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**Report on the Remedial Investigation of Bear Creek Valley
at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee**

**Volume 3. Appendix D—Nature and Extent
of Contamination Report**

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Energy Systems Environmental Restoration Program

**Report on the Remedial Investigation of Bear Creek Valley
at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee**

**Volume 3. Appendix D—Nature and Extent
of Contamination Report**

Date Issued—September 1996

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Oak Ridge, Tennessee 37831-8169
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LOCKHEED MARTIN ENERGY SYSTEMS, INC.
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Science Applications International Corporation

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PREFACE

This Remedial Investigation Report on the Bear Creek Valley Characterization Area at the Oak Ridge Y-12 Plant (DOE/OR/01-1455/V1&D1, -1455/V2&D1, -1455/V3&D1, -1455/V4&D1, -1455/V5&D1, and -1455/V6&D1) was prepared in accordance with requirements under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) for reporting the results of a site characterization for public review. This work was performed under Work Breakdown Structure 1.4.12.1.1.02.41 (Activity Data Sheet 2302 "Bear Creek Valley"). Publication of this document on September 15, 1996, will meet a Federal Facilities Agreement milestone. This document provides the Environmental Restoration Program with information on the Bear Creek Valley remedial investigations that include results of the Bear Creek Valley OU 1 (1995) and OU 4 (1994) and Bear Creek Valley Floodplain Soils (1995) investigations, plus results of numerous other investigations and monitoring conducted in Bear Creek Valley. It includes information on risk assessments that have evaluated long-term impacts to human health and the environment. Information provided in this document forms the basis for the development of the Feasibility Study/Environmental Assessment Report.

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ACRONYMS AND ABBREVIATIONS

AFI	areas for further investigation
amsl	above mean sea level
ARARs	applicable or relevant and appropriate requirements
BCBG	Bear Creek Burial Ground
BCHR	Bear Creek Hydrogeologic Regime
BCK	Bear Creek Kilometer
BCV	Bear Creek Valley
bgs	below ground surface
BNAE	base/neutral and acid extractable
BSCP	Background Soil Characterization Project
BYBY	Boneyard/Burnyard
CE	chloroethane
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	cubic feet/second
COC	contaminant of concern
DBH	diameter at breast height
DCA	dichloroethane
DCE	dichloroethene
DNAPL	dense non-aqueous phase liquid
DQO	data quality objective
EM	electromagnetic
Energy Systems	Lockheed Martin Energy Systems, Inc.
FA	functional area
FPSS	Floodplain soils and sediments
GFAA	gas furnace atomic absorption
GWPP	Groundwater Protection Program
GWQR	Groundwater Quality Report
HCDA	Hazardous Chemical Disposal Area
ICP	inductively coupled plasma
LNAPL	light non-aqueous phase liquid
MCL	maximum contaminant level
MDA	minimum detectable activity
NPDES	National Pollutant Discharge Elimination System
NT	North Tributary
OLF	Oil Landfarm
ORNL	Oak Ridge National Laboratory
ORP	Oil Retention Pond
ORR	Oak Ridge Reservation
OU	operable unit
PAH	polyaromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation

RIFA	RI field activities
SDWA	Safe Drinking Water Act
SL 1	Sanitary Landfill 1
SRC	site-related contaminant
SVOC	semivolatile organic compound
TCA	trichloroethane
TCE	trichloroethene
TDS	total dissolved solids
TSS	total suspended solids
UEFPC	Upper East Fork Poplar Creek
USGS	U. S. Geological Survey
USRADS	Ultra Sonic Ranging and Data System
UTL	upper tolerance limit
VOC	volatile organic compound
WIP	Walk-in Pits

EXECUTIVE SUMMARY

This Remedial Investigation (RI) Report characterizes the nature and extent of contamination, evaluates the fate and transport of contaminants, and assesses risk to human health and the environment resulting from waste disposal and other U.S. Department of Energy (DOE) operations in Bear Creek Valley (BCV). BCV, which is located within the DOE Oak Ridge Reservation (ORR) (Fig. ES.1), encompasses multiple waste units containing hazardous and radioactive wastes arising from operations at the adjacent Oak Ridge Y-12 Plant (Fig. ES.2). The primary waste units discussed in this RI Report are the S-3 Site, Oil Landfarm (OLF), Boneyard/Burnyard (BYBY), Sanitary Landfill 1 (SL 1), and Bear Creek Burial Grounds (BCBG). These waste units, plus the contaminated media resulting from environmental transport of the wastes from these units, are the subject of this RI.

