Y/SUB/01-006512/5

BWXT Y-12
A BWXT/Bechtel Enterprise

Y-12 NATIONAL SECURITY COMPLEX

Y-12 GROUNDWATER PROTECTION PROGRAM CALENDAR YEAR 2000 GROUNDWATER MONITORING DATA EVALUATION REPORT FOR THE BEAR CREEK HYDROGEOLOGIC REGIME AT THE U.S. DEPARTMENT OF ENERGY Y-12 NATIONAL SECURITY COMPLEX, OAK RIDGE, TENNESSEE

September 2001

Prepared by

AJA TECHNICAL SERVICES, INC.
Under Subcontract No. 4300006512

for the

Environmental Compliance Department
Environment, Safety, and Health Organization
Y-12 National Security Complex
Oak Ridge, Tennessee 37831

Managed by

BWXT Y-12, L.L.C.
for the U.S. Department of Energy
Under Contract No. DE-AC05-00OR22800

MANAGED BY
BWXT Y-12, L.L.C.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

UCN-13672 (10-00)

Y/SUB/01-006512/5

Y-12 GROUNDWATER PROTECTION PROGRAM
CALENDAR YEAR 2000
GROUNDWATER MONITORING DATA EVALUATION REPORT
FOR THE
BEAR CREEK HYDROGEOLOGIC REGIME
AT THE
U.S. DEPARTMENT OF ENERGY Y-12 NATIONAL SECURITY COMPLEX,
OAK RIDGE, TENNESSEE

September 2001

Prepared by

AJA TECHNICAL SERVICES, INC.
Under Subcontract No. 4300006512

for the

Environmental Compliance Department
Environment, Safety, and Health Organization
Y-12 National Security Complex
Oak Ridge, Tennessee 37831

Managed by

BWXT Y-12, L.L.C.
for the U.S. Department of Energy
Under Contract No. DE-AC05-00OR22800

CONTENTS

List of In-Text Tables

List of In-Text Tables (continued)

List of Figures

List of Tables

List of Acronyms and Abbreviations

AJA	AJA Technical Services, Inc.
BCBG	Bear Creek Burial Grounds
BCV	Bear Creek Valley
BCK	Bear Creek kilometer
Bear Creek Regime	Bear Creek Hydrogeologic Regime
BG	Burial Ground
bgs	below ground surface
BJC	Bechtel Jacobs Company LLC
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CE	counting error
CY	calendar year
DNAPL	dense nonaqueous phase liquids
DOE	U.S. Department of Energy
DQO	data quality objective
East Fork Regime	Upper East Fork Poplar Creek Hydrogeologic Regime
ft	feet
GWMR	Groundwater Monitoring Report
GWPP	Groundwater Protection Program
HCDA	Hazardous Chemical Disposal Area
MCL	maximum contaminant level
MDA	minimum detectable activity
µg/L	micrograms per liter
mg/L	milligrams per liter
msl	mean sea level
NT	North Tributary (Bear Creek)
ORR	Oak Ridge Reservation
PCE	tetrachloroethene
pCi/L	picoCuries per liter
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
SDWA	Safe Drinking Water Act
SS	south side (Bear Creek)
TCE	trichloroethene
TDS	total dissolved solids
VC	vinyl chloride
VOC	volatile organic compound
WMA	waste management area
WRRP	Water Resources Restoration Program
111TCA	1,1,1-trichloroethane
11DCA	1,1-dichloroethane
11DCE	1,1-dichloroethene
12DCA	1,2-dichloroethane
12DCE	1,2-dichloroethene
c12DCE	cis-1,2-dichloroethene
t12DCE	trans-1,2-dichloroethene
Tc-99	technetium-99
U-234	uranium-234
U-238	uranium-238
Y-12	Y-12 National Security Complex

1.0 INTRODUCTION

This report presents an evaluation of the groundwater and surface water monitoring data obtained during calendar year (CY) 2000 in the Bear Creek Hydrogeologic Regime (Bear Creek Regime). The Bear Creek Regime encompasses many confirmed and potential sources of groundwater and surface water contamination associated with the U.S. Department of Energy (DOE) Y-12 National Security Complex (hereafter referenced as Y-12) in Oak Ridge, Tennessee (Figure A.1). Prepared by the Y-12 Groundwater Protection Program (GWPP), this report addresses applicable provisions of DOE Order 5400.1 (*General Environmental Protection Program*) that require: (1) an evaluation of the quantity and quality of groundwater and surface water in areas that are, or could be, affected by Y-12 operations, (2) an evaluation of groundwater and surface water quality in areas where contaminants from Y-12 operations are most likely to migrate beyond the DOE Oak Ridge Reservation (ORR) property line, and (3) an evaluation of long-term trends in groundwater quality at Y-12. The following sections of this report contain relevant background information (Section 2.0); describe the results of the respective data evaluations required under DOE Order 5400.1 (Section 3.0); summarize significant findings of each evaluation (Section 4.0); and list the technical reports and regulatory documents cited for more detailed information (Section 5.0). Illustrations (maps and trend graphs) are presented in Appendix A. Brief data summary tables referenced in each section are contained within the sections. Supplemental information and extensive data tables are provided in Appendix B.

2.0 BACKGROUND INFORMATION

The Bear Creek Regime encompasses a portion of Bear Creek Valley (BCV) west of Y-12 that, beginning in the early 1950s, has been used primarily for the treatment, storage, and disposal of various hazardous and nonhazardous wastes. Many of the historical waste-management sites are confirmed or suspected sources of groundwater and surface water contamination. The primary contaminant sources are the S-3 Site (formerly the S-3 Ponds), the Oil Landfarm waste management area (WMA), which includes the Boneyard/Burnyard/Hazardous Chemical Disposal Area (HCDA), and the Bear Creek Burial Grounds (BCBG) WMA, all of the which have undergone some level of engineered closure (e.g., installation of multilayer, low-permeability caps) and are currently regulated under the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), or both. Contaminated receptor media in the regime (groundwater, surface water, and Bear Creek stream sediments and floodplain soils) are also regulated under CERCLA. The following discussion presents background information regarding the Bear Creek Regime, including an overview of the groundwater monitoring programs and the associated CY 2000 sampling and analysis activities, along with brief descriptions of the geology and groundwater flow system in BCV and the extent of groundwater and surface water contamination.

2.1 CY 2000 MONITORING SUMMARY

Groundwater and surface water monitoring in the Bear Creek Regime during CY 2000 was performed primarily: (1) as needed to support the data evaluation requirements specified under applicable provisions of DOE Order 5400.1, (2) in accordance with the requirements for RCRA post-closure corrective action monitoring, as defined in the RCRA post-closure permit for the Bear Creek Regime, and (3) as needed for the purposes of CERCLA baseline and remediation effectiveness monitoring. The following discussion provides a brief overview of the associated sampling and analysis activities for CY 2000, including the organizations responsible for monitoring at Y-12; the sampling locations, dates, and methods; and the field measurements and laboratory analyses. A more detailed description of these sampling and analysis activities is provided in the annual Groundwater Monitoring Report (GWMR) for CY 2000 (AJA Technical Services, Inc. [AJA] 2001).

The Y-12 GWPP, which was managed by Lockheed Martin Energy Systems, Inc. until November 2000 when management was taken over by BWXT Y-12, L.L.C., implemented the groundwater sampling and analysis activities in the Bear Creek Regime that were needed to support the monitoring data evaluations specified under applicable provisions of DOE Order 5400.1. The Water Resources Restoration Program (WRRP) Organization, which is managed by Bechtel Jacobs Company LLC (hereafter referenced as BJC), implemented the sampling and analysis activities associated with the RCRA and CERCLA groundwater monitoring programs. Although performed separately, the respective CY 2000 sampling activities planned for Y-12 by the GWPP and WRRP were coordinated to achieve mutual programmatic objectives, including the use of functionally equivalent groundwater sampling procedures and laboratory analytical methods. Accordingly, the monitoring results obtained by the GWPP and the WRRP are suitable to the purposes of each organization.

As shown in Table 1, seven springs, ten surface water stations, and 49 monitoring wells, including four wells with dedicated multi-port sampling equipment (hereafter referenced as Westbay™ wells), were sampled for the purposes of DOE Order 5400.1 monitoring, RCRA monitoring, and CERCLA monitoring during CY 2000.

Table 1. CY 2000 sampling locations in the Bear Creek Regime

Monitoring Driver	Monitoring Wells	Springs	Surface Water Stations
DOE Order 5400.1	28	4	7
RCRA	8	0	0
CERCLA	20	6	4
Totals:	**49**	**7**	**10**

Note: Several sampling locations serve multiple monitoring purposes (i.e., RCRA, CERCLA, DOE Order)

Figure A.2 shows the locations of these monitoring wells, springs, and sampling locations along Bear Creek. Samples were collected at least semiannually from all of the springs and Bear Creek sampling locations, and from each of the monitoring wells except the Westbay™ wells (GW-727, GW-729, GW-730, and GW-790), which were sampled only once, and nine other monitoring wells (GW-006, GW-043, GW-044, GW-615, GW-835, GW-838, GW-840, GW-904, and GW-905) that were sampled at least three times (Table B.1). Semiannual sampling was performed during seasonally wet (January-March 2000) and seasonally dry (July-September 2000) flow conditions.

The low-flow minimal drawdown sampling method (hereafter referenced as low-flow sampling) was used to collect groundwater samples from all monitoring wells except the Westbay wells. Under low-flow sampling, which is intended to obtain representative groundwater samples that do not include stagnant water in the well casing, field personnel first pump the well at a flow rate that is low enough (<300 milliliters per minute) to minimize drawdown of the water level in the well (<0.1 feet [ft] per quarter-hour) and regularly check the pH, conductivity, temperature, oxidation-reduction potential, and dissolved oxygen in the groundwater pumped from the well. Samples of the groundwater are collected immediately after the field measurements for each parameter indicate minimal variation over four consecutive readings. Additionally, groundwater samples were collected from selected monitoring wells (Table B.1) using the "conventional" sampling method, which involved purging at least three well volumes of groundwater at a much higher pumping rate (1.0 - 1.8 gallons per minute) before collecting samples, on the day after collecting samples with the low-flow sampling method.

2.2 TOPOGRAPHY AND BEDROCK GEOLOGY

The Bear Creek Regime is bound to the north by Pine Ridge and to the south by Chestnut Ridge and encompasses the portion of BCV extending from a surface water and shallow groundwater divide at the west end of Y-12 near the S-3 Site to the western boundary of the Bear Creek watershed. Surface elevations range from 900 ft above mean sea level (msl) in the Bear Creek channel along the floor of BCV to about 1,200 ft msl along the crests of Pine Ridge and Chestnut Ridge (Figure A.3).

The geology of the Bear Creek Regime is characterized by alternating sequences of clastic and carbonate strata that form the distinctive topography of the Valley and Ridge Physiographic Province. On the ORR, shale and siltstone beds of the Rome Formation form Pine Ridge to the north, limestone and shale formations of the Conasauga Group form BCV, and the primarily dolostone formations of the Knox Group form Chestnut Ridge to the south (Figure A.3). Strike and dip of bedding are generally N 55°E and 45°SE, respectively (as referenced to true north). Bedrock is overlain by up to 50 ft of several materials, including man-made fill, alluvium, colluvium, fine-grained residuum from the weathering of the bedrock, and saprolite (weathered bedrock which retains relict bedding and fractures).

2.3 HYDROGEOLOGIC FRAMEWORK

The following overview of the groundwater and surface water systems in the Bear Creek Regime is based on the conceptual hydrogeologic model described in the CERCLA remedial investigation (RI) report for the Bear Creek Characterization Area (DOE 1997), which is hereafter referenced as the RI Report. This conceptual model incorporates: (1) the general hydrologic framework and associated nomenclature described in Solomon et al. (1992); (2) groundwater flow characteristics presented in Moore (1988 and 1989) and Moore and Toran (1992); (3) results of hydrologic studies and investigations in BCV, including Dreier et al. (1987), Shevenell (1994), and Turner et al. (1991); and (4) findings of sampling and analysis activities performed specifically for RI purposes. Key aspects of the conceptual model regarding the principal hydrogeologic units and respective groundwater flow characteristics and the general hydrology of Bear Creek are summarized in the following discussion.

2.3.1 Groundwater System

There are two basic hydrogeologic units in the Bear Creek Regime: the aquifer, consisting of the Maynardville Limestone (upper Conasauga Group) and Copper Ridge Dolomite (lower Knox Group); and the aquitard, consisting of the remaining Conasauga Group formations (Nolichucky Shale, Maryville Limestone, Rogersville Shale, Rutledge Limestone, and Pumpkin Valley Shale) and the Rome Formation (Figure A.3). Components of the aquifer underlie the axis of BCV (Maynardville Limestone) and the steep flank and crest of Chestnut Ridge (Copper Ridge Dolomite). Formations comprising the aquitard form the northern slope of BCV (Conasauga Group) and Pine Ridge (Rome Formation). The aquitard, which underlies the primary contaminant source areas in the Bear Creek Regime, is hydraulically upgradient of the aquifer, which functions as a hydrologic drain in BCV. Fractures provide the principal groundwater flowpaths in both units, and dissolution of carbonates in the aquifer has enlarged fractures and produced solution cavities and conduits that greatly enhance its hydraulic conductivity relative to the aquitard. Flow through the porous rock matrix is minimal in both units, although matrix diffusion processes play an important role in contaminant migration.

Groundwater flow in the aquitard and the aquifer is primarily parallel to bedding (along strike and dip), which in the aquitard may or may not coincide with the direction of maximum hydraulic gradient inferred from water level isopleths. Flow across bedding occurs primarily along permeable zones formed by cross-cutting fractures or fracture zones (and possibly small faults). The northern tributaries of Bear Creek are possibly the surficial expression of these cross-cutting structures. Such structures provide preferred flowpaths that channel groundwater from the aquitard to the aquifer or act as barriers to lateral flow, causing groundwater from deeper intervals to upwell and discharge to the shallower flow system in each hydrogeologic unit.

In the aquitard, most groundwater flow occurs in a highly conductive interval near the bedrock/residuum interface. Flow above the water table occurs in response to precipitation when flowpaths in the residual soils become saturated and rapidly transmit water laterally (stormflow) down slope toward springs, seeps, streams and vertically (recharge) to the water table interval. Recharge to the water table interval promotes strike-parallel groundwater flow toward discharge areas in nearby northern tributaries of Bear Creek. Although the presence of contaminants in groundwater more than 200 ft below ground surface (bgs) in the Nolichucky Shale clearly indicates permeable flowpaths at depth, flow is most active at depths less than 100 ft bgs, and only a small percentage of total flow ultimately recharges the deeper bedrock, where upward hydraulic gradients predominate. Overall, about 94% of the available groundwater in the aquitard discharges to Bear Creek tributaries, about 5% flows along cross-cutting fractures into the aquifer, and about 1% flows through strike-parallel pathways in the deeper subsurface (DOE 1997).

Decreasing groundwater flux with depth in the aquitard also is reflected by distinct changes in groundwater geochemistry. Most water table interval and shallow (i.e., <100 ft bgs) bedrock wells monitor calcium-magnesium-bicarbonate groundwater. A fairly abrupt change to sodium-bicarbonate groundwater, which is interpreted to be a function of longer groundwater residence time related to reduced fracture aperture or increased fracture spacing (Solomon et al. 1992), occurs at a depth of about 100 ft bgs. Further reduced groundwater flux is indicated by the transition from sodium-bicarbonate groundwater to sodium-chloride groundwater that usually occurs at a depth of about 400 ft bgs. The transition to the sodium-chloride groundwater is accompanied by a general increase in total dissolved solids (TDS).

Most groundwater flow in the aquifer occurs at shallow depths (i.e., <100 ft bgs) in an extensively interconnected network of solution conduits and cavities (karst network). Below the shallow karst network, fractures provide the primary flowpaths. Also, there are seven stratigraphic zones in the Maynardville Limestone (numbered from bottom to top) that are differentiated by distinct lithologic and hydrologic characteristics (Shevenell et al. 1995). The more permeable zones are at the bottom (Zone 2) and top (Zone 6) of the formation, but the uppermost zones are the most permeable and probably transmit the bulk of the groundwater in the Maynardville Limestone (Goldstrand 1995). Groundwater geochemistry is more homogeneous in the aquifer than in the aquitard; almost every monitoring well in the Maynardville Limestone, regardless of depth, monitors calcium-magnesium-bicarbonate groundwater. Some shallow wells monitor sulfate-enriched groundwater, which probably reflects dissolution of locally disseminated sulfides, including gypsum and anhydrite, and several deep wells monitor calcium-magnesium-sulfate groundwater with very high TDS.

Flow in the shallow karst network in the aquifer is relatively rapid and occurs as "quickflow" discharge to Bear Creek during rainfall. Active groundwater circulation in the aquifer occurs at greater depth than in the aquitard, and groundwater from the deeper flow system discharges along major gaining (influent) reaches of Bear Creek. These discharge areas are probably related to large-scale structural (e.g., cross-strike faults) or stratigraphic discontinuities in the Maynardville Limestone. Overall, about 81% of the available groundwater in the aquifer (Maynardville Limestone) discharges directly to Bear Creek, 16% flows into the creek from spring SS-5, and 3% follows strike-parallel flowpaths in the subsurface (DOE 1997).

Isopleths of seasonal groundwater surface elevations in the Bear Creek Regime during CY 2000 (Figure A.4) indicate generally southwesterly flow in the aquitard toward the aquifer (Maynardville Limestone) and westerly (strike-parallel) flow in the aquifer toward the west end of BCV. Seasonal water level fluctuations, which were typically less than 10 ft in most water table interval and bedrock interval monitoring wells, influenced the magnitude of hydraulic gradients but did not significantly alter the overall groundwater flow patterns.

2.3.2 Surface Water System

Surface water in the Bear Creek Regime is drained by Bear Creek and its tributaries (Figure A.3). From its headwaters near the west end of Y-12, Bear Creek flows southwest for approximately 4.5 miles, where it turns northward to flow into East Fork Poplar Creek. Monitoring locations along the main channel of Bear Creek are specified by the Bear Creek kilometer (BCK) value corresponding to the distance upstream from the confluence with East Fork Poplar Creek (e.g., BCK-09.40). Sections of the main channel are referenced as upper Bear Creek (upstream of BCK-11.97), middle Bear Creek (between BCK-11.97 and BCK-09.40), and lower Bear Creek (downstream of BCK-09.40). Tributaries are designated as north tributary (NT) or south tributary along with a value representing the tributary number counted downstream from the headwaters

(e.g., NT-1). Major springs along the south side (SS) of Bear Creek are numbered in ascending order downstream from the headwaters (e.g., SS-1).

Approximately half of the annual precipitation in BCV exits via surface water flow in Bear Creek, and possibly higher proportions during winter and early spring (DOE 1997). Flow in the creek increases rapidly during rainfall and afterward reflects the relative contributions of overland flow, stormflow, and groundwater discharge. Flow in the main channel and tributaries generally returns to pre-precipitation levels within one or two days. Major sections of upper and middle Bear Creek are seasonally dry, but flow is perennial in lower Bear Creek.

The main channel of Bear Creek functions as a major conduit of the shallow karst network within the Maynardville Limestone (DOE 1997). Discharge from numerous springs located along the Maynardville Limestone/Copper Ridge Dolomite boundary on the north slope of Chestnut Ridge dominate the hydrology of the creek, especially during droughts when they provide most of the flow in the main channel. Additionally, the main channel contains alternating gaining and losing reaches. Each gaining reach generally correlates with a major aquifer discharge area. Losing reaches in upper and middle Bear Creek, particularly a section of the main channel directly south of Sanitary Landfill I, play an important role in transferring contaminants from Bear Creek to the aquifer.

2.4 GROUNDWATER CONTAMINATION

The following discussion is based on the contaminant transport models for the primary source areas in the Bear Creek Regime (the S-3 Site, the Oil Landfarm WMA, and the BCBG WMA) and the principal contaminant migration pathways (the Maynardville Limestone and Bear Creek) described in the RI Report. These models incorporate the bulk of the geologic, hydrologic, and water quality data available for Y-12 and essentially represent the culmination of hydrogeologic characterization and contamination assessment efforts performed since the mid-1980s.

2.4.1 S-3 Site

Operation of the former S-3 Ponds emplaced a large reservoir of contamination in the aquitard (Nolichucky Shale) consisting of a heterogeneous mix of inorganic, organic, and radioactive constituents. The principal groundwater contaminants are nitrate, technetium-99 (Tc-99), uranium isotopes (primarily uranium-234 [U-234] and uranium-238 [U-238]), trace metals (e.g., cadmium), and volatile organic compounds (VOCs). Contaminant concentrations in the aquitard nearest the site have probably reached maximum levels, with the center of mass of the plume slowly moving westward. Westward, strike parallel migration of contaminants in the aquitard occurs until they encounter a cross-cutting structure that promotes upward discharge into the shallow flow system, or cross-strike flow into the aquifer.

The S-3 Site contaminant plume in the aquitard extends south toward the upper reach of Bear Creek and along strike in the water table interval and the deeper bedrock for over 3,000 ft to the west (Figure A.5). Nitrate is a highly mobile and chemically stable contaminant that delineates the maximum extent of groundwater transport and effectively traces the principal migration pathways. Nitrate (as N) concentrations (hereafter synonymous with “nitrate” concentrations) within the plume exceed 10,000 milligrams per liter (mg/L) in the deep bedrock directly below the S-3 Site, 1,000 mg/L in the shallow groundwater near the site, and 10 mg/L near the plume boundaries.

Gross alpha activity and gross beta activity within the S-3 Site contaminant plume exceed 1,000 picoCuries per liter (pCi/L). Although a diverse population of radioisotopes is present in the groundwater closest to the site, elevated gross alpha and gross beta activity in the groundwater (Figure A.5) probably delineate migration of uranium isotopes and Tc-99, respectively since these were the dominant radiological constituents in wastes placed into the S-3 ponds.

Other components of the S-3 Site contaminant plume are trace metals and VOCs. The distribution of trace metals is less extensive than that of nitrate and radioactivity, but the most mobile metals within the plume (e.g., barium) have been transported beyond the acidic groundwater (pH <5) nearest the site. Acetone and tetrachloroethene (PCE) are the principal VOCs within the plume. Concentrations of PCE exceed 5,000 micrograms per liter (µg/L) in wells adjacent to the site, indicating the presence of dense nonaqueous phase liquids (DNAPL) in the subsurface, but decrease to less than 50 µg/L about 500 ft downgradient of the site. Therefore, the suspected DNAPL emplaced during operation of the S-3 Ponds is the potential source of aqueous phase PCE observed in groundwater near the site, and the limited extent of PCE migration suggests substantial natural attenuation.

The S-3 Site contains varying amounts of sludge produced by denitrification of the waste water during closure of the former S-3 Ponds. Sludge within the saturated zone may release Tc-99 and uranium isotopes to the shallow groundwater flow system in the aquitard, which then may be transported southward towards Bear Creek and westward through the water table interval toward discharge points in NT-1 (DOE 1997). Additionally, matrix diffusion and advective transport processes are slowly releasing contaminants (e.g., nitrate) from the deeper reservoir into the more active (shallow) aquitard flow system.

2.4.2 Oil Landfarm WMA

The primary sources of groundwater contaminants in the Oil Landfarm WMA (listed in order of importance) are the Boneyard/Burnyard/HCDA, the Oil Landfarm, and the Sanitary Landfill I (Figure A.6). Each of these sites is a source of VOCs in the shallow groundwater, and the Boneyard/Burnyard/HCDA is a major source of elemental uranium and alpha radioactivity.

Uranium isotopes are the principal groundwater contaminants at the Boneyard/Burnyard. Contamination delineated by soil sampling and geophysical and radiological surveys indicate a major source area located immediately northwest of the HCDA cap. Wastes in the Boneyard/Burnyard are probably within the saturated zone during seasonally high groundwater levels, and uranium isotopes may be leached and transported with the shallow groundwater that discharges into NT-3 or recharges directly into the Maynardville Limestone. Gross alpha and gross beta activity exceed 1,000 pCi/L in the shallow groundwater along NT-3 from the northwest corner of the site to the confluence of NT-3 and Bear Creek (Figure A.5).

The Boneyard/Burnyard/HCDA also is the source of a dissolved VOC plume in the shallow groundwater. Primary components of the plume are trichloroethene (TCE), cis-1,2-dichloroethene (c12DCE), and PCE. Because the high gross alpha and beta levels in surface water at NT-3 characterize the plume originating from the Boneyard/Burnyard (Figure A.5), the lack of VOCs in these samples indicate that the HCDA is most likely the principal source of these VOCs.

Groundwater contaminants at the Oil Landfarm are principally VOCs, and a commingled plume containing two distinct suites of VOCs are evident: one to the northeast dominated by 1,1,1-trichloroethane (111TCA), 1,1-dichloroethane (11DCA), and 1,1-dichloroethene (11DCE); and one to the south dominated by PCE,

c12DCE, trans-1,2-dichloroethene (t12DCE), and TCE. The dissolved VOC plume appears to be restricted to the shallow flow system. Summed VOC concentrations exceed 1,000 µg/L in the northeast part of the plume and 100 µg/L in the southern part of the plume; maximum concentrations within the plume do not indicate the presence of DNAPL in the subsurface.

Sanitary Landfill I is a probable source of 11DCA, c12DCE, and t12DCE in the shallow groundwater (aquitard and aquifer) downgradient to the south of the site (Figure A.5). Maximum VOC concentrations are typically less than 50 µg/L. In the aquifer (Maynardville Limestone), these constituents have intermingled with the VOC plume (primarily TCE and c12DCE) originating from upgradient sources. Sanitary Landfill I also may be a source of boron in the groundwater at several wells immediately downgradient (west) of the site.

2.4.3 Bear Creek Burial Grounds WMA

Groundwater in the aquitard underlying the BCBG WMA is extensively contaminated with VOCs at both shallow (water table) and deep (bedrock) intervals (Figure A.5). There are five primary source areas: Burial Ground (BG)-A (North and South), BG-C (East and West), and the Walk-In Pits (Figure A.6). Dissolved VOC plumes in the shallow groundwater at several of these source areas are probably related to widespread occurrence of DNAPL in the subsurface. Contamination in the deeper groundwater flow system reflects density-driven, downward migration of DNAPL.

The disposal trenches comprising BG-A (North and South) received almost two million gallons of waste oils and coolants, and DNAPL has been encountered at 260 ft and 330 ft bgs in monitoring wells downdip of source trenches in BG-A South. Dissolved VOC plumes in the groundwater underlying both areas are dominated by PCE, TCE, and c12DCE. Other common plume constituents are 111TCA, 11DCA, and 1,2-dichloroethane (12DCA). Summed concentrations of these plume constituents exceed 100,000 µg/L. Groundwater in the water table interval transports the plume constituents along strike toward discharge areas in NT-7. Strike-parallel migration also occurs below the water table interval, as reflected by westward (strike-parallel) transport of PCE indicated by data obtained from deeper bedrock wells at BG-A South.

Separate plumes of dissolved VOCs apparently occur in the shallow groundwater at BG-C East and BG-C West (Figure A.5), both dominated by c12DCE with lesser amounts of vinyl chloride (VC). Concentrations within the plume are generally less than 500 µg/L. Groundwater containing these VOCs discharges to the NT-8 catchment on the northwest side of the Burial Grounds WMA. Data for both source areas do not clearly indicate the presence of DNAPL in the subsurface (DOE 1997).

Groundwater near the Walk-In Pits contains a distinct plume of dissolved VOCs dominated by PCE. Concentrations exceed 2,000 µg/L, which is about 1% of the maximum PCE solubility and possibly indicates DNAPL in the subsurface (DOE 1997). Contaminants in the shallow groundwater flow system may not discharge extensively to surface water (DOE 1997).

Although large quantities of uranium wastes were disposed in the BCBG WMA, few monitoring wells in the area yield radioactive groundwater samples (Figure A.5). However, RI data for soil samples and surface water samples collected from NT-6, NT-7, and NT-8 indicate that BG-A South and BG-C East are probable sources of radioactivity (DOE 1997). Maximum gross alpha and gross beta activities in the samples from these tributaries ranged from about 20 pCi/L to more than 100 pCi/L. The disparity with the groundwater sample data may be an artifact of the monitoring well network (few wells are screened within the shallowest water table interval where radioactive contamination likely occurs), but the relatively low levels of radioactivity

in the groundwater also suggest that the bulk of the uranium wastes in BG-A South and BG-C East are not within the saturated zone (DOE 1997).

Boron is the primary trace metal contaminant in the groundwater at the BCBG WMA. Elevated boron concentrations occur primarily in the shallow groundwater near BG-A South and BG-C (East and West) and probably resulted from disposal of borax wastewater from Y-12. Boron is most likely present in the groundwater as borate [$B(OH)_3$], which is chemically stable and relatively mobile, and is transported toward discharge points in Bear Creek tributaries NT-7 and NT-8.

2.4.4 Maynardville Limestone Exit Pathway

The principal groundwater contaminants in the Maynardville Limestone are nitrate, VOCs, radioactivity, and trace metals. These contaminants primarily originate from the S-3 Site (nitrate, trace metals, and radionuclides), the Boneyard/Burnyard/HCDA (uranium isotopes and VOCs), Sanitary Landfill I (VOCs), the BCBG WMA (VOCs and radionuclides), and the Rust Spoil Area (VOCs) or an unidentified source area (VOCs) in the Bear Creek floodplain adjacent to the Rust Spoil Area. These contaminants enter the Maynardville Limestone through direct recharge, hydrologic communication with surface water in Bear Creek, and inflow of shallow groundwater from the aquitard. Relative contributions from the source areas and the geochemical characteristics of the contaminants have produced two primary plumes of contamination in the groundwater: one containing nitrate and radioactivity and another containing VOCs. Both occur in the shallow karst network and the deeper fracture flowpaths and are commingled downgradient of the Boneyard/Burnyard/HCDA. Trace metal contaminants are more sporadically distributed and chiefly occur in the shallow karst network near the primary source areas (S-3 Site, Boneyard/Burnyard/ HCDA, and BCBG WMA).

The nitrate plume in the aquifer essentially delineates the maximum extent of contaminant transport and effectively traces the primary migration pathways in the Maynardville Limestone (Figure A.5). The plume is continuous in the deeper bedrock from south of the S-3 Site for about 10,000 ft along strike to the west, whereas attenuation from more active recharge and groundwater flux has reduced nitrate levels and produced a more discontinuous plume in the shallow karst network. Nitrate concentrations within the plume exceed 500 mg/L south of the S-3 Site, but rapidly decrease to less than 50 mg/L south of the Oil Landfarm WMA, and are typically highest in the fracture-dominated groundwater flow system at depths greater than 100 ft bgs.

The distribution of VOCs in the Maynardville Limestone reflects the relative contributions of several source areas and commingling during downgradient transport (Figure A.5). Plume constituents in the upper part of BCV are TCE, c12DCE, and PCE; probable source areas are Spoil Area I, the S-3 Site, and possibly the Fire Training Facility located in the Upper East Fork Poplar Creek Hydrogeologic Regime (East Fork Regime). The major inputs to the plume occur from the Rust Spoil Area (TCE) or a nearby source in the Bear Creek floodplain, the Boneyard/Burnyard/HCDA (TCE and c12DCE), Sanitary Landfill I (111TCA and 11DCA), and discharge from the Bear Creek tributary (NT-7) that traverses BG-A North and A South (c12DCE and 12DCA). The highest concentrations within the plume (i.e., >300 µg/L) occur in the deeper groundwater south (down dip) of the Boneyard/Burnyard. These high concentrations coincide with the downward vertical hydraulic gradients in the Maynardville Limestone in this area and the major losing reach of middle Bear Creek south of Sanitary Landfill I.

Radioactivity in the groundwater in the Maynardville Limestone is primarily from uranium isotopes and Tc-99. The extent of these radionuclides are generally delineated by gross alpha activity and gross beta activity,

respectively. The distribution of gross beta activity mirrors that of nitrate, indicating both a common source of nitrate and Tc-99 (the S-3 Site) and migration along common flowpaths. Increased gross alpha activity in the groundwater downstream of the NT-3 catchment reflects inputs of uranium isotopes from sources in the Boneyard/Burnyard/HCDA.

Most trace metal contamination in the Maynardville Limestone occurs in the shallow groundwater near the S-3 Site and the Boneyard/Burnyard/HCDA. Near the S-3 Site, the principal trace metal contaminants are barium, boron, cadmium, copper, lead, mercury, strontium, and uranium. Some of these metals (e.g., cadmium) were entrained in the highly acidic wastes disposed at the site, and others (e.g., strontium) were dissolved from the underlying bedrock. Trace metal contamination is sporadic in the groundwater at the Boneyard/Burnyard/HCDA, and the principal contaminants are beryllium, manganese, mercury, nickel, and uranium. Boron and uranium are the most common trace metal contaminants in the aquifer downgradient of the S-3 Site and the Boneyard/Burnyard/ HCDA, which indicates that relatively mobile ionic species of both metals are present in the groundwater.

2.5 SURFACE WATER CONTAMINATION

Many of the principal components of the groundwater contaminant plumes in the Bear Creek Regime, including nitrate, Tc-99, uranium isotopes, several trace metals, and a few VOCs (PCE, TCE, and c12DCE), occur in Bear Creek upstream of BCK-09.40 and several of its northern tributaries. However, the quality of surface water in Bear Creek improved dramatically after waste disposal at the S-3 Site ceased in 1983. Nitrate concentrations in upper Bear Creek at BCK-12.46, for example, exceeded 1,000 mg/L in 1983, but were less than 200 mg/L in 1994. Currently, input from several northern tributaries (primarily NT-1, NT-2, NT-3, and NT-8) during seasonally high flow conditions contribute the bulk of the contamination to the creek. During dry periods, contaminant flux into Bear Creek is generally lower, but because of less dilution in the creek channel, concentrations are typically higher and are probably controlled by contaminant levels in the groundwater discharged from springs SS-1, SS-4, and SS-5 (DOE 1997).

3.0 MONITORING DATA EVALUATION

The following sections provide an evaluation of the monitoring data for the network of CY 2000 sampling locations in the Bear Creek Regime. Each section addresses a corresponding requirement of DOE Order 5400.1. Section 3.1 (Surveillance Monitoring Data Evaluation) contains an evaluation of groundwater quality in areas that are, or could be, affected by Y-12 operations. Section 3.2 (Exit Pathway/Perimeter Monitoring Data Evaluation) contains an evaluation of surface water and groundwater quality where contaminants are most likely to migrate beyond the ORR property line. Section 3.3 (Contaminant Concentration Trend Evaluation) presents a review of long-term trends in groundwater quality near Y-12, as illustrated by data for applicable CY 2000 sampling locations in the Bear Creek Regime.

These respective DOE Order 5400.1 data evaluations focus on the primary groundwater contaminants in the regime (see discussion in Section 2.4) as defined by: (1) nitrate concentrations that exceed the 10 mg/L maximum contaminant level (MCL) for drinking water, (2) total uranium concentrations that exceed the federal MCL (0.03 mg/L), (3) individual VOC concentrations that exceed MCLs or summed VOC concentrations that exceed 5 µg/L, and (4) gross alpha radioactivity above the MCL (15 pCi/L) and/or gross beta radioactivity above the Safe Drinking Water Act (SDWA) screening level (50 pCi/L) for a 4 millirem per year dose equivalent (the MCL for gross beta). Each evaluation is based on historical and CY 2000 monitoring results that meet the applicable data quality objectives (DQO) defined in: *Y-12 Plant Groundwater Protection Program - Groundwater Monitoring Program Data Management Plan* (Science Applications International Corporation 2000). Detailed descriptions of the DQO criteria and associated data screening process, along with summaries of the CY 2000 data that do not meet applicable DQOs, are provided in the CY 2000 GWMR (AJA 2001).

