sites still represent potential sources of release.

UT-Battelle facilities that were determined to have potential vulnerabilities with respect to potential subsurface contaminant releases during the FEVA (Van Hoesen and Vogel 2001) include the sewage treatment plant and Buildings 2026, 3019A, 3047, 3525.

Aeration lagoons at the sewage treatment plant are suspected to release sanitary wastewater into the shallow groundwater beneath and adjacent to the ponds. Because of the condition of ORNL infrastructure and the presence of widespread legacy contaminated soil and groundwater in the area, contamination is periodically detected in wastewater at the sewage treatment plant. The contamination infiltrates into the sanitary sewer

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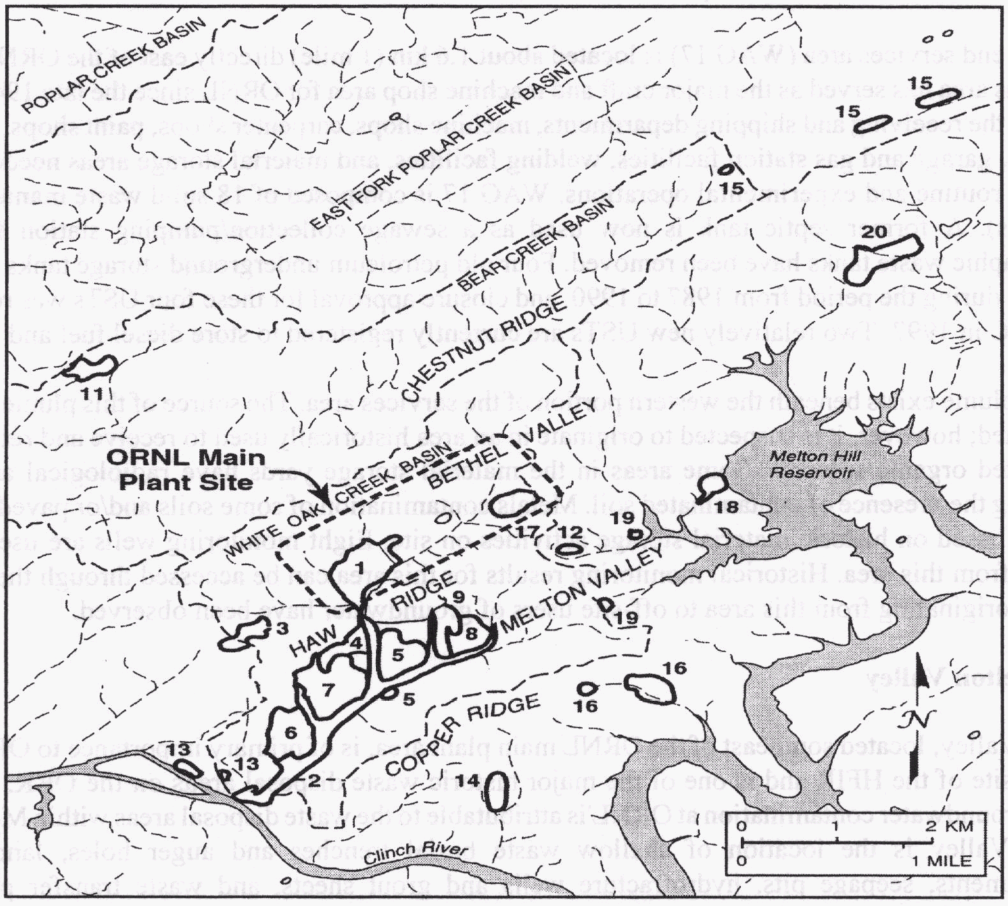

Fig. 6.1. Location of Waste Area Groupings in the vicinity of ORNL.

system in some areas when the groundwater table is high. Although portions of the sanitary sewer system have been improved by installation of pipe sleeves to prevent or reduce infiltration some contamination continues to enter the system. Seepage of wastewater from the aeration lagoons into the groundwater creates problems particularly when this wastewater is contaminated.

The principal vulnerability associated with the listed buildings is the presence and ongoing discharge of contaminated wastewater into the deteriorated drain lines, which may subsequently leak outward into soil or groundwater. Four monitoring wells are located at the southern perimeter of the main plant area and are used in monitoring releases from this area. Historical monitoring results for this area can be accessed through the ASERs. No releases originating from this area to off-site users of groundwater have been observed.

6.2.1.2 East End Services Area (WAG 17 Area)

The east end services area (WAG 17) is located about 1.6 km (1 mile) directly east of the ORNL main plant area. This area has served as the major craft and machine shop area for ORNL since the late 1940s. The area includes the receiving and shipping departments, machine shops, carpenter shops, paint shops, lead-melting facilities, garage and gas station facilities, welding facilities, and material storage areas needed to support ORNL's routine and experimental operations. WAG 17 is composed of 18 solid waste management units (SWMUs). A former septic tank is now used as a sewage collection/pumping station for the area. Photographic waste tanks have been removed. Four old petroleum underground storage tanks (USTs) were removed during the period from 1987 to 1990, and closure approval for these four USTs was received from the TDEC in 1997. Two relatively new USTs are currently registered to store diesel fuel and gasoline.

A VOC plume exists beneath the western portion of the services area. The source of this plume has not been determined; however, it is suspected to originate in an area historically used to receive and return drums of chlorinated organic solvents. Some areas in the material storage yards have radiological area postings, indicating the presence of contaminated soil. Metals contamination of some soils and/or paved areas is also possible based on historic material storage activities on site. Eight monitoring wells are used to monitor releases from this area. Historical monitoring results for this area can be accessed through the ASERs. No releases originating from this area to off-site users of groundwater have been observed.

6.2.2 Melton Valley

Melton Valley, located southeast of the ORNL main plant area, is of primary importance to ORNL because it is the site of the HFIR and is one of the major historic waste disposal areas on the ORR. Much of the legacy groundwater contamination at ORNL is attributable to the waste disposal areas within Melton Valley. Melton Valley is the location of shallow waste burial trenches and auger holes, landfills, tanks, impoundments, seepage pits, hydrofracture wells and grout sheets, and waste transfer pipelines and associated leak sites. In addition to legacy waste disposal areas, several active research facilities are located within Melton Valley. As with Bethel Valley, groundwater plumes within Melton Valley generally enter the surface water system where contaminants are frequently encountered.

6.2.2.1 White Oak Creek and Tributary Floodplains (WAG 2 Area)

The White Oak Creek and tributaries floodplains (WAG 2) are the bottomland areas adjacent to the major streams that drain the Melton Valley area. White Oak Creek is the principal receiving water body for storm water runoff, permitted wastewater discharges, and nonpoint discharges of groundwater seepage from clean and contaminated areas. White Oak Creek, its tributaries, and the associated floodplain areas are pathways through which water, dissolved contaminants, and eroded soil and sediment are transported. Most of the floodplain areas are rather densely vegetated with trees, and many areas are wetlands. White Oak Lake and the White Oak Creek embayment are located at the downstream end of White Oak Creek, just upstream of the confluence of White Oak Creek with the Clinch River. Surface water flow volume and contaminant concentrations are monitored continuously at White Oak Dam. White Oak Lake and the White Oak Creek embayment are both still water areas where sediment settles from the water column. During the early years of ORNL's operation, wastewater discharges from the main plant area to White Oak Creek resulted in contamination of much of the White Oak Creek floodplain in Melton Valley as well as accumulation of contaminated sediment in the beds of White Oak Lake and the embayment. The principal radiological contaminant in the floodplain and lake bed is cesium-137 although lower concentrations of cobalt-60, americium-241, and isotopes of plutonium are detectable in some areas. Very little strontium-90 is detected in floodplain soil or lake bed sediment samples because strontium is more soluble and has less affinity for sorption to soils than the more abundant radiological contaminants. PCBs are also detectable in some of the floodplain and lake bed soils and sediments. Because most of the contaminated lake bed sediments were deposited during the 1940s and 1950s, cleaner sediment has accumulated, burying the older more contaminated materials several meters below the current lake bed.

Although White Oak Creek and the floodplain areas function as pathways for contaminant migration to the Clinch River little evidence exists that the floodplain areas themselves are significant sources of the strontium-90 and tritium, the major contaminants detected at White Oak Dam. Sixteen monitoring wells are used in monitoring releases from this area. Historical monitoring results for this area can be accessed through the ASERs. No releases originating from this area to off-site users of groundwater have been observed.

6.2.2.2 HFIR, MSRE, and HRE Areas (WAG 8 and 9 Areas)

The HFIR, Molten Salt Reactor Experiment (MSRE), and HRE areas are in the eastern portion of Melton Valley. The MSRE and HRE sites are no longer active, and contaminated facilities and areas associated with them are listed in the FFA for remedial action under the CERCLA Program. BJC is responsible for the environmental management of these areas.

The HFIR and associated facilities, the Radionuclide Engineering Development Center, MSRE, and a number of inactive facilities are included in WAG 8. WAG 8 includes 36 SWMUs associated with the reactor facilities in Melton Valley. The SWMUs consist of active LLLW collection and storage tanks, leak/spill sites, a contractors' soils area, radioactive waste ponds and impoundments, and chemical and sewage waste treatment facilities.

Liquid radioactive wastes from WAG 8 facilities are collected in on-site LLLW tanks and are periodically pumped to the main plant area (WAG 1) for treatment and disposal. The waste includes demineralizer backwash, regeneration effluents, decontamination fluids, experimental coolant, and drainage from the compartmental areas of filter pits. Because of a leak from a PWD line at HFIR, characterization monitoring activities were carried out to determine the leak location and the nature and extent of the contamination emanating from the leak. As a result of the characterization monitoring, operational monitoring of the HFIR site is currently on-going. See Sect. 6.4 for a brief description of HFIR monitoring activities.

WAG 9 is located in Melton Valley about 1 km (0.6 mile) southeast of the ORNL main plant area and adjacent to WAG 8. WAG 9 is composed of eight SWMUs, including the HRE pond, which was used from 1958 to 1961 to hold contaminated condensate and shield water from the reactor, and LLLW collection and storage tanks, which were used from 1957 to 1986.

Because of the small number of groundwater monitoring wells in WAG 8 and WAG 9, they are sampled together. The analytical results for the two WAGs are also reported together. Eleven monitoring wells are used to monitor releases from this area. Historical monitoring results for each of these areas can be accessed through the ASERs. No releases originating from this area to off-site users of groundwater have been observed.

6.2.2.3 Exit-Pathway Monitoring

The ORNL exit-pathway monitoring program is designated to monitor surface and groundwater at locations that are thought to be likely exit pathways for groundwater affected by activities at ORNL. The program was initiated in 1993 and was reviewed in 1996, which resulted in White Oak Creek/Melton Valley being the focus of UT-Battelle monitoring efforts. Four of the ten wells identified in the EMP (DOE 1998) for ORNL's exit-pathway monitoring program are also part of the WAG perimeter-monitoring program. These four wells are located in WAG 2. The surface water location (White Oak Creek at White Oak Dam) is also sampled as part of the exit-pathway monitoring program. Ten monitoring wells are used in monitoring releases from this area. Historical monitoring results for each of these areas can be accessed through the ASERs.

Based on ORNL's existing groundwater monitoring, no indication exists of releases of contaminants to off-site users of groundwater. In addition, TDEC monitors several off-site users of groundwater that are located downgradient of ORNL. According to TDEC, all samples collected since 1996 from monitored residential wells indicate contaminant levels well below EPA's primary drinking water standards (Benfield 2001). The surface water location exit pathway monitoring point at White Oak Dam monitors small releases of contaminants to the Clinch River. Historical surface water exit pathway monitoring data can be accessed through the ASERs.

6.3 SURFACE, SEDIMENT, AND BIOLOGICAL SURVEILLANCE

The purpose of surface water, sediment, and biological surveillance is to evaluate discharges from ORNL facilities and their impacts on receiving streams. Measurement of water quality parameters in surface water, sediment, and biological samples provides a general guide to the environmental health of the system. DOE requirements for surveillance of radiological constituents in surface water mandate that ORNL demonstrate that the annual impact to drinking water is not greater than 4 mrem and that the impact to aquatic life is not greater than 1 rad/day.

The surface water, sediment, and biological sampling sites included in the ORNL ES Program are located on selected receiving streams immediately downstream from possible contaminant sources. Contaminant sources include both point sources (e.g., effluent outfalls) and nonpoint sources (e.g., waste disposal areas or burial grounds). Public drinking water supply intake surveillance and reference location surveillance is performed under the auspices of the EMP. Biological monitoring is also conducted as part of the NPDES compliance programs. Sampling stations are based on a body of information that is supplemented by other ongoing projects, such as delineation of contaminated groundwater plumes.

Historical results of ORNL's surface water, sediment, and biological surveillance monitoring are found in the ASERs.

6.4 HFIR OPERATIONAL MONITORING PROGRAM

Because of a leak from a PWD line[2] at HFIR, characterization monitoring activities were carried out to determine the leak location and the effect of the leak on the environment. The characterization was carried out from 2000 through 2001, resulting in locating and repairing the PWD line leak. Operational changes made by HFIR management in its wastewater system and repair of the leak site led to a reduction of tritium

[2]Tritium was the major contaminant of concern from the leakage of waste water from the PWD line at HFIR.

concentrations at monitoring locations nearest the leak site. However, a tritium plume occurred in the local groundwater downgradient of the HFIR building, and the HFIR Operational Monitoring Plan was implemented to serve three purposes: (1) provide early detection of groundwater contamination caused by operational activities or system failures, (2) monitor changes in groundwater contamination caused by the leak from the PWD line, and (3) monitor sources of groundwater contamination located hydraulically upgradient of the HFIR building. Data collected during the characterization phase of the tritium leak that occurred in 2000, as well as data collected under the HFIR Operational Monitoring Plan, indicate that tritium levels have declined in downgradient monitoring wells closest to the leak site, but have increased in monitoring wells located further downgradient of the leak site, indicating movement of the tritium plume in the downgradient direction.

6.5 ENVIRONMENTAL MANAGEMENT GROUNDWATER MONITORING PROGRAM (CERCLA, RCRA)

The DOE EM Program is responsible for determining the nature and extent of CERCLA contamination, reaching environmental cleanup decisions acceptable to state and federal regulatory agencies, implementing the remedial actions, and performing environmental monitoring to measure the effectiveness of remedial actions as they are performed at ORNL. BJC is the management and integration contractor responsible for implementing the EM Program on the ORR. Within BJC, environmental monitoring to measure effectiveness of remedial actions is performed under the WRRP. At each of the three Oak Ridge installations on the ORR, BJC water quality programs are managed at the site level and are integrated with the respective site EM projects. For the ORNL site, BJC plans and implements environmental monitoring through the X-10 Water Quality Program (XWQP). Off-site monitoring (off DOE property) related to CERCLA actions is also included in the scope of the WRRP. Overall, the planning, implementation, and reporting of EM-related monitoring are integrated across the ORR. The annual WRRP Sampling and Analysis Plan (SAP) includes the full scope of EM monitoring activities for each of the site monitoring programs and the off-site monitoring requirements. The WRRP SAP is a living document that is issued annually. As site monitoring requirements vary, the monitoring scope in the SAP varies, and modifications to monitoring activities are made as required and documented through SAP addenda.

Because the principal pathways of contaminant migration from EM sites are via groundwater and surface water, these are the primary focus of environmental monitoring for the EM Program. The XWQP monitoring scope includes measurement of surface water flow and contaminant discharge fluxes at key White Oak Creek tributary locations as well as in Raccoon Creek. These sites are monitored for the purpose of showing changes in the locations and fluxes of contaminant releases into the surface water system, which ultimately discharge to the Clinch River. Because surface water is an effective integrator of contaminant releases from near-surface contaminant sources surface water monitoring data are usually the first and most cost-effective indicator of a contaminant release in a watershed or subwatershed area.

Groundwater monitoring performed by the EM Program at the ORNL site includes

- Preremediation baseline groundwater sampling at sites scheduled for remedial action within approximately12 months,
- Postremediation monitoring to verify remedy effectiveness as specified in action memoranda or remedial action design documents (or equivalent),
- Groundwater monitoring at active waste management areas including the SWSA 5 North TRU waste burial area,

- RCRA groundwater monitoring at SWSA 6, and
- Discretionary groundwater sampling and analysis from existing wells in the event that surface water or other monitoring data indicate a high likelihood that a new release is in progress.

In addition to the preceding rationales for groundwater monitoring, the EM Program is committed by the *Record of Decision for Interim Actions for the Melton Valley Watershed at the Oak Ridge National Laboratory, Oak Ridge, Tennessee* (DOE 2000) to install and monitor deep groundwater monitoring instrumentation in two areas in Melton Valley--at the hydrofracture waste disposal area and at the Melton Valley groundwater exit pathway between Tennessee Hwy. 95 and the Clinch River. The Melton Valley record of decision also requires DOE to prepare a monitoring plan for the Melton Valley watershed to document the strategy for implementing surface water and groundwater monitoring throughout that area to ensure that appropriate, integrated monitoring is performed. The *Melton Valley Monitoring Plan, Oak Ridge, Tennessee* (DOE 2001) has been submitted by DOE to TDEC and EPA for review.

Results of environmental monitoring performed by the EM Program at Oak Ridge are reported annually in the *Remediation Effectiveness Report for the U.S. Department of Energy Oak Ridge Reservation, Oak Ridge, Tennessee* (RER) (BJC 2000) describes, in detail, the current RCRA and CERCLA monitoring efforts at ORNL. Data are archived in the Oak Ridge Environmental Information System (OREIS) within 30 days of issuance of each annual D1 RER. The OREIS database makes all EM data that are used to prepare the RER publically accessible using an internet data browser.

6.6 ORNL FACILITY ENVIRONMENTAL VULNERABILITY ASSESSMENT AND FUTURE ACTIONS

As previously stated, the overall goal of the GWPPD is to ensure compliance with DOE Order 5400.1. Current ORNL groundwater monitoring programs comply with the applicable requirements of DOE Order 5400.1, and ORNL has not detected off-site migration of contaminants via the groundwater pathway to users of groundwater outside of ORNL. However, because of the leak of tritium discovered at HFIR during the autumn of 2000, UT-Battelle management directed that an assessment be performed at all facilities managed by UT-Battelle. This necessitated an "inward look" at facilities managed by UT-Battelle to determine if these facilities are adding contaminants to groundwater at ORNL. This "inward look" began with the FEVA, as introduced in Sect. 4.2. The primary goal of the FEVA was to establish an environmental vulnerability baseline at ORNL that could be used to support the Laboratory planning process and place environmental vulnerabilities in perspective. The information developed during the FEVA was intended to provide the basis for management to initiate immediate, near-term, and long-term actions to respond to all identified vulnerabilities. The FEVA team was able to develop information about sources and pathway analyses although several factors impacted the team's ability to provide quantitative information. Among these factors were (1) the complexity and scope of facilities, infrastructure, and programs; (2) the significantly degraded physical condition of the facilities and infrastructure; (3) the large number of known environmental vulnerabilities; (4) the scope of legacy contamination issues; (5) the lack of facility process and environmental pathway analysis performed by the accountable line management or facility owner; and (6) poor facility and infrastructure drawings.

The FEVA did not identify any major vulnerabilities associated with the UT-Battelle managed facilities that warranted immediate "stop work" or "initiate immediate response" actions. The FEVA team evaluated 11 Priority 1 facilities that contain significant hazardous material inventories and typically conduct hot cell or glove box type operations that use relatively small quantities of hazardous materials. The FEVA team also evaluated 64 Priority 2 facilities with smaller inventories of hazardous materials. No situations were identified where significant release of contaminants to the environment was occurring or where an imminent threat of a release existed. A number of facilities were identified in the FEVA that have the potential to release contaminants to the soil and groundwater zones. Most of the potential releases would occur because of liquid waste disposition via deteriorated infrastructure such as occurred during the tritium release incident at HFIR. Additionally, the FEVA determined that significant environmental impacts could be associated with off-normal conditions such as inadvertent sprinkler discharge, fire, high winds, or seismic events. These lower probability events are evaluated on the basis of facility safety, and environmental vulnerabilities are typically mitigated by a combination of safety and defense-in-depth systems.

Through existing UT-Battelle groundwater and surface water surveillance and BJC CERCLA and RCRA groundwater monitoring efforts, ORNL is able to detect large, acute, chronic, or intermittent releases of contaminants to the environment. However, the same assurance cannot be provided with respect to chronic or infrequent low-volume, low-concentration releases from individual sites within ORNL. This situation is due to significant masking from leaks from a deteriorated infrastructure (e.g., potable water, storm water, process waste, sanitary sewer), the large amount of legacy contamination at ORNL, and volumetric dilution due to the use of large quantities of single-pass cooling water. Low-volume or low-concentration sources are difficult to detect at present because of this masking.