Consistent with the Watershed Approach to remedial investigation/feasibility study (RI/FS) planning adopted by the Oak Ridge Federal Facility Agreement (FFA) parties, the environmental media and waste sites in BCV have been combined into a single Characterization Area (CA) encompassing the entire Bear Creek watershed. The benefits of this approach have included:

- a significantly reduced site investigation phase, with more reliance on historical data as the basis for remedial action decisions;
- development of more consistent Remedial Goal Options (RGOs) across the multiple source units;
- an increased focus on development of an integrated prioritization for remedial actions, particularly for sites appropriate for near-term actions; and
- an overall reduction in cost and schedule for the RI/FS process.

Accordingly, the BCV RI Report documents and interprets the results of numerous historical field characterization efforts conducted in BCV prior to 1994 as well as three limited RI field projects covering specific portions of the watershed in 1994 and 1995. This interpretation provides a comprehensive evaluation of the conditions at and risks associated with the waste sites, associated floodplain, and groundwater in the valley.

Inherent in the accelerated watershed approach is the heavy reliance on historical data to form the basis of the RI. For BCV, a significant historical data set existed, thus minimal effort was spent by the watershed RI team in gathering additional extent of contamination information. While this approach greatly reduces the schedule and cost of the RI, it does result in higher levels of uncertainty in the evaluation results. The likelihood of important data gaps in the BCV RI was minimized by adherence to the Data Quality Objective (DQO) process during the planning phase, and by proactive uncertainty management during the data collection and evaluation phases. The resulting FS will accommodate the identified uncertainties through selection of contingent actions that will allow for flexibility within the remedy selection.

This BCV RI Report represents the first major step in the decision-making process for the BCV watershed. The RI results, in concert with the follow-on FS (to be available for public review in April 1997), will form the basis for the Proposed Plan and Record of Decision for all BCV sites. This comprehensive decision document process will meet the objectives of the watershed approach for

LEGEND:

- REACH 1 OF BEAR CREEK
NT-1 and Bear Creek to NT-3
- REACH 2 OF BEAR CREEK
NT-3 To BCK-9.40
- REACH 3 OF BEAR CREEK
BCK-9.47 to ET-4
- REACH 4 OF BEAR CREEK
ET-4 to EFPC
- ⊕ GROUNDWATER WELL (individual wells not
labeled unless mentioned in text.)
- SS-6 MAJOR SPRINGS
- / TS1 SOIL TRANSECT LOCATION

Figure ES.1. Location map for the Bear Creek Valley Characterization Area showing major geographical and hydrological features.

ES-2

SAC CAD DWG: 94020\DWG\507REACH

BEAR CREEK VALLEY

LEGEND:

- ===== ROADS
- BEAR CREEK & TRIBUTARIES
- SS4 OU4 SURFACE WATER SAMPLE AT SPRINGS
- ⊕ GW-684 GROUNDWATER WELL
- WASTE AREA UNITS

ES-3

Figure ES.2. Location map for waste areas in the Bear Creek Valley Characterization Area.

BCV, which include: (1) prioritization of remedial action decisions, (2) expeditious implementation of highest priority remedial actions, and (3) increased cost effectiveness of remedial action by setting watershed Remedial Action Objectives (RAOs) based on an integrated, valley-wide, future land use plan. By conducting the evaluation within the watershed framework, DOE can ensure consistent actions that achieve the RAOs across all the units and cost effectively optimize the extent and type of remedies, regardless of location.

ES.1 MAJOR CONCLUSIONS FOR THE RI REPORT

The BCV RI Report contains a detailed analysis of environmental data for BCV. The major conclusions from the analysis are conveyed via conceptual models for the nature and extent of contamination and fate and transport of contaminants. Common to each of the major waste units located on the north side of Bear Creek are the following major conclusions:

