1. Site and Operations Overview

The Oak Ridge Reservation (ORR), a government-owned, contractor-operated facility, contains three major operating sites: the Y-12 National Security Complex, Oak Ridge National Laboratory, and East Tennessee Technology Park. The ORR was established in the early 1940s as part of the Manhattan Project, a secret undertaking that produced the materials for the first atomic bombs. The reservation's role has evolved over the years, and it continues to adapt to meet the changing defense, energy, and research needs of the United States. Both the work carried out for the war effort and subsequent research, development, and production activities have involved, and continue to involve, the use of radiological and hazardous materials.

The *Oak Ridge Reservation Annual Site Environmental Report* and supporting data are available at http://www.ornl.gov/Env_Rpt or from the project director.

1.1 BACKGROUND

This document is prepared annually to summarize environmental activities, primarily environmental-monitoring activities, on the ORR and within the ORR surroundings. The document fulfills the requirement of U.S. Department of Energy (DOE) Order 231.1, "Environment, Safety and Health Reporting," for an annual summary of environmental data to characterize environmental performance. The environmental monitoring criteria are described in DOE Order 450.1, "Environmental Protection Program." The results summarized in this report are based on data collected prior to and through 2003. This report is not intended to provide the results of all sampling on the ORR. Additional data collected for other site and regulatory purposes, such as environmental restoration remedial investigation reports, waste management characterization sampling data, and environmental permit compliance data, are presented in other documents that have been prepared in accordance with applicable DOE guidance and/or laws. Corrections to the report for the previous year are found in Appendix A.

Environmental monitoring on the ORR consists primarily of two major activities: effluent monitoring and environmental surveillance. Effluent monitoring involves the collection and analysis of samples or measurements of liquid and gaseous effluents at the point of release to the environment; these measurements allow the quantification and official reporting of contaminants, assessment of radiation and chemical exposures to the public, and demonstration of compliance with applicable standards and permit requirements. Environmental surveillance consists of the collection and analysis of environmental samples from the site and its environs; these activities provide direct measurement of contaminants in air, water, groundwater, soil, foods, biota, and other media subsequent to effluent release into the environment. Environmental surveillance data provide information regarding conformity with applicable DOE orders and, combined with data from effluent monitoring, allow the determination of chemical and radiation dose/exposure assessments of ORR operations and effects, if any, on the local environment.

1.2 DESCRIPTION OF SITE LOCALE

The city of Oak Ridge lies within the Great Valley of Eastern Tennessee between the Cumberland and Great Smoky Mountains and is bordered on two sides by the Clinch River. The Cumberland Mountains are 16 km (10 miles) to the northwest; the Great Smoky Mountains are 51 km (32 miles) to the southeast (Fig. 1.1).

The ORR encompasses about 13,658 hectares (33,749 acres) of mostly contiguous land owned by DOE in the Oak Ridge area. The majority lies within the corporate limits of the city of Oak Ridge; 246 hectares (608 acres) west of the East Tennessee Technology Park (ETTP), are outside the city limits. The residential section of Oak Ridge forms the northern boundary of the reservation. The Tennessee Valley Authority's (TVA's) Melton Hill and Watts Bar reservoirs on

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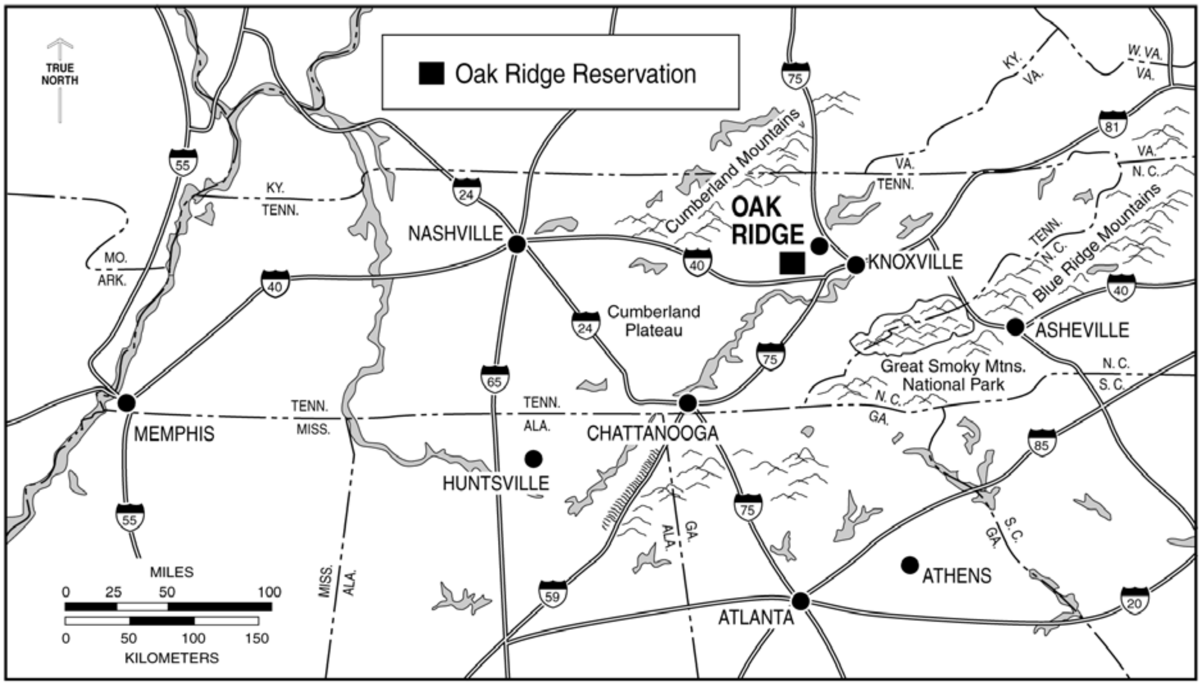

Fig. 1.1. Location of the city of Oak Ridge.

the Clinch and Tennessee rivers form the southern and western boundaries (Fig. 1.2).

The population of the ten-county region surrounding the ORR is approximately 862,424 (Tennessee 2004), with about 4% of its labor force employed on the reservation (Fig. 1.3). Other towns in close proximity to the reservation include Oliver Springs, Clinton, Karns, Lenoir City, Farragut, Kingston, and Harriman (Fig. 1.4).

Knoxville, the major metropolitan area nearest Oak Ridge, is located about 40 km (25 miles) to the east and has a population of about 173,661 (U.S. Census 2002). Except for the city of Oak Ridge, the land within 8 km (5 miles) of the ORR is semirural and is used primarily for residences, small farms, and cattle pasture. Fishing, boating, water skiing, and swimming are popular recreational activities in the area.

1.3 CLIMATE

The climate of the region may be broadly classified as humid continental. The Cumberland Mountains to the northwest help to modify the effects of 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, anti-cyclonic circulation around high-pressure systems centered in the western Atlantic Ocean can produce subsidence over the region, leading to occasional periods of drought.

1.3.1 Temperature

The mean annual temperature for the Oak Ridge area is 14.2°C (57.6°F) (NOAA 2001). The coldest month is usually January, with temperatures averaging about 2.6°C (36.6°F) but once dipping as low as –31°C (–24°F). July is typically the hottest month of the year, with temperatures averaging 25.2°C (77.3°F) but rarely peaking at over 37.8°C (100°F). In the course of a year, the difference between maximum and minimum daily temperatures averages 12.6°C (22.7°F). The 2003 average temperature as measured at the official Oak Ridge meteorological tower, near the DOE Oak Ridge Operations Office (DOE-ORO) Headquarters, was 14.8°C (58.7°F).

1.3.2 Winds

Winds in the Oak Ridge area are significantly affected by the ridge-and-valley terrain features as well as by the size and orientation of the Great Valley of Eastern Tennessee. Prevailing winds tend to follow both the axis of the Great Valley and that of the local ridges and valleys, resulting in a dominance of winds from the east-northeast or southwest. Various forcing mechanisms affect the resultant winds on the ORR. These include (1) pressure-driven channeling, (2) vertically coupled flow, (3) thermal forcing, and (4) direct channeling (Birdwell 1996). Wind shear associated with some of these patterns can greatly complicate estimates of atmospheric dispersion, particularly just above local ridge top heights (100 to 200 m above local valley bottoms). Wind speeds are less than 11.9 km/h (7.4 mph) 75% of the time; tornadoes and winds exceeding 30 km/h (18.5 mph) are relatively rare. Wind speeds at a height of 10 m at the ORR meteorological towers averaged 1.4 m/s (3.1 mph) during 2003. Air stagnation is relatively common in eastern Tennessee (about twice that of western Tennessee). On average, about two multiple-day air stagnation episodes occur annually in eastern Tennessee, to cover an average of about 8 days per year. August, September, and October are the most likely months for air stagnation episodes.

1.3.3 Precipitation

The 30-year annual average precipitation is 1398 mm (55.05 in.), including about 24.4 cm (9.6 in.) of snowfall (NOAA 2001). Total rainfall during 2003 as measured at the official Oak Ridge meteorological tower on Laboratory Road in Oak Ridge (near the DOE-ORO Headquarters) was 1699.5 mm (66.91 in.).

1.3.4 Evapotranspiration

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 vicinity of the ORR encompasses about 220 days, from mid-March through mid-October. During the growing season, evapotranspiration may exceed the rate of precipitation, resulting in soil moisture deficits.

1.3.5 Mixing Heights

The mixing height (atmospheric layer nearest the surface where active diffusion and mixing occur) varies significantly with respect to time of day, synoptic weather, and season. The depth of the surface mixing layer is directly related to atmospheric stability (the tendency of the atmosphere to mix vertically). Local ridge-and-valley terrain primarily affects stability through the reduction of surface winds, which tends to allow for the development of very stable surface layers at night, particularly under clear sky and light synoptic winds. Hourly mixing height statistics for the ORR during 2003 are given in Table 1.1. Data were derived primarily from hourly sonic detection and ranging (sodar) data (< 500 meters) and the National Weather Service Rapid Update Cycle forecast model initializations (> 500 meters). The annual average mixing height for 2003 was 682 meters (standard deviation 715 meters).

1.3.6 Physiography

The ORR lies within the Valley and Ridge Physiographic Province, which has developed on thick, folded beds of sedimentary rock deposited during the Paleozoic era. 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 comprised in the lithology determine local relief.

1.4 SURFACE WATER SETTING

Waters drained from the ORR eventually reach the Tennessee River via the Clinch River, which forms the southern and western boundaries of the ORR (Fig. 1.2). The ORR lies within the

Table 1.1. Hourly mixing height statistics for the Oak Ridge Reservation during 2003

Hour	Average height (m)				
	Annual	Dec–Feb	Mar–May	Jun–Aug	Sep–Nov
0100	445	467	492	545	276
0200	348	445	360	311	277
0300	318	426	310	271	269
0400	319	425	323	270	260
0500	331	448	308	319	250
0600	318	426	293	290	262
0700	355	477	301	298	347
0800	348	437	308	341	308
0900	330	364	309	299	339
1000	344	387	295	370	323
1100	342	407	300	349	314
1200	337	385	331	288	346
1300	352	395	354	329	330
1400	412	380	412	484	372
1500	601	449	530	804	627
1600	854	557	709	1260	884
1700	1094	654	929	1627	1155
1800	1228	740	1017	1867	1279
1900	1273	821	1051	1777	1435
2000	1397	881	1315	1877	1505
2100	1463	934	1374	1945	1589
2200	1444	953	1389	1895	1528
2300	1273	760	1321	1872	1126
2400	831	509	882	1536	386

Valley and Ridge Physiographic Province, which is composed of a series of drainage basins or troughs containing many small streams feeding the Clinch River. Surface water at each of the major facilities of the ORR drains into a tributary or series of tributaries, streams, or creeks within different watersheds. Each of these watersheds drains into the Clinch River.

The largest of the drainage basins is that of Poplar Creek, which receives drainage from a 352-km^2 (136-mile^2) area, including the northwestern sector of the ORR. It flows from northeast to southwest, approximately through the center of the ETTP, and discharges directly into the Clinch River.

East Fork Poplar Creek, which discharges into Poplar Creek east of the ETTP, originates within the Y-12 National Security Complex (Y-12 Complex) near the former S-3 Ponds and flows northeast along the south side of the Y-12 Complex. Various Y-12 Complex wastewater discharges to the upper reaches of East Fork Poplar Creek from the late 1940s to the early 1980s left a legacy of contamination [e.g., mercury, polychlorinated biphenyls (PCBs), uranium] that has been the subject of water quality improvement initiatives over the past 12 to 15 years. Bear Creek also originates within the Y-12 Complex with headwaters near the former S-3 Ponds, where the creek flows southwest. Bear Creek is mostly affected by stormwater runoff, groundwater infiltration, and tributaries that drain former waste disposal sites in the Bear Creek Valley Burial Grounds Waste Management Area.

Both the Bethel Valley and Melton Valley portions of Oak Ridge National Laboratory (ORNL) are in the White Oak Creek drainage basin, which has an area of 16.5 km^2 (6.37 mile^2). White Oak Creek headwaters originate on Chestnut Ridge, north of ORNL, near the Spallation Neutron Source (SNS) site. At the ORNL site, the creek flows east along the southern boundary of the developed area and then flows southwesterly through a gap in Haw Ridge to the western portion of Melton Valley, where it forms a confluence with Melton Branch. The waters of White Oak Creek enter White Oak Lake, which is an impoundment formed by White Oak Dam. Water flowing over White Oak Dam enters the Clinch River after passing through the White Oak Creek embayment area.

1.4.1 Surface Water Monitoring

Surface water is monitored at each of the sites as well as elsewhere on the ORR. Program details and results are given in the facility-specific environmental effluent and surveillance chapters: Sect. 7.4 for the ORR, Sects. 4.4 and 4.9 for the ETTP, Sect. 5.8 for ORNL, and Sect. 6.5 for the Y-12 Complex.