6.6.1 Quantitative Facility Assessment and Prioritization Plan

Difficulty in detecting low or intermediate volumes or concentrations of contaminants is compounded by the WAG-boundary approach used in UT-Battelle's current groundwater monitoring efforts. Further evaluation of the vulnerabilities identified during the FEVA assessment will support a more quantitative characterization of the sources, help evaluate contaminant pathways, and better define risks. A Quantitative Facility Assessment and Prioritization Plan (QFAPP) will be developed to perform these tasks for UT-Battelle facilities. The findings from the implementation of the QFAPP coupled with interpretation of site hydrogeology and review of available UT-Battelle and BJC groundwater data for the subject facilities will help decision makers assess prioritization of UT-Battelle groundwater monitoring activities. Strategic changes to the current groundwater monitoring program are anticipated; consequently, WAG-based monitoring efforts will be modified to incorporate monitoring of groundwater impacted by facilities operated by UT-Battelle as well as continued exit-pathway groundwater monitoring. The findings of the QFAPP will also aid in evaluating the adequacy of the current groundwater surveillance and exit-pathway monitoring programs.

The QFAPP will (1) address sources of contamination within the facilities; (2) evaluate the risk of release of contaminants based on the operational history of the facility, the condition of facility infrastructure, etc.; (3) review fate and transport characteristics of contaminants found in the facilities; and (4) review the hydrogeological characteristics underlying the facilities. From these information sources, UT-Battelle will prioritize the risks posed by facilities requiring groundwater monitoring improvements and schedule these improvements or additional wells as appropriate.

6.6.2 Groundwater Implementation Plan

UT-Battelle will generate a Groundwater Implementation Plan (GWIP) from the findings of the QFAPP. The GWIP will be written for all facilities identified as requiring groundwater monitoring and will include information regarding roles and responsibilities, health and safety, sampling and analysis, statistical analysis and data validation, data management, chain-of-custody, standard operating procedures, quality assurance plan, reporting, groundwater monitoring improvements plan, monitoring well abandonment, pollution prevention/waste minimization, and hydrogeological interpretation. As part of the GWIP, UT-Battelle will

- Establish data quality objectives (DQOs) to ensure that the rationale for the monitoring programs is well understood and defined (e.g., future well installation, parameters sampled, and monitoring frequency) and to ensure that the programs for collecting the data are designed to meet all requirements and that the program will optimize the groundwater monitoring network and

- Upgrade procedures for groundwater monitoring, well installation, and maintenance and abandonment.

6.6.3 Groundwater Contingency Plan

An important premise of the ORNL GWPPD is that groundwater monitoring is, in itself, not protective of groundwater quality. Rather, groundwater resources can be adequately protected only by the prevention and/or timely remediation of contaminant releases. However, groundwater monitoring is one approach to evaluate the effectiveness of prevention programs. UT-Battelle facilities selected through QFAPP for groundwater monitoring will have monitoring sites located as close as possible to potential source areas within each of the UT-Battelle facilities. Such methods may include monitoring wells, springs, seeps, or sump monitoring locations, or other monitoring approaches such as surface monitoring. The improved groundwater monitoring network will provide ORNL with timely information related to potential impacts that UT-Battelle facility operations may have on groundwater quality. Expanded information on the adequacy of its pollution prevention programs will also be available through the QFAPP. Close proximity monitoring will establish baseline monitoring thresholds for each of the facilities at these identified locations. If unexpected levels of contamination are detected, appropriate investigations as to the source of the contamination and/or corrective measures will be taken. UT-Battelle will develop a Groundwater Contingency Plan (GWCP) that will describe the process used by ORNL management to respond to unexpected detection of contaminants in groundwater at these facilities. The GWCP will be a stand-alone document that will (1) outline appropriate thresholds for groundwater contaminants for each UT-Battelle facility, (2) describe a process for investigating a release to groundwater, and (3) describe the method to communicate to DOE the existence of such a release.

Assessment of the adequacy of the ORNL groundwater monitoring well network will be an ongoing process. The need for additional monitoring wells at either new or significantly modified facilities will be identified during the ORNL facility design review process (see Sect. 5.5).

7. GROUNDWATER RESTORATION ACTIVITIES

Areas of contaminated groundwater at ORNL exceed 500 acres. Groundwater contaminants and concentrations vary widely and include radionuclides, metals, and VOCs. Radiological contamination dominates the groundwater problem at ORNL, followed by VOCs; areas of metals contamination are much less significant. Contaminant source areas include (1) contaminated soils at waste transfer pipeline leak or spill sites, (2) contaminant plumes that originated from historic liquid waste handling and disposal activities in unlined ponds and waste seepage basins, and (3) leachate seepage from approximately 150 acres of unlined shallow land trenches that contain low-level radioactive and mixed waste. The EM Program strategy for handling the broad range of contaminant release problems at ORNL has been to collect and treat only the most contaminated groundwater plumes that contribute significantly to degraded surface water quality while, planning and implementing measures to control contaminant sources.

Through past monitoring and assessment activities, the EM Program prioritized areas of groundwater release to surface water and has used the CERCLA Removal Action authority to install collect-and-treat systems at three sites.

The first two sites at ORNL to receive groundwater collection and treatment were groundwater seeps into Melton Branch in Melton Valley. The seep collection and treatment systems were constructed in 1994 and have been in continuous operation since construction. The sites are known as "Seep C" and "Seep D." The principal contaminant of concern at both is strontium-90, although tritium and other contaminants are also present. The source of contaminated groundwater for both seeps is leachate from unlined shallow land burial trenches in SWSA 5. Both systems use zeolite (a mineral ion exchange media) to adsorb the strontium-90 in the collected groundwater. The Seep C system is a gravity-head driven system that uses sealed 55-gal drums filled with zeolite; Seep D system uses a pump to lift groundwater from a vault constructed beneath the stream channel. The pump at Seep D pushes the collected water through a series of two treatment cylinders that contain the zeolite. The performance criterion that is applied to the two treatment systems is removal of more than 90% of the strontium-90 from the collected groundwater. Remedial actions planned for SWSA 5 will replace the Seep C system; however; operation of the Seep D system will be required indefinitely because of the seep's location 150 to 300 m (500 to 1000 ft) away from contaminant source trenches in SWSA 5.

The third groundwater collect-and-treat site is known as the "Corehole 8" plume, which is located in the ORNL main plant area. The source of this plume is LLLW that leaked from a waste transfer pipeline associated with a stainless steel tank in the North Tank Farm. The plume was first discovered in the mid 1980s when groundwater in a well approximately 300 m (1000 ft) from the tank farm was found to contain elevated beta activity and strontium-90 and contamination was detected in First Creek at the western edge of the main plant area. Definitive identification of the plume and its source did not occur until the early 1990s. The plume seeps through bedrock for several hundred meters before upwelling to the water table in shallow soils where plume inleakage into storm drains provides a direct discharge pathway to the creek. In 1995 a CERCLA Removal Action was performed to install two shallow groundwater collection sumps with level-controlled pumps in areas of plume discharge that affected storm drains. This system captures plume water which is pumped to an existing manhole in the process waste treatment system drain network. Collected groundwater is treated in the process waste treatment plant to remove strontium-90 and isotopes of uranium prior to discharge of the treated water through the nonradiological wastewater treatment plant, which has an NPDES-permitted outfall to White Oak Creek. In addition to the shallow plume collection sumps, a well was installed near the plume source to verify plume geometry and to enable a pumping test in the plume. This well can be pumped at rates up to 5 gpm to control head in the most contaminated portion of the plume. When pumped at low volume (2 gpm or less), the well withdraws approximately 500,000 pCi/L of strontium-90, more than 10,000 pCi/L of uranium isotopes, as well as americium-241.

When ORNL facilities and infrastructure were constructed during the 1940s and 1950s, a complex system of buried wastewater collection pipelines was installed to receive building wastewater and water from drywells associated with below-grade LLLW holding tanks. Much of the original piping in this system, known as the PWD system, was vitreous clay pipe. Because of the pipeline material type, method of installation, and deterioration through time, the system developed leaks—both inleakage where piping is submerged in groundwater and outleakage where the piping is above the water table. During the late 1980s, much of this system was lined with synthetic InSituForm® lining. Some sections that were know to receive contaminated groundwater inleakage were left unlined to facilitate the groundwater collection for treatment and to prevent plumes from seeping to local streams. Additionally, drywell sump pumps and gravity drain systems at many of the tank farms continue to direct groundwater into the PWDs. The process waste system collects and treats 30 to 50 million gallons per year of groundwater from the ORNL main plant area. Most of the collected groundwater is contaminated before it enters the drain system. All the water that enters the process waste system is treated prior to discharge under an NPDES permit.

8. GROUNDWATER MONITORING PROGRAM COORDINATION

BJC is responsible for groundwater and surface water cleanup at ORNL. Under agreements with DOE, BJC monitors cleanup activities that will require monitoring of groundwater and surface water in selected areas of the ORNL site. Productive interaction between UT-Battelle and BJC is crucial to the overall effectiveness of the GWPPD; ensuring that no duplication of monitoring efforts occur and that available resources are effectively directed toward mutual programmatic objectives. Although responsible for different programmatic monitoring activities, UT-Battelle and BJC will continue to cooperate in coordinating monitoring activities, sharing monitoring data, and providing technical support. Specifically, UT-Battelle will continue to submit groundwater data to the OREIS in a timely manner. Additionally, UT-Battelle will continue to fund the maintenance and updating of the database of subsurface geologic data and construction details for monitoring wells, currently managed by BJC. BJC groundwater experts will be available to aid in hydrogeological interpretation, groundwater coordination activities, etc.

The objectives of groundwater protection coordination are to

- Manage, protect, and restore the groundwater resource in a coordinated fashion;
- Ensure coordination on planning, projects, and systems, enabling cost-effective, valid application of data for analysis of the entire groundwater flow system and contaminant transport; and
- Accomplish timely reporting and interpretation of high quality groundwater data.

9. COMMUNICATIONS

Communication among stakeholders is important in the implementation of the GWPPD. The stakeholders consist of UT-Battelle, BJC, DOE, TDEC, EPA, and the public, represented by various local organizations. The CERCLA process has been the basis for the majority of the communication and community involvement activities related to environmental restoration and protection. It is important to keep all stakeholders informed about groundwater quality at ORNL.

UT-Battelle plans to establish better internal and external avenues of communication. It is particularly important that UT-Battelle line managers be aware of the impacts, if any, that their facilities are having on groundwater quality to enable them to initiate appropriate, timely corrective actions.

For CERCLA remediation projects, communication occurs through routine meetings with TDEC and EPA. For non-CERCLA groundwater surveillance, communication will be performed through DOE's ORNL Site Office.

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APPENDIX A

APPENDIX A: BACKGROUND INFORMATION

A.1 HYDROGEOLOGIC FRAMEWORK

The following description of ORNL's hydrogeology was taken from *Characterization Plan for the Oak Ridge National Laboratory Area-Wide Groundwater Program, Oak Ridge, Tennessee* (SAIC 1994). This section presents an overview of the hydrogeologic system at ORNL. It presents a conceptual model for subsurface flow and contaminant transport at ORNL. The conceptual model represents the integration of data, information, and interpretations from many technical studies. The model is intended to describe the concepts of groundwater flow within ORNL and the physical factors that define those concepts.

The conceptual model is described in three sections. The first of these is the geological setting (Sect. A.2), which describes the groundwater regime in terms of its underlying lithologic and structural characteristics. The second section is the hydrological conceptual model (Sect. A.3), which describes the behavior of subsurface water and the strong stratigraphic and structural controls on groundwater flow. The ORNL flow boundaries and pathways narrative makes up the third section (Sect. A.4). These three sections emphasize the hydrogeology of ORNL, but use information related to any rock unit within the Oak Ridge Reservation (ORR) when appropriate. In particular, considerable attention is paid to the Knox Group and to the Knox aquifer whose rocks bound the groundwater regime at ORNL but lie outside of its boundaries. The hydrologic properties of these rocks, however, make them effective barriers to groundwater; therefore, they play an important role in boundary considerations.

The site conceptual model is presented in Sects. A.1.1 through A.1.3 that outline the fundamental points of the site conceptual model. Sections A.2 through A.4 then provide details on each of these components.

A.1.1 Geological Setting of ORNL

- The geology of ORNL displays a layer-cake-style stratigraphy that is observed on a regional scale where limestone- and dolomite-dominated rock groups are interbedded with dominantly clastic groups. This style is repeated on the outcrop scale where clastic beds are interlayered with limestone/dolomite beds.

- Because of their susceptibility to chemical weathering, limestone/dolomite beds often exhibit karstic features. This is most apparent in the Knox Group rocks, but is also present to a more limited extent in the Chickamauga Group.

- Knox Group and Rome formation rocks represent the competent units that supported the folding and low-angle thrust faulting associated with the Alleghenian orogeny, and as a result, constitute ridge-forming units within ORNL and the ORR.

- Residuum (weathered bedrock) covers most of ORNL to variable thickness. It is thicker on ridges, thinner in the valleys, and nearly disappears in stream channels.

- The rocks found within ORNL and the ORR are extensively fractured.

- Fracture density and aperture width decrease with depth. Apertures are greatest near the residuum/bedrock interface, probably as a result of weathering.

A.1.2 Hydrological Conceptual Model

- The rocks comprising the geology of ORNL can be broadly characterized in terms of their hydrologic properties: (1) the Knox aquifer, composed of rocks of the Knox Group and the Maynardville Limestone of the Conasauga Group; and (2) aquitards, the bulk of the rocks inside ORNL's groundwater regime.

- In general, groundwater is recharged on ridges and is discharged into lakes, streams, springs, and seeps entirely within the boundaries of ORNL.

- The subsurface flow system can be divided into three distinct parts: the storm flow zone; the vadose zone; and the groundwater zone that is subdivided into the water table interval, the intermediate interval, the deep interval, and the aquiclude.

- Subsurface flow occurs predominantly within the storm flow zone, the vadose zone, and the water table interval of the groundwater zone. Therefore, subsurface flow is relatively shallow.

- Subsurface flow occurs mainly through fractures and fracture systems that are sometimes enlarged by solutioning.

- Within the aquifer units, a large portion of subsurface flow occurs within solution cavities.

A.1.3 ORNL Flow Boundaries and Pathways

- Because groundwater is recharged on ridges and because groundwater elevations roughly mimic topography in the groundwater regime at ORNL, the boundaries of the groundwater regime are largely defined by ridges and other topographic highs and lows.

- The previously mentioned boundaries are located along Chestnut Ridge to the north, Copper Ridge to the south, the Clinch River and the Bearden Creek watershed to the east, the Clinch River to the west, and the base of saline/freshwater interface at the base of the groundwater regime. Additionally, Haw Ridge represents a medial boundary that separates Bethel and Melton Valleys.

- Chestnut Ridge and Copper Ridge are held up by the Knox aquifer, which lies outside of the ORNL groundwater regime. The high hydrostatic pressure of the Knox aquifer constitutes an effective pressure barrier that confines the ORNL groundwater regime.

- The Rome formation, predominantly an aquitard, holds up Haw Ridge and contains a dolostone unit with high hydraulic head that serves a pressure barrier, which separates the groundwater of Bethel Valley from the groundwater of Melton Valley.

- Nearly all subsurface flow in the ORNL groundwater regime is discharged to White Oak Creek (WOC) and its tributaries and exits ORNL via the White Oak Dam (WOD) outfall.

A.2 GEOLOGICAL SETTING

The physical geology and the geological controls on groundwater flow and occurrence on the ORR have been the subject of considerable study over the past few years. One of the goals of these studies has been to establish correlations between fracture systems and associated subsurface fluid flow, thereby formulating a structural-hydrologic model that enables interpretation of the behavior of groundwater and other subsurface fluids on the ORR. Understanding the structural setting and its controls on fluid flow is essential to developing a model for groundwater movement in this area. Descriptions of the results of work carried out to date and of the site conceptual model that has been developed are contained in Hatcher et al. (1992) and Solomon et al. (1992).

A.2.1 Location and Physiography

The 35-mile^2 ORR is located on the western side of the valley and ridge Physiographic Province, approximately 32 km (20 miles) west of Knoxville, Tennessee (Fig. A.1). The general features that distinguish this province are (1) parallel ridges and valleys typically oriented from northeast to southwest, (2) topography influenced by alternating weak and strong strata exposed to erosion through a relatively great amount of folding and faulting, (3) a few major transverse streams with subsequent streams forming a trellis-like drainage pattern, (4) many ridges with accordant summit levels suggesting former erosion surfaces (peneplantation), and (5) many water and wind gaps through resistant ridges. The scarp (northwest-facing) slopes of these ridges are relatively short, steep, and smooth. The dip (southeast-facing) slopes are longer, shallower, and hummocky to dissected. Elevations range from 225 to 410 m (738 to 1345 ft) above sea level. Surface slopes average ~0.075 and generally have a range of 0.03 to 0.3. However, the steepest part of a scarp slope may be less than 0.5, whereas slopes on the floodplain of the Clinch River are ~0.015. Drainage patterns have a dendritic shape in headwater areas and a trellis shape farther downstream.

The surface boundaries of the ORNL groundwater regime, as they are known to exist today, are shown in Fig. A.2. The northern boundary is located on Chestnut Ridge at the contact point of the Knox Group with the underlying Chickamauga Group. The southern boundary is located along Copper Ridge where the Knox Group contacts the underlying Conasauga Group. The eastern boundary is defined by the Clinch River at Melton Valley and the Bearden Creek watershed in Bethel Valley, both of which are topographically higher than the Clinch River to the west that defines the western boundary. Haw Ridge, which separates Bethel Valley and Melton Valley, also separates the valleys' groundwater, and therefore is considered to be a medial boundary within ORNL's groundwater regime. An additional subsurface boundary, not depicted in Fig. A.2, exists within the deep groundwater system where salinity exceeds 10,000 mg/L.

A.2.2 Stratigraphy

Rock units of the stratigraphic section in the ORR range in age from Early Cambrian to Silurian (Table A.1). The stratigraphic units comprise a complex assemblage of lithologies, with representatives from the entire Cambrian and Ordovician section. The total thickness of the section in the ORR is approximately 2.5 km (1.6 miles).

In general, the Cambro-Ordovician Knox Group and part of the overlying Chickamauga Group form the competent units within the major thrust sheets in this area. Each major stratigraphic unit (and formations within those units), because of compositional and textural properties, possesses unique mechanical characteristics that respond differently to the strain fields affecting these rocks through time. Therefore, each may have experienced a slightly different scheme of brittle deformation that subsequently may affect the transmission of fluids through them. For general descriptions of the stratigraphy of geological characteristics that respond differently to the strain fields affecting these rocks through time. Therefore, each may have experienced a slightly different scheme of brittle deformation that subsequently may affect the transmission of fluids through them. For general descriptions of the stratigraphy of geological units in the ORR, see Hatcher et al. (1992) for an overview of the ORR geology; Haase, Walls, and Farmer (1985) for the Conasauga Group and Rome formation; Lee and Ketelle (1987) for the Knox Group; and Lee and Ketelle (1988) for the Chickamauga Group.

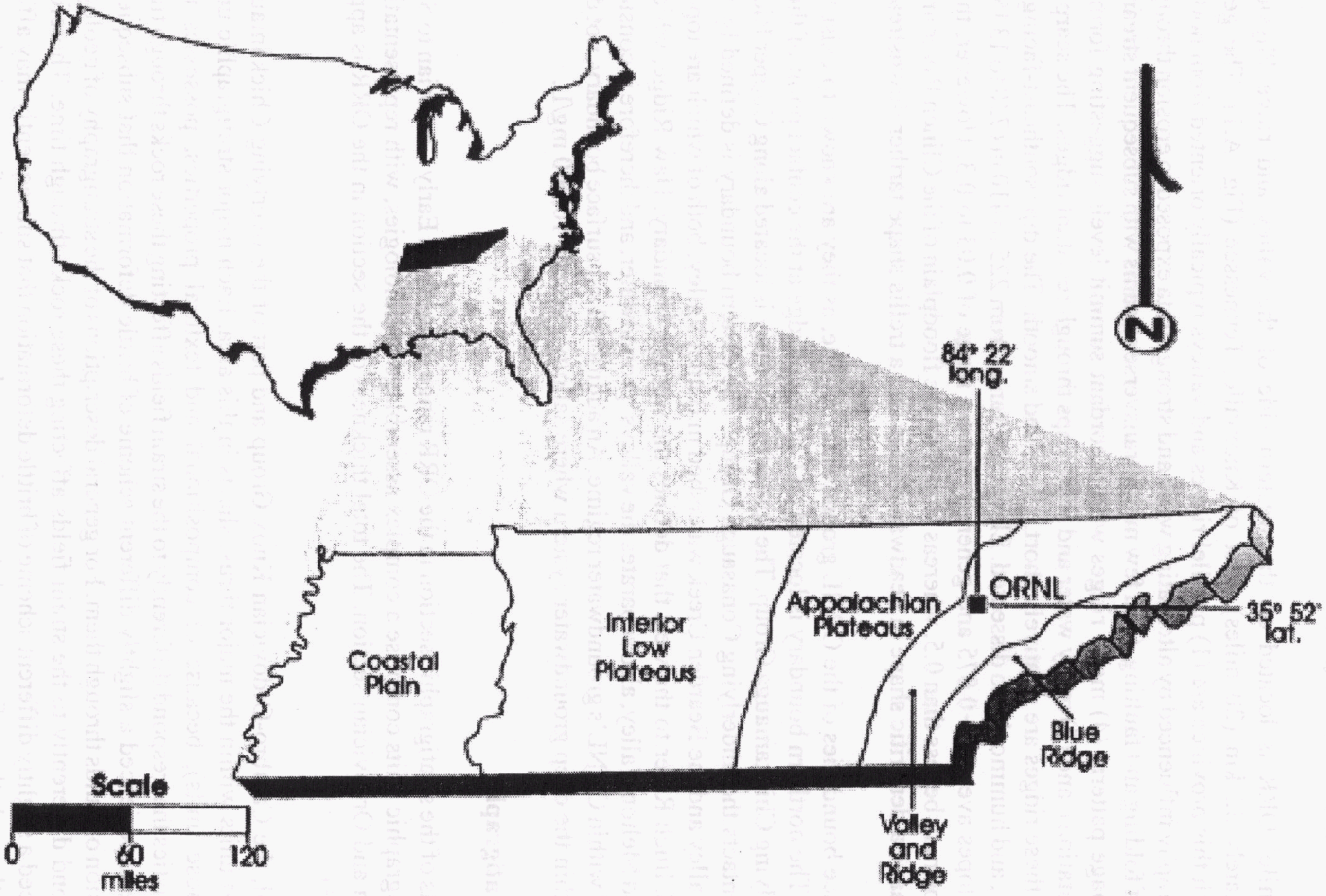

Fig. A.1. Location map showing the relationship of ORNL to the physiographic provinces of Tennessee.