- There are a number of physical and chemical aspects of the source sites that will complicate cleanup of the sources areas and will limit the ability to allow unrestricted, e.g., residential or industrial, use at these sites (S-3 Site, BYBY, and the BCBG). These are:
 - large volumes of buried waste exist at each source area in unlined trenches;
 - portions of the waste at each source area are inundated by shallow groundwater;
 - groundwater at the sources is contaminated to over 120 m (400 ft) depth and dense non-aqueous phase liquid (DNAPL) is present; at the S-3 Site and BCBG, contamination in groundwater is a secondary source that is of equal or greater magnitude than the primary waste source; and
 - the sources are situated on low permeability, fractured shale rock. Diffusion of contaminated groundwater into the rock pores has resulted in a reservoir of contaminated groundwater that can only be released from the rock at a slow rate.
- Contaminants migrating from the waste sites in BCV converge at Bear Creek Kilometer (BCK) 9.47/South Spring (SS)-5 (Fig. ES.1): more than 99% of available water from the upper portion of the valley passes through this location as either surface water or groundwater. Thus a north-south line drawn at BCK 9.47/SS-5 is a convenient location to conduct an integrator point/plane (IP) assessment of contaminant fluxes from the waste areas (Note: in some of the FS alternatives, unrestricted land use starts to the west of this line). At the IP, potential risks from exposure to groundwater or surface water exceed 10^{-6} or a Hazard Index (HI) >1 (Fig ES.3). The chemicals of concern (COCs) at the IP are uranium, nitrate, boron, and fluoride. In addition, applicable or relevant and appropriate requirements (ARARs) for nitrate are exceeded in groundwater at the IP and also most likely for uranium (Note: uranium contamination in GW-684 at the IP does not exceed the ARAR; however, groundwater discharge at SS-5 periodically exceeds the uranium ARAR). Although it is not clear how far the elevated hazard and ARAR exceedances extend to the west, they do not extend as far as Highway 95.
- Contaminated groundwater at waste areas migrates along geological strike to nearby tributaries of Bear Creek [i.e., North Tributary (NT) -1, -2, -3, -6, -7, and -8] causing the tributaries and Bear Creek to become contaminated. This is the principal exit pathway for contaminants leaving the waste areas and moving to the IP. Figure ES.3 shows what sources and tributaries contribute the most to contamination at the IP. The S-3 Site (NT-1, NT-2, and Bear Creek above

Potential Risks and Toxic Effects at the Integrator Plane

BCK 9.4/SS-5 Aggregate

GW 684 Groundwater

*COPCs not listed individually have individual potential risk < 10⁻⁵ or HI < 0.1

Relative Contribution of Uranium and Nitrate at the IP from Source Areas

Uranium Flux

*Assumed distribution of ungauged flux is 70% BYBY, 30% S-3 Site.

Nitrate Flux

Figure ES.3. Potential risks and hazards at the Integrator point/plane and the relative magnitude of the sources for nitrate and uranium.

BCK 12.36) and BYBY (NT-3) sites are currently contributing more than 80% of the potential hazard at the IP through releases of uranium and, to a lesser extent, nitrate. The total flux from NT-1 and NT-2 is expected to increase in the foreseeable future and may result in a greater hazard at the IP. A 50 to 75% reduction in the current contaminant flux through tributaries or shallow groundwater at the S-3 Site and BYBY could reduce the total HI at the IP below 0.8.

- Discharges to surface water from a plume of contaminated groundwater at the S-3 Site are the primary causes of current impacts on the aquatic ecology in Bear Creek, east of BCK 9.47.
- Impacts of contamination at waste areas have been lessened by capping waste areas. In addition, seep collection at BCBG has lessened the downgradient impact of contamination migrating away from this source.

ES.2 BCV HYDROGEOLOGICAL CONCEPTUAL MODEL

The hydrogeological system in BCV is governed by the valley's geology. Rocks underlying BCV fall into two broad categories: those that are dominated by clastic lithologies (e.g., Nolichucky Shale) and those that are predominantly carbonates (e.g., Maynardville Limestone). The primary permeability of the rocks underlying BCV is very low. The formations are extensively fractured and, in the case of carbonate formations, karstified, creating a secondary porosity that results in substantially increased permeability.

Groundwater flows through fractures or solution conduits, which are well-connected and mostly parallel to geological strike (Fig. ES.4). Fracture aperture width generally decreases with depth, restricting the depth of active groundwater circulation. The shallow interval [top 30 m (100 ft)] of the Maynardville Limestone contains a well-connected maze of conduits that is able to transport water rapidly along strike, west in the axis of BCV. Groundwater in this interval is closely connected to flow in Bear Creek. Below 30 m (100 ft) in this formation, along strike flow occurs through discrete solution conduits and fractures that are not as well-interconnected than those in the shallow interval.

The Nolichucky Shale is the principal clastic formation that forms the northern flank of BCV. Most groundwater flow in the clastic formations occurs during and immediately following precipitation at the water table and shallow bedrock intervals [probably <15 m (50 ft) depth]. Flow is predominantly along strike, and discharge is to tributaries of Bear Creek after short flowpaths. During storms, flow in these shallow intervals may be rapid (up to 40 m/d).

As a result of predominantly short and shallow flow paths for groundwater in the clastic formations in BCV, although the largest mass of water (and consequently the largest mass of contaminants) exits BCV via surface water, groