ES/ESH-20

GROUNDWATER SURVEILLANCE PLAN FOR THE OAK RIDGE RESERVATION

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ABBREVIATIONS AND ACRONYMS LIST

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DCGs	derived concentration guides
EPA	U.S. Environmental Protection Agency
FFA	Federal Facilities Agreement
MCL	maximum contaminant level
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OUs	Operable Units
PCBs	polychlorinated biphenyls
PCE	tetrachloroethylene
RCRA	Resource Conservation and Recovery Act
SR	State Route
SWSA	Solid Waste Storage Area
SWMUs	Solid Waste Management Units
TCE	trichloroethylene
TCL	Target Compound List
TDEC	Tennessee Department of Environment and Conservation
TVA	Tennessee Valley Authority
UEFPC	Upper East Fork Poplar Creek
USDOE	U.S. Department of Energy
VOCs	volatile organic compounds
WAGs	Waste Area Groupings
WOC	White Oak Creek
WOL	White Oak Lake
WOM	White Oak Mountain

EXECUTIVE SUMMARY

PURPOSE AND SCOPE OF DOCUMENT

U.S. Department of Energy (DOE) Order 5400.1 requires the preparation of environmental monitoring plans and implementation of environmental monitoring programs for all DOE facilities. The order identifies two distinct components of environmental monitoring, namely effluent monitoring and environmental surveillance. In general, effluent monitoring has the objectives of characterizing contaminants and demonstrating compliance with applicable standards and permit requirements, whereas environmental surveillance has the broader objective of monitoring the effects of DOE activities on on- and off-site environmental and natural resources. The purpose of this document is to support the Environmental Monitoring Plan for the Oak Ridge Reservation (ORR) by describing the groundwater component of the environmental surveillance program for the DOE facilities on the ORR.

The distinctions between groundwater effluent monitoring and groundwater surveillance have been defined in the Martin Marietta Energy Systems, Inc., Groundwater Surveillance Strategy. As defined in the strategy, a groundwater surveillance program consists of two parts, plant perimeter surveillance and off-site water well surveillance. This document identifies the sampling locations, parameters, and monitoring frequencies for both of these activities on and around the ORR and describes the rationale for the program design. The program was developed to meet the objectives of DOE Order 5400.1 and related requirements in DOE Order 5400.5 and to conform with DOE guidance on environmental surveillance and the Energy Systems Groundwater Surveillance Strategy.

PLANT PERIMETER SURVEILLANCE

The Energy Systems Groundwater Surveillance Strategy states that plant perimeter groundwater surveillance locations should be selected on the basis of exit pathways. Because most exit pathways are closely associated with surface waters that may receive groundwater discharge, groundwater surveillance is coordinated with surveillance of nearby surface water locations.

The Groundwater Surveillance strategy states that perimeter surveillance parameters will be selected from lists of potential plant groundwater contaminants determined from review of groundwater data and other records. The strategy suggests that it may be possible to limit perimeter surveillance to a list of key indicator contaminants; i.e., those facility contaminants that, due to their mobility in the hydrogeologic environment and proximity of sources to surveillance locations, would be expected to reach the plant perimeter first and thus serve as indicators of groundwater contamination. The Strategy also states that perimeter surveillance frequency should be determined on the basis of consideration of rates of contaminant migration in groundwater and vulnerability of potential off-site receptors.

OFF-SITE WATER WELL SURVEILLANCE

The Energy Systems Groundwater Surveillance Strategy calls for a review of the existing off-site water well monitoring program to ensure that it is consistent with the DOE orders and satisfies public interest or concern and to make certain that all the program elements are appropriate and consistent with their level of technical significance.

Off-site groundwater surveillance is currently conducted at 20 off-site locations around the ORR. The majority of monitoring locations are wells that serve as drinking water sources for private residences, although they also include irrigation wells and two springs.

The two U.S. Geological Survey wells on Scarboro Road have been withdrawn from the off-site surveillance program to eliminate duplication of effort between the off-site program and the Y-12 Plant perimeter surveillance program. Also a former process-water well exists at the Rogers Group Quarry in Union Valley east of the Y-12 Plant. Although reportedly not used for potable water, this well, should it be reactivated might provide a pathway for exposure to groundwater contamination exiting the Y-12 Plant. Monitoring of wells off of the ORR in Union Valley will be included in the scope of a CERCLA remedial investigations for the Upper East Fork Poplar Creek groundwater operable unit.

Samples from the ORR off-site surveillance wells are currently analyzed for an extensive list of parameters. Field measurements of pH, temperature, and specific conductance are also conducted as part of the sampling protocol. The parameter list, which is more extensive than the range of key indicator parameters identified for the three ORR plants, includes the full range of contaminants that have been detected at the three plants, except for PCBs and the few semivolatile contaminants.

Sampling for ORR off-site water well surveillance is presently conducted semiannually. Although this is not consistent with the annual frequency established for perimeter surveillance around the three major ORR facilities, semiannual monitoring will be continued in response to the interest and concern of program participants and the public at large.

PROCEDURES FOR IMPLEMENTING GROUNDWATER SURVEILLANCE

Sampling, analysis, and quality assurance procedures for groundwater surveillance should follow the guidelines established in the current Energy Systems Environmental Surveillance Procedures Quality Control Program.

DOE Order 5400.1 and the DOE guidance on environmental surveillance monitoring contain few specific requirements for interpretation of data from groundwater surveillance. Comparisons are to be made, as appropriate, against applicable environmental standards and background or baseline levels. DOE also recommends comparisons against previous measurements or estimates in order to identify changes or inconsistencies. Similarly, the Energy Systems Groundwater Surveillance Strategy calls for groundwater surveillance results to be compared with background conditions, and background groundwater quality is defined as the quality of groundwater that is completely unaffected by the plant or its operations.

The background concentrations of surveillance monitoring parameters in ORR groundwater have not yet been determined. Pending determinations of background groundwater quality, interpretation of groundwater surveillance monitoring data should emphasize comparisons with available standards and with previous measurements in the surveillance monitoring sites. For substances that are not naturally present in groundwater or found in ambient rainwater (e.g., ^{99}Tc and most or all of the VOCs), however, background levels in groundwater should be considered to be equal to the analytical quantitation limits.

Sources of environmental standards to be considered in data interpretation include the maximum contaminant levels established by EPA for public drinking water supplies and the derived concentration guides for drinking water ingestion of specific radionuclides that are promulgated in

DOE Order 5400.5. Standards and action levels for additional parameters included in the off-site water well surveillance program are given in the sampling and analysis plan for that program.

The results of plant perimeter groundwater surveillance for each of the three ORR facilities will be summarized and listed in the data volume each year in the annual environmental report. These reports are published each year on June 1 and contain summary data for the previous calendar year. The results of off-site groundwater surveillance for the ORR are reported in the annual ORR Environmental Report.

1. INTRODUCTION

1.1 PURPOSE AND SCOPE OF DOCUMENT

U.S. Department of Energy (DOE) Order 5400.1 (USDOE 1988) requires the preparation of environmental monitoring plans and implementation of environmental monitoring programs for all DOE facilities, effective November 9, 1991. The order identifies two distinct components of environmental monitoring, namely effluent monitoring and environmental surveillance. In general, the objectives of effluent monitoring are to characterize contaminants and demonstrate compliance with applicable standards and permit requirements, whereas environmental surveillance has the broader objective of monitoring the effects of DOE activities on on- and off-site environmental and natural resources. The purpose of this document is to support the Environmental Monitoring Plan for the Oak Ridge Reservation (ORR) (Martin Marietta Energy Systems, Inc., 1992) by describing the groundwater component of the environmental surveillance program for the DOE facilities on ORR.

The distinctions between groundwater effluent monitoring and groundwater surveillance have been defined in the Energy Systems Groundwater Surveillance Strategy (Forstrom 1990a) and are summarized in Table 1.1.1. As defined in the strategy, a groundwater surveillance program consists of two parts, plant perimeter surveillance and off-site water well surveillance, as described in Table 1.1.2. This document identifies the sampling locations, parameters, and monitoring frequencies for both of these activities on and around ORR and describes the rationale for the program design. The program described was developed to meet the objectives of DOE Order 5400.1 and related requirements in DOE Order 5400.5 (DOE 1990) and to conform with the department's guidance on environmental surveillance (DOE 1991) and the Energy Systems Groundwater Surveillance Strategy.

1.2 BACKGROUND INFORMATION ON THE ORR FACILITIES

The ORR is located within the corporate limits of the City of Oak Ridge in eastern Tennessee (Fig. 1.2.1). The reservation consists of ~14,300 ha (35,300 acres) of federally owned lands. The ORR contains three major operating facilities, which are owned by DOE and managed by Energy Systems (Fig. 1.2.2): the Y-12 Plant, Oak Ridge National Laboratory (ORNL), and the K-25 Site (formerly called the Oak Ridge Gaseous Diffusion Plant). The following discussions about plant sites and operations are derived primarily from the *ORR environmental report* (Energy Systems 1990), except as otherwise noted.

1.2.1 Y-12 Plant

The U.S. Army Corps of Engineers built the Y-12 Plant in 1943 as part of the Manhattan Project. Its original mission was to separate the fissile ^{235}U isotope from natural uranium with the use of the electromagnetic process. Production of ^{235}U by this method was discontinued after the war in favor of the more economical gaseous diffusion process. Since then, the plant has developed into a sophisticated manufacturing, development, and engineering organization. Currently, the Y-12 Plant is refocusing its technical capabilities and expertise to serve DOE and other DOE-approved customers. The Y-12 Plant continues to serve as a key manufacturing technology center for the development and demonstration of unique materials, components, and services of importance to the DOE and the nation. Specific focus areas for the Y-12 Plant in coming years include: (1) weapons dismantlement and storage; (2) enriched uranium material warehousing and management; (3) nuclear weapons process technology and development support; (4) Y-12 Plant management/landlord activities including taking standby or shutdown facilities into a safe, legally compliant condition; (5) identifying

Table 1.1.1 Definitions and generalized characteristics of groundwater effluent monitoring versus groundwater surveillance

	Groundwater Effluent Monitoring		Groundwater Surveillance
Definition:	(1) Groundwater monitoring activities conducted at a unit or facility to comply with regulations, permit conditions, or environmental commitments made in environmental impact statements, environmental assessments, or other official documents; (2) Ground- water monitoring activities conducted to investigate, characterize, quantify, or otherwise define ground-water contamination associated with waste treatment, storage, disposal, or spill sites, or groupings thereof (waste area groupings, WAGs); or groundwater monitoring activities conducted to monitor the effec-tiveness of environmental restoration activities at such sites.	**Definition:**	(1) Groundwater surveillance activities conducted to monitor the effects, if any, of the plant as a whole on local groundwater and/or surface water quality, thus providing verification of compliance with regulatory requirements and environmental commitments, as well as providing a means of detecting previously unidenti-fied on-site groundwater quality problems (plant perimeter surveillance); (2) Groundwater surveillance activities conducted to monirot drinking water sources and to address the public interest in or concern about potential contamination of off-site wells (off-site water well surveillance).
Characteristics:		**Characteristics:**	
Regulation, permit, or investigation driven.		DOE-order driven.	
Monitors individual units, facilities, or WAGs.		Monitors plant as a whole.	
Monitoring locations are generally on-site.		Monitoring locations are at the plant perimeter and off-site.	
Temporary—short, intermediate, and/or long-term monitoring.		Permanent.	
Constantly changing—establish new sites, add wells, delete wells, change parameters, change frequencies.		Rarely changes after full implemention.	

Table 1.1.2. Summary and comparison of the components of plant perimeter surveillance and off-site water well surveillance

	Program basis	Locations	Parameters	Frequency
Plant perimeter surveillance	Monitor effects of plants on local GW[a] and/or surface water quality	Plant perimeter using existing effluent monitoring wells or new WQ[b] wells, based on exit pathways, discharge areas, preferred pathways, and downgradient	Based on plant GW contaminants and key indicator contaminants	Based on contaminant migration rates and distance to off-site groundwater users
Off-site water well surveillance	Monitor drinking water and address area of public interest or concern	Off-site using existing drinking water or other wells, based on availability, hydrogeologic setting, direction and distance, public concern, and economics	Based on plant GW contaminants, economics, legal implications, and level of public concern	Based on regional GW flow rate, level of public concern, and economics

[a]GW = groundwater.
[b]WQ = water quality.

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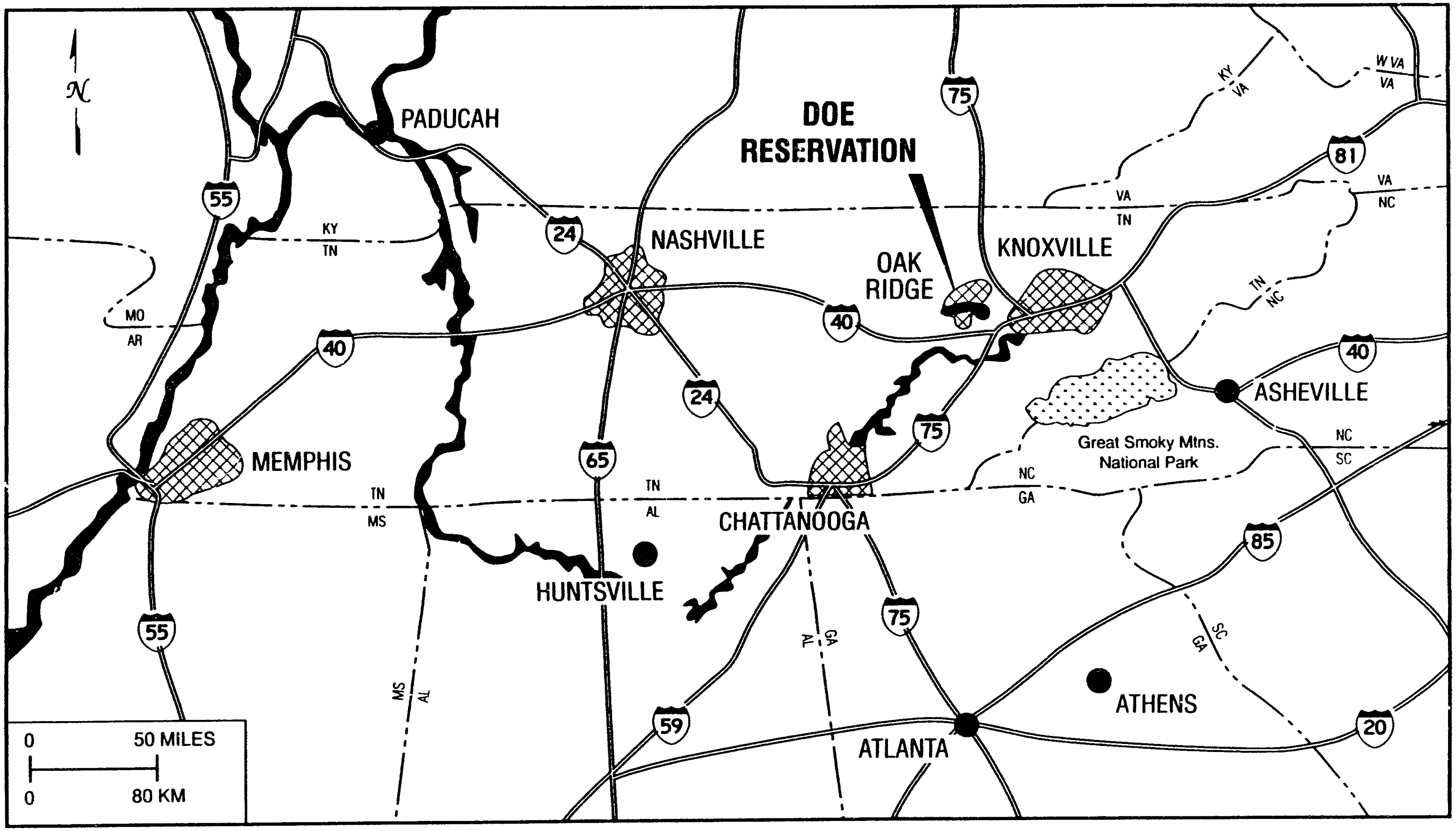

Fig. 1.2.1. Location of the Oak Ridge Reservation.

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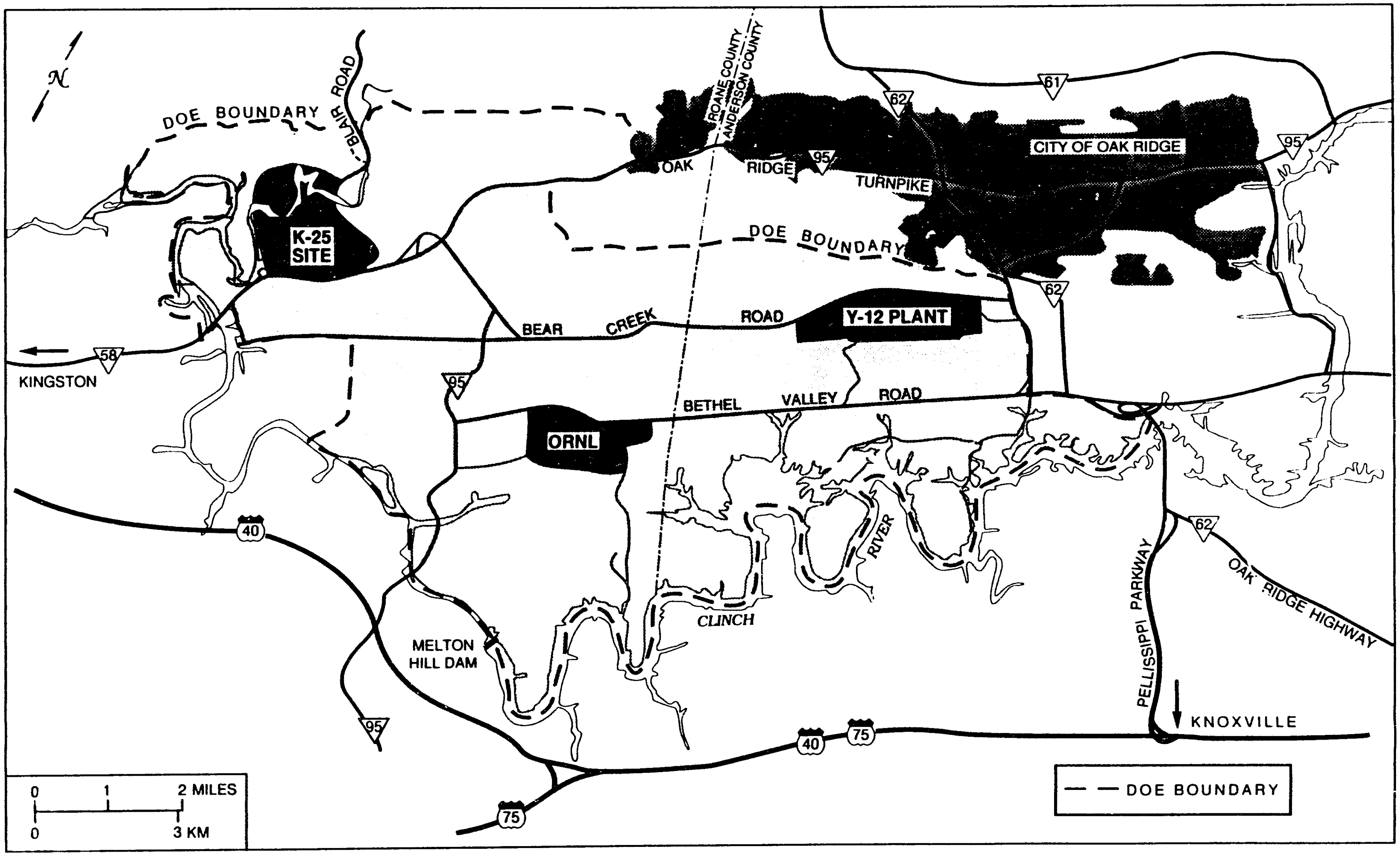

Fig. 1.2.2. Location of the three major facilities on the Oak Ridge Reservation.

and managing the decontamination and decommissioning of facilities; (6) providing unique capabilities and technologies not found in the private sector on DOE-approved tasks; (7) transferring technology developed at DOE facilities to enhance our industrial competitive edge in worldwide markets; and (8) maintain and support the National Security Program Office for DOE.

Operations at the Y-12 Plant have produced radioactive, organic and inorganic hazardous, and mixed wastes. Through the years these wastes have been managed and disposed of in burial grounds and seepage ponds and on an oil landfarm. Most of these facilities are now closed and are under remedial investigation. Current waste disposal activities at the Y-12 Plant include the following:

- One Industrial Landfill (Class II), permitted for sanitary wastes;
- Two Industrial Landfills (Class II), permitted for industrial, noncombustible waste only;
- Two Construction/Demolition Debris Landfills (Class IV);
- Above-ground mixed-waste storage units.

1.2.2 ORNL

ORNL began operation in 1943 with a wartime mission of producing plutonium for the atomic bomb through controlled fission of enriched uranium within a graphite reactor. Since World War II, the basic mission of this large, multipurpose research laboratory has been to expand knowledge, both basic and applied, in areas related to energy. To accomplish this mission, ORNL conducts research in fields of modern science and technology. Facilities at ORNL include nuclear reactors, chemical pilot plants, research laboratories, radioisotope production laboratories, accelerators, and support facilities.

The research and isotope production activities at ORNL have generated substantial volumes of radioactive wastes over the years. These wastes have been buried in trenches and silos in six separate Solid Waste Storage Areas (SWSAs), stored in underground liquid low-level waste tanks, disposed in shale by underground injection, or stored in aboveground tumuli. In addition, radioactive wastes were received from other sites from 1955 to 1963, when SWSAs 4 and 5 were designated as the Southern Regional Burial Ground by the Atomic Energy Commission. ORNL activities have also required the use of commercially available chemicals, resulting in the production of organic and inorganic hazardous and mixed wastes.

1.2.3 K-25 Site

The K-25 Site also was constructed as part of the Manhattan Project during World War II. Its wartime mission was to enrich uranium in the ^{235}U element by the gaseous diffusion process, for use in the production of the first atomic bombs. From the end of WWII to 1985 the K-25 Site continued the enrichment of uranium for use as fuel in nuclear power plants. Since the permanent shutdown of the enrichment cascade in 1985, the mission of the K-25 Site has shifted to technology development and waste management operations.

Operations at the K-25 Site have produced radioactive, organic and inorganic hazardous, and mixed wastes. Through the years these wastes have been managed and disposed of in burial grounds and surface impoundments. Most of these facilities are now closed and are under remedial investigation. Current waste management activities include the operation of storage facilities for low-level radioactive wastes from the ORR sites and the operation of a Resource Conservation and Recovery Act/Toxic Substances Control Act/mixed waste incinerator, which handles wastes from all Energy Systems sites. These facilities operate under permits issued by TDEC and/or the U.S. Environmental Protection Agency

2. HYDROGEOLOGIC SETTING

2.1 ORR GEOLOGY AND HYDROLOGY

This section describes aspects of the ORR hydrogeologic setting that are common to all three plants on the ORR. This information was derived primarily from the *ORR Environmental Report* (Energy Systems 1990), except where noted otherwise. Subsequent sections focus on the hydrogeology of the individual operating facilities and are based on site-specific documents.

Note that in the remainder of this report, directional information is based on one of two grid systems: Universal Transverse Mercator (true north) or the ORR administrative grid. The ORR administrative grid north deviates from true north by 34°12'51" to the west. The administrative grid is employed for convenience in mapping and directional specifications; most major topographic features on the ORR are roughly parallel to the grid axes. Most directional information in this report is given in terms of the administrative grid system; where directional information is based on true north it is differentiated by underlining. Each of the three ORR facilities also employs a local grid system that differs from the ORR grid; maps in this report that were plotted in accordance with these site grid systems indicate the orientations of true north and site north.

2.1.1 Surface Water System

The ORR is bounded on the south and west by a 63-km (39-mile) stretch of the Clinch River (Fig. 2.1.1), which has its headwaters near Tazewell, Virginia. At Kingston, Tennessee, the Clinch flows into the Tennessee River, which is the seventh largest river in the United States. Three dams operated by the Tennessee Valley Authority (TVA) control the flow of the Clinch River. Norris Dam, constructed in 1936, is ~50 km (31 miles) upstream from the ORR. Melton Hill Dam, completed in 1963, controls the flow of the river along the southern boundary of the ORR. Watts Bar Dam on the Tennessee River affects the flow of the lower reaches of the Clinch, along the western boundary of the ORR.

Both groundwater and surface water are drained from the ORR by a network of tributaries of the Clinch River (Fig. 2.1.1). Each of the three DOE plants affects different tributaries. Drainage from the Y-12 Plant enters both Bear Creek and East Fork Poplar Creek. Most ORNL facilities are in the White Oak Creek (WOC) watershed, but several smaller tributaries also receive drainage from ORNL. The K-25 Site drains primarily into Poplar Creek, both directly and through Mitchell Branch, a small Poplar Creek tributary, although a portion of the site drains directly to the Clinch River. The surface water system on the ORR exhibits a trellis drainage pattern, which is typical of the Valley and Ridge physiographic province.

2.1.2 Geology

The ORR is in the Tennessee Valley and Ridge Province, part of the Southern Appalachian fold and thrust belt (Fig. 2.1.2). The area is characterized by a succession of <u>northeast-southwest</u> trending thrust faults that structurally stack and duplicate the Paleozoic rocks of this area (Figs. 2.1.3 and 2.1.4). As a result of thrusting and subsequent differential erosion, a series of valleys and ridges has formed that parallels the thrust faults. In general, the more resistant siltstone, sandstone, and chert-rich dolomite units are the ridge formers, and the less resistant shales and shale-rich carbonates underlie the valleys of the region.

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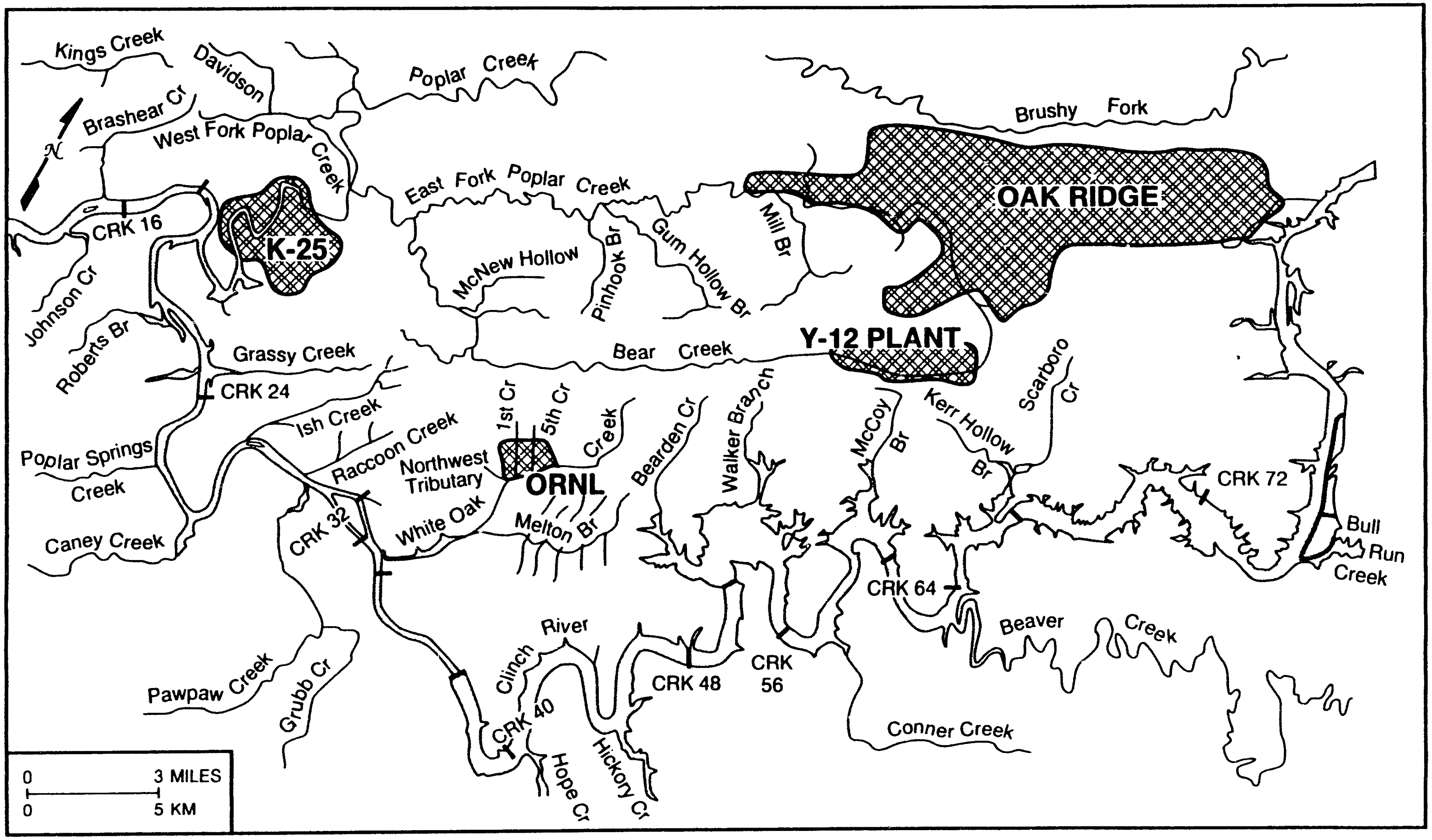

Fig. 2.1.1. Surface water features in the vicinity of the Oak Ridge Reservation.

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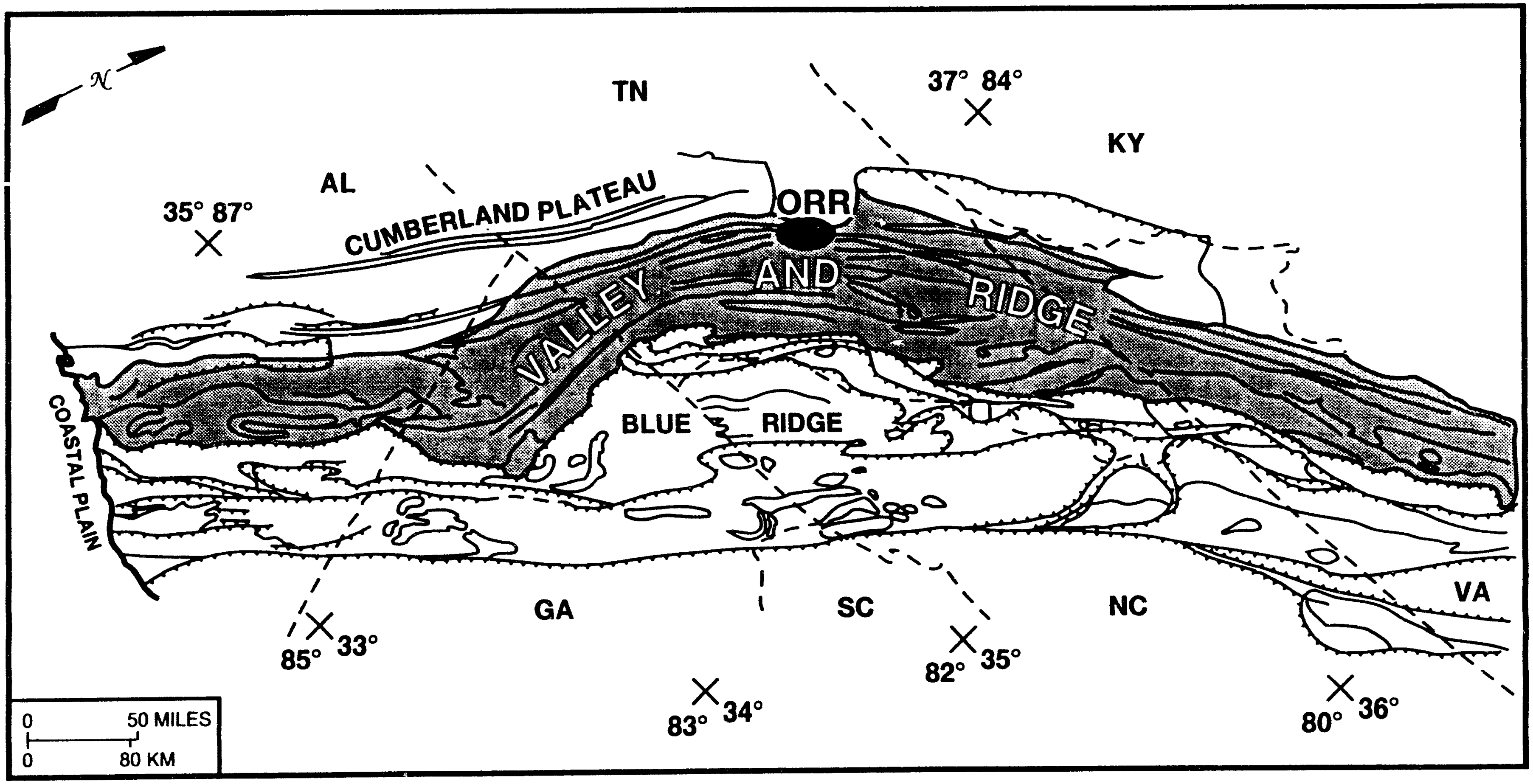

Fig. 2.1.2. Geology of the southern Appalachians.

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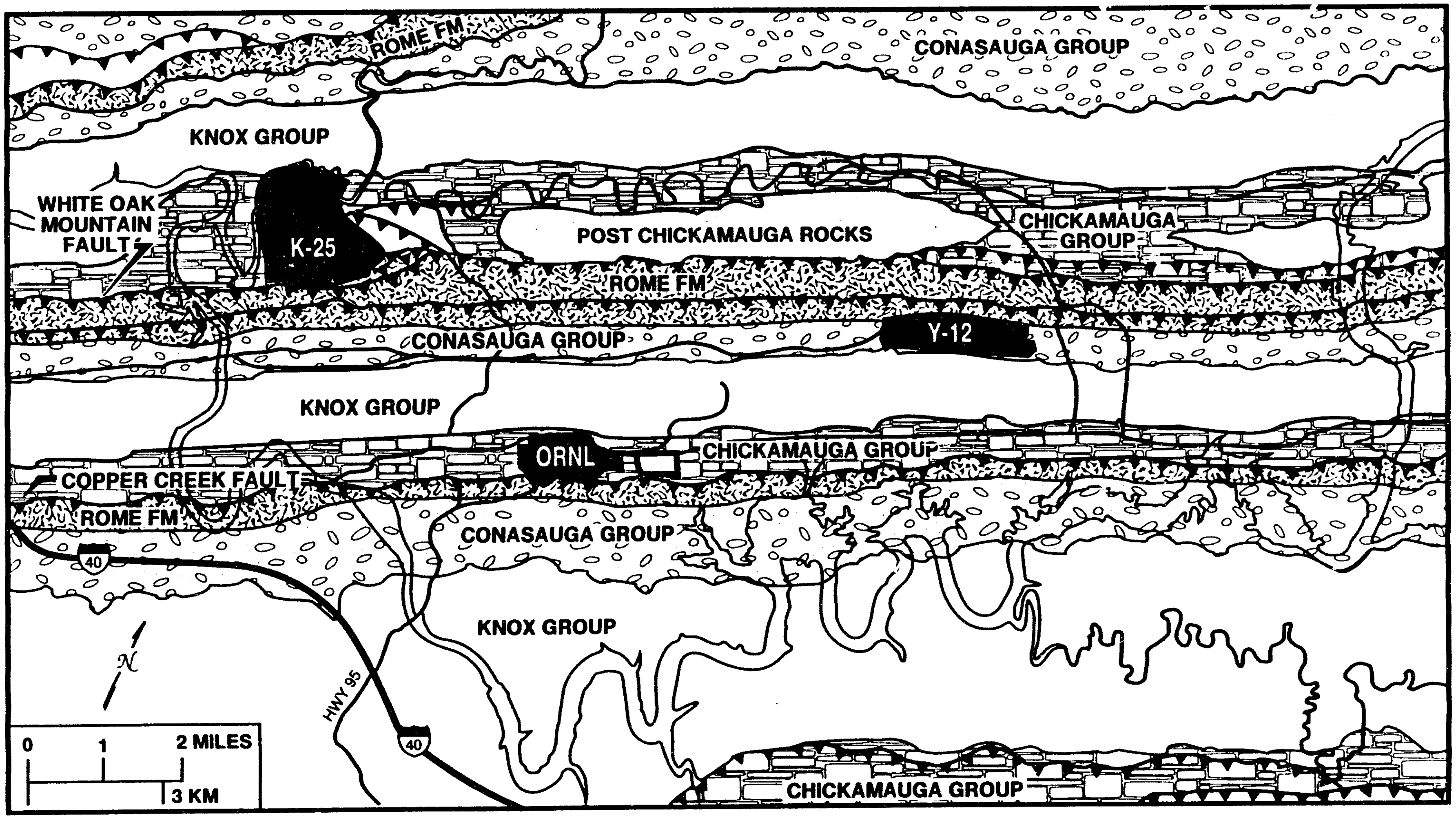

Fig. 2.1.3. Geology of the Oak Ridge Reservation.

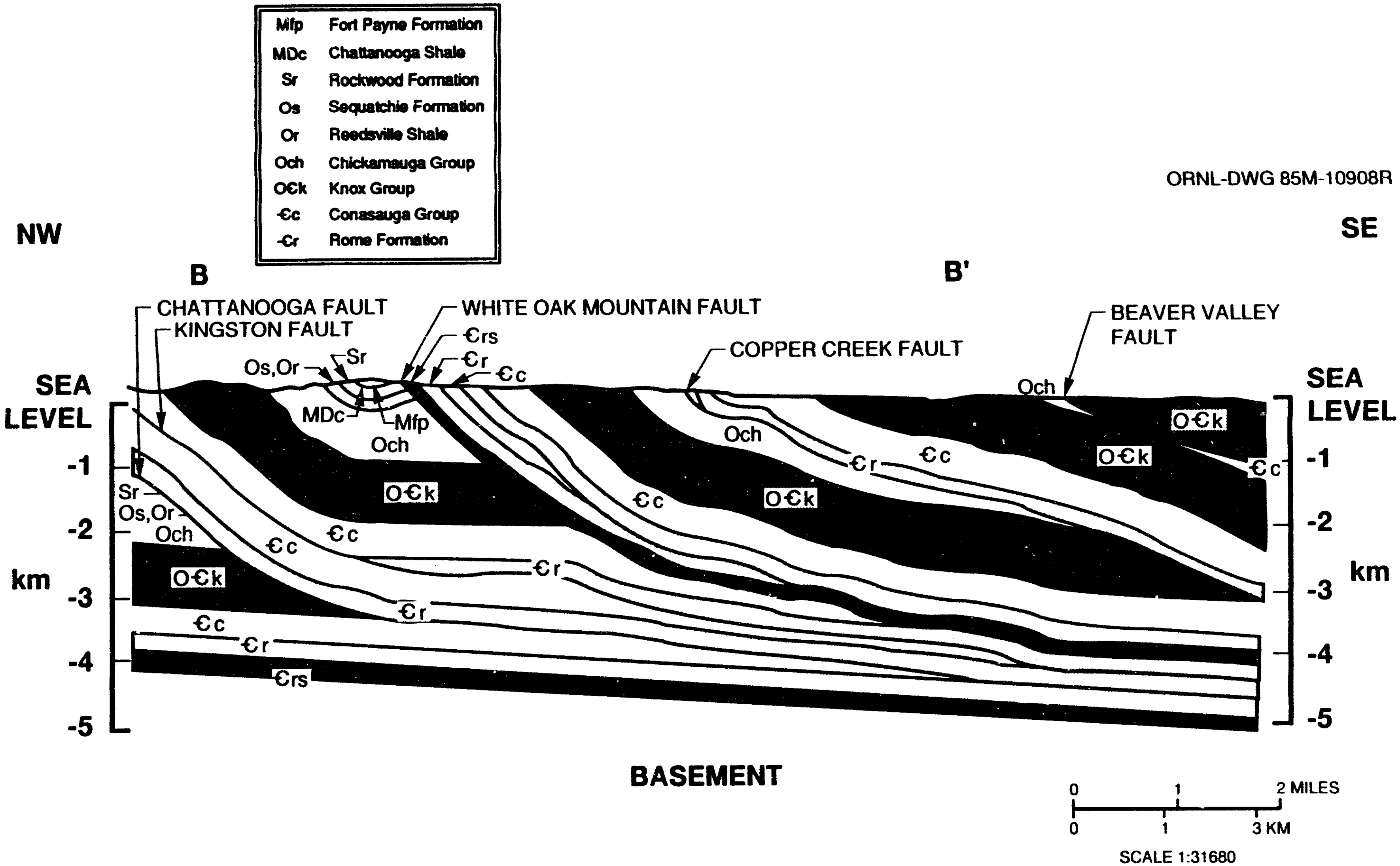

Fig. 2.1.4. Geologic cross section of the Oak Ridge Reservation.

The bedrock stratigraphy of the area is summarized in Table 2.1.1 (Hatcher et al. 1992). The principal bedrock units underlying DOE facilities on the ORR are, in ascending order, the Lower Cambrian Rome Formation, the Cambrian Conasauga Group, the Cambro-Ordovician Knox Group, and the Middle Ordovician Chickamauga Group. Younger Upper Ordovician to Mississippian rocks are exposed locally in the cores of two synclines north of the White Oak Mountain (WOM) Thrust Fault (Fig. 2.1.3). No DOE facilities are located on these units.

The Rome Formation crops out on Haw Ridge and Pine Ridge and is the basal decollement for the Copper Creek and WOM thrust faults. The Rome consists of massive to thinly bedded sandstones interbedded with thinly bedded silty mudstones, shales, and dolomite. The Rome is commonly subdivided into lower and upper members in which the massive sandstones and thinly bedded shales, respectively, predominate.

The Conasauga Group crops out in Melton and Bear Creek valleys. In this area of eastern Tennessee, the Conasauga Group is divided into six formations of alternating shale and carbonate-rich lithologies (Table 2.1.1). As a whole, the Conasauga Group weathers to a thick fractured saprolite of ~12 m (40 ft) that is covered by a veneer of upper soil horizons.

The Knox Group crops out on Copper Ridge, Chestnut Ridge, McKinney Ridge, and Blackoak Ridge. In eastern Tennessee, the Knox Group generally consists of thin- to thick-bedded dolomite with interbeds of limestone and is divided into five formations (Table 2.1.1). The Knox Group weathers to a thick [up to 45 m (150 ft)], dark orange-red clay residuum that commonly contains abundant chert. Significant portions of the Knox are characterized by karst features.

The Chickamauga Group crops out in East Fork Valley, at the K-25 Site, and in Bethel Valley. These rocks comprise the footwall immediately below the major thrust faults on the ORR. In general, the Chickamauga Group consists of thin- to medium-bedded argillaceous limestones interbedded with carbonate-rich shales. Although the Chickamauga Group has been subdivided into formations on the ORR (Weiss 1981, Lee and Ketelle 1989), it is generally considered as a single unit for hydrogeologic purposes.

As a result of its location in a foreland fold and thrust belt, the geology of the ORR is strongly influenced by structural features at all scales, including regional thrust faults, local thrust faults and tear faults, local folding of relatively weak units, and widespread fracture development. Two regionally extensive thrust faults, the WOM and Copper Creek faults, crop out on the ORR (Fig. 2.1.3). A number of cross-cutting imbricate splay faults are also associated with the WOM fault. Numerous minor, localized faults have resulted in the stacking and thickening of units and complex folding of less competent units.

All geologic units on the ORR are highly fractured, both throughout the units and in fault zones. The secondary porosity and permeability provided by these fractures strongly influence groundwater flow on the ORR. Primary fracture orientations are bedding-parallel, strike-parallel, and approximately strike-perpendicular, the latter two sets being oriented approximately perpendicular to bedding. Fractures deeper than ~45 m (150 ft) below land surface tend to be sealed by mineral precipitates and do not contribute to secondary permeability. Solution enlargement of shallower fractures in the more carbonate-rich units serves to enhance secondary permeability. Such karstification has been reported in the Knox Group, Chickamauga Group, Maynardville Limestone, and carbonate-rich portions of the Nolichucky Shale.

Table 2.1.1. Bedrock stratigraphic units of the Oak Ridge Reservation

Unit	Age	Thickness (m)	Lithology
Rockwood Formation	Silurian	190–200	Sandstone, shale
Sequatchie Formation	Upper Ordovician	60–75	Argillaceous limestone
Reedsville Shale	Upper Ordovician	60–70	Calcareous shale
Chickamauga Group	Middle Ordovician	545–875	Limestone, argillaceous limestone, shale, siltstone
Knox Group	Lower Ordovician, Upper Cambrian		
Mascot Dolomite		75–150	Massive dolomite, siliceous dolomite, bedded chert, limestone, some clastics
Kingsport Formation		90–150	
Longview Dolomite		40–60	
Chepultepec Dolomite		152–213	
Copper Ridge Dolomite		244–335	
Conasauga Group	Middle, Upper Cambrian		
Maynardville Limestone		100–110	Dolomitic limestone, limestone
Nolichucky Shale		150–180	Shale, silestone, calcareous siltstone and shale, shaly limestone, limestone
Dismal Gap Formation (formerly Maryville Limestone)		98–125	
Rogersville Shale		25–34	
Friendship Formation		31–37	
Pumpkin Valley Shale		56–70	
Rome Formation	Lower Cambrian	122–450+	Shale, siltstone, sandstone, local dolomite lenses

2.1.3 Groundwater Flow Systems

In the Valley and Ridge Province of Tennessee, groundwater occurs in bedrock, in the regolith, and in a few alluvial aquifers along the largest rivers. In the shale and carbonate bedrock that dominate the region, groundwater flow occurs in fractures and solution cavities. According to a conceptual model developed by Solomon et al. (1992); Moore and Toran (1992); and Moore (1988, 1989), groundwater on the ORR occurs in and flows through four subsurface zones (Fig. 2.1.5): the stormflow zone, the vadose zone, the shallow aquifer, and the deeper aquifer. The following discussion is based largely upon this model.

2.1.3.1 Stormflow Zone

The stormflow zone extends from land surface to a depth of 0.3 to 2 m (1 to 7 ft) and generally corresponds to the root zone. It is thicker and more permeable in forested areas than in grassy or brushy areas; it is also more permeable at the land surface than at deeper levels.

Essentially all precipitation on the ORR enters the stormflow zone. Infiltration first recharges any soil moisture deficit in the root zone, with additional water percolating to the vadose zone. Continued infiltration will form a perched water table at the level at which the percolation rate exceeds hydraulic conductivity. Groundwater then moves laterally through the stormflow zone, at an average linear velocity of ~3 m/d (10 ft/d), toward downslope springs and streams along flow paths that follow the land surface. Because the stormflow zone is an average of 100 times more permeable than the underlying material, a large majority of all groundwater flow on the ORR takes place in this zone.

2.1.3.2 Vadose Zone

The vadose (unsaturated) zone separates the stormflow zone from the shallow aquifer. The thickness of the vadose zone varies from >30 m (98 ft) under Chestnut Ridge to essentially zero near streams, where the water table may be located within the stormflow zone. The material in most of the vadose zone is regolith. Water is added to the vadose zone by percolation from the stormflow zone; water is removed by transpiration and by recharge of the shallow aquifer. Most of the flow paths are nearly vertical, and average linear velocity is in the range of 0.1 to 10 m/d (0.3 to 33 ft/d). Lateral flow may occur in fractures or cavities under saturated conditions.

2.1.3.3 Shallow Aquifer

The shallow aquifer extends from the water table to a depth of ~30 m (98 ft) in the Rome Formation, Conasauga Group, and Chickamauga Group. In the Knox Group, the base of the shallow aquifer is at a depth of ~50 to 100 m (164 to 328 ft). The shallow aquifer is generally composed of two parts: an upper zone of unconsolidated materials (regolith) and a lower bedrock zone. The unconsolidated zone is composed of weathered bedrock, residuum, man-made fill, alluvium, and colluvium. There is no difference in permeability between regolith and bedrock.

Groundwater in the shallow aquifer is unconfined near the water table, but there is a gradual change to confined conditions at deeper levels. The water table generally forms a subdued replica of the topography. It is usually located within the unconsolidated zone on lower slopes and in valleys, and within the bedrock beneath ridges.

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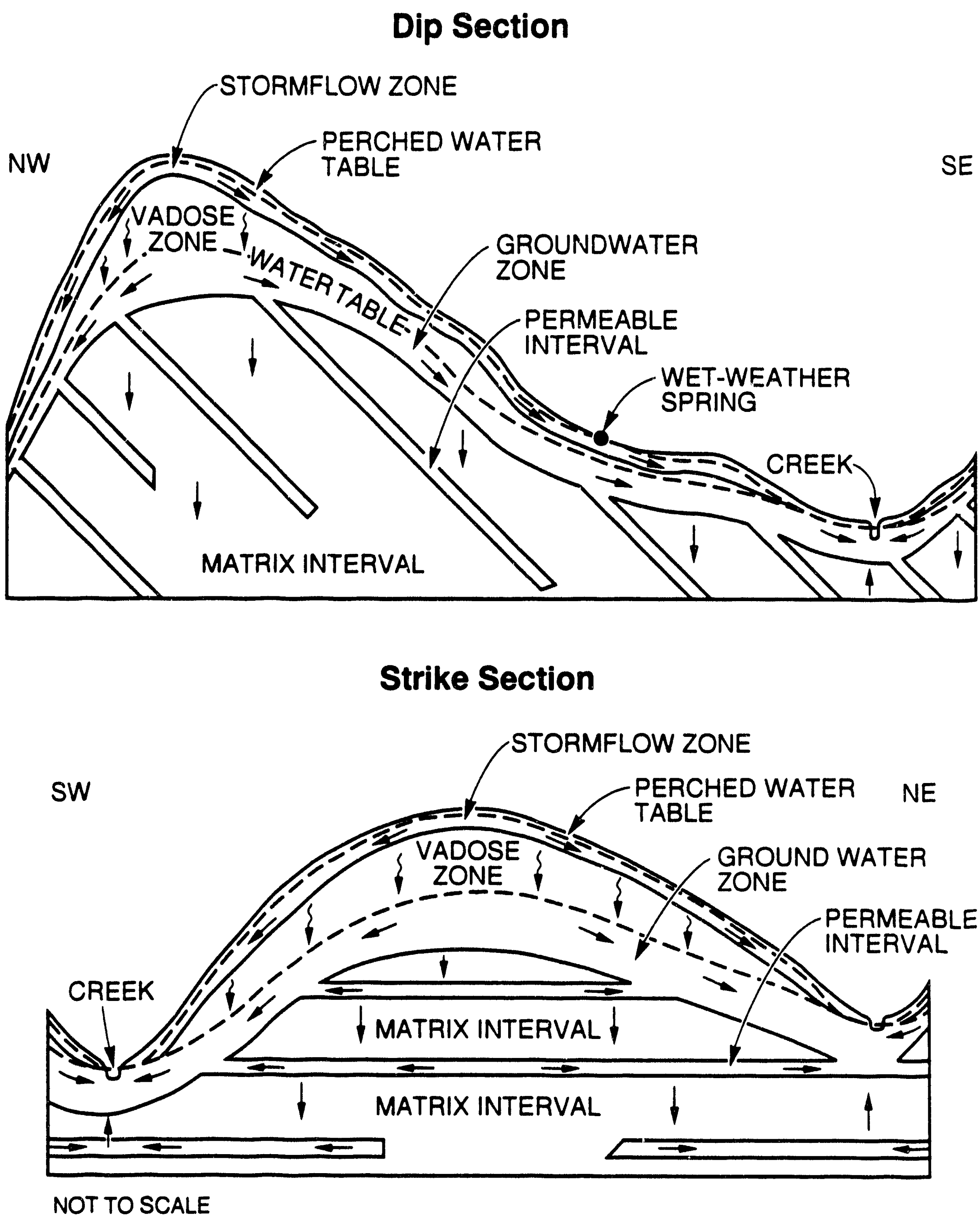

Fig. 2.1.5. Conceptual model of the occurrence and flow of groundwater on the Oak Ridge Reservation.

A convergence of evidence indicates that most groundwater is transmitted through a layer of closely spaced connected fractures near the water table (Fig. 2.1.5). Outcrops display many open fractures that extend only a short distance into the rock, and the near correspondence of the water table with the top of weathered bedrock on the ORR 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 changes 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 water level above stream level. Opposite changes in hydraulic gradient and saturated thickness occur from one physiographic location to another, and the product of transmissivity and hydraulic gradient is constant along any flow path.

At deeper levels the shallow aquifer is characterized by water-producing (enlarged fracture or cavity) intervals averaging 0.6 m (2 ft) in thickness, separated by an average of 10 m (33 ft) of relatively impermeable matrix materials. In the thin but really extensive networks of pervious fractures, some groundwater probably flows along strike and thus follows relatively permeable flow paths to discharge locations in cross-cutting tributary streams (Fig. 2.1.5). The remaining water may flow downdip to locations beneath main-valley streams and then seep upward through much less permeable matrix intervals to discharge locations in the streams (Fig. 2.1.5). Groundwater in the shallow aquifer flows into the stormflow zone near these discharge locations. The average linear velocity of groundwater flow throughout the shallow aquifer is ~.01 to 1 m/d (0.03 to 3.3 ft/d).

2.1.3.4 Deeper Aquifer

The deeper aquifer occurs below most water-producing intervals and generally has the same characteristics as the matrix intervals within the shallow aquifer. All water in the deeper aquifer occurs under confined conditions. This water comes from shallower levels and eventually returns to shallow levels before discharge to springs and streams. However, the geometric mean of hydraulic conductivity in the deeper aquifer is much smaller than that of water-producing intervals in the shallow aquifer, indicating that rates and quantities of groundwater flow are much smaller than in the shallow aquifer. Only ~10% of the groundwater that reaches the shallow aquifer follows flow paths through the deeper aquifer. The base of the deeper aquifer is defined as the base of fresh water, which occurs at depths below ~150 m (492 ft) in Melton Valley, but which has not been determined over the rest of the ORR.

The possibility of deep groundwater flow on the ORR (especially along faults) and thus of contaminant transport beneath drainage divides to off-site wells and springs has been raised in the past. In limestone formations and members in the Conasauga and Chickamauga Groups, along-valley groundwater flow across low surface water divides and into an adjacent drainage basin at a lower elevation should be considered as a possibility. Because of interbedded shales, low average permeability, and the resulting likelihood of discontinuities along fracture flow paths, groundwater flow beneath the main ridges or beneath the Clinch River is considered nearly a hydrogeologic impossibility. In the Knox Group, openings with a relatively large aperture are common at deeper levels, and large rates of groundwater flow may occur. Cross-strike flows beyond the valleys that bound the Knox outcrop belt are almost impossible, but along-strike flows within the outcrop belt may occur for distances of at least a few kilometers.

2.1.3.5 Groundwater/Surface Water Interaction

As noted throughout the above discussions of groundwater zones, groundwater and surface water form an integrated hydrologic system on the ORR. Most streamflow on the ORR is derived from groundwater flow, most of that originating in the stormflow zone. Similarly, essentially all groundwater on the ORR discharges to surface water within the reservation or at its boundary (i.e., the Clinch River). Because of this phenomenon, surface water monitoring must be regarded as an important complement to groundwater surveillance on the ORR.

2.2 HYDROGEOLOGIC SETTING OF THE Y-12 PLANT

The Y-12 Plant is located on the floor of Bear Creek Valley at an elevation of ~290 m (950 ft) above sea level. Bear Creek Valley is bounded on the north and south by parallel ridges (Pine and Chestnut ridges, respectively) that rise ~91 m (300 ft) above the valley floor. The plant and its fenced buffer area are ~1 km (0.6 mile) wide by 5 km (3.2 miles) long and covers ~1980 ha (4,900 acres). The main industrialized section of the plant encompasses ~324 ha (800 acres).

Numerous investigations of the hydrology, geology, and hydrogeology of the Y-12 Plant have been conducted. These are summarized in HSW, Inc. (1993) and Geraghty & Miller, Inc. (1990a). The discussions in the remainder of Sect. 2.2 were derived primarily from these two references, except where noted otherwise.

2.2.1 Y-12 Plant Surface Water System

Most of the Y-12 Plant and waste management facilities are within Bear Creek Valley, which is drained to the west by Bear Creek and to the east by Upper East Fork Poplar Creek (UEFPC; Fig. 2.2.1). A few waste management facilities are also on Chestnut Ridge, from which surface water flows primarily southward through a number of small tributaries to the Clinch River (Melton Hill Lake).

Headwaters of both Bear Creek and UEFPC are at the west end of the Y-12 Plant near the S-3 Site (Fig. 2.2.1). UEFPC is contained within below ground culverts or man-made channels over most of its course through the plant area. Most dry-weather flow in UEFPC consists of Y-12 Plant effluents, including cooling water, storm drain runoff, steam system condensate, and cooling tower blowdown. The flow in UEFPC as it leaves the eastern end of the plant is regulated by Lake Reality, a lined surface impoundment. Below Lake Reality, East Fork Poplar Creek flows northward through a water gap in Pine Ridge into the developed areas of Oak Ridge, then west toward its confluence with Poplar Creek near the K-25 Site.

Bear Creek flows west from the west end of the Y-12 Plant. In its upper reaches it follows a relatively straight course along geologic strike overlying the Maynardville Limestone. Due to the presence of a solution cavity (karst) system within the Maynardville, Bear Creek has both gaining and losing reaches within the valley. It is fed by several small tributaries and springs over its course. About 7.2 km (4.5 miles) west of the plant, Bear Creek flows northward through a water gap in Pine Ridge. It flows into East Fork Poplar Creek ~4.8 km (3 miles) east of the K-25 Site.

Some surface water runoff from Chestnut Ridge is to the north, into Bear Creek and UEFPC, but most surface drainage is southward to tributaries to the Clinch River, including Walker Branch, McCoy Branch, Tributary No. 4, and Kerr Hollow Branch. In addition to surface runoff, flow in

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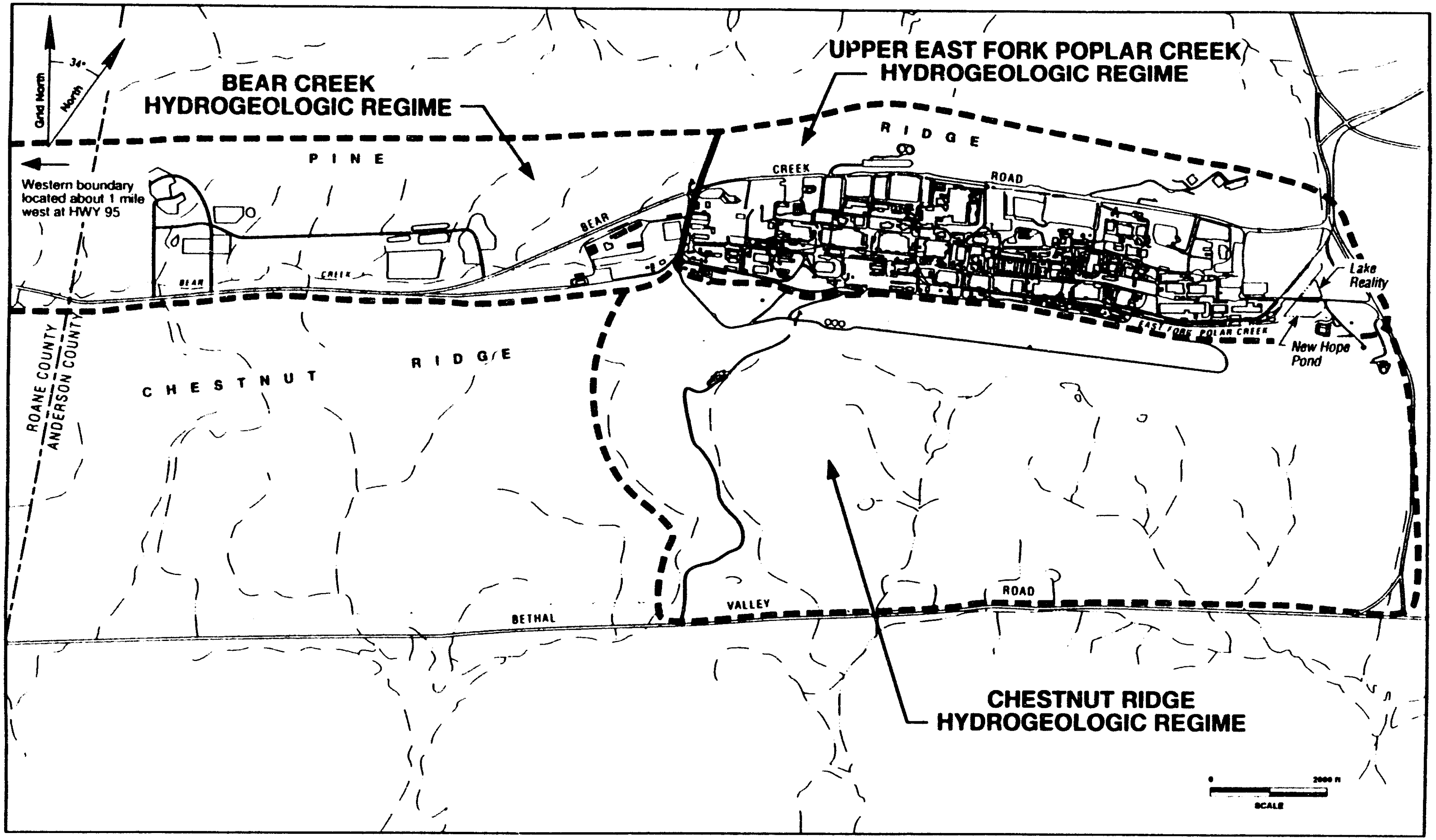

Fig. 2.2.1. Surface water system and hydrogeologic regimes at the Y-12 Plant.

these tributaries is also sustained by groundwater discharge through springs located in the stream beds. Studies show that McCoy Branch and Tributary No. 4 have both gaining and losing reaches (Evaldi 1984).

2.2.2 Y-12 Plant Geology

The geology of the Y-12 Plant area is illustrated in Fig. 2.2.2. Bear Creek Valley, in which the main plant area and most of the waste management units are located, is underlain by the shales and limestones of the Conasauga Group. Pine Ridge to the north is formed by the siltstones and shales of the Rome Formation. The Knox Group underlies Chestnut Ridge to the south, and the Chickamauga Group underlies Bethel Valley south of Chestnut Ridge.

Strike and dip of bedding in the Y-12 Plant area are generally N55E and 45SE, respectively (strike is approximately east-west on the administrative grid, and dip is approximately due south). Joints and fracture sets are common. The development of solution cavities in the Knox Group and the carbonate units of the Conasauga Group, especially the Maynardville Limestone, has been enhanced by the structural features. Solution cavities commonly occur in the upper part of the saturated zone and may be partly to completely filled with sediment.

Unconsolidated deposits of varying thickness consisting of residuum, man-made fill, alluvium, and colluvium generally overlay bedrock units throughout the Y-12 Plant area. A majority of the unconsolidated materials in this area consists of residuum, which is especially well developed on Chestnut Ridge.

2.2.3 Y-12 Plant Groundwater Flow Regimes and Effluent Monitoring

The configuration of the water table in the Y-12 Plant area (Fig. 2.2.3) suggests that groundwater flow patterns are similar to surface water drainage patterns. For the purpose of implementing a comprehensive groundwater and surface water monitoring plan to meet regulatory requirements and site characterization needs (Geraghty & Miller, Inc. 1990a), the Y-12 Plant has been subdivided into three distinct hydrogeologic regimes (Fig. 2.2.1): the Bear Creek Hydrogeologic Regime, the UEFPC Hydrogeologic Regime, and the Chestnut Ridge Hydrogeologic Regime. These subdivisions are based on topography, surface water drainage, and groundwater flow patterns.

2.2.3.1 Bear Creek Hydrogeologic Regime

The Bear Creek Hydrogeologic Regime encompasses Bear Creek Valley from the west end of the Y-12 main plant area westward to State Route (SR) 95. Surface water drainage is through Bear Creek and its tributaries. Groundwater flow in the stormflow zone, shallow aquifer (unconsolidated zone and bedrock), and deeper aquifer generally is toward Bear Creek and the underlying Maynardville Limestone karst system, which are the groundwater discharge avenues for the regime. Actual flow paths through the bedrock and Conasauga residuum may be skewed to the west due to anisotropy.

Sites within the Bear Creek Hydrogeologic Regime that could cause groundwater contamination include the S-3 Ponds, Oil Landfarm, Sanitary Landfill I, Bear Creek Burial Ground, and several other active or abandoned waste facilities and tanks (Fig. 2.2.4). There is an extensive groundwater monitoring well network to characterize the potential contamination within the regime. Primary contaminants detected include metals, radionuclides, volatile organic compounds (VOCs), nitrates in

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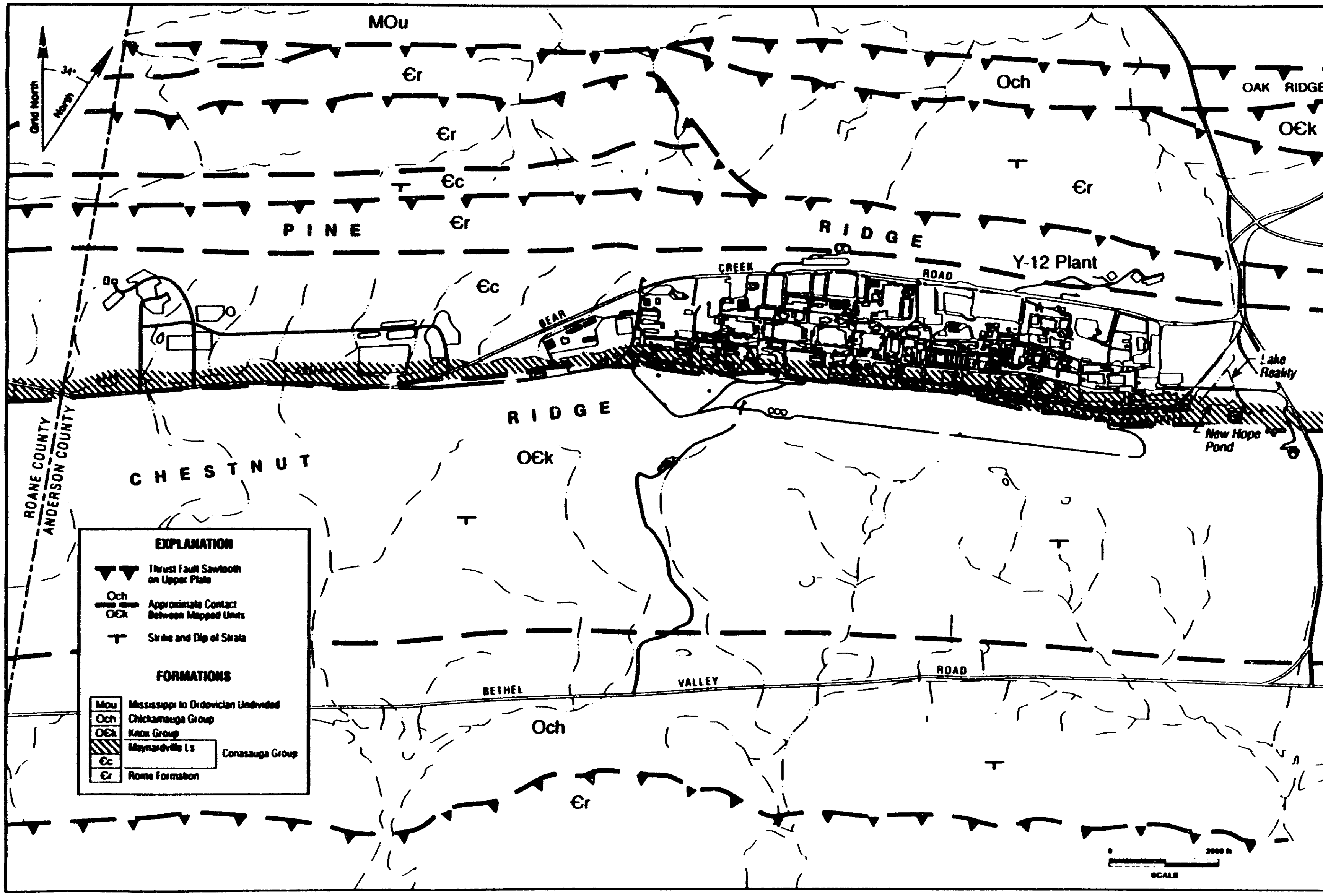
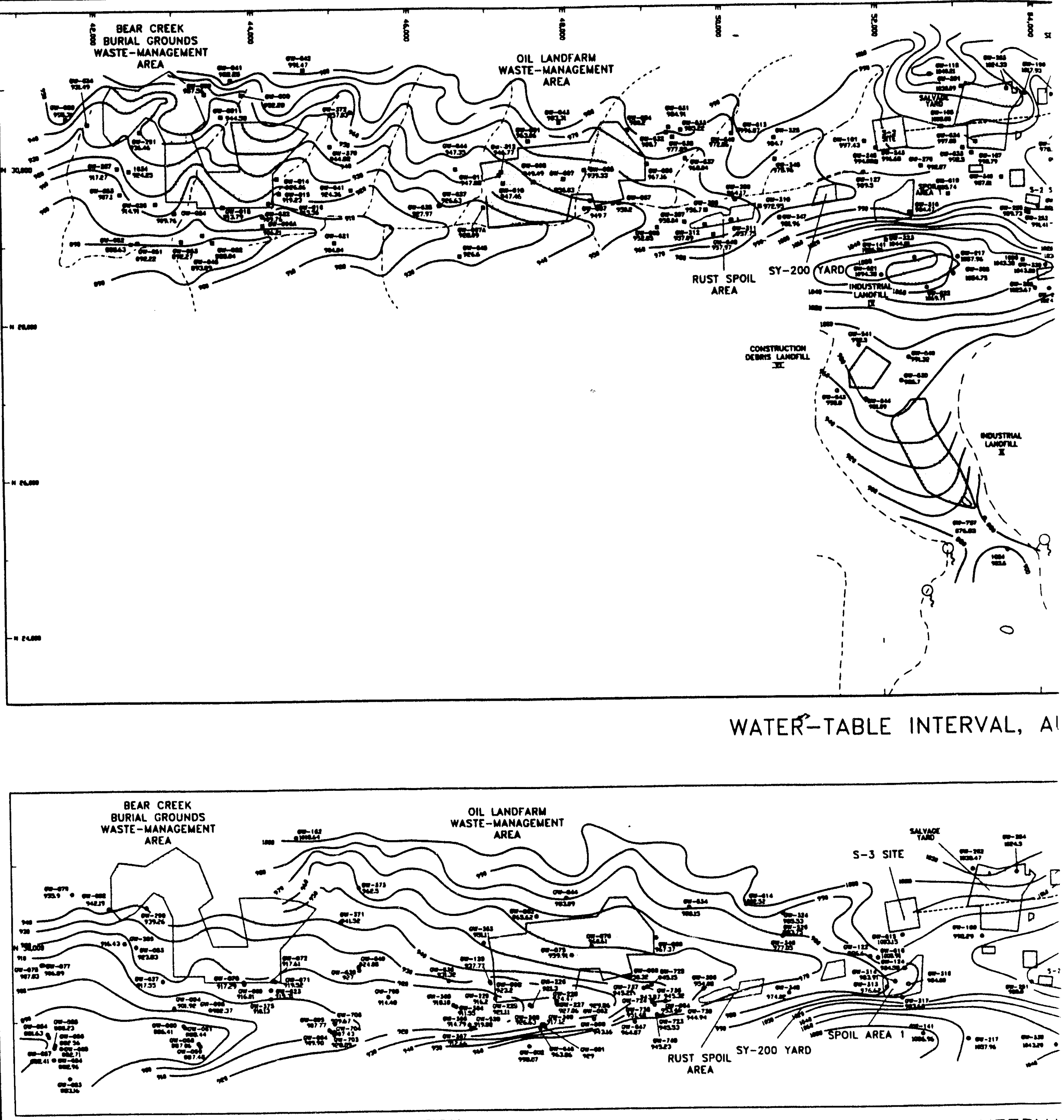


Fig. 2.2.2. Geology of the Y-12 Plant area.

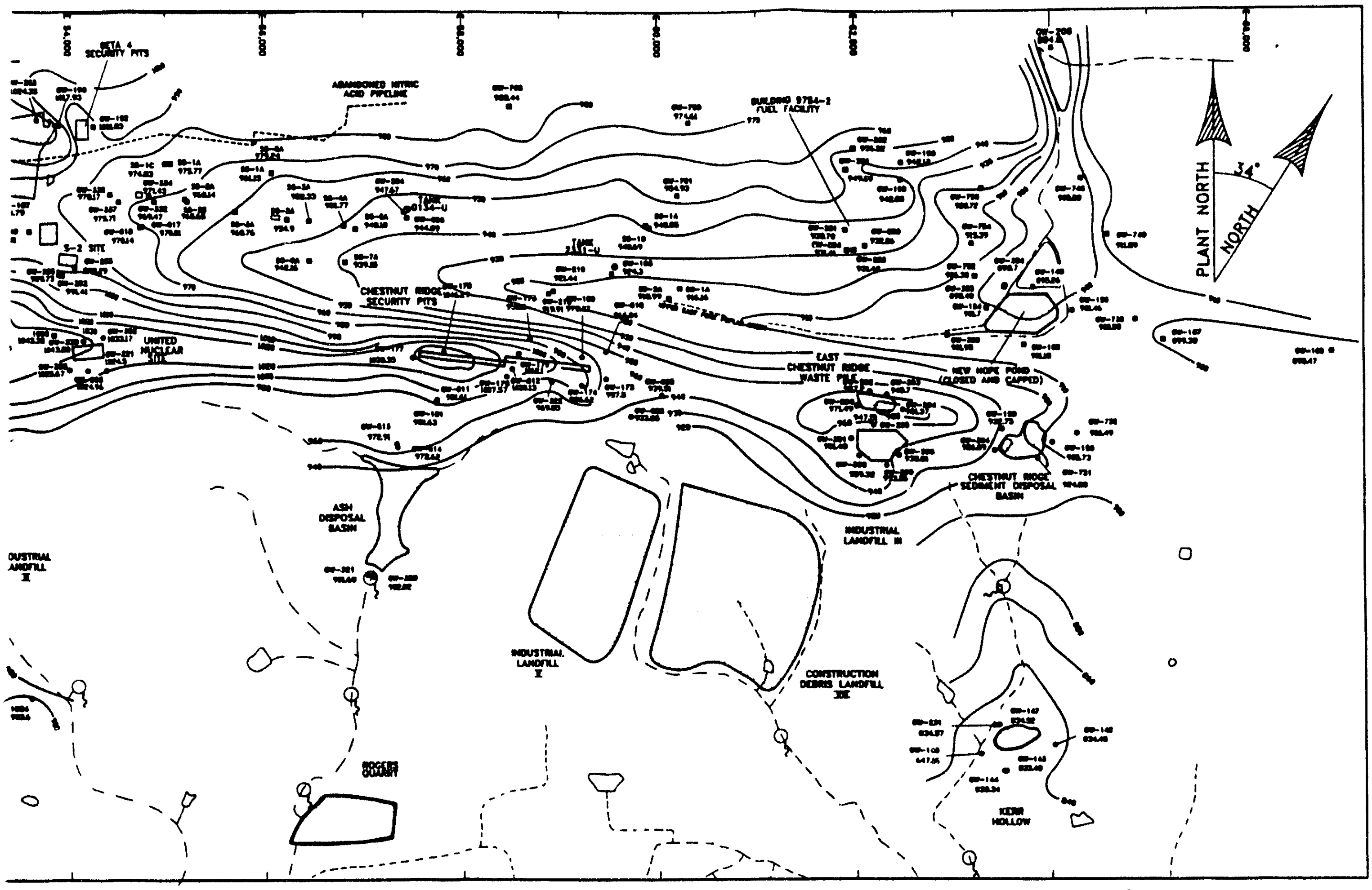


EXPLANATION

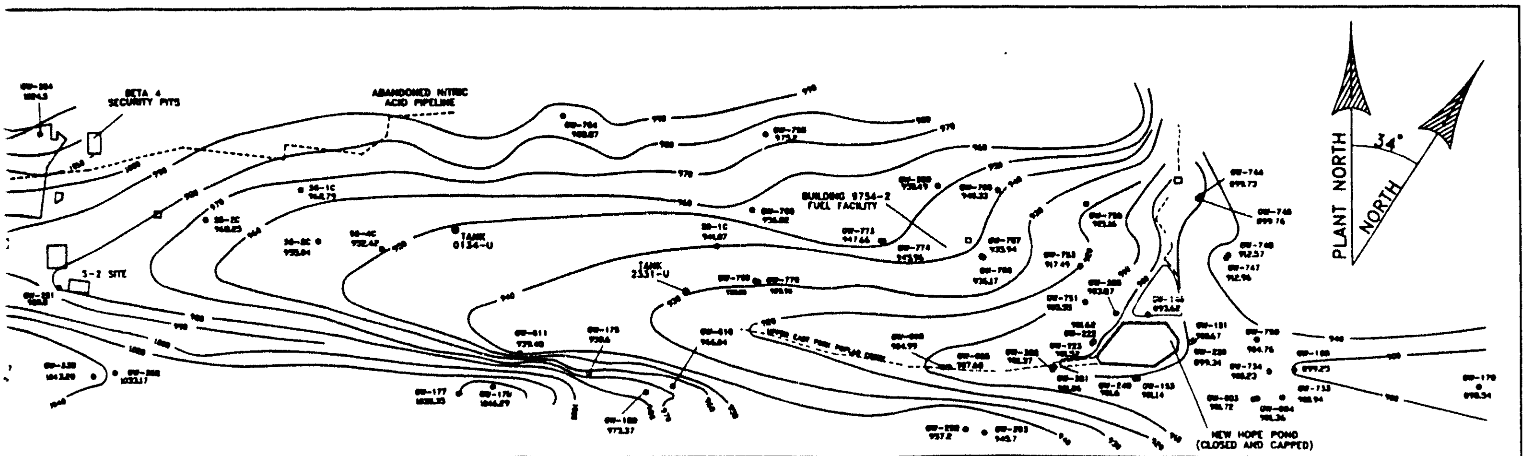
- Shallow and Bedrock Water Table Monitoring Well
- Bedrock Monitoring Well and Water-Level Elevations
- Water-Level Isopleth (ft msl)
- Surface Drainage Feature

0
SCALE (ft)

Fig. 2.2.3



AL, AUGUST-SEPTEMBER, 1993



TERVAL, AUGUST-SEPTEMBER, 1993

1000

ALE (ft)

LOCATION:	Y-12 PLANT OAK RIDGE, TN.	FIGURE 1
DATE:	5-21-94	? ?
DWG ID.:	OR392-HC	

ORNL-DWG 91M-15841

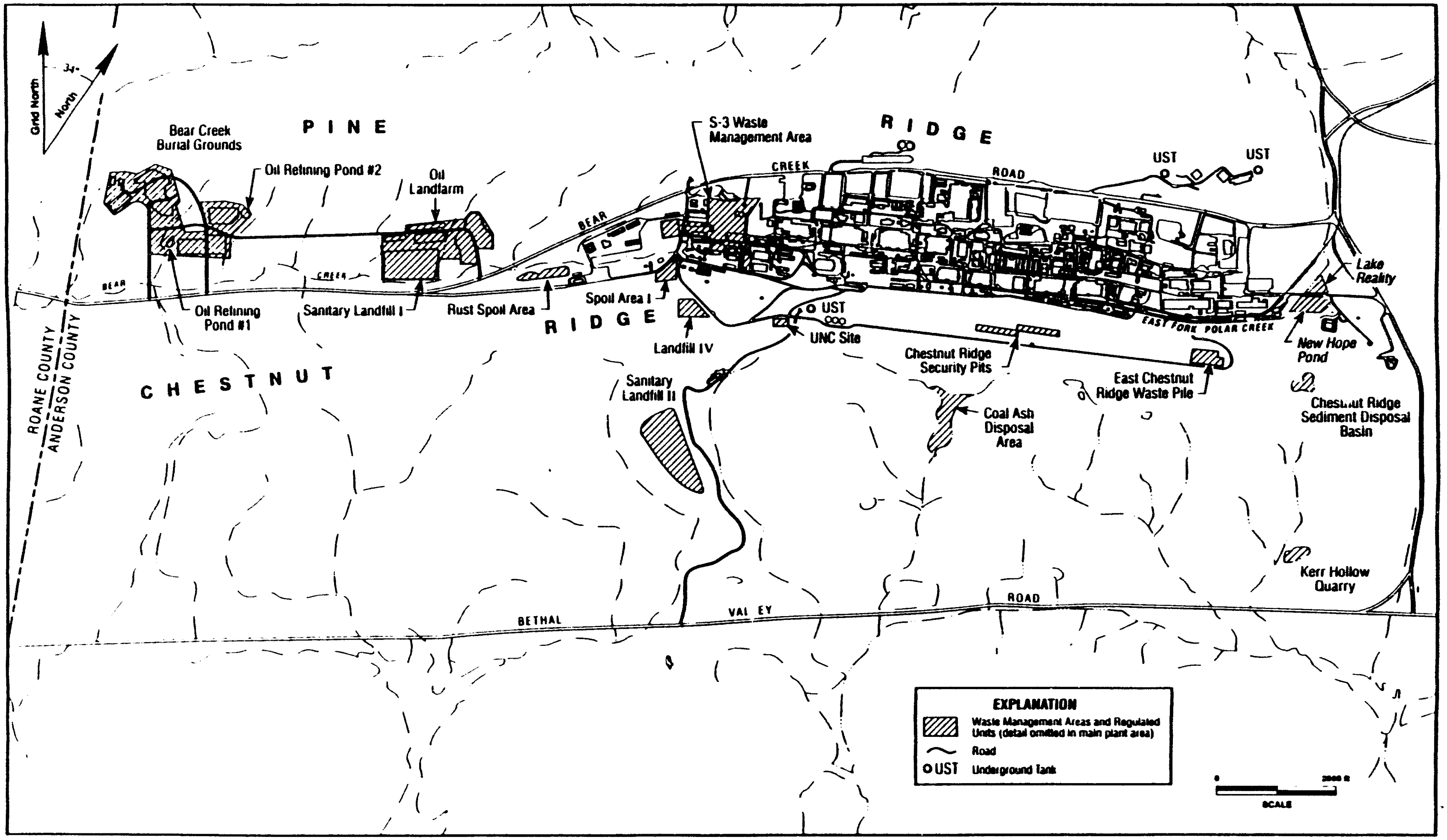


Fig. 2.2.4. Potential groundwater contamination sites at the Y-12 Plant.

the S-3 Pond area, and polychlorinated biphenyls (PCBs) in the Bear Creek Burial Ground area (HSW, Inc. 1994a). Free product solvents and PCBs have been discovered south of the Bear Creek Burial Ground at depths as great as 270 ft (Haase and King 1990).

2.2.3.2 UEFPC Hydrogeologic Regime

The UEFPC Hydrogeologic Regime encompasses the main plant area of Bear Creek Valley, from the west end of the plant eastward to Scarboro Road. Surface water drainage is through UEFPC. Groundwater flow in the stormflow zone, shallow aquifer (unconsolidated zone and bedrock), and deeper aquifer is toward UEFPC and the Maynardville Limestone karst system, which are the groundwater discharge avenues for the regime. Actual flow paths through the bedrock and Conasauga residuum may be skewed to the east due to anisotropy. Construction of the Y-12 Plant involved extensive modifications to the site topography and emplacement of man-made fill, which is composed largely of building debris and contains many voids. This fill material is generally more permeable than the surrounding residuum and provides preferential flow paths in the upper unconsolidated zone (HSW, Inc. 1994b).

There are numerous active and abandoned facilities and waste sites that could cause groundwater contamination in the UEFPC Hydrogeologic Regime (HSW, Inc. 1993). Potential contaminant sources are located throughout the main plant area and the S-3 Waste Management Area (Fig. 2.2.4). An extensive network of groundwater monitoring wells is located within the regime to characterize the potential contamination, as described in annual groundwater quality assessments for the regime (HSW, Inc. 1994b). Primary contaminants detected include nitrates, metals, radionuclides, VOCs, and petroleum products (HSW, Inc. 1994b).

2.2.3.3 Chestnut Ridge Hydrogeologic Regime

The Chestnut Ridge Hydrogeologic Regime encompasses the entire width of the ridge, from Bear Creek Valley on the north to Bethel Valley Road on the south, along a section running from Scarboro Road on the east to just west of the Centralized Sanitary Landfill II and Classified Landfill IV. South of the ridge crest, surface water drainage is through a series of small tributaries to the Clinch River. Groundwater flow in the Chestnut Ridge Hydrogeologic Regime is probably greatly affected by solution features in the carbonate bedrock and has, therefore, been investigated through dye-trace studies. An initial study (Geraghty & Miller, Inc. 1990f) indicated that conduit flow predominates and that groundwater flow in the regime not only travels to nearby springs and surface streams on the slopes of the ridge, but also has significant strike-parallel components. Following injection of fluorescein dye in a monitoring well in the vicinity of the Chestnut Ridge Security Pits near the crest of Chestnut Ridge, fluorescence was detected in springs and surface water in Bear Creek, UEFPC, the eastern tributary to Kerr Hollow Branch, and Scarboro Creek, but not in the watersheds of several other small tributary streams on the southern slope of Chestnut Ridge (Geraghty & Miller, Inc. 1990f).

To confirm the preliminary findings of the initial tracer study, a second study was initiated in March 1992 using two different dyes (Rhodamine WT and Fluorescent Brightener 28). Most of the same locations monitored during the first test also were monitored during the second test. The dyes were simultaneously injected into well GW-178, and passive monitoring was performed weekly until July 1992. Results of the second dye tracer test were inconclusive; none of the monitoring results could be characterized on a quantitative or qualitative basis as positively indicating the detection of either dye at any of the monitored locations (Science Applications International Corporation 1992).

To resolve discrepancies between the results of the two tests, a formal comparison and evaluation was conducted (Goldstrand and Haas 1994).

Goldstrand and Haase (1994) concluded that both dye-tracer tests conducted at the CRSP have not yet provided information on any hydraulic connections with the surrounding areas. If dye was indeed present at the monitoring locations, it occurred in such low concentrations that it was difficult to distinguish any possible dye fluorescence peaks from natural background fluorescence. There are several reasons that dye was not detected: inappropriate injection well, affects of the CRSP cap, abnormally low precipitation, adsorption of dye within the matrix of the aquifer, slow travel times for the dye, or deep migration of groundwater.

Several major waste disposal sites, storage tanks, and other units that could cause groundwater contamination are in the Chestnut Ridge Hydrogeologic Regime (Fig. 2.2.4). Groundwater monitoring wells to detect and characterize any contamination are in the vicinity of the individual potential contaminant sources (HSW, Inc. 1994c). Contaminant releases to groundwater have been confirmed only in the vicinity of the Chestnut Ridge Security Pits, where VOCs are the principal contaminants detected (HSW, Inc. 1994c).

2.3 HYDROGEOLOGIC SETTING OF ORNL

The main ORNL complex is in the western portion of Bethel Valley (Fig. 1.2.2). Elevation of the main complex is ~250 m (820 ft) above sea level. Bethel Valley is bounded on the north and south by Chestnut and Haw Ridges, respectively. A number of additional ORNL facilities, including most of the waste disposal areas, are located south of the main complex in Melton Valley, which is situated between Haw Ridge and Copper Ridge.

Numerous investigations of the hydrology, geology, and hydrogeology of ORNL have been conducted. Findings of these investigations have been summarized by Energy Systems (1989a) and McMaster (1990). The discussions in the remainder of Sect. 2.3 are based on these two references, except where noted otherwise.

2.3.1 ORNL Surface Water System

Most of the ORNL complex and associated waste management facilities are within the 16.8 km^2 (6.5 mile^2) WOC drainage basin (Fig. 2.1.1). The headwaters of WOC are on the southern flank of Chestnut Ridge. Flow is southward off the ridge, then east in Bethel Valley through the ORNL main complex. Near the west end of the complex the creek turns south and flows through a water gap in Haw Ridge into Melton Valley, where it is joined by its largest tributary, Melton Branch. WOC then flows westward into White Oak Lake (WOL), a man-made impoundment built in 1943 to form a holding basin for ORNL waste effluent (Sherwood and Loar 1987). After discharge through White Oak Dam at SR 95, WOC flows west 1 km (0.6 miles) to its confluence with the Clinch River at a point 3.7 km (2.3 miles) downstream of the Melton Hill Dam.

In addition to natural drainage, the WOC watershed has received treated and untreated effluents from ORNL activities since 1943. Controlled releases include those from the Process Waste Treatment Plant, the Sewage Treatment Plant, and various process waste holding ponds located throughout the ORNL complex. WOC also receives effluent from non-point sources, such as the SWSAs and low-level waste pits and trenches located primarily in Melton Valley (see Sect. 2.3.4), through both surface and groundwater flow. Sediments within the watershed have sorbed the released chemical and radioactive contaminants and have subsequently accumulated in the floodplain and lake bed areas. Under high-flow conditions these sediments can be carried over White Oak Dam and thus become a source of contaminant discharge to the Clinch River (Sherwood and Loar 1987).

2.3.2 ORNL Geology

The geology of the ORNL area is illustrated in Fig. 2.3.1. Bethel Valley, in which the main ORNL complex is located, is underlain by limestones of the Chickamauga Group. The Knox Group underlies Chestnut Ridge to the north of Bethel Valley, and Haw Ridge to the south is formed by the sandstones, siltstones, and shales of the Rome Formation. The Copper Creek Fault forms the contact between the Chickamauga Group of Bethel Valley and the Rome Formation of Haw Ridge. Melton Valley, in which most of the ORNL waste areas are located, is underlain by the shales and limestones of the Conasauga Group. Further to the south, the Knox Group underlies Copper Ridge.

Strike and dip of bedding in the ORNL area are generally N55E and 30° to 40° SE, respectively (strike is approximately east-west on the administrative grid, and dip is approximately due south). Joints and fracture sets are common, as previously described. The development of solution cavities in the Knox Group and the carbonate units of the Conasauga Group, especially the Maynardville Limestone, has been enhanced by the structural features. Solution cavities are common in the upper part of the saturated zone and may be partly to completely filled with detritus and sediment.

Bedrock units throughout the ORNL area generally are overlain by unconsolidated deposits of varying thickness consisting of residuum, man-made fill, alluvium, and colluvium. Residuum comprises a majority of the unconsolidated materials in this area and is especially well developed on Chestnut Ridge.

2.3.3 Groundwater Flow Systems and Effluent Monitoring at ORNL

Groundwater flow in the ORNL area generally follows the topography, with water flowing from recharge areas on ridges to discharge areas at streams in valley bottoms. Thus groundwater flow is toward WOC in much of Bethel Valley, toward Melton Branch or WOC and WOL in Melton Valley, and toward the Clinch River or its embayments and minor tributaries in other parts of the ORNL area.

Groundwater effluent monitoring at ORNL is focused primarily on investigating and characterizing sites for remediation under RCRA 3004(u) and CERCLA. Because of the large number and close association of individual waste sites and their areal distribution, the individual waste management units have been clustered for purposes of analysis into 20 waste area groupings (WAGs), as shown in Fig. 2.3.2 and Table 2.3.1. Most of the WAGs are hydrologically definable areas, such as small watersheds, that contain several adjacent potential sources of contamination from radioactive and/or hazardous materials.

A screening process was used to evaluate the potential for releases of contamination at each of the WAGs. This process resulted in the recommendation that 12 WAGs undergo remedial investigations that include groundwater investigations (Table 2.3.1). One of these, WAG 6, is considered to be in RCRA interim status assessment monitoring as well as under remedial investigation because the WAG includes SWSA 6, which is classified as a RCRA interim status unit (Energy Systems 1989a).

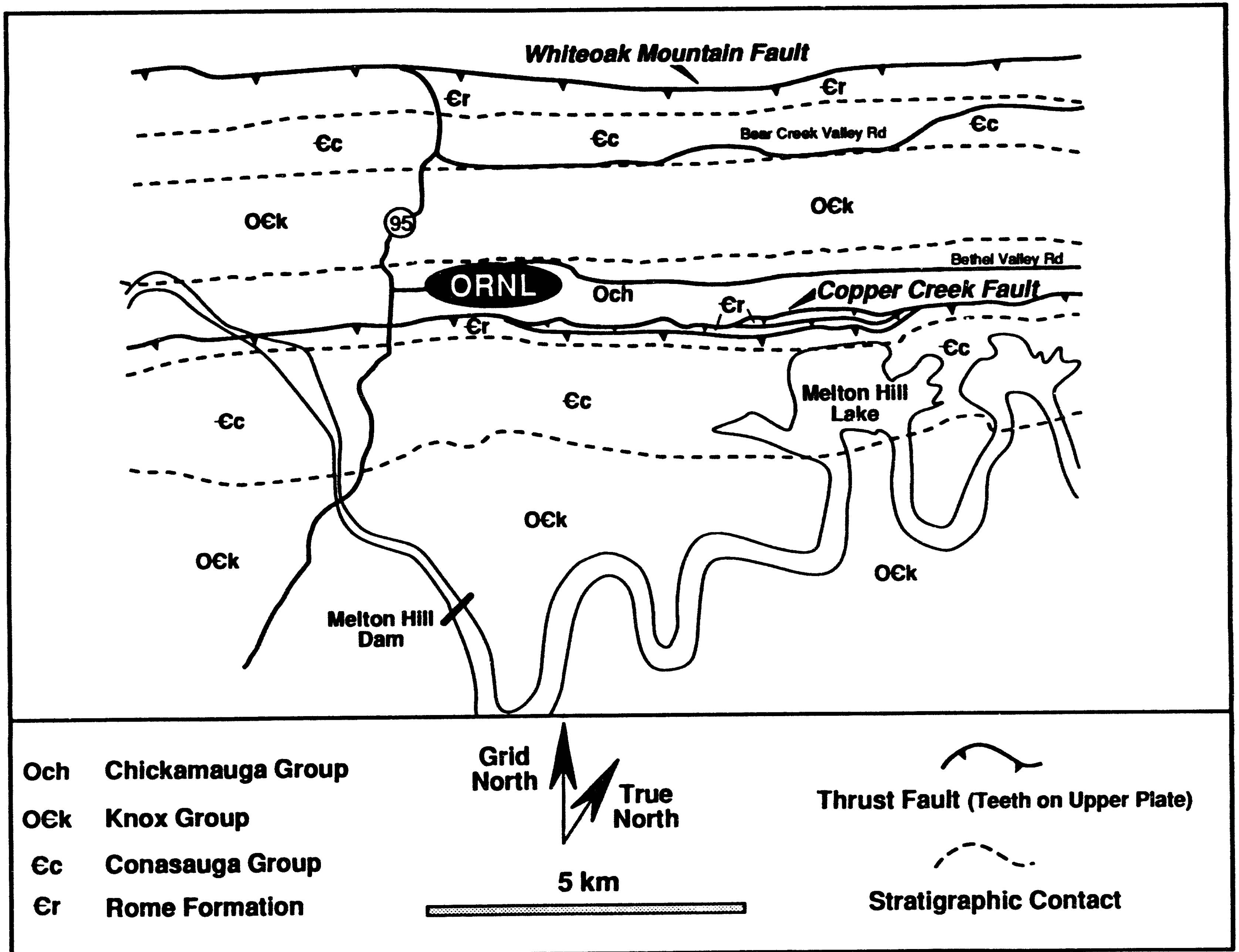


Fig. 2.3.1. Geology of the ORNL area

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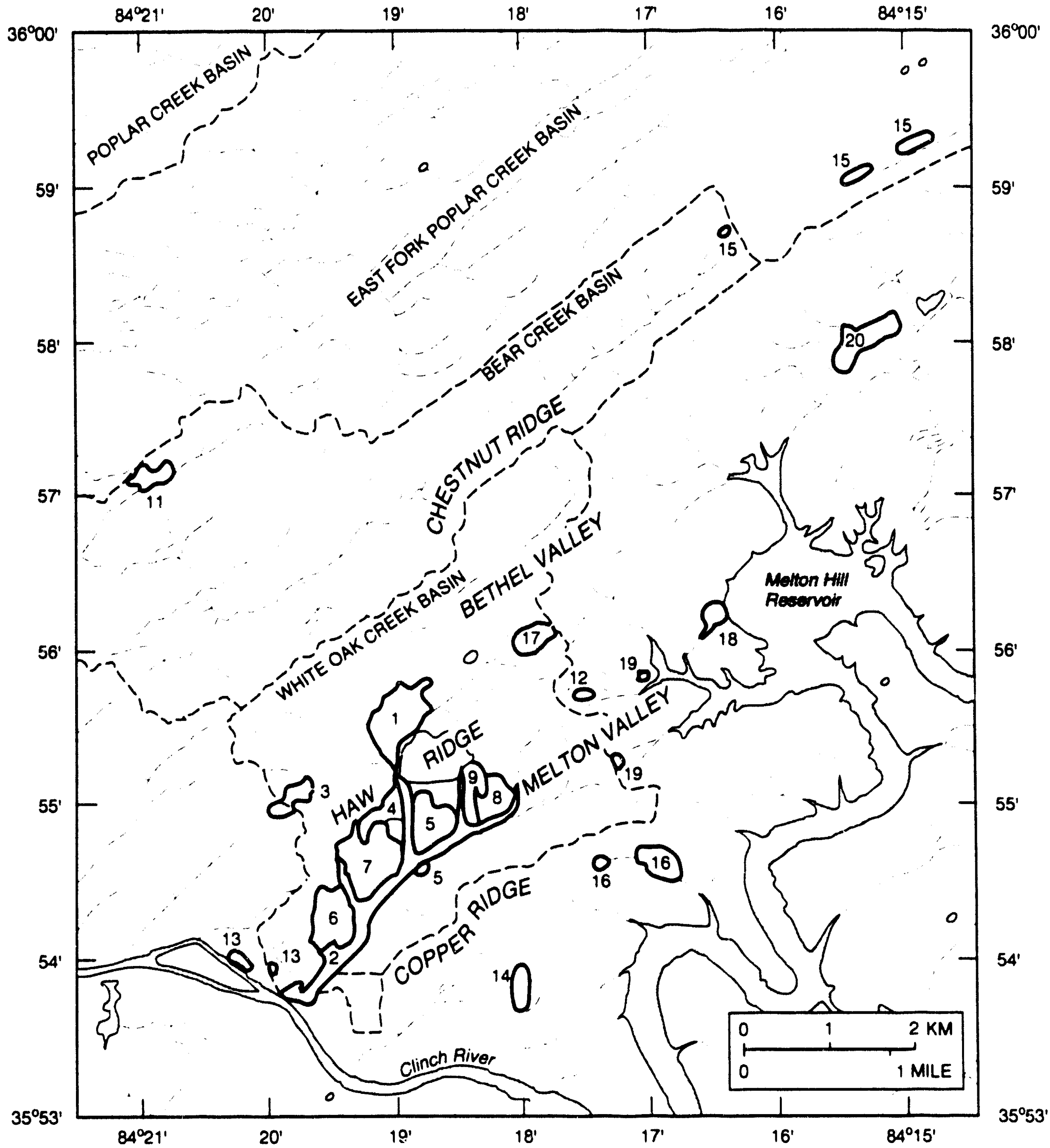

Fig. 2.3.2. Waste area groupings (WAGs) at Oak Ridge National Laboratory.

Table 2.3.1. Summary of information on waste area groupings at Oak Ridge National Laboratory

WAG number	Description	Number of sites	Require investigation?
1	Main plant area	99	Yes
2	White Oak Creek/White Oak Lake	2	Yes
3	SWSA[a] 3	3	Yes
4	SWSA 4	3	Yes
5	SWSA 5	25	Yes
6	SWSA 6	3	Yes
7	Low level waste pits and trenches area	15	Yes
8	Melton Valley area	20	Yes
9	Homogeneous reactor experiment (HRE) area	6	Yes
10	Hydrofracture injection wells and grout sheets	4[b]	Yes
11	White Wing scrapyard	1	Yes
12	Closed contractors' landfill	1	No
13	Environmental research areas	2	No
14	Tower Shielding Facility	2	No
15	ORNL facilities at Y-12 Plant	5	No
16	Health Physics Research Reactor area	5	No
17	ORNL services area	10	Yes
18	Consolidated fuel reprocessing area	9	No
19	Hazardous waste treatment and storage facility	7	No
20	Oak Ridge land farm	1	No
	Total	223	
	Additional sites		
	Surplus-contaminated failities[c]	29	

[a]SWSA = Solid waste storage area.
[b]Principal sites located underground beneath WAG 5.
[c]Not applicable.

The strategy being followed at 11 of the 12 WAGs under remedial investigation is to install and sample a series of groundwater quality monitoring wells at the perimeter of each WAG. (WAG 10, the hydrofracture injection wells and grout sheets, requires a modified investigation approach because of the depth and character of contamination.) Both upgradient and downgradient wells are included at the WAG perimeter. Results from the WAG perimeter monitoring help to guide subsequent well placement and other follow-on investigations.

Groundwater quality monitoring results for WAGs 1 and 6 indicate contamination by radionuclides and VOCs. WAG 1 results also exhibit metals contamination (Energy Systems 1990).

2.4 HYDROGEOLOGIC SETTING OF THE K-25 SITE

The K-25 Site is at the northwestern end of the ORR (Fig. 1.2.2). Elevation of the main plant area is ~238 m (780 ft) above sea level. The K-25 Site is bounded by Blackoak Ridge to the north, Pine Ridge to the south, McKinney Ridge to the east, and the Clinch River to the west.

A number of investigations of the hydrology, geology, and hydrogeology of the K-25 Site have been conducted. These are summarized by Geraghty & Miller (1989a) and Forstrom (1990b). The discussions in the remainder of Sect. 2.4 are derived primarily from these two references, except where noted otherwise.

2.4.1 K-25 Surface Water System

The K-25 Site lies near the confluence of Poplar Creek and the Clinch River (Fig. 2.4.1), at the mouth of the Poplar Creek drainage basin. Most of the K-25 Site drains directly to Poplar Creek or the Clinch River through numerous very small ephemeral drainages. The three major exceptions to this are as follows: (1) the northeast portion of the plant where surface runoff, storm drain flow, and discharged process water flow through Mitchell Branch to Poplar Creek; (2) some areas of the southern portion of the plant where storm drain flow, some surface runoff, and (in the past) process water are directed to the K-1007-B holding pond before discharge to Poplar Creek; and (3) a small area of the northwest portion of the plant where surface water runoff and (in the past) cooling tower blowdown have been directed to the K-901-A holding pond before discharge to the Clinch River. In addition to these drainages, the K-25 Site has a number of permitted point-source discharges to Poplar Creek and the Clinch River.

2.4.2 K-25 Geology

The most recent interpretation of the geology of the K-25 area is illustrated in Fig. 2.4.2. Considerable uncertainty exists concerning the geology of this area. The least uncertain aspects of the geology are that most of the main plant area is underlain by limestones of the Chickamauga Group; the dolomites of the Knox Group underlie Blackoak Ridge to the north and McKinney Ridge to the east; the sandstones, siltstones, and shales of the Rome Formation underlie Pine Ridge to the south; and the WOM thrust fault forms the contact between the Chickamauga and Rome Formations along the southern boundary of the site. Considerable uncertainty exists concerning the precise location and attitude of the splay fault that emanates from the WOM Fault and cuts across the eastern part of the site, the actual sequence of rock units within this splay fault block (especially the presence or absence of the Conasauga Group), and the attitude (strike and dip) of the units within this splay fault block. Unfortunately, the zone of geologic uncertainty is also the area of the K-25 Site that has the greatest density of potential contamination sources and some of the highest levels of groundwater contamination observed at the plant (see Sect. 2.4.4).

Strike and dip of bedding outside the splay fault block generally corresponds to that of the ORR area; N55°E and 45° to 60° SE, respectively (strike is approximately east-west on the administrative grid, and dip is approximately due south). Joints and fracture sets are common, as previously described. The development of solution-enlarged fractures in the Chickamauga Group may be particularly important to the groundwater flow system at K-25. These features are numerous but not necessarily cavernous.

Bedrock units throughout the K-25 area generally are overlain by unconsolidated deposits of varying thickness consisting of man-made fill, residuum, alluvium, and colluvium. Man-made fill

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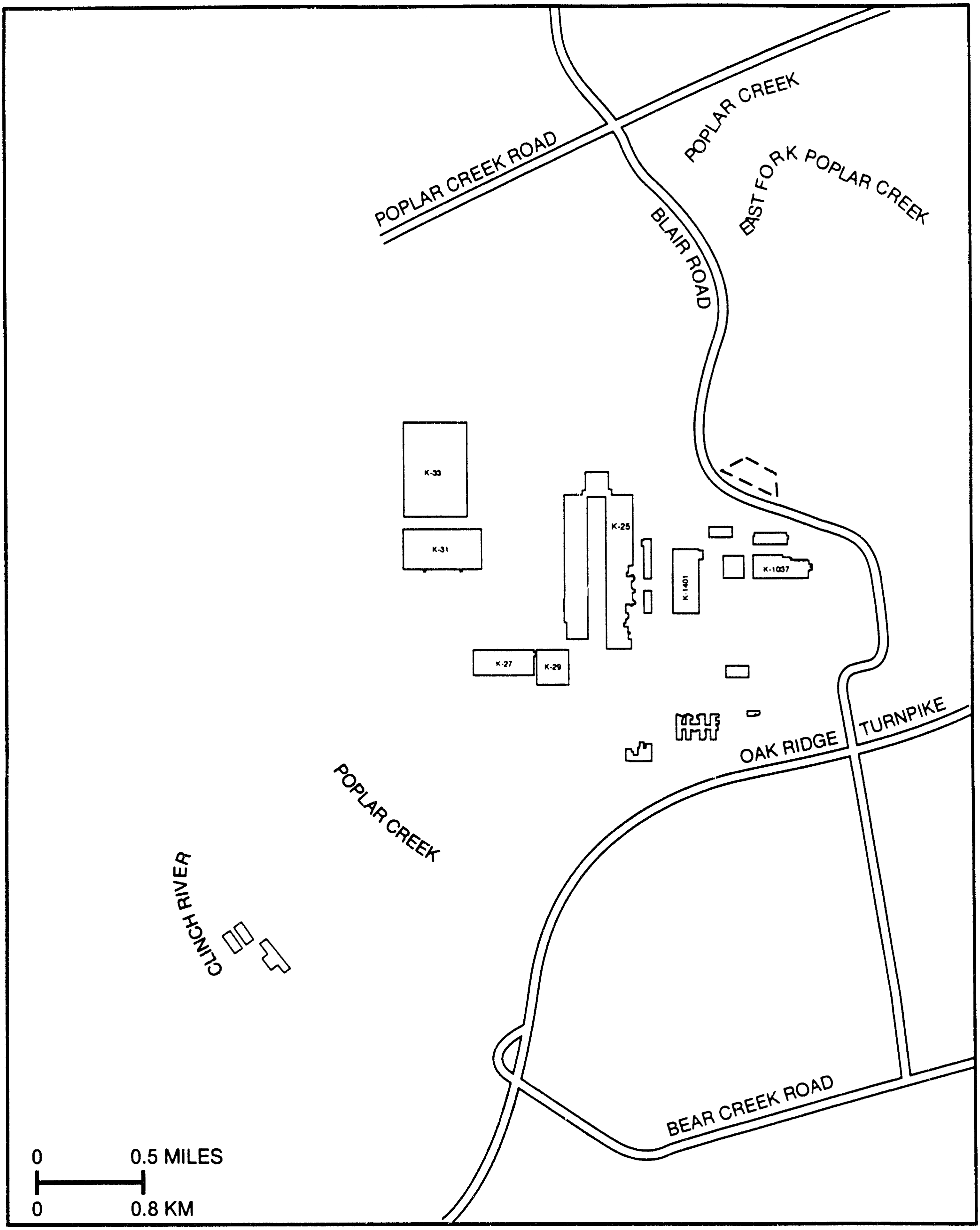

Fig. 2.4.1. Surface water system at the K-25 Site.

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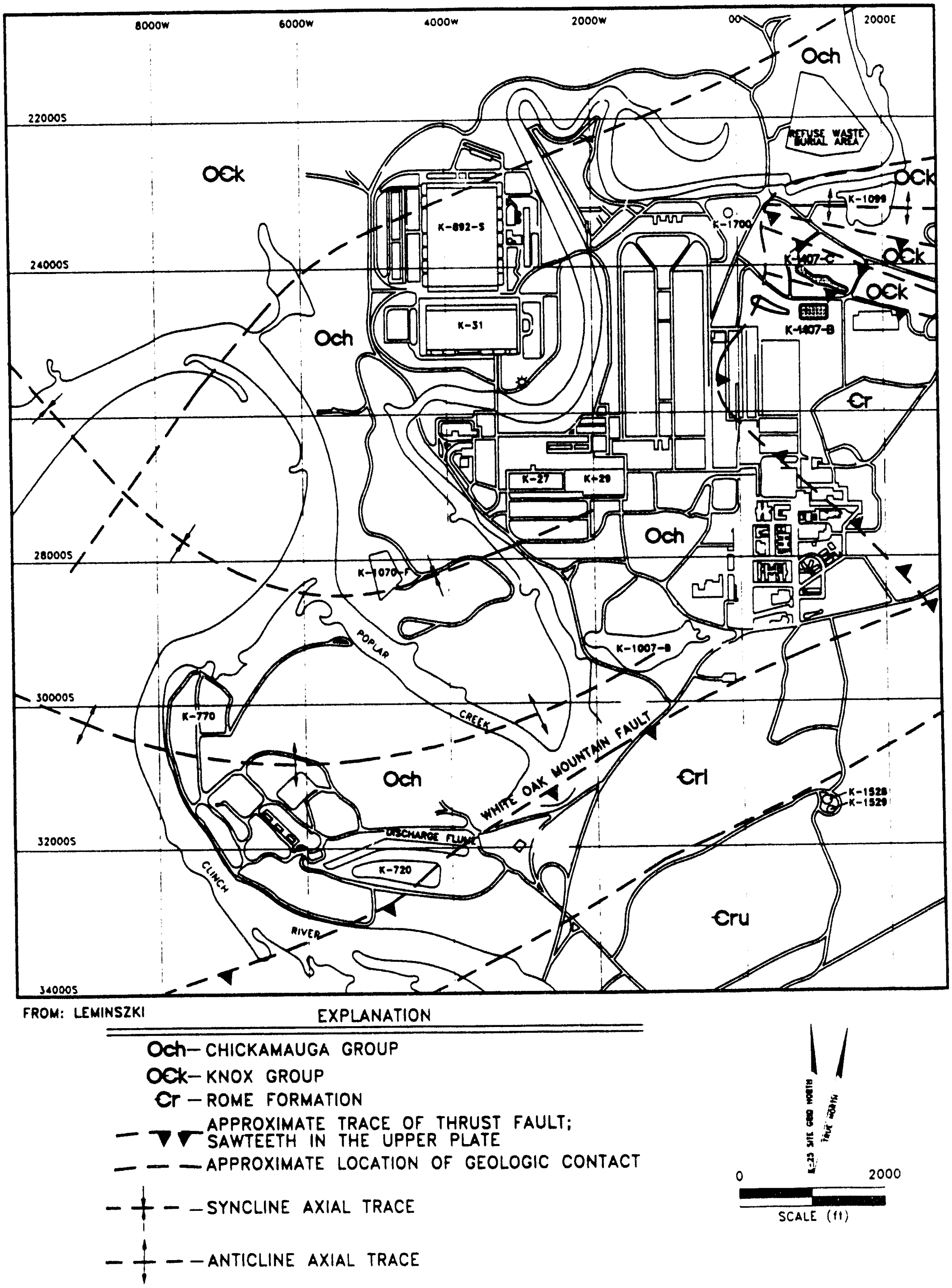

Fig. 2.4.2. Geology of the K-25 Site.

comprises a majority of the unconsolidated materials in the main plant area, as the site underwent extensive cut-and-fill leveling during plant construction. The depth of fill may exceed 9 m (30 ft) in areas of the plant that are underlain by preconstruction surface water drainages (Ketelle 1989). The effect of this extensive fill material on groundwater flow and contaminant transport through the unconsolidated zone of the shallow aquifer at K-25 has not been determined. Alluvium constitutes a significant portion of the unconsolidated materials in low-lying areas along the Clinch River and Poplar Creek.

2.4.3 K-25 Groundwater Flow Systems and Effluent Monitoring

Groundwater flow at K-25 generally follows the patterns previously discussed for the reservation. As illustrated in Figs. 2.4.3 and 2.4.4, both the unconsolidated zone water table and the bedrock piezometric surface at K-25 generally follow a subdued replica of the present plant topography. The water table in the unconsolidated zone is significantly influenced by preconstruction surface topography (Forstrom 1990c). Groundwater flow generally is toward Mitchell Branch, Poplar Creek, and the Clinch River. Actual flow paths in both the shallow and deeper bedrock may not be perpendicular to water table or piezometric contours but may be skewed along strike (east-west outside the splay fault block) due to the anisotropy of the system.

Downward hydraulic gradients in some unconsolidated deposits document groundwater flow into the carbonate aquifer underlying much of the K-25 Site area. Analysis of water levels in K-25 carbonate wells reveals markedly disparate levels between nearby wells, since many fractures encountered in boreholes are poorly interconnected within the aquifer. Thirty-four percent of all carbonate borings at the K-25 Site encountered cavities, revealing the presence of an extensive karst conduit network. Cavities depicted on foundation boring logs also document a well-developed carbonate aquifer at the K-25 Site. A systematic approach to defining the hydrogeology of unconsolidated, non-carbonate, and carbonate K-25 aquifers has been put forth (Poling et al. 1992) and is in the preliminary stage of implementation.

Groundwater effluent monitoring at K-25 focuses primarily on investigating and characterizing sites for remediation under Resource Conservation and Recovery Act and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In the past, all activities under CERCLA investigations were conducted for individual Solid Waste Management Units (SWMUs) or groupings of SWMUs. As a result of the Federal Facilities Agreement (FFA), the principal regulatory driver at K-25 Site is CERCLA. In accordance with the FFA, the potentially contaminated units were grouped into Operable Units (OUs). A groundwater OU was designated as encompassing those areas in and around the K-25 Site, including existing OUs, that may contain unknown waste sites or groundwater contaminant plumes (Fig. 2.4.5).

Presently, 222 groundwater quality monitoring wells exist at K-25. One-hundred and ninety-one of these wells have been sampled for an extended list of baseline monitoring parameters (Forstrom 1990d). The remaining wells will be scheduled for baseline monitoring. Results indicate widespread groundwater contamination by VOCs, especially trichloroethylene (TCE), along with more localized contamination by metals, radionuclides, petroleum products, and PCBs (Geraghty & Miller 1989b). The K-1407 OU, which is located almost entirely within a splay fault block (Fig. 2.4.2), exhibits particularly elevated levels of many contaminants.

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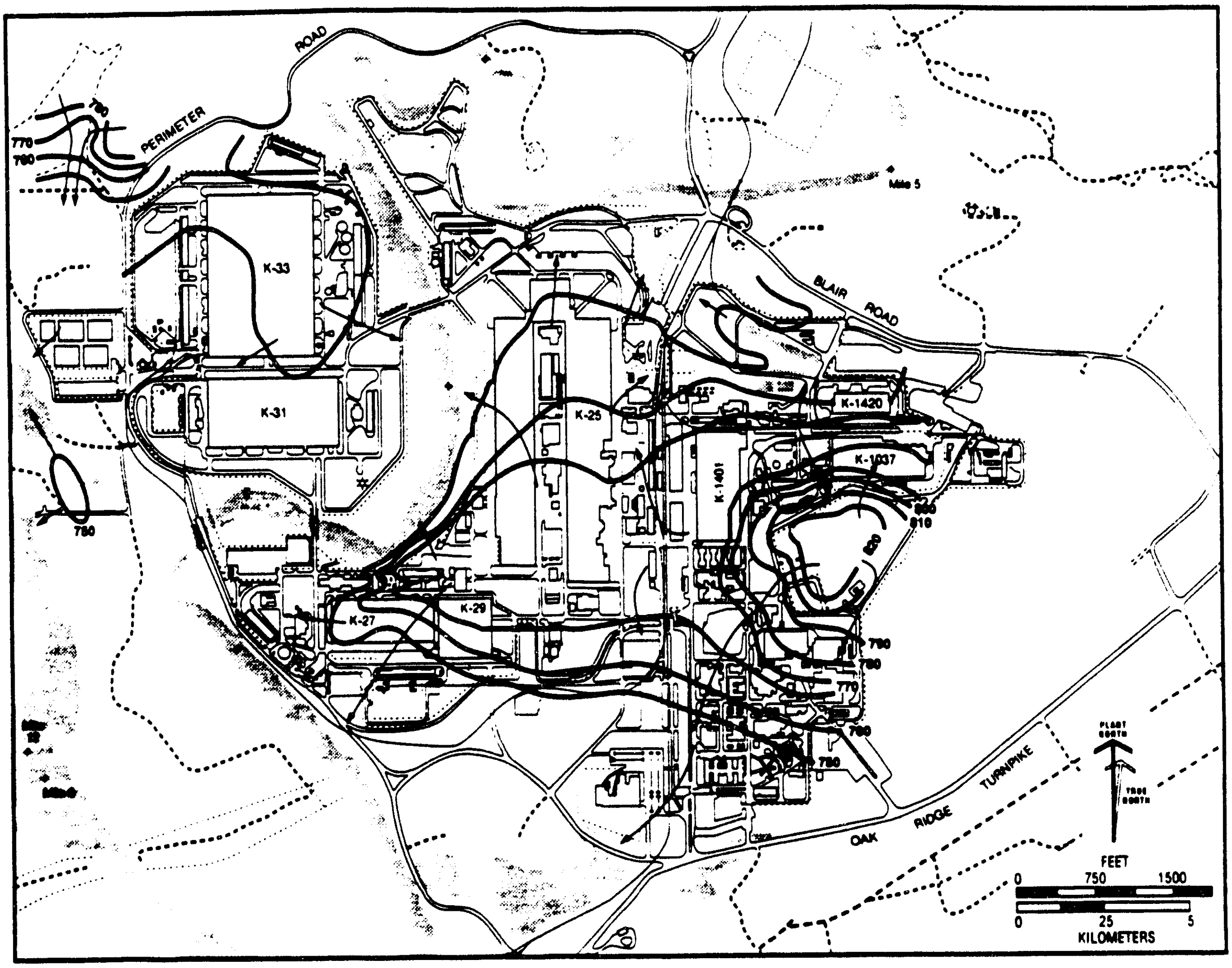

LEGEND

WATER TABLE CONTOUR (ft, msl)

GROUNDWATER FLOW LINE

SURFACE WATER, TRIBUTARIES, AND PONDS

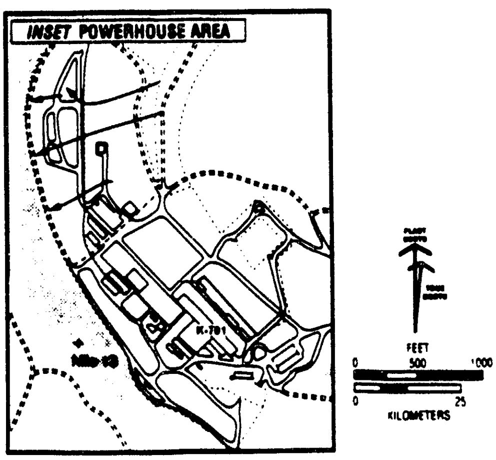

Fig. 2.4.3. Contours of the water table and inferred groundwater flow paths in the unconsolidated zone at the K-25 Site.

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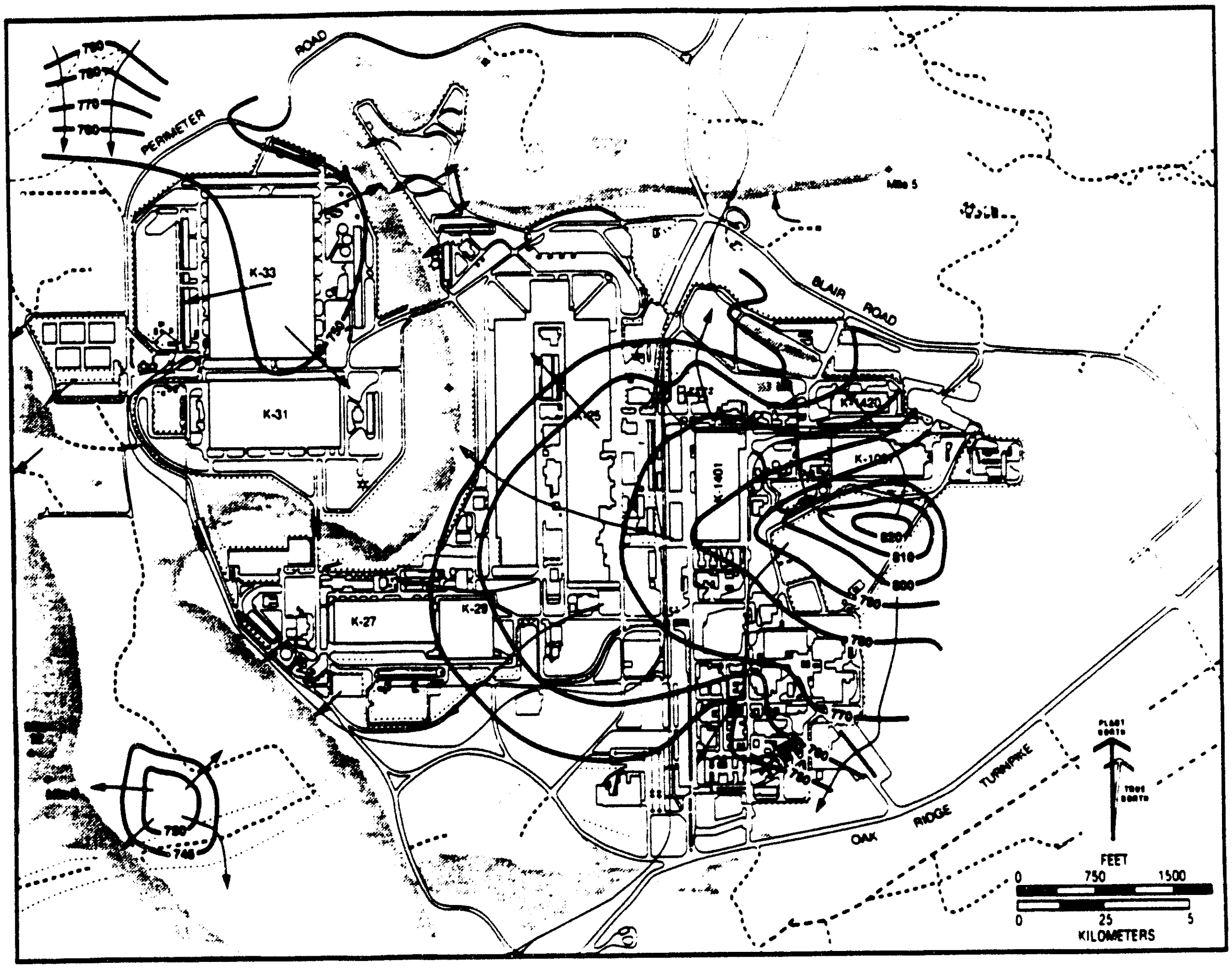

LEGEND

WATER TABLE CONTOUR (ft, msl)

GROUNDWATER FLOW LINE

SURFACE WATER, TRIBUTARIES, AND PONDS

Fig. 2.4.4. Contours of the potentiometric surface and inferred groundwater flow paths in the bedrock at the K-25 Site.

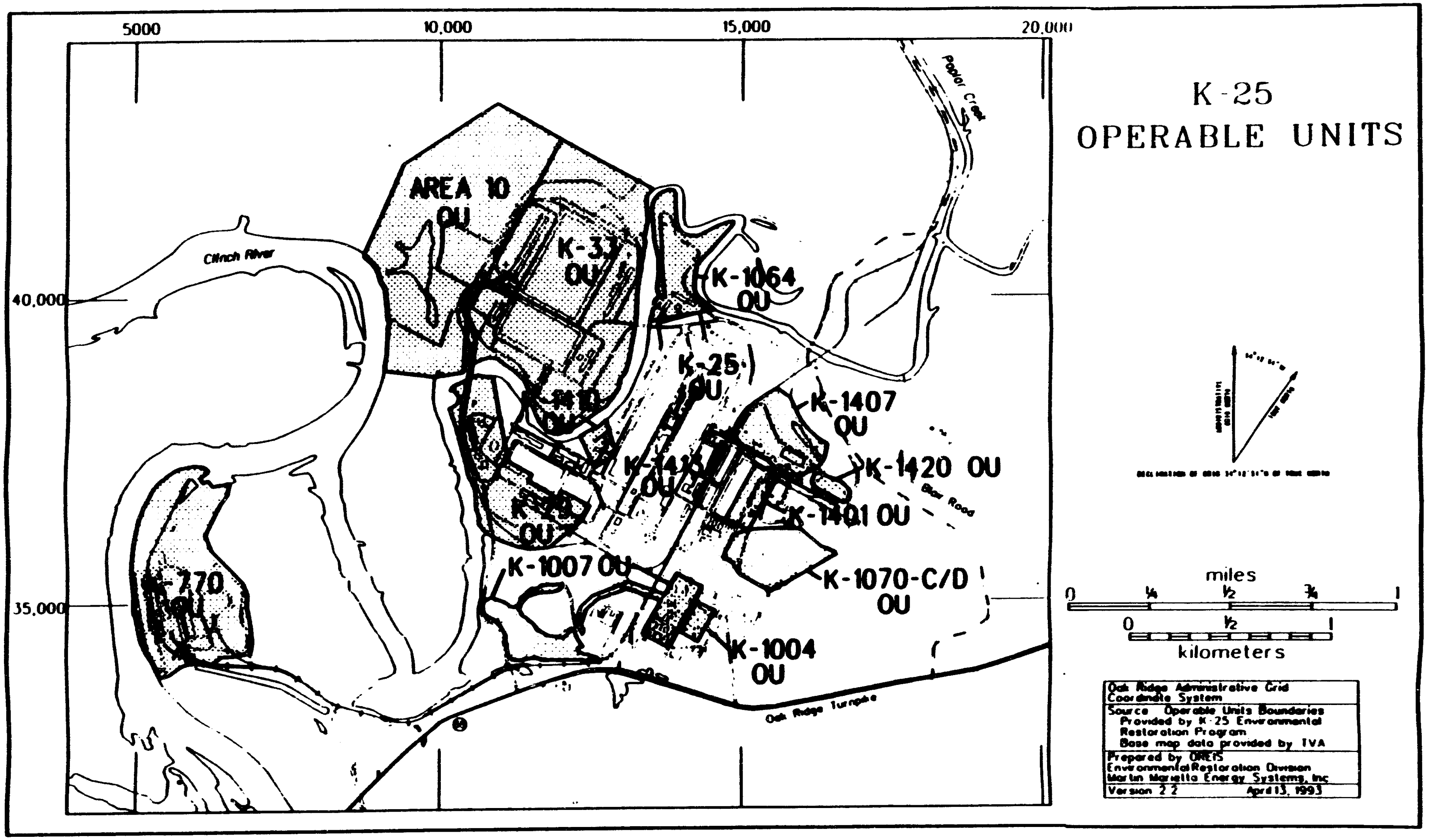

Fig. 2.4.5. Waste Area Groupings (WAGs) at the K-25 Site.

3. PLANT PERIMETER SURVEILLANCE

The Energy Systems Groundwater Surveillance Strategy (Forstrom 1990a) states that plant perimeter groundwater surveillance locations should be selected on the basis of exit pathways. Because most exit pathways are closely associated with surface waters that may receive groundwater discharge, groundwater surveillance is coordinated with surveillance of nearby surface water locations. This section identifies the exit pathways for each of the major facilities on the ORR, designates existing and proposed wells to be included in the perimeter groundwater surveillance network, and identifies surface water surveillance locations that complement perimeter groundwater surveillance.

The Groundwater Surveillance Strategy states that perimeter surveillance parameters will be selected from lists of potential plant groundwater contaminants determined from a review of groundwater data and other records. The strategy suggests that it may be possible to limit perimeter surveillance to a list of key indicator contaminants; i.e., those facility contaminants that, due to their mobility in the hydrogeologic environment and proximity of sources to surveillance locations, would be expected to reach the plant perimeter first and thus serve as indicators of groundwater contamination. This section identifies the parameters for perimeter groundwater surveillance at each plant on the ORR and presents the rationale for their selection.

The strategy also states that perimeter surveillance frequency should be determined on the basis of consideration of rates of contaminant migration in groundwater and vulnerability of potential off-site receptors. This section discusses rates of contaminant migration, identifies potential off-site receptors, and presents the rationale for plant perimeter surveillance sampling frequency for each of the facilities on the ORR.

3.1 Y-12 PLANT

3.1.1 Perimeter Groundwater Surveillance Locations

3.1.1.1 Identification of Exit Pathways

The comprehensive groundwater monitoring plan for the Y-12 Plant identified exit pathways in all three hydrogeologic regimes for the purpose of effluent monitoring (Geraghty & Miller, Inc. 1990a). These same pathways will be monitored for surveillance purposes but only at perimeter locations. The geologic unit identified as requiring the greatest attention in effluent monitoring due to the potential for off-site migration of contaminants from the Y-12 Plant is the Maynardville Limestone. Various studies evaluating exit pathways are ongoing. The Annual Environmental Report for the ORR (DOE 1993) contains a discussion of ongoing programs. The adequacy of the current surveillance network will be reviewed and the network modified accordingly based on data and results of these studies.

The perimeter surveillance exit pathways identified for the Y-12 Plant are illustrated in Fig. 3.1.1. In the Bear Creek Hydrogeologic Regime, groundwater would exit the west end of the valley at SR 95 in one of three ways: (1) as discharge to Bear Creek; (2) as shallow downvalley groundwater flow parallel to the creek; or (3) as flow through the Maynardville Limestone toward western Bear Creek Valley, bypassing Bear Creek. In the UEFPC Hydrogeologic Regime, groundwater would exit the east end of the valley either (1) as discharge to UEFPC; (2) as shallow (and possibly deep) groundwater flow parallel to the creek where it flows through the Pine Ridge water gap; or

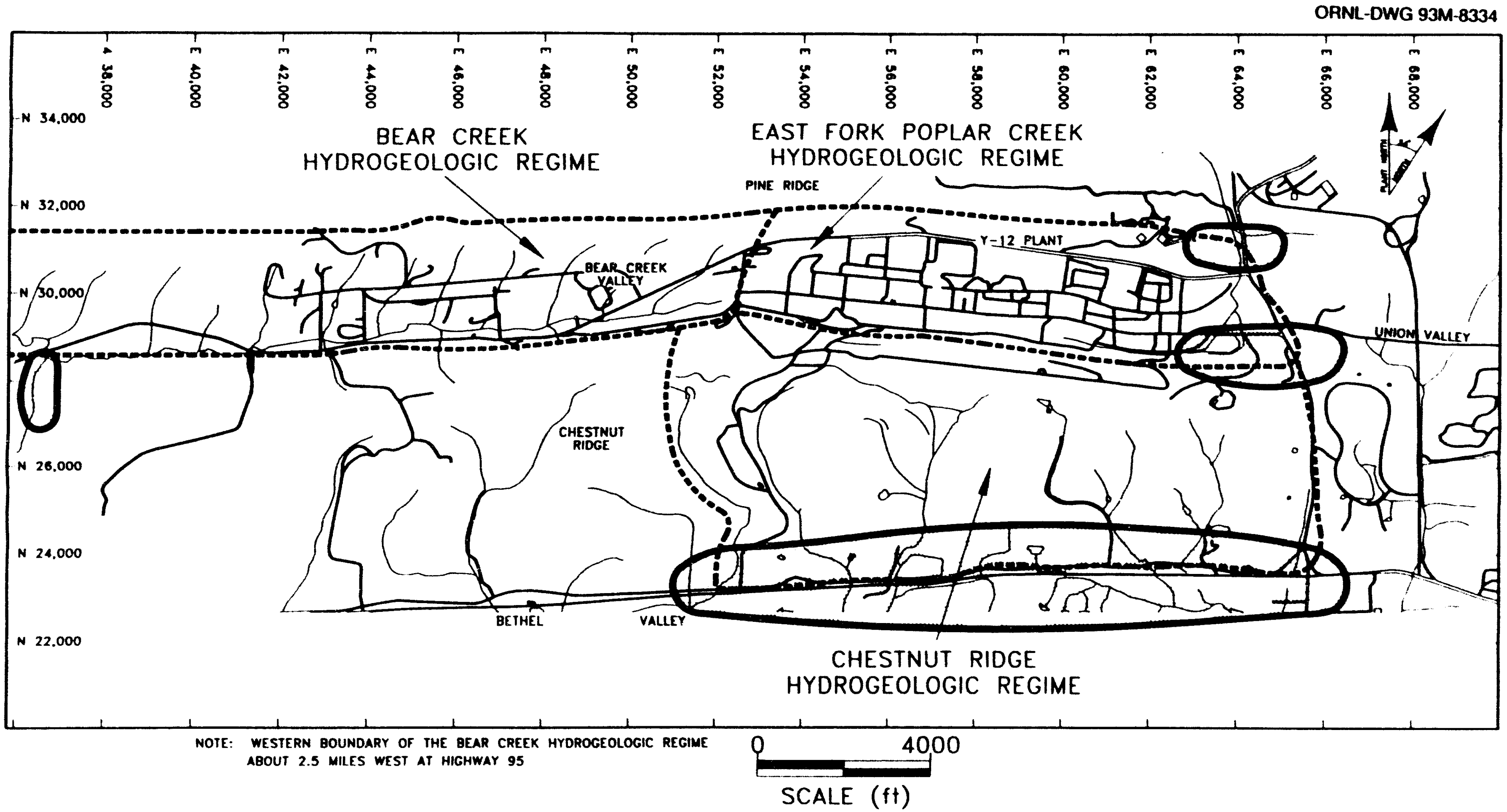

Fig. 3.1.1. Exit pathways at the Y-12 Plant.

(3) possibly as intermediate and deep along-strike flow in the Conasauga Group (primarily in the Maynardville Limestone), passing under the low surface water divide at Scarboro Road and into Union Valley. In the Chestnut Ridge Hydrogeologic Regime, groundwater may flow into the Bear Creek or UEFPC flow regimes or exit the southern or eastern sides of the ridge as (1) discharge to springs or tributary streams, (2) shallow southward groundwater flow, or (3) deeper groundwater flow discharging in Bethel Valley at one of the embayments of Melton Lake (Clinch River) that are formed by water gaps in Haw Ridge.

3.1.1.2 Perimeter Well and Surface Water Surveillance Locations for the Y-12 Plant

Figs. 3.1.2, 3.1.3, 3.1.4, and 3.1.5 illustrate the locations for perimeter surveillance wells and surface water surveillance monitoring in each of the Y-12 Plant hydrogeologic regimes, and Table 3.1.1 summarizes the Y-12 Plant perimeter groundwater surveillance network. In accordance with the Energy Systems Groundwater Surveillance Strategy, existing and planned wells have been incorporated into the perimeter surveillance network wherever possible, and the sites identified for complementary surface water surveillance are locations included in the existing Y-12 Plant surface water monitoring program.

Perimeter surveillance for the Bear Creek hydrologic regime will be conducted by monitoring six wells completed in the Maynardville Limestone ~1.6 km (1 mile) west of the Bear Creek Burial Ground (inset, Fig. 3.1.2). Wells GW-710, GW-711, and GW-712 monitor deep groundwater within the Maynardville Limestone. Wells GW-713 and GW-714 are completed at different, moderate depths, but both are designed to monitor a single stratigraphic interval in the Maynardville that may be a cavernous zone. Well GW-715 is a shallow well designed to monitor the base of the unconsolidated zone, which is hypothesized to be a zone of preferential contaminant transport. Its completion zone straddles the interface between the unconsolidated zone and weathered bedrock.

Table 3.1.1. Summary of the Y-12 Plant perimeter groundwater surveillance network

Exit pathway	Surveillance wells	Surface water surveillance location
Bear Creek Regime	GW-710, GW-711, GW-712 GW-713, GW-714, GW-715	BCK[a] 4.70
UEFPC Regime		UEFPC[b] 17
Pine Ridge Gap	GW-206, GW-207, GW-208	
Scarboro Road	GW-722 (Westbay), GW-733, GW-735	
Chestnut Ridge Regime	Undetermined	SCR 4.3 SP; additional springs, seeps, and spring-fed streams to be identified

[a]BCK = Bear Creek kilometer.
[b]UEFPC = Upper East Fork Poplar Creek.

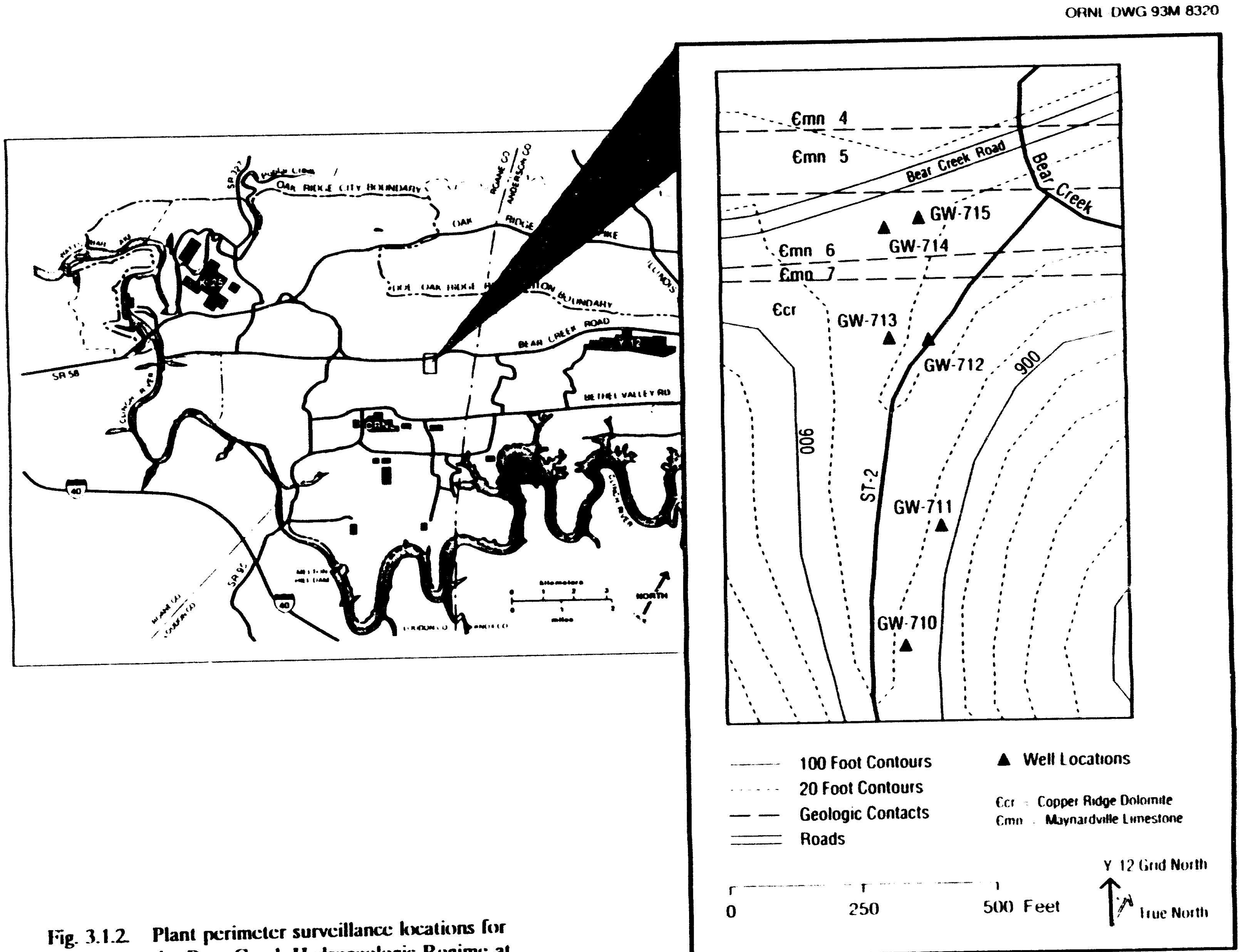

Fig. 3.1.2. **Plant perimeter surveillance locations for the Bear Creek Hydrogeologic Regime at the Y-12 Plant.**

Monitoring of these wells will be supplemented by surface water monitoring in Bear Creek at station BCK 4.70, which is ~2.5 km west of the monitoring wells (Fig. 3.1.2). These monitoring sites are sufficiently far downvalley from the nearest contaminant source that any contaminated groundwater is expected to have either discharged to Bear Creek or entered the Maynardville Limestone before reaching the monitoring stations, even if the contamination originated in another geologic unit. As a result, the proposed surveillance network should adequately monitor any potential contamination migrating out the west end of the Bear Creek Hydrogeologic Regime.

In the UEFPC Hydrogeologic Regime, any contaminants migrating through the Pine Ridge water gap will be monitored at existing wells GW-206, GW-207, and GW-208 and at surface water surveillance point UEFPC 17 (Fig. 3.1.3). Wells GW-722, GW-733, and GW-735 will monitor contamination migrating toward Union Valley through the Maynardville Limestone (Fig. 3.1.4). Well GW-722 is instrumented with a Westbay multilevel monitoring system, which provides surveillance of several different depths. Because groundwater flow in the adjacent geologic units is primarily toward the Maynardville Limestone or UEFPC, these monitoring wells in the Maynardville Limestone will continue to assess contaminants exiting in groundwater from the east end of the UEFPC flow regime. The eastern perimeter of the UEFPC regime is not very far downgradient of a number of potential sources, however, so there is a possibility for along-strike flow of contaminated groundwater through units of the Conasauga Group other than the Maynardville. Monitoring of groundwater effluent monitoring wells being installed near the east end of the Y-12 Plant (GW-744, -745, -746, -735, -750; Figs. 3.1.3 and 3.1.4) should be adequate to detect any potential off-site contaminant movement in these units.

In the Chestnut Ridge Hydrogeologic Regime, plant perimeter monitoring will be conducted in springs, seeps, and surface streams that are identified in future dye-trace studies or other investigations, or are suspected to be groundwater discharge sites. Currently, spring location SCR 4.3 SP is being monitored to partially fulfill perimeter monitoring requirements as well as a best-management-practice for Landfills V and VII (Fig. 3.1.5). Figure 3.1.5 shows the area from which additional monitoring points may be selected. The monitoring network may be modified following additional investigations. The monitoring points shown on Fig. 3.1.5 were the monitoring locations used during the dual dye-trace study completed in November 1992. Any deep groundwater flow in this regime is expected to converge on the Melton Hill Lake embayments into which the streams draining Chestnut Ridge flow, so surface water monitoring where the tributaries enter Bethel Valley should monitor any groundwater contamination exiting this hydrogeologic regime.

3.1.2 Monitoring Parameters

3.1.2.1 Y-12 Plant Groundwater Contaminants

Groundwater monitoring results have been compiled and evaluated in comprehensive, annual reports for each hydrogeologic regime since 1989. These reports have provided a basis for identifying known and potential Y-12 Plant groundwater contaminants. The most common groundwater contaminants, detected in all three hydrogeologic regimes, are VOCs such as the solvents TCE, tetrachloroethylene (PCE), and carbon tetrachloride. VOC migration off of the ORR has been confirmed east of the Y-12 Plant through the Maynardville Limestone at depths of 100 to 300 feet. Nitrate, metal, and radionuclide contamination is found throughout the S-3 Pond area (Bear Creek and UEFPC regimes). The most common radionuclides detected are uranium and technetium (^{99}Tc). PCBs also have been found in the Bear Creek regime. No semivolatile organic compounds have been established as groundwater contaminants.

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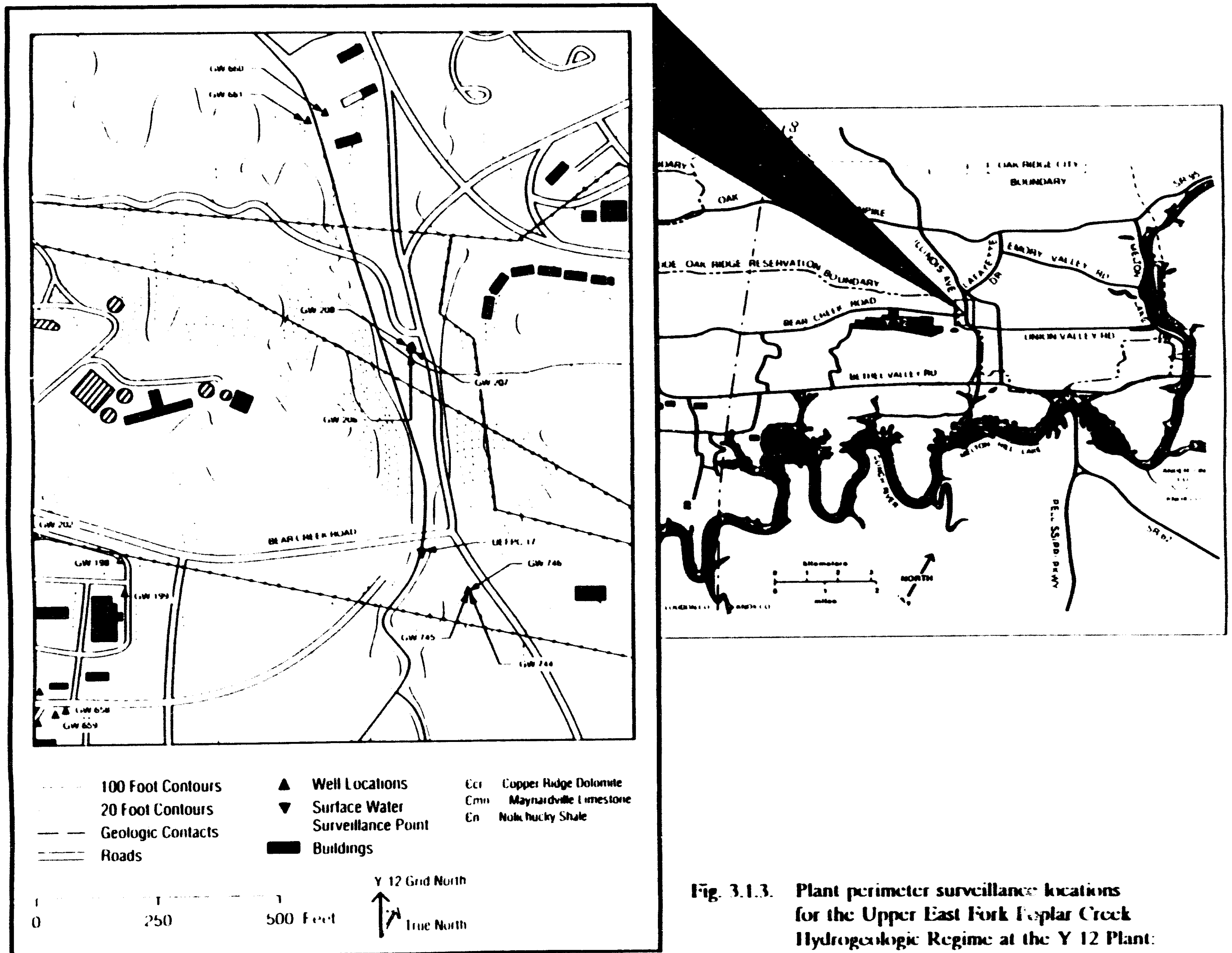

Fig. 3.1.3. Plant perimeter surveillance locations for the Upper East Fork Poplar Creek Hydrogeologic Regime at the Y 12 Plant: Pine Ridge Gap.

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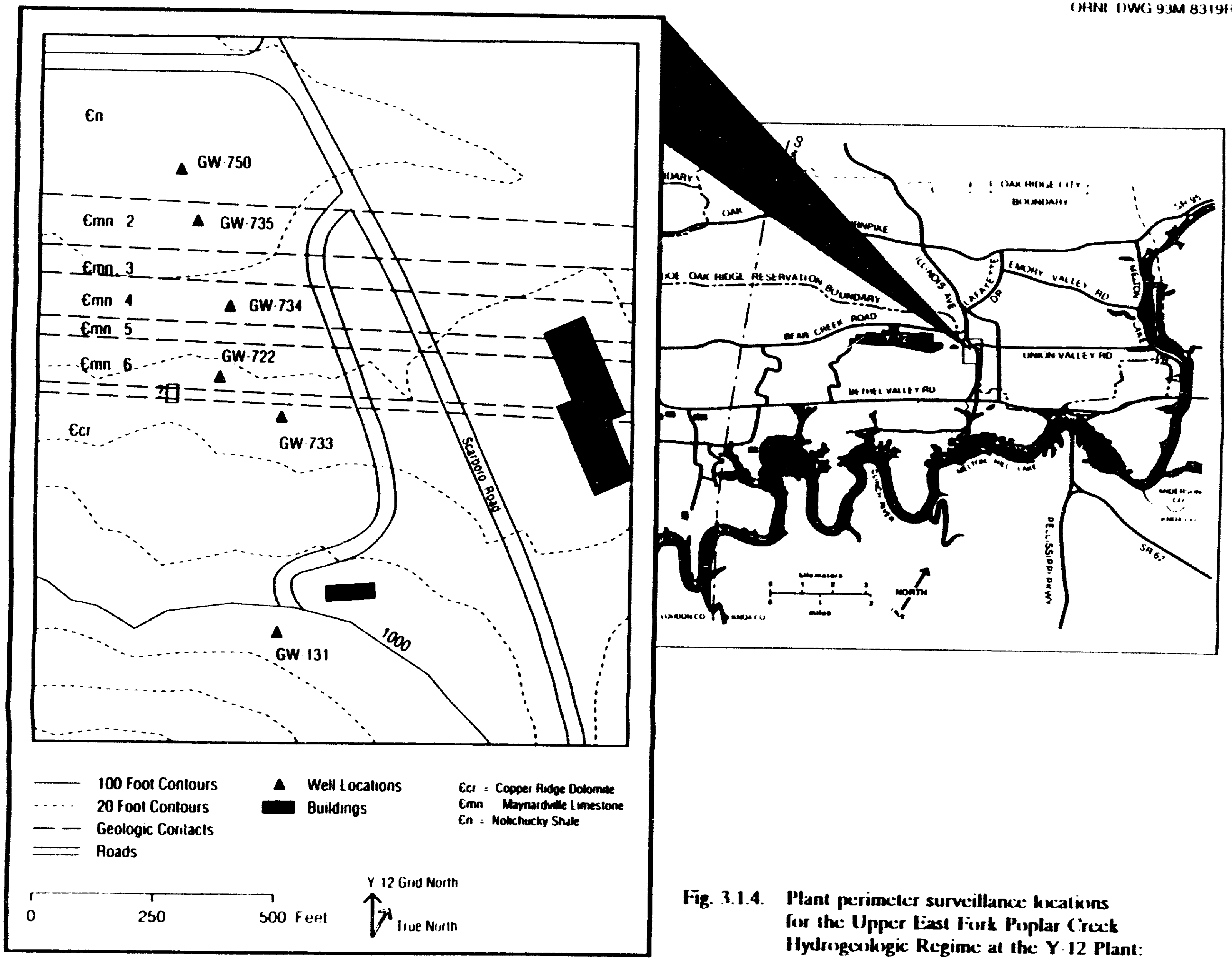

Fig. 3.1.4. Plant perimeter surveillance locations for the Upper East Fork Poplar Creek Hydrogeologic Regime at the Y-12 Plant: Scarboro Road.

ORNL-DWG 93M-8335

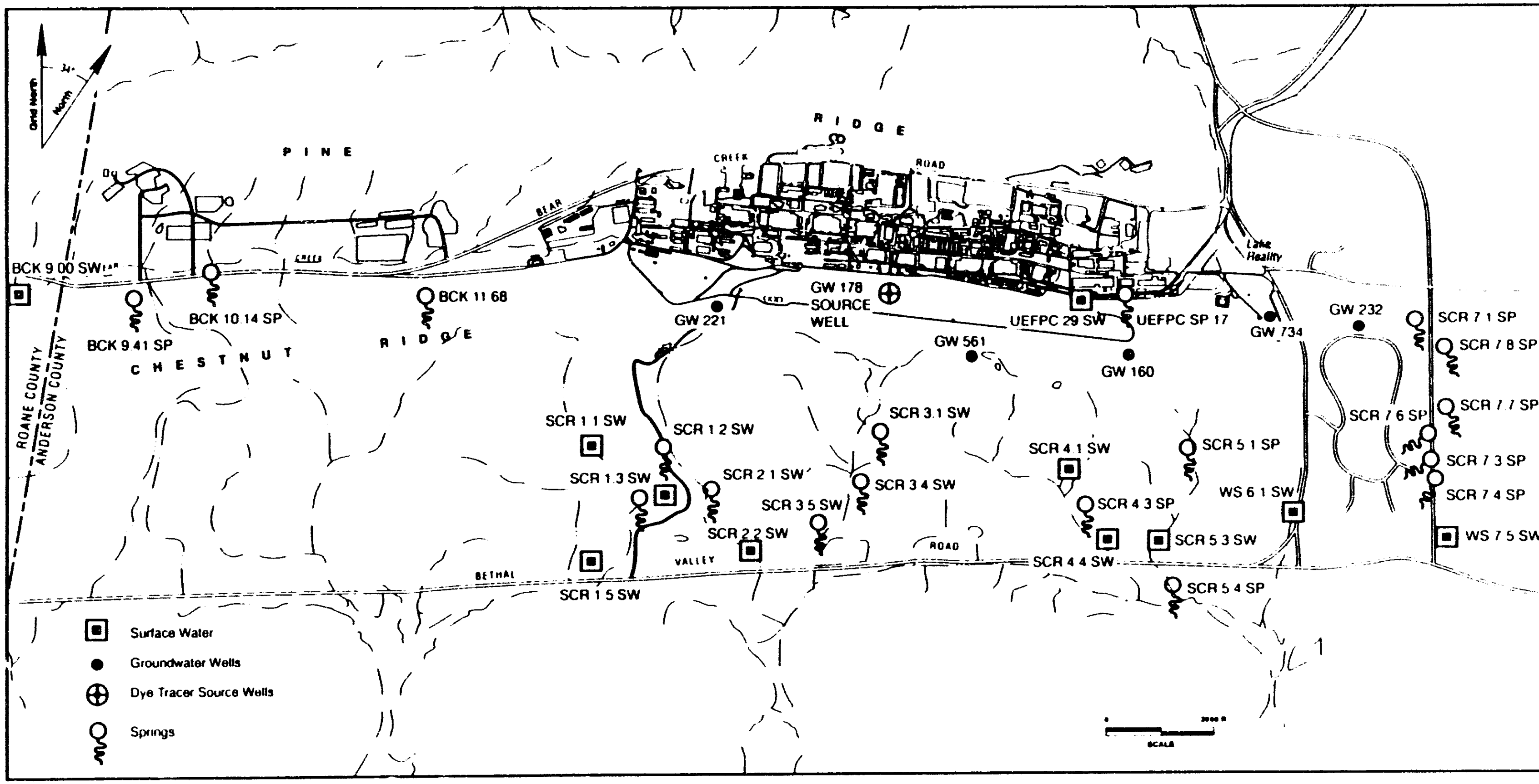

Fig. 3.1.5. Possible plant perimeter monitor stations based on the second dye-tracer test at the Chestnut Ridge Hydrogeologic Regime.

3.1.2.2 Key Indicator Contaminants for the Y-12 Plant

Key indicator contaminants for Y-12 Plant groundwater surveillance are VOCs, nitrate, uranium, and ^{99}Tc (Table 3.1.2). VOCs are included because of the wide distribution of VOC contamination at the Y-12 Plant, indicating both the widespread distribution of sources and the mobility of certain VOCs in the Y-12 Plant hydrogeologic environment. There are several reasons for monitoring for the entire Target Compound List (TCL) of VOCs as key indicator contaminants instead of analyzing only for selected individual VOCs. First, no single VOC is predominant at all Y-12 Plant sites. The predominant organic contaminant varies from PCE at the Bear Creek Burial Ground and S-3 Ponds, to TCE at the Oil Landfarm, carbon tetrachloride in the UEFPC Hydrogeologic Regime, and 1,1,1-trichloroethane at the Chestnut Ridge Security Pits (Geraghty & Miller, Inc. 1990b, 1990c, 1990d). Breakdown products, which are included on the TCL, may also be present at some sites. Finally, the cost of analysis for the entire TCL is often no greater than the cost of analysis for specific VOCs.

Nitrate was chosen as an indicator contaminant because of the magnitude of the nitrate plume near the S-3 Ponds and because nitrate is an anionic species that is generally very mobile in groundwater (Bouwer 1978). Uranium and ^{99}Tc were selected as key indicator contaminants because of their widespread distribution in the groundwater and in other potential sources across the Y-12 Plant. Both uranium and ^{99}Tc are mobile in groundwater under many geochemical conditions. Total uranium will be analyzed for all samples due to the fact that it is more widespread than ^{99}Tc. Analysis for ^{99}Tc will be conducted if gross beta values occur above drinking water standard for 4 or more quarterly sampling events (2 or more semiannual sampling events).

The parameters to be monitored for plant perimeter surveillance at the Y-12 Plant (Table 3.1.2) are these key indicator contaminants plus gross alpha and gross beta radioactivity, which will be analyzed as trend indicators as noted above. Field measurement of other water quality indicators

Table 3.1.2. Summary of plant perimeter surveillance monitoring parameters

Parameter	Y-12 Plant	ORNL	K-25 Site
Mercury	X		
Uranium	X		X
Fluoride			X
Nitrate (as N)	X		
VOCs	X	X	X
Gross alpha radioactivity	X	X	X
Gross beta radioactivity	X	X	X
^{137}Cs		X	
^{60}Co		X	
^{90}Sr		X	
^{99}Tc	X		X
^{3}H		X	

(such as pH, specific conductance, dissolved oxygen content, and oxidation/reduction potential) will be conducted as specified in Y-12 Plant sampling protocols.

3.1.3 Sampling Frequency

3.1.3.1 Contaminant Migration Rates at the Y-12 Plant

Several different approaches have been used to estimate contaminant migration rates in groundwater at the Y-12 Plant. Groundwater flow velocities in four of the geologic units at the Y-12 Plant have been estimated on the basis of available data on hydraulic parameters (HSW Environmental Consultants 1991a, 1991b; Geraghty & Miller, Inc. 1990d). Velocities estimated in this manner ranged from 17 to 1840 m/year (55 to 6025 ft/year) in the Maryville Limestone, from 33 to 3340 m/year (110 to 10,950 ft/year) in the Nolichucky Shale (HSW 1991a, 1991b), and from 167 to 3,115 m/year (548 to 10,220 ft/year) in the Knox Group (Geraghty & Miller, Inc. 1990d). The estimated velocity along geologic strike in the Maynardville Limestone was estimated at 135 to 6450 m/year (438 to 21,170 ft/year) (HSW 1991b). A dye-tracer test in the Maynardville Limestone in the Bear Creek Hydrogeologic Regime yielded a measured velocity of as much as 60 m/day (200 ft/day), which is equivalent to over 22,000 m/year (Geraghty & Miller, Inc. 1989c).

Observations of groundwater contaminant plumes at the Y-12 Plant indicate that actual contaminant migration rates in the groundwater system are in the lower end of the range of calculated flow velocities. Groundwater monitoring results from 1993 indicated that nitrate from the S-3 Site had migrated a maximum of 600 m and 2895 m in the Nolichucky Shale and Maynardville Limestone, respectively of Bear Creek Valley over the 39-year period since the construction of the S-3 Site waste ponds in 1951 (HSW, Inc. 1994a). These data are consistent with a contaminant migration rate of 11 m/year in the ORR Aquitards, 77 m/yr in the Maynardville Limestone, and approximately 33 m/yr in the water table interval in general. Because these values were derived from actual field observations of a conservative (nonreactive) contaminant, it is considered to be more valid than the velocities calculated on the basis of theoretical considerations.

Several factors may contribute to the disparity among the measured and calculated values of contaminant migration rate. Heterogeneity of the flow media is one such factor. Although tracer studies show very rapid transport to springs and surface streams along discrete flow conduits in the Maynardville Limestone and in the Knox Group, flow in most parts of the groundwater system seems to be quite sluggish. Calculations of groundwater velocity also do not reflect the tortuosity of the flow paths, variability of hydraulic properties along a flow path, and chemical phenomena that affect contaminant migration, such as adsorption, matrix diffusion, and chemical reactions. Even the velocity of contaminants (such as nitrate) that are relatively mobile (i.e., they are not significantly affected by adsorption or chemical reactions) may be greatly reduced by matrix diffusion.

3.1.3.2 Locations of Potential Off-Site Receptors

Very few private water wells are in use near the Y-12 Plant, because the City of Oak Ridge public water supply is available to most residents and businesses. The well log data base maintained by the State of Tennessee Department of Conservation shows a few water wells in residential areas north of the Y-12 Plant. One or more small-diameter wells, used primarily for lawn and garden irrigation, may be located in the Gamble Valley area ~1100 m (3700 ft) north of the Y-12 Plant.

Several residences on East Fork Ridge, about 2200 m (7400 ft) north of the Y-12 Plant, obtain household water supplies from private wells. Because these locations are physically separated from the Y-12 Plant by Pine Ridge and are upgradient from East Fork Poplar Creek. In addition, a major, regional geologic structural feature (White Oak Mountain Fault) separates these residences from the groundwater regimes at the Y-12 Plant. There is no plausible pathway through which contaminated groundwater from the Y-12 Plant could migrate to these wells.

The nearest water-supply well within a plausible pathway for contaminant migration is at the Rogers Group quarry, ~3400 m (11,200 ft) east of the Y-12 Plant in Union Valley. The well at this location is not used as a source of potable water supply but formerly produced water for potable uses. The known contaminant migration route is along-strike flow within the Maynardville Limestone from the east end of the Y-12 Plant, under the surface water divides at Scarboro Road and Illinois Avenue, and eastward toward the quarry. The Rogers Group well is considered the nearest potential receptor well for the purpose of determining surveillance frequency for the Y-12 Plant. Various groundwater discharge points in Union Valley such as springs, surface water stations, and abandoned the quarry west of Roger's Group Quarry will be evaluated as possible receptor points. These locations may be included as surveillance monitoring at some future point.

3.1.3.3 Determination of Sampling Frequency for the Y-12 Plant

An estimate of potential contaminant travel time from the Y-12 Plant to the Rogers Group well may be obtained by dividing the distance to the Rogers Group well (3400 m) by the best available measurement of the rate of contaminant migration in the Y-12 Plant groundwater system (50 m/year), with a result of 68 years. Given that VOC contamination has been detected in wells located in Union Valley approximately 1500 ft. east of the ORR, annual sampling will be employed only as a minimum baseline frequency. An annual sampling frequency is appropriate as the minimum baseline frequency to facilitate data comparisons and to be consistent with schedules for annual reporting and annual dose assessments. A semiannual sampling frequency should provide sufficient data to monitor VOC migration and ample time to effect control measures should they be required. Therefore, monitoring of Y-12 Plant groundwater surveillance sites will be conducted semiannually, in accordance with general guidance from DOE (1991). Additional sampling will be done as part of this and CERCLA remedial investigations and will involve a greater frequency or sampling in conjunction with rainfall events.

3.2 ORNL

3.2.1 Perimeter Groundwater Surveillance Locations

3.2.1.1 Identification of Exit Pathways

The WAG perimeter monitoring strategy that is followed for remedial investigations at ORNL involves monitoring of exit pathways for specific WAGs. For the purpose of ORNL perimeter surveillance, however, groups of WAGs are considered to share the same ORNL perimeter exit pathways. The four perimeter surveillance exit pathways identified for ORNL are illustrated in Fig. 3.2.1. They include WOC/Melton Valley, West Bethel Valley, East Bethel Valley, and White Wing Scrapyard. Exit pathways are not identified for ORNL sites that have not been targeted for groundwater investigations (e.g., WAGs 14 and 16 on Copper Ridge).

WOC/Melton Valley is the primary exit pathway for ORNL. Eleven of the WAGs to be investigated are within the WOC drainage basin and eight are within Melton Valley. Groundwater would exit through the WOC/Melton Valley pathway as (1) discharge to WOC, Melton Branch, or

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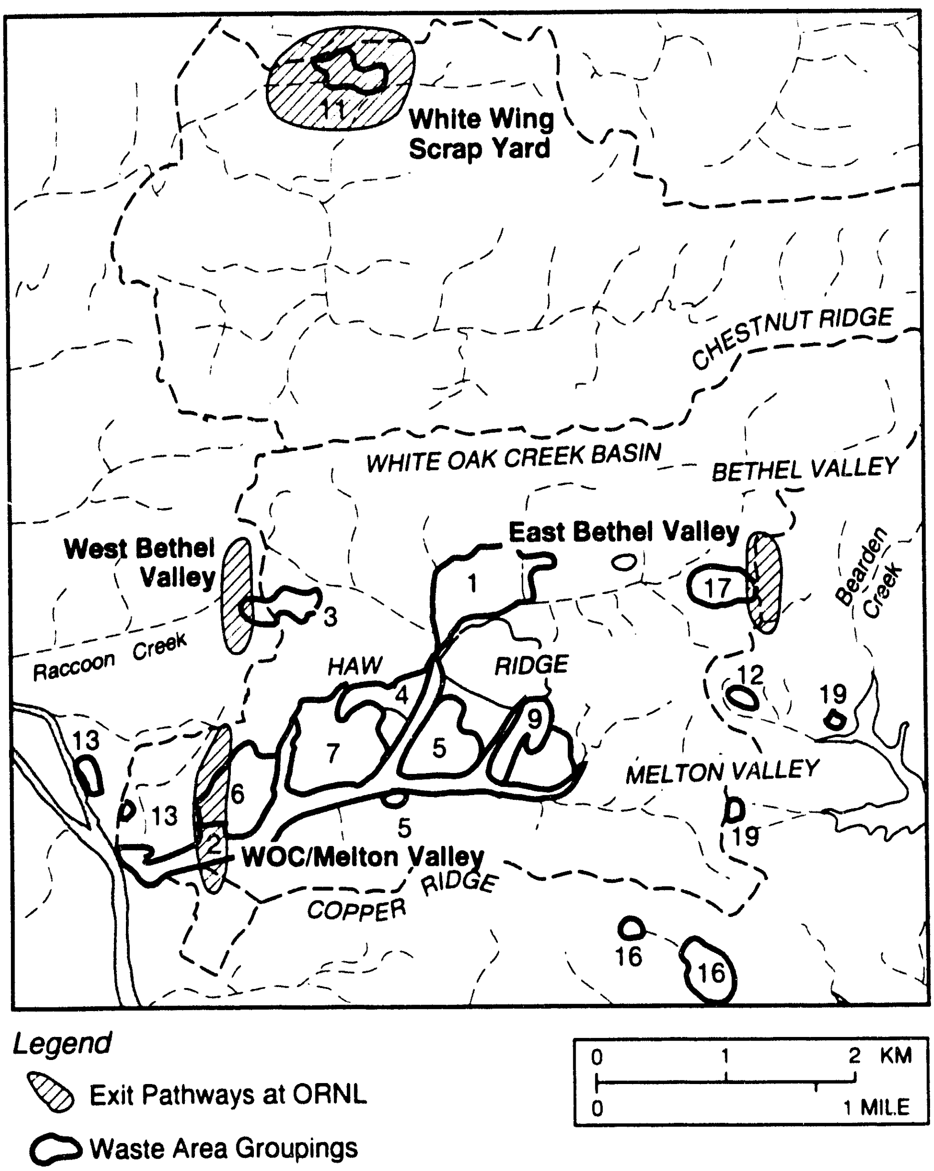

Fig. 3.2.1. Oak Ridge National Laboratory exit pathways.

WOL; (2) shallow groundwater seepage through or around White Oak Dam; or (3) shallow or deep along-strike flow through the Conasauga in Melton Valley, crossing the ORNL perimeter at SR 95.

The West Bethel Valley exit pathway is west of WAG 3, which straddles the surface water divide between WOC and Raccoon Creek. Groundwater would exit this pathway as (1) discharge to Raccoon Creek; (2) shallow groundwater flow from the west side of WAG 3 moving toward Raccoon Creek; or (3) deep along-strike flow through the Chickamauga, possibly contaminated by WAGs 3, 1, or 17, passing under the WOC/Raccoon Creek surface water divide and exiting the ORNL perimeter at SR 95.

The East Bethel Valley exit pathway is just east of WAG 17. Groundwater would exit this pathway as (1) discharge to the Bearden Creek tributary or (2) shallow or deep groundwater flow potentially contaminated by WAG 17 moving eastward toward Bearden Creek.

The White Wing Scrapyard exit pathway is associated with the isolated White Wing Scrapyard SWMU, which comprises WAG 11. Groundwater would exit this pathway as (1) discharge to one of the Bear Creek tributaries or (2) shallow or deep groundwater flow towards the tributaries or along strike westward toward Bear Creek.

3.2.1.2 Perimeter Well and Surface Water Surveillance Locations for ORNL

The locations for perimeter surveillance wells and surface water surveillance monitoring in each exit pathway are illustrated in Figs. 3.2.2 through 3.2.5. Table 3.2.1 summarizes the perimeter surveillance network for ORNL. In accordance with the Energy Systems Groundwater Surveillance Strategy, existing wells are used in the perimeter surveillance network. However, only two of the sites identified for complementary surface water surveillance (i.e., Raccoon Creek and WOC at White Oak Dam) are currently monitored in the existing ORNL surface water monitoring program.

Table 3.2.1. Summary of the Oak Ridge National Laboratory perimeter groundwater surveillance network

Exit pathway	Surveillance wells	Surface water surveillance location
WOC[a] Melton Valley	0859, 0860, 1236, 0857, 0858, 1239, 1189, 1190, 1191, 1192	WOC at White Oak Dam
West Bethel Valley	1247, 1248, 0990	Raccoon Creek
East Bethel Valley	1196, 1197, 1198, 1199	Bearden Creek
White Wing Scrapyard	1139, 1143, 1146	Bear Creek

[a]WOC - White Oak Creek

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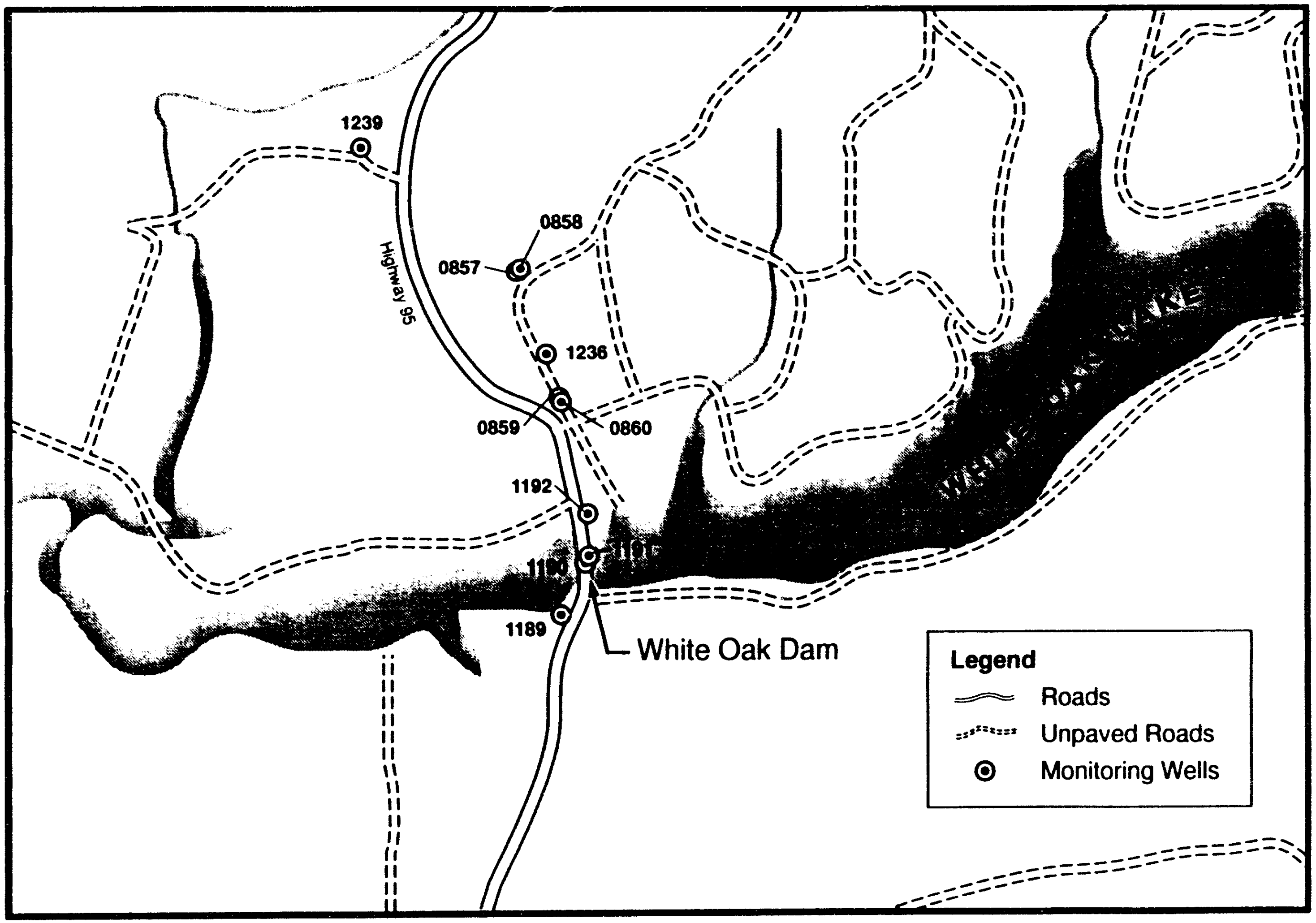

Fig. 3.2.2. Plant perimeter surveillance locations for the White Oak Creek/Melton Valley exit pathway.

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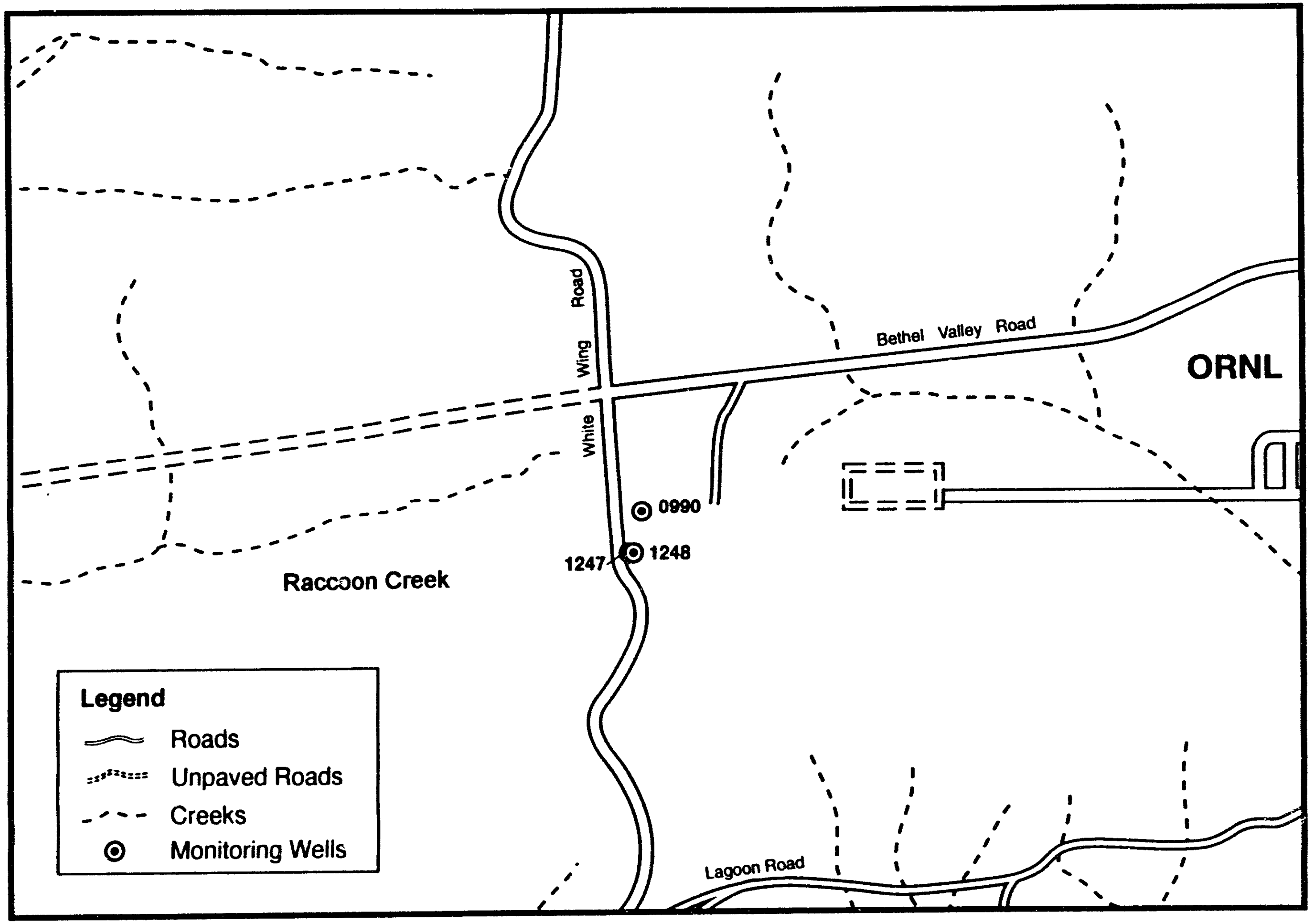

Fig. 3.2.3. Plant perimeter surveillance locations for the West Bethel Valley exit pathway.

ORNL-DWG 93-8330

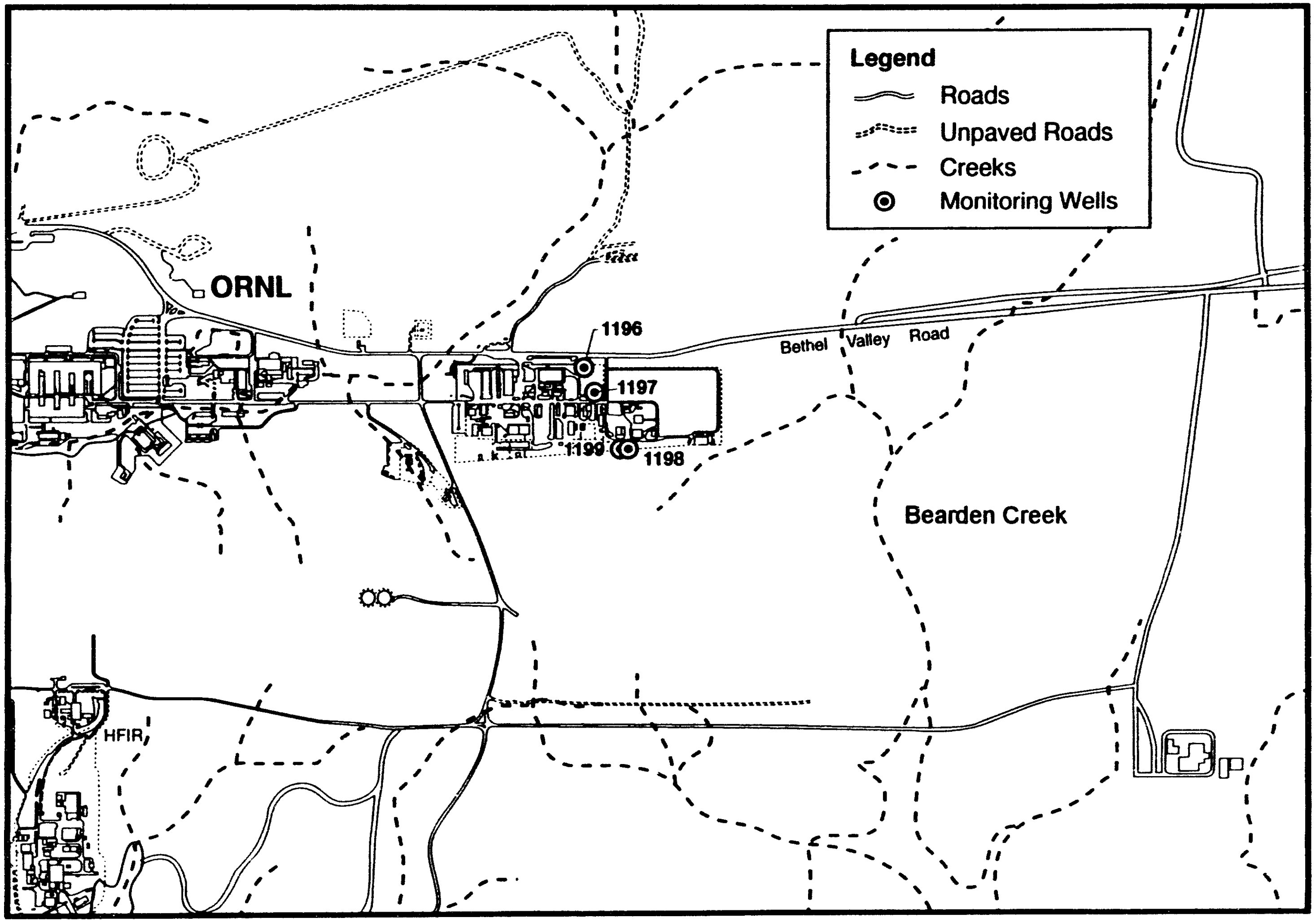

Fig. 3.2.4. Plant perimeter surveillance locations for the East Bethel Valley exit pathway.

ORNL-DWG 93-8331

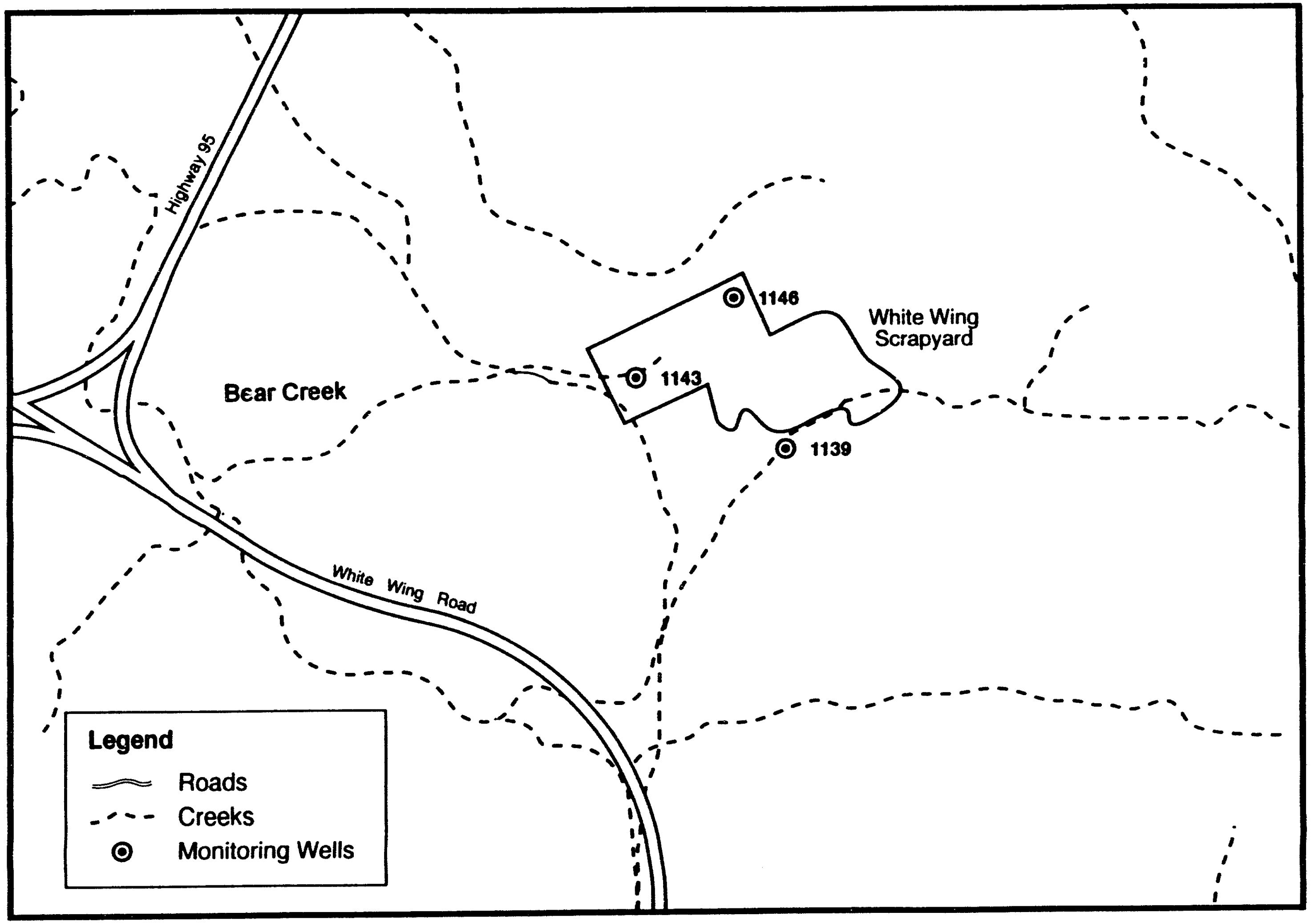

Fig. 3.2.5. Plant perimeter surveillance locations for the White Wing Scrapyard exit pathway.

Perimeter groundwater surveillance of the WOC/Melton Valley exit pathway (Fig. 3.2.2) will be conducted in 10 existing water quality wells that monitor the western perimeters of WAGs 2 and 6. These 10 wells form a traverse of Melton Valley along SR 95, from White Oak Dam north to the base of Haw Ridge. Surface water surveillance will be conducted at the discharge of WOC through White Oak Dam.

In the West Bethel Valley exit pathway (Fig. 3.2.3) perimeter groundwater surveillance will be conducted in three existing water quality wells, that monitor the western perimeter of WAG 3. These three wells form a partial traverse of Bethel Valley along SR 95 and downgradient of WAG 3. Surface water surveillance will be conducted in the upper reaches of Raccoon Creek.

Perimeter groundwater surveillance of the East Bethel Valley exit pathway (Fig. 3.2.4) will be conducted in four existing water quality wells which form a partial traverse of Bethel Valley between WAG 17 and Bearden Creek and which monitor the eastern perimeter of WAG 17. Surface water surveillance will be conducted in Bearden Creek.

Three of the 11 existing water quality wells that monitor WAG 11 will be sampled for perimeter groundwater surveillance of the White Wing Scrapyard exit pathway (Fig. 3.2.5). These three wells are located closest to the Bear Creek tributaries that drain the site. Surface water surveillance will be conducted in Bear Creek downstream from its juncture with the tributaries that drain the Scrapyard area.

3.2.2 Monitoring Parameters

3.2.2.1 ORNL Groundwater Contaminants

Groundwater contaminant data generated from RCRA-protocol sampling and analysis of water quality wells are available for WAGs 1 through 9 and WAGs 11 and 17. For this document, data and descriptions of potential contaminants in WAGs 1 and 6 (McMaster 1990) were reviewed to identify ORNL groundwater contaminants.

The groundwater contaminants that are probably of greatest concern at ORNL are the radionuclides, of which ^{3}H, ^{90}Sr, ^{137}Cs, ^{60}Co are the most widespread. VOCs, including TCE, PCE, carbon tetrachloride, vinyl chloride, and others, have been detected in WAG 1 and WAG 6 groundwater. The metals cadmium, chromium, and barium have been detected above drinking water standards in unfiltered water samples from a few wells. The only semivolatile organic that has been detected is naphthalene, found in one well within WAG 6.

3.2.2.2 Key Indicator Contaminants for ORNL

The key indicator contaminants for ORNL are VOCs and the four radionuclides ^{3}H, ^{90}Sr, ^{137}Cs, and ^{60}Co. All of the VOCs on the TCL were chosen as key indicator contaminants because of uncertainty as to the extent, severity, and range of organic contamination at ORNL. TCE may be the predominant VOC in WAGs 1 and 6, but that conclusion has not yet been confirmed. The extent of organic contamination in other WAGs is not yet known, but VOC contamination sources are widespread at ORNL, and experience at the other two ORR facilities demonstrates the mobility of several VOCs in the ORR hydrogeologic environment.

The four radionuclides ^{3}H, ^{90}Sr, ^{137}Cs, and ^{60}Co were chosen as key indicator contaminants because sources of these radionuclides are widely distributed across ORNL and because they have all been detected in groundwater. It is appropriate to analyze for all four radionuclides rather than designating a single mobile radionuclide as an indicator, primarily because there are large uncertainties in, as well as differences among, the radionuclide inventories at ORNL contaminant source areas.

The parameters to be monitored for perimeter groundwater surveillance at ORNL (Table 3.2.1) are these key indicator contaminants plus gross alpha and gross beta radioactivity, which will be analyzed as trend indicators. Field measurement of other water quality indicators (such as pH, specific conductance, dissolved oxygen content, and oxidation/reduction potential) will be conducted as specified in ORNL sampling protocols.

3.2.3 Sampling Frequency

According to the Energy Systems Groundwater Surveillance Strategy, sampling frequency for perimeter groundwater surveillance should be determined from a calculation of the travel time to the nearest potential off-site receptors, on the basis of estimated contaminant migration rates and distances to potential off-site receptors. However, this would be a moot exercise for ORNL. If, consistent with available evidence, the Clinch River and its tributaries are considered the hydrogeologic discharge points for all groundwater on the ORR, there are no potential receptors of ORNL-contaminated groundwater because the nearest groundwater users are beyond the Clinch River. Even if groundwater does flow below the Clinch River, the length of the flow paths and the slow migration rates caused by the low hydraulic conductivities and gradients of deep flow would combine to result in very long calculated groundwater travel times and perimeter surveillance monitoring frequencies of several years to tens of years.

An annual sampling frequency is appropriate to facilitate data comparisons and to be consistent with schedules for annual reporting and annual dose assessments. Therefore, perimeter groundwater surveillance sampling will be conducted annually at ORNL.

3.3 K-25 SITE

3.3.1 Perimeter Groundwater Surveillance Locations

3.3.1.1 Identification of Exit Pathways

As indicated by the configurations of the unconsolidated zone water table and bedrock piezometric surface illustrated in Figs. 2.4.4 and 2.4.5, respectively, groundwater at the K-25 Site discharges either to on-site surface water features, including Mitchell Branch, the K-1007-B Pond, or the K-901-A Pond, or directly to Poplar Creek or the Clinch River at the plant boundaries. The entire shoreline of the Clinch River and Poplar Creek can therefore be considered an exit pathway for groundwater at the perimeter of the site.

It clearly would be impractical to attempt to monitor groundwater along this entire perimeter. As an alternative, perimeter groundwater surveillance at K-25 will be conducted at locations where groundwater flow from relatively large areas of the plant converges before discharge to the creek or river. Three such convergence points have been identified and are illustrated in Fig. 3.3.1.

The point where Mitchell Branch flows into Poplar Creek is the convergence point for potentially contaminated groundwater from K-1420, K-1471, and K-1407 OUs, which encompasses much of the northeastern portion of the K-25 Site.

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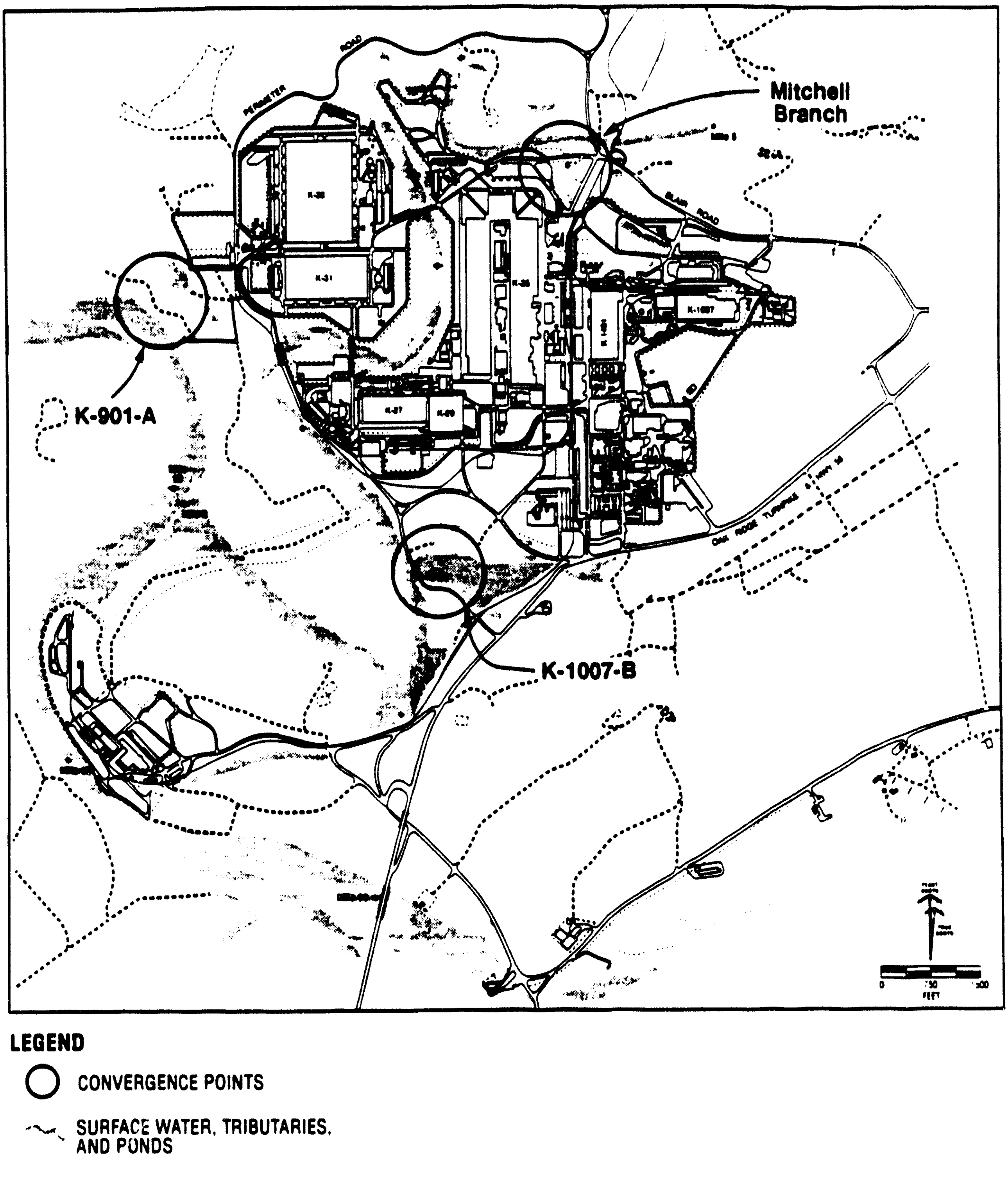

Fig. 3.3.1. Perimeter groundwater convergence points at the K-25 Site.

Groundwater would exit through this convergence point as (1) discharge to Mitchell Branch, (2) shallow groundwater flow through the unconsolidated zone essentially parallel to or under the branch, or (3) groundwater flow through the shallow bedrock, as deeper flow moves up to the discharge zone. The uncertainty regarding strike and dip of the geologic units in WAG 1 imposes a similar uncertainty as to the direction of contaminant transport through the bedrock at this convergence point.

The convergence point for potentially contaminated groundwater in the southern portion of the K-25 Site is located where flow from the K-1007-B holding pond enters Poplar Creek. Groundwater would exit through this convergence point as (1) discharge to the K-1007-B pond, (2) groundwater seepage through or around the earthen embankment which impounds the pond, or (3) along-strike groundwater flow through the shallow bedrock, as deeper flow moves up to the discharge zone.

The point where water from the K-901-A holding pond flows into the Clinch River is the convergence point for potentially contaminated groundwater from the K-901 OU, which encompasses the waste areas in the northwestern portion of the K-25 Site. Groundwater would exit through this convergence point as (1) discharge to the K-901-A pond, (2) groundwater seepage through or around the earthen embankment which impounds the pond, or (3) along-strike groundwater flow through the shallow bedrock, as deeper flow would be moves up to the discharge zone.

3.3.1.2 Perimeter Well and Surface Water Surveillance Locations for K-25

The perimeter groundwater surveillance network for K-25, including perimeter surveillance wells and associated surface water surveillance monitoring, is illustrated in Fig. 3.3.2 and summarized in Table 3.3.1. At each of the three convergence points (Fig. 3.3.1), groundwater monitoring in both the unconsolidated zone and the bedrock will be supported by the monitoring of surface water. In accordance with the Energy Systems Groundwater Surveillance Strategy (Forstrom 1990a), existing wells have been incorporated into the perimeter surveillance network wherever possible, and the sites identified for complementary surface water surveillance are locations included in the existing K-25 Site surface water monitoring program.

At the Mitchell Branch convergence point, groundwater surveillance will be conducted in a pair of new monitoring wells. One well (UNW-107) will be completed at the top of bedrock to monitor groundwater quality in the unconsolidated zone. The second well (BRW-83) will be completed at the first water-producing zone within the bedrock to monitor shallow bedrock groundwater quality. Surface water surveillance will be conducted at the K-1700 NPDES monitoring station.

At the K-1007-B holding pond convergence point, groundwater surveillance will be conducted in a pair of new monitoring wells. One well (UNW-108) will be completed at the top of bedrock to monitor the quality of groundwater in the unconsolidated zone, and the second well (BRW-84) will be completed at the first water-producing zone within the shallow bedrock to monitor shallow bedrock groundwater quality and along-strike flow. Surface water surveillance will be conducted at the K-1007-B NPDES monitoring station.

At the K-901-A holding pond convergence point, groundwater surveillance will be conducted at two existing groundwater quality monitoring wells at the locations illustrated in Fig. 3.3.2. Wells UNW-66 and BRW-35 are paired to monitor groundwater quality in the unconsolidated zones and bedrock, respectively, where groundwater seepage from the pond may discharge directly into the Clinch River. Wells UNW-67 and BRW-68 are paired to monitor groundwater quality in the

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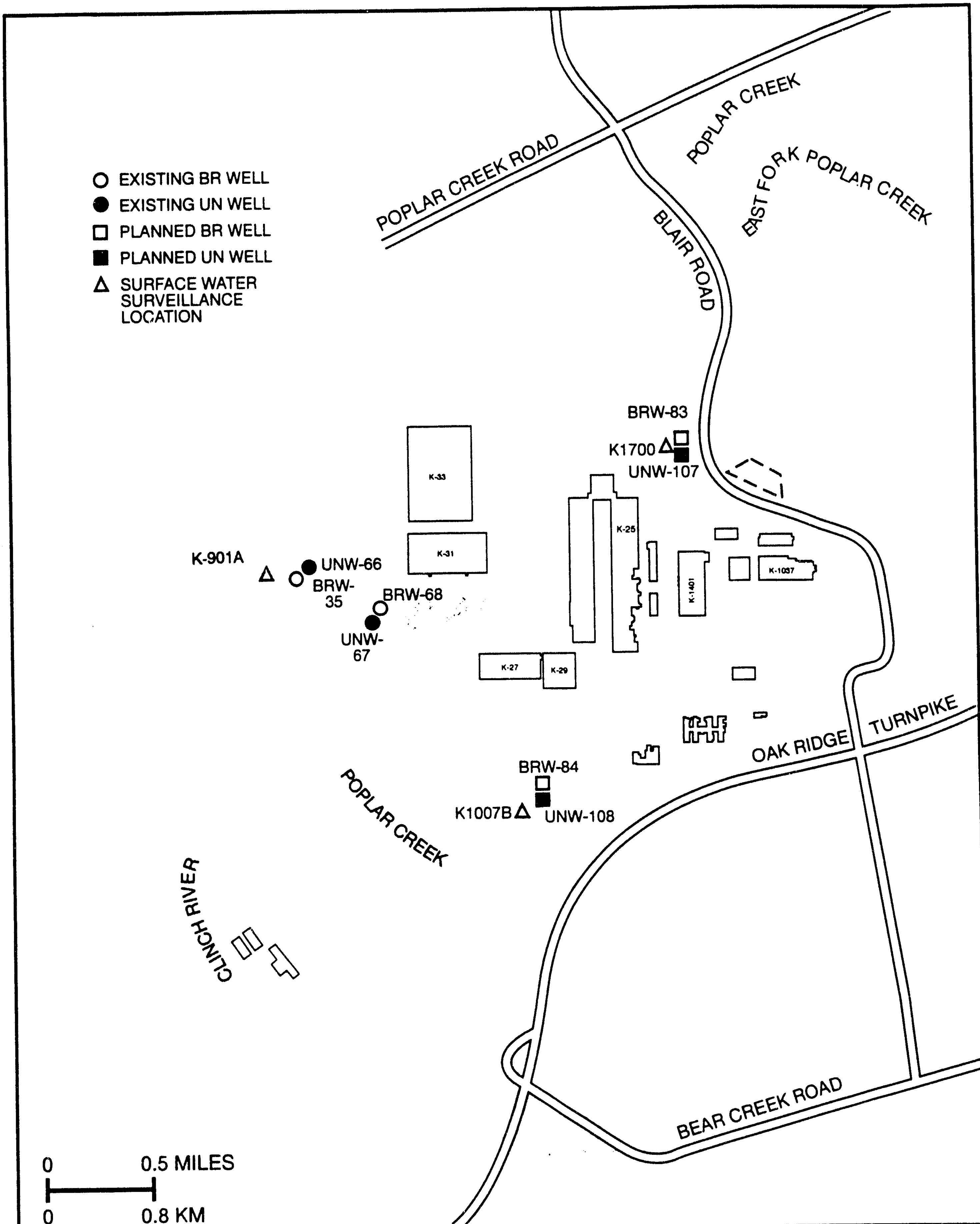

Fig. 3.3.2. Plant perimeter surveillance locations for the K-25 Site.

Table 3.3.1. Summary of the K-25 perimeter groundwater surveillance network

Convergence point	Surveillance wells	Surface water surveillance location
Mitchell Branch	UNW[a]-107[b], BRW[c]-83[b]	K-1700 NPDES[d]
K-1007-B Pond	UNW[a]-108[b], BRW[c]-84[b]	K-1007-B NPDES[d]
K-901-A Pond	UNW[a]-56, BRW[c]-35, UNW[c]-67, BRW[b]-68	K-901-A NPDES[d]

[a]UNW = unconsolidated zone well.
[b]planned wells.
[c]BRW = bedrock well.
[d]NPDES = National Pollutant Discharge Elimination System.

unconsolidated and shallow bedrock, respectively, at a topographic low point where groundwater seepage from the K-901-A pond may discharge into Popular Creek.

3.3.2 Monitoring Parameters

3.3.2.1 K-25 Site Groundwater Contaminants

Geraghty & Miller (1989b) developed a list of known groundwater contaminants for ~80 wells sampled through 1988. Forstrom (1989) developed a comprehensive list of known groundwater contaminants for all wells sampled through mid-1989. According to these compilations the contaminants most commonly detected in groundwater at K-25 are VOCs, including TCE (the most widespread), PCE, carbon tetrachloride, vinyl chloride, and others. Elevated levels of gross alpha and gross beta radioactivity have been detected in a number of wells. Uranium and ^{99}Tc, respectively, appear to be primarily responsible for the elevated gross alpha and beta activities. The metals chromium (most widespread), lead, arsenic, and barium have been detected in a number of wells at levels exceeding drinking water standards. Elevated levels of fluoride have been detected in some wells; PCBs also have been detected at a few wells.

3.3.2.2 Key Indicator Contaminants for K-25

The key indicator contaminants for K-25 are VOCs, uranium, ^{99}Tc, and fluoride. VOCs are appropriate indicator contaminants for the K-25 Site because potential VOC contamination sources are widely distributed at K-25 and because several VOCs have been observed to be quite mobile in the K-25 hydrogeologic environment. All of the VOCs on the TCL were chosen as key indicator contaminants because of uncertainty as to the extent, severity, and range of organic contamination at K-25.

Uranium and ^{99}Tc were chosen as key radioactive indicator contaminants because of the former nature of K-25 operations, because of the widespread distribution of their potential sources across K-25, and because they have been detected in the plant groundwater. Fluoride was identified as a key indicator contaminant because (1) large quantities of fluoride were used in the gaseous diffusion process formerly conducted at the K-25 Site, (2) fluoride is an anionic species that can be quite mobile in groundwater, and (3) fluoride concentrations above the drinking water MCL have been consistently detected in several areas of the plant. No metals were selected as indicator contaminants because metals contamination has generally been detected only in turbid unfiltered samples and has not been consistently detected in wells from which it was reported, suggesting that metals are not very mobile in K-25 Site groundwater.

The parameters to be monitored for perimeter groundwater surveillance at K-25 (Table 3.1.2) are these key indicator contaminants plus gross alpha and gross beta radioactivity, which will be analyzed as trend indicators. Field measurement of other water quality indicators (such as Ph, specific conductance, dissolved oxygen content, and oxidation/reduction potential) will be conducted as specified in K-25 Site sampling protocols.

3.3.3 Sampling Frequency

According to the Energy Systems Groundwater Surveillance Strategy, sampling frequency for perimeter groundwater surveillance should be determined from a calculation of the travel time to the nearest potential off-site receptors, on the basis of estimated contaminant migration rates and distances to potential off-site receptors. However, this would be a moot exercise for K-25. If, consistent with all available evidence, the Clinch River and its tributaries are considered the hydrogeologic discharge points for all groundwater on the ORR and groundwater does not flow beneath the main ridges (especially not northward against regional dip), then there are no potential receptors of groundwater contaminated by K-25 because the nearest groundwater users are either beyond the Clinch River or north of Blackoak Ridge. Even if groundwater does flow below the Clinch River or Blackoak Ridge, the length of the flow paths and the slow migration rates caused by the low hydraulic conductivities and gradients of deep flow would combine to result in very long calculated groundwater travel times and perimeter surveillance monitoring frequencies of several years to tens of years.

An annual sampling frequency is appropriate to facilitate data comparisons and to be consistent with schedules for annual reporting and annual dose assessments. Therefore, perimeter groundwater surveillance sampling will be conducted on an annual frequency at K-25.

4. OFF-SITE WATER WELL SURVEILLANCE

4.1 LOCAL GROUNDWATER USE

Industrial and drinking water supplies in the Oak Ridge area are obtained predominantly from surface water sources. However, several industrial water supplies and small public water supplies in the general area are derived wholly or partially from groundwater (Boyle et al. 1982), and single family wells are common in adjacent rural areas not served by public water-supply systems. According to information on groundwater users compiled by Boyle et al. (1982) from sources including the well log computer data file maintained by the State of Tennessee Department of Environment and Conservation, most water-supply wells and springs are across the Clinch River from the ORR or to the north of Blackoak Ridge. With one exception, the only water-supply wells within the City of Oak Ridge are separated from the major ORR facilities by one or more ridges. Only one well, the Rogers Group well located east of the Y-12 Plant, lies along a potential flow path from a DOE facility that is not blocked by a hydrogeologic barrier.

4.2 REVIEW OF EXISTING PROGRAM

The Energy Systerns Groundwater Surveillance Strategy (Forstrom 1990a) calls for a review of the existing off-site water well monitoring program to ensure that it is consistent with the DOE orders, that it satisfies public interest or concern, and that all the program elements are appropriate and consistent with their level of technical significance.

4.2.1 Monitoring Locations

Off-site groundwater surveillance is currently conducted at 20 off-site locations around the ORR (Fig. 4.2.1). The majority of monitoring locations are wells that serve as drinking water sources for private residences, although they also include irrigation wells and two springs on Freels Bend. Table 4.1.1 lists the present off-site water well surveillance locations for the ORR.

Review of the existing locations indicates that they are generally consistent with the siting considerations outlined in Table 1.1.2. The two USGS wells on Scarboro Road have been withdrawn from the off-site surveillance program to eliminate duplication of effort between the off-site program and the Y-12 Plant perimeter surveillance program. Also, although the Rogers Group wells in Union Valley east of the Y-12 Plant are reportedly not used for potable water, wells in this area might provide a pathway for exposure to groundwater contamination exiting the Y-12 Plant. Therefore, if the well owner agrees to participate, these wells should be evaluated to determine whether there is a well that is suitable for inclusion in the program.

Periodically Energy Systems receives requests to have additional wells included in the off-site well water surveillance program. These wells and their locations will be evaluated to determine whether their locations, physical characteristics, and hydrogeologic settings warrant their addition to the program. Similarly, if the owners of wells included in the current program decide to quit the program, an evaluation will be done to determine whether the remaining well locations are adequate to meet program objectives or to identify another available well to replace the one dropped.

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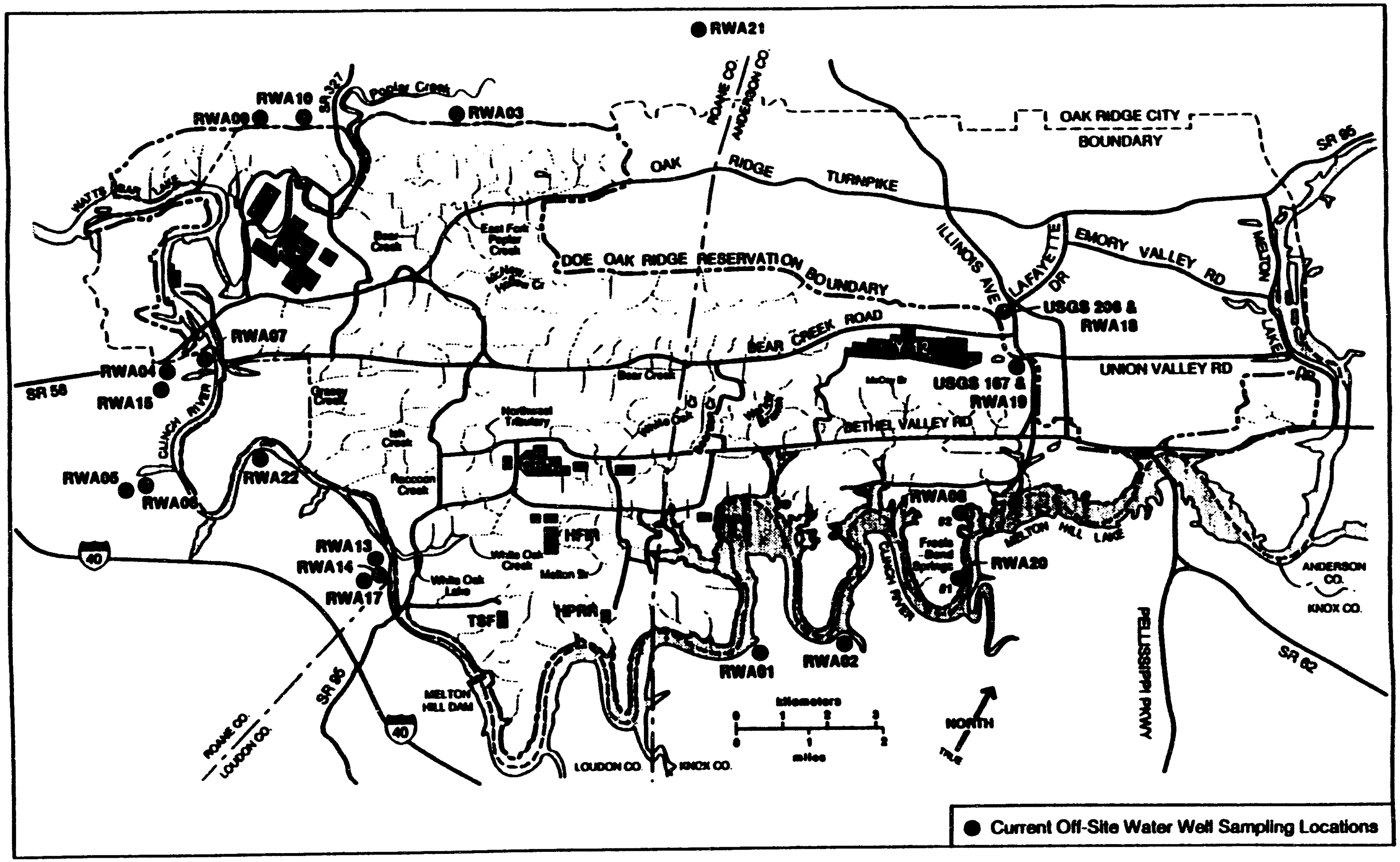

Fig. 4.2.1. Off-site water well surveillance locations around the Oak Ridge Reservation.

Table 4.1.1 Current offsite water well surveillance locations

Well Number	Location
RWA01	Gallaher Bend
RWA02	Williams Bend
RWA03	Hartland Estates
RWA04	Gallaher Valley
RWA05	Poplar Springs
RWA06	Poplar Springs
RWA07	Gallaher Valley
RWA09	Sugar Grove Valley
RWA10	Sugar Grove Valley
RWA11	Melton Hill Dam
RWA12	Johnson Creek Valley
RWA13	Jones Island Area
RWA14	Jones Island Area
RWA15	Gallaher Valley
RWA17	Jones Island Area
RWA21	Poplar Creek Valley
RWA22	Grubb Island Area
USGS167[a]	Scarboro Road
USGS206[a]	Scarboro Road
Spring #1	Freels Bend
Spring #2	Freels Bend

[a]Withdrawn from program to eliminate duplication with Y-12 Plant perimeter groundwater surveillance.

4.2.2 Parameters

Samples from the ORR off-site surveillance wells are currently analyzed for an extensive list of parameters (Table 4.2.1). Field measurements of pH, temperature, and specific conductance are also conducted as part of the sampling protocol (Energy Systems 1989b). The parameter list, which is more extensive than the range of key indicator parameters identified for the three ORR plants, includes the full range of contaminants that have been detected at the three plants, except for PCBs and the few semivolatile contaminants.

Table 4.2.1 Parameters for off-site water well surveillance around the Oak Ridge Reservation[a]

Metals	Anions	Radionuclides	Volatile organics
Arsenic	Chloride	Uranium (total)	Trichloroethene
Lead	Sulfate	^{60}Co	Carbon tetrachloride
Selenium	Fluoride	^{137}Cs	Benzene
Mercury	Nitrate	Total radiostrontium	Vinyl chloride
Silver	Nitrite	^{3}H	Xylene (total)
Barium		Gross alpha	Chlorobenzene
Beryllium		Gross beta	Toluene
Cadmium		^{99}Tc	Methylene chloride
Calcium			1,1-Dichloroethene
Chromium			1,2-Dichloroethene
Cobalt			1,2-Dichloroethane
Copper			1,1-Dichloroethane
Iron			1,1,1-Trichloroethane
Magnesium			1,2-Dichloropropane
Manganese			Chloromethane
Nickel			Bromomethane
Sodium			Chloroethane
Vanadium			Chloroform
Zinc			Bromodichloromethane
			cis-1,3-Dichloropropane
			Dibromochloromethane
			1,1,2-Trichloroethane
			trans-1,3-Dichloropropene
			Bromoform
			Tetrachloroethene
			1,1,2,2-Tetrachlorethane
			Ethyl benzene
			Styrene
			1,4-Dichlorobenzene
			2-Butanone (Methyl ethyl ketone)
			2-Hexanone (methyl ethyl ketone)
			4-Methyl-2-pentanone
			Acetone
			Carbon disulfide
			Vinyl acetate

[a]Source: Energy Systems 1989b.

The current parameter list is probably more extensive than necessary to meet DOE requirements or to respond to public interest or concern. It may be appropriate at some time in the future to limit the off-site water well surveillance parameters to the range of plant perimeter surveillance parameters, i.e. VOCs, nitrate, and selected radioactive parameters. This shortened list of off-site water well surveillance parameters for the ORR would continue to meet or exceed DOE Order requirements and satisfactorily address public interest or concern.

4.2.3 Sampling Frequency

Sampling for ORR off-site water well surveillance is presently conducted semiannually. Although this is not consistent with the annual frequency established for perimeter surveillance around the three major ORR facilities, semiannual monitoring will be continued in response to the interest and concern of program participants and the public at large.

5. PROCEDURES FOR IMPLEMENTING GROUNDWATER SURVEILLANCE

5.1 PROCEDURES

Sampling, analysis, and quality assurance procedures for groundwater surveillance should follow the guidelines established in the current Energy Systems Environmental Surveillance Procedures Quality Control Program (e.g., Kimbrough, Long, and McMahon 1990). Procedures for site perimeter surveillance should be documented in sampling and analysis plans for the individual facilities. Procedures for off-site water well surveillance are contained in a sampling and analysis plan for that activity (Energy Systems 1989b).

5.2 DATA INTERPRETATION

DOE Order 5400.1 and the DOE guidance on environmental surveillance monitoring (DOE 1991) contain few specific requirements for interpretation of data from groundwater surveillance. Comparisons are to be made, as appropriate, against applicable environmental standards and background or baseline levels. DOE (1991) also recommends comparisons against previous measurements or estimates in order to identify changes or inconsistencies. Similarly, the Energy Systems Groundwater Surveillance Strategy (Forstrom 1990a) calls for groundwater surveillance results to be compared with background conditions, with background groundwater quality defined as the quality of groundwater that is completely unaffected by the plant or its operations.

The background concentrations of surveillance monitoring parameters in ORR groundwater have not yet been determined. Due to the age of the ORR facilities, baseline (preconstruction) groundwater quality data are not available. The density of development in the vicinity of the three ORR plants and waste management areas complicates the determination of background groundwater quality by preventing or restricting the establishment of monitoring locations that are upgradient from facilities and operations. Facility groundwater effluent monitoring is, however, expected to yield data appropriate for determining background groundwater quality for surveillance purposes. A specific plan has been developed for the installation of background wells appropriate for defining background groundwater quality for the K-25 Site (Geraghty & Miller 1990e). Surface water monitoring data are available to aid in defining baseline conditions for most of the surface water stations associated with exit pathways, but it may be difficult to distinguish surface-water quality changes caused by groundwater discharge from surface water quality changes due to direct discharges to streams and other factors.

Pending determinations of background groundwater quality, interpretation of groundwater surveillance monitoring data should emphasize comparisons with available standards and with previous measurements in the surveillance monitoring sites. For substances that are not naturally present in groundwater or found in ambient rainwater (e.g., ^{99}Tc and most or all of the VOCs), however, background levels in groundwater should be considered to be equal to the analytical quantitation limits.

Sources of environmental standards to be considered in data interpretation include the maximum contaminant levels (MCLs) established by EPA for public drinking water supplies and the derived concentration guides (DCGs), promulgated in DOE Order 5400.5, for drinking water ingestion of specific radionuclides. Existing and proposed standards applicable to the ORR plant perimeter surveillance parameters are in Table 5.2.1.

Standards and action levels for additional parameters included in the off-site water well surveillance program are given in the sampling and analysis plan for that program (Energy Systems 1989b).

Specific actions to be taken when perimeter surveillance shows contaminant concentrations to exceed applicable standards, background levels, or historical levels should be documented in groundwater protection program plans for the individual facilities and in the sampling and analysis plan for the off-site water well surveillance program. In virtually all instances, increases or exceedances should be investigated through such measures as reanalysis of samples, resampling, analysis for a more extensive list of parameters, increased sampling frequency, reconnaissance investigation of site conditions and well integrity, or sampling at additional monitoring stations. If surveillance monitoring results indicate off-site migration of contaminants or a threat to human health, appropriate measures should be initiated to stem the migration or to eliminate the health threat (e.g., by providing alternative water supplies to off-site water users).

5.3 DATA MANAGEMENT AND REPORTING

The results of plant perimeter groundwater surveillance for each of the three ORR facilities will be reported each year in the annual environmental report for that facility. These reports are published each year on June 1 and contain data for the previous calendar year. The results of off-site groundwater surveillance for the ORR are reported in the annual *ORNL Environmental Report*. In addition, letter reports detailing and interpreting the results of off-site well surveillance are provided to each well owner within 90 days of the receipt of data from the analytical laboratory. To maintain confidentiality, individual wells are identified only by code numbers, so that only the homeowner and those individuals with a "need to know" are able to associate data with an actual residence location.

Surveillance data will be maintained in facility compliance data bases and in the DOE Oak Ridge Field Office Environmental Information System data base.

Table 5.2.1. Existing and proposed standards for plants perimeter surveillance monitoring parameters

Parameter	Existing EPA drinking water MCL[a]	Proposed EPA drinking water MCL[b]	(pCi/L)[c]
Mercury	0.002 mg/L		NA[d]
Uranium[e]		0.020 mg/L	600
Fluoride	4 mg/L; 2 mg/L[f]		NA
Nitrate (as N)	10 mg/L		NA
VOCs			
Vinyl chloride	0.002 mg/L		
Benzene	0.005 mg/L		
Carbon tetrachloride	0.005 mg/L		
1,2-Dichloroethane	0.005 mg/L		
Trichloroethylene	0.005 mg/L		
para-Dichlorobenzene	0.075 mg/L		
1,1-Dichloroethylene	0.007 mg/L		
1,1,1-Trichloroethane	0.2 mg/L		
cis-1,2-Dichloroethylene	0.07 mg/L		
1,2-Dichloropropane	0.005 mg/L		
Ethylbenzene	0.7 mg/L		
Monochlorobenzene	0.1 mg/L		
o-Dichlorobenzene	0.6 mg/L		
Styrene	0.1 mg/L		
Tetrachloroethylene	0.005 mg/L		
Toluene	1 mg/L		
trans-1,2-Dichloroethylene	0.1 mg/L		
Xylenes (total)	10 mg/L		
Gross alpha radioactivity	15 pCi/L[g]	15 pCi/L[g]	NA
Gross beta radioactivity	50 pCi/L[h]	no change	NA
^{137}Cs	see footnote[i]	119 pCI/L[i]	3000
^{60}Co	see footnote[i]	218 pCI/L[i]	5000
^{90}Sr	8 pCi/L	42 pCi/L[i]	1000
^{99}Tc	see footnote[i]	3790 pCI/L[i]	10,000
^{3}H 20,000 pCi/L	60,900 pCi/L	2×10^6	

[a]Primary (health-based) maximum contaminant levels (MCLs) in 40 CFR 141, except where noted otherwise.

[b]Proposed standards for radionuclides (amendment to 40 CFR 141) published July 18, 1991, at 56 FR 33050.

[c]DOE Order 5400.5; based on 100 mrem/year exposure limit for ingestion of water by memebers of the public.

[d]NA = not applicable.

[e]MCL is for total uranium; derived concentration guideline (DCG) listed is for natural uranium. DOE order also gives DCGs for individual isotopes of uranium.

[f]2 mg/L limit is secondary (not health-based) MCL in 40 CFR 142.

[g]Existing standard applies to gross alpha radioactivity excluding ^{226}Ra, radon, and uranium. Proposed standard would exclude only radon and uranium.

[h]MCL for beta- and gamma-emitting radionuclides is 4 mrem/year effective dose equivalent. Compliance determined by summing the calculated doses from the specific radionuclides in the water. In routine monitoring, when gross beta exceeds 50 pCi/L, additional analysis must be performed to identify the major radioactive constituents, and doses associated with those constituents must be calculated to determine compliance with the 4 mrem/year standard.

[i]Limits not specifically enumerated; covered by MCL for beta- and gamma-emitting radionuclides. Proposed limits listed for ^{137}Cs, ^{60}Co, ^{90}Sr, ^{99}Tc, and ^{3}H are concentrations equivalent to an effective dose equivalent of 4 mrem/year, as listed in an appendix to the proposed rule.

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