Y-12

OAK RIDGE Y-12 PLANT

LOCKHEED MARTIN

**GROUNDWATER PROTECTION PROGRAM
CALENDAR YEAR 1998
EVALUATION OF GROUNDWATER QUALITY DATA
FOR THE
CHESTNUT RIDGE HYDROGEOLOGIC REGIME
AT THE
U.S. DEPARTMENT OF ENERGY Y-12 PLANT,
OAK RIDGE, TENNESSEE**

September 1999

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Prepared by

**AJA TECHNICAL SERVICES, INC.
Under Subcontract No. 70Y-MVM64**

for the

**Environmental Compliance Department
Environment, Safety, and Health Organization
Oak Ridge Y-12 Plant
Oak Ridge, Tennessee 37831**

Managed by

**LOCKHEED MARTIN ENERGY SYSTEMS, INC.
for the U.S. Department of Energy
Under Contract No. DE-AC05-84OR21400**

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

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List of Acronyms and Abbreviations

BCV	Bear Creek Valley
bgs	below ground surface
Chestnut Ridge Regime	Chestnut Ridge Hydrogeologic Regime
CY	calendar year
DOE	U.S. Department of Energy
DQO	data quality objective
ft	feet
ft/d	feet per day
GWMR	Groundwater Monitoring Report
GWPP	Groundwater Protection Program
MCL	Maximum Contaminant Level
MDA	minimum detectable activity
µg/L	micrograms per liter
mg/L	milligrams per liter
msl	mean sea level
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
PCE	tetrachloroethene
pCi/L	picoCuries per liter
PCP	post closure permit (RCRA)
RCRA	Resource Conservation and Recovery Act
Security Pits	Chestnut Ridge Security Pits
Sediment Disposal Basin	Chestnut Ridge Sediment Disposal Basin
TCE	trichloroethene
TCFM	trichlorofluoromethane
TDEC	Tennessee Department of Environment and Conservation
TDS	total dissolved solids
UTL	upper tolerance limit
VOC	volatile organic compound
1,1-DCA	1,1-dichloroethane
1,2-DCA	1,2-dichloroethane
1,1-DCE	1,1-dichloroethene
cis-1,2-DCE	cis-1,2-dichloroethene
1,1,1-TCA	1,1,1-trichloroethane

1.0 INTRODUCTION

The Chestnut Ridge Hydrogeologic Regime (Chestnut Ridge Regime) encompasses a section of Chestnut Ridge south of the U.S. Department of Energy (DOE) Y-12 Plant (Figure 1). Groundwater monitoring is performed at several hazardous and nonhazardous waste management facilities located in the regime per the requirements of applicable operating/post closure permits and governing state/federal regulations and guidelines, including DOE Order 5400.1A - *General Environmental Protection Program*. Applicable provisions of DOE Order 5400.1A require evaluation of available monitoring data with regard to: (1) groundwater quality in areas that are, or could be, affected by Y-12 Plant operations, (2) the quality of surface water and groundwater where contaminants are most likely to migrate beyond the DOE Oak Ridge Reservation (ORR) property line, and (3) long-term trends in groundwater quality at the Y-12 Plant. This report presents the results of these DOE Order 5400.1A evaluations based on available data for the network of monitoring wells and springs in the Chestnut Ridge Regime sampled during calendar year (CY) 1998.

The following sections of this report contain relevant background information (Section 2.0); describe the results of the respective data evaluations required under DOE Order 5400.1A (Section 3.0); summarize significant findings of each evaluation (Section 4.0); and list the technical reports and regulatory documents cited for more detailed information (Section 5.0). All of the illustrations (maps and trend graphs) and data summary tables referenced in each section are presented in Appendix A and Appendix B, respectively.

2.0 BACKGROUND INFORMATION

The following sections contain background information regarding the Chestnut Ridge Regime, including a summary of waste management sites in the regime and the associated groundwater monitoring programs, a brief description of topography and bedrock geology in the regime, an overview of the hydrogeologic characteristics and groundwater flow patterns in the Knox Aquifer, and a short description of surface water drainage features.

2.1 WASTE MANAGEMENT SITES AND MONITORING PROGRAMS

Several waste management sites are in the Chestnut Ridge Regime (Figure 2), including closed hazardous waste sites and operating nonhazardous solid waste landfills (Table 1). Groundwater monitoring managed by the Y-12 Plant Groundwater Protection Program (GWPP) at these sites during CY 1998 was performed for the multiple programmatic purposes of: (1) post closure corrective action monitoring at the Chestnut Ridge Security Pits (Security Pits) as specified in the Resource Conservation and Recovery Act (RCRA) post closure permit (PCP) for the Chestnut Ridge Regime; (2) RCRA post closure detection monitoring at the Chestnut Ridge Sediment Disposal Basin (Sediment Disposal Basin) and Kerr Hollow Quarry as required under the PCP; (3) detection monitoring at Industrial Landfills II, IV, and V, and Construction/Demolition Landfill VI in accordance with the regulations governing nonhazardous solid waste management and disposal and applicable conditions of operating permits issued by the Tennessee Department of Environment and Conservation (TDEC); and (4) regime-wide DOE Order 5400.1A surveillance monitoring and exit pathway/perimeter monitoring. Groundwater and surface water monitoring managed by the Integrated Water Quality Program was also performed to comply with requirements of Comprehensive Environmental Response, Compensation, and Liability Act Records of Decision at the United Nuclear Corporation Site, Kerr Hollow Quarry, and the Filled Coal Ash Pond (U.S. Department of Energy 1999).

2.2 TOPOGRAPHY AND BEDROCK GEOLOGY

The Chestnut Ridge Regime encompasses a section of Chestnut Ridge bordered by the Y-12 Plant in Bear Creek Valley (BCV) to the north, Scarboro Road to the east, Bethel Valley Road to the south, and an unnamed surface drainage feature to the west (Figure 3). The northern flank of the ridge forms a steep slope rising more than 200 feet (ft) above the floor of BCV. The ridge crest slopes toward the east from an elevation of about 1200 ft above mean sea level (msl) southwest of the Y-12 Plant to about 1060 ft msl east of the Sediment Disposal Basin. A series of prominent hills dominates the central part of the broad southern flank of Chestnut Ridge, which is dissected by several tributaries, including McCoy Branch in the middle of the regime.

Bedrock geology in the vicinity of the Chestnut Ridge Regime is generally characterized by thrust-faulted sequences of southeast-dipping, clastic (primarily shale and siltstone) and carbonate (limestone and dolostone) strata of Lower Cambrian to Upper Ordovician age. Interbedded

limestone and shale formations of the Conasauga Group directly underlie the Y-12 Plant in BCV, primarily dolostone strata of the Knox Group form Chestnut Ridge, and the argillaceous limestones and interbedded shales of the Chickamauga Group underlie Bethel Valley (Figure 3). Strike and dip of bedding in the area is generally N55°E and 45°SE, respectively (as referenced to true north).

Many waste sites in the Chestnut Ridge Regime are directly underlain by red-brown to yellow-orange residuum overlying the Knox Group. The residuum is characteristically acidic, predominantly composed of clays and iron sesquioxides, and contains semicontinuous, relict beds of fractured chert and other lithologic inhomogeneities (such as silt bodies) that provide a weakly connected network through which saturated flow can occur (Solomon *et al.* 1992). The residuum is thin or nonexistent near karst features such as dolines (sink holes), swallets (sinking streams), and solution pan features (Ketelle and Huff 1984). Depth to bedrock varies throughout the Chestnut Ridge Regime but is usually less than 100 ft below ground surface (bgs).

Residuum throughout all but the southernmost portion of the Chestnut Ridge Regime is underlain by the Knox Group (Figure 3). The Knox Group, which consists of about 2600 to 3300 ft of gray to blue-gray, thin- to thick-bedded cherty dolostone with interbedded limestone, is divided into five formations (listed from oldest to youngest): Copper Ridge Dolomite, Chepultepec Dolomite, Longview Dolomite, Kingsport Formation, and Mascot Dolomite (Figure 3). Topographic and stratigraphic relationships suggest that the Copper Ridge Dolomite underlies the steep northern flank of the ridge, the Longview Dolomite forms the series of prominent hills across the middle of the southern flank of the ridge, and the Mascot Dolomite disconformably underlies the Chickamauga Group along the southern boundary of the regime (Hatcher *et al.* 1992).

The most pervasive structural features in the Chestnut Ridge Regime are extensional, hybrid, and shear fractures (Solomon *et al.* 1992). Three major fracture orientations are evident: one that roughly parallels bedding, one steeply dipping set that parallels geologic strike, and one steeply dipping set oriented perpendicular to strike (Dreier *et al.* 1987). Most fractures are short, ranging from tenths of inches to a few feet in length (Solomon *et al.* 1992). Dissolution of carbonates along fractures has produced many surface karst features on Chestnut Ridge, including a series of sinkholes along the crest of the ridge that show a prominent alignment parallel to strike. This linear trend may result from dissolution along a bedding plane or fracture set (Ketelle and Huff 1984; Smith *et al.* 1983).

2.3 GROUNDWATER SYSTEM

The Knox Aquifer, consisting of the Knox Group and the underlying Maynardville Limestone formation (Conasauga Group), is the principal hydrogeologic unit in the Chestnut Ridge Regime. Overall, groundwater flow in the Knox Aquifer is characterized by conduit flow that discharges at springs located along drainage features. The groundwater flow system in the Knox Aquifer generally consists of three vertically gradational subsystems: (1) the stormflow zone, (2) the vadose zone, and (3) the groundwater zone. The subsystems are distinguished by groundwater flux, which decreases with depth (Solomon *et al.* 1992).

Although detailed studies have not been conducted in the Chestnut Ridge Regime, investigations on Chestnut Ridge approximately 4000 ft west of the regime in the Walker Branch watershed show that groundwater occurs intermittently above the water table in a shallow "stormflow zone" that extends to a depth of about 8 ft bgs (Wilson *et al.* 1990). Macropores and mesopores provide the primary channels for lateral flow in the stormflow zone, which lasts only a few days or weeks after rainfall. Most groundwater within the stormflow zone is either lost to evapotranspiration or recharge to the water table, and the remaining water discharges at nearby seeps, springs, or streams (Moore 1989).

The vadose zone occurs between the stormflow zone and the water table, which typically occurs near the bedrock/residuum interface. Soil moisture content in the vadose zone is below the saturation limit except in the capillary fringe above the water table and within wetting fronts during periods of vertical percolation from the stormflow zone (Moore 1989). Most recharge through the vadose zone is episodic and occurs along discrete permeable fractures that become saturated, although surrounding micropores remain unsaturated (Solomon *et al.* 1992). Moore (1988) determined a geometric mean hydraulic conductivity of about 0.006 feet per day (ft/d) for residuum on Chestnut Ridge near the Oak Ridge National Laboratory (ORNL). However, the residuum is hydrologically heterogeneous with quickflow via dolines to conduits in the subsurface.

Groundwater below the vadose zone occurs within orthogonal sets of permeable, planar fractures that form water-producing zones within an essentially impermeable matrix. Dissolution of bedrock carbonates has enlarged fractures and produced an interconnected conduit-flow system characteristic of karst aquifers. Because the occurrence of solution features and the frequency, aperture, and connectivity of permeable fractures decrease with depth, the bulk hydraulic conductivity of the groundwater zone is vertically gradational. Most groundwater flux occurs within the transitional horizon between residuum and unweathered bedrock (water table interval); lower flux (and longer solute residence times) occurs at successively greater depths in the bedrock (Solomon *et al.* 1992).

The water table in the Chestnut Ridge Regime is a subdued replica of surface topography and occurs at the greatest depth (>100 ft bgs) along the crest of Chestnut Ridge, which is a groundwater flow divide and a recharge area. Groundwater generally flows from west to east parallel to the flow divide across the northern part of the regime, with radial components of flow north into BCV and south toward tributary headwaters on the southern flank of the ridge (Figure 4). The central part of the regime is characterized by radial flow directions from local groundwater flow divides along hilltops between tributaries. Groundwater flow directions in the southern part of the regime are generally south toward Melton Hill Reservoir. The overall directions of groundwater flow throughout the Chestnut Ridge Regime do not significantly change during seasonal groundwater flow conditions (Figure 4). Horizontal hydraulic gradients throughout the year are highest along the steep northern flank of Chestnut Ridge (i.e., across geologic strike) and in the upper reaches of tributaries on the southern ridge flank, and are nearly flat along the southern boundary of the regime.

Available data show that hydraulic conductivity in the Knox Group varies over multiple orders of magnitude, which is typical of karst aquifers. Results of straddle packer tests in core holes indicate hydraulic conductivity ranging from 0.0002 to 3.1 ft/d at depths generally less than 600 ft bgs in the lower Knox Group (King and Haase 1988). Average hydraulic conductivity values calculated from results of 122 falling-head slug tests performed between July 1994 and October 1997 in

17 monitoring wells completed at shallow depths (60 to 195 ft bgs) in the middle Knox Group range from about 0.003 to 14 ft/d (GW-560) (Jones 1998). Results of a preliminary dye-tracer test at the Security Pits indicate flow rates of about 100 to 300 ft/d (Geraghty & Miller, Inc. 1990). Although not confirmed by a second test using different tracers (Science Applications International Corporation 1993), these findings are supported by the range of flow rates (490 to 1250 ft/d) indicated by results of a dye-tracer test performed on Chestnut Ridge near ORNL (Ketelle and Huff 1984).

The geochemistry of the groundwater in the Knox Aquifer is fairly homogeneous. Most wells yield calcium-magnesium bicarbonate groundwater with pH of 7.5 to 8.0; total dissolved solids (TDS) above 150 milligrams per liter (mg/L); equal or nearly equal molar concentrations of calcium and magnesium; low proportions (<5%) of chloride, sodium, sulfate, and potassium; and very low (i.e., <1 mg/L) carbonate alkalinity and nitrate (as N) concentrations. Some wells yield groundwater with enriched chloride and sulfate concentrations that probably reflect the geochemical influence of locally disseminated sulfides (e.g., pyrite) or evaporites (e.g., gypsum). Additionally, groundwater within low permeability (matrix) intervals in the upper Knox Group (e.g., Mascot Dolomite), as indicated by data for several wells at Kerr Hollow Quarry, has greater proportions of sulfate and potassium and higher trace metal concentrations (e.g., strontium) than typical of the groundwater from low yield intervals within the lower Knox Group formations (e.g., Copper Ridge Dolomite). These geochemical differences potentially reflect corresponding differences between carbonate mineralogies in the upper and lower sections of the Knox Group or the proximity to and types of disseminated secondary minerals (AJA Technical Services, Inc. 1996).

2.4 CONTAMINANT SOURCE AREAS

Monitoring data obtained since the mid-1980s indicate that groundwater contamination is fairly limited in the Chestnut Ridge Regime and that volatile organic compounds (VOCs) are the most common groundwater contaminant. Dissolved VOCs (primarily chloroethanes and chloroethenes) have been detected in the groundwater samples collected from monitoring wells downgradient from the Security Pits, Industrial Landfill IV, and Kerr Hollow Quarry. However, a clearly distinct plume of dissolved VOCs is indicated only by the data for wells at the Security Pits.

The Security Pits are located on the crest of Chestnut Ridge directly south of the central portion of the Y-12 Plant (Figure 2), and consist of two areas, each containing a series of east-west oriented trenches that are about 8 to 10 feet (ft) wide, 10 to 18 ft deep, and 700 to 800 ft long. This site was used for disposal of hazardous waste until December 1984, and for disposal of nonhazardous waste until the site was closed in November 1988. Data obtained from monitoring wells at the Security Pits indicate that a narrow, elongated plume of dissolved VOCs extends parallel with geologic strike for at least 2,600 ft downgradient to the east, and perpendicular to strike for at least 500 ft downgradient to the north and south. The primary components of the plume are 1,1-dichloroethene (1,1-DCE), 1,1-dichloroethane (1,1-DCA), and 1,1,1-trichloroethane (1,1,1-TCA) in the western trench area; and tetrachloroethene (PCE), trichloroethene (TCE), and 1,2-dichloroethene (1,2-DCE) in the eastern trench area.

Data obtained since the early 1990s indicate very low concentrations (1 to 2 µg/L) of 1,1,1-TCA in the groundwater at two wells downgradient of the western disposal trenches at the Security Pits: well GW-796, located at Industrial Landfill V about 400 ft south of the disposal trenches, and well GW-514, located at the Filled Coal Ash Pond about 900 ft south of the disposal trenches. Although the concentrations are estimated (i.e., less than the analytical reporting limit), the repeated detection of this compound in the groundwater samples from both wells probably reflects southward migration from the Security Pits, possibly along “quickflow” conduits oriented perpendicular to geologic strike.

Industrial Landfill IV, located along the crest of Chestnut Ridge in the northwest corner of the regime (Figure 2), has received waste since October 1989 and is a suspected source of 1,1,1-TCA, 1,1-DCA, 1,1-DCE, boron, and nickel. Elevated total boron concentrations have consistently been reported in samples from a well located downgradient to the east of the site (GW-217), while VOCs and total nickel have been reported in samples from a well located south of the eastern portion of the site (GW-305). These results indicate groundwater transport along permeable flowpaths from the unlined portion (about 150 ft X 150 ft) of Industrial Landfill IV. Although the source of these contaminants has not been formally confirmed, no other site is located upgradient of these wells.

Kerr Hollow Quarry is located in the southeast corner of the Chestnut Ridge Regime (Figure 2) and served as a source of stone construction material until it filled with water and was abandoned in the late 1940's. From the early 1950's until November 1988, the quarry was used for the disposal of reactive materials from the Y-12 Plant and the ORNL. Wastes were removed from the quarry between mid-1990 and late-1993 to obtain certified clean-closure status from the TDEC, but the site was finally closed with some wastes remaining in place. Low levels (<5 µg/L) of carbon tetrachloride, chloroform, and PCE occur in the groundwater at monitoring wells located to the south (GW-144) and southeast (GW-142) of Kerr Hollow Quarry. Each of these VOCs are probably present at low concentrations in the groundwater downgradient of the site, possibly as a consequence of wastes being disturbed during attempts to obtain clean closure of the site. Because of the low concentrations, the apparently sporadic detection of VOCs in the groundwater samples from these wells potentially reflects volatilization during sampling.

2.5 SURFACE WATER SYSTEM

Surface streams in the Chestnut Ridge Regime include four primary drainage basins on the southern flank of Chestnut Ridge: two unnamed tributaries located west and east of Industrial Landfill II in the western part of the regime; the McCoy Branch drainage basin in the central part of the regime; and an unnamed drainage basin in the eastern part of the regime (Figure 3). These tributaries are mainly intermittent above an elevation of 900 ft msl and receive flow via surface runoff, stormflow discharge, and groundwater baseflow. Baseflow contributions increase downstream along the length of the streams, and spring discharge represents substantial contributions to the total flow in most of the tributaries. All of the tributaries discharge into Melton Hill Reservoir (Clinch River) south of the Chestnut Ridge Regime.

3.0 CY 1998 MONITORING DATA EVALUATION

An evaluation of the monitoring data for the network of CY 1998 sampling locations in the Chestnut Ridge Regime, as reported in the CY 1998 Groundwater Monitoring Report (GWMR) issued by Lockheed Martin Energy Systems, Inc. in March 1999 (AJA Technical Services, Inc. 1999), is provided in the following sections. This evaluation mirrors the applicable requirements of DOE Order 5400.1A. Section 3.1 contains an evaluation of groundwater quality in areas that are, or could be, affected by Y-12 Plant operations (hereafter referenced as Surveillance Monitoring). Section 3.2 contains an evaluation of surface water/groundwater quality where contaminants are most likely to migrate beyond the ORR property line (hereafter referenced as Exit Pathway/Perimeter Monitoring). Long-term groundwater quality trends near the Y-12 Plant, based on data for selected sampling locations in the Chestnut Ridge Regime, are described in Section 3.3. Each evaluation is based on historical data (if available) and CY 1998 results that meet the applicable data quality objectives (DQOs) defined in *Y-12 Plant Groundwater Protection Program - Groundwater Monitoring Program Data Management Plan* (Martin Marietta Energy Systems, Inc. 1993). Descriptions of the DQO criteria and associated data screening process, along with summaries of the CY 1998 data that do not meet applicable DQOs, are provided in Section 2.6 of the CY 1998 GWMR.

3.1 SURVEILLANCE MONITORING

The CY 1998 monitoring results reported for 31 monitoring wells and one surface water sampling location (Outfall 301) in the Chestnut Ridge Regime (Figure 5) were evaluated for the purposes of Surveillance Monitoring. Groundwater samples were collected semiannually from all of these locations except well GW-322 and Outfall 301, which were sampled only once during CY 1998 (Table 2). Additionally, four replicate samples were collected during each semiannual sampling event from each of the RCRA post closure detection monitoring wells at the Sediment Disposal Basin (GW-156, GW-159, GW-731, and GW-732) and Kerr Hollow Quarry (GW-142, GW-143, GW-144, GW-145, and GW-231).

Dedicated bladder pumps (Well Wizards™) were used to collect filtered and unfiltered groundwater samples from each well in accordance with the Y-12 Plant GWPP technical procedure (SESD-TP-8204, Rev.3) for low-flow minimal drawdown sampling (hereafter referenced as low-flow sampling). Under this procedure, samples (including duplicates) are collected immediately after field measurements show stable (minimal variation over four consecutive readings) pH, conductivity, water temperature, oxidation-reduction potential, and dissolved oxygen values in the groundwater purged from the well at a rate low enough (<300 milliliters per minute) to ensure minimal drawdown of the water level in the well (<0.1 ft per quarter-hour). This differs from the groundwater sampling method used by the Y-12 Plant GWPP until October 1997, which involved pumping at least three well volumes (if the well did not purge dry) before collecting samples from each well (hereafter referenced as conventional sampling).

Depending on the requirements of the governing monitoring program, the filtered and/or unfiltered groundwater samples from each well were analyzed for inorganics (major ions and trace metals),

volatile organic compounds (VOCs), gross alpha and beta activities, and several miscellaneous laboratory analyses, including TDS, total suspended solids, and turbidity (Table 3). Analytical results for each sample are reported in Appendix E of the CY 1998 GWMR. An evaluation of the analytical results for each major group of analytes (major ions, trace metals, VOCs, and radioactivity) is provided in the following sections.

3.1.1 Major Ions

Principal ion data for groundwater samples from most of wells sampled during CY 1998 are characteristic of uncontaminated, calcium-magnesium-bicarbonate groundwater in the Knox Aquifer (Figure 6). Results for most of the wells are generally characterized by equal or nearly equal molar concentrations of calcium and magnesium, which is typical of water in contact with dolomite; low molar proportions (<5%) of chloride, potassium, sodium, and sulfate; and carbonate alkalinity, fluoride, and nitrate as N (hereafter synonymous with “nitrate”) concentrations below 1 mg/L or the respective analytical reporting limit. Apart from the distinctive geochemistry of the groundwater at Kerr Hollow Quarry (wells GW-143 and GW-145), the principal ion data for several wells located elsewhere in the Chestnut Ridge Regime are conspicuous with respect to results for nitrate, potassium, and sodium.

Wells GW-143 and GW-145 at Kerr Hollow Quarry yield moderately-mineralized, sulfate-enriched, calcium-magnesium-bicarbonate groundwater (Figure 6). Groundwater samples from these wells are characterized by unequal molar proportions of calcium and magnesium; sulfate levels of 10 to 30 mg/L; and much higher sodium (>20 mg/L), chloride (>10 mg/L), and fluoride (>2 mg/L) concentrations than typical of most Knox Group wells. Dissolution of locally disseminated gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) probably accounts for the sulfate-enriched geochemistry of the groundwater in wells GW-143 and GW-145, both of which monitor low-yield intervals in the Mascot Dolomite at depths of 253 ft bgs and 110 ft bgs, respectively. Enriched levels of other solutes (e.g., sodium) in the groundwater at these wells may be a legacy of the sedimentary basin brines that are encountered at depth elsewhere on the ORR (Saunders and Toran 1992).

The CY 1998 monitoring results for nitrate are consistent with historical data and show that concentrations in groundwater from the Knox Group in the Chestnut Ridge Regime rarely exceed 1 mg/L. Of the 31 wells used for Surveillance Monitoring data evaluation purposes, nitrate concentrations above 1 mg/L were reported only for wells GW-144 and GW-231 at Kerr Hollow Quarry, well GW-609 at the Security Pits, and well GW-799 at Industrial Landfill V. The highest nitrate levels (4.39 - 6.89 mg/L) were reported for the replicate groundwater samples collected from well GW-144 in April 1998 (seasonally high groundwater flow). Historical data for this well, completed at a depth of 195 ft bgs in the Upper Knox Group (Mascot Dolomite), show that the nitrate concentrations fluctuate seasonally and have generally increased since the early 1990s (see Section 3.3). Nitrate in the groundwater at well GW-144 (and GW-231) may reflect migration from municipal sewage sludge application sites in hayfields located about 800 ft west-northwest of Kerr Hollow Quarry (AJA Technical Services, Inc. 1998). In an effort to better determine if downgradient transport from the sludge application site is a source of the nitrate, groundwater samples collected in October 1998 from each of the RCRA wells at Kerr Hollow Quarry (GW-142, GW-143, GW-144,

GW-145, and GW-231) and Outfall 301 were analyzed for ammonia, fecal coliform, nitrate (as N), and total phosphate (as phosphorous). Nitrate (as N) was only detected in the sample from Outfall 301 (1.38 mg/L) and trace levels of ammonia were detected in samples from wells GW-145 (0.42 mg/L) and GW-231 (0.22 mg/L); fecal coliform and total phosphate did not exceed respective analytical reporting limits.

Atypically high concentrations of potassium and sodium, along with unusually high pH (field measurements), were reported for each of the groundwater samples (including duplicates) collected from well GW-757 at Industrial Landfill II. These unusual potassium, sodium, and pH results strongly indicate localized contamination from cement grout circulated into fractures and solution features in the surrounding bedrock during the installation of the well. Moreover, as shown in the following summary, comparison with historical data for well GW-757 shows that the increased potassium, sodium, and pH levels coincide with the change from conventional sampling to low-flow sampling.

Indications of grout contamination at well GW-757

Analyte	Conventional Sampling			Low-Flow Sampling		
	April 1996	November 1996	April 1997	October 1997	April 1998	October 1998
Total Potassium (mg/L)	1.3	3.1	6.2	9.1	14	15.8
Total Sodium (mg/L)	2.1	5.8	6.7	14	26	35.3
pH (standard units)	8.13	8.3	7.9	9	9.44	9.41

Apparently, the conventional sampling method induced flow of clean groundwater into the well which diluted the grout-contaminated groundwater near the well screen. Well GW-757 should be redeveloped to collect representative samples using the low-flow minimal drawdown method.

3.1.2 Trace Metals

The following evaluation of the CY 1998 trace metal data focuses on total concentrations that meet applicable DQO criteria and exceed the applicable upper tolerance limit (UTL) reported in *Determination of Reference Concentrations for Inorganic Analytes in Groundwater at the Department of Energy Y-12 Plant, Oak Ridge, Tennessee* (HSW Environmental Consultants, Inc. *et al.* 1995). The UTLs for each metal were determined from statistical analysis of historical (1986 - 1993) data for specific groups of wells (i.e., clusters) differentiated by similar geochemical characteristics and they represent the maximum concentrations expected in the groundwater monitored by the wells comprising each cluster. The total concentrations of eight trace metals reported for 60 unfiltered groundwater samples collected from 17 monitoring wells during CY 1998 exceed applicable UTLs. The bulk (60%) of these results, as shown in the following summary, are for boron and elemental strontium, and more than 80% of the elevated concentrations of these metals were reported for the replicate groundwater samples collected from Kerr Hollow Quarry wells GW-142, GW-143, GW-144, and GW-145.

Summary of CY 1998 trace metal concentrations that exceed upper tolerance limits

Trace Metal	Results > UTL		Maximum CY 1998 Concentration			
	No. of Results	No. of Wells	UTL (mg/L)	Result (mg/L)	Location	Date
Barium	9	2	0.34	0.488	GW-142	04/27/98
Boron	18	3	0.12	0.938	GW-143	04/28/98
Chromium	1	1	0.029	0.036	GW-799	01/13/98
Lead	9	2	0.0096	0.014	GW-145	04/30/97
Nickel	2	1	0.02	0.0502	GW-305	07/13/98
Silver	4	4	0.006	0.0094	GW-305	01/14/98
Strontium	23	3	0.079	7.78	GW-145	04/27/98
Zinc	3	2	0.041	0.16	GW-217	01/07/98

Few of these elevated trace metal concentrations indicate groundwater contamination from waste disposal activities in the regime and none of the elevated results exceed the respective maximum contaminant level (MCL) for drinking water. Results for several of these trace metals (e.g., silver) are probably analytical artifacts that just barely exceed the analytical detection limit (and the applicable UTL), and other results probably reflect ambient levels in the groundwater. For instance, the unusually high boron and strontium concentrations that are characteristic of the unfiltered groundwater from several wells at Kerr Hollow Quarry (particularly GW-143 and GW-145) may be caused by advective mixing of sulfate-enriched groundwater with deeper bedrock brines, upward diffusion of solutes from the deeper brine, diffusion of residual brine solutes from the bedrock matrix, or a combination of these natural processes (Saunders and Toran 1992). Based on comparison with historical monitoring results, only the elevated metal concentrations reported for wells GW-217 (boron) and GW-305 (nickel), both located at Industrial Landfill IV, potentially reflect groundwater contamination.

Total (and dissolved) boron concentrations reported for the groundwater samples collected from well GW-217 in January (0.14 mg/L) and July 1998 (0.136 mg/L) significantly exceed the applicable UTL (0.028 mg/L). These results are consistent with historical data and show that boron levels in well GW-217 remain at least an order of magnitude higher than evident in all the other Knox Group wells in the Chestnut Ridge Regime (including wells not sampled during CY 1998) except those at Kerr Hollow Quarry. Well GW-217 is hydraulically downgradient (along geologic strike) of Industrial Landfill IV (Figure 4), approximately 100 ft east of an unlined portion (about 22,500 ft²) of the landfill that began receiving waste in October 1989 (Figure 5). Because the significant boron solute species are anionic (uncharged), they are probably not extensively absorbed onto mineral surfaces and are therefore highly mobile in groundwater (Hem 1985). Results of falling head hydraulic conductivity tests (Jones 1998) indicate that the monitored interval in well GW-217 intercepts moderately permeable (0.01 - 0.2 ft/d) flowpaths 165 ft to 180 ft bgs. These hydraulic conductivity values generally support advective transport of boron to well GW-217 within the time period between initial disposal of wastes in October 1989 and a sharp concentration "spike" in January 1992 (0.69 mg/L), which is followed by a generally increasing concentration trend through October 1994 (see Section 3.3). Moreover, historical data show that three of the four lowest boron concentrations (i.e., ≤ 0.0074 mg/L) were reported for samples collected from the well before Industrial Landfill IV began receiving wastes in October 1989. Thus, the elevated boron concentrations in the groundwater

at well GW-217 potentially reflect migration of boron originating from wastes disposed in the landfill.

As shown in the preceding data summary, the total nickel concentrations reported for the groundwater samples collected from well GW-305 in January (0.039 mg/L) and July 1998 (0.0502 mg/L) exceed the applicable UTL (0.02 mg/L). These initial low-flow sampling results are generally consistent with historical (conventional sampling) data for the well, which show total (and dissolved) nickel concentrations near the analytical reporting limit (0.01 mg/L) punctuated by several concentration “spikes” that exceed the UTL (see Section 3.3), including a series of elevated nickel concentrations between July 1991 (0.18 mg/L total; 0.12 dissolved) and January 1993 (0.033 mg/L total; 0.049 dissolved). Additionally, the CY 1998 nickel results, along with additional (preliminary) data obtained from low-flow sampling during CY 1999, reflect a clearly increasing concentration trend (see Section 3.3).

However, it seems unlikely that the sporadically elevated nickel concentrations, several of which exceed the drinking water MCL (0.1 mg/L), and the apparently increasing concentration trend reflect downgradient transport of nickel from wastes in Industrial Landfill IV (assuming the landfill received nickel-bearing wastes). For instance, the total nickel concentration evident in March 1989 (0.024 mg/L) indicates that the elevated nickel levels in the well predate initial disposal of wastes in the landfill (October 1989). Also, considering the neutral to slightly basic pH of the groundwater in the Knox Aquifer, natural attenuation mechanisms (e.g., cation exchange and sorption onto mineral surfaces) would be expected to substantially inhibit the migration of nickel from the landfill. Although mobility of nickel may be enhanced if mobile colloids and/or natural (or synthetic) chelating agents are present in the groundwater (Hem 1995), advective transport from the landfill is not supported by the very low hydraulic conductivity values (0.025 - 0.028 ft/d) indicated by falling head slug tests in well GW-305 (Jones 1998; see discussion in Section 3.1.3). Additionally, the general lack of any positive relationship between elevated total (or dissolved) nickel concentrations and seasonally (or episodically) high groundwater flow conditions (as indicated by presampling groundwater elevations in the well) does not support flow-related transport of nickel in groundwater. Instead of contamination from Industrial Landfill IV, corrosion of the stainless steel well casing and screen may account for the elevated total (and dissolved) nickel concentrations; geochemical conditions expected to be corrosive to stainless steel (e.g., dissolved oxygen >1 mg/L; Driscoll 1986) are evident in well GW-305, and microbiologically induced corrosion is possible if bacteria (including iron-reducing and sulfate-reducing organisms) are present in the groundwater (Sarouhan *et al.* 1998). Downhole visual inspection is the most direct means of confirming corrosion of the well casing and screen.

3.1.3 Volatile Organic Compounds

Excluding a few spurious results for common laboratory reagents (e.g., acetone and 2-butanone), one or more VOCs (primarily chloroethenes and chloroethanes) were detected in at least one groundwater sample collected during CY 1998 from eight monitoring wells (Figure 7). These compounds were reported for wells located at Kerr Hollow Quarry (wells GW-145 and GW-231), Industrial Landfill IV (GW-305), the Security Pits (wells GW-322 and GW-609),

Construction/Demolition Landfill VI (well GW-543), and Industrial Landfill V (wells GW-796 and GW-801). Tetrachloroethene (PCE) and/or trichloroethene (TCE) were detected in wells GW-145, GW-231, GW-322, and GW-609; cis-1,2-dichloroethene (cis-1,2-DCE) was detected in well GW-609; 1,1,1-TCA, 1,1-DCE, and/or 1,1-DCA were detected in wells GW-305, GW-322, GW-543, GW-796, and GW-801; and 1,2-dichloroethane (1,2-DCA), trichlorofluoromethane (TCFM), and ethylbenzene were detected in well GW-322. As shown in the following summary, the maximum concentrations of the compounds detected in each well except GW-322 are less than 10 micrograms per liter ($\mu\text{g/L}$). Only the concentrations of PCE (GW-322 and GW-609), 1,1-DCE (GW-322), and 1,1,1-TCA (GW-322) exceed applicable drinking water MCLs.

Maximum CY 1998 VOC concentrations

Monitoring Well	Maximum CY 1998 VOC Concentration and Applicable MCL ($\mu\text{g/L}$)								
	PCE	TCE	cis-1,2-DCE	1,1-DCE	1,1,1-TCA	1,2-DCA	1,1-DCA	TCFM	Ethylbenzene
GW-145	.	(4)	.	.	.	.	.	.	.
GW-231	.	(3)	.	.	.	.	.	.	.
GW-305	.	.	.	(2)	17	.	(4)	.	.
GW-322	10	.	.	170	220	(3)	160	54	(1)
GW-543	.	.	.	.	(1)	.	.	.	.
GW-609	7	.	5	.	.	.	.	(4)	.
GW-796	.	.	.	.	(1)	.	.	.	.
GW-801	.	.	.	.	(4)	.	.	.	.
MCL	5	5	70	7	200	.	.	.	.

Note: "." = Not detected; () = Estimated concentration below the reporting limit; Bold = Exceeds MCL.

Historical data confirm the Security Pits as the source of the chloroethenes and chloroethanes in the groundwater at wells GW-322 and GW-609; trace levels of 1,1,1-TCA in well GW-796 may likewise reflect migration from this site. Industrial Landfill IV is the most likely source of the chloroethanes and chloroethenes in the groundwater at well GW-305. Sporadic detection of chloroethenes (and chloromethanes) in samples from wells GW-145 and GW-231 is consistent with historical data for these and other wells (e.g., GW-144) at Kerr Hollow Quarry. However, the trace levels of 1,1,1-TCA detected in the samples collected from well GW-543 (October 1998) and well GW-801 (January 1998) are not supported by historical results for either well and may be analytical artifacts.

Monitoring results obtained from the network of monitoring wells at the Security Pits generally define a narrow, elongated plume of dissolved chloroethanes and chloroethenes extending parallel with geologic strike for at least 2600 ft downgradient to the east, and perpendicular to strike for at least 500 ft downgradient to the north and south. The primary components of the plume include 1,1-DCE, 1,1-DCA, and 1,1,1-TCA in the western trench area and PCE, TCE, and cis-1,2-DCE in the eastern trench area. The distribution of the plume constituents relative to the respective source areas and elongation of the plume along the axis of Chestnut Ridge, despite steeper hydraulic gradients toward the ridge flanks, suggest primarily eastward strike-parallel horizontal transport in the groundwater. The maximum depth of vertical transport has not been conclusively determined,

however, available monitoring data show that VOCs occur at least 150 ft bgs in the western trench area, 250 ft bgs near the middle of the site, and 270 ft bgs downgradient of the eastern trench area (AJA Technical Services, Inc. 1997).

Well GW-322 was selected for one-time sampling during CY 1998 to provide current data regarding the concentration and distribution of constituents within the dissolved VOC plume originating from the Security Pits. This well is completed with a screened monitored interval from 128 ft - 193 ft bgs about 200 ft directly south of the eastern trench area (Figure 5). Historical data show that this well yields calcium-magnesium-bicarbonate groundwater containing a mixture of dissolved chloroethenes and chloroethanes, including suspected parent compounds (PCE and 1,1,1-TCA) and potential degradation products (1,1-DCE, 1,1-DCA, and 1,2-DCA). As shown in the following summary, analytical results for the groundwater sample collected using the low-flow sampling method in January 1998 are consistent with these historical (conventional sampling) findings and, in terms of the types of VOCs detected and the respective concentration levels, suggest little, if any, conclusive difference between conventional and low-flow sampling results.

Comparison of VOC concentrations and sampling methods at well GW-322

VOC	MCL (µg/L)	Well GW-322 Concentration (µg/L)		
		Conventional Sampling		Low-Flow Sampling
		April 1992 (Diluted Sample)	July 1992 (Diluted Sample)	January 1998
Parent Compounds				
PCE	5	5	7	10
1,1,1-TCA	200	350	360	220
Degradation Products				
1,1-DCE	7	82	99	170
1,2-DCA	.	<10	<10	(3)
1,1-DCA	.	58	76	160
Note: () = Estimated concentration below the reporting limit.				

Moreover, the CY 1998 results show that the concentration of potential degradation products (e.g., 1,1-DCE and 1,1-DCA) have significantly increased since the early 1990s, whereas the concentration of the parent compounds have remained fairly constant (PCE) or have significantly decreased (1,1,1-TCA) (see Section 3.3). The relatively unchanged concentrations of PCE combined with the overall lack of intermediate PCE degradation products (particularly cis-1,2-DCE) suggest little if any biotic degradation in the groundwater at well GW-322. In contrast, abiotic degradation of 1,1,1-TCA, which is the only major chlorinated solvent that can be chemically transformed under all likely groundwater conditions (McCarty 1996), is strongly indicated by the decreasing 1,1,1-TCA concentration trend coupled with the increasing concentrations of 1,1-DCA and 1,1-DCE.

Historical data show that well GW-609, located about 800 ft east (along geologic strike) of the Security Pits, yields calcium-magnesium-bicarbonate groundwater containing relatively low concentrations of dissolved chloroethenes. Similar concentrations of PCE, TCE, cis-1,2-DCE, and

TCFM were detected in both groundwater samples collected from well GW-609 during CY 1998, and as shown in the following summary, results for each of these compounds are less than respective concentrations evident in the samples collected from the well during CY 1997.

VOC concentrations in samples from well GW-609

Compound	Concentration (µg/L)			
	January 1997	July 1997	January 1998	July 1998
PCE	13	12	5	7
TCE	(1)	(1)	<5	<5
cis-1,2-DCE	9	10	(3)	5
TCFM	5	5	(4)	(4)
Note: () = Estimated concentration below the reporting limit.				

These results are consistent with historical VOC data for well GW-609, which show decreasing long-term concentration trends that began after the disposal trenches at the Security Pits were closed and capped in the mid to late 1980s.

Very low (estimated) concentrations of 1,1,1-TCA were detected in the groundwater samples collected from well GW-796 in January (1 µg/L) and July 1998 (1 µg/L). These results are consistent with historical data for the well; similarly low 1,1,1-TCA concentrations (2 µg/L or less) have been detected in all but one of the 15 groundwater samples collected from the well since it was first sampled in May 1993. Well GW-796, which serves as an upgradient/background well for detection monitoring at Industrial Landfill V and as a point-of-compliance well for RCRA post closure corrective action monitoring at the Security Pits, is completed with a screened monitored interval 122 - 136 ft bgs in the Copper Ridge Dolomite about 500 ft directly south (across geologic strike) of the Security Pits (Figure 5). Because the western trench area at the Security Pits is the only confirmed source of 1,1,1-TCA in the Chestnut Ridge Regime and is hydraulically upgradient of well GW-796, the repeated detection of this compound in the well potentially reflects downgradient transport from this source, possibly along the "quickflow" conduits described by Shevenell (1994). This interpretation is supported by the consistently low TDS (<150 mg/L) of the groundwater samples from the well, which suggests short groundwater residence time, and the relatively high hydraulic conductivity (1.2 - 4.2 ft/d) of the groundwater flowpaths intercepted by the monitored interval, as indicated by falling head permeability tests in the well (Jones 1998). Moreover, assuming (1) unimpeded, advective transport in the groundwater (i.e., ignoring vapor-phase transport in the vadose zone and natural attenuation in the subsurface), (2) a migration pathway length of 516 ft determined from a simple algebraic calculation (i.e., $a^2 + b^2 = c^2$) using the horizontal distance from the Security Pits (500 ft) and the depth of the monitored interval midpoint (129 ft bgs), and (3) the range of hydraulic conductivity indicated by the falling head tests, the travel time estimated for 1,1,1-TCA to migrate into well GW-796 (120 to 450 days) is within the range of possibility, considering that the Security Pits first received wastes in 1973.

Historical data show that well GW-305, which is located directly south (hydraulically downgradient) of the eastern (unlined) portion of Industrial Landfill IV (Figure 4), yields groundwater containing

relatively low levels of 1,1,1-TCA, 1,1-DCE, and 1,1-DCA. The CY 1998 monitoring results for this well, which has been sampled on a quarterly or semiannual basis since March 1990, show that: (1) 1,1,1-TCA concentrations steadily increased following the initial detection in January 1992 (0.6 µg/L) to a peak of 17 µg/L in January 1998 (see Section 3.3); (2) the first-time detection of 1,1-DCA in July 1996 (1 µg/L) was followed by similarly low concentrations in January 1997 (2 µg/L), July 1997 (3 µg/L), and January 1998 (4 µg/L); and (3) the initial detection of 1,1-DCE in January 1997 (1 µg/L) was confirmed in July 1997 (2 µg/L) and January 1998 (2 µg/L).

These results suggest the breakthrough of a dissolved VOC plume, beginning with the arrival of the parent product (1,1,1-TCA), followed by the degradation products (1,1-DCA and 1,1-DCE) that arrived several years later. Although 1,1,1-TCA, 1,1-DCE, and 1,1-DCA are components of the VOC plume originating from the disposal trenches at the Security Pits, well GW-305 is more than one mile west of the Security Pits; seasonal groundwater elevations in well GW-305 are more than 20 ft higher than in any of the wells (e.g., GW-322 and GW-609) at the Security Pits (Figure 8); and the elongated geometry of the dissolved VOC plume originating from the Security Pits suggests primarily eastward (downgradient) rather than westward (upgradient) strike-parallel migration in the groundwater (AJA Technical Services, Inc. 1996). Industrial Landfill IV is the only potential contaminant source area hydraulically upgradient of well GW-305, and the screened interval for the well (165.3 - 179.6 ft bgs) potentially intercepts dip-parallel groundwater flowpaths that subcrop below the unlined eastern portion of the landfill. Industrial Landfill IV initially received wastes in October 1989, however none of the documentation for the site indicates disposal of 1,1,1-TCA.

Assuming rapid migration to the saturated zone and unimpeded advective transport in the groundwater, the range of hydraulic conductivity values (0.025 - 0.028 ft/d) indicated by falling head tests in well GW-305 (Jones 1998) do not support transport of 1,1,1-TCA to the well within the time period between the initial waste disposal (October 1989) and the first-time detection of 1,1,1-TCA on January 4, 1992 (795 to 825 days). Moreover, the low hydraulic conductivity values also do not support vertical migration from the water table (about 120 ft bgs) to the monitored interval in the well GW-305 during this time frame. Therefore, the repeated detection of 1,1,1-TCA (and the associated degradation products) despite the apparently low permeability of the flowpaths intercepted by the well suggest: (1) the hydraulic conductivity test results do not account for stratigraphic and lithologic heterogeneities (e.g., chert layers) in the residuum which could provide more permeable pathways from the landfill to the monitored interval of the well, (2) the permeability test results are representative and the presence of VOCs reflect migration from an unknown source area located very close to the well, or (3) the permeability test results are representative and the presence of VOCs reflect migration from Industrial Landfill IV via a combination of mechanisms (e.g., vapor phase transport), possibly including migration as dense nonaqueous phase liquid (which may occur independent of groundwater flow), that greatly increase the relative rate of transport to the well. The low VOC concentrations reported for the well thus far do not indicate the presence of a DNAPL source.

Trace levels of TCE were detected in one of the replicate groundwater samples collected in April 1998 from Kerr Hollow Quarry wells GW-145 (4 µg/L) and GW-231 (3 µg/L). Sporadic detection of TCE (and other VOCs) is consistent with the historical data for these and other wells at the site, which show: (1) concentrations of each compound are very low (less than respective analytical

reporting limits); (2) carbon tetrachloride and chloroform are detected more often (although many of the chloroform results are false positives because of contamination in the associated trip blanks) than PCE and TCE; and (3) these compounds are rarely detected (excluding false-positive results) in each of the replicate samples collected during each sampling event. Because the concentrations are so low, the sporadic detection of these VOCs, particularly in samples collected using the conventional sampling method, potentially reflects volatilization during sample collection and handling rather than the absence of the compounds in the groundwater at the site. Additionally, no spatial or temporal patterns are evident in the detection of VOCs in the wells at the site, although quarterly RCRA interim status detection monitoring results show that these compounds (particularly carbon tetrachloride) were detected most frequently in the groundwater samples collected between the first quarter of 1990 and the fourth quarter of 1993, which suggests a causal relationship with the closure activities performed at the site during that time (HSW Environmental Consultants, Inc. 1995).

3.1.4 Radioactivity

Historical monitoring data for the bulk of the monitoring wells in the Chestnut Ridge Regime do not indicate radiological contamination. The CY 1998 monitoring results are consistent with these historical findings; gross alpha and gross beta results reported for the groundwater samples collected from all but seven of the 31 Surveillance Monitoring wells are less than the corresponding minimum detectable activity (MDA) for each result. Moreover, the gross alpha and gross beta results that exceed the corresponding MDA have high proportional counting errors (i.e., a high degree of analytical uncertainty). Additionally, all of the gross alpha results that exceed MDAs are less than the 15 picoCuries per liter (pCi/L) MCL for drinking water except the result for one of the replicate samples collected from well GW-145 (20 ± 6 pCi/L) in October 1998. Similarly, all the gross beta results that exceed MDAs are less than the Safe Drinking Water Act screening value of 50 pCi/L. The highest beta activity reported for replicate samples collected in October 1998 from wells GW-143 (17 ± 5.9 pCi/L) and GW-145 (18 ± 6.1 pCi/L). None of these results are clearly indicative of groundwater contamination.

3.2 EXIT PATHWAY/PERIMETER MONITORING

The CY 1998 monitoring results reported for six springs in the Chestnut Ridge Regime were evaluated for the purposes of Exit Pathway/Perimeter Monitoring because groundwater flow in the regime is predominantly through conduits that discharge at springs. Each of these springs is located in surface drainage features that exit the ORR and flow into the Clinch River/Melton Hill Lake south of the Chestnut Ridge Regime. As shown on Figure 5, two of the springs are in Bethel Valley, one about 2000 ft west of Rogers Quarry (SCR2.5SP) and one about 1500 ft south of Kerr Hollow Quarry (SCR5.4SP). The other four springs are located in surface drainage features that traverse the southern flank of Chestnut Ridge: the unnamed drainage feature in the western part of the regime (SCR2.1SP), McCoy Branch (SCR3.4SP) and an unnamed drainage feature (SCR4.3SP) in the central part of the regime, and the unnamed drainage feature in the eastern part of the regime (SCR5.1SP). Grab samples were collected (in accordance with Y-12 Plant procedures) from each spring semiannually during CY 1998 (Table 2). As shown on Table 3, the samples were analyzed

for inorganics (major ions and trace metals), VOCs, gross alpha and gross beta activity, and several miscellaneous field (e.g., water temperature) and laboratory analytes (e.g., TDS). Analytical results for each spring are reported in Appendix E of the CY 1998 GWMR.

Principal ion data for the samples from each of the springs generally reflect the calcium-magnesium-bicarbonate geochemistry of groundwater in the Knox Aquifer (Figure 6). The results for these springs are characterized by a wide range of calcium:magnesium ratios; variable but generally low molar proportions (<10%) of chloride, potassium, sodium, and sulfate; nitrate concentrations below 1 mg/L; carbonate alkalinity and fluoride concentrations below respective analytical reporting limits; and low TDS (<200 mg/L). Results for several of the springs also show distinctly seasonal geochemical changes. For instance, chloride concentrations in the samples collected from springs SCR2.1SP (14.6 mg/L), SCR2.2SP (8.11 mg/L), SCR4.3SP (9.83mg/L), and SCR5.4SP (12.5 mg/L) during January 1998 (seasonally high flow) are two to four times higher than respective chloride levels in the samples collected from each spring during July 1998 (seasonally low flow). Unusually high nitrate levels (i.e., >1 mg/L) are evident in springs SCR2.2SP, SCR5.1SP, and SCR5.4SP, with the highest concentrations reported for the samples from spring SCR5.1SP in January (3.16 mg/L) and July 1998 (2.18 mg/L). This spring, located north of Kerr Hollow Quarry, discharges into an unnamed drainage feature about 750 ft downstream of a large sewage sludge application site east of Construction Demolition Landfill VII (Figure 5). Elevated nitrate concentrations in the spring may therefore reflect migration of nitrate leached from the sludge at this site, although the nitrate levels are substantially below the 10 mg/L MCL for drinking water.

Total concentrations of one or more of four trace metals (boron, strontium, lead, and manganese) reported for at least one sample collected during CY 1998 from each of the springs used for Exit Pathway/Perimeter Monitoring except SCR5.1SP exceed the applicable UTL. However, these elevated concentrations most likely reflect analytical variability (boron, lead, and manganese) or ambient levels (strontium) rather than groundwater contamination.

Although VOCs were detected in at least one sample collected during CY 1998 from each of the springs used for Exit Pathway/Perimeter Monitoring, all but one of these results are false positive or spurious results for acetone and/or 2-butanone (i.e., common laboratory reagents). The sample collected from spring SCR2.1SP in July 1998 contained a trace level (2 µg/L) of carbon tetrachloride. Assuming this result is an analytical artifact, the CY 1998 monitoring data do not indicate VOC contamination in any of the springs used for the purposes of Exit Pathway/Perimeter Monitoring.

The gross alpha and gross beta results reported for each of the samples collected from all of the springs used for Exit Pathway/Perimeter Monitoring during CY 1998 reflect essentially background levels. All of the gross beta results were below the MDAs and only the gross alpha results reported for samples collected from two of the springs exceed the respective MDAs. The gross alpha reported for the samples collected in July 1998 from springs SCR2.1SP (9.7 ± 4 pCi/L) and SCR4.3SP (2.4 ± 2 pCi/L) slightly exceed the respective MDAs, but have large proportional counting errors which indicates a high degree of analytical uncertainty.

3.3 CONTAMINANT CONCENTRATION TRENDS

For the purposes of DOE Order 5400.1A requirements, the following discussion is focused on CY 1998 sampling locations in the Chestnut Ridge Regime that exhibit increasing long-term contaminant concentration trends (Table 2). Increasing trends are indicated by the monitoring results for well GW-144 (nitrate) at Kerr Hollow Quarry, wells GW-217 (boron) and GW-305 (1,1,1-TCA, 1,1-DCA, 1,1-DCE, and nickel) at Industrial Landfill IV, and well GW-322 (1,1-DCE, 1,1-DCA, and PCE) at the Security Pits.

As noted in Section 3.1.1, the nitrate concentrations reported for the replicate groundwater samples collected from well GW-144 were the higher than those reported for all the other CY 1998 sampling locations and potentially reflect migration of nitrate leached from municipal sewage sludge application sites to the northeast and northwest of the well. Historical data for this well show that nitrate levels increased from less than 1 mg/L during CYs 1990 to 1991, to generally between 1 and 2 mg/L during CYs 1992 to 1995, to between 2 and 6 mg/L since CY 1996 (Figure 9). The nitrate concentrations also show generally seasonal concentration fluctuations, with higher concentrations unusually evident during winter and spring (seasonally high flow) and lower concentrations evident during summer and fall (seasonally low flow). The seasonal nitrate fluctuations may be partially attributed to nitrate uptake by vegetation, as plants consume more nitrate during the growing season (summer and fall) than in the non-growing season (winter and spring).

As noted in Section 3.1.2, total (and dissolved) boron concentrations in the groundwater at well GW-217 substantially exceed the applicable UTL (0.028 mg/L) and are more than an order of magnitude higher than evident in all the other monitoring wells in the Chestnut Ridge Regime except those at Kerr Hollow Quarry. Historical boron results for this well show a conspicuous concentration “spike” (0.69 mg/L) in January 1992 (Figure 10) followed by a steadily increasing trend through October 1994 (0.22 mg/L) and a generally decreasing trend through July 1998 (0.136 mg/L). These results potentially reflect a “pulse” of boron-enriched groundwater that may coincide with one or more disposals of boron wastes at Industrial Landfill IV.

As discussed in Section 3.1.3, historical results for well GW-305 show that the concentration of 1,1,1-TCA increased from 0.6 µg/L in January 1992 to 17 µg/L in January 1998 (Figure 11). This increasing trend is supported by the preliminary 1,1,1-TCA result for the sample collected from the well in January 1999 (18 µg/L), which suggests that the much lower 1,1,1-TCA concentration reported for the sample collected in July 1998 (3 µg/L) may be a sampling or analytical artifact. The January 1999 results also suggest that concentrations of 1,1-DCA (5 µg/L) and 1,1-DCE (3 µg/L) continue to increase over time (Figure 11). The sequential detection of 1,1,1-TCA (January 1992), 1,1-DCA (July 1996), and 1,1-DCE (January 1997) and the subsequent increases in the concentration of each compound potentially reflect eastward (parallel with geologic strike) migration of the center of mass of a dissolved VOC plume comprised primarily of 1,1,1-TCA, with 1,1-DCA and 1,1-DCE present as biotic and/or abiotic degradation products.

Historical (conventional sampling) data for well GW-305 generally show total (and dissolved) nickel concentrations near the analytical reporting limit punctuated by several concentration “spikes” that exceed the UTL (0.02 mg/L), with the elevated nickel concentrations indicated by the low-flow

sampling results obtained during CY 1998 (and preliminary results obtained in CY 1999) reflecting an increasing concentration trend evident since January 1996 (Figure 11). However, linear regression ($R^2=0.93$) of the four total nickel results obtained from low-flow sampling between January 1998 and July 1999 shows a substantially stronger upward trend than indicated by linear regression ($R^2=0.18$) of the four total nickel results obtained from conventional sampling between January 1996 and July 1997 (Figure 11). This suggests that the increasing concentration trend may be an artifact of the change to low-flow sampling. Using conventional sampling, the influx of a larger volume of groundwater from the bedrock interval may have diluted the nickel-bearing groundwater surrounding the well screen. As discussed in Section 3.1.2, corrosion of the stainless steel well casing and screen is a likely source of the elevated nickel concentrations in well GW-305.

As noted in Section 3.1.3, the CY 1998 monitoring results for well GW-322 indicate that the concentration of 1,1-DCA and 1,1-DCE have increased substantially and PCE has slightly increased since the well was last sampled during CY 1992 (Figure 12). Instead of increased flux from the disposal trenches at the Security Pits, the increasing 1,1-DCA and 1,1-DCE concentrations probably result from abiotic degradation of 1,1,1-TCA, which may likewise explain the substantial decrease in the concentration of 1,1,1-TCA. If so, the groundwater at the well may contain acetic acid as a result of chemical transformation of 1,1,1-DCE (McCarty 1996).

4.0 CONCLUSIONS AND RECOMMENDATIONS

Monitoring data obtained in the Chestnut Ridge Regime during CY 1998 are consistent with historical results regarding the known sources of groundwater contamination in the regime, the primary types of groundwater contaminants, and the extent of contaminant transport in the Knox Aquifer.

Based on evaluation of the Surveillance Monitoring data for DOE Order 5400.1A, groundwater contamination is indicated by results for seven monitoring wells in the Chestnut Ridge Regime that were sampled during CY 1998. Results for these wells are summarized below.

CY 1998 groundwater contaminants and sources

Sampling Location	Known (●) and Suspected (▲) Groundwater Contaminants					Known/Suspected Source of Contamination
	Boron	Potassium	Nitrate	Sodium	VOCs	
GW-144	.	.	▲	.	●	Kerr Hollow Quarry/Sludge Landfarming
GW-217	▲	.	.	.	.	Industrial Landfill IV
GW-305	.	.	.	.	●	Industrial Landfill IV
GW-322	.	.	.	.	●	Security Pits
GW-609	.	.	.	.	●	Security Pits
GW-757	.	▲	.	▲	.	Localized grout contamination
GW-796	.	.	.	.	●	Security Pits
SCR5.1SP	.	.	▲	.	.	Sludge Landfarming

With the possible exception of elevated nitrate levels in spring SCR5.1SP, which may reflect migration from a nearby sewage sludge disposal site, the monitoring results for the network of springs used for the purposes of DOE Order 5400.1A Exit Pathway/Perimeter Monitoring during CY 1998 do not indicate the presence of anthropogenic contaminants in the surface drainage features that traverse the Chestnut Ridge Regime and ultimately exit the ORR.

Along with historical data, evaluation of the CY 1998 monitoring results for the purposes of DOE Order 5400.1A indicates increasing long-term concentrations of known or suspected groundwater contaminants in well GW-144 (nitrate) at Kerr Hollow Quarry, wells GW-217 (boron) and GW-305 (1,1,1-TCA) at Industrial Landfill IV, and well GW-322 (1,1-DCE and 1,1-DCA) at the Security Pits.

Based on review of the CY 1998 monitoring data, the following actions are recommended:

- Well GW-757 should be redeveloped to help mitigate localized grout contamination, as indicted by the unusually high pH, potassium, and sodium levels in the groundwater samples from this well. Historical results for well GW-757 show that pH levels and potassium/sodium concentrations have steadily increased since the Y-12 Plant GWPP initiated the low-flow sampling method in October 1997. If redeveloping the wells fails to

improve sample quality (i.e., reduce pH, potassium, and sodium levels), reverting to the conventional sampling method should be considered to ensure collection of more representative groundwater samples.

- Well GW-305 should be examined with a down-hole television camera to assess the presence of bacterial colonies (nodules) and/or the condition of the well casing and screen.
- Collection of filtered groundwater samples obtained using the low-flow sampling method could be discontinued. Analytical results for the filtered samples are used primarily to qualify (discount) the corresponding trace metal results for turbid unfiltered samples. As shown in the following data summary, the general occurrence and concentration of suspended solids in samples decreased significantly with the change from conventional sampling to low-flow sampling.

	Results for Suspended Solids		
	Percent Detected	Mean (mg/L)	Maximum (mg/L)
Conventional Method (280 samples) January - September 1997	65	50.5	2,750
Low-flow Method (407 samples) October 1997 - December 1998	48	12.2	391

Because the low-flow sampling method results in the collection of fewer turbid unfiltered samples, the dissolved concentrations reported for filtered samples generally correspond with the total concentrations reported for unfiltered samples. The concentration of suspended solids, turbidity, and commonly associated trace metal artifacts (e.g., aluminum, iron) should provide ample data to qualify other trace metal results.

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APPENDIX A

FIGURES

Fig. 1. Hydrogeologic regimes at the Y-12 Plant.

0 2000
SCALE (ft)

EXPLANATION

- 1200 — TOPOGRAPHIC CONTOUR
- - - SURFACE DRAINAGE FEATURE
- q SPRING

Fig. 2. Waste management sites in the Chestnut Ridge Hydrogeologic Regime.

Fig. 3. Topography and bedrock geology in the Chestnut Ridge Hydrogeologic Regime.

EXPLANATION

- WATER TABLE INTERVAL MONITORING WELL
- BEDROCK INTERVAL MONITORING WELL

Fig. 4. Seasonal groundwater elevations in the Chestnut Ridge

GROUNDWATER ELEVATIONS
APRIL 6 - 8, 1998

GROUNDWATER ELEVATIONS
OCTOBER 5 - 8, 1998

WATER-LEVEL ISOPLETH (ft msl)
SURFACE DRAINAGE FEATURE
SPRING

96-033 7/13/99

Fig. 5. CY 1998 sampling locations in the Chestnut Ridge Hydrogeologic Regime.

EXPLANATION

- GROUNDWATER COMPOSITIONS CLUSTER IN THESE AREAS
- - WATER TABLE MONITORING WELL
- - BEDROCK MONITORING WELL, LESS THAN 100 FT DEEP
- - BEDROCK MONITORING WELL, 100 TO 300 FT DEEP
- ▲ - BEDROCK MONITORING WELL, GREATER THAN 300 FT DEEP
- ◇ - SPRING

— Volatile Organic Compound (VOC) Plume
Based on historic data
Results are in micrograms/liter

(MAX) — Data shown for wells at Kerr Hollow Quarry are the maximum concentrations for each sampling event (4 samples per event)

Q — Quarter of CY 1998

J — Estimated value below reporting limit

ND — Not Detected

NS — Not Sampled

1,1-DCA — 1,1-Dichloroethane

1,2-DCA — 1,2-Dichloroethane

1,1-DCE — 1,1-Dichloroethene

1,2-DCE — 1,2-Dichloroethene

PCE — Tetrachloroethane

1,1,1-TCA — Trichloroethane

1,1,1,2-TCE — Trichloroethene

1,1,1,2,2-TCE — Trichloroethane

1,1,1,2,2,2-TCE — Trichloroethane

— Surface Drainage Feature

Fig. 7. Maximum VOC concentrations for CY 1998 sampling locations in the Chestnut Ridge Hydrogeologic Regime.

Fig. 8. Presampling groundwater elevations in well GW-305 at Industrial Landfill IV and wells GW-322 and GW-609 at the Chestnut Ridge Security Pits.

Note: The median value of four replicate results are shown beginning in October 1996.

Fig. 9. Presampling groundwater elevations and nitrate concentrations in well GW-144.

Fig. 10. Boron concentrations in well GW-217.

Industrial Landfill IV: Well GW-305

Note: 1,1,1-TCA MCL = 200 ug/L; 1,1-DCE MCL = 7 ug/L.

Fig. 11. VOC and nickel concentrations in well GW-305.

Fig. 12. VOC concentrations in well GW-322.

APPENDIX B

TABLES

**Table 1. Waste management sites and associated groundwater monitoring programs
in the Chestnut Ridge Hydrogeologic Regime**

GROUNDWATER MONITORING PROGRAM		RCRA Post Closure Corrective Action Monitoring ¹															
		RCRA Post Closure Detection Monitoring ²															
		SWDF Detection Monitoring ³															
		CERCLA Record of Decision Monitoring ⁴															
		DOE Order 5400.1A Monitoring ⁵															
Waste Management Site	Regulatory Classification	General Waste Inventory	Status														
			Operation	Active	Closed												
Chestnut Ridge Sediment Disposal Basin	RCRA/ CERCLA	Approximately 11,100 yd ³ of sediments and soils from the Y-12 Plant containing heavy metals; approximately 100,000 gallons of methanol-brine waste (70/30% water/methyl alcohol); and 55-110 gallons of toluene.	1973-1987		●					●							
East Chestnut Ridge Waste Pile	RCRA/ CERCLA	Contaminated soil from the Y-12 Plant.	1987	●		●											
Kerr Hollow Quarry	RCRA/ CERCLA	Approximately 50 tons of water-reactive materials (alkali metals, metal hydrides); unstable organic materials (picric acid, ethers, peroxides, and hydrazone); reactive metals (phosphorous and magnesium); potentially explosive materials (e.g., gas cylinders); ammonia; and inorganic acids.	1951-1988		●		●			●							
Chestnut Ridge Security Pits	RCRA/ CERCLA	Metals (lead); reactive materials (lithium hydride, lithium deuteride, zirconium); corrosive materials (acids); ignitable materials (alcohols); and chlorinated solvents.	1973-1988		●						●						
Filled Coal Ash Pond (formerly the Ash Disposal Basin)	CERCLA	Coal fly-ash slurry from the Y-12 Steam Plant.	1955-1967		●		●										
United Nuclear Corporation Site	CERCLA	Approximately 11,000 drums (55-gallon) of sludge fixed in cement, 18,000 drums of contaminated soil, and 288 boxes of contaminated process and demolition material.	1982-1992		●		●										

Table 1 (continued)

GROUNDWATER MONITORING PROGRAM		RCRA Post Closure Corrective Action Monitoring ¹									
		RCRA Post Closure Detection Monitoring ²								SWDF Detection Monitoring ³	
		CERCLA Record of Decision Monitoring ⁴									
		DOE Order 5400.1A Monitoring ⁵									
		Waste Management Site	Regulatory Classification	General Waste Inventory	Status						
Operation	Active				Closed						
Rogers Quarry	CERCLA	Coal fly-ash slurry that bypassed the Filled Coal Ash Pond via spillway into McCoy Branch.	1967-1993		●	●					
Chestnut Ridge Borrow Area Waste Pile	CERCLA	Soils removed from the Oak Ridge Civic Center properties and the Oak Ridge Sewer Line Beltway contaminated with mercury and other metals, and possibly some organic compounds that originated from the Y-12 Plant.	Mid-1980			●					
Industrial Landfill II	SWDF	Combustible and decomposable solid waste and construction spoil material including scrap metal, glass, paper products, plastics, wood, organic garbage, textile products, asphalt roofing materials, and special wastes such as asbestos and beryllium oxide.	1983-1996		●			●			
Industrial Landfill IV	SWDF	Approximately 12,000 ft ³ per year of non-hazardous, nonradioactive industrial wastes including cardboard, plastics, rubber, scrap metal, wood, paper, and special waste.	1989-	●				●			
Industrial Landfill V	SWDF	Combustible/decomposable solid wastes.	1994-	●				●			
Construction/Demolition Landfill VI	SWDF	Construction spoil: concrete, wood, metal, plastic, roofing materials, and soil.	1994-	●				●			
Construction/Demolition Landfill VII	SWDF	No wastes emplaced to date. On standby until Construction/Demolition Landfill VI is closed.	1994-					●			
Receptor Media	Not Regulated	Groundwater and surface water exiting the Chestnut Ridge Hydrogeologic Regime.	Not Applicable			●					

Table 1 (continued)

Notes:

- 1 Resource Conservation and Recovery Act (RCRA) post-closure corrective action monitoring in accordance with the requirements specified in the RCRA post-closure permit for the Chestnut Ridge Regime (Permit No. TNHW-088).
- 2 RCRA post-closure detection monitoring in accordance with the applicable requirements of the RCRA post closure permit for the Chestnut Ridge Regime (Permit No. TNHW-088).
- 3 Detection monitoring in accordance with operating permits issued by the Tennessee Department of Environment and Conservation (TDEC) for the specified non-hazardous solid waste disposal facility and applicable TDEC solid waste management regulations. Groundwater monitoring has been suspended at Construction/Demolition Landfill VII until the site begins accepting waste.
- 4 Monitoring in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Record of Decision for the specified facility.
- 5 Monitoring performed in accordance with U.S. Department of Energy Order 5400.1A.

Table 2. CY 1998 groundwater and surface water sampling locations and dates

MONITORING PROGRAM		Increasing Contaminant Trend						
		Exit Pathway/Perimeter Monitoring						
								Surveillance Monitoring
		Sampling Point ¹	Sampling Location ²	CY 1998 Sampling Date ³				
1st Quarter	2nd Quarter			3rd Quarter	4th Quarter			
GW-141	LIV	01/08/98 D	.	07/09/98 D	.	●		
GW-142	KHQ	.	04/27 - 30/98 D	.	10/19 - 22/98 D	●		
GW-143	KHQ	.	04/27 - 30/98	.	10/19 - 22/98	●		
GW-144	KHQ	.	04/27 - 30/98	.	10/19 - 22/98	●		●
GW-145	KHQ	.	04/27 - 30/98	.	10/19 - 22/98	●		
GW-156	CRSDB	.	04/13 - 16/98 D	.	10/26 - 29/98 D	●		
GW-159	CRSDB	.	04/13 - 16/98	.	10/26 - 29/98	●		
GW-217	LIV	01/07/98	.	07/08/98	.	●		●
GW-231	KHQ	.	04/27 - 30/98 D	.	10/19 - 22/98 D	●		
GW-301	CRBAWP	01/06/98	.	07/10/98	.	●		
GW-305	LIV	01/12/98	.	07/13/98	.	●		●
GW-322	CRSP	01/12/98	.	.	.	●		●
GW-521	LIV	01/07/98	.	07/09/98	.	●		
GW-522	LIV	01/08/98	.	07/09/98	.	●		
GW-540	LII	03/11/98	04/20/98	.	10/13/98	●		
GW-542	CDLVI	.	04/21/98	.	10/14/98	●		
GW-543	CDLVI	.	04/22/98	.	10/15/98	●		
GW-544	CDLVI	.	04/22/98	.	10/15/98	●		
GW-557	LV	01/13/98 D	.	07/14/98 D	.	●		
GW-609	CRSP	01/05/98	.	07/16/98	.	●		
GW-709	LII	.	04/20/98	.	10/13/98	●		
GW-731	CRSDB	.	04/13 - 16/98 D	.	10/26 - 30/98 D	●		
GW-732	CRSDB	.	04/13 - 16/98	.	10/26 - 29/98	●		
GW-757	LII	.	04/21/98 D	.	10/13/98 D	●		
GW-796	LV	01/14/98	.	07/15/98	.	●		
GW-797	LV	01/14/98	.	07/15/98	.	●		
GW-798	CDLVII	01/12/98	.	07/09/98	.	●		
GW-799	LV	01/13/98	.	07/14/98	.	●		
GW-801	LV	01/13/98	.	07/15/98	.	●		
GW-827	CDLVI	.	04/21/98	.	10/14/98	●		
GW-831	FCAP	01/06/98	.	07/10/98	.	●		

Table 2 (continued)

MONITORING PROGRAM		Increasing Contaminant Trend						
		Exit Pathway/Perimeter Monitoring						
Surveillance Monitoring								
Sampling Point ¹	Sampling Location ²	CY 1998 Sampling Date ³						
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter			
SCR2.1SP	EXP	01/13/98	.	07/08/98	.		●	
SCR2.2SP	EXP	01/12/98	.	07/08/98	.		●	
SCR3.4SP	EXP	01/13/98	.	07/08/98	.		●	
SCR4.3SP	CDLVII	01/12/98	.	07/14/98	.		●	
SCR5.1SP	EXP	01/12/98	.	07/08/98	.		●	
SCR5.4SP	EXP	01/12/98	.	07/08/98	.		●	
Outfall 301	KHQ	.	.	.	10/19/98	●		

Notes:

- 1
 - GW - Groundwater monitoring well
 - Outfall301 - Surface water station located where water exits Kerr Hollow Quarry
 - SCR - South Chestnut Ridge (tributary prefix)
 - SP - Spring location (suffix)

- 2
 - CDLVI - Construction/Demolition Landfill VI
 - CDLVII - Construction/Demolition Landfill VII
 - CRBAWP - Chestnut Ridge Borrow Area Waste Pile
 - CRSDB - Chestnut Ridge Sediment Disposal Basin
 - CRSP - Chestnut Ridge Security Pits
 - EXP - Exit Pathway
 - FCAP - Filled Coal Ash Pond
 - KHQ - Kerr Hollow Quarry
 - LII - Industrial Landfill II
 - LIV - Industrial Landfill IV
 - LV - Industrial Landfill V

- 3
 - . = Not Sampled.
 - D = Duplicate sample was collected on the date specified (shown in bold).

Duplicate samples were collected only on one of the dates during each sampling event for wells in RCRA post closure detection monitoring: wells GW-142 (04/29 and 10/21/98), GW-156 (04/16 and 10/29/98), GW-231 (04/28 and 10/20/98), and GW-731 (04/14 and 10/27/98).

**Table 3. Field measurements and laboratory analytes for CY 1998
groundwater and surface water samples**

Field Measurements	Analytical Method ¹	Detection Limit ²	Units ³
Depth to Water	ESP 302-1	NA	ft
Water Temperature	ESP 307-1	NA	centigrade
pH	ESP 307-1	NA	pH units
Conductivity	ESP 307-1	NA	µmho/cm
Dissolved Oxygen	ESP 307-3	NA	ppm
Oxidation-Reduction Potential	ESP 307-5	NA	mV
Miscellaneous Laboratory Analytes			
pH	EPA-9040	NA	pH units
Conductivity	EPA-9050	NA	µmho/cm
Total Dissolved Solids	EPA-160.1	1	mg/L
Total Suspended Solids	EPA-160.2	1	mg/L
Turbidity	EPA-180.1	0.1	NTU
Anions			
Alkalinity - HCO ₃	EPA-310.1	1.0	mg/L
Alkalinity - CO ₃	EPA-310.1	1.0	mg/L
Chloride	EPA-300.0	0.2	mg/L
Fluoride	EPA-340.2	0.1	mg/L
Nitrate (as Nitrogen)	EPA-300.0	0.028	mg/L
Sulfate	EPA-300.0	0.25	mg/L
Metals/Cations: Unfiltered & Filtered ⁴			
Aluminum	EPA-6010A	0.02 / 0.2	mg/L
Antimony	EPA-6010A/ -200.8	0.05 / 0.0005	mg/L
Arsenic	EPA-200.8	0.005	mg/L
Barium	EPA-6010A	0.001 / 0.004	mg/L
Beryllium	EPA-6010A	0.0003 / 0.001	mg/L
Boron	EPA-6010A	0.004 / 0.1	mg/L
Cadmium	EPA-6010A/ -200.8	0.003 / 0.0005	mg/L
Calcium	EPA-6010A	0.008 / 0.2	mg/L
Chromium	EPA-6010A	0.01 / 0.02	mg/L
Cobalt	EPA-6010A	0.005 / 0.02	mg/L
Copper	EPA-6010A	0.004 / 0.02	mg/L
Iron	EPA-6010A	0.005 / 0.05	mg/L
Lead	EPA-200.8	0.0005	mg/L
Lithium	EPA-6010A	0.004 / 0.01	mg/L
Magnesium	EPA-6010A	0.003 / 0.2	mg/L
Manganese	EPA-6010A	0.001 / 0.005	mg/L
Mercury	EPA-7470	0.0002	mg/L
Molybdenum	EPA-6010A	0.01 / 0.05	mg/L

Table 3 (continued)

Metals/Cations (continued)	Analytical Method ¹	Detection Limit ²	Units ³
Nickel	EPA-6010A	0.01 / 0.05	mg/L
Potassium	EPA-6010A	0.6 / 2	mg/L
Selenium	EPA-6010A/ -200.8	0.05 / 0.01	mg/L
Silver	EPA-6010A	0.006 / 0.02	mg/L
Sodium	EPA-6010A	0.02 / 0.2	mg/L
Strontium	EPA-6010A	0.0004 / 0.005	mg/L
Thallium	EPA-200.8	0.0005	mg/L
Thorium	EPA-6010A	0.2	mg/L
Uranium	EPA-200.8	0.0005	mg/L
Vanadium	EPA-6010A	0.005 / 0.02	mg/L
Zinc	EPA-6010A	0.002 / 0.05	mg/L
Volatile Organic Compounds		CRQL⁵	
Acetone	EPA-8260	10	µg/L
Acrolein	EPA-8260	10	µg/L
Acrylonitrile	EPA-8260	10	µg/L
Benzene	EPA-8260	5	µg/L
Bromochloromethane	EPA-8260	10	µg/L
Bromodichloromethane	EPA-8260	5	µg/L
Bromoform	EPA-8260	5	µg/L
Bromomethane	EPA-8260	10	µg/L
2-Butanone	EPA-8260	10	µg/L
Carbon disulfide	EPA-8260	5	µg/L
Carbon tetrachloride	EPA-8260	5	µg/L
Chlorobenzene	EPA-8260	5	µg/L
Chloroethane	EPA-8260	10	µg/L
2-Chloroethyl vinyl ether	EPA-8260	10	µg/L
Chloroform	EPA-8260	5	µg/L
Chloromethane	EPA-8260	10	µg/L
Dibromochloromethane	EPA-8260	5	µg/L
1,2-Dibromo-3-chloropropane	EPA-8260	10	µg/L
1,2-Dibromoethane	EPA-8260	5	µg/L
Dibromomethane	EPA-8260	10	µg/L
1,2-Dichlorobenzene	EPA-8260	5	µg/L
1,4-Dichlorobenzene	EPA-8260	5	µg/L
1,4-Dichloro-2-butene	EPA-8260	5	µg/L
trans-1,4-Dichloro-2-butene	EPA-8260	5	µg/L
Dichlorodifluoromethane	EPA-8260	5	µg/L
1,1-Dichloroethane	EPA-8260	5	µg/L
1,2-Dichloroethane	EPA-8260	5	µg/L
1,1-Dichloroethene	EPA-8260	5	µg/L
cis-1,2-Dichloroethene	EPA-8260	5	µg/L

Table 3 (continued)

Volatiles Organic Compounds (cont'd)	Analytical Method ¹	CROL ⁵	Units ³
trans-1,2-Dichloroethene	EPA-8260	5	µg/L
1,2-Dichloropropane	EPA-8260	5	µg/L
cis-1,3-Dichloropropene	EPA-8260	5	µg/L
trans-1,3-Dichloropropene	EPA-8260	5	µg/L
Dimethylbenzene	EPA-8260	5	µg/L
Ethanol	EPA-8260	500	µg/L
Ethylbenzene	EPA-8260	5	µg/L
Ethyl methacrylate	EPA-8260	5	µg/L
2-Hexanone	EPA-8260	10	µg/L
Iodomethane	EPA-8260	5	µg/L
4-Methyl-2-pentanone	EPA-8260	10	µg/L
Methylene chloride	EPA-8260	5	µg/L
Styrene	EPA-8260	5	µg/L
1,1,1,2-Tetrachloroethane	EPA-8260	10	µg/L
1,1,2,2-Tetrachloroethane	EPA-8260	5	µg/L
Tetrachloroethene	EPA-8260	5	µg/L
Toluene	EPA-8260	5	µg/L
1,1,1-Trichloroethane	EPA-8260	5	µg/L
1,1,2-Trichloroethane	EPA-8260	5	µg/L
Trichloroethene	EPA-8260	5	µg/L
Trichlorofluoromethane	EPA-8260	5	µg/L
1,2,3-Trichloropropane	EPA-8260	5	µg/L
Vinyl acetate	EPA-8260	10	µg/L
Vinyl chloride	EPA-8260	10	µg/L
Radiological Analytes (pCi/L)		Target MDA⁶	
Gross Alpha Activity	EPA-900.0	3.5	pCi/L
Gross Beta Activity	EPA-900.0	7.0	pCi/L

Notes:

- 1 The analytical method for three trace metals (antimony, cadmium, and selenium) changed from inductively coupled plasma spectroscopy to inductively coupled plasma mass spectroscopy, effective April 1, 1998, to obtain lower detection limits. Analytical/field methods/procedures from:
 - *Test Methods for Evaluating Solid Waste Physical/Chemical Methods* (U.S. Environmental Protection Agency 1986)
 - *Methods for Chemical Analysis of Water and Wastes* (U.S. Environmental Protection Agency 1983)
 - *Environmental Surveillance Procedures Quality Control Manual* (Lockheed Martin Energy Systems, Inc. 1988)
 - Lockheed Martin Energy Systems ASO radiological methods

Table 3 (continued)

Notes: (continued)

2 NA - not applicable

Detection limits for metals/cations by inductively coupled plasma spectroscopy changed during the second quarter sampling event. The first detection limit was used until April; the second one listed was used thereafter.

3 ft - feet
 µg/L - micrograms per liter
 µmho/cm - micromhos per centimeter
 mg/L - milligrams per liter
 mV - millivolts
 NTU - nephelometric turbidity units
 ppm - parts per million
 pCi/L - picoCuries per liter

4 Samples for dissolved metals analysis were collected using a 0.45-micron filter.

5 CRQL - contract-required quantitation limit

6 MDA - minimum detectable activity. The target MDA may be obtained under optimal analytical conditions; actual MDAs are sample-specific and may vary significantly from the target value.

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