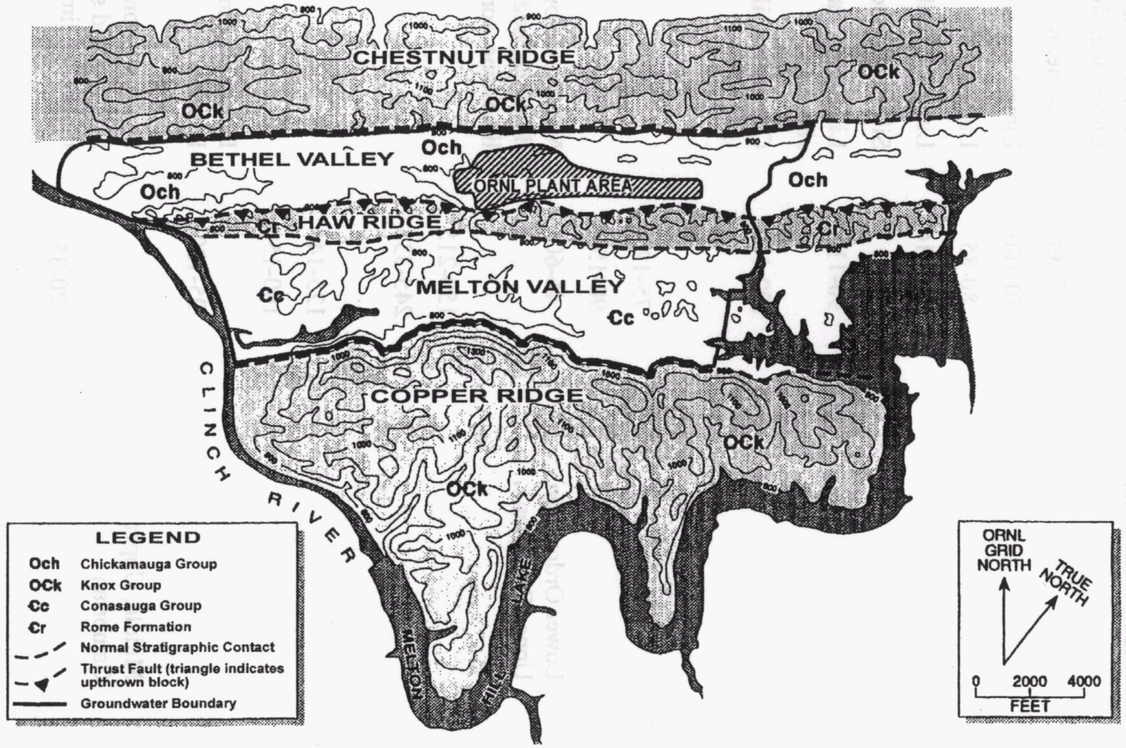

Fig. A.2. Generalized geologic map of the vicinity around ORNL.

Table A. 1. Geologic units of the ORR[a]

Unit	Age	Thickness (m)	Lithology
Rockwood Formation	Silurian	120	Sandstone, shale
Sequatchie Formation	Upper Ordovician	60	Argillaceous limestone
Reedsville Shale	Upper Ordovician	60	Calcareous shale
Chickamauga Group	Middle Ordovician	400-700	Limestone, argillaceous Limestone, shale, siltstone
Blackford Formation		50-80	Siltstone, limestone
Lincolnshire Formation		70-100	Limestone, siltstone
Rockdell Formation		80-85	Limestone
Benbolt Formation		110-116	Limestone, siltstone
Bowen Formation		5-10	Siltstone, limestone
Witten Formation		90-110	Limestone, calcarenite, siltstone
Mocassin Formation		100-170	Calcareous siltstone, limestone
Knox Group			
Mascot Dolomite		75-120	
Kingsport Formation		90-150	
Longview Dolomite	Lower Ordovician, Upper Cambrian	46-60	Massive dolomite, siliceous dolomite, bedded chert, limestone, some clastics
Chepultepec Dolomite		150-215	
Copper Ridge Dolomite		245-335	
Conasauga Group			
Maynardville Limestone		125-145	
Nolichucky Shale		100-150	
Dismal Gap Formation (formerly Maryville Limestone)		95-120	Dolomitic limestone, limestone
Rogersville Shale	Middle, Upper Cambrian	20-35	Shale, siltstone, calcareous siltstone and shale, shaly limestone, limestone
Rutledge Limestone		30-40	
Pumpkin Valley Shale		90-100	
Rome Formation	Lower Cambrian	90-125	Shale, siltstone, sandstone, local dolomite lenses

[a]Names in italic are units that make up the Knox aquifer. Other units form the ORR aquitards.

The following is a brief description of the formations in the vicinity of ORNL and their relative importance with respect to groundwater occurrence and groundwater flow.

A.2.2.1 Rome Formation

The Rome Formation outcrops at ORNL on Haw Ridge and dips beneath Melton Valley. It is the oldest rock unit exposed in the ORR. In the Copper Creek thrust sheet, this formation is 122 to 183 m (400 to 600 ft) thick. Maroon, green, and/or yellow-brown micaceous shale is the most common lithology in the Rome Formation. Siltstone, sandstone, dolomitic sandstone, and dolomite are interbedded with shale. Some dolomite and dolomitic sandstone beds in the upper Rome Formation are laterally continuous in the Copper Creek thrust sheet. It is the massive dolomite and the dolomitic sandstone beds that provide the best potential pathways for groundwater flow (in the Rome Formation), especially where these beds have developed karst. In one instance, sinkholes occur on Haw Ridge at the Rome Formation outcrop. These sinkholes are indicative of karst formation in the Rome Formation that may represent a layer with good permeability.

A.2.2.2 Conasauga Group

The Conasauga Group outcrops above the Rome Formation on the southern flank of Haw Ridge and in the central axis of Melton Valley. The average thickness of the Conasauga Group in Melton Valley is 567 m (1860 ft). The Group is traditionally subdivided in central East Tennessee into the Middle Cambrian Pumpkin Valley Shale, Rutledge Limestone, Rogersville Shale, and Maryville Limestone (the Dismal Gap Formation referred to by Hatcher et al. 1992), and the Upper Cambrian Nolichucky Shale and Maynardville Limestone.

With the exception of the Maynardville Limestone, the Conasauga is a monotonous sequence of shale, siltstone, and thin-bedded limestone and is considered a regional aquitard. Some formations, however, include laterally continuous limestone beds that can be several meters thick and, where karstification has enlarged fractures in limestone beds, strata-bound high permeability zones may exist. The Maynardville, the uppermost member of the Conasauga Group, is a massively bedded limestone and dolomite with extreme karstification.

Because of the many years of extensive waste disposal activities in Melton Valley at ORNL and Bear Creek Valley at the Y-12 complex, the Conasauga Group is the most thoroughly studied rock unit in the ORR. The main Waste Area Groupings (WAGs) in Melton Valley are located on the Conasauga Group outcrop.

A.2.2.3 Knox Group

The Knox Group underlies and forms Copper Ridge and Chestnut Ridge in the vicinity of ORNL and dips southward underneath Bethel Valley. On the ORR the Knox Group is divided into five separate units: the Copper Ridge Dolomite, the Chepultepec Dolomite, the Longview Dolomite, the Kingsport Formation, and the Mascot Dolomite. Total thickness of the Knox Group ranges between 600 and 900 m (1970 and 2950 ft), with the Copper Ridge Dolomite making up roughly one-third of the total. This formation forms the principal strong unit to support the folding and low-angle thrust faulting that occurs throughout the valley and ridge Physographic province in East Tennessee.

The Knox Group is composed of a series of medium to thickly bedded, massive, grey, green, and pink dolomite. The Copper Ridge and Longview Formation dolomites are siliceous, and these formations tend to be ridge formers. All formations within the group contain subordinate amounts of chert, some in nodular form that characteristically remains in the soils after weathering of the dolomite matrix. The Knox Group, along with the Maynardville Limestone from the Conasauga Group, forms the regionally important Knox aquifer. Although the dolomite lithologies have little matrix porosity, extensive karst formation in the Knox

Group formations has resulted in substantial secondary porosity and high permeability. Sinkholes are common at outcrop, and springs and seeps are common features at the upper and lower geologic contacts.

A.2.2.4 Chickamauga Group

At ORNL the Chickamauga Group underlies Bethel Valley. The lower contact with the Knox Group outcrops on the south face of Chestnut Ridge and the upper contact is faulted against the Rome Formation by the Copper Creek Fault on the north face of Haw Ridge. All the WAGs in Bethel Valley (WAGs 1, 3, and 17) are located on Chickamauga Group formations.

The Chickamauga Group represents deposition on a regionally extensive disconformity on the top of the Knox Group. Relief on this surface accounts for variable stratigraphic thicknesses in the lower Chickamauga unit. The Group consists primarily of calcareous shale interbedded with shaley to silty limestone and is considered a regional aquitard. In Bethel Valley, where the section is incomplete, the Chickamauga Group consists of more than 400 m (1312 ft) of variable thick maroon shale-dominated units separated by gray limestones. Some formations include laterally continuous limestone beds that can be several meters thick. Where karstification has enlarged fractures in limestone beds, strata-bound high permeability zones may exist.

A.2.2.5 Unconsolidated materials

Unconsolidated material overlying bedrock at ORNL consists of weathered bedrock (referred to as residuum), human-made fill, alluvium, and colluvium. Residuum comprises a majority of the unconsolidated material in this area. The depths to unweathered bedrock differ throughout ORNL because of the different thicknesses of fill and alluvium and the particular weathering characteristics of the bedrock units. The total thickness of these materials typically ranges from 3 to 15 m (10 to 50 ft) (Hoos and Bailey 1986).

Residuum overlies bedrock throughout the ORNL except in scattered outcrop areas and ranges from silty to sandy clay overlying shale units to a slightly sandy clay overlying limestone units; predominant colors are shades of brown, orange, and grey. With increasing depth, the colors darken and the clay grades to weathered rock that has retained its structural characteristics (saprolite). Bedding planes and joint surfaces in the weathered bedrock commonly are marked by dark reddish-brown and yellow-brown oxide coloration, indicative of a high degree of weathering by circulating groundwater. Most groundwater flow through residuum is by way of matrix flow. Hydraulic conductivities are generally low and range from 1×10^{-4} to 1.7×10^{-7} cm/s. Conduits may exist in the residuum where major flow paths emerge from the underlying bedrock (Moore 1988).

A.2.3 Structural Geology

The Oak Ridge area is underlain by two major northeast/southwest-trending thrust faults that dip to the southeast and define two thrust sheets: the White Oak Mountain and the Copper Creek Fault (Hatcher et. al. 1992). Chestnut Ridge and Bethel Valley are underlain by the White Oak Mountain thrust sheet, which is soled by the White Oak Mountain fault. Haw Ridge, Melton Valley, and Copper Ridge are underlain by the Copper Creek thrust sheet, which is soled by the Copper Creek thrust fault. Both thrusts are regional thrust faults of the Valley and Ridge Physiographic Province, which demonstrate at least several kilometers of translation (see Fig. A.3). The faults formed during the Permian-Pennsylvanian age Alleghenian Orogeny and have not been historically active. At the ORR, both faults trend parallel to regional strike (N55E) and dip steeply (45°) to the southeast (King and Haase 1987). Bedding plane dip values measured in outcrops cluster around 45° but may steepen to vertical as a result of localized small-scale folding or faulting.

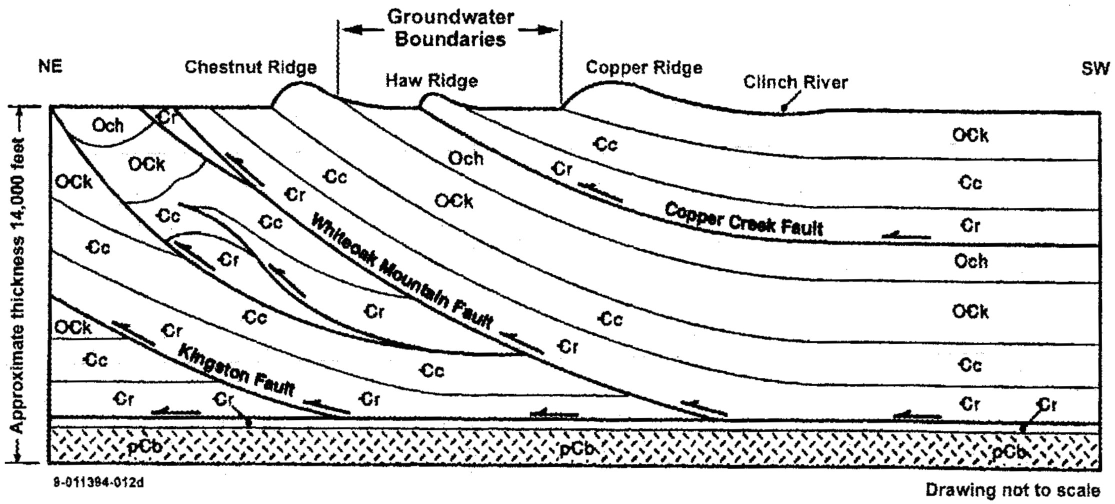

Fig. A.3. Schematic geologic cross section in the vicinity of ORNL.

The ORR contains a variety of geologic structures on several scales. The map-scale structure is dominated by southeast-dipping beds interrupted by the two major thrust faults and the locally overturned East Fork Ridge and Pilot Knob synclines (McMaster 1962). Overall, the faults and stratigraphy strike northeast and dip to the southeast, except in the synclines where dips swing to the northwest. Outcrop-scale structures include minor folds, faults, and fractures. The formation of most of these structures is closely related to map-scale structures. Most minor folds and faults observed occur in either the Rome Formation or Conasauga Group, a function of lithology, stratigraphy, and proximity to map-scale faults and folds.

A.2.4 Fractures

Because of the large-scale faulting, all geologic units within ORNL are highly fractured. The most pervasive structural features are extensional, hybrid, and shear fractures, which are important factors in groundwater flow in this region. A majority of fractures constitute a single cubic system (three orthogonal sets) of extension fractures (Dreier, Solomon, and Beaudoin 1987; Sledz and Huff 1981). One fracture set is formed by bedding planes, which have an average strike of approximately N55E; the dip is variable, but commonly is approximately 30 to 40°SE (Stockdale 1951). Two other joint sets are approximately strike parallel and dip parallel; at shallow depths, these sets are commonly angled approximately 50 to 60° below horizon. These three fracture sets may occur in any locality, and other extension and shear fractures may also be present. The parallel bedding fractures are mainly release joints, and recent studies elsewhere in the Appalachians suggest that release joints can form at depths up to a kilometer (Engelder 1985).

Fractures are abundant on rock outcrops, in saprolite, and at shallow depths in fresh bedrock. Dreier, Solomon, and Beaudoin (1987) measured an average fracture density of ~200/m (60/ft) in saprolite of the Maryville Limestone and Nolichucky Shale at WAG 6 near ORNL. At the other extreme, Sledz and Huff (1981) measured a minimum fracture density of 5/m (1.5/ft) in fresh rock. Fewer open fractures occur at deeper levels. As described by Haase, Walls, and Farmer (1985), fracture frequency is variable, but most fractures observed in cores occur within limestone or sandstone layers greater than 0.5 m (1.6 ft) thick, and many fractures are filled or partly filled with secondary minerals.

Most fractures are short, a few centimeters to approximately 1 m (3.3 ft) in length (longest dimension). Sledz and Huff (1981) found a relatively uniform fracture length of approximately 12 cm (5 in.) in shale but a fracture length that increases with bed thickness in siltstone. Haase, Walls, and Farmer (1985) observed numerous fractures approximately 0.1 to 1.5 m (0.3 to 5 ft) long within limestone and sandstone units of the Conasauga Group and the Rome Formation. Groundwater flow occurs only through networks of pervious, connected fractures. In limestone, typical fracture spacings range from less than 5 cm (2 in.) for very thin beds to greater than 3 m (10 ft) for very thick to massive beds. The areal extent of fractures may be only a few square meters for thin to very thin beds, but pervious bedding-plane fractures may be 10^3 to 10^6 m^2 for medium to massive beds (Ford and Williams 1989). Also, many pervious fractures cross one to several rock layers but terminate at the connections with other fractures (Ford and Williams 1989).

A.2.5 Cavities and Solution Openings

In the Knox Group and, to a much more limited extent, in other carbonate rocks within ORNL, fractures are enlarged by solution. As solution progresses in an upgradient direction of the water table, some conduits, as they intercept smaller cavities, become dominant flow channels, in a way somewhat analogous to the development of a surface drainage system. It is only in the Knox Group and the adjacent Maynardville Limestone (together in this report called the Knox aquifer) that cavity systems are highly developed and are extensive; however, many of the smaller limestone or dolomite beds within the aquitards exhibit solution openings and cavities at shallow depth. Solution cavities probably are a significant factor in groundwater flow in the ORR.

Cavities in the Chickamauga Group were first described by Stockdale (1951). Since then, cavities have been reported in all other rock units with limey layers. A general principle of cavity occurrence is that the largest cavities are found in the purest and most massively bedded limestones. Cavities in the Conasauga Group have been reported only in the Maryville Limestone (now Dismal Gap Formation), Nolichucky Shale, and Maynardville Limestone. All three of these formations contain limestone layers, and cavities are presumed to occur in these layers. Similarly, cavities in Rome Formation bedrock may occur in dolostone layers, which have been described in the upper part of this formation (Stockdale 1951).

The records of 802 wells within the ORR and ORNL show that only 97 wells (12%) intercept a cavity, and most of these intercept only one cavity. However, some distinctive differences exist in cavity occurrence among the geologic units (Table A.2). None of the wells in the Rome Formation and only one (8%) in the Chickamauga Group intercept more than one cavity. In the Conasauga Group, 27 wells (46%) intercept more than one cavity, but only 11 wells (19%) intercept more than two cavities, and none intercept more than four cavities. More Knox wells (48%) intercept two cavities than one or any larger number. A total of ten cavities was reported in one Knox well, but only four wells (19%) intercept more than three cavities. Thus, multiple cavities are rare except in the Conasauga Group and the Knox Group, and more than three cavities are uncommon in these units.

Table A.2. Number of cavities in wells by geologic unit

		Number of wells with one or more cavities				
Geologic unit	Number of wells	One cavity	Two cavities	Three cavities	Four cavities	Five or more cavities
Chickamauga Group	13	12	1	0	0	0
Knox Group	21	5	10	2	3	1
Conasauga Group	59	32	16	9	2	0
Rome Formation	4	4	0	0	0	0
Total population	97	53	27	11	5	1

There is also a correlation between formations and the cavity geometry. The average cavity height (vertical dimension of a cavity in a boring) at ORNL in the 97 occurrences is 0.59 m (1.8 ft). The largest cavities are generally found in the Knox Group [mean = 1.0 m (3.3 ft)] and, although large cavities were found in the Conasauga Group, the average height of cavities in the Knox Group is almost twice as large as that in the Conasauga Group [mean = 0.16 m (0.5 ft)].

An analysis of cavity depths by geologic unit shows that the geometric mean depth of cavities in the Knox Group [mean = 34 m (112 ft)] is much larger than those in the Rome Formation [mean = 12 m (39 ft)], the Conasauga Group [mean = 8.3 m (27 ft)], and the Chickamauga Group [mean = 9.7 m (31.8 ft)]. This result was expected because of the larger regolith thickness in the outcrop area of the Knox Group is almost twice as large as that in the Conasauga Group [mean = 0.16 m (0.5 ft)].

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A.3 HYDROLOGICAL CONCEPTUAL MODEL

Two broad hydrologic units are identified in the ORR, each having fundamentally different hydrologic characteristics. The Knox Group and the Maynardville Limestone of the Conasauga Group constitute the Knox aquifer, in which flow is dominated by solution conduits formed along fractures and bedding planes. The remaining geologic units constitute the ORR aquitards, in which flow is dominated by fractures. For hydrological purposes, the Cambro-Ordovician Knox Group and the uppermost member of the Cambrian Conasauga Group (Maynardville Limestone) make up the Knox aquifer, an aquifer that is of regional importance. The remaining formations are considered aquitards on the ORR. Subsurface flow in both the Knox aquifer and in the ORR aquitards is recharged mainly on ridges and discharged into lakes, streams, springs, and seeps (Fig. A. 4). The subsurface flow system can be divided as follows: the stormflow zone; the vadose zone; the groundwater zone, which is subdivided into the water table interval, the intermediate interval, and the deep interval; and the aquiclude. Although many factors influence the groundwater flow regime within ORNL, topography, surface cover, geologic structure, and lithology exhibit strong influence on the hydrogeology. Variations in these features result in water flux variations.

The following are descriptions of the subsections of the hydrological conceptual model with emphasis placed on the groundwater subsection. Thorough discussions of the hydrological conceptual model can be found in Moore (1988), Solomon et al. (1992), and Moore and Toran (1992), from which the following section is summarized.

A.3.1 Storm Flow Zone

Detailed water budgets indicate that approximately 90% of active subsurface flow occurs through the 1- to 2-m-(3.3- to 6.6-ft-) deep storm flow zone (Moore 1988; Solomon et al. 1992). Natural areas of ORNL are heavily vegetated, and the stormflow zone corresponds approximately to the root zone. Infiltration tests indicate that this zone is as much as 1000 times more permeable than the underlying vadose zone. According to this conceptual model, during rain events, the storm flow zone partially or completely saturates and then transmits water laterally to the surface-water system. When the storm flow zone becomes completely saturated, overland flow occurs.

Between rain events, as the storm flow zone drains, flow rates decrease dramatically and flow becomes nearly vertical toward the underlying vadose zone. The transmissive capability of the storm flow zone is created primarily by root channels, worm holes, clay aggregation, fractures, etc., collectively referred to as large pores. Although highly transmissive, large pores comprise only approximately 0.2% of the total void volume of the storm flow zone. Because most of the water mass resides within less transmissive small pores, advective-diffusive exchange between large and small pores substantially reduces contaminant migration rates relative to fluid velocities in large pores (Solomon et al. 1992).

A.3.2 Vadose Zone

A vadose zone exists throughout the ORR and the ORNL site except where the water table is at land surface, such as along perennial stream channels. The thickness of the vadose zone is greatest beneath ridges and thins towards valley floors. Beneath ridges underlain by the Knox aquifer (Copper Ridge, Chestnut Ridge, McKinney Ridge, and Blackoak Ridge), the vadose zone commonly is as much as 50 m (160 ft) thick, whereas beneath ridges underlain by the Rome Formation (Haw Ridge and Pine Ridge) the vadose zone is typically less than 20 m (65 ft) thick. In lowland areas near streams, a permanent vadose zone does not exist because the storm flow zone intersects the water table. The vadose zone consists of regolith composed mostly of clay and silt, most of which is derived from the weathering of bedrock materials, and which has significant water storage capacity. Most recharge through the vadose zone is episodic and occurs along discrete

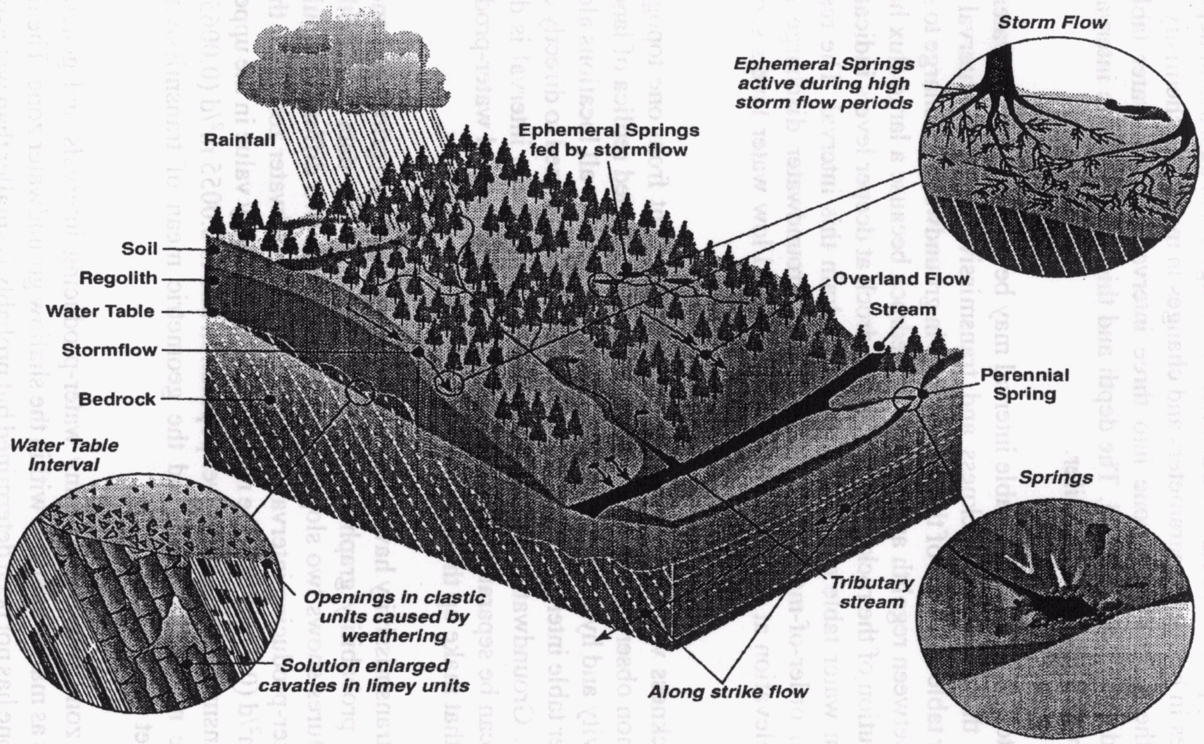

Fig. A.4. Schematic drawing showing conceptual groundwater flow at ORNL.

permeable features that may become saturated during rain events, even though surrounding micropores remain unsaturated and contain trapped air. During recharge events, flow paths in the vadose zone are complex, controlled by the orientation of structures of the materials, such as relict fractures. Between recharge events, flow rates decrease dramatically, and flow paths are toward the groundwater zone.

A.3.3 Groundwater Zone

The permanent water table typically is near the transition from regolith to bedrock at depths of less than 1 to 5 m (3.3 to 16 ft). Changes in hydraulic parameters and changes in major ion chemistry with depth suggest vertical subdivision of the groundwater zone into three intervals: (1) a water table interval, (2) an intermediate interval, and (3) a deep interval. The depth and thickness of these intervals vary, especially between the ORR aquitards and the Knox aquifer.

A thin (approximately 1 to 3 m thick) permeable interval may be present near the water table. Spatial and temporal differences in the saturated thickness and transmissivity of this interval explain both the configuration of the water table and most of the fluctuations in groundwater discharge to streams. The water table is near the contact between regolith and weathered bedrock because a large flux has formed regolith at shallower levels by solution of the rock cement; fresh bedrock at deeper levels indicates a smaller water flux. Seasonal declines in water table elevation can nearly drain this interval. The resulting changes in transmissivity explain an order-of-magnitude fluctuation in groundwater discharge rates even though contours of water table elevation at the times of annual high and low water levels show little change in hydraulic gradients.

Changes in saturated thickness with the inverse of hydraulic gradient from one topographic location to another explain the common observation that the water table is a subdued replica of land surface, because the product of transmissivity and hydraulic gradient is nearly constant at all locations along any flow path. The concept of a thin water table interval is new and detailed studies designed to directly define this interval have not been conducted. Groundwater movement below the water table interval is dominated by flow through fractures, which can be separated into the larger and well connected water-producing fractures as well as smaller fractures that make up the matrix.

More than 600 values of transmissivity have been measured by slug tests (primarily) and other tests in the study area. A cumulative probability graph (Fig. A.5) of transmissivity data from both water-producing openings and matrix fractures shows two slopes, thereby indicating two different populations. The upper population represents water-producing intervals in the shallow groundwater zone, and the geometric mean of transmissivity is 0.23 m^2/d (0.27 yd^2/d). The minimum transmissivity value in the upper population is the same as the maximum transmissivity in the lower population and is 0.0055 m^2/d (0.0065 yd^2/d). The lower population represents the matrix intervals, and the geometric mean of transmissivity is 0.0011 m^2/d (0.0013 yd^2/d) (Solomon et al. 1992).

The deeper groundwater zone occurs below any water-producing intervals and generally has the same hydrologic characteristics as matrix intervals within the shallow groundwater zone. The fracture porosity of the deeper groundwater zone has not been determined but probably is smaller than water-producing intervals of the shallow groundwater zone. Open fractures at depth have a smaller spatial frequency , and the average aperture is smaller because of a larger overburden pressure. A typical effective porosity in the deeper groundwater zone might be in the range of 1×10^{-5} to 1×10^{-4}, and the geometric mean of transmissivity in the deeper groundwater zone is 0.00044 m/d (0.00143 ft/d).

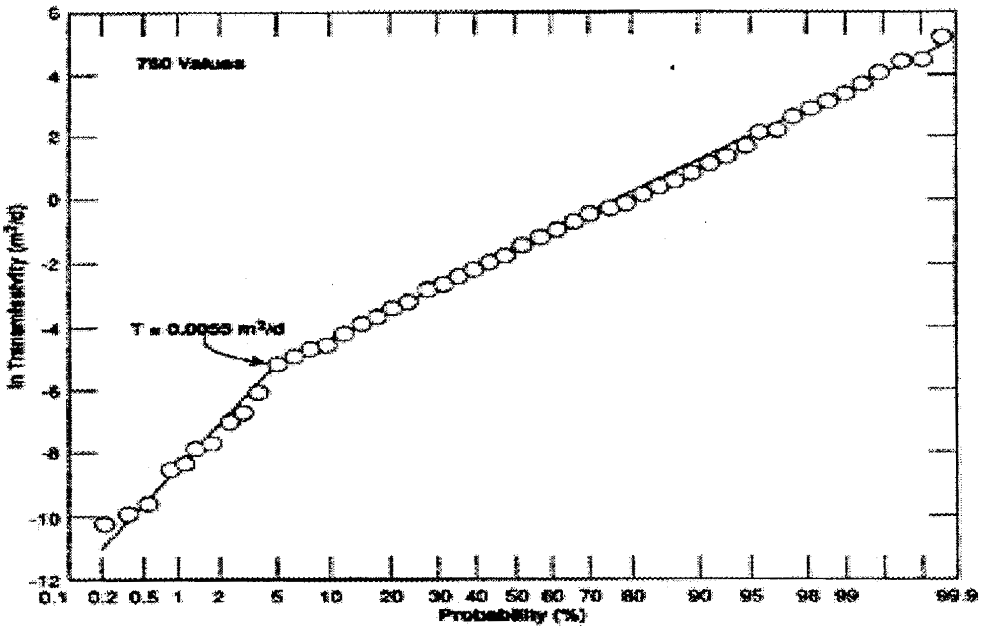

Fig. A.5. Cumulative probability graph of transmissivity data for water producing intervals and matrix fractures. ***Source*****: Adapted from Solomon et al. 1992.**

The small geometric mean of transmissivity in the deeper groundwater zone, as compared to water-producing intervals in the shallow groundwater zone, indicates that rates and quantities of groundwater flow are much smaller than in the shallow groundwater zone. Transmissivity has not been measured in the brine section of the groundwater zone; however, it is probably very low.

A.3.3.1 Flow at the Soil/Bedrock Interface

A convergence of evidence indicates that most water in the groundwater zone of the aquitards is transmitted through a layer, approximately 1 to 5 m (3 to 15 ft) thick, of closely spaced, connected fractures near the water table. Many open fractures, which extend only a short distance into the rock, can be seen on outcrops, and the near correspondence of the water table with the top of weathered bedrock is probably not coincidental. Regolith above this level has been formed by a large water flux, and the presence of unweathered bedrock at deeper levels apparently indicates a smaller water flux. Cyclic variations in water table elevation change the saturated thickness of the permeable layer. The resulting changes in transmissivity explain an order-of-magnitude fluctuation in groundwater discharge rates even though (1) contours of annual high and low water table elevations show little change in hydraulic gradient and (2) seasonal changes of water level in most wells are small compared with height of the water level above stream level. Compensating changes in hydraulic gradient and saturated thickness occur from one topographic location to another in order to conserve mass in the aquifer. The product of transmissivity and hydraulic gradient is constant (or increases with recharge) along each flow path.

The range of seasonal fluctuations in depth to the water table and in rates of groundwater flow vary significantly across the reservation. In the areas of the Knox aquifer, seasonal fluctuations in water levels average 5 m (16 ft), and the specific discharge through the active groundwater zone is typically 9 m/year (30 ft/year). In the aquitards of Bear Creek Valley, Melton Valley, East Fork Valley, and Bethel Valley, seasonal fluctuations in water levels average 1.5 m (5 ft), and typical specific discharge is 5 m/year (16 ft/year).

As in the storm flow zone, the bulk of water mass in the water table interval resides within porous matrix blocks between fractures, and diffusive exchange between matrix and fractures reduces contaminant migration rates relative to fracture fluid velocities. For example, the leading edge of a geochemically nonreactive contaminant plume migrates along fractures at a typical rate of 1 m/d (3 ft/d); however, the center of mass of a contaminant plume typically migrates at only 0.05 m/d (0.16 ft/d).

A.3.3.2 Fracture Control of Flow Paths

Below the water table interval, fracture control becomes dominant in flow path directing, particularly in the aquitards. The base of the water table interval corresponds to the zone of transition from regolith to bedrock. In the intermediate interval of the groundwater zone, groundwater movement occurs primarily in permeable fractures (Sledz and Huff 1981; Smith and Vaughan 1985; Dreier, Solomon, and Beaudoin 1987; Moore 1988).

Rocks in the ORR have little intergranular porosity and permeability, but fractures, both parallel to bedding planes and crosscutting, are present throughout the area. Flow through fractures, therefore, dominates the movement of groundwater on the ORR. The cube law (doubling a fracture's aperture increases the rate of flow through that fracture by 8 times) results in groundwater flow being dominated by the few fractures that have the largest apertures (Domenico and Schwartz 1990). Key parameters that determine whether fracture systems result in good hydraulic permeability relative to their orientation are the connectivity of fractures and lateral continuity of the individual fractures. Fracture systems that tend to contain laterally continuous fractures or that contain numerous small fractures that are well connected to each other (such as anastomosing fracture patterns) will tend to form higher permeability.

Both fracture density and average aperture are probably larger in water-producing intervals than in matrix intervals. Dreier, Solomon, and Beaudoin (1987) measured a fracture density of 200/m in saprolite of the WAG 6 area, but fewer fractures occur in rock that is less weathered. Sledz and Huff (1981, pp. 44-51) measured a minimum fracture density of 5/m in fresh rock. It may be reasonable to assume that average fracture density is 50 to 100/m in water-producing zones and 5 to 10/m in matrix zones. Moore (1988) calculated that the average aperture in water-producing zones is 0.019 to 0.025 m (0.062 to 0.082 ft), and that fracture porosity is 0.001 to 0.002. Similarly, he calculated that the average aperture in matrix zones is 0.009 to 0.011 mm (0.0003 to 0.0004 in.), and fracture porosity is 6×10^{-5} to 9×10^{-5}. The calculated porosity for water-producing zones is only slightly smaller than the average previously determined by hydrograph analysis (0.0042). Within a fracture, groundwater can flow downdip, laterally, or in both directions. Changes in flow direction, as well as splits and joins of flow paths, may occur at fracture intersections, and groundwater flow paths may locally resemble stair steps in both plan and section views. Tracer tests, however, show that most groundwater flow is nearly parallel to the water table. Because of the apparent lithological controls on fracture development, these fracture systems tend to form more densely at certain stratigraphic intervals. Thus, along-valley flow paths are almost entirely along strike and within water-producing intervals toward crosscutting, tributary valleys and streams. Cross-valley flow paths occur partly in water-producing intervals but also cross matrix intervals toward main-valley streams.

Below the intermediate interval, small quantities of water are transmitted through discrete fractures. Other than this, little is known about the deep interval. The hydrologically active fractures in the deep interval are thought to be significantly fewer in number and shorter in length than in the other intervals, and the spacing is thought to be greater, partly because of less dissolution of fracture fillings. Fracture orientations are thought to be similar to those described earlier for the water table interval.

A.3.3.3 Karst Control of Flow Paths

Karst is a type of topography that forms over gypsum, limestone, and dolomite bedrock as a result of both surface and subsurface dissolution of the bedrock. Because it is directly related to subsurface activity, karst also refers to all of the features that arise as a result of dissolution, including subsurface cavities. Karst occurs worldwide. It is actively developing today and has developed in the past to become a part of today's rock record (paleokarst). In the case of ORNL, karst involves dissolution of carbonate rocks, i.e., limestone and dolomite, which occurs in response to complex chemical equilibria between atmospheric CO_2, groundwater, and the carbonate rock. Dissolution occurs more readily at low pH but, as a chemical reaction, it is also highly dependent upon other parameters such as groundwater composition.

Karst-related features have great potential for enhancing a rock's ability to transmit groundwater and for directing its flow. Cavities are the most obvious example in this regard. Open cavity systems that are well-connected to exit points are highly transmissive; cavities that are poorly connected or filled with detritus can be less transmissive. Less obvious karstic feature for transmitting groundwater are topographic irregularities, such as solution valleys, that formed on paleosurfaces and today provide preferred groundwater pathways along bedding planes.

Cavities have been identified in many drill holes in the ORR. In most instances, they appear to have formed along existing fractures by solution enlargement of voids. However, Moore (1988) presented arguments that many cavities may have formed in the geologic past. For example, many cavities are filled with terrace gravels that developed on paleosurfaces, and Moore (1988) argues that the cavities which contain the gravels must have formed contemporaneously with the gravels. These cavities may represent ancient flow paths that are active today. The likelihood of ancient cavities in the rocks of the ORR imply the possibility of other paleokarst features, such as solution valleys, which today may serve as conduits for groundwater. Solution valleys and other paleokarst, surficial features are today more occult than cavities. Whereas cavities are readily apparent when intercepted during drilling, the surficial features are camouflaged along bedding planes. However, likely locations for paleokarst topographic conduits are at unconformities where the stratigraphically lower bed is composed of carbonate rock.

Solution cavities within ORNL are not well characterized. As a result, understanding of their origin and abundance is lacking, and the data for comparing the transmissive quality of cavities to that of fractured rock is inconclusive. The reason for the poor characterization of cavities is that they tend to occur only in the purest, most massively bedded carbonate rocks. In the whole ORR, this type of rock is dominated by the Knox aquifer which, because it occurs along ridges, is apparently unimportant for contaminant transport and has not been extensively studied as have rocks occurring in ORR valleys. At ORNL, massively bedded, pure carbonates are relatively sparse. They occur mainly in the Rockdell and Witten formations in Bethel Valley, in a dolostone unit in the Rome Formation on Haw Ridge, and in the Maynardville Limestone of the Conasauga Group along ORNL's southern boundary in Melton Valley. Transmissivity data for cavities, including those in the Knox aquifer, show them to be, on average, twice as transmissive as fractures (0.085 m/d vs. 0.041 m/d, respectively) (Moore 1988). However, the difference between the averages is not statistically significant (Moore 1988). Apparently, this is a result of the relatively few data for cavities (25) compared to the total number of data points (407), and the fact that the transmissivity data for cavities constitute both the highest and the lowest values of the data set with few values for cavities in between. This latter point probably arises because active, cavity-dominated flow systems are highly transmissive but, apparently, some of the fossil cavity flow paths are no longer active.

The velocity of groundwater in cavities is at present poorly defined as a result of the contradictory evidence from tracer tests and groundwater hydraulic gradients. The velocity of flow in the main conduits is an important parameter in predicting the rate of migration of contaminants in the subsurface. The stratigraphic location and depth of cavities in the aquitard formations are needed to better define flow paths.