1.5 GEOLOGICAL SETTING

The ORR is located in the Tennessee portion of the Valley and Ridge Physiographic Province, which is part of the southern Appalachian fold-and-thrust belt. As a result of thrust faulting and

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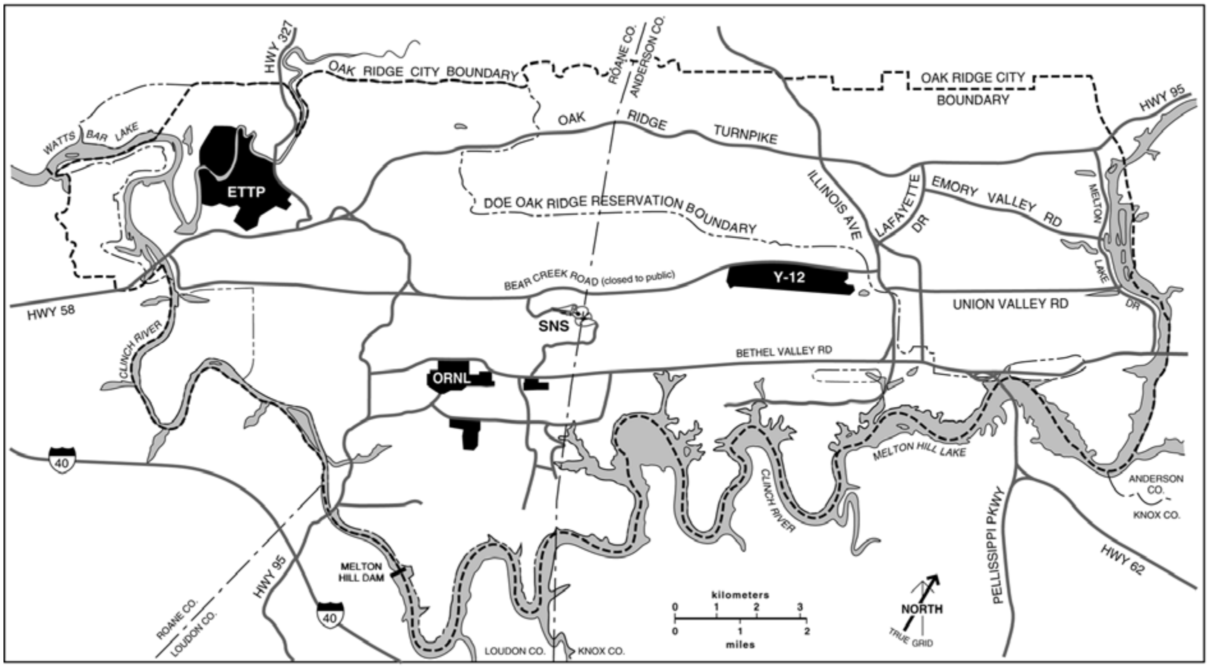

Fig. 1.2. The Oak Ridge Reservation.

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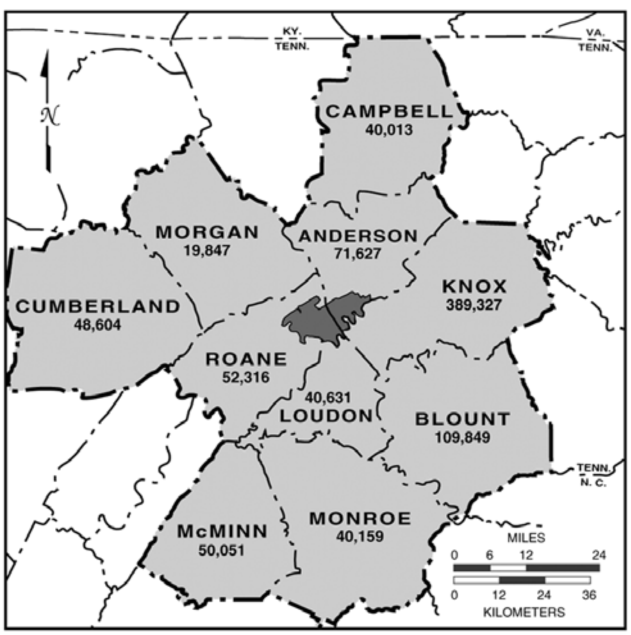

Fig. 1.3. The ten-county region surrounding the Oak Ridge Reservation (U.S. Census 2002).

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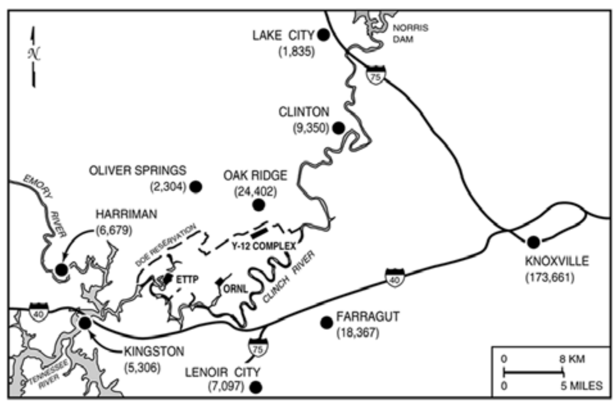

Fig. 1.4. Locations and populations of towns nearest to the Oak Ridge Reservation (UTCBER 2000).

differential erosion rates, a series of parallel valleys and ridges have formed that trend southwest-northeast.

Two geologic units on the ORR, designated as the Knox Group and the Maynardville Limestone of the Conasauga Group, both consisting of dolostone and limestone, constitute the Knox Aquifer. A combination of fractures and solution conduits in this aquifer control flow over substantial areas, and large quantities of water may move 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 remaining geologic units on the ORR (the Rome Formation, the Conasauga Group below the Maynardville Limestone, and the Chickamauga Group) constitute the ORR Aquitards, which consist mainly of siltstone, shale, sandstone, and thinly bedded limestone of low to very low permeability (Fig. 1.5). Nearly all groundwater flow in the ORR Aquitards occurs through fractures. The typical yield of a well in the ORR Aquitards is less than 3.8 L/min (1 gal/min), and the base flows of streams draining areas underlain by the ORR Aquitards are poorly sustained because of such low flow rates.

1.5.1 Hydrogeological Setting

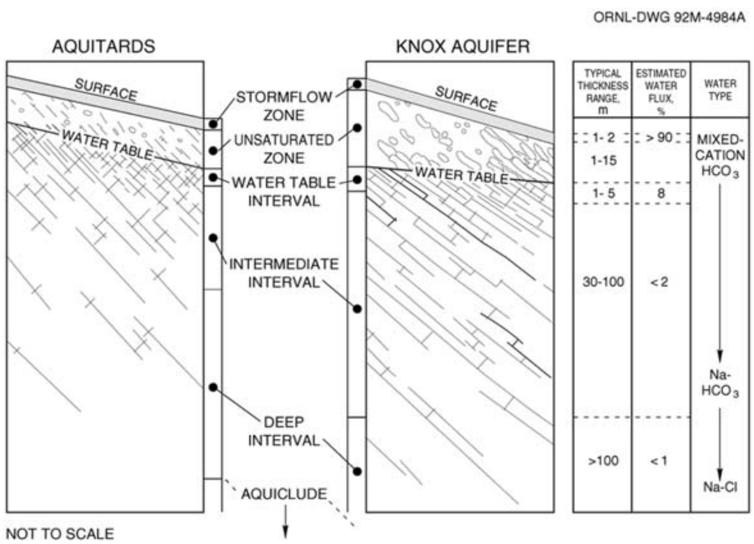

Fig. 1.5. Vertical relationships of flow zones of the ORR: estimated thicknesses, water flux, and water types.

1.5.1.1 Groundwater Hydrology

A portion of the rainwater that falls on the land surface accumulates as groundwater by infiltrating into the subsurface. The accumulation of groundwater in pore spaces of sediments and bedrock creates sources of usable water; the water flows in response to external forces. Groundwater eventually reappears at the surface in springs, swamps, stream and river beds, and pumped wells. Thus, groundwater is a reservoir for which the primary input is recharge from infiltrating rainwater and whose output is discharge to springs, swamps, rivers, streams, and wells.

Because groundwater distribution and movement on the ORR are quite complex and are key components of the pollution potential of the ORR, it is considered important to discuss here some of the technical essentials necessary for understanding the role of groundwater in the overall existence and movement of contaminants on the reservation. Appendix B contains a glossary of technical terms that may be useful for clarifying some of the language used in this section.

Groundwater on the ORR 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.

Two broad hydrologic units are identified on the ORR: the Knox Aquifer, which includes the Maynardville Limestone and is highly permeable, and the ORR Aquitards, which consist of less permeable geologic units. The geologic regime referred to as the ORR Aquitards comprises bedrock and residuum of the Cambrian age Rome formation and Conasauga Group (excluding the Maynardville Limestone) and the Chickamauga Group. Bedrock included in these formations is predominantly clastic sediment (shales, siltstones, well-cemented sandstones, and argillaceous to silty limestones). The ORR Aquitards include local zones where groundwater occurs in quantities sufficient to provide a potential resource of limited use. These zones typically occur within karstic carbonate members of the clastic bedrock formations. Although marginal localized groundwater resources occur within the ORR Aquitards, these formations are far less important to regional water resources, including being a source of potable water for private and public water supply and a source of baseflow to regional surface water bodies than is the Knox Aquifer. Figure 1.6 is a generalized map showing surface distribution of the Knox/Maynardville Aquifer and the ORR Aquitards. Many waste areas on the ORR are located in areas underlain by the ORR Aquitards.

Portions of the ORR underlain by carbonate bedrock commonly exhibit karst geomorphic features. Approximately 60 percent of the ORR is underlain by carbonate-dominated bedrock. Karst geomorphic features form in carbonate-rich bedrock and are evident as sinkholes, solution caverns, and sinking creeks. In addition to creation of subsurface voids in bedrock the weathering process leaves behind the insoluble mineral components of the rock that combine with organic residues of decaying plant materials to form a soil mantle over most of the ORR. The soil mantle forms a physical and geochemical filter that reduces the direct infiltration of rainfall and contaminants into the groundwater system. Geochemical retardation of contaminants in the soil mantle reduces the mobility of many types of contaminants. Groundwater flow in most of the carbonates is quite different from flow in porous media where advective flow conditions largely govern flow and solute transport. Groundwater flow in karst terranes manifests itself in multiple scales of porosity, ranging from seepage and diffusion in intergranular pores of weathered or inherently porous bedrock, to flow by seepage in rock fractures with water and rock matrix interaction on fracture surfaces, to flow in conduits where rapid velocities limit the interaction between the water and bedrock. Groundwater discharge from springs and seeps is abundant on the ORR and accounts for the normal baseflow of natural stream systems in the area. Most recharge to the groundwater system occurs through dispersed percolation of rainwater through the soil mantle and via capture in surface dolines during the winter and early spring months, when evapotranspiration losses of soil moisture are negligible. Groundwater storage in thick soil profiles and in the weathered bedrock zone of the Knox Group outcrop areas such as Blackoak, Chestnut, and Copper Ridges provides most of the dry season baseflow and feeds the area's largest springs. Most of groundwater flow in the carbonate bedrock groundwater basins on the ORR originates as intergranular or fracture seepage through the soil mantle, and flow progresses through coalescing networks of conduits that culminate at spring discharges. Baseflow springs often occur near major geologic outcrop boundaries where semi-confining bedrock lithologies tend to limit the orientation of conduit development and promote upward flow of groundwater to discharge at the land surface. In portions of the ORR underlain by shale-rich bedrock, such as the Conasauga Group bedrock of Bear Creek Valley and Melton Valley, groundwater seepage is typically through fractures in weathered bedrock with discharge to nearby streams. Discrete baseflow springs are not common in the shale-dominated outcrop areas; however, small seeps are abundant.

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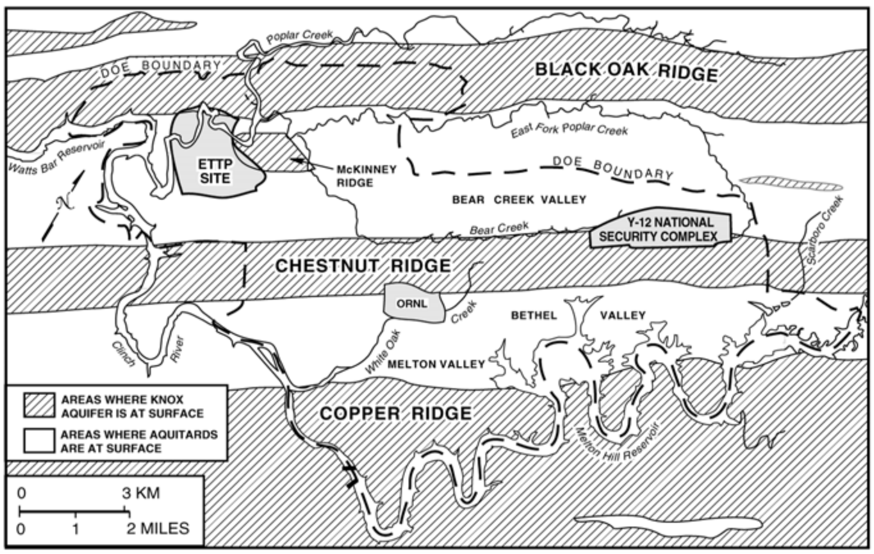

Fig. 1.6. The Knox Aquifer and the ORR Aquitards on the Oak Ridge Reservation.

1.5.1.2 Unsaturated Zone Hydrology

Terrain at the ORR is hilly with slopes that average approximately 7.5% and range from less than 3% to more than 50%. Because ORR landforms consist almost entirely of sloping land surfaces, the concepts of hillslope hydrology are appropriate to describe the active hydrologic process. Based on soil percolation capacity and soil structure, as well as direct measurement of water transmission in soil test areas, it is estimated that in undisturbed, naturally vegetated areas on the ORR, about 90% of the infiltrating precipitation does not reach the water table but travels through the 1- to 2-m (3- to 7-ft) stormflow zone, which approximately corresponds to the root zone. This condition exists because of the permeability contrast between the shallow stormflow zone and the underlying unsaturated zone.

Recharge of the groundwater system is strongly seasonal at the ORR, and percolation processes in the shallow soil are moderated by the amount soil moisture present. During the active growing season (April through October) moisture evapotranspiration by plants removes moisture from the soil within the root zone. When soil moisture levels are low, any percolating rainwater is absorbed in the root zone to replenish the soil moisture deficit. During that phase little or no water reaches the water table. When rainfall amounts exceed any existing soil moisture deficits and saturation of the shallow soils begins to occur, seepage of water begins. When saturation of the shallow soils occurs on sloping land, the downslope gradient allows lateral drainage of water through macropores (e.g., holes left by decay of dead plant roots, animal burrows) as well as vertical seepage to the water table through pervious zones. During the nongrowing season (November through March), there is little evapotranspiration to remove water from the root zone, and saturation of the shallow soils occurs more rapidly than during the summer months. Typical evapotranspiration losses from the root zone range from a low of about 0.01 in./day rainfall equivalent during January and February to a high of about 0.16 in./day rainfall equivalent during July. Thus, development of a 1-in. water deficit would require only a week without rainfall during July but would require over two months without rainfall during the winter.

The amount of water that actually recharges the groundwater zone is highly variable across the ORR, depending on shallow soil characteristics, permeability and degree of fracturing of regolith beneath the surface soils, presence of dolines that capture stormflow and focus recharge in small areas, and the presence of paved or covered areas, where little or no rainfall infiltration occurs. Higher recharge is expected in areas of karst hydrogeology such as the Knox Aquifer because of internal drainage through dolines than in areas underlain by the clastic bedrock formations.

1.5.1.3 Saturated Zone Hydrology

As shown in Fig. 1.5, the saturated zone on the ORR can be divided conceptually into four flow zones in a vertical cross section: an uppermost water table interval, an intermediate interval, a deep interval, and an aquiclude. The presence and thickness of any zone may vary across the ORR. Available evidence indicates that most water in the saturated zone in the ORR Aquitards is transmitted through a 1- to 6-m (3- to 20-ft) layer of closely spaced, well-connected fractures near the water table (the water table interval) as shown in Fig. 1.7.

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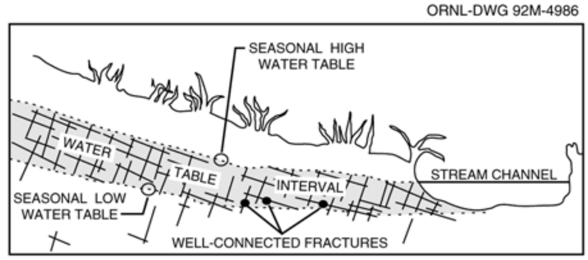

Fig. 1.7. Water table interval.

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 (^{3}H) 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 (2 ft/day).

In the ORR Aquitards, chemical characteristics of groundwater change from a mixed-cation-HCO_3 water type at shallow depth to an Na-HCO_3 water type at deeper levels [30.5 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. There is no evidence 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 vary significantly across the reservation. 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 ORR 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 mean discharge is 98 L/min (26 gal/min) per square mile.

In the intermediate interval, groundwater flow paths are products 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 ORR 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 an 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 ORR 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 evaporating water bodies. 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 (near ORNL), and it is believed to approach 305 m (1000 ft) in portions of Bear Creek Valley (near the Y-12 Complex) underlain by aquitard formations. Depth to the aquiclude in areas of the Knox Aquifer is not known but is believed to be greater than 366 m (1200 ft); depth to the aquiclude has not been established in the vicinity of the ETTP.

1.5.2 Groundwater Flow

Many factors influence groundwater flow on the ORR. Topography, surface cover, geologic structure, karst features (see Sect.1.5.1.1), and rock type exhibit especially strong influences on the hydrogeology. Variations in these features result in variations of the total amount of groundwater moving through the system (flux). (Average flux ratios for the ORR Aquitards and the Knox Aquifer formations are shown in Fig. 1.5.) As an example, the overall decrease in open fracture density with depth results in a decreased groundwater flux with depth.

Topographic relief on the ORR 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 ORR 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 on the ORR. Conversely, in the Knox Aquifer it is believed that solution conduit flow paths may be considerably longer, perhaps as much as 1.6 km (1 mile) long in the along-strike direction. No evidence at this time substantiates the existence of any deep, regional flow off the ORR or between basins within the ORR in either the Knox Aquifer or the ORR Aquitards. Data collected in the calendar years 1994 and 1995, however, have demonstrated that groundwater flow and contaminant transport occur off the ORR in the intermediate interval of the Knox Aquifer, near the east end of the Y-12 Complex.

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 ORR 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 ORR Aquitards because rapid flow along solution features allows minimal time for diffusion to occur.

1.5.3 Groundwater Monitoring Considerations

The groundwater monitoring programs on the ORR were designed to gather information to determine the effects of DOE operations, past and present, on groundwater quality. Because of the complexity of the hydrogeologic framework on the ORR, groundwater flow and, therefore, contaminant transport are difficult to predict on a local scale. Also, detailed delineation of groundwater contaminant plumes is not always feasible. Monitoring wells and piezometers are used to perform ongoing surveillance and characterization of groundwater flow and quality. Since stormflow and most groundwater discharge to ORR surface water drainages, springs, and seeps, these features are monitored for water quality to assess the extent to which groundwater from a large portion of the ORR transports contaminants.

1.5.3.1 Groundwater Monitoring Programs on the ORR

Groundwater monitoring programs at each of the major ORR facilities are discussed in the facility-specific chapters: Sect. 4.11 for the ETTP, Sect. 5.11 for ORNL, and Sect. 6.10 for the Y-12 Complex.

1.6 DESCRIPTION OF SITE FACILITIES AND OPERATIONS

The facilities on the ORR began operating in 1942 as part of the Manhattan Project, producing components for the first nuclear weapons. The ORR remains government-owned, although the nature of the work at the facility has changed. The primary missions of the three sites have evolved during the past 60 years and continue to adapt to meet the changing defense, energy, and research needs of the United States. The reservation contains three major DOE installations: the Y-12 Complex, ORNL, and the ETTP. DOE also operates a number of facilities in addition to the major installation sites:

- 55 Jefferson,
- American Museum of Science and Energy,
- Atmospheric Turbulence and Diffusion Division—National Oceanic and Atmospheric Administration (ATDD-NOAA) Facility,
- Buildings 2714 and 2715,
- Central Training Facility,
- checking stations (gatehouses),
- Clark Center Recreation Park,
- DOE Information Center,
- Federal Office Building,
- George Jones Memorial Baptist Church,
- National Transportation Research Center (NTRC),
- Office of Scientific and Technical Information (OSTI), Building 1916-T1, Building 1916-T2,
- Parcel ED-1,
- Parcel ED-2,
- Office of Secure Transportation Firing Range,
- Office of Secure Transportation Vehicle Facility,
- Union Valley Sample Preparation Facility, and
- Vance Road Facility.

The facility at 55 Jefferson is a DOE-owned facility comprising approximately 46,000 ft^2 on a 3-acre site located on Jefferson Circle along the Oak Ridge Turnpike in Oak Ridge. The primary facility use is to support the DOE Office of Environmental Management (DOE-EM). The building is a temporary wood-frame structure constructed in the 1940s.

In 1975, the American Museum of Science and Energy was moved from its original facility (55–59 Jefferson Circle) to a 17-acre site contiguous to the Oak Ridge Associated Universities (ORAU) campus, on South Tulane Avenue in Oak Ridge. The masonry structure contains about 55,400 ft^2 (33,932 ft^2 for exhibition space and 21,468 ft^2 for offices and related space). This facility contains the energy house, which is licensed to the city of Oak Ridge for use by the Convention and Visitors' Bureau. The museum also has warehouse space in OSTI's Building 1916T-2 complex. The museum is managed by UT-Battelle.

The ATDD-NOAA Facility is composed of a wood-frame building built in the 1940s and several smaller buildings at 456 South Illinois Avenue in Oak Ridge. ATDD conducts meteorological and atmospheric diffusion research that is jointly supported by DOE and NOAA. It also provides services to other DOE contractors and operates the Weather Instrument Telemetering Monitoring System for DOE.

Buildings 2714 (referred to as the "Laboratory Road Facility") and 2715 are DOE-owned facilities that DOE shares with the Oak Ridge Institute of Science and Education (ORISE). The facilities are used for general offices and hands-on, laboratory-based training in the areas of radiation safety (health physics) . The ORISE-occupied facilities comprise approximately 36,084 ft^2 and are located in Oak Ridge immediately south of the Federal Office Building.

The Central Training Facility is used primarily by security forces and consists of a small office building, an indoor firing range, two classroom/storage trailers, on-site parking, fitness facilities (an outdoor track), and numerous outdoor firing ranges. The site, including a buffer area, is south of Bear Creek Road, less than 1 mile southeast of ETTP, and currently occupies about 150 acres.

DOE-ORO properties included in the *National Register of Historic Places* (National Park Service 2003) are three checking stations: (1) the Oak Ridge Turnpike Checking Station (Turnpike Checking Station), (2) the Scarboro Road Checking Station (Midway Checking Station), and (3) the Bethel Valley Road Checking Station. Although these structures are listed as checking stations in the *National Register*, they were originally called and today are commonly called "gatehouses." The main building of the Bethel Valley Road Checking Station is located on a parcel of land that was transferred to the city of Oak Ridge. However, the small associated block building just opposite the main structure is still owned by DOE-ORO.

Clark Center Recreation Park is an area containing approximately 80 acres. It is currently being used for recreational park purposes and is available to DOE and its contractor personnel and to the public on a limited basis. The area lies within landholdings under the jurisdictional control of DOE and is managed by DOE.

The DOE Information Center, located at 475 Oak Ridge Turnpike, provides centralized public access to DOE documents and information. The Information Center consolidates Freedom of Information Act documents that were previously available at the DOE Public Reading Room and information about the DOE Environmental Management Program that were previously located at the Information Resource Center. The building, which is leased to DOE by R&R Rental Properties, has about 8000 ft^2 of space and provides public meeting rooms and office space for the Oak Ridge Site Specific Advisory Board.

The Federal Office Building, located in Oak Ridge, is owned by the General Services Administration and is maintained by DOE. DOE-ORO offices occupy the vast majority of the 113,000 ft^2 of space in the building.

George Jones Memorial Baptist Church, located within the ETTP, predates World War II and is included in the *National Register of Historic Places*.

The NTRC is a collaborative effort among DOE, ORNL, the University of Tennessee (UT), and the Development Corporation of Knox County. The NTRC's activities span the whole range of transportation research. The center is an 85,000-ft^2 building, located on a 6-acre site in the

Pellissippi Corporate Center and is leased to ORNL and UT separately by Pellissippi Investors LLC.

OSTI is located in two masonry buildings constructed as warehouses in the 1940s: Buildings 1916T-1 and 1916T-2. Building 1916T-1 houses the main OSTI functions as well as other occupants. Portions of this building were converted to office space in the 1950s, and additional bays were added in the 1950s and 1960s. Currently, the building has one office bay and seven other bays for a total space of 135,000 ft^2. Building 1916T-2 houses ORISE and DOE-ORO operations, including warehousing, procurement, and safety staff. The two DOE buildings are located on a 7-acre tract that parallels the Oak Ridge Turnpike about 2 miles east of the Federal Office Building. Because of their age and configuration, they are classified as Class B buildings (i.e., semipermanent buildings, constructed primarily of wood, which may need to be renewed, renovated, or rehabilitated in the near future) but are deemed adequate for current functions.

Parcel ED-1 (“Horizon Center”) was leased to the Community Reuse Organization of East Tennessee (CROET) (effective April 28, 1998), and 489 acres were transferred (by quit claim deed) to CROET in April 2003. The developable portions of the parcel were transferred and the other portions (the natural area that surrounds the East Fork Poplar Creek floodplain and other locations) remain part of the CROET leasehold. CROET may sublease the land transferred to it or may sell it to others for purposes of economic development. CROET is responsible for the protection and maintenance of all portions of the property.

Parcel ED-2 consists of a barge facility and an adjacent 15-acre area located in the K-700 area west of the main ETTP site. ED-2 and the barge facility have already been leased to CROET, which intends to offer the barge facility to the business community on a fee basis. Present CROET plans are to develop the facility, in conjunction with the adjacent rail service and interstate corridor, as a mini-port authority. The balance of ED-2, also leased to CROET, includes subleased portions and another portion proposed for use as a laydown area supporting the barge facility.

The Office of Secure Transportation Firing Range is located to the east of the Central Training Facility and is operated by the National Nuclear Security Administration (NNSA) Albuquerque Service Center. The surface danger zones for the Central Training Facility and the Office of Secure Transportation Firing Range overlap and together comprise about 2500 acres.

The Office of Secure Transportation Vehicle Maintenance Facility, is located about 1 mile east of ETTP, on the south side of State Route 58 (Oak Ridge Turnpike), near the intersection with Blair Road. The building is situated on a 20-acre site and has undergone major modifications, including the addition of security fencing, paved parking, and paved access around the building. The total site area constitutes about 100 acres. The facility is maintained by the Y-12 Complex’s Facilities, Infrastructure, and Services Organization and is funded by the NNSA Albuquerque Service Center.

The Union Valley Sample Preparation Facility is located on Union Valley Road. This facility houses laboratories that provide sample analysis for the three sites.

The Vance Road Facility is a DOE-owned facility operated by ORISE. The 59,800 ft^2 building is located in the middle of the Oak Ridge Methodist Medical Center complex. ORISE plans to vacate this building by June 30, 2005, to allow DOE to make it available for community reuse.

The Water Intake Station, located at Solway Bend, and the Water Treatment Plant, located on Pine Ridge just north of the Y-12 Complex, were transferred to the city of Oak Ridge on April 1, 2000.

1.6.1 Y-12 Complex

The Y-12 National Security Complex (Fig. 1.8) is a manufacturing facility that plays an integral role in DOE’s nuclear weapons complex. The NNSA is the semi-independent agency within DOE that oversees the operation of the Y-12 National Security Complex. The complex was constructed as part of the World War II Manhattan Project. Construction for the Manhattan Project began with the first shovelful of dirt turned at Y-12 in February 1943, and operations began in

Y-12 PHOTO 306208

Fig. 1.8. The Y-12 National Security Complex.

November of that year. The first site mission was the separation of uranium-235 from natural uranium by the electromagnetic separation process.

Today the NNSA mission of the Y-12 National Security Complex focuses on re-manufacture, surveillance, and assessment of weapon components. The president and the Congress have directed DOE to maintain the safety and reliability of the nation's nuclear deterrent without underground nuclear testing. To do that, DOE has established a program of science-based stockpile stewardship. Y-12 is an integral part of that mission.

The focus at Y-12 on national security ensures its safe operation and management. Y-12 is the nation's "Fort Knox" for highly enriched uranium; the leader in uranium and lithium materials research, development, and processing; and the country's assembly and disassembly plant for nuclear weapon secondary components.

NNSA is in the process of tearing down old buildings, planning new state-of-the-art facilities, revitalizing the workforce, and bringing in new technology to ensure that Y-12 will continue to meet its vital national security missions. Y-12 is pursuing an aggressive program of infrastructure reduction, modernization, and investment in technology to make the plant as safe and efficient as possible and to improve production capabilities. The *Y-12 National Security Complex Ten-Year Comprehensive Site Plan* (Y/MOD-102) outlines the new construction, recapitalization, maintenance requirements, and excess facility making all these improvements while maintaining demolition required to modernize Y-12. Y-12 is safety, security, and environmental stewardship as its highest priorities.

1.6.2 East Tennessee Technology Park

The ETTP was built as the home of the Oak Ridge Gaseous Diffusion Plant (ORGDP) (Fig. 1.9). Construction of ORGDP began in the 1940s as part of the U.S. Army's Manhattan Project. The plant's mission was production of highly enriched uranium for nuclear weapons.

Enrichment was initially carried out in two process buildings, K-25 and K-27. Later, the K-29, K-31, and K-33 buildings were built to increase the production capacity of the original facilities by raising the assay of the feed material entering K-27. After military production of highly enriched uranium was concluded in 1964, the two original process buildings were shut down. For the next 20 years, the plant's primary missions were

DOE ORO 89-1063

Fig. 1.9. The East Tennessee Technology Park.

production of only slightly enriched uranium to be fabricated into fuel elements for nuclear reactors and the recycling of fuel elements from nuclear reactors. Other missions during the latter part of this 20-year period included development and testing of the gas centrifuge method of uranium enrichment and the laser isotope separation research and development (R&D).

By 1985, demand for enriched uranium had declined, and the gaseous diffusion cascades at ORGDP were placed in standby mode. That same year, the gas centrifuge program was canceled. The decision to permanently shut down the diffusion cascades was announced in late 1987, and actions necessary to implement that decision were initiated soon thereafter. Because of the termination of the original and primary missions, ORGDP was named the "Oak Ridge K-25 Site" in 1990. In 1997, the K-25 Site was named the "East Tennessee Technology Park" to reflect its new mission.

DOE's long-term goal for ETTP is to convert the site into a private industrial park. The site is undergoing environmental cleanup, which is now expected to be completed on an accelerated schedule. The new accelerated closure plan will achieve cleanup several years ahead of the original plan, and, therefore, environmental and safety risks will be reduced more quickly and will save in long-term maintenance costs. The reuse of key site facilities through title transfer is part of the closure plan for the site.

The accelerated cleanup approach offers uncontaminated buildings, suitable for immediate private industrial use, for title transfer to CROET. CROET then leases the property to private industry and also recruits business to the area. The private entities at ETTP that have leased facilities from CROET are responsible for their own compliance programs, including requirements to obtain environmental permits as applicable. Any facilities at ETTP that remain unused will be demolished.

CROET leases portions of ETTP and then subleases these federally owned properties to business and industry. The ETTP mission is to reindustrialize and reuse site assets through leasing of excess or underutilized land and facilities and incorporation of commercial industrial organizations as partners in the ongoing environmental restoration, decontamination and decommissioning, and waste treatment and disposal. Since 2003, DOE has been actively working toward title transfer of a number of ETTP facilities, which is consistent with the *Accelerated Closure Plan*.

1.6.3 Oak Ridge National Laboratory

ORNL was the smallest of the three facilities built on the ORR for the Manhattan Project. (Fig. 1.10). From its modest beginning as a wartime pilot plant, ORNL has grown to become one of the world's premier scientific research centers and is DOE's largest and most diversified multiprogram national laboratory. As a multi-program national laboratory, 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.

Scientists and engineers at ORNL conduct basic and applied R&D to create scientific knowledge and technological solutions that strengthen the nation's leadership in key areas of science; increase the availability of clean, abundant energy; restore and protect the environment; and contribute to national security. ORNL also performs other work for DOE, including isotope production, information management, and technical program management, and provides research and technical assistance to other organizations.

The management of ORNL also includes the management and planning for most of the ORR's undeveloped land area. This responsibility includes planning for approximately 18,000 acres of undeveloped and developed land.

The SNS site is located on 80 acres of Chestnut Ridge near ORNL. The SNS, an accelerator-based neutron source, will provide neutron beams with up to ten times more intensity than any other such source in the world. Construction began in 1999 and is scheduled for completion in 2006 at a total cost of $1.4 billion. Design and construction is being performed by a partnership of six DOE national laboratories (Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge). When completed, the SNS will be open to scientists and engineers from universities, industries, and government laboratories in the United States and abroad.

ORNL 2415-2003

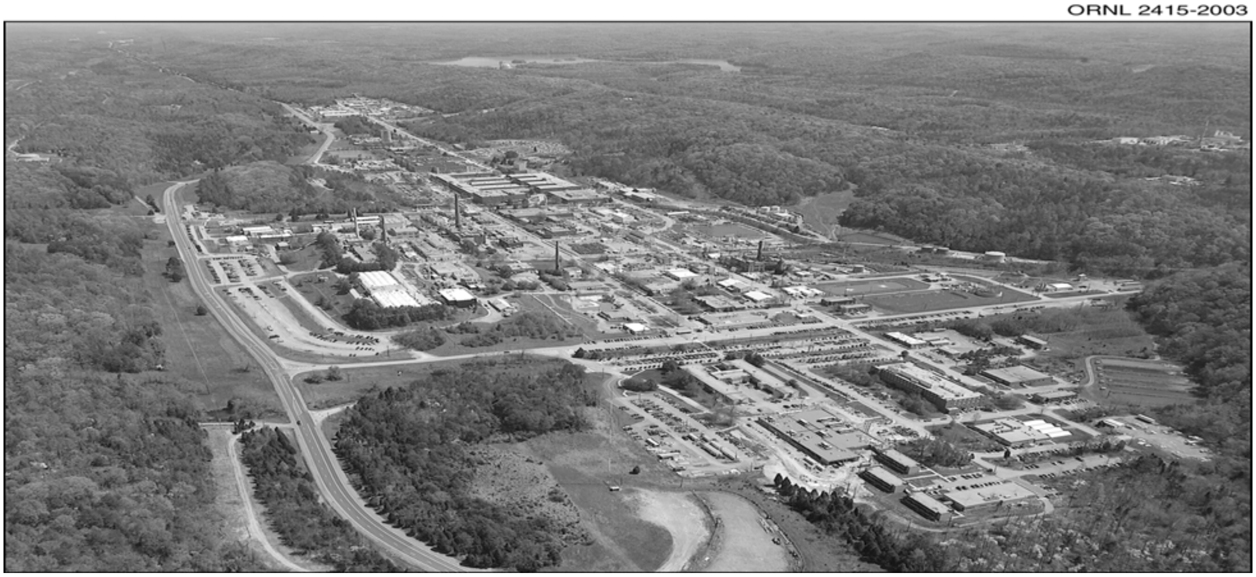

Fig. 1.10 The Oak Ridge National Laboratory.

1.6.3.1 Oak Ridge National Environmental Research Park

The Oak Ridge National Environmental Research Park is an approximately 8,100-hectare (20,000-acre) "outdoor laboratory" with relatively undisturbed ecosystems (Fig. 1.11). The Research Park provides a protected, biologically diverse land area for environmental research and education. It represents the eastern deciduous forest, with more than 1100 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 (see Chap. 2, Tables 2.8, 2.9, and 2.10 for listings). 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 Freel's Cabin and the Graphite Reactor.

As part of a DOE commitment to protect the environmental assets of its sites, the secretary of energy set aside 1215 hectares (3000 acres) of the ORR at Freels, Gallaher, and Solway bends as the "Three Bend Scenic and Wildlife Refuge" in June 1999. The area, which remains part of the Research Park, is managed for conservation and wildlife enhancement by Tennessee Wildlife Resources Agency (TWRA) under a cooperative agreement between TWRA and DOE.

The biological diversity of the Research Park serves as a foundation for ecological research into how the development and use of energy as well as other issues of national importance affect the environment. More than 700 individuals have performed research in the Research Park User Facility during the last 5 years. Users include students and faculty from more than 75 colleges and universities as well as participants from ORNL and other state and federal agencies. Field research facilities occur across the reservation and include Walker Branch Watershed, the Global Change Field Research Facility, Melton Branch

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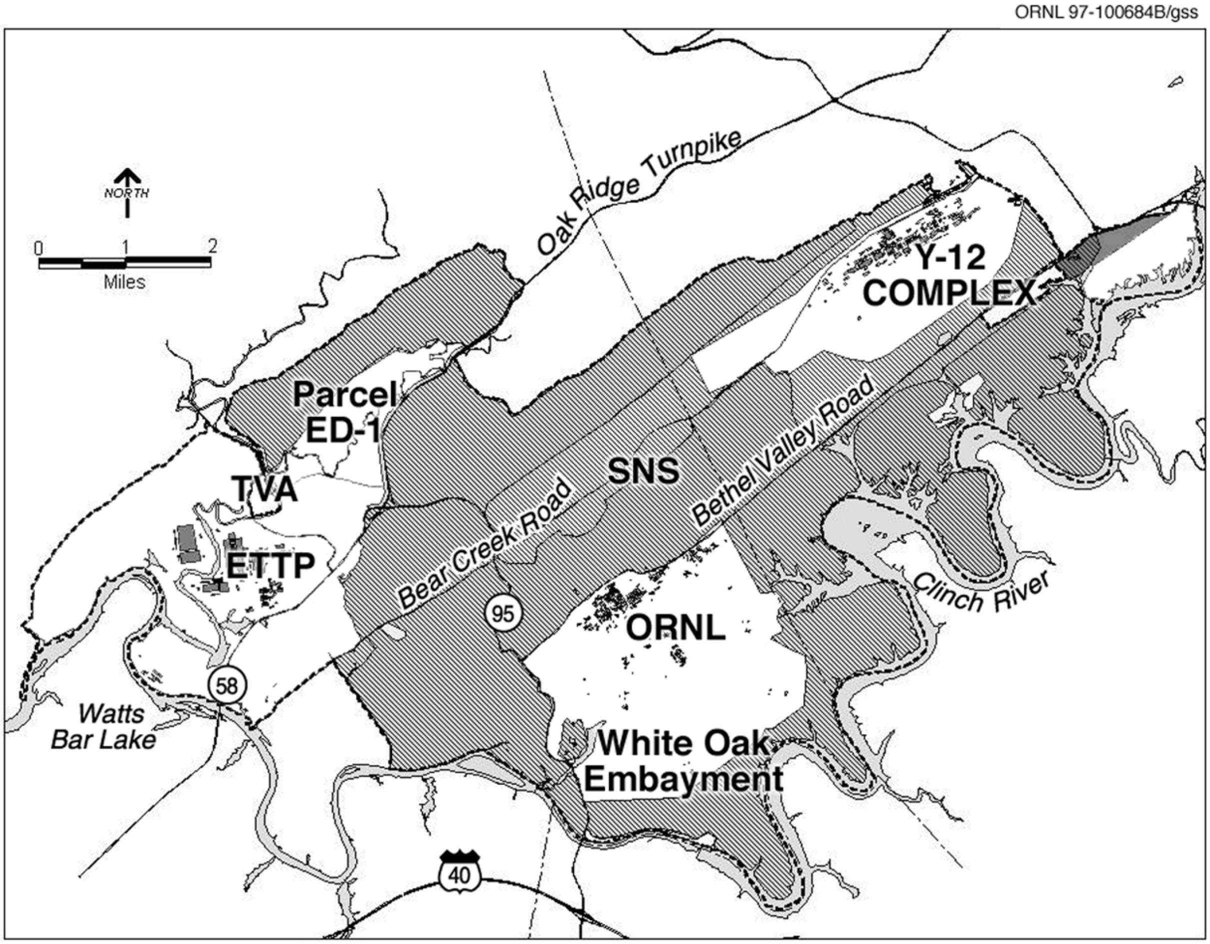

Fig. 1.11. The Oak Ridge National Environmental Research Park covers approximately 20,000 acres on the reservation.

Watershed, and the Bear Creek Valley Hydrology Field Sites.

The park has supported research in the following areas.

- **Ecosystems dynamics and biodiversity.** The large, unfragmented land provides a base for investigations into biogeochemical cycling, climate-change impacts, air quality, and biotechnology and offers opportunities for wildlife restoration.
- **Environmental characterization.** As the most hydrologically and geologically complex of all DOE sites, the park provides opportunities for hydrogeologic and geophysical investigations, contaminant transport and fate studies, tracers for fractured media, microbial ecology, wetland surveys, and characterization of flora and fauna and their communities.

1.6.4 Oak Ridge Institute for Science and Education

ORISE is managed for DOE by ORAU, a nonprofit consortium of 88 doctoral-granting members and 9 associate members. ORISE includes 94.3 hectares (233 acres) on the southeastern border of the ORR that from the late 1940s to the mid-1980s was part of an agricultural experiment station owned by the federal government and, until 1981, was operated by UT.

The ORISE South Campus lies immediately southeast of the intersection of Bethel Valley Road and Pumphouse Road. The site houses offices, laboratories, and storage areas for ORISE's program offices and support departments, and it is being developed for other productive uses.

For more information, visit the ORAU home page at http://www.orau.org and the ORISE home page at http://www.orau.gov/orise.htm.