7. Groundwater

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Abstract

Most residents in the Oak Ridge area do not rely on groundwater for potable supplies, although suitable water is available. Local groundwater provides some domestic, municipal, farm, irrigation, and industrial uses, however, and must be viewed as both a potential pathway for exposure to hazardous wastes and as a means for contaminant transport. Statutes codified into regulations by the EPA specifically target the protection of groundwater from contamination by hazardous wastes. The regulations guide groundwater monitoring at the DOE plants in Oak Ridge. Monitoring programs established on the ORR assess groundwater contamination and transport on and off the reservation and are intended to comply with established regulatory requirements.

7.1 INTRODUCTION

The groundwater monitoring programs at the ORR are designed to gather information to determine the effects of DOE operations on groundwater quality in compliance with all applicable requirements.

The location and movement of groundwater must be determined to identify the extent of contamination in groundwater and to predict the possible fate of contaminants. To make this determination, an understanding is required of how groundwater moves in general and how that movement will be influenced by the geological setting.

7.1.1 Geological Setting

The ORR is located in the Tennessee portion of the Valley and Ridge Province, which is part of the southern Appalachian fold and thrust belt. As a result of thrust faulting and varying erosion rates, a series of parallel valleys and ridges have formed that trend southwest-northeast.

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

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

7.1.2 Hydrogeological Setting

7.1.2.1 Groundwater Hydrology

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

Water infiltrates by percolating downward through the pore spaces between sediment grains and also through fractures in bedrock. The smaller the pore spaces or fractures, the slower the flow of water through the subsurface. The physical property that describes the ease with which water may move through the pore spaces and fractures in a given material is called permeability, and it is largely determined by the volume and size of these features and how well they are connected.

As water infiltrates the earth, it travels down through the unsaturated zone, where the pore spaces and fractures are partly filled with water and partly filled with air. Water moving down through the unsaturated zone will eventually reach the saturated zone, where the pore spaces and fractures are completely filled with water. The boundary between the unsaturated and the saturated zones is known as the water table, which generally follows, in subtle form, the contour of the surface topography. Springs, swamps, and beds of streams and rivers are the outcrops of the water table, where groundwater is discharged to the surface.

Because the earth's permeability varies greatly, groundwater flowing through subsurface strata does not travel at a constant rate or without impediment. Strata that transmit water easily (such as those composed primarily of sand) are called aquifers, and strata that restrict water movement (such as clay layers) are called aquitards. An aquifer with an aquitard lying above and beneath it is termed a confined aquifer. Groundwater moves through aquifers toward natural exits, or discharge points, to reappear at the surface.

The direction of groundwater flow through an aquifer system is determined by the permeability of the strata containing the aquifer and by the hydraulic gradient, which is a measure of the difference in hydraulic head over a specified distance. The driving force for groundwater movement through the saturated zone comprises differences in hydraulic head. The hydraulic head at any given point in an aquifer is a function of the energy associated with the water's elevation above sea level and the pressures exerted on it by surrounding water. Because hydraulic head is not solely a function of elevation, downgradient is not necessarily synonymous with downhill. The downgradient direction will have a horizontal and vertical component, just as a household drain moves wastewater both horizontally and vertically, seeking the lowest point of exit. Aquitards deflect groundwater movement just as drain pipe walls control the direction of wastewater movement. In an aquifer constrained by aquitards such as horizontal clay layers, the downgradient direction tends to be more horizontal than vertical.

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

Several distinct flow intervals occur within the aquifer: the uppermost water table interval, the intermediate interval, the deep interval, and the aquiclude. The divisions within the saturated zone grade into one another vertically and are not separated by distinct boundaries but reflect an overall decrease in the rate of groundwater flow with depth. Within the ORR aquitards, the greatest groundwater flow rates occur in the stormflow zone and the smallest within the deep zone. Water does not flow in the aquiclude, which is defined by a transition to saline water (Fig. 7.1). In the Knox Aquifer, the greatest groundwater flow is in the water table and intermediate intervals [depths to approximately 300 ft (91.5 m)].

As noted earlier, two broad hydrologic units are identified on the ORR: the Knox Aquifer and

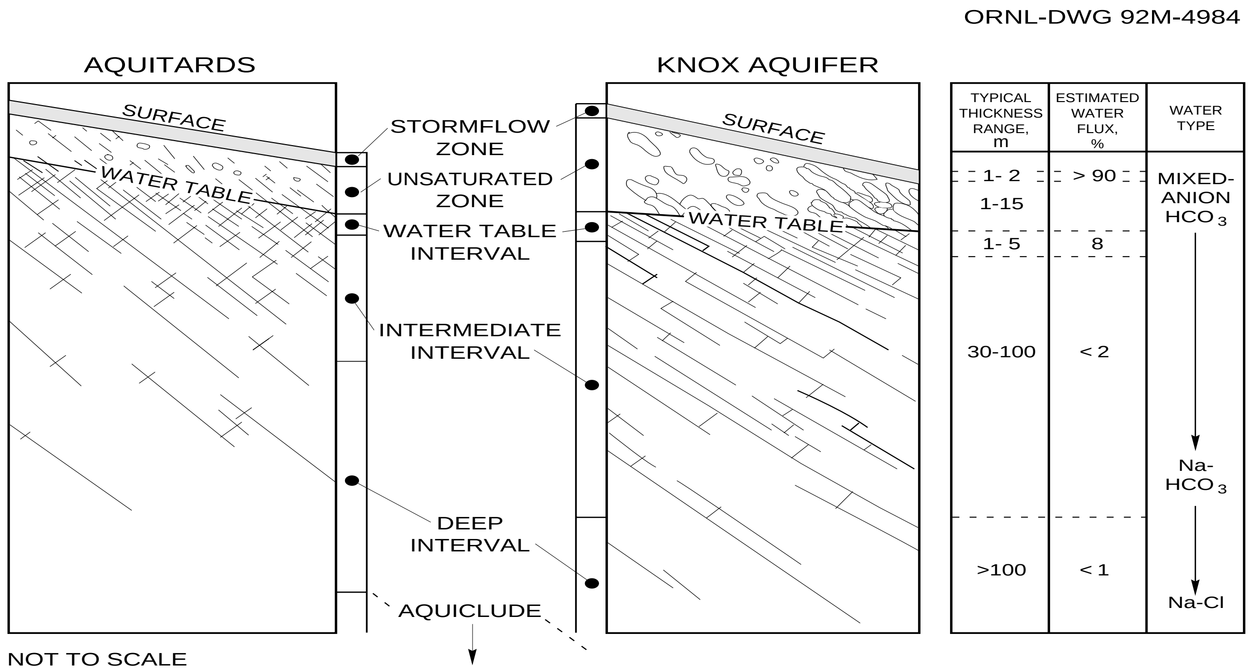

Fig. 7.1. Vertical relationships of flow zones of the ORR: estimated thicknesses, water flux, and water types.

the ORR Aquitards, which consist of less permeable geologic units. Figure 7.2 is a generalized map showing surface distribution of the Knox Aquifer and the ORR Aquitards. Many waste areas on the ORR are located in areas underlain by the ORR Aquitards.

7.1.2.2 Unsaturated Zone Hydrology

In undisturbed, naturally vegetated areas on the ORR, about 90% of the infiltrating precipitation does not reach the water table but travels through the 1- to 2-m-deep stormflow zone, which approximately corresponds to the root zone. Because of the permeability contrast between the stormflow zone and the underlying unsaturated zone, the stormflow zone partially or completely saturates during rainfall events, and then water flows laterally, following very short flow paths to adjacent streams. When the stormflow zone becomes completely saturated, flow of water over the land occurs. Between rainfall events, as the stormflow zone drains, flow rates decrease dramatically and water movement becomes nearly vertical toward the underlying water table.

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

7.1.2.3 Saturated Zone Hydrology

As shown in Fig. 7.1, the saturated zone on the ORR can be divided into four vertically distinct flow zones: an uppermost water table interval, an intermediate zone, a deep zone, and an aquiclude. Available evidence indicates that most water in the saturated zone in the aquitards is transmitted through a 1- to 6-m-thick (3- to 20-ft) layer of closely spaced, well-connected fractures near the water table (the water table interval) as shown in Fig. 7.3.

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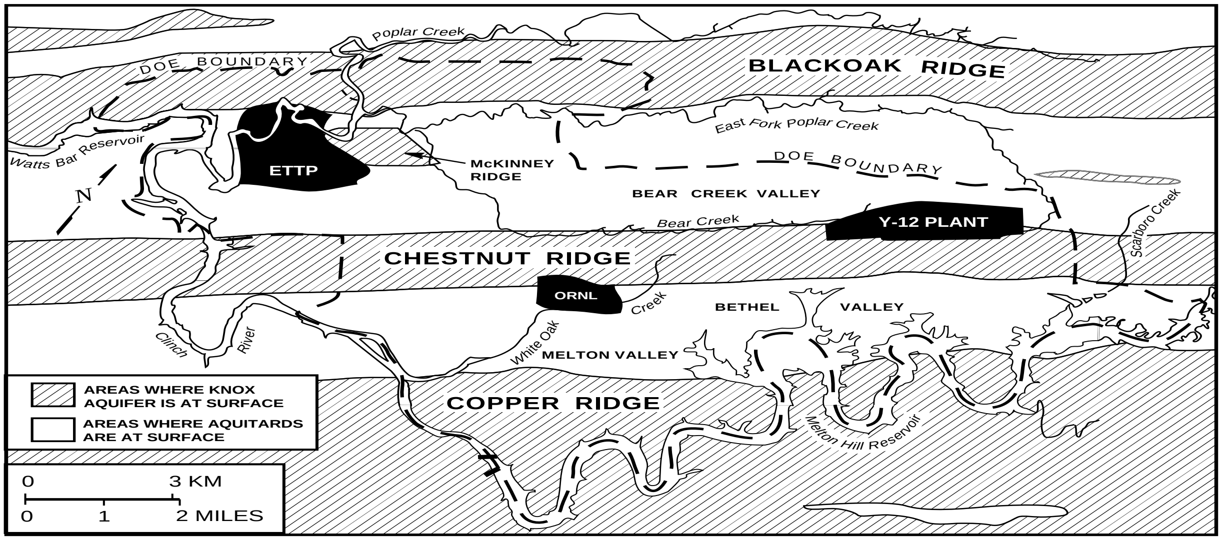

Fig. 7.2. The Knox Aquifer and the aquitards on the Oak Ridge Reservation.

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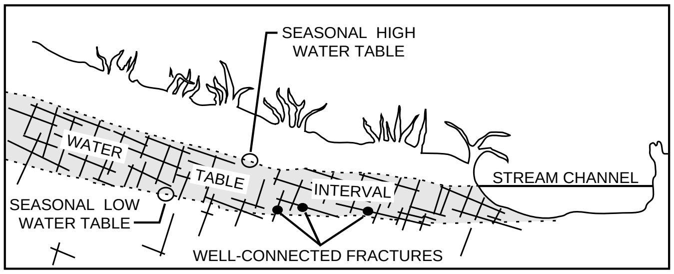

Fig. 7.3. Water table interval.

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

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

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

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

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

In the aquitards, saline water characterized by total dissolved solids ranging up to 2.75×10^5 mg/L and chlorides generally in excess of 5×10^4 mg/L (ranging up to 1.63×10^5 mg/L) lies beneath the deep interval of the groundwater zone, delineating an aquiclude. Chemically, this water resembles brines typical of major sedimentary basins, but its origin is not known. The chemistry suggests extremely long residence times (i.e., very low flow rates) and little or no mixing with shallow groundwater.

The aquiclude has been encountered at depths of 125 and 244 m (400 and 800 ft) in Melton and Bethel valleys, respectively (near ORNL), and it is believed to approach 305 m (1000 ft) in portions of BCV (near the Y-12 Plant) underlain by aquitard formations. Depth to the aquiclude in areas of the Knox Aquifer is not known but is believed to be greater than 366 m (1200 ft); depth to the aquiclude has not been established in the vicinity of the ETTP.

7.1.3 Groundwater Flow

Many factors influence groundwater flow on the ORR. Topography, surface cover, geologic structure, and rock type exhibit especially strong influence on the hydrogeology. Variations in these features result in variations of the total amount of groundwater moving through the system (flux). (Average flux ratios for the aquitards and the Knox Aquifer formations are shown in Fig. 7.1.) As an example, the overall decrease in open fracture density with depth results in a decreased groundwater flux with depth.

Topographic relief on the ORR is such that most active subsurface groundwater flow occurs at shallow depths. U.S. Geological Survey modeling (Tucci 1992) suggests that 95% of all groundwater flow occurs in the upper 15 to 30 m (50 to 100 ft) of the saturated zone in the aquitards. As a result, flow paths in the active-flow zones (particularly in the aquitards) are relatively short, and nearly all groundwater discharges to local surface water drainages on the ORR. Conversely, in the Knox Aquifer, it is believed that solution conduit flow paths may be considerably longer, perhaps as much as 1.6 km (2 miles) long in the along-strike direction. No evidence at this time substantiates the existence of any deep, regional flow off the ORR or between basins within the ORR in either the Knox Aquifer or the aquitards. Data collected in CY 1994 and 1995, however, have demonstrated that groundwater flow and contaminant transport occur off the ORR in the intermediate interval of the Knox Aquifer, near the east end of the Y-12 Plant.

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

7.1.4 Groundwater Monitoring Considerations

Because of the complexity of the hydrogeologic framework on the ORR, groundwater flow and, therefore, contaminant transport are difficult to predict on a local scale. Consequently, individual plume delineation is not always feasible on the ORR. Stormflow and most groundwater discharge to the surface water drainages on the ORR. For that reason, monitoring springs, seeps, and surface water quality is one of the best ways to assess the extent to which groundwater from a large portion of the ORR transports contaminants; however, contaminant transport may occur at depth as well. The center of mass of the VOC plume in the Maynardville Limestone east of the Y-12 Plant lies at a depth of 300 ft (91.5 m). Transport of the highest VOC concentrations occurs in this interval because VOCs are more dense than water, and there is little dilution.

7.1.5 Groundwater Monitoring Program on the ORR

The groundwater surveillance monitoring programs implemented at the DOE facilities have been designed to obtain full compliance with regulatory requirements and to meet technical objectives. Site-specific regulatory monitoring programs are supported technically by site characterization and regional studies of the geohydrologic and chemical aspects of the flow system. Monitoring at each ORR facility is coordinated through a site-level groundwater program. The site-level programs provide oversight for surveillance and effluent monitoring and coordination of monitoring required under CERCLA drivers. An integrated water quality program has been established at the DOE level to track and prioritize CERCLA monitoring across all of the ORR facilities. QC procedures for every aspect of data collection and analysis have been established, and data bases are used to organize and report analytical results.

Although the groundwater surveillance monitoring program for the ORR is disposal site- and facility-specific, it contains a number of common components that are interrelated and coordinated to allow both time- and cost-effective project management.

7.2 GROUNDWATER MONITORING AT THE Y-12 PLANT

7.2.1 Background and Regulatory Setting

Most of the groundwater monitoring at the Y-12 Plant is conducted within the scope of a single, comprehensive groundwater monitoring program, which included the following elements in 1996:

- monitoring to comply with requirements of RCRA interim-status and postclosure regulations,
- monitoring to support CERCLA RI/FS efforts and RODs,
- compliance with TDEC solid waste management (SWM) regulations,
- monitoring to support DOE Order 5400.1 requirements (exit-pathway and surveillance monitoring), and
- monitoring to support best management practices.

Through incorporation of these multiple considerations, the comprehensive monitoring program at the Y-12 Plant addresses multiple regulatory considerations and technical objectives. It eliminates redundancy between different regulatory programs and ensures consistent data collection and evaluation.

More than 200 sites have been identified at the Y-12 Plant that represent known or potential sources of contamination to the environment as a result of past waste management practices. These sites are being addressed either by the ER Program under exclusively CERCLA programs or a combination of CERCLA and RCRA regulations. The ER Program and Y-12 Plant management share responsibilities for sites regulated under dual CERCLA and RCRA drivers.

In 1992 a number of the inactive waste management sites were grouped into operable units (OUs) under CERCLA as part of an FFA negotiated between EPA, TDEC, and DOE. Two types of OUs were identified: (1) source OUs consisting of sites or groups of sites that were known sources of contamination to the environment and (2) integrator OUs consisting of media, such as groundwater, soils, and/or surface water, that had been impacted by the source OUs. An agreement was reached among regulatory agencies and DOE in 1994 to proceed with an integrated RI/FS strategy. In the integrated strategy, former source OUs and integrator OUs are addressed concurrently in a characterization area (CA) defined by physical limits, such as watershed boundaries and/or groundwater flow regimes (Fig. 7.4). Specific sites or locations of high risk or concern within the CA are targeted for focused, rapid remedial actions, while a general remedial strategy and/or administrative controls for other sites in the CA progress. Individual focused action sites are designated as OUs and documented under separate RODs.

Two CAs incorporating 27 known source units have been established for the Y-12 Plant, the UEFPC CA, and the BCV CA.

In addition, four individual source OUs remain on Chestnut Ridge, where available data indicate that contamination from each unit is distinct and separable. The remaining sites have been grouped into Y-12 Plant study areas that constitute lower-priority units that will be investigated under CERCLA as preliminary assessment/site investigations (PA/SIs). New OUs or additions to existing CAs will be made if the degree of contamination determined by the PA/SI warrants further study under an RI/FS.

Postclosure maintenance, monitoring, and reporting requirements of RCRA also apply to seven inactive CERCLA-regulated units that meet the definition of RCRA hazardous waste TSD facilities. These units include the S-3 Site, portions of the Bear Creek Burial Grounds, Oil Landfarm, New Hope Pond, Chestnut Ridge Security Pits, Chestnut Ridge Sediment Disposal Basin, and Kerr Hollow Quarry. Postclosure requirements are now outlined in RCRA postclosure permits issued by TDEC. These requirements are integrated with CERCLA programs. Corrective actions addressing contaminant releases will be deferred to the CERCLA RI/FS process. While corrective actions are progressing, the permits require focused monitoring of selected exit pathways and compliance boundaries.

Additional primary regulatory drivers for groundwater monitoring at the Y-12 Plant are the TDEC regulations governing nonhazardous SWDFs and TDEC regulations governing petroleum USTs. Two facilities (Centralized Sanitary Landfill II and Industrial Landfill IV) have been subject to groundwater monitoring under the SWDF regulations since the late 1980s. Construction of three additional landfill facilities was completed between 1993 and 1994 (Industrial Landfill V, Construction/Demolition Landfill VI, and Construction/Demolition Landfill VII). All of the landfill sites are now under a semiannual detection monitoring program. Groundwater monitoring to support the petroleum UST program at the Y-12 Plant has progressed past the assessment phase into the corrective action phase, which requires only limited monitoring and is no longer included under the comprehensive monitoring program.

Specific regulatory requirements do not address all groundwater monitoring concerns at the Y-12 Plant. Selected areas, from which contamination is most likely to migrate to potential exposure points off the ORR, are monitored as part of DOE Order 5400.1 requirements for exit-pathway monitoring. Also, monitoring is performed as part of DOE 5400.1 surveillance monitoring in areas not specifically regulated and not representing specific exit pathways off the reservation, such as a large part of the industrialized portion of the Y-12 Plant. Surveillance monitoring is conducted to monitor contaminant plume boundaries and to trend contaminant concentra-

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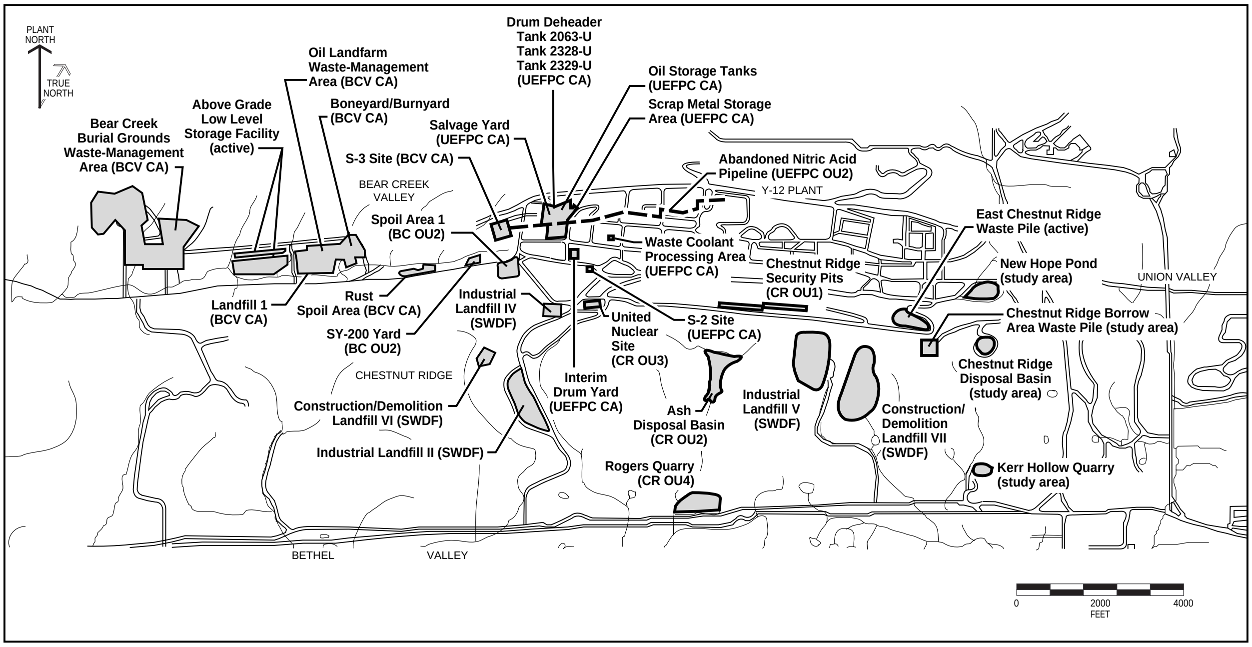

Fig. 7.4. Y-12 Plant inactive regulated units, study areas, and active facilities for which groundwater monitoring was conducted in CY 1996.

tions specifically to augment regulatory and exit-pathway monitoring programs. BMP monitoring is conducted at a number of selected sites or locations either at the request of internal organizations or of TDEC/DOEO, or in lieu of regulatory monitoring required at active facilities.

7.2.2 Hydrogeologic Setting and Summary of Groundwater Quality

In the comprehensive monitoring program, the Y-12 Plant is divided into three hydrogeologic regimes delineated by surface water drainage patterns, topography, and groundwater flow characteristics. The regimes are further defined by the waste sites they contain. These regimes include the Bear Creek Hydrogeologic Regime (Bear Creek regime), the Upper East Fork Poplar Creek Hydrogeologic Regime (East Fork regime), and the Chestnut Ridge Hydrogeologic Regime (Chestnut Ridge regime) (Fig. 7.5). Most of the Bear Creek and East Fork regimes are underlain by the ORR aquitards. The extreme southern portion of these two regimes is underlain by the Maynardville Limestone, which is part of the Knox Aquifer. The entire Chestnut Ridge regime is underlain by the Knox Aquifer.

In general, groundwater flow in the water table interval follows topography. Shallow groundwater flow in the Bear Creek and East Fork regimes is divergent from a topographic and groundwater table divide located near the western end of the Y-12 Plant. The flow directions of shallow groundwater east and west of the divide are predominantly easterly and westerly, respectively. This divide defines the boundary between the Bear Creek and Chestnut Ridge regimes. In addition, flow converges toward the primary surface streams from Pine Ridge to the north and Chestnut Ridge to the south of the Y-12 Plant. In the Chestnut Ridge regime, a groundwater table divide exists that approximately coincides with the crest of the ridge. Shallow groundwater flow, therefore, tends to be toward either flank of the ridge, with discharge primarily to surface streams and springs located in Bethel Valley to the south and BCV to the north.

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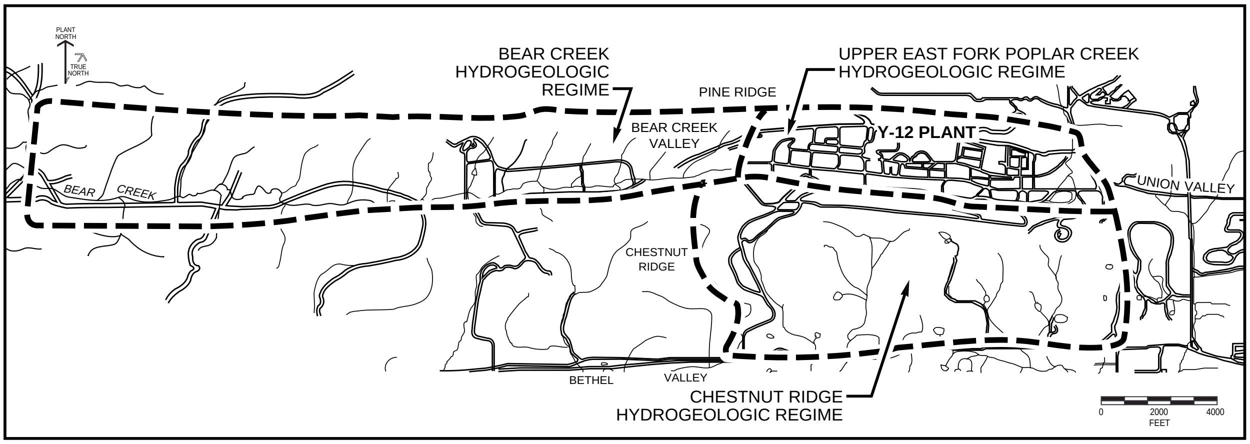

Fig. 7.5. Hydrogeologic regimes at the Y-12 Plant.

In BCV, groundwater in the intermediate and deep intervals moves predominantly through fractures in the ORR aquitards, converging toward and moving through fractures and solution conduits in the Maynardville Limestone. Karst development in the Maynardville Limestone has a significant impact on groundwater flow paths in the water table and intermediate intervals. In general, groundwater flow parallels geologic strike. Groundwater flow rates in BCV vary widely; they are very slow within the deep interval of the ORR aquitards but can be quite rapid within solution conduits in the Maynardville Limestone.

The rate of groundwater flow perpendicular to geologic strike from the ORR aquitards to the Maynardville Limestone has been estimated to be very slow below the water table interval. Most contaminant migration appears to be via surface tributaries to Bear Creek or along utility traces and buried tributaries in the East Fork regime. Recent data obtained as part of hydrologic studies in the Bear Creek regime suggest that strike-parallel transport of some contaminants can occur within the ORR aquitards for significant distances. Continuous elevated levels of nitrate within the ORR aquitards are now known to extend west from the S-3 Site for a distance of about 3000 ft, approximately twice the previous estimates. VOCs at source units in the ORR aquitards, however, tend to remain close to source areas because they tend to adsorb to the bedrock matrix, diffuse into pore spaces within the matrix, and degrade prior to migrating to exit pathways, where rapid transport for long distances can occur.

Groundwater flow in the Chestnut Ridge regime is almost exclusively through fractures and solution conduits in the Knox Group. Discharge points for intermediate and deep flow are not well known. Groundwater is currently presumed to flow primarily toward BCV to the north and Bethel Valley to the south. Groundwater from intermediate and deep zones may discharge at certain spring locations along the flanks of Chestnut Ridge. Along the crest of the ridge, water table elevations decrease from west to east, demonstrating an overall easterly trend in groundwater flow.

Historical monitoring efforts have shown that groundwater quality at the Y-12 Plant has been affected by four types of contaminants: nitrate, VOCs, metals, and radionuclides. Of these, nitrate and VOCs are the most widespread, although data obtained since 1988 show that the extent of some radionuclides, particularly ^{99}Tc is also significant, particularly in the Bear Creek regime. Trace metals, the least extensive groundwater contaminants, generally occur in a small area of low-pH groundwater at the west end of the Y-12 Plant, in the vicinity of the S-3 Site. Historical data have shown that plumes from multiple source units have mixed with one another and that contaminants (other than nitrate and possibly ^{99}Tc) are no longer easily associated with a single source.

7.2.3 1996 Well Installation and Plugging and Abandonment Activities

A number of monitoring devices are routinely used for groundwater data collection at the Y-12 Plant. Monitoring wells are permanent devices used for collection of groundwater samples; these are installed according to established regulatory and industry specifications. Piezometers are primarily temporary devices used to measure groundwater table levels and are often constructed of PVC or other low-cost materials. Other devices or techniques are sometimes employed to gather data, including well points and push probes.

One new monitoring well was installed in CY 1996 southwest of the Chestnut Ridge Security Pits for compliance monitoring. Eight piezometers were installed in the vicinity of the S-3 Site and Oil Landfarm waste management area to gather additional data on groundwater table levels. One specially designed, large diameter shallow well was installed near New Hope Pond for conducting aquifer characterization and evaluating the feasibility of groundwater extraction and treatment.

The Y-12 Plant GWPP conducts well plugging and abandonment activities as part of an overall program to maintain the Y-12 Plant monitoring well network. Wells that are damaged beyond rehabilitation, that interfere with planned construction activities, or from which no useful data can be obtained, are selected for plugging and abandonment. In 1996, 32 wells were plugged and abandoned. These wells were located along lower EFPC, at the Ash Disposal Basin, and in the extreme western portion of the Bear Creek regime. The wells were plugged and abandoned because they impeded remedial actions, were in poor condition, had a historical lack of security or identity, or had no identifiable future use.

7.2.4 1996 Monitoring Program

Groundwater monitoring in 1996 addressed multiple requirements from regulatory drivers, DOE orders, and BMPs. Table 7.1 contains a summary of monitoring activities conducted by the Y-12 Plant GWPP, as well as the programmatic requirements that apply to each site.

Figure 7.6 shows the locations of ORR perimeter monitoring stations as specified in the EMP.

Detailed data reporting for monitoring activities conducted by the Y-12 Plant GWPP is contained within the annual groundwater monitoring reports for each hydrogeologic regime (LMES 1997b, 1997c, and 1997d). Details of small-scale monitoring efforts performed outside the scope of the comprehensive monitoring program specifically for CERCLA OUs are published in RI reports.

7.2.5 Y-12 Plant Groundwater Quality

7.2.5.1 Upper East Fork Poplar Creek Hydrogeologic Regime

The 1996 monitoring locations, waste management sites, and petroleum fuel USTs in the East Fork regime that are addressed in this document are shown in Fig. 7.7. Regulatory status of waste management sites in the East Fork Regime is summarized on Fig. 7.4. Brief descriptions of the waste management sites are presented in Table 7.2. Detailed operational histories of these sites have been published in previous ORR ASERs.

The East Fork Regime contains the UEFPC CA, which consists of source units, surface water, and groundwater components of the hydrogeologic system within the East Fork regime and Union Valley to the east of the Y-12 Plant. Numerous sources of contamination to both surface water and groundwater exist within the

Table 7.1. Summary of the comprehensive groundwater monitoring program at the Y-12 Plant, 1996[a]

Hydrogeologic regime/waste disposal site	Requirements[b]	Number of wells/locations
Bear Creek Hydrogeologic Regime		
Bear Creek Springs	EXP	3
Bear Creek surface water	EXP	8
Maynardville Limestone	EXP/RCRA-CM	21
Oil Landfarm	RCRA-CM/SMP	9
Rust Spoil Area	SMP	1
S-3 Site	RCRA-CM	4
Spoil Area I	SMP	1
Y-12 Burial Grounds	RCRA-CM/SMP	14
Above-Grade Low-Level Storage Facility	BMP	3
East Fork Poplar Creek Hydrogeologic Regime		
Springs/Seeps	EXP/RIFS	2
Maynardville Limestone	EXP/RCRA-CM	10
Scarboro Road north of Y-12	EXP	3
S-3 Site Eastern Plume	RCRA-CM	2
Y-12 Plant –Active Facilities –S-2 Site –Rust Garage –Waste Coolant Area –Salvage Yard –Fire Training Facility –Beta-4 Security Pits –Grid Network	SMP/BMP/RIFS	47
New Hope Pond	RCRA-AM/SMP	13
Union Valley	EXP/RIFS	10
UEFPC Diversion Channel	RIFS	1
Chestnut Ridge Hydrogeologic Regime		
Springs	EXP	1
Surface Water	ROD	1
Ash Disposal Basin	BMP	4
Chestnut Ridge Security Pits	RCRA-AM/CM	11
East Chestnut Ridge Waste Pile	BMP	4
Kerr Hollow Quarry	RCRA-DM	7
Landfill II	SWDF	3
Chestnut Ridge Borrow Area Waste Pile	BMP	6

Table 7.1 (continued)

Hydrogeologic regime/waste disposal site	Requirements[b]	Number of wells/locations
Landfill IV	SWDF	5
Landfill V	SWDF	4
Landfill VI	SWDF	7
Landfill VII	SWDF	6
Rogers Quarry	BMP	4
Sediment Disposal Basin	RCRA-DM	4
United Nuclear Site	ROD	6

[a] Baseline analytical parameters include ICP metals scan; U (total), thallium, Pb, and As by plasma mass spectroscopy; Hg; VOCs; major anions; gross alpha; gross beta; pH; conductance; TSS; TDS; turbidity; and standard field parameters, including dissolved oxygen, water level, pH, temperature, conductance, and redox potential. RCRA corrective action monitoring in the Bear Creek regime includes ^{241}Am, ^{129}I, ^{237}Np, ^{238}Pu, total radium, total strontium, ^{99}Tc, ^{3}H, ^{234}U, ^{235}U, and ^{238}U. SWDF monitoring required by TDEC Rule 1200-1-7-.04 includes chemical oxygen demand, cyanide, total organic carbon (TOC), total organic halides (TOX), ammonia (as N), gamma activity, and additional VOC list required by TDEC Rule 1200-1-7-.04. Analyte lists for some sites were tailored to meet specific programmatic, technical, or regulatory requirements.

[b] BMP = best management practices monitoring; EXP = exit-pathway or perimeter monitoring under DOE Order 5400.1; RCRA-AM = RCRA Assessment Monitoring at interim status units; RCRA-DM = RCRA Detection Monitoring; RCRA-CM = RCRA post-closure corrective action monitoring; SMP = DOE Order 5400.1 surveillance monitoring; SWDF = monitoring for solid waste disposal facilities under TDEC Rule 1200-1-7.04; ROD = CERCLA record of decision postclosure monitoring; RIFS = CERCLA remedial investigation monitoring.

plant area. Chemical constituents from the S-3 Site dominate groundwater contamination in the western portion of the UEFPC CA. In addition to potential surface water and groundwater contamination sources identified as OUs, a majority of the Y-12 study areas are within the East Fork regime. Potential surface-water contamination associated with the storm sewer system and East Fork mercury use areas is of primary interest and will also be addressed in the UEFPC CA RI/FS.

Discussion of Monitoring Results

The objectives of the 1996 groundwater monitoring program in the East Fork regime were (1) to further define contaminant nature and extent, (2) to evaluate potential contaminant exit pathways for both CERCLA RI and RCRA postclosure technical objectives, and (3) to trend contaminant levels over time. Locations of monitoring stations are shown in Fig. 7.7.

Plume Delineation

As denoted in previous ORR ASERs, the primary groundwater contaminants in the East Fork regime are nitrate, VOCs, trace metals, and radionuclides. Sources of nitrate, trace metals, and radionuclides are the S-2 Site, the Abandoned Nitric Acid Pipeline, and the S-3 Site. Although it is located west of the current hydrologic divide that separates the East Fork regime from the Bear Creek regime, the S-3 Site has contributed to groundwater contamination in the western part of the regime during its operation. Sources of VOCs in the East Fork regime include the S-3 Site,

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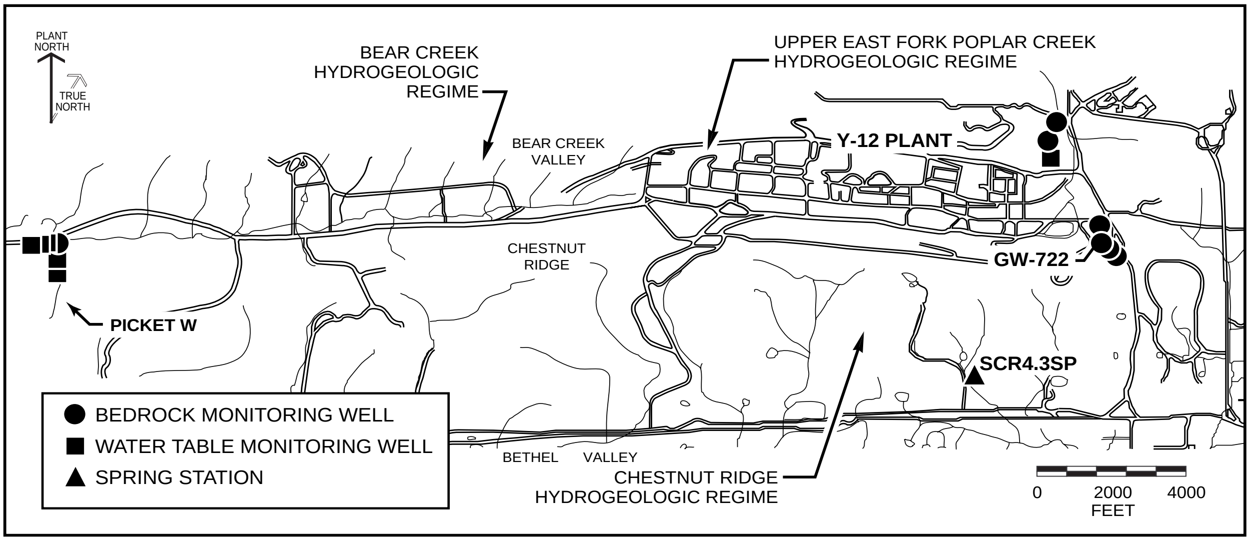

Fig. 7.6. Locations of ORR perimeter surveillance wells and multiport monitoring wells specified in the *Environmental Monitoring Plan (Rev. 1)*. Well GW-722 is a multiport monitoring well that is also designated as a perimeter surveillance well.

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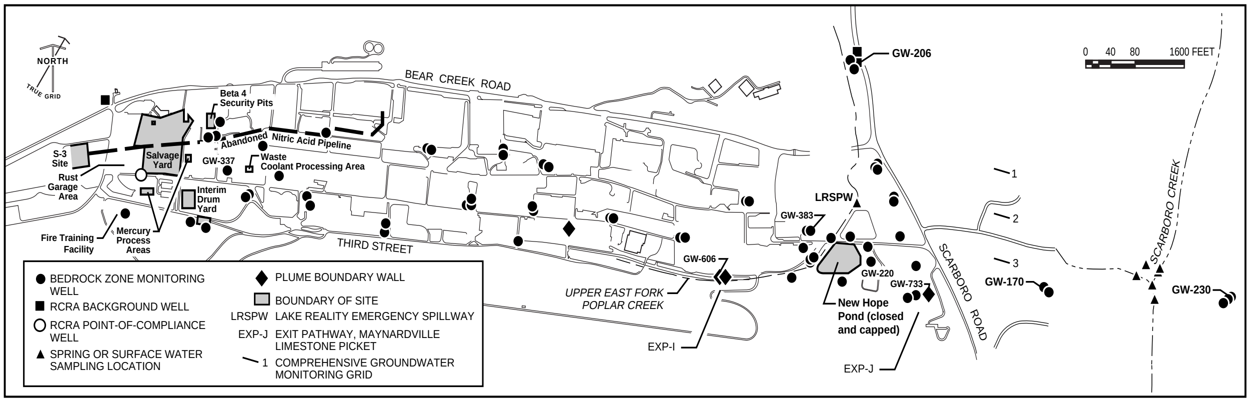

Fig. 7.7. Locations of waste management sites and monitoring wells sampled during 1996 in the Upper East Fork Poplar Creek Hydrogeologic Regime.

several sites located within the Y-12 Salvage Yard, the Waste Coolant Processing Area, petroleum USTs, and process/production buildings in the plant.

Nitrate

Nitrate concentrations exceed the 10 mg/L maximum contamination level in a large part of the western portion of the East Fork regime (Fig. 7.8). (A complete list of DWSs is presented in Appendix D.) Groundwater containing nitrate concentrations as high as 10,000 mg/L occurs in the unconsolidated zone and at shallow bedrock depths just east of the S-3 Site.

The extent of the nitrate plume is essentially defined in the unconsolidated zone and the shallow bedrock zone. In both zones, the nitrate plume extends about 2500 ft (762.5 m) eastward from the S-3 Site to just downgradient of the S-2 Site. Nitrate has traveled farthest in groundwater in the Maynardville Limestone. Although the nitrate

Table 7.2. Regulatory status and operational history of waste management units and underground storage tanks included in the 1996 Comprehensive Groundwater Monitoring Program; Upper East Fork Poplar Creek Hydrogeologic Regime

Site	Historical/current regulatory classification[a]	Historical data
New Hope Pond	TSD/Study Area	Built in 1963. Regulated flow of water in UEFPC before exiting the Y-12 Plant grounds. Sediments include PCBs, mercury, and uranium but not hazardous according to toxicity characteristic leaching procedure. Closed under RCRA in 1990.
Abandoned Nitric Acid Pipeline	SWMU/UEFPC OU2	Used from 1951 to 1983. Transported liquid nitric acid wastes and dissolved uranium from Y-12 Plant process areas to the S-3 Site. Leaks were the release mechanisms to groundwater. A CERCLA ROD has been issued.
Salvage Yard Scrap Metal Storage Area	SWMU/UEFPC CA	Used from 1950 to present for scrap metal storage. Some metals contaminated with low levels of depleted or enriched uranium. Runoff and infiltration are the principal release mechanisms to groundwater.
Salvage Yard Oil/ Solvent Drum Storage Area	SWMU/UEFPC CA	Primary wastes included waste oils, solvents, uranium, and beryllium. Both closed under RCRA. Leaks and spills represent the primary contamination mechanisms for groundwater.
Salvage Yard Oil Storage Tanks	SWMU/UEFPC CA	Used from 1978 to 1986. Two tanks used to store PCB-contaminated oils, both within a diked area.
Salvage Yard Drum Deheader Facility	SWMU/UEFPC CA	Used from 1959 to 1989. Sump tanks 2063-U, 2328-U, and 2329-U received residual drum contents. Sump leakage is a likely release mechanism to groundwater.
S-2 Site	SWMU/UEFPC CA	Used from 1945 to 1951. An unlined reservoir received liquid wastes. Infiltration is the primary release mechanism to groundwater.
Waste Coolant Processing Area	SWMU/UEFPC CA	Former biodegradation facility used to treat waste coolants from various machining processes. Closed under RCRA in 1988.
Building 81-10 Area	NA/UEFPC CA	Staging facility. Potential historical releases to groundwater from leaks and spills of liquid wastes or mercury.
Coal Pile Trench	SWMU/UEFPC CA	Located beneath the current steam plant coal pile. Disposals included solid materials (primarily alloys). Trench leachate is a potential release mechanism to groundwater.

Table 7.2 (continued)

Site	Historical/current regulatory classification[a]	Historical data
Interim Drum Yard	SWMU/Study Area	Diked outdoor storage area once used to store drums of liquid and solid wastes. Partially closed under RCRA in 1988 and 1996. Further action deferred to CERCLA.
Beta-4 Security Pits	SWMU/Study Area	Used from 1968 to 1972 for disposal of classified materials, scrap metals, and liquid wastes. Site is closed and capped. Primary release mechanism to groundwater is infiltration.
Rust Garage Area	UST/Study Area	Former vehicle and equipment maintenance area, including four former petroleum USTs. Petroleum product releases to groundwater are documented.
Garage Underground Tanks	SWMU/Study Area	Fuel USTs used from 1944 to 1978. Converted to waste oil storage in 1978; removed in 1989. Petroleum and waste oil leaks represent probable releases to groundwater. The unit was clean-closed under RCRA in 1995.

[a] Regulatory status before the 1992 Federal Facility Agreement: TSD-RCRA—regulated, land-based treatment, storage, or disposal unit; SWMU—RCRA-regulated solid waste management unit; and UST—petroleum underground storage tank. Current regulatory status: study area—Y-12 Plant study area; UEFPC OU2—Upper East Fork Poplar Creek Operable Unit 2; UEFPC CA—Upper East Fork Poplar Creek Characterization Area.

plume is dispersing and moving eastward, concentrations near the source have been trending downward since disposal operations ceased and the site was closed and capped.

Trace Metals

Concentrations of barium, cadmium, chromium, and lead exceeded MCLs during 1996 in samples collected from various monitoring wells at the S-2 Site, the Y-12 Salvage Yard, the Waste Coolant Processing Area, exit-pathway wells, and upgradient of New Hope Pond. Elevated concentrations of these metals were most commonly reported for groundwater samples collected from monitoring wells in the unconsolidated zone. A definable plume of elevated metals contaminants is not present; metals above maximum contaminant levels tend to occur adjacent to the source units.

Volatile Organic Compounds

Because of the many source areas, VOCs are the most widespread groundwater contaminants in the East Fork regime. Dissolved VOCs in the regime generally consist of two types of compounds: chlorinated solvents and petroleum hydrocarbons. The highest concentrations of dissolved chlorinated solvents (about 12 mg/L) are found at the Waste Coolant Processing Area and Y-12 Salvage Yard. The highest dissolved concentrations of petroleum hydrocarbons (about 60 mg/L) occur in groundwater near the Rust Garage Area.

Concentrations of chlorinated VOCs in the vicinity of source areas have remained relatively constant or have decreased since 1988 (Fig. 7.9). Within the exit pathway on the east end of the regime, some monitoring locations (e.g., GW-220 and GW-733) east of New Hope Pond, have

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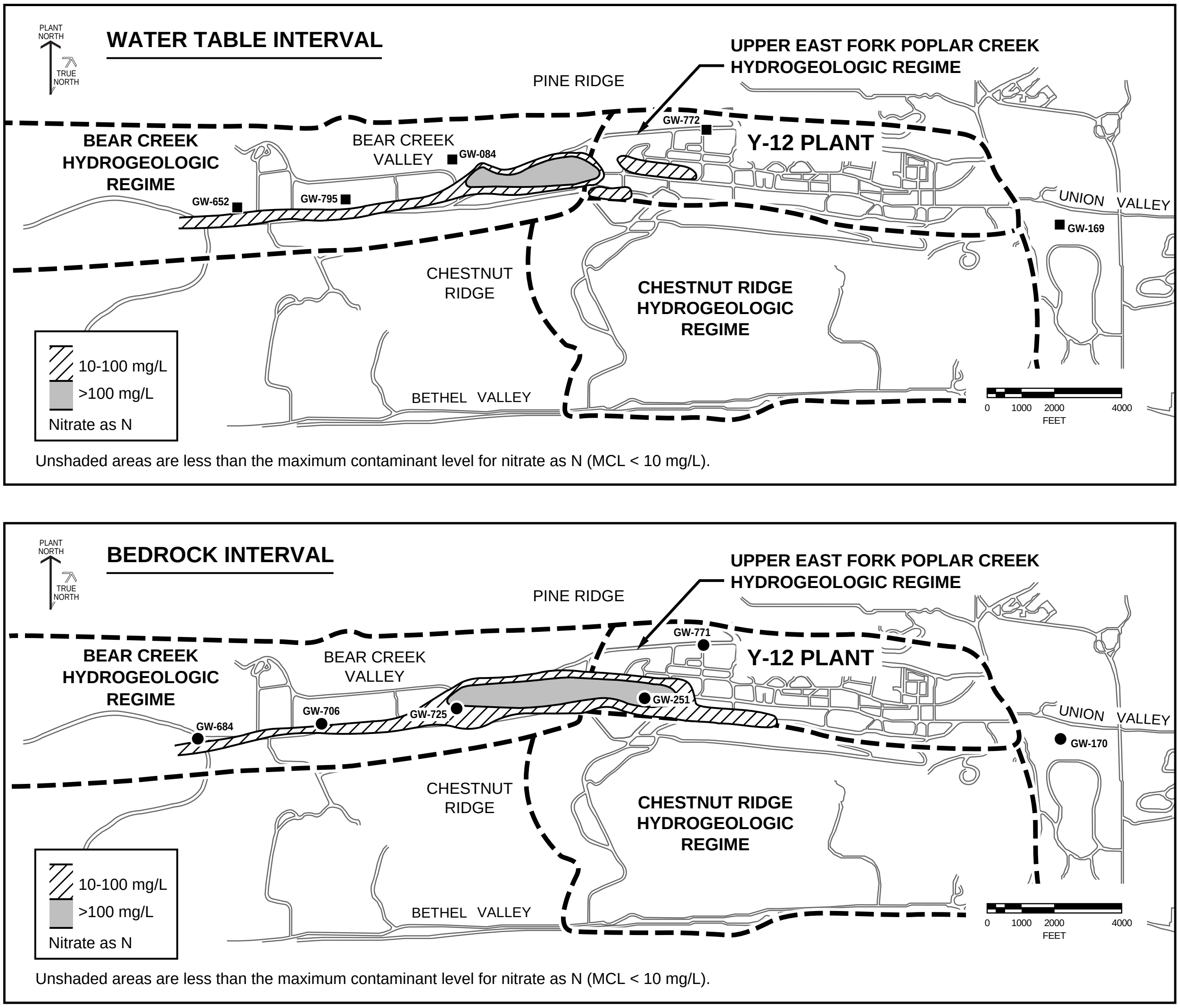

Fig. 7.8. Nitrate (as N) observed in groundwater at the Y-12 Plant.

shown increasing VOC concentrations, indicative of an easterly movement of part of the plume (Fig. 7.10). Data show that VOCs are the most extensive in shallow groundwater; however, data indicate that when contaminants migrate into the Maynardville Limestone, they tend to concentrate at depths between 100 and 500 ft. The highest VOC concentrations appear to be between 200 and 500 ft, as exemplified by vertical carbon tetrachloride distribution at the east end of the Y-12 Plant (Fig. 7.11).

The 1996 monitoring results generally confirm findings from the previous five years of monitoring. A continuous dissolved VOC plume in groundwater in the bedrock zone extends eastward from the S-3 Site over the entire length of the regime (Fig. 7.12). The primary sources are the Waste Coolant Processing Facility, the Building 9754 and 9754-2 fuel facilities, and process areas in the central portion of the plant.

Chloroethene compounds (perchloroethene, trichloroethene, dichloroethene, and vinyl chloride) tend to dominate the VOC plume composition in the western and central portions of the Y-12 Plant. However, perchloroethene and isomers of dichloroethene are almost ubiquitous

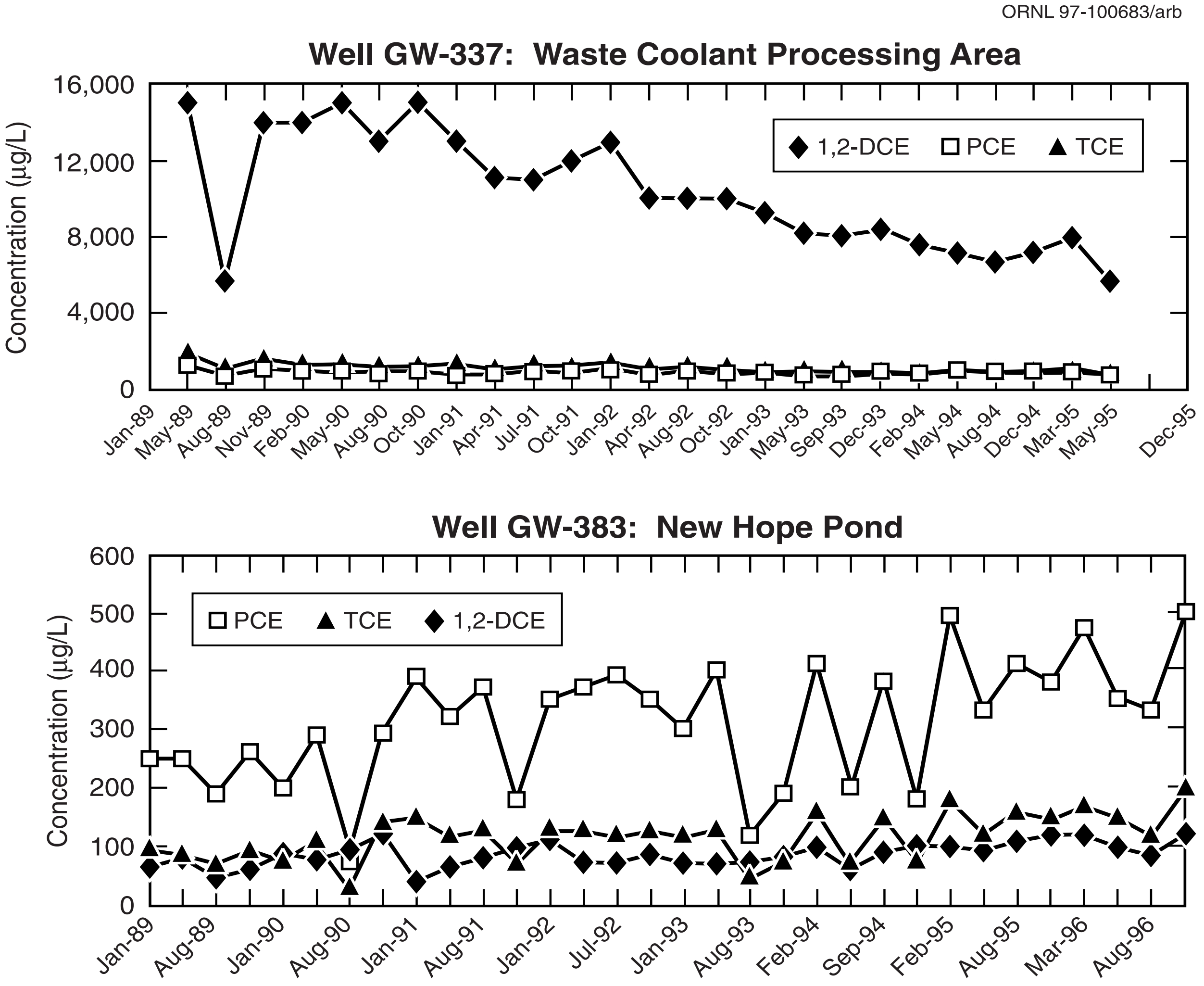

Fig. 7.9. Quarterly VOC concentrations in groundwater in selected wells in East Fork regime. 1,2-DCE: 1,2-dichloroethene; PCE; perchloroethene; TCE: trichloroethene.

throughout the extent of the VOC plume, indicating many source areas. Chloromethane compounds (carbon tetrachloride, chloroform, and methylene chloride) are the predominant VOCs in the eastern and southeastern portions of the plant.

Radionuclides

As in the Bear Creek regime, the primary alpha-emitting radionuclides found in the East Fork regime are isotopes of uranium, radium, neptunium, and americium. The primary beta-emitting radionuclide is technetium.

Groundwater with gross alpha activity greater than 15 pCi/L occurs in scattered areas throughout the East Fork regime (Fig. 7.13). Historical data show that gross alpha activity that consistently exceeds the MCL for drinking water (annual average activity level of 15 pCi/L) is most extensive in groundwater in the unconsolidated zone in the western portion of the Y-12 Plant near the S-3 site. Surveillance data also show that gross beta activity levels remained elevated well above the MCL in the western portion of the plant. An area of elevated gross alpha activity is also present west of New Hope Pond. Sporadic gross alpha activity was also observed in several shallow

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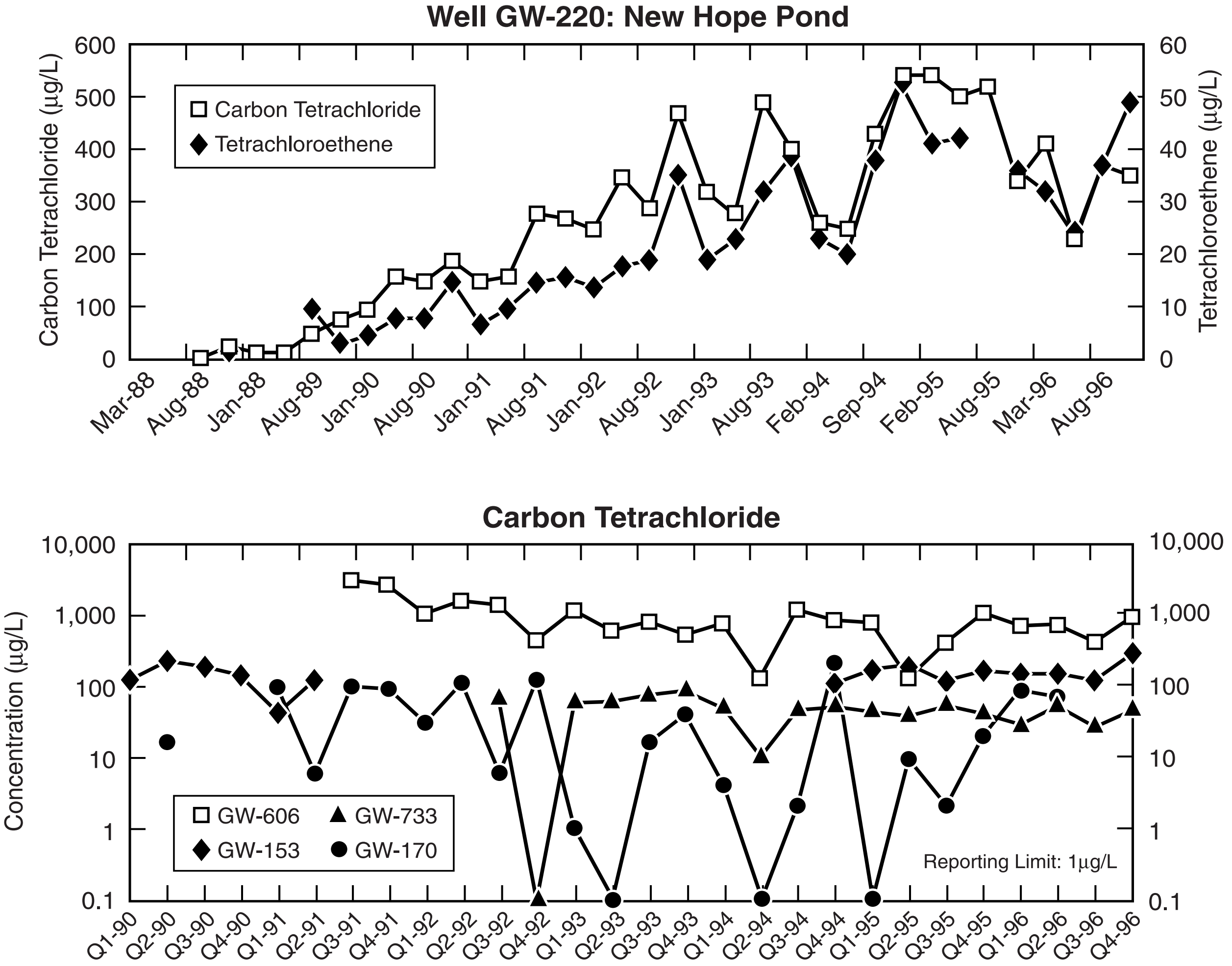

Fig. 7.10. Quarterly VOC concentrations in selected wells near New Hope Pond and exit-pathway wells.

wells scattered across the East Fork regime. Erratic data distribution, coupled with high turbidity and TSS content in samples from most of the wells, indicates that these sporadic values are false positives.

Elevated gross beta activity in groundwater in the East Fork regime shows a pattern similar to that observed for gross alpha activity (Fig. 7.14). In general, gross beta activity consistently exceeds the annual average MCL of 50 pCi/L in groundwater in the western portion of the regime, with the primary source being the S-3 Site. Also, consistent with historical patterns, elevated gross beta activity was observed in an area immediately west of New Hope Pond within the Maynardville Limestone. Elevated sporadic gross alpha and beta activity observed in 1994 in off-site exit-pathway wells GW-169 and GW-170, located in Union Valley, was not observed during 1995 or 1996.

Exit-Pathway and Perimeter Monitoring

Exit-pathway groundwater monitoring activities in the East Fork regime in 1996 involved continued collection and trending of data from exit-pathway monitoring stations. In addition, data collected under the scope of the UEFPC remedial investigation (RI) were integrated into evaluations of contaminant exit pathways. The RI effort included sampling of springs, seeps, surface

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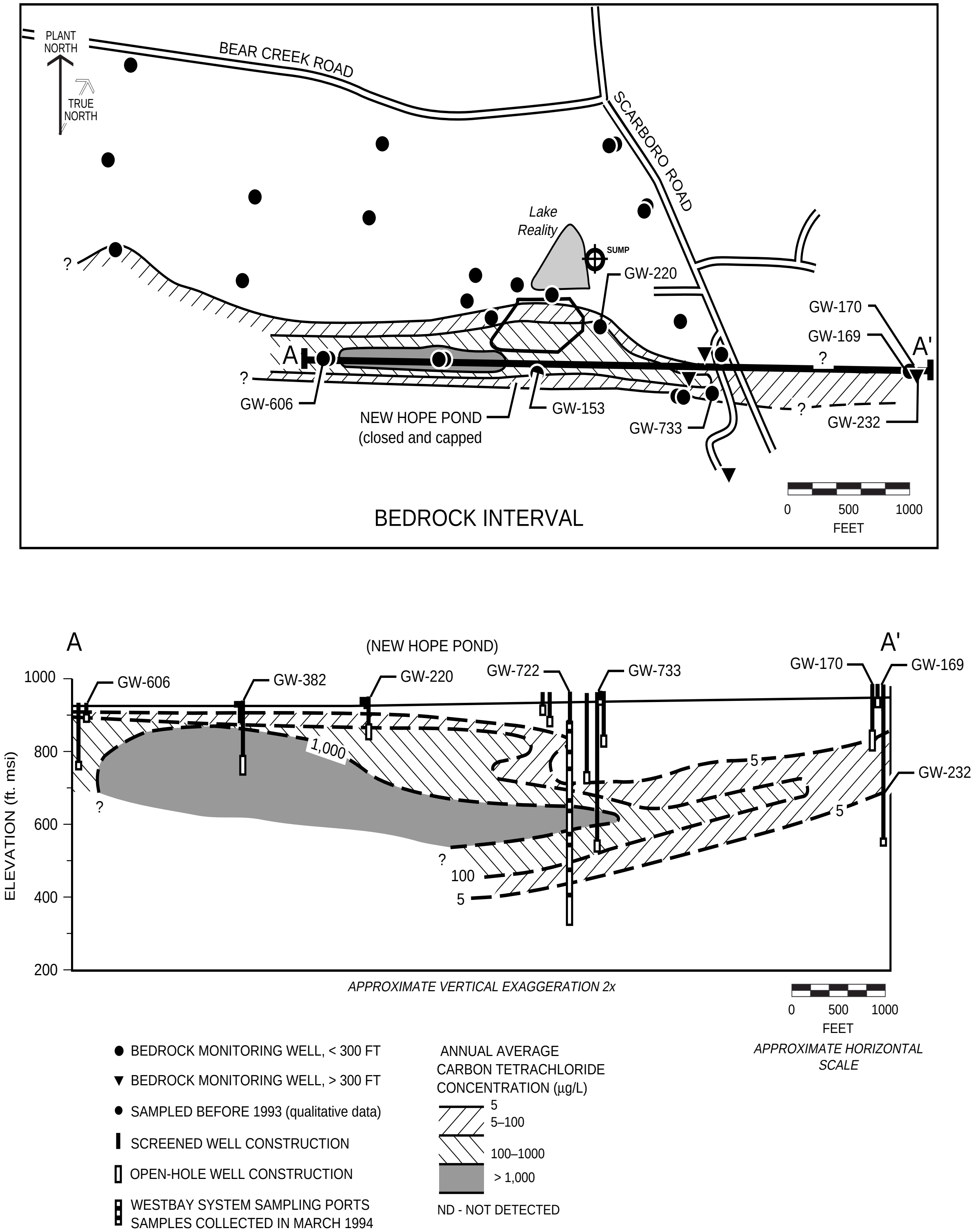

Fig. 7.11. VOC concentrations in Maynardville Limestone at depths between 200 and 500 ft.

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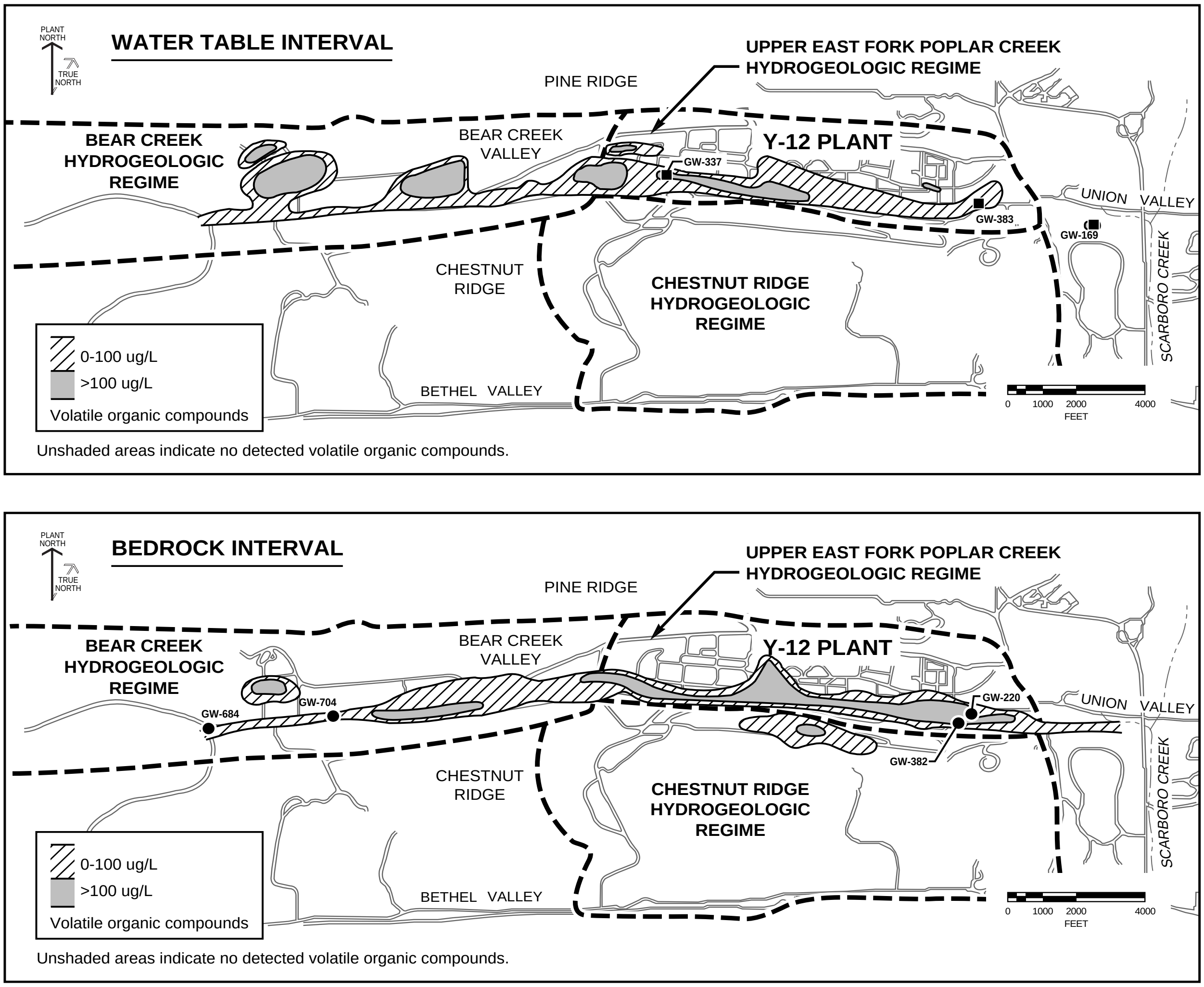

Fig. 7.12. Summed VOCs in groundwater at the Y-12 Plant.

water, and wells in Union Valley and a few selected locations within the Y-12 Plant. Surface water quality in UEFPC is regularly monitored in accordance with NPDES permits, and the results are summarized in Chap. 4.

Data collected to date indicate that VOCs are the primary class of contaminants that are migrating through the exit pathways in the East Fork regime. The VOCs are migrating predominantly at depths between 200 and 500 ft and appear to be restricted to the Maynardville Limestone. An aerial distribution of VOCs is shown in Fig. 7.12. A vertical profile of VOC contamination is depicted in Fig. 7.11. Concentrations of VOCs are typically higher at depth because most dilution and mixing with rainfall occurs in the shallow portions of the Maynardville limestone. In addition, the majority of the VOCs are more dense than water; therefore, they tend to migrate downward within the subsurface. The deep fractures and solution channels that constitute flowpaths within the Maynardville Limestone appear to be well connected. The characteristics of the flowpaths combined with the chemical characteristics of the contaminants have resulted in migration for substantial distances off the ORR into Union Valley to the east of the Y-12 Plant. The EMP specifies monitoring of three wells near the eastern ORR boundary for this exit pathway (Fig. 7.6).

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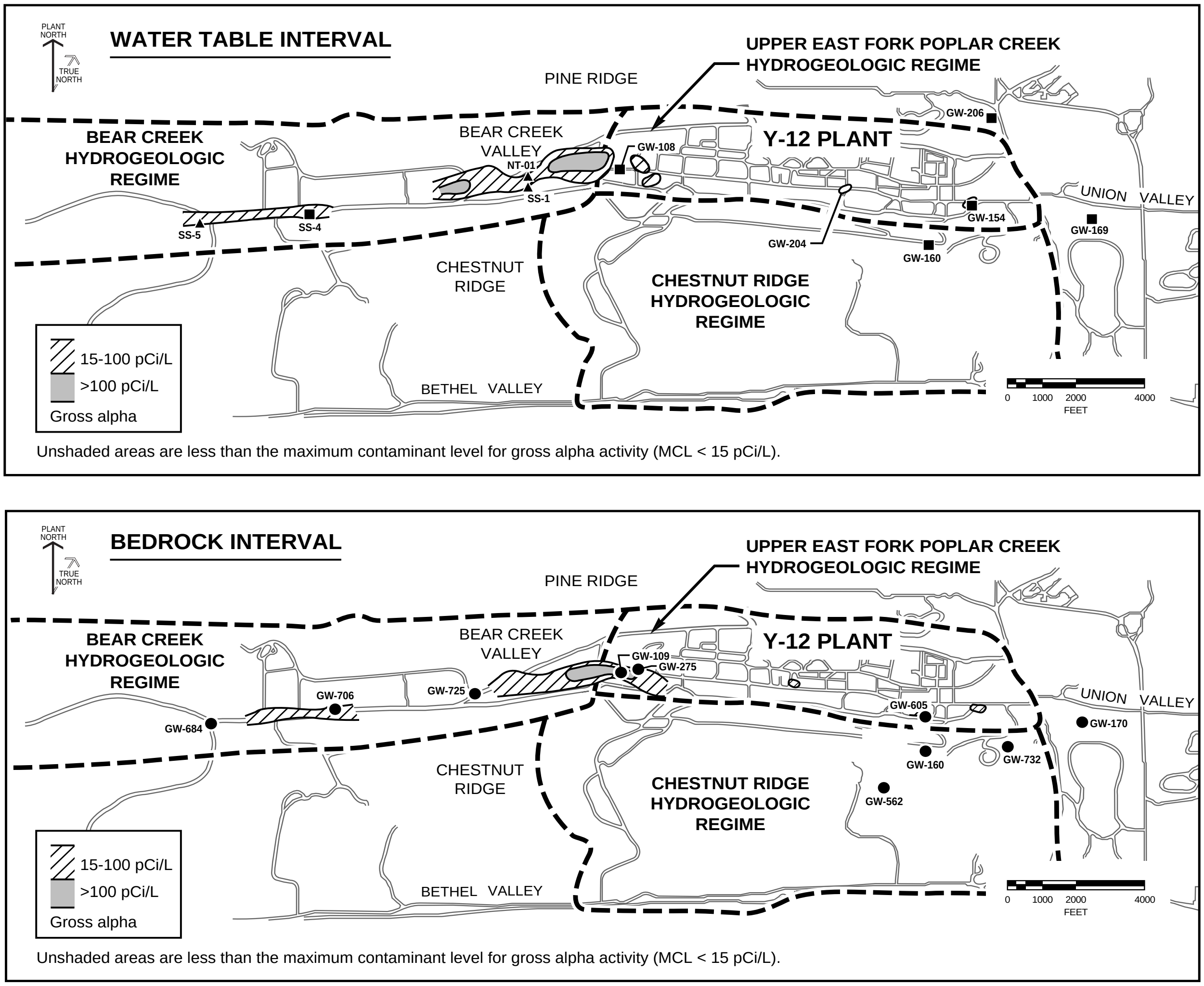

Unshaded areas are less than the maximum contaminant level for gross alpha activity (MCL < 15 pCi/L).

Unshaded areas are less than the maximum contaminant level for gross alpha activity (MCL < 15 pCi/L).

Fig. 7.13. Gross alpha activity in groundwater at the Y-12 Plant.

In addition to the deep pathways within the Maynardville Limestone, two other groundwater exit pathways are also monitored. The first of these is a gravel fill material that was emplaced beneath a concrete diversion channel for UEFPC constructed in the late 1980s. The diversion channel runs from the eastern portion of the Y-12 Plant to the east of New Hope Pond and discharges to Lake Reality. The gravel fill is located within the water table interval and is highly permeable. Part of the monitoring actions for the UEFPC RI have focused on this exit pathway. Monitoring results from a well installed into the fill and seepage points at its terminus showed low but consistent carbon tetrachloride levels. Thus, the diversion channel acts as a preferential pathway for groundwater and contaminant migration.

Groundwater movement and contaminant migration along the diversion channel also appear to be accelerated by the effects of a large dewatering sump located near Lake Reality. Past studies have shown that when this sump is activated, groundwater table levels are lowered over a large area and contaminant levels in the sump discharge increase over time. Thus, operation of the dewatering sump has been kept to minimal levels with monitoring of discharge when operation is required. Shallow to intermediate depth wells located in this area (well GW-220) show

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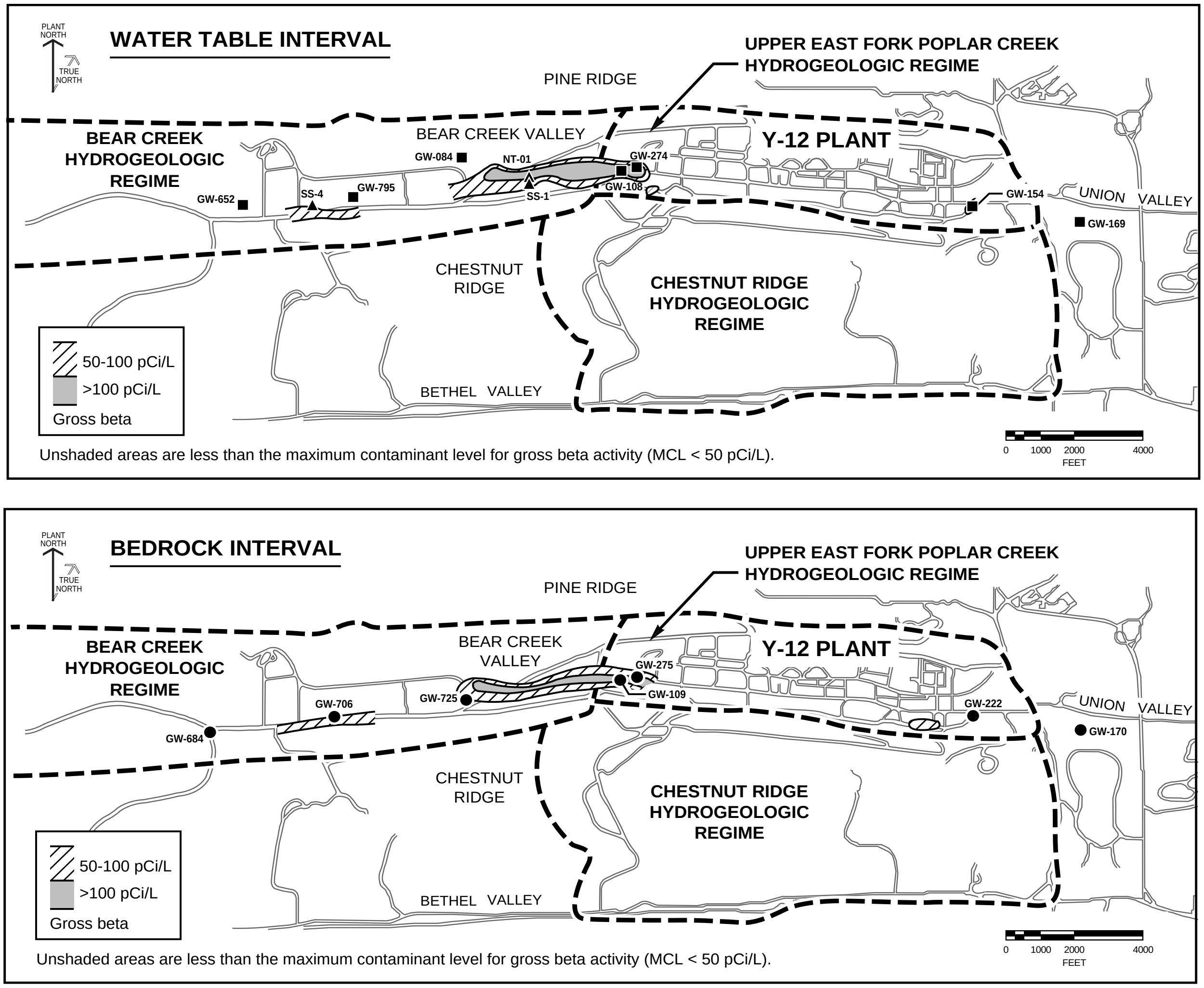

Fig. 7.14. Gross beta activity in groundwater at the Y-12 Plant.

increasing concentrations of VOCs over time (Fig. 7.10).

The second exit pathway that is monitored is the large gap in Pine Ridge through which UEFPC exits the Y-12 Plant. Three wells are located in this water gap that monitor shallow, intermediate, and deep groundwater intervals; these wells are monitored under the scope of the EMP. Shallow groundwater moves through this exit pathway and very strong upward vertical flow gradients exist; two of the three wells located in this area are strongly artesian. Monitoring since about 1990 has shown no contaminants moving via this exit pathway.

7.2.5.2 Union Valley Focus Study

Groundwater monitoring data obtained in 1993 provided the first strong indication that VOCs were being transported off the ORR through the deep Maynardville Limestone exit pathway. The 1995 ASER provided a discussion of the nature and extent of the VOCs and short-term response actions taken. In 1996, monitoring of numerous locations continued under the lead of the ER Program. These data showed no significant changes in the types and concentrations of contaminants comprising the groundwater contaminant plume in Union Valley.

The current conceptual model for Union Valley suggests that Scarboro Creek (Fig. 7.12) functions as a shallow (and possible intermediate) groundwater divide. Contaminants appear to be upwelling under the influence of vertical gradients and discharging at low concentrations to several springs and possibly within the creek channel itself. Under the terms of an interim proposed plan, administrative controls, such as restriction of potential future groundwater use, have been established. Long-term remedial actions in this area will be addressed along with those for the entire UEFPC CA in conjunction with DOE, TDEC, EPA, and the public.

7.2.5.3 Bear Creek Hydrogeologic Regime

Located west of the Y-12 Plant in BCV, the Bear Creek regime is bounded to the north by Pine Ridge and to the south by Chestnut Ridge. The regime encompasses the portion of BCV extending from the west end of the Y-12 Plant to Highway 95. Figures 7.15 and 7.16 show the Bear Creek regime, locations of stations sampled in 1996, and the locations of its waste management sites. The BCV CA lies within the regime and includes all source units, groundwater, surface water, and soils/sediments, with the exception of the SY-200 Yard and Spoil Area I, which are separate actions (Fig. 7.4; Table 7.3).

Characterization of the nature and extent of contamination in the regime is essentially complete. A draft RI report has been issued to TDEC and EPA for technical review and comment. Upon completion of the regulatory agency review and incorporation of comments, the document will be released for public use. The RI report will contain a detailed description of site history, nature and extent of contamination, and human health and ecological risk assessments.

As the next step in the CERCLA process, remedial actions under the scope of a feasibility study will be evaluated and initiated where sufficient data exist to identify acceptable alternatives. Where data gaps exist preventing full evaluation of remedial alternatives, focused studies with limited scopes and short durations will be completed to obtain the specific data required to fully evaluate potential remedial actions.

Currently, the focus . of monitoring efforts is RCRA postclosure corrective action monitoring, exit-pathway monitoring, and surveillance of contaminant plume boundaries. These objectives were met by sampling of a composite monitoring network of 53 wells, 3 springs, and 8 surface water locations specified by the RCRA postclosure permit, the ORR EMP, and primary exit-pathway and surveillance-monitoring points. The network was sampled at a baseline semiannual frequency. Any future monitoring requirements dictated by CERCLA RODs issued for the BCV CA will be integrated into the long-term corrective action/surveillance-monitoring network for the regime.

Discussion of Monitoring Results

Groundwater monitoring in the Bear Creek regime during 1996 was conducted (1) to maintain surveillance of contaminant plumes (both extent and concentration of contaminants); (2) to conduct trending within contaminant exit pathways in the Maynardville Limestone using existing monitoring locations; and (3) to conduct corrective action monitoring at point-of-compliance sites, exit pathways, and background wells in accordance with the Bear Creek regime RCRA postclosure permit.

Plume Delineation

The primary groundwater contaminants in the Bear Creek regime are nitrate, trace metals, VOCs, and radionuclides. The S-3 Site is the primary source of nitrate, radionuclides, and trace metals. Sources of VOCs include the S-3 Site, the Rust Spoil Area, Oil Landfarm waste management area, and the Bear Creek Burial Grounds waste management area; the latter two sites are the principal sources. Dense nonaqueous phase liquids (DNAPLs) exist at a depth of 270 ft below the Bear Creek Burial Grounds. The DNAPLs consist primarily of tetrachloroethene, trichloroethene, 1,1-dichloroethene, 1,2-dichloroethene, and high concentrations of PCBs.

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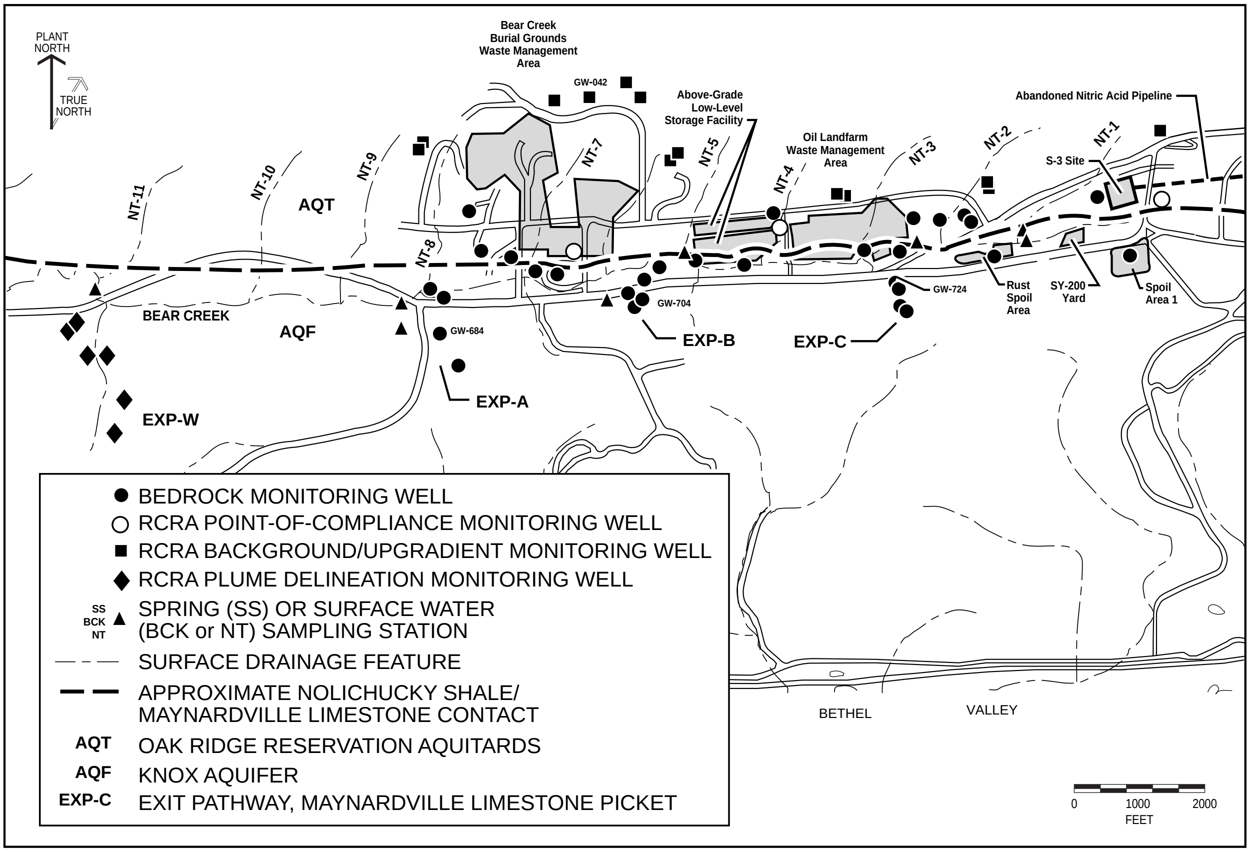

Fig. 7.15. Locations of waste management sites and monitoring wells sampled during 1996 in the Bear Creek Hydrogeologic Regime.

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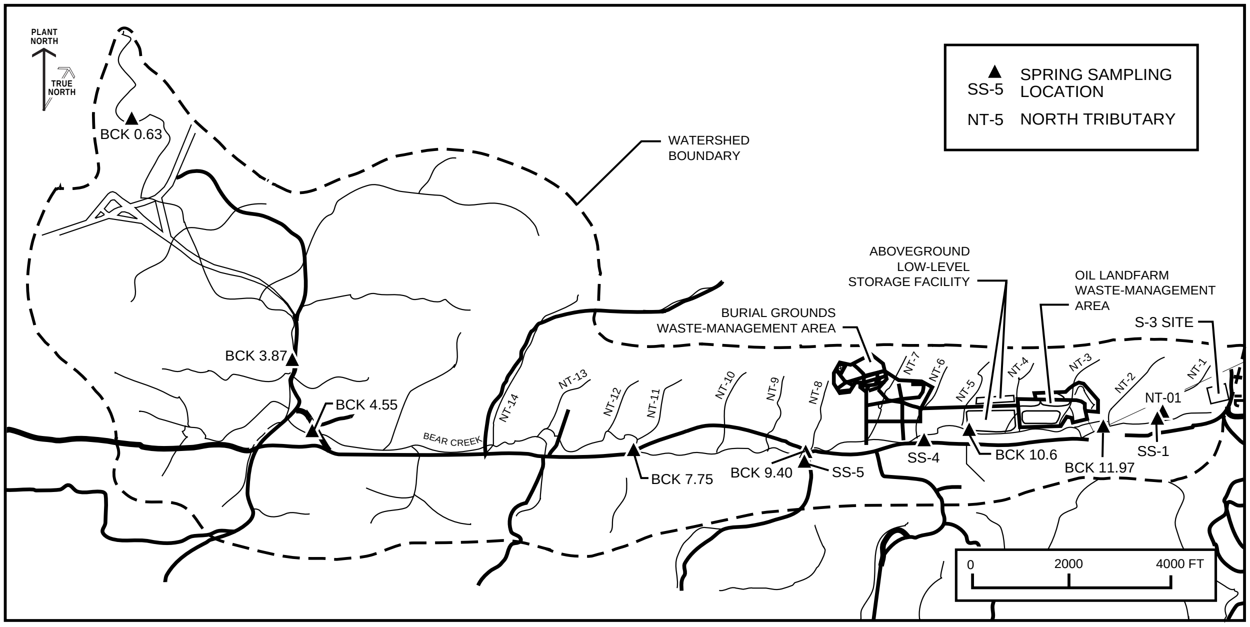

Fig. 7.16. Surface water and spring stations sampled during 1996 in the Bear Creek Hydrogeologic Regime.

Table 7.3. Regulatory status and operational history of waste management units included in the 1996 Comprehensive Groundwater Monitoring Program; Bear Creek Hydrogeologic Regime

Site	Historical/current regulatory classification[a]	Historical data
S-3 Site	TSD/TSD-BCV CA	Four unlined surface impoundments constructed in 1951. Received liquid nitric acid/uranium-bearing wastes via the Nitric Acid Pipeline until 1984. Closed and capped under RCRA in 1988. Infiltration was the primary release mechanism to groundwater.
Oil Landfarm	TSD/TSD-BCV CA	Operated from 1973 to 1982. Received waste oils and coolants tainted with metals and PCBs. Closed and capped under RCRA in 1989. Infiltration was the primary release mechanism to groundwater.
Boneyard	SWMU/BCV CA	Unlined shallow trenches used to dispose of construction debris and to burn magnesium chips and wood.
Burnyard	SWMU/BCV CA	Used from 1943 to 1968. Wastes, metal shavings, solvents, oils, and laboratory chemicals were burned in two unlined trenches.
Hazardous Chemical Disposal Area	SWMU/BCV CA	Built over the burnyard. Handled compressed gas cylinders and reactive chemicals. Residues placed in a small, unlined pit.
Sanitary Landfill I	SWMU/BCV CA	Used from 1968 to 1982. TDEC-permitted, nonhazardous industrial landfill. May be a source of certain contaminants to groundwater. Closed and capped under TDEC requirements in 1983.
Bear Creek Burial Grounds: A, C, and Walk-in Pits	TSD/TSD-BCV CA	A and C received waste oils, coolants, beryllium and uranium, various metallic wastes, and asbestos into unlined trenches and standpipes. Walk-in Pits received chemical wastes, shock-sensitive reagents, and uranium saw fines. Activities ceased in 1981. Final closure certified for A (1989), C (1993), and the Walk-in Pits (1995). Infiltration is the primary release mechanism to groundwater.
Bear Creek Burial Grounds: B, D, E, J, and Oil Retention Ponds 1 and 2	SWMUs/BCV CA	Burial Grounds B, D, E, and J, unlined trenches, received depleted uranium metal and oxides and minor amounts of debris and inorganic salts. Ponds 1 and 2, built in 1971 and 1972, respectively, captured waste oils seeping into two Bear Creek tributaries. The ponds were closed and capped under RCRA in 1989. Certification of closure and capping of Burial Grounds B and part of C was granted 2/95.

Table 7.3 (continued)

Site	Historical/current regulatory classification[a]	Historical data
Rust Spoil Area	SWMU/BCV CA	Used from 1975 to 1983 for disposal of construction debris, but may have included materials bearing solvents, asbestos, mercury, and uranium. Closed under RCRA in 1984. Site is a source of VOCs to shallow groundwater according to CERCLA RI.
Spoil Area I	SWMU/BC OU 2	Used from 1980 to about 1987 for disposal of construction debris and other stable, nonrad wastes. Permitted under TDEC solid waste management regulations in 1986; closure began shortly thereafter. Soil contamination is of primary concern. CERCLA ROD issued in 1996.
SY-200 Yard	SWMU/BC OU 2	Used from 1950s to 1986 for equipment and materials storage. No documented waste disposal at the site occurred. Leaks, spills, and soil contamination are concerns. CERCLA ROD issued in 1996.
Above-Grade LLW Storage Facility	Active	Constructed in 1993. Consists of six above-grade storage pads used to store inert, low-level radioactive debris and solid wastes packaged in steel containers.

[a] Regulatory status before the 1992 Federal Facilities Agreement: TSD—RCRA regulated, land-based treatment, storage, or disposal unit; SWMU—RCRA-regulated solid waste management unit; NA—not regulated. Current regulatory status: BCV CA—Bear Creek Valley Characterization Area; BC OU 02—Bear Creek Operable Unit 02; active—active waste storage facility.

Contaminant plume boundaries are essentially defined in the bedrock formations that directly underlie many waste disposal areas in the Bear Creek regime, particularly the Nolichucky Shale. The elongated shape of the contaminant plumes in the Bear Creek regime is the result of preferential transport of the contaminants parallel to strike in both the Knox Aquifer and the ORR Aquitards. A review of historical data suggests that contaminant concentrations near source areas within the ORR Aquitards have remained relatively constant since 1986. As detailed in previous ORR ASERs, certain contaminants at specific sites, such as nitrate levels adjacent to the S-3 site, have shown decreasing concentration trends. Other constituents, such as gross alpha, exhibit upward trends. In exit-pathway wells located in the Bear Creek regime (Fig. 7.17), slight increases or decreases are observed for selected contaminants, depending on mobility of the contaminants and relative location of the monitoring station with respect to source areas.

Nitrate

Unlike most of the other groundwater contaminants, nitrate moves easily with the groundwater. The limits of the nitrate plume probably define the maximum extent of subsurface contamination in the Bear Creek regime.

Data obtained during 1996 indicate that nitrate concentrations exceed the 10 mg/L MCL in an area that extends west from the S-3 Site for approximately 12,000 ft down BCV (Fig. 7.8). Nitrate concentrations greater than 100 mg/L extend about 3000 ft (915 m) west of the S-3 Site. Data obtained since 1986 suggest that the nitrate plume extends more than 600 ft (183 m) below the

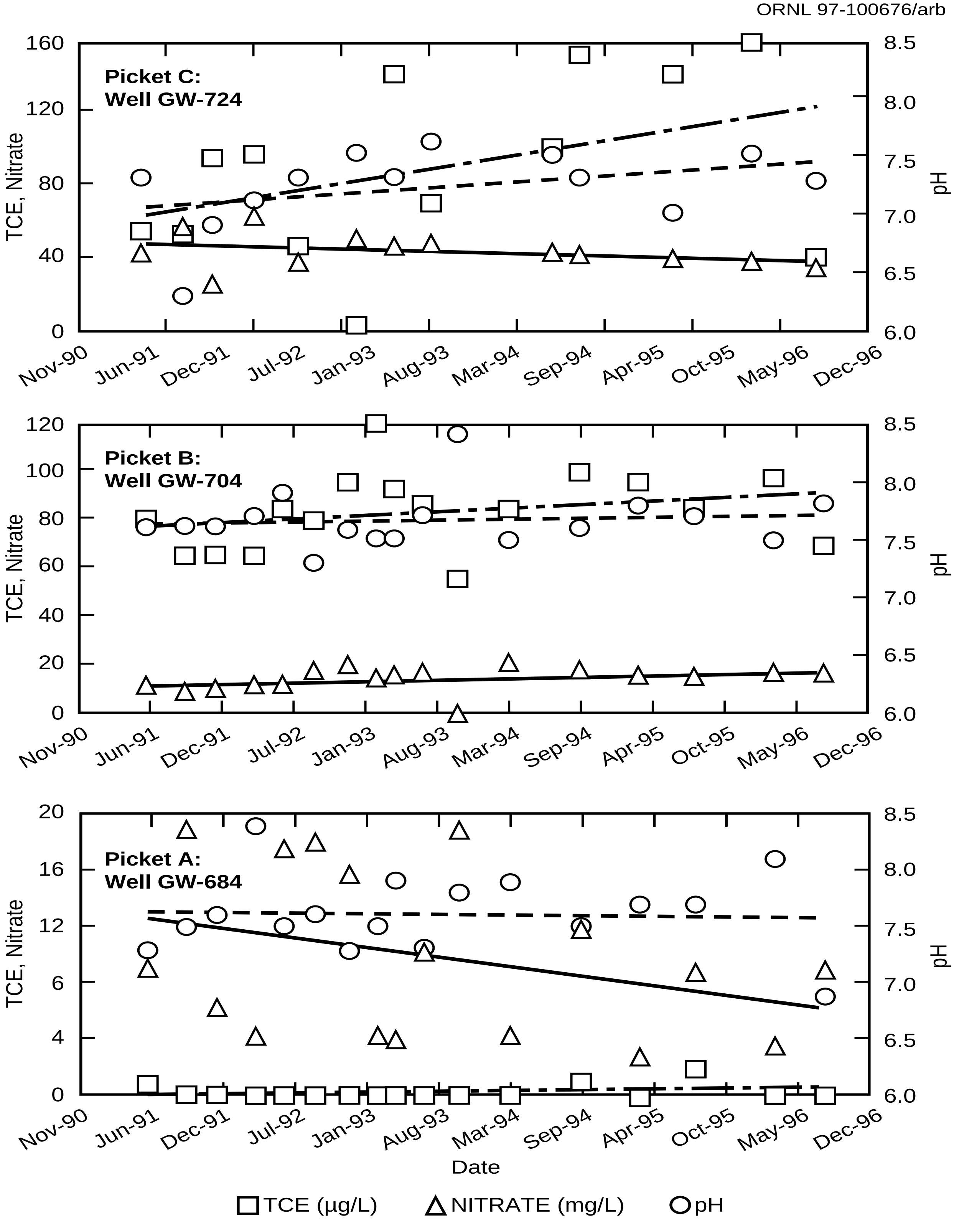

Fig. 7.17. Concentrations of selected contaminants in exit-pathway monitoring wells GW-724, GW-704, and GW-684 in the Bear Creek Hydrogeologic Regime.

ground surface within the ORR aquitards at the S-3 Site. During 1996, the highest nitrate concentrations continued to be seen adjacent to the S-3 Site in groundwater in the unconsolidated zone and at shallow depths [less than 100 ft (30.5 m) below the ground surface] in the Nolichucky Shale.

The horizontal extent of the nitrate plume is essentially defined in groundwater in the upper part of the aquifer [less than 200 ft (61 m) below the ground surface]. Data obtained from exit-pathway monitoring wells indicate that the nitrate plume in groundwater within bedrock in the Maynardville Limestone has not migrated appreciably during the past year and concentrations remain relatively constant.

Trace Metals

Barium, cadmium, chromium, lead, and mercury have been identified from previous monitoring as the principal trace metal contaminants in groundwater in the Bear Creek regime. Historically, the concentrations of these metals exceeded MCLs or natural (background) levels primarily in low-pH groundwater at shallow depths near the S-3 Site. Disposal of acidic liquid wastes at this site reduced the pH of the groundwater, which allows the metals to remain in solution. Elsewhere in the Bear Creek regime, where relatively high pH conditions prevail, only sporadic occurrences of elevated trace metal concentrations are evident.

Other trace metal contaminants in the Bear Creek regime are beryllium, boron, cobalt, copper, nickel, strontium, and uranium. Concentrations of these metals have commonly exceeded background levels in groundwater near the S-3 Site, Bear Creek Burial Grounds, and Oil Landfarm waste management areas. Selected stream and spring locations and exit-pathway study wells also have exhibited total uranium and strontium concentrations above background values.

Volatile Organic Compounds

Like nitrate, VOCs are widespread in groundwater in the Bear Creek regime (Fig. 7.12). The primary compounds are tetrachloroethene, trichloroethene, 1,2-dichloroethene, 1,1,1-trichloroethane, and 1,1-dichloroethane. In most areas, the VOCs are dissolved in the groundwater, but nonaqueous phase accumulations of tetrachloroethene and trichloroethene occur in bedrock more than 250 ft below the Bear Creek Burial Grounds waste management area.

Groundwater in the unconsolidated zone overlying the aquitards that contains detectable levels of VOCs occurs primarily within about 1000 ft (305 m) of the source areas. The highest VOC concentrations (greater than 10,000 mg/L) in the unconsolidated zone occur at the Bear Creek Burial Grounds waste management area. The extent of the dissolved VOC plumes is slightly greater in the underlying bedrock.

Significant transport of the VOCs has occurred in the Maynardville Limestone. Data obtained from exit-pathway monitoring locations show that in the vicinity of the water table, an apparently continuous dissolved VOC plume extends for about 12,000 ft (3,660 m) westward from the S-3 Site to just west of the Bear Creek Burial Grounds waste management area. The highest levels of VOCs in the Bear Creek regime occur in bedrock, just south of the Bear Creek Burial Grounds Waste Management Area. Historical levels have been as high as 7000 mg/L in groundwater near the source area. Typical VOC levels in the exit pathway (Maynardville Limestone) range from about 160 µg/L in the eastern part of the regime to less than detectable levels in the western part of the regime.

Radionuclides

Uranium, neptunium, americium, and naturally occurring isotopes of radium have been identified as the primary alpha-particle-emitting radionuclides in the Bear Creek regime. Technetium is the primary beta-particle emitting radionuclide in the regime, but tritium and isotopes of strontium are also present in groundwater near the S-3 Site.

Evaluations of the extent of these radionuclides in groundwater in the Bear Creek regime during 1996 were based primarily on measurements of gross alpha activity and gross beta activity. If the annual average gross alpha activity in groundwater samples from a well exceeded 15 pCi/L (the MCL for gross alpha activity), then one (or more) of the alpha-emitting radionuclides was assumed to be present in the groundwater monitored by the well. A similar rationale was used for annual average gross beta activity that exceeded 50 pCi/L.

As shown in Fig. 7.13, groundwater with elevated levels of gross alpha activity occurs in the water table interval in the vicinity of the S-3 Site, the Bear Creek Burial Grounds, and the Oil Landfarm waste management areas. In the bedrock interval, gross alpha activity exceeds 15 pCi/L in groundwater in the Nolichucky Shale near the S-3 Site, the southern sides of the Bear Creek Burial Grounds, and east of the Oil Landfarm waste management areas. Gross alpha activities near the S-3 site source appear to be increasing, while gross beta activity is decreasing. Data obtained from exit-pathway monitoring stations show that gross alpha activity in groundwater in the Maynardville Limestone exceeds the MCL for 10,000 ft (3,050 m) west of the S-3 Site.

The distribution of gross beta radioactivity in groundwater in the unconsolidated zone is similar to that of gross alpha radioactivity (Fig. 7.14). During 1996 gross beta activity exceeded 50 pCi/L within the water table interval in the Maynardville Limestone from south of the S-3 Site to the Oil Landfarm waste management area. Within the intermediate bedrock interval in the Maynardville Limestone, the elevated gross beta activity extends as far west as does gross alpha activity, just to the west of the Bear Creek Burial Grounds waste management area.

Exit-Pathway and Perimeter Monitoring

Exit-pathway monitoring began in 1990 to provide data on the quality of groundwater and surface water exiting the Bear Creek regime. The Maynardville Limestone is the primary exit pathway for groundwater. Bear Creek, which flows across the Maynardville Limestone in much of the Bear Creek regime, is the principal exit pathway for surface water. Various studies have shown that surface water in Bear Creek, springs along the valley floor, and groundwater in the Maynardville Limestone are hydraulically connected. The western exit-pathway well transect (Picket W) serves as the ORR perimeter wells for the Bear Creek Regime (Fig. 7.6).

Exit-pathway monitoring consisted of continued monitoring at four well transects (pickets) and selected springs and surface water stations. Groundwater quality data obtained during 1996 from the exit-pathway monitoring wells confirmed previous data, indicating that contaminated groundwater does not seem to occur much beyond the western side of the Bear Creek Burial Grounds waste management area. However, low levels of nitrate (1 to 4 mg/L) have been observed in surface water and one Picket W well west of the Burial Grounds.

Surface water and spring samples collected during CY 1996 (Fig. 7.16) indicate that spring discharges and water in upper reaches of Bear Creek contain many of the compounds found in the groundwater; however, the concentrations in the creek and spring discharges decrease rapidly with distance downstream of the waste disposal sites (Fig. 7.18).

7.2.5.4 Chestnut Ridge Hydrogeologic Regime

The Chestnut Ridge regime is south of the Y-12 Plant and is flanked to the north by BCV and to the south by Bethel Valley Road (Fig. 7.5). The regime encompasses the portion of Chestnut Ridge extending from Scarboro Road east of the Y-12 Plant to an unnamed drainage basin on the ridge located just west of Centralized Sanitary Landfill II. Figure 7.19 shows the approximate boundaries of the regime and locations of waste management units and monitoring wells sampled in 1996.

Four categories of sites are located within the Chestnut Ridge regime: (1) RCRA-regulated TSD units, (2) RCRA 3004(u) SWMUs and solid waste disposal units, (3) TDEC-permitted SDWFs, and (4) CERCLA OUs. The Chestnut Ridge Security Pits is the only documented source of groundwater contamination in the regime. No integrating CA

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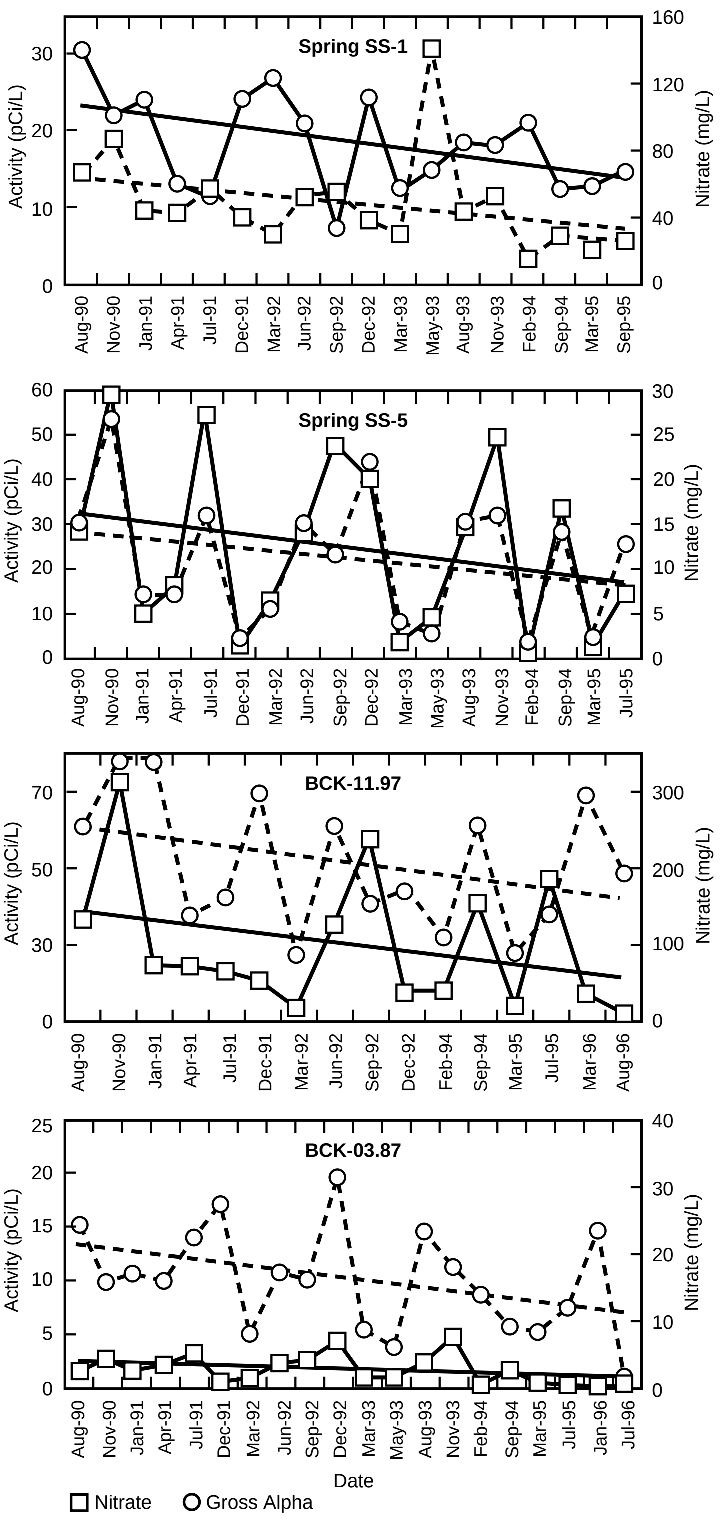

Fig. 7.18. Concentrations of selected groundwater contaminants in springs and surface water in the Bear Creek Hydrogeologic Regime (refer to Fig. 7.16 for station locations).

has been established for the regime because contamination from the Security Pits is distinct and is not mingled with plumes from other sources. Analytes found in groundwater will be addressed as part of the RI/FS for each source. Table 7.4 summarizes the regulatory status and operational history of waste management units in the regime. Detailed discussions of these sites have been included in previous ASERs.

Discussion of Monitoring Results

A more comprehensive suite of analytical tests is applied to most sites in the Chestnut Ridge regime because of various permitting requirements. Volatile organics and trace metals are the only categories in which findings currently consistently exceed background levels, and these are predominantly associated with the Chestnut Ridge Security Pits. Gross alpha and beta activities have sporadically exceeded screening levels in the past in samples taken from wells at the Chestnut Ridge Sediment Disposal Basin, United Nuclear Site, Industrial Landfill III, and Kerr Hollow Quarry, although no discernable pattern or consistency to the data has been determined.

All units in the Chestnut Ridge regime, with the exception of the Chestnut Ridge Security Pits and the United Nuclear Site, are monitored under either a regulatory detection monitoring program or as a BMP. The Chestnut Ridge Security Pits are monitored in accordance with RCRA postclosure corrective action requirements. The United Nuclear Site is monitored under the provisions of a CERCLA ROD. In 1996, no releases of contaminants to groundwater were determined for those units under formal detection monitoring programs (Table 7.1). No observable changes of groundwater quality relative to past years were noted for units monitored under surveillance practices or a CERCLA

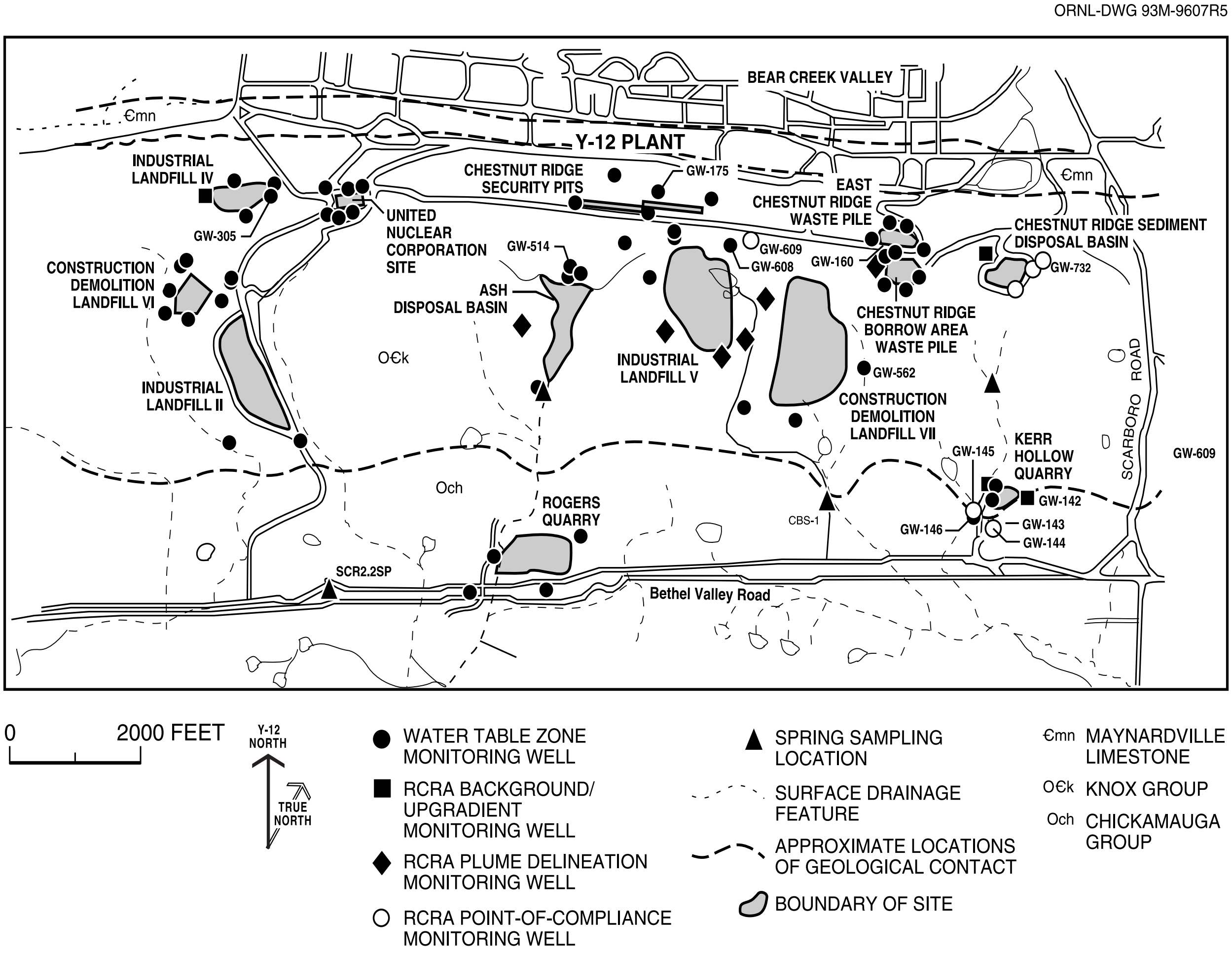

Fig. 7.19. Locations of waste management sites and monitoring wells sampled during 1996 in the Chestnut Ridge Hydrogeologic Regime.

ROD. Plume delineation and contaminants of interest are discussed in the following sections. Two additional issues are also discussed. These two issues include the occurrence of trace levels of VOCs, total strontium, and total uranium at Kerr Hollow Quarry and the occurrence of VOCs in one well located at Industrial Landfill IV.

Plume Delineation

The horizontal extent of the VOC plume at the Chestnut Ridge Security Pits is reasonably well defined in the water table and shallow bedrock zones (Fig. 7.12). Groundwater quality data obtained during 1996 continues to indicate that the lateral extent of the VOC plume at the site is increasing slightly, as evidenced by detectable signature VOCs (1,1,1-trichloro-ethane) in wells GW-608, GW-609, GW-514, GW-796, and GW-175.

There are two distinct VOCs in groundwater at the security pits. In the western portion of the site, the VOC plume is characterized by high concentrations of 1,1,1-trichloroethane. Tetrachloroethene is a principal component of the VOC plume in the eastern portion of the site. The distinct difference in the composition of the plume is probably related to differences in the types of wastes disposed of in the eastern and western trench areas.

Table 7.4. Regulatory status and operational history of waste management units included in the 1996 Comprehensive Groundwater Monitoring Program; Chestnut Ridge Hydrogeologic Regime

Site	Historical/current regulatory classification[a]	Historical data
Chestnut Ridge Sediment Disposal Basin	TSD/TSD-Study Area	Operated from 1973 to 1989. Received soil and sediment from New Hope Pond and mercury-contaminated soils from the Y-12 Plant. Site was closed under RCRA in 1989. Not a documented source of groundwater contamination.
Kerr Hollow Quarry	TSD/TSD-Study Area	Operated from 1940s to 1988. Used for the disposal of reactive materials, compressed gas cylinders, and various debris. RCRA closure (waste removal) was conducted between 1990 and 1993. Certification of closure with some wastes remaining in place was approved by TDEC 2/95.
Chestnut Ridge Security Pits	TSD/TSD-CR OU 1	Operated from 1973 to 1988. Series of trenches for disposal of classified materials, liquid wastes, thorium, uranium, heavy metals, and various debris. Closed under RCRA in 1989. Infiltration is the primary release mechanism to groundwater.
East Chestnut Ridge Waste Pile	TSD/TSD	Lined, RCRA-interim status hazardous waste storage facility for contaminated soils from the Y-12 Plant.
Ash Disposal Basin	SWMU/CR OU 2	Used until 1967. Site received Y-12 Steam Plant coal ash slurries. Leaching of metals to groundwater are of concern. A CERCLA ROD has been issued.
United Nuclear Corporation Site	SWMU/CR OU 3	Received about 29,000 drums of cement-fixed sludges and soils demolition materials, and low-level radioactive contaminated soils. Closed in 1992; CERCLA ROD has been issued.
Rogers Quarry	SWMU/CR OU 4	Used from 1960s until 1993 for disposal of steam-plant coal ash and process debris. Metals contaminants are of primary concern.
Chestnut Ridge Borrow Area Waste Pile	Not regulated/Study Area	Contains soils from off-site locations in Oak Ridge bearing low levels of mercury and other metals.
Centralized Sanitary Landfill II	TDEC-permitted Class II industrial SWDF	Central sanitary landfill for the ORR. Detection monitoring under postclosure plan has been ongoing since 1996.
Industrial Landfill IV	TDEC-permitted Class II industrial SWDF	Permitted to receive only, nonhazardous industrial solid wastes. Detection monitoring under TDEC-SWM regulations has been ongoing since 1988.

Table 7.4 (continued)

Site	Historical/current regulatory classification[a]	Historical data
Industrial Landfill V	TDEC-permitted Class II industrial SWDF	New facility completed 4/94. Baseline groundwater monitoring began 5/93 and was completed 1/95. Currently under TDEC-SWM detection monitoring.
Construction/Demolition Landfill VI	TDEC-permitted Class IV construction/demolition SWDF	New facility completed 12/93. Baseline groundwater quality monitoring began 5/93 and was completed 12/93. Waste disposal began 4/94. Currently under permit-required detection monitoring per TDEC.
Construction/Demolition Landfill VI	TDEC-permitted Class IV construction/demolition SWDF	New facility; construction completed in 12/94. TDEC granted approval to operate 1/95. Baseline groundwater quality monitoring began in 5/93 and was completed in 1/95. Currently under permit-required detection monitoring per TDEC.

[a] Regulatory classification before the 1992 Federal Facilities Agreement: TSD—RCRA regulated, land-based treatment, storage, or disposal facility; SWMU—RCRA-regulated solid waste management unit. Current regulatory status: study area—Y-12 Plant study area; CR OU 1—Chestnut Ridge Operable Unit 1; CR OU 2—Chestnut Ridge Operable Unit 2; CR OU 3—Chestnut Ridge Operable Unit 3; CR OU 4—Chestnut Ridge Operable Unit 4; SWDF—solid waste disposal facility (active landfill).

Nitrate

Nitrate concentrations were well below the DWS of 10 mg/L at all monitoring stations.

Trace Metals

Chromium, lead, nickel, arsenic, barium, and cadmium concentrations sporadically exceeded DWSs in a number of wells during 1996. Most of the elevated results were attributable to elevated turbidity and suspended solids in the samples. Verification sampling required under detection monitoring programs was performed for a number of the exceedences; no releases of metals contamination were confirmed. Total strontium and total uranium levels continued to be elevated above background levels at wells GW-142, GW-143, GW-145, and GW-146 at Kerr Hollow Quarry. These two constituents do not appear to have a radiogenic source in that isotopic and gross activity analyses remained well below applicable DWSs and 4% of the DCGs during 1996.

Volatile Organic Compounds

Efforts to delineate the extent of VOCs in groundwater attributable to the security pits (previously discussed) have been in progress since 1987. A review of historical data suggests that VOC concentrations in groundwater at the site have generally decreased since 1988 (Table 7.5). Well GW-305 (Fig. 7.19) located immediately to the east of Industrial Landfill IV has shown low levels of VOCs since the first quarter of 1992 (exclusively 1,1,1-trichloroethane until the fourth quarter of 1996). Concentrations of the VOCs have remained well below applicable DWSs, although an upward trend is evident over time.

The source of the VOCs in this well was originally thought to be the Chestnut Ridge Security Pits. However, evaluation of water table levels in wells in the area have shown that the water table at Industrial Landfill IV is typically about 10 feet higher than that at the Security Pits. Therefore, a connection with the Security Pits is, therefore, not the most feasible explanation. Additional monitoring data are being reviewed

Table 7.5. Annual average summed VOC concentrations in groundwater at the Chestnut Ridge Security Pits

Well number	Summed average VOCs[a] (μg/L)								Percentage decrease
	1989	1990	1991	1992	1993	1994	1995	1996	
GW-173	17.0	13.5	11.8	11.7	NS	NS	NS	NS	31
GW-174	47.8	48.5	43.7	34.0	NS	NS	NS	14	71
GW-175	31.8	38.5	31.0	29.5	17.0	25.3	21.5	13	59
GW-176	285.3	233.5	170.5	139.7	NS	NS	NS	NS	51
GW-177	66.7	18.8	26.3	25.5	33.0	28.3	24.3	22	67
GW-178	43.4	40.0	34.0	29.0	NS	NS	NS	NS	32
GW-179	838.0	455.0	328.3	262.3	NS	NS	NS	NS	69
GW-180	145.8	99.5	74.2	52.3	NS	NS	NS	NS	64
GW-322	696.0	730.3	633.0	538.3	NS	NS	NS	NS	23
GW-607	NS	16.9	ND	ND	ND	NS	NS	NS	100
GW-608	NS	14.8	15.5	(4.5)	(4.0)	(4.3)	(0.8)	(12)	19
GW-609	NS	78.0	67.5	35.5	28.4	54.5	28.5	20	74
GW-610	NS	1.0	0.5	ND	ND	(0.3)	ND	ND	100
GW-611	NS	16.0	9.0	13.5	10.5	12.4	5.5	(5)	69
GW-612	NS	505.8	451.3	358.3	NS	NS	NS	266	47
GW-742	NS	NS	NS	ND	ND	ND	ND	ND	–
GW-743	NS	NS	NS	ND	ND	ND	(2)	ND	–

[a] NS = not sampled, ND = not detected, and ( ) = qualitative result; summed average determined exclusively from estimated concentrations reported below the reporting limit.

and collected in the area to attempt to establish the source of the VOCs. Low levels of VOCs have also been observed at a few additional monitoring locations in 1996. Of particular note, trace levels of carbon tetrachloride continued to be observed in two samples from one Kerr Hollow Quarry monitoring well (Well GW-144).

Radionuclides

Only four samples exceeded the DWS of 15 pCi/L; no well has demonstrated consistent radiological contamination. Gross beta activities were below the DWS of 50 pCi/L at all locations.

Exit-Pathway and Perimeter Monitoring

Contaminant and groundwater flow paths in the karst bedrock underlying the Chestnut Ridge regime have not been well characterized using conventional monitoring techniques. Dye-tracer studies have been used in the past to attempt to identify exit pathways. Based on the results of dye-tracer studies to date, no springs or surface streams that represent discharge points for groundwater have been conclusively identified for water quality monitoring. Future dye-tracer studies are possible. TDEC/DOE-O conducted a small-scale tracer study east of the Sediment Disposal Basin in 1995; the results indicated preferential migration of groundwater along strike with discharge to a spring located off the ORR along Scarboro Creek in Union Valley. Off-site locations, including the spring, are monitored as part of the Union Valley focus study (Sect. 7.2.5.2).

On the ORR, monitoring of one large spring south of Industrial Landfill V and Construction/ Demolition Landfill VII was continued in 1996 at the request of the TDEC/DOE-O and as a BMP. Periodically, additional springs within the Chestnut Ridge regime will be sampled as part of overall exit-pathway monitoring for the regime.

7.2.5.5 Special Studies

Planning or initiation of a number of special projects related to groundwater occurred in 1996. These special projects may be divided into three general categories: technical studies, characterization activities, and technology feasibility studies/demonstrations.

Technical Studies

A plant-wide survey for dewatering sumps located within the Y-12 Plant was completed in 1996. Dewatering sumps are of interest because they may be influencing groundwater and contaminant migration. A number of large sumps were previously known to exist, and two of these were demonstrated to have a significant impact on shallow groundwater flow patterns. The data from the survey indicated that a number of additional sumps are located within the plant and may also have significant impact on contaminant transport patterns. Results of the survey and selection of sumps to be sampled have been provided to ongoing CERCLA RI programs for consideration as part of the scope of these activities.

Another large effort was initiated in 1996 to review the distribution of major utility lines within the Y-12 Plant that may act as preferential pathways for shallow groundwater flow and contaminant transport. This effort was initiated because several instances had been previously documented in which utility pipeline traces acted as either preferential flowpaths or truncated shallow groundwater contaminant plumes. This effort is scheduled to be completed in 1997 and results will be incorporated into characterizations efforts of the UEFPC RI.

Characterization Activities

In addition to the routine effluent and surveillance monitoring, a plant-wide sampling effort was completed in 1996 in conjunction with the UEFPC CERCLA RI to collect detailed characterization data on the nature and extent of radioisotopes in groundwater. Groundwater samples and sediments extracted from groundwater were collected and analyzed for a comprehensive list of isotopes using methods capable of detecting very low activities. These data will be used as part of the CERCLA RI baseline risk assessment and in general groundwater quality evaluations.

Technology Feasibility Studies/ Demonstrations

Planning activities began in 1996 to design a groundwater capture and treatment system for the VOC plume emanating from the plant and moving eastward along exit pathways as far as Union Valley. The capture system will involve installation of a deep well on the ORR near the east end of the Y-12 Plant. This well will target the mass of contamination (carbon tetrachloride in particular) in the intermediate and deep intervals of the Maynardville Limestone. In addition, the gravel underdrain system beneath the concrete diversion channel of UEFPC is being considered as part of the groundwater capture system, specifically for shallow groundwater. The underdrain will function as a capture trench. The underdrain system traverses a large portion of the east end of the Y-12 Plant and is already known to transmit large quantities of shallow groundwater. The combined pumping of these two capture systems will theoretically intercept the VOC plume both in the shallow and deeper flow systems. Design, installation, and testing of the concept are planned for 1997. Groundwater contaminants will be treated using a mobile air-stripper unit. If the feasibility study indicates the design to be successful, groundwater extraction and treatment will be seriously considered as a long-term remedial action.

A multiphase treatability study within the Bear Creek regime continued in 1996. This effort involved evaluation of remedial technologies for contaminated groundwater and surface water, with particular focus on the primary S-3 Site contaminants. The initial phase of the feasibility study conducted in 1996 involved laboratory-scale testing of various types of treatment methods for contaminated groundwater. In addition, remediation of contaminants in surface water using wetlands and biological uptake methods was tested using field-scale experiments. The second phase of the effort to begin in 1997 will involve collection of focused hydrologic data around the S-3 Site and evaluation of the feasibility of installing capture trenches and horizontal wells for shallow groundwater extraction and treatment.

Three additional special studies (termed technology demonstrations) of the applicability of groundwater and soils remedial technologies are currently in various planning stages. These efforts are conducted using DOE funds available to research promising remedial technologies or solutions to unique and complex contamination problems. One of the technology demonstrations involves removal of uranium from soils using electrokinetic methods. Field activities for this demonstration are scheduled to begin in 1997. The remaining two demonstrations will research trench capture and treatment technologies for shallow groundwater contamination.

7.3 GROUNDWATER MONITORING AT THE OAK RIDGE NATIONAL LABORATORY

7.3.1 Background

The groundwater monitoring program at ORNL consists of a network of wells of two basic types and functions: (1) water quality monitoring wells built to RCRA specifications and used for site characterization and compliance purposes and (2) piezometer wells used to characterize groundwater flow conditions. The EMEF Program, formerly the ER Program, provides comprehensive cleanup of sites where past and current research, development, and waste management activities may have resulted in residual contamination of the environment. Individual monitoring and assessment is assumed to be impractical for each of these sites because their boundaries are indistinct and because there are hydrologic interconnections between many of them. Consequently, the concept of WAGs was developed to facilitate evaluation of potential sources of releases to the environment. A WAG is a grouping of multiple sites that are geographically contiguous and/or that occur within hydrologically (geohydrologically) defined areas. WAGs allow establishment of suitably comprehensive groundwater and surface water monitoring and remediation programs in a far shorter time than that required to deal with every facility, site, or SWMU individually. Some WAGs share boundaries, but each WAG represents a collection of distinct small drainage areas, within which similar contaminants may have been introduced. Monitoring data from each WAG are used to direct further groundwater studies aimed at addressing individual sites or units within a WAG as well as contaminant plumes that extend beyond the perimeter of a WAG.

Recently there has been a shift away from the use of the WAG concept to more of a watershed approach to remediation. To provide continuity with previous reports and comparability of activities and sampling results, the following discussions use the WAG concept.

At ORNL, 20 WAGs were identified by the RCRA Facility Assessment (RFA) conducted in 1987. Thirteen of these have been identified as potential sources of groundwater contamination. Additionally, there are a few areas where potential remedial action sites are located outside the major WAGs. These individual sites have been considered separately (instead of expanding the area of the WAG). Water quality monitoring wells have been established around the perimeters of the WAGs determined to have a potential for release of contaminants. Figure 7.20 shows the location of each of the 20 WAGs.

For discussion purposes, the WAGs are grouped by the valley in which they are located: Bethel Valley WAGs include 1, 3, and 17; Melton Valley WAGs include 2, 4, 5, 6, 7, 8, and 9; and WAG 11 includes the White Wing Scrapyard.

The ORNL exit-pathway program, which is discussed later in this section, is designated to monitor groundwater at four general locations that are thought to be likely exit pathways for groundwater affected by activities at ORNL (Fig. 7.21). The locations are White Wing Scrap Yard, WOC/Melton Valley, West Bethel Valley, and East Bethel Valley.

7.3.1.1 Bethel Valley

WAG 1

WAG 1, the ORNL main plant area, contains about one-half of the remedial action sites identified to date by the EMEF Program. WAG 1 lies within the Bethel Valley portion of the WOC drainage basin. The boundaries of the basin extend to the southeast and northeast along Chestnut Ridge and Haw Ridge. The WAG boundary extends to the water gap in Haw Ridge. The total area of the basin in Bethel Valley is about 2040 acres. Bedrock beneath the main plant area is limestone, siltstone, and calcareous shale facies of the Ordovician Chickamauga Group.

Many of the WAG 1 sites were used to collect and to store LLW in tanks, ponds, and waste treatment facilities, but some sites also include landfills and contaminated sites resulting from spills and leaks occurring over the last 50 years. Because of the nature of cleanup and repair, it is not possible to determine which spill or leak sites still represent potential sources of release. Most of the SWMUs are related to ORNL’s waste management operations. Recent EMEF activities within WAG 1 include several CERCLA actions associated with sources of contamination; e.g., a treatability study associated with the GAAT remedial action, and the demolition of the Waste Evaporator Facility (Building 3506) via a CERCLA removal action.

WAG 3

WAG 3 is located in Bethel Valley about 1 km (0.6 mile) west of the main plant area. WAG 3 is composed of three SWMUs: SWSA 3, the Closed Scrap Metal Area (1562), and the Contractors Landfill (1554).

SWSA 3 and the Closed Scrap Metal Area are inactive landfills known to contain radioactive solid wastes and surplus materials generated at ORNL from 1946 to 1979. Burial of solid waste ceased at this site in 1951; however, the site continued to be used as an aboveground scrap metal storage area until 1979. Sometime during the period from 1946 to 1949, radioactive solid wastes removed from SWSA 2 were buried at this site. In 1979, most of the scrap metal stored above ground at SWSA 3 was either transferred to other storage areas or buried on site in a triangular-shaped disposal area immediately south of SWSA 3.

Records of the composition of radioactive solid waste buried in SWSA 3 were destroyed in a fire in 1961. Sketches and drawings of the site indicate that alpha and beta-gamma wastes were segregated and buried in separate areas or trenches. Chemical wastes were probably also buried in SWSA 3 because there are no records of disposal elsewhere. Although the information is

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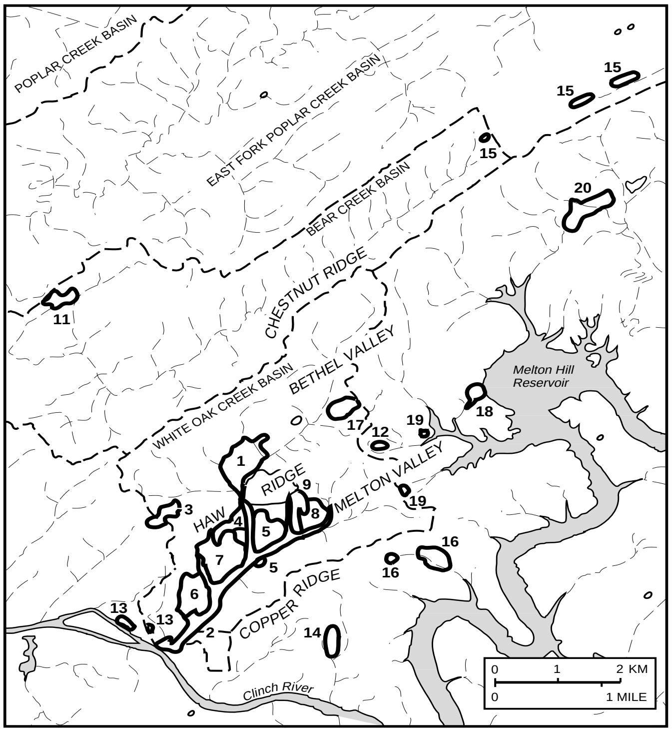

Fig. 7.20. Locations of ORNL waste area groupings (WAGs). (WAG 10 sites are underground, beneath WAG 5.)

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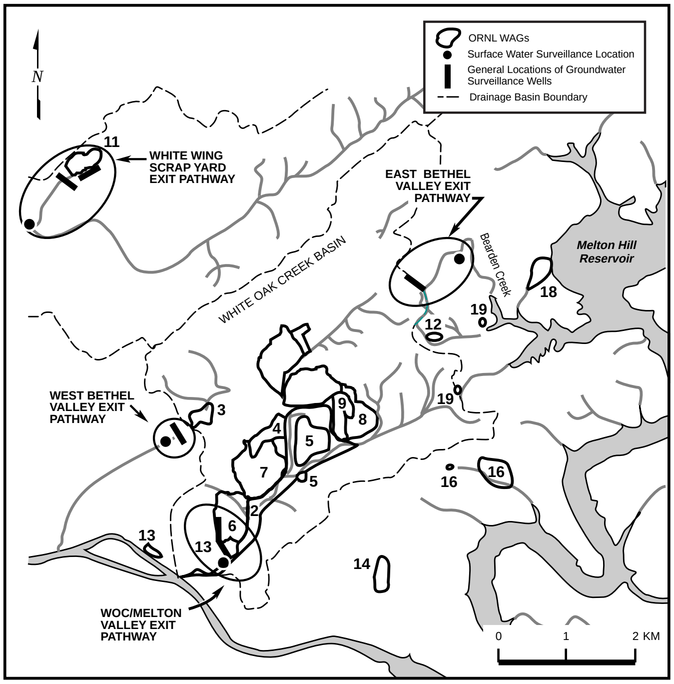

Fig. 7.21. Groundwater exit pathways on the Oak Ridge Reservation that are likely to be affected by Oak Ridge operations.

sketchy, the larger scrap metal equipment (such as tanks and drums) stored on the surface at this site was also probably contaminated. Because only a portion of this material is now buried in the closed Scrap Metal Area, it is not possible to estimate the amount of contamination that exists in this SWMU.

The Contractors' Landfill was opened in 1975 and is now closed. It was used to dispose of various uncontaminated construction materials. No contaminated waste or asbestos was allowed to be buried at the site. ORNL disposal procedures require that only non-RCRA, nonradioactive solid wastes were to be buried in the Contractors' Landfill.

WAG 17

WAG 17 is located about 1.6 km (1 mile) directly east of the ORNL main plant area. This area has served as the major craft and machine shop area for ORNL since the late 1940s. The area includes the receiving and shipping departments, machine shops, carpenter shops, paint shops, lead-burning facilities, garage facilities, welding facilities, and material storage areas that are needed to support ORNL's routine and experimental operations. It is composed of 17 SWMUs. A former septic tank is now used as a sewage collection/pumping station for the area, and seven tanks are used for waste oil collection and storage and for storage of photographic reproduction wastes.

7.3.1.2 Melton Valley

WAG 2

WAG 2 is composed of WOC discharge points and includes the associated floodplain and subsurface environment. It represents the major drainage system for ORNL and the surrounding facilities.

In addition to natural drainage, WOC has received treated and untreated effluents and reactor cooling water from ORNL activities since 1943. Controlled releases include those from the NRWTF, the STP, and a variety of process waste holdup ponds throughout the ORNL main plant area (WAG 1). It also receives groundwater discharge and surface drainage from WAGs 1, 4, 5, 6, 7, 8, and 9.

There is little doubt that WAG 2 represents a source of continuing contaminant release (radionuclides and/or chemical contaminants) to the Clinch River. Although it is known that WAG 2 receives groundwater contamination from other WAGs, the extent to which WAG 2 may be contributing to groundwater contamination has yet to be determined. Recent EMEF activities include continued monitoring and support of the WAG 5 seeps removal action, as well as performing an RI of the WOC Watershed.

WAG 4

WAG 4 is located in Melton Valley about 0.8 km (0.5 mile) southwest of the main ORNL plant site. It comprises the SWSA 4 waste disposal area, LLLW transfer lines, and the experimental Pilot Pit Area (Area 7811).

SWSA 4 was opened for routine burial of solid radioactive wastes in 1951. From 1955 to 1963, Oak Ridge was designated by the Atomic Energy Commission as the Southern Regional Burial Ground; as such, SWSA 4 received a wide variety of poorly characterized solid wastes (including radioactive waste) from about 50 sources. These wastes consisted of paper, clothing, equipment, filters, animal carcasses, and related laboratory wastes. About 50% of the waste was received from sources outside of Oak Ridge facilities. Wastes were placed in trenches, shallow auger holes, and in piles on the ground for covering at a later date.

From 1954 to 1975, LLLW was transported from storage tanks at the main ORNL complex to waste pits and trenches in Melton Valley (WAG 7), and later to the hydrofracture disposal sites, through underground transfer lines. The Pilot Pit Area (Area 7811) was constructed for use in pilot-scale radioactive waste disposal studies from 1955 to 1959; three large concrete cylinders containing experimental equipment remain embedded in the ground. A removal action was initiated at WAG 4 during 1995 to grout in place sources of ^{90}Sr contamination emanating from selected trenches located within the WAG. A control building and asphalt pad have been used for storage through the years.

WAG 5

WAG 5 contains 33 SWMUs, 13 of which are tanks that were used to store LLLW prior to disposal by the hydrofracture process. WAG 5 also includes the surface facilities constructed in support of both the old and new hydrofracture facilities. The largest land areas in WAG 5 are devoted to TRU wate in SWSA 5 South and SWSA 5 North. The remaining sites are support facilities for ORNL’s hydrofracture operations, two LLW pipeline leak/spill sites, and an impoundment in SWSA 5 used to dewater sludge from the original Process Waste Treatment Facility. Currently, LLW tanks at the New Hydrofracture Facility are being used to store evaporator concentrates pending a decision regarding ultimate disposal of these wastes.

SWSA 5 South was used to dispose of solid LLW generated at ORNL from 1959 to 1973. From 1959 to 1963 the burial ground served as the Southeastern Regional Burial Ground for the Atomic Energy Commission. At the time SWSA 5 burial operations were initiated, about 10 acres of the site was set aside for the retrievable storage of TRU wastes.

The WAG 5 boundary includes the Old and New Hydrofracture Facilities. Because Melton Branch flows between the old and new hydrofracture facilities, the new hydrofracture facility has a separate boundary. Studies of the contents of several tanks at the Old Hydrofracture Facility were performed in preparation for a removal action. The scope of the removal action is to remove the contents of the tanks. A CERCLA removal action was initiated in 1994 to remove ^{90}Sr from Seeps C and D located along the southern boundary of WAG 5 and continued during 1996.

WAG 6

WAG 6 consists of four SWMUs: (1) SWSA 6, (2) Building 7878, (3) the explosives detonation trench, and (4) Building 7842. SWSA 6 is located in Melton Valley, northwest of WOL and southeast of Lagoon Road and Haw Ridge. The site is about 2 km (1.2 miles) south of the main ORNL complex. Waste burials at the 68-acre site were initiated in 1973 when SWSA 5 was closed. Various radioactive and chemical wastes were buried in trenches and auger holes. SWSA 6 is the only currently operating disposal area for LLW at ORNL. The emergency waste basin was constructed in 1961 to provide storage of liquid wastes that could not be released from ORNL to WOC. The basin is located northwest of SWSA 6 and has a capacity of 15 million gal, but has never been used. Radiological sampling of the small drainage from the basin has shown the presence of some radioactivity. The source of this contamination is not known.

WAG 6 was among the first WAGs to be investigated at ORNL by the EMEF Program. WAG 6 is an interim-status RCRA unit because of past disposal of RCRA-regulated hazardous waste. Environmental monitoring is carried out under CERCLA and RCRA. A proposed CERCLA remedial action, which involved capping WAG 6, was abandoned after a public meeting in which members of the community objected to the high cost of capping. Groundwater monitoring continues to be carried out under the auspices of the EMP for WAG 6 at ORNL, which was implemented after abandonment of the remedial action chosen at WAG 6.

WAG 7

WAG 7 is located in Melton Valley about 1.6 km (1 mile) south of the ORNL main plant area. The major sites in WAG 7 are the seven pits and trenches used from 1951 to 1966 for disposal of LLLW. WAG 7 also includes a decontamination facility, three leak sites, a storage area containing shielded transfer tanks and other equipment, and seven fuel wells used to dispose of acid solutions primarily containing enriched uranium from Homogeneous Reactor Experiment fuel. WAG 7 is being used to demonstrate the efficacy of in situ vitrification technology to immobilize radioactive waste streams buried in the WAG. However, because of a release of fission products (^{137}Cs) during testing of the in situ vitrification technology, the project was placed in shutdown mode awaiting redesign and additional site characterization.

WAGs 8 and 9

WAG 8, located in Melton Valley, south of the main plant area, is composed of 36 SWMUs that are associated with the reactor facilities in Melton Valley. The SWMUs consist of active LLLW collection and storage tanks, leak/spill sites, a contractors' soils area, radioactive waste ponds and impoundments, and chemical and sewage waste treatment facilities. WAG 8 includes the MSRE facility, the HFIR, and the REDC. A removal action was initiated at the MSRE during 1995 to remove filtration devices contaminated with uranium.

Radioactive wastes from WAG 8 facilities are collected in on-site LLLW tanks and are periodically pumped to the main plant area (WAG 1) for storage and treatment. The waste includes demineralizer backwash, regeneration effluents, decontamination fluids, experimental coolant, and drainage from the compartmental areas of filter pits.

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

Because of the small number of groundwater monitoring wells in WAG 8 and WAG 9, they are sampled together. The analytical results for the two WAGs are also reported together.

WAG 10

WAG 10 consists of the Old Hydrofracture Facility (OHF) grout sheets, New Hydrofracture Facility, and New Hydrofracture grout sheets. The surface facilities are associated with WAGs 5, 7, and 8.

Hydrofracture Experiment Site 1 is located within the boundary of WAG 7 (south of Lagoon Road) and was the site of the first experimental injection of grout (October 1959) as a testing program for observing the fracture pattern created in the shale and for identifying potential operating problems. Injected waste was water tagged with ^{137}Cs and ^{141}Ce. Grout consisted of diatomaceous earth and cement.

Hydrofracture Experiment Site 2 is located about 0.8 km (0.5 mile) south of the 7500 (experimental reactor) area (WAG 8). The second hydrofracture experiment was designed to duplicate, in scale, an actual disposal operation; however, radioactive tracers were used instead of actual waste. Cement, bentonite, and water tagged with ^{137}Cs were used in formulating the grout.

The OHF is located about 1.6 km (1.0 mile) southwest of the main ORNL complex near the southwest corner of WAG 5. The facility, commissioned in 1963, was used to dispose of liquid radioactive waste in impermeable shale formations at depths of 800 to 1000 ft by hydrofracture methods. Wastes used in the disposal operations included concentrated LLLW from the Gunite tanks in WAG 2, ^{90}Sr, ^{137}Cs, ^{244}Cm, TRU, and other, unidentified radionuclides.

The New Hydrofracture Facility is located 900 ft southwest of the OHF on the south side of Melton Branch. The facility was constructed to replace the OHF. Wastes used in the injections were concentrated LLLW and sludge removed from the Gunite tanks, ^{90}Sr, ^{137}Cs, ^{244}Cm, TRU, and other nuclides. Plans to plug and abandon several deep injection wells at WAG 10 were made in 1995.

White Wing Scrap Yard (WAG 11)

The White Wing Scrap Yard (WAG 11), a largely wooded area of about 30 acres, is located in the McNew Hollow area on the western edge of East Fork Ridge. It is 1.4 km (0.9 miles) east of the junction of White Wing Road and the Oak Ridge Turnpike. Geologically, the White Oak thrust fault bisects WAG 11. Lower-Cambrian-age strata of the Rome Formation occur southwest of the fault and overlie the younger Ordovician-age Chickamauga Limestone northeast of the fault. There is only one SWMU in WAG 11.

The White Wing Scrap Yard was used for aboveground storage of contaminated material from ORNL, the K-25 Site, and the Y-12 Plant. The material stored at the site by ORNL consisted largely of contaminated steel tanks; trucks; earth-moving equipment; assorted large pieces of steel, stainless steel, and aluminum; and reactor cell vessels removed during cleanup of Building 3019. An interim ROD was agreed to by the TDEC, EPA, and DOE requiring surface debris to be removed from the site. This work was completed in 1994.

The area began receiving material (primarily metal, glass, concrete, and trash with alpha, beta, and gamma contamination) in the early 1950s. Information regarding possible hazardous waste contamination has not been found. The precise dates of material storage are uncertain, as is the time when the area was closed to further storage. In 1966, efforts were begun to clean up the area by disposing of contaminated materials in ORNL's SWSA 5 and by the sale of uncontaminated material to an outside contractor for scrap. Cleanup continued at least into 1970, and removal of contaminated soil began in the same year. Some scrap metal, concrete, and other trash are still located in the area. Numerous radioactive areas, steel drums, and PCB-contaminated soil were identified during surface radiological investigations conducted during 1989 and 1990 at WAG 11. The amount of material or contaminated soil remaining in the area is not known.

7.3.2 1996 Groundwater Quality Well Installation, Development, and Sampling Activities

Groundwater quality monitoring wells for the WAGs are designated as hydraulically upgradient or downgradient (perimeter), depending on their location relative to the general direction of groundwater flow. Upgradient wells are located to provide groundwater samples that are not expected to be affected by possible leakage from the site. Downgradient wells are positioned along the perimeter of the site to detect possible groundwater contaminant migration from the site. There are no groundwater quality monitoring wells installed for the WAG 10 grout sheets.

A summary of the groundwater surveillance program is presented in Table 7.6. The program was reviewed in 1996, and modifications were made effective Oct. 1, 1996, which resulted in some WAGs not being sampled in the calendar year. WAGs, other than WAG 6, are currently monitored to comply with DOE orders 5400.1 and 5400.5, which do not specify sampling schedules. ORNL samples groundwater quality wells at the remaining WAGs in its current program on a rotational basis.

WAG 6 has been monitored under RCRA auspices for a number of years. RCRA assessment data for WAG 6 were submitted to TDEC in March 1996. As part of the WAG 6 RCRA/CERCLA integrated monitoring approach, RCRA assessment groundwater monitoring continued during 1995 and 1996 under the auspices of the *Environmental Monitoring Plan for WAG 6 at ORNL*, a CERCLA-driven monitoring plan, agreed to in principle by DOE, EPA, and TDEC in June 1994. Baseline groundwater monitoring under the plan was initiated in October 1994 and ended in September 1995. All 24 RCRA groundwater monitoring wells were sampled during that time (eight quarterly and 16 semiannually). Routine groundwater monitoring conducted under the plan was initiated in October 1995 and continued into 1996. A subset of 12 RCRA groundwater monitoring wells were sampled on a semiannual basis during 1996 under the routine monitoring scenario. The 9 downgradient wells involved in routine monitoring are 835, 837, 841, 842, 843, 844, 4315, 4316, and 4317. The remaining wells are located upgradient of the hazardous waste disposal area. These wells are 846, 857, and 858. VOCs and radionuclides were monitored during routine monitoring.

The plant perimeter surveillance program, as stipulated in the WAG 6 plan, was initiated in 1993. The program was reviewed in 1996. Modifications were made in the locations sampled and the parameters. A summary of the program is presented in Table 7.7.

7.3.3 ORNL Groundwater Quality

The following section describes the 1996 groundwater monitoring results for the ORNL WAG perimeter monitoring network and the ORNL plant perimeter surveillance (about 130 sampling events). In a few cases, no samples could be collected because the wells were dry.

Eighteen of the 20 wells identified by the ORR EMP represent ORNL's exit pathway and are also part of the WAG perimeter monitoring program (WAG s 2, 3, 6, 11, and 17). As such, 1996 result data from sampling conducted under the WAG perimeter program are used for the monitoring plan program. Several of the wells were not sampled in 1996: two were dry, one is a deep well and does not have a dedicated pump, and the others were not sampled because of changes in the WAG perimeter monitoring program. The four surface water locations (Bear Creek, Raccoon Creek, Bearden Creek, and WOC at WOD) were sampled in September 1996. The results of the plant perimeter monitoring program are discussed as part of the OU discussions.

Groundwater quality is regulated under RCRA by referring to the SDWA standards. The standards are applied when a site undergoes RCRA permitting. None of the ORNL WAGs are under RCRA permits at this time; therefore, no permit standards exist with which to compare sampling results. In an effort to provide a basis for evaluation of analytical results and for assessment

Table 7.6. Summary of the groundwater surveillance program at ORNL, 1996

WAG	Regulatory status	Wells		Parameters monitored[a] prior to program change	Frequency and last date sampled in 1996	New program	
		Upgradient	Downgradient			Locations	Parameters
				Bethel Valley			
1	CERCLA and DOE Orders 5400.1 and 5400.5	3	24	Standard	Rotation Apr–Jun 1996	4 wells	Radionuclides[b] and field measurements[c]
3	DOE Orders 5400.1 and 5400.5	3	12	Standard	Rotation Jun–Jul 1996	*d*	*d*
17	DOE Orders 5400.1 and 5400.5	4	4	Standard	Rotation Apr 1996	All wells	Volatile organics, radionuclides,[b] and field measurements[c]
				Melton Valley			
2	CERCLA and DOE Orders 5400.1 and 5400.5	12	8	Standard	Rotation Mar–Apr 1996	4 wells 16 wells	Full set[e] and field measurements[c] radionuclides[b] and field measurements[c]
4	CERCLA and DOE Orders 5400.1 and 5400.5	4	11	Standard	Rotation Jan–Feb 1996	*d*	*d*
5	CERCLA and DOE Orders 5400.1 and 5400.5	2	20	Standard	Rotation Aug–Sep 1996	*d*	*d*
6	RCRA/CERCLA and DOE Orders 5400.1 and 5400.5	7	17	Volatile organics, radionuclides,[b] and field measurements[c]	Semiannually May, Nov–Dec 1996	12 wells semiannually	Volatile organics, radionuclides,[b] and field measurements[c]

Table 7.6 (continued)

WAG	Regulatory status	Wells		Parameters monitored[a] prior to program change	Frequency and last date sampled in 1996	New program	
		Upgradient	Downgradient			Locations	Parameters
7	CERCLA and DOE Orders 5400.1 and 5400.5	2	14	Standard	Rotation	*d*	*d*
8 and 9	DOE Orders 5400.1 and 5400.5	2	9	Standard	Rotation	All wells	Radionuclides[b] and field measurements[c]
				White Wing Scrap Yard			
11	DOE Orders 5400.1 and 5400.5	6	5	Standard	Rotation	*d*	*d*

[a] Standard: volatile organics, total organic carbon, total organic halides, metals, anions, total phenolics, total suspended solids, alkalinity, gross alpha and beta, ^{3}H, ^{137}Cs, ^{60}Co, and total radioactive strontium. Standard field measurements: pH, conductivity, turbidity, oxidation/reduction potential, temperature, and dissolved oxygen.

[b] Gross alpha and beta, ^{3}H, ^{137}Cs, ^{60}Co, and total radioactive strontium.

[c] Standard field measurements: pH, conductivity, turbidity, oxidation/reduction potential, temperature, and dissolved oxygen.

[d] Not applicable.

[e] Volatile organics, metals, gross alpha and beta, ^{3}H, ^{137}Cs, ^{60}Co, and total radioactive strontium.

Table 7.7. Summary of the plant perimeter surveillance program at ORNL, 1996

Exit pathway	WAG	Number of wells	Surface water locations	Sampled under modified program[a,b]
White Oak Creek/ Melton Valley	6 and 2[c]	10	White Oak Creek at White Oak Dam	Yes
West Bethel Valley	3	3	Raccoon Creek	No
East Bethel Valley	17	4	Bearden Creek	No
White Wing Scrapyard	11	3	Bear Creek	No

[a] Parameters monitored under the old program were volatile organics, tritium, total radioactive strontium, gross alpha and beta, ^{60}Co, and ^{137}Cs.

[b] Parameters monitored for under the modified program are volatile organics, ICP metals, tritium, total radioactive strontium, gross alpha and beta, ^{60}Co and ^{137}Cs.

[c] Four wells are part of the ORNL WAG 6 perimeter network, and four wells are part of the ORNL WAG 2 perimeter network. Two wells are deep wells. One well was not sampled pending a decision regarding installation of a dedicated pump (well no. 1236). The second was sampled in a separate sampling event.

of groundwater quality at ORNL WAGs, federal DWSs and Tennessee water quality criteria for domestic water supplies are used as reference values in the following discussions. When no federal or state standard has been established for a radionuclide, then 4% of the DOE DCG has been used. Although DWSs are used, it is unrealistic to assume that members of the public are going to drink groundwater from ORNL WAGs. There are no groundwater wells furnishing drinking water to personnel at ORNL.

7.3.3.1 Bethel Valley

WAG 1

In 1996, as in the past, radionuclides have been detected in a number of WAG 1 wells, with gross beta activity and total radioactive strontium above DWSs at three wells. The highest levels of radioactivity have historically been observed in the same four wells: one in the northwest WAG area and three in the southwest and western WAG area. During 1996, two wells could not be sampled because of construction activities; historically, both wells have had high levels of radioactivity.

The gross beta activity at the wells of concern is attributable mainly to total radioactive strontium and its daughters. Gross alpha activity at WAG 1 ranged from below detection to 780 pCi/L; beta activity ranged from below detection to 19,000 pCi/L (the DWS is 50 pCi/L); and total radioactive strontium ranged from below detection to 6,800 pCi/L (the DWS is 8 pCi/L).

VOCs were detected in some of the wells; however, most of these were also detected in the laboratory blanks. One well had vinyl chloride detected above DWSs and has had similar vinyl chloride concentrations in the past. Another well had trichloroethene detected above DWSs, similar to historical trichloroethene concentrations.

Fluoride at one well was detected above the DWS; this is the fourth time fluoride has exceeded the DWS. Nitrate at one well was detected above DWSs; this is the second time nitrate has exceeded the DWS at this well. No well values for metals exceeded DWSs.

WAG 3

Analytical results for 1996 at WAG 3 are similar to those obtained in the previous five years. WAG 3 is located on a north-facing slope, with its upgradient wells to the south. The long axis of the site runs east to west; consequently, most of the downgradient wells are along the northern border.

Strontium has been detected historically in wells along the entire northern perimeter of the site. Values exceeding the primary DWS for total radioactive strontium and gross beta activity have consistently been observed at four wells in every sampling event. The gross beta signatures are mainly attributable to total radioactive strontium. The data for the wells along the eastern and northeastern boundaries show evidence of radioactive contamination, including ^{3}H and gross alpha activity. The data for the northwest boundary show the presence of ^{3}H.

Gross alpha activity at WAG 3 ranged from not detected to 12 pCi/L (the DWS is 15 pCi/L); beta activity ranged from not detected to 1700 pCi/L (the DWS is 50 pCi/L); and total radioactive strontium ranged from not detected to 730 pCi/L (the DWS is 8 pCi/L). Tritium ranged from not being detected to 16,000 pCi/L (the DWS is 20,000 pCi/L).

In a few of the downgradient wells, VOCs were detected. Trichloroethene has consistently been detected above DWSs in every sampling event at one well located in the northeast part of the WAG. During this event, trichloroethene was detected below the DWS. Vinyl chloride was detected at estimated levels just slightly above the DWS. Two wells were dry when sampled; they have been dry during previous sampling events.

WAG 17

WAG 17 is located on a northwest-facing slope, with its upgradient wells on the eastern border and downgradient wells on the western border. Although none of the wells had radiological levels above any DWSs, the data for wells along the eastern and western boundaries show evidence of radioactivity, including gross beta activity and ^{3}H. In the past, gross alpha activity has exceeded the DWS at two wells; however, this has not occurred in the past three sampling events. The highest gross alpha activity was 8.6 pCi/L; gross beta was 7.3 pCi/L; total radioactive strontium was 1.7 pCi/L; and ^{3}H was 6200 pCi/L.

The data for the wells along the southeastern and southwestern boundaries show evidence of VOCs. The contamination has consistently been located primarily in one well. The pollutants include trichloroethene, 1,2-dichloroethene, vinyl chloride, tetrachloroethene, 1,1-dichloroethene, and benzene.

Exit Pathway

Historically, no wells in the East and West Bethel Valley exit pathways have had VOC or radiological constituents detected above any DWSs. At the East Bethel Valley surface-water location, neither VOCs nor radiological constituents were detected above any DWS. In the West Bethel Valley exit pathway, gross beta activity was detected above DWSs at the Raccoon Creek surface water location at 54 pCi/L. One of the three wells in the West Bethel Valley exit pathway has always been dry when sampled; a second well has also been dry during the last two sampling events.

7.3.3.2 Melton Valley

WAG 2

At WAG 2, most of the downgradient wells are to the west and downstream. The upgradient wells are to the east and upstream. As a major drainage system, WAG 2 is influenced by other WAGs, and this seems to be reflected in the analytical results. Major contributors of ^{3}H and total radioactive strontium to WAG 2 (in order of contribution) are WAGs 5, 8, 9, 4, 1, 6, and 7 (see Fig. 7.20).

For example, four of the WAG 2 wells that exhibited high levels of ^{3}H are located south of and downgradient of WAGs 5, 6, and 8. All of the WAG 2 wells show evidence of radioactivity, including gross alpha and gross beta activity and ^{3}H. Gross beta activity above primary DWSs was detected at one well on the west side of WAG 7 and at one well south of WAG 6. The elevated levels of ^{3}H and total radioactive strontium in the perimeter wells at WOD are believed to be the result of surface-water underflow at the dam, not groundwater contamination. Gross alpha activity at WAG 2 ranged from not being detected to 10 pCi/L (the DWS is 15 pCi/L); beta activity ranged from not being detected to 730 pCi/L (the DWS is 50 pCi/L); and total radioactive strontium ranged from not being detected to 350 pCi/L (the DWS is 8 pCi/L). Tritium ranged from not being detected to 350,000 pCi/L (the DWS is 20,000 pCi/L).

Chromium was detected above DWS at two wells south of WAG 6. Chromium has been found to be above the DWS in the past four sampling events at one of the wells; this is the first time it has exceeded DWS at the other well.

WAG 4

In 1996, as in the past, radionuclides (including gross beta activity, total radioactive strontium, and ^{3}H) have been detected in a number of WAG 4 wells. The highest levels of radioactivity continue to be observed in the same six wells along the eastern boundary. Gross alpha activity at WAG 4 ranged from not being detected to 13 pCi/L (the DWS is 15 pCi/L); beta activity ranged from not being detected to 1200 pCi/L (the DWS is 50 pCi/L); and total radioactive strontium ranged from not being detected to 620 pCi/L (the DWS is 8 pCi/L). Tritium ranged from not being detected to 7.3×10^6 pCi/L (the DWS is 20,000 pCi/L).

VOCs continue to be detected in wells on the eastern boundary. Two wells have consistently had VOC concentrations above DWSs. Fluoride has been detected above the DWS at one well five out of the six times it has been sampled.

WAG 5

The results for 1996 sampling are similar to results from previous sampling events. WAG 5 contributes a significant percentage of the ^{3}H and total radioactive strontium that exits the ORNL site at WOD via Melton Branch. Tritium contamination is particularly prevalent in one well on the southern and western boundaries, with values as high as 2.7×10^8 pCi/L.

Total radioactive strontium appears to be the major beta emitter found in WAG 5 groundwater. It is found mainly in one well on the southern perimeter. Alpha activity above DWSs has historically been consistently observed in one well on the northwestern boundary of the WAG. This well was pumped dry in 1996 (and in 1994).

Gross alpha activity at WAG 5 ranged from not detected to 18 pCi/L (the DWS is 15 pCi/L); beta activity ranged from not detected to 1900 pCi/L (the DWS is 50 pCi/L); and total radioactive strontium ranged from not detected to 10,000 pCi/L (the DWS is 8 pCi/L).

VOCs were detected in the wells along the southern and western boundaries, including vinyl chloride, 1,2-dichloroethene, benzene, and trichloroethene. Several wells have consistently exceeded DWSs for these contaminants.

No upgradient wells exceeded DWSs for radioactivity or volatile organics.

WAG 6

Results obtained during 1996 were comparable with past results. VOC contamination is apparently isolated in the area around a pair of wells in the northeastern corner of the WAG. During 1996, carbon tetrachloride and trichloroethene were detected above DWSs at one of these wells in every sampling event.

Elevated levels of ^{3}H are found in wells along the eastern perimeter. Gross alpha activity at WAG 6 ranged from not detected to 25 pCi/L (the DWS is 15 pCi/L); and total radioactive strontium ranged from not detected to 41 pCi/L (the DWS is 8 pCi/L). Tritium ranged from not detected to 3.4×10^6 pCi/L (the DWS is 20,000 pCi/L).

WAG 7

WAG 7 was not sampled in 1996. It is not a part of the revised ORNL groundwater surveillance program (see the “WAG 7” subsection in Sect. 7.3.1.2).

WAGs 8 and 9

WAGs 8 and 9 were not sampled in 1996; they will be sampled in 1997 under the revised groundwater surveillance program.

Exit Pathway

In the Melton Valley exit pathway, WOC at WOD had gross beta activity (410 pCi/L), total radioactive strontium (150 pCi/L), and ^{3}H concentrations (110,000 pCi/L) detected above the DWSs. One of the wells also had gross beta activity, total radioactive strontium, and ^{3}H concentrations detected above DWSs; a second well had ^{3}H concentrations detected above DWSs. This is consistent with historical data. No VOCs were detected above DWSs in either the wells or the surface-water location. Several of the wells were not sampled because of changes in other programs.

White Wing Scrapyard (WAG 11)

WAG 11 was not sampled in 1996. It is not a part of the revised ORNL groundwater surveillance program. Refer to the previous discussion in this document.

Exit Pathway

In the White Wing Scrapyard exit pathway, the wells were not sampled in 1996 because of program changes. The surface-water location considered in this exit pathway did not have any radionuclide concentrations above DWSs.

7.3.4 Well Plugging and Abandonment at ORNL

The purpose of the ORNL well plugging and abandonment program is to remove unneeded wells and boreholes as possible sources of cross-contamination of groundwater from the surface or between geological formations. Because of the complex geology and groundwater pathways at ORNL, it has been necessary to drill many wells and boreholes to establish the information base needed to predict groundwater properties and behavior. However, many of the wells that were established before the 1980s were not constructed satisfactorily to serve current long-term monitoring requirements. Where existing wells do not meet monitoring requirements, they become candidates for plugging and abandonment.

7.3.4.1 Wells Plugged During 1996

No wells were plugged and abandoned at ORNL during 1996. A total of 232 wells have been recommended for plugging and abandonment as soon as funds are available.

7.3.4.2 Methods Used

Plugging and abandonment are accomplished by splitting the existing well casing and filling the casing and annular voids with grout or bentonite to create a seal between the ground surface and water-bearing formations and between naturally isolated water-bearing formations.

Splitting and abandoning the well casing in place also minimize the generation of waste that would be created if other methods were used. Special tools were developed to split the casings of different sizes and material. A down-hole camera was used during development of the splitting tools to evaluate their effectiveness.

Detailed procedures have been developed and documented regarding the use of specific grout materials in different well environments. These procedures were tested and evaluated during the 1993 plugging and abandonment activities.

7.4 GROUNDWATER MONITORING AT THE ETTP

7.4.1 Background and Hydrogeologic Setting

Groundwater effluent monitoring at the ETTP is focused primarily on investigating and characterizing sites for remediation under CERCLA. As a result of the FFA and certification of closure of the K-1407-B and C Ponds, the principal driver at the ETTP is CERCLA.

The ETTP Groundwater Program is a component in the ORR ER strategy that is described in the *Oak Ridge Reservation Site Management Plan for the Environmental Restoration Program* (DOE 1995a). The cleanup strategy described in the site management plan has been developed to accelerate the transition of areas of concern from characterization to remediation by making decisions at the watershed scale based on recommended land use. The watershed is a surface drainage basin that includes an area of concern or multiple areas of concern to be investigated and/or remediated. This approach allows for the systematic monitoring and evaluation of contaminant sources and migration through the use of integrated surface-water and groundwater monitoring.

During the fall of 1996, efforts began on incorporating the ETTP Groundwater Protection Program requirements into the Integrated Water Quality Program (IWQP). The IWQP, which was established to provide a consistent approach to watershed monitoring across the ORR, will be responsible for conducting groundwater surveillance monitoring at the ETTP during 1997. Six watersheds have been designated at the ETTP for monitoring and reporting groundwater quality data. The watershed designations and associated areas of concern are described in the following section.

Unlike the other ORR facilities where many source areas are located in relatively undeveloped areas of the reservation, most source areas at the ETTP are located within the highly industrialized areas of the site. The surface topography has been considerably altered as a result of site construction. Large areas have been excavated or filled to yield the present, low-relief landscape. As much as 60 ft of materials have been excavated locally, with equal amounts of fill placed in adjacent low areas. These filled areas may represent primary pathways for contaminant migration when located below the water table. A number of sinkholes have been identified on historic aerial photos that are not visible on the surface today. Many of these have been filled during site construction; and buildings (such as K-33) have been erected directly above them.

The storm drain network discharges to either Mitchell Branch, the K-1007-P1 pond, the K-901-A pond, or directly to Poplar Creek and the Clinch River. Storm drain video surveys show both infiltrating and exfiltrating water along the lines, suggesting that the storm drains may serve as groundwater sinks (where located below the water table) or sources in other areas of the plant. In addition, at least ten buildings have been determined to have basements with sumps below the seasonal low water table. Water that accumulates in the sumps is discharged either to the sanitary sewer or CNF system, storm drains, or, on rare occasions, to the ground. All of these systems have been active since building construction in the 1940s.

Bedrock underlying the ETTP can be broadly categorized as carbonate (Knox and Chickamauga groups) or clastic (Rome Formation and possibly the Conasauga Group). The carbonates underlie most of the main plant area, including the K-27/29 Peninsula, K-1070-A Burial Ground, the K-25 Building, and the K-1004 laboratory area. The eastern portion of the site, including the K-1070-C/D site and much of the Mitchell Branch area is underlain by clastics of the Rome formation and possibly the Conasauga Group. The structural geology of the ETTP is perhaps the most complicated on the ORR and includes “map-scale” folds and faults and “outcrop-scale” fractures, folds, and faults. Complex faulting, fracturing, and folding in the clastic bedrock preclude definition of simple bedding geometry. Therefore, groundwater flow paths cannot be predicted in this area of the site.

Cavities have been encountered in 39% of all subsurface penetrations at the ETTP. Cavity heights are typically greater in the Knox Group carbonates. During recent drilling in the vicinity of the K-1070-A Burial Ground cavernous bedrock with cavities up to 22 ft (6.7 m) in height has been encountered; however, based on camera and sonar surveys, the lateral extent of these cavities appears limited. Although large cavities have been reported in some locations in the Chickamauga bedrock, typical cavity heights are generally less than 5 ft (1.5 m).

Groundwater occurs in both the unconsolidated zone and bedrock, primarily as a single water table aquifer. Perched water may be of local significance. With few exceptions, the water table occurs in the overburden above bedrock across the site, with saturated overburden thickness ranging up to 70 ft. Because bedrock is exposed along the bottom of the Clinch River and Poplar Creek, the unconsolidated zone flowpaths are truncated at these boundaries. Water level data indicate that groundwater flows radially from higher elevations toward the bounding surface water features.; however, the sumps and drains that lie below the seasonal low water table affect the configuration of the water table surface and thus affect the contaminant flow directions.

Groundwater flow in the unconsolidated zone is expected to be in the direction of the mapped hydraulic gradients. In the carbonate bedrock, groundwater flow is expected to be controlled by hydraulic gradients and geologic strike. In the Rome Formation groundwater flow directions cannot be predicted with any certainty. Recent studies have shown that hydraulic gradients are steepest (and consequently, overall flux is greatest) during the wet season and low pool stage periods. Much of the site is paved or otherwise covered, reducing direct recharge by groundwater; however, leaking underground utilities and storm drains are likely to recharge the groundwater substantially.

Few perennial springs have been identified along Poplar Creek or the Clinch River. Wet-season springs located along the exposed low pool stage shores of Poplar Creek and the Clinch River do not appear consistently from year to year. In general, both springs and seeps at the ETTP are characterized by moderate to low flow rates.

7.4.2 Watersheds

Six watersheds, each defined as a geographic area that encompasses a surface water drainage basin, have been defined at the ETTP. These watersheds are described in the following sections and are indicated on Fig. 7.22.

7.4.2.1 K-1007-B Watershed

The K-1007-B Watershed encompasses the southern area of the ETTP. Areas of concern in this watershed include the K-1004-J Vaults, the K-1004-L UST, the K-1004-L recirculating cooling water (RCW) lines, the K-1004 cooling tower basin, the K-1004 laboratory drain, the K-1007-P1 Pond, the K-1007 UST, and the K-1200 Centrifuge complex. Potential contaminants include heavy metals, acids, organic solvents, other organic chemicals, and radioactivity.

7.4.2.2 Mitchell Branch Watershed

The Mitchell Branch Watershed encompasses the northeastern portion of the ETTP and includes the K-1407-A Neutralization Pit, the former K-1407-B and C Ponds, the K-1407-C soil, the K-1700 stream (Mitchell Branch), the K-1070-B Old Classified Burial Ground, the K-1401 acid line, the K-1401 degreasers, the K-1401 basement, the K-1413 neutralization pit, the K-1420 building process lines, the K-1420 oil storage area, the K-1420 incinerator, the K-1413 treatment tanks, the K-1413 building and process lines, the K-1070-C/D Classified Burial Ground, the K-1070 concrete pad, the K-1070-D storage dikes, the K-1070 pits, and the K-1414 Garage. The potential contaminants include organic solvents, waste oils, heavy metals, PCBs, and radioactivity.

7.4.2.3 Ungaged Watershed

The Ungaged Watershed encompasses areas where groundwater and surface water discharge directly to Poplar Creek and includes the western half of the K-25 Building, the K-1064 peninsula, the K-27/29 peninsula, the K-31 Building, and the eastern half of the K-33 Building. Areas of contamination (AOCs) in this watershed include the K-1066-J cylinder storage yard; K-1024 dilution pit; K-1064 drum storage and burn area; K-1064 drum deheading facility; the K-802-B, K-802-H, K-832-H, K-892-G, K-892-H, K-892-J, and K-862-E cooling tower basins; the K-31 and K-33 RCW lines; the K-732, K-762, and K-792 switchyards; the K-27 and K-29 RCW lines; the

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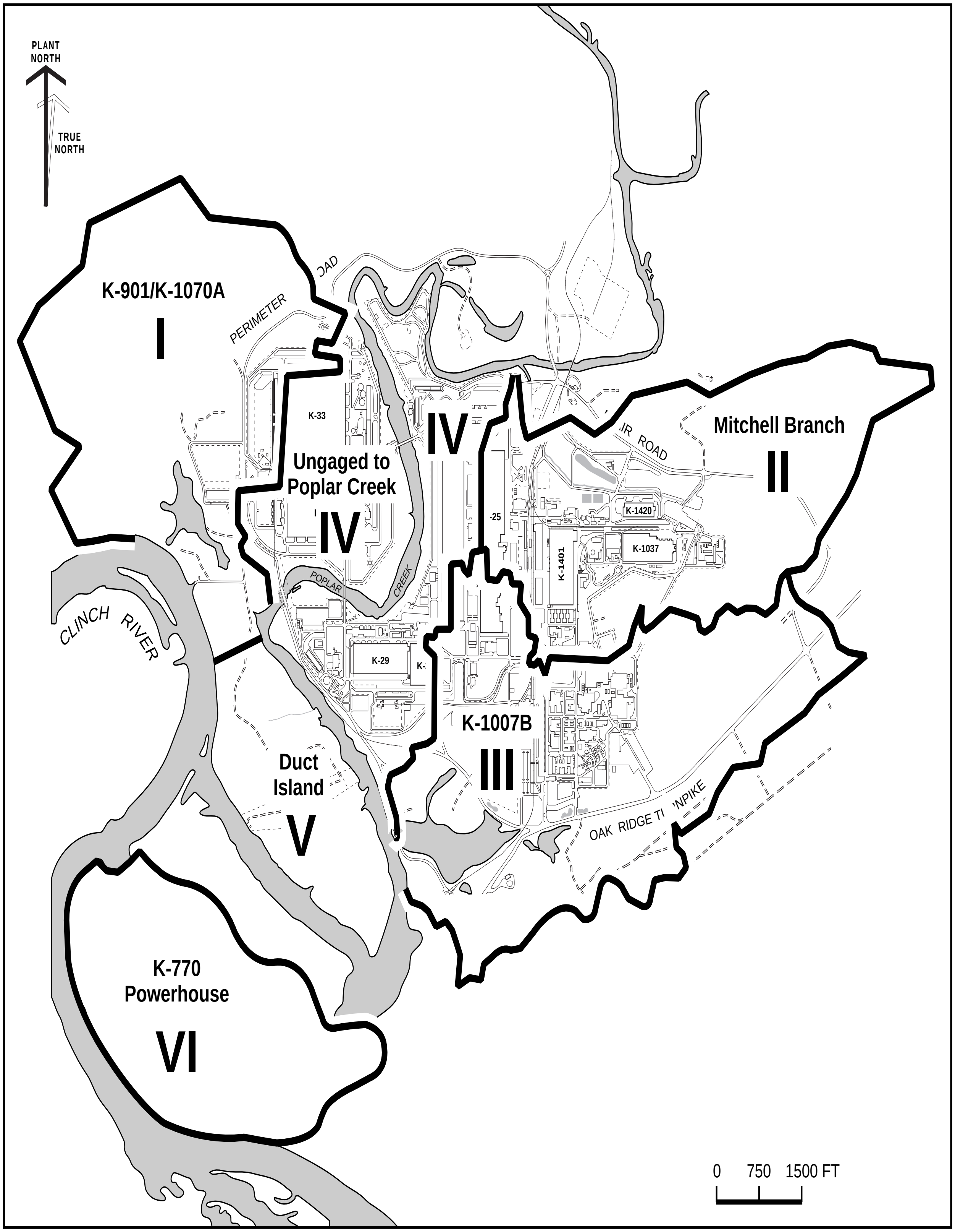

Fig. 7.22. ETTP waste area groupings.

K-1410 neutralization pit; the K-1131 facility; the K-1232 chemical recovery facility lagoon; and the K-1231 facility. Potential contaminants include waste oils, heavy metals, organic solvents, PCBs, and radioactivity.

7.4.2.4 K-901/K-1070-A Watershed

The K-901/K-1070-A Watershed encompasses the northwestern portion of the ETTP. The areas of concern include the K-1070-A burial ground, the K-1070-A landfarm, the K-901-A holding pond, K-901 north and south disposal areas, K-895 cylinder destruct facility, and the K-1066-K cylinder storage yard. Potential contaminants are organics, heavy metals, PCBs, and radioactivity.

7.4.2.5 Duct Island Watershed

The Duct Island Area consists of the K-1070-F peninsula on Poplar Creek and contains the K-1070-F contractor's burial ground, the K-900 bottle smasher, and the Duct Island Road. Potential contaminants are heavy metals, organics, and uranium.

7.4.2.6 K-770/Powerhouse Watershed

The K-770/Powerhouse Watershed borders the Clinch River in the southwestern portion of the ETTP. Areas of concern included in this watershed are the K-770 Scrap Yard, the K-725 Beryllium Building, the K-720 ash pile, the F-05 laboratory, the K-709 switchyard, the K-710 sludge beds and Imhoff tanks, and the K-1085 Firehouse Burn Area. The potential contaminants are waste oils, organics, heavy metals, PCBs, and radioactivity.

7.4.3 1996 Well Installation and Plugging and Abandonment Activities

At the end of 1996 there were 241 water quality monitoring wells at the ETTP. There were no monitoring wells installed, nor were there any wells plugged or abandoned at the ETTP during 1996. Wells considered obsolete for monitoring or wells whose construction or annular seal integrity are questionable will be candidates for plugging and abandonment at some time in the future.

7.4.4 1996 Groundwater Monitoring Program

Groundwater samples were collected from the K-1407-B and C Ponds monitoring wells during February and August in 1996. Monitoring of these wells, located in the Mitchell Branch Watershed, was conducted to satisfy post-remediation monitoring requirements specified by the TDEC/DOE-O and EPA. Monitoring at two wells (UNW-3 and UNW-9) and one surface water location in Mitchell Branch (SD-195) are required for evaluating remedial action effectiveness at the former ponds (Fig. 7.23). Groundwater samples were collected using micropurge and low-flow sampling procedures. Field measurements of temperature, specific conductance, pH, dissolved oxygen, and oxidation/reduction potential, were collected at each well during sampling. The groundwater samples were analyzed for nitrate, selected metals, and selected radionuclides. No other wells were sampled during 1996 at the ETTP.

7.4.5 1996 Groundwater Monitoring Results

The results from both the wet weather (February) and the dry weather (August) sampling events at the two K-1407-B and C Ponds wells are consistent with results from previous sampling events at these wells. None of the metals analyzed exceeded a primary DWS. As is common in groundwater from the region, manganese and iron concentrations in both wells exceeded the secondary DWSs for these constituents. The secondary DWSs are nonenforceable taste, odor, or appearance guidelines.

Gross alpha activity, with a maximum of 8.76 pCi/L, did not exceed the DWS. Gross beta activity ranged from 0.96 to 19.3 pCi/L (limits of

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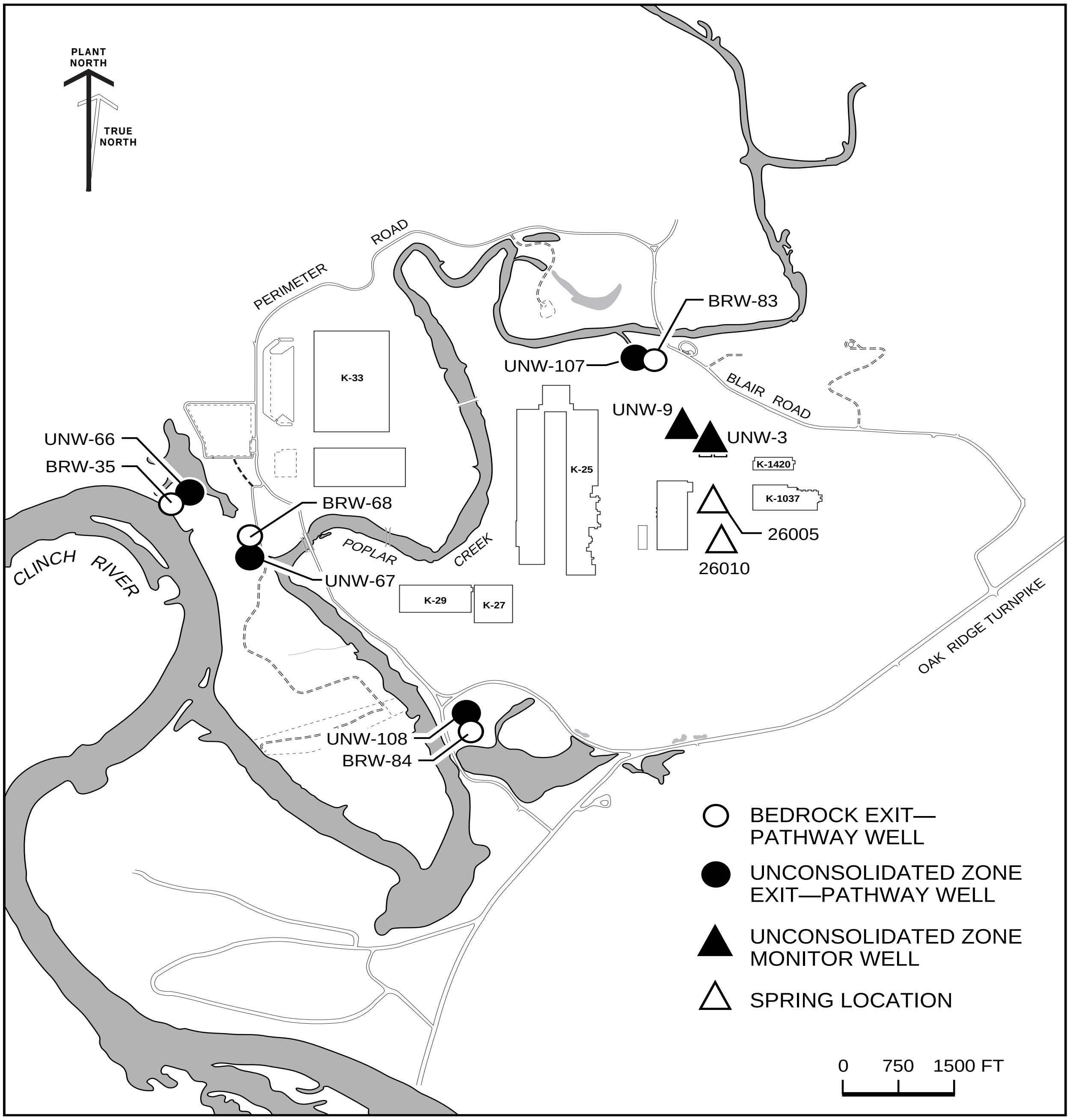

Fig. 7.23. Background and exit-pathway monitoring locations at the ETTP.

error ranged from 3.2 to 9.6 pCi/L), well below the reference value of 50 pCi/L. Also, the radiological results for the individual isotopes analyzed were well below the 4% of their respective DCGs used for determining compliance with the 4 mrem/year drinking water standard for man-made beta.

7.4.5.1 ETTP Springs

Groundwater samples were collected from two springs at the ETTP during 1996. These springs are located north of the K-1070 C/D Classified Burial Ground and are designated as springs 26005 and 26010 (Fig. 7.23).

Previous sampling results for the 26005 spring had shown that the discharge contained contaminants similar to those detected in nearby groundwater monitoring wells. Sampling conducted in 1995 downstream of both springs did not allow a determination of whether only one or both of the springs were contaminated. The discharge from both springs is captured by the storm drain SD-170 network.

Samples were collected from the 26005 and 26010 springs in May 1996 and were analyzed for VOCs, which are the contaminants of concern in groundwater in this area of the ETTP. The laboratory results for these samples confirmed the presence of trichloroethene, tetrachloroethene, 1,2-dichloroethene, and freon 113 in the discharge from both springs. The contaminant concentrations are generally an order of magnitude greater in the 26005 spring located approximately 250 ft north and downgradient of the 26010 spring. Reported concentrations for trichloroethene, the primary contaminant present at both springs, were 490 μg/L at spring 26005 and 40 μg/L at spring 26010.