Y-12

OAK RIDGE
Y-12
PLANT

MARTIN MARIETTA

Y/SUB/95-EAQ10C/1/P2

CALENDAR YEAR 1994 GROUNDWATER QUALITY REPORT FOR THE BEAR CREEK HYDROGEOLOGIC REGIME Y-12 PLANT, OAK RIDGE, TENNESSEE

1994 Groundwater Quality Data Interpretations and Proposed Program Modifications

October 1995

Prepared by:

HSW ENVIRONMENTAL CONSULTANTS, INC.
Under Purchase Order 70Y-EAQ10C

for the

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

Managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract
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MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
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LIST OF ACRONYMS AND ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
ASO	Analytical Services Organization
BCV	Bear Creek Valley
BCK	Bear Creek Kilometer
bgs	below ground surface
BQR	Blank Qualification Result
CA	Characterization Area
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CY	Calendar Year
DNAPL	Dense, Non-Aqueous Phase Liquid
DOE	U.S. Department of Energy
DQO	data quality objectives
Energy Systems	Lockheed Martin Energy Systems, Inc.
EPA	U.S. Environmental Protection Agency
ft	feet
ft/d	feet per day
ft^2/d	feet squared per day
FFA	Federal Facility Agreement
gpm	gallons per minute
GWPP	Groundwater Protection Program
GWQR	Groundwater Quality Report
HSEA	Health, Safety, Environment, and Accountability
HSWA	Hazardous and Solid Waste Amendment
ICP	Inductively Coupled Plasma (spectroscopy)
K-25	Oak Ridge K-25 Site
MCL	Maximum Contaminant Level
MDA	minimum detectable activity
MDL	method detection limit
μg/L	micrograms per liter
mg/L	milligrams per liter
mrem/yr	millirem per year
msl	mean sea level
NT	northern tributaries
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OU	Operable Unit
PCE	Tetrachloroethene
pCi/L	picoCuries per liter
PCPA	Post-Closure Permit Application

LIST OF ACRONYMS AND ABBREVIATIONS (cont'd)

QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
RPD	Relative Percent Difference
SESD	Sampling and Environmental Support Department
SWMU	Solid Waste Management Unit (RCRA)
TCE	Trichloroethene
TDEC	Tennessee Department of Environment and Conservation
TDS	Total Dissolved Solids
TSD	Treatment, Storage, and Disposal (unit)
TSS	Total Suspended Solids
UTL	Upper Tolerance Limit
VOC	Volatile Organic Compound
WMA	Waste-Management Area
1,2-DCE	1,2-Dichloroethene
1,1,1-TCA	1,1,1-Trichloroethane
1,1,2,2-TCA	1,1,2,2-tetrachloroethane

1.0 INTRODUCTION

This groundwater quality report (GWQR) contains an evaluation of the groundwater quality data obtained during the 1994 calendar year (CY) at several hazardous and non-hazardous waste management facilities at the U.S. Department of Energy (DOE) Y-12 Plant located on the DOE Oak Ridge Reservation (ORR) southeast of Oak Ridge, Tennessee (Figure 1). These sites lie in Bear Creek Valley (BCV) west of the Y-12 Plant within the boundaries of the Bear Creek Hydrogeologic Regime (Bear Creek Regime), which is one of three hydrogeologic regimes defined for the purposes of groundwater quality monitoring at the Y-12 Plant (Figure 2). The Environmental Management Department of the Y-12 Plant Health, Safety, Environment, and Accountability (HSEA) Organization manages the groundwater monitoring activities under the auspices of the Y-12 Plant Groundwater Protection Program (GWPP). The purpose of the GWPP is to characterize the hydrogeology and to monitor groundwater quality at the Y-12 Plant and surrounding area to protect local groundwater resources in accordance with federal, state, and local regulations, DOE Orders, and Lockheed Martin Energy Systems, Inc. (Energy Systems) corporate policy.

The annual GWQR for the Bear Creek Regime is completed in two parts. Part 1 consists primarily of data appendices and serves as a reference for the groundwater quality data obtained each CY under the lead of the Y-12 Plant GWPP. Because it contains information needed to comply with reporting requirements of Resource Conservation and Recovery Act (RCRA) interim status assessment monitoring, the Part 1 GWQR is submitted to the Tennessee Department of Environment and Conservation (TDEC) by the RCRA reporting deadline (March 1 of the following CY); Energy Systems submitted the 1994 Part 1 GWQR for the Bear Creek Regime to the TDEC in February 1995 (HSW Environmental Consultants, Inc. 1995a). Part 2 (this report) contains an evaluation of the data with respect to regime-wide groundwater quality, summarizes the status and findings of ongoing hydrogeologic studies, describes changes in monitoring priorities, and presents planned modifications to the groundwater sampling and analysis activities.

2.0 BACKGROUND INFORMATION

The Bear Creek Regime encompasses a portion of BCV extending from a surface water and shallow groundwater divide at the west end of the Y-12 Plant to the western boundary of the Bear Creek watershed (unless otherwise noted, directions in this report are in reference to the Y-12 Plant administrative grid system). Bear Creek Valley is flanked to the north by Pine Ridge and to the south by Chestnut Ridge. Ground surface elevations range from about 1,300 feet (ft) above mean sea level (msl) on the ridge crests to 900 ft msl along Bear Creek.

Groundwater quality monitoring activities at the waste-management sites in the Bear Creek Regime have been in progress since the late 1970s and have evolved in response to regulatory changes and monitoring results. The following discussion provides a brief description of the regulatory framework under which the monitoring is currently performed.

2.1 Regulatory Framework

In 1984, the U.S. Environmental Protection Agency (EPA) and the TDEC determined that several of the waste management sites at the Y-12 Plant were hazardous waste treatment, storage, and disposal (TSD) units subject to regulation under RCRA. Three of the TSD units are located in the Bear Creek Regime: the S-3 Site, the Oil Landfarm waste-management area (WMA), and the Bear Creek Burial Grounds WMA (Figure 3). These sites were granted RCRA interim status until operating or post-closure RCRA permits were obtained by the DOE. The RCRA Post-Closure Permit Applications (PCPAs) for these sites were initially submitted to the TDEC in 1987. Also in 1987, Spoil Area I, the Rust Spoil Area, and the SY-200 Yard were identified as solid waste management units (SWMUs) subject to regulation under section 3004(u) of RCRA (Welch et al. 1987). A RCRA Facility Investigation, as required under the Hazardous and Solid Waste Amendment (HSWA) permit issued for the ORR by the EPA in CY 1986, was planned for each of these sites to determine if contaminant releases to the environment had occurred.

In November 1989, the ORR was added to the National Priority List and in January 1992, the DOE, the EPA, and the TDEC negotiated a Federal Facility Agreement (FFA) regarding environmental restoration at the ORR under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Although this agreement superseded the HSWA permit and changed the regulatory status of RCRA-regulated TSD units and SWMUs to CERCLA operable units (OUs), the TDEC did not waive the RCRA permitting, post-closure care, corrective action, and groundwater monitoring requirements applicable to some of these sites. The DOE appeal of this regulatory interpretation was formally resolved with an Agreed Order signed in April 1994 by DOE, the TDEC, and Energy Systems regarding the RCRA post-closure permit for the S-3 Site. The Agreed Order allowed DOE to proceed with CERCLA as the lead regulatory program, with RCRA applied as an appropriate, relevant, and applicable requirement to the extent that post-closure maintenance and care of former TSD facilities will comply with the terms of RCRA post-closure permits. Groundwater monitoring is to be integrated with the CERCLA remedial investigation/feasibility study (RI/FS), and data reporting will comply with RCRA post-closure permit conditions as well as RI/FS requirements. Three RCRA post-closure permits will be issued for the Y-12 Plant encompassing each of the hydrogeologic regimes. Specific requirements for interim status sites within each regime will be incorporated into the permits as separate modifications.

Efforts were initiated early in CY 1994 by DOE and Energy Systems to modify the FFA strategy for RI/FS implementation. The FFA defined two types of CERCLA OUs for which an RI/FS would be performed: (1) source control OUs comprised of individual or groups of waste-management sites, and (2) integrator OUs that encompass groundwater and surface water, independent of the source control OUs that may contribute to the contamination of these media. However, as the RIs for OUs within the Bear Creek Regime progressed, it became increasingly evident that separation of source control and integrator OUs was not the most technically feasible approach to implementation of the RI/FS process. An agreement was reached among regulatory agencies and the DOE to proceed with an integrated RI/FS approach whereby source and integrator OUs are addressed concurrently in a Characterization Area (CA) defined by water shed boundaries, and specific sites or locations of highest risk or concern are targeted for focused studies. Additionally, efforts were initiated to develop a conceptual model of groundwater flow and contaminant migration that is tailored to the specific characteristics of the groundwater flow system in BCV.

2.2 Site Descriptions

Groundwater quality monitoring in the Bear Creek Regime during CY 1994 was performed at (1) the Bear Creek CA (which includes the RCRA TSD units and former RCRA SWMUs that comprised the original CERCLA OUs defined in the FFA) (2) and; the Above Grade Low Level Waste Disposal Facility (Table 1). Locations of these sites are shown on Figure 3. General descriptions of each type of site are provided in the following sections; detailed site descriptions and discussions of the regulatory status and groundwater monitoring history of each site are included in Section 2.0 of the Part 1 GWQR.

2.2.1 Bear Creek Characterization Area

The Bear Creek CA encompasses the three CERCLA OUs established for the Bear Creek Regime in the FFA: Bear Creek OUs 01 and 02, the former source control OUs for the regime, and Bear Creek OU 04, the former integrator OU for the regime (surface water in Bear Creek and contaminated sediments within the Bear Creek flood plain were originally defined in the FFA as Bear Creek OU 03).

The three RCRA TSD units in the regime comprise Bear Creek OU 01: the S-3 Site, the Oil Landfarm WMA, and the Bear Creek Burial Grounds WMA (Table 1). An RI work plan for this OU was prepared and approved by the EPA (Region IV) and the TDEC (U.S. Department of Energy 1993a). Field activities for the RI were initiated in August 1994 and are expected to be completed in 1995.

Bear Creek OU 02 consists of three former RCRA SWMUs: Spoil Area I, the SY-200 Yard, and the Rust Spoil Area (Table 1). Remedial investigation field work for this OU, performed in accordance with the EPA- and TDEC-approved RI work plan (U.S. Department of Energy 1993b), was completed in December 1993 and included a single round of groundwater sampling from monitoring wells located at each of the SWMUs. The RI report for this OU was completed in August 1994, and in November 1994 a FS/Environmental Assessment was submitted for review by the EPA and TDEC (U.S. Department of Energy 1994b and 1994c) (regulatory approval has not been received to date). A proposed plan describing actions to be taken under CERCLA Record of Decision is also being prepared.

Bear Creek OU 04 was the integrator OU negotiated by the DOE to address contaminated groundwater in the regime, as wells as contaminated surface water and sediments within Bear Creek and its tributaries. The RI field work for this OU, which began in September 1993 and continued through January 1995, focused on surface water and soil/sediment sampling, and stormflow characterization (U.S. Department of Energy 1993c and 1994d); aspects of the RI relating to groundwater monitoring were renegotiated to maximize use of historical data obtained for the purposes of the Y-12 GWPP. Groundwater monitoring for the multiple purposes of the Y-12 GWPP has been performed in accordance with the technical approach described in the *Comprehensive Groundwater Monitoring Plan for the Department of Energy Y-12 Plant Oak Ridge, Tennessee* (Comprehensive Monitoring Plan; Geraghty & Miller, Inc. 1990a). This plan established a single, integrated groundwater monitoring program for the Bear Creek Regime designed to achieve the following objectives and priorities:

(1) monitor the horizontal boundaries of the groundwater contaminant plumes for evidence of further contaminant migration,

(2) define the maximum depth of groundwater contamination to the extent necessary for the evaluation and selection of remedial alternatives,

(3) perform all groundwater monitoring activities in accordance with RCRA interim status assessment monitoring standards to ensure compliance with applicable regulatory requirements, and

(4) monitor the principal subsurface migration pathway (the Maynardville Limestone) and surface migration pathway (Bear Creek) for evidence of contaminated groundwater and/or surface water exiting the Bear Creek Regime.

Implementation of the Comprehensive Monitoring Plan approach has provided a substantial portion of the groundwater and surface water quality data needed to effectively characterize the extent of contamination in the Bear Creek Regime.

2.2.2 Above Grade Low-Level Waste Storage Facility

The Above Grade Low-Level Waste Storage Facility is located west of the Oil Landfarm WMA (Figure 3), and is divided by an access road into northern and southern sections. Construction of the northern section was completed in the second quarter of CY 1993; construction of the southern section has not begun. The facility consists of six, 52 x 171 ft prefabricated rubber buildings engineered with concrete, slab-on-grade foundations with floor dikes as secondary containment. These buildings are used to store low-level radioactive solid wastes including construction/demolition debris, process materials, rubbish, sludge and soil, and beryllium in drums and B-25 boxes.

3.0 GROUNDWATER AND SURFACE WATER SAMPLING PROGRAM FOR CY 1994

The following sections describe the groundwater and surface water sampling activities performed during CY 1994 in the Bear Creek Regime under the lead of the Y-12 Plant GWPP. Included are brief descriptions of the monitoring programs for which the sampling was performed, as well as details regarding the sampling (locations, frequencies, and procedures), analytical parameters, and results of quality assurance/quality control (QA/QC) sampling.

3.1 Sampling Locations

A total of 71 monitoring wells, 3 springs, and 6 surface water stations were sampled during CY 1994 (Figure 4 and Table 2). The monitoring wells were sampled to meet goals of the following monitoring programs:

- RCRA post-closure corrective action monitoring;
- RCRA interim status assessment monitoring;
- DOE Order 5400.1 perimeter and exit-pathway monitoring;
- surveillance and maintenance monitoring; and
- best-management practice monitoring.

Data regarding the aquifer zone and the depth of the screened or open hole interval for each well are provided in Table 3; detailed well construction information is contained in Appendix C of the Part 1 GWQR. The springs, located south of Bear Creek along the base of Chestnut Ridge, contribute significant year-round flow to Bear Creek. Sampling locations along Bear Creek are designated by the distance in kilometers from the confluence of Bear Creek and East Fork Poplar Creek. Four of the surface water sampling stations are located along the main creek channel: Bear Creek Kilometer (BCK)-00.63, BCK-04.55, BCK-09.40, and BCK-11.97. Two of the sampling stations are located on northern tributaries (NT) to Bear Creek (NT-01 and NT-13). Background station NT-13 is in a tributary that has not been affected by waste-management activities in the Bear Creek Regime; water at station NT-01 has been impacted by discharge of groundwater containing contaminants (e.g., nitrate) from the S-3 Site.

3.1.1 RCRA Corrective Action Monitoring

RCRA corrective action monitoring for the Bear Creek Regime was initiated in October 1993 in accordance with the S-3 Site post-closure permit modification issued at that time. The terms of the permit were renegotiated in March 1994, and the TDEC began the process of issuing a new permit modification for the Bear Creek Regime incorporating provisions for both the S-3 Site and Oil Landfarm. Corrective action monitoring in CY 1994 followed the October 1993 permit in addition to agreed changes negotiated in March 1994. In CY 1994, this program involved semiannual collection of groundwater samples from 13 monitoring wells (Table 2) located throughout the Bear Creek Regime, and analysis of the samples for the parameters specified in the post-closure permit. Two wells (GW-243 and GW-276) were sampled as the eligible point-of-compliance wells; however, well GW-243 was dropped from this monitoring program after the first quarter sampling event as a result of permit negotiations in March 1994, which required semiannual monitoring of only one point-of-compliance well. Two other wells (GW-324 and GW-325) also were dropped after the first quarter sampling as a result of these permit negotiations. In addition to the wells specified in the post-closure permit for the S-3 Site, groundwater samples were collected from 11 other wells as part of a regime-wide background characterization that will be a permit requirement for the entire regime. Analytical results for the corrective action wells are included in Appendix E of the Part I GWQR. An evaluation of groundwater flow directions, a requirement of the monitoring program specified in the post-closure permit, is provided in Section 4.3 of the Part I GWQR.

The modification for the Oil Landfarm post-closure permit was issued by TDEC on June 30, 1995. According to current schedules provided by TDEC, the Burial Grounds/Walk-in Pits modification to the Bear Creek Regime post-closure permit will be final by September 30, 1995. As discussed in Section 9.0, the focus of groundwater monitoring will change from assessment to corrective action/surveillance upon issuance of the final permit modification.

3.1.2 RCRA Interim Status Assessment Monitoring

Formal assessment monitoring in accordance with RCRA interim status requirements was continued during CY 1994 and included only five monitoring wells (Table 2). Although data from all monitoring wells sampled during CY 1994 were used to assess groundwater contamination throughout the regime, reduced emphasis on site-specific assessment monitoring is expected in CY 1995. The program will be replaced by corrective action monitoring when the RCRA post-closure permit modifications for the Bear Creek Burial Grounds WMAs are issued by the TDEC.

3.1.3 Perimeter and Exit Pathway Monitoring

The exit pathway monitoring program involves groundwater and surface water sampling where contamination is most likely to be transported beyond the ORR boundaries. This monitoring is performed to comply with DOE revised Order 5400.1 requirements for protecting groundwater that is, or could be, affected by operations at DOE facilities. Exit pathway monitoring during CY 1994 involved semiannual sampling of groundwater from 19 monitoring wells completed in the Maynardville Limestone (the principal subsurface migration pathway) and from three springs discharging to Bear Creek, and surface water from 6 locations along Bear Creek and its tributaries (Table 2). Additionally, six wells completed in the Maynardville Limestone and installed at the western-most exit pathway traverse, were used for RCRA corrective action monitoring (GW-710 through GW-715) and to meet ORR perimeter monitoring requirements specified in the Environmental Monitoring Plan for the Oak Ridge Reservation (U.S. Department of Energy 1995).

3.1.4 Surveillance and Maintenance Monitoring

During CY 1994, 20 wells were used to satisfy requirements of the surveillance and maintenance monitoring program implemented by the Y-12 Plant Environmental Restoration Program (Table 2). The wells are located near the closed and capped source control OUs, and are sampled quarterly to provide data needed to evaluate cap effectiveness in terms of water-quality trends over time and to provide data on the extent of contamination within the Bear Creek Regime. Two wells (GW-345 and GW-601) were dropped from this monitoring program after the first quarter sampling event. Surveillance and maintenance monitoring will be phased out during CY 1995 as RCRA post-closure permits are issued.

3.1.5 Best-Management Practice Monitoring

Groundwater samples were collected from three monitoring wells at the Above Grade Low-Level Storage Facility as a best-management practice of the Y-12 Plant GWPP during CY 1994 (Figure 4 and Table 2). Groundwater monitoring at this site was requested by the TDEC and has been performed since CY 1991.

3.2 Sampling Frequency

Groundwater samples were collected during each quarter of CY 1994. First through fourth quarter sampling events were performed from February 8 to March 30, May 17 to June 29, July 28 to September 20, and November 2 to December 20, respectively. As summarized below, the number of wells included in each quarterly sampling event varied depending on the requirements or status of the monitoring programs. For example, five wells that were dropped from the RCRA corrective action and the surveillance and maintenance monitoring programs were sampled only during the first quarter.

Monitoring Program	**Number of Sampling Points**			
	1st Qtr	**2nd Qtr**	**3rd Qtr**	**4th Qtr**
RCRA Corrective Action Monitoring	24	11	21	11
RCRA Interim Status Assessment Monitoring	5	5	5	5

Monitoring Program	Number of Sampling Points			
	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr
Perimeter/Exit Pathway Monitoring	28	0	14	14
Surveillance/Maintenance Monitoring	20	18	18	18
Best Management Practice Monitoring	3	3	3	3
Total	**80**	**37**	**61**	**51**

3.3 Sample Collection

Personnel from the Oak Ridge K-25 Site Sampling and Environmental Support Department (SESD) collected groundwater samples from the monitoring wells, and personnel from the Y-12 HSEA Organization collected samples from springs and surface water stations. Sampling was performed in accordance with the most recent version of the technical procedures for groundwater (SESD-TP-8204) and surface water sampling approved by the Y-12 Plant GWPP Manager.

Filtered and unfiltered samples were collected from each monitoring well and surface water location. Filtering was performed in the field with an in-line 0.45 micron filter. To minimize the potential for cross-contamination, samples were collected from each monitoring well following a sequence that generally involved sampling from the least contaminated wells to the most contaminated wells at a site or in a sampling group (a series of monitoring wells grouped for sampling and data-tracking purposes). In areas where no groundwater contamination is present, samples were collected from the farthest upgradient wells first.

3.4 Laboratory Analysis

Groundwater and surface water samples were analyzed for a standard suite of analytes that included:

- principal cations and anions;
- trace metals (a term used to differentiate metals that are typically minor groundwater constituents, such as cobalt and nickel, from metals that are principal ions in groundwater, such as magnesium and sodium);
- volatile organic compounds (VOCs);
- gross alpha activity and gross beta activity;
- total suspended solids (TSS), total dissolved solids (TDS), and turbidity;
- field and laboratory determinations of pH and specific conductance; and
- field determinations of temperature, dissolved oxygen, and oxidation-reduction potential.

Unfiltered groundwater samples were analyzed for the entire standard suite of constituents and parameters; filtered samples were analyzed only for trace metals.

Samples from wells used for RCRA corrective action monitoring were analyzed for several additional analytes (e.g., radionuclides) required under the RCRA post-closure permit for the S-3 Site. Analyses for cadmium, chromium, lead, and mercury using atomic absorption methods also were performed on samples from selected wells with historically elevated concentrations of these metals. Samples from wells with elevated gross alpha and/or gross beta activity, as determined from CY 1993 data, were analyzed for selected radionuclides. The specific analytes for each well, spring, and surface water sampling station are presented in the Part 1 GWQR, and the *Sampling and Analysis Plan for Groundwater and Surface Water Monitoring at the Y-12 Plant During Calendar Year 1994* (HSW Environmental Consultants, Inc. 1993).

The bulk of the analyses were performed by the K-25 Analytical Services Organization (ASO). Selected radiochemical analyses were performed by the Oak Ridge National Laboratory (ORNL) ASO. Analytical results for all groundwater and surface water samples are presented in Appendix E of the Part 1 GWQR.

3.5 Quality Assurance/Quality Control Sampling

Quality assurance/quality control samples included laboratory blanks, trip blanks, equipment rinsates, field blanks, and duplicate groundwater samples. A total of 87 laboratory blanks, 124 trip blanks, three field blanks, 35 equipment rinsate samples, and 27 duplicate samples were analyzed during CY 1994. Similar numbers of QA/QC samples were analyzed during each quarterly sampling event: 18 to 26 laboratory blanks, 22 to 43 trip blanks, one field blank (a field blank was not collected in the second quarter), five to 12 equipment rinsates, and five to eight duplicate samples.

Laboratory blanks were samples of deionized water analyzed along with a specific number of associated groundwater and surface water samples. Trip blanks were samples of deionized water transported in each cooler containing groundwater and surface water samples scheduled for VOC analysis. Field blanks were samples of deionized water collected at the well head after samples were collected from selected wells at Spoil Area I, the S-3 Site, and the Oil Landfarm WMA. Equipment rinsates were samples of the deionized water that was used to decontaminate the groundwater sampling equipment, and were collected after a sampling team had completed sampling at a site or finished a sampling group. If more than one team collected groundwater samples at a site or within a sampling group, each collected an equipment rinsate sample.

Laboratory blanks, trip blanks, field blanks, and equipment rinsate samples were analyzed for VOCs; selected equipment rinsates were also analyzed for nitrate (as N), trace metals, gross alpha and gross beta activity, and selected radionuclides. Analytical results are summarized in Appendix I of the Part 1 GWQR. Duplicate groundwater samples were analyzed for the constituents and parameters specified for the well from which the duplicate sample was collected. Analytical results for the duplicate samples are presented in Appendix F of the Part 1 GWQR.

Review of the CY 1994 data reported for the laboratory blanks, trip blank, and equipment rinsates shows that the percent of samples that contained VOCs during CY 1994 decreased to the lowest levels since CY 1991 (Figure 5). Overall, at least one of ten VOCs was detected in 23% of the total QA/QC samples analyzed during CY 1994, including 22% of the laboratory blanks, 24% of the trip blanks, 23% of the equipment rinsate samples, and 33% of the field blanks (Table 4). In contrast, VOCs were detected in 70%, 79%, and 58% of the QA/QC samples analyzed during CYs 1991, 1992 and 1993, respectively (excluding field blanks, which were not collected before CY 1994). In general, four groups of VOCs have been detected in the QA/QC samples: (1) common laboratory reagents, (2) suspected source water contaminants, (3) VOC plume constituents, and (4) miscellaneous compounds.

Common Laboratory Reagents

The common laboratory reagents detected in the QA/QC samples are methylene chloride, acetone, 2-butanone, 4-methyl-2-pentanone, toluene, and 2-hexanone. Each of these compounds, except toluene and 2-hexanone, were detected in at least one laboratory blank, trip blank, or equipment rinsate sample analyzed during CY 1994. Methylene chloride and acetone are the laboratory reagents most commonly detected in the QA/QC samples, particularly laboratory and trip blanks; since CY 1991, methylene chloride has generally been detected in more than half of the laboratory and trip blanks that contained VOCs (Figure 5). However, a significant reduction in the percentage of QA/QC samples containing common laboratory reagents occurred during CY 1994. For example, methylene chloride was detected in 11 (42%) of the laboratory blanks analyzed during the first quarter, but was not detected in any of the laboratory blanks analyzed in the fourth quarter of the year.

Source Water Contaminants

Two groups of compounds are suspected contaminants of the deionized water used to prepare the QA/QC samples: laboratory blank source-water contaminants and trip blank/equipment rinsate source-water contaminants. Suspected contaminants of the deionized water used for laboratory blanks are 1,1,2,2-tetrachloroethane (1,1,2,2-TCA), bromoform, 1,1,2-trichloroethane, and vinyl acetate (these compounds have rarely been detected in trip blanks or equipment rinsate samples). Since CY 1991, at least one of these compounds (particularly 1,1,2,2-TCA) has been detected in about 10% of the contaminated laboratory blanks. Chloroform and 1,2-dichloropropane are the suspected contaminants of the deionized water used to prepare trip blanks and decontaminate sampling equipment. During this same time period, at least one of these compounds was detected in 42% of the trip blanks and equipment rinsate samples with VOCs, but only 4% of the VOC-contaminated laboratory blanks.

Since CY 1993, the K-25 ASO has virtually eliminated these compounds from the source water used for these QA/QC samples. For example, chloroform was detected in up to 100% of the contaminated trip blanks and equipment rinsates analyzed during various quarters of CYs 1991 and 1992, but was detected only in one trip blank and one equipment rinsate analyzed during CYs 1993 and 1994 (Figure 5). Likewise, 1,1,2,2-TCA was detected in only one laboratory blank analyzed during CY 1994 and none of the laboratory blanks analyzed during CY 1993. In CY 1992, however, 1,1,2,2-TCA was detected in 6 to 28% of the laboratory blanks analyzed each quarter.

Results of Inductively Coupled Plasma (ICP) analyses reported (in milligrams per liter [mg/L]) for an equipment rinsate and a field blank sample indicate that deionized water was not always used to rinse sampling equipment. As summarized in the following table, the calcium, magnesium, potassium, and sodium concentrations reported for these equipment rinsate samples are uncharacteristic of deionized water:

Sample Identity	**Concentration (mg/L)**			
	Ca	**Mg**	**K**	**Na**
Equipment Rinsate				
ER BC 1	29	8.1	1.3	3.8
Field Blank				
FB BC 1	30	8.2	1.4	3.9

The results for these samples are at least an order-of-magnitude greater than the respective concentrations reported for the other field blanks and equipment rinsates that were analyzed for inorganic compounds.

VOC Plume Constituents

Two compounds known to be components of the VOC plumes in the Bear Creek Regime were detected in five QA/QC samples analyzed during CY 1994: 1,1,1-trichloroethane (1,1,1-TCA) in four trip blanks and tetrachloroethene (PCE) in one equipment rinsate sample (Table 4). Review of the analytical sequence, sampling dates and times, and data reported for the associated groundwater samples does not indicate that contamination of the trip blank samples occurred during transportation; thus, these results are probably analytical artifacts. However, the PCE result for equipment rinsate sample ER BC 1 is likely a sampling artifact. This sample was collected after decontamination of the pump used to sample well GW-243 at the S-3 Site, and PCE concentrations consistently exceed 5,000 micrograms per liter (μg/L) in groundwater monitored by this well. No cross contamination resulted because this pump (no.4) was not used again until the third quarter of the year.

Miscellaneous Compounds

Other compounds that have been detected in the QA/QC samples analyzed since CY 1991 are benzene, bromodichloromethane, carbon disulfide, chlorobenzene, chloromethane, ethylbenzene, styrene, and xylenes. Of these, only bromodichloromethane was detected in any of the QA/QC samples analyzed during CY 1994; a concentration of 5 μg/L was reported for a field blank sample analyzed during the third quarter. Review of the historical data for these compounds indicates no clear pattern of occurrence, except that most of the samples that contained these compounds were analyzed during CYs 1991 and 1992, and that bromodichloromethane and carbon disulfide have been detected the most frequently.

4.0 INTERPRETIVE ASSUMPTIONS AND LIMITATIONS

Evaluation of groundwater quality in the Bear Creek Regime was based primarily on data collected during CY 1994; however, historical data were used to corroborate results, identify trends, and define concentration distributions within contaminant plumes. In addition, evaluation of CY 1994 and historic data were constrained by the interpretive assumptions and limitations described in the following sections.

4.1 General Assumptions

Interpretive assumptions related to the evaluation of less-than-detection limit results, diluted sample results, and duplicate groundwater sample results are described in the following sections.

4.1.1 Less-than-Detection Limit Results

Less-than-detection limit results comprised a substantial proportion of the analytical data for many of the inorganic and organic analytes. There are several approaches described in the technical literature and EPA guidance documents regarding how these data should be treated in quantitative evaluations. Each approach basically involves replacing the less-than detection limit results with one of three types of surrogate values: zero, the analytical detection limit (or fraction thereof), or a missing value (i.e., no analytical result).

Organic Compounds

For the purposes of this report, zero was used as the surrogate value for less-than-detection limit results reported for organic compounds. Zero was selected as the surrogate value for VOCs because estimated concentrations below the specified analytical detection limit are often reported for these compounds. Estimated results (reported by the K-25 ASO with a "J" qualifier) represent discernable but unquantified responses from the analytical instrumentation and were, therefore, considered qualitative.

Inorganic Compounds

For the purposes of geochemical evaluation, zero was used as the surrogate value for the less-than-detection limit results reported for the principal cations and anions. Half the specified analytical detection limit was used as the surrogate value for the less-than-detection limit results reported for each trace metal. This type of surrogate value was used to ensure comparability with the reference concentrations used to evaluate the CY 1994 trace metal data (see Section 4.2.2.3).

Beginning in the second quarter of CY 1994, the reporting limit for total and dissolved uranium analyses changed from 0.001 to 0.015 mg/L. The reporting limit was increased in response to an assessment of the K-25 Uranium Fluorometry Laboratory performed by the K-25 ASO in January 1995. As part of this assessment, EPA contract laboratory program protocols were followed to recalculate the method detection limit (MDL) for total and dissolved uranium, which historically had been equal to the instrument detection limit (0.001 mg/L), at three times the new instrument detection limit of 0.005 mg/L. Because the new MDL did not comply with the data quality objectives (DQOs) of the Y-12 Plant GWPP, missing values were used as surrogates for these data. An alternative analytical method (ICP mass spectroscopy; EPA Method 200.8) was implemented in the first quarter of CY 1995. This method has a standard reporting limit of 0.0005 mg/L.

Radioanalytes

The detection limit for radioanalytes (i.e., gross alpha activity, gross beta activity, and radionuclide activity) is expressed as the minimum detectable activity (MDA) in picoCuries per liter (pCi/L). Radioanalyte results for samples collected during CY 1994 were evaluated with respect to the following MDAs provided by the K-25 and ORNL ASOs (Jago 1995).

Radioanalyte	MDA (pCi/L)	Radioanalyte	MDA (pCi/L)
Americium-241	17	Ruthenium-106	26
Cesium-137	3.9	Strontium (Total)	33
Iodine-129	35	Technetium-99	110

Radioanalyte	MDA (pCi/L)	Radioanalyte	MDA (pCi/L)
Iodine-131	35	Thorium-234	250
Neptunium-237	52	Tritium	950
Plutonium-238	84	Uranium-234	55
Plutonium-239	52	Uranium-235	14
Potassium-40	190	Uranium-238	22
Protactinium-234m	700	Gross Alpha Activity	4.7
Radium	1.5	Gross Beta Activity	11

For the purposes of this report, radioanalyte activities that were less than the specified MDA were considered unusable; missing values were used as surrogates for these results.

Results of recent inquires by the Y-12 Plant GWPP and other Energy Systems organizations indicate QA/QC deficiencies relating to MDAs associated with the radioanalytical results reported by the K-25 ASO (Jago 1995). The QA/QC concerns initially arose when it was determined that MDAs had neither been routinely reported by the K-25 ASO, nor used on a consistent basis to qualify individual radiological results. Further inquiry determined that the method-specific MDAs currently obtained by the K-25 ASO for many parameters were too high to comply with: (1) the DQOs established for pending RI/FS-related risk assessments, (2) the DQOs needed for Y-12 Plant GWPP monitoring for compliance with existing regulatory requirements, operating or post-closure permit conditions, or (3) 4% of the DOE Order 5400.5 derived concentration guidelines. Actions intended to address these QA/QC problems, both at the Y-12 Plant and elsewhere on the ORR, are currently being formulated by the Y-12 Plant GWPP in conjunction with Energy Systems central management, compliance and environmental restoration organizations from all three DOE facilities on the ORR, and central and site ASO staff. A set of guidelines will be published that describes a consistent process for projects to use to determine radiological data needs and document the quality of a set of radiological data. These guidelines will be incorporated into applicable Y-12 Plant GWPP procedures and plans.

The end result of the process will be much lower MDAs and relevant QA/QC information will be reported along with individual results.

4.1.2 Diluted Sample Results

Groundwater samples collected from wells known or suspected to contain high concentrations of organic or inorganic contaminants were diluted in the laboratory to avoid obtaining results that exceed the calibration range of the analytical instrumentation. As a result, analytical detection limits reported for the diluted samples were much higher than those reported for undiluted samples. Groundwater samples collected from wells GW-071, GW-225, GW-291, GW-623, GW-624, and GW-626 during one or more quarters of CY 1994 were diluted by the K-25 ASO before they were analyzed for VOCs. The summed average VOC concentration determined for each of these wells was considered qualitative (see Section 4.2.1), and the data for these samples were excluded from the screening procedure for anomalous VOC results (see Section 4.2.1.2). Groundwater samples collected from wells GW-243, GW-537, GW-710, and GW-711 were diluted before they were analyzed for trace metals.

4.1.3 Duplicate Sample Results

Duplicate groundwater samples were collected during at least one quarter of CY 1994 from each of the following monitoring wells:

GW-064
GW-069
GW-095
GW-162
GW-315
GW-348
GW-363
GW-370
GW-372
GW-537
GW-621
GW-627
GW-683
GW-704
GW-712
GW-713
GW-724
GW-738
GW-793
GW-795
GW-800

As part of the data verification process described in the Part 1 GWQR, the duplicate groundwater sample data for each well were reviewed to identify statistically significant differences between corresponding analytical results, and the appropriate analytical laboratory was then contacted to determine if reporting errors were responsible for such differences. All the statistically significant differences identified in the CY 1994 duplicate sample data, except those summarized below, were attributed to laboratory reporting errors and corrected (Paradigm Data Services, Inc. 1994a, 1994b, 1995a, and 1995b).

Well	Date Sampled	Analyte(s)
GW-348	8/30/94	Dissolved Fe
GW-363	11/2/94	Dissolved Fe, Mn
GW-370	5/24/94	Gross Alpha and Gross Beta Activity
GW-372	3/9/94	Americium-241, Uranium-234
GW-537	2/11/94	Technetium-99
GW-537	12/15/94	Technetium-99, Uranium-235, Gross Beta Activity
GW-712	2/24/94	Technetium-99

Because the differences for the compounds listed above could not be resolved, these results were assigned missing values as surrogates for the purposes of quantitative evaluation (e.g., calculation of mean annual gross alpha activity).

4.2 Specific Assumptions

The following sections describe the interpretive assumptions specific to the evaluation of CY 1994 data reported for VOCs, trace metals, principal ions, nitrate (as N), and radiological parameters.

4.2.1 Volatile Organic Compounds

The extent of dissolved VOCs in groundwater was evaluated with respect to the summed annual average concentration of each VOC detected in samples from each monitoring well. In cases where elevated analytical detection limits were reported (i.e., diluted samples), the summed average VOC concentrations were considered qualitative.

To determine the summed average VOC concentration for each well, the data were screened to identify probable artifacts of sampling or analysis (false positive results), and results that potentially reflect other extraneous factors unrelated to groundwater quality (anomalous results). False positive results were identified through evaluation of the VOC data reported for selected blanks associated with each groundwater sample. Anomalous results were identified from a review of CY 1991-1994 data for each well to quantify the frequency at which individual VOCs were detected (including estimated concentrations). Zero was used as the surrogate value for all false positive and most anomalous VOC results for the purposes of calculating average VOC concentrations.

4.2.1.1 False Positive Results

False positive results were identified using a procedure developed by the EPA that involves determining the blank qualification result (BQR) for each VOC detected in the laboratory and trip blanks, and comparing the BQRs to the VOC results reported for the associated groundwater samples. Blank qualification results were determined by multiplying the highest concentration of a VOC detected in either associated blank by a qualification factor. A factor of 5 was used to determine the BQR for most compounds, but a factor of 10 was used to determine the BQRs for the following common laboratory reagents: methylene chloride, acetone, 2-butanone, and toluene. The BQR determined for each compound was then compared to the corresponding result reported for the groundwater sample. If the compound was detected in the groundwater sample at a concentration less than or equal to the BQR, the result was screened as a false positive (U.S. Environmental Protection Agency 1988b).

Fourteen VOCs were detected in the groundwater samples collected from monitoring wells in the Bear Creek Regime during CY 1994, and false positive results were identified for methylene chloride, acetone, and 2-butanone. These compounds were detected in 96% of the laboratory and trip blank samples containing one or more VOCs, though fewer false positive results were generated compared to previous years (Figure 6). Of 22 results for these compounds reported for the groundwater samples, 15 were screened as false positives. All of these false positive results were less than 10 μg/L (i.e., estimated values below the analytical detection limit for each compound), and most were screened by BQRs determined from laboratory blank data (Table 5). In contrast, these three compounds accounted for 271 groundwater sample results in CY 1993, 254 of which were screened as false positives.

The number of false positive results identified in the groundwater data fluctuated through the year (Figure 6). This fluctuation does not appear to correlate with the number of samples analyzed for VOCs; increases in the number of false positives occur independent of the number of samples analyzed for VOCs. For instance, the total number of samples analyzed for VOCs decreased 11% from the third to the fourth quarter of 1994, but the number of false positive results increased 300% during this period. Additionally, increases in the number of false positives do not appear directly related to the number of laboratory blank and trip blank samples that contained VOCs, including the common laboratory reagents.

4.2.1.2 Anomalous Results

One characteristic of the VOC data collected for the purposes of the Y-12 Plant GWPP is the sporadic occurrence of typically low (less than 10 μg/L) concentrations of various compounds in samples from wells with no history of VOC contamination. Such results occur for compounds, such as methylene chloride, that otherwise are typically identified as false positives, as well as compounds, such as trichloroethene (TCE), that are in the groundwater near known VOC source areas. A decision rule based on frequency of detection has been used to identify these results in previous GWQRs; results for compounds detected (including estimated concentrations below the detection limit) in only one out of four consecutive undiluted samples collected each CY from a particular sampling point were considered anomalous and assigned a surrogate value of zero (i.e., considered the same as less-than-detection limit VOC results). This approach has effectively reduced overly subjective interpretations of the VOC data and avoided widely divergent annual assessments of the extent of VOC plumes.

Screening anomalous results from the VOC data has two primary drawbacks. First, it may negate evidence of groundwater contamination. For example, the apparently sporadic detection of a known plume constituent may be a sampling artifact; a compound present at very low concentrations in the groundwater may be occasionally volatilized during sample collection. Alternatively, the infrequent detection of plume constituents may reflect transport during seasonal or episodic groundwater flow conditions. The second drawback is that a decreasing number of wells at the Y-12 Plant are being sampled at the quarterly frequency upon which the decision rule for identifying anomalous VOC results has historically been based.

To determine if evidence of VOC contamination or VOC plume migration has been negated in past GWQRs, and to accommodate the reduced sampling frequency of most monitoring wells at the Y-12 Plant, the VOC data reported for all wells in the Bear Creek Regime sampled since CY 1991 were re-evaluated for anomalous results. For the purposes of this evaluation, anomalous results were defined as results (including estimated concentrations) for compounds detected in 25% or less of the undiluted samples from a particular location (i.e., 1 of 4 samples, 2 of 8 samples, 3 of 12 samples, etc.). Based on this decision rule, a total of 214 anomalous results have been reported for 27 compounds (Table 6): six laboratory reagents (61 results), five suspected blank source water contaminants (27 results), eight miscellaneous compounds (27 results), and eight VOC plume constituents (99 results).

Laboratory reagents, suspected blank source water contaminants, and miscellaneous compounds account for 115 of the 214 anomalous VOC results. The number of anomalous results for these compounds decreased after the first quarter of CY 1993 (15 results) to less than 5 results during each quarter of CY 1994 (Figure 6). The decrease generally coincides with the decrease in the number of VOC-contaminated QA/QC samples (Figure 5), and with the decrease in the number of wells sampled (Figure 6). Additionally, the total number of anomalous results for each of these compounds shows an equal or nearly equal ratio with the number of wells for which they were reported (i.e., most were reported for only one sample from one well). These findings suggest that anomalous results for laboratory reagents, suspected blank source water contaminants, and miscellaneous compounds are probably sampling or analytical artifacts. Accordingly, for evaluation purposes in this report, anomalous results for these compounds identified in the CY 1994 VOC data were assigned zero as a surrogate value (Table 7).

The anomalous results identified for VOC plume constituents were primarily for TCE (20 results), 1,2-dichloroethene (1,2-DCE) (16 results), 1,1,1-TCA (16 results), and PCE (14 results) (Table 6). Most of the anomalous results for the VOC plume constituents were reported for samples from wells located near confirmed source areas in which other constituents have consistently been detected. Thus, screening these results as anomalous had no impact on the evaluation of the overall extent of the VOC plume in groundwater in these areas. Review of the remaining anomalous VOC results indicates that only those reported for samples collected from the following wells potentially represent groundwater contamination:

Well Number	Location	Compound
GW-061	BG	TCE
GW-069	BG	Vinyl Chloride
GW-287	BG	PCE
GW-348	S3	TCE and PCE
GW-683	EXP-A	TCE and 1,2-DCE
GW-684	EXP-A	TCE and 1,2-DCE

Trichloroethene was detected at very low concentrations (less than 1 μg/L) in samples collected from well GW-061 in the third quarter of CY 1991 and the second quarter of CY 1994 (Table 7). This compound is the principal component of the VOC plume in groundwater in the Maynardville Limestone hydraulically upgradient from well GW-061.

Vinyl chloride was detected (2 μg/L) in three of the four quarterly samples collected from well GW-069 in CY 1994 (Table 7), and in the first quarter of 1993 (1 μg/L). This well is located directly above a dense, non-aqueous phase liquid (DNAPL) accumulation, and vinyl chloride is a degradation product of the principal DNAPL constituents (chloroethenes). The occurence of vinyl chloride in samples from well GW-069 suggests transport from the DNAPL.

Water table well GW-287 has historically been used to define the VOC plume boundary downgradient and along strike to the west of the Bear Creek Burial Grounds WMA, a known source of PCE in groundwater. The detection of PCE in the sample collected during the first quarter of CY 1993 (0.7 μg/L), and again in the samples collected during the first and second quarter of CY 1994 (2 μg/L each) (Table 7), may indicate downgradient migration of the VOC plume.

Two samples collected from well GW-348, completed in the Maynardville Limestone downgradient from the S-3 Site and Spoil Area I (Figure 4), had low concentrations of TCE and PCE (Table 7). Trichloroethene was detected in samples collected in the third quarter of 1991 (0.5 μg/L) and the second quarter of 1994 (6 μg/L), while PCE was detected in samples collected in the first quarter of 1992 (0.4 μg/L) and the first quarter of 1994 (0.9 μg/L). The occurrence of these compounds in different samples suggests that separate preferential pathways connecting separate source areas for TCE (Spoil Area I) and PCE (S-3 Site) may be influencing groundwater monitored by this well.

Low concentrations (1 μg/L) of TCE and 1,2-DCE were detected in the samples from exit pathway wells GW-683 and GW-684 collected during the third quarter of 1994 (Table 7). These wells monitor groundwater that is indicative of quickflow conditions (Shevenell 1994), and are located hydraulically downgradient from all waste management sites in the regime. It is likely that these compounds were transported from the VOC plume in the Maynardville Limestone south of the Oil Landfarm WMA.

4.2.2 Trace Metals

As required by the TDEC, evaluation of groundwater quality with respect to trace metals was based on total concentrations reported for unfiltered groundwater samples. Evaluation of these data included: (1) consideration of analytical methods, (2) comparison to corresponding dissolved metal concentrations reported for filtered groundwater samples, (3) identification of median trace metal concentrations that exceeded corresponding reference values, and (4) review of the elevated median concentrations to identify those potentially biased from contamination during laboratory analysis.

4.2.2.1 Analytical Methods

Four analytical methods were used to determine trace metal concentrations in the filtered and unfiltered groundwater samples: (1) Atomic Absorption Spectroscopy (AAS) for cadmium, chromium, and lead; (2) Cold Vapor Atomic Absorption spectroscopy for mercury; (3) fluorometry for uranium (total); and (4) ICP spectroscopy for aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, silver, strontium, thorium, vanadium, and zinc.

The AAS results for cadmium, chromium, and lead were evaluated in lieu of the ICP data because analytical interferences inherent to the ICP method can cause inaccurate results for these metals (U.S. Environmental Protection Agency 1986). However, the K-25 ASO reported that recent procedural improvements have, in general, eliminated analytical interferences that may be associated with ICP analyses for cadmium and chromium. This is supported by results of a statistical analysis of CY 1994 ICP and AAS data reported for these metals, which showed no statistically significant differences between data obtained by each respective analytical method (Paradigm Data Services, Inc. 1995c). Accordingly, continued AAS analyses for cadmium and chromium will not be necessary for the purposes of the Y-12 Plant GWPP.

4.2.2.2 Total/Dissolved Concentrations

To qualitatively gauge the validity of the total metal concentrations reported for unfiltered groundwater samples from each well, they were compared to the corresponding dissolved metal concentrations reported for filtered groundwater samples. If the dissolved metal concentration exceeded the corresponding total concentration by an order-of-magnitude or more, both results were considered unusable. Order-of-magnitude differences between total and dissolved metal concentrations are summarized below.

Sampling Point	Date Sampled	Trace Metal	Concentration (mg/L)	
			Dissolved	Total
GW-044	11/30/94	Boron	0.099	0.0084
GW-057	2/26/94	Boron	0.51	0.029
GW-315	8/30/94	Manganese	0.092	0.0015
GW-800	12/14/94	Aluminum	0.2	<0.02
GW-800	12/14/94	Iron	0.19	<0.005
GW-800	12/14/94	Manganese	0.029	0.002

These results were assigned missing values as surrogates for the purposes of quantitative evaluation.

4.2.2.3 Identification of Elevated Concentrations

Evaluation of groundwater quality with respect to trace metals was based on median total (unfiltered) concentrations determined from CY 1994 data for each well. The evaluation was based on median trace metal concentrations because, as described below, median values were used to calculate the reference concentrations used to evaluate the CY 1994 data for many of the trace metals. Medians were used to determine reference concentrations because they are less sensitive to extreme values (outliers) and imply no assumptions regarding the distribution (i.e., normal or lognormal) of the data.

Reference concentrations used for comparison to the median trace metal concentrations were: (1) statistically-derived upper tolerance limits (UTLs) assumed to be representative of respective metal concentrations in uncontaminated groundwater, and (2) maximum contamination levels (MCLs) for drinking water.

Elevated concentrations of aluminum, antimony, beryllium, boron, cobalt, copper, iron, manganese, molybdenum, nickel, strontium, thorium, uranium, vanadium and zinc were defined as median concentrations that exceeded respective UTLs determined from statistical evaluation of groundwater quality data obtained since CY 1986 from all monitoring wells at the Y-12 Plant, including wells monitoring contaminated groundwater (HSW Environmental Consultants, Inc. et. al. 1995). The technical approach used in the determination of UTLs for these metals generally involved:

- principal component analysis to identify the dominant sources of variation in the groundwater chemistry data;
- cluster analysis to identify subsets of similar geochemical data;
- classification modeling to assign monitoring wells to the identified clusters;
- review of cumulative probability graphs to identify potentially biased results (i.e., sampling or analytical artifacts) and results indicative of contamination that were excluded from determination of the UTLs; and
- statistical analysis of the data for the wells in each cluster using parametric and nonparametric techniques, as appropriate, to determine the UTL for each inorganic compound applicable only to the wells in the cluster.

The principal component analysis identified carbonate and bicarbonate alkalinity, magnesium, sodium, nitrate (as N), and specific conductance as the primary sources of variation in the groundwater geochemistry data. Classification modeling using median concentrations of these parameters identified ten separate groups of wells (i.e., clusters) characterized by similar geochemical data (Figure 7). Cluster 1 is represented by data from shallow wells located throughout BCV. Cluster 2 is represented primarily by data for shallow wells that monitor groundwater with very low dissolved solids. Cluster 3 is similar in many respects to Cluster 1 in that it is represented by data for shallow wells located throughout BCV, but the geochemical data for these wells are less variable. Cluster 4 is represented almost exclusively by the data for wells completed in the Copper Ridge Dolomite of the Knox Group. Clusters 5, 7, 8, and 9 are represented chiefly by data for wells that monitor nitrate-contaminated groundwater near the west end of the Y-12 Plant. Clusters 6 and 10 are represented by data for deeper monitoring wells at the Y-12 Plant; intermediate depth wells monitoring sodium-bicarbonate type groundwater (Cluster 6), and deep (>400 ft below ground surface [bgs]) wells monitoring sodium-chloride-bicarbonate type groundwater (Cluster 10). Reference concentrations for evaluating groundwater quality reported for wells classified into Clusters 1, 2, 3, 4, 6, and 10 were then determined using data for the wells in each cluster; details regarding the groundwater classification scheme and methods used to determine the UTLs for each cluster are included in a report to be issued in late-1995 (HSW Environmental Consultants, Inc. et al. 1995)

Wells installed during CY 1994 that were not included in the background study were assigned cluster designations using results reported for the parameters identified by the principal component analysis in conjunction with the decision criteria defined by the classification model. Additionally, wells in the Bear Creek Regime that were included in the contaminated groundwater clusters (Clusters 5, 7, 8, and 9) were re-assigned to the noncontaminated groundwater clusters (Clusters 1, 2, 3, 4, 6, and 10) based on a classification model that used selected well construction and water quality data as decision criteria (Figure 8). These surrogate cluster assignments were necessary because UTLs were not calculated using data from wells that monitor contaminated groundwater.

The cluster designations for the wells in the Bear Creek Regime that were sampled during CY 1994 are listed on Table 3; trace metal UTLs applicable to the wells in each cluster are listed in Table 8. These UTLs are generally more conservative than those used to evaluate trace metal data reported in previous GWQRs for the Bear Creek Regime. The conservative bias may be primarily attributable to differences in the data sets used to determine the reference levels. The UTLs used to evaluate the CY 1994 data were determined from data reported for a total of 430 monitoring wells located throughout the Y-12 Plant, whereas the UTLs presented in previous GWQRs were determined from data reported for 53 wells (29 in the Bear Creek Regime) located hydraulically upgradient of known contaminant sources. Regardless of the cause, the net affect was a lower reference level for every metal for which a drinking water MCL has not been determined except cobalt; the 0.019 mg/L UTL determined for cobalt is slightly higher than the 0.011 mg/L UTL used in the CY 1993 GWQR. The most significant differences are evident between the reference levels for boron, beryllium, strontium, and vanadium. The lowest UTL for each of these metals (UTLs for beryllium and vanadium are the same for each well cluster) is more than an order-of-magnitude less than the respective UTLs used as reference values for these metals in previous GWQRs.

Upper tolerance limits for the following metals were calculated as part of the study outlined above, but elevated concentrations of these metals were defined as median concentrations that exceeded the drinking water MCL specified below:

Trace Metal	MCL (mg/L)	Trace Metal	MCL (mg/L)
Arsenic	0.05	Lead	0.05
Barium	2.0	Mercury	0.002
Beryllium	0.004	Nickel	0.1
Cadmium	0.005	Selenium	0.05
Chromium	0.10	Silver	0.05

The MCLs were used to identify elevated concentrations to maintain consistency with historical evaluations of the data for these metals.