3.1 SURVEILLANCE MONITORING DATA EVALUATION

The CY 2000 monitoring results reported for a total of 45 monitoring wells in the Bear Creek Regime were evaluated for the surveillance monitoring purposes of DOE Order 5400.1 (Figure A.2 and Table B.1). Twenty seven of these wells yield groundwater from the geologic formations comprising the aquitard (Maryville Limestone, Nolichucky Shale, Rogersville Shale, Pumpkin Valley Shale, and Rome Formation), and 20 of the wells (two Westbay wells have monitoring ports in both hydrogeologic units) yield groundwater from the geologic formations comprising the aquifer (Maynardville Limestone and Copper Ridge Dolomite). The following sections present separate evaluations of the CY 2000 monitoring data for the wells in each hydrogeologic unit.

3.1.1 Aquitard Monitoring Wells

As shown in Table 2, elevated concentrations of one or more of the principal groundwater contaminants in the Bear Creek Regime were reported for one or more of the groundwater samples collected during CY 2000 from 11 of the aquitard wells that serve the surveillance monitoring purposes of DOE Order 5400.1.

Table 2. Principal groundwater contaminants detected in aquitard wells used for CY 2000 Surveillance Monitoring

Well Number	Monitored Interval Depth (ft bgs)	Inorganics		Summed VOCs (>5 µg/L)	Radioactivity	
		Nitrate (>10 mg/L)	Uranium (>0.03 mg/L)		Gross Alpha (>15 pCi/L)	Gross Beta (>50 pCi/L)
GW-006	15.3 - 46.8	.	.	!	.	.
GW-008	13.0 - 25.5	.	.	!	.	.
GW-046	5.0 - 20.3	.	.	!	.	.
GW-085	48.4 - 58.8	!	.	.	.	!
GW-276	11.3 - 18.5	!	!	!	!	!
GW-526	101.0 - 123.0	!	.	.	!	.
GW-537	4.8 - 23.3	!	.	.	.	!
GW-615	222.5 - 245.0	!	!	!	.	.
GW-627	254.0 - 270.0	.	.	!	.	.
GW-653	26.3 - 39.0	.	.	!	.	.
GW-829	102.9 - 114.6	!	.	.	.	.

Note that elevated contaminant concentrations reported for samples from well GW-115 (benzene) and several ports in Westbay wells GW-727, GW-729, GW-730, and GW-790 (benzene, alpha activity, and beta activity) are considered sampling and/or analytical artifacts and not representative of actual groundwater conditions; therefore, these locations are not included on Table 2. Well GW-115 is located upgradient of all waste disposal sites and is a background monitoring location for RCRA monitoring purposes. Low levels of benzene (and other petroleum hydrocarbons) were reported for 28 of the 38 samples collected during CY 2000 from the four Westbay wells (some at depths greater than 1000 ft bgs) and possibly reflect sampling artifacts introduced in the field by using a gasoline-powered generator to collect samples. The elevated gross alpha and gross beta activity (> 150 pCi/L) at two sampling ports (GW-729-15 and GW-790-12, both deeper than 1000 ft bgs) are nearly equal to the associated minimum detectable activity (MDA) and have a large proportional counting error (CE), which reflects a high degree of uncertainty.

Groundwater contaminants in the monitoring wells shown in Table 2 originate primarily from subsurface contaminant plumes emplaced during historical operations of the former S-3 Ponds (GW-085, GW-276, GW-526, GW-537, GW-615, and GW-829); the Oil Landfarm (GW-006 and GW-008); and the BCBG WMA (GW-046, GW-627, and GW-653). The following sections provide separate discussions of the CY 2000 monitoring results for each major type of contaminant (inorganics, VOCs, and radioactivity).

3.1.1.1 Inorganic Contaminants

As shown in Table 3, elevated concentrations of nitrate and/or total uranium were reported for at least one groundwater sample collected during CY 2000 from aquitard monitoring wells GW-085, GW-276, GW-526, GW-537, GW-615, and GW-829.

Table 3. Elevated nitrate and uranium concentrations in aquitard wells used for Surveillance Monitoring during CY 2000

Well Location / Number		Distance and Direction from S-3 Site (Figure A.2)	Nitrate (mg/L)		Uranium (mg/L)	
			1st Qtr. 2000	3rd Qtr. 2000	1st Qtr. 2000	3rd Qtr. 2000
S-3 Site	GW-615	80 ft South	**12,300**	**14,700**	**0.877**	<0.004
	GW-276	200 ft Southeast	**96.1**	**105**	**0.947**	**0.96**
	GW-526	1,300 ft West	NA	**1,340**	<0.004	<0.004
Oil Landfarm WMA	GW-829	1,800 ft West	**21.1**	**20.3**	0.00127	0.0014
	GW-537	2,500 ft West	**680**	**734**	0.00137	0.00143
	GW-085	3,000 ft West	**186**	**227**	<0.0005	<0.0005

Notes: NA =Not analyzed; **BOLD** = Exceeds MCL for nitrate (10 mg/L) or uranium (0.03 mg/L)

Aquitard well GW-615 is located adjacent to the south side of the S-3 Site (Figure A.2). The CY 2000 monitoring results for this well indicate that nitrate and total uranium concentrations remain very high in the deep bedrock interval (>200 ft bgs) in the Nolichucky Shale directly down-dip (south) of the S-3 Site, and reflect an increasing long-term trend (see Section 3.3). Note that the anomalously low total uranium result (<0.004 mg/L) reported for the groundwater sample collected from the well in August 2000 is probably an analytical error (discredited by the high U-234 [115.8 pCi/L] and U-238 [296.1 pCi/L] activities reported for the sample) and, accordingly, is considered unusable for the surveillance monitoring purposes of DOE Order 5400.1. Very high nitrate and uranium concentrations occur in the Nolichucky Shale down-dip of the former S-3 Ponds because the higher hydraulic head maintained by operational waste water levels in the ponds, combined with the higher relative density of the waste water compared to ambient groundwater, created a strong driving force for downward (dip-parallel) migration of the waste constituents (DOE 1997).

Aquitard well GW-276 yields moderately contaminated, calcium-magnesium-bicarbonate groundwater from the water table interval (<20 ft bgs) in the Nolichucky Shale about 200 ft southeast (across geologic strike) of the S-3 Site (Figure A.2). Although the CY 2000 monitoring data show that nitrate levels in the well remain near 100 mg/L, the data continue the generally decreasing concentration trend indicated by historical monitoring results (Figure A.7). Decreasing nitrate concentrations in the shallow groundwater at this well primarily reflect substantially reduced flux of nitrate following closure of the former S-3 Ponds. Nitrate levels in the well appear to be decreasing at a slower and more variable rate relative to that of the other groundwater contaminants in the well. Additionally, the CY 2000 monitoring results show that total uranium concentrations in the well remain more than an order-of-magnitude higher than the MCL and show a clearly decreasing long-term trend. However, the uranium results for well GW-276 show a moderately increasing short-term trend evident since July 1998. This trend essentially coincides with the change from conventional sampling to low-flow sampling and encompasses several changes in the analytical method used for total uranium analyses.

Aquitard well GW-526 yields nitrate-contaminated sodium-bicarbonate groundwater from the intermediate depth bedrock interval (>100 ft bgs) in the Nolichucky Shale about 1,300 ft west (parallel with geologic strike) of the S-3 Site (Figure A.2). Monitoring results obtained during CY 2000 are consistent with historical data and show the concentrations of the more mobile components of the S-3 plume remain very high in the well, as indicated by the nitrate level evident in August 2000 (1,340 mg/L). These monitoring results also indicate relatively stable contaminant concentration trends over the long-term, which suggests little flushing of the nitrate from the deeper flow system upward into NT-1. This interpretation is supported by the vertical hydraulic gradients, which are typically upward from the deeper bedrock interval (GW-526) to the shallow bedrock interval and downward from the water table interval to the shallow bedrock interval.

Historical data show that well GW-829 yields moderately contaminated sodium-bicarbonate groundwater from the Nolichucky Shale about 500 ft west (along geologic strike) of well GW-526 (Figure A.2). Respective results for inorganic contaminants detected in the groundwater samples collected from well GW-829 during CY 2000 are consistent with previous low-flow sampling results obtained during CY 1998 and CY 1999, and show that nitrate levels in the well remain above the MCL (Table 3). Elevated nitrate concentrations in the groundwater at this well, which is completed at a depth of about 115 ft bgs, reflect strike-parallel migration of the nitrate plume in the shallow bedrock interval in the Nolichucky Shale west of NT-1 (DOE 1997). However, nitrate results obtained from low-flow sampling, including the anomalously low nitrate level reported for the sample collected from the well in March 1999 (3.17 mg/L), are at least 15% lower than nitrate levels previously evident in the well. Although conventional sampling results show a generally decreasing nitrate concentration trend (Figure A.7), the overall decreasing trend that includes the low-flow sampling results obtained since CY 1998 may be at least partially attributable to the change from the conventional sampling method. Higher nitrate concentrations in the groundwater samples previously collected using the conventional sampling method may be evident because the hydrologic response to aggressively purging the well may increase the migration of nitrate (and other contaminants) into the well and consequently "inflate" the nitrate concentrations compared to those obtained from low-flow sampling.

The CY 2000 monitoring data show nitrate concentrations near 700 mg/L in the groundwater at aquitard well GW-537, which is completed in the water table interval (23 ft bgs) in the Nolichucky Shale about 700 ft west (along geologic strike) of well GW-829 (Figure A.2). Considering that the bulk of the most highly contaminated groundwater has been flushed from the shallow flow system following closure of the former S-3 Ponds, the high nitrate levels in the shallow groundwater at this well are probably maintained via upward discharge of nitrate from the deeper flow system in the Nolichucky Shale. Moreover, assuming that the center of mass of the nitrate plume in the aquitard is slowly migrating westward (along geologic strike), upwelling of nitrate from the deeper bedrock near NT-2 should produce relatively stable or increasing long-term concentration trends in the shallow groundwater near well GW-537 (DOE 1997). Nitrate results obtained during CY 2000, combined with each of the historical nitrate results obtained since January 1990 except the conspicuously low nitrate concentration reported for the groundwater sample collected from the well in September 1994 (81 mg/L), support this interpretation and reflect a widely variable but relatively stable long-term concentration trend (Figure A.7).

Elevated nitrate concentrations in the calcium-magnesium-bicarbonate groundwater at well GW-085, which is completed at a depth of about 55 ft bgs in the Nolichucky Shale (shallow bedrock interval) about 500 ft west of well GW-537 (Figure A.2), reflect strike parallel migration of the nitrate plume to the west of NT-2 and indicate that the leading edge of the nitrate plume lies west of the well toward NT-3 (DOE 1997). Historical (conventional sampling) data show that nitrate levels in this well generally increased between May 1991 (115 mg/L) and October 1993 (312.6 mg/L) and subsequently decreased through September 1997 (63 mg/L). This long-term nitrate concentration trend suggests westward, strike parallel migration of a "pulse" of nitrate in the shallow flow system in the Nolichucky Shale west of the S-3 Site. Results obtained since 1998 (low-flow sampling) show a steadily increasing trend in nitrate concentration from March 1998 (31 mg/L) through September 2000 (227 mg/L) (see Section 3.3).

3.1.1.2 Volatile Organic Compounds

Several types of VOCs were detected in at least one of the groundwater samples collected from 15 of the aquitard monitoring wells during CY 2000, including dissolved chlorinated solvents (chloroethenes, chloroethanes, and chloromethanes), petroleum hydrocarbons (benzene, toluene, ethylbenzene, and

dimethylbenzene), and a few miscellaneous compounds such as acetone, carbon disulfide, and styrene. As shown in the following data summary (Table 4), maximum CY 2000 concentrations of PCE, TCE, c12DCE, 111TCA, 11DCE, VC, and benzene exceed respective MCLs in samples from five of these wells.

Table 4. CY 2000 maximum VOC concentrations in aquitard wells that exceed MCLs

Well Number	Concentration (µg/L)						
	PCE	**TCE**	**c12DCE**	**111TCA**	**11DCE**	**VC**	**Benzene**
GW-008	**75**	**12**	24	.	5	.	(2)
GW-046	**8,400**	**4,800**	**11,000**	**300**	**170**	**760**	**25**
GW-276	**14**	.	.	.	.	.	.
GW-627	**500**	**170**	8	.	**16**	**17**	.
GW-653	**8**	5	**89**	.	.	.	.
MCL (µg/L)	5	5	70	200	7	2	5

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

Historical data for several aquitard monitoring wells located adjacent to the S-3 Site show dissolved PCE concentrations above 5,000 µg/L and indicate the presence of DNAPL in the Nolichucky Shale down-dip of the site (DOE 1997). However, the PCE concentrations detected in the groundwater samples collected in January 2000 (9 µg/L) and July 2000 (14 µg/L) from aquitard well GW-276, which is located less than 250 ft southeast of the S-3 Site (Figure A.2), illustrate the substantial attenuation of dissolved VOCs in the shallow flow system. Also, considering the overall lack of PCE degradation products in the well, such as TCE and c12DCE, biotic degradation does not appear to be a primary mechanism for natural attenuation of dissolved VOCs in the shallow flow system near the former S-3 Ponds. Additionally, PCE levels in the well remain above the drinking water MCL (5 µg/L), but are at least an order-of-magnitude lower than historically evident in the well (e.g., 230 µg/L in March 1988) and reflect the substantially reduced flux of dissolved VOCs along the groundwater flowpaths intercepted by the well following closure of the site in November 1988.

Aquitard well GW-008 is completed at a depth of about 25 ft bgs in the Nolichucky Shale (water table interval) along the south-central boundary of the Oil Landfarm WMA (Figure A.2). Historical (low-flow sampling) data show that this well typically yields calcium-magnesium-bicarbonate groundwater containing traces (<5 µg/L) of benzene along with relatively low levels of several dissolved chlorinated solvents (PCE, TCE, c12DCE, 11DCE, and 11DCA). Monitoring results obtained during CY 2000 are consistent with the historical data and show that the concentrations of each VOC except PCE and TCE remain below the applicable MCL (Table 4), with a conspicuous spike in the concentration of PCE (75 µg/L) evident in January 2000. Such wide short-term changes in the concentration of dissolved VOCs in the shallow groundwater at this well potentially mirror temporal fluctuations in the advective flow of these compounds that correspond to seasonal and/or episodic recharge/discharge cycles. This interpretation is supported by the unusually low TDS of the groundwater samples from well GW-008 (e.g., 64 mg/L in January 2000), which suggests short groundwater residence time and implies that the well intercepts highly permeable recharge/discharge flowpaths.

Monitoring results obtained during CY 2000 show that the groundwater in well GW-046, which is completed at a depth of 20 ft bgs in the Nolichucky Shale (water table interval) near the southwest corner of BG-A South (Figure A.2), contains very high dissolved concentrations of several chloroethenes, chloroethanes, chloromethanes, and petroleum hydrocarbons. These results are consistent with historical monitoring data and show that the concentrations of major compounds (e.g., PCE) remain above 1,000 µg/L, and probably indicate the presence of subsurface DNAPL (DOE 1997). Also, some of the compounds detected in the well are

probably present in the groundwater because of the biotic and/or abiotic degradation of related parent compounds. The high concentrations of c12DCE (>5,000 µg/L) and VC (>500 µg/L), for instance, may at least partially result from biotic degradation (dechlorination) of PCE, which generally occurs as shown below (Hinchee et al. 1995):

PCE ÷ TCE + Chloride (Cl) ÷ DCE isomers + 2Cl ÷ VC + 3Cl ÷ Ethene + 4Cl.

Several factors influence this degradation process, including the availability of electron donors (such as petroleum hydrocarbons), and the efficiency of the process differs under methanogenic, sulfate-reducing, iron-reducing, and nitrate-reducing conditions (Chapelle 1996). Also, as shown above, inorganic chloride accumulates throughout the degradation process, which may account for the atypically high chloride levels (>40 mg/L) evident in the shallow groundwater at this well. Likewise, the unusual acidity of the groundwater samples collected from this well (field pH measurements of 4.79 and 5.28 during CY 2000) may indicate abiotic degradation of dissolved 111TCA in the groundwater because nearly 80% of this compound may be chemically transformed to acetic acid (McCarty 1996). In any case, the highest concentration of several of the VOCs in well GW-046 are typically evident during seasonally low groundwater flow conditions (i.e., summer and fall). For example, the concentration of PCE in July 2000 (8,400 µg/L) is substantially higher than evident in January 2000 (1,300 µg/L). Additionally, PCE degradation compounds such as TCE and c12DCE likewise exhibit similar seasonal concentration fluctuations. In contrast, the concentrations of dissolved chloroethanes and petroleum hydrocarbons in the well exhibit substantially less short-term variation. For instance, there is no significant difference between the benzene concentrations evident in January 2000 (21 µg/L) and July 2000 (25 µg/L). Assuming that the well monitors a commingled plume of dissolved VOCs, it is unclear why some components of the plume exhibit wide concentration fluctuations while other plume components do not.

Historical monitoring data show that well GW-627, which is completed at a depth of 270 ft bgs in the Nolichucky Shale (deep bedrock interval) about 500 ft west of well GW-046 (Figure A.2), yields groundwater samples containing a mixture of dissolved chlorinated solvents dominated by PCE, TCE, and 11DCA. The initial detection of VOCs in the groundwater at this well in June 1990 followed the January 1990 discovery (and disturbance) of DNAPL (PCE and TCE) in the Nolichucky Shale 260 to 330 ft down dip of BG-A South (Haase and King 1990). Subsequent conventional sampling data show a clearly increasing trend in PCE concentrations through September 1997 (84 µg/L), and sharply higher PCE concentrations beginning in March 1998 (210 µg/L) (see Section 3.3). This abrupt increase in the concentration of PCE (and other VOCs) coincides with the change from conventional sampling to low-flow sampling. To further evaluate this phenomenon, the GWPP used each sampling method to obtain samples from well GW-627 on consecutive days during February and August 2000, with the low-flow sampling method used one day and the conventional sampling method used the next. As shown in Table 5, groundwater samples obtained with the conventional sampling method had substantially lower VOC concentrations than the groundwater samples obtained with the low-flow sampling method.

Table 5. VOC results obtained from well GW-627 using conventional sampling and low-flow sampling methods during CY 2000

VOC	Concentration (µg/L)			
	Low-Flow Sampling	Conventional Sampling	Low-Flow Sampling	Conventional Sampling
	Feb. 21, 2000	Feb. 22, 2000	August 22, 2000	August 23, 2000
PCE	500	73	340	80
TCE	170	15	85	17
c12DCE	8	.	5	.
VC	17	.	7	.
11DCE	16	.	9	.
11DCA	62	5	34	7
Summed VOCs:	773	93	480	104

Note: "." = Not detected

Several factors may explain the disparity between the concentrations of VOCs in the groundwater samples collected by each sampling method. For instance, conventional sampling may yield groundwater samples with lower VOC concentrations because purging at higher flow rates for three well volumes may induce greater flow of uncontaminated groundwater into the well, thereby diluting the VOC concentration in the samples. Alternatively, using the low-flow sampling method may obtain a sample from a narrow stratigraphic zone within the well near the midpoint of the monitored interval (at the pump intake) which may yield higher concentrations of VOCs than from the potentially larger stratigraphic interval intercepted when using the conventional sampling method (i.e., the entire screened interval).

Well GW-653 is completed at a depth of 39 ft bgs in the Nolichucky Shale (water table interval) about 1,000 ft west (along geologic strike) of BG-A South (Figure A.2). Groundwater samples collected from this well during CY 2000 contained relatively low concentrations (3 - 89 µg/L) of PCE, TCE, c12DCE, and 11DCA, with slightly higher summed concentrations evident during seasonally high flow (107 µg/L in February 2000) than during seasonally low flow (78 µg/L in August 2000). These findings are consistent with similar seasonal concentration fluctuations indicated by historical (conventional and low-flow sampling) data, which show higher summed VOC concentrations evident during seasonally high flow conditions (winter and spring) and lower concentrations evident during seasonally low flow conditions (summer and fall). Although dominated by these seasonal fluctuations, the CY 2000 VOC results for well GW-653 continue the increasing long-term concentration trend indicated by historical data (see Section 3.3).

3.1.1.3 Radioactivity

Gross alpha and/or gross beta results that exceed the associated MDA and the corresponding CE, which is a value that expresses the degree of analytical uncertainty, were reported only for the groundwater samples collected during CY 2000 from 12 aquitard wells. As shown in Table 6, gross alpha activity above the MCL (15 pCi/L) or gross beta activity above the SDWA screening level (50 pCi/L) was reported only for the samples collected from wells GW-085, GW-276, GW-526, and GW-537.

Table 6. Elevated gross alpha and gross beta results for aquitard wells used for CY 2000 Surveillance Monitoring

Well	Date Sampled	Gross Alpha (pCi/L)				Gross Beta (pCi/L)			
		MDA	Activity ± CE			MDA	Activity ± CE		
GW-085	02/29/00	3.8	9.1	±	4.3	8.9	**120**	±	11
GW-085	09/08/00	13	<MDA			28	**200**	±	32
GW-276	01/04/00	2.49	**117.7**	±	8.95	1.72	**175.3**	±	4.75
GW-276	07/12/00	4.67	**5**	±	13.21	3.62	**4**	±	10.18
GW-526	02/22/00	27.64	**293.0**	±	27.87	43.19	**567.3**	<MDA	
GW-537	03/01/00	39	**8**	<MDA		58	**1**	±	72
GW-537	09/11/00	11	**31.04**	<MDA		28		±	42
							600		
							620		

Note: BOLD = Exceeds MCL (gross alpha) or SDWA screening level (gross beta)

The elevated gross alpha activity reported for the sample collected from well GW-526 in February 2000 is probably an analytical artifact considering that this result just exceeds the MDA and has a large proportional CE, and that this well does not have a history of radiological contamination.

As noted in Section 2.4, operation of the former S-3 Ponds emplaced a heterogeneous mixture of alpha- and beta-emitting radionuclides in the groundwater, several of which were detected (i.e., >MDA) in the groundwater samples collected from well GW-276 during CY 2000, with the highest concentrations of Tc-99 (734 pCi/L), U-234 (153 pCi/L), and U-238 (366 pCi/L) reported for the sample collected from the well in January 2000 (i.e., seasonally high flow conditions). As with other contaminants in the shallow groundwater at this well, historical data show that gross alpha and gross beta radioactivity decreased substantially following closure of the S-3 Ponds in the late 1980s, although gross beta activity has generally decreased at a faster rate. Alpha activity levels are probably maintained by the slow release of alpha-emitting isotopes adsorbed onto sludge remaining in the S-3 Ponds, onto mineral surfaces, and in the rock matrix in the aquitard. More rapidly decreasing beta activity in the shallow flow system reflects the greater flushing of Tc-99, which is more mobile and less readily adsorbed in the subsurface (DOE 1997).

Gross beta results obtained during CY 2000 show that beta radioactivity remains substantially above 50 pCi/L in the shallow groundwater at wells GW-085 and GW-537 (Table 6). These results are consistent with respective historical data for each well and reflect the migration of Tc-99 along strike-parallel flowpaths in the Nolichucky Shale west of the former S-3 Ponds (DOE 1997). Moreover, the very low levels of alpha radioactivity in the groundwater at both of these wells, as illustrated by the CY 2000 gross alpha results (Table 6), illustrates the greater attenuation of uranium isotopes (and other alpha-emitting radionuclides) relative to Tc-99. Historical (conventional and low-flow sampling) gross beta results for both of these wells reflect substantial temporal fluctuations, some of which probably reflect analytical variability, but generally increasing trends over time (see Section 3.3).

The groundwater samples collected from aquitard well GW-615 during CY 2000 were analyzed for uranium isotopes, which are the principal alpha-emitting (and decay products are beta-emitting) isotopes. The high levels of U-234 (109 - 150 pCi/L) and U-238 (287 - 376 pCi/L) detected in these samples are similar to those reported for well GW-276 (see above) and indicate that gross alpha activity and possibly gross beta activity remain above 15 pCi/L and 50 pCi/L, respectively, in the deep groundwater (245 ft bgs) at this well. Note that

gross alpha activity and gross beta activity results were not reported for well GW-615 during CY 2000. Although limited data are available, historic results show a generally increasing trend in U-234 and U-238 activities from August 1991 (76.3 and 242 pCi/L, respectively) and May 1992 (20.5 and 61.6 pCi/L, respectively).

3.1.2 Aquifer Wells

As shown in the following summary (Table 7), elevated concentrations of one or more of the principal groundwater contaminants in the Bear Creek Regime were detected in the groundwater samples collected during CY 2000 from 16 aquifer monitoring wells (Maynardville Limestone or Knox Group) that serve the surveillance monitoring purposes of DOE Order 5400.1.

Table 7. Principal groundwater contaminants detected in aquifer wells used for CY 2000 Surveillance Monitoring

Well Number	Monitored Interval Depth (ft bgs)	Nitrate (>10 mg/L)	Uranium (>0.03 mg/L)	Summed VOCs (>5 µg/L)	Radioactivity (Gross Alpha>15 pCi/L and/or Gross Beta>50 pCi/L)
GW-053	11.4 - 32.8	.	.	!	.
GW-056	49.1 - 55.2	.	.	.	!
GW-226	45.0 - 55.0	!	.	!	.
GW-311	25.6 - 40.3	.	.	!	!
GW-315	90.0 - 104.0	.	.	!	.
GW-683	133.9 - 196.8	.	!	.	!
GW-684	106.4 - 128.4	.	!	.	.
GW-695	50.6 - 62.6	!	.	!	!
GW-703	135.0 - 182.0	!	.	!	!
GW-704	246.0 - 256.0	!	.	!	.
GW-706	157.0 - 182.5	!	!	!	!
GW-724	289.6 - 301.6	!	.	!	!
GW-725	132.5 - 142.5	!	.	!	.
GW-738	63.5 - 88.0	!	.	!	.
GW-740	165.6 - 190.0	.	.	!	.
GW-835	Unknown - 19.2	!	!	!	.

Note that 11 of these monitoring wells are components of the three Exit Pathway Pickets in the Bear Creek Regime: Picket A (GW-056, GW-683, and GW-684), Picket B (GW-695, GW-703, GW-704, and GW-706), and Picket C (GW-724, GW-725, GW-738, and GW-740). Monitoring wells that comprise each Exit Pathway Picket are completed at various depths within different hydrostratigraphic zones along a strike-normal transect across the Maynardville Limestone and lower Knox Group.

3.1.2.1 Inorganic Contaminants

As shown in Table 8, elevated nitrate levels and/or total uranium concentrations were reported for at least one groundwater sample collected during CY 2000 from 11 of the aquifer monitoring wells that serve the surveillance monitoring purposes of DOE Order 5400.1.

Table 8. Elevated nitrate and uranium concentrations in aquifer wells used for CY 2000 Surveillance Monitoring

Well Location / Number		Distance and Direction from S-3 Site (Figure A.2)	Nitrate (mg/L)		Uranium (mg/L)	
			1st Qtr. 2000	3rd Qtr. 2000	1st Qtr. 2000	3rd Qtr. 2000
S-3 Site	GW-835	750 ft West	**24.2**	**33.6**	**0.734**	**0.833**
Exit Pathway Picket C	GW-724	3,000 ft West	**26.4**	**17.6**	0.00056	ND
	GW-725		**22.4**	**18.6**	0.0101	0.00986
	GW-738		**17.3**	9.36	0.00229	0.0018
Oil Landfarm WMA	GW-226	4,500 ft West	**19.1**	**11.3**	0.015	0.00751
Exit Pathway Picket B	GW-695	7,000 ft West	8.85	**11.6**	0.00331	0.00458
	GW-703		**10.4**	**15.2**	0.00426	0.00466
	GW-704		**17.2**	1.14	0.00744	0.0018
	GW-706		**41.6**	**22.9**	**0.0808**	**0.139**
Exit Pathway Picket A	GW-683	10,000 ft West	9.4	1.93	**0.0667**	0.0203
	GW-684		5.96	1.53	**0.0347**	0.0199

Notes: ND = Not detected; **BOLD** = Exceeds MCL

Well GW-835 is located adjacent to Bear Creek about 800 ft downstream of the S-3 Site and approximately 1,200 ft west-southwest of aquitard well GW-276 (Figure A.2). Installed in early 1997, this well intercepts strike-parallel contaminant migration pathways at a shallow depth (19 ft bgs) in the basal Maynardville Limestone (water table interval) near the contact with the underlying Nolichucky Shale. This well has a fairly extensive sampling history that includes consecutive daily sampling in October, November, and December 1997. Monitoring results obtained during CY 2000 are generally consistent with the historical data and, as shown in Table 8, indicate that the nitrate and uranium concentrations in the shallow groundwater at this well remain substantially above respective MCLs (10 mg/L and 0.03 mg/L). Also, the CY 2000 monitoring results continue the widely fluctuating but generally decreasing concentration trends evident for both nitrate and uranium.

Four of the monitoring wells that comprise Exit Pathway Picket C, which is located about 2,300 ft west-southwest (downgradient) of well GW-835 (Figure A.2), were sampled during CY 2000: GW-724, GW-725, GW-738, and GW-740 (Table B.1). Analytical results for these samples show that nitrate concentrations in the groundwater at three of these wells (GW-724, GW-725, and GW-738) remain above the MCL, with the highest concentrations (>25 mg/L) reported for the deepest well (GW-724 at 301 ft bgs). These results also continue the decreasing long-term nitrate concentration trends evident for each well (Figure A.8), which probably reflect the long-term effects of reduced contaminant flux and prolonged attenuation (i.e., dilution) following closure of the S-3 Site (DOE 1997). However, it is possible that the decreasing trends may be an artifact of the change from conventional sampling to low-flow sampling. Nitrate data for well GW-725, for example, show an average concentration of just over 60 mg/L based on results for the four groundwater samples obtained with the conventional sampling method between March 1996 and September 1997, whereas nitrate levels averaged just under 25 mg/L in the four samples obtained with the low-flow sampling method between March 1998 and August 1999 possibly indicating a shift in the trend. Therefore, the decreasing nitrate concentration trend may be at least partially attributable to the change from conventional sampling to low-flow sampling (Figure A.8). In order to evaluate this possibility, each sampling method was used to obtain samples from well GW-725 on consecutive days during February and August 2000, with the low-flow sampling method used one day and the conventional sampling method used the next. The nitrate results for these samples, as

shown in Table 9, suggest the conventional sampling is more likely to yield groundwater samples with higher nitrate concentrations.

Table 9. Nitrate results obtained from well GW-725 using conventional sampling and low-flow sampling methods during CY 2000

Sampling Method	Nitrate Concentration (mg/L)			
	February 7, 2000	February 8, 2000	August 8, 2000	August 9, 2000
Low-Flow Sampling	22.4	.	18.6	.
Conventional Sampling	.	27.3	.	30.5

Moreover, it is not clear which sampling method provides the more representative monitoring results.

The CY 2000 groundwater monitoring results show that nitrate levels in well GW-226 remain above the MCL (see Table 8). Not only are these nitrate results consistent with the previous low-flow sampling data obtained during CY 1998 and CY 1999, but they confirm the substantial increase in the concentration of nitrate in the well (see Section 3.3). Located south of Sanitary Landfill I in the Oil Landfarm WMA (Figure A.2), this well yields calcium-magnesium-bicarbonate groundwater from a depth of 55 ft bgs in the highly permeable basal portion (Zone 2) of the Maynardville Limestone. Elevated (and increasing) nitrate levels in the groundwater at well GW-226 probably reflect inflow of nitrate (and other mobile groundwater contaminants) into the Maynardville Limestone along the losing reach of Bear Creek south of Sanitary Landfill I and downgradient transport along the strike-parallel flowpaths intercepted by the well (DOE 1997).

Nitrate concentrations that exceed the MCL also were detected in the groundwater samples collected during CY 2000 from Exit Pathway Picket B wells GW-695, GW-703, GW-704, and GW-706 (Table 8). Nitrate levels in the groundwater at these wells, which are located about 2,500 ft west (downgradient) of well GW-226 (Figure A.2), are probably maintained via infiltration of nitrate-contaminated groundwater and surface water along the losing reach of Bear Creek south of the Oil Landfarm WMA (DOE 1997). Although above the MCL, the nitrate concentrations are typically lowest in well GW-695, which is the shallowest well in Exit Pathway Picket B. This illustrates a key characteristic of the nitrate plume in the aquifer, whereby nitrate concentrations in the shallow karst network (e.g., GW-695) are usually lower than nitrate levels in the deeper flow system (e.g., GW-706) because of the greater degree of attenuation (dilution) in the shallow flow system (DOE 1997). Additionally, the CY 2000 nitrate results for well GW-695 are generally consistent with historical (conventional sampling and low-flow sampling) data, which indicate an increasing long-term concentration trend (see Section 3.3). Conversely, nitrate concentrations evident in wells GW-704 and GW-706 indicate fluctuating or relatively indeterminate long-term trends (Figure A.9). For example, nitrate concentrations in well GW-706 increased from 10 mg/L in June 1991 to almost 50 mg/L in September 1992, steadily decreased below 20 mg/L through February 1997, and subsequently increased above 40 mg/L through January 2000. However, the most recent increase in the nitrate levels in well GW-706 generally coincides with the change from conventional sampling to low-flow sampling. Accordingly, each sampling method was used to obtain groundwater samples from well GW-706 on consecutive days during each CY 2000 sampling event, with low-flow sampling used the first day and conventional sampling used the next. The nitrate results for these samples, as shown in the following summary (Table 10), suggest that the low-flow sampling is more likely to yield groundwater samples with higher nitrate concentrations.

Table 10. Nitrate and uranium results obtained from well GW-706 using conventional sampling and low-flow sampling methods during CY 2000

Inorganic Contaminant	Concentration (mg/L)			
	Low-Flow Sampling	Conventional Sampling	Low-Flow Sampling	Conventional Sampling
	January 31, 2000	February 1, 2000	July 25, 2000	July 26, 2000
Nitrate	41.6	23.4	22.9	14.9
(total) Uranium	0.0808	0.277	0.139	0.125

Thus, rather than an indication of increased advective migration of nitrate along the flowpaths intercepted by the well, the recent increase in the concentration of nitrate in well GW-706 is probably attributable to the change to low-flow sampling. Uranium results obtained with conventional and low-flow sampling methods substantially exceed the MCL (0.03 mg/L) and are the highest reported for any aquifer wells in the Bear Creek Regime that were sampled during CY 2000 except well GW-835 (Table 8). Also, as shown in Table 10, these uranium results do not reflect the same responses to conventional sampling and low-flow sampling shown by nitrate results. Moreover, these uranium results are generally consistent with historical data for the well which, aside from atypically low (June 1991=0.009 mg/L, March 1993=0.002 mg/L, and September 1993=0.008 mg/L) and high (February 2000=0.277 mg/L) conventional sampling results, reflect a relatively stable long-term concentration trend (Figure A.10). This is probably because influx of uranium from Boneyard/Burnyard helps maintain the elevated concentrations evident in the downgradient wells (DOE 1997).

Groundwater samples were collected during CY 2000 from four Exit Pathway Picket A monitoring wells: GW-056, GW-683, GW-684, and GW-685 (Table B.1). These wells are located immediately downstream of the confluence of Bear Creek and NT-7, approximately 3,500 ft west (downgradient) of Exit Pathway Picket B (Figure A.2). The CY 2000 monitoring results for these wells are generally consistent with respective historical (conventional and low-flow sampling) data and show that nitrate levels remain below the MCL, with the highest concentrations evident in the samples collected from wells GW-683 (9.4 mg/L) and GW-684 (5.96 mg/L) in January 2000 (seasonally high groundwater flow). This suggests increased seasonal (and episodic) flux of nitrate along the groundwater flowpaths intercepted by each well. Uranium concentrations also exhibit this same seasonal fluctuation (Figure A.10), as illustrated by the CY 2000 monitoring results, which show the highest concentrations in the samples collected during seasonally high flow (January 2000) from wells GW-683 (0.0667 mg/L) and GW-684 (0.0347 mg/L). Elevated uranium concentrations in the groundwater at these wells probably reflect downgradient, strike-parallel transport of uranium from the Boneyard/Burnyard/HCDA, but may also be at least partially attributed to inflow of radiologically contaminated groundwater/surface water from the Bear Creek tributaries that drain the BCBG WMA (DOE 1997). In either case, the uranium results for both wells reflect widely variable but generally decreasing long-term concentration trends (Figure A.10).

3.1.2.2 Volatile Organic Compounds

Excluding false-positive results, one or more dissolved chloroethenes, chloroethanes, petroleum hydrocarbons, or miscellaneous VOCs were detected in at least one groundwater sample collected during CY 2000 from 15 of the aquifer wells that serve the surveillance monitoring purposes of DOE Order 5400.1. As shown in Table 11, the maximum concentrations of PCE, TCE, and VC reported for 12 of these wells (arranged in order from hydraulically upgradient [east] to downgradient [west]) exceed respective MCLs.

Table 11. CY 2000 maximum VOC concentrations in aquifer wells that exceed MCLs

Well Number	Concentration (µg/L)		
	PCE	TCE	VC
GW-315	**13**	**6**	.
GW-311	.	**6**	.
GW-724	.	**130**	.
GW-725	(3)	**90**	.
GW-738	.	**35**	.
GW-740	.	**63**	.
GW-226	.	**160**	.
GW-695	.	**6**	.
GW-703	.	**21**	.
GW-704	.	**69**	.
GW-706	.	**19**	.
GW-053	.	(3)	**5**
MCL (µg/L)	5	5	2

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

Dissolved chloroethenes (PCE, TCE, and c12DCE) were detected in the groundwater samples from well GW-315 during CY 2000, which is completed at a depth of 104 ft bgs on the northern flank of Chestnut Ridge at the Spoil Area I (Figure A.2). Maximum summed concentration of the VOCs detected in each sample are dominated by PCE (13 µg/L) with lesser amounts of TCE (6 µg/L) and c12DCE (3 µg/L). These low-flow sampling results are consistent with historical (conventional and low-flow sampling) data for the well and reflect influx of dissolved chloroethenes from Spoil Area I or possibly the Fire Training Facility, which is a confirmed source of chloroethenes located in the East Fork Regime about 1,000 ft east of the well (DOE 1997). As illustrated by the CY 2000 results for PCE, the concentrations of VOCs in the groundwater at well GW-315 have decreased about 50% from the maximum concentration during CY 1991 (38 µg/L).

Monitoring results obtained during CY 2000 for well GW-311 are consistent with historical (conventional sampling and low-flow sampling) data and show relatively low levels of TCE (6 µg/L) in the shallow groundwater (40 ft bgs) near the Rust Spoil Area (Figure A.2). The source of the TCE is either the Rust Spoil Area or an unidentified nearby source in the Bear Creek floodplain (DOE 1997). Compared with the TCE concentrations evident during the early 1990s (e.g., 30 µg/L in January 1991), the CY 2000 monitoring results show that the TCE levels have decreased substantially (>75%). However, considering the similarity between the maximum TCE concentrations evident in the well during CY 2000 (6 µg/L), CY 1999 (7 µg/L), and CY 1998 (10 µg/L), the rate of concentration decrease appears to have slowed.

Monitoring results obtained during CY 2000 show that TCE concentrations in the groundwater at Exit Pathway Picket C wells GW-724, GW-725, GW-738, and GW-740 remain above the MCL (Table 11), with the highest concentration evident in well GW-724 (130 µg/L) and the lowest concentration evident in well GW-738 (31 µg/L). Also, trace levels (<5 µg/L) of PCE and/or c12DCE were detected in the groundwater samples collected from wells GW-724 and GW-725. These results are consistent with respective historical data for each well and reflect the strike-parallel transport of TCE from the Rust Spoil Area, with the trace concentrations of the other VOCs (e.g., c12DCE) indicating transport from another upgradient source, possibly the S-3 Site (DOE 1997). Moreover, the respective TCE results for each of these wells continue the generally decreasing or indeterminate long-term concentration trends indicated by the historical (conventional sampling

and low-flow sampling) data (Figure A.11). However, as shown in the following data summary (Table 12), the TCE results for well GW-725 that were obtained from consecutive daily low-flow sampling and conventional sampling in February and August 2000 show substantially higher TCE concentrations in the samples obtained with the latter method.

Table 12. TCE results obtained from well GW-725 using conventional sampling and low-flow sampling methods during CY 2000

Sampling Method	TCE Concentration (µg/L)			
	February 7, 2000	February 8, 2000	August 8, 2000	August 9, 2000
Low-Flow Sampling	12	.	13	.
Conventional Sampling	.	55	.	90

Considering that the groundwater samples collected from well GW-725 using the conventional sampling method also had higher nitrate concentrations relative to the samples collected using the low-flow sampling method (see Section 3.1.1), these TCE results likewise suggest that aggressively purging the well for conventional sampling induces greater flux of contaminants into the well.

Historical data show that well GW-226 yields TCE-contaminated groundwater from about 55 ft bgs in the Maynardville Limestone (shallow bedrock interval) approximately 1,500 ft west (hydraulically downgradient) of Exit Pathway Picket C (Figure A.2). Monitoring results obtained during CY 2000 show that TCE concentrations in this well remain higher than evident in any of the Picket C wells, probably as a result of the migration of TCE from the Boneyard/Burnyard/HCDA (DOE 1997), which is located about 1,000 ft east-northeast of well GW-226 (Figure A.2). Trace levels (<5 µg/L) of c12DCE also were detected in the groundwater samples collected from the well during CY 2000. These monitoring results are consistent with historical data for the well, which show significant concentration changes that correlate to the change from conventional sampling to low-flow sampling. Data for total 1,2-dichloroethene (12DCE) show an overall decreasing long-term trend, even though the conventional sampling results show a generally increasing trend from 1988-1991 and the low-flow sampling results show an indeterminate trend from 1998-2000 (Figure A.12). Conversely, an overall increasing TCE concentration trend that occurs between February 1991 (6 µg/L) and March 1998 (210 µg/L) also may reflect the change to the low-flow sampling method (see Section 3.3).

Several dissolved chloroethenes (primarily TCE and c12DCE) were detected in the groundwater samples collected from Exit Pathway Picket B wells GW-695, GW-703, GW-704, and GW-706 during CY 2000, with the highest summed VOC concentrations evident for well GW-704 (74 µg/L). These monitoring results, which show that TCE concentrations in each well remain above the MCL (Table 11), reflect the TCE-dominated composition of the dissolved VOC plume in the Maynardville Limestone. Moreover, considering that the highest TCE concentrations occur in the groundwater at well GW-704 (69 µg/L in July 2000), which is the deepest well (256 ft bgs) in Exit Pathway Picket B, the composition of the dissolved VOC plume reflects strike-parallel transport from source areas in the upper reaches of Bear Creek (i.e., the Rust Spoil Area) and vertical migration via the losing reach of Bear Creek south of Sanitary Landfill I (DOE 1997). Additionally, the CY 2000 TCE results for these monitoring wells continue the indeterminate long-term concentration trends indicated by respective historical (conventional sampling and low-flow sampling) data for each well (Figure A.13). Note also that the CY 2000 monitoring results for well GW-706 do not show any substantial and consistent disparity between TCE concentrations in the groundwater samples obtained from the well using either conventional sampling (<15 µg/L) and low-flow (<20 µg/L) sampling data.

Dissolved VOCs in the shallow groundwater at well GW-053, which is completed at a depth of 33 ft bgs in the upper Maynardville Limestone (water table interval) about 500 ft south of the BCBG WMA (Figure A.2), reflect migration of these compounds from beneath BG-A South (DOE 1997). Trichloroethene, c12DCE, VC, and 11DCA were detected in the groundwater samples collected from this well during CY 2000, with the highest concentrations reported for c12DCE (15 - 16 µg/L), although only the maximum concentration of VC exceeds the applicable MCL (see Table 11). These monitoring results are consistent with historical (conventional and low-flow sampling) data and continue the stable (indeterminate) long-term concentration trends indicated by historical VOC data for the well.

3.1.2.3 Radioactivity

As noted in Section 2.4, elevated gross alpha and gross beta activity in the aquifer is primarily from uranium isotopes (U-234 and U-238) and Tc-99, respectively. The distribution of elevated gross alpha activity in the aquifer reflects the influx of uranium isotopes from several sources and transport pathways, including inflow from the buried tributary of Bear Creek that extends beneath the S-3 Site, direct recharge from the Boneyard/Burnyard (and inflow from the NT-3 catchment), and inflow from tributary catchments to the east (NT-6) and west (NT-7 and NT-8) of BG-A North and BG-A South (DOE 1997). Conversely, the contaminant plume emplaced during operation of the former S-3 Ponds is the only known source of Tc-99, and the distribution of elevated gross beta activity generally mirrors that of nitrate from this site. Monitoring results obtained during CY 2000 are somewhat consistent with the known distribution of elevated gross alpha and gross beta activity in the aquifer. As summarized in Table 13 (in sequence from upgradient to downgradient locations), elevated gross alpha (>15pCi/L) or gross beta activity (>50 pCi/L) was reported for at least one sample from seven wells.

Table 13. Elevated gross alpha and gross beta radioactivity reported for aquifer wells used for Surveillance Monitoring during CY 2000

Well	Date Sampled	Gross Alpha (pCi/L)		Gross Beta(pCi/L)	
		MDA	Activity ± CE	MDA	Activity ± CE
GW-311	02/28/00	3.7	**18** ± 5	9.3	32 ± 7.7
GW-724	02/03/00	2.9	<MDA	7.6	**60** ± 8.2
GW-695	07/13/00	0.78	**25** ± 5.3	5.1	34 ± 5.5
GW-703	01/24/00	2.4	**24** ± 5.5	8.3	46 ± 7.7
GW-706	01/31/00	3.1	**33** ± 6.8	5.1	**88** ± 8.3
GW-706	*02/01/00*	3.4	**120** ± 13	5.6	**83** ± 8.2
GW-706	07/25/00	3.6	**72** ± 10	8	**110** ± 11
GW-706	*07/26/00*	2	**54** ± 8.5	6.8	**57** ± 7.5
GW-683	01/18/00	2.7	**31** ± 6.2	5.8	42 ± 6.3
GW-056	01/12/00	4.2	**18** ± 6.4	8.8	20 ± 6.5

Notes: BOLD = Exceeds MCL (gross alpha) or SDWA screening level (gross beta);
Italics = Conventional sampling method used on specified date

Although five of the wells (GW-056, GW-311, GW-695, GW-703, and GW-724) shown above (Table 13) are located hydraulically downgradient from known source areas, the results for these wells may reflect analytical artifacts because they are unsupported by results for other samples from the wells. Only one sample collected during CY 2000 from these wells had elevated gross alpha or gross beta activity. Historical (conventional and low-flow sampling) gross alpha results for wells GW-056, GW-311, GW-695, and GW-703 are typically less

than 5 pCi/L, and gross beta activity at well GW-724 generally ranges from 25-45 pCi/L. Furthermore, preliminary results for these wells obtained during the first quarter of CY 2001 show that gross alpha and gross beta activities are within the normal range for each well (i.e., none of the samples from these wells have elevated alpha or beta activity).

Of the locations shown in Table 13, only wells GW-706 and GW-683 have a history of radiological contamination. The CY 2000 gross alpha and gross beta results reported for well GW-706 are consistent with historical data and have the highest values reported for any of the aquifer wells. To evaluate the change in analytical results from conventional to low-flow sampling (previously noted in Sections 3.1.2.1 and 3.1.2.2), the GWPP used both sampling methods to collect samples from well GW-706 on subsequent days during each sampling event of CY 2000. As shown in the above data summary (Table 13), the CY 2000 results show that low-flow sampling provides samples with generally higher beta activity (and nitrate concentrations, see Table 10). However, this pattern is not clearly demonstrated in the gross alpha results, which correspond with the total uranium results for these samples (see Table 10). Migration of uranium isotopes from the source(s) associated with the Boneyard/Burnyard probably explains the elevated radioactivity in the groundwater at well GW-706 (DOE 1997). This is supported by radiological results obtained during CY 2000, which indicate elevated levels of U-234 (16-30 pCi/L) and U-238 (31-50 pCi/L) in the groundwater samples from well GW-706. Historical data suggest that the gross beta activity at well GW-706 reflects commingling of uranium decay products (e.g., thorium-234) of the Boneyard/Burnyard plume with Tc-99 (and nitrate, see Section 3.2.1.1) of the S-3 Ponds plume; Tc-99 activity showed a decreasing trend in the data for the well from 1993 (>250 pCi/L), 1994 (100 - 200 pCi/L), and 1995 through 1996 (<100 pCi/L).

Only the gross alpha activity reported for the groundwater sample collected from well GW-683 in January 2000 (i.e., seasonally high groundwater flow) exceeds the MCL. Review of the historical data for well GW-683 show that alpha activity has exceeded the MCL in over half (14) of the 25 samples collected from the well since May 1991. Elevated gross alpha activity in the groundwater at this well probably reflects the transport of uranium isotopes from upgradient sources (e.g., the Boneyard/Burnyard) into successively higher hydrostratigraphic zones in the Maynardville Limestone and ultimately into the lower Copper Ridge Dolomite (DOE 1997).

The groundwater samples collected from aquifer well GW-835 during CY 2000 were analyzed for uranium isotopes. No gross alpha or gross beta activity results were obtained. The high levels of U-234 (79-184 pCi/L) and U-238 (277 - 472 pCi/L) detected in these samples indicate that gross alpha activity and gross beta activity in the groundwater at these wells probably exceed 15 pCi/L and 50 pCi/L, respectively. Note that the uranium activities reported for well GW-835 are significantly higher than the uranium activities reported for well GW-706 (see above), which has the highest gross alpha and gross beta activities reported for the aquifer wells in CY 2000 (Table 13). As with the elemental uranium (and nitrate), the uranium isotopes in the shallow groundwater at this well reflect transport from the S-3 Ponds contaminant plume (see Section 3.1.2.1).

3.2 EXIT PATHWAY/PERIMETER MONITORING DATA EVALUATION

The CY 2000 monitoring results for the following monitoring wells, springs, and sampling locations in Bear Creek and selected northern tributaries (Table 14), along with respective historical data, serve as the basis for the following DOE Order 5400.1 evaluation of surface water and groundwater quality where contaminants from Y-12 are most likely to migrate beyond the boundaries of the Bear Creek Regime.

Table 14. Sampling locations used for Exit Pathway/Perimeter Monitoring during CY 2000

Monitoring Wells		Springs		Surface Water Stations		
				Bear Creek Mainstream		
Well Number	Monitored Interval Depth (ft bgs)					Bear Creek Tributaries
GW-712	441.5 - 457.5	SS-1	SS-6.6	BCK-00.63	BCK-09.47	NT-01
GW-713	305.0 - 315.2	SS-4	SS-7	BCK-04.55	BCK-11.97	NT-07
GW-714	115.1 - 145.0	SS-5	SS-8	BCK-07.87		NT-08
GW-715	32.0 - 44.0	SS-6		BCK-09.40		

This exit-pathway/perimeter monitoring data evaluation is focused on the principal components of the groundwater contaminant plumes in the regime: nitrate, uranium, VOCs, and radioactivity (gross alpha and gross beta). For evaluation purposes, the above-listed sampling locations are assigned to one of three areas: Upper Bear Creek encompasses the sampling locations upstream (east) of BCK-11.97; Middle Bear Creek encompasses sampling locations between BCK-11.97 and BCK-09.40; and Lower Bear Creek encompasses the sampling locations downstream of BCK-09.40, which includes each of the monitoring wells listed above (Figure A.2).

3.2.1 Upper Bear Creek

As shown in Table 15, the CY 2000 monitoring results for the sampling locations in Upper Bear Creek show elevated concentrations of nitrate, total uranium, gross alpha activity and gross beta activity, but only trace levels (<5 µg/L) of VOCs.

Table 15. CY 2000 maximum contaminant concentrations at Exit Pathway/Perimeter Monitoring sampling locations along Upper Bear Creek

Sampling Point	Inorganics (mg/L)		Organics (µg/L)	Radioactivity (pCi/L)	
	Nitrate	Uranium	PCE	Gross Alpha	Gross Beta
NT-01	**217**	**0.14**	(4)	**51**	**450**
SS-1	**19.8**	**0.0444**	.	**19**	**56**
BCK-11.97	**75.6**	**0.193**	.	**68**	**310**

Notes: ( ) = Estimated value; "." = not detected; **BOLD** = exceeds MCL (gross alpha) or SDWA screening level (gross beta)

These monitoring results show that the quality of surface water in Upper Bear Creek continues to be controlled by the inflow of groundwater containing the primary components of the contaminant plume emplaced during operation of the former S-3 Ponds. Highly contaminated groundwater discharges from the aquitard (Nolichucky Shale) into NT-1 and NT-2, which enter Bear Creek about 1,500 ft and 2,500 ft, respectively, downstream (west) of the S-3 Site. Contaminated groundwater also discharges directly into Bear Creek via seeps and springs (including spring SS-1) in the Maynardville Limestone, which underlies the main creek channel (Figure A.2). The CY 2000 monitoring results show that nitrate and gross beta activity are the primary contaminants in Upper Bear Creek. These results also reflect the overall lack of dissolved VOCs, particularly compared to downstream VOC levels evident in Middle Bear Creek, and show that gross alpha radioactivity, although above the MCL, remains substantially lower than gross beta radioactivity (Table 15). This is consistent with the results of specific radionuclide analyses of the samples collected from Bear Creek

at BCK-11.97 during CY 2000. These radiological results show higher levels of Tc-99 (350-390 pCi/L), which is a beta-emitter, relative to any alpha-emitting radionuclides, such as U-234 (21 -38 pCi/L) and U-238 (35 - 67 pCi/L).

As illustrated by the nitrate results for samples collected from Bear Creek at BCK-11.97 (Figure A.14), contaminant levels in Upper Bear Creek fluctuate seasonally, with the highest concentrations typically evident during the seasonally dry periods of the year (summer and fall) when groundwater discharge sustains the bulk of the flow in the creek (DOE 1997). Along with these seasonal fluctuations, the nitrate (and gross alpha) results for BCK-11.97 also show a generally decreasing long-term concentration trend (Figure A.14) similar to that evident in several monitoring wells (e.g., GW-276; see Figure A.7) downgradient of the former S-3 Ponds.

3.2.2 Middle Bear Creek

The quality of water in Middle Bear Creek is primarily impacted by the relative inflow of groundwater containing contaminants from the S-3 Site (nitrate, uranium, and radioactivity), the Boneyard/Burnyard (uranium and VOCs), and the BCBG WMA (uranium, VOCs, and radioactivity). Moreover, much of Middle Bear Creek loses flow to the Maynardville Limestone, particularly the section of the channel immediately south of Sanitary Landfill I, which plays an important role in transferring contaminants from the creek into the groundwater system (DOE 1997). As shown in the following data summary of CY 2000 monitoring results for the Middle Bear Creek sampling locations (Table 16), elevated concentrations of at least one of the principal groundwater contaminants in the Bear Creek Regime were detected in at least one sample collected at each of these sampling locations (arranged in sequence from upstream to downstream).

Table 16. CY 2000 maximum concentrations of selected contaminants at Exit Pathway/Perimeter Monitoring sampling locations along Middle Bear Creek

Sampling Point	Inorganics (mg/L)		Chloroethenes (µg/L)				Radioactivity (pCi/L)	
	Nitrate	Uranium	PCE	TCE	c12DCE	VC	Gross Alpha	Gross Beta
SS-4	**42.6**	**0.332**	.	**10**	(3)	.	**130**	**170**
NT-07	0.31	0.0206	**92**	**74**	**410**	**22**	NA	NA
NT-08	5.4	**0.442**	**12**	**8**	**100**	**5**	NA	NA
BCK-09.47	**11.4**	**0.304**	5	(4)	33	.	**53.48**	**75.77**
SS-5	**10.5**	**0.132**	.	.	9	.	**57**	**58**
BCK-09.40	**23.3**	**0.25**	(4)	(3)	34	.	**96**	**120**

Notes: Results for each sampling point may be from more than one sampling date. ( ) = Estimated value; "**.**" = not detected; **BOLD** = exceeds MCL or SDWA screening level (gross beta); NA=not analyzed

Discharge of (contaminated) groundwater from springs SS-4 and SS-5 sustains flow in Bear Creek during seasonally low flow periods (summer and fall) and contributes to surface water contamination downstream of BCK-11.97 (DOE 1997). Monitoring results obtained during CY 2000 show that both springs continue to discharge groundwater with elevated concentrations of nitrate, uranium, and gross alpha and gross beta radioactivity; VOCs also were detected in the samples collected from both springs during CY 2000, including TCE concentrations in Spring SS-4 that exceed the MCL (Table 16). Note that the contaminant concentrations in spring SS-4 are higher than respective levels reported for spring SS-1, which is located about a mile closer to the S-3 Site (Figure A.2). Higher concentrations in the groundwater discharged from spring

SS-4 probably reflect transfer of contaminants from Bear Creek into the aquifer along the losing reach of the creek upgradient of the spring (DOE 1997). Moreover, as shown in Table 17, uranium isotopes were detected in the samples collected from each spring, and Tc-99 was detected in the samples collected from spring SS-5.

Table 17. CY 2000 analytical results for Tc-99, U-234, and U-238 in springs SS-4 and SS-5

Sampling Point	Concentration (pCi/L)					
	February 9, 2000			August 3, 2000		
	Tc-99	U-234	U-238	Tc-99	U-234	U-238
SS-4	NA	73	137	NA	11	19
SS-5	55	39	69	48	12	23

Note: NA = Not analyzed

The radiological results for each spring also suggest seasonal concentration fluctuations, as illustrated by the higher U-234 and U-238 concentrations in the samples collected in February 2000 (seasonally high flow) compared to concentrations in the samples collected in August 2000 (seasonally low flow).

The surface water sampling locations in NT-7 and NT-8 are each located immediately upstream of the respective confluence of each tributary with the main channel of Bear Creek (Figure A.2). Samples of the water in each tributary that were collected during CY 2000 are clearly distinguished by surprisingly high levels of VOCs (considering the potential for volatilization), including respective c12DCE concentrations of 100 µg/L and 410 µg/L; maximum PCE and VC levels also exceed respective MCLs (Table 16). These results show that the plume of dissolved chloroethenes in the shallow groundwater near BG-C (East and West) continues to discharge into these tributaries (DOE 1997). In addition to VOCs, historical monitoring data show fairly extensive radiological contamination of surface water in the Bear Creek tributaries that drain the BCBG WMA, with the highest levels of gross alpha (>15 pCi/L) and gross beta (>50 pCi/L) radioactivity evident in the southern branch of NT-8 (DOE 1997). Instead of gross alpha and gross beta activity, samples collected from NT-7 and NT-8 during CY 2000 were analyzed only for uranium isotopes. These analytical results are generally consistent with respective historical radiological data, and show very low levels (i.e., <10 pCi/L) of U-234 and U-238 in NT-7, but substantially higher levels of U-234 (>30 pCi/L) and U-238 (>100 pCi/L) in NT-8.

The quality of surface water in Bear Creek at BCK-09.47 and BCK-09.40 is impacted by inflow of: (1) contaminated surface water (and groundwater) from NT-7 and from NT-8, which enters Bear Creek immediately upstream of the BCK-09.47 sampling location and (2) contaminated groundwater from springs SS-4 and SS-5, which discharges from the south side of Bear Creek upstream of the BCK-09.40 sampling location (Figure A.2). Inflow from the NT-7 and NT-8 catchments probably explains the relatively low levels of VOCs detected in the samples from both BCK-09.47 and BCK-09.40 (note that the maximum VOC concentrations do not exceed applicable MCLs; see Table 16), whereas the elevated nitrate concentrations at BCK-09.47 and BCK-09.40 are probably sustained by downstream transport from Upper Bear Creek discharge augmented by inflow of nitrate-contaminated groundwater from springs SS-4 and SS-5. Conversely, the elevated uranium concentrations in Bear Creek at BCK-09.47 and BCK-09.40, which remain substantially above the uranium MCL (0.03 mg/L) and are higher than uranium concentrations in Upper Bear Creek (Table 15), probably reflects the relative contributions of downstream transport from the Boneyard/Burnyard, inflow from the NT-8 catchment, and input from groundwater discharged into the creek from springs SS-4 and

SS-5. Along with historical data, the CY 2000 monitoring results for nitrate concentration and alpha activity continue the relatively steady indeterminate long-term trend in Bear Creek at BCK-09.40 (Figure A.14).

Impacts on Middle Bear Creek from a combination of contaminant sources also is indicated by the results of radiological analyses of the surface water samples collected from BCK-09.47 during CY 2000. Relatively high levels of U-234 (29 - 37 pCi/L) and U-238 (86 - 96 pCi/L) in the samples suggest a transport from relatively nearby source area, such as inflow from NT-8, but even higher levels of Tc-99 (74 - 111 pCi/L) in these samples confirm transport from the contaminant plume emplaced during operation of the former S-3 Ponds, which are more than two miles upstream of BCK-09.47.

3.2.3 Lower Bear Creek

As shown in Table 18, the primary groundwater contaminants in the Bear Creek Regime were detected at elevated concentrations only in a few of the samples collected during CY 2000 from the wells, springs, and surface water stations Lower Bear Creek sampling locations (arranged in sequence from upstream to downstream), with elevated (total) uranium concentrations and gross alpha activity detected most frequently.

Table 18. CY 2000 maximum contaminant concentrations at exit pathway/perimeter monitoring sampling locations along Lower Bear Creek

Sampling Point	Inorganics (mg/L)		Organics (µg/L)	Radioactivity (pCi/L)	
	Nitrate	Uranium		Gross Alpha	Gross Beta
GW-712	1.4	.	.	2.58	4.52
GW-713	1.3	.	.	.	17.92
GW-714	[4]	.	.	.	5.37
GW-715	2.9	0.0194	.	9.56	9.64
SS-6	2.33	0.0212	.	7.6	10
SS-6.6	0.97	0.00793	.	**16.32**	16
SS-7	1.7	0.0168	.	7.11	9.5
SS-8	0.29	.	.	.	.
BCK-07.87	**11.5**	**0.155**	.	**72**	**62**
BCK-04.55	4.86	**0.0691**	.	**35**	32
BCK-00.63	2.78	**0.0399**	.	**22**	16

Notes: Results for each sampling point may be from more than one sampling date. "**.**" = not detected;
[ ] = qualitative nitrate result, high charge balance error; **BOLD** = exceeds MCL (uranium and gross alpha) or SDWA screening level (gross beta)

Exit Pathway Picket W monitoring wells GW-712, GW-713, GW-714, and GW-715 are completed at various depths within different hydrostratigraphic zones along a strike-normal transect across the Maynardville Limestone (and lower Knox Group) located about 5,000 ft west of the BCBG WMA (Figure A.2). These wells yield calcium-magnesium-bicarbonate groundwater, with the deeper wells (GW-712 and GW-713) clearly distinguished by enriched levels of sulfate (>50% of total anions). As shown in Table 18, the principal groundwater contaminants were not detected at elevated concentrations in any of the groundwater samples collected from these wells during CY 2000.

Aside from these contaminants, however, the CY 2000 monitoring results show that well GW-715 continues to yield groundwater samples with elevated concentrations of chromium and nickel that most likely reflect corrosion of the stainless steel well screen (BJC 2001). To evaluate the potential for microbiologically induced corrosion of the stainless steel monitoring well casing and screen, the GWPP performed microbiologic sampling

during CY 2000 in the Bear Creek Regime to determine what types of bacteria (if any) were present in the groundwater in selected wells (Table B.1). Most of the selected wells yield uncontaminated groundwater and do not show indications of corrosion (geochemistry or elevated nickel and chromium concentrations). Microbial activity was determined in semiannual (February and August) samples from wells GW-714 (open-hole construction) and GW-715 (stainless steel well casing and screen), and results show similar colony counts of iron-related, slime-forming, and sulfate-reducing bacteria in the February 2000 samples, although the August 2000 sample from well GW-715 has significantly higher counts (see Appendix D of the CY 2000 GWMR). Elevated nickel and chromium concentrations are not present in well GW-714, probably because the well is not constructed of stainless steel casing and screen. The presence of these bacteria (also observed in a borehole camera survey performed in well GW-715 during CY 1999) supports the theory that elevated nickel and chromium concentrations in the well are corrosion artifacts.

Spring SS-6.6 discharges into the main channel of Bear Creek just downstream of the confluence with NT-13 and about 1,000 ft west of Exit-Pathway Picket W (Figure A.2). As shown in Table 18, the gross alpha activity reported for the sample collected from this spring in August 2000 slightly exceeds the MCL; however, only trace levels (<5 pCi/L) of uranium isotopes (i.e., the principal alpha-emitting radionuclides in the Maynardville Limestone) were detected in this sample. The uranium activities reported for SS-6.6 are similar to the uranium activities reported for spring SS-6 in CY 2000, which has much lower gross alpha activity (see Table 18). Technetium-99 was detected in this sample, although the reported Tc-99 activity (29 pCi/L) just exceeds the associated MDA (20 pCi/L) and has a large proportional CE (12 pCi/L). Because spring SS-6.6 has no history of radiological contamination, the significance of these radiological results is not clear.

The highest uranium and gross alpha levels in Lower Bear Creek were detected in the samples collected from the creek at BCK-07.87 (Table 18), which is near the confluence with NT-11 (Figure A.2) and is more than a mile downstream of the closest known source of uranium (and uranium isotopes) in the Bear Creek Regime (the BCBG). Note also that the samples collected from BCK-07.87 contained nitrate concentrations (10.5 - 11.5 mg/L) that slightly exceed the MCL and gross beta activity just above (62 pCi/L) and below (48 pCi/L) and the SDWA screening level (50 pCi/L). Uranium isotopes in the creek probably account for the elevated levels of gross alpha and gross beta activity, as indicated by the concentrations of U-234 (29 - 37 pCi/L) and U-238 (86 - 96 pCi/L) detected in the samples collected at BCK-07.87 during CY 2000. Also, the sample collected in August 2000 contained Tc-99 (29 pCi/L), although this result has a relatively high MDA (23 pCi/L) and a large proportional CE (14 pCi/L); a similarly low level of Tc-99 (14 pCi/L) also was detected in the sample collected at BCK-07.87 in February 1999. These monitoring results suggests transport of Tc-99 from the S-3 Site with inputs of uranium isotopes from the Boneyard/Burnyard and the BCBG WMA.

The CY 2000 monitoring results show elevated concentrations of uranium and gross alpha in Bear Creek at BCK-04.55 (Table 18), which is located just upstream of where the creek exits BCV through a gap in Pine Ridge (Figure A.2). These results, along with historical data, show significant temporal fluctuations but a generally steady (indeterminate) long-term concentration trend for gross alpha activity (Figure A.14). Additionally, the CY 2000 monitoring show that elevated concentrations of total uranium and gross alpha radioactivity (presumably from uranium isotopes) occur at BCK-00.63 in Bear Creek, which is less than one kilometer from its confluence with East Fork Poplar Creek (Figure A.2).

3.3 CONTAMINANT CONCENTRATION TRENDS

Monitoring data obtained since the late 1980s and early 1990s show indeterminate or generally decreasing long-term contaminant concentration trends for the majority of sampling locations in the Bear Creek Regime,

including most of the CY 2000 sampling locations (Table B.2). The decreasing concentration trends probably reflect a combination of several factors, including compliance with waste management regulations, waste minimization and source control measures, remedial actions, natural attenuation mechanisms (including biotic and/or abiotic degradation of VOCs), and, possibly in some cases, changes in sampling procedures and analytical methods. For the trend-analysis purposes of DOE Order 5400.1, the following discussion is focused on CY 2000 sampling locations with elevated and increasing long-term concentrations of one or more of the principal groundwater contaminants in the Bear Creek Regime (nitrate, uranium, VOCs, gross alpha activity, and gross beta activity). Evaluation of the increasing trends is based on least-squares linear regression of the long-term data sets for each applicable sampling location, which include both conventional sampling and low-flow sampling data, with the corresponding coefficient of determination (R^2 value) used as an indicator of the goodness of fit of the data with respect to each trend line. Linear regression of short-term data sets for several of these sampling locations also was used to evaluate concentration trends based on low-flow sampling data alone. Only data that meet applicable DQO criteria were used for trend analysis purposes.

As shown in Table 19, increasing long-term contaminant concentration trends are indicated by the monitoring data for eight of the CY 2000 sampling locations in the Bear Creek Regime.

Table 19. CY 2000 sampling locations with increasing long-term contaminant concentration trends

Sampling Location	Nitrate	Uranium	VOCs	Radioactivity
GW-085	!	.	.	!
GW-226	!	.	!	.
GW-537	.	.	.	!
GW-615	!	!	.	.
GW-627	.	.	!	.
GW-653	.	.	!	.
GW-695	!	.	.	.
SS-4	.	.	!	.

Elevated nitrate concentrations and gross beta activity in the shallow groundwater at aquitard well GW-085 reflect westward, strike-parallel migration from the plume emplaced during operation of the former S-3 Ponds (see Section 3.1.1.1), and both nitrate and gross beta results obtained during CY 2000 continue respectively increasing concentration trends evident since low-flow sampling began in March 1998 (Figure A.15). Historical (conventional sampling) data for this well show that nitrate concentrations and gross beta activity, which is from Tc-99, generally increased between June 1991 and January1994, then generally decreased through September 1997. This portion of the long-term trend potentially reflects westward, strike-parallel migration of a "pulse" of nitrate and Tc-99 in the Nolichucky Shale (shallow bedrock interval) west of NT-2. The subsequent increasing trend in both constituents may reflect the change to low-flow sampling, or may reflect arrival of another "pulse" of nitrate and Tc-99.

As noted in Section 3.1.2.1, the CY 2000 monitoring data for well GW-226 indicate an overall increase in the concentration of nitrate in the well (Figure A.16). However, the conventional sampling data show a clearly decreasing trend between March 1987 (4.1 mg/L) and May 1991 (<0.2 mg/L), whereas the much higher concentrations indicated by the low-flow sampling results show an indeterminate trend dominated by wide (seasonal) concentration fluctuations (Figure A.16). Thus, the apparent long-term increase in the concentration of nitrate in the well is a direct consequence of the large disparity between the conventional and low-flow sampling results, which may be an artifact of one or both sampling methods. Aggressively purging the well using the conventional sampling method may have induced flow of relatively uncontaminated groundwater into the well from certain fracture zones and thereby resulted in the collection of groundwater samples with

"diluted" nitrate concentrations. This same rationale may likewise explain the substantial overall increase in the TCE concentration in the well (Figure A.17). As with nitrate, the conventional sampling results for TCE show a strongly decreasing trend between March 1987 (32 µg/L) and May 1991 (3 µg/L), with the low-flow sampling results showing substantially higher TCE concentrations (>100 µg/L) and an indeterminate short-term trend (Figure A.17).

The CY 2000 gross beta results for groundwater samples from aquitard well GW-537 are generally consistent with historical data (Figure A.18), which show significant temporal fluctuations (some of which probably reflect analytical variability) but a moderately increasing long-term trend. The long-term increase in the level of gross beta radioactivity in the shallow groundwater at this well potentially reflects the slow, westward migration of the center of mass of the S-3 Site contaminant plume (DOE 1997). This may likewise explain the strongly increasing short-term trend indicated by the low-flow sampling data (Figure A.18).

Monitoring results obtained during CY 2000 show increasing long-term concentration trends for nitrate and uranium in aquitard well GW-615 (Figure A.19), with the uranium results indicating a more clearly increasing trend compared to that of nitrate. Note that these long-term trends encompass the nearly eight-year gap (August 1992 - February 2000) in the monitoring data for the well; the uranium trend also spans several changes in the analytical methods used for uranium analyses. Moreover, the CY 2000 nitrate and uranium results were obtained with the low-flow sampling method, whereas all the previous results were obtained with the conventional sampling method. These considerations raise questions as to the significance of the increasing nitrate and uranium trends indicated by the CY 2000 monitoring data for well GW-615.

Monitoring results obtained during CY 2000 show that the concentration of dissolved chloroethenes in aquitard well GW-627, as illustrated by the results for PCE, reflect a strongly increasing long-term trend through February 2000 (Figure A.20). Interestingly, the conventional sampling data show a more clearly increasing trend compared to the low-flow sampling results. This may be an artifact of the respective sampling methods, whereby aggressively purging the well for conventional sampling during CY 2000 may have induced flow of uncontaminated groundwater into the bedrock near the well. Note that the low-flow sampling result obtained in August 2000 (six months after aggressively purging the well) was much lower (340 µg/L) than the February 2000 low-flow sampling result (500 µg/L), which was collected more than two years after the previous conventional sample (September 1997). Excluding this possibly affected sample result (August 2000), the increasing trend for low-flow data is more significant than the conventional trend. Nevertheless, as noted in Section 3.1.1.2,the detection of PCE in this well and the subsequent concentration increase indicates strike parallel migration of this and other VOCs at depth in the aquitard beneath the BCBG WMA (westward).

Monitoring results reported for the groundwater samples collected from well GW-653 during CY 2000 continue the increasing long-term trend evident since early 1993, as illustrated by results for 12DCE (Figure A.21), which is the dominant VOC in the well. The conventional sampling results show substantial short-term variability and, consequently, reflect a less significant increasing trend than is indicated by the low-flow sampling results. Additionally, based on comparison with pre-sampling groundwater elevations in the well, the 12DCE concentrations are often highest during winter and spring when water levels are highest, with a particularly sharp "spike" in the 12DCE concentration evident in February 2000 (Figure A.21). This pattern suggests seasonally variable flux of dissolved VOCs toward discharge areas in NT-8.

The CY 2000 nitrate results for well GW-695 generally continue the increasing long-term concentration trend indicated by historical data (Figure A.22). This combination of conventional sampling and low-flow sampling results show that nitrate levels increased steadily from 1 mg/L in June 1991 to almost 10 mg/L (the MCL for nitrate) in February 1994, and subsequently remained near 10 mg/L through July 2000. The relatively indeterminate trend evident since February 1994 is reflected by the short-term trend based on the low-flow

sampling data, which reflect a slightly increasing trend dominated by wide seasonal concentration fluctuations (Figure A.22). This suggests that the increasing concentrations of nitrate over the long term reflect a corresponding increase in the overall flux of nitrate in the shallow groundwater at Exit Pathway Picket B.

The CY 2000 monitoring results for TCE in spring SS-4 generally continue the increasing long-term concentration trend indicted by historical data (Figure A.23). Samples of the groundwater discharged from spring SS-4 have been collected since January 1991 on a quarterly (1991-1993) or semiannual (1994-2000) basis. Review of the results for these samples indicate that the increasing trend appears to have begun in 1995; a slightly decreasing is indicated by the TCE results obtained before then (Figure A.23). Also, the TCE concentrations are typically higher in the samples collected from the spring during seasonally low-flow conditions (summer and fall). This suggests that the TCE concentrations reflect variable degrees of dilution during seasonally high flow conditions (winter and spring), and that the increasing long-term trend reflects increased overall flux of TCE in the shallow karst network connected with spring SS-4.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The groundwater and surface water quality data obtained during CY 2000 are generally consistent with historical results regarding the sources of contamination in the Bear Creek Regime, the types of contaminants from each source area, the pattern and extent of contaminant transport, and long-term contaminant trends. This conclusion is based on evaluation of the data for the primary groundwater and surface water contaminants (nitrate, uranium, VOCs, and radioactivity). A summary of significant findings based on the evaluation of these CY 2000 results for the purposes of DOE Order 5400.1 is provided below.

The CY 2000 monitoring results reported for 45 monitoring wells, including 23 aquitard wells, 18 aquifer wells, and four Westbay™ wells (two with sampling ports in both hydrogeologic units), were evaluated for the surveillance monitoring purposes of DOE Order 5400.1. These monitoring results indicate migration of contaminants from the S-3 Site and the BCBG WMA in the aquitard, and transport of contaminants from the S-3 Site, Spoil Area I, Rust Spoil Area (or nearby source in the Bear Creek floodplain), the Oil Landfarm WMA, and the BCBG WMA in the aquifer. The CY 2000 monitoring results for most of the monitoring wells reflect historical data and do not indicate any significant change in the extent or distribution of groundwater contaminants in the Bear Creek Regime.

The CY 2000 monitoring results reported for nine surface water stations in Bear Creek (including three northern tributaries), seven springs that discharge into Bear Creek, and four aquifer wells at the westernmost Exit Pathway Picket (Picket W) were evaluated for the exit pathway/perimeter monitoring purposes of DOE Order 5400.1. These results are generally consistent with historical data and show that contaminant concentrations generally decrease with distance from the S-3 Site, but localized segments of the Bear Creek downstream of this site show increases in the concentration of some contaminants that reflect contribution of contaminated groundwater from other waste sites. Moreover, the CY 2000 monitoring results for the surface water samples collected from Bear Creek at BCK-00.63, which is outside the boundaries of the Bear Creek Regime near the confluence of Bear Creek and East Fork Poplar Creek, show that total uranium concentrations and gross alpha activity exceed the respective MCL for drinking water (0.03 mg/L and 15 pCi/L).

Evaluation of the CY 2000 monitoring results with respect to contaminant concentration trends in the Bear Creek Regime, as required under DOE Order 5400.1, indicates that increasing long-term concentration trends are evident for selected groundwater contaminants (primarily VOCs) in eight of the CY 2000 sampling locations, including five aquitard wells (GW-085, GW-537, GW-615, GW-627, and GW-653), two aquifer wells (GW-226 and GW-695), and one spring that discharges into Bear Creek (SS-4). The increasing trends in the groundwater at the aquitard wells potentially represent westward contaminant migration along strike near the plume boundaries, while the increasing trends in the groundwater at the aquifer wells and spring SS-4 may reflect the hydrochemical dynamics within the groundwater plumes or increased flux of contaminants in the shallow karst system in the Maynardville Limestone. Monitoring results for the remaining CY 2000 sampling locations generally continue the decreasing (or indeterminate) concentration trends evident since the late 1980s and early 1990s.

Based on evaluation of the CY 2000 groundwater monitoring data, the following actions are recommended:

- Low-flow and conventional sampling should be performed on subsequent days (as performed during CY 2000 at three wells) at wells GW-226 and GW-287 (and possibly at other wells) during CY 2002.

These wells have substantial data gaps which span the change to low-flow sampling, and results for each method appear to differ significantly.

- Collect samples twice during CY 2002 from the following wells which have not been sampled in several years:

Table 20. Recommended sampling locations for surveillance monitoring during CY 2002

Site	Well	Last Sampled	Site	Well	Last Sampled
BCBG	GW-014	1995Q3	OLF	GW-066	1995Q3
BCBG	GW-061	1995Q3	OLF	GW-075	1992Q3
BCBG	GW-069	1997Q3	OLF	GW-087	1999Q1
BCBG	GW-071	1991Q2	OLF	GW-229	1995Q3
BCBG	GW-072	1991Q2	S-3	GW-243	1994Q1
BCBG	GW-091	no data	EXP-B	GW-694	1996Q3
BCBG	GW-288	1995Q3	EXP-C	GW-723	1996Q3
BCBG	GW-289	1995Q3	EXP-C	GW-736	1995Q3
BCBG	GW-291	1995Q3	EXP-C	GW-737	1995Q3
BCBG	GW-626	1993Q4	EXP-C	GW-739	1995Q3

Note that groundwater samples from all of these wells (except for well GW-087) have not been collected using the low-flow sampling method.

5.0 REFERENCES

AJA Technical Services, Inc. 2001. *Calendar Year 2000 Groundwater Monitoring Report for the Groundwater Protection Program, U.S. Department of Energy Y-12 National Security Complex, Oak Ridge, Tennessee*. Prepared for BWXT Y-12, L.L.C. (Y/SUB/01-006512/1).

Bechtel Jacobs Company LLC. 2001. *Calendar Year 2000 Annual Resource Conservation and Recovery Act Groundwater Monitoring Report for the Bear Creek Hydrogeologic Regime at the U.S. Department of Energy Y-12 National Security Complex, Oak Ridge, Tennessee*. Prepared by AJA Technical Services, Inc. (Y/SUB/01-006512/1).

Chapelle, F.H. 1996. *Identifying Redox Conditions That Favor the Natural Attenuation of Chlorinated Ethenes in Contaminated Ground-Water Systems*. Reported in: Symposium on Natural Attenuation of Chlorinated Organics in Ground Water. U.S. Environmental Protection Agency, Office of Research and Development (EPA/540/R-96/509).

Dreier, R.B., D.K. Solomon, and C.M. Beaudoin. 1987. Fracture Characterization in the Unsaturated Zone of a Shallow Land Burial Facility. *Flow and Transport Through Fractured Rock*. American Geophysical Union Monograph 42.

Goldstrand, P.M. 1995. *Stratigraphic Variations and Secondary Porosity Within the Maynardville Limestone in Bear Creek Valley, Y-12 Plant, Oak Ridge, Tennessee.* Prepared for Martin Marietta Energy Systems, Inc. (Y/TS-1093).

Haase, S. and H.L. King. 1990. *Report and Preliminary Assessment of the Occurrence of Dense, Nonaqueous Phase Liquids in the Bear Creek Burial Grounds Hazardous Waste Disposal Unit at the Oak Ridge Y-12 Plant.* Martin Marietta Energy Systems, Inc. (Y/TS-629).

Hinchee, R.E., J.A. Kittel, and H.J. Reisinger, eds. 1995. *Applied Bioremediation of Petroleum Hydrocarbons*. Batelle Press, Columbus, OH.

King, H.L. and C.S. Haase. 1987. *Subsurface-Controlled Geological Maps for the Y-12 Plant and Adjacent Areas of Bear Creek Valley*. Oak Ridge National Laboratory (ORNL/TM-10112).

McCarty, P.L. 1996. *Biotic and Abiotic Transformations of Chlorinated Solvents in Ground Water*. Reported in: Symposium on Natural Attenuation of Chlorinated Organics in Ground Water. U.S. Environmental Protection Agency, Office of Research and Development (EPA/540/R-96/509).

Moore, G.K. 1988. *Concepts of Groundwater Occurrence and Flow Near Oak Ridge National Laboratory*. Oak Ridge National Laboratory (ORNL/TM-10969).

Moore, G.K. 1989. *Groundwater Parameters and Flow System Near Oak Ridge National Laboratory*. Oak Ridge National Laboratory (ORNL/TM-11368).

Moore, G.K. and L.E. Toran. 1992. *Supplement to a Hydrogeologic Framework for the Oak Ridge Reservation, Oak Ridge, Tennessee.* Oak Ridge National Laboratory (ORNL/TM-12191).

Science Applications International Corporation. 2000. *Y-12 Plant Groundwater Protection Program Data Management Plan* (Y/SUB/00-KFX63C/1).

Shevenell, L.A. 1994. *Chemical Characteristics of Waters in Karst Formations at the Oak Ridge Y-12 Plant*. Oak Ridge National Laboratory (Y/TS-1001).

Shevenell, L.A., B.W. McMaster, and K.M. Desmarais. 1995. *Evaluation of Cross Borehole Tests at Selected Wells in the Maynardville Limestone and Copper Ridge Dolomite at the Oak Ridge Y-12 Plant*. Prepared for Lockheed Martin Energy Systems, Inc.(Y/TS-1166).

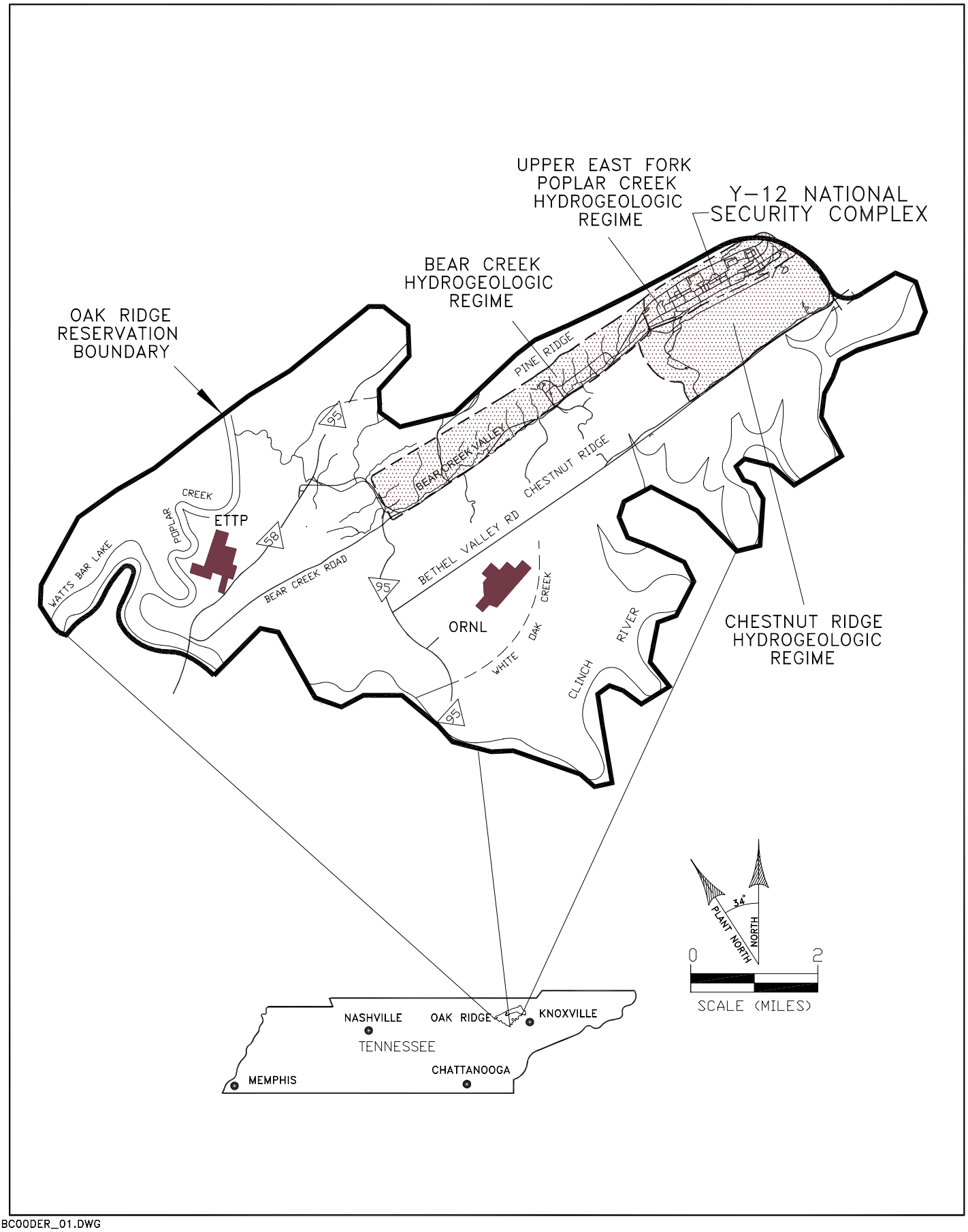
Solomon, D.K., G.K. Moore, L.E. Toran, R.B. Dreier, and W.M. McMaster. 1992. *Status Report - A Hydrologic Framework for the Oak Ridge Reservation.* Oak Ridge National Laboratory (ORNL/TM-12053).

Turner, R.R., M.A. Bogel, R.B. Clapp, K.C. Dearstone, R.B. Drier, T.O. Early, S.E. Herbes, J.M. Loar, P.D. Parr, and G.R. Southworth. 1991. *Remedial Investigation Work Plan for Bear Creek (Y02-S600) at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.* Martin Marietta Energy Systems, Inc. (ES/ER-19&D2).

U.S. Department of Energy. 1997. *Report on the Remedial Investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee.* Volume 1. Prepared for the U.S. Department of Energy (DOE/OR/01-1455/V1&D2).

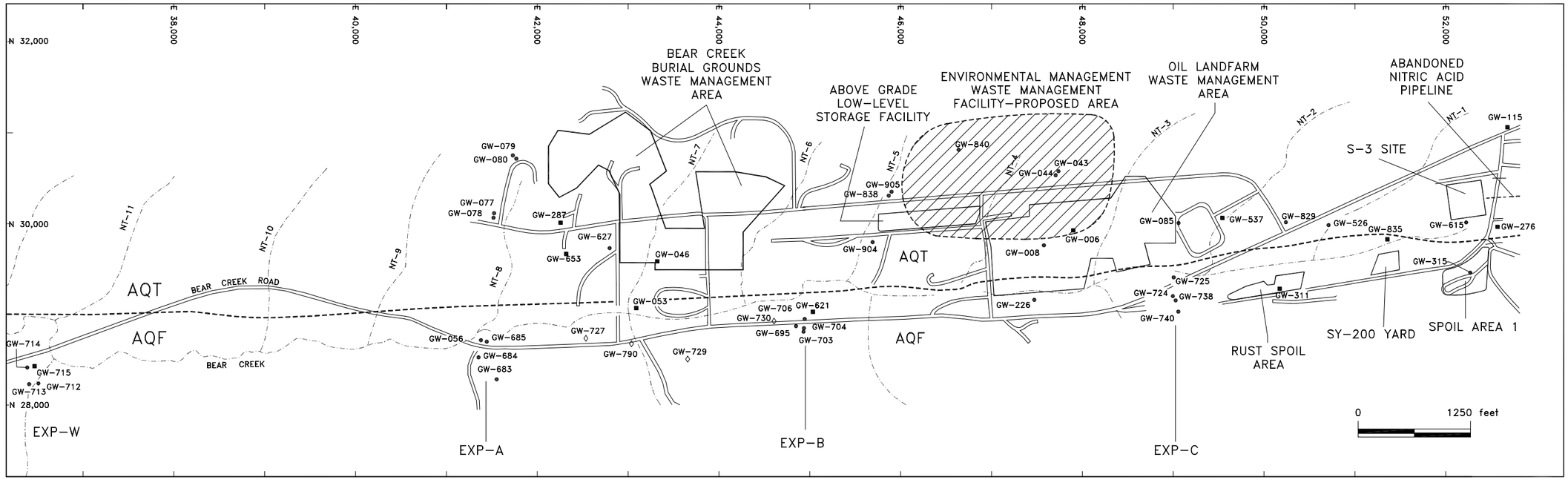
APPENDIX A

FIGURES

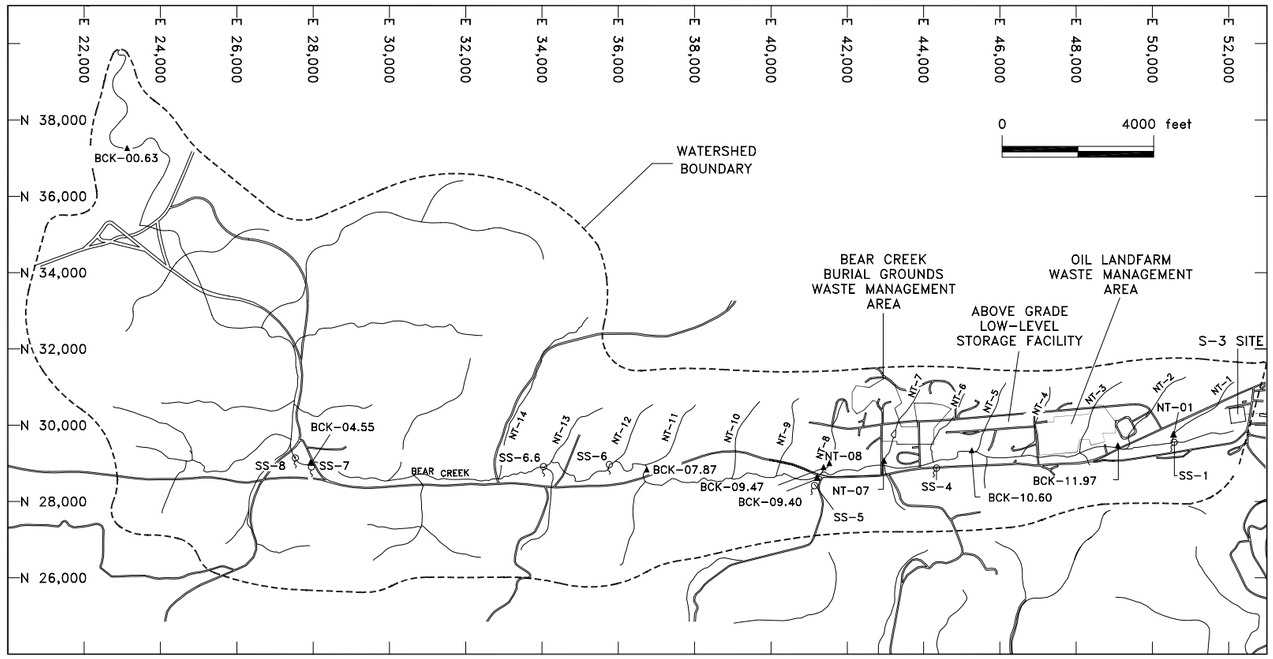


BC00DER_01.DWG

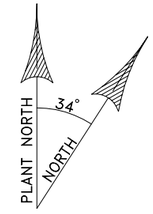
Fig. A.1. Hydrogeologic regimes at the Y-12 National Security Complex.



MONITORING WELL LOCATIONS



SPRINGS AND SURFACE WATER SAMPLING LOCATIONS

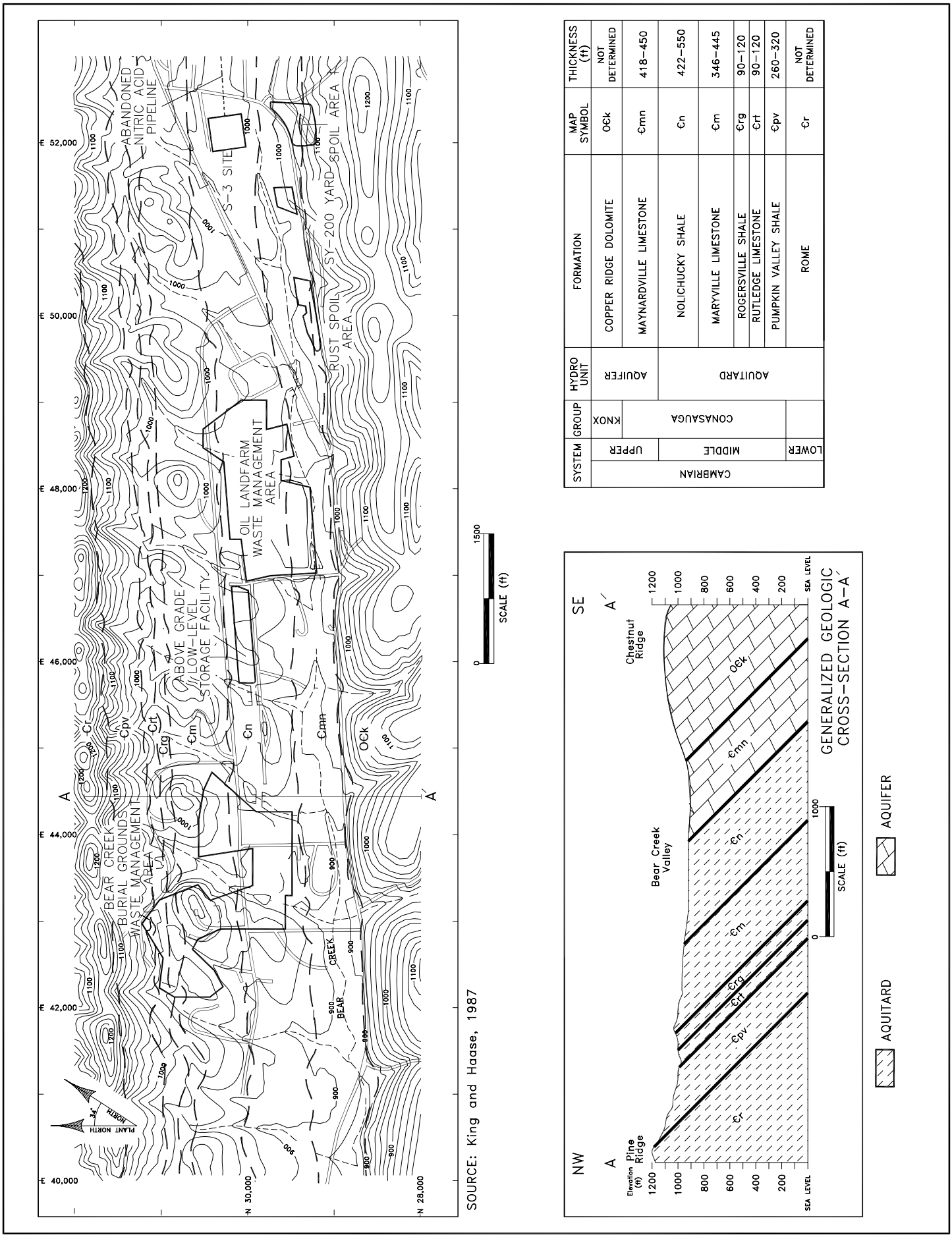


EXPLANATION

- ■ — Water Table Monitoring Well
- • — Bedrock Monitoring Well
- ◊ — Well With Westbay Multiport Monitoring System
- ▲ — Surface Water Sampling Station
- ♀ — Spring Sampling Station
- EXP-C — Exit Pathway, Maynardville Limestone Picket
- — · — · — Surface Drainage Feature
- NT-5 — North Tributary
- AQT — Aquitard
- — — — Approximate Nolichucky Shale\Maynardville Limestone Contact
- AQF — Aquifer

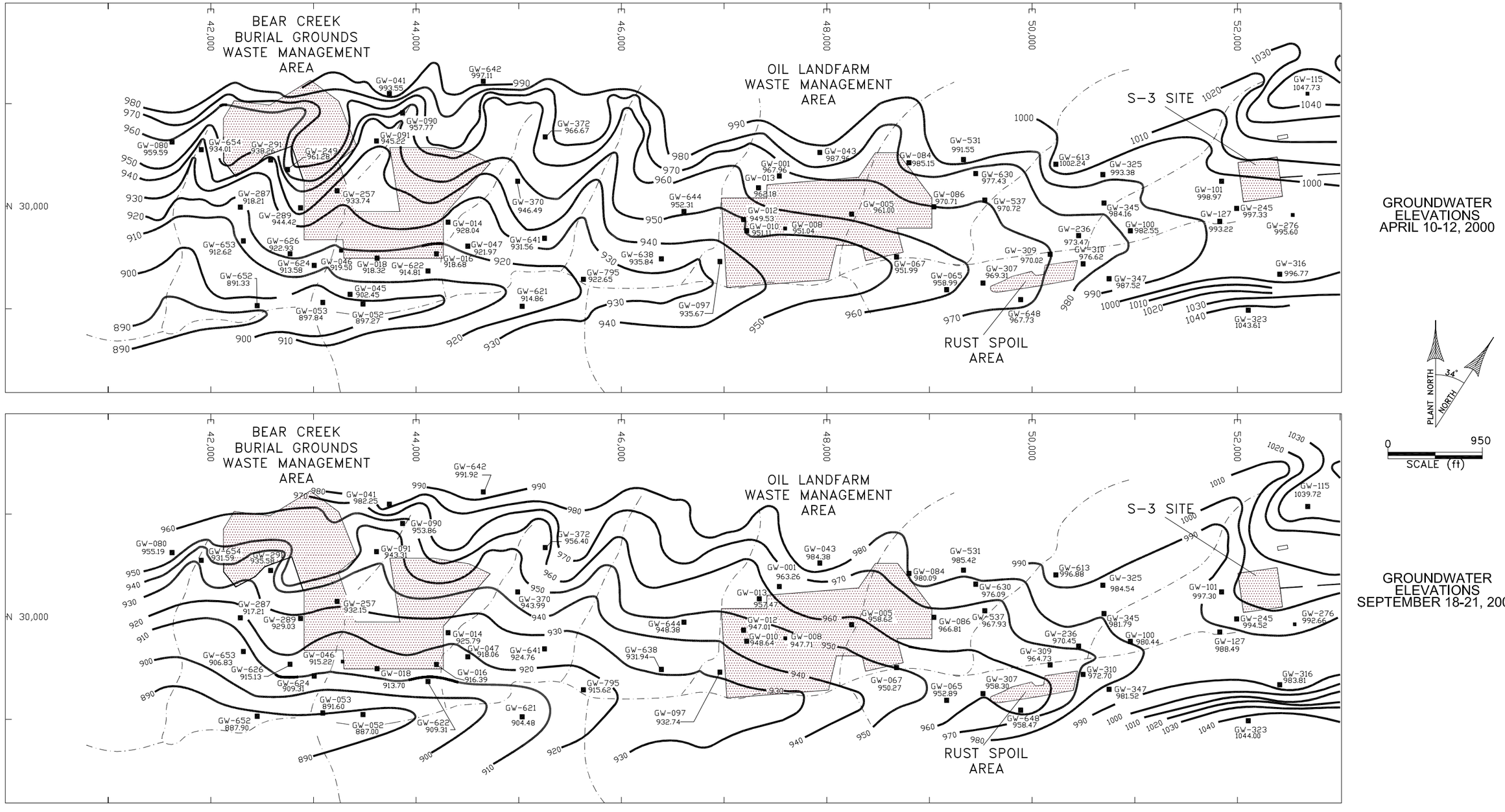
BC00DER_2.DWG 09/22/2001

Fig. A.2. CY 2000 sampling locations in the Bear Creek Hydrogeologic Regime.



BC00DER_3a.DWG 09/22/2001

Fig. A.3. Topography and bedrock geology in the Bear Creek Hydrogeologic Regime.



GROUNDWATER ELEVATIONS APRIL 10-12, 2000

GROUNDWATER ELEVATIONS SEPTEMBER 18-21, 2000

PLANT NORTH
34°
NORTH

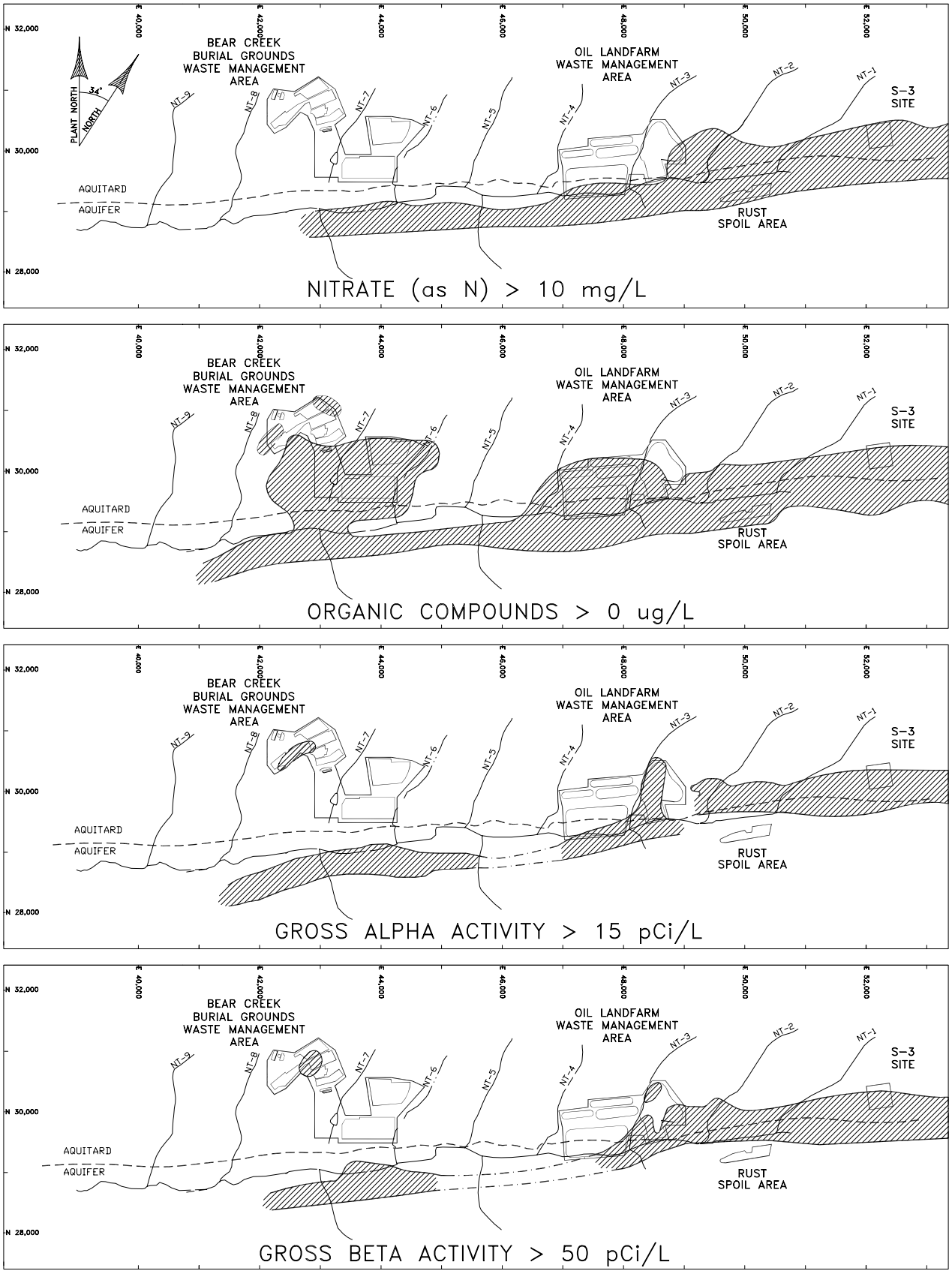
0 950
SCALE (ft)

EXPLANATION

- WATER TABLE INTERVAL MONITORING WELL
- 920 WATER-LEVEL ISOPLETH (ft msl)
- SURFACE DRAINAGE FEATURE

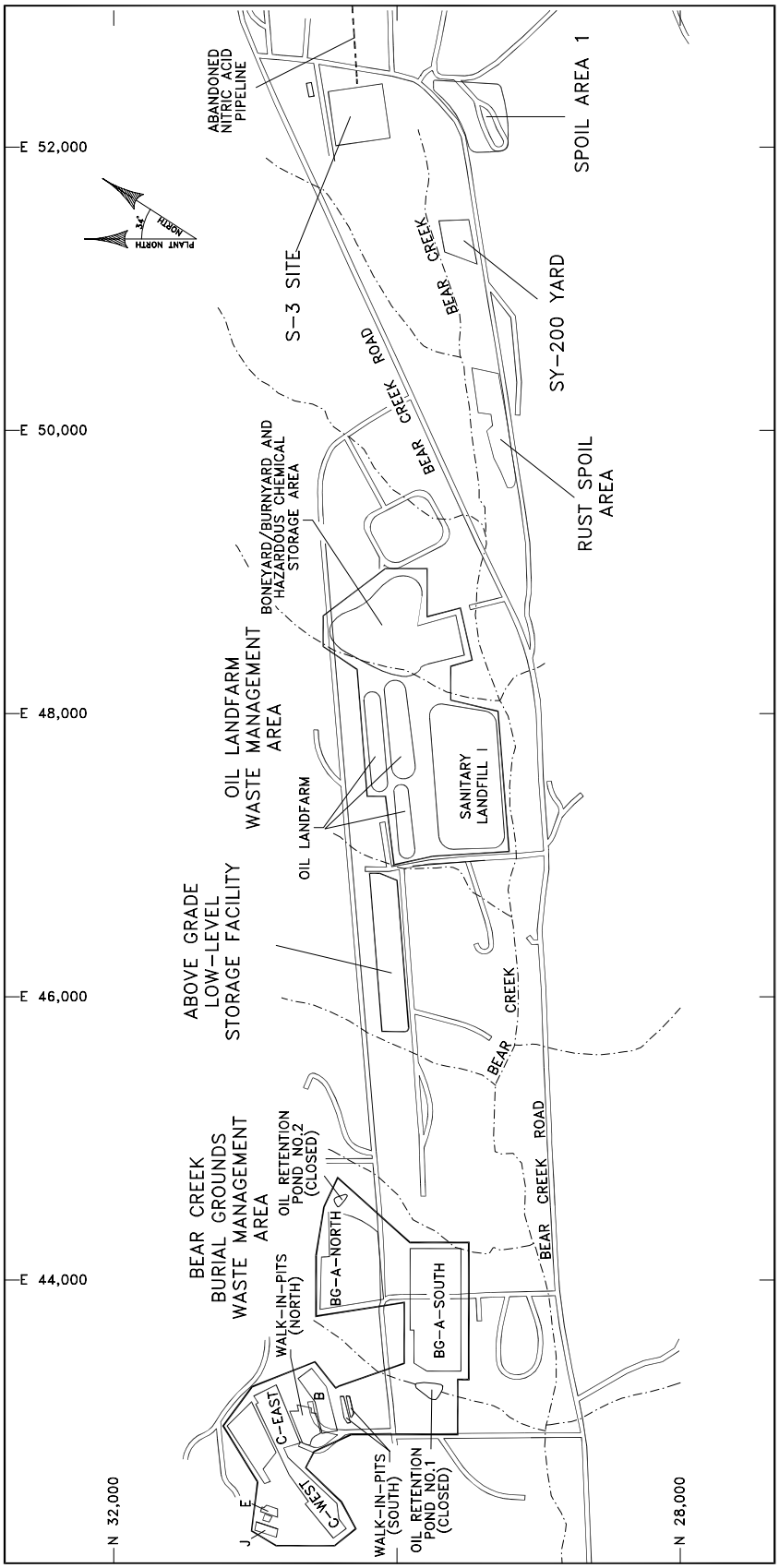
BC00DER_4.DWG

Fig. A.4. Seasonal groundwater elevations in the Bear Creek Hydrogeologic Regime.



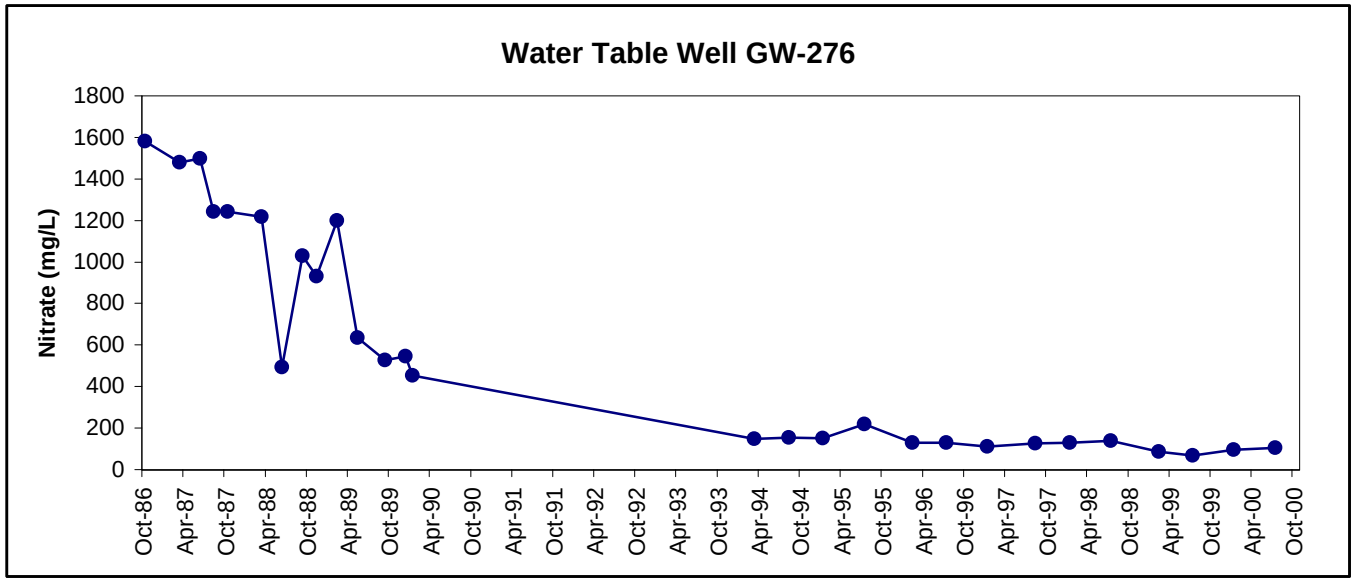
BC00DER_5.DWG

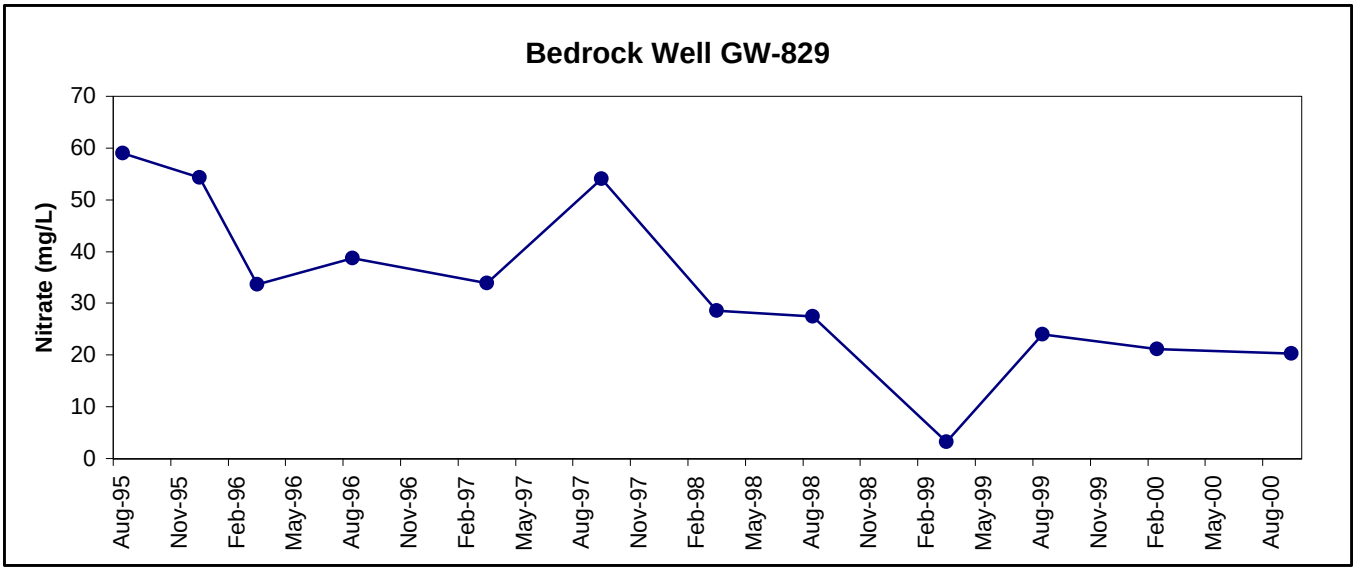
Fig. A.5. Generalized extent of groundwater contamination in the Bear Creek Hydrogeologic Regime.

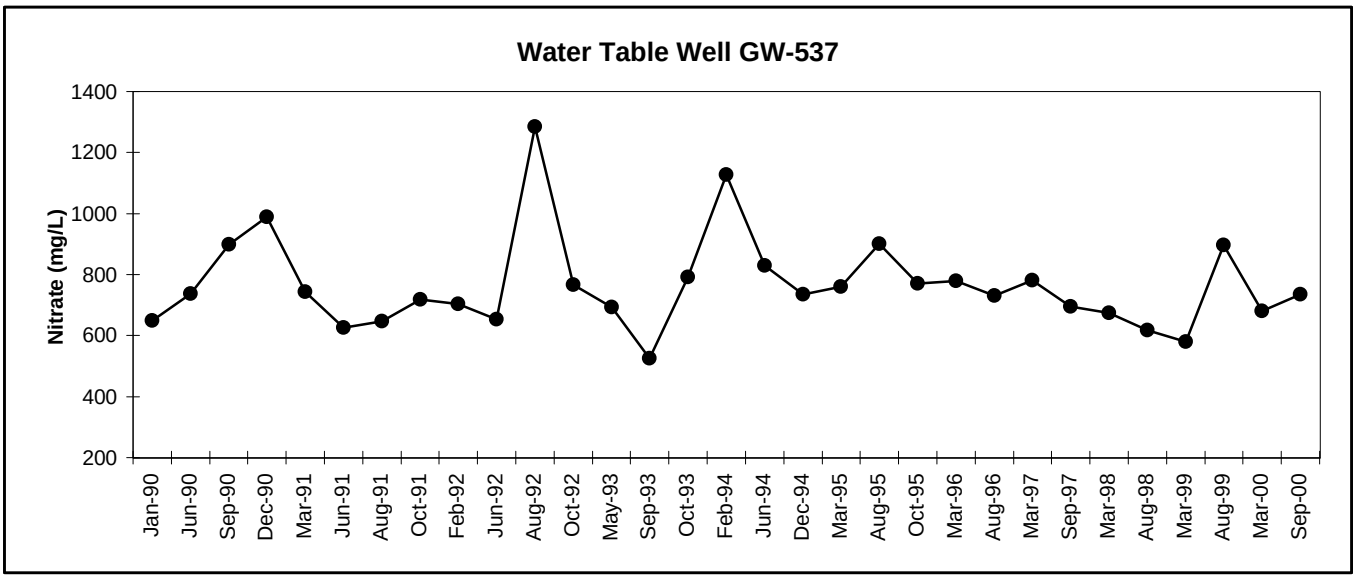


BCOODER_6.DWG

Fig. A.6. Waste management sites and regulated units in the Bear Creek Hydrogeologic Regime.



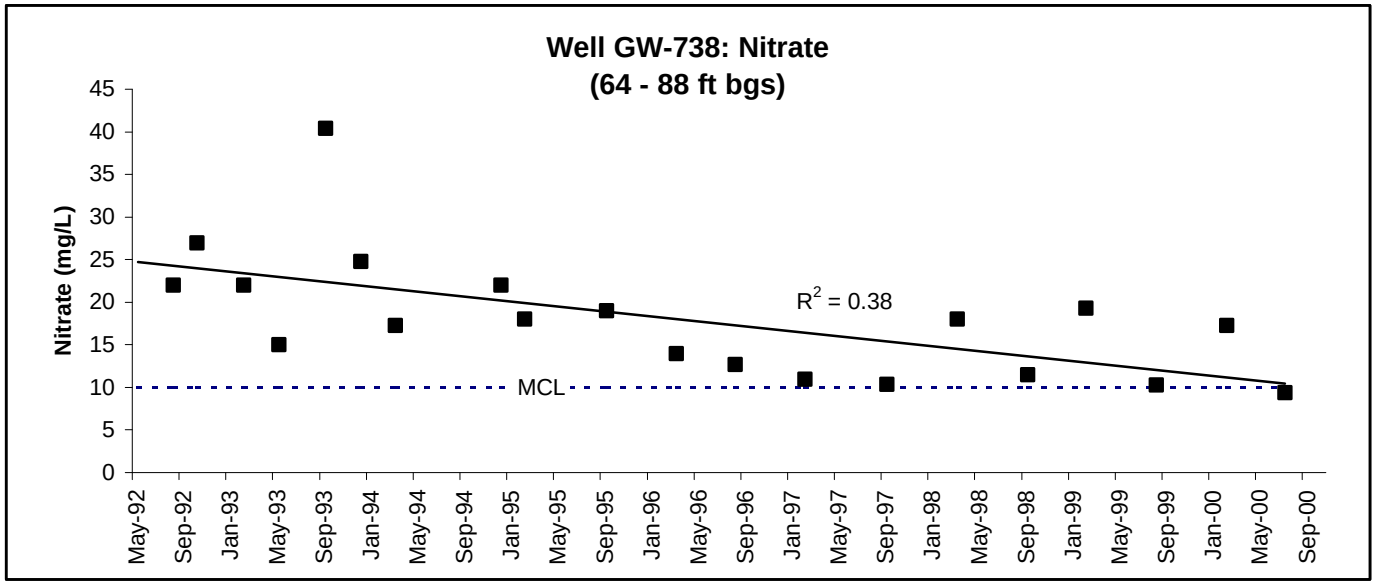


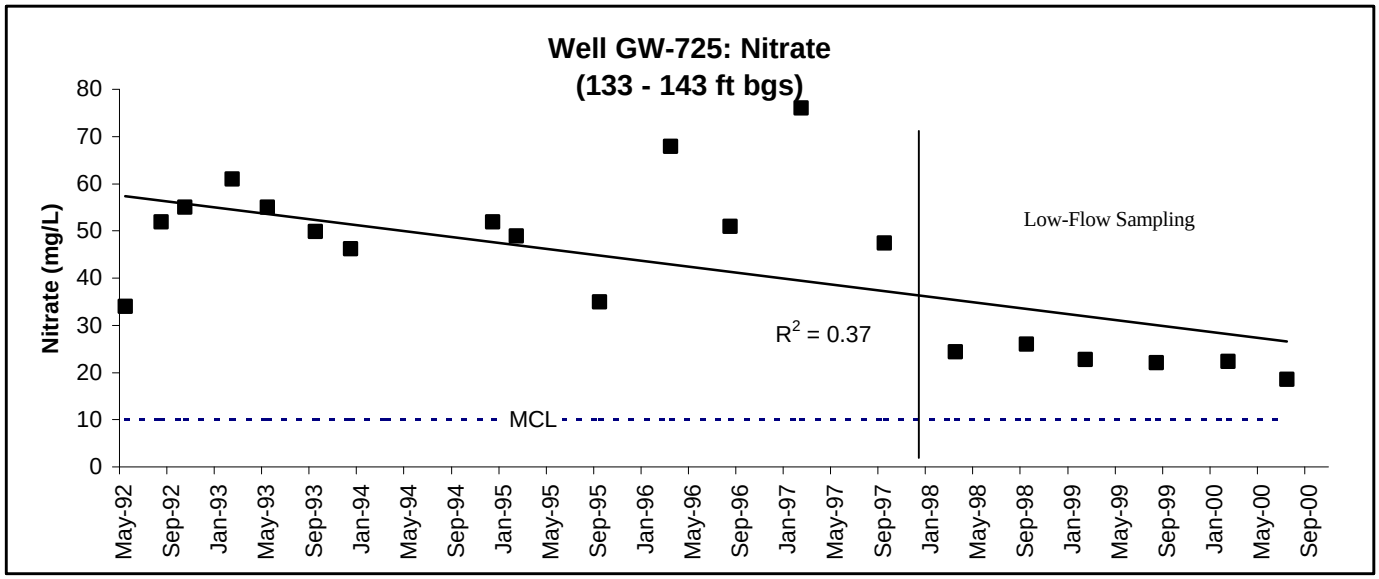


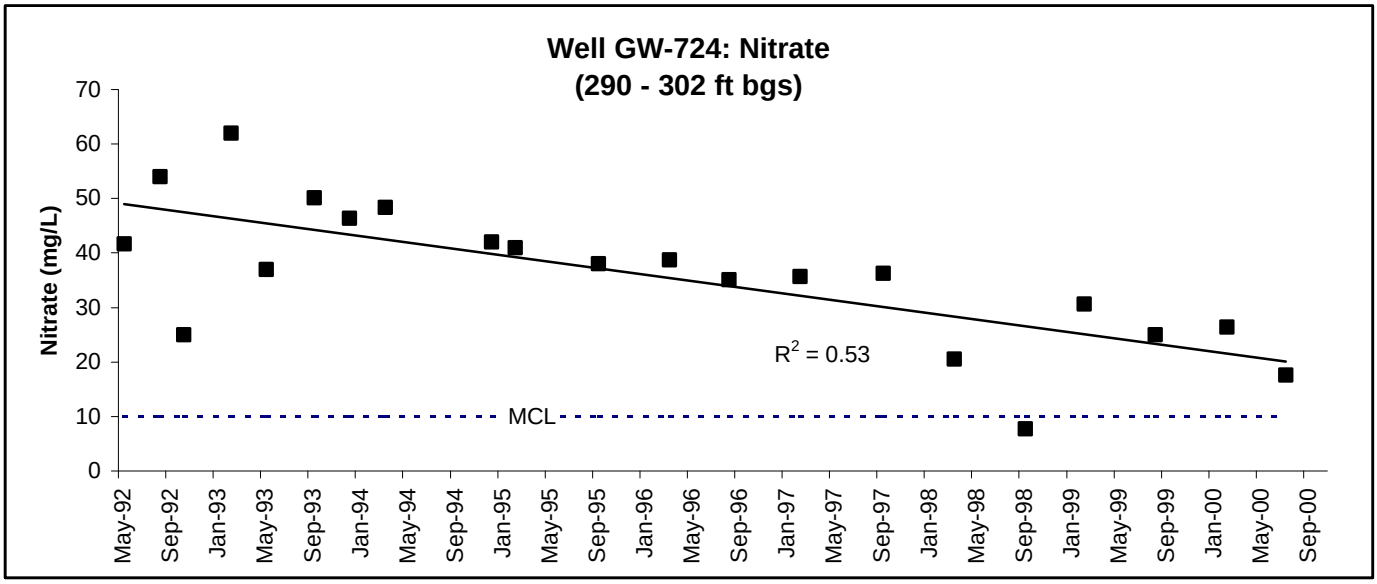
Note: Nitrate MCL = 10 mg/L

BC00DER 09/06/01

Fig. A.7. Nitrate concentration trends in aquitard wells GW-276, GW-537, and GW-829.

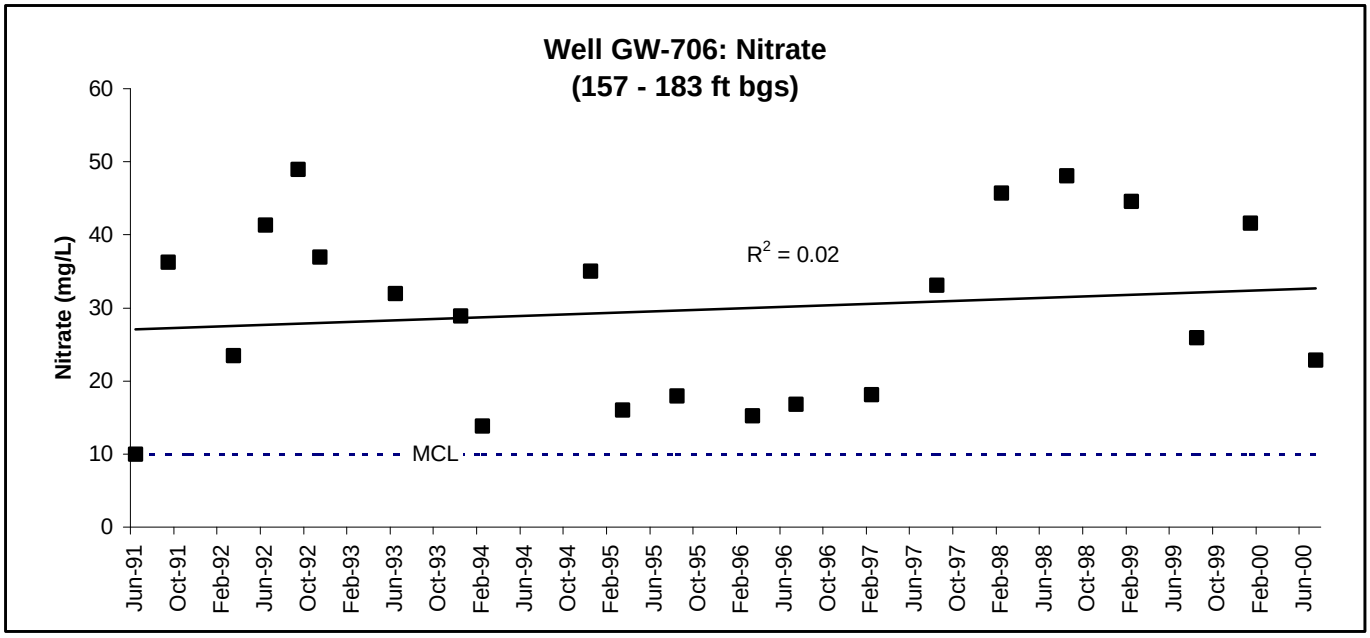


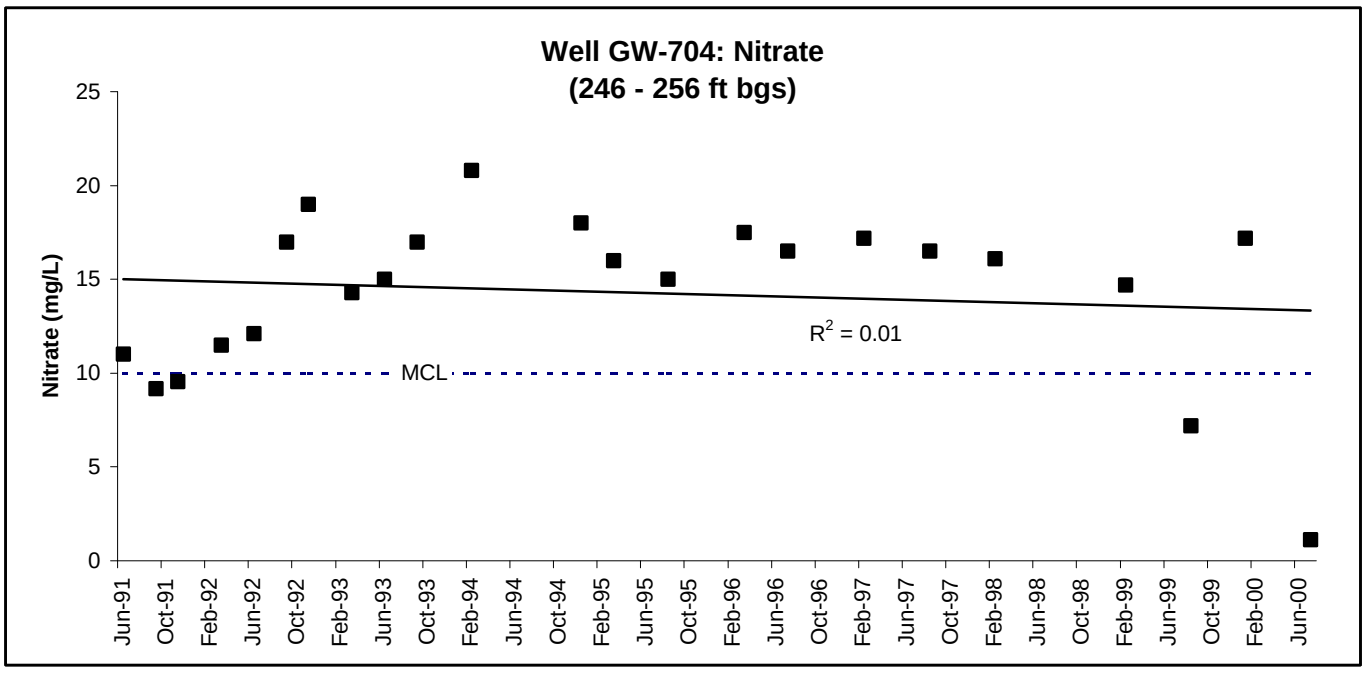




BC00DER 09/06/01

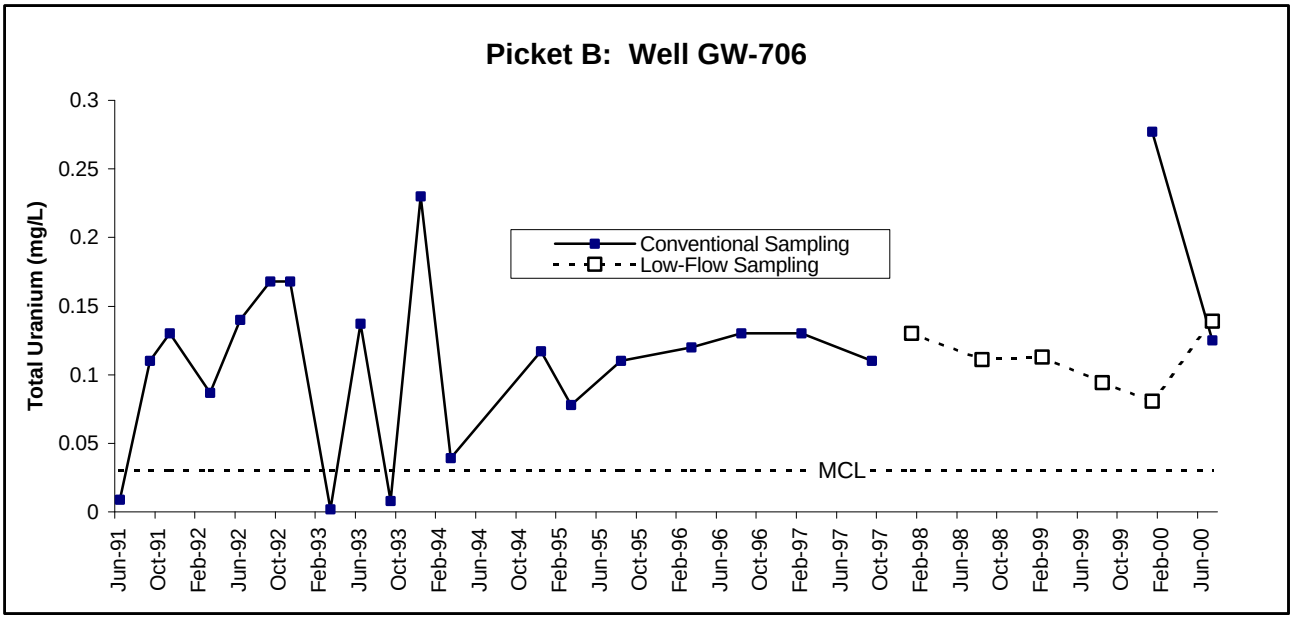
Fig. A.8. Nitrate concentration trends in aquifer wells GW-724, GW-725, and GW-738.

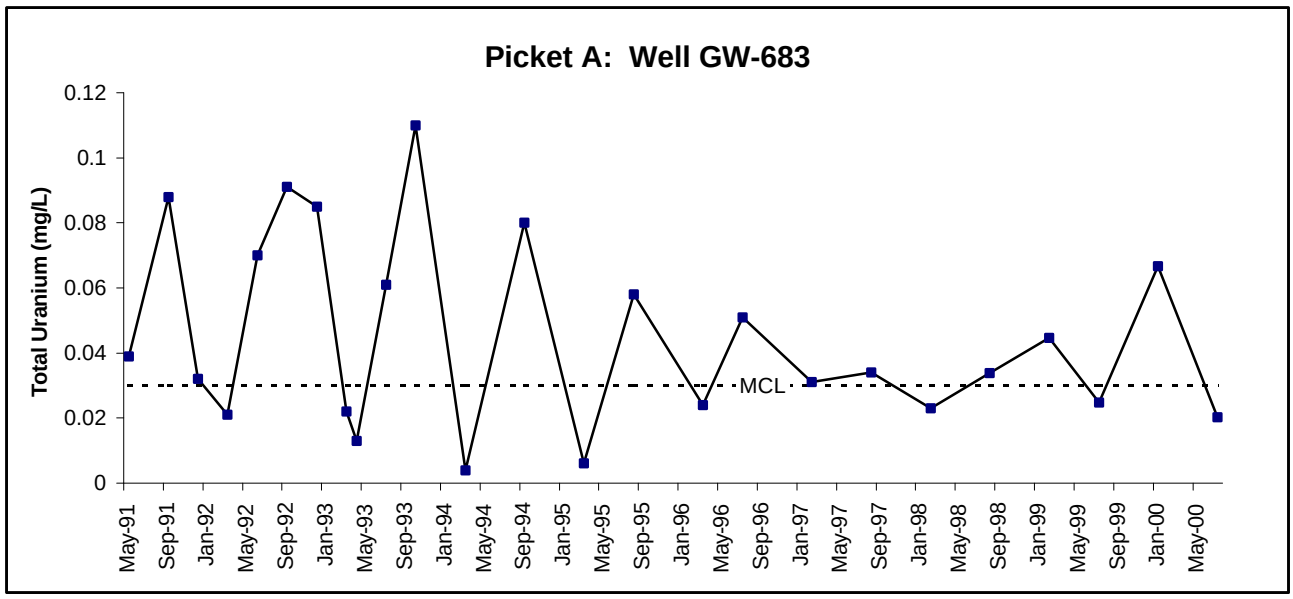


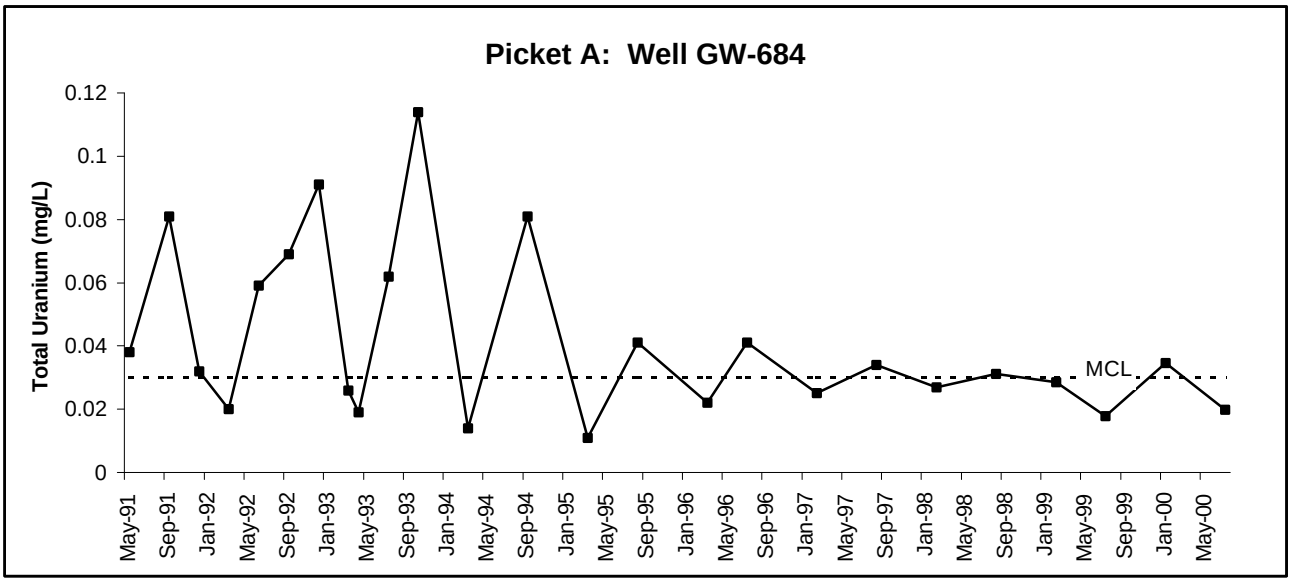


BC00DER 09/06/01

Fig. A.9. Nitrate concentration trends in aquifer wells GW-704 and GW-706.

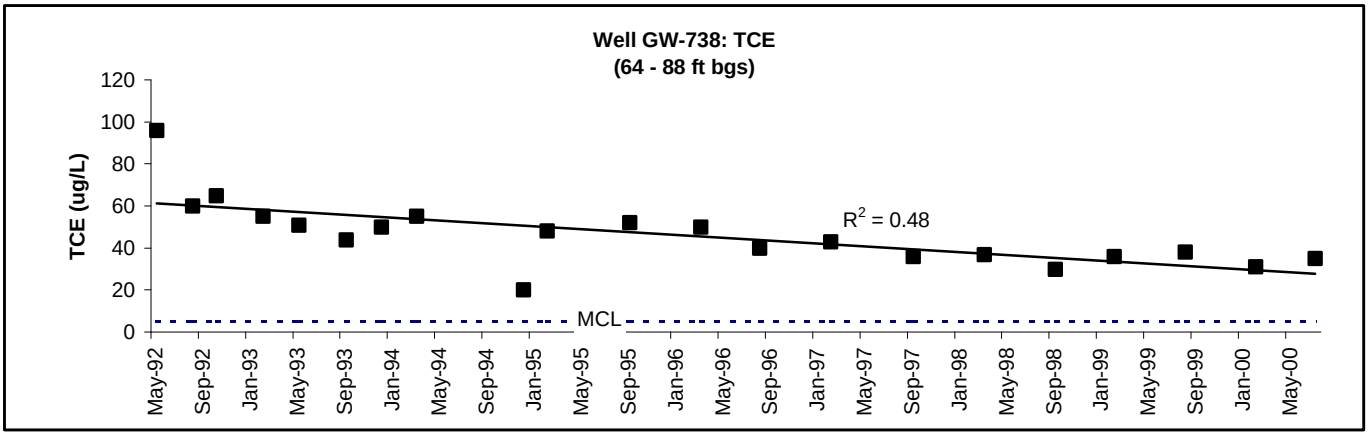


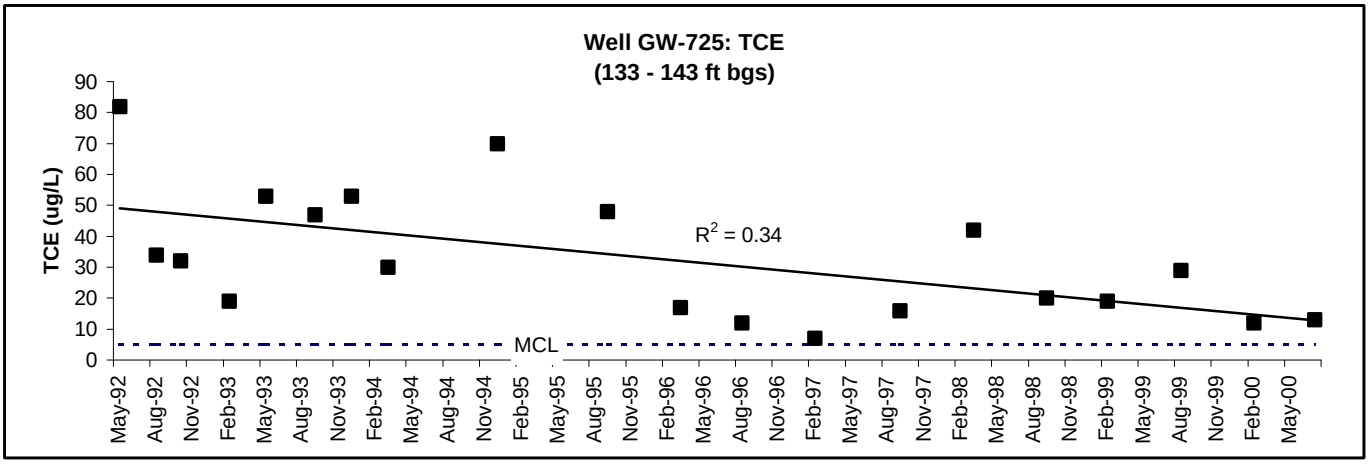


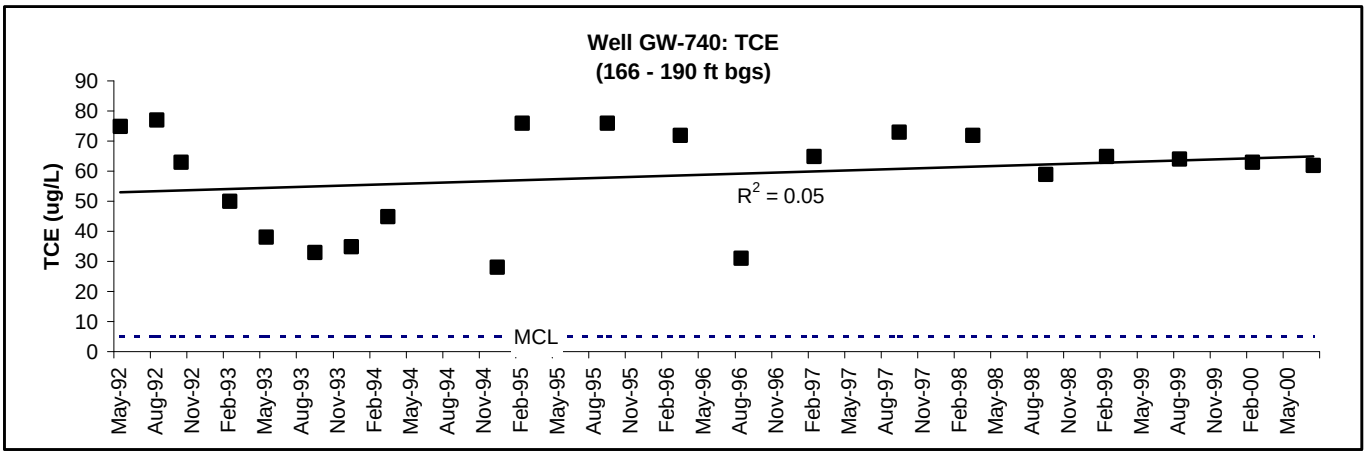


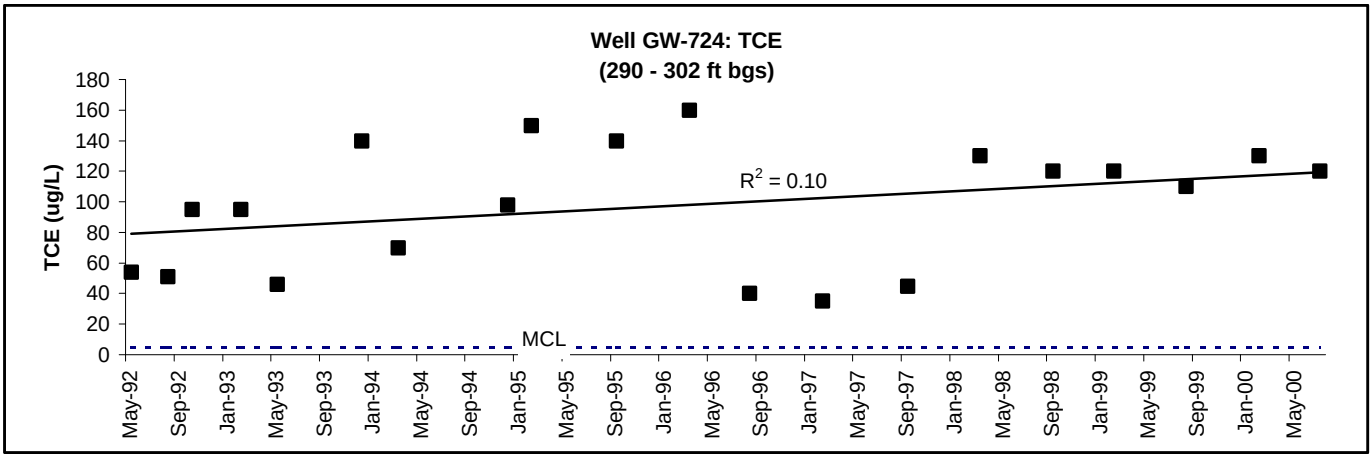
BC00DER 09/06/01

Fig. A.10. Uranium concentration trends in aquifer wells GW-683, GW-684, and GW-706.



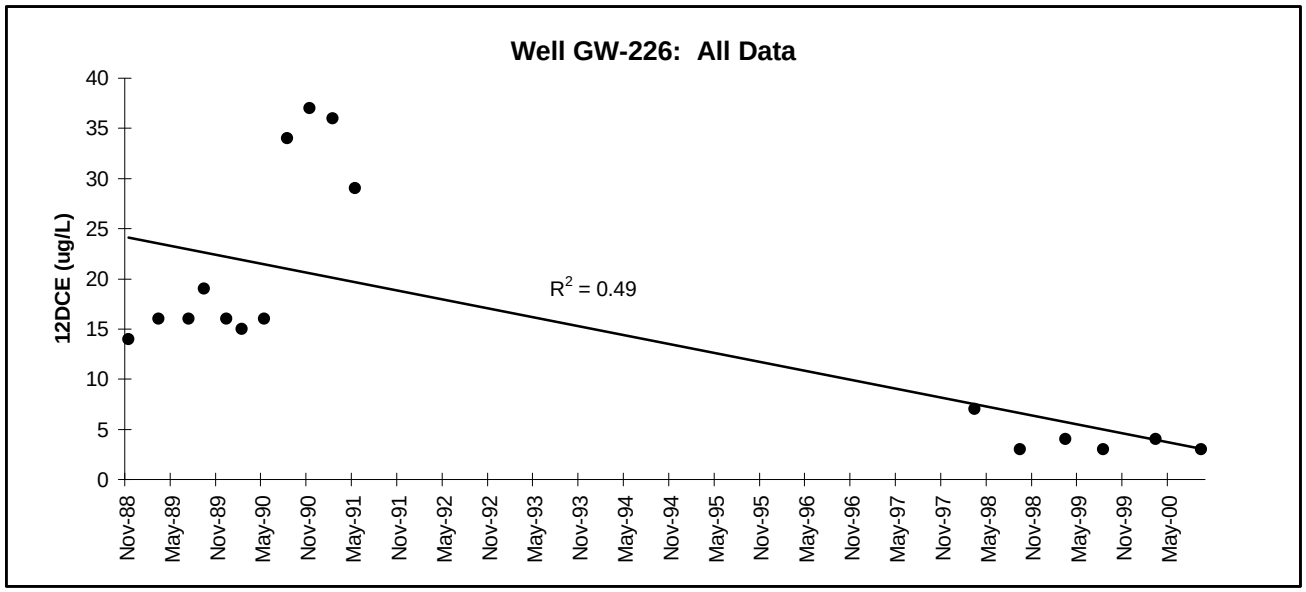


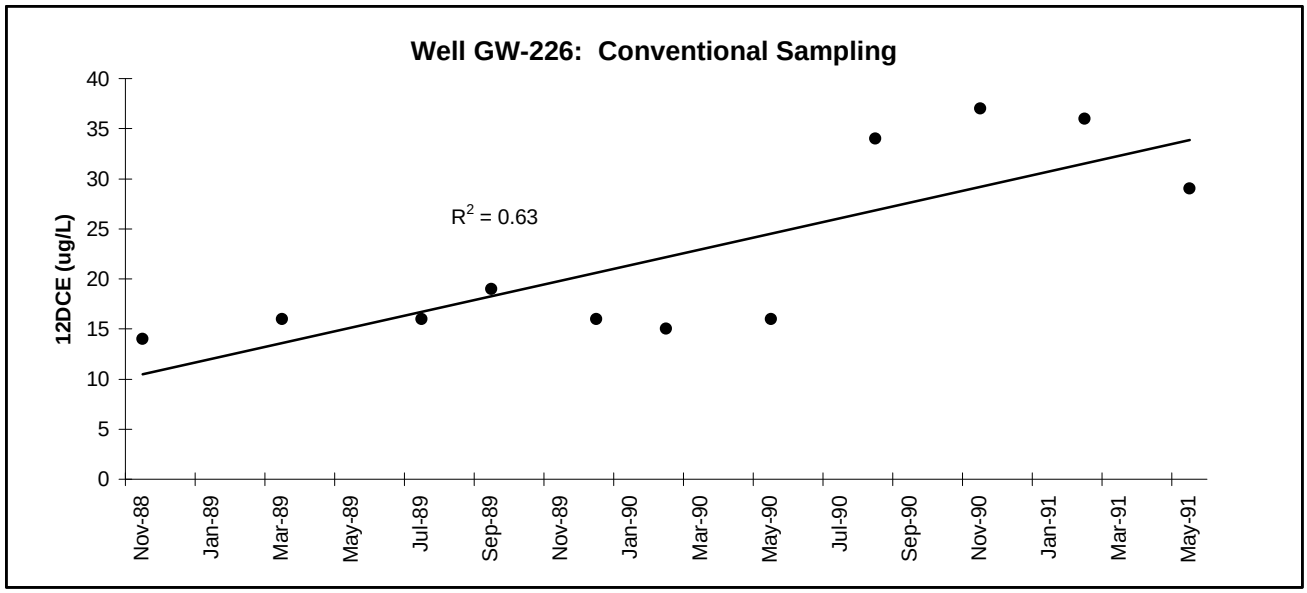


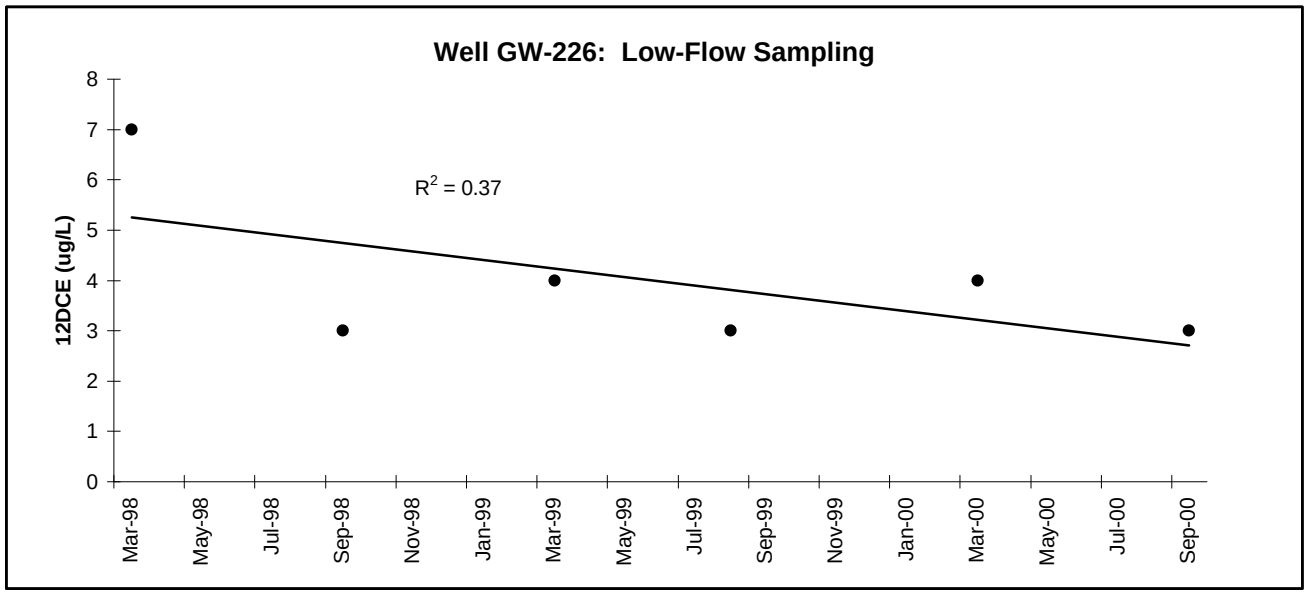


BC00DER 09/06/01

Fig. A.11. TCE concentration trends in aquifer wells GW-724, GW-725, GW-738, and GW-740.

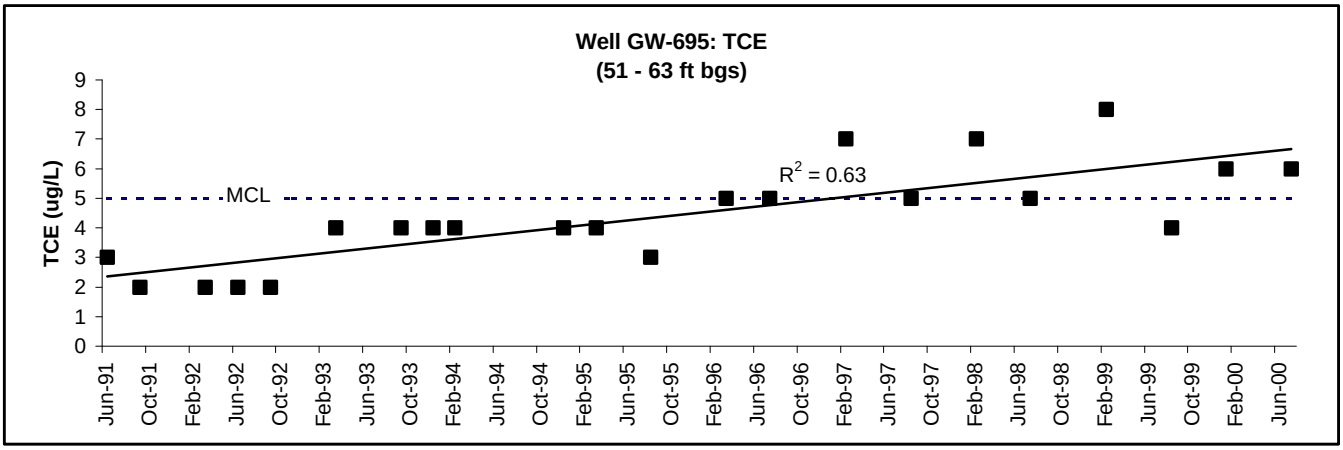


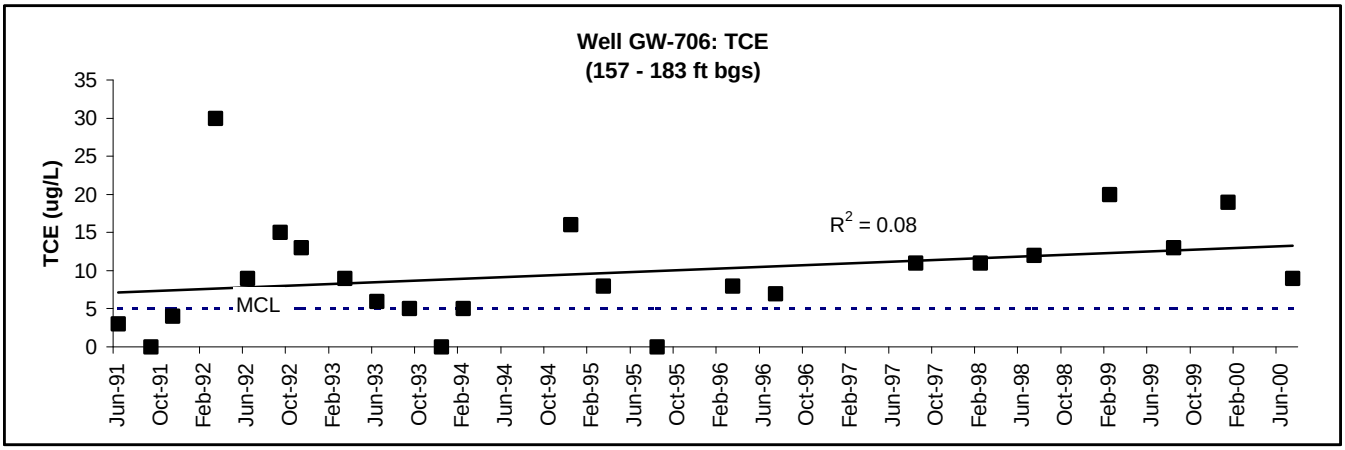


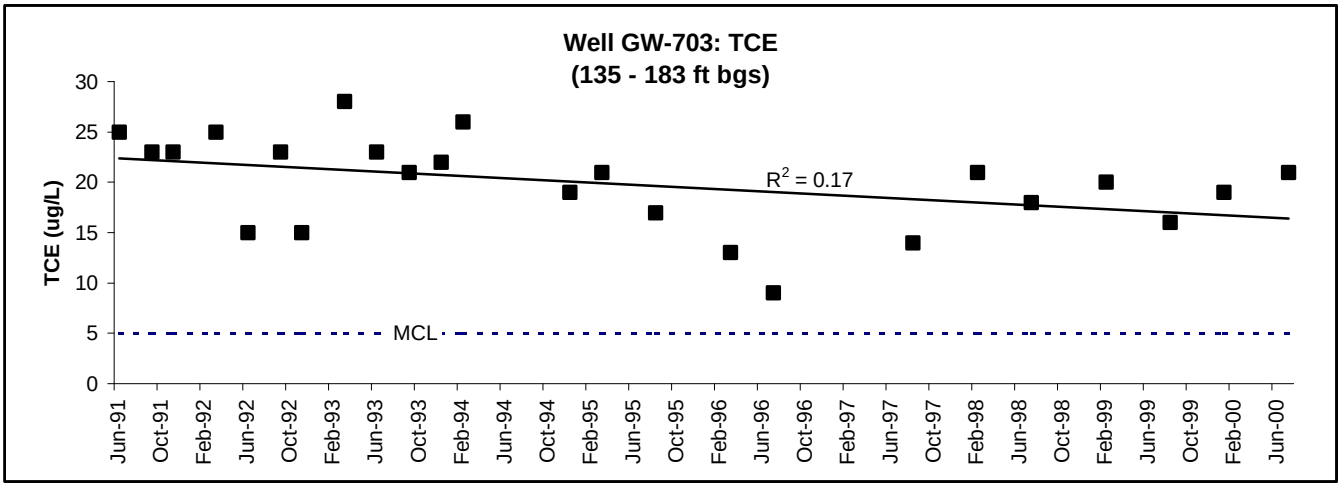


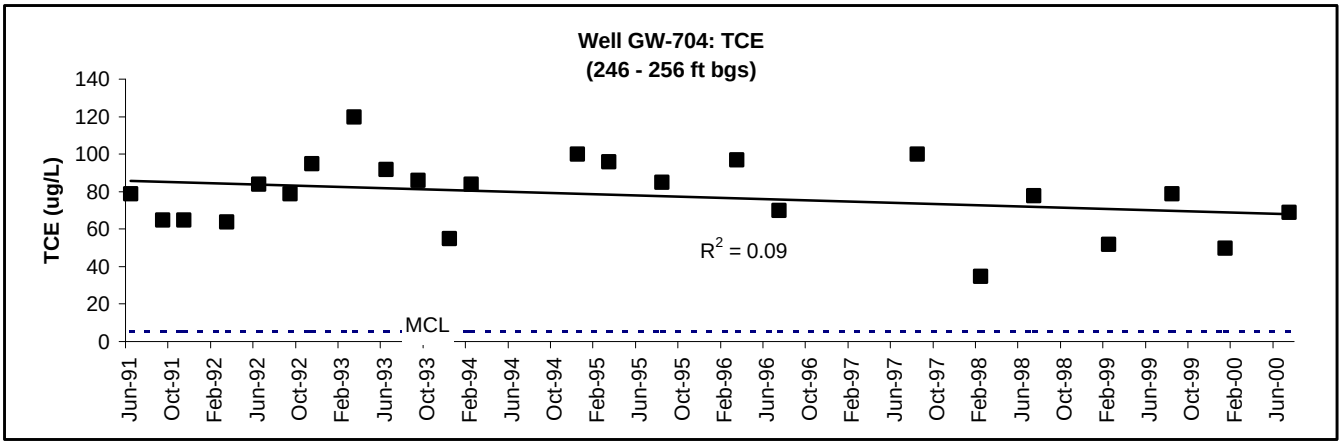
BC00DER 09/06/01

Fig. A.12. Total 12DCE concentration trends in aquifer well GW-226.



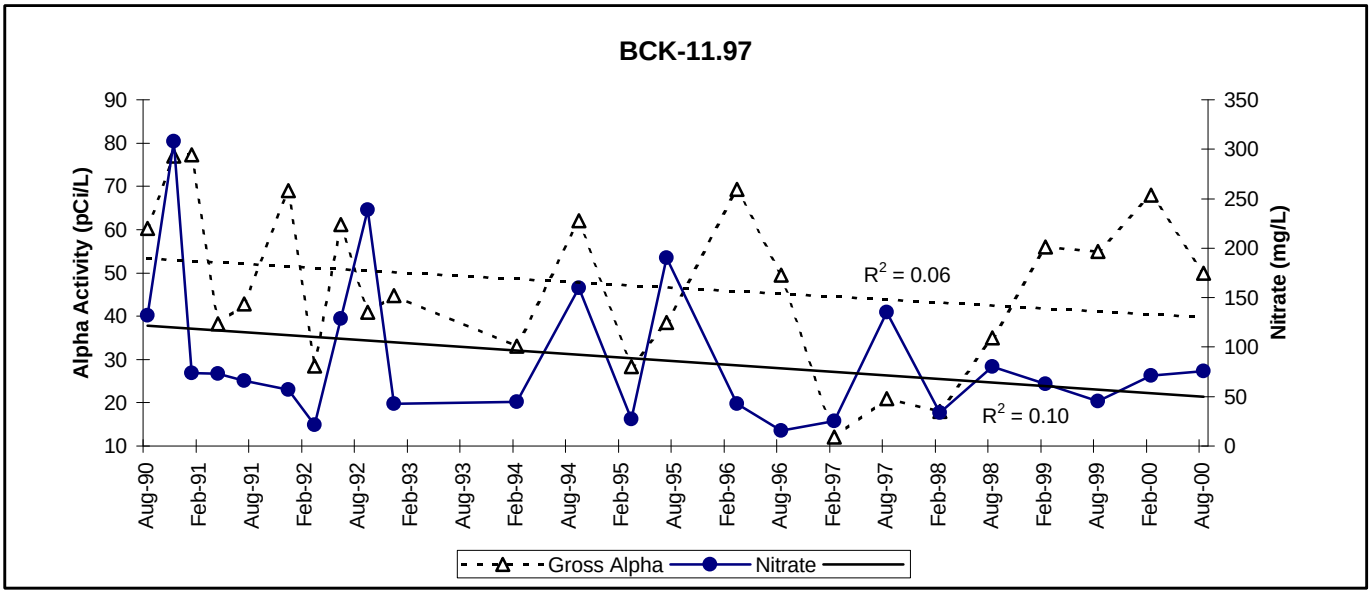


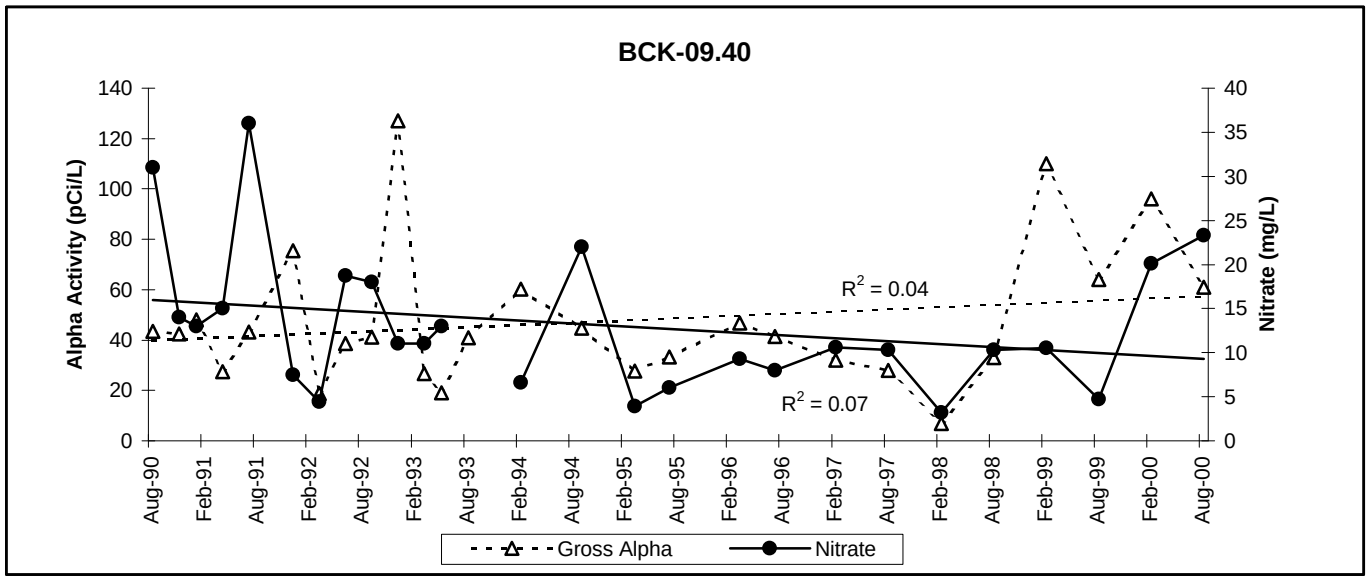


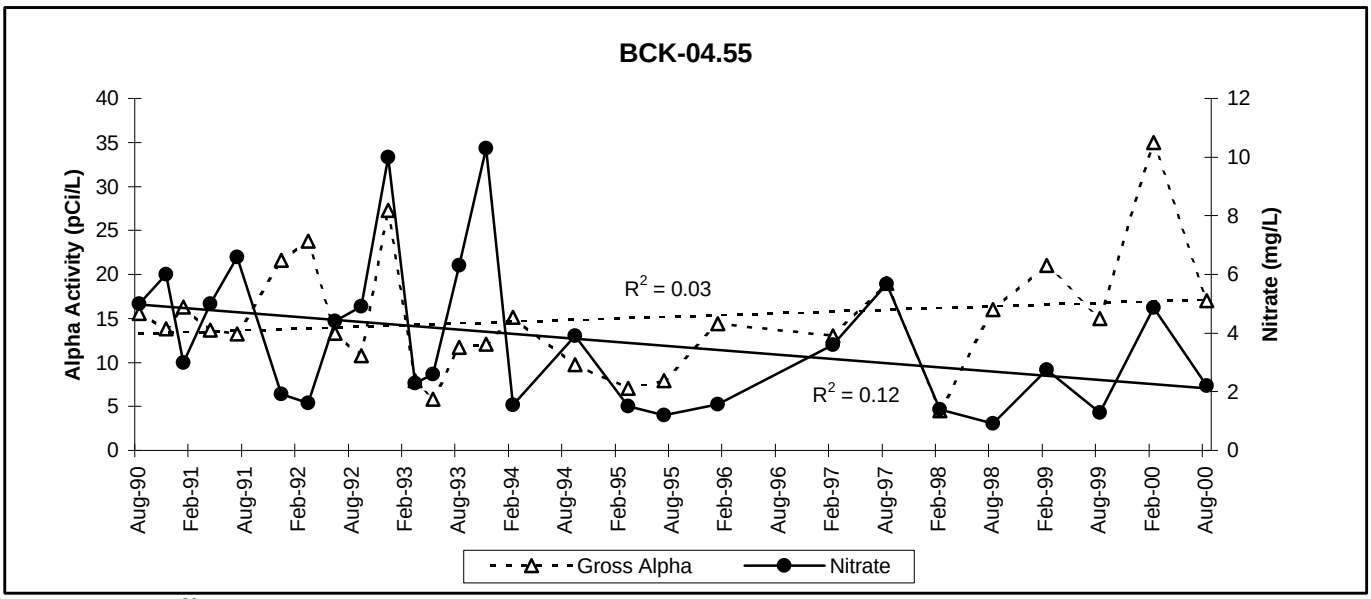


BC00DER 09/06/01

Fig. A.13. TCE concentration trends in aquifer wells GW-695, GW-703, GW-704, and GW-706.



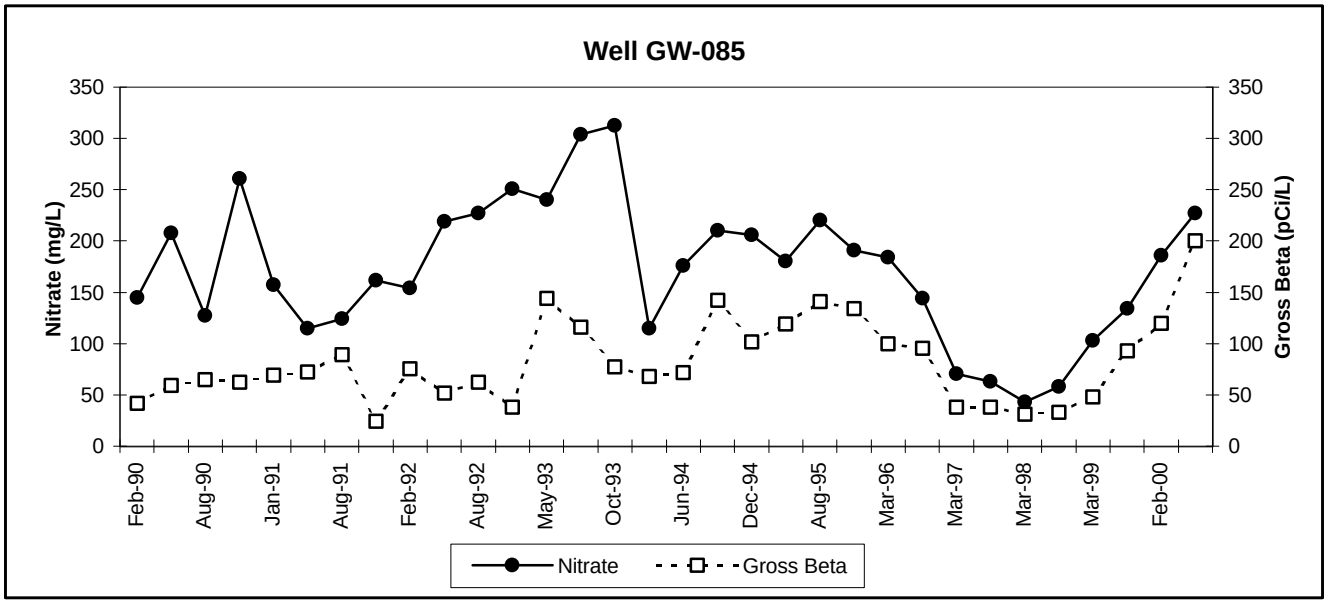


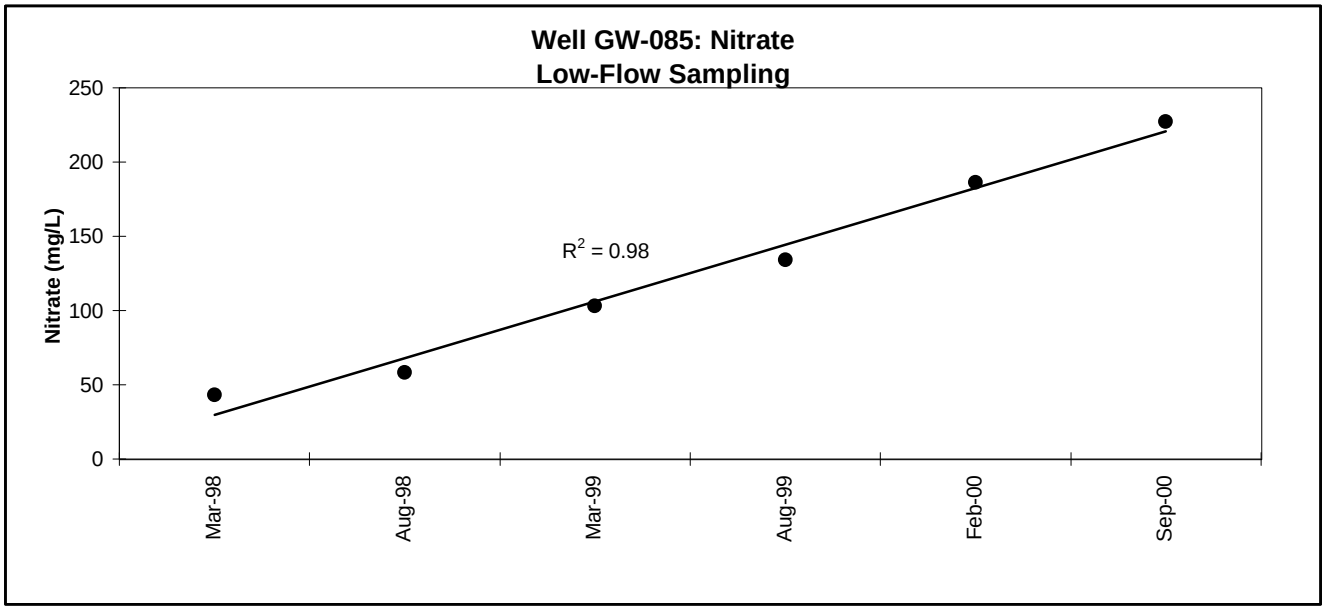


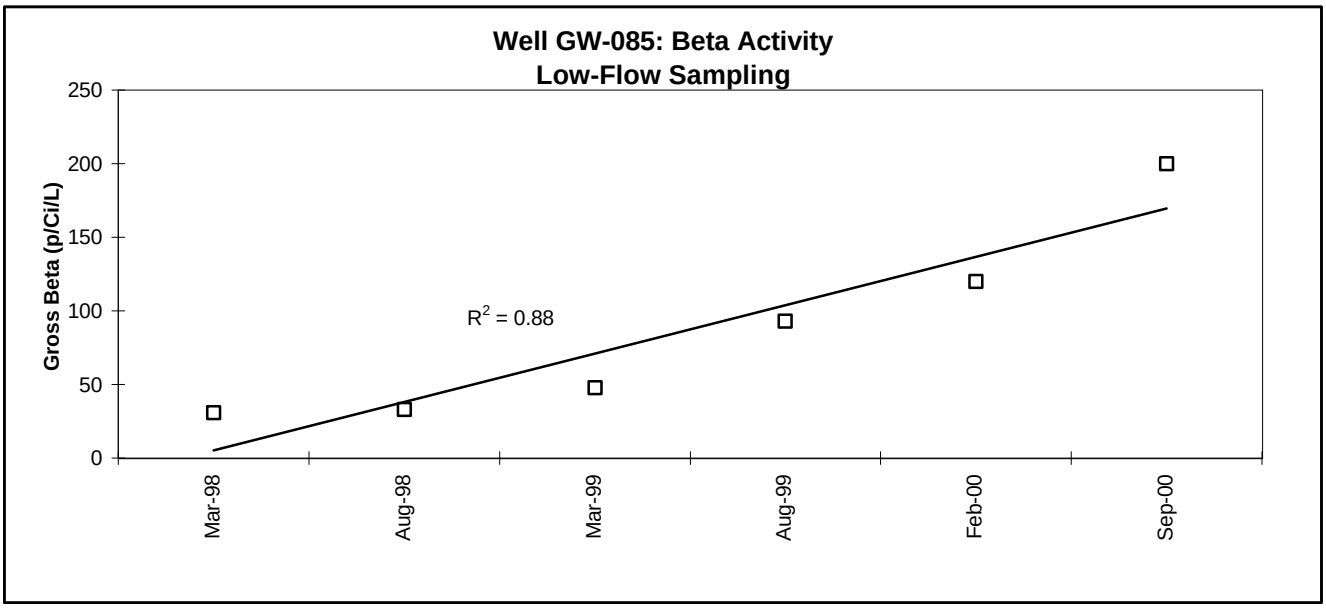
Notes: Nondected and anomalously high results are not plotted.
Gross Alpha MCL = 15 pCi/L; Nitrate MCL = 10 mg/L.

BC00DER 09/06/01

Fig. A.14. Nitrate and gross alpha concentration trends in Bear Creek.

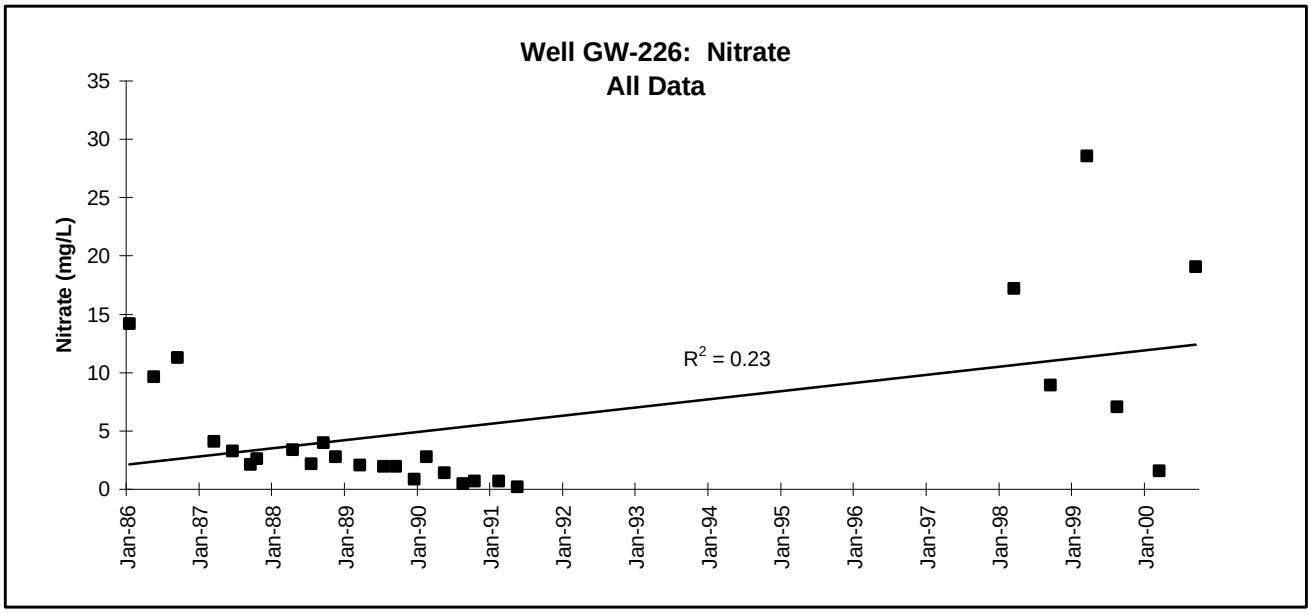


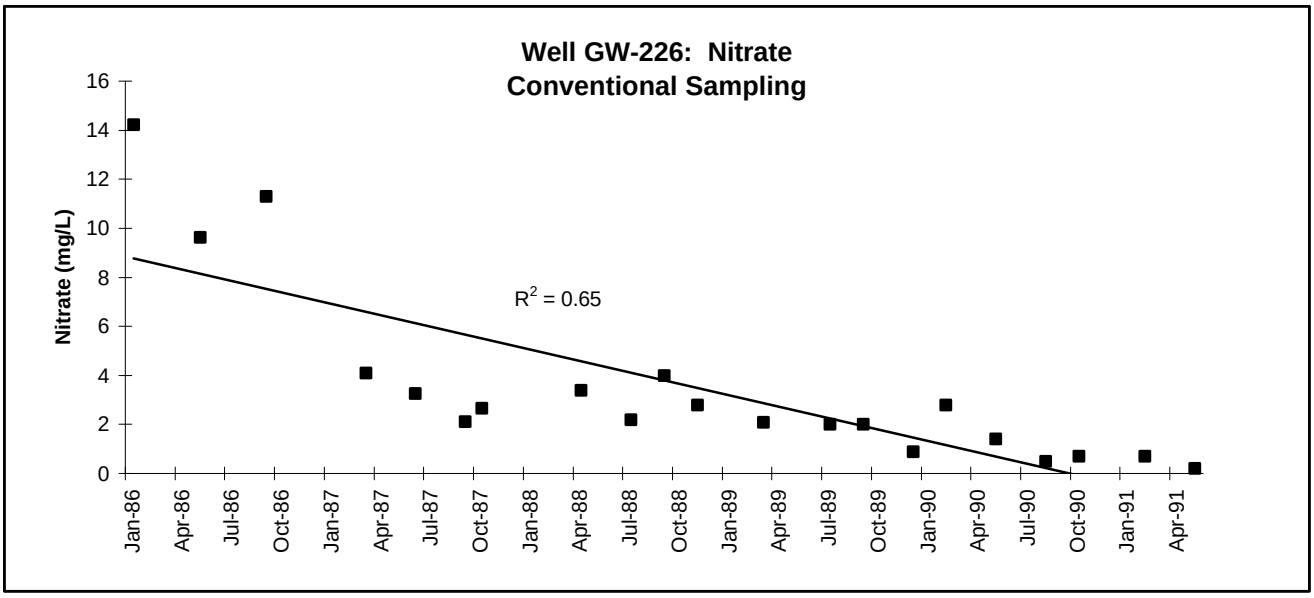


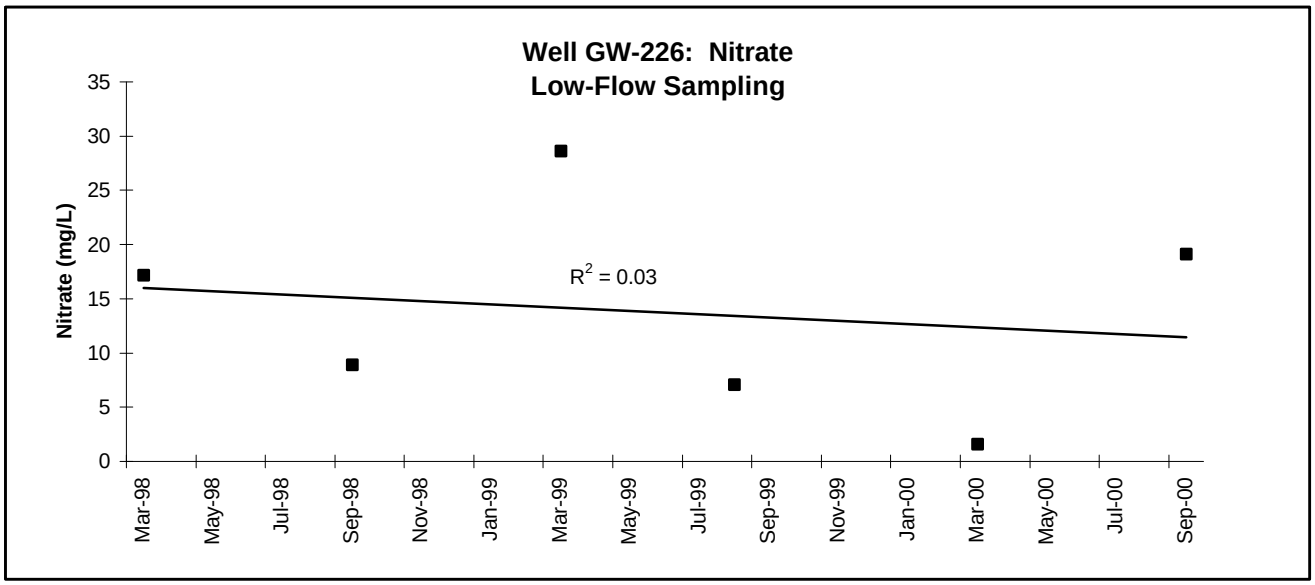


BC00DER 09/06/01

Fig. A.15. Nitrate and gross beta concentration trends in aquitard well GW-085.

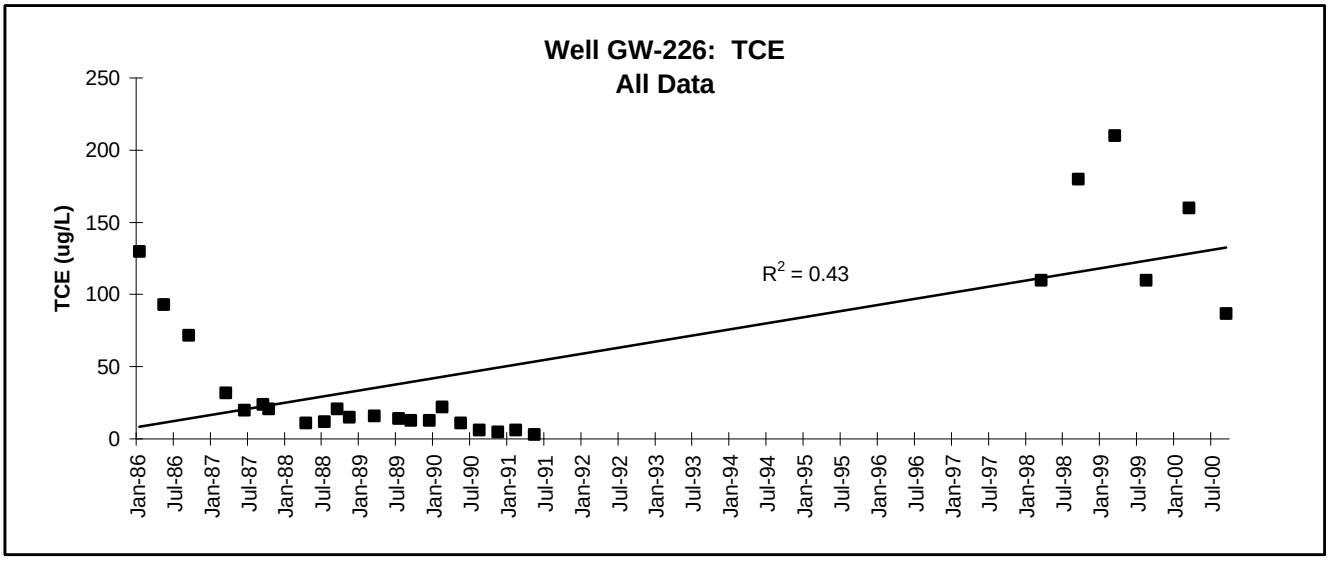


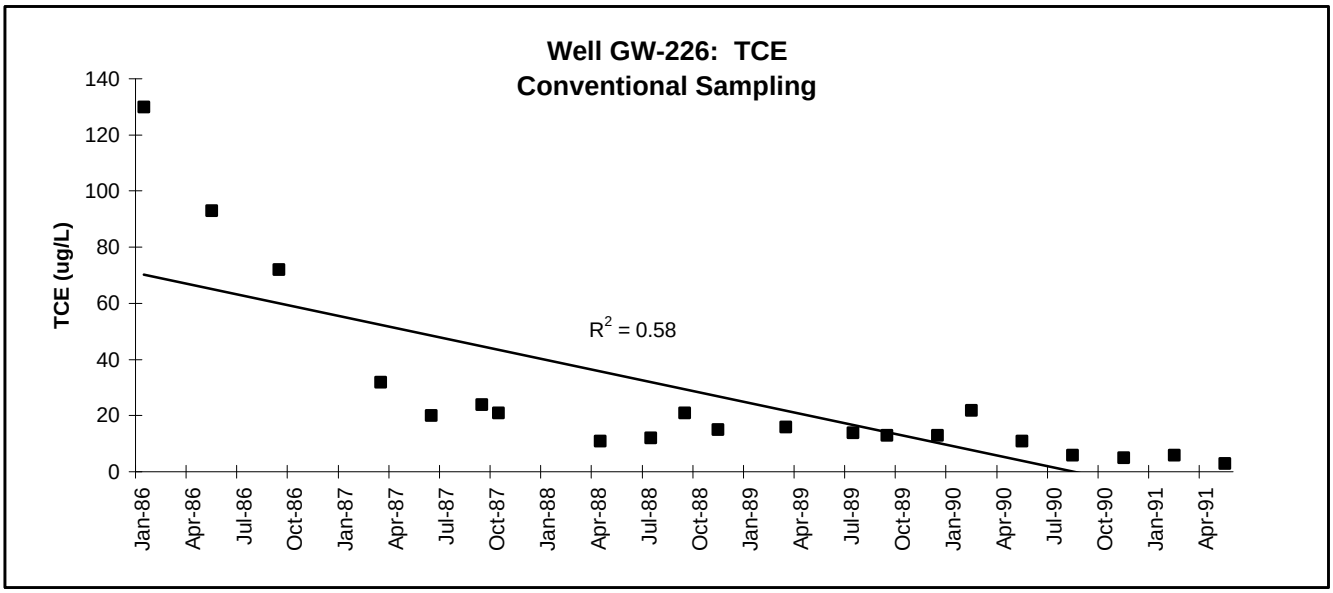


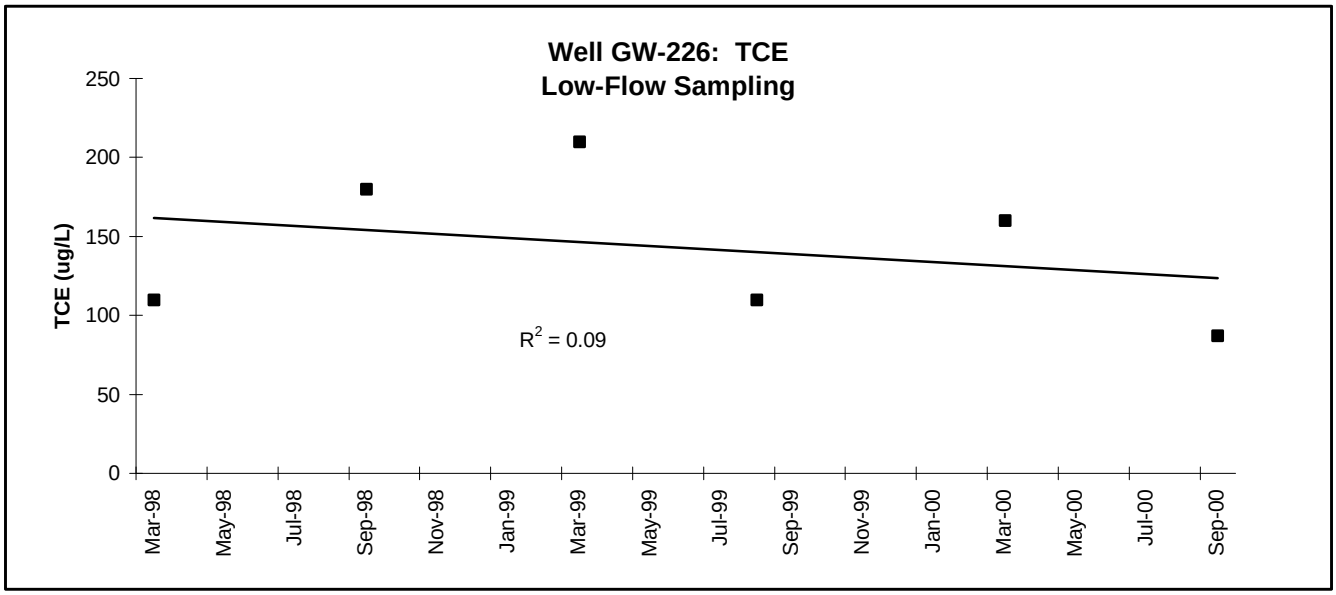


BC00DER 09/06/01

Fig. A.16. Nitrate concentration trends in aquifer well GW-226.

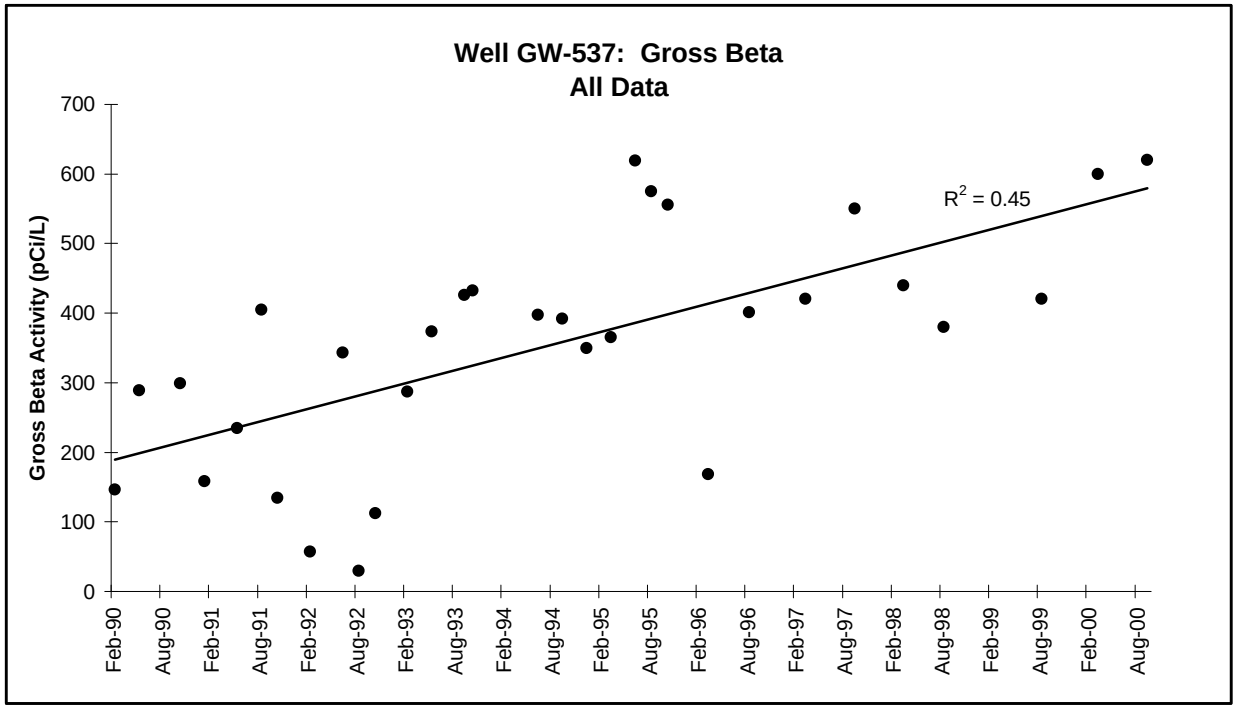


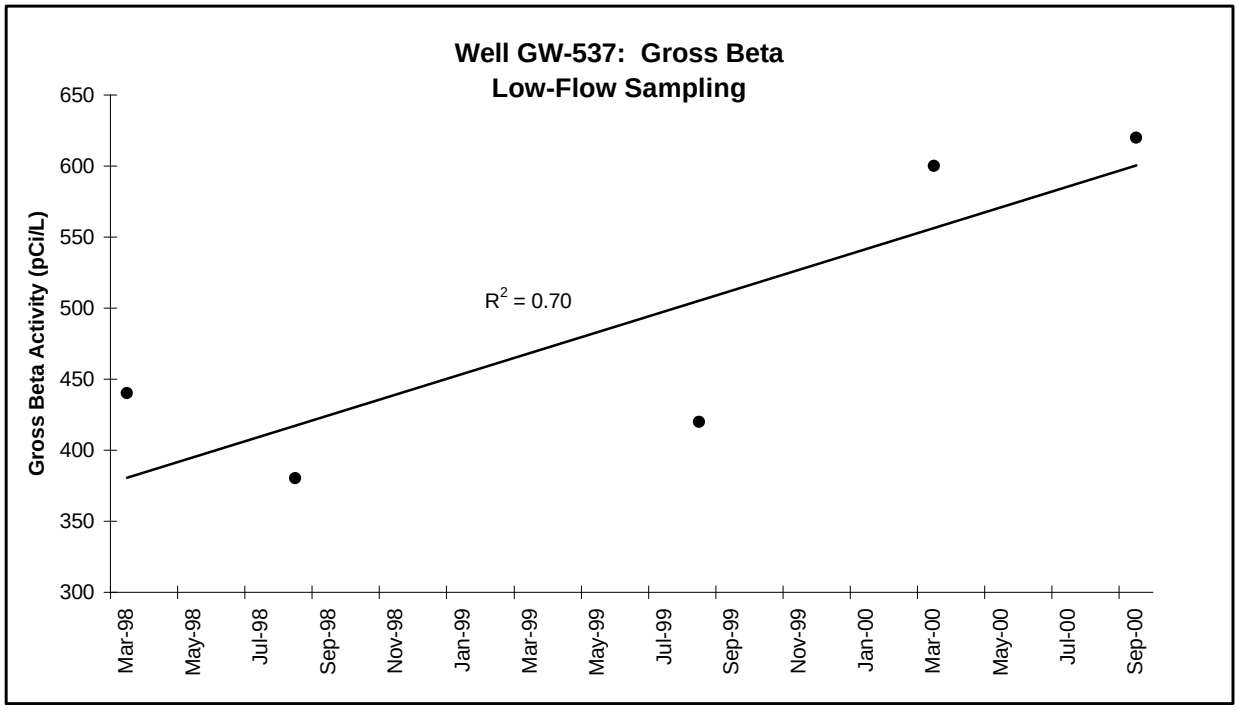




BC00DER 09/06/01

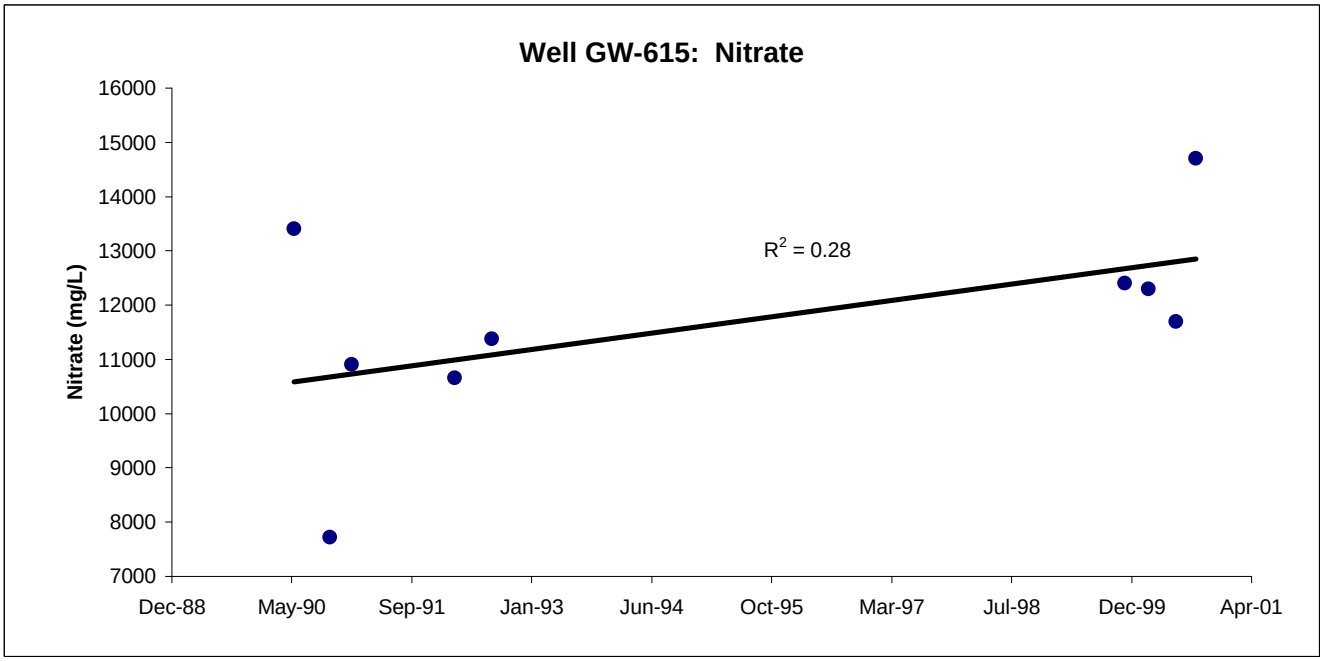
Fig. A.17. TCE concentration trends in aquifer well GW-226.

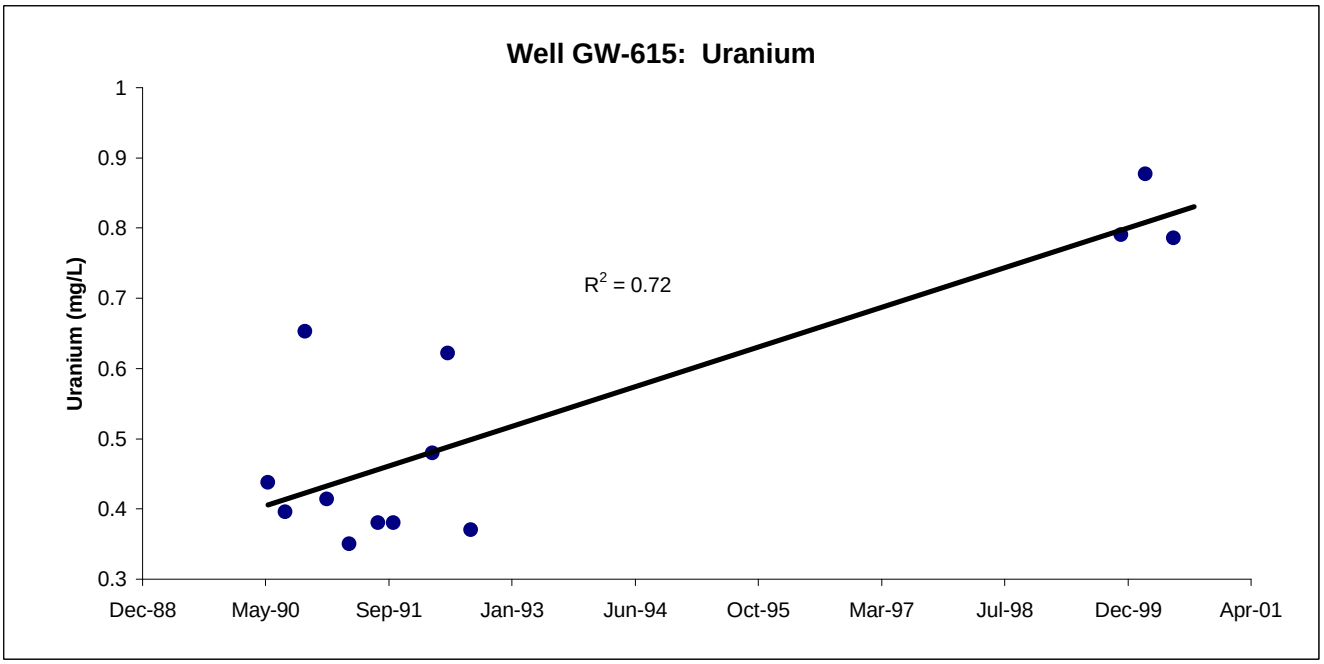




BC00DER 09/06/01

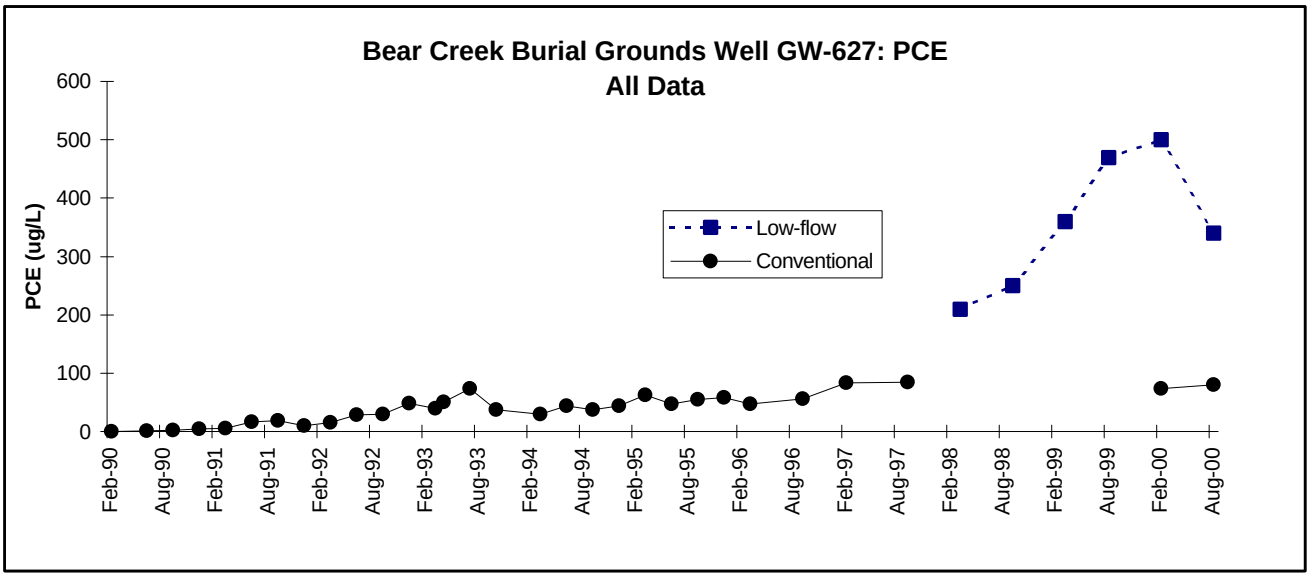
Fig. A.18. Gross beta concentration trends in aquitard well GW-537.

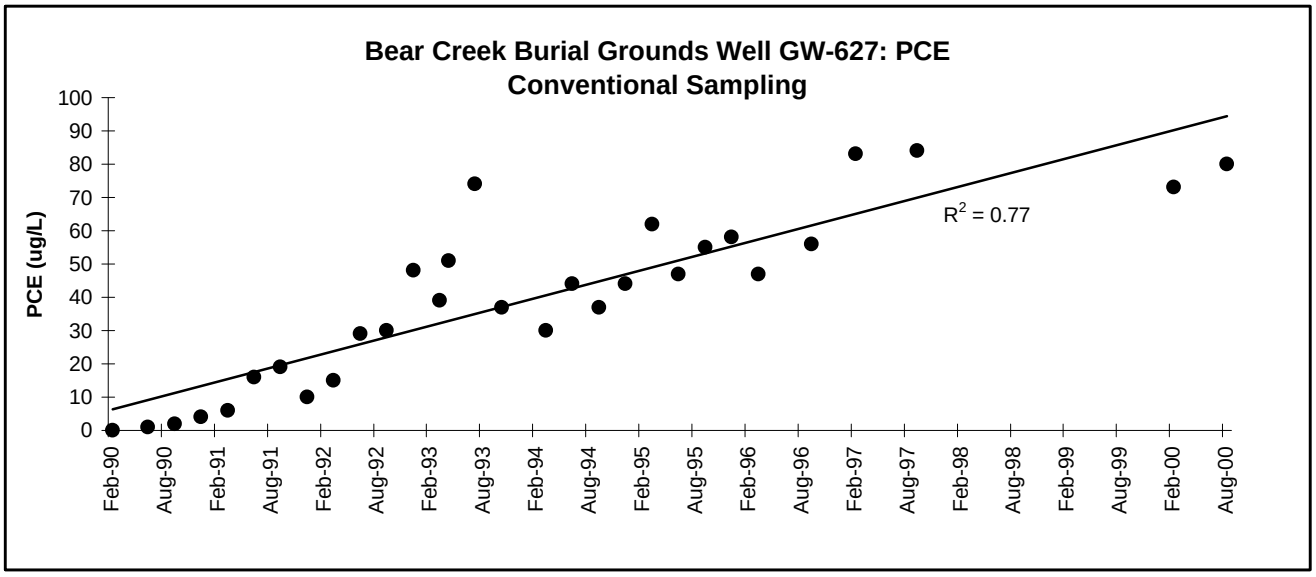


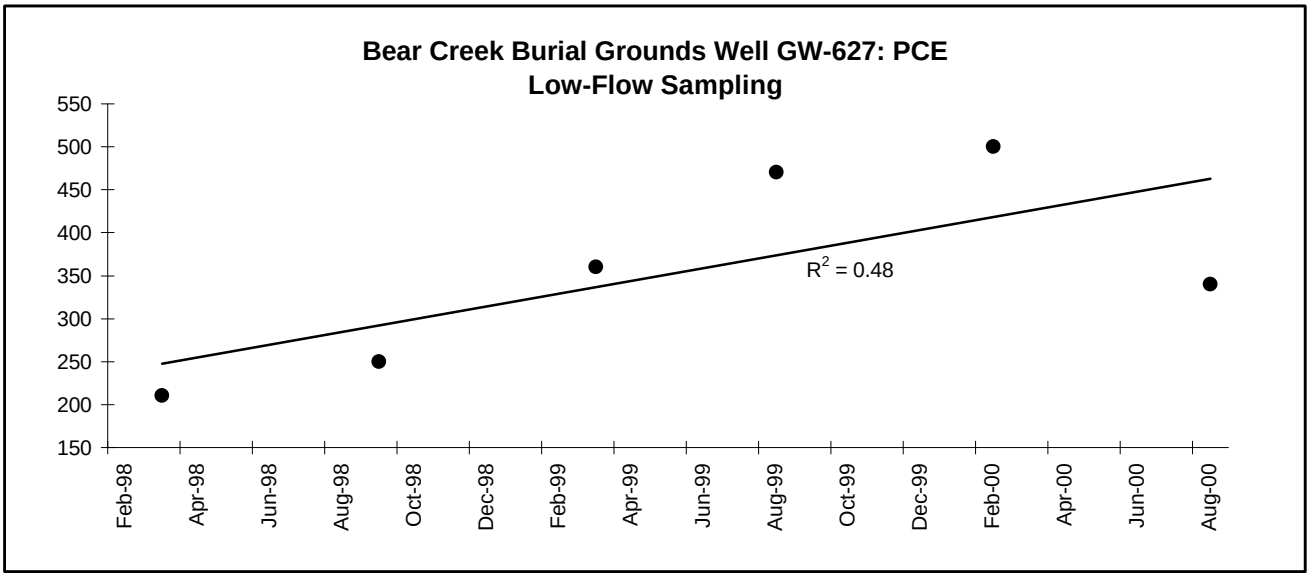


BC00DER 09/06/01

Fig. A.19. Nitrate and uranium concentration trends in aquitard well GW-615.