A.3.3.4 Strata-Bound Flow Paths

Groundwater flow near valley floors within ORNL is often confined within discrete beds where movement occurs preferentially along strike toward crosscutting drainage ways. This type of flow is called strata-bound flow. Elongated cones of depression during pumping tests and first arrivals of tracers in wells located along geologic strike from the point of injection have been interpreted in some previous studies as indicating anisotropic flow and rock masses that are more permeable in the along-valley direction than in the cross-valley direction. Instead, these observations and measurements are best explained by strata-bound flow that results from the occurrence of solution cavities within only the purest and most massively bedded carbonate units, and by the development of fracture networks within discrete beds where flow paths within networks have a much larger average permeability than do flow paths across matrix intervals from one fracture network to another.

Examples of strata-bound flow at ORNL have been identified from the distribution of contaminants in plumes and from groundwater elevation measurements. The following are presently known examples of preferred flow paths at the ORNL site:

- A plume of radiologically contaminated groundwater has been identified at WAG 1 (Ketelle and Lee 1992). In this situation, radiologic contamination identified in Well 4005 at WAG 1 led to the development of a hypothesis for strata-bound contaminant migration in the Witten Formation. A 18-m (36-ft) thick limestone bed of apparent biothermal origin contained the highest levels of contamination in Well 4005 (487,093 pCi/L and 585,497 pCi/L gross beta/gamma). The subsurface extent of this bed was mapped using key stratigraphic indicators. Then using the hypothesis for strata-bound flow paths, the discharge points to storm drains and First Creek were predicted for this flow path. The predicted outfalls were subsequently tested by analyzing historical data for surface water and groundwater quality and the hypothesis was confirmed.

- Groundwater contamination has been identified at WAG 3 in Bethel Valley in monitoring wells and in surface water bodies that drain the site. Contamination in surface water appears in two distinct areas, one in the northwest tributary of WOC and a second in an unnamed tributary to Raccoon Creek. Studies of these tributaries have identified specific reaches that appear to be the sources of each stream's contamination. The hypothesis that strata-bound flow in the Witten Formation is controlling the distribution of contamination at WAG 3 comes from the observation that a line drawn between the seeps along each stream runs approximately parallel to strike and passed through SWSA 3, the expected main contributor to groundwater contamination in WAG 3. The distribution of contaminants in monitoring wells at this site is difficult to explain. The hypothesis for preferential flow needs to be further developed and tested for this site.

- Well 0883 is a 15-m (49-ft) open hole with a 0.3-m (1-ft) cavity at the bottom. The well is located in WAG 1 on the south side of the impoundments near WOC. Water levels in Well 0883 fluctuate only about 1.5 m (5 ft) [between 226 m and 227 m (741 ft and 746 ft) above mean sea level], even during heavy rains, which is relatively little compared to other wells in the ORR. Additionally, these water levels are some 8 to 9 m (25 to 30 ft) below the water level of WOC and more in line with the elevation of the Clinch River on the west end of ORNL. These observations imply that the stratum into which well 0883 penetrates contains a well-connected, cavity-dominated exit pathway whose water level is controlled by the level of the Clinch River.

A.3.3.5 Flow in Alluvium Deposits

Along WOC and Melton Branch, alluvium is less than 1 m (3.3 ft) thick, fine grained and difficult to distinguish from residual and colluvial soils. Subangular to rounded terrace gravels have been commonly described as mixed with clay and silt in near-surface samples from many wells. At one location, near Well 270 in WAG 6, a terrace deposit approximately 5 m (16 ft) thick was found to consist of "well-rounded pebbles and cobbles of quartzite and other resistant materials along with sand, silt, and clay. The pebbles and cobbles, which are not representative of the surrounding bedrock, are thought to be remnants of an ancient flood plain of the nearby Clinch River" (Lomenick and Wyrick 1965, p. 5).

Groundwater flow through alluvium deposits is probably locally important. These materials are usually porous and have high transmissivities. Most streams are probably hydraulically connected to the alluvium which may effectively act as a porous liner for the stream channels.

Alluvium may provide an alternative down-valley flow path for water in streams. This has important ramifications for analyzing surface water hydrographs and measuring flow in streams. Stream flow may be matched by a similar flux in the stream alluvium, and the flux in a stream channel at any one point may not represent the total along channel flux. Another possibility is that the stream alluvium provides a buffer to high-flow stages by providing bank storage.

A.3.3.6 Depth of Flow and Brine Interaction

Wells finished in the deep interval of the ORR and ORNL aquitards typically yield less than 0.1 L/min and thus have no potential for water supply. The specific storage of the bedrock aquitard is small and, as a result, some hydraulic heads in the deep interval respond to precipitation events, even though the associated water flux is small. The chemical characteristics of groundwater in the deep interval are different from those of the water table interval and probably reflect longer water residence times. Although diffusive transfer between fractures and matrix blocks is an important process in the deep interval, the total matrix porosity is less than that of the water table interval, the vadose zone, or the storm flow zone, thereby reducing the retarding effect on contaminant migration rates relative to more shallow zones.

Identification of a deep groundwater interval is based on limited hydraulic and geochemical data from borehole depths ranging from 30 to 300 m (98 to 984 ft). Hydraulic conductivity data come primarily from straddle packer tests (King and Haase 1987) and are supplemented by slug tests and slow-recovery analysis (Dreier and Toran 1989). In general, the intermediate groundwater interval shows hydraulic conductivities that are greater than 10^{-6} cm/s. The deep groundwater interval shows conductivities that are as high as in the intermediate range; however, measured conductivities in this interval are also as low as 10^{-9} cm/s. The low conductivities may be the result of either reduced matrix permeability or increased fracture spacing. The high conductivities presumably occur when the test interval intersects a permeable fracture.

The extent to which deep brines interact with water in the intermediate flow paths within ORNL is not known; however, some wells in Melton Valley that are screened at intermediate depths [(30 to 61 m (98 to 200 ft)] show anomalously high sodium concentrations (60 to 300 mg/L). This suggests that the deep brine aquifer is not completely isolated from flow paths in the intermediate and shallow level.

In the deep aquifer, hydraulic conduits are probably few and therefore are more important for identifying preferred flow paths. Determining the location of flow paths in the deep aquifer will be important to addressing long-term contaminant migration in the deep aquifer.

A.3.3.7 Rate of Flow

For porous media, advective groundwater flow is in the direction of the maximum hydraulic gradient. In fractured rock, however, groundwater flow occurs in all directions where there are open fractures and a hydraulic gradient. Folds, faults, sealed fractures, and water table rises are common barriers to lateral flow in a fracture system, but in the absence of such barriers, advective flow from one point in one fracture may eventually occupy a semicylindrical volume of the aquifer. Splits and joins of the flow paths have considerable importance for the spread of pollutants from a source near the water table, and various amounts of longitudinal dispersivity may occur along all branches of the flow paths.

Calculations of hydraulic gradient assume linear flow paths between the points where potentiometric heads are measured. In fractured rocks, the path length between two points may be nearly the same as map distance in the directions of the fracture sets. In other directions, the length of a stair-step path is up to 1.4 times longer than the map distance in a two-dimensional view and up to 1.7 times longer in three dimensions. Path length corrections are generally unnecessary for calculations of hydraulic gradient because map distance errors are small and because both permeability and porosity are spatially variable.

Measurements of hydraulic grading indicate a range of 0.01 to 0.1 for cross-valley hydraulic gradient; the average gradient near the water table is approximately 0.05. In the along-valley direction, the hydraulic gradient has a range of 0.001 to 0.01, and the average may be approximately 0.005. A hydraulic gradient in the range for cross-valley flow may also occur along strike on the slopes of tributary valleys. Gradients near the lower ends of these ranges occur in relatively flat areas, and gradients closer to the upper ends occur on steeper slopes. However, any apparent hydraulic gradient larger than approximately 0.06 may represent a cascade, a different flow path, or other discontinuity in flow and should be considered suspect. Smaller hydraulic gradients would be expected at deeper levels in the aquifer, but at depths of approximately 20 m (65 ft), gradients are not greatly different than those near the water table in the Conasauga Group and the

Chickamauga Group. Smaller hydraulic gradients are shown at depths of 30 to 70 m (98 to 229 ft) on sections of Melton Valley by Webster and Bradley (1987, pp. 82, 89) but are based on sparse data.

The best approach to calculation of average groundwater flow rate in the shallow aquifer is uncertain because of (1) truncated populations of hydraulic conductivity values for water-producing intervals and matrix fractures and (2) large flow rates in a small percentage of fractures with large apertures. In calculating representative groundwater flow rates, Moore (1988) assumed that flow towards the center of valleys from ridges is by way of matrix fractions and that flow along strike in valleys is mainly by way of water-producing fractures. Using cumulative probability graphs for conductivity derived from aquifer tests in the ORR, Moore (1988) determined that flow rates in a tube 1 m (3.3 ft) wide is greater than 10.3 m^3/year for cross-valley but less than 15 m^3/year 19.6 yd^3/year). The average flow rate for a tube 1 m (3.3 ft) wide and 30 m (98 ft) high was 12.5 m^3/year (16.3 yd^3/year).

The water table is deeper beneath ridges in areas of the Knox aquifer, and the average hydraulic gradient toward nearby streams is approximately 0.01 to 0.03. Assuming an average hydraulic conductivity that is ten times greater than the ORR aquitards, the average specific discharge in the Knox aquifer is approximately 45 m/year (147 ft/year).

The coarse detrital material reported as fill in some cavities and the reported washing away of sand during construction of a few wells suggest large groundwater velocities in at least a few cavities. A velocity of approximately 40 cm/s (3.5 km/d) is required to move sand with a particle diameter of 0.2 to 1 mm (0.007 to 0.39 in.) (Gregory and Walling 1973, pp. 238-239). One tracer test in the Knox Group showed a water velocity of approximately 200 to 300 m/d (656 to 984 ft/d) between a swallow hole and a discharge point farther downstream (Ketelle and Huff 1984). Another tracer test in the Chickamauga Group showed a groundwater velocity of approximately 20 to 80 m/d (65 to 260 ft/d) between an excavated cavity in limestone and a sump in a reactor building at ORNL. In contrast, low water velocities are indicated by the range of hydraulic conductivity values and by the hydraulic gradients that have been measured in the shallow aquifers. Typical lateral gradients in the study area are 0.005 to 0.05, following Darcy's law; if the gradient is 0.05, groundwater velocity near the cavity well that has the largest hydraulic conductivity [7.6 m/d (25 ft/d)] is only 0.38 m/d (1.24 ft/d).

A.4 ORNL FLOW BOUNDARIES AND PATHWAYS

The present boundary condition hypothesis is that contaminants residing within the ORNL site do not migrate outside of the conceptual boundaries. The conceptual boundaries of the ORNL site (Fig. A.6) are defined by presumed groundwater divides that define the hydrologic regimes of Bethel Valley, Melton Valley, and Raccoon Creek. Three of these boundaries parallel the regional strike: Chestnut Ridge to the north, Copper Ridge to the south, and Haw Ridge, a medial groundwater boundary that acts as a divide between Bethel and Melton Valleys. All three ridges constitute surface water divides and, for reasons explained in this section, are assumed to constitute groundwater divides. The remaining boundaries are the east, west, and a basal boundary.

A.4.1 North and South Boundaries

The northern groundwater conceptual boundary is the contact between the Knox Group and the overlying Chickamauga Group near the base of Chestnut Ridge (Fig. A.6). Because of repetitions of surface rock units that result from the compressional tectonics that formed the geology of East Tennessee, the Knox Group is also an important component of the southern boundary. This boundary is marked by the contact of the Knox

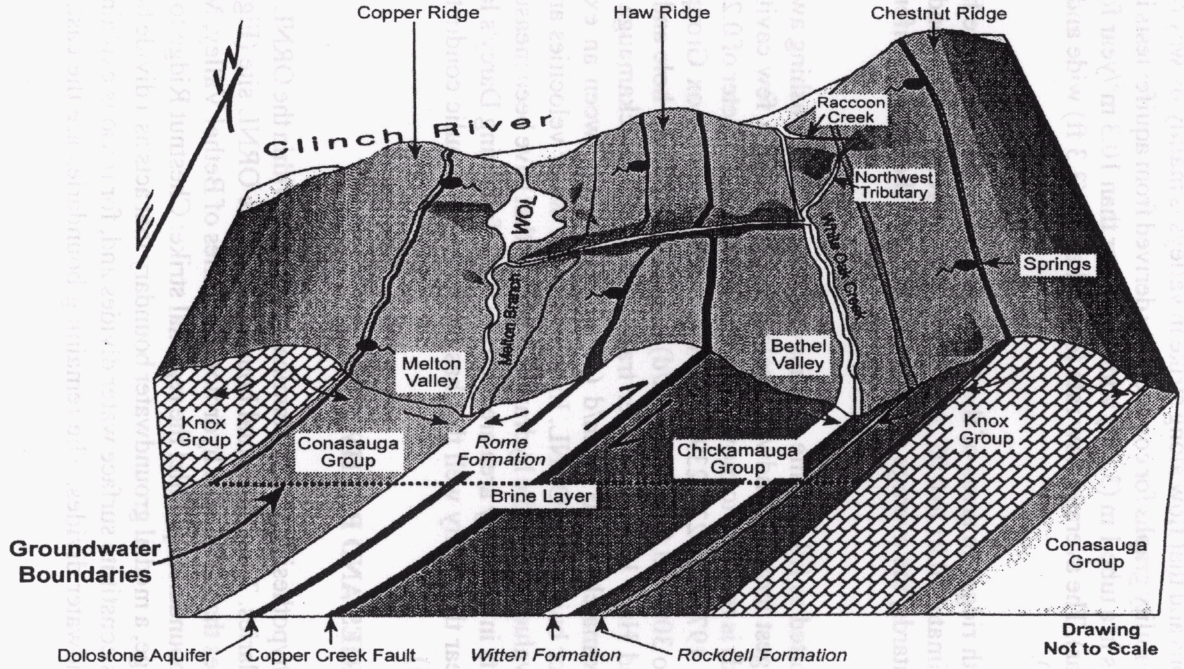

Fig. A.6. Schematic representative of the ORNL groundwater flow regime showing its boundaries, major surface features, and major subsurface geologic features.

Group with the underlying Conasauga Group at Copper Ridge (Fig. A.6). Because of the importance of the Knox Group at both boundaries, the two are considered together here.

The Knox aquifer, at Chestnut Ridge, is confined between aquitards. As a result, it is believed that the hydraulic head on the Knox aquifer exceeds that in the rocks surrounding it, and this pressure difference acts as a divide, effectively separating the groundwater of Bethel Valley from that in Bear Creek Valley to the north. Visual evidence of the confined head lies in numerous springs, seeps, and perennial creeks that arise from the Knox aquifer along Chestnut Ridge. Solomon et al. (1992) estimated an average specific discharge in the Knox aquifer of approximately 45 m/year (147 ft/year), compared to approximately 11 m/year (36 ft/year) for more permeable intervals of the aquitards. However, though on average the Knox aquifer is more permeable and transmissive than the aquitards, it is heterogeneous with respect to its hydrologic properties. For example, two creeks arising from the Knox aquifer on Chestnut Ridge that are marked as perennial creeks on USGS topographic sheets are, in fact, ephemeral creeks that flow only during and immediately after heavy rains. This heterogeneity probably results from the distribution and connectedness of solution cavities in the Knox aquifer.

The Knox aquifer along the southern boundary of the ORNL site holds up Copper Ridge. Similar hydrologic conditions are thought to exist at the southern boundary as exist at the northern boundary, but little or no data are available to support this assumption.

Hydrologic isolation of the ORNL site along its north and south boundaries is dependent on the ability of the Knox formation to prevent groundwater from escaping. Most of the present understanding of the hydrologic character of the Knox at ORNL comes from studies conducted along Chestnut Ridge. For the most part, these indicate a closed boundary with the possible exception of the heterogeneous distribution of permeability. Little if any work has been conducted on the Knox aquifer along Copper Ridge and it is not known if these rocks exhibit similar characteristics to those along the northern boundary.

A.4.2 Medial Boundary

The assumed boundary for groundwater between Bethel Valley and Melton Valley is the Rome Formation which holds up Haw Ridge (Fig. A.6). Four factors contribute to this boundary. First, the Rome Formation is one of the aquitard units in the ORR. Second, Haw Ridge is a topographic high and, because groundwater flow is thought to be relatively shallow at the ORNL site, the ridge prevents groundwater from crossing valleys. Third, a karstified dolomite unit within the Rome Formation exhibited artesian water pressure when intercepted during drilling on Haw Ridge. This dolostone may act as a pressure barrier between any deep groundwater within Bethel Valley and Melton Valley. Fourth, the Copper Creek Fault, which lies beneath the Rome Formation on Haw Ridge, has traditionally been interpreted to be impermeable to groundwater (de Laguna et al. 1968).

A.4.3 West Boundary

The boundary west of the ORNL site is the Clinch River (Fig. A.6). Piezometric measurements indicate that, in general, the hydraulic gradient throughout the ORNL site is from east to west, and present understanding is that the bulk of the groundwater within the ORNL site is intercepted by surface streams and exits the site as surface water (Solomon et al. 1992). Melton Valley surface water drains to the west into the Clinch River via WOC and White Oak Lake (WOL). In Bethel Valley, westward surface drainage directly into the Clinch River is interrupted by a topographic divide. All of the water in Bethel Valley to the east of this divide drains through the water gap in Haw Ridge into WOL and ultimately into the Clinch River (Fig. A.6). The water to the west of the divide drains to the west by means of Raccoon Creek into the Clinch River (Fig. A.6). Additionally, the Clinch River is assumed to be the local base level for the ORNL groundwater system.

Therefore, it is currently thought that any groundwater within the ORNL site that is not intercepted by surface streams within the site boundaries ultimately is intercepted by the Clinch River.

A major question regarding the west boundary of the ORNL site is the topographic divide that separates Bethel Valley from the Clinch River. It is not known whether the divide also constitutes a groundwater divide or if groundwater from Bethel Valley underflows it into Raccoon Creek. This question holds important implications for contaminant transport, especially from WAG 3, and therefore for a mass balance of contaminants that flow out of Bethel Valley via the water gap.

A.4.4 East Boundary

The boundary of the ORNL site to the east is Bearden Creek at Bethel Valley and the Clinch River at Melton Valley. Bearden Creek represents a surface water divide and is the deepest incision of eastern Bethel Valley tributaries to the Clinch River. Piezometric measurements throughout Bethel Valley indicate that the hydraulic gradient decreases from the valley's eastern end to its western end. Because of Melton Lake Dam, the Clinch River at Melton Valley's eastern end is about 15 m (50 ft) higher than at its western end. This implies a higher head in the east and, combined with piezometric measurements, indicates groundwater flow is to the west.

A.4.5 Basal Boundary

The base boundary at ORNL is taken to be the top of the aquiclude of the subsurface flow system within the ORR (Figs. 2.6, 2.7, and 2.8) (i.e., the contact between freshwater and brine) (Solomon et al. 1992). For the purposes of this investigation, brine is defined as water with salinity that exceeds 10,000 mg/L. Core hole measurements have shown that the elevation of the aquiclude is variable throughout the ORNL site. For example, brine is encountered in aquitard rock units of Melton Valley at depths ranging between 180 and 240 m (590 and 787 ft) (Haase, Switek, and Stow 1987; Switek, Haase, and Stow 1987). Brine has not been encountered within the Knox aquifer but is believed to be greater than 350 m (1148 ft) deep (Hatcher et al. 1992).

The aquiclude marks the base of the ORNL site because it is thought to have negligible flow because of diminishing permeability in the rocks with depth. As a direct result, contaminant transport into the brine should also be negligible. Evidence for the presumed rate of flow comes from evidence for long residence times of water in the aquiclude. The origin of the brine is unknown but its composition is consistent with one that would develop from formation waters during long term water-rock interaction or dissolution of evaporites (Solomon et al. 1992). Brine composition and temperature are spatially and temporally variable, observations that Nativ and Hunley (1993) interpreted to indicate communication with overlying freshwater. Additional evidence for communication with the overlying freshwater through mixing and/or chemical diffusion lies in the presence of brackish water at intermediate depths above the aquiclude.

The assumed unimportance of deep groundwater flow is key to placement of the basal boundary. It implies that the probability of contaminants reaching the aquiclude is small and, if they were to reach the aquiclude, the likelihood that they would be transported out of the ORNL site is even smaller. However, little is known about the hydrologic properties of the rocks at the depths of the aquiclude, and a number of observations begin to raise questions about assumptions regarding these properties. For example, variable depth, variable composition, and variable temperature of the deep brine all hint at nonuniform physical and chemical conditions in the aquiclude that could arise from greater than expected communication with overlying, shallower groundwater. This, in turn, could mean greater than expected flow into and within the aquiclude.

A.4.6 Flow Systems and Exit Pathways

A key component of the ORNL site groundwater model is shallow groundwater flow. Fully 90% of all subsurface water is thought to flow through the storm flow zone to be quickly discharged into the WOC drainage system. The storm flow zone resides mainly in the regolith and is therefore relatively shallow. Beneath the regolith is bedrock that is dominated by carbonates and shales, rocks with little porosity and low permeability. The permanent groundwater zone exists within fractures in the bedrock, but because fracture apertures and density are thought to decrease with depth, the groundwater zone is relatively shallow and meets the surface in stream beds where the regolith has been eroded and washed away exposing the underlying bedrock. As a result of shallow flow, 99% or more of all subsurface water in the ORNL site is modeled as being discharged into the WOC drainage system, where it ultimately exits over WOD.

Understanding groundwater flow systems and exit pathways is key to modeling contaminant fluxes and pathways. The current model for groundwater flow at ORNL implies that subsurface contamination will follow shallow pathways and ultimately be discharged from the subsurface into the WOC drainage system. Discharge from the subsurface flow system into the surface water system occurs through seeps and springs. Within Bethel and Melton Valleys, these are the discharge points for contaminants carried in the subsurface flow system; therefore, flow measurements and contaminant concentrations at these points are crucial to characterizing contaminant fluxes. However, many perennial seeps and springs that contribute surface water occur on ridges both inside and outside the ORNL site boundaries. For example, seeps and springs along Chestnut Ridge and Copper Ridge arise from groundwater flow in solution cavities in the Knox aquifer; others occur along Haw Ridge and arise from the dolostone aquifer in the Rome Formation. These springs and seeps are not contaminant discharge points because they are recharged on ridges, and contaminant sources reside solely in the valleys. However, because they are important contributors to the surface water of the ORNL site, characterizing their flow is vital to quantifying contaminant fluxes and to understanding the dynamic behavior of water as it changes back and forth between surface and groundwater.

APPENDIX B

APPENDIX B: UT-BATTELLE/ BJC FACILITIES

Prop_FISR_Reporting_Source:
OR4 = ORNL; ORR = BJC
PBLD_HQPO_PROGRAM_OFFICE:
SC = ORNL
NNSA = ORNL
EM = BJC

FISR data is accounting perspective
HQPO data is Land and Facilities Planning perspective
FIMS data as of 11/14/01

PROP_PROPERTY_ID	PROP_NAME	PROP_PROPERTY_TYPE	PBLD_HQPO_PROGRAM_OFFICE
0814	Trailer	T	EM
0857	Goat Building	B	EM
2034	Manhole 95 Monitoring Station	B	EM
2099	Monitoring Control Station for Bldg 2026	B	EM
2101	WMO Health&Hygiene Support	B	EM
2531	Radioactive Waste Evaporator	B	EM
2532	Hi-Level Waste Stor Cooling Pool	B	EM
2537	Evapr Sev Tank&Cont Bldg. 2531	B	EM
2568	Cell Vent & Off-Gas Filter-2531	B	EM
2647	Construction Engineering Trail	T	EM
2649	Transported Waste Rec. Fac	B	EM
2650	Evaporator Chemical Shed	B	EM
2657	Manhole 243 Monitoring Station	B	EM
2658	F- 4005 Monitoring Station	B	EM
2660	Operation Compliance Training	B	EM
3001	Graphite Reactor Building	B	EM
3002	Filter Hse	B	EM
3003	Solid State Accel. Fac.	B	EM
3005	Low-Int Test Rac Fac	B	EM
3009	Pump House For Bldg. 3010	B	EM
3010	Bulk Shielding Reactor	B	EM
3019B	Radchem. Proc. Plant-Analytic	B	EM
3026C	Radioisotope Dev Lab-B	B	EM
3026D	Dismtng & Exam Hot Cells	B	EM
3028	Radioisotope Production Lab-A	B	EM
3029	Radioisotope Production Lab-B	B	EM
3030	Radioisotope Production Lab-C	B	EM
3031	Radioisotope Production Lab-D	B	EM
3032	Radioisotope Production Lab-E	B	EM
3033	Radioisotope Production Lab-F	B	EM
3033A	Radioisotope Prod Lab Annex	B	EM
3038	Radioisotope Laboratory	B	EM
3042	Oak Ridge Research Reactor	B	EM
3082	Stor Misc. Material	B	EM
3083	Neutron Spectrometer Station 1	B	EM
3085	Pump House-Orr	B	EM
3093	Storage Cubical for Krypton	B	EM
3105	Waste Monitor Control	B	EM
3107	25 Meter Target Hse.	B	EM
3109	O.G. Filter-Orr	B	EM
3110	Bldg. Cell Filter House	B	EM
3116	Nitrogen Cylinder Storage Bldg.	B	EM
3118	Radioisotope Prod Lab-H	B	EM
3119	Heat Exchanger and Pump House	B	EM
3125	3039 Stack Area Emergency Generator	B	EM
3127	Non-Nuclear Res. Matl'S Vault	B	EM
3130	Waste Operation Cont Ctr	B	EM
3145	LLW Collection Building	B	EM
3154	Manhole 112 Monitoring Bldg	B	EM
3158	N Monitoring Bldg 3025/3026	B	EM

PROP_PROPERTY_ID	PROP_NAME	PROP_PROPERTY_TYPE	PBLD_HQPO_PROGRAM_OFFICE
3159	S Monitoring Bldg 3500/4500	B	EM
3502B	Data Concen 4 WOCC DAS 3502	B	EM
3505	Fis Prod Dev Lab Annex	B	EM
3515	Fission Prod Lab No 1	B	EM
3517	Fission Products Dev Lab	B	EM
3518	Proc Waste Water Trtmt	B	EM
3544	Proc Waste Treatment Plt	B	EM
3544B	Filter Press Building	B	EM
3594	Waste Mgmt Stor Bldg	B	EM
3608	NRWWT Bldg	B	EM
3618	WC-10 Building	B	EM
4507	High Level Chemical Dev Lab	B	EM
6556A	ER Field Operations	T	EM
6556B	ER Field Operations	T	EM
6556C	ER Field Operations	T	EM
6556D	ER Field Operations	T	EM
6556G	ER Field Operations	T	EM
6556J	Trailer, Single Wide	T	EM
6556K	Trailer, Single Wide	T	EM
6556L	Trailer, Single Wide	T	EM
6556M	ER Field Operations	T	EM
6556R	ER Field Operations	T	EM
6556-ST-1	ER Field Operations	T	EM
6556-ST-2	ER Field Operations	T	EM
6556-ST-3	ER Field Operations	T	EM
6556-ST-4	ER Field Operations	T	EM
6556-ST-5	ER Field Operations	T	EM
6556-ST-6	ER Field Operations	T	EM
6556-ST-7	ER Field Operations	T	EM
6556-ST-8	Storage Trailers	T	EM
6556-ST-9	Storage Trailers	T	EM
6556T	ER Field Operations	T	EM
7025	Tritium Target Prep Facility	B	EM
7038	Synthetic Fuel Storage Facilit	T	EM
7075	Waste Storage Building	B	EM
7078A	7078A ER Office Trailer	T	EM
7078B	7078B ER Office Trailer	T	EM
7078C	7078C ER Office Trailer	T	EM
7078D	Trailer	T	EM
7078E	Trailer	T	EM
7078F	Trailer	T	EM
7500	Nuc Safety Pilot Plant	B	EM
7503	Msre Bldg	B	EM
7505	Cpaf Headquarters	B	EM
7506	Cpff Contractor	B	EM
7507	Substores	B	EM
7507W	Mixed Hazardous Waste Storage	B	EM
7509	Msre Off. Bldg.	B	EM
7516	Field Ser. Shop	B	EM
7555	Diesel Gen Hse For 7503	B	EM
7567	Intermed-Lev Waste Pumpg	B	EM
7569	Collection Tank Melton	B	EM
7572	CH-TRU Waste Storage Facility	B	EM
7574	NFS Waste Storage Bunker	B	EM
7582	LGWOD Spare Parts Storage Facility	B	EM
7602	Chem. Sys. Lab	B	EM
7651	Storage Shed	B	EM
7652	Haz Waste Stor Fac	B	EM
7653	Chem Waste Stor Fac	B	EM
7654	Haz Waste Stor Fac	B	EM
7661	Electrical Utility Building	B	EM
7666	Environmental Emer. Resp_Fac	B	EM
7666A	Trailer, Dbl Wide-7666A Area	T	EM
7667	Chem Waste Disp Fac	B	EM

PROP_PROPERTY_ID	PROP_NAME	PROP_PROPERTY_TYPE	PBLD_HQPO_PROGRAM_OFFICE
7668	Mixed Waste Storage Facility	B	EM
7702	Control House-Twr Shldg Fac	B	EM
7703	Hoist House - Tower Shielding Facility	B	EM
7704	Control House-Tsf	B	EM
7705	Pump House-Tsf	B	EM
7707	Battery House-Tsf	B	EM
7708	Reactor Shield Storage-Tsf	B	EM
7716	Filter Pump House Main. Pool	B	EM
7720	Civil Defense Bunker	B	EM
7751	Sen Post 22 Tsf Exclu	B	EM
7802C	Deep Monitoring Well #1 Bldg	B	EM
7802D	Deep Monitoring Well #2 Bldg	B	EM
7802F	Garage at SWSA5	B	EM
7811	Geosciences Storage Building	B	EM
7819	Interim Decontamination	B	EM
7823	Underground Storage Bldg	B	EM
7824	Radioactive Waste Strg.	B	EM
7824A	WEAF Support Facility Trailer	T	EM
7826	Retrievable Waste Strg	B	EM
7830	Ilw Waste Stor Tank Fac	B	EM
7831	Field Office & Compactor Facility	B	EM
7831A	Solid Waste Compactor	B	EM
7831C	Straw Shed (SWSA 5 on right)	B	EM
7833	Alpha Greenhouse Facility.	B	EM
7834	Retriev Waste Strg Fac 2	B	EM
7842	Storage Shelter Swsa #6	B	EM
7847	Vehicle/Personnel Monitor Sta	B	EM
7852	Old Hydofracture Facility	B	EM
7853	Gen Storage Bldg 7852	B	EM
7855	Strg Fac Hrl Retriev Wst	B	EM
7856	MVST Capacity Increaase Project	B	EM
7857	IWMF Monitoring Station	B	EM
7860	Hydrofacture Facility	B	EM
7863	Gen Strg For Bldg 7860	B	EM
7876	Office Trailer	T	EM
7877	Llw Solidifac Fac	B	EM
7878	SWSA 6 Staging Facility	B	EM
7879	Tru Solid Llw Storage Facility	B	EM
7881	Guard Post 24 (W End of Plant)	B	EM
7883	RH-TRU Waste Storage Bunker	B	EM
7919	Process Waste Monitor (HFIR)	B	EM
7922	Breeching & Fan Area for 7920	B	EM
7934	Volume Reduction Fac	B	EM
7935	Waste Storage Fac	B	EM
7952	Low Lev Waste Pmp Sta	B	EM
7966	LLW Monitoring&Collection Sta	B	EM
3019A	Radchem. Proc. Pilot Plnt	B	NNSA
0813	Field Laboratory #1	T	SC
0817	Ozone Generator Building	B	SC
0818	Atmospheric Instrument Trailer	T	SC
0819	Farm Implement Storage Buildin	B	SC
0822	ESD/NOAA USAF Instru Trl	T	SC
0823A	Shed, Face Ring #1	T	SC
0823B	Shed, Face Ring #2	T	SC
0823C	Shed, Face Ring #3	T	SC
0823D	Shed, Face Ring #4	T	SC
0823E	Shed, Face CO2 Tank / Evaporators	B	SC
0855	Operations Building 0800 Area	B	SC
0858	Sycamore Plantation Trailer	T	SC
0903	Bethel Valley Church	B	SC
0907	Walker Br. Watershed Lab	B	SC
0927	Storage Building for 0902	T	SC
0931	Ish Creek Monitoring Station	B	SC
0934	Walk Br Weir Sub-Sur Weir Ints	T	SC

PROP_PROPERTY_ID	PROP_NAME	PROP_PROPERTY_TYPE	PBLD_HQPO_PROGRAM_OFFICE
0937	ATDD/NOAA Rain Gage 2 Instr	B	SC
0940	ATDD/NOAA Instrument Bldg 1	B	SC
0941	ATDD/NOAA Instrument Bldg 2	B	SC
0942	ESD Trailer	T	SC
0943	ATDD/NOAA Facility	B	SC
0945F	Throughfall Storage Building	T	SC
0950	Walker Br E. weir Instr H	B	SC
0951	walker Br. W Weir Instru Hs	B	SC
0955	Walker Br storage Bldg	B	SC
0957	Sample Storage Building	B	SC
0961	Ornl Visitor Overlook	B	SC
0963	White Oak Creek Headwaters monitoring st	B	SC
0964	Waste Inspection Building	B	SC
1000	Engineering Office Building	B	SC
1059	Health Effects Information	B	SC
1061	Health Protection Services Fac	B	SC
1062	West Office Building	B	SC
1503	Plant Sciences Lab	B	SC
1504	Aquatic Ecology Lab	B	SC
1505	Environmental Science Lab	B	SC
1506	Controlled Env & Animal Bldg.	B	SC
1507	Life Sciences Data Analysis Bl	B	SC
1508	Aquatic Storage Building	T	SC
1509	Environmental Engineering Faci	B	SC
1510	Aquatic Storage Building 1	T	SC
1511	Aquatic Storage Building 2	T	SC
1512	Aquatic Storage Building 3	T	SC
1513	Aquatic Storage Building 4	T	SC
1514	Aquatic Storage Building 5	T	SC
1515	Aquatic Storage Building 6	T	SC
1542	Cylinder Storage Shed	B	SC
1552	Water Monitoring Equipment Bldg	T	SC
1560	East Greenhouse	B	SC
1561	West Greenhouse	B	SC
2000	Solid St. Lab & Qual Assur/Ins	B	SC
2001	Information Center Complex	B	SC
2003	Process Water Cont Station	B	SC
2007	Calibration Lab	B	SC
2008	ORNL Whole Body Counter	B	SC
2009	Cafeteria Warehouse	B	SC
2010	ORNL Cafeteria	B	SC
2011	Electric & AC Service Center	B	SC
2013	West Maintenance Serv Ctr	B	SC
2016	West Portal Security HQ Annex	B	SC
2017	East Research Service Shop	B	SC
2018	Elect & Air Cond Service Ctr	B	SC
2019	Solar Energy Lab/Laser Lab	B	SC
2024	Quality Assurance & Inspect	B	SC
2026	Hi-Rad Lvl Analytical Lab	B	SC
2029	Information Centr Com. Annex C	T	SC
2030	Mobile Office Unit	T	SC
2033	Measurements & Controls Fac	B	SC
2069	Change House	B	SC
2087	Storage I-E	B	SC
2088	Emerg Generator B 2000	B	SC
2092	Storage	B	SC
2093	Enviromental Storage Building	B	SC
2500	Guard & Fire Headquarters	B	SC
2506	Fab Shop & Timekeeping	B	SC
2508	Instrumentation, at West Tanks	T	SC
2510	Air Compressor Buillding	B	SC
2517	HR&Diversity Programs / Training	B	SC
2518	P&E Division Offices	B	SC
2519	Steam Plant	B	SC

PROP_PROPERTY_ID	PROP_NAME	PROP_PROPERTY_TYPE	PBLD_HQPO_PROGRAM_OFFICE
2523	Decontamination Laundry	B	SC
2523A	Decontamination Laundry Annex	B	SC
2525	Fabrication Department Shop A	B	SC
2528	Coal Research Lab	B	SC
2536	Coal Sample Preparation Bldg.	B	SC
2540	Steam Plant Substation	B	SC
2546	2545 Monitoring Building	B	SC
2547	General Machine Shop	B	SC
2548	Sludge Drying Facility	B	SC
2549	Storage Bluilding Steam Plant	B	SC
2572	Emergency Generator 2500	B	SC
2609	Sentry Post No. 3	B	SC
2621	ES&H Offices	B	SC
2628	Fire Protect Maint & Storage	B	SC
2638	Steam Plant Scale House	B	SC
2640	Sentry Post #6 SW Vehicle Gate	B	SC
2641	Sentry Post #6B (Coal Yard Del	B	SC
2643	Chlorinator Building	B	SC
2644	Coal Yard Runoff Treatment Plt	B	SC
2648	Fire Training Facility	B	SC
2652A	2652A Office Trailer	T	SC
2652B	2652B Office Trailer	T	SC
2652C	2652C Office Trailer	T	SC
2653	Coal Yard Building	B	SC
2656	Sewage Trt Plt-Wtr Monitor Sta	B	SC
2661	ORNL Regional Science Ed Ctr	B	SC
2664	Sodium Metabisulfie Building	B	SC
3008	Source & Spec Mat Vault	B	SC
3010A	BSR Facility Building	B	SC
3012	Rolling Mill	B	SC
3013	Geo. Disp. Lab	B	SC
3017	Chem Tech Div Annex	B	SC
3025E	Sol-State Lab & Hot Cells	B	SC
3025M	IMET Facility Hot Cells&Solid	B	SC
3027	Safeguard (SMN) Vault	B	SC
3034	Radioisotope Area Services	B	SC
3036	Isotope Area Stor & Servic Bld	B	SC
3037	Chemical Technology Offices	B	SC
3044	Special Materials Machine Shop	B	SC
3047	Isotope Technology Bldg	B	SC
3074	Interim Manipulator Repair Fac	B	SC
3080	Reactor Exper Control Room	B	SC
3084	Neutron Spectrometer Sta 2	B	SC
3095	Reac Area Equip Bldg	B	SC
3100	Source & Sp Mat Vault	B	SC
3104	W. Research Serv. Ctr.	B	SC
3108	Cell & Hood Vent Filters	B	SC
3111	Sentry Post No 8b	B	SC
3112	Misc. Storage Building	B	SC
3114	Roof Test Development Lab	B	SC
3115	Solid State Off.	B	SC
3121	Cell Off Gas Filter Hse for	B	SC
3129	Personnel Monitoring Station	B	SC
3135	Sentry Post - 8D	B	SC
3136	Mock Up Test Facility	B	SC
3137	Surface Science Lab	B	SC
3138	Roof Thermal Test Fac	B	SC
3143	ORR Demineralization System	B	SC
3144	Roof Test Center	B	SC
3147	Efficiency & Renewable Res.	B	SC
3150	Solid State Research Facility	B	SC
3156	Energy Office & Support Fac	B	SC
3500	I&C Building	B	SC
3501	Sewage Pumping Sta.	B	SC

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3502	East Res Service Ctr	B	SC
3503	High Rad Lvl Chm Eng Lab	B	SC
3504	Geosciences Lab	B	SC
3508	Elect. Services	B	SC
3523	I&C Storage	B	SC
3525	High-Rad Level Exam Lab.	B	SC
3531A	Trailer	T	SC
3531B	Trailer	T	SC
3532	Container, Paint Storage	T	SC
3534	Liquid Metal Cleaning Fac	B	SC
3534A	Health Physics Trailer	T	SC
3534B	Health Physics Trailer	T	SC
3536	Nitrogen Cyl Tank Stor Bldg	B	SC
3537	Hydrogen & Oxygen Dist St	B	SC
3541	MSR Process Dev. Lab.	B	SC
3542	Str Bldg For 3505 & 3517	B	SC
3543	Msr Dev Lab	B	SC
3544A	ORNL WstWtr Treatment Fac	T	SC
3546	I&C Office Annex	B	SC
3550	Research Lab Annex	B	SC
3550T	Trailer, Van Type (Itercomparison SDL)	T	SC
3587	Instru Lab Annex	B	SC
3592	Coal Conversion Facility	B	SC
3598	Emerg Gen For 3500 Area	B	SC
3602	Cylinder Tank Stor Bldg 3525	B	SC
3605	TSD Storage Building	B	SC
3606	I&C Office Bldg	B	SC
3607	Cask Tool Stor	B	SC
3610	Storage Building	B	SC
3610A	Flammable Storage	B	SC
3621	Tent, Spill Response Vehicle Shelter	T	SC
3622	Contaminated Tool Crib	T	SC
4005	Sentry Post Portal	B	SC
4007	Waste Operations Support Facil	B	SC
4500N	Cen Res & Admin. North	B	SC
4500S	Cen Res & Admin. South	B	SC
4501	Radiochemistry Laboratory	B	SC
4505	Exper Eng	B	SC
4508	M&C Laboratory	B	SC
4509	Compressor House	B	SC
4512	Lab Emer. Response Center	B	SC
4514	Equipment Building - Html	B	SC
4515	High Temp. Materials Lab	B	SC
4557	Sentry Post #7- South Parking	B	SC
5000	Main Portal	B	SC
5002	Guest Users Facility	B	SC
5500	High Voltage Accel Lab	B	SC
5500A	Center for Transportation	B	SC
5505	Transuranium Research Lab	B	SC
5506	East Portal Bldg.	B	SC
5507	Electron Spectrometer Fac	B	SC
5507A	RDTE Facility	T	SC
5510	Mass Spectrometry Laboratory	B	SC
5510A	Inorganic Mass Spectrometer La	B	SC
5553	Sentry Post 1e	B	SC
6000	Hhirf	B	SC
6000B	Atomic Physics Research Lab	B	SC
6003	Modular Bldg. For Offices	B	SC
6005	Gas Compressor Hse 6000	B	SC
6007	Joint Institute For Hir	B	SC
6008	Joint Inst-Heavy Ion Res	B	SC
6010	Orela	B	SC
6011	C&Td Office_Building	B	SC
6012	Computer Science Research Fac.	B	SC

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6013	Chemical Feed System Enclosure	B	SC
6016	Outfall 314 Dechlorination Sys	B	SC
6025	Eng Physics Office Bldg	B	SC
6026A	6026A Office Trailer	T	SC
6026B	6026B Office Trailer	T	SC
6026C	6026C Office Trailer	T	SC
6026D	6026D Office Trailer	T	SC
6026E	6026E Office Trailer	T	SC
6026F	6026F Trailer	T	SC
6026G	Office Trailer, Double Wide	T	SC
6556E	ER Field Operations Trailer	T	SC
6556Q	ER Field Operations Trailer	T	SC
6556S	ER Field Operations	T	SC
6556U	Environment Management Office	T	SC
7001	General Stores	B	SC
7002	Garage & Ironwrkg Shop	B	SC
7003	Welding & Brazing Shop	B	SC
7005	Lead Shop	B	SC
7006	Paint Stores	B	SC
7007	Paint Shop	B	SC
7009	Carpenter Shop	B	SC
7010	Dry Lumber Storage	B	SC
7012	Central Mechanical Shops	B	SC
7013	Acid Chem & Flam Liq Stg	B	SC
7015	Metal Storage & Cut Fac.	B	SC
7018	Salvage & Reclam Fac	B	SC
7019	Haz Materials Storage	B	SC
7020	Interim Grnds Equip Stg	B	SC
7020A	HVAC Decontamination Facility	B	SC
7020B	Container, Biological Refrigerator	T	SC
7020C	Container, Biological Refrigerator	T	SC
7020D	Office Trailer	T	SC
7020E	Trailer, Temp Waste Storage Facility	T	SC
7020F	HP Office Trailer	T	SC
7021	Fab Equip Storage	B	SC
7026	M&C Storage	B	SC
7031	Fabrication Storage Shed	B	SC
7033	Electrical Material Strg.	B	SC
7035	Bldg Maint/Mat & Equip	B	SC
7035A	Storage	B	SC
7035B	Storage	B	SC
7035C	Storage	B	SC
7035D	Storage	B	SC
7035E	Utility Mechanics Storage	B	SC
7035F	Shed Storage Facility	B	SC
7037	Cold Storage Bldg	B	SC
7039	Storage for LLW Line Item	B	SC
7040	Gas Cylinder Storage	B	SC
7041	Cold Storage Building	B	SC
7042	Core Storage Facility	B	SC
7046	ESH&Q Office Building	T	SC
7055	Storage Bldg. (Pickling Vats)	B	SC
7057	Sandblast Cleaning Fac	B	SC
7058	Machine Auxiliaries Strg	B	SC
7060	Steel Yard Office	B	SC
7061	Hlth.Phys. Envrn. Stg.	B	SC
7062	Storage-Miscel Materials	B	SC
7063	Emerg Gen For Bldg 7003	B	SC
7065	Rigger Equip Storage	B	SC
7066	Grounds Maint.Storage	B	SC
7067	Com Gas Hoses & Reg	B	SC
7069	Gas Service Facility	B	SC
7070	Storage Shed	B	SC
7072	Sentry Post 20b	B	SC

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7073	Air Monitoring Station	B	SC
7074	Sentry Post #20C-PedGte 7012	B	SC
7077	Grounds & Laborers Building	B	SC
7077A	Reservation Services Offices	T	SC
7079	Bottle Storage Building	B	SC
7082	Salt Storage Building	B	SC
7083	ESD Model Airplane Shop	T	SC
7085	90-Day Waste Storage	B	SC
7086	Flammable Gas Storage	B	SC
7087	Oxidizer Storage	B	SC
7088	Corrosive Storage	B	SC
7089	Flammable Storage	B	SC
7090	Electrical Storage West	T	SC
7091	Electrical Storage East	T	SC
7092	Hustler Mower Storage	T	SC
7093	Physics Division Storage 1	T	SC
7094	Physics Division Storage 2	T	SC
7095	Physics Division Storage 3	T	SC
7096	Environmental Protection Storage	T	SC
7548	Hazardous Waste Storage Shed	T	SC
7549	Cryogenics Barrier Project Facility	T	SC
7553	Pump House - Tsf Water	B	SC
7554A	MK-Ferguson Trailer	T	SC
7600	Containment Building	B	SC
7601	R&Ps Division Offices	B	SC
7603	Robotic Sys. Lab	B	SC
7604	Utility Building	B	SC
7605	Storage Building	B	SC
7606A	Robotics R&D Lab	B	SC
7606B	S Res Serv Maint Bldg	B	SC
7607	Egcr River Pump Station	B	SC
7608	Component Dev-R&Ps	B	SC
7609	Stack Monitoring House	B	SC
7610	Storage House - R&Ps	B	SC
7611	Guard House-Cfrp	B	SC
7615	REDC Storage	B	SC
7621	Headquarters Building for 7620	B	SC
7623	Bath House for 7620	B	SC
7624	Robotics Storage Building	B	SC
7671	Storage Building	T	SC
7709	Health Physics Research Reactor	B	SC
7710	Dosar Fac-Hprr	B	SC
7712	Dosar Low-Eng Accelerator	B	SC
7735	Rad Calibration Lab	B	SC
7740	Radio Trans. Fac. (Melton	B	SC
7740A	Melton Hill Radio Facility	B	SC
7740C	Nelton Hill Paging Building	B	SC
7756	Meter House Hpm	B	SC
7758	HFIR Parts Storage	B	SC
7803	Lab Trailer	T	SC
7848	Epicore II Storage Building	B	SC
7849	White Oak Crk Weir & Gaging St	B	SC
7858	White Oak Lake Storage Bldg	B	SC
7859	Sample Equipment Storage Bldg.	B	SC
7859A	Sample Storage Buildings	B	SC
7859B	Sample Storage Buildings	B	SC
7870	Rubb Structure at HW Facility	T	SC
7874	ESD Stor Bldg (SW SWSA 4)	B	SC
7875	Monitoring Storage Bldg.	B	SC
7878B	Equipment Storage Tent	T	SC
7891	SWSA Office Trailer	T	SC
7892	Storage Building for 7856 Operations	B	SC
7900	Hi Flux Isotope Reac Fac	B	SC
7901	Elec Bldg For 7900	B	SC

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7903	Cooling Twr Equip Bldg	B	SC
7910	Office Bldg For 7900	B	SC
7911C	Instrument Shed for 7911	B	SC
7912	Fan Shed for 7911	B	SC
7914	Eqp & Parts Strge Bldg	B	SC
7914A	Equipment Storage	B	SC
7915	Oper. Stor. Bldg.	B	SC
7916	HFIR Cooling Tower Softener	B	SC
7917	Research Reactors Office Bldg.	B	SC
7918	REDC Office & Training Facilit	B	SC
7920	Transur. Proc. Facility	B	SC
7921	Emerg Gen Bldg (For B7920	B	SC
7922A	Data Concentrator #6 for WOCC DAS	B	SC
7924A	Storage Building	B	SC
7924B	Storage Building	B	SC
7925A	Storage Building	B	SC
7925B	Storage Building	B	SC
7927	Tent, Storage	T	SC
7930	Thorium-U Recycle Fac	B	SC
7930A	Filter Pit for 7930	B	SC
7931	Emerg Gen Bldg For B7930	B	SC
7932	Waste Sample Bldg. (7930)	B	SC
7933	7933 Storage Trailer	T	SC
7936	Storage Bldg for REDC	B	SC
7953	Hprr Pump House	B	SC
7953A	Trailer	T	SC
7953B	Research Reactors Storage Trailer	T	SC
7953C	Trailer	T	SC
7955	Sentry Post No. 19A	B	SC
7957	Office Trailer For 7920	T	SC
7958	Sentry Post 23 - Hprr	B	SC
7960	Cask Tool Stor	B	SC
7962	Neutron Users Office	B	SC
7964A	Triple Wide Office Trailer	B	SC
7964B	Triple Wide Office Trailer	B	SC
7964C	TRAILER, OFFICE	T	SC
7964D	7964D Office Trailer	T	SC
7964E	7964E Conference Trailer	T	SC
7964F	7964F Office Trailer	T	SC
7964G	Office Trailer, Triplewide	B	SC
7964H	Solid State Office Trailer	T	SC
7964I	Solid State Office Trailer	T	SC
7965A	Trailer, Office	T	SC
7965B	7965B Office Trailer	T	SC
7965C	7965C Office Trailer	T	SC
7966A	7966 Filter House	B	SC
7967B	Subsurface Wier Instr Bldg	B	SC
7968	Trailer	T	SC
7969	Haz Material Enclosure	B	SC
7970	Neutron Science Support Building	B	SC
7971	H.O.G. Filter Facility	B	SC
7975	Water Monitoring Storage Bldg	B	SC
7977	Cold Source Equipment Building	B	SC
7980A	HFIR Storage 1	T	SC
7980B	HFIR Storage 2	T	SC
7980C	HFIR Storage 3	T	SC
7980D	HFIR Storage 4	T	SC
7980E	HFIR Storage 5	T	SC
7981A	P&E/HFIR Storage 1	T	SC
7981B	P&E/HFIR Storage 2	T	SC
7981C	P&E/HFIR Storage 3	T	SC
7982	TRU Staging Area Storage	T	SC
7983	TRU Facility Storage Building	T	SC
910022	Guard House Filter Plant	B	SC

PROP_PROPERTY_ID	PROP_NAME	PROP_PROPERTY_TYPE	PBLD_HQPO_PROGRAM_OFFICE
X176230	3515 Area Trailer	T	SC
X185248	X185248 Trailer-SWSA #6	T	SC
X185249	X185249 Trailer-SWSA #6	T	SC
X186600	Trailer-7002 Area	T	SC
X186689	Trailer Mobile House Unit-2531	T	SC
XE1451	Barn B	B	SC
XF1301	Barn D	B	SC
XF1302	Shed D Butler	B	SC
XF1303	Barn E	B	SC
XF1401	Barn Twin I	B	SC
XF1576	Shed D, Old Swine Barn	B	SC
XF1577	Solway Bend, Shed W	B	SC
XF1578	Solway Bend, Shed E	B	SC
XF1579	New Swine Barn	B	SC
XF1580	Barn Solway	B	SC
XF158X	Solway Bend, Barn	B	SC
XG1401	Freels Bend, Log Cabin	B	SC
XG1402	Freels Bend, Machine Storage Shed	B	SC
XG1403	Freels Bend, Van Gilder Barn	B	SC
XG1404	Freels Bend, Var Dose Irradiation Facili	B	SC
XG1405	Freels Bend, Shed	B	SC
XG1406	Freels Bend, Exposure Field Control Room	B	SC
XG1407	Freels Bend, Block Building	B	SC
XG1408	Freels Bend, Portable Aluminum Building	B	SC
XG1409	Freels Bend, Pump House Building	B	SC
XH1326	Freels Bend, Barn	B	SC
XH1327	Freels Bend, Donkey Barn	B	SC
XH1401	Freels Bend, Sheep Barn	B	SC
XH1402	Freels Bend, White Barn	B	SC
XH1405	Freels Bend, Silo 14x41	B	SC
0043	Oric Accelerator	S	
0807	CS -137 Erosion/Runoff Studys	L	
0816	Cesium Plots Study Area	L	
0821	Ambient Air Station NO. 39	S	
0830	White Oak Creek Embayment Structure	S	
0853	White Oak Creek Below Dam	S	
0856	NOAA Tower	S	
0870	Mont Weir Raccoon Crk	S	
0900	Firearms Range	S	
0901	161 KV Substation	S	
0902	Main Reservoir	S	
0910	Booster Pump Station (Y-12)	S	
0932	WBW Soil Block 1	S	
0933	WBW Soil Block 2	S	
0935	WBW Subsurface Weir	S	
0936	ESD Twin Towers Walker Branch	S	
0938	ATDD/NOAA Stairway Tower	S	
0939	ATDD/NOAA	S	
0945A	Rain Gage 1 Site	S	
0945B	Rain Gage 2 Site	S	
0945C	Rain Gage 3 Site	S	
0945D	Rain Gage 4 Site	S	
0945E	Through-fall Experiment Site	S	
0946	Water Well, Bldg. 0907	S	
0952	E Weir Walker Br Wtrshed	S	
0953	W Weir Walker Br Wtrshed	S	
0954	Refuse Transfer Station	S	
0956	Spring Water Pumphouse	S	
0958	Water Well No. 1	S	
0960	Water Well No. 2	S	
1001	SWSA #3 Burial Ground	S	
1055	Water Well No9 1505	S	
1057	Tower Meterological-1000 Area	S	
1058	Substation No. 7-2	S	

PROP_PROPERTY_ID	PROP_NAME	PROP_PROPERTY_TYPE	PBLD_HQPO_PROGRAM_OFFICE
1096	Passenger shelter, West Parking Lot	S	
1553	Service Pit For Bldg 1504	S	
1554	Contractor Disposal Area	S	
1556	Cooling Twr. For Esl (E)	S	
1557	Cooling Twr. For Esl (W)	S	
1558	N.W. Tributary Weir 1558	S	
1559	Boat Shed	S	
1562	Scrap Metal Area	S	
1563	Substation No. 234-4	S	
1566	First Creek Monitoring Station	S	
2026A	Tank SE of Building 2026	S	
2032	Monitor Station 1	S	
2061	Stack Smoke	S	
2097	Tower Cooling Marl-2026, Roof	S	
2098	Substation No. 6-3	S	
2521	Sewage Treatment Plant	S	
2521F	Sewage Digester Building	S	
2522	Fuel Oil Tank	S	
2533	Cell Vent. Filter Pit	S	
2534	Off-Gas Filter Pit	S	
2535	Cooling Tower-2535	S	
2539	Cooling Tower For Bd 2539	S	
2543	East Aeration Pond	S	
2544	West Aeration Pond	S	
2545	Sewage Treatment Facility	S	
2600	Bethel Valley Storage Tank	S	
2624	SWSA #1 Burial Ground	S	
2630	Cask Component Drop Test	S	
2632	5000-KVA Substation	S	
2636	West Precipitator	S	
2637	East Precipitator	S	
2642	Sentry Post 7, S. End, 3rd St.	S	
2645	Emerg. Generator-Coal Handling	S	
2646	Substation No. 33-6	S	
2651	Emerg. Generator for 2600 Area	S	
3000	Elec. Substations	S	
3001REACTOR	Graphite Reactor	S	
3002A	Drain Tank South of 3003	S	
3003A	Drain Tank South of 3003	S	
3005REACTOR	Low Int.Test Reactor	S	
3010REACTOR-POOL	Swim'G Pool Reactor-3010	S	
3010REACTOR-SHIELD	Bulk Shield'G Reactor	S	
3018	Cv & Og Exh Stack-3018	S	
3020	Cv & Og Exh. Stack-3020	S	
3023	North Tank Farm	S	
3039	Cent. Rad. Off-Gas Disp.	S	
3042REACTOR	Oak Ridge Research Reactor	S	
3078	Septic Tank for 3000 Pump Sta.	S	
3087	Heat Exchanger- Orr	S	
3089	Cooling Twr No.2-Orr	S	
3091	Filters (For Bd. 3019)	S	
3092	Off-Gas Facility	S	
3098	Filter Fac For Litr & Bsr	S	
3099	Stor Pad 3031/3032	S	
3102	Heat Exch No. 2-Orr	S	
3106	Cell Vent. Filters	S	
3117	Bsr Cooling Twr	S	
3117A	Sulfuric Acid Tank	S	
3123	Emer. Gen. Storage House	S	
3126	Charcoal Filt (Nog) Orr	S	
3131	Emergency Generator	S	
3132	Emer Gener for 3127, 3129, 3027	S	
3133	BV Valve Box 1A	S	
3139	Cell Ventilation Filters-ORR	S	

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3140	Cell Ventilation Filters-3026	S	
3146	Emerg Generator for 3020 Stack	S	
3151	Monitor Station 2	S	
3153	Envelope Systems Research Ctr.	S	
3155	Manholes 114 and 234 Monitoring Station	S	
3507	South Tank Farm	S	
3513	Settling Basin 3513	S	
3518A	LGWOD Spare Parts Trailer	S	
3524	Equalization Basin	S	
3535	Filter Enclosure, S Tank Farm	S	
3538	Cooling Tower (For 3525)	S	
3539	Proc Waste Pond #1	L	
3540	Waste Pond No.2	L	
3584	Solvent Operations Contaminent	S	
3597	Hot Storage Garden	S	
3609	Substation No. 25-1-C	S	
3613	Monitor Station 3	S	
3614	Monitor Station 4	S	
3615	Monitor Station 5	S	
3616	Monitor Station 6	S	
3617	Monitor Station 7	S	
3619	White Oak Creek Flume	S	
4000	13.8/2.4 KV Substation	S	
4001	Pumping Station	S	
4003	SWSA #2 Burial Ground	S	
4503	Standby Emergency Generator for 4500N	S	
4510	Cooling Tower-4510	S	
4511	Cooling Tower-4511	S	
4513	Html Substation	S	
4516	Html Cooling Tower	S	
4521	Cooling Tower for Bldg 4509	S	
4556	Filter Pit for Bldg 4507	S	
5500ACCELERATOR	Van De Graaf Entandem Accelerator 10 Me	S	
5554	Elect Substation For 5505	S	
6001	Cooling Tower-6001	S	
6010ACCELERATOR	Oak Ridge Electron Linear Accelerator	S	
6551	W. Reservoir, Haw Ridge	S	
6552	E. Reservoir, Haw Ridge	S	
6553	Bldg. 6553 Gen. Storage House	S	
6555	30M Meteorological Tower-B	S	
6556	Contractor's Storage & Staging	L	
7000	Septic Tank for 7000 Area	S	
7043	Passenger Shelter, West of 7000	S	
7044	Substation 27-8, West of 7003	S	
7053	Passenger Shelter	S	
7069E	Underground Storage Tank	S	
7069F	Underground Storage Tank	S	
7080	Cardboard Compressor	S	
7501	Septic Tank	S	
7502	Radioactive Waste Evaporator	S	
7511	Filter Pit (For 7503)	S	
7512	Stack (For 7503)	S	
7513	Cooling Twr (For 7503)	S	
7514	Filter House For 7503	S	
7556	HRE Settling Pond	S	
7557	Charcoal Absorber Pit for 7500	S	
7558	Waste Evap. Load Pit	S	
7559	Absorber Valve Pit	S	
7560	Waste Condensation Tank for 7500	S	
7561	Valve Pit 7500	S	
7562	Waste Tank 7500	S	
7563	Circulator Pump Pit for 7500	S	
7571	Tower Meterological-7002 Area	S	
7575	SWSA #7 Burial Ground	S	

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7613	Wast Retention Basin	S	
7614	Exhaust Stack	S	
7616	Septic Tank	S	
7618	Diesel Generator for 7600	S	
7619	Cooling Tower	S	
7620	Clark Center Life Guard Stand	S	
7622	Barbecue Shelter for 7620	S	
7658	Closed Contractors Landfill	S	
7659	Leaking OLs Gas Cylinder Area	S	
7662	Energency Generator	S	
7700	Tower Shielding Facility (TSF)	S	
7701	Tower Sheilding Facility Pool	S	
7703REACTOR	Tower Shielding Reactor	S	
7703REACTOR-VESSEL	Vessel Pressure REA-7702,1	S	
7706	Cooler T S F	S	
7709REACTOR	Fast Burst Reactor (HPRR)	S	
7711	Process Waste Basin	S	
7734	Freels Bend Area	S	
7750	Septic Tank TSF, Manhole	S	
7755	DOSAR (HPRR) Reservoir	S	
7759	Cesium Forest Research Area	S	
7800	SWSA #4 Burial Ground	S	
7802	SWSA #5 Burial Ground	S	
7802A	Seep C Collection and Treatment Unit	S	
7802B	Seep D Collection & Treat. Sys	S	
7802N	SWSA 5 North Trench Disposal Area	S	
7805	Waste Pit No.1	S	
7807	Waste Pit No. 3	S	
7808	Waste Pit No.4	S	
7809	Waste Trench No. 5	S	
7810	Chemical Waste Trench No. 6	S	
7810A	Interim Non-reg Wst Stor Fac	S	
7811A	Pilot Pits Experiments Area	S	
7813	White Oak Creek Dam	S	
7818	Waste Trench No. 7	S	
7821	Emergency Waste Basin	S	
7822	SWSA #6 Burial Ground	S	
7822A	High Range Disposal Wells	S	
7822F	Tumulus 1	S	
7822G	Tumulus II	S	
7822H	Asbestos Silos	S	
7822J	Solid Waste Staging and Storage	S	
7823A	Underground Storage Facility Well	S	
7827	Shielded Dry Well Facility	S	
7829	Shielded Dry Well Facility	S	
7830A	Hazardous Waste Storage Tank	S	
7831D	SWSA 5 Storage Pad	S	
7835	Sludge Waste Pond	L	
7841	Fenced Area - Contaminated Equip Storage	L	
7842A	LWSP II Solidified Waste Storage	S	
7846	White Oak Lake	S	
7847A	Vehicle/Person Monitor Sta	S	
7847B	Vehicle/Person Monitor Sta	S	
7851	Environmental Study Area #717	S	
7855A	SWASA 5 Equipment Tent	S	
7864	Gaging Station-E. Seep	S	
7865	Gaging Station-W. Seep	S	
7866	Sampl. Station-7500	S	
7867	Wier-Melton Br	S	
7868	Sampling Stat-Wht Oak Cr	S	
7869	Monitor Sta 5	S	
7871	Monitor Sta 3	S	
7872	Monitor Sta 4	S	
7882	Emergency Generator for 7877	S	

PROP_PROPERTY_ID	PROP_NAME	PROP_PROPERTY_TYPE	PBLD_HQPO_PROGRAM_OFFICE
7886	Interim Waste Storage Pad # 1	S	
7888	Cask Loading Facility	S	
7900REACTOR	High Flux Isotope Reactor	S	
7902	Cooling Twr (For 7900)	S	
7904	Sewage Treatment Plant	S	
7905	Ret. Pond No1 (For HFIR)	L	
7906	Ret. Pond #2 (For HFIR)	L	
7907	Ret. Pond No.3 (For TPP)	L	
7908	Retention Pond No. 4	L	
7911	Stack (For 7900)	S	
7911A	Electrical Switch Room - 7920	S	
7911B	Monitoring Equipment Building for 7911	S	
7913	Filter Pit for 7911 Stack	S	
7950	Environmental Study Area #851	S	
7961	Melton Valley Collection Tanks	S	
7967A	Melton Branch Subsurface Weir	S	
7967C	Underground Weir	S	
910015	Bridge D Road	L	
910016	Bridge Pop Creek 509	L	
910017	Bridge Pop Creek 510	L	
910018	Bridge Pop Creek 511	L	
910019	Bridge Pop Creek 512	L	
910028	Billboard Bethel Valley Rd.	S	
910029	Billboard Highway 95	S	
920000	Elect. Sys. Plant Dist.	S	
920001	Fire Alarm System	S	
920003	Sidewalks	S	
920004	Area Fences	S	
920005	Off-Site Fences	S	
920008	Parking Area-08	L	
920009	Parking Area-09	L	
920010	Parking Area-10	L	
920011	Parking Area-11	L	
920012	Parking Area North	L	
920013	Steam Lines - Plnt Wide	S	
920014	Water Transmission Lns	S	
920015	Comlpressed Air Ln Sys	S	
920016	Sanitary Sewer-Undergnd	S	
920017	Fire Line Syst. Undergnd.	S	
920018	Parking-2018	L	
920020	Bridge White Oak Creek	L	
920021	Telephone System	S	
920022	West End Steam Distribution	S	
920023	Storm Wtr Drainage Syst	S	
920023L	Storm Wtr Drain Syst	L	
920024	Landscaping	L	
920025	Site Preparation	L	
920026	Land Improvements Gen Gdg	L	
920027	Hot Wst Undergr Piping	S	
920028	Off Gas Vent Sys.	S	
920029	Off Gas Vent Sys. B	S	
920030	Nat. Gas Distrib. Piping	S	
920033	Radioactive Liq. Wste Sys	S	
920034	HTML Vehicular Bridge	L	
920045	Parking Area-45	L	
920050	Streets, Primary	S	
920051	Roads, Secondary	S	
920052	Ug Wtr Line Dist. Syst.	S	
920054	Egcr Transline, Fire, Tel	S	
920058	Data Link To Y12	S	
920059	X-10 Broadband	S	
920060	Chilled Water Line	S	
920061	Mv Process Waste Transfer Line	S	
920100	Parking Area-Grp. Rea.	L	

PROP_PROPERTY_ID	PROP_NAME	PROP_PROPERTY_TYPE	PBLD_HQPO_PROGRAM_OFFICE
922500	Security Alarm Systems	S	
922501	Offrsite Warning Device -Offsi	S	
924500	Sign Ornl	S	
927600	Land Impr.-7600 Area	L	
927601	Road-7600 Area	L	
927602	Wtr Main 7600 Area	S	
927620	Road Bull Bluff	L	
940000	Well Groundwater Monitor Sys.	S	
940001	Well Groundwater Monitor NotCa	S	
K400192	Melton Valley Access Road	S	
K400193	Melton Valley Access Road Fence	S	
K600816	Lighting and Utilities, MVAR	S	
SSCT5000	Sanitary Sewage Collection System	S	
X150806	Alarm Sys CC20 AP2 - 3508,2	S	
X151029	Reagent Water Sys-1505, 375	S	
X151683	Milli Q System 2D3-2024, 41	S	
X152340	Turbine Steam, 217HP-2519	S	
X152654	Turbine Steam, Copp - 2519	S	
X152666	Diesel Generator - 2519	S	
X152670	Turbine Steam, Cast - 2519	S	
X152684	Turbine Steam, Hot - 2519	S	
X152703	Turbine Steam, SN#7 - 2519	S	
X153656	Chilling Equipment-3026C,OSide	S	
X153931	Radio Frequency-7900, HB4	S	
X154324	Klystron Tube Litt - 6010	S	
X154802	Condenser Air Cool-3508, OSide	S	
X154803	Condenser Air Cool -3508,OSide	S	
X155820	Klystron Tube Var-6000,Storage	S	
X155877	Water Purifier Sys - 4501, 106	S	
X155998	Accelerator Tandem-3003, Accer	S	
X156366	Encolder MT160 KLIN-2019	S	
X156613	Boiler Water Tube-2519, HiBay	S	
X156983	Alarm Display SN #0-3508,Cage	S	
X157987	Turbine Steam Terry - 4500N	S	
X158159	Fermentation System-4505, 26	S	
X158160	Reagent Water Sys - 4505, 26	S	
X158684	Radio Frequency-4500N,F33	S	
X159377	Transformer SN #331-4508, 130	S	
X160670	Transformer HeviD-4500N,SCell	S	
X161210	Radio Frequency-4508,130	S	
X161565	Transformer SN#116 - 4500S,B54	S	
X162321	Ref Magnetometer-4500S, G155	S	
X162323	Ref Magnotmeter-4500S, G155	S	
X163087	CPT Printer - 5500, Attic	S	
X163371	Ion Beam Kit Source-4500X,S119	S	
X163891	Transformer GE 225 - 6010, H	S	
X163905	Transformer 334 KVAS - 6010, B	S	
X163906	Transformer 480 V - 6010, B	S	
X163907	Transformer 334 KVAS-6010,Mod	S	
X163909	Transformer 334 KVAS - 6010, B	S	
X164080	Power Supply Mod8-6010, Cage	S	
X164084	Transformer 480 V - 6010, 226	S	
X164115	Transformer 750 KV-6010, OSide	S	
X164116	Transformer 225 KV-6010, OSide	S	
X164117	Transformer 750 KV-6010, OSide	S	
X164196	Grade Wtr Sys M1- 4500S, C247	S	
X164317	Accelerator SN#60- 5500, 113	S	
X164695	Transformer 150 KV-3544, OSide	S	
X165069	Transformer 300 KV-6025, OSide	S	
X165861	Ionization Gauge - 6000, 107	S	
X166081	Patch Panel B-6000,C103	S	
X166085	Patch Panel B-6000, C103	S	
X166095	Magnet Positioner-6000, T106	S	
X167097	Power Supply Sys S-6000,T308	S	

PROP_PROPERTY_ID	PROP_NAME	PROP_PROPERTY_TYPE	PBLD_HQPO_PROGRAM_OFFICE
X167238	Substation Unit 2-6000, Blower	S	
X167262	Demineralizer Two-6000, T308	S	
X167350	Coulutron Velocity-7041, 4K31	S	
X167947	Reator Vessel Par-2024, 42	S	
X168093	Generator - 2011, Outside	S	
X168217	Pressure Reactor-4505, Cage10	S	
X168218	Pressusre Reactor-4505,Cage10	S	
X168468	Cooling Tower Marl-2029,OSide	S	
X168469	Transformer GE 112-2029, OSide	S	
X168620	Transformer 150 KV-2500, OSide	S	
X168661	Detection Unit Mdl - 2621,Cage	S	
X168685	Transformer 2256 KV-3025,OSide	S	
X168976	Analyzer Magnet B-6010, B	S	
X169114	Transformer Dry We-4500N, Shop	S	
X169272	Roughing Pump Sta-6000, Bay	S	
X169397	Generator, SN#08736 - 3017	S	
X169437	Water Softener & - 3544, 1	S	
X169822	Radio Frequency-4500N,F33	S	
X170158	Generator, Diesel - 2088	S	
X170160	Cooling Tower Marl-2532, OSide	S	
X170173	Clorimetors -2521, 1	S	
X170827	Accelerator -3003, Vandy	S	
X171312	Transformer HeviD - 7025	S	
X172063	Tower Meterological-3503, Bay	S	
X172066	Transformer 100KV-3001,OSide	S	
X172227	Transformer 300 KV- 4501,OSide	S	
X172313	Auto Badge Entry D-7900	S	
X172314	Auto Badge Entry D-7900	S	
X172317	Auto Badge Entry - 3042	S	
X172318	Auto Badge Entry - 3042	S	
X172319	Auto Badge Entry - 3010	S	
X172320	Auto Badge Entry - 3010	S	
X172325	Cable Patch Panel-6000, B	S	
X172326	Cable Patch Panel -6000, B	S	
X172661	Transformer 150 KV - 4500N	S	
X172704	Water Treatment Sys - 7930, 4	S	
X173493	Carrier CondnsgUnit-3026C,Roof	S	
X173627	Paging System SN#5-3017	S	
X173700	Tower Cooling 400-3026C, OSide	S	
X173812	Power Boiler - 7605	S	
X174272	Turbine Steam, 21HP - 2519	S	
X174273	Turbine Steam, 21HP - 2519	S	
X174274	Boiler Steam - 2519	S	
X174275	Boiler Steam - 2519	S	
X174276	Boiler Steam - 2519	S	
X174277	Boiler Furnace -2519	S	
X174281	Turbine Steam, Coppus - 2519	S	
X174461	Ion Source 4MaSN#0-3003,Accer	S	
X174495	Accelerator WaveGu-6010,Storag	S	
X174516	Turbine Steam, 5HP - 7500	S	
X174545	Klystron Tube - 6010, Mod R	S	
X174546	Klystron Tube - 6010, Mod R	S	
X174547	Klystron Tube 6010, Mod R	S	
X174548	Klystron Tube - 6010, Mod R	S	
X174549	Klystron Tube - 6010, Mod R	S	
X174550	Klystron Tube - 6010, Mod R	S	
X174659	Turbine Steam, 60HP - 3039	S	
X174786	Accelerator Vandeg-5500,211	S	
X175092	Accelerator Tandem-6000, TOW	S	
X175711	Waste Disposal - 1505, 153	S	
X175777	Fence Protect Sys- 3019	S	
X175778	Signal Processor Sys-3019,OSid	S	
X175779	Signal Processor Sys-3019,OSid	S	
X175780	Signal Processor Sys-2621,Cage	S	

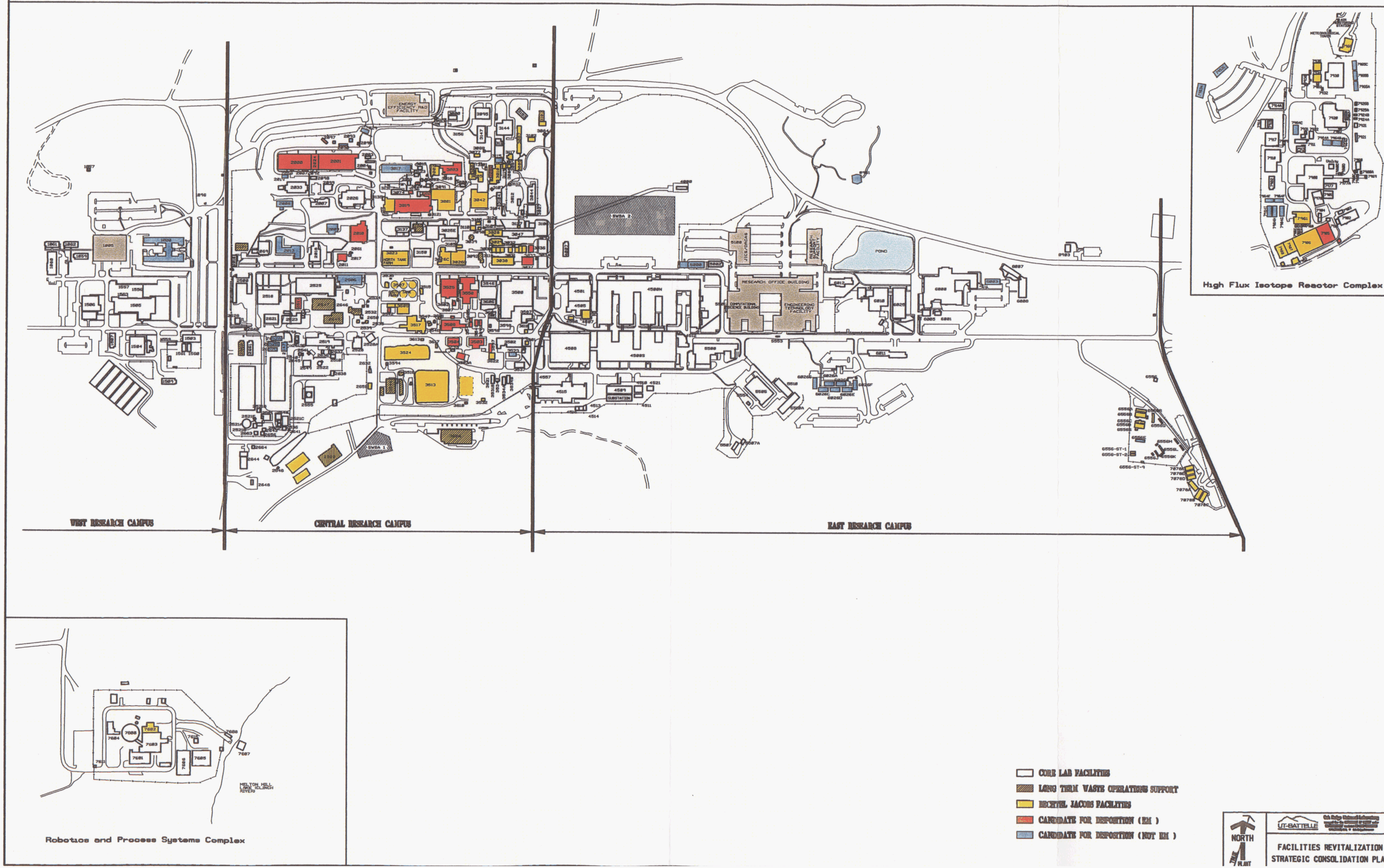
PROP_PROPERTY_ID	PROP_NAME	PROP_PROPERTY_TYPE	PBLD_HQPO_PROGRAM_OFFICE
X175846	Diesel Generator Set - 3123, 0	S	
X175860	Water Colled Condnsr-2018,Shop	S	
X176264	Transformer 225 KV-3017, OSide	S	
X176364	Cable Patch Panel-6000SA,NBase	S	
X176365	Cable Patch Panel-6000, MEZZ	S	
X176522	Accelerator - 6010, B	S	
X176545	Complete Electron - 6010	S	
X176546	Complete Electron - 6010	S	
X176547	Complete Electron - 6010	S	
X176549	Electron Injection - 6010	S	
X176563	Klystron Tube SN#2- 6010,Conso	S	
X176564	Klystron Tube SN202-6010, Con	S	
X177799	Emergency Generator - 4500S	S	
X177800	Emergency Generator-4500N K135	S	
X177874	Tower Meterologica-110 CRBR	S	
X180000	Electron Injection - 6010	S	
X180140	Carrier Slug - 3019, 9860	S	
X180201	Carrier Slug - 3042, Conta	S	
X180379	Neutron Shipping C-7920, Conta	S	
X180740	Transformer 13.8 KV - 901	S	
X182064	Boosstivac Pump Sta-4500S,B247	S	
X182065	Boostivac Pump Sta- 4500S,B247	S	
X182260	Console Radio 8 Ch-4500S, T20	S	
X182332	Transformer West 2-6000	S	
X182333	Transformer West 1-6000,T308	S	
X182334	Transformer West1-6000,T308	S	
X182335	Transformer West7-6000, T308	S	
X182336	Transformer West 1 - 4509	S	
X182337	Transformer West5-2026, OSide	S	
X182420	Transformer - 2525	S	
X182813	Transformer - 4512, 116	S	
X182954	Turbine Steam, 65 HP - 3039	S	
X182960	Turbine Steam - 3039	S	
X183092	Router (Cisco Agst)-Midway 97B	S	
X183338	Condensing Unit - 3505	S	
X183459	Microwave Signal Trans-3500	S	
X183460	Microwave Signal Trans-3500	S	
X183728	Transformer 100KV-4508, SCreek	S	
X183729	Transformer 750KVA-3047,OSide	S	
X183730	Transformer 1000KV-4508,SCreek	S	
X183731	Transformer 750 KVA - 7033	S	
X183732	Transformer Elec 1 - 7033	S	
X183897	Transformer 225RV - 6011	S	
X184004	Cooling Tower - 3517	S	
X184181	Industrial Floor Scales - 7831	S	
X184269	Environmental Monitoring Shelter - 7900	S	
X184270	Environmental Monitoring Shelter - 7900	S	
X184271	Environmental Monitoring Shelter - 7601	S	
X184438	Alarm System -3029	S	
X184528	Water Data Monitoring Sta- 853	S	
X184682	Badge Reader - Burial #4	S	
X184683	Badge Reader - Burial #4	S	
X184685	Badge Reader - SWSA6	S	
X184686	Badge Reader - Burial #6	S	
X184687	Badge Reader - SWASA 5	S	
X184688	Badge Reader - Burial #5	S	
X184689	Badge Reader - 3606, 101	S	
X185197	Purifier - 1506, 120	S	
X185479	Cooling Tower -2026, Roof	S	
X185557	Cooling Tower - 3047, Roof	S	
X185589	Cooling Tower - 3025, Roof	S	
X185623	Exit Device - 3019, Out Door	S	
X185994	Emergency Generator - 3125	S	
X186256	Radion Frequency-920102,ICRF	S	

PROP_PROPERTY_ID	PROP_NAME	PROP_PROPERTY_TYPE	PBLD_HQPO_PROGRAM_OFFICE
X186348	Steam Boiler-7603	S	
X186370	Radio Frequency-3003	S	
X186436	Turbine Steam - 3039, OutArea	S	
X186665	Demineralizer-3004 Area	S	
X186667	Demineralizer-7900 Area	S	
X186825	Microwave System-2026, 103	S	
X187019	Turbine Steam - 2519, ID#1	S	
X187068	Decontam Pad (Grating)-WAG5	S	
X187100	Chilling Tower 100 Ton	S	
X187170	Cooling Tower 100 - 2001,Oside	S	
X187173	Power Supply-3080 Lab	S	
X187355	Recorder, Universal Input-2531	S	
X187358	72"Conveyor Modl 1650-4515,230	S	
X187385	Amps Radio Signals-6000, 102	S	
X187422	Mini Cooling Tower-6000, Roof	S	
X187452	Network ATM Analyzer-6012, 115	S	
X187459	H2O Purification Kit-5510, 118	S	
X187723	Fuel Control System-7069,Gas	S	
X187772	Ash Conditioner	S	
X187778	Ash Conditioner	S	
X187950	Steam Turbine -2519	S	
XB0951	OR Turnpike Gatehouse	L	
XF1304	Silo E	S	
XF1402	Silo Tva	S	
XF1426	Kerr Hollow Gate House	L	
XG1410	Freels Bend, Shielding Wall Donkey Arena	S	
XH1403	Freels Bend, Lagoon 2	S	
XH1404	Freels Bend, Underground Silo	S	

T = Trailer
B = Building
S = Structure
L = Land

APPENDIX C

OAK RIDGE NATIONAL LABORATORY



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