4.2.2.4 Potentially Biased Results

Individual trace metal concentrations that exceeded MCLs or background levels were reviewed to determine if they may have been biased from contamination during laboratory analysis. For example, boron concentrations may be biased by traces of borax, which is commonly used to clean laboratory glassware. Trace metal results that reflect potential laboratory contamination are flagged by the K-25 ASO with a "c" qualifier. Results of this review show that potentially biased concentrations of aluminum (5 results), boron (13 results), copper (2 results), iron (1 result), nickel (3 results), and zinc (8 results) were reported for samples collected from 21 wells and two surface water sampling points during CY 1994 (Table 9). These results were considered unusable, and missing values were used as surrogates for quantitative evaluation purposes (e.g., calculation of median concentrations).

4.2.3 Principal Ions

Water is electrically neutral and, therefore, the total charges on the principal anions (bicarbonate and carbonate alkalinity, chloride, fluoride, nitrate, and sulfate) and cations (calcium, magnesium, sodium, and potassium) should be equal. Total positive and negative charges were determined by summing the milliequivalents (i.e., molecular weight of the ion divided by the net ionic charge) of the dissolved cation concentrations (which exclude digested cations that do not contribute charge to the groundwater) and the total (unfiltered sample) anion concentrations. The charge balance error was expressed as the relative percent difference (RPD) between the respective summed milliequivalent concentrations of the principal cations and anions.

Principal ion data reported for samples in which the RPD exceeded 10% were excluded from further evaluation. Based on this criterion, principal ion data reported for 21 of the groundwater samples collected during CY 1994 were not evaluated. Unusually low alkalinity or unusually high calcium concentrations typically caused positive RPDs greater than 10%. High nitrate concentrations (probably reflecting contamination), high alkalinity, and high manganese concentrations (not included in the charge balance) typically caused negative RPDs greater than 10%. Charge balance errors for all groundwater and surface water samples collected in the Bear Creek Regime during CY 1994 are included in Appendix G of the Part 1 GWQR.

4.2.4 Nitrate

Nitrate concentrations reported by the K-25 ASO are for nitrate nitrogen (i.e., nitrate as N). For the purposes of this report, "nitrate concentrations" and "nitrate (as N) concentrations" are synonymous. To evaluate groundwater quality with respect to nitrate, the annual average nitrate concentration was determined for each well and compared to the 10 mg/L MCL for drinking water.

4.2.5 Radiochemical Parameters

The CY 1994 data reported for radioanalytes were evaluated with respect to: (1) negative values, (2) the respective MDAs reported by the K-25 and ORNL ASOs, and (3) the uncertainty associated with each result that exceeded the specified MDA. Radioanalyte activities reported by the ASOs are background corrected; i.e., each result represents the total activity minus the background activity associated with the analytical environment. If the activity in a sample was below the background level, the result was reported as a negative value; otherwise, the radioanalyte activity reported for each groundwater sample was compared to each respective MDA listed in Section 4.1.1. Furthermore, the degree of analytical uncertainty associated with quantifying gross alpha, gross beta, and radionuclide activity in a sample is expressed by the counting error reported for each result which is defined as two times the sample standard deviation. Thus, if the radioanalyte activity was less than background, the MDA, or the associated counting error, it was considered unusable; missing values were used as a surrogate.

Only 14% of the CY 1994 radioanalyte data passed the evaluation criteria (Table 10). Of the data that failed the QA/QC criteria, 28% were negative values, 69% were less than the applicable MDA, and 3% were results that exceeded the MDA but were less than the associated counting errors.

The annual average gross alpha and gross beta activities were determined using data that passed the validation criteria and the applicable surrogate values noted in the preceding paragraphs. The associated average counting error (**e**) was calculated using the following formula from Evans (1955):

$$e=\sqrt{\frac{E_1^2}{n^2}+\frac{E_2^2}{n^2}\ldots}$$

where **E**$_1$, **E**$_2$, ... are the individual errors reported for each sample, and **n** is the number of samples that passed the validation criteria. This formula is appropriate for calculating the mean error of a series of errors.

4.3 Limitations

Groundwater quality data obtained for most wells sampled during CY 1994 are generally not synchronous; sampling required 51, 43, 55, and 49 days, respectively during the first through fourth quarters of the year. Although wells at each waste-management site were generally sampled within one to three days, sampling of wells at adjacent waste-management sites were not always concurrent. For example, during the first quarter sampling period, Maynardville Limestone wells at the Rust Spoil Area and the upgradient surface water sampling stations and spring (BCK-11.97, NT-01, and SS-1) were sampled on February 9 and 14, 1994, respectively. However, Maynardville Limestone wells at EXP-C (Figure 4), located in the same general area, were not sampled until March 14-21, 1994. Overall, the fourth quarter data are generally the most contemporaneous; samples were collected during a 17 day time period (December 4-20, 1994), from 35 of the 51 wells included in the fourth quarter monitoring schedule. Additionally, wells located at the S-3 Site were usually sampled during the shortest time period (2 to 16 days), and wells at the Oil Landfarm Area WMA and the Burial Grounds Area WMA were sampled during the longest time (35 to 49 days). Thus, comparison of quarterly data between wells at different waste-management sites with regard to concurrent concentration changes is generally not valid.

Continuous water-level monitoring performed as part of the RI for the Bear Creek CA show that water levels at shallow depths in the Conasauga Shales and throughout the Maynardville Limestone change significantly in response to precipitation events. Thus, groundwater flow conditions are generally dependent upon the amount of precipitation, which is variable during each quarterly sampling event and from quarter to quarter (Figure 9). For example, 46% of the 71 wells included in the first quarter sampling schedule were collected during or within two days of a 0.5-in or greater rainfall, whereas 21% of the 52 wells included in the third quarter sampling schedule were sampled during or within two days of similar magnitude storms (Figure 9). Such relationships between rainfall and sampling activity indicate that groundwater samples may have been collected under variable flow conditions during the first quarter, but similar (low) flow conditions during the third quarter.

5.0 HYDROGEOLOGIC FRAMEWORK

This section contains a general overview of the hydrogeologic system in the Bear Creek Regime. In past GWQRs, the hydrogeologic overview was based primarily on the conceptual framework and associated nomenclature presented in: *Status Report - A Hydrologic Framework for the Oak Ridge Reservation* (Solomon et al. 1992). However, the overview for this report has been revised because flow in the Maynardville Limestone, a key component of the groundwater flow system in the Bear Creek Regime, is not specifically addressed in Solomon et al. (1992), and some components of the ORR hydrogeologic framework (e.g., the stormflow zone) appear to be of lesser hydrologic significance at the Y-12 Plant than indicated for other areas on the ORR. In general, the revised description of the hydrogeologic system incorporates: (1) applicable aspects of the conceptual framework described in Solomon et al. (1992), (2) hydrologic characteristics evaluated by Moore (1988 and 1989), and (3) findings of the RI for the Bear Creek CA (Science Applications International Corporation 1995a and b).

5.1 Geology

Geology on the ORR 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 Lower Ordovician age. In the Y-12 Plant area, shale and siltstone beds of the Rome Formation form Pine Ridge to the north, BCV is underlain by limestone and shale formations of the Conasauga Group, and dolostone strata of the Knox Group form Chestnut Ridge to the south (Figure 10). Bedrock is overlain by any of several materials, including man-made fill, alluvium, colluvium, fine-grained residuum from the weathering of the bedrock, and saprolite (weathered bedrock), which in some areas retains primary textural features of the bedrock, including fractures (Solomon et al. 1992). The overall thickness of these materials is typically less than 40 ft in BCV (Geraghty & Miller, Inc. 1987).

The most important geologic unit with respect to groundwater contamination in the Bear Creek Regime is the Conasauga Group, which includes the following formations listed in sequence from youngest to oldest: Maynardville Limestone, Nolichucky Shale, Maryville

Limestone, Rogersville Shale, Rutledge Limestone, and Pumpkin Valley Shale (Figure 10). The Maynardville Limestone is partially exposed along the axis of BCV at the base of Chestnut Ridge; the remaining formations are partially exposed successively to the north toward Pine Ridge (Figure 10).

The Maynardville Limestone consists of about 300 to 620 ft of fine- to coarse-grained, thin-bedded to massive limestone and dolostone (King and Haase 1987; Shevenell et al. 1993). Most of the basal portion of the formation (the Low Hollow member) is not present in an area southeast of the Bear Creek Burial Grounds WMA; this loss of stratigraphic section also is evident in the basal Maynardville exposed in a quarry located in Union Valley about two miles east of the Y-12 Plant (D. Watson 1995) and is believed to represent a lateral facies change (Shevenell et al. 1993). The underlying Nolichucky Shale and Maryville Limestone formations consist of 350 to 550 ft of primarily massive to thin-bedded mudstone with interbedded limestone (King and Haase 1987). Beneath the Maryville Limestone are the massive mudstones of the Rogersville Shale and the interbedded limestone and shale of the Rutledge Limestone. The thickness of each of these formations ranges from 90 to 120 ft (King and Haase 1987). The Pumpkin Valley Shale consists of 260 to 320 ft of massive shale and mudstone with thin beds of siltstone and sandstone (King and Haase 1987).

Strike and dip of bedding are generally N 55°E, and 45°SE, respectively (as referenced to true north); however, small-scale folding and faulting produce locally variable bedding orientations (King and Haase 1987). The bedrock is extensively fractured. Three major fracture orientations are evident: one that roughly parallels bedding, and two that dip more steeply, one generally parallel with and one perpendicular to bedding (Dreier et al. 1987). Most fractures are short, usually only tenths of inches to a few feet in length; fracture densities ranging from about 1 to 60/ft have been observed in rock outcrops near the ORNL (Dreier et al. 1987; Sledz and Huff 1981). Dissolution along fractures in carbonates, particularly in the Maynardville Limestone, has produced karst features ranging from less than an inch to tens of feet in thickness. These features tend to occur in strata near the top and bottom of the formation (Shevenell et al. 1993).

5.2 Groundwater System

Groundwater occurs in two basic hydrogeologic units in the Bear Creek Regime: the Maynardville Limestone, and the Conasauga Shales (Nolichucky Shale, Maryville Limestone, Rogersville Shale, Rutledge Limestone, and Pumpkin Valley Shale). These units are respectively analogous to the Knox Aquifer and the ORR Aquitards described by Solomon et al. (1992). The hydrologic boundary between these units corresponds with the geologic contact between the Nolichucky Shale and the Maynardville Limestone.

The Maynardville Limestone and Conasauga Shales each have distinctly different hydrologic characteristics, but both consist of three general subsystems: (1) the stormflow/vadose zone, (2) the groundwater zone, and (3) the aquiclude (Figure 11). The subsystems are vertically gradational in each unit, and are differentiated by groundwater flux, which decreases with depth. However, solutionally-enlarged flowpaths in the Maynardville Limestone are about ten times more permeable than in the Conasauga Shales (Solomon et al. 1992). Because of its greater permeability and its location along the floor of BCV, the Maynardville Limestone is the hydrologic low in the Bear Creek Regime and functions both as a drain for the groundwater flow system and the principal contaminant migration pathway in the subsurface.

5.2.1 Stormflow/Vadose Zone

Groundwater occurs intermittently above the water table in a shallow "stormflow zone" that extends from ground surface to a depth of about 6 ft bgs. The stormflow zone is thicker and more permeable in forested areas than in grassy or brushy areas, and is more permeable near the land surface than at deeper levels (Moore 1989). Lateral flow in the stormflow zone is intermittent, lasting only a few days or weeks after rainfall; some of the water is lost to evapotranspiration and recharge to the water table, and the remaining water discharges at nearby seeps, springs, and streams. Hydrologic characteristics of the stormflow zone are based primarily on information obtained in Bethel Valley and Melton Valley near ORNL (Moore 1988 and 1989). Although data obtained for RI purposes show that the shallow subsurface flow in the stormflow zone also occurs at the Y-12 Plant (Figure 12) (Science Applications International

Corporation 1994), the significance of groundwater flux and contaminant transport in the stormflow zone in BCV has not been fully characterized, and may be less than indicated in Bethel Valley and Melton Valley.

The vadose zone occurs between the stormflow zone and the water table, which typically occurs at depths less than 20 ft bgs in the Conasauga Shales and the Maynardville Limestone. The vadose zone in undeveloped areas primarily occurs in regolith; the effective porosity (the porosity through which significant advective transport can occur) of the regolith is estimated at of 0.01 to 0.15 (Moore 1989). The vadose zone is unsaturated except in the capillary fringe above the water table and within wetting fronts during periods of vertical percolation from the stormflow zone (Moore 1989).

5.2.2 Groundwater Zone

Groundwater below the vadose zone in the Conasuaga Shales and Maynardville Limestone occurs within orthogonal sets of permeable, planar fractures that form water-producing zones within an essentially impermeable matrix. Water-producing zones commonly develop within a single layer of rock, and have an average thickness (assuming an average dip of 35°) of 2 ft or less (Dreier et al. 1987). Dissolution of carbonates has greatly increased permeability of the water-producing zones in the Maynardville Limestone; enlarged fractures and solution cavities in the Maynardville Limestone yield as much as 200 to 300 gallons per minute (gpm) (Shevenell et al. 1993), which is several orders-of-magnitude greater than the typical yield (0.25 gpm) of water-producing zones in the Conasauga Shales (Solomon et al. 1992). Additionally, stratiform fractures provide the principal flowpaths in both hydrogeologic units, and groundwater flows primarily in the direction of geologic strike (which may or may not correlate with the maximum hydraulic gradient) toward springs, seeps, and cross-cutting tributary streams (Moore and Toran 1992).

Because the frequency, aperture, and connectivity of permeable fractures decreases with depth, the bulk hydraulic conductivity of the Conasuaga Shales and the Maynardville Limestone is vertically gradational. Most of the groundwater flux in each unit occurs in a highly permeable zone (the water table interval) within the transitional horizon between regolith and unweathered bedrock; lower flux (and longer solute residence times) occurs at successively greater depths in the bedrock. Changes in the geochemistry of the groundwater suggest that active flow in the Conasauga Shales occurs at depths less than 100 ft bgs. Active groundwater flow occurs deeper in the Maynardville Limestone, as indicated by pressure responses to rainfall that are evident in some wells completed at depths of 200 to 400 ft bgs (Science Applications International Corporation 1995b).

The bulk of the groundwater flux in the Conasauga Shales and Maynardville Limestone occurs within the water table interval, which transmits an estimated 90% or more of the groundwater flow below the stormflow/vadose zone. This highly permeable zone is relatively thin in both units (3 to 15 ft), and the saturated thickness changes with cyclic variations in the water table elevation (Moore 1989). Transient saturation of permeable flowpaths in the water table interval during and immediately after rainfall causes rapid lateral groundwater movement (quickflow) toward nearby seeps, springs, and tributaries. Quickflow in the water table interval is reflected by stream hydrographs, which are characterized by rapid responses to rainfall and little or no change in baseflow before and after major storms (Science Applications International Corporation 1995). For some wells screened in the water table interval, substantial decreases in TDS reported for samples collected after rainfall also indicate quickflow recharge.

Groundwater flux below the water table interval in the Conasauga Shales occurs primarily in the shallow bedrock (i.e., <100 ft bgs). Bedrock at shallow depths in the Conasauga Shales is characterized by heterogeneous permeability that varies over several orders-of-magnitude. For instance, results of 82 hydraulic conductivity tests performed in shallow Nolichucky Shale monitoring wells range from 0.001 to 4.6 feet per day (ft/d) (Geraghty & Miller, 1989a). The higher conductivity values represent permeable water-producing intervals and the lower conductivity values represent effectively less permeable matrix intervals (Moore 1989). Additionally, results of aquifer pumping tests suggest strongly anisotropic flow at shallow depths in the Conasauga Shales. Twenty five aquifer pumping tests have been performed in the Nolichucky Shale, each characterized by an elliptical cone of depression elongated parallel to geologic strike; transmissivity values (determined from Theis drawdown analysis) ranged from about 5 to 530 ft squared per day (ft^2/d) and averaged about 62 ft^2/d (Law Engineering Testing Company 1983; Geraghty & Miller, Inc. 1986; Golder Associates, Inc. 1987; Golder Associates, Inc. 1988). Results for some of the pumping tests also showed strike-parallel transmissivities as much as 30 times greater than strike-normal transmissivities (Golder Associates, Inc. 1988).

Decreasing groundwater flux with depth in the Conasauga Shales is clearly indicated by distinct changes in groundwater geochemistry, as well as hydraulic conductivity test results. The first transitional decrease generally occurs at a depth of 100 ft bgs and is indicated by a change from calcium-magnesium-bicarbonate groundwater to sodium-bicarbonate groundwater. This geochemical change is probably a function of longer groundwater residence time, which reflects lower hydraulic conductivity related to reduced fracture apertures or increased fracture spacings (Solomon et al. 1992). Results of eight hydraulic conductivity tests in wells completed at depths of 132 to 374 ft bgs in the Rutledge Limestone, Maryville Limestone, and Nolichucky Shale, as summarized in Geraghty & Miller, Inc. (1989a), range from 3×10^{-5} to 0.01 ft/d, and average about 0.004 ft/d. A second transitional decrease in groundwater flux generally occurs at approximately 400 ft bgs and is indicated by a change from sodium-bicarbonate groundwater to sodium-chloride groundwater accompanied by a general increase in specific conductance and TDS. Data obtained from straddle packer tests, slug tests, and slow-recovery analyses indicates that hydraulic conductivity in the deep bedrock of the Conasauga Shales is as low as 2.83×10^{-6} ft/d (Solomon et al. 1992).

The permeability of the shallow bedrock in the Maynardville Limestone also varies over several orders-of-magnitude, but overall is significantly greater than in the Conasauga Shales; hydraulic conductivity test results for wells less than 100 ft bgs in the Maynardville Limestone range from 0.13 to 99 ft/d, and average about 22 ft/d (Geraghty & Miller, Inc. 1989a). A comparable flow rate (25 ft/d) also was estimated from results of a dye tracer test performed in the Maynardville Limestone south of the Oil Landfarm WMA (Geraghty & Miller, Inc. 1989b). Additionally, aquifer pumping tests performed in the Maynardville Limestone produced generally symmetrical cones of depression, potentially indicating lower anisotropy compared to the Conasauga Shales. Transmissivity values obtained from these pumping tests (determined from Theis drawdown analysis) ranged from about 372 to 7,690 ft^2/d, with storage coefficients between 6×10^{-5} and 0.002 (Golder Associates, Inc. 1988). Results of some of these tests also indicated substantially greater strike-parallel transmissivity than strike-normal transmissivity.

Indications of decreasing groundwater flux in the Maynardville Limestone are less clearly evident than for the Conasauga Shales. For example, changes in groundwater geochemistry that occur with depth in the Conasauga Shales are not evident; calcium-magnesium bicarbonate groundwater is present in the Maynardville Limestone to depths of 1,000 ft bgs (Dreier et al. 1993). Moreover, decreased permeability with depth in the Maynardville Limestone has not been characterized because hydraulic conductivity tests have been performed primarily in shallow (<100 ft bgs) monitoring wells. As noted previously, however, active groundwater flow may occur to depths of at least 400 ft bgs in the Maynardville Limestone.

5.2.3 Aquiclude

The aquiclude is generally marked by the presence of saline water with TDS concentrations as high as 300,000 mg/L; the water in the aquiclude is a sodium-, calcium-, and chloride-rich brine that is chemically similar to brines associated with major sedimentary basins. Whereas saline water typically occurs at depths of about 600 to 700 ft bgs in Melton Valley (Solomon et al. 1992), it has not been encountered at depth in BCV. However, several wells completed at depths of about 500 to 1,000 ft bgs in the Conasauga Shales monitor groundwater with TDS concentrations ranging from several thousand to several tens of thousand mg/L. This highly mineralized groundwater may represent a mixing zone or diffusion zone between the fresh and saline groundwater, suggesting that the aquiclude is present at greater depth in the BCV than in Melton Valley (Solomon et al. 1992).

5.3 Groundwater Flow Directions

The water table in the Bear Creek Regime under both seasonally high and low flow conditions is a subdued replica of surface topography, with steep gradients along the flanks of Pine Ridge and Chestnut Ridge and a gentle slope down the axis of BCV (Figure 13). The horizontal hydraulic gradient averages about 0.038 across BCV (strike-normal) in the Conasauga Shales, and about 0.011 along the axis of BCV (strike-parallel) in the Maynardville Limestone.

Groundwater in the Conasauga Shales generally flows parallel to bedding (along strike and dip), which may not coincide with the direction of maximum hydraulic gradient inferred from water level isopleths (Figure 14). Flow tangent to bedding occurs primarily along permeable zones formed by cross-cutting fractures or fracture zones (and possibly small faults). This groundwater flow pattern is clearly illustrated by the geometry of the nitrate plume from the S-3 Site. As discussed in Section 6.2, this plume extends west along strike (parallel to potentiometric contours) in the Nolichucky Shale, then abruptly trends south (perpendicular to potentiometric contours) toward the Maynardville Limestone. The southward trend of the plume occurs near a tributary to Bear Creek (NT-3) located at the east side of the Oil Landfarm WMA. The tributary, and others that traverse the Conasauga Shales along the northern flank of Pine Ridge, is probably the surface expression of a cross-cutting structure in the bedrock (e.g., fracture zone or fault) that forms a preferred flowpath which channels groundwater in the Nolichucky Shale toward the Maynardville Limestone. Some of these cross-cutting structures may act as barriers, possibly causing groundwater from deeper intervals in the Conasauga Shales to upwell and discharge to the shallower flow system.

Groundwater in the Maynardville Limestone also flows parallel to bedding (along strike and dip) which, unlike the Conasauga Shales, generally coincides with the direction of maximum hydraulic gradient (Figure 14). Bear Creek and springs located on the south side of the creek near the contact with the overlying Copper Ridge Dolomite (Knox Group) are the principal discharge areas for groundwater in the Maynardville Limestone.

5.4 Groundwater Geochemistry

Groundwater geochemistry in the Bear Creek Regime was evaluated through a review of trilinear plots (Piper diagrams) prepared using the average annual concentration (in millequivalents per liter) of the principal cations and anions determined for each groundwater sample collected during CY 1994 (excluding the samples with charge balance errors noted in Section 4.2.3). Separate Piper diagrams were prepared to evaluate the geochemistry of groundwater in the Conasauga Shales (Figure 15) and the Maynardville Limestone (Figure 16).

Results of this evaluation support the geochemical evaluation presented as part of the current hydrogeologic model (Section 5.2.2). Although there are a few exceptions, data for most wells completed in the Conasauga Shales show that the calcium-magnesium-bicarbonate groundwater in the water table interval and shallow bedrock changes to sodium-bicarbonate groundwater at a depth of about 100 ft bgs (Figure 15). The sodium-bicarbonate groundwater typically grades to a sodium-chloride groundwater at depths below about 400 ft bgs, and TDS concentration increases with depth; however, no wells completed at this depth in the Conasauga Shales were sampled in CY 1994. Virtually every well completed at depths less than 300 ft bgs in the Maynardville Limestone monitors calcium-magnesium-bicarbonate groundwater (Figure 16). Several Maynardville Limestone wells that are greater than 300 ft deep (GW-710, GW-711, GW-712, and GW-713) monitor a calcium-magnesium-sulfate groundwater with elevated sodium, chloride, and TDS concentrations (Figure 16).

Most atypical geochemistry observed in the CY 1994 data reflect natural variations in the Conasauga Shales and the Maynardville Limestone. For instance, shallow groundwater (less than 40 ft bgs) in the Pumpkin Valley and Rogersville shales have a greater proportion of magnesium than calcium (Figure 15), and may have sulfate proportions greater than 20 percent (e.g., GW-040, GW-042, GW-080, and GW-642).

Exceptions to the geochemical change at 100 ft bgs in the Conasauga Shales include sodium-bicarbonate groundwater in shallow wells GW-069, GW-363, and GW-654, and calcium-magnesium-bicarbonate groundwater in well GW-162 (Figure 15). The sodium-bicarbonate groundwater in shallow well GW-069 and calcium-magnesium-bicarbonate groundwater in deeper well GW-162 may be expected because the monitored interval of both wells (Table 3) lies near the depth at which the calcium-magnesium-bicarbonate groundwater changes to sodium-bicarbonate groundwater. Sodium-bicarbonate groundwater in water table well GW-654 and shallow bedrock well GW-363 may result from more than one factor. These wells may monitor less permeable zones where the groundwater is stagnant and the geochemistry resembles that which is more often encountered at greater depths. In addition, these wells are located near tributaries to Bear Creek (Figure 4) that are probably surface expressions of cross-cutting structures in the bedrock that potentially form flowpaths for upward migration of sodium-bicarbonate groundwater.

Groundwater in the Maynardville Limestone with a high proportion of magnesium (greater than 35%) may indicate hydraulic connection with groundwater in the Copper Ridge Dolomite or may reflect higher magnesium at depth in the Maynardville Limestone. Ten Maynardville wells, including all six wells completed with total depths from 300 to 500 ft bgs, had groundwater with elevated magnesium (Figure 16): well GW-317 at Spoil Area I; wells GW-723, GW-724, GW-739, and GW-740 at EXP-C; well GW-601 located south of the Oil Landfarm WMA; wells GW-703 and GW-704 at EXP-B; and wells GW-712, GW-713, GW-714 at EXP-W (Figure 4). In contrast, well GW-683 is completed from about 146 to 197 ft bgs in the Copper Ridge Dolomite at EXP-A and has a relatively low magnesium proportion (about 30%) that indicates hydraulic connection with groundwater in the Maynardville Limestone.

Atypical geochemistry observed in several wells reflect impacts on groundwater quality from waste disposal or other activities in the regime. The most significant impact is the occurrence of elevated nitrate proportions in wells that monitor groundwater in the nitrate plume originating from the S-3 Site (see Section 6.2). Elevated average nitrate (greater than 190 mg/L) and TDS (greater than 1,000 mg/L) concentrations were reported for wells GW-085 and GW-537 completed in the Conasauga Shales (Figure 15). Groundwater contamination near these wells probably reflects upward migration from the nitrate plume in the Nolichucky Shale; these wells are located near NT-2 about 2,500 ft west of the S-3 Site (Figure 4). Elevated nitrate proportions also were determined for samples from Maynardville Limestone wells GW-601, GW-704, GW-706, GW-724, GW-725, GW-736, and GW-737 (Figure 16).

Groundwater in Conasauga Shale wells GW-325 and GW-345 had chloride and sulfate proportions greater than 20% of the total anions (Figure 15). Elevated sodium and chloride proportions (greater than 20%) were determined for samples from shallow Maynardville Limestone wells GW-056 and GW-057 (Figure 16). These wells are located next to Bear Creek Road (Figure 4), and the groundwater in these wells may be impacted by surface runoff containing dissolved salts used to de-ice the road surface in the winter.

The groundwater geochemistry of well GW-312, located next to Old Bear Creek Road near the Rust Spoil Area, is atypical in several aspects: (1) the RPD exceeds 10% in most samples from the well, (2) the average pH is about 12, (3) the oxidation/reduction potential values are usually negative, (3) the calcium-to-magnesium ratio is about 2,250:1 in samples with a RPD less than 10%, and (4) all alkalinity is from carbonate ion concentration (bicarbonate alkalinity is not detected). Well GW-312 monitors the water table interval from a depth interval of about 30 to 40 ft bgs, and usually has had about 3 to 9 ft of water when samples were collected. The unique geochemistry observed in samples from well GW-312 may reflect well construction deficiencies or degeneration of construction debris buried at the site.

6.0 GROUNDWATER QUALITY EVALUATION

Groundwater quality data obtained during CY 1994 are generally consistent with historical findings. Groundwater contaminants in the Bear Creek Regime are VOCs, nitrate, trace metals, and radionuclides. Plume boundaries, however, have changed based on data from new sampling stations and perimeter wells located west of the Bear Creek Burial Grounds WMA. Evaluation of CY 1994 data that is consistent with historical findings shows:

- volatile organic compounds in the Conasauga Shales are comprised of chloroethenes and to a lesser extent chloroethanes and chloromethanes, and principal source areas are the S-3 Site, the Oil Landfarm WMA, and the Bear Creek Burial Grounds WMA;
- VOCs in the Maynardville Limestone are primarily chloroethenes originating from multiple sources that have intermingled to form a continuous plume that spans a little less than half of the Bear Creek Regime;
- VOC concentrations throughout the regime have, in general, remained relatively stable;
- nitrate has migrated from the Conasauga Shales near the S-3 Site into the Maynardville Limestone forming a continuous plume that is thought to reflect the maximum extent of groundwater contamination in the Bear Creek Regime;
- nitrate concentrations in the Conasauga Shales have generally steadily decreased since closure of the S-3 Site in 1984, but concentrations in the Maynardville Limestone fluctuate with seasonal variations in the potentiometric surface;
- trace metal contamination occurs primarily in the shallow groundwater near the S-3 Site, and to a lesser extent, the Oil Landfarm and the Bear Creek Burial Grounds WMAs;
- trace metal contaminants in the groundwater near the source areas are primarily barium, cadmium, mercury, strontium, and uranium (S-3 Site); and cadmium, lead, mercury, and uranium (Oil Landfarm WMA); whereas the only trace metals shown to have migrated into the Maynardville Limestone are strontium and uranium;

- data from cap performance wells at the S-3 Site indicate that concentrations in trace metals have decreased since CY 1987; and
- the extent of alpha- and beta-emitting radionuclides is similar to that represented by historic data, which is considered to be delineated by the nitrate plume.

Data obtained in CY 1994 for the purposes of the GWPP has allowed some refinement of the contaminant plume in the Bear Creek Regime and indicates:

- the VOC plume at the Bear Creek Burial Grounds WMA may be migrating both vertically and horizontally;
- VOCs, nitrates, and metals in groundwater on the east side of the Oil Landfarm WMA are migrating upward from deeper intervals and, based on current data, this area appears to reflect the western extent of the plume migrating from the S-3 Site;
- the Bear Creek Burial Grounds WMA is a source of boron; and
- a separate source of VOCs and radionuclides are located in an area on the east side of the Oil Landfarm WMA.

Details regarding these findings are presented in the following sections.

6.1 Volatile Organic Compounds

Previous and current groundwater monitoring results show that VOCs, primarily chlorinated solvents, are pervasive in groundwater in the Bear Creek Regime, and that most, if not all, waste-management sites are source areas. Chloroethenes are the most frequently detected compounds, particularly in the Maynardville Limestone, although chloroethanes and chloromethanes are present in groundwater at the Oil Landfarm WMA and Bear Creek Burial Grounds WMA (Figure 17), and acetone is a primary component of the plume at the S-3 Site.

The horizontal and vertical extent of VOCs in the groundwater throughout the regime is similar to that observed since CY 1990. Horizontal plume boundaries in the Conasauga Shales generally occur within 1,000 ft of the source areas; however, data obtained in early CY 1995 indicate that VOCs from the S-3 Site have migrated along strike in the Nolichucky Shale to just east of the Oil Landfarm WMA. In the Maynardville Limestone, VOCs from source areas in the Conasauga Shales have intermingled where downgradient transport along strike has produced an apparently continuous VOC plume that extends west from the eastern end of the regime to about 1,500 ft southwest of the Bear Creek Burial Grounds WMA (Figure 18). Vertical plume boundaries range from 70 ft bgs to at least 500 ft bgs, but are deepest in the Conasauga Shales down-dip of the S-3 Site and the Bear Creek Burial Grounds WMA, and in the Maynardville Limestone south of the Oil Landfarm WMA (Figure 19).

6.1.1 Conasauga Shales

The VOC plumes in the shallow groundwater near each waste-management site are composed primarily of PCE and 1,2-DCE (Figure 20), but are characterized by distinguishing secondary compounds (Table 11): acetone, methylene chloride, and chloroform at the S-3 Site; 1,1-dichloroethane at the Oil Landfarm; and vinyl chloride at the Bear Creek Burial Grounds WMA. Summed VOC concentrations historically exceeded 1,000 μg/L nearest the source areas and, as shown by data for wells GW-243 (S-3 Site) and GW-627 (Bear Creek Burial Grounds), have remained relatively stable since CY 1992 (Figure 21).

With the exception of the S-3 Site, horizontal VOC plume boundaries in the Conasauga Shales occur within 1,000 ft of each waste-management site (Figure 18). In general, plume boundaries have remained unchanged since CY 1991, but plume advancement is indicated by CY 1994 data reported for wells GW-069 and GW-287 at the Bear Creek Burial Grounds WMA.

Data obtained during RI field activities indicate that VOCs from the S-3 Site (primarily acetone) have migrated (Figure 18) along strike-parallel (possibly stratabound) pathways in the Nolichucky Shale for at least 3,000 ft to the west. For example, acetone concentrations reported for groundwater samples collected from well GW-829 during installation (18 - 30 ft bgs) and upon completion (103 - 115 ft bgs) were 49 and 173 μg/L, respectively. This well is located about 2,000 ft west of the S-3 Site, which is the only known source of acetone in the Bear Creek Regime. Data from this well further suggest that the chloroform detected in the samples from well GW-537 define the downgradient extent of the plume from the S-3 Site. Estimated concentrations (3 and 4 μg/L) were reported for both samples, and chloroform has consistently been detected in groundwater at the S-3 Site.

Recent data (March 1995) from two samples obtained with a HydroPunch system indicate that another VOC source area lies on the east side of the Oil Landfarm WMA. The primary VOCs detected in these samples were 1,2-DCE (1,100 μg/L), PCE (620 μg/L), and TCE (2,000 μg/L) (Science Applications International Corporation 1995). The high TCE concentrations may explain the increase in TCE concentrations observed in the Maynardville Limestone downgradient of this area.

Two separate VOC plumes are evident in the shallow groundwater at the Bear Creek Burial Grounds WMA (Figure 18): a larger plume underlying Burial Grounds A North and A South, and a smaller plume, topographically separated by a small hill formed by the Maryville Limestone (Figure 10), to the north underlying Burial Grounds C and D. The shape of the plume underlying Burial Grounds C and D suggests that migration basically follows surface drainage; the plume extends from the source areas to the west and southwest along a small drainage feature. Such patterns of VOC migration are predicted by the conceptual model of the hydrogeologic flow system whereby groundwater in the water table interval and shallow bedrock interval flows along fairly short flow paths to discharge points along surface drainage features (Solomon et al. 1992). Additionally, data obtained from well GW-089 during CY 1992 support results obtained since 1990 that indicate the VOC plume in this area also has migrated towards a surface drainage feature east and northeast of the hill separating Burial Ground C from Burial Ground A North.

Advancement of the VOC plume at the Bear Creek Burial Grounds WMA is suggested by CY 1994 data from wells GW-069 and GW-287 (Table 11). Vinyl chloride was detected in samples collected from well GW-069 with a monitored interval (79 to 99.2 ft bgs) above the DNAPL discovered south of the site (Figure 18). Tetrachloroethene was detected in samples collected from well GW-287, located in the water table interval west of the site (Figure 18).

Vertical VOC plume boundaries vary at each waste-management site, but are deepest at the S-3 Site and the Bear Creek Burial Grounds WMA. The VOC plume at the S-3 Site apparently extends to more than 500 ft bgs, but summed average VOC concentrations (primarily acetone and PCE) steadily decrease with depth from 8,345 μg/L in water table well GW-243, to 157 μg/L in intermediate depth bedrock well GW-615, to 1 μg/L in deep bedrock well GW-125 (Figure 19). Historical data for wells GW-117 and GW-119 at the Bear Creek Burial Grounds WMA show that low concentrations (less than 20 μg/L) of PCE and 1,1-dichloroethene are present at depths of at least 500 ft (Figures 19 and 20). The occurrence of VOCs in these deep bedrock wells is believed to be associated with DNAPLs discovered in January 1990. The DNAPLs were encountered at a depth of about 270 ft bgs in wells located along the southern boundary of the site, and consisted primarily of PCE, TCE, and 1,1,1-TCA with high concentrations (19,000 μg/L) of polychlorinated biphenyls (Haase and King 1990).

Dissolved VOCs in the Conasauga Shales underlying the Oil Landfarm WMA are generally confined to the water table and shallow bedrock intervals near the Oil Landfarm disposal plots and Sanitary Landfill I (Figure 18). As indicated by historical data for well GW-076, the vertical extent of VOCs in the Conasauga Shales at the Oil Landfarm is apparently shallower than at the other waste-management sites (Figure 19). This well monitors groundwater from 69.7 to 80.3 ft bgs near the center of the Oil Landfarm, and no VOCs were detected in any of the samples collected in CY 1991 (the last time this well was sampled).

6.1.2 Maynardville Limestone

The VOC plume in the Maynardville Limestone extends from the S-3 Site west for at least 11,500 ft (Figure 18). Inputs to the plume apparently occur from the S-3 Site, Spoil Area I, the Oil Landfarm WMA, and possibly the Rust Spoil Area and the Bear Creek Burial Grounds WMA. The Fire Training Facility, a confirmed VOC source area in the East Fork Regime about 1,000 ft east of Spoil Area I, also may be a source of VOCs in the Maynardville Limestone in the Bear Creek Regime (HSW Environmental Consultants, Inc. 1995b).

The composition of the VOC plume in the Maynardville Limestone is generally more homogeneous than in the Conasauga Shales, and is characterized by TCE as the principal component (Figure 20). This TCE-dominated plume can be traced in the water table and shallow bedrock intervals from wells about 1,500 ft southwest of the Bear Creek Burial Grounds, upgradient along strike to wells located at Spoil Area I.

Summed VOC concentrations determined from CY 1994 data were typically less than 100 μg/L, and were highest (106 μg/L) in samples from well GW-704 located southeast of the Bear Creek Burial Grounds WMA downgradient of the Oil Landfarm WMA (Table 11). As indicated by results for TCE, VOC concentrations in the Maynardville Limestone in eastern and western areas of the Bear Creek Regime have generally decreased or remained fairly stable since CY 1991 (Figure 22).

The vertical extent of VOCs in the Maynardville Limestone is deepest (at least 500 ft bgs) south and southwest of the Oil Landfarm WMA, but is relatively shallower (250 to 150 ft bgs, respectively) at the eastern and western extremities of the plume (Figure 23). In the easternmost part of the regime, the VOC plume originating from the S-3 Site apparently enters the Maynardville Limestone at shallow depths along the contact with the Nolichucky Shale and intermingles with a plume originating from Spoil Area I (Figure 19; dip section C-C'), or possibly the Fire Training Facility. Increased VOC concentrations in the groundwater at shallow depths, further downgradient to the west, suggest input of VOCs from the Rust Spoil Area or the Oil Landfarm WMA (Figure 23; strike section X-X'). Moreover, the plume boundary is deeper in this area, indicating potential down-dip migration from source areas in the Oil Landfarm WMA (Figure 23; dip section C-C'). Farther west and downgradient, VOC concentrations are highest in samples from well GW-704 (106 μg/L), the deepest well of this Maynardville Limestone transect (Figure 23; dip section B-B'). The VOC plume apparently crosses the contact between the Maynardville Limestone and the Copper Ridge Dolomite further downgradient, as shown by data from wells GW-683 and GW-684 (Figure 22; dip section A-A'). Data for well GW-683 had previously indicated that VOCs were not migrating into the Copper Ridge Dolomite; however, groundwater with elevated nitrate concentrations, gross alpha activity, and gross beta activity has consistently been shown to cross this geologic contact somewhere between wells GW-704 and GW-683 (see sections 6.2.2, 6.4.1, and 6.4.2, respectively). Very low VOC concentrations in wells located west of the Bear Creek Burial Grounds (Figure 23, dip section A-A' and X-X') indicate that the westernmost extent of the VOC plume probably occurs in this area.

6.2 Nitrate

Nitrate is a pervasive groundwater contaminant in the Bear Creek Regime, particularly near the S-3 Site, which is the principal source. Furthermore, the extent of the nitrate plume in the Conasauga Shales and the Maynardville Limestone is thought to delineate the maximum extent of migration of all contaminants from the S-3 Site because it is transported in groundwater with little or no retardation and has a low propensity for chemical alteration (Figure 24).

6.2.1 Conasauga Shales

Nitrate contaminated groundwater occurs primarily in the Nolichucky Shale in the eastern part of the regime near the S-3 Site where concentrations in the shallow groundwater (e.g., GW-243) exceeded 8,000 mg/L during CY 1994 and where historical data indicate concentrations in excess of 1,000 mg/L occur in the groundwater at depths of 770 ft bgs (Dreier et al. 1993). The high nitrate concentrations in the groundwater at depth below the S-3 Site probably reflects density-driven movement along bedding-plane-parallel fractures (Drier et al 1993). In the shallower groundwater, nitrate from the S-3 Site has been transported about 3,000 ft along strike to the east side of the Oil Landfarm WMA (Figure 24). A separate source of nitrate in this area was previously suspected because concentrations in the groundwater at water table wells GW-085 (average 176 mg/L in CY 1994) and GW-537 (average 693 mg/L in CY 1994) have consistently been much higher than the concentrations reported for other water table wells (e.g., GW-345; average 1.9 mg/L in CY 1994) located much closer to the S-3 Site (HSW Environmental Consultants, Inc. 1994).

Bedrock wells GW-828 and GW-829 were installed in April 1995 about 2,000 ft west of the S-3 Site (well GW-828 is about 100 ft north of well GW-829) specifically for the purpose of determining if the nitrate in the groundwater at wells GW-085 and GW-537 originated from a source other than the S-3 Site. As summarized below, groundwater samples were collected from two depth intervals during the installation of each well; nitrate concentrations were lowest in the samples collected at the shallower depths in each well, and were highest in the samples collected from each respective deeper interval.

Well Number	Interval	Depth (ft bgs)	Nitrate Concentration (mg/L)
GW-828	BDR	70 - 83	43
	BDR	153 - 168	623
GW-829	WT	18 - 29	259
	BDR	103 - 115	2,210

Results for these wells suggest stratabound nitrate transport along strike from the S-3 Site at depths greater than 100 ft bgs in the Nolichucky Shale. Upward discharge of this groundwater into the shallower flow system would explain why the nitrate concentrations in samples collected from well GW-537 are consistently higher than those reported for wells of similar depth located closer to the S-3 Site. This interpretation is supported by the following observations: (1) well GW-537 is located next to Bear Creek tributary NT-2, which is probably a surface expression of a fractured zone in the bedrock that potentially provides a preferred flowpath for upward migration of groundwater at depth (Figure 25, Section X-X'), (2) milli-equivalent sodium concentrations determined for samples from well GW-537 are typically an order-of-magnitude higher than those determined for samples from other monitoring wells of similar depth, suggesting that the geochemistry of the groundwater near the well is influenced by upward discharge of the deeper sodium-bicarbonate groundwater, and (3) artesian (flowing) conditions observed in April 1995 at well GW-828 clearly indicate upward hydraulic gradients in this area.

Evaluation of the nitrate data for CYs 1990-1994 shows that annual average nitrate concentrations have decreased, with few exceptions, in the groundwater at most of the wells near the S-3 Site (Table 12). Shevenell et al. (1994) consider the concentration decreases to indicate that the current source of nitrate lies within the unfractured rock matrix underlying the S-3 Site. The large contaminant mass introduced into the groundwater system during site operations produced a significant concentration gradient between contaminated water in the fractures and the water in the less permeable, but more porous, rock matrix. This concentration gradient induced molecular diffusion of nitrate (and probably other contaminants) from the fractures into the rock matrix. After closure of the S-3 Site and cessation of contaminant influx, the concentration gradient reversed, causing nitrate to diffuse from the matrix back into the fractures, where it is subsequently flushed out of the shallow groundwater flow system by natural recharge and discharge cycles (Shevenell et al. 1994).

6.2.2 Maynardville Limestone

Nitrate flux into the Maynardville Limestone probably results from: (1) migration of contaminated groundwater through the water table interval directly south of the S-3 Site, (2) discharge of contaminated groundwater along a preferred migration pathway formed by a filled tributary to Bear Creek located about 1,800 ft west of the S-3 Site, and (3) hydraulic communication with nitrate-contaminated surface water in Bear Creek (see Section 7.0). As noted in Section 5.2.2, however, groundwater flux in the Maynardville Limestone is considerably greater than in the Nolichucky Shale and results in significant dilution; nitrate concentrations throughout the plume in the Maynardville Limestone are typically less than 100 mg/L (Figure 24). The highest annual average nitrate concentration determined for Maynardville Limestone wells that were sampled during CY 1994 was 79 mg/L for well GW-725 (Table 12).

Groundwater containing nitrate concentrations exceeding the 10 mg/L MCL occurs in the water table and bedrock intervals in the Maynardville Limestone for about 10,000 ft downgradient of the S-3 Site (Figure 24). Along strike, the plume is generally confined to an interval between 550 and 900 ft msl (Figure 26, Section X-X'). Wells GW-683, GW-684, and GW-685 (located at EXP-A) effectively define the extent of nitrate contamination in the western part of the regime in the Maynardville Limestone at 750 ft msl (Figure 26, Sections X-X' and A-A'). Migration of the nitrate plume into the Copper Ridge Dolomite between Section B-B' and A-A' (Figure 26) may be related to thinning of the Maynardville Limestone that occurs southeast of the Bear Creek Burial Grounds WMA (Section 5.1).

An elevated nitrate concentration (68 mg/L) reported for a sample collected from 617 ft msl (284 ft bgs) in multi-port instrumented well GW-790, located south of the Burial Grounds WMA, suggests that a preferred pathway may exist below the interval monitored by the wells at EXP-A (Figure 26, Section X-X'). The sample from well GW-790 was analyzed using ion chromatography and was considered qualitative; but the sample was collected from a zone which monitors bicarbonate water with low TDS, rather than the high chloride water reported for samples from the other ports in the well (Dreier and Caldanaro 1995). Very low TCE concentration also was reported for this sample (Figure 22, Sections X-X' and A-A').

Nitrate concentrations in the Maynardville Limestone fluctuate with seasonal variations in the potentiometric surface. For example, nitrate concentrations reported for samples collected from wells GW-694 and GW-683 since CY 1991 were lowest during the first quarter sampling event of each CY when the water levels in the wells were highest (Figure 27). The seasonality of water level fluctuations is evident for many other wells throughout the regime, and the seasonal concentration trend likely indicates varying degrees of dilution by the infiltration of relatively clean groundwater during periods of high precipitation.

6.3 Trace Metals

Comparison of median trace metal concentrations determined from CY 1994 data to applicable UTLs and MCLs, as summarized below, shows that the median concentration of 17 metals determined for 26 wells (11 in the Conasauga Shales and 15 in the Maynardville Limestone) exceeded the applicable reference value.

Metal	Number of Wells	Metal	Number of Wells
Boron	14	Copper	3
Uranium	7	Cobalt	2
Strontium	7	Zinc	2
Aluminum	5	Barium	2
Nickel	4	Arsenic	2
Beryllium	4	Iron	1
Manganese	3	Chromium	1
Vanadium	4	Mercury	1
Cadmium	3		

However, review of the historical data for these wells suggests that few of the elevated median concentrations actually reflect trace metal contamination in the groundwater. The apparent occurrence of elevated concentrations of some metals is probably an artifact of overly conservative UTLs applicable to most of the wells in the regime. For example, the boron UTLs calculated for Clusters 1, 2, 3, and 4, which are applicable to most of the wells in the regime, are one to two orders-of-magnitude lower than UTLs used to identify elevated boron concentrations in previous GWQRs. Additionally, the elevated median concentrations determined for some of the other metals listed above (e.g. aluminum) reflect probable sampling or analytical artifacts relating to several factors including: (1) preservation (acidification) of turbid groundwater samples; (2) potential analytical interferences; and (3) corrosion of stainless steel well casing and screen (HSW Environmental Consultants, Inc. 1994).

Based on the considerations described above, the CY 1994 data are consistent with following historical monitoring results: (1) the principal trace metal source area is the S-3 Site where elevated concentrations of several trace metals occur in the low pH groundwater within the underlying Nolichucky Shale, (2) trace metal contamination is limited in the Conasauga Shales elsewhere in the Bear Creek Regime, and (3) few metals have migrated from the source areas into the Maynardville Limestone. Additionally, as indicated by the CY 1994 trace metal data, preliminary RI results, and information obtained from the background study described in Section 4.2.2, some of the metals present in the low pH groundwater at the S-3 Site appear to have migrated along strike at depth in the Nolichucky Shale, and the Bear Creek Burial Grounds WMA is a probable source of boron.

6.3.1 Conasauga Shales

The S-3 Site is the primary source of trace metal contamination in the Bear Creek Regime. The principal trace metal contaminants in groundwater at this site include barium, beryllium, cadmium, chromium, manganese, mercury, strontium, and uranium. Some of these metals (e.g., uranium) were probably entrained in the acidic wastewater disposed at the site, and others (e.g., barium) were probably dissolved from the underlying saprolite and bedrock (particularly carbonates).

Two wells (GW-243 and GW-276) within the low pH groundwater at the S-3 Site were sampled during CY 1994, and samples from both wells contained the highest trace metal concentrations in the regime (Table 13). However, comparison of the CY 1994 data to historical monitoring results for these wells shows a steady decrease in the total concentrations of most the trace metal contaminants. For example, the total barium, cadmium, and uranium concentrations reported for well GW-276 in CY 1994 are 71%, 58%, and 57% lower, respectively, than the concentrations evident in the first quarter of CY 1990 (Figure 28). Additionally, the pH reported for this well has increased from about 3.5 to 4.5 during the same period. Total concentrations of most of the metals in the groundwater at well GW-243 have similarly decreased, but barium and cadmium concentrations have increased, and the groundwater pH has remained comparatively stable (Figure 29).

Elevated barium and strontium concentrations in the groundwater at well GW-537 (Table 13) may similarly reflect stratabound transport westward from the S-3 Site described in the VOC and nitrate discussions. Total concentrations of both metals exceed 20 mg/L in the low pH groundwater at the S-3 Site. Groundwater with elevated barium and strontium concentrations has probably migrated along strike at depths greater than 100 ft bgs in the bedrock, then upward into the shallower groundwater near well GW-537. Although nitrate and VOC data obtained from wells GW-828 and GW-829 support this inferred migration pathway, none of the samples from these wells were analyzed for trace metals. Additionally, the barium, strontium, and pH levels reported for well GW-537 have increased since CY 1987 (Figure 29). The increase in barium concentration is similar to the trend identified for well GW-243, which monitors a stratigraphic horizon similar to GW-537 (the upper Nolichucky Shale).

If the barium and strontium in the groundwater at well GW-537 originate from the S-3 Site, the neutral pH (6.8 to 7.2) of the groundwater near the well probably precludes transport of these metals as disassociated ions or ion complexes, suggesting colloidal-facilitated transport of these metals. Preliminary findings of an on-going study of colloids in the groundwater at the Y-12 Plant indicate that they are significantly more prevalent in groundwater with sodium as the dominant anion. These findings support along-strike colloidal co-transport of trace metals in sodium-bicarbonate groundwater in the deeper bedrock, then upward discharge to the shallow flow system.

Trace metal contamination in the groundwater within the Conasauga Shales elsewhere at the Oil Landfarm WMA was not indicated by the data reported for the wells at this site that were sampled during CY 1994. However, historical data for well GW-005 indicate that elevated concentrations of cadmium, lead, mercury, and uranium reflect contamination of the shallow groundwater from metals entrained in waste oils and coolants applied to surficial soils at the Oil Landfarm; each of these metals, except mercury, were detected in the oils and coolants known or suspected to have been disposed at this site (Geraghty & Miller, Inc. 1988). Concentrations of these metals decreased by an order-of-magnitude between the second quarter of CY 1990 and the second quarter of CY 1991; because landfarming of waste oils and coolants at the site was discontinued in CY 1982, the decreased trace metal concentrations probably resulted from installation of the low-permeability cap at the site in CY 1989.

Data obtained during CY 1994 indicate that total cadmium concentrations have decreased in the groundwater at well GW-042 located along the northern (upgradient) side of the Bear Creek Burial Grounds WMA. Total cadmium concentrations reported for every sample collected from this well between the first quarter of CY 1990 and the first quarter of CY 1994 exceeded the 0.005 mg/L MCL for drinking water. Concentrations decreased to below the MCL in the samples collected during the second quarter (0.0037 mg/L) and third quarter (0.0028 mg/L) of the year. The source of the cadmium in the groundwater at well GW-042 has not been determined (the well is hydraulically upgradient of waste disposal areas).

Information obtained in support of determining trace metal UTLs showed that the waste stream for the Bear Creek Burial Grounds WMA included substantial amounts of waste water containing borax. The median boron concentration determined from CY 1994 data for well GW-654 was 0.12 mg/L, which was the highest median concentration determined for any Conasauga Shale well located outside the low pH groundwater at the S-3 Site. If the elevated boron concentration in the groundwater at well GW-654 reflect contamination at the site, it appears that the contaminated groundwater is moving from disposal areas in Burial Ground C and D toward discharge points along a Bear Creek tributary (NT-8) located west of the site (Figure 28).

6.3.2 Maynardville Limestone

As previously stated, only a few trace metals appear to have been transported from the source areas in the Conasauga Shales into the Maynardville Limestone. Detailed evaluation of trace metal data reported for exit-pathway wells sampled during CY 1994 indicate that only elevated concentrations of boron, strontium, and uranium appear to reflect impacts on groundwater quality; other metals characteristic of the groundwater at the source areas (e.g., barium, cadmium, and mercury at the S-3 Site) are generally not present in the Maynardville Limestone.