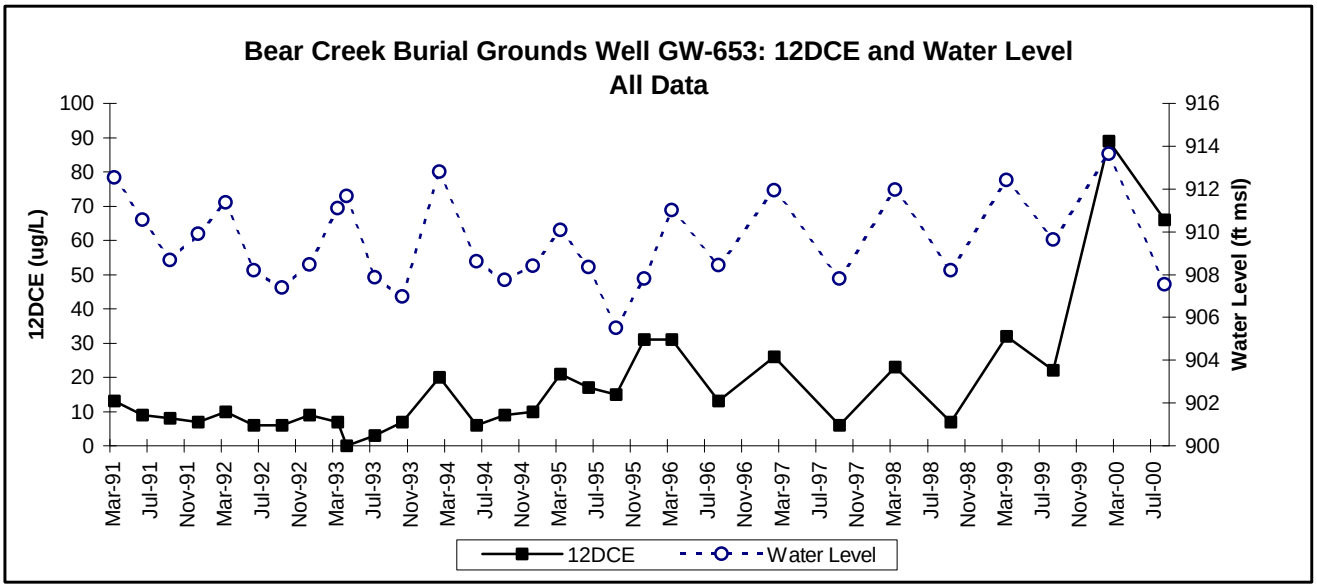


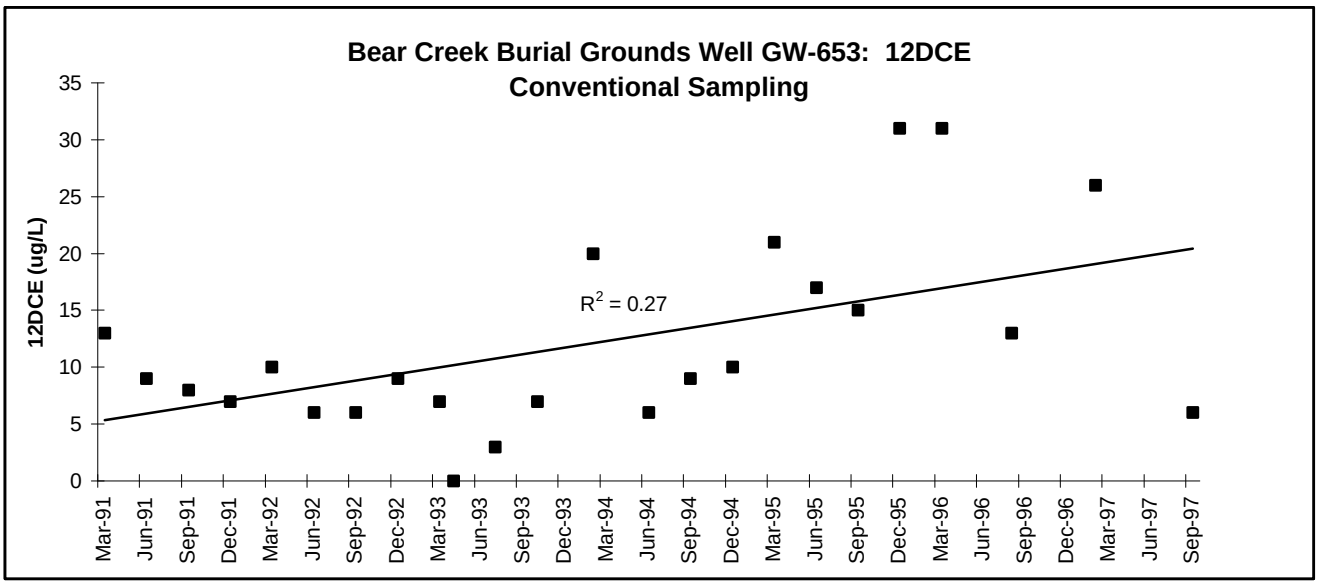


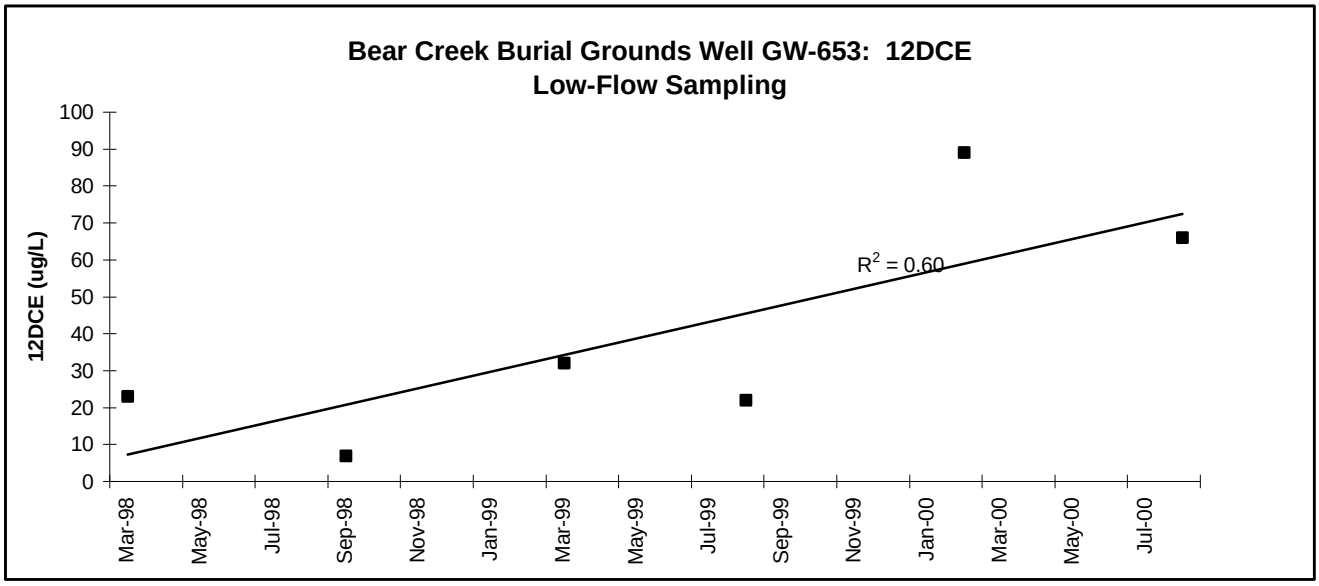


BC00DER 09/06/01

Fig. A.20. PCE concentration trends in aquitard well GW-627.

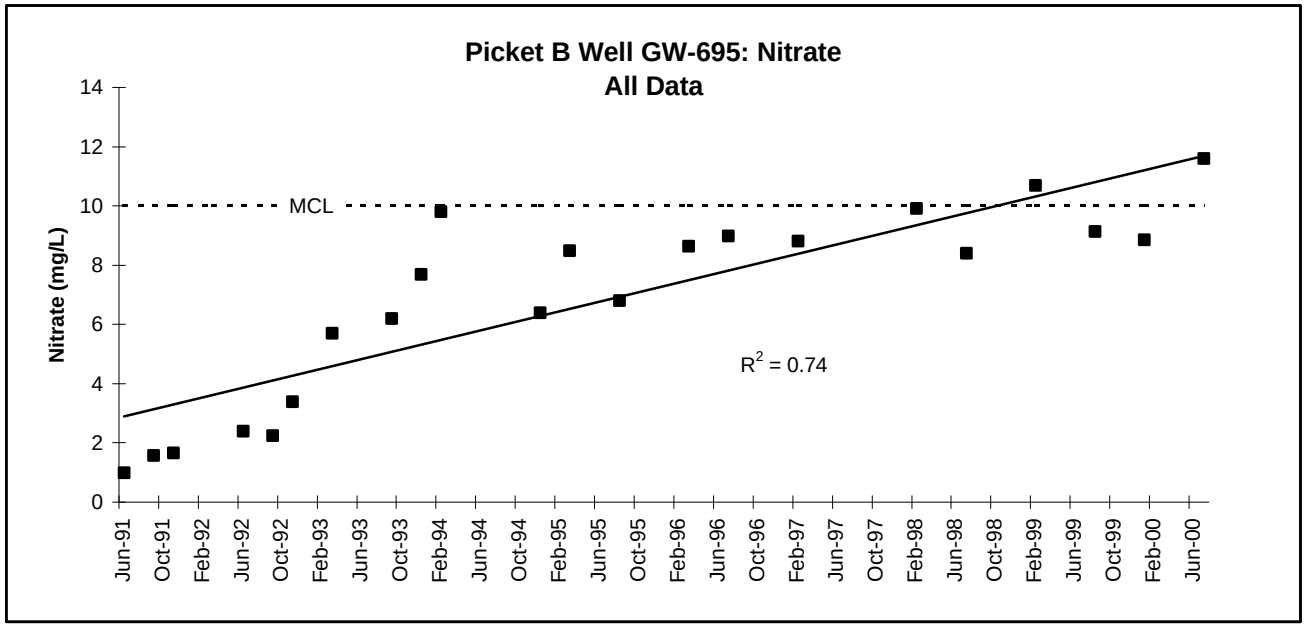


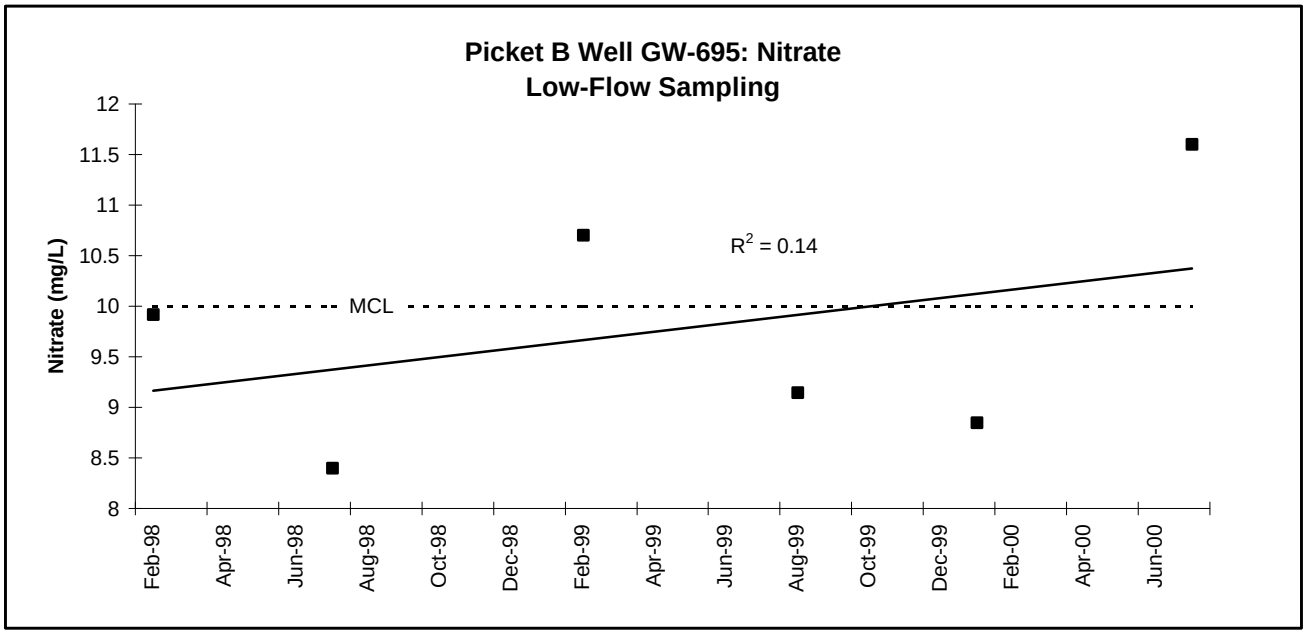




BC00DER 09/06/01

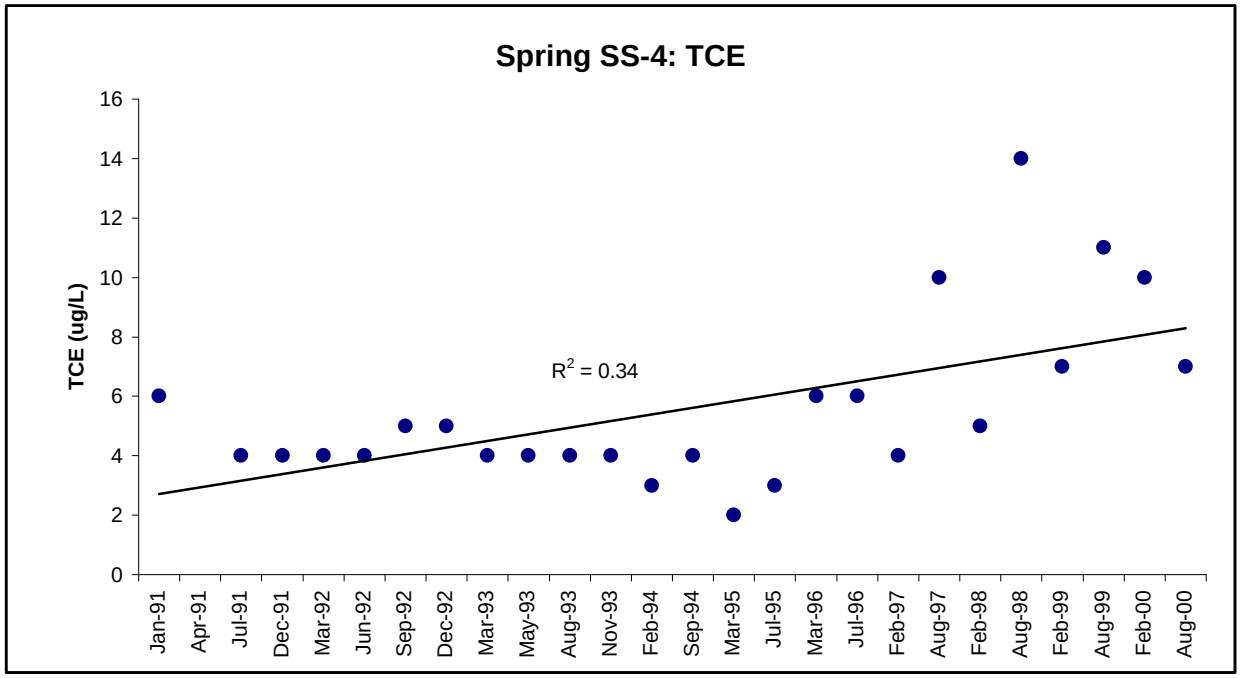
Fig. A.21. Total 12DCE concentration trends in aquitard well GW-653.

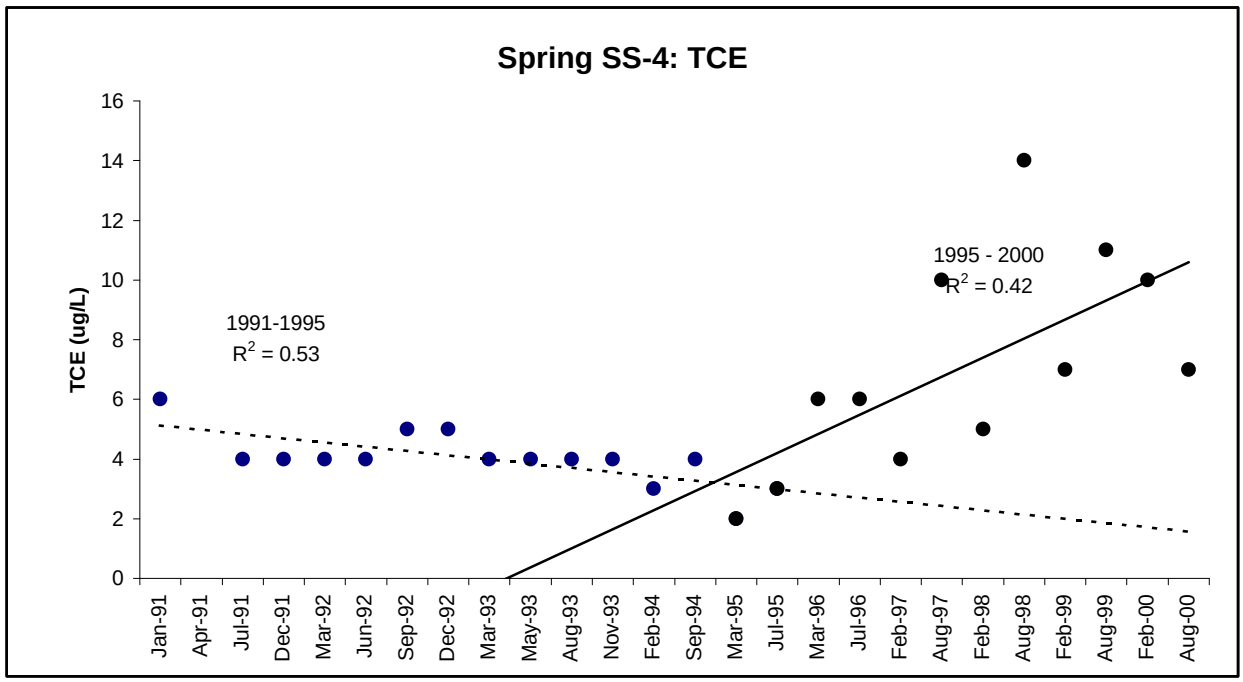




BC00DER 09/06/01

Fig. A.22. Nitrate concentration trends in aquifer well GW-695.





BC00DER 09/06/01

Fig. A.23. TCE concentration trends in spring SS-4.

APPENDIX B

TABLES

Table B.1. CY 2000 groundwater and surface water sampling locations and dates

Evaluation Purpose [1]		DOE Order 5400.1 Exit Pathway/Perimeter Monitoring DOE Order 5400.1 Surveillance Monitoring					
Sampling Point [2]	Sampling Location [3]	CY 2000 Sampling Date [4]					
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
BCK-00.63	EXP-SW	02/09/00	.	08/01/00	.		!
BCK-04.55	EXP-SW	02/09/00	.	08/01/00	.		!
BCK-07.87	EXP-SW	02/09/00	.	08/03/00	.		!
BCK-07.87	EXP-SW	02/09/00	.	08/01/00	.		!
BCK-09.40	EXP-SW	02/10/00	.	08/02/00	.		!
BCK-09.47	EXP-SW	01/25/00	.	08/16/00	.		!
BCK-10.60	EXP-SW	DRY	.	DRY	.		!
BCK-11.97	EXP-SW	02/10/00	.	08/02/00	.		!
GW-006	EMWMF	**02/08/00 D**	**04/12/00 D**	**08/02/00 D**		!	
GW-008	OLF	01/10/00	.	07/12/00	.	!	
GW-043	EMWMF	02/09/00	04/13/00	08/03/00		!	
GW-044	EMWMF	02/09/00	04/13/00	08/03/00		!	
GW-046	BG	01/11/00	.	07/13/00*	.	!	
GW-053	BG	02/21/00	.	08/22/00	.	!	
GW-056	EXP-A	**01/12/00 D**	.	07/11/00	.	!	
GW-077	BG	02/17/00	.	08/15/00	.	!	
GW-078	BG	02/17/00	.	08/15/00	.	!	
GW-079	BG	02/22/00	.	08/15/00	.	B	
GW-079	BG	02/22/00	.	08/16/00	.	!	
GW-080	BG	02/21/00	.	08/14/00	.	B	
GW-080	BG	**02/21/00 D**	.	**08/16/00 D**	.	!	
GW-085	OLF	02/29/00	.	09/08/00	.	!	
GW-115	S3	02/15/00	.	.	.	B	
GW-115	S3	01/04/00	.	07/12/00	.	!	
GW-226	OLF	03/01/00	.	09/11/00	.	!	
GW-276	S3	01/04/00	.	07/12/00	.	!	
GW-287	BG	**02/17/00 D**	.	08/21/00	.	!	
GW-311	RS	02/28/00	.	09/06/00	.	!	
GW-315	SPI	02/28/00	.	09/05/00	.	!	
GW-526	S3	02/22/00	.	08/16/00	.	!	
GW-537	OLF	03/01/00	.	**09/11/00 D**	.	!	
GW-615	S3	02/15/00	06/08/00	08/30/00	.	!	
GW-621	EXP-B	01/19/00	.	07/13/00	.	!	

Table B.1 (continued)

Evaluation Purpose [1]		DOE Order 5400.1 Exit Pathway/Perimeter Monitoring DOE Order 5400.1 Surveillance Monitoring					
Sampling Point [2]	Sampling Location [3]	CY 2000 Sampling Date [4]					
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
GW-627	BG	02/21/00	.	08/22/00	.	!	
GW-627	BG	02/23/00 **C**	.	08/23/00 **C**	.	!	
GW-653	BG	02/17/00	.	08/21/00	.	!	
GW-683	EXP-A	01/18/00	.	07/12/00	.	!	
GW-684	EXP-A	01/13/00	.	07/12/00	.	!	
GW-685	EXP-A	01/13/00	.	07/11/00	.	!	
GW-695	EXP-B	01/24/00	.	07/13/00	.	!	
GW-703	EXP-B	01/24/00	.	07/24/00	.	!	
GW-704	EXP-B	01/25/00	.	07/24/00	.	!	
GW-706	EXP-B	01/31/00	.	07/25/00	.	!	
GW-706	EXP-B	02/01/00 **C**	.	07/26/00 **C**	.	!	
GW-712	EXP-W	01/10/00	.	07/10/00	.		!
GW-713	EXP-W	01/06/00	.	07/10/00	.		!
GW-714	EXP-W	02/16/00	.	08/14/00	.	B	
GW-714	EXP-W	01/05/00	.	07/11/00	.		!
GW-715	EXP-W	02/16/00	.	08/14/00	.	B	
GW-715	EXP-W	**01/5/00 D**	.	**07/11/00 D**	.		!
GW-724	EXP-C	02/03/00	.	**07/31/00 D**	.	!	
GW-725	EXP-C	02/07/00	.	08/08/00	.	!	
GW-725	EXP-C	02/08/00 **C**	.	08/09/00 **C**	.	!	
GW-727-02	BG	.	05/02/00	.	.	!	
GW-727-05	BG	.	05/03/00	.	.	!	
GW-727-08	BG	.	05/30/00	.	.	!	
GW-727-13	BG	.	06/01/00	.	.	!	
GW-727-15	BG	.	06/01/00	.	.	!	
GW-727-18	BG	.	**06/05/00 D**	.	.	!	
GW-727-22	BG	.	06/02/00	.	.	!	
GW-727-25	BG	.	06/06/00	.	.	!	
GW-727-27	BG	.	06/07/00	.	.	!	
GW-727-30	BG	.	06/07/00	.	.	!	
GW-729-02	BG	.	.	07/10/00	.	!	
GW-729-06	BG	.	.	07/11/00	.	!	

Table B.1 (continued)

Evaluation Purpose [1]		DOE Order 5400.1 Exit Pathway/Perimeter Monitoring DOE Order 5400.1 Surveillance Monitoring					
Sampling Point [2]	Sampling Location [3]	CY 2000 Sampling Date [4]					
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
GW-729-15	BG	.	.	07/11/00	.	!	
GW-729-18	BG	.	.	07/12/00	.	!	
GW-729-22	BG	.	.	07/12/00	.	!	
GW-729-26	BG	.	.	07/13/00**	.	!	
GW-729-30	BG	.	.	07/17/00	.	!	
GW-729-34	BG	.	.	07/17/00	.	!	
GW-729-39	BG	.	.	07/18/00	.	!	
GW-729-44	BG	.	.	**07/18/00 D**	.	!	
GW-730-02	BG	.	.	08/15/00	.	!	
GW-730-11	BG	.	.	08/16/00	.	!	
GW-730-18	BG	.	.	08/17/00	.	!	
GW-730-21	BG	.	.	08/17/00	.	!	
GW-730-25	BG	.	.	08/21/00	.	!	
GW-730-28	BG	.	.	08/21/00	.	!	
GW-730-30	BG	.	.	**08/22/00 D**	.	!	
GW-730-35	BG	.	.	08/22/00	.	!	
GW-738	EXP-C	02/03/00	.	07/31/00	.	!	
GW-740	EXP-C	02/02/00	.	07/27/00	.	!	
GW-790-02	BG	.	06/08/00	.	.	!	
GW-790-05	BG	.	06/12/00	.	.	!	
GW-790-07	BG	.	06/13/00	.	.	!	
GW-790-14	BG	.	**06/14/00 D**	.	.	!	
GW-790-19	BG	.	06/15/00	.	.	!	
GW-790-23	BG	.	06/15/00	.	.	!	
GW-790-29	BG	.	06/19/00	.	.	!	
GW-790-32	BG	.	06/19/00	.	.	!	
GW-790-35	BG	.	06/19/00	.	.	!	
GW-790-39	BG	.	06/19/00	.	.	!	
GW-829	OLF	02/29/00	.	09/08/00	.	!	
GW-835	S3	02/15/00	06/16/00	08/29/00	11/14/00	!	
GW-838	EMWMF	02/14/00	04/12/00	08/07/00	.	!	
GW-840	EMWMF	02/10/00	04/11/00	08/07/00	.	!	
GW-904	EMWMF	02/08/00	04/10/00	08/02/00	.	!	
GW-905	EMWMF	02/14/00	04/12/00	08/07/00	.	!	

Table B.1 (continued)

Evaluation Purpose [1]		DOE Order 5400.1 Exit Pathway/Perimeter Monitoring DOE Order 5400.1 Surveillance Monitoring					
Sampling Point [2]	Sampling Location [3]	CY 2000 Sampling Date [4]					
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
NT-01	EXP-SW	02/10/00	.	08/02/00	.		!
NT-07	EXP-SW	01/25/00	.	08/17/00	.		!
NT-08	EXP-SW	01/25/00	.	08/17/00	.		!
SS-1	EXP-SW	02/10/00	.	08/02/00	.		!
SS-4	EXP-SW	02/09/00	.	08/01/00	.		!
SS-4	EXP-SW	**02/09/00 D**	.	**08/03/00 D**	.		!
SS-5	EXP-SW	02/09/00	.	08/01/00	.		!
SS-5	EXP-SW	02/09/00	.	08/03/00	.		!
SS-6	EXP-SW	**02/09/00 D**	.	08/01/00	.		!
SS-6	EXP-SW	02/09/00	.	08/03/00	.		!
SS-6.6	EXP-SW	**01/25/00 D**	.	**08/16/00 D**	.		!
SS-7	EXP-SW	01/25/00	.	08/16/00	.		!
SS-8	EXP-SW	01/25/00	.	08/16/00	.		!

Notes:

1 Although samples were collected from the sampling locations for a variety of monitoring purposes (e.g., RCRA), this report uses all of the monitoring results for DOE Order 5400.1 data evaluation purposes. The monitoring program for each location is provided in the CY 2000 GWMR (AJA Technical Services, Inc. 2001).

B - Sample collected for biological testing

2
BCK - Bear Creek Kilometer
GW - Groundwater Monitoring Well; Westbay wells are GW-727, GW-729, GW-730, and GW-790.
NT - Northern Tributary (to Bear Creek)
SS - Spring sampling location (south side of Bear Creek)

Table B.1 (continued)

Notes: (continued)

3	BG	-	Bear Creek Burial Grounds Waste Management Area
	EMWMF	-	Environmental Management Waste Management Facility
	EXP-A	-	Exit Pathway (Maynardville Limestone) Picket A
	EXP-B	-	Exit Pathway Picket B
	EXP-C	-	Exit Pathway Picket C
	EXP-W	-	Exit Pathway Picket W
	EXP-SW	-	Exit Pathway (Bear Creek) Surface Water
	OLF	-	Oil Landfarm Waste Management Area
	RS	-	Rust Spoil Area
	SPI	-	Spoil Area I
	S3	-	S-3 Site
4	**.**	-	Not sampled
	C	-	Sample collected using the conventional (three well volume purge) method
	D	-	Duplicate sample was collected (shown in bold typeface)
	*	-	re-sampled on July 19 for nitrate analysis (GW-046)
	**	-	re-sampled on August 14 for volatile organic analyses (GW-729-26)

Table B.2. Long-term concentration trends for the principal contaminants detected at CY 2000 monitoring locations

CY 2000 Sampling Location [1]	Unit [2]		Contaminant Type and Long-Term Trend [3]						
			Inorganics [4]		VOCs [5]			Radioactivity [6]	
	AQT	AQF	Nitrate	Uranium	Chloro-ethenes	Chloro-ethanes	Chloro-methanes	Gross Alpha	Gross Beta
BCK-00.63			.	"	.	.	.	"	.
BCK-04.55			.	"	.	.	.	"	.
BCK-07.87			"	"	.	.	.	"	"
BCK-09.40			"	–	"			"	–
BCK-09.47			"	"	"			"	"
BCK-11.97			–	–	.	.	.	–	–
GW-006	!		.	.	"	"	.	.	.
GW-008	!		.	.	"	"	.	.	.
GW-043	!		.	.	.	.	.	.	.
GW-044	!		.	.	.	.	.	.	.
GW-046	!		.	.	"	"	.	.	.
GW-053		!	.	.	"	"	.	.	.
GW-056		!	.	.	.	.	.	"	.
GW-077	!		.	.	.	.	.	.	.
GW-078	!		.	.	.	.	.	.	.
GW-079	!		.	.	.	.	.	.	.
GW-080	!		.	.	.	.	.	.	.
GW-085	!		"	.	.	.	.	.	[
GW-115	!		.	.	.	.	.	.	.
GW-226		!	[	.	[–	.	.	.	.
GW-276	!		–	–	–	.	.	–	"
GW-287	!		.	.	.	.	.	.	.
GW-311		!	.	.	–	.	.	"	.
GW-315		!	.	.	–	.	.	.	.
GW-526	!		"	.	.	.	.	"	.
GW-537	!		"	.	.	.	.	.	[
GW-615	!		[	[	.	.	.	.	.
GW-621		!	.	.	.	.	.	.	.
GW-627	!		.	.	[	[	.	.	.
GW-653	!		.	.	[	"	.	.	.
GW-683		!	.	–	.	.	.	"	.
GW-684		!	.	–	.	.	.	.	.
GW-685		!	.	.	.	.	.	.	.
GW-695		!	[	.	"	.	.	"	.
GW-703		!	"	.	"	.	.	"	.
GW-704		!	"	.	"	.	.	.	.
GW-706		!	"	"	"	.	.	"	"
GW-712		!	.	.	.	.	.	.	.
GW-713		!	.	.	.	.	.	.	.
GW-714		!	.	.	.	.	.	.	.
GW-715		!	.	.	.	.	.	.	.

Table B.2 (continued)

CY 2000 Sampling Location [1]	Unit [2]		Contaminant Type and Long-Term Trend [3]						
			Inorganics [4]		VOCs [5]			Radioactivity [6]	
	AQT	AQF	Nitrate	Uranium	Chloro-ethenes	Chloro-ethanes	Chloro-methanes	Gross Alpha	Gross Beta
GW-724		!	–	.	"	.	.	.	"
GW-725		!	–	.	–	.	.	.	.
GW-727-02	!		.	.	.	.	.	.	.
GW-727-05	!		.	.	.	.	.	.	.
GW-727-08	!		.	.	.	.	.	.	.
GW-727-13	!		.	.	.	.	.	.	.
GW-727-15	!		.	.	.	.	.	.	.
GW-727-18	!		.	.	.	.	.	.	.
GW-727-22	!		.	.	.	.	.	.	.
GW-727-25	!		.	.	.	.	.	.	.
GW-727-27	!		.	.	.	.	.	.	.
GW-727-30	!		.	.	.	.	.	.	.
GW-729-02	!		.	.	.	.	.	.	.
GW-729-06	!		.	.	.	.	.	.	.
GW-729-15	!		.	.	.	.	.	"	"
GW-729-18	!		.	.	.	.	.	.	.
GW-729-22	!		.	.	.	.	.	.	.
GW-729-26	!		.	.	.	.	.	.	.
GW-729-30	!		.	.	.	.	.	.	.
GW-729-34	!		.	.	.	.	.	.	.
GW-729-39		!	.	.	.	.	.	.	.
GW-729-44		!	.	.	.	.	.	.	.
GW-730-02	!		.	.	.	.	.	.	.
GW-730-11	!		.	.	.	.	.	.	.
GW-730-18	!		.	.	.	.	.	.	.
GW-730-21	!		.	.	.	.	.	.	.
GW-730-25	!		.	.	.	.	.	.	.
GW-730-28	!		.	.	.	.	.	.	.
GW-730-30	!		.	.	.	.	.	.	.
GW-730-35	!		.	.	.	.	.	.	.
GW-738		!	–	.	–	.	.	.	.
GW-740		!	.	.	"	.	.	.	.
GW-790-02	!		.	.	.	.	.	"	.
GW-790-05	!		.	.	.	.	.	.	.
GW-790-07	!		.	.	.	.	.	.	.
GW-790-14	!		.	.	.	.	.	.	.
GW-790-19	!		.	.	.	.	.	.	.
GW-790-23	!		.	.	.	.	.	.	.
GW-790-29	!		.	.	.	.	.	.	.
GW-790-32	!		.	.	.	.	.	.	.
GW-790-35		!	.	.	.	.	.	.	.

Table B.2 (continued)

CY 2000 Sampling Location [1]	Unit [2]		Contaminant Type and Long-Term Trend [3]						
			Inorganics [4]		VOCs [5]			Radioactivity [6]	
	AQT	AQF	Nitrate	Uranium	Chloro-ethenes	Chloro-ethanes	Chloro-methanes	Gross Alpha	Gross Beta
GW-790-39		!	.	.	.	.	.	.	.
GW-829	!		–	.	.	.	.	.	.
GW-835		!	"	"	"	.	.	.	.
GW-838	!		.	.	.	.	.	.	.
GW-840	!		.	.	.	.	.	.	.
GW-904	!		.	.	.	.	.	.	.
GW-905	!		.	.	.	.	.	.	.
NT-01			"	"	.	.	.	"	"
NT-07			.	.	"	"	"	.	.
NT-08			.	"	"	"	.	.	.
SS-1			–	"	.	.	.	"	"
SS-4			"	"	[	.	.	"	"
SS-5			"	"	.	.	.	"	"
SS-6			.	.	.	.	.	.	.
SS-6.6			.	.	.	.	.	"	.
SS-7			.	.	.	.	.	.	.
SS-8			.	.	.	.	.	.	.

Notes:

1 All CY 2000 sampling locations are included on the table. The exit pathway/perimeter monitoring locations are in bold typeface.

2 Hydrostratigraphic unit.

AQT - Aquitard: Conasauga Group, excluding the Maynardville Limestone.
AQF - Aquifer: Maynardville Limestone and Knox Group.

3 Trend types were interpreted from data tables or plots of concentration changes over time.

. - Not a contaminant (criteria defined below, in notes 4, 5, and 6).
" - Indeterminate trend: insufficient data, fairly stable trend, affected by sampling methods or highly fluctuating with no clear upward or downward trend.
– - Generally decreasing trend.
[- Generally increasing tend.

Note that different VOCs have different long-term concentration trends at well GW-226: 12DCE shows a decreasing trend and TCE shows an increasing trend (see Figures A.11 and A.16, respectively).

4 CY 2000 nitrate concentration greater than or equal to 10 mg/L.
Total uranium concentration greater than or equal to 0.03 mg/L.

Notes (continued):

5 Summed CY 2000 concentration of a solvent group greater than or equal to 5 µg/L.

Ethenes = Summed chloroethenes (PCE, TCE, 12DCE, 11DCE, 11DCE, vinyl chloride)
Ethanes = Summed chloroethanes (111TCA, 11DCA, chloroethane)
Methanes = Summed chloromethanes (carbon tetrachloride, chloroform, methylene chloride)

6 Maximum CY 2000 gross alpha activity greater than or equal to 15 pCi/L.
Maximum CY 2000 gross beta activity greater than or equal to 50 pCi/L.

DISTRIBUTION

U.S. DEPARTMENT OF ENERGY

J.D. Darby, DOE-EM
J.P. Donnelly, DOE-NNSA
M.S. Ferre, DOE-EM

BWXT Y-12, L.L.C.
ENVIRONMENTAL COMPLIANCE
DEPARTMENT

S.M. Field
S.B. Jones
C.C. Hill
J.E. Powell
E.R. Schultz
L.O. Vaughan
GWPP-File-RC (2)

BWXT Y-12, L.L.C.
ANALYTICAL CHEMISTRY
ORGANIZATION

D.D. Altom

Y-12 Central Files

Y-12 Records Services (Electronic copy- OSTI)

BECHTEL JACOBS COMPANY LLC

H.M. Clancy
C.S. Haase (2)
D.W. McCune
E. Trujillo
File-EMEF-DMC

SCIENCE APPLICATIONS
INTERNATIONAL CORPORATION

W.K. Jago

UT-BATTELLE, LLC

D.B. Watson

AJA TECHNICAL SERVICES, INC.

T.R. Harrison
J.R. Walker

TENNESSEE DEPARTMENT OF
ENVIRONMENT AND
CONSERVATION DOE OVERSIGHT
DIVISION

D. Gilmore (3)