Median boron concentrations determined for three wells near the Bear Creek Burial Grounds WMA exceeded the applicable UTL (Table 13): GW-053 (0.36 mg/L), GW-683 (0.082 mg/L), and GW-714 (0.099 mg/L). Total boron concentrations have exceeded the UTL in all of the samples collected from these wells since the second quarter of CY 1990, the third quarter of CY 1991, and the third quarter of CY 1992, respectively. However, no discernable concentration trends are evident over the respective sampling periods. Elevated boron in the groundwater at well GW-053 may be related to surface water transport; this well is located adjacent to a Bear Creek tributary (NT-7) that flows through the Bear Creek Burial Grounds WMA and may be a discharge area for boron-contaminated groundwater. Wells GW-683 and GW-714 are both downgradient of well GW-053. Additionally, surface water samples collected from Bear Creek downgradient of well GW-053 also contained elevated boron concentrations. These findings suggest that boron contaminated groundwater at the Bear Creek Burial Grounds is discharged to tributary NT-7 and subsequently impacts downgradient groundwater (and surface water) quality.

The median strontium concentration determined from CY 1994 data for well GW-800, located south of the Oil Landfarm WMA, exceeded the 0.079 mg/L (Table 13 and Figure 28), and has consistently exceeded the UTL since the well was installed in CY 1993 (Figure 30). In addition, strontium concentrations detected in samples from this well fluctuate inversely with the water level (i.e., concentrations are highest when the water level in the well is lowest). Elevated strontium concentrations have also been reported for well GW-646, located about 1,000 ft west of well GW-800, but only in samples collected before CY 1994 (Figure 28). The elevated strontium concentrations reported for both of these wells may show downgradient migration from the S-3 Site, or may reflect strontium locally dissolved from the carbonate bedrock (Knox Group).

Median uranium concentrations determined for wells GW-061 (0.0345 mg/L), GW-683 (0.042 mg/L), GW-684 (0.0475 mg/L), GW-694 (0.116 mg/L), and GW-706 (0.078 mg/L) exceeded the UTL (Table 13) and reflect transport from the S-3 Site and Oil Landfarm WMA. The highest concentrations were reported for wells GW-694 and GW-706, which are located nearest to the source areas (about 7,000 ft west of the S-3 Site). Since CY 1991, total and dissolved uranium concentrations reported for well GW-694 have ranged from about 0.05 to 0.3 mg/L (Figure 30). These fluctuations generally correspond with seasonal changes in groundwater flow; the highest uranium concentrations have consistently occurred in samples collected from the well during the third or fourth quarter of each CY. Elevated uranium concentrations reported for well GW-683, as with VOC and nitrate concentrations (Sections 6.1 and 6.2, respectively), show hydraulic connection between groundwater in the Maynardville Limestone and the upper Knox Group somewhere between the EXP-B and EXP-A transects (Figure 4). Although the uranium concentrations reported for well GW-683 generally show a seasonal fluctuation similar to well GW-694 (Figure 30), the concentration range reported for well GW-683 is much lower (about 0.004 to 0.1 mg/L).

6.4 Radioactivity

As noted in Section 4.2.5, only 14% of the CY 1994 radioanalyte data passed the evaluation criteria regarding negative values, MDAs, and counting errors; consequently insufficient CY 1994 data were available for plume maps and cross-sections included in previous GWQRs. Nevertheless, CY 1994 results are generally similar to historical data, indicating that the principal source of alpha- and beta-emitting radioisotopes in the Bear Creek Regime is the S-3 Site. Because the S-3 Site is also the principal source for highly mobile nitrate in groundwater, the extent of nitrate in the water table and bedrock intervals (Figures 24, 25, and 26) is a conservative representation of the extent of alpha- and beta-emitting radioisotopes in the regime.

A comprehensive sampling event designed to obtain data of acceptable QA/QC needed to characterize radioactive contamination in the Bear Creek Regime was completed in August 1995. This event involved collection of samples from selected monitoring wells, springs, seeps, surface water stations, and leachate collection points at the Bear Creek Burial Grounds WMA. Analyses of the samples were performed by the Y-12 Plant ASO, and low MDAs were specified. Results of this sampling event will be available by October 1995.

6.4.1 Alpha Radioactivity

Annual average gross alpha activity determined from CY 1994 data exceeded 15 pCi/L in samples from three wells in the Conasauga Shales and four wells in the Maynardville Limestone (Table 14). As summarized below, results for all samples from all these wells except GW-537 and GW-683 passed the evaluation criteria.

Well Number	Location	Interval	CY 1994 Annual Average Gross Alpha Activity (pCi/L)	Number of Samples	
				Passed Criteria	Total Collected
Conasauga Shales					
GW-243	S3	WT	3,530 ± 440	1	1
GW-276	S3	WT	426 ± 39	2	2
GW-537	OLF	WT	33 ± 14	1	4
Maynardville Limestone					
GW-694	EXP-B	BDR	50 ± 6	2	2
GW-706	EXP-B	BDR	31 ± 4	2	2
GW-061	BG	BDR	21 ± 3	4	4
GW-683	EXP-A	BDR	22 ± 5	1	2

The highest annual average gross alpha activity in CY 1994 was determined for wells GW-243 and GW-276, both of which monitor shallow groundwater in the Conasauga Shales within about 500 ft of the S-3 Site. However, results for both wells are less than half of the average alpha activity determined from CY 1990 data: 8,205 pCi/L and 971 pCi/L, respectively (HSW Environmental Consultants, Inc. 1994). Notably, annual average gross alpha activity determined for well GW-243 increased from 8,205 pCi/L in CY 1990 to 10,115 pCi/L in CY 1991 and 15,000 pCi/L in CY 1992 (HSW Environmental Consultants 1994).

Preliminary groundwater quality data obtained during installation of well GW-829, located about 1,000 ft east of well GW-537 in the Nolichucky Shale, showed gross alpha activity below the MDA in the groundwater from about 18 to 29 ft bgs, but gross alpha activity of 70.4 ± 35 pCi/L in the groundwater at depths of 103 to 115 ft bgs (Science Applications International Corporation, 1995). Results from this well show that alpha-emitting radionuclides have migrated along strike in the Nolichucky Shale for at least 2,000 ft west of the S-3 Site.

The extent of elevated alpha activity in groundwater is less in the Conasauga Shales than in the Maynardville Limestone, reflecting the lower hydraulic conductivity of the Conasauga Shales. Well GW-537, located east of the Oil Landfarm WMA (Figure 4), is the well farthest from the S-3 Site (about 2,500 ft) in the Conasauga Shales that monitors groundwater with gross alpha activity above 15 pCi/L. However, only the third quarter sample from this well had gross alpha activity that exceeded the MDA (Table 14). The elevated gross alpha activity reported for this well may reflect upward migration from the Nolichucky Shale, because all results for wells located closer to the S-3 Site were below the MDA.

An additional source of alpha-emitting radionuclides located east of the Oil Landfarm WMA is indicated by historic data for wells GW-005 and GW-087, and preliminary data from field work performed in support of the RI for the Bear Creek CA. Groundwater samples from wells GW-005 and GW-087 (last sampled in CY 1990) had elevated gross alpha activity (31 and 54 pCi/L, respectively), but not the elevated nitrate concentrations that are characteristic of the contaminant plume originating from the S-3 Site. Groundwater samples that were collected in CY 1995 using a HydroPunch system in soil borings located east of the Oil Landfarm also had elevated gross alpha activity and similarly low nitrate concentrations (Science Applications

International Corporation 1995). The highest activity (2,200 ± 270 pCi/L) was reported for a sample collected from a boring located about 200 ft south of well GW-005.

The gross alpha plume in the Maynardville Limestone downgradient from the S-3 Site is first intersected by wells GW-694 and GW-706, located about 2,000 ft west of the Oil Landfarm WMA (Figure 4). Groundwater with elevated gross alpha activity apparently enters the Maynardville Limestone near the Oil Landfarm WMA or migrates through flowpaths not intercepted by monitoring wells in the Maynardville Limestone closer to the S-3 Site. Downgradient of well GW-694 and GW-706, the gross alpha activity plume extends about 2,000 ft west to well GW-061, located south of the Burial Grounds WMA (Figure 4). Gross alpha activity ranged from about 13 to 37 pCi/L in samples collected from this well during CY 1994.

Data reported for well GW-683 show that groundwater with gross alpha activity above 15 pCi/L extends nearly 11,000 ft from the S-3 Site, or about 6,500 ft from the Oil Landfarm WMA. Well GW-683 is completed from about 134 to 197 ft bgs in the Copper Ridge Dolomite. Migration of contaminated groundwater into the Copper Ridge Dolomite may be related to the substantial thinning of the Maynardville Limestone that occurs southeast of the Bear Creek Burial Grounds WMA (Shevenell et al 1993).

6.4.2 Beta Radioactivity

The CY 1994 annual average gross beta activity exceeded 50 pCi/L in samples from four wells in the Conasauga Shales and two wells in the Maynardville Limestone (Table 14). As summarized in the following table, all results for these wells passed the evaluation criteria.

Well Number	Location	Interval	CY 1994 Annual Average Gross Beta Activity (pCi/L)	Number of Samples	
				Passed Criteria	Total Collected
Conasauga Shales					
GW-243	S3	WT	22,700 ± 650	1	1
GW-276	S3	WT	1,145 ± 85	2	2
GW-537	OLF	WT	463 ± 27	4	4
GW-085	OLF	BDR	96 ± 16	4	4
Maynardville Limestone					
GW-694	EXP-B	BDR	58 ± 6	2	2
GW-706	EXP-B	BDR	51 ± 5	2	2

The occurrence of gross beta activity in groundwater in the Conasauga Shales near the S-3 Site is similar to that of nitrate and gross alpha activity; samples from wells GW-243 and GW-276 had the highest gross beta activity of all samples collected in CY 1994. However, the CY 1990 annual average gross beta activity for these wells was about 300% higher: 60,750 pCi/L for well GW-243, and 4,110 pCi/L for well GW-276 (HSW Environmental Consultants 1994).

Gross beta activity also exceeded 50 pCi/L in the groundwater monitored by wells GW-537 and GW-085 located at the eastern border of the Oil Landfarm WMA. The elevated gross beta activity reported for the samples from well GW-537, as with the nitrate concentrations and gross alpha activities, may reflect upward migration from the Nolichucky Shale; gross beta activities reported for samples from wells of similar depth located closer to the S-3 Site were below the MDA.

Groundwater in the Maynardville Limestone with gross beta activity above 50 pCi/L was reported only for wells GW-694 and GW-706 (Table 14). These wells are completed from about 155 to 200 ft bgs in the Maynardville Limestone about 7,000 ft from the S-3 Site. Annual average gross beta activity just below 50 pCi/L was reported for several Maynardville Limestone bedrock interval wells located upgradient (GW-736, GW-737, and GW-738) and downgradient (GW-061) from wells GW-694 and GW-706.

6.4.3 Dose Equivalent Calculations

All monitoring wells sampled during CY 1994 that had annual average gross beta activity above 50 pCi/L were analyzed for specific beta-emitting isotopes: strontium, technetium, and tritium. Dose equivalents were calculated using dose factors proposed by the EPA (Federal Register, Vol. 56 No. 138, July 18, 1991). These dose factors represent the radionuclide activity that will deliver a 4 millirem per year (mrem/yr) dose equivalent to a critical organ or to the total body assuming a 2-liter per day intake of the affected water.

The dose equivalents calculated for the individual radionuclides, using only results that passed the evaluation criteria (Table 15), were summed to determine the cumulative dose (Table 16). Results of these calculations show that only the cumulative dose for groundwater monitored by wells GW-243 (67.79 mrem/yr) and GW-276 (6 mrem/yr) exceeded the 4 mrem/yr MCL for beta activity. The cumulative dose for wells GW-085, GW-537, GW-694, and GW-706 was calculated only from technetium activity because all results for strontium and tritium were below the respective MDAs. Technetium activity contributed about 85% of the cumulative dose for well GW-243 and about 24% of the cumulative dose for well GW-276. Strontium was the primary radionuclide in samples from well GW-276.

7.0 SURFACE WATER QUALITY

Water samples from Bear Creek and from springs discharging to Bear Creek were collected to provide data needed to evaluate the quality of surface water moving through the Bear Creek Regime (Figure 4). Exit pathway monitoring was changed from quarterly to semiannual sampling and, thus, fewer samples were collected during CY 1994 than previous CYs. However, data from these samples support previous results indicating that several of the common groundwater contaminants occur in surface water in the upper reaches of Bear Creek. Additionally, surface water quality data obtained during CY 1995 in support of the RI for the Bear Creek CA showed: contaminants from the S-3 Site occur in the upper reaches of Bear Creek and in upgradient spring samples (SS-1, SS-4, and SS-5), and VOCs occur in surface water downstream from the Burial Grounds WMA (Science Applications International Corporation 1995a). Moreover, data from samples collected between March and August 1995 from several Bear Creek tributaries (NT-1 through NT-8) near the contact between the Nolichucky Shale and the Maynardville Limestone (Figure 4) suggest additional sources of surface water contamination (primarily radionuclides) are at the Oil Landfarm and Bear Creek Burial Grounds WMAs. These results are supported by data obtained for RI purposes during 1995.

7.1 Surface Water Sampling Locations

As shown by data from CY 1994 and previous CYs, surface water in the upper reaches of Bear Creek contains several of the common groundwater contaminants in the regime, including low levels of VOCs, elevated nitrate and trace metal concentrations, and gross alpha and gross beta activity above 15 and 50 pCi/L, respectively. Although concentration increases were recently observed for nitrate, trace metals, and gross alpha and gross beta activity at several of the sampling locations, these conditions are probably attributed to temporal variations in seasonal flow conditions and most likely do not reflect an overall concentration trend.

The primary VOCs (1,2-DCE, PCE, and TCE) detected in groundwater samples from wells in the Bear Creek Regime also were detected in surface water samples collected from Bear

Creek tributary NT-01, located in the creek headwaters near the S-3 Site, and in samples collected from Bear Creek at BCK-09.40, located southwest of the Bear Creek Burial Grounds WMA (Figure 18). Tetrachloroethene was detected in both surface water samples collected from NT-01 during CY 1994 (Table 11), probably reflecting discharge of groundwater from the PCE-dominated VOC plume in the Conasauga Shales near the S-3 Site. Concentrations have remained relatively stable since the first quarter of CY 1993 (the first time this location was sampled), ranging from 1 μg/L for the sample collected during the second quarter of CY 1993, to 6 μg/L for the sample collected during the second half of CY 1994.

Samples collected from Bear Creek at BCK-09.40 during CY 1994 contained low concentrations of 1,2-DCE (5 and 6 μg/L), PCE (1 μg/L), and TCE (0.6 μg/L). Although all three of these compounds have been detected in samples collected since CY 1991, 1,2-DCE has been detected in 12 of 14 samples, whereas PCE was detected in only 5 samples and TCE was detected in only 4 samples. The source of these VOCs is probably either the Oil Landfarm WMA, the Bear Creek Burial Grounds WMA, or both.

Annual average nitrate concentrations in excess of the 10 mg/L MCL were calculated from the CY 1994 data reported for samples collected from three surface water sampling locations (BCK-09.40, BCK-11.97, and NT-01) (Table 17). The annual average nitrate concentration (155.8 mg/L) at Bear Creek tributary NT-01 corroborates CY 1993 data, which indicated that groundwater impacted by effluent from the S-3 Site discharges to this surface drainage feature (Figure 24). In addition, as shown below, the nitrate concentrations reported for all three of these sampling locations exhibit order-of-magnitude increases from the first quarter samples to the third quarter samples.

Sampling Location	**Nitrate (as N) (mg/L)**		**CY 1994 Annual Average**
	1st Qtr.	**3rd Qtr.**	
BCK-04.55	1.56	3.9	2.73
BCK-09.40	6.62	22	14.31
BCK-11.97	44.66	160	102.33
NT-01	83.62	228	228

Furthermore, nitrate concentrations reported for BCK-04.55 more than doubled from the first quarter sample to the third quarter sample, even though neither sample exceeded the MCL. The annual average nitrate concentrations reported for these sampling locations nevertheless continue to decrease from previous CYs (Table 17).

The apparent increase in the nitrate concentrations from the first to third quarter probably is related to seasonal flow conditions in Bear Creek. Although flow data were not obtained when samples were collected from each sampling point, results reported since CY 1991 show that nitrate concentrations typically are highest in samples collected during seasonally dry periods of the year, presumably reflecting less dilution during low flow conditions, and comparatively lower in the samples collected during seasonally wet periods of the year, suggesting greater dilution during high flow periods (Figure 31). Deviations from this general pattern probably reflect unseasonably wet or dry conditions prior to collection of the samples.

Comparison of the temporal changes in the nitrate concentrations at each sampling point (appropriate because samples were collected from each location on the same day during each quarterly sampling event) also show generally concordant fluctuations of similar magnitude at downstream locations BCK-00.63 and BCK-04.55, but generally discordant fluctuations of more varying magnitude at upstream locations BCK-09.40 and BCK-11.97 (Table 17). For example, concurrent increases and decreases in nitrate concentrations occurred between BCK-00.63 and BCK-04.55 during 12 of the 13 quarterly sampling events after the first quarter of CY 1991, and the range between the highest concentration increase and the greatest concentrations decrease was less than 14 mg/L. In contrast, concurrent increases and decreases in nitrate concentrations occurred at BCK-11.97 and BCK-09.40 during 5 of the 8 quarterly sampling events completed between the first quarter of CY 1991 and the third quarter of CY 1994 (BCK-11.97 was not sampled during CY 1993), and the range between the greatest concentration increase and decrease at each location was about 311 and 50 mg/L, respectively (Table 17). These more widely fluctuating nitrate concentrations in the upper reaches of Bear Creek, particularly at BCK-11.97, may indicate varying rates at which nitrates are flushed from the fracture flow system underlying the S-3 Site.

Elevated concentrations of the following trace metals were determined from historic data and CY 1994 data for five surface water sampling locations from Bear Creek: boron, cadmium, manganese, and uranium. However, evaluation of these data suggest that only the elevated concentrations of boron, uranium, and manganese potentially reflect impacts on surface water quality (Table 13).

The CY 1994 median total boron concentrations determined for three Bear Creek locations exceeded the UTL (Table 13). Median concentrations were the highest for BCK-09.40 (0.22 mg/L), which is located the closest to the suspected Bear Creek Burial Ground WMA boron source area. Total boron concentration decreases significantly from BCK-09.40 to the next downstream location BCK-04.55 (0.07 mg/L), while only a minor decrease in concentration is evident between sampling locations BCK-04.55 to BCK-00.63 (0.067 mg/L). Similarly significant decreases in uranium concentrations and gross alpha and gross beta activities occur between sampling stations BCK-09.40 and BCK-04.55. The apparent decrease in concentration suggests that the addition of "cleaner" water is greater between locations BCK-09.40 and BCK-04.55 than between locations BCK-04.55 and BCK-00.63.

Elevated median concentrations were determined for manganese and uranium in samples from NT-01, and for uranium in four surface water samples from Bear Creek. The presence of elevated concentrations of these trace metals confirms that acidic effluent released from the S-3 Site has impacted surface water. Historic data and CY 1994 data indicate that only uranium is present in elevated concentrations in samples collected downstream in Bear Creek (Figure 28). This suggests that other trace metals (i.e., manganese) are less mobile, or are more readily attenuated in comparison to uranium. As expected, total uranium concentrations at surface water monitoring stations decrease downstream from the S-3 Site source (Figure 32).

Annual average gross alpha and/or gross beta activity determined for surface water stations NT-01, BCK-11.97, and BCK-09.40 exceeded drinking water screening levels (Table 14); all results reported for these sampling points passed the evaluation criteria. As summarized in the table below, gross beta activity decreases steadily with distance from the S-3 Site. However, gross alpha activity increases between BCK-11.97 and BCK-09.40, then decreases further downstream. This suggests that the Oil Landfarm WMA, is a source of alpha-emitting radionuclides to Bear Creek between stations BCK-11.97 and BCK-09.40.

Sampling Point	CY 1994 Annual Average Activity (pCi/L)	
	Gross Alpha	Gross Beta
NT-01	[7 ± 2]	265 ± 21
BCK-11.97	48 ± 6	262 ± 22
BCK-09.40	52 ± 6	64 ± 6
BCK-04.55	[12 ± 3]	[13 ± 3]
BCK-00.63	[9 ± 2]	[12 ± 3]

Elevated gross alpha activity was reported for samples from NT-3, NT-6, NT-7, and NT-8; the highest levels were reported for NT-3 (874 ± 33.8 pCi/L) at the Oil Landfarm WMA and NT-8 (135 ± 13.9 pCi/L) west of the Burial Grounds WMA. Notably, nitrate concentrations (typical of the S-3 Site) in samples from these locations were generally below 1 mg/L, suggesting the presence of additional radionuclide source areas in these WMAs. Gross beta activity was highest in samples from NT-3, ranging from 15.7 ± 2.88 pCi/L to 351.00 ± 12.90 pCi/L, showing that the Oil Landfarm WMA also is a source of beta-emitting radionuclides.

All sampling stations that had annual average gross beta activity above 50 pCi/L during CY 1994 were analyzed for the beta-emitting isotopes strontium, technetium, and tritium. Dose equivalents, calculated from activities that passed the evaluation criteria, were determined using dose factors proposed by the EPA, and individual doses were summed to determine the cumulative dose (Table 16). The cumulative dose exceeded 4 mrem/yr only for samples from BCK-11.97, and strontium was the principal isotope. Strontium activity (374 pCi/L) reported for the first quarter sample from BCK-11.97 contributed 35.6 mrem/yr (about 99%) to the cumulative dose for this sampling point. Notably, the third quarter sample collected at BCK-11.97 had gross beta activity that was nearly four times greater than the first quarter sample, but the strontium activity reported for the third quarter sample was below the MDA.

7.2 Springs

Releases from waste sites in the Bear Creek Regime (primarily the S-3 Site) have affected the quality of groundwater discharged from springs in the upper reaches of Bear Creek, particularly springs SS-1, SS-4, and SS-5 (Figure 4). Results obtained during CY 1994 and previous CYs show that samples from these springs contain low levels of VOCs, nitrate concentrations in excess of the 10 mg/L MCL, total uranium concentrations that exceed the Maynardville Limestone screening level (0.007 mg/L), and gross alpha and gross beta activity above 15 and 50 pCi/L, respectively.

In CY 1994, VOCs detected in the samples collected from springs included PCE (spring SS-1), 1,2-DCE (spring SS-4), and TCE (springs SS-1 and SS-4). Concentrations of these compounds were generally less than 5 μg/L (Table 11); similar concentrations of each compound have been reported for the samples collected from these springs since the first quarter of CY 1991. The presence of PCE in the samples collected from spring SS-1 suggests possible transport from the PCE-dominated VOC plume in the Conasauga Shales near the S-3 Site. The 1,2-DCE and TCE in the samples from spring SS-4 may be degradation products of the PCE in the groundwater near the S-3 Site upgradient of these springs, or may indicate additional inputs of VOCs from other sources, such as the new source detected at the Oil Landfarm WMA during the RI performed for the regime.

Annual average nitrate concentrations determined for springs SS-1 (24 mg/L) and SS-4 (20 mg/L) exceeded 10 mg/L. As shown in the following table, nitrate concentrations at each spring increased from the first to the third quarter sample of the year:

Sampling Location	Nitrate (as N) (mg/L)		CY 1994 Annual Average
	1st Qtr.	3rd Qtr.	
SS-1	17.8	30	23.9
SS-4	3.12	37	20.1
SS-5	0.7	17	8.8

The apparent increase in the nitrate concentrations at these springs probably reflects temporal fluctuations related to seasonally high and low groundwater flow conditions. Review of nitrate data reported since CY 1991 for springs SS-1, SS-4, and SS-5 shows that similar nitrate concentration increases were subsequently followed by concentration decreases (Figure 33). For example, nitrate concentrations reported for the samples collected from springs SS-4 and SS-5 during the first quarter of CY 1993 were about 37.7 and 17.5 mg/L, respectively, which was less than the nitrate concentrations reported for the samples collected from the respective locations during the fourth quarter of CY 1992 (Table 17).

Nitrate concentrations reported for spring SS-5 further substantiate the hydraulic connection with Maynardville Limestone wells GW-683 and GW-684 reported by Shevenell et al. (1993). The elevation of the monitored intervals for these wells overlap by about 15 ft (Table 3), but well GW-683 is completed in the Copper Ridge Dolomite of the Knox Group and well GW-684 is completed in the Maynardville Limestone. As shown below, nitrate concentrations reported for the samples collected from these wells during CY 1994 mirror the concentration trend evident in samples from spring SS-5, including the order-of-magnitude increases.

Qtr. 1994	Well GW-683		Well GW-684		SS-5
	Nitrate (as N) (mg/L)	**Sample Delay (Days)**	**Nitrate (as N) (mg/L)**	**Sample Delay (Days)**	**Nitrate (as N) (mg/L)**
1st	0.5	18	4.3	18	0.7
3rd	12	14	12	14	17.0

Similar nitrate concentration trends in wells GW-683, GW-684, and spring SS-5 are somewhat surprising because groundwater samples were collected from the wells 14 to 18 days after the samples were collected from the spring. Additionally, considering that water-level elevations in the wells reflect flow conditions (i.e., elevations are higher when flow is greater), then the lack of significant increases in the water-level elevations despite nitrate concentration increases suggest relatively uniform rates of nitrate transport in the Maynardville Limestone. Alternatively, the fluctuating nitrate concentrations may reflect "slug" type transport that is not adequately characterized by current quarterly monitoring protocols.

The median total uranium concentrations determined for all three springs exceeded the UTL (Table 13). Elevated uranium concentrations have been reported for each sample except the sample collected from spring SS-5 in first quarter of CY 1994 (Figure 32). Elevated total uranium concentrations also were reported for samples from several Maynardville Limestone wells in CY 1994, including wells GW-683, GW-684, GW-694, and GW-706. Historic data indicate temporal fluctuations in total uranium concentrations, as does data for CY 1994, with the exception of the apparent decrease in concentrations at spring SS-1. These fluctuations appear to be a function of seasonal groundwater flow conditions (Figure 32).

Annual average gross alpha and gross beta activity determined for samples collected from springs during CY 1994 are provided in the following table. Results for all samples passed the evaluation criteria, except the first quarter sample from SS-5 (results were all below respective MDAs) (Table 14). As shown in the data summarized below, annual average gross alpha activity exceeded 15 pCi/L and gross beta exceeded 50 pCi/L at each sampling point, and the highest activities were reported for samples from spring SS-4.

Sampling Point	**CY 1994 Annual Average Activity (pCi/L)**	
	Gross Alpha	**Gross Beta**
SS-1	18 ± 3	54 ± 5
SS-4	41 ± 5	66 ± 7
SS-5	29 ± 6	50 ± 7

Samples from SS-1 and SS-4 were analyzed for the beta-emitting isotopes strontium, technetium, and tritium. Dose equivalents were calculated from activities that passed the data evaluation criteria using dose factors proposed by the EPA, and individual doses were summed to determine the cumulative dose (Table 16). Only the cumulative dose calculated for SS-4 (29.97 mrem/yr) exceeded 4 mrem/yr MCL for beta activity. Strontium activity (313 pCi/L) reported only for the first quarter sample from SS-4 contributed 29.1 mrem/yr to the cumulative dose. Similar to surface water station BCK-11.97, the third quarter sample collected at SS-4 had gross beta activity that was about five times greater than reported for the first quarter sample, but the strontium activity reported for the third quarter sample was below the MDA.

8.0 CONCLUSIONS

Data obtained during CY 1994 support previous monitoring results. The primary groundwater contaminants in the Bear Creek Regime are VOCs, nitrate, trace metals, and radionuclides. The following items summarize the CY 1994 evaluation process and findings.

- Several of the interpretive assumptions used in the evaluation of the CY 1994 data differed from those used in previous GWQRs. The changes primarily involved: (1) modification of the decision rule used to identify anomalous results for VOCs, (2) use of more conservative reference values for identification of elevated trace metal concentrations, and (3) application of updated evaluation criteria relating to background corrected values, counting uncertainty, and MDAs for radioanalyte results. These modifications had no significant overall impact on the evaluation of the data reported for VOCs or trace metals. However, only about 14% of the CY 1994 results for radioanalytes were suitable for evaluation based on the revised interpretive assumptions.

- A variety of VOCs, primarily methylene chloride and acetone, were detected in 22% of the laboratory blanks, 24% of the trip blanks, 33% of the field blanks, and 23% of the equipment rinsate samples analyzed during CY 1994. These results reflect a continued reduction in the percentage of VOC-contaminated QA/QC samples evident since the fourth quarter of CY 1992. The results reported for laboratory and trip blanks were used to identify a total of 15 false positive VOC results in the CY 1994 groundwater samples. All of the false positives were for common laboratory reagents (methylene chloride, acetone, and 2-butanone) that were most frequently detected in laboratory blanks.

- The CY 1994 results reported for major cations and anions show that calcium-magnesium bicarbonate groundwater typically occurs at shallow depths in the Conasauga Shales and the Maynardville Limestone throughout the Bear Creek Regime. However, significant geochemical differences exist between the two units in the bedrock interval below about 100 ft bgs. These differences support the conceptual model of groundwater flow in the Bear Creek Regime.

- The S-3 Site is the principal source of nitrate, trace metals, and radionuclides; most waste-management sites in the regime are probable VOC source areas. Groundwater affected by releases from these source areas primarily occurs in the Conasauga Shales, which underlie many sites, and in the Maynardville Limestone along the axis of Bear Creek Valley. The horizontal extent of VOCs, nitrate, trace metals, and radionuclides (as indicted by gross alpha and gross beta activity) generally shows a similar pattern of limited migration (usually less than 1,000 ft from the source areas) in the Conasauga Shales but extensive migration (more than 10,000 ft for VOCs and nitrate) in the Maynardville Limestone. The maximum depth of the plumes is fairly well defined in the Conasauga Shales, but less so in the Maynardville Limestone. However, given the nature of groundwater flow and contaminant transport in a karst aquifer such as the Maynardville Limestone, complete delineation of the contaminant plumes in this hydrogeologic unit may not be practical or possible.

- The primary VOCs in the groundwater (in descending frequency) are TCE, 1,2-DCE, PCE, 1,1-DCA, and 1,1,1-TCA. Plumes of these and other compounds are present in the groundwater in the Conasauga Shales at the S-3 Site, Oil Landfarm WMA, and Bear Creek Burial Grounds WMA. The VOC plume in the Maynardville Limestone, which extends for at least 11,500 ft from the eastern end of the regime to west of the Bear Creek Burial Grounds WMA, is dominated by TCE and probably receives inputs from multiple sources, possibly including Spoil Area I, the Rust Spoil Area, and the Fire Training Facility (located on the northern flank of Chestnut Ridge in the East Fork Regime about 1,000 ft east of Spoil Area I). Dissolved VOC concentrations are highest in the Conasauga Shales near the Bear Creek Burial Grounds WMA. Additionally, preliminary data collected in support of the RI for the regime indicate that a separate source area of VOCs is located east of the Oil Landfarm WMA.

- Nitrate is a pervasive groundwater contaminant in the Bear Creek Regime. The highest nitrate concentrations (>5,000 mg/L) have historically been reported for samples from wells located south (downdip) of the S-3 Site in the Conasauga Shales, and CY 1994 data for GW-243 (8,927 mg/L) corroborate these findings. The nitrate plume in the Conasauga Shales extends about 3,000 ft west of the S-3 Site to the eastern portion of the Oil Landfarm WMA. Recent data from newly installed wells show that nitrate migrates from the S-3 Site laterally in the bedrock interval, with upward discharge into the water table interval. Nitrate entering the Maynardville Limestone along the contact with the Nolichucky Shale has migrated along strike to the west more than 5,000 ft. Annual average nitrate concentrations near the source area have generally decreased in shallow groundwater since CY 1990.

- Groundwater quality with respect to trace metal concentrations was evaluated through comparison with one of two types of reference concentrations: available MCLs for drinking water, or UTLs determined from statistical analysis of groundwater quality data obtained since CY 1986. Median concentrations determined from the CY 1994 data for aluminum, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, strontium, uranium, vanadium, and zinc exceeded the applicable reference concentration. However, elevated median concentrations for most of these metals were probably biased by sampling or analytical artifacts. Additionally, the UTL for some of the metals, particularly boron and vanadium, appears to be too conservative for the purposes of the Y-12 Plant GWPP. Evaluation of the CY 1994 data based on these considerations showed elevated concentrations of barium, boron, cadmium, cobalt, copper, mercury, strontium, and uranium potentially reflect impacts on groundwater quality in the Bear Creek Regime.

Most of the wells that consistently yield samples with elevated concentrations of these metals are located downgradient of the S-3 Site.

- Review of the useable radioanalyte results reported for wells sampled during CY 1994 show that annual average gross alpha and gross beta activities were consistent with results of previous assessments. The S-3 Site is the primary source of gross alpha- and gross beta-emitting radionuclides in groundwater in the regime. As shown by historic data from monitoring wells and preliminary data collected in support of the RI for the regime, an additional source area of radionuclides (and not nitrate) is located east of the Oil Landfarm WMA.

- Samples from well GW-243 and GW-276 (S-3 Site RCRA point-of-compliance wells) had the highest gross alpha and gross beta activities in CY 1994, but results for both wells show a significant decrease in radioactivity since CY 1990. Gross alpha activity above 15 pCi/L in groundwater in the Conasauga Shales extends about 2,500 ft west of the S-3 Site. Groundwater with elevated gross alpha activity in the Maynardville Limestone is first encountered about 7,000 west of the S-3 Site, southwest of the Oil Landfarm WMA, and extends about 4,000 ft downgradient to the west. Groundwater with elevated gross beta activity extends about 3,000 ft to the west of the S-3 Site in the Conasauga Shales. Samples from only two Maynardville Limestone wells, located about 7,000 ft west of the S-3 Site, had average gross beta activity above 50 pCi/L. Samples from the four Conasauga Shales wells and two Maynardville Limestone wells with CY 1994 annual average gross beta activity exceeding 50 pCi/L were speciated for beta-emitting radionuclides to determine the cumulative dose equivalent. Results show that ^{99}Tc and ^{90}Sr are the primary beta-emitting radionuclides, and only the cumulative dose calculated for wells GW-243 and GW-276 exceeded the 4 mrem/yr MCL for beta activity.

- Surface-water quality data obtained in CY 1994 are consistent with historical results and show that the upper reaches of Bear Creek are affected by releases from several of the waste sites in the Bear Creek Regime. Surface-water samples collected from the upper reaches of the creek contained low concentrations of VOCs, nitrate concentrations above the 10 mg/L MCL, and annual average gross alpha and gross beta activity that exceed 15 and 50 pCi/L, respectively. Samples from all the surface water stations sampled along Bear Creek, including the farthest downstream sampling location near the confluence of Bear Creek and East Fork Poplar Creek, contained uranium concentrations that exceeded calculated reference values. Additionally, nitrate and uranium concentrations, as well as gross alpha and gross beta activity, increased throughout CY 1994 at most of the sampling points along Bear Creek and the springs that discharge to the creek. However, review of historical data for the springs and surface water sampling stations indicates that these apparent increases probably reflect temporal fluctuations related to seasonal groundwater flow conditions.

9.0 PLANNED AND PROPOSED MONITORING CHANGES

Numerous changes to the groundwater monitoring program in the Bear Creek Regime are planned by the Y-12 Plant GWPP for implementation in CY 1996 because of changing monitoring requirements. Transitional changes to monitoring priorities began in CY 1993 with a shift in the monitoring emphasis from assessment and characterization to long-term surveillance. Additionally, RCRA interim status monitoring is being phased out as RCRA post-closure permits are finalized by the TDEC; the final RCRA post-closure permit (for the Bear Creek Burial Grounds) is anticipated to be issued by the end of September 1995. Because RCRA is a relevant requirement under CERCLA at the Y-12 Plant, final RODs for various operable units will have to incorporate these long-term, post-closure permit requirements. The Y-12 Plant GWPP will implement these requirements following an integrated strategy similar to that outlined in the Comprehensive Monitoring Plan. Under this approach, an integrated surveillance monitoring well network will be used for long-term monitoring. This network will consist predominantly of sampling locations required by RCRA postclosure permits, and critical monitoring points or exit pathways not required by permits will be captured under DOE Order 5400.1 perimeter and surveillance monitoring.

9.1 Sampling Locations, Frequency, and Analytical Parameters

A total of 56 monitoring wells, 7 surface water stations, and 3 springs will be sampled semiannually during CY 1996 for the purposes of the following programs:

Monitoring Program	**Monitoring Wells**	**Surface Water**	**Springs**
RCRA Post-Closure Corrective Action Monitoring:	23	.	.
DOE Order 5400.1 Surveillance and Exit Pathway Monitoring:	30	7	3
Best-Management Practice Monitoring:	3	.	.
Total	**56**	**7**	**3**

Groundwater and surface water samples will be collected in the sequence shown on Table 18, and will be analyzed for the parameters and constituents specified in the *Sampling and Analysis Plan for Groundwater and Surface Water Monitoring at the Y-12 Plant During Calendar Year 1996* (HSW Environmental Consultants, Inc. 1995c).

9.2 Proposed Modifications

Proposed modifications to the monitoring programs implemented in CY 1994 involve data management and metals analyses. The following items describe the proposed changes:

- Dissolved iron and manganese concentrations should be included in charge balance determinations. The charge contributed by these cations is negligible in most samples, but omitting these cations in some instances causes consistently negative charge balance errors greater than 10%.
- Analyses for cadmium and chromium by AAS should be discontinued if not a site-specific or well-specific requirement. Statistical evaluation of the CY 1994 data showed no significant difference between results obtained by ICP and AAS methods for these metals.
- The reference concentrations for boron and vanadium are too conservative and should be re-evaluated.

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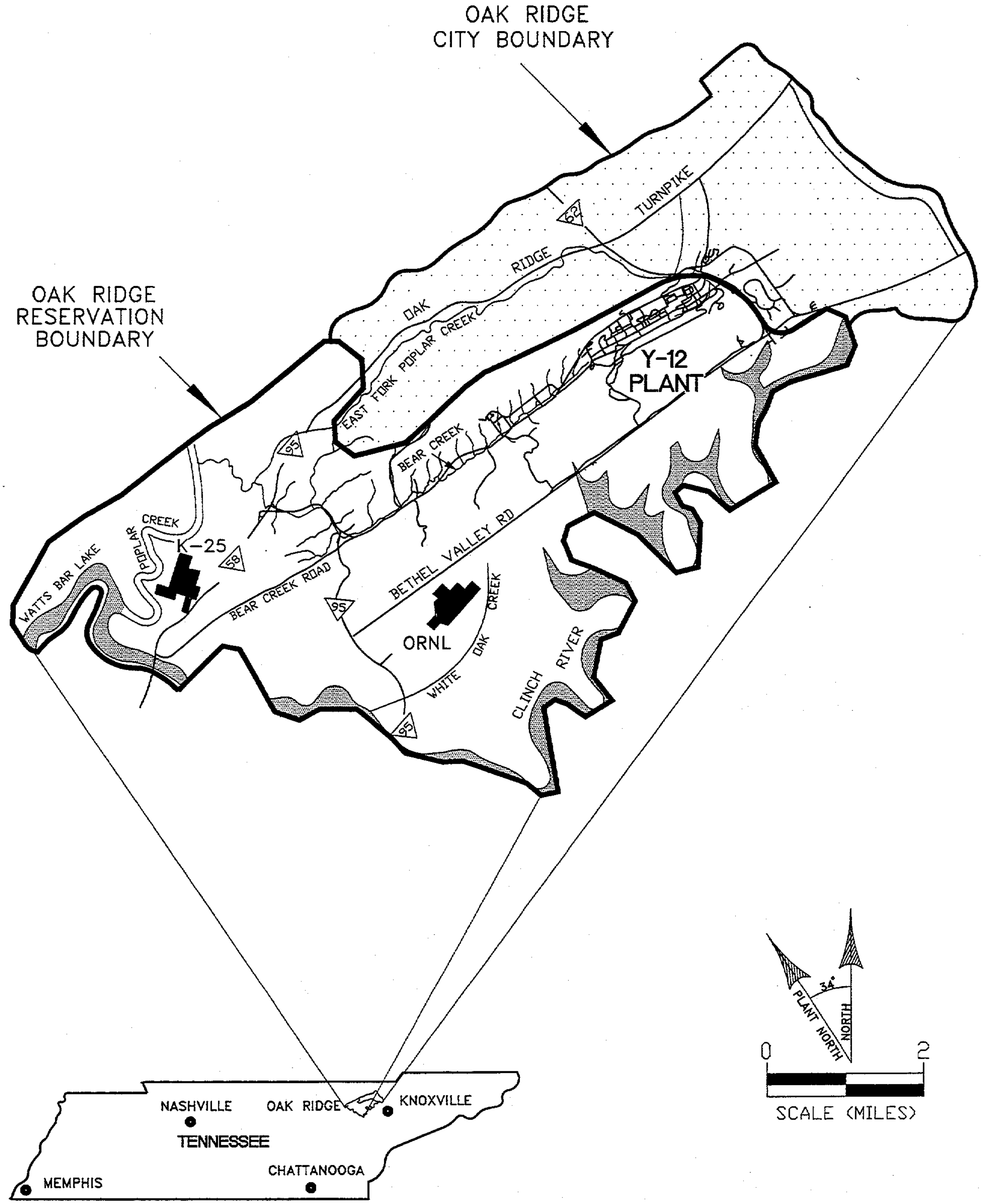
APPENDIX A

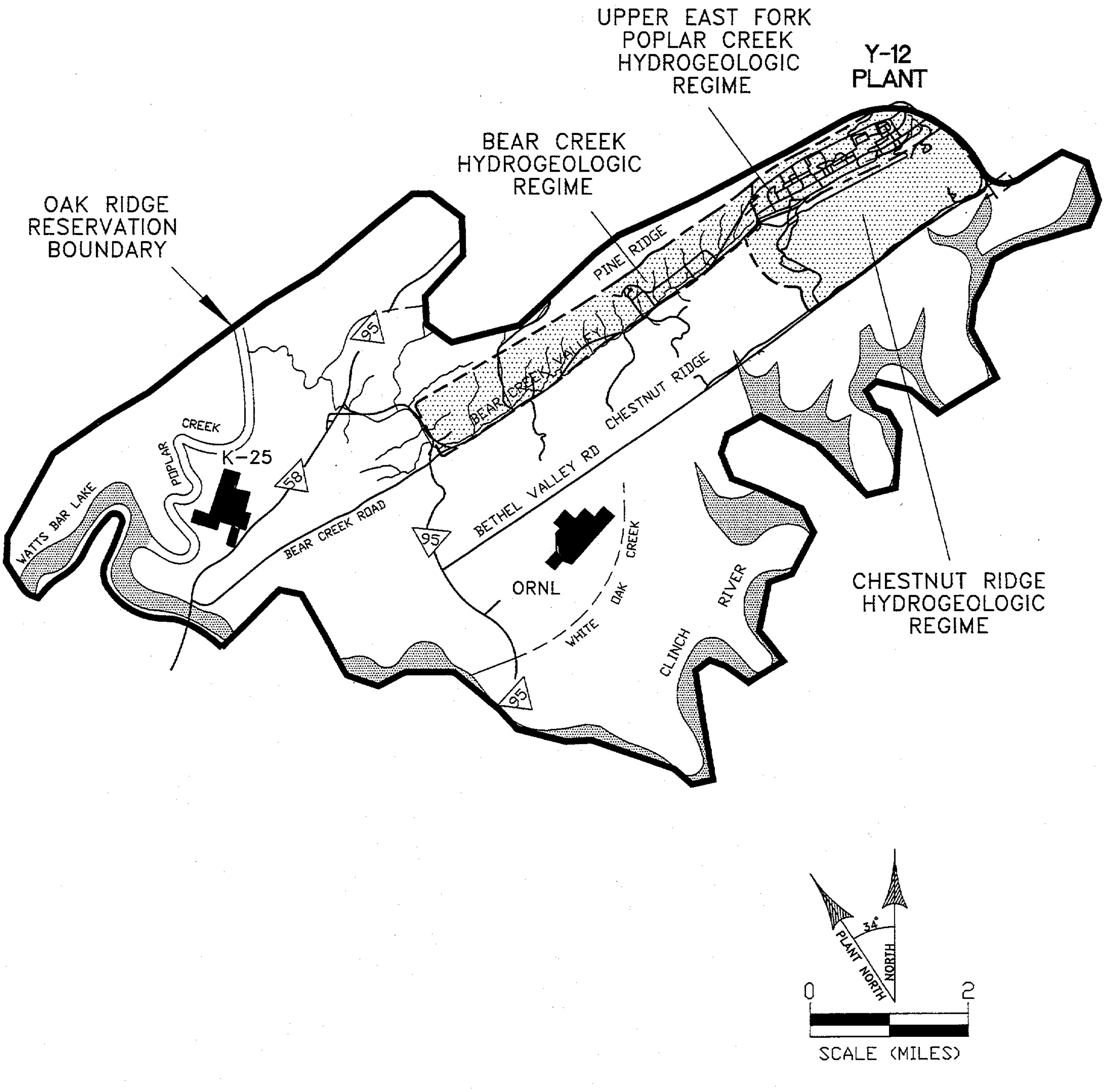
Figures



LOCATION:	Y-12 PLANT OAK RIDGE, TN.
DATE:	8-6-95
DWG ID.:	OR250-HC

FIGURE 1

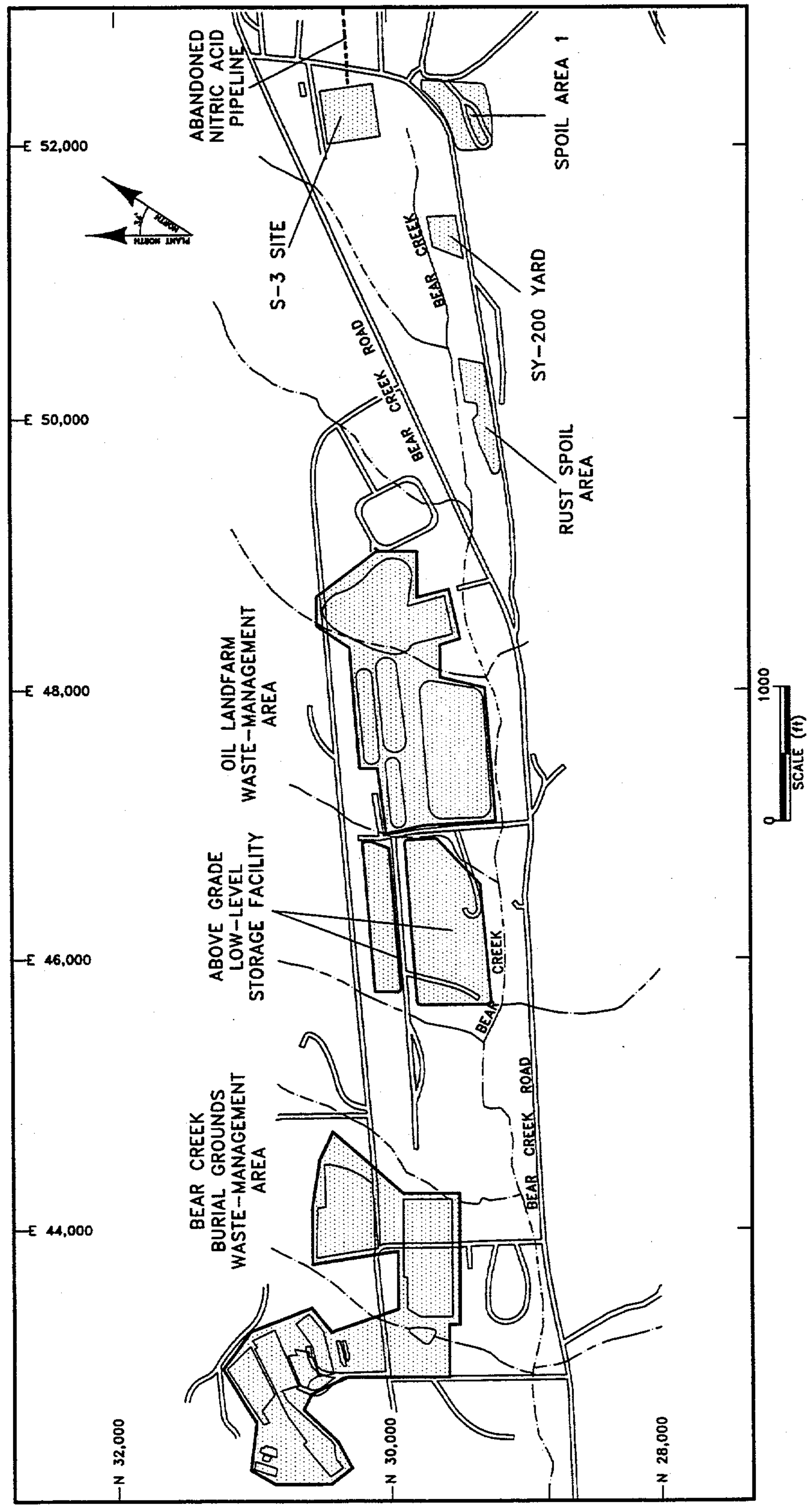
REGIONAL LOCATION OF THE Y-12 PLANT



LOCATION:	Y-12 PLANT OAK RIDGE, TN.
DATE:	8-6-95
DWG ID.:	OR321-HC

FIGURE 2

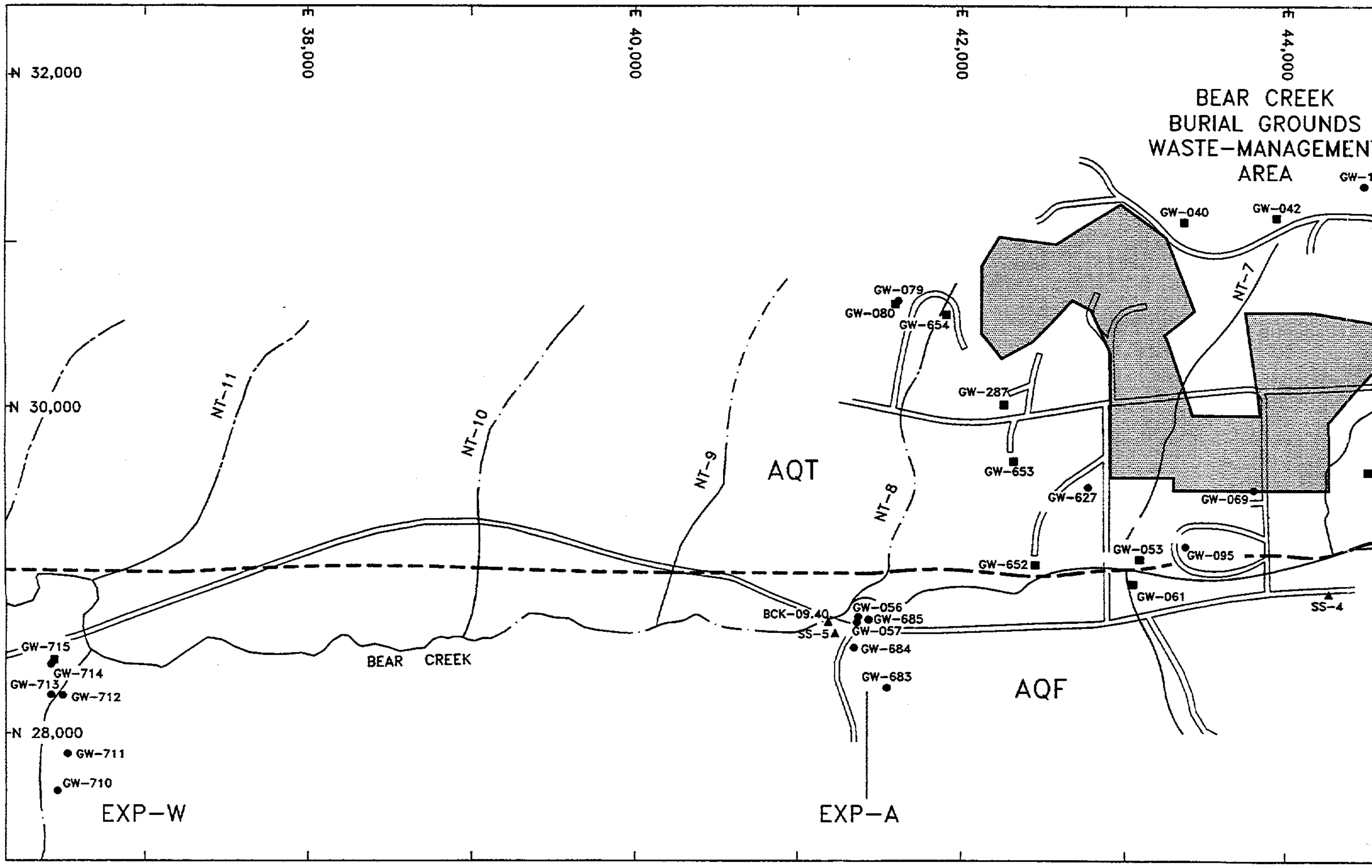
HYDROGEOLOGIC REGIMES AT THE Y-12 PLANT

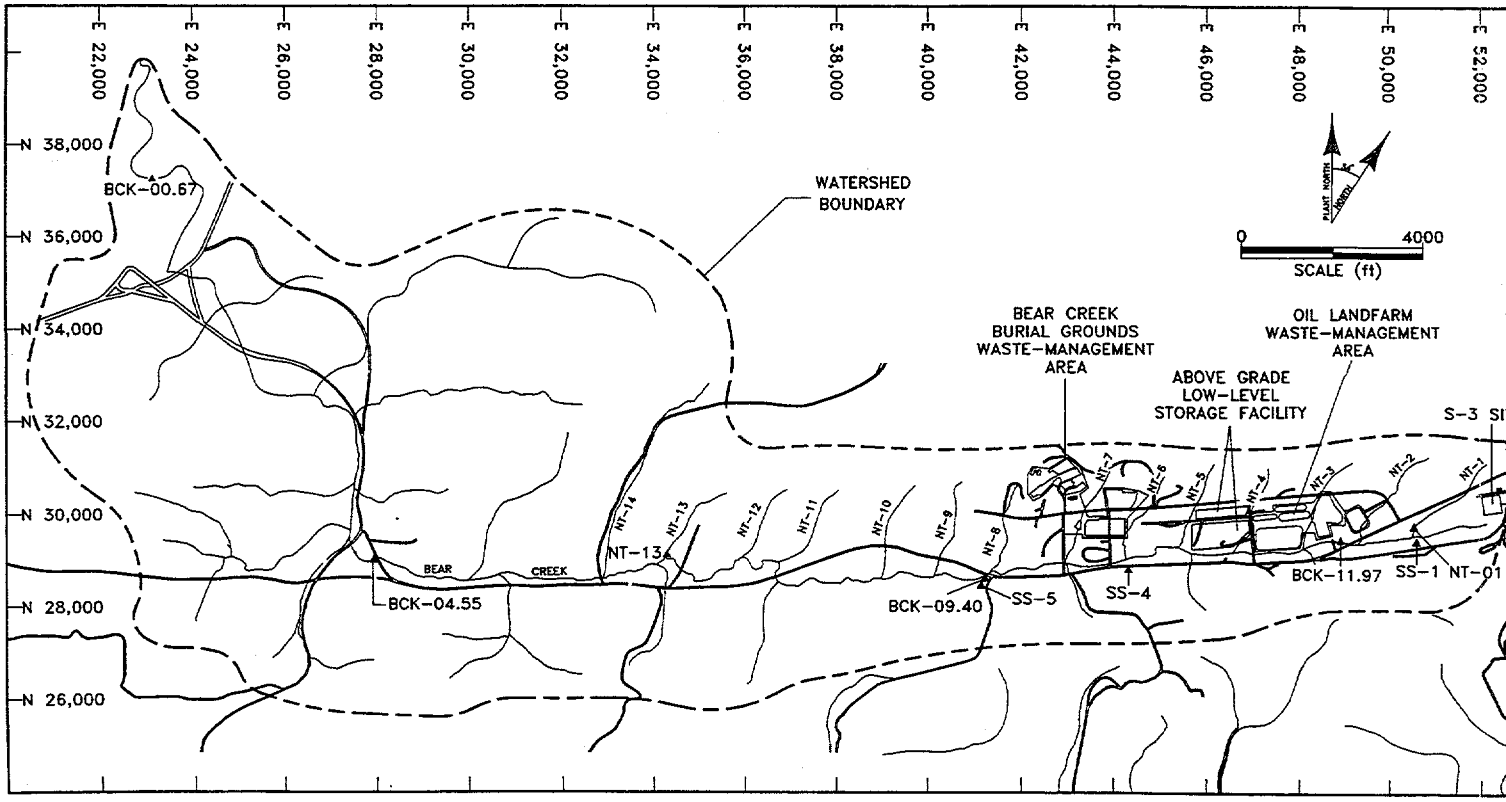


LOCATION:	Y-12 PLANT OAK RIDGE, TN.
DATE:	9-26-95
DWG ID.:	OR003-HC

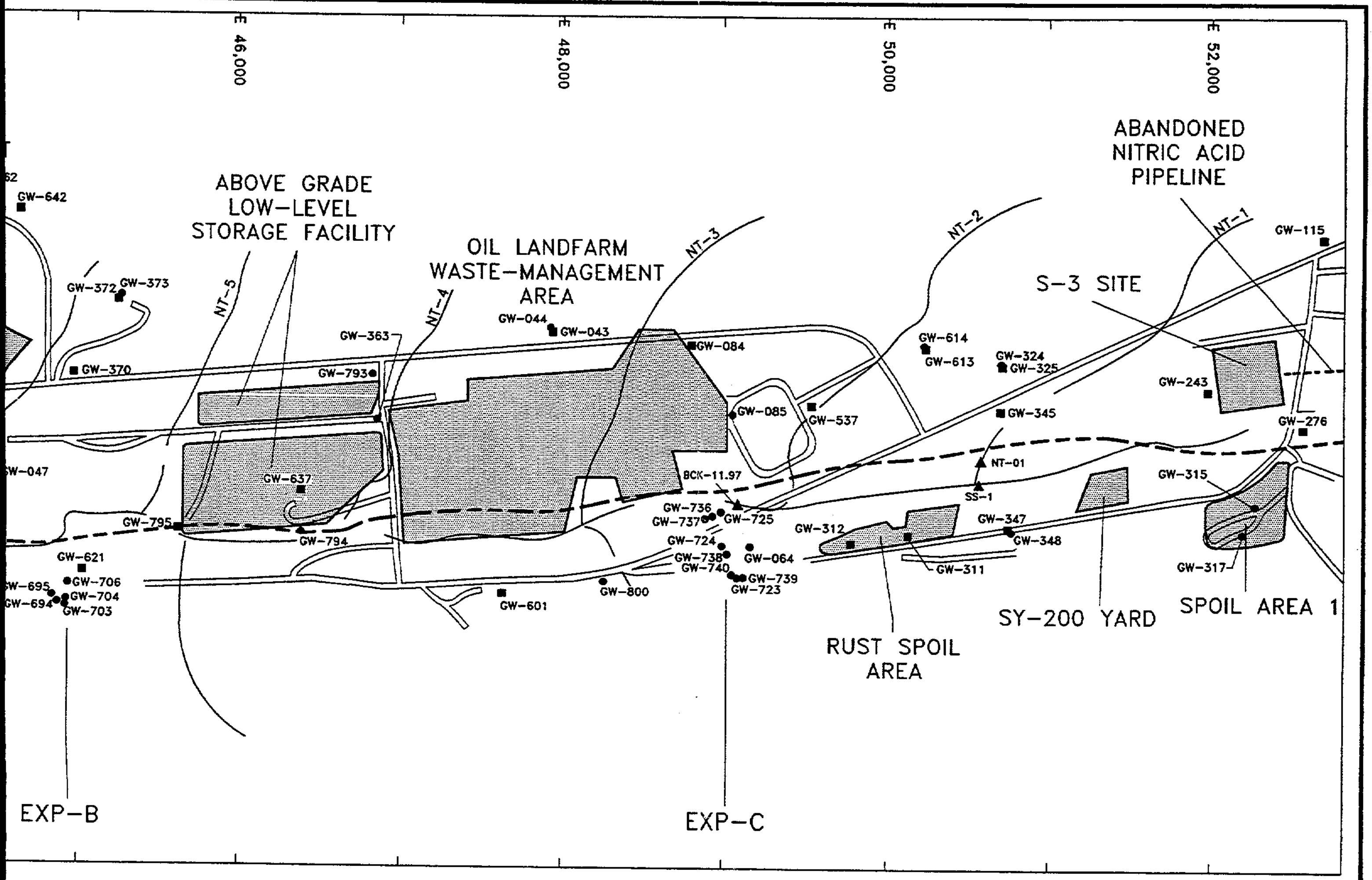
FIGURE 3

WASTE-MANAGEMENT SITES IN THE BEAR CREEK HYDROGEOLOGIC REGIME





SPRINGS AND SURFACE WATER SAMPLING STATIONS



EXPLANATION

GW – ■ – Water Table Monitoring Well

GW – ● – Bedrock Monitoring Well

SS –
BCK – ▲ – Spring (SS) or Surface-Water (BCK or NT) Sampling Station
NT –

EXP-C – Exit Pathway, Maynardville Limestone Transverse

——— – Surface Drainage Feature

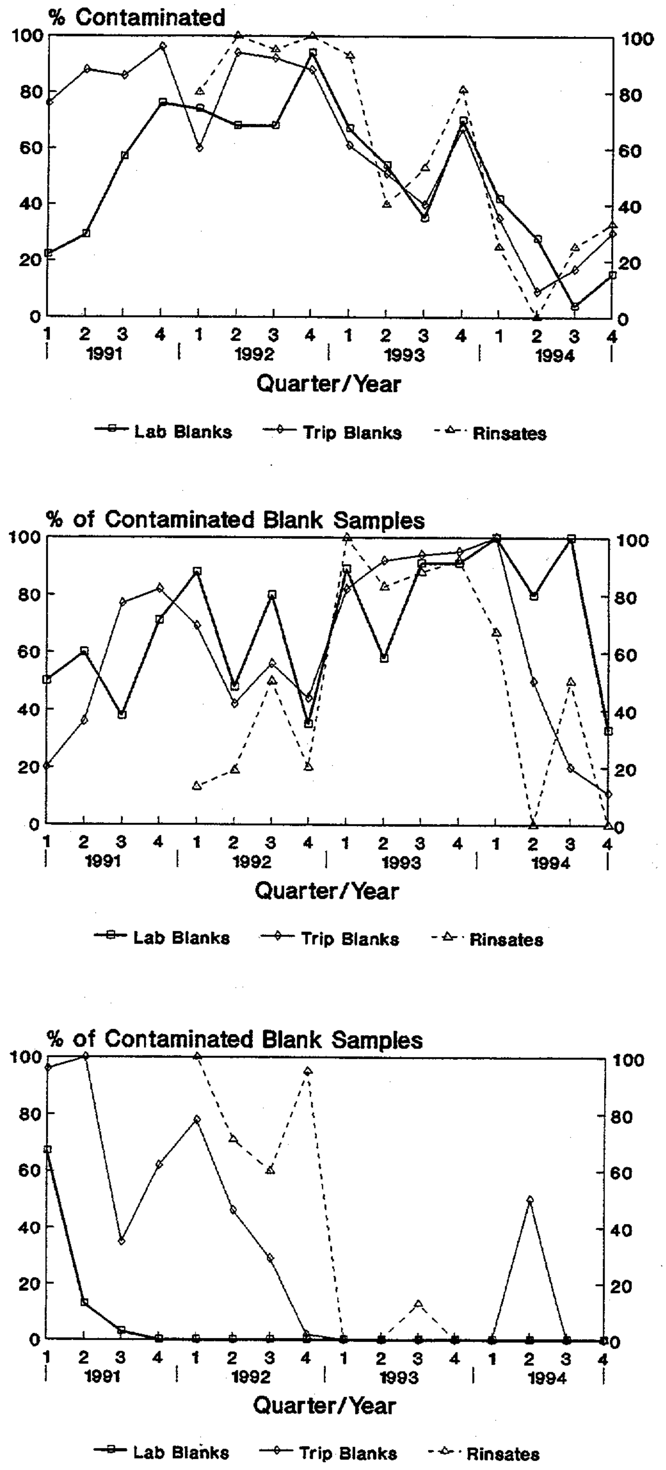
NT-5 – North Tributary

AQT – Conasauga Shales

— — — – Approximate Nolichucky Shale\Maynardville Limestone Contact

AQF – Maynardville Limestone

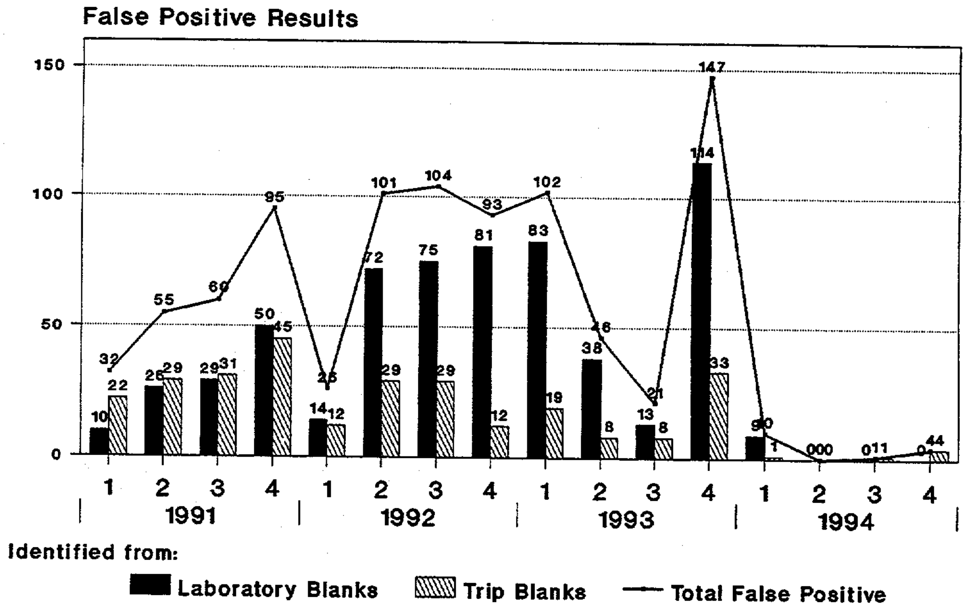
LOCATION:	Y-12 PLANT OAK RIDGE, TN.	FIGURE 4
DATE:	8-26-95	SAMPLING LOCATIONS FOR GROUNDWATER AND SURFACE WATER MONITORING DURING CY 1994
DWG ID.:	OR469-HC	

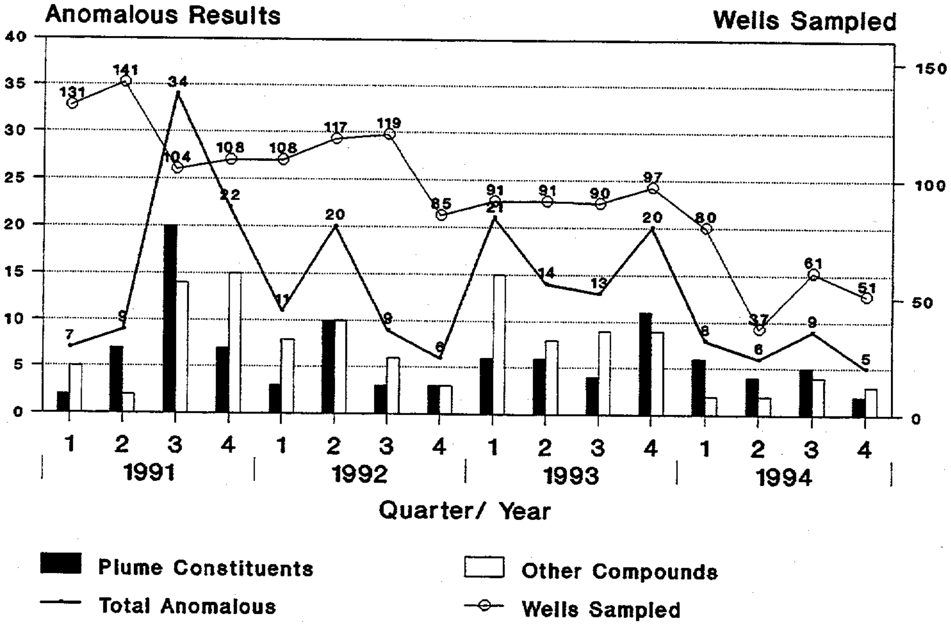

All Compounds

Chloroform

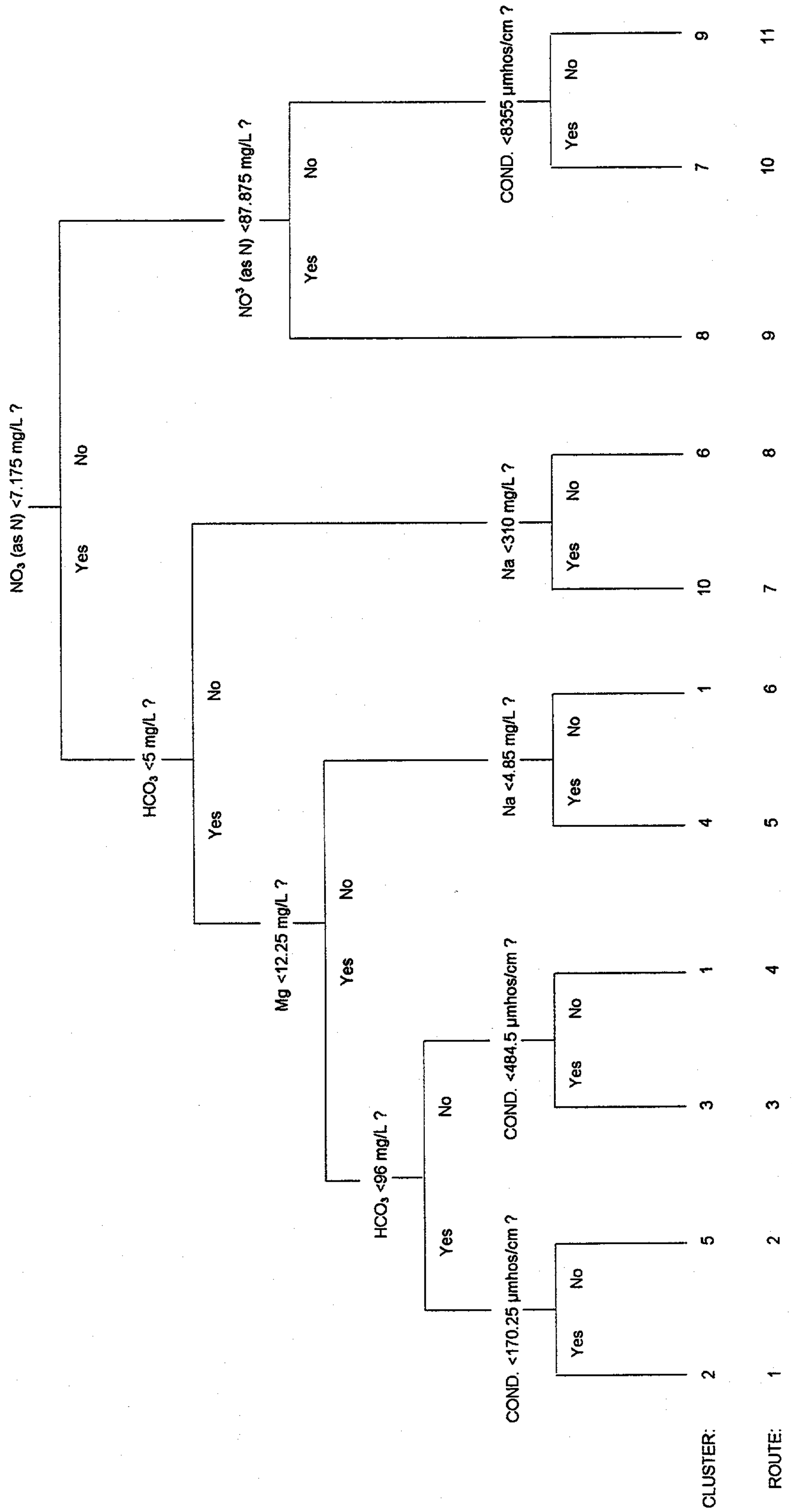
Methylene Chloride

LOCATION:	Y-12 PLANT OAK RIDGE, TN.	FIGURE 5
DATE:	8-6-95	VOCs IN QA/QC SAMPLES, 1991 - 1994
DWG ID.:	HG7	





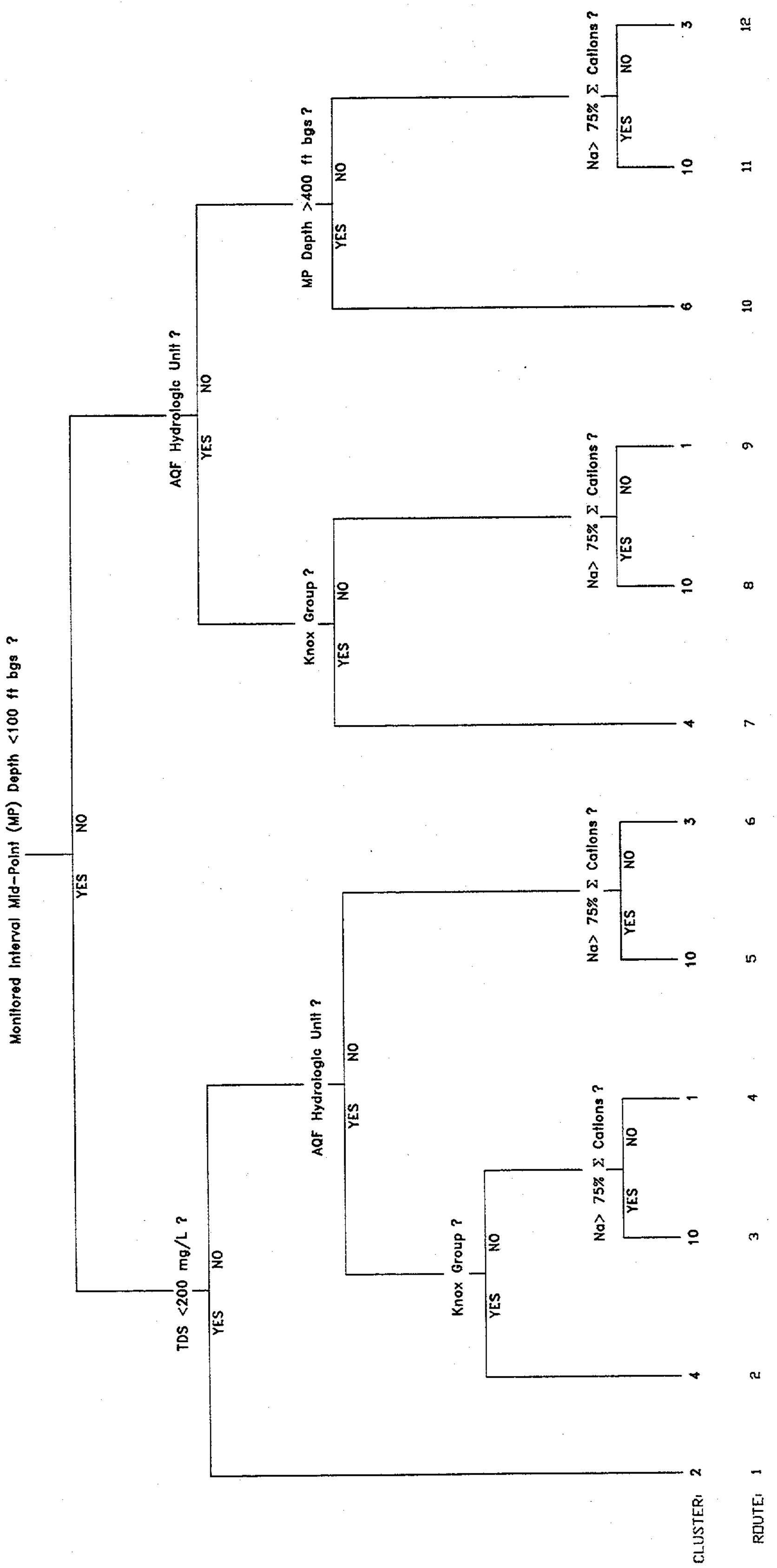
LOCATION:	Y-12 PLANT OAK RIDGE, TN.	FIGURE 6
DATE:	8-6-95	FASLE POSITIVE AND ANOMALOUS VOC RESULTS, 1991-1994
DWG ID.:	HG7	



LOCATION:	Y-12 PLANT OAK RIDGE, TN.
DATE:	7-12-95
DWG ID.:	24

FIGURE 7

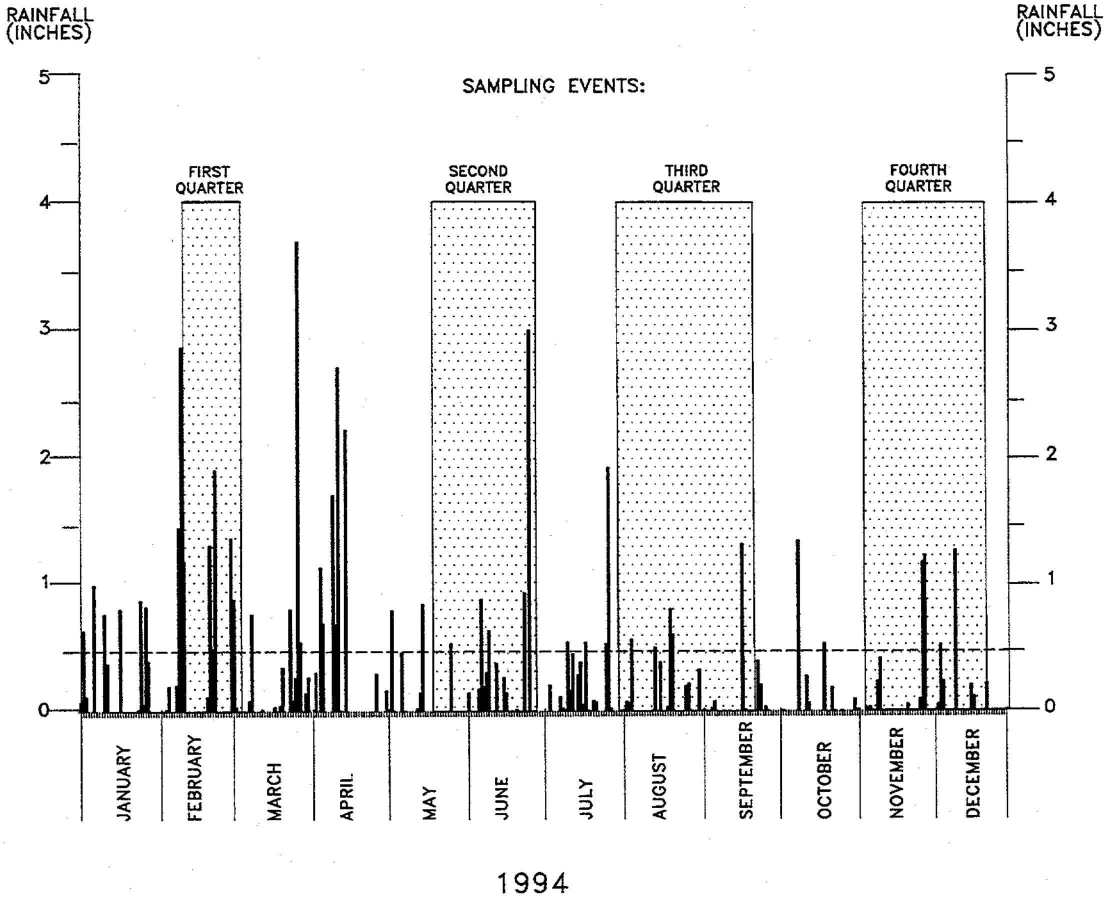
CLASSIFICATION MODEL FOR DETERMINING TRACE METAL UTLs



LOCATION:	Y-12 PLANT OAK RIDGE, TN.
DATE:	7-12-95
DWG ID.:	FIG8

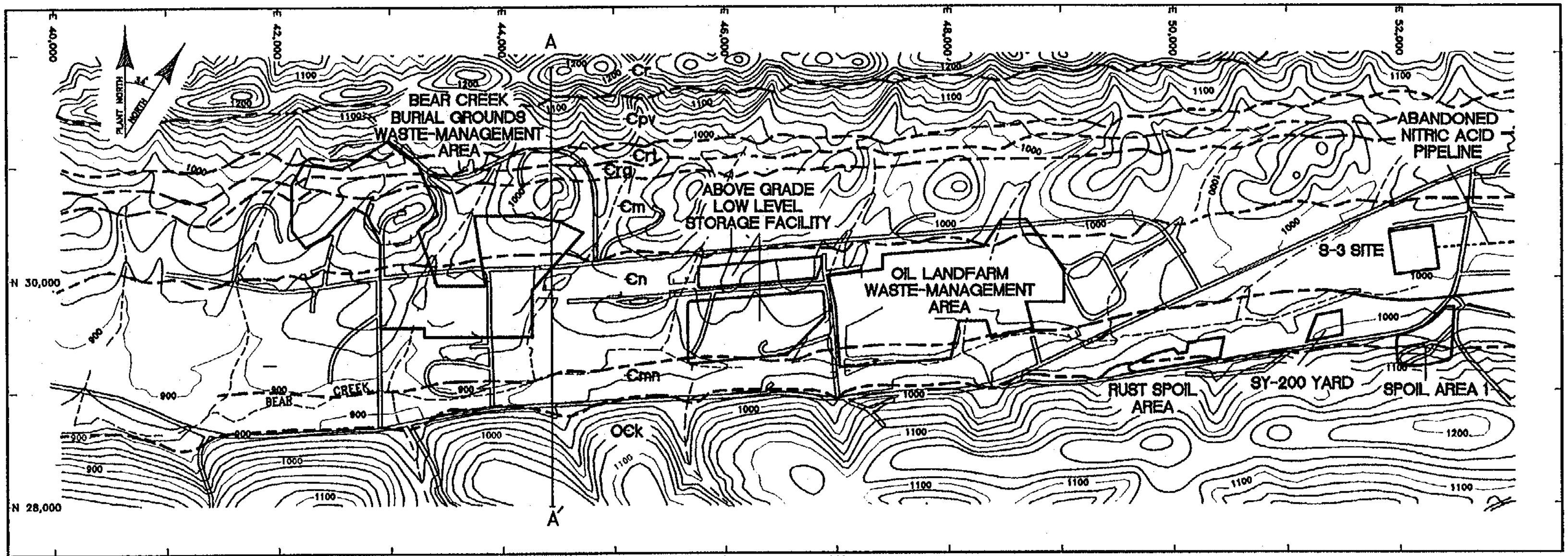
FIGURE 8

SURROGATE CLUSTER
CLASSIFICATION MODEL

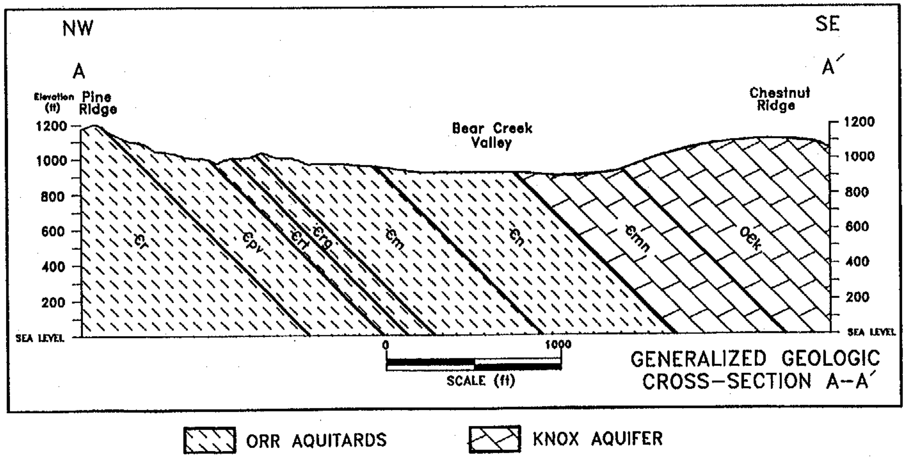


SOURCE: National Oceanic and Atmospheric Administration

LOCATION:	Y-12 PLANT OAK RIDGE, TN.	**FIGURE 9**
DATE:	8-9-95	**RAINFALL DURING SAMPLING EVENTS IN CY 1994**
DWG ID.:	RAIN2	



SOURCE: King and Haase, 1987



GENERALIZED GEOLOGIC CROSS-SECTION A-A´

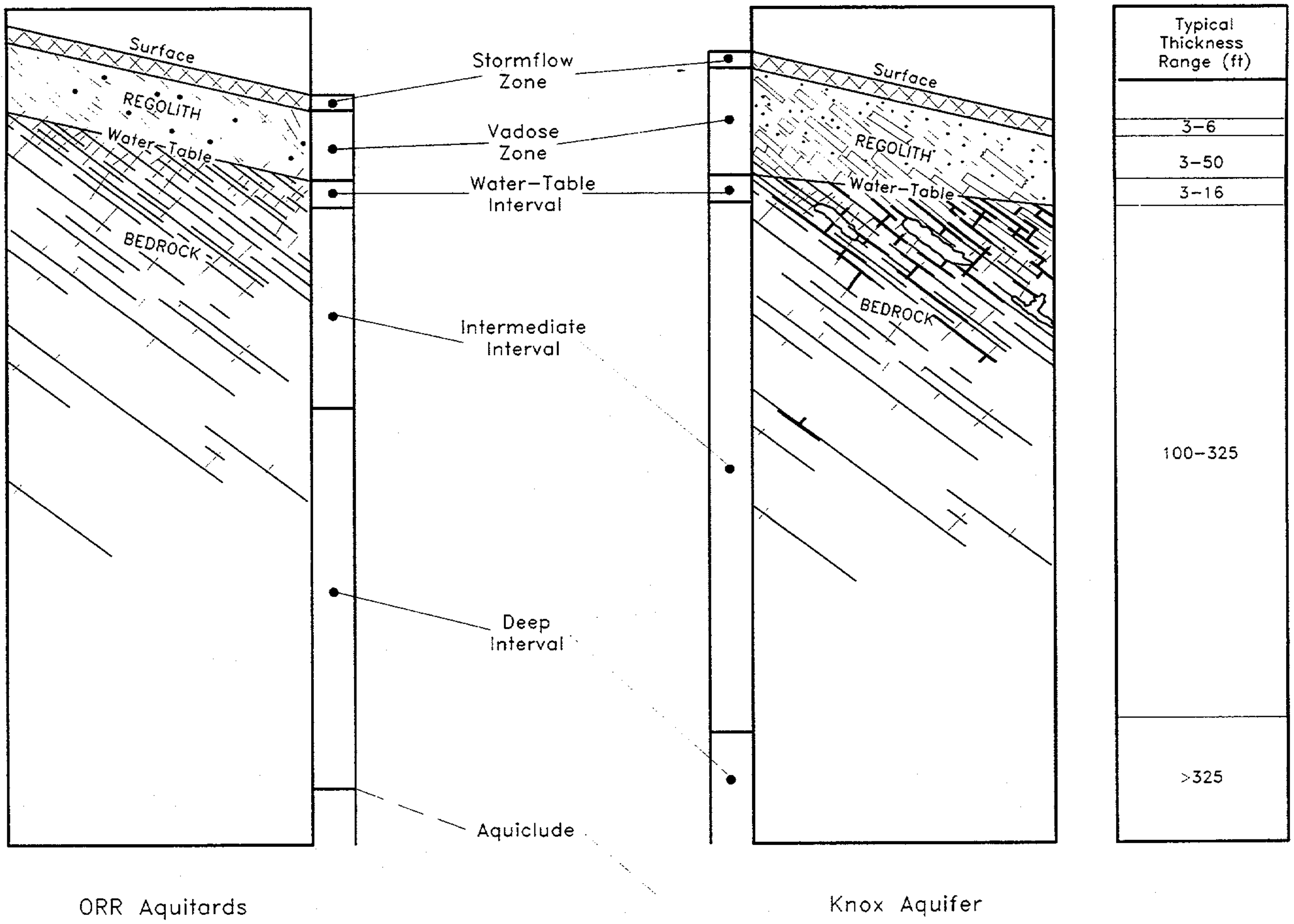
SYSTEM		GROUP	HYDRO UNIT	FORMATION	MAP SYMBOL	THICKNESS (ft)
CAMBRIAN	UPPER	KNOX	KNOX AQUIFER	COPPER RIDGE DOLOMITE	OꞒk	NOT DETERMINED
		CONASAUGA		MAYNARDVILLE LIMESTONE	Ꞓmn	418–450
	MIDDLE		ORR AQUITARDS	NOLICHUCKY SHALE	Ꞓn	422–550
				MARYVILLE LIMESTONE	Ꞓm	346–445
				ROGERSVILLE SHALE	Ꞓrg	90–120
				RUTLEDGE LIMESTONE	Ꞓrt	90–120
				PUMPKIN VALLEY SHALE	Ꞓpv	260–320
	LOWER			ROME	Ꞓr	NOT DETERMINED

LOCATION:	Y-12 PLANT OAK RIDGE, TN.
DATE:	8-6-95
DWG ID.:	OR006-HC

FIGURE 10

TOPOGRAPHY AND BEDROCK GEOLOGY IN THE BEAR CREEK HYDROGEOLOGIC REGIME

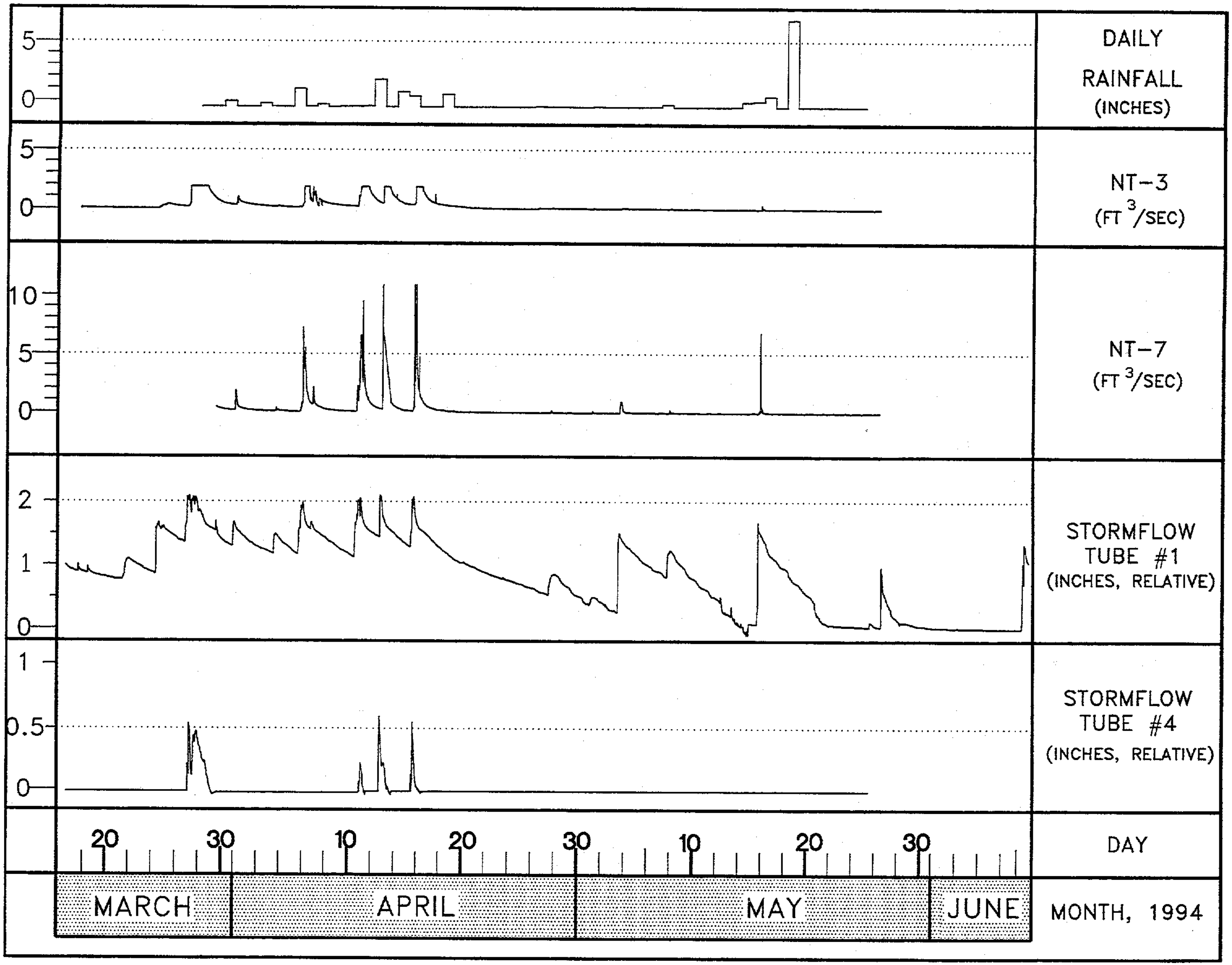
HYDROSTRATIGRAPHIC UNITS
PROPOSED BY SOLOMON *et al*. (1992)



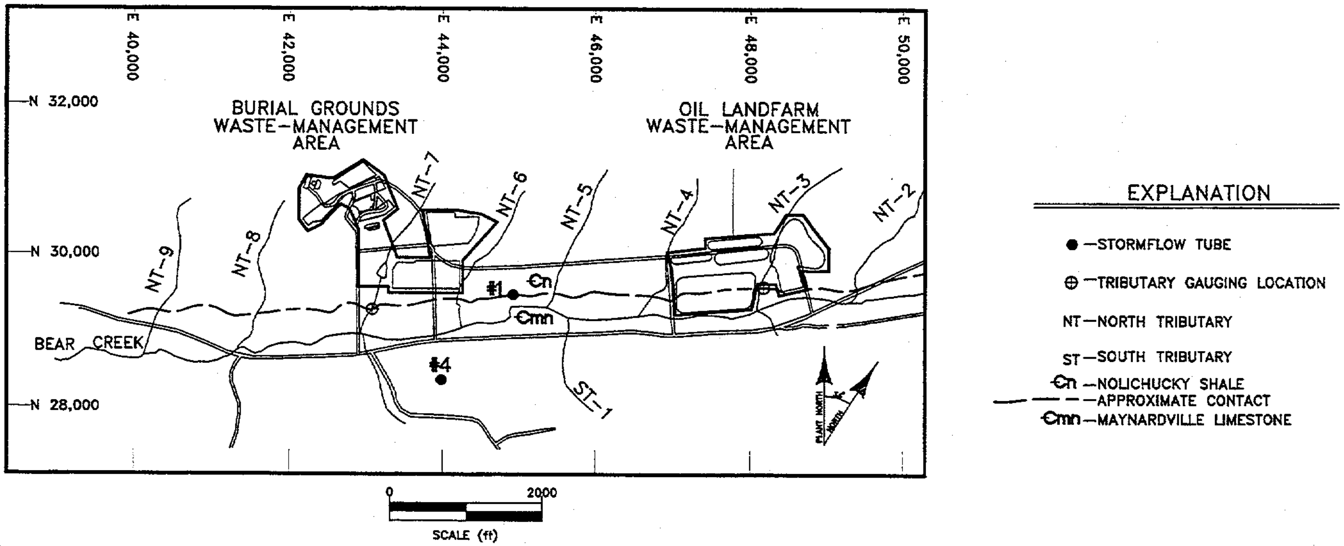
LOCATION:	Y-12 PLANT OAK RIDGE, TN.
DATE:	8-6-94
DWG ID.:	OR213-HC

FIGURE 11

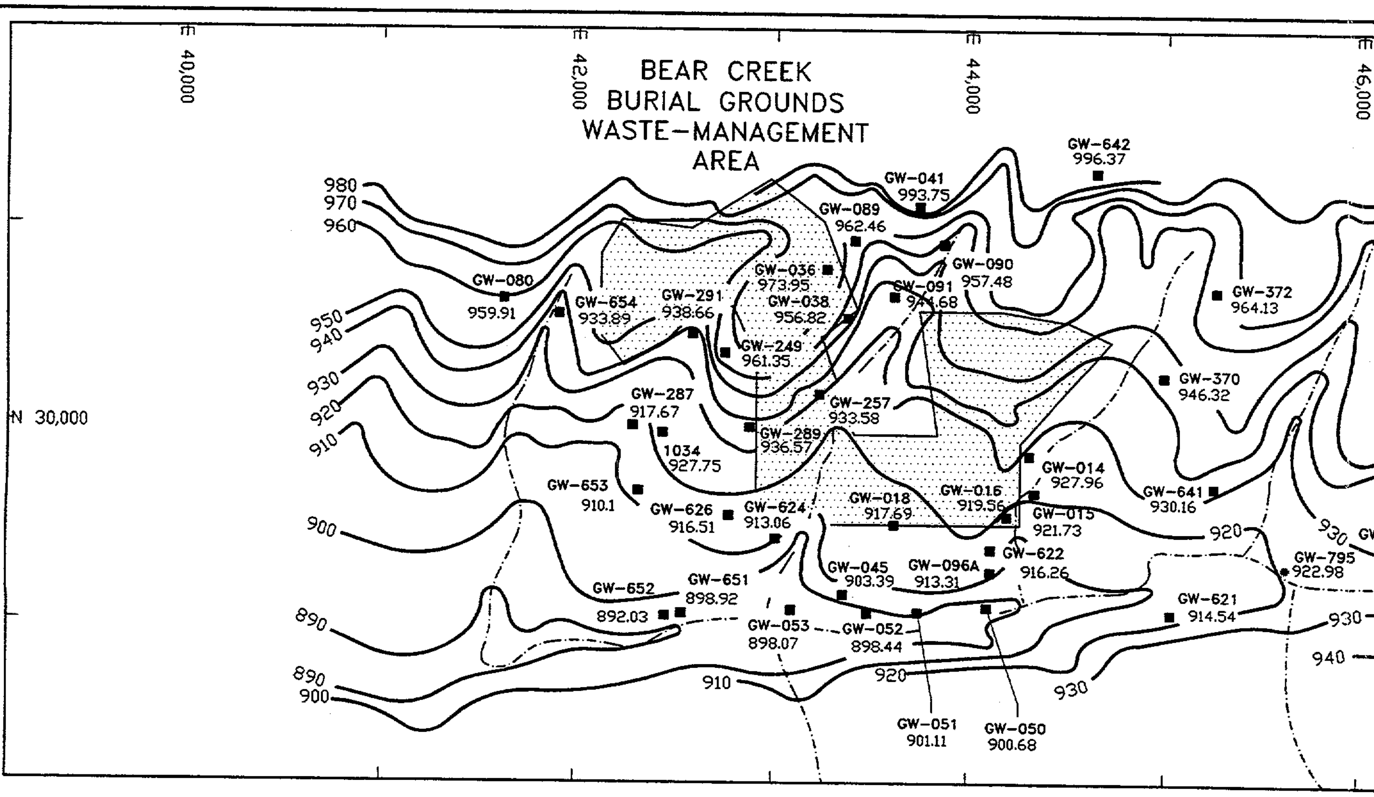
SCHEMATIC PROFILE
OF HYDROSTRATIGRAPHIC UNITS IN THE
BEAR CREEK HYDROGEOLOGIC REGIME



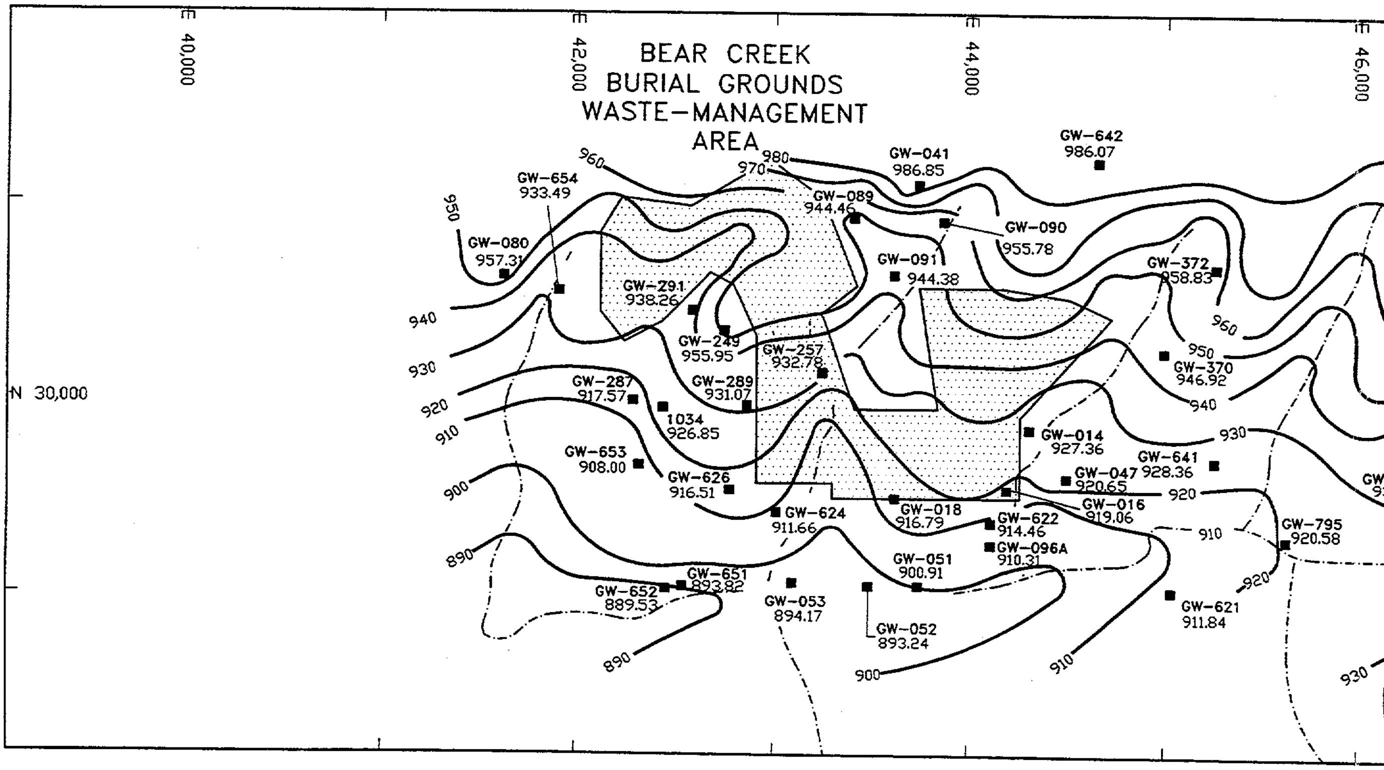
SOURCE: SAIC, 1994.



LOCATION:	Y-12 PLANT OAK RIDGE, TN.	**FIGURE 12**
DATE:	2-13-95	**RAINFALL RESPONSES IN THE STORMFLOW ZONE**
DWG ID.:	OR414-HC	



Janu



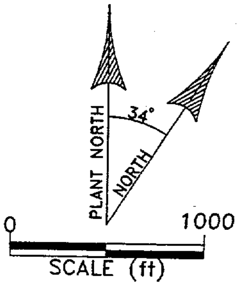
Augu

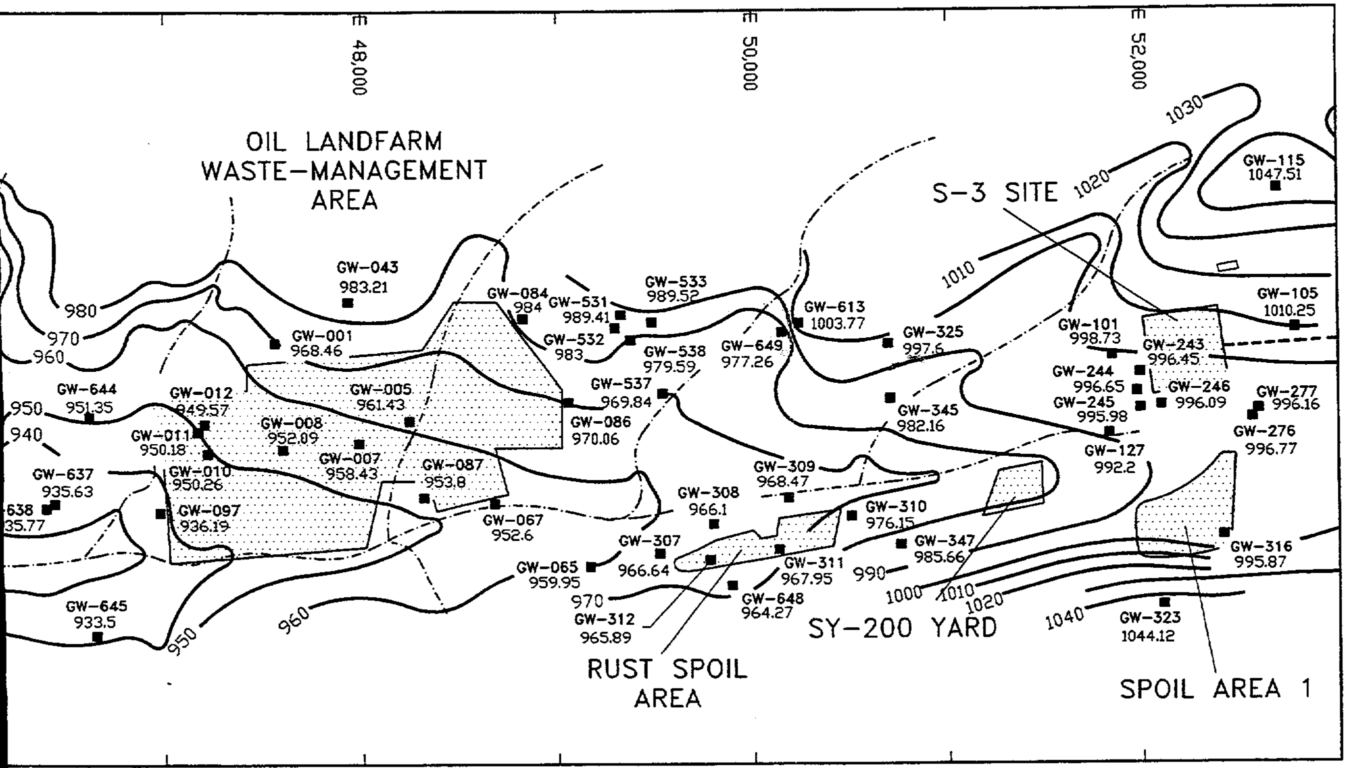
EXPLANATION

GW-372 ■ 967.63 — Water Table Monitoring Well

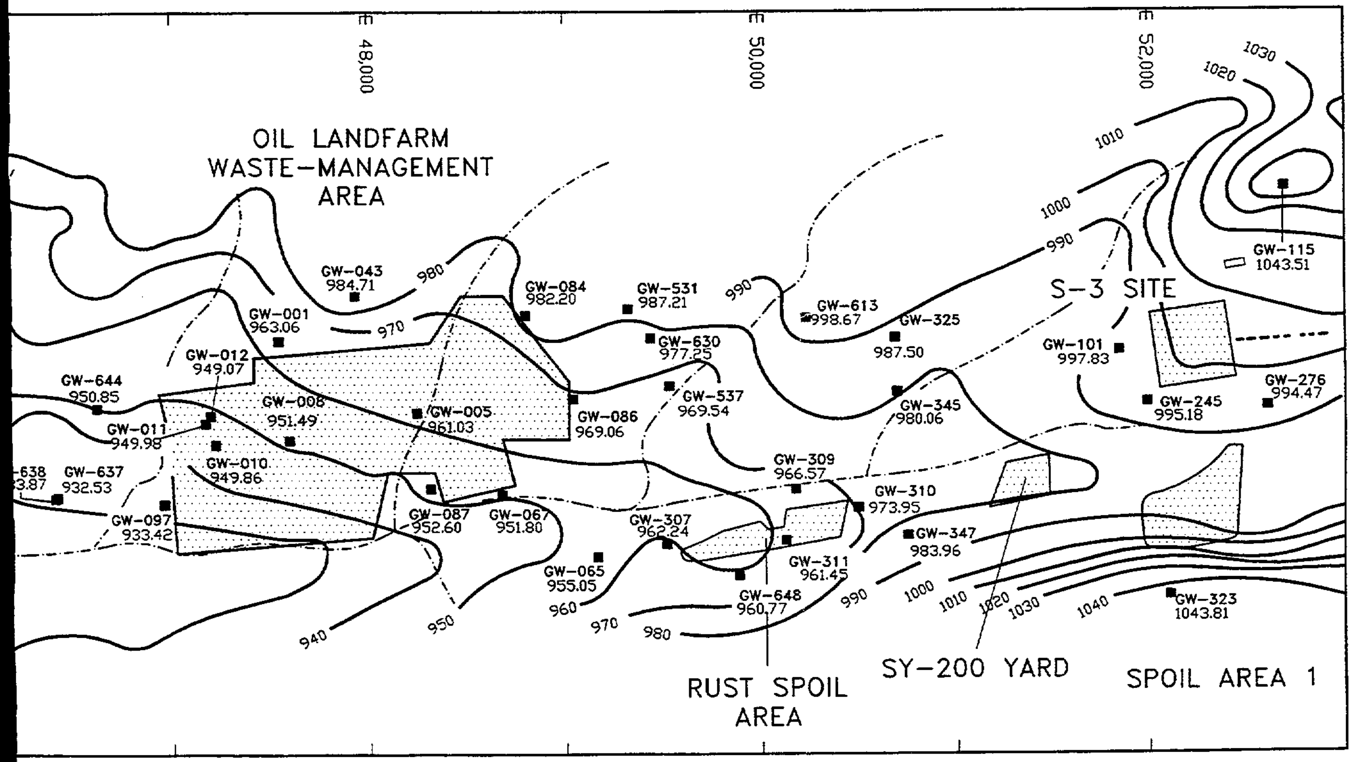
— Approximate Water Level Isopleth (ft msl)

— Surface Drainage Feature



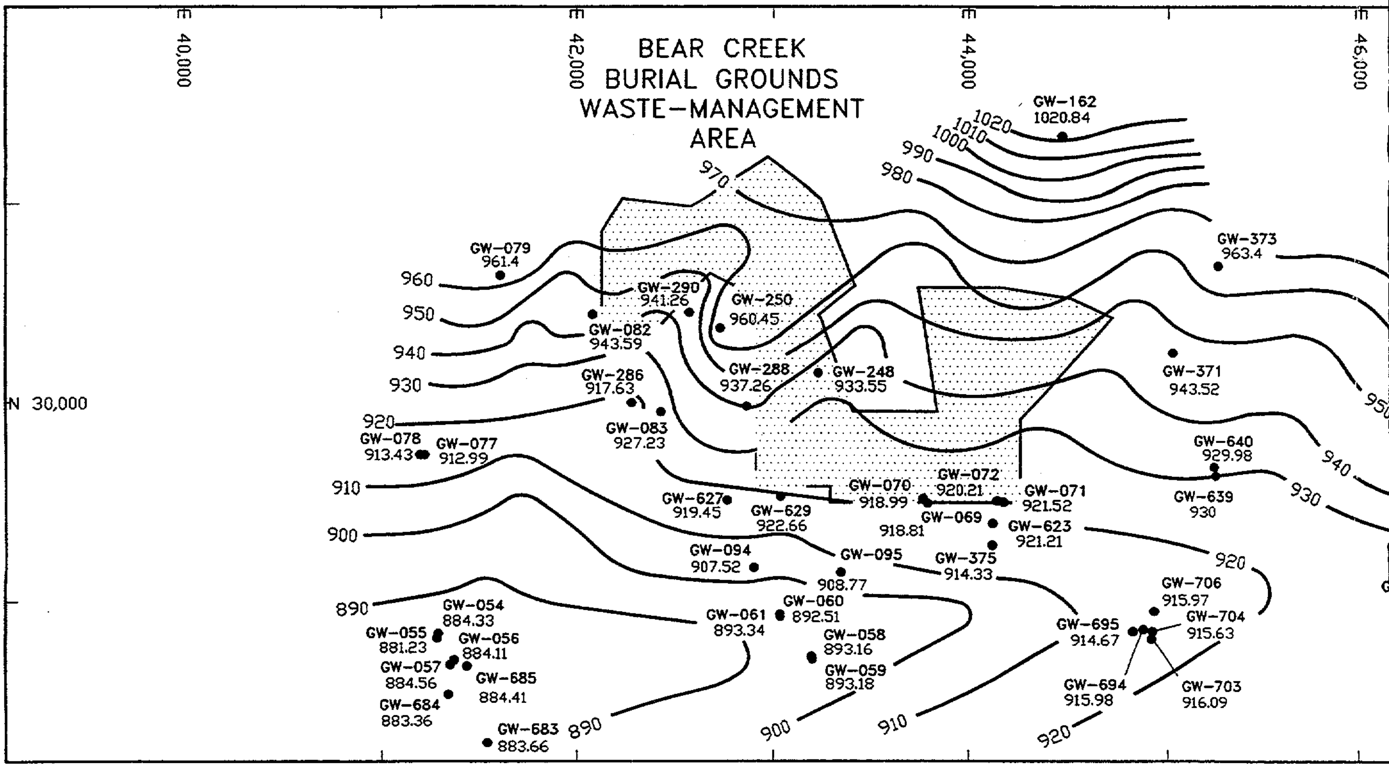


ary 10–13, 1994

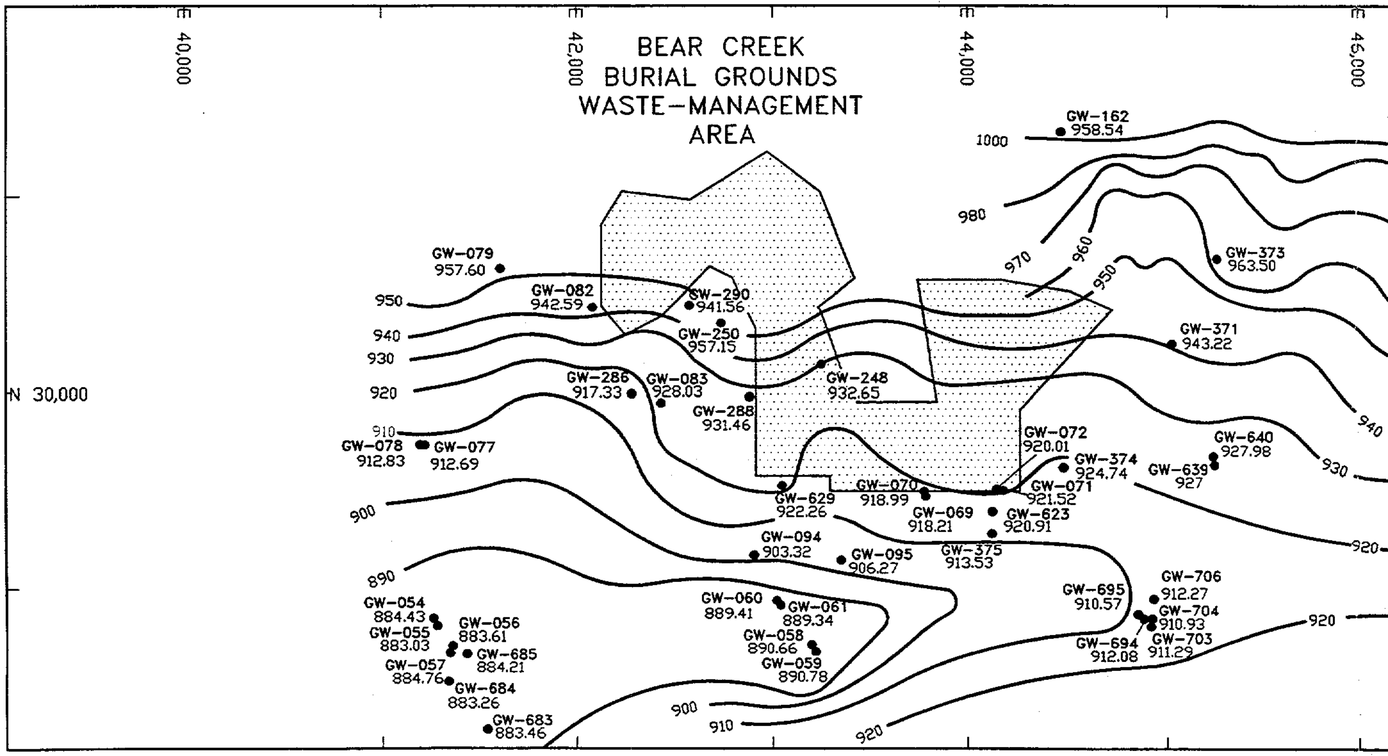


ust 23–31, 1994

LOCATION:	Y–12 PLANT OAK RIDGE, TN.	**FIGURE 13**
DATE:	8–6–95	**GROUNDWATER ELEVATIONS IN THE WATER TABLE INTERVAL**
DWG ID.:	OR471–HC	



Janu



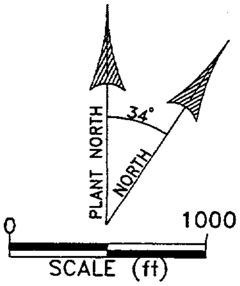
Augu

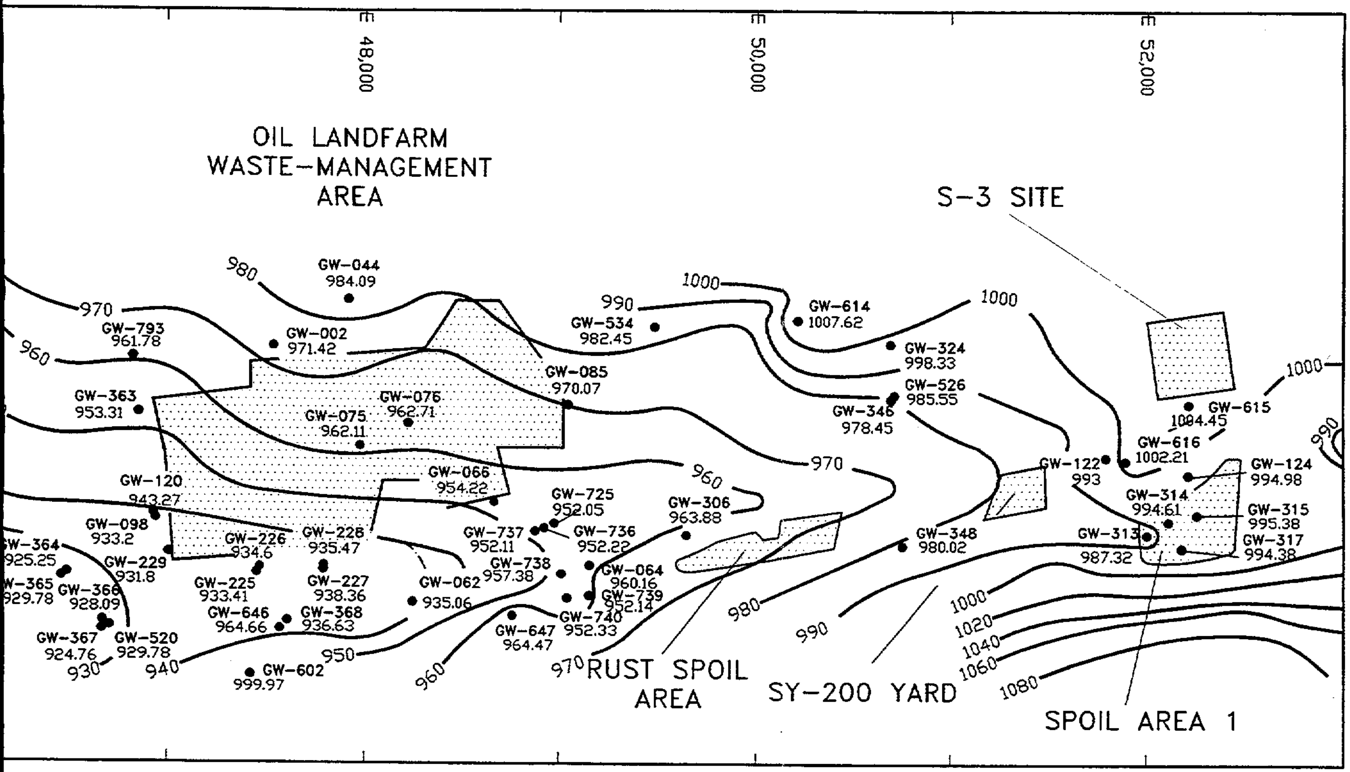
EXPLANATION

GW-627 917.55 ● — Bedrock Monitoring Well and Water Level Elevations

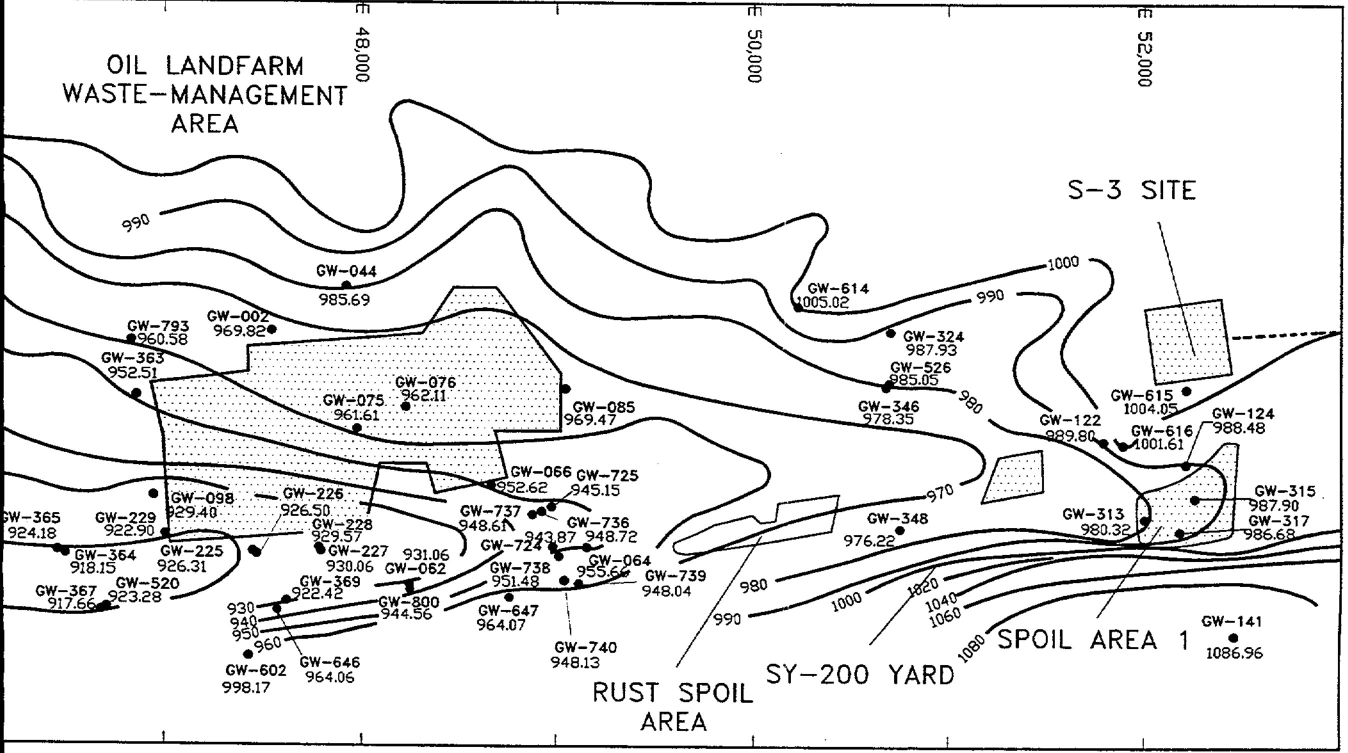
— Approximate Water Level Isopleth (ft msl)

— Surface Drainage Feature



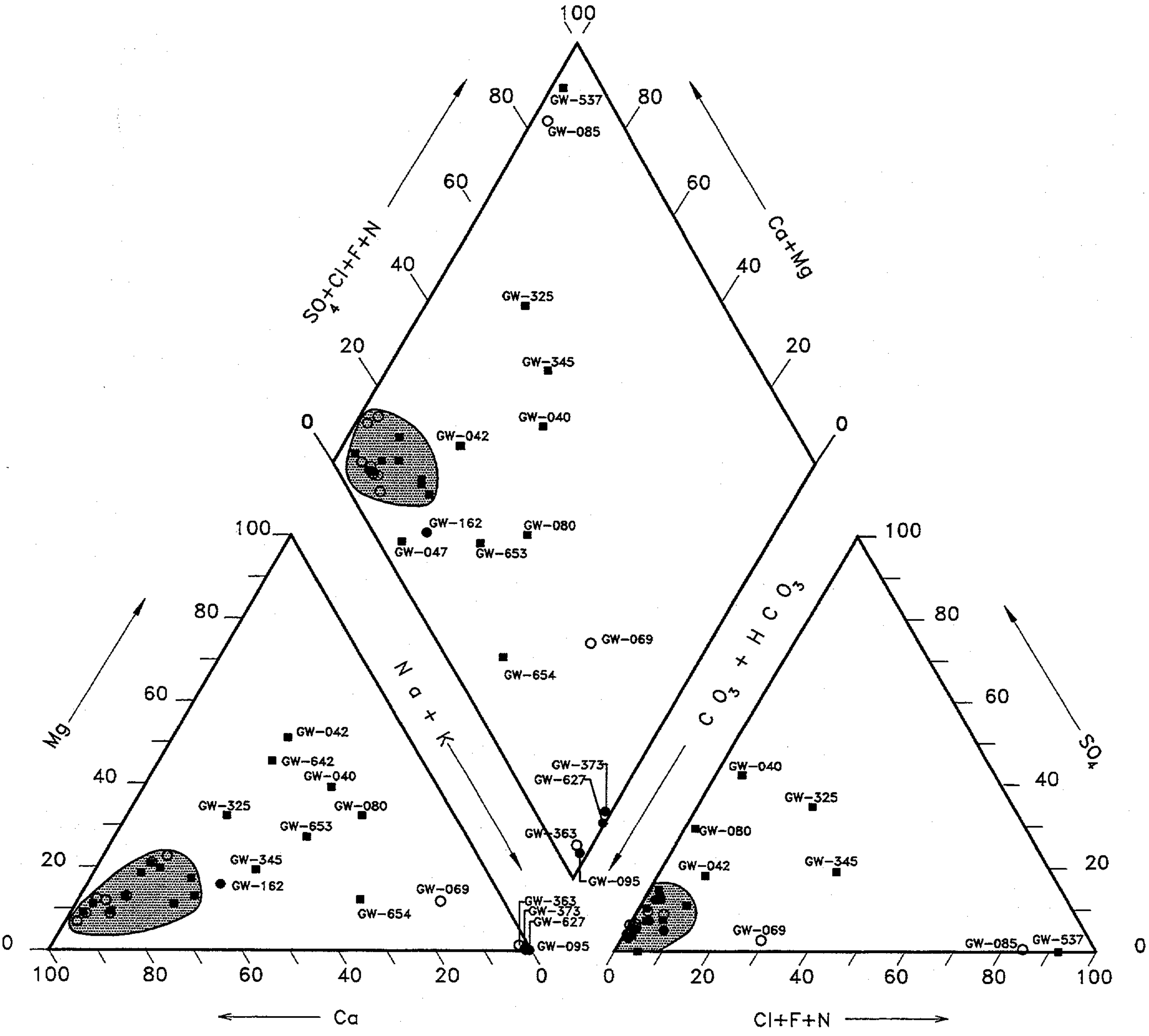


…ary 10-13, 1994



…st 23-31, 1994

LOCATION:	Y-12 PLANT OAK RIDGE, TN.	**FIGURE 14**
DATE:	8-6-95	**GROUNDWATER ELEVATIONS IN THE SHALLOW AND INTERMEDIATE BEDROCK INTERVALS**
DWG ID.:	OR470-HC	



EXPLANATION

▨ — GROUNDWATER COMPOSITIONS CLUSTER IN THESE AREAS; 31 WELLS ARE PLOTTED

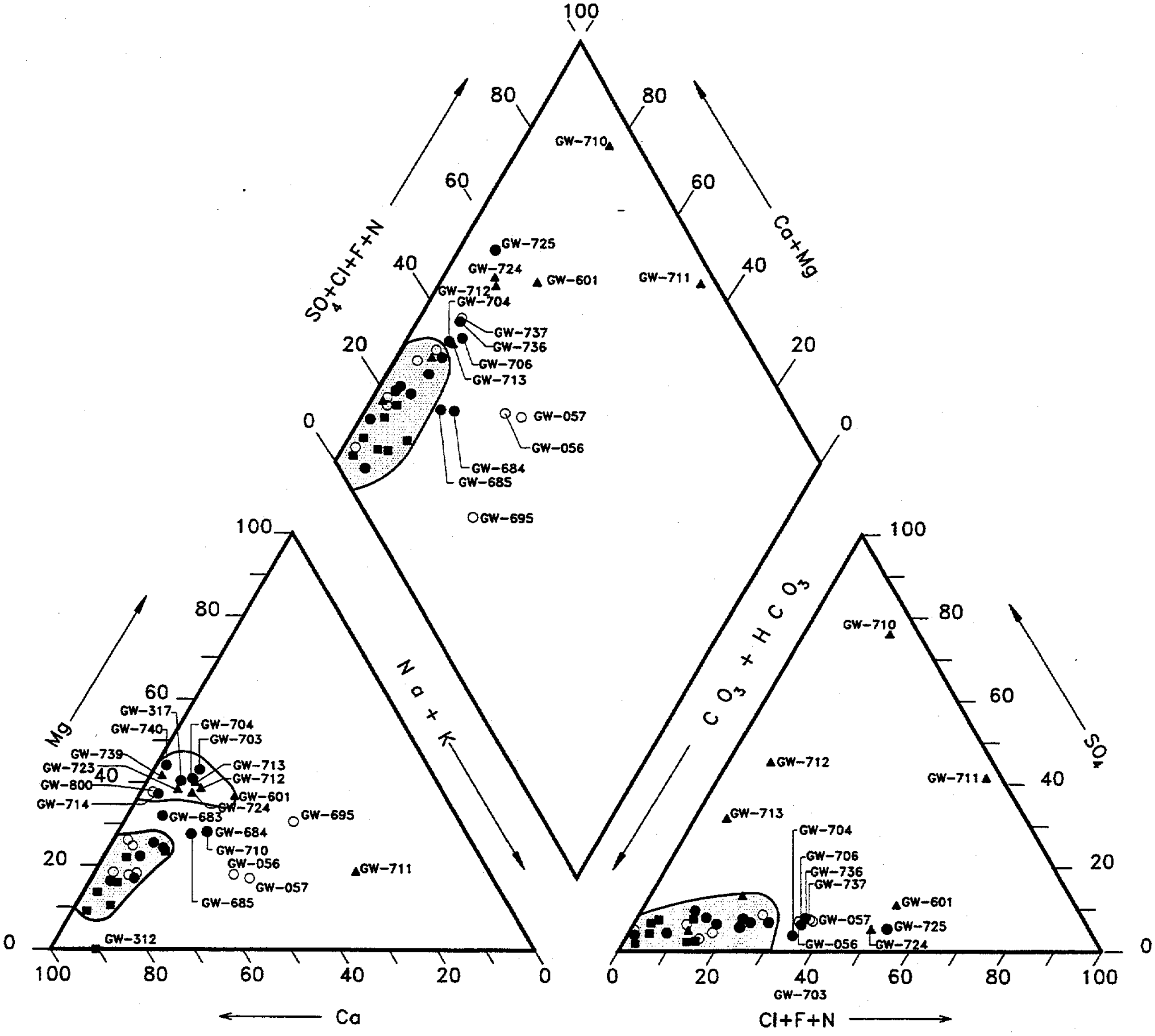
■ — WATER TABLE MONITORING WELL

○ — BEDROCK MONITORING WELL, LESS THAN 100 FT DEEP

● — BEDROCK MONITORING WELL, 100 TO 300 FT DEEP

▲ — BEDROCK MONITORING WELL, GREATER THAN 300 FT DEEP

LOCATION:	Y-12 PLANT OAK RIDGE, TN	FIGURE 15
DATE:	8-9-95	GROUNDWATER GEOCHEMISTRY IN THE CONASAUGA SHALES
DWG ID.:	OR488-HC	



EXPLANATION

▭ — GROUNDWATER COMPOSITIONS CLUSTER IN THESE AREAS; 38 WELLS ARE PLOTTED

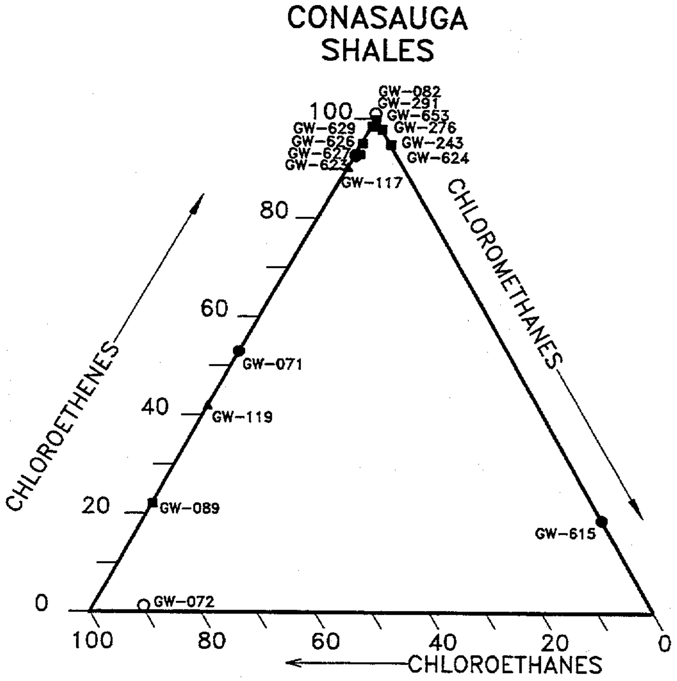
■ — WATER TABLE MONITORING WELL

○ — BEDROCK MONITORING WELL, LESS THAN 100 FT DEEP

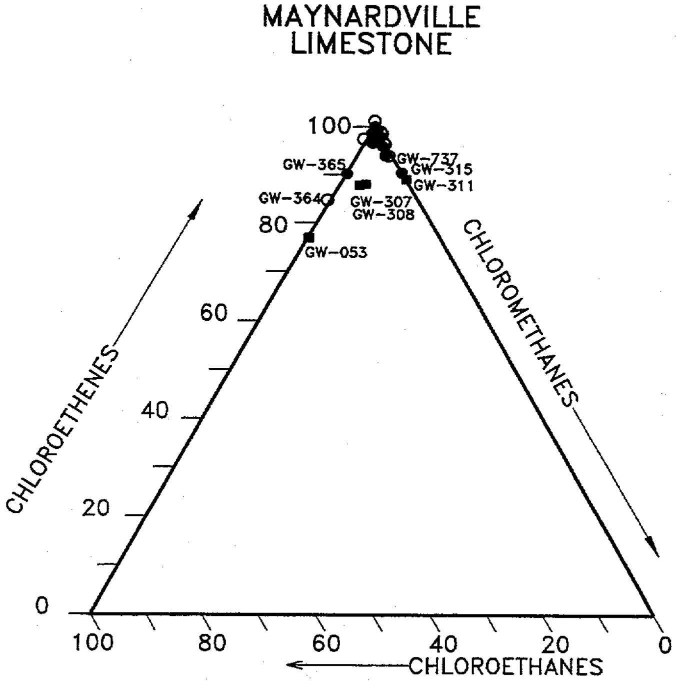
● — BEDROCK MONITORING WELL, 100 TO 300 FT DEEP

▲ — BEDROCK MONITORING WELL, GREATER THAN 300 FT DEEP

LOCATION:	Y-12 PLANT OAK RIDGE, TN	**FIGURE 16**
DATE:	9-26-95	**GROUNDWATER GEOCHEMISTRY IN THE MAYNARDVILLE LIMESTONE**
DWG ID.:	OR487-HC	



CONASAUGA SHALES



MAYNARDVILLE LIMESTONE

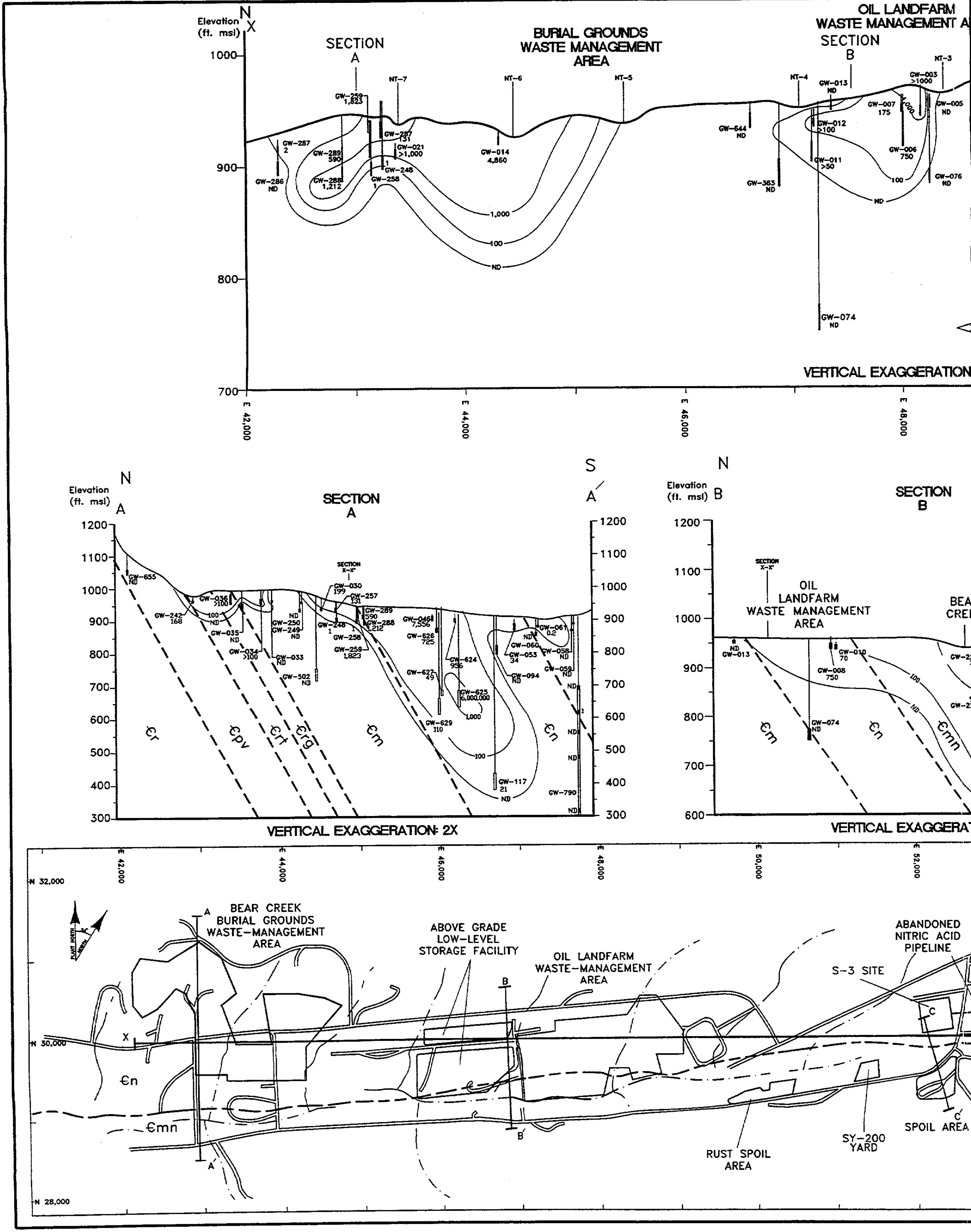
EXPLANATION

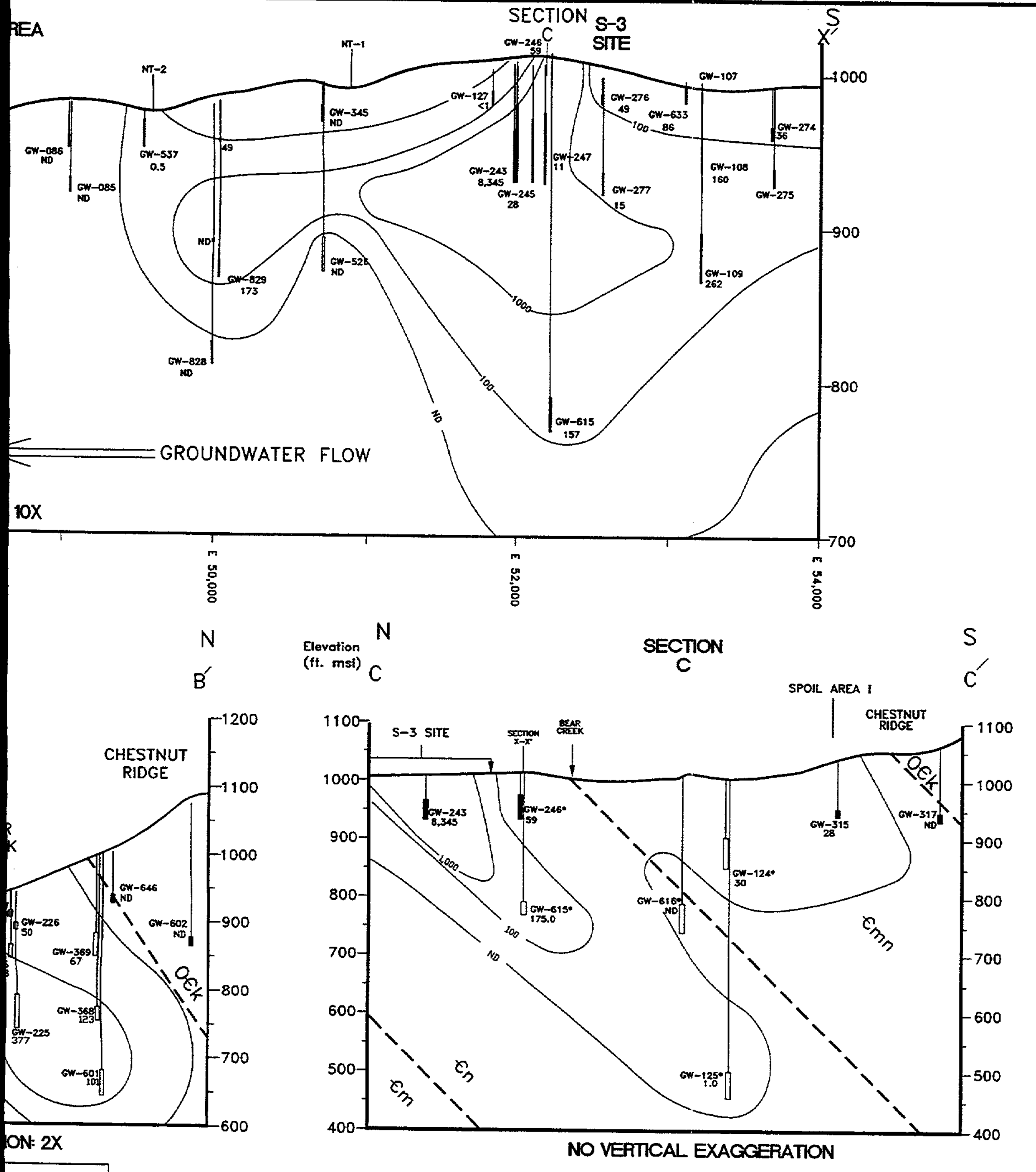
■ — WATER-TABLE INTERVAL MONITORING WELL
○ — BEDROCK INTERVAL MONITORING WELL, <100 FT DEEP
● — BEDROCK INTERVAL MONITORING WELL, 100 TO 300 FT DEEP
▲ — BEDROCK INTERVAL MONITORING WELL, >300 FT DEEP

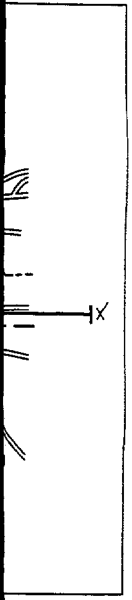
Compound Proportions Determined from CY 1991–1994 Average Concentrations.

CHLOROETHENES: PCE, TCE, 1,2-DCE, 1,1-DCE, VINYL CHLORIDE
CHLOROETHANES: 1,1,1-TCA, 1,1-DCA
CHLOROMETHANES: CARBONTETRACHLORIDE, CHLOROFORM, METHYLENE CHLORIDE

LOCATION:	Y-12 PLANT OAK RIDGE, TN	FIGURE 17
DATE:	8-27-95	DISTRIBUTION OF VOCs IN GROUNDWATER
DWG ID.:	OR609-HC	


Elevation (ft. msl)
N
X
1000
900
800
700
SECTION A
BURIAL GROUNDS WASTE MANAGEMENT AREA
OIL LANDFARM WASTE MANAGEMENT A
SECTION B
NT-7
NT-6
NT-5
NT-4
NT-3
GW-259 1,823
GW-287 2
GW-289 590
GW-288 1,212
GW-286 ND
GW-257 131
GW-021 >1,000
GW-248 1
GW-258 1
GW-014 4,860
GW-644 ND
GW-363 ND
GW-013 ND
GW-012 >100
GW-011 >50
GW-074 ND
GW-007 175
GW-003 >1000
GW-005 ND
GW-006 750
GW-076 ND
1,000
100
ND
VERTICAL EXAGGERATION
E 42,000
E 44,000
E 46,000
E 48,000
N
S
A
A′
SECTION A
SECTION X-X′
1200
1100
1000
900
800
700
600
500
400
300
GW-655 ND
GW-036 >100
GW-242 168
GW-035 ND
GW-034 >100
GW-250 ND
GW-249 ND
GW-033
GW-502 ND
GW-030 199
GW-257 131
GW-248 1
GW-258
GW-289 590
GW-288 1,212
GW-259 1,823
GW-046 7,556
GW-626 725
GW-624 956
GW-627 49
GW-625 6,000,000
GW-629 110
GW-117 21
GW-061 0.2
GW-060
GW-053 34
GW-058 ND
GW-059 ND
GW-094 ND
GW-790
€r
€pv
€rt
€rg
€m
€n
1,000
100
ND
VERTICAL EXAGGERATION: 2X
N
B
SECTION B
SECTION X-X′
OIL LANDFARM WASTE MANAGEMENT AREA
BEA CREE
GW-013 ND
GW-010 70
GW-008 750
GW-074 ND
€m
€n
€mn
100
ND
1200
1100
1000
900
800
700
600
VERTICAL EXAGGERAT
E 42,000
E 44,000
E 46,000
E 48,000
E 50,000
E 52,000
N 32,000
N 30,000
N 28,000
PLANT NORTH
NORTH
BEAR CREEK BURIAL GROUNDS WASTE-MANAGEMENT AREA
ABOVE GRADE LOW-LEVEL STORAGE FACILITY
OIL LANDFARM WASTE-MANAGEMENT AREA
ABANDONED NITRIC ACID PIPELINE
S-3 SITE
SPOIL AREA
SY-200 YARD
RUST SPOIL AREA
X
A
A′
B
B′
C
C′
€n
€mn



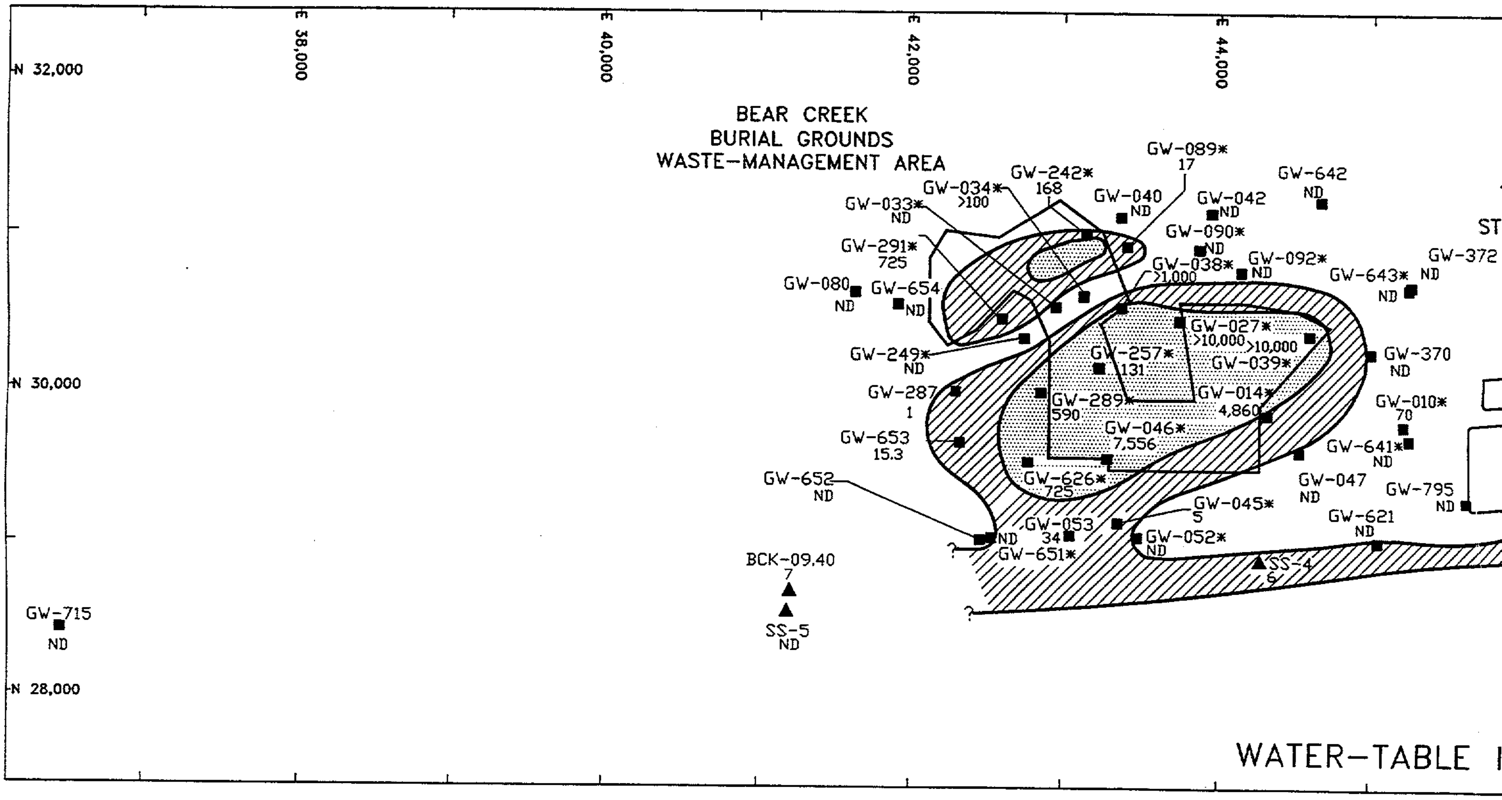


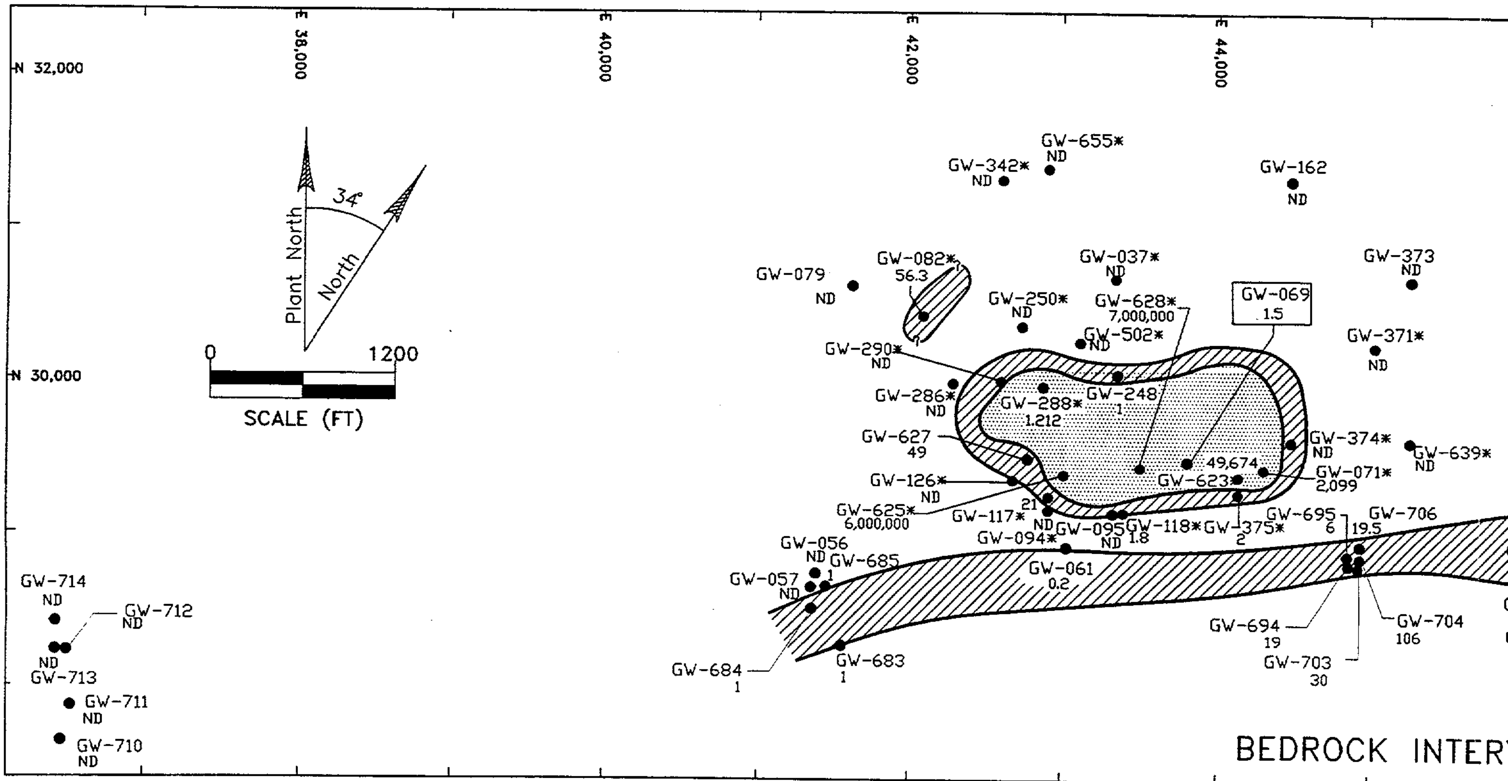
EXPLANATION

GW-685 0.2 ——	WELL NUMBER AND SUMMED AVERAGE VOC CONCENTRATION (ug/L)
* ——	WELLS SAMPLED BEFORE 1994 (DATA QUALITATIVE)
—100— — ——	APPROXIMATE LINE OF EQUAL CONCENTRATION (ug/L)
ND ——	NOT DETECTED
▮ ——	SCREENED WELL CONSTRUCTION
▯ ——	OPEN-HOLE WELL CONSTRUCTION
▮ ——	WEST BAY SYSTEM SAMPLING PORTS SAMPLES COLLECTED IN DECEMBER 1994

– – – ——	APPROXIMATE GEOLOGIC CONTACT MODIFIED FROM KING AND HAAS 1987
OЄk ——	KNOX GROUP
Єmn ——	MAYNARDVILLE LIMESTONE
Єn ——	NOLICHUCKY SHALE
Єm ——	MARYVILLE LIMESTONE
Єrg ——	ROGERSVILLE SHALE
Єrt ——	RUTLEDGE LIMESTONE
Єpv ——	PUMPKING VALLEY SHALE
Єr ——	ROME

LOCATION:	Y-12 PLANT OAK RIDGE, TN.	**FIGURE 19**
DATE:	8-27-95	**VERTICAL DISTRIBUTION OF VOCs IN THE BEAR CREEK HYDROGEOLOGIC REGIME**
DWG ID.:	OR600-HC	





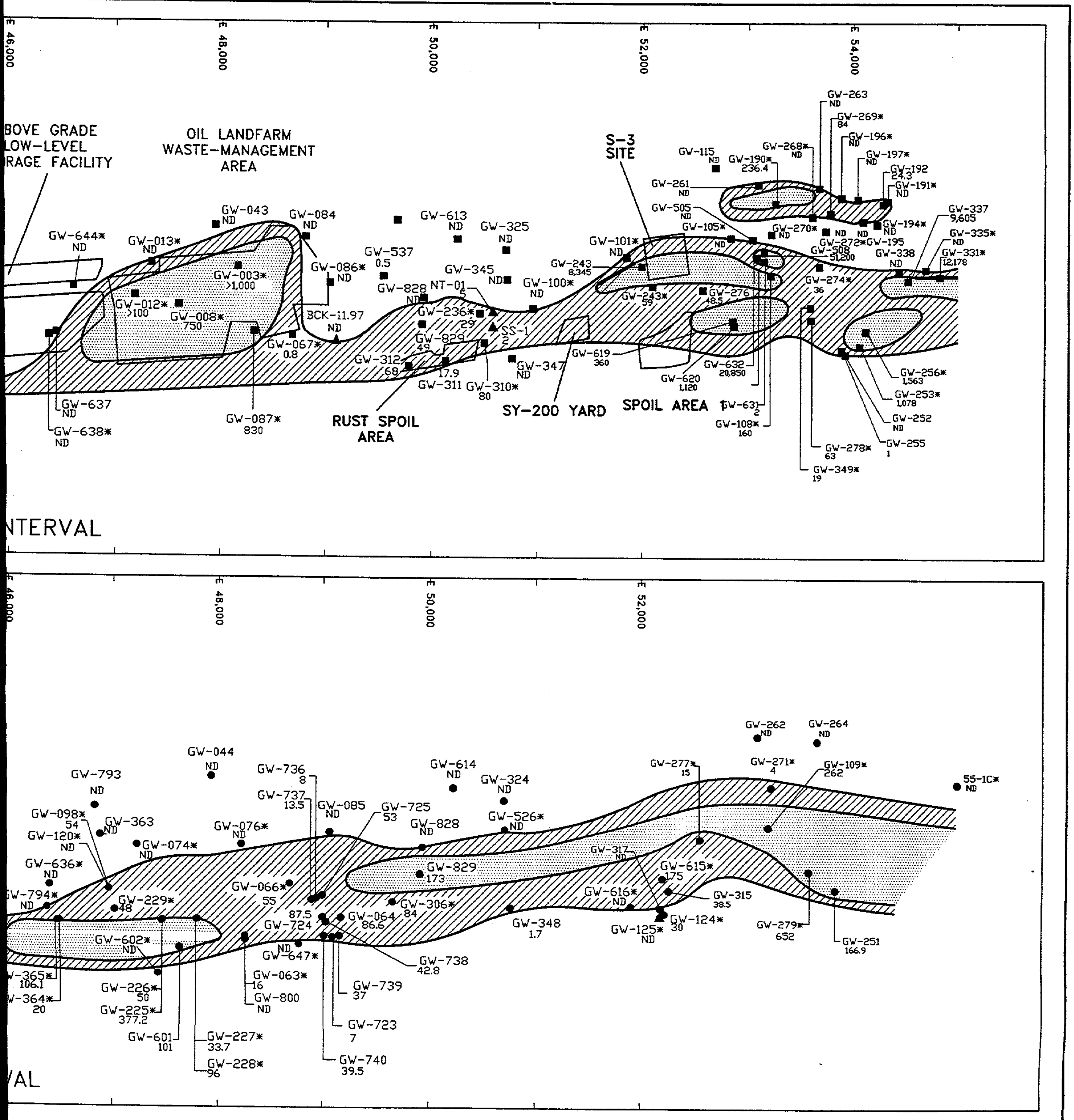
EXPLANATION

GW-739 Well Number
37 Summed Average VOC Concentration (ug/L)
ND Not Detected
■ Water Table Monitoring Well
✳ Indicates a Well Sampled Before 1994 (Data Qualitative)
● Bedrock Monitoring Well
▲ Spring (SS) or Surface-Water (BCK) Sampling Station

▨ — ND - Not Detected
— >100 ug/L

Boundary of Site or Waste-Manager

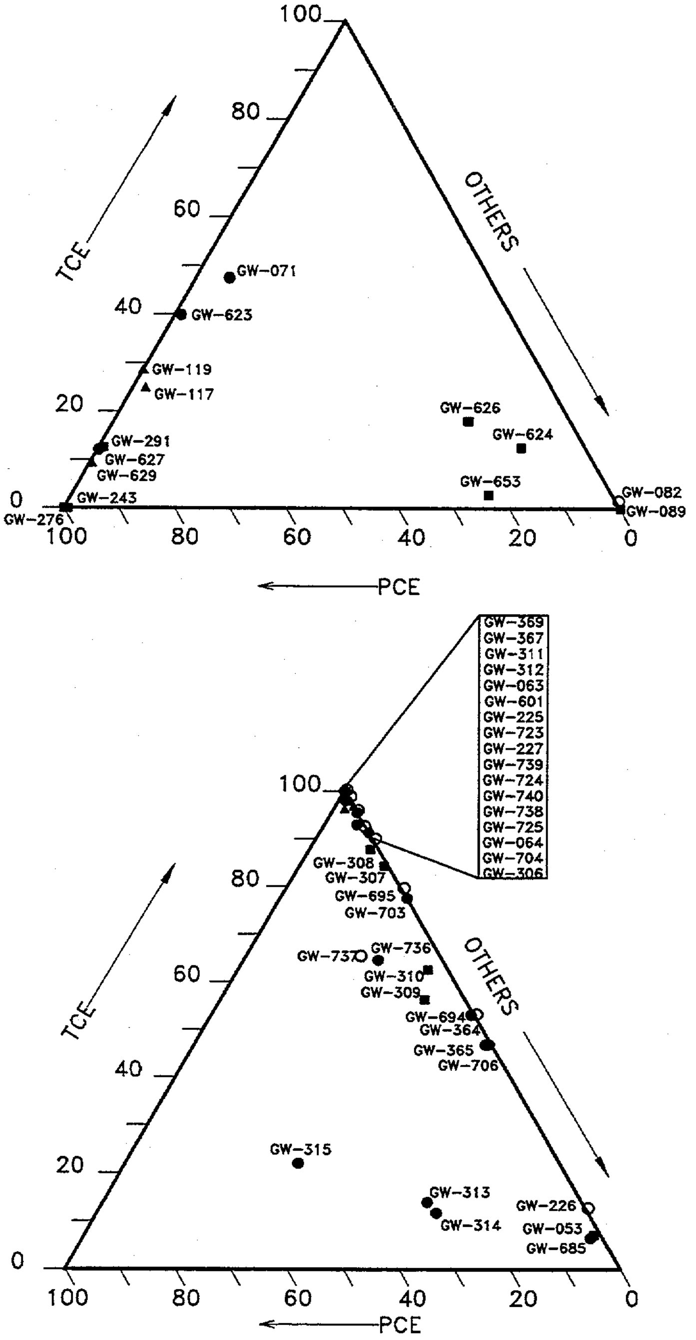
Surface Drainage Feature



	LOCATION:	Y-12 PLANT OAK RIDGE, TN.
ent Area	DATE:	8-21-95
	DWG ID.:	OR601-HC

FIGURE 18

VOCS IN GROUNDWATER AND SURFACE WATER IN THE BEAR CREEK HYDROGEOLOGIC REGIME



EXPLANATION

- ▲ — SURFACE WATER MONITORING WELL
- ■ — WATER-TABLE INTERVAL MONITORING WELL
- ○ — BEDROCK INTERVAL MONITORING WELL, <100 FT DEEP
- ● — BEDROCK INTERVAL MONITORING WELL, 100 TO 300 FT DEEP
- ▼ — BEDROCK INTERVAL MONITORING WELL, >300 FT DEEP

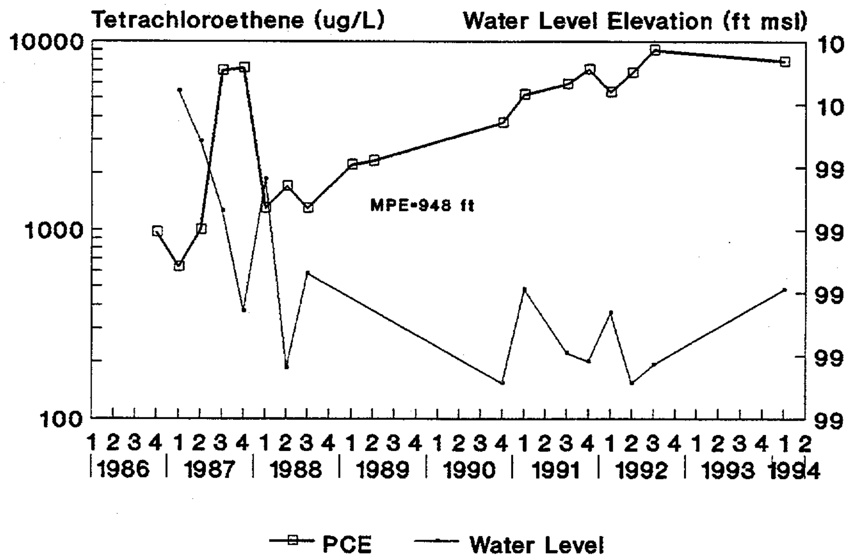
Compound Proportions Determined from CY 1991–1994 Average Concentrations.

CHLOROETHENES:	PCE, TCE, 1,2-DCE, 1,1-DCE, VINYL CHLORIDE
CHLOROETHANES:	1,1,1-TCA, 1,1-DCA
CHLOROMETHANES:	CARBONTETRACHLORIDE, CHLOROFORM, METHYLENE CHLORIDE
PETROLEUM HYDROCARBONS:	BENZENE, TOLUENE, ETHYLBENZENE, XYLENES

LOCATION:	Y-12 PLANT OAK RIDGE, TN	FIGURE 20
DATE:	8-27-95	DISTRIBUTION OF CHLOROETHENES IN GROUNDWATER
DWG ID.:	OR609-HC	

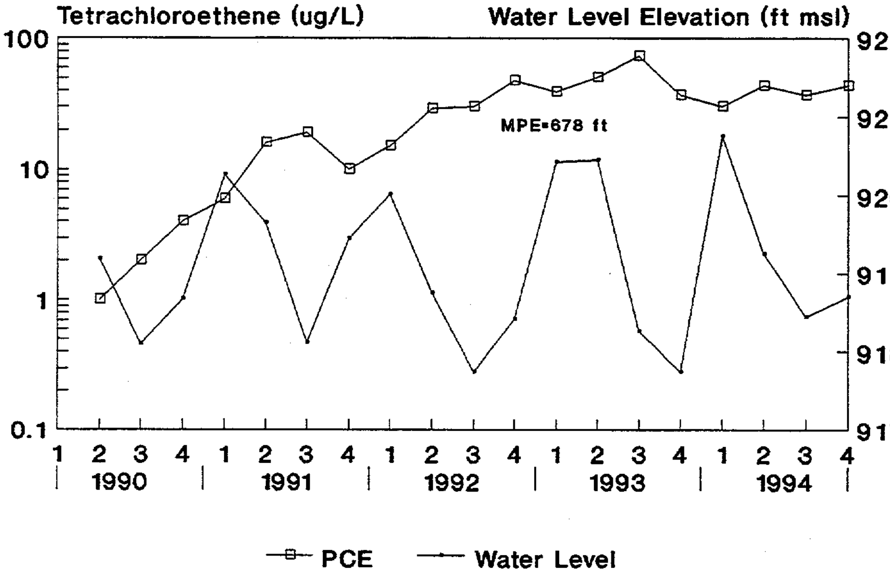
GW-243

S-3 Site



GW-627

Burial Grounds WMA

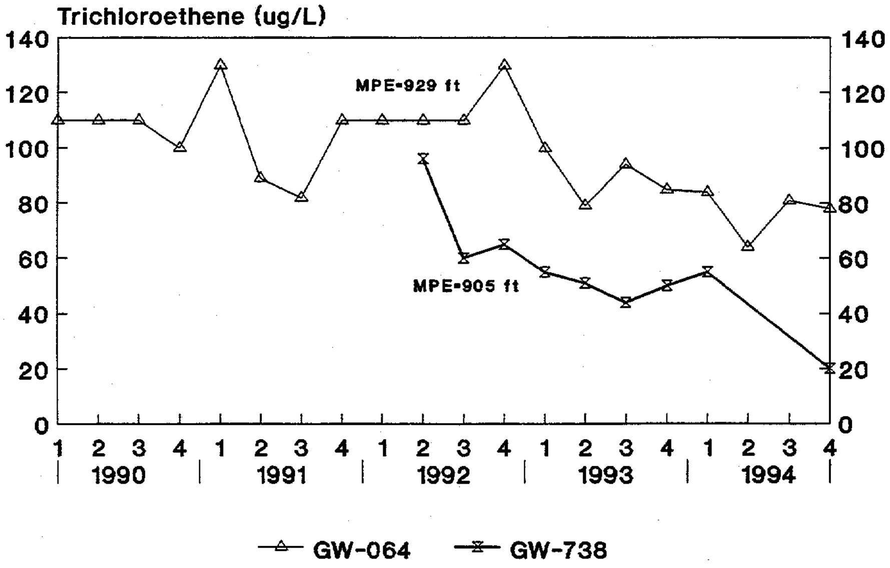


MPE: Midpoint Elevation (ft,msl)
of the Monitoring Interval

LOCATION:	Y-12 PLANT OAK RIDGE, TN.	FIGURE 21
DATE:	8-6-95	TETRACHLOROETHENE CONCENTRATIONS IN CONASAUGA SHALE WELLS GW-243 AND GW-627
DWG ID.:	HG21	

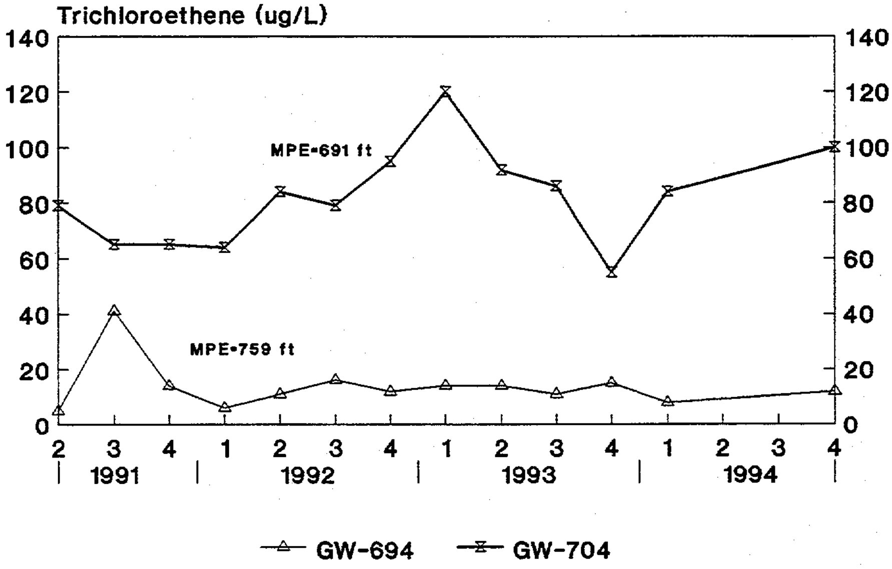
Section C *

(Upgradient)



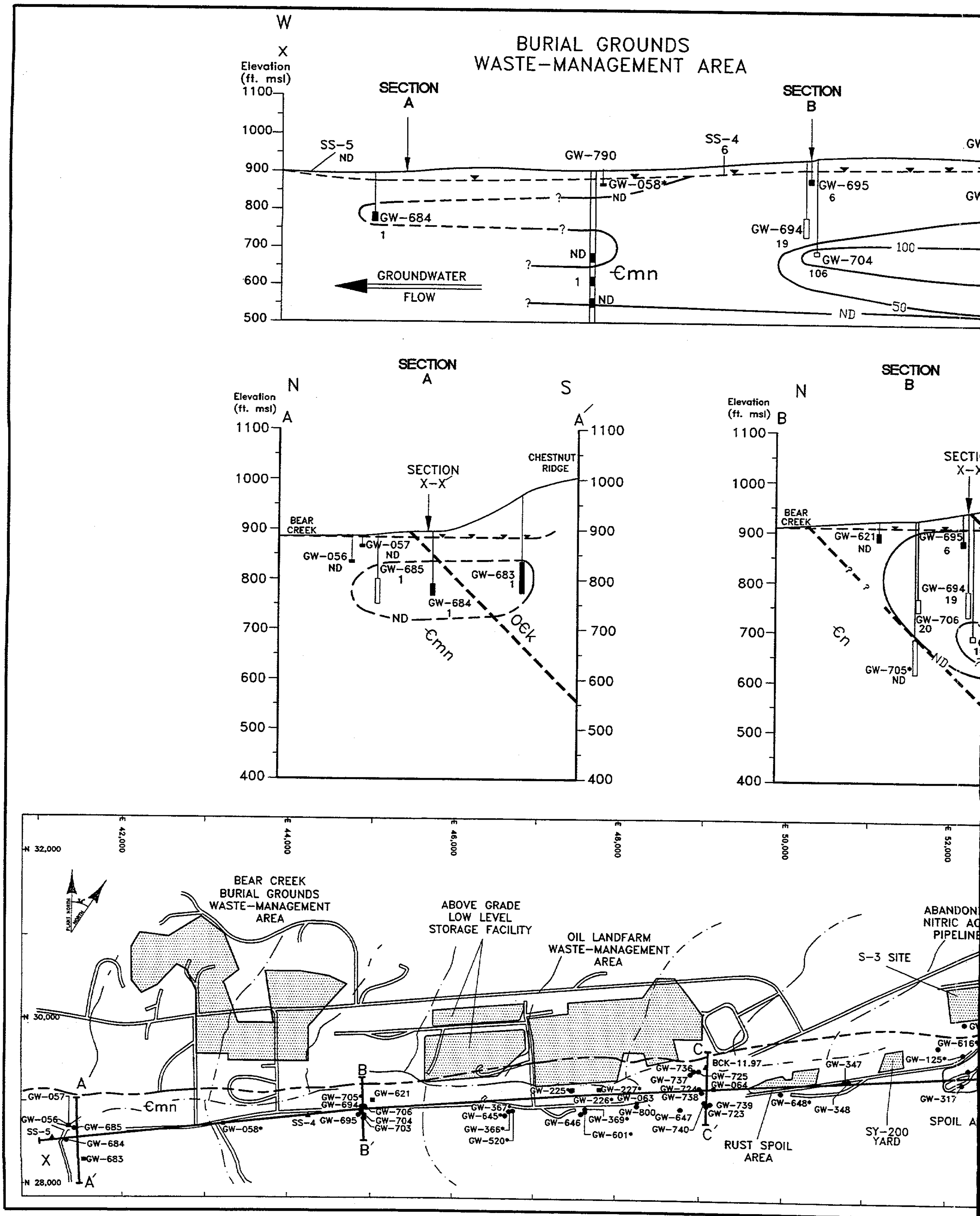
Section B *

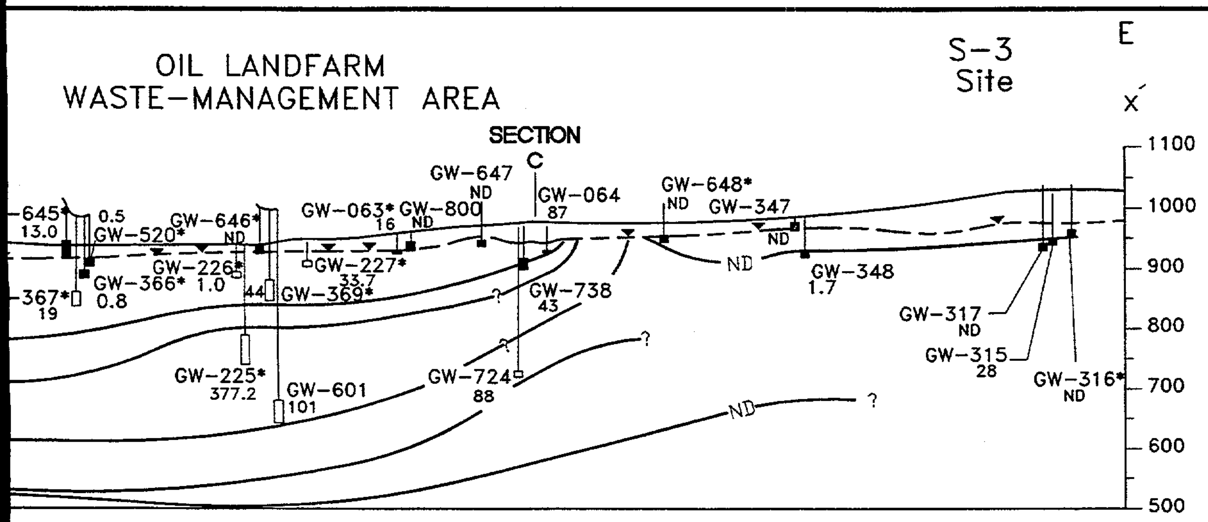
(Downgradient)

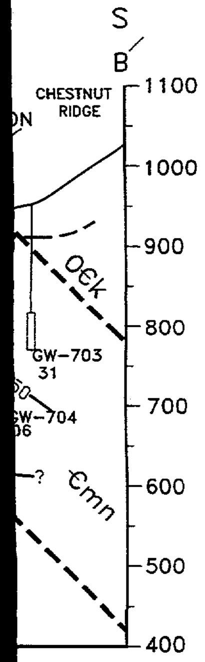


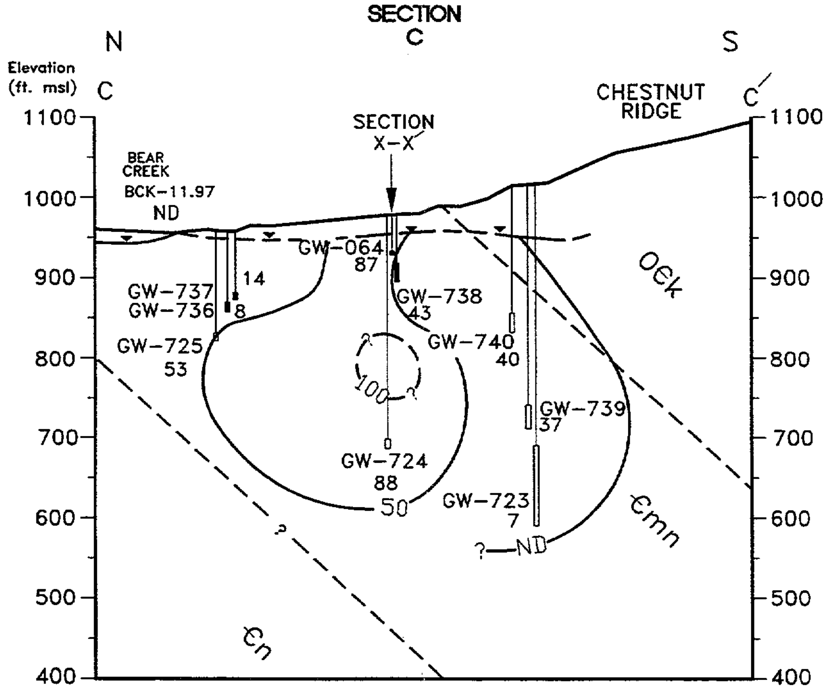
* Refer to Figure 23 for section locations
MPE: Midpoint Elevation (ft, msl)
of the Monitoring Interval

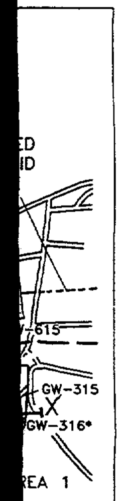
LOCATION:	Y-12 PLANT OAK RIDGE, TN.	FIGURE 22
DATE:	8-6-95	TRICHLOROETHENE CONCENTRATIONS IN MAYNARDVILLE LIMESTONE WELLS GW-064, GW-738, GW-694, AND GW-704
DWG ID.:	HG22	


W
X
BURIAL GROUNDS
WASTE-MANAGEMENT AREA
Elevation (ft. msl)
1100
1000
900
800
700
600
500
SECTION A
SECTION B
SS-5
ND
SS-4
6
GW-790
GW-058
ND
GW-684
1
ND
1
ND
Ꞓmn
GW-695
6
GW-694
19
GW-704
106
100
50
ND
GROUNDWATER FLOW
N
S
A
A′
SECTION X-X
CHESTNUT RIDGE
BEAR CREEK
GW-057
ND
GW-056
ND
GW-685
1
GW-683
1
GW-684
1
ND
Ꞓmn
OꞒk
400
B
BEAR CREEK
GW-621
ND
GW-706
20
GW-705
ND
Ꞓn
ND
E 42,000
E 44,000
E 46,000
E 48,000
E 50,000
E 52,000
N 32,000
N 30,000
N 28,000
PLANT NORTH
NORTH
BEAR CREEK BURIAL GROUNDS WASTE-MANAGEMENT AREA
ABOVE GRADE LOW LEVEL STORAGE FACILITY
OIL LANDFARM WASTE-MANAGEMENT AREA
S-3 SITE
ABANDONED NITRIC ACID PIPELINE
RUST SPOIL AREA
SY-200 YARD
SPOIL A
C
C′
B′
X
GW-057
GW-056
GW-685
SS-5
GW-684
GW-683
GW-058
SS-4
GW-695
GW-705
GW-694
GW-621
GW-706
GW-704
GW-703
GW-367
GW-645
GW-366
GW-520
GW-225
GW-226
GW-227
GW-063
GW-800
GW-369
GW-646
GW-601
GW-736
GW-737
GW-724
GW-738
GW-647
GW-740
BCK-11.97
GW-725
GW-064
GW-739
GW-723
GW-648
GW-348
GW-347
GW-125
GW-616
GW-317









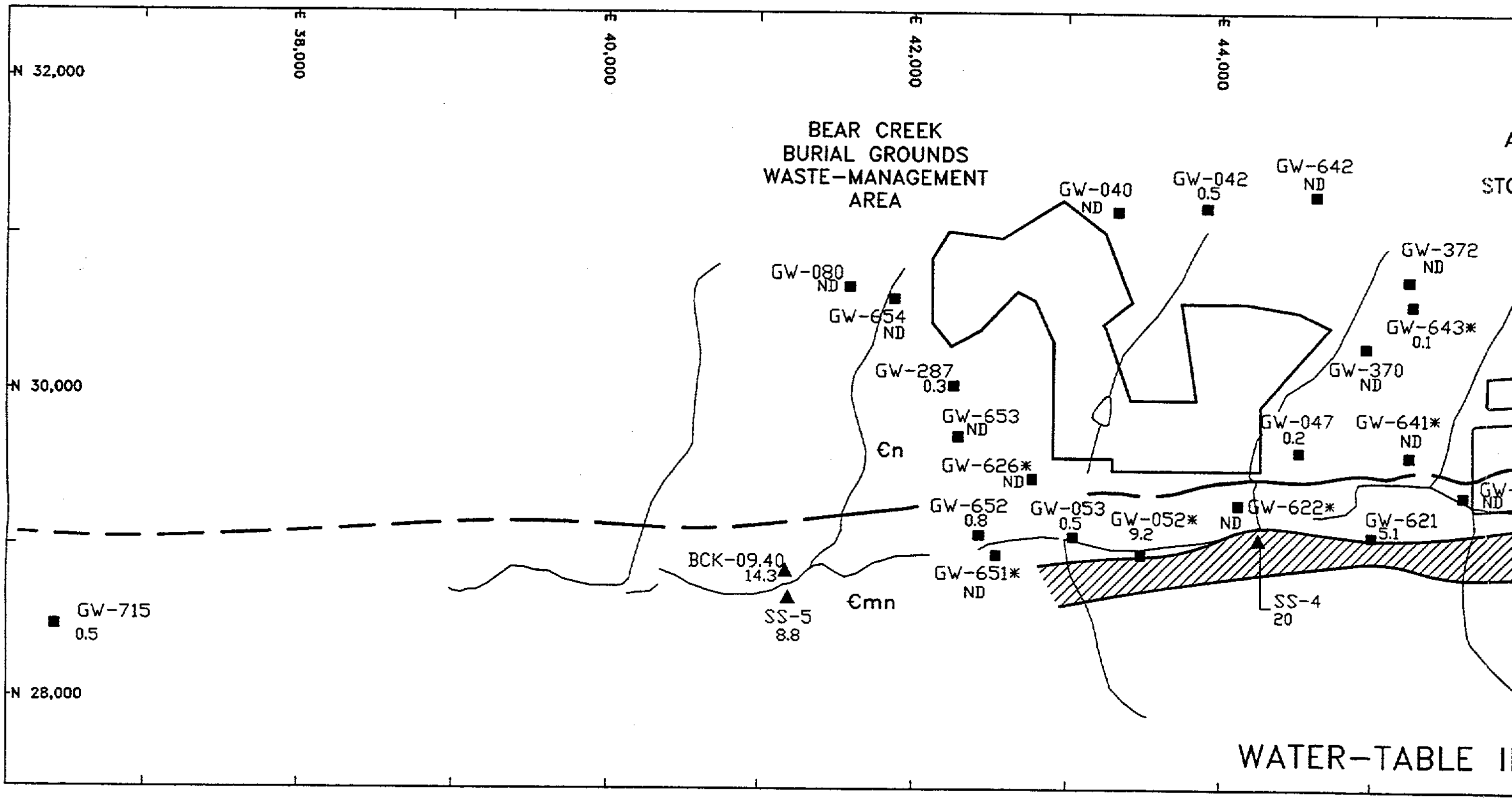
EXPLANATION

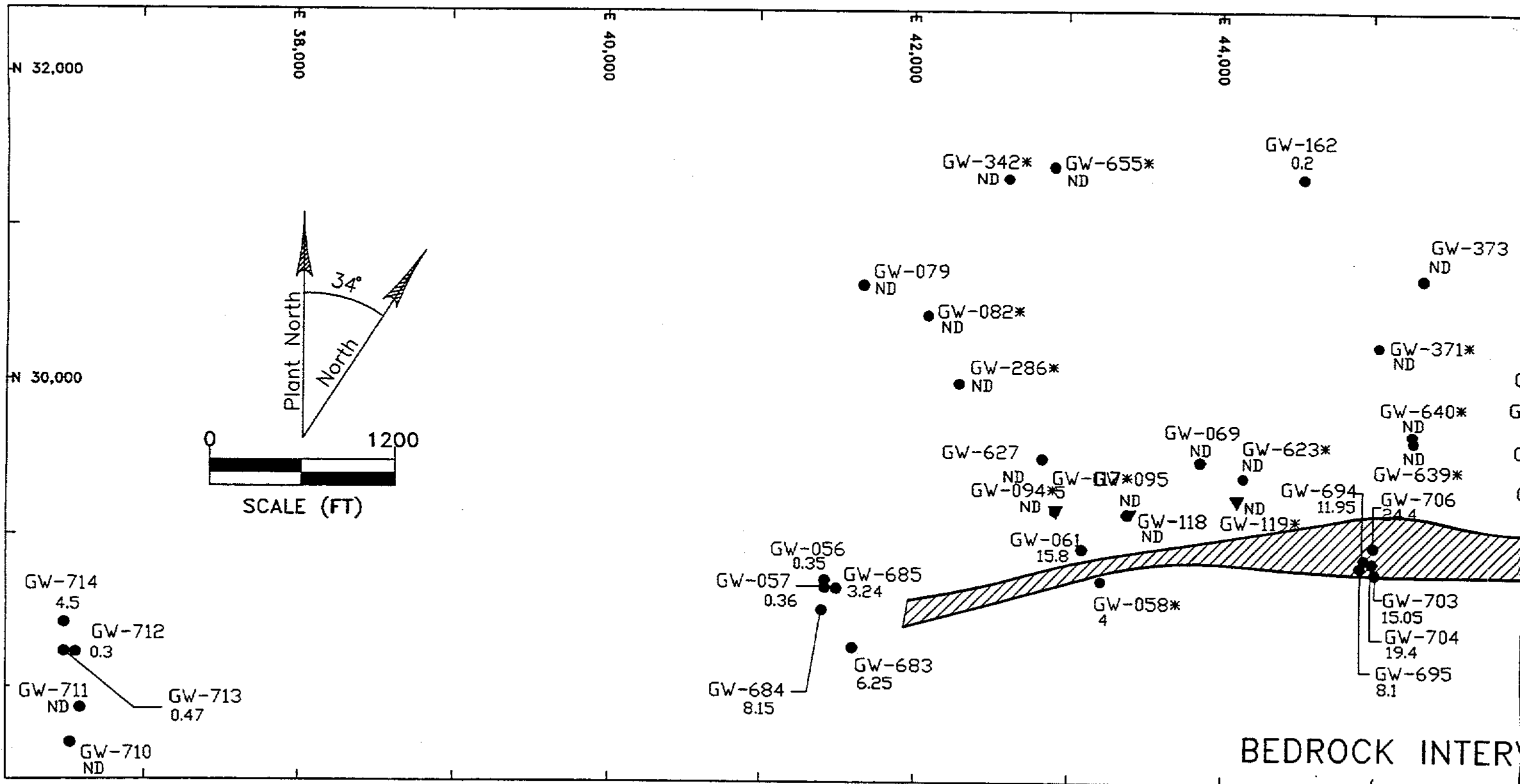
GW-685 1	WELL NUMBER AND SUMMED AVERAGE VOC CONCENTRATION (ug/L)
*	WELLS SAMPLED BEFORE 1994 (DATA QUALITATIVE)
50	APPROXIMATE LINE OF EQUAL CONCENTRATION (ug/L)
ND	NOT DETECTED
▮	SCREENED WELL CONSTRUCTION
▯	OPEN-HOLE WELL CONSTRUCTION

- - ▾ -	GROUNDWATER ELEVATION
- - -	APPROXIMATE GEOLOGIC CONTACT
O€k	KNOX GROUP
€mn	MAYNARDVILLE LIMESTONE
€n	NOLICHUCKY SHALE
€m	MARYVILLE LIMESTONE

VERTICAL EXAGGERATION : SECTION X-X' IS 3:1
OTHER SECTIONS ARE 1:1

LOCATION:	Y-12 PLANT OAK RIDGE, TN.	**FIGURE 23**
DATE:	8-6-95	**VOCS IN GROUNDWATER IN THE MAYNARDVILLE LIMESTONE**
DWG ID.:	VOCKA	





EXPLANATION

GW-739 Well Number and
7 Average Nitrate Concentration (mg/L)

■ Water Table Monitoring Well

∗ Indicates a Well Sampled Before 1994 (Data Qualitative)

● Bedrock Monitoring Well

▲ Spring (SS) or Surface-Water (BCK) Sampling Station

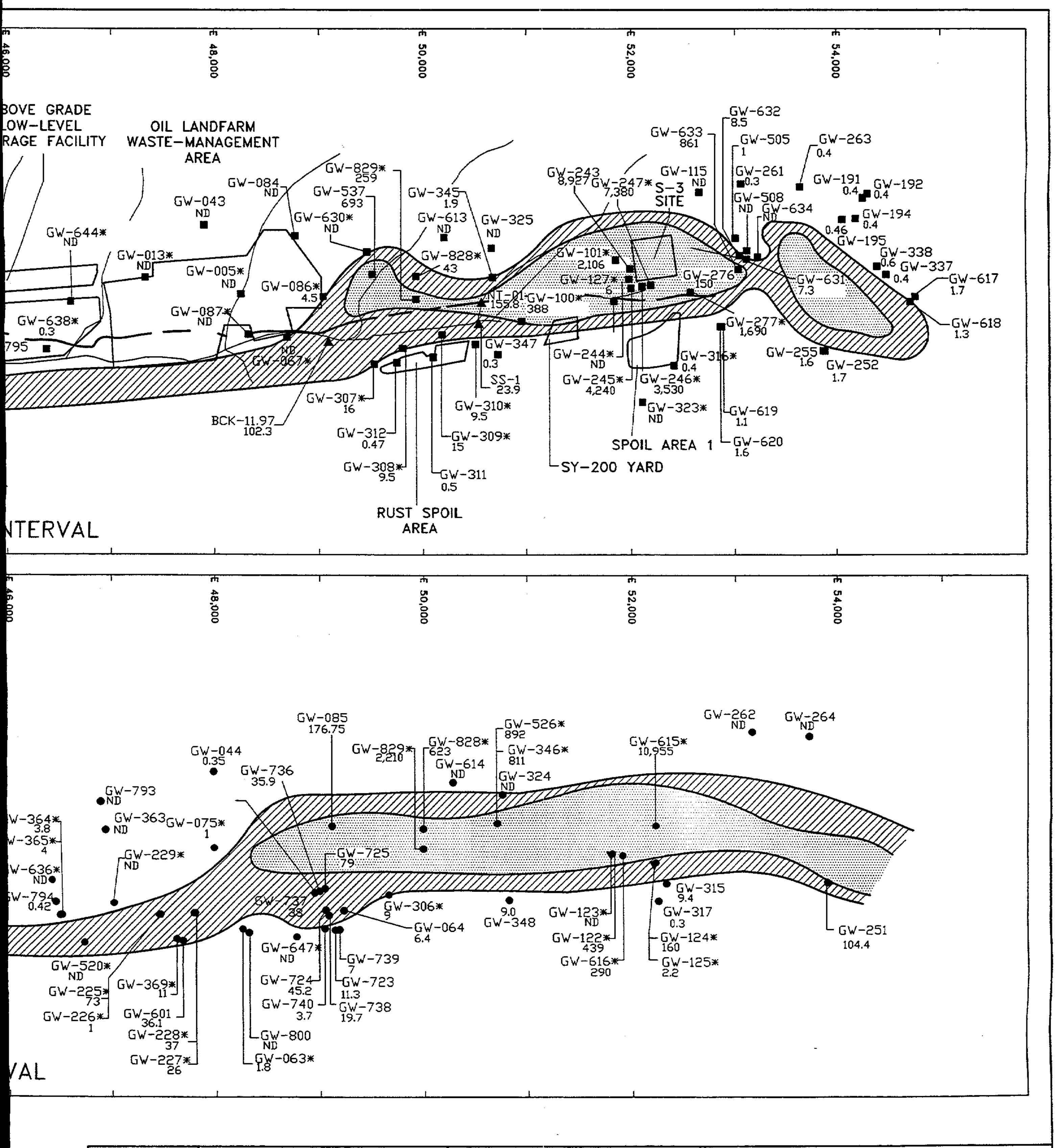
ND — NOT DETECTED

▨ — 10

▨ — >100

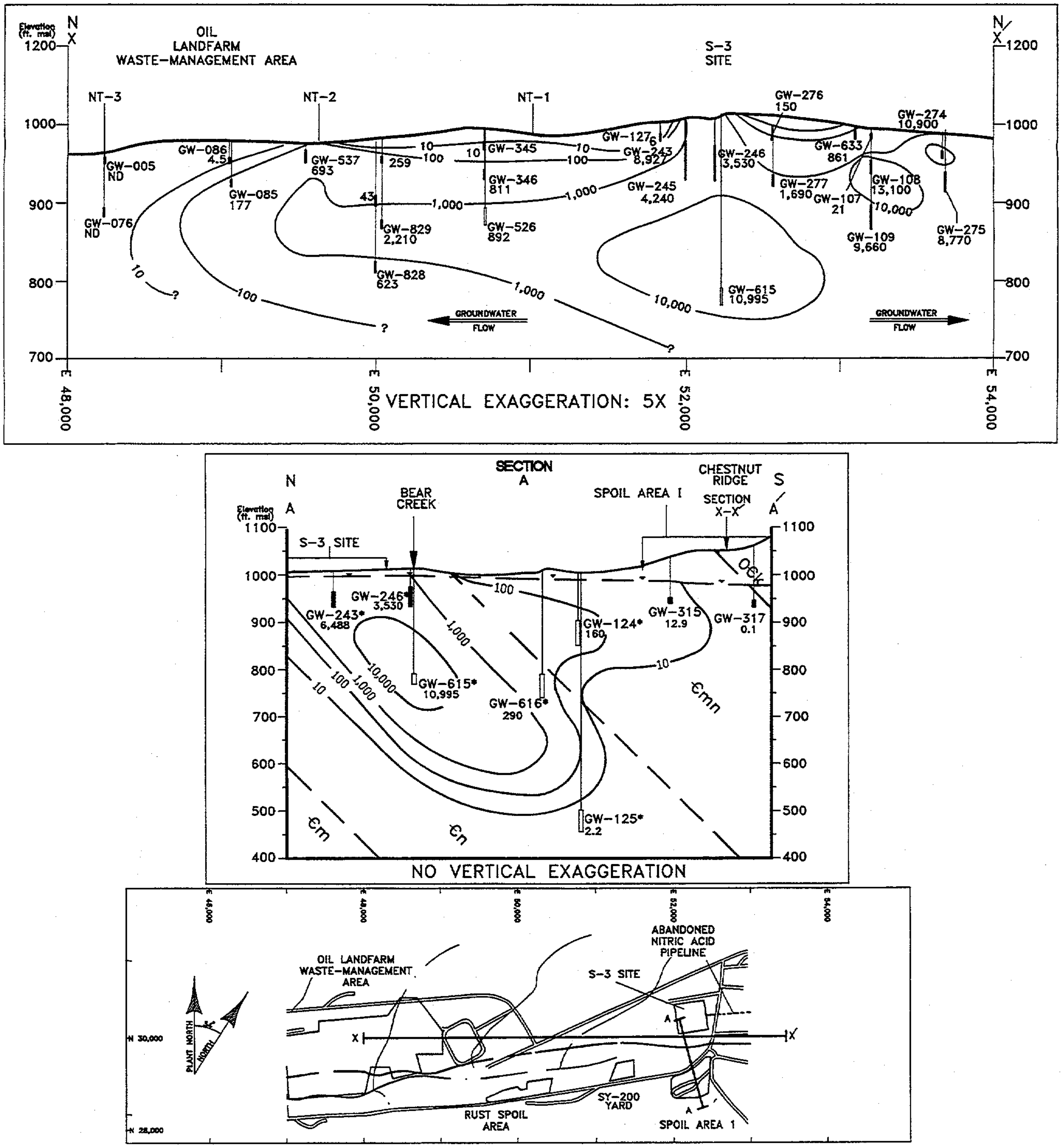
Boundary of Site or Waste-Managem

Surface Drainage Feature



ent Area

LOCATION:	Y-12 PLANT OAK RIDGE, TN.	FIGURE 24
DATE:	8-21-95	NITRATE IN GROUNDWATER AND SURFACE WATER IN THE BEAR CREEK HYDROGEOLOGIC REGIME
DWG ID.:	OR603-HC	



EXPLANATION

GW-243 6,488 — WELL NUMBER AND AVERAGE NITRATE CONCENTRATION (mg/L)

* — WELLS SAMPLED BEFORE 1994 (DATA QUALITATIVE)

— 70 — — APPROXIMATE LINE OF EQUAL CONCENTRATION (mg/L)

ND — NOT DETECTED

▮ — SCREENED WELL CONSTRUCTION

▯ — OPEN-HOLE WELL CONSTRUCTION

— GROUNDWATER ELEVATION

— APPROXIMATE GEOLOGIC CONTACT

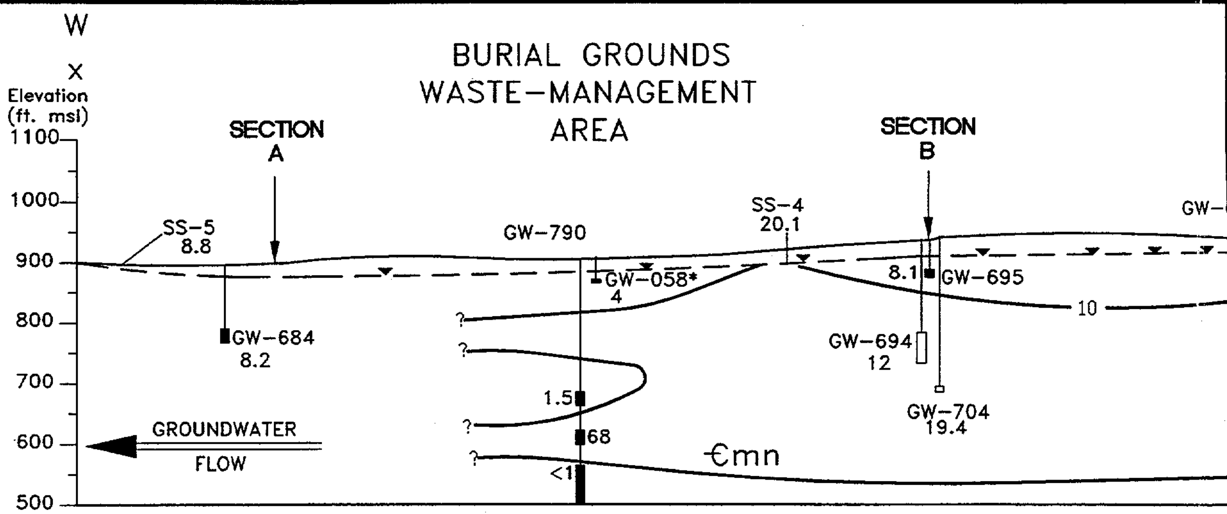
O€k — KNOX GROUP

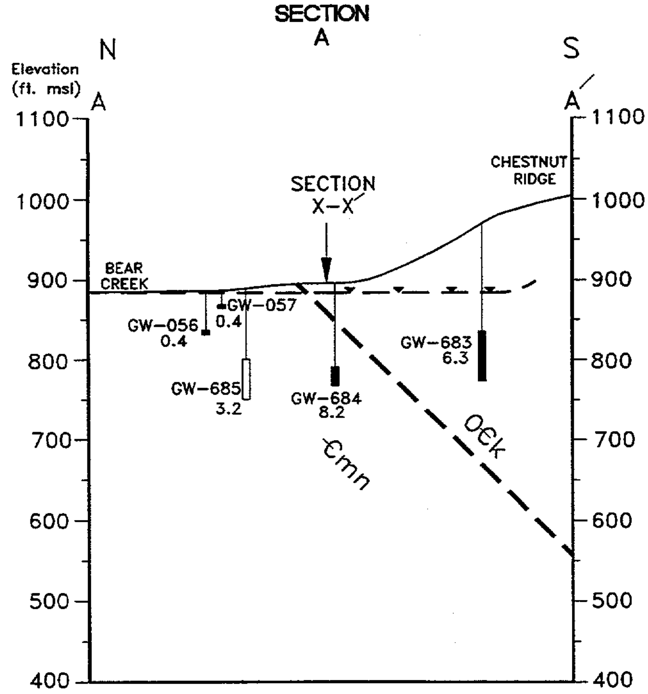
€mn — MAYNARDVILLE LIMESTONE

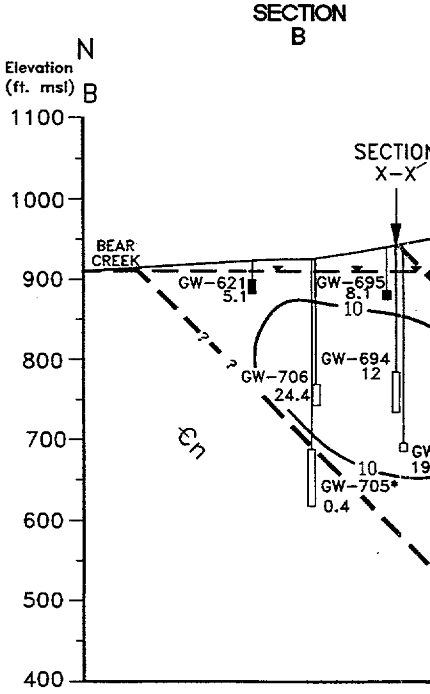
€n — NOLICHUCKY SHALE

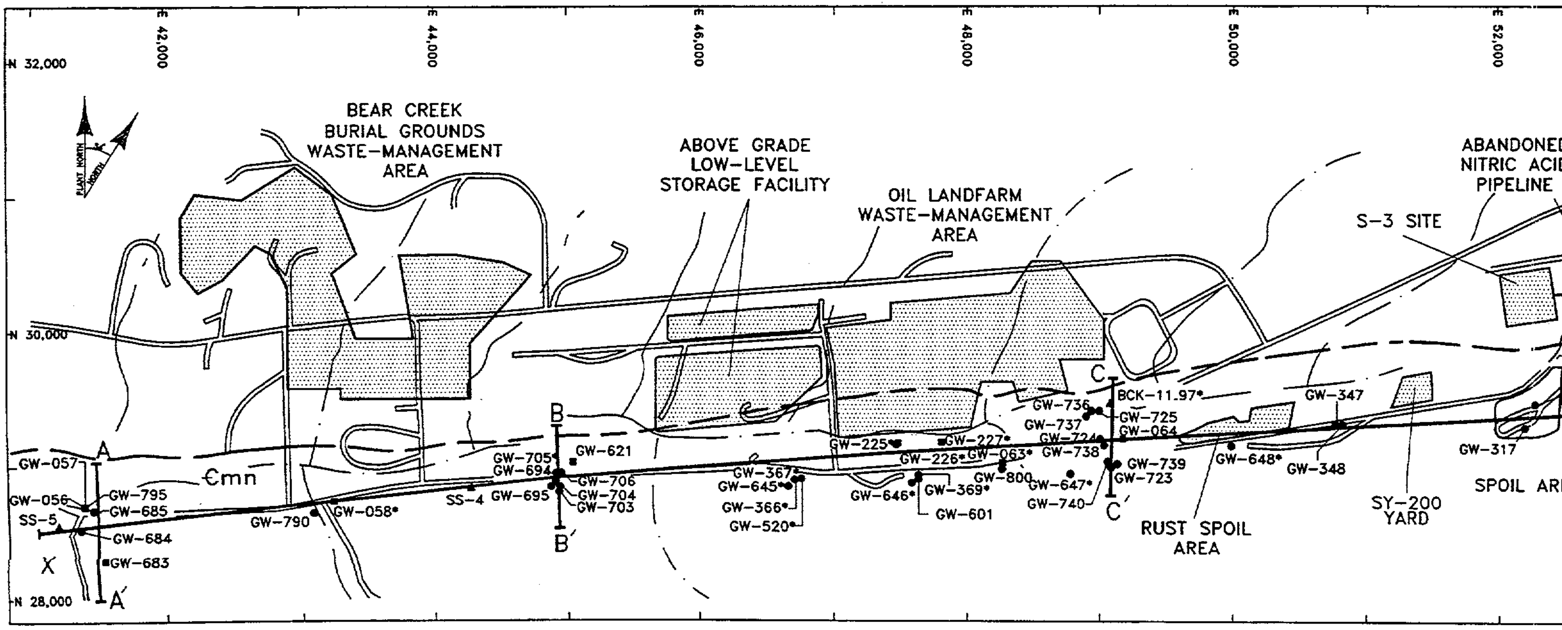
€m — MARYVILLE LIMESTONE

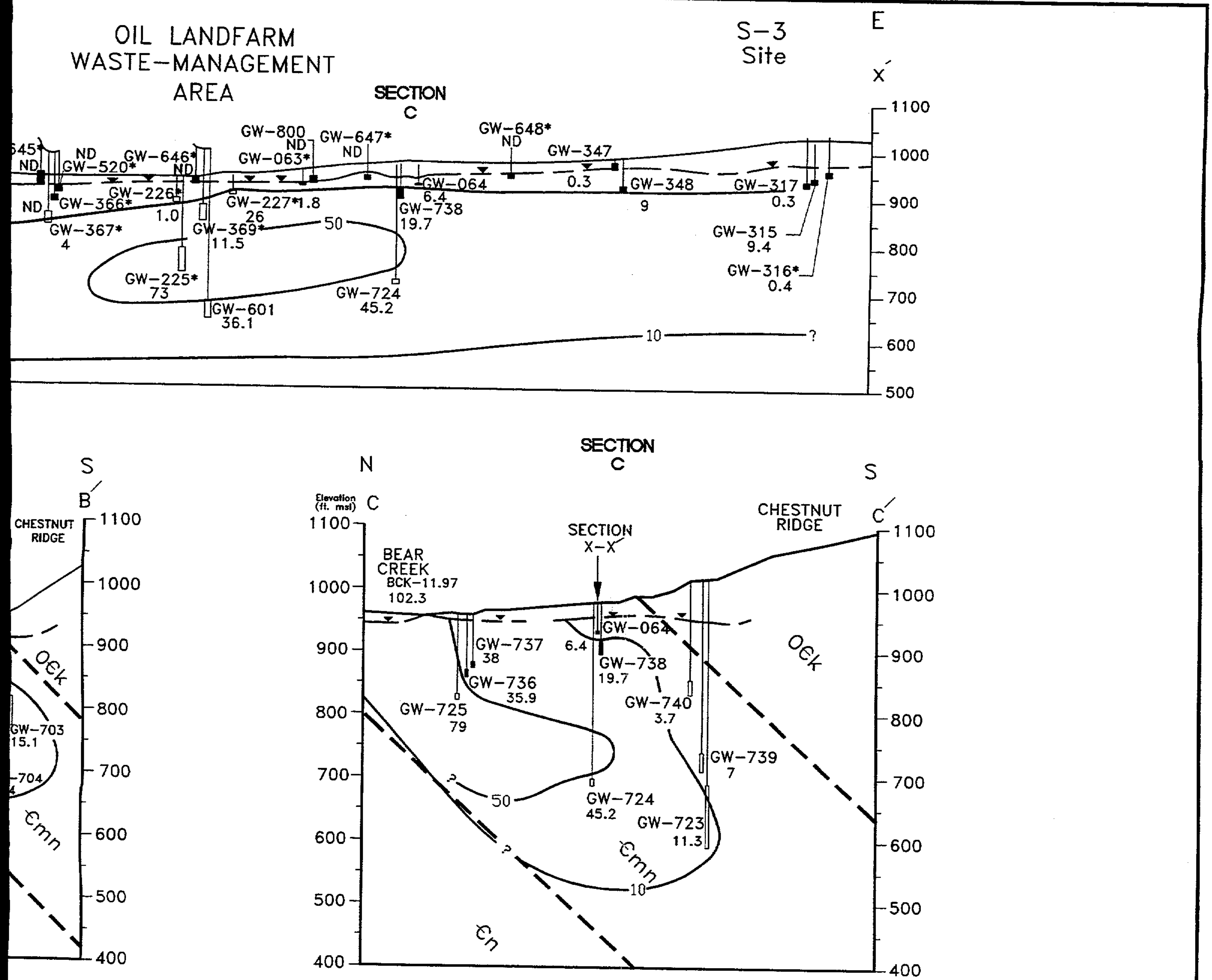
LOCATION:	Y-12 PLANT OAK RIDGE, TN.	FIGURE 25 NITRATE IN GROUNDWATER IN THE CONASAUGA SHALES
DATE:	8-29-95	
DWG ID.:	OR606-HC	


W
X
Elevation (ft. msl)
1100
1000
900
800
700
600
500
BURIAL GROUNDS WASTE-MANAGEMENT AREA
SECTION A
SECTION B
SS-5
8.8
GW-684
8.2
GW-790
GW-058*
4
1.5
68
<1
SS-4
20.1
8.1
GW-695
GW-694
12
GW-704
19.4
10
GW-
GROUNDWATER FLOW
?
Ꞓmn


SECTION A
N
S
Elevation (ft. msl)
A
A′
1100
1000
900
800
700
600
500
400
CHESTNUT RIDGE
SECTION X-X′
BEAR CREEK
GW-056
0.4
GW-057
0.4
GW-685
3.2
GW-684
8.2
GW-683
6.3
Ꞓmn
OꞒk


SECTION B
N
Elevation (ft. msl)
B
1100
1000
900
800
700
600
500
400
SECTION X-X′
BEAR CREEK
GW-621
5.1
GW-695
8.1
10
GW-694
12
GW-706
24.4
GW-705*
0.4
10
GW
19
?
Ꞓn


E 42,000
E 44,000
E 46,000
E 48,000
E 50,000
E 52,000
N 32,000
N 30,000
N 28,000
PLANT NORTH
NORTH
BEAR CREEK BURIAL GROUNDS WASTE-MANAGEMENT AREA
ABOVE GRADE LOW-LEVEL STORAGE FACILITY
OIL LANDFARM WASTE-MANAGEMENT AREA
S-3 SITE
ABANDONED NITRIC ACID PIPELINE
RUST SPOIL AREA
SY-200 YARD
SPOIL AR
Ꞓmn
A
A′
B
B′
C
C′
X
GW-057
GW-056
GW-795
GW-685
SS-5
GW-684
GW-683
GW-790
GW-058*
SS-4
GW-695
GW-705*
GW-694
GW-621
GW-706
GW-704
GW-703
GW-367*
GW-645*
GW-366*
GW-520*
GW-225*
GW-227*
GW-226*
GW-063*
GW-646*
GW-369*
GW-800
GW-601
GW-736
GW-737
GW-724
GW-738
GW-647*
GW-740
BCK-11.97*
GW-725
GW-064
GW-739
GW-723
GW-648*
GW-347
GW-348
GW-317

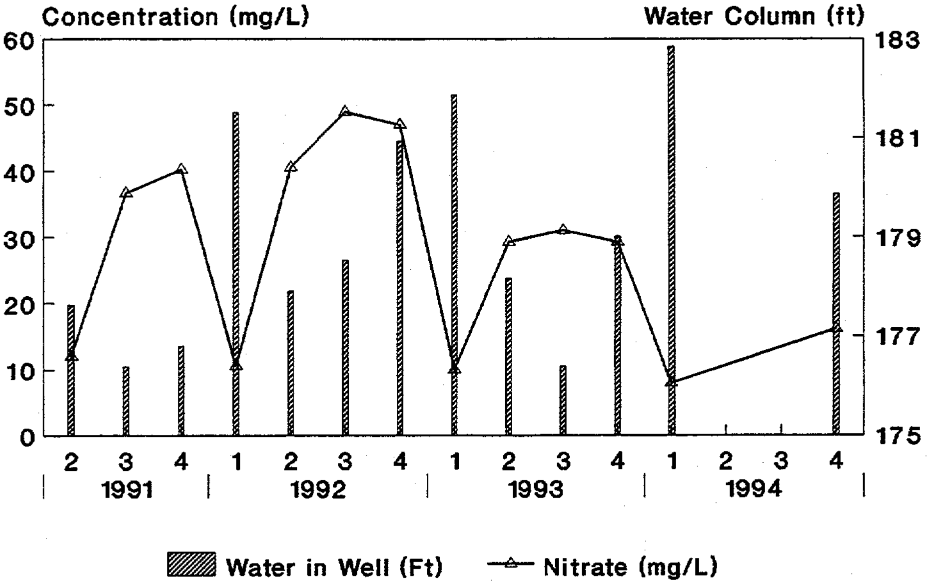


EXPLANATION

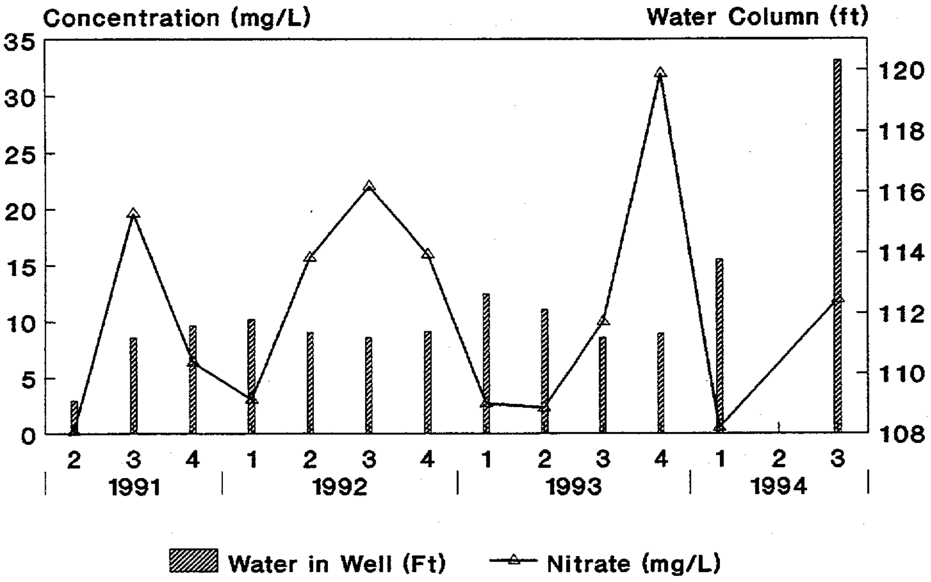
GW-685 0.2 —	WELL NUMBER AND AVERAGE NITRATE CONCENTRATION (mg/L)	— —	GROUNDWATER ELEVATION
* —	WELLS SAMPLED BEFORE 1994 (DATA QUALITATIVE)	— —	APPROXIMATE GEOLOGIC CONTACT
— 70 —	APPROXIMATE LINE OF EQUAL CONCENTRATION (mg/L)	0€k —	KNOX GROUP
ND —	NOT DETECTED	€mn —	MAYNARDVILLE LIMESTONE
▮ —	SCREENED WELL CONSTRUCTION	€n —	NOLICHUCKY SHALE
▯ —	OPEN-HOLE WELL CONSTRUCTION	€m —	MARYVILLE LIMESTONE
▮ —	WEST BAY SYSTEM SAMPLING PORTS SAMPLES COLLECTED IN DECEMBER 1994	VERTICAL EXAGGERATION :	SECTION X-X' IS 3:1 OTHER SECTIONS ARE 1:1

LOCATION:	Y-12 PLANT OAK RIDGE, TN.	FIGURE 26
DATE:	8-27-95	NITRATE IN GROUNDWATER IN THE MAYNARDVILLE LIMESTONE
DWG ID.:	OR605-HC	

GW-694
Section B *

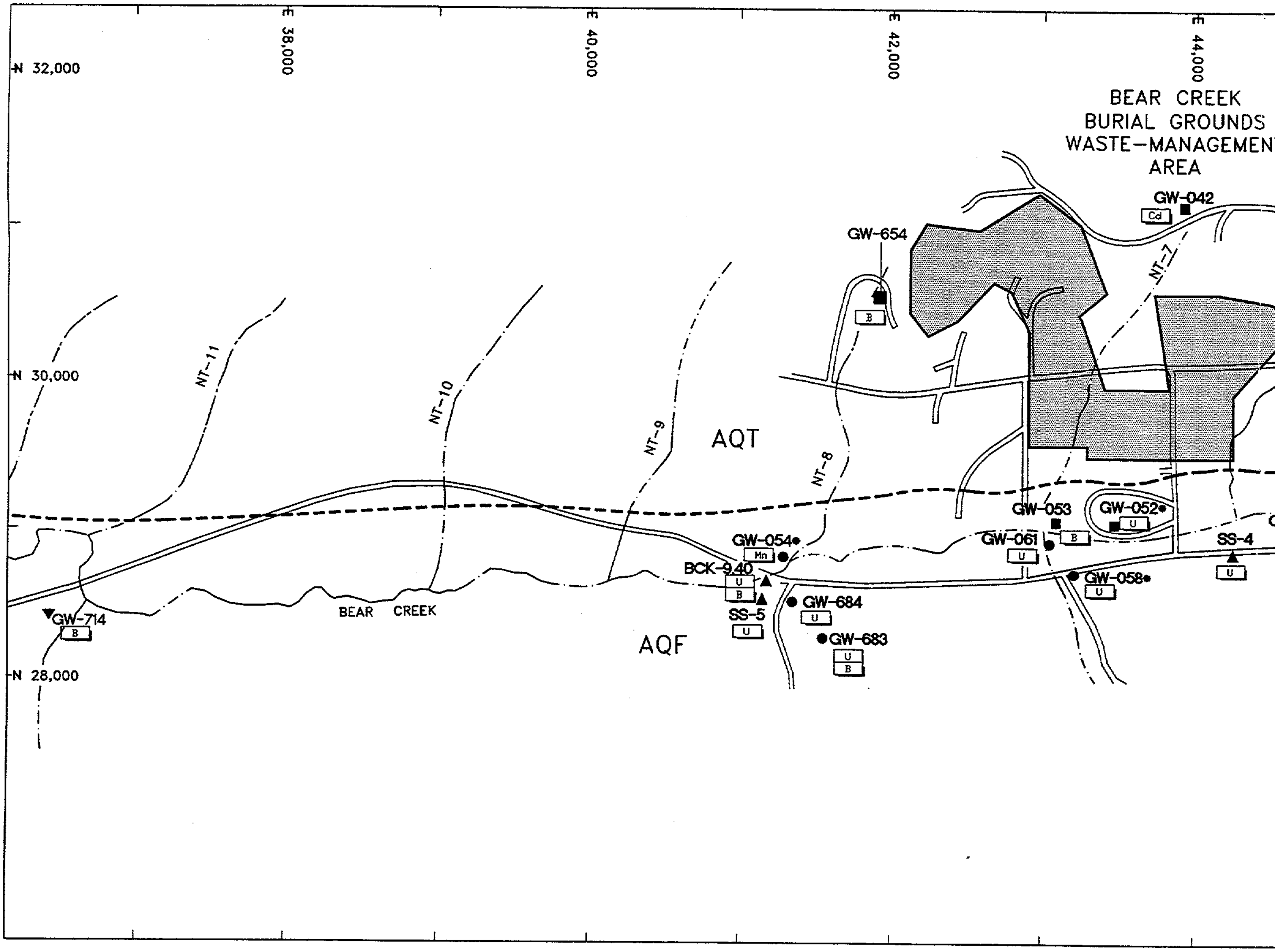


GW-683
Section A *



* Refer to Figure 26 for section locations

LOCATION:	Y-12 PLANT OAK RIDGE, TN.	FIGURE 27
DATE:	8-6-95	NITRATE CONCENTRATIONS IN MAYNARDVILLE LIMESTONE WELLS GW-694 AND GW-683
DWG ID.:	HG27	



Note: BCK-4.55 U/B AND BCK-0.63 U/B are located downstream from BCK-9.40.

EXPLANATION

GW – ■ — Water Table Monitoring Well

GW – • — Bedrock Monitoring Well

* — Not Sampled in CY 1994

SS –
BCK – ▲ — Spring (SS) or Surface-Water (BCK or NT) Sampling Station
NT –

—·—·—·— — Surface Drainage Feature

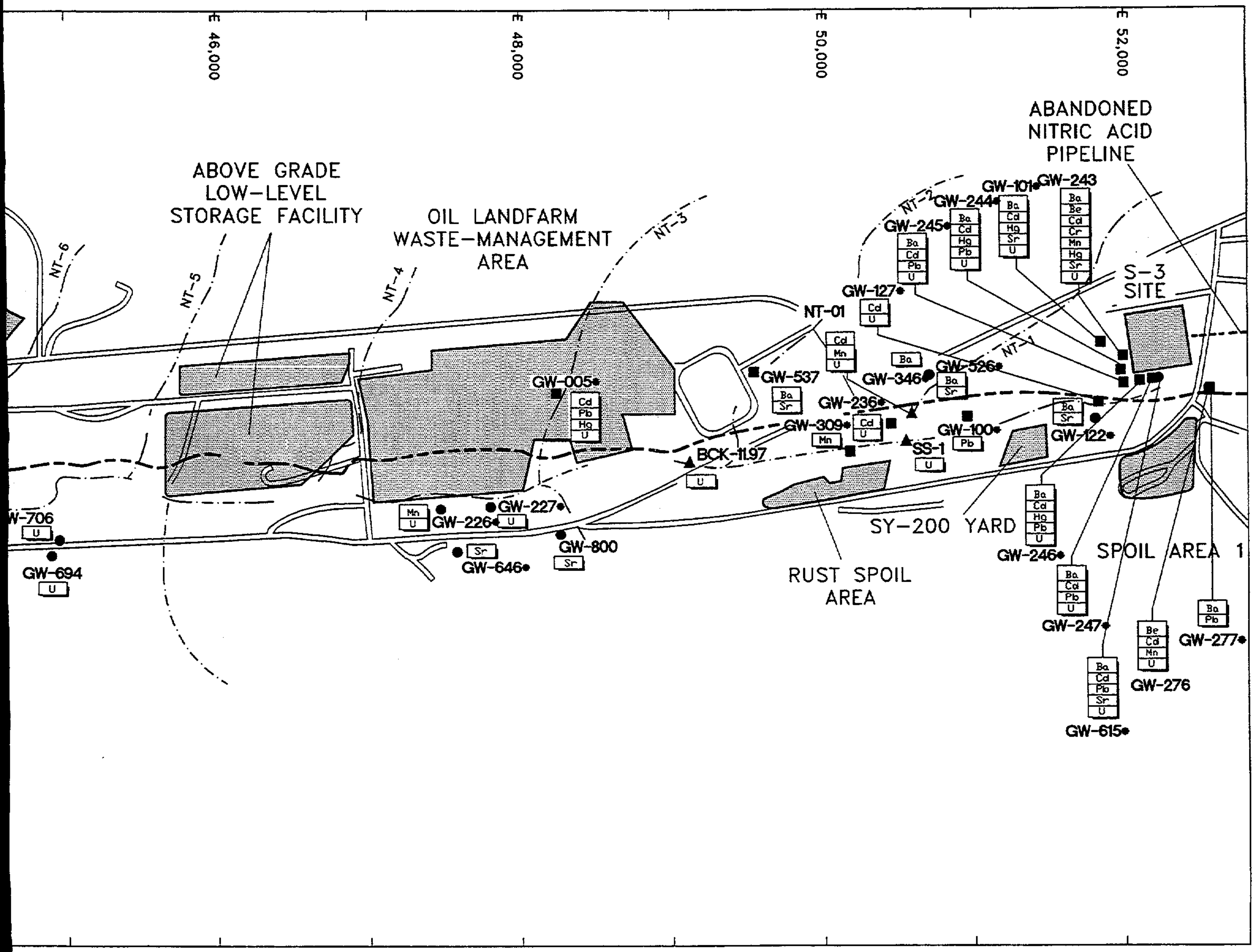
AQT — Conasauga Shales

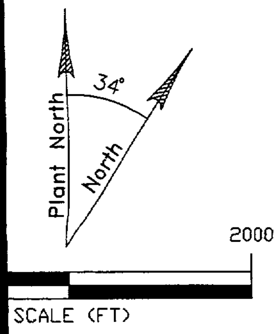
– – – – — Approximate Nolichucky Shale\Maynardville Limestone Contact

AQF — Maynardville Limestone

Ba	Barium
Be	Beryllium
B	Boron
Cd	Cadmium (AAS)
Cr	Chromium
Mn	Manganese
Pb	Lead (AAS)
Hg	Mercury (CVAA)
Sr	Strontium
U	Uranium (FLUOR)

0



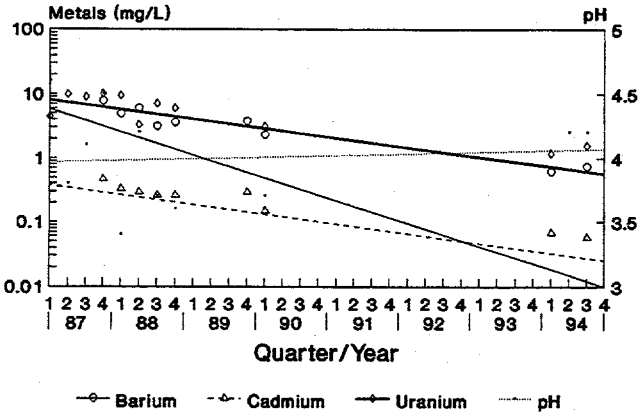


LOCATION:	Y-12 PLANT OAK RIDGE, TN.
DATE:	8-27-95
DWG ID.:	METALS

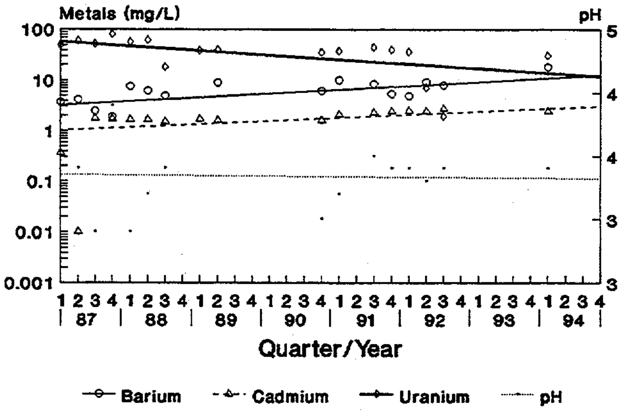
FIGURE 28

SELECTED TRACE METAL CONCENTRATIONS IN GROUNDWATER AND SURFACE WATER SAMPLES THAT EXCEED MCLs OR UTLs

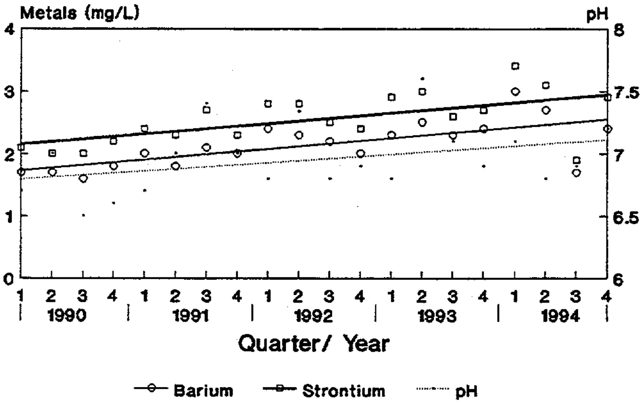
GW-276
S-3 Site



GW-243
S-3 Site

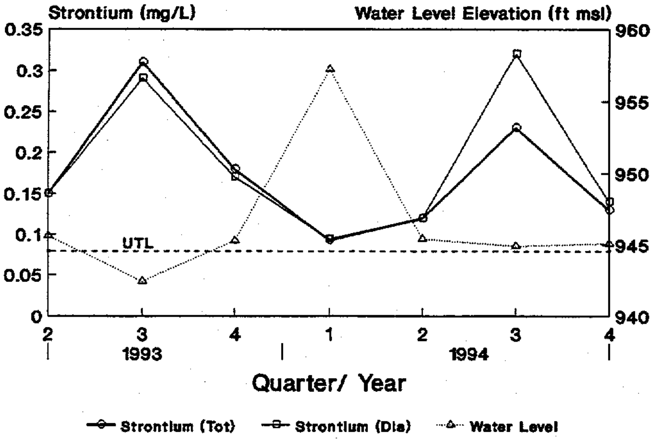


GW-537
Oil Landfarm WMA

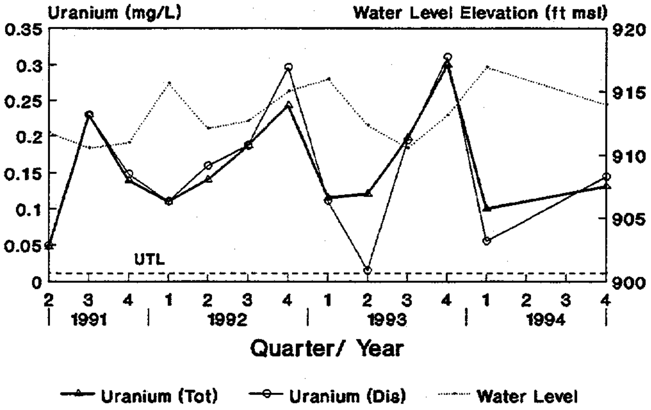


LOCATION:	Y-12 PLANT OAK RIDGE, TN.	FIGURE 29
DATE:	8-18-95	SELECTED METAL CONCENTRATIONS IN WELLS GW-276, GW-243, AND GW-537
DWG ID.:	HG29	

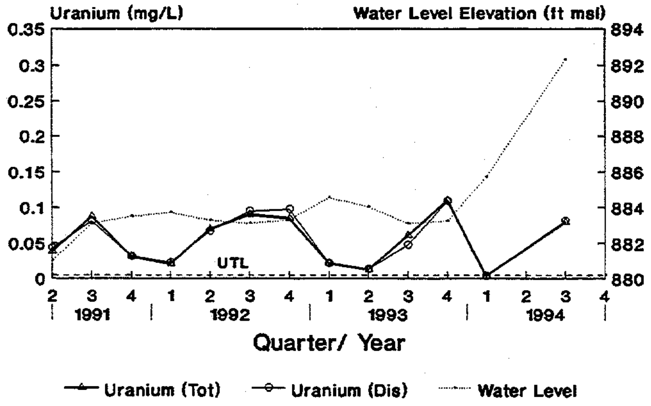
GW-800



GW-694
EXP-B

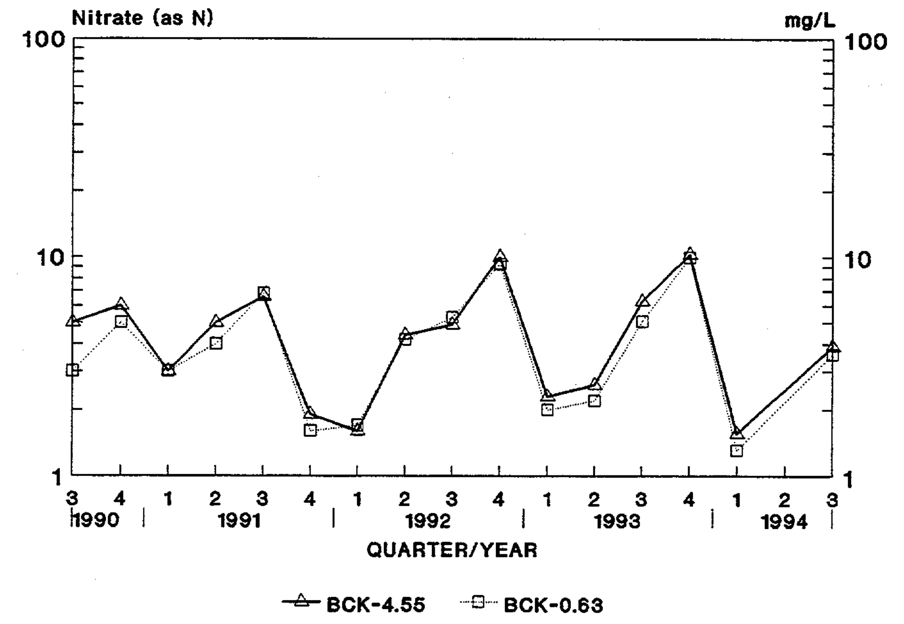


GW-683
EXP-A

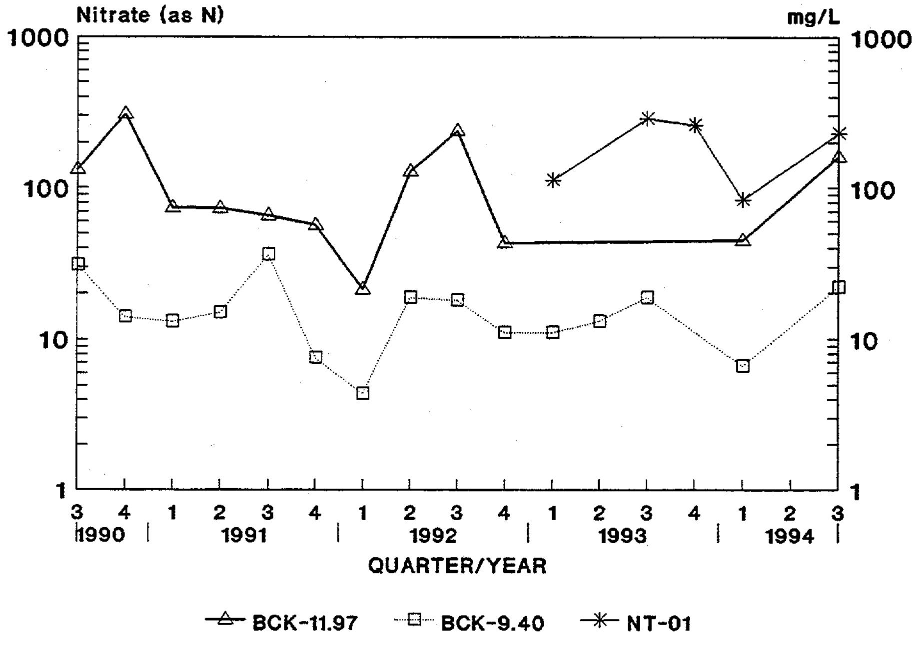


LOCATION:	Y-12 PLANT OAK RIDGE, TN.	FIGURE 30
DATE:	8-18-95	STRONTIUM CONCENTRATIONS IN WELL GW-800 AND URANIUM CONCENTRATIONS IN WELLS GW-694 AND GW-683
DWG ID.:	HG30	

DOWNSTREAM

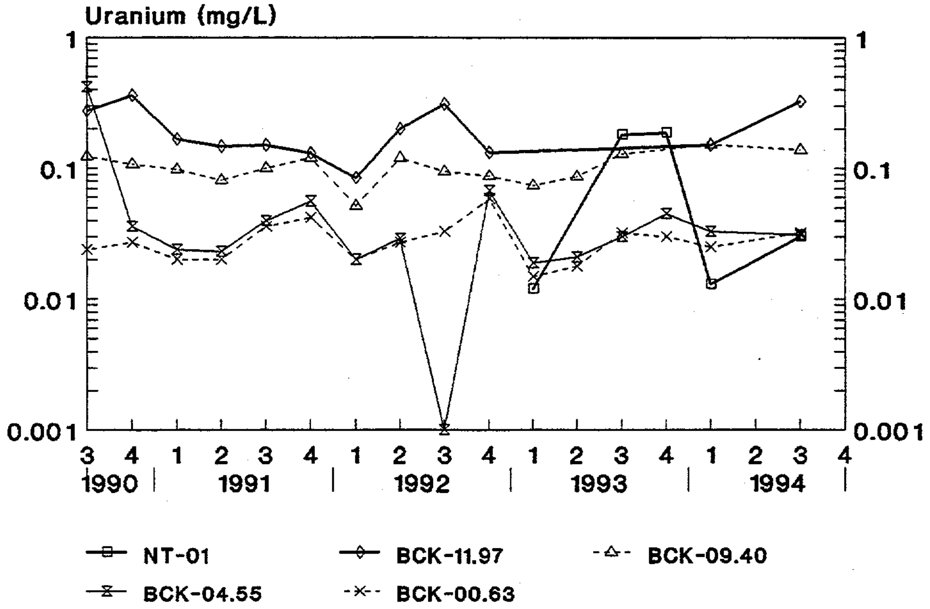


UPSTREAM

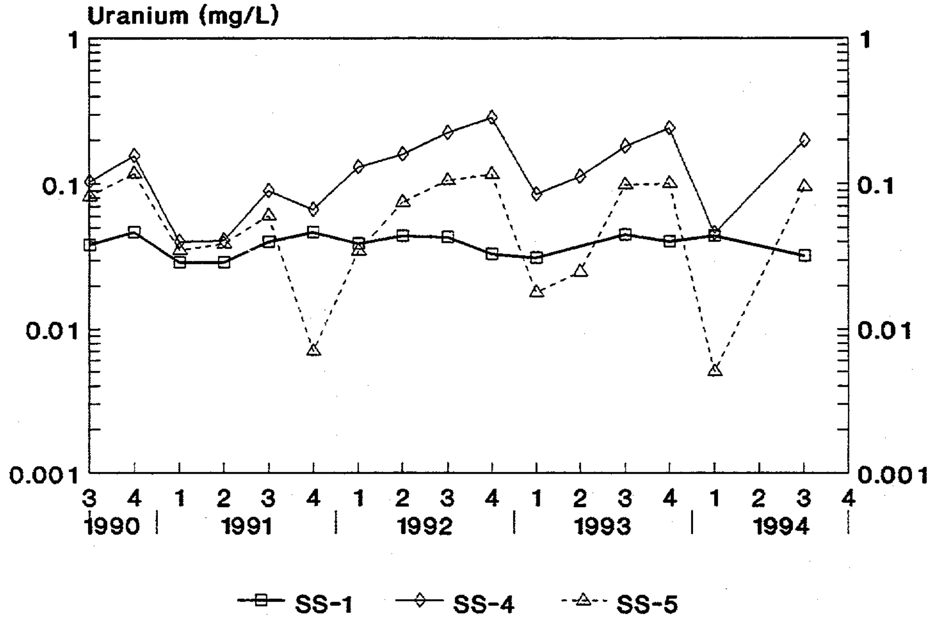


LOCATION:	Y-12 PLANT OAK RIDGE, TN.	FIGURE 31
DATE:	8-6-95	NITRATE CONCENTRATIONS IN SELECTED SURFACE WATER SAMPLES, CYs 1990 - 1994
DWG ID.:	HG31	

Surface Water

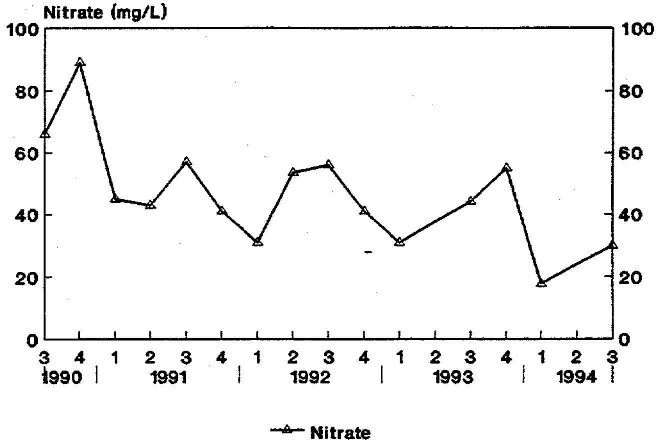


Springs

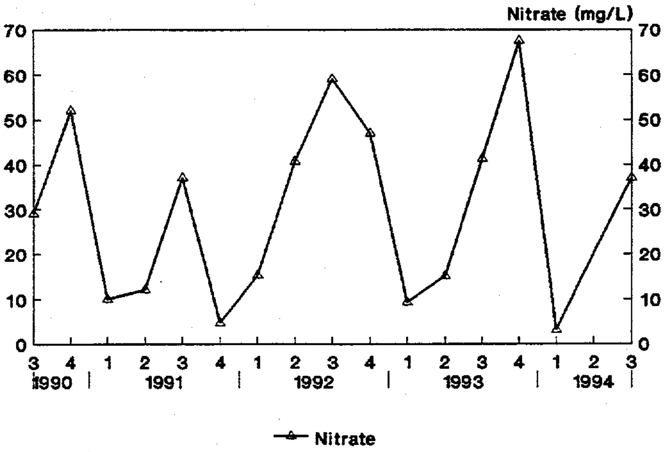


LOCATION:	Y-12 PLANT OAK RIDGE, TN.	FIGURE 32
DATE:	8-18-95	TOTAL URANIUM CONCENTRATIONS IN SURFACE WATER SAMPLES AND SPRINGS
DWG ID.:	HG32	

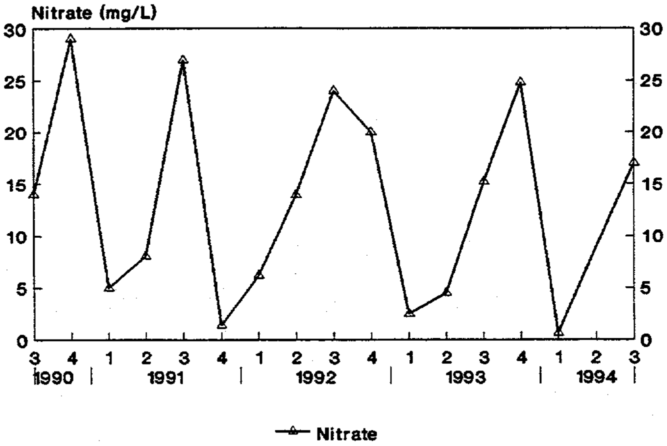
SS-1



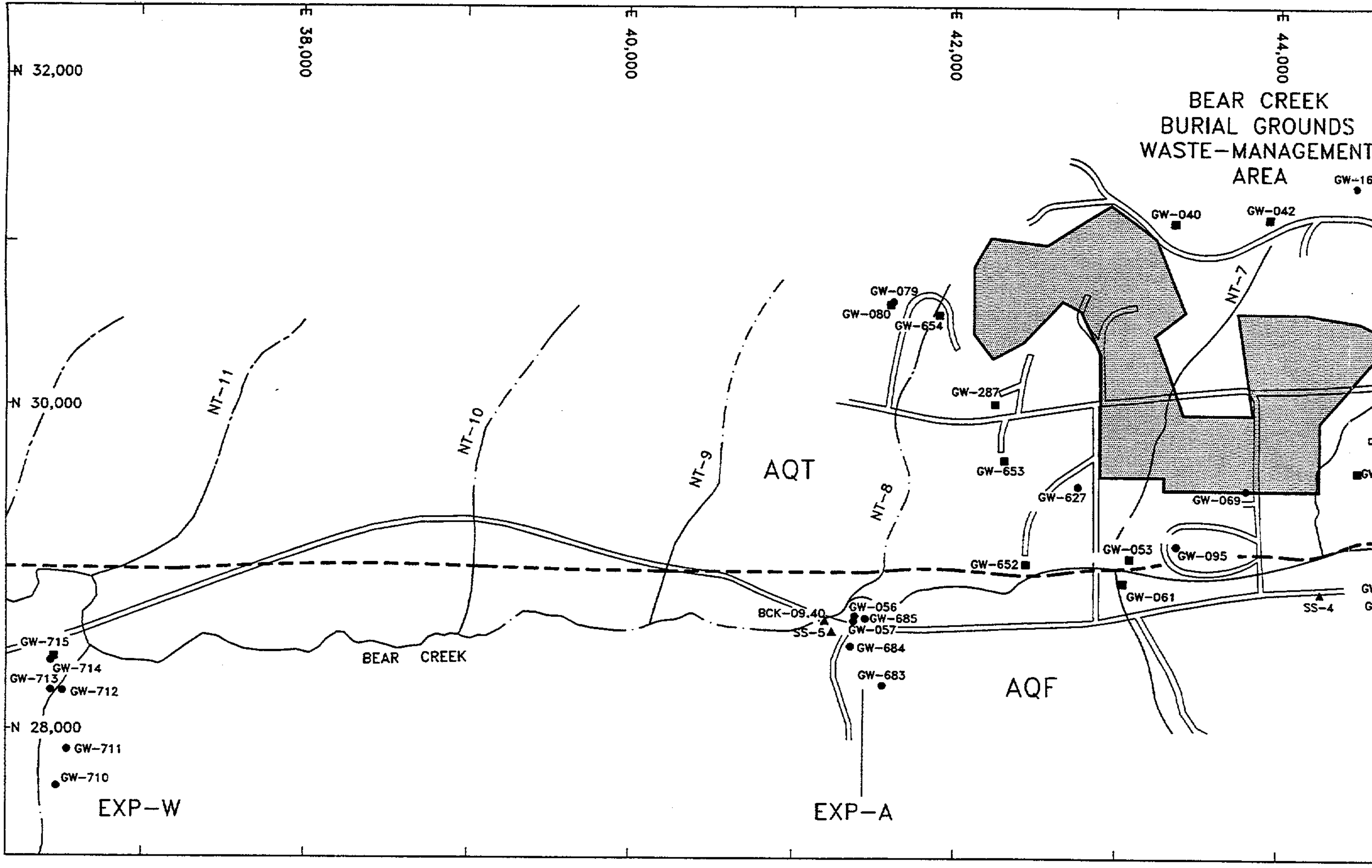
SS-4

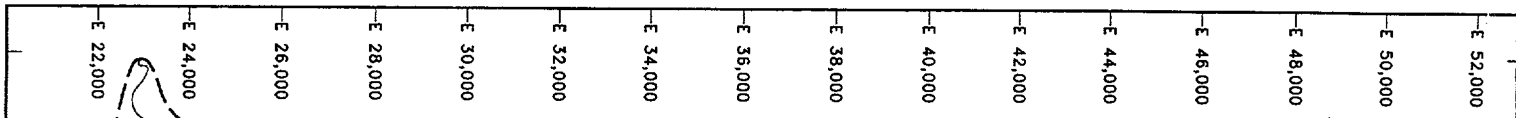


SS-5

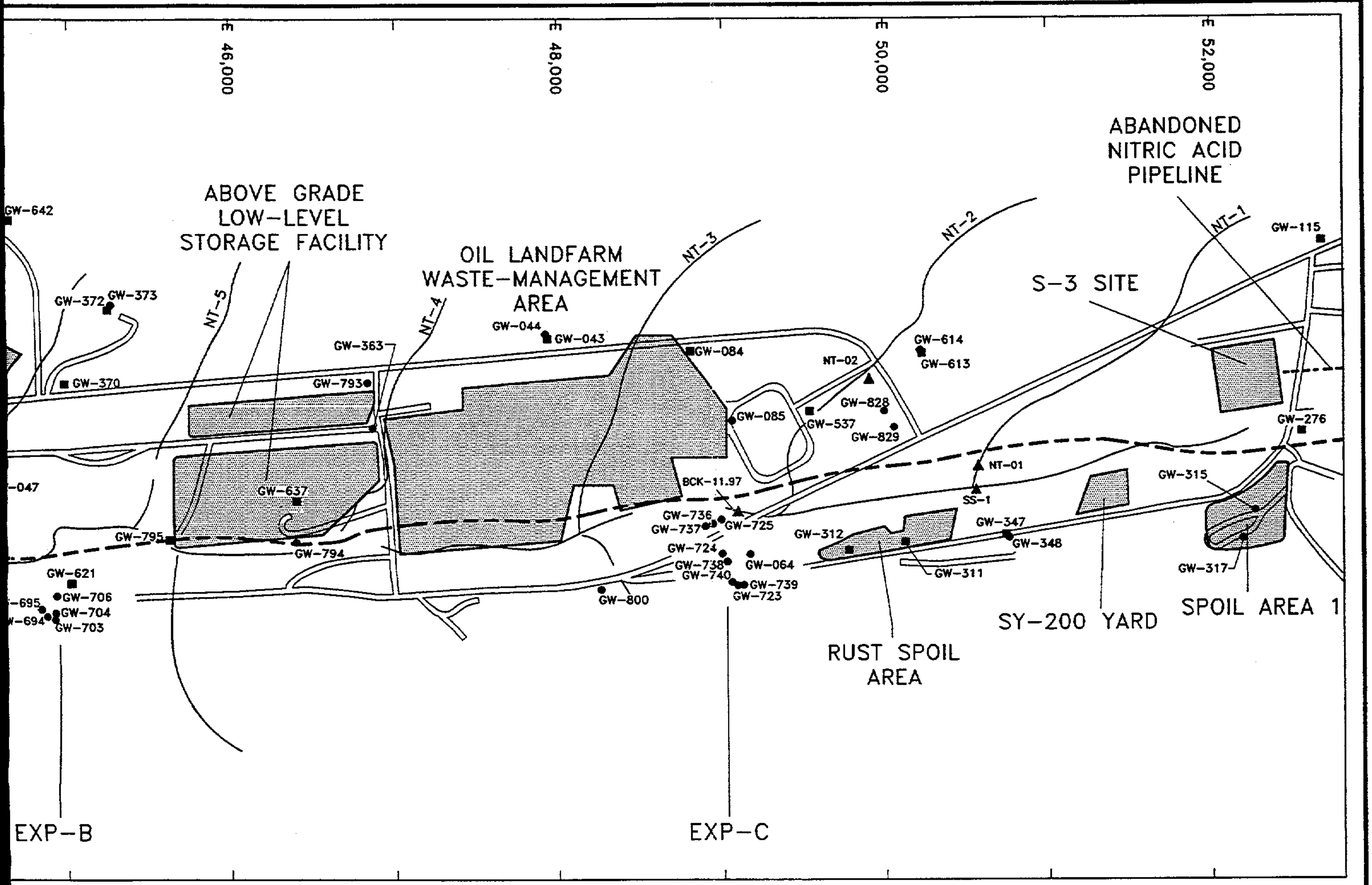


LOCATION:	Y-12 PLANT OAK RIDGE, TN.	FIGURE 33
DATE:	8-18-95	NITRATE CONCENTRATIONS IN SPRINGS SS-1, SS-4, AND SS-5, CYs 1990 - 1994
DWG ID.:	HG33	





SPRINGS AND SURFACE WATER SAMPLING STATIONS



EXPLANATION

GW – ■ – Water Table Monitoring Well

GW – ● – Bedrock Monitoring Well

SS –
BCK – ▲ – Spring (SS) or Surface-Water (BCK or NT) Sampling Station
NT –

EXP-C – Exit Pathway, Maynardville Limestone Transverse

——— – Surface Drainage Feature

NT-5 – North Tributary

AQT – Conasauga Shales

– – – – Approximate Nolichucky Shale\Maynardville Limestone Contact

AQF – Maynardville Limestone

LOCATION:	Y-12 PLANT OAK RIDGE, TN.	FIGURE 34
DATE:	8-26-95	SAMPLING LOCATIONS PLANNED FOR GROUNDWATER AND SURFACE WATER MONITORING DURING CY 1996
DWG ID.:	OR608-HC	

APPENDIX B

Tables

Table 1. Waste-Management Sites Located in the Bear Creek Hydrogeologic Regime

Site Name	Regulatory Classification	
	Historical[1]	Current[2]
S-3 Site	TSD Unit	TSD/BC OU 01/CA
Oil Landfarm Waste-Management Area		
Oil Landfarm	TSD Unit	TSD/BC OU 01/CA
Burnyard, Boneyard, and Hazardous Chemical Storage Area	SWMU	BC OU 01/CA
Sanitary Landfill I	SWMU	BC OU 01/CA
Bear Creek Burial Grounds Waste-Management Area		
Burial Grounds A (North and South)	TSD Unit	TSD/BC OU 01/CA
Burial Grounds C	TSD Unit	TSD/BC OU 01/CA
Walk-In Pits	TSD Unit	TSD/BC OU 01/CA
Burial Grounds B, D, E, and J	SWMUs	BC OU 01/CA
Oil Retention Pond No. 1	SWMU	BC OU 01/CA
Oil Retention Pond No. 2	SWMU	BC OU 01/CA
Spoil Area I	SWMU	BC OU 02
SY-200 Yard	SWMU	BC OU 02
Rust Spoil Area	SWMU	BC OU 02
Bear Creek Groundwater, Surface Water, Creek Sediments, and Flood Plain Soils	N/A	BC OU 04/CA
Above Grade Low-Level Storage Facility	N/A	N/A

Notes:

1 Regulatory status before 1992 Federal Facility Agreement.

TSD Unit - RCRA-regulated land-based treatment, storage, or disposal unit.
SWMU - RCRA-regulated solid waste management unit.
N/A - Not Applicable (not previously regulated as a separate unit or not currently regulated).

2 Modified from: *Oak Ridge Reservation Site Management Plan for the Environmental Restoration Program* (U.S. Department of Energy 1994a).

BC OU 01 - Former Bear Creek Operable Unit 01 (Source Control OU)
BC OU 02 - Former Bear Creek Operable Unit 02 (Source Control OU)
BC OU 04 - Former Bear Creek Operable Unit 04 (Integrator OU)
CA - Characterization Area

Table 2. Monitoring Programs Implemented During CY 1994

Monitoring Program	Sampling Point[1]	Location[2]	Quarter Sampled[3]			
			1st	2nd	3rd	4th
RCRA Corrective Action Monitoring						
	GW-040	BG	■	■	■	■
	GW-042	BG	■	■	■	■
	GW-043	OLF	■	■	■	■
	GW-044	OLF	■	■	■	■
	GW-079	BG	■	■	■	■
	GW-080	BG	■	■	■	■
	GW-084	OLF	■	■	■	■
	GW-115	S3	■	.	■	.
	GW-162	BG	■	■	■	■
	GW-243	S3	■	.	.	.
	GW-276	S3	■	.	■	.
	GW-324	S3	■	.	.	.
	GW-325	S3	■	.	.	.
	GW-372	BG	■	■	■	■
	GW-373	BG	■	■	■	■
	GW-613	S3	■	.	■	.
	GW-614	S3	■	.	■	.
	GW-642	BG	■	■	■	■
	GW-710	EXP-W	■	.	■	.
	GW-711	EXP-W	■	.	■	.
	GW-712	EXP-W	■	.	■	.
	GW-713	EXP-W	■	.	■	.
	GW-714	EXP-W	■	.	■	.
	GW-715	EXP-W	■	.	■	.

Table 2 (cont'd)

Monitoring Program	Sampling Point[1]	Location[2]	Quarter Sampled[3]			
			1st	2nd	3rd	4th
RCRA Assessment Monitoring						
	GW-047	BG	■	■	■	■
	GW-064	OLF	■	■	■	■
	GW-311	RS	■	■	■	■
	GW-312	RS	■	■	■	■
	GW-317	SPI	■	■	■	■
Exit Pathway Monitoring						
	GW-056	EXP-A	■	.	■	.
	GW-057	EXP-A	■	.	■	.
	GW-621	EXP-B	■	.	.	■
	GW-683	EXP-A	■	.	■	.
	GW-684	EXP-A	■	.	■	.
	GW-685	EXP-A	■	.	■	.
	GW-694	EXP-B	■	.	.	■
	GW-695	EXP-B	■	.	.	■
	GW-703	EXP-B	■	.	.	■
	GW-704	EXP-B	■	.	.	■
	GW-706	EXP-B	■	.	.	■
	GW-723	EXP-C	■	.	.	■
	GW-724	EXP-C	■	.	.	■
	GW-725	EXP-C	■	.	.	■
	GW-736	EXP-C	■	.	.	■
	GW-737	EXP-C	■	.	.	■
	GW-738	EXP-C	■	.	.	■
	GW-739	EXP-C	■	.	.	■

Table 2 (cont'd)

Monitoring Program	Sampling Point[1]	Location[2]	Quarter Sampled[3]			
			1st	2nd	3rd	4th
Exit Pathway Monitoring (cont'd)						
	GW-740	EXP-C	■	.	.	■
	BCK-00.63	EXP-SW	■	.	■	.
	BCK-04.55	EXP-SW	■	.	■	.
	BCK-09.40	EXP-SW	■	.	■	.
	BCK-11.97	EXP-SW	■	.	■	.
	NT-01	EXP-SW	■	.	■	.
	NT-13	EXP-SW	■	.	■	.
	SS-1	EXP-SW	■	.	■	.
	SS-4	EXP-SW	■	.	■	.
	SS-5	EXP-SW	■	.	■	.
Surveillance and Maintenance Monitoring						
	GW-053	BG	■	■	■	■
	GW-061	BG	■	■	■	■
	GW-069	BG	■	■	■	■
	GW-085	OLF	■	■	■	■
	GW-095	BG	■	■	■	■
	GW-287	BG	■	■	■	■
	GW-315	SPI	■	■	■	■
	GW-345	S3	■	.	.	.
	GW-347	S3	■	■	■	■
	GW-348	S3	■	■	■	■
	GW-363	OLF	■	■	■	■
	GW-370	BG	■	■	■	■
	GW-537	OLF	■	■	■	■

Table 2 (cont'd)

Monitoring Program	Sampling Point[1]	Location[2]	Quarter Sampled[3]			
			1st	2nd	3rd	4th
Surveillance and Maintenance Monitoring (cont'd)						
	GW-601	OLF	■	.	.	.
	GW-627	BG	■	■	■	■
	GW-637	OLF	■	■	■	■
	GW-652	BG	■	■	■	■
	GW-653	BG	■	■	■	■
	GW-654	BG	■	■	■	■
	GW-800	OLF	■	■	■	■
Best-Management Practice Monitoring						
	GW-793	AGLLSF	■	■	■	■
	GW-794	AGLLSF	■	■	■	■
	GW-795	AGLLSF	■	■	■	■

<u>Notes</u>:

1 BCK - Bear Creek Kilometer
GW - Monitoring Well
NT - Northern Tributary
SS - Spring

2 AGLLSF - Above Grade Low-Level Storage Facility
BG - Bear Creek Burial Grounds WMA
EXP - Exit Pathway Monitoring Location:
Maynardville Limestone Transverse (-A, -B, -C, -W)
Spring or Surface Water Sampling Location (-SW)
OLF - Oil Landfarm WMA
RS - Rust Spoil Area
S3 - S-3 Site
SPI - Spoil Area I

Table 2 (cont'd)

<u>Notes</u>: (cont'd)

3 ■ - sample collected during specified quarter of CY 1994
. - sample not collected
First Quarter: February 14 - March 31
Second Quarter: May 17 - June 28
Third Quarter: July 28 - September 20
Fourth Quarter: November 2 - December 20

Table 3. Construction Information[1] for Monitoring Wells Sampled During CY 1994

Well	Location[2]	Cluster Designation[3]	Aquifer[4]			Monitored Interval Depths[5]
			Unit	Fm	Interval	
GW-040	BG	3	AQT	Cpv	WT	21.0 - 29.0
GW-042	BG	2	AQT	Cpv	WT	13.4 - 28.2
GW-043	OLF	2	AQT	Cm	WT	10.0 - 40.0
GW-044	OLF	3	AQT	Cm	BDR	42.5 - 70.0
GW-047	BG	2	AQT	Cn	WT	12.5 - 25.5
GW-053	BG	1	AQF	Cmn	WT	11.4 - 32.8
GW-056	EXP-A	1	AQF	Cmn	BDR	49.1 - 55.2
GW-057	EXP-A	1	AQF	Cmn	BDR	17.5 - 22.8
GW-061	BG	1	AQF	Cmn	BDR	17.5 - 24.6
GW-064	OLF	1	AQF	Cmn	BDR	46.8 - 52.7
GW-069	BG	10	AQT	Cn	BDR	79.0 - 99.2
GW-079	BG	3	AQT	Crg	BDR	49.9 - 64.9
GW-080	BG	2	AQT	Crg	WT	20.8 - 29.7
GW-084	OLF	3	AQT	Cm	WT	18.5 - 27.8
GW-085	OLF	3	AQT	Cn	BDR	48.4 - 58.8
GW-095	BG	10	AQT	Cn	BDR	130.2 - 156.0
GW-115	S3	3	AQT	Cm	WT	37.6 - 53.0
GW-162[a]	BG	3	AQT	Cpv	BDR	92.0 - 125.0
GW-243	S3	3	AQT	Cn	WT	43.2 - 77.0
GW-276	S3	3	AQT	Cn	WT	11.3 - 18.5
GW-287	BG	3	AQT	Cn	WT	5.6 - 12.5
GW-311	RS	3	AQF	Cmn	WT	25.6 - 40.3
GW-312	RS	1	AQF	Cmn	WT	29.6 - 41.0
GW-315	SPI	1	AQF	Cmn	BDR	90.0 - 104.0
GW-317	SPI	4	AQF	Cmn	BDR	117.0 - 132.0
GW-324	S3	3	AQT	Cn	BDR	66.5 - 80.0
GW-325	S3	2	AQT	Cn	WT	5.1 - 17.9

Table 3 (cont'd)

Well	Location[2]	Cluster Designation[3]	Aquifer[4]			Monitored Interval Depths[5]
			Unit	Fm	Interval	
GW-345	S3	2	AQT	Cn	WT	15.2 - 26.3
GW-347	S3	3	AQF	Cmn	WT	9.5 - 27.8
GW-348	S3	2	AQF	Cmn	BDR	68.1 - 80.9
GW-363[a]	OLF	10	AQT	Cn	BDR	50.0 - 75.0
GW-370	BG	3	AQT	Cm	WT	21.1 - 33.1
GW-372	BG	3	AQT	Cm	WT	39.8 - 51.6
GW-373[a]	BG	10	AQT	Cm	BDR	123.0 - 158.0
GW-537	OLF	3	AQT	Cn	WT	4.8 - 23.3
GW-601[a]	OLF	1	AQF	Cmn	BDR	318.5 - 356.0
GW-613	S3	2	AQT	Cn	WT	30.0 - 42.0
GW-614	S3	3	AQT	Cn	BDR	71.6 - 90.2
GW-621[a]	EXP-B	3	AQF	Cmn	WT	23.3 - 40.5
GW-627	BG	10	AQT	Cn	BDR	254.0 - 270.0
GW-637	OLF	3	AQT	Cn	WT	14.5 - 27.5
GW-642	BG	2	AQT	Crg	WT	18.5 - 36.9
GW-652	BG	3	AQF	Cmn	WT	13.4 - 31.2
GW-653	BG	2	AQT	Cn	WT	26.3 - 39.0
GW-654	BG	3	AQT	Cm	WT	4.2 - 15.3
GW-683	EXP-A	4	AQF	OCk	BDR	133.9 - 196.8
GW-684	EXP-A	1	AQF	Cmn	BDR	106.4 - 128.4
GW-685[a]	EXP-A	1	AQF	Cmn	BDR	88.5 - 138.3
GW-694[a]	EXP-B	1	AQF	Cmn	BDR	154.0 - 204.5
GW-695	EXP-B	1	AQF	OCk	BDR	50.6 - 62.6
GW-703[a]	EXP-B	1	AQF	Cmn	BDR	135.0 - 182.0
GW-704[a]	EXP-B	1	AQF	Cmn	BDR	246.0 - 256.0
GW-706[a]	EXP-B	1	AQF	Cmn	BDR	157.0 - 182.5
GW-710[a]	EXP-W	1	AQF	OCk	BDR	539.7 - 744.5

Table 3 (cont'd)

Well	Location[2]	Cluster Designation[3]	Aquifer[4]			Monitored Interval Depths[5]		
			Unit	Fm	Interval			
GW-711[a]	EXP-W	1	AQF	Cmn	BDR	616.0	-	666.2
GW-712[a]	EXP-W	1	AQF	OCk	BDR	441.5	-	457.5
GW-713[a]	EXP-W	1	AQF	Cmn	BDR	305.0	-	315.2
GW-714[a]	EXP-W	3	AQF	Cmn	BDR	115.1	-	145.0
GW-715	EXP-W	1	AQF	Cmn	WT	32.0	-	44.0
GW-723[a]	EXP-C	1	AQF	Cmn	BDR	340.6	-	444.5
GW-724[a]	EXP-C	1	AQF	Cmn	BDR	289.6	-	301.6
GW-725[a]	EXP-C	1	AQF	Cmn	BDR	132.5	-	142.5
GW-736	EXP-C	1	AQF	Cmn	BDR	92.0	-	105.0
GW-737	EXP-C	1	AQF	Cmn	BDR	79.0	-	89.5
GW-738	EXP-C	1	AQF	Cmn	BDR	63.5	-	88.0
GW-739[a]	EXP-C	1	AQF	Cmn	BDR	289.2	-	320.0
GW-740[a]	EXP-C	4	AQF	Cmn	BDR	165.6	-	190.0
GW-793	AGLLSF	3	AQT	Cn	BDR	16.9	-	29.0
GW-794	AGLLSF	3	AQT	Cn	BDR	25.8	-	39.3
GW-795	AGLLSF	3	AQT	Cn	WT	7.5	-	20.1
GW-800	OLF	4	AQF	OCk	BDR	19.3	-	31.5

Notes:

1 Well construction information compiled from: *Updated Subsurface Data Base for Bear Creek Valley, Chestnut Ridge, and Parts of Bethel Valley on the U.S. Department of Energy Oak Ridge Reservation* (Jones et al. 1994).

2 AGLLSF - Above Grade Low-Level Storage Facility
BG - Bear Creek Burial Grounds WMA
EXP - Exit Pathway Monitoring Location:
Maynardville Limestone Transverse (-A, -B, -C, -W)
OLF - Oil Landfarm WMA
RS - Rust Spoil Area
S3 - S-3 Site
SPI - Spoil Area I

Table 3 (cont'd)

Notes: (cont'd)

3 Cluster designation for trace metal data evaluation purposes (see Table 4). Springs (S-1, S-4, and S-5) and upgradient surface water stations (NT-01, BCK-11.97 and BCK-09.40) were assigned to cluster 1. The background surface water station (NT-13) was assigned to cluster 2. Downgradient surface water stations (BCK-04.55 and BCK-00.63) were assigned to cluster 3.

4 Unit: Hydrostratigraphic unit

AQF - Maynardville Limestone
AQT - Conasauga Shales

Fm: Geologic Formation

OCk - Knox Group
Cmn - Maynardville Limestone
Cn - Nolichucky Shale
Cm - Maryville Limestone
Crg - Rogersville Shale
Cpv - Pumpkin Valley Shale

Interval: determined from the placement of the top of the monitored interval

BDR - Bedrock Interval
WT - Water Table Interval (above unweathered bedrock)

5 Depth in feet below ground surface.

a Open-hole well construction.

Table 4. VOCs Detected in QA/QC Samples During CY 1994

Compound	Number of QA/QC Samples Containing Specified Compound (by Sample Type)				
	Laboratory Blanks	Trip Blanks	Field Blanks	Equipment Rinsates	Total
Total Samples	87	124	3	35	249
Laboratory Reagents					
Methylene chloride	16	17	0	3	36
Acetone	1	9	0	2	12
2-Butanone	1	3	0	3	7
4-Methyl-2-pentanone	1	0	0	0	1
Source Water Contaminants					
Chloroform	0	1	1	0	2
1,2-Dichloropropane	0	1	1	0	2
1,1,2,2-Tetrachloroethane	1	0	0	0	1
VOC Plume Constituents					
1,1,1-Trichloroethane	0	4	0	0	4
Tetrachloroethene	0	0	0	1	1
Miscellaneous Compounds					
Bromodichloromethane	0	1	1	0	2
Total Number of Contaminated Samples:	**19**	**30**	**1**	**8**	**58**
Percent of Total Samples:	**22%**	**24%**	**33%**	**23%**	**23%**

Table 5. Summary of False Positive VOC Results for CY 1994 Groundwater and Surface Water Samples

Compound	Groundwater and Surface Water Sample Results[1]	False Positive Results Identified From[2]		Total False Positive Results	Percent of Groundwater Sample Results
		Laboratory Blanks	Trip Blanks		
Laboratory Reagents					
Methylene chloride	12	9 (7)	2 (2)	11	92
Acetone	5	0	2 (1)	2	40
2-Butanone	5	0	2 (2)	2	40
Source Water Contaminants					
Chloroform	24	0	0	0	0
VOC Plume Constituents					
Trichloroethene	61	0	0	0	0
1,2-Dichloroethene	49	0	0	0	0
Tetrachloroethene	35	0	0	0	0
Carbon tetrachloride	11	0	0	0	0
1,1-Dichloroethane	10	0	0	0	0
Vinyl chloride	7	0	0	0	0
1,1,1-Trichloroethane	6	0	0	0	0
1,1-Dichloroethene	4	0	0	0	0
Miscellaneous Compounds					
Benzene	1	0	0	0	0
Bromodichloromethane	3	0	0	0	0
Total:	**233**	**9**	**6**	**15**	**6**

Notes:

1 The number of samples in which the compound was detected.
2 The number of false positive results identified by each blank. Number in parentheses indicates the number of samples from which the false positives were identified.

Table 6. Summary of Anomalous VOC Results, CYs 1991 - 1994

Compound	Number of Anomalous Results[1]	Number of Wells	Maximum Concentration[2] (μg/L)
Laboratory Reagents			
Acetone	24	21	180.0
4-Methyl-2-pentanone	11	11	86.0
Methylene chloride	9	9	5.0
2-Butanone	8	8	16.0
Toluene	7	7	2.0
2-Hexanone	2	2	3.0
Source Water Contaminants			
Chloroform	19	15	25.0
Vinyl acetate	5	4	6.0
Bromoform	1	1	1.0
1,1,2,2-Tetrachloroethane	1	1	1.0
1,1,2-Trichloroethane	1	1	1.0
Miscellaneous Compounds			
Benzene	9	7	1.0
Ethylbenzene	4	4	2.0
Chloroethane	3	2	3.0
Chlorobenzene	3	3	1.0
Xylenes	3	3	5.0
Bromodichloromethane	2	1	3.0
Carbon disulfide	2	2	2.0
Styrene	1	1	1.0

Table 6 (cont'd)

Compound	Number of Anomalous Results[1]	Number of Wells	Maximum Concentration[2] (μg/L)
Plume Constituents			
Trichloroethene	20	15	9.0
1,2-Dichloroethene	16	13	7.0
1,1,1-Trichloroethane	16	13	2.0
Tetrachloroethene	14	11	2.0
Carbon tetrachloride	11	9	2.0
Vinyl chloride	8	3	3.0
1,1-Dichloroethene	8	6	11.0
1,1-Dichloroethane	6	6	2.0

<u>Notes</u>:

1 Total samples analyzed: 1,511
Samples with anomalous results: 155 (10% of total)
Total anomalous results: 214

2 Concentration in micrograms per liter

Table 7. Anomalous VOC Results Reported for CY 1994 Groundwater Samples

Compound	Sampling Point	Location[1]	Date Sampled	Anomalous Result[2]	Surrogate Value[3]
Laboratory Reagents					
Acetone					
	GW-053	BG	9/15/94	6	0
	GW-061	BG	9/15/94	6	0
	GW-627	BG	3/14/94	16	0
Chloroform					
	GW-085	OLF	6/24/94	25	0
	GW-085	OLF	12/15/94	15	0
2-Butanone					
	GW-053	BG	9/15/94	16	0
	GW-061	BG	9/15/94	8	0
	GW-723	EXP-C	12/20/94	10	0
Miscellaneous					
Benzene					
	GW-725	EXP-C	3/18/94	1	0
Bromodichloromethane					
	GW-085	OLF	6/24/94	2	0
	GW-085	OLF	12/15/94	3	0
Plume Constituents					
Trichloroethene					
	GW-061	BG	6/24/94	0.7	N/A
	GW-348	S3	6/20/94	6	N/A
	GW-683	EXP-A	9/20/94	1	N/A

Table 7 (cont'd)

Compound	Sampling Point	Location[1]	Date Sampled	Anomalous Result[2]	Surrogate Value[3]
Plume Constituents (cont'd)					
Trichloroethene (cont'd)					
	GW-684	EXP-A	9/20/94	1	N/A
1,2-Dichloroethene					
	GW-312	RS	12/14/94	1	0
	GW-683	EXP-A	9/20/94	1	N/A
	GW-684	EXP-A	9/20/94	1	N/A
1,1,1-Trichloroethane					
	GW-653	BG	2/26/94	0.7	0
Tetrachloroethene					
	GW-287	BG	3/9/94	2	N/A
	GW-287	BG	6/9/94	2	N/A
	GW-348	S3	2/16/94	0.9	N/A
	GW-738	EXP-C	3/16/94	0.8	0
1,1-Dichloroethane					
	GW-653	BG	2/26/94	2	0
1,1-Dichloroethene					
	GW-725	EXP-C	12/18/94	1	0
Vinyl chloride					
	GW-069	BG	3/11/94	2	N/A
	GW-069	BG	6/8/94	2	N/A
	GW-069	BG	9/9/94	2	N/A

Table 7 (cont'd)

Notes:

1 BG - Bear Creek Burial Grounds WMA
EXP - Exit Pathway Monitoring Location:
Maynardville Limestone Transverse (-A, -B, -C)
OLF - Oil Landfarm WMA
RS - Rust Spoil Area
S3 - S-3 Site

2 Concentration (in micrograms per liter) of a compound detected in 25 percent or less of the samples collected from a well.

3 Most anomalous results were replaced with zero as a surrogate value for the purposes of determining summed average VOC concentrations. Results considered potentially representative of groundwater contamination were not replaced with a surrogate value; these results are denoted with "N/A".

Table 8. Upper Tolerance Limits for Selected Trace Metals

Trace Metal	Upper Tolerance Limit[1] (mg/L)				
	Cluster 1 Sampling Point	Cluster 2 Sampling Point	Cluster 3 Sampling Point	Cluster 4 Sampling Point	Cluster 10 Sampling Point
Aluminum	2.4	6.1	2.4	2.4	2.4
Antimony	0.05[a]	0.05[a]	0.05[a]	0.05[a]	0.05[a]
Boron	0.12	0.028	0.041	0.028	3.1
Cobalt	0.019	0.019	0.019	0.019	0.019
Copper	0.012	0.012	0.012	0.012	0.012
Iron	8.7	8.7	8.7	4.6	6.9
Manganese	1.7	1.7	1.7	0.13	0.13
Molybdenum	0.018	0.018	0.018	0.018	0.018
Strontium	4.4	0.079	0.92	0.079	0.92
Thorium	0.2[a]	0.2[a]	0.2[a]	0.2[a]	0.2[a]
Uranium	0.012	0.004	0.005	0.005	0.005
Vanadium	0.0044[b]	0.0044[b]	0.0044[b]	0.0044[b]	0.0044[b]
Zinc	0.041	0.043	0.041	0.041	0.040

Note:

1 - Concentrations values assumed to be representative of uncontaminated groundwater at the Y-12 Plant. Results in milligrams per liter.

a - Analytical detection limit.

b - Below the analytical detection limit.

Table 9. Potentially Biased Trace Metal Concentrations

Sampling Point	Date Sampled	Trace Metal Concentration[1] (mg/L)					
		Aluminum	Boron	Copper	Iron	Nickel	Zinc
BCK-00.63	2/14/94	.	0.071	.	.	.	.
BCK-04.55	2/14/94	.	0.13	.	.	.	.
GW-047	3/24/94	.	0.071	.	.	.	0.17
GW-053	3/10/94	.	0.24	.	.	.	0.044
GW-056	2/26/94	.	.	.	.	0.23	.
GW-061	3/21/94	.	.	.	.	.	0.042
GW-080	3/9/94	11	.	0.043	9.4	.	.
GW-084	2/8/94	2.5	.	.	.	.	.
GW-085	2/11/94	.	0.047	.	.	.	0.047
GW-095	3/10/94	.	.	.	.	.	0.2
GW-276	3/30/94	15	.	0.037	.	0.6	0.26
GW-287	3/9/94	.	0.049	.	.	.	0.073
GW-312	2/9/94	3.9	.	.	.	.	.
GW-325	2/15/94	.	.	.	.	.	0.059
GW-345	2/18/94	.	0.03	.	.	.	.
GW-601	3/25/94	.	0.13	.	.	.	.
GW-621	2/18/94	.	.	.	.	0.056	.
GW-652	3/9/94	3.2	.	.	.	.	.
GW-654	3/9/94	.	0.067	.	.	.	.
GW-683	3/4/94	.	0.043	.	.	.	.
GW-714	2/25/94	.	0.093	.	.	.	.
GW-794	3/23/94	.	0.1	.	.	.	.
GW-800	2/11/94	.	0.11	.	.	.	.

Note:

1 Results in milligrams per liter

Table 10. Summary of CY 1994 Radioanalyte Data

Analyte	Total Results Reported	Results that Failed Evaluation Criteria			Results that Passed Evaluation Criteria	
		Negative Results	Less Than MDA[1]	Error Exceeds Activity	Total Number	Percent of Total Results
234-Thorium	9	0	1	3	5	56
137-Cesium	2	0	0	1	1	50
99-Technetium	103	5	59	0	39	38
40-Potassium	6	0	2	2	2	33
Radium	67	3	42	0	22	33
Gross Beta	229	35	121	0	73	32
Gross Alpha	229	53	137	1	38	17
Strontium	103	57	34	0	12	12
235-Uranium	90	31	23	31	5	6
234-Uranium	90	13	74	0	3	3
238-Uranium	90	18	69	0	3	3
241-Americium	66	22	43	0	1	2
237-Neptunium	66	13	51	1	1	2
Tritium	102	41	60	0	1	1
129-Iodine	67	3	64	0	0	0
131-Iodine	38	19	19	0	0	0
133-Iodine	3	1	N/A	2	0	0
135-Iodine	3	1	N/A	2	0	0
238-Plutonium	66	23	43	0	0	0
239-Plutonium	66	26	40	0	0	0
Total	**1,495**	**364**	**882**	**43**	**206**	**14**

Notes:

1 Results less than the minimum detectable activity.

Table 11. Annual Average VOC Concentrations, CY 1994

Sampling Point[1]	MCL[3]	Average VOC Concentration[4] (μg/L)					
		GW-053	GW-061	GW-064	GW-069	GW-243	GW-276
Location[2]		BG	BG	OLF	BG	S3	S3
Qualitative Results							
Bromodichloromethane	-	0	0	0	0	0	0
Carbon tetrachloride	5	0	0	1.3	0	0	0
Chloroform	-	0	0	1.5	0	0	1
1,1-Dichloroethane	-	7.3	0	0	0	0	0
1,1-Dichloroethene	7	0	0	0	0	0	0
1,2-Dichloroethene	-	0	0	6	0	75	0
Methylene chloride	5	0	0	0	0	370	0
Tetrachloroethene	5	0.7	0	0.8	0	0	0
1,1,1-Trichloroethane	200	0	0	0.4	0	0	0
Trichloroethene	5	2.3	0.2	0	0	0	0
Vinyl chloride	2	8.8	0	0	1.5	0	0
Qualitative Summed Average[5]		**19.1**	**0.2**	**10**	**1.5**	**445**	**1**
Quantitative Results							
1,2-Dichloroethene	-	15	0	0	0	0	0
Tetrachloroethene	5	0	0	0	0	7,900	48
Trichloroethene	5	0	0	77	0	0	0
Quantitative Summed Average[6]		**15**	**0**	**77**	**0**	**7,900**	**48**
Plume Delineation Value[7]		**34**	**0.2**	**87**	**1.5**	**8,345**	**49**

Table 11 (cont'd)

Sampling Point[1]	MCL[3]	Average VOC Concentration[4] (μg/L) GW-287	GW-311	GW-312	GW-315	GW-348	GW-537
Location[2]		BG	RS	RS	SPI	S3	OLF
Qualitative Results							
Bromodichloromethane	-	0	0	0	0.3	0	0
Carbon tetrachloride	5	0	0.7	0	0	0	0
Chloroform	-	0	1	1.3	3.3	0	0.5
1,1-Dichloroethane	-	0	0	0	0	0	0
1,1-Dichloroethene	7	0	0	0	0	0	0
1,2-Dichloroethene	-	0	0	0	0	0	0
Methylene chloride	5	0	0	0	0	0	0
Tetrachloroethene	5	1	0	0	0	0.2	0
1,1,1-Trichloroethane	200	0	0	0	0	0	0
Trichloroethene	5	0	0	0	8.5	1.5	0
Vinyl chloride	2	0	0	0	0	0	0
Qualitative Summed Average[5]		**1**	**1.7**	**1.3**	**12.1**	**1.7**	**0.5**
Quantitative Results							
1,2-Dichloroethene	-	0	0	0	11	0	0
Tetrachloroethene	5	0	0	0	15	0	0
Trichloroethene	5	0	16	67	0	0	0
Quantitative Summed Average[6]		**0**	**16**	**67**	**26**	**0**	**0**
Plume Delineation Value[7]		**1**	**18**	**68**	**38**	**1.7**	**0.5**

Table 11 (cont'd)

Sampling Point[1]	MCL[3]	GW-601	GW-627	GW-653	GW-683	GW-684	GW-685
Location[2]		OLF	BG	BG	EXP-A	EXP-A	EXP-A
		Average VOC Concentration[4] (µg/L)					
Qualitative Results							
Bromodichloromethane	-	0	0	0	0	0	0
Carbon tetrachloride	5	2	0	0	0	0	0
Chloroform	-	0	0	0	0	0	0
1,1-Dichloroethane	-	0	3.8	0	0	0	0
1,1-Dichloroethene	7	0	0	0	0	0	0
1,2-Dichloroethene	-	0	0	0	0.5	0.5	1
Methylene chloride	5	0	0	0	0	0	0
Tetrachloroethene	5	1	0	2.8	0	0	0
1,1,1-Trichloroethane	200	0	0	0	0	0	0
Trichloroethene	5	0	5.8	0.7	0.5	0.5	0
Vinyl chloride	2	0	0	0	0	0	0
Qualitative Summed Average[5]		**3**	**9.6**	**3.5**	**1**	**1**	**1**
Quantitative Results							
1,2-Dichloroethene	-	0	0	11	0	0	0
Tetrachloroethene	5	0	39	0	0	0	0
Trichloroethene	5	98	0	0	0	0	0
Quantitative Summed Average[6]		**98**	**39**	**11**	**0**	**0**	**0**
Plume Delineation Value[7]		**101**	**49**	**15**	**1**	**1**	**1**

Table 11 (cont'd)

Sampling Point[1]	MCL[3]	Average VOC Concentration[4] (μg/L) GW-694	GW-695	GW-703	GW-704	GW-706	GW-723
Location[2]		EXP-B	EXP-B	EXP-B	EXP-B	EXP-B	EXP-C
Qualitative Results							
Bromodichloromethane	-	0	0	0	0	0	0
Carbon tetrachloride	5	0	0	0	1.5	0	0
Chloroform	-	0	0	0	0	0	0
1,1-Dichloroethane	-	0	0	0	0.5	0	0
1,1-Dichloroethene	7	0.5	0	0	7	0	0
1,2-Dichloroethene	-	8.5	2	7.5	3	9	0
Methylene chloride	5	0	0	0	0	0	0
Tetrachloroethene	5	0	0	0	0	0	0
1,1,1-Trichloroethane	200	0	0	0	2	0	0
Trichloroethene	5	0	4	0	0	0	7
Vinyl chloride	2	0	0	0	0	0	0
Qualitative Summed Average[5]		**9**	**6**	**7.5**	**14**	**9**	**7**
Quantitative Results							
1,2-Dichloroethene	-	0	0	0	0	0	0
Tetrachloroethene	5	0	0	0	0	0	0
Trichloroethene	5	10	0	23	92	11	0
Quantitative Summed Average[6]		**10**	**0**	**23**	**92**	**11**	**0**
Plume Delineation Value[7]		**19**	**6**	**31**	**106**	**20**	**7**

Table 11 (cont'd)

Sampling Point[1]	MCL[3]	Average VOC Concentration[4] (μg/L) GW-724	GW-725	GW-736	GW-737	GW-738	GW-739
Location[2]		EXP-C	EXP-C	EXP-C	EXP-C	EXP-C	EXP-C
Qualitative Results							
Bromodichloromethane	-	0	0	0	0	0	0
Carbon tetrachloride	5	0	0	0	0	1	0.5
Chloroform	-	0	0	0	0	1	0
1,1-Dichloroethane	-	0	0	0	0	0	0
1,1-Dichloroethene	7	0	0	0	0	0	0
1,2-Dichloroethene	-	2	2	2.5	3	2.5	1.5
Methylene chloride	5	0	0	0	0	0	0
Tetrachloroethene	5	1.5	1	0.5	2.5	0	0
1,1,1-Trichloroethane	200	0	0	0	0	0.4	0
Trichloroethene	5	0	0	5	8	0	0
Vinyl chloride	2	0	0	0	0	0	0
Qualitative Summed Average[5]		**3.5**	**3**	**8**	**13.5**	**4.9**	**2**
Quantitative Results							
1,2-Dichloroethene	-	0	0	0	0	0	0
Tetrachloroethene	5	0	0	0	0	0	0
Trichloroethene	5	84	50	0	0	38	35
Quantitative Summed Average[6]		**84**	**50**	**0**	**0**	**38**	**35**
Plume Delineation Value[7]		**88**	**53**	**8**	**14**	**43**	**37**

Table 11 (cont'd)

Sampling Point[1]	MCL[3]	Average VOC Concentration[4] (μg/L) GW-740	BCK-09.40	NT-01	SS-1	SS-4
Location[2]		EXP-C	EXP-SW	EXP-SW	EXP-SW	EXP-SW
Qualitative Results						
Bromodichloromethane	-	0	0	0	0	0
Carbon tetrachloride	5	0	0	0	0	0
Chloroform	-	1	0	0	0	0
1,1-Dichloroethane	-	0	0	0	0	0
1,1-Dichloroethene	7	0	0	0	0	0
1,2-Dichloroethene	-	2	5.5	0	0	2.5
Methylene chloride	5	0	0	0	0	0
Tetrachloroethene	5	0	0.5	5	1	0
1,1,1-Trichloroethane	200	0	0	0	0	0
Trichloroethene	5	0	0.3	0	1	3.5
Vinyl chloride	2	0	0	0	0	0
Qualitative Summed Average[5]		**3**	**6.3**	**5**	**2**	**6**
Quantitative Results						
1,2-Dichloroethene	-	0	0	0	0	0
Tetrachloroethene	5	0	0	0	0	0
Trichloroethene	5	37	0	0	0	0
Quantitative Summed Average[6]		**37**	**0**	**0**	**0**	**0**
Plume Delineation Value[7]		**40**	**6**	**5**	**2**	**6**

Table 11 (cont'd)

Notes:

1 BCK - Bear Creek Kilometer (Surface-Water Sampling Station)
GW - Groundwater Monitoring Well
NT - Northern Tributary to Bear Creek (Surface-Water Sampling Station)
SS - Spring

2 BG - Bear Creek Burial Grounds Waste Management Area
EXP - Exit Pathway (Maynardville Limestone, Bear Creek, and Springs)
OLF - Oil Landfarm Waste Management Area
RS - Rust Spoil Area
SPI - Spoil Area I

3 MCL - Maximum Contaminant Level

4 All results in micrograms per Liter (μg/L).
0 - False positive, anomalous, or not detected
() - Qualitative summed average (diluted sample)

5 Summed average concentration determined from estimated concentrations reported below the analytical detection limit.

6 Summed average concentration determined from concentrations reported above the analytical detection limit.

7 Values used for plume delineation purposes (Figures 18, 20, and 22).

Table 12. Annual Average Nitrate Concentrations That Exceed 10 mg/L[1], CYs 1990 - 1994

Location[2]	Sampling Point[3]	Nitrate (as N) Concentration[4] (mg/L)				
		1990	1991	1992	1993	1994
Conasauga Shales						
OLF	GW-085	185	139	213	749	177
S3	GW-101	2,200	1,967[a]	NS	NS	NS
S3	GW-125	28	2	2	NS	NS
S3	GW-243	6,230	7,322	6,488	NS	8,927[b]
S3	GW-245	4,545[a]	NS	NS	NS	NS
S3	GW-246	3,530[b]	NS	NS	NS	NS
S3	GW-247	7,380[b]	NS	NS	NS	NS
S3	GW-276	454[b]	NS	NS	NS	150[a]
S3	GW-277	1,690[b]	NS	NS	NS	NS
S3	GW-345	398	85	NS	10[a]	2[b]
S3	GW-346	811[b]	NS	NS	NS	NS
S3	GW-526	845	786	1,043	893[a]	NS
OLF	GW-537	819	1,321	852	698	693
S3	GW-615	9,690	6,758	10,955	NS	NS
S3	GW-616	274	492	290	NS	NS
Maynardville Limestone						
BG	GW-052	28	12	20	9	NS
BG	GW-061	11	11	19	NS	16
S3	GW-100	388[b]	NS	NS	NS	NS
S3	GW-122	770	439[a]	NS	NS	NS
S3	GW-124	160[b]	NS	NS	NS	NS
OLF	GW-225	97	82	73	NS	NS
OLF	GW-227	17	25	26	NS	NS
OLF	GW-228	37[b]	NS	NS	NS	NS
S3	GW-307	18	11	NS	NS	NS
S3	GW-308	15	10	NS	NS	NS
RS	GW-309	18	15	15	NS	NS
SPI	GW-314	8	7	17	NS	NS
SPI	GW-315	16	16	23	13	9
S3	GW-348	10	10	11	10	9
OLF	GW-369	11	12	NS	NS	NS
OLF	GW-601	29	66	32	34	36[b]
EXP	GW-683	NS	13	14	12	6[b]
EXP	GW-684	NS	11	14	9	8

Table 12 (cont'd)

Location[2]	Sampling Point[3]	Nitrate (as N) Concentration[4] (mg/L)				
		1990	1991	1992	1993	1994
EXP	GW-694	NS	30	37	25	12[a]
EXP	GW-703	NS	6	17	19	15[a]
EXP	GW-704	NS	10	15	12	19[a]
EXP	GW-706	NS	43	38	31	24[a]
EXP	GW-710	NS	NS	ND	75	ND[a]
EXP	GW-723	NS	NS	14	12	11[a]
EXP	GW-724	NS	NS	40	49	45[a]
EXP	GW-725	NS	NS	47	53	79[a]
EXP	GW-736	NS	NS	48	47	36[a]
EXP	GW-737	NS	NS	53	47	38[a]
EXP	GW-738	NS	NS	17	26	20[a]
Surface Water						
EXP	NT-01	NS	NS	NS	219[a]	156[a]
EXP	SS-1	78	47	45	43[a]	24[a]
EXP	SS-4	41	16	40	33	20[a]
EXP	SS-5	22	10	16	12	9[a]
EXP	BCK 9.40	23	18	13	14	14[a]
EXP	BCK 11.97	220	68	108	NS	102[a]

Notes:

1 Maximum Contaminant Level (MCL) for drinking water.

2 BG - Bear Creek Burial Grounds WMA
EXP - Exit Pathway (Maynardville Limestone, Bear Creek, and Springs)
OLF - Oil Landfarm WMA
RS - Rust Spoil Area
S3 - S-3 Site
SPI - Spoil Area I

3 BCK - Bear Creek Kilometer (Surface-Water Sampling Station)
GW - Groundwater Monitoring Well
NT - North Tributary to Bear Creek
SS - Spring

Table 12 (cont'd)

Notes: (cont'd)

4 Annual average nitrate (as N) concentration in milligrams per liter (mg/L).
NS - Not Sampled
ND - Not Detected
Boldface type indicates annual average concentration less than 10 mg/L.

a Annual average concentration calculated for two samples.

b Concentration represents single CY sampling event.

Table 13. Selected Median Trace Metal Concentrations That Exceed UTLs and MCLs, CY 1994

Metal[1]	Sampling Point	Location[2]	Cluster[3]	UTL/ MCL[4] (mg/L)	CY 1994 Median Concentration[4] (mg/L)	Number of Samples[5]
Conasauga Shales						
Barium						
	GW-243	S3	NA	2.0	18	1
	GW-537	OLF	NA	2.0	2.55	4
Beryllium						
	GW-243	S3	NA	0.004	0.059	2
	GW-276	S3	NA	0.004	0.011	2
Boron						
	GW-654	BG	3	0.041	0.12	3
Cadmium (AAS)						
	GW-042	BG	NA	0.005	0.009	4
	GW-243	S3	NA	0.005	2.4	1
	GW-276	S3	NA	0.005	0.067	2
Chromium						
	GW-243	S3	NA	0.1	0.3	1
Manganese						
	GW-243	S3	3	1.7	210	1
	GW-276	S3	3	1.7	10.25	2
Mercury (CVAA)						
	GW-243	S3	NA	0.002	0.11	1
Strontium						
	GW-243	S3	3	0.92	12	1
	GW-537	OLF	3	0.92	3	4
Uranium (fluorometric)						
	GW-243	S3	3	0.005	30	1
	GW-276	S3	3	0.005	1.355	2

Table 13 (cont'd)

Metal[1]	Sampling Point	Location[2]	Cluster[3]	UTL/ MCL[4] (mg/L)	CY 1994 Median Concentration[4] (mg/L)	Number of Samples[5]
Maynardville Limestone						
Boron						
	GW-053	BG	1	0.12	0.36	3
	GW-683	EXP-A	4	0.028	0.082	1
	GW-714	EXP-W	3	0.041	0.099	1
Strontium						
	GW-800	OLF	4	0.079	0.125	4
Uranium (fluorometric)						
	GW-061	BG	1	0.012	0.035	4
	GW-683	EXP-A	4	0.005	0.042	2
	GW-684	EXP-A	1	0.012	0.048	2
	GW-694	EXP-B	1	0.012	0.116	2
	GW-706	EXP-B	1	0.012	0.078	2
Surface Water						
Boron						
	BCK-00.63	EXP-SW	3	0.041	0.067	1
	BCK-04.55	EXP-SW	3	0.041	0.07	1
	BCK-09.40	EXP-SW	1	0.12	0.22	2
Cadmium (AAS)						
	NT-01	EXP-SW	NA	0.005	0.022	2
Manganese						
	NT-01	EXP-SW	1	1.7	4	2

Table 13 (cont'd)

Metal[1]	Sampling Point	Location[2]	Cluster[3]	UTL/ MCL[4] (mg/L)	CY 1994 Median Concentration[4] (mg/L)	Number of Samples[5]
Uranium (fluorometric)						
	NT-01	EXP-SW	1	0.012	0.022	2
	BCK-00.63	EXP-SW	3	0.005	0.029	2
	BCK-04.55	EXP-SW	3	0.005	0.032	2
	BCK-09.40	EXP-SW	1	0.012	0.146	2
	BCK-11.97	EXP-SW	1	0.012	0.237	2
Springs						
Uranium (fluorometric)						
	SS-1	EXP-SW	1	0.012	0.038	2
	SS-4	EXP-SW	1	0.012	0.122	2
	SS-5	EXP-SW	1	0.012	0.05	2

Notes:

1 Results obtained by ICP spectroscopy unless otherwise noted.
AAS - Atomic Absorption Spectroscopy
CVAA - Cold Vapor Atomic Absorption Spectroscopy

2 BG - Bear Creek Burial Grounds WMA
EXP - Exit Pathway Monitoring Location:
Maynardville Limestone Transverse (-A, -B, -C, -W)
Spring or Surface Water Sampling Location (-SW)
OLF - Oil Landfarm WMA
S3 - S-3 Site

3 Cluster designation for trace metal data evaluation purposes (see Section 4.2.2.3).
NA - Not applicable for metal concentrations compared to MCLs.

4 Concentrations in milligrams per liter.

5 The number of samples used to determine median concentrations, excluding samples potentially contaminated in the laboratory (see Section 4.2.2.4).

Table 14. Gross Alpha and Beta Activities That Meet Evaluation Criteria

Sampling Point	Location[1]	Date Sampled	Activity[2] (pCi/L)	
			Gross Alpha	Gross Beta
GW-040	BG	8/22/94	9.44 ± 3.6	35.9 ± 5.5
GW-061	BG	3/21/94	14.6 ± 3.8	26.9 ± 4.7
		6/24/94	18 ± 4.3	57.1 ± 7.4
		9/15/94	37.1 ± 8.9	71.7 ± 11
		12/12/94	12.8 ± 3.5	36 ± 5.4
GW-064	OLF	2/10/94	.	16.9 ± 3.6
		6/23/94	.	13.4 ± 3.1
		9/1/94	.	15.8 ± 3.7
		12/15/94	.	13.8 ± 3.4
GW-085	OLF	2/11/94	.	67.9 ± 57
		6/24/94	.	71.5 ± 14
		9/7/94	13.2 ± 10	142 ± 17
		12/15/94	.	102 ± 12
GW-243	S3	3/30/94	3,530 ± 440	22,700 ± 650
GW-276	S3	3/30/94	398 ± 56	1,110 ± 120
		8/20/94	454 ± 53	1,180 ± 120
GW-315	SPI	6/20/94	.	25.6 ± 4.4
		8/30/94	.	30.6 ± 5.1
		12/5/94	.	30 ± 26
GW-348	S3	2/16/94	.	28.7 ± 4.7
		6/20/94	.	17.7 ± 3.5
		8/30/94	.	25.6 ± 4.6
		12/5/94	.	27.9 ± 4.6
GW-537	OLF	2/11/94	.	713 ± 88
		6/24/94	.	397 ± 46
		9/7/94	32.6 ± 14	392 ± 25
		12/15/94	.	350 ± 39

Table 14 (cont'd)

Sampling Point	Location[1]	Date Sampled	Activity[2] (pCi/L)					
			Gross Alpha			Gross Beta		
GW-601	OLF	3/25/94		.		25.5	±	4.5
GW-613	S3	2/14/94		.		15.8	±	3.7
GW-621	EXP-B	2/18/94		.		16.1	±	3.7
GW-652	BG	9/13/94	5.92	±	2.5		.	
GW-653	BG	12/7/94	5.9	±	2.7	19	±	4
GW-683	EXP-A	9/20/94	22.2	±	5	34.3	±	5.4
GW-684	EXP-A	3/4/94	8.37	±	2.7	20.1	±	4.1
		9/20/94	16.4	±	4.2	40.2	±	6
GW-685	EXP-A	9/19/94	4.94	±	2.5	11.4	±	3.2
GW-694	EXP-B	3/2/94	37	±	6.5	30	±	5
		12/13/94	63.4	±	9.4	85.9	±	10
GW-695	EXP-B	2/21/94	6	±	2.5	21.2	±	4.1
GW-703	EXP-B	2/23/94	4.92	±	2.3	44.5	±	6.3
		12/12/94		.		19.4	±	3.9
GW-704	EXP-B	2/25/94		.		14.6	±	3.5
GW-706	EXP-B	3/4/94	24.6	±	5	24.3	±	4.5
		12/15/94	38.1	±	6.8	78	±	9.5
GW-714	EXP-W	8/20/94		.		12.6	±	3.5
GW-723	EXP-C	3/17/94		.		19.2	±	4
		12/20/94	6.07	±	2.4	37.5	±	5.5
GW-724	EXP-C	3/18/94		.		41.8	±	6.1
		12/18/94		.		39.4	±	5.7
GW-725	EXP-C	3/18/94		.		33	±	5.3
		12/18/94		.		36	±	5.4
GW-736	EXP-C	3/21/94		.		49.5	±	6.8
		12/19/94		.		47.9	±	6.5

Table 14 (cont'd)

Sampling Point	Location[1]	Date Sampled	Activity[2] (pCi/L)					
			Gross Alpha			Gross Beta		
GW-737	EXP-C	3/21/94		.		44.1	±	6.3
		12/18/94		.		42.7	±	6
GW-738	EXP-C	3/16/94		.		48.3	±	6.7
		12/17/94		.		50	±	6.8
GW-739	EXP-C	3/16/94		.		13.9	±	3.5
		12/18/94		.		12.9	±	3.3
BCK-00.63	EXP-SW	2/14/94	11.1	±	2.9	11.1	±	3.1
		9/6/94	7.31	±	3.4	13.4	±	4.2
BCK-04.55	EXP-SW	2/14/94	15.1	±	3.5	13.7	±	3.4
		9/6/94	9.74	±	3.7	12.9	±	4.1
BCK-09.40	EXP-SW	2/14/94	60.2	±	8.9	58.9	±	7.6
		9/6/94	44.6	±	7.6	68.2	±	8.7
BCK-11.97	EXP-SW	2/14/94	33.1	±	6.5	118	±	13
		9/6/94	62	±	11	405	±	42
NT-01	EXP-SW	2/14/94	6.26	±	2.8	166	±	18
		9/7/94	8.11	±	3.8	364	±	38
SS-1	EXP-SW	2/14/94	21.9	±	5.2	43.5	±	6.1
		9/7/94	13.1	±	4.2	65	±	8.4
SS-4	EXP-SW	2/14/94	15.3	±	3.8	20.6	±	4
		9/6/94	67.4	±	10	111	±	13
SS-5	EXP-SW	9/6/94	28.8	±	6.1	50.3	±	7.3

Table 14 (cont'd)

Notes:

1 BG - Bear Creek Burial Grounds WMA
EXP - Exit Pathway Monitoring Location:
Maynardville Limestone Transverse (-A, -B, -C, -W)
Spring or Surface Water Sampling Location (-SW)
OLF - Oil Landfarm WMA
RS - Rust Spoil Area
S3 - S-3 Site
SPI - Spoil Area I

2 Activity reported in picoCuries per liter
. - results did not meet evaluation criteria

Table 15. CY 1994 Radionuclide Results That Meet Evaluation Criteria

Isotope	Sampling Point	Location[1]	Date Sampled	Activity[2]		
Americium-241						
	GW-243	S3	3/30/94	31.5	±	9.7
Cesium-137						
	GW-795	AGLLSF	11/8/94	5.13	±	4.8
Neptunium-237						
	GW-243	S3	3/30/94	374	±	280
Potassium-40						
	GW-047	BG	5/31/94	388	±	330
	GW-162	BG	5/18/94	517	±	360
Radium (total)						
	GW-040	BG	8/22/94	0.1	±	0.04
	GW-043	OLF	2/8/94	0.11	±	0.06
	GW-043	OLF	11/30/94	0.077	±	0.047
	GW-044	OLF	2/8/94	0.14	±	0.06
	GW-044	OLF	8/31/94	0.068	±	0.028
	GW-044	OLF	11/30/94	0.06	±	0.044
	GW-080	BG	3/9/94	0.06	±	0.047
	GW-080	BG	6/7/94	0.093	±	0.074
	GW-162	BG	5/18/94	0.071	±	0.067
	GW-162	BG	11/7/94	0.11	±	0.06
	GW-243	S3	3/30/94	1.3	±	0.3
	GW-276	S3	3/30/94	0.2	±	0.08
	GW-276	S3	8/20/94	0.13	±	0.04
	GW-372	BG	11/8/94	0.095	±	0.067
	GW-613	S3	2/14/94	0.062	±	0.045

Table 15 (cont'd)

Isotope	Sampling Point	Location[1]	Date Sampled	Activity[2]		
Radium (total) (cont'd)						
	GW-642	BG	5/19/94	0.06	±	0.057
	GW-642	BG	11/7/94	0.08	±	0.06
	GW-710	EXP-W	2/24/94	0.21	±	0.11
	GW-710	EXP-W	8/19/94	0.26	±	0.08
	GW-711	EXP-W	2/23/94	0.19	±	0.07
	GW-711	EXP-W	8/18/94	0.19	±	0.07
	GW-714	EXP-W	2/25/94	0.13	±	0.08
Strontium (total)						
	BCK-11.97	EXP-SW	2/14/94	374	±	46
	GW-042	BG	3/11/94	47.3	±	24
	GW-044	OLF	11/30/94	51	±	23
	GW-061	BG	12/12/94	65.7	±	26
	GW-080	BG	3/9/94	33.4	±	23
	GW-162	BG	11/7/94	34	±	30
	GW-243	S3	3/30/94	103	±	28
	GW-276	S3	3/30/94	48.1	±	23
	GW-324	S3	2/15/94	33.5	±	20
	GW-642	BG	3/9/94	33.2	±	23
	GW-683	EXP-A	3/4/94	78.2	±	27
	SS-4	EXP-SW	2/14/94	313	±	43
Technetium-99						
	BCK-09.40	EXP-SW	2/14/94	158	±	64
	BCK-11.97	EXP-SW	2/14/94	263	±	67
			9/6/94	751	±	56
	GW-061	BG	3/21/94	362	±	70

Table 15 (cont'd)

Isotope	Sampling Point	Location[1]	Date Sampled	Activity[2]
Technetium-99 (cont'd)				
	GW-085	OLF	2/11/94	331 ± 69
			6/24/94	291 ± 68
			9/7/94	273 ± 45
			12/15/94	255 ± 44
	GW-115	S3	2/17/94	197 ± 37
	GW-243	S3	3/30/94	54,700 ± 740
	GW-276	S3	3/30/94	1,570 ± 190
			8/20/94	1,120 ± 64
	GW-315	SPI	6/20/94	194 ± 65
			8/30/94	114 ± 40
			12/5/94	117 ± 40
	GW-324	S3	2/15/94	146 ± 66
	GW-345	S3	2/18/94	162 ± 64
	GW-373	BG	5/21/94	123 ± 63
	GW-537	OLF	2/11/94	1,460 ± 95
			6/24/94	1,040 ± 86
			9/7/94	1,020 ± 62
			12/15/94	1,070 ± 63
	GW-683	EXP-A	3/4/94	166 ± 64
	GW-684	EXP-A	3/4/94	125 ± 63
	GW-694	EXP-B	3/2/94	163 ± 64
	GW-706	EXP-B	3/4/94	142 ± 63
	GW-710	EXP-W	2/24/94	130 ± 36
	GW-711	EXP-W	2/23/94	166 ± 37
	GW-712	EXP-W	2/24/94	203 ± 38

Table 15 (cont'd)

Isotope	Sampling Point	Location[1]	Date Sampled	Activity[2]		
Technetium-99 (cont'd)						
	GW-713	EXP-W	2/27/94	111	±	36
	GW-714	EXP-W	2/25/94	126	±	36
	GW-715	EXP-W	2/26/94	145	±	37
	GW-793	AGLLSF	3/22/94	373	±	70
	NT-01	EXP-SW	2/14/94	458	±	72
			9/7/94	786	±	57
	SS-1	EXP-SW	2/14/94	223	±	66
			9/7/94	166	±	42
	SS-4	EXP-SW	2/14/94	137	±	63
			9/6/94	156	±	42
Thorium-234						
	GW-276	S3	8/20/94	946	±	780
	GW-710	EXP-W	8/19/94	638	±	620
	GW-713	EXP-W	8/19/94	1,000	±	630
	GW-715	EXP-W	8/20/94	870	±	670
	GW-794	AGLLSF	8/4/94	1,010	±	510
Tritium						
	GW-243	S3	3/30/94	140	±	30
Uranium-234						
	GW-243	S3	3/30/94	4,210	±	120
	GW-276	S3	3/30/94	179	±	13
			8/20/94	225	±	10

Table 15 (cont'd)

Isotope	Sampling Point	Location[1]	Date Sampled	Activity[2]
Uranium-235				
	GW-047	BG	11/8/94	22.7 ± 18
	GW-079	BG	6/7/94	18.8 ± 18
	GW-243	S3	3/30/94	86.2 ± 85
	GW-373	BG	8/24/94	117 ± 110
	GW-795	AGLLSF	3/23/94	18.2 ± 17
Uranium-238				
	GW-243	S3	3/30/94	7,810 ± 160
	GW-276	S3	3/30/94	387 ± 20
			8/20/94	519 ± 15

Notes:

1 AGLLSF - Above Grade Low-Level Storage Facility
BG - Bear Creek Burial Grounds WMA
EXP - Exit Pathway Monitoring Location:
Maynardville Limestone Transverse (-A, -B, -C, -W)
Spring or Surface Water Sampling Location (-SW)
OLF - Oil Landfarm WMA
S3 - S-3 Site
SPI - Spoil Area I

2 Activity reported in picoCuries per liter.

Table 16. Dose Equivalent Calculations

Parameter[1]	Dose Factor[2]	Sampling Point Location[3]					
		GW-085 OLF	GW-243 S-3	GW-276 S-3	GW-537 OLF	GW-694 EXP-B	GW-706 EXP-B
Gross Beta							
Mean Activity		96	22,700	1,145	463	58	51
Technetium	3,790						
Mean Activity		287.50	54,700	1,345	1,030	163	142
Dose Equivalent		0.3	57.73	1.42	1.09	0.17	0.15
Strontium[4]	42						
Mean Activity		NP	103	48.1	NP	NP	NP
Dose Equivalent			9.81	4.58			
Tritium[5]	60,900						
Mean Activity		NP	140	NP	NP	NP	NP
Dose Equivalent			0.25				
Cumulative Dose[6]		**0.3**	**67.79**	**6.00**	**1.09**	**0.17**	**0.15**

Table 16 (cont'd)

Parameter[1]	Dose Factor[2]	Sampling Point Location[3] NT-01 EXP-SW	 BCK-11.97 EXP-SW	 BCK-9.40 EXP-SW	 SS-1 EXP-SW	 SS-4 EXP-SW
Gross Beta						
Mean Activity		265	262	64	54	66
Technetium	3,790					
Mean Activity		622	507	158	194.50	146.50
Dose Equivalent		0.66	0.54	0.17	0.21	0.16
Strontium[4]	42					
Mean Activity		NP	374	NP	NP	313
Dose Equivalent			35.6			29.81
Tritium[5]	60,900					
Mean Activity		NP	NP	NP	NP	NP
Dose Equivalent						
Cumulative Dose[6]		**0.66**	**36.14**	**0.17**	**0.21**	**29.97**

Notes:

1 Dose equivalents are annual mean activities converted to millirems per year (mrem/yr):
Activity (pCi/L) ÷ Dose Factor (pCi/L per 4 mrem/yr) x 4 = Dose equivalent (mrem/yr)

2 Radionuclide activity that will yield a 4 mrem/yr dose equivalent assuming a 2-liter per day drinking-water intake. Values from U.S. Environmental Protection Agency as published in the Federal Register, Vol. 56 No. 138, July 18, 1991.

3 EXP - Exit Pathway (Maynardville Limestone and Bear Creek)
OLF - Oil Landfarm WMA
S3 - S-3 Site

4 The dose equivalent for ^{90}Sr is calculated from the total Sr mean activity.

5 Tritium activity is reported in becquerels/Liter (Bq/L) and must be converted to pCi/L:
Activity (Bq/L) x 27 = Activity (pCi/L)

6 The cumulative dose is the sum of the isotopic dose equivalents: 4 mrem/yr is the MCL

NP - No results passed QA/QC criteria (Table 15).

Table 17. Nitrate Concentration Variations in Surface Water and Spring Samples, CYs 1992 - 1994

Year/Qtr.		Month	Net Change in Nitrate (as N) Concentration (mg/L)								
			Upstream								Downstream
			NT-01	SS-1	BCK-11.97	SS-4	BCK-09.40	SS-5	SS-8	BCK-04.55	BCK-00.63
1992	1st	Mar.	NS	**- 10.0**	**- 35.8**	+ 10.4	**- 3.0**	+ 4.8	+ 0.11	**- 0.3**	+ 0.1
	2nd	June	NS	+ 22.5	+ 107.4	+ 25.5	+ 14.3	+ 7.8	**- 0.11**	+ 2.8	+ 2.5
	3rd	Sep.	NS	+ 2.5	+ 110.4	+ 18.4	**- 0.7**	+ 10.1	0.0	+ 0.5	+ 1.1
	4th	Dec.	NS	**- 15.0**	**- 196.0**	**- 12.0**	**- 7.0**	**- 4.0**	+ 0.11	+ 5.1	+ 4.0
1993	1st	Mar.	.	**- 10.0**	NS	**- 37.7**	0.0	**- 17.5**	+ 0.04	**- 7.7**	**- 7.3**
	2nd	May	NA	NA	NS	+ 5.7	+ 2.0	+ 2.0	- 0.02	+ 0.3	+ 0.2
	3rd	Aug.	.	.	NS	+ 26.3	+ 5.8	+ 10.7	+ 1.18	+ 3.7	+ 2.9
	4th	Nov.	**- 27.1**	+ 10.7	NS	+ 26.3	NA	+ 9.6	**- 1.15**	+ 4.0	+ 4.8
1994	1st	Jan.	**- 175.4**	**- 37.1**	.	**- 64.5**	.	**- 24.2**	NS	**- 8.7**	**- 8.6**
	2nd	Apr.	NS	NS	NS	NS	NS	NS	NS	NS	NS
	3rd	Jul.	+ 144.4	+ 12.2	+ 115.3	+ 33.9	+ 15.4	+ 16.4	NS	+ 2.3	+ 2.3
	4th	Dec.	NS	NS	NS	NS	NS	NS	NS	NS	NS
Maximum Increase:			+ 144.4	+ 22.5	+ 115.3	+ 33.9	+ 21.0	+ 19.0	+ 1.18	+ 5.1	+ 4.8
Maximum Decrease:			- 175.4	- 37.1	- 196.0	- 64.5	- 28.5	- 25.6	- 1.15	- 8.7	- 8.6
Range:			319.8	59.6	311.34	98.4	49.5	44.6	2.33	13.8	13.4

Table 17 (cont'd)

Notes:

BCK - Bear Creek Kilometer
NA - Not available (data considered unusable; see discussion in Section 7.0.)
NS - Not sampled
SS - Spring

Table 18. Sampling Frequency[1] and Sequence Proposed for CY 1996

Sample Group	Location[2]	Sampling Point[3]	Monitoring Program[4]
BC-1	S3	GW-115	CMP
	S3	GW-613	CMP
	S3	GW-614	CMP
	OLF	GW-044	CMP
	OLF	GW-043	CMP
	OLF	GW-084	CMP
	OLF	GW-363	CMP
	S3	GW-276	CMP
BC-2	BG	GW-079	CMP
	BG	GW-080	CMP
	BG	GW-040	CMP
	BG	GW-042	CMP
	BG	GW-162	CMP
	BG	GW-642	CMP
	BG	GW-372	CMP
	BG	GW-373	CMP
	BG	GW-069	CMP
BC-3	EXP-W	GW-710	CMP/EXP
	EXP-W	GW-711	CMP/EXP
	EXP-W	GW-712	CMP/EXP
	EXP-W	GW-713	CMP/EXP
	EXP-W	GW-714	CMP/EXP
	EXP-W	GW-715	CMP/EXP
BC-4	EXP-A	GW-056	EXP
	EXP-A	GW-685	EXP

Table 18 (cont'd)

Sample Group	Location[2]	Sampling Point[3]	Monitoring Program[4]
BC-4 (cont'd)	EXP-A	GW-683	EXP
	EXP-A	GW-684	EXP
	EXP-B	GW-621	EXP
	EXP-B	GW-695	EXP
	EXP-B	GW-703	EXP
	EXP-B	GW-704	EXP
	EXP-B	GW-694	EXP
	EXP-B	GW-706	EXP
BC-5	EXP-C	GW-740	EXP
	EXP-C	GW-723	EXP
	EXP-C	GW-738	EXP
	EXP-C	GW-724	EXP
	EXP-C	GW-725	EXP
BC-6	RS	GW-311	SMP
	SPI	GW-315	SMP
	OLF	GW-828	SMP
	OLF	GW-085	SMP
	OLF	GW-537	SMP
	OLF	GW-829	SMP
BC-7	AGLLSF	GW-793	BMP
	AGLLSF	GW-794	BMP
	AGLLSF	GW-795	BMP

Table 18 (cont'd)

Sample Group	Location[2]	Sampling Point[3]	Monitoring Program[4]
BC-7 (cont'd)	BG	GW-095	SMP
	BG	GW-287	SMP
	BG	GW-653	SMP
	BG	GW-053	SMP
	BG	GW-627	SMP
BC-8	EXP-SW	BCK-00.63	EXP
	EXP-SW	BCK-04.55	EXP
	EXP-SW	BCK-07.75	EXP
	EXP-SW	SS-5	EXP
	EXP-SW	BCK-09.40	EXP
	EXP-SW	SS-4	EXP
	EXP-SW	BCK-10.60	EXP
	EXP-SW	SS-1	EXP
	EXP-SW	BCK-11.97	EXP
	EXP-SW	NT-01	EXP

Notes:

1 Samples from all locations will be collected semiannually, during the first and third quarters of CY 1996.

2 AGLLSF - Above Grade Low-Level Storage Facility
BG - Bear Creek Burial Grounds WMA
EXP - Exit Pathway (Maynardville Limestone, Bear Creek, and Springs)
OLF - Oil Landfarm WMA
RS - Rust Spoil Area
S3 - S-3 Site
SPI - Spoil Area I

Table 18 (cont'd)

3 BCK - Bear Creek Kilometer (Surface-Water Sampling Station)
GW - Groundwater Monitoring Well
NT - North Tributary to Bear Creek
SS - Spring

4 AMP - RCRA Assessment Monitoring Program
BMP - Best-Management Practice Monitoring
CMP - RCRA Corrective Action Monitoring Program
EXP - Exit-Pathway Monitoring
SMP - Surveillance and Maintenance Program

a Background sampling location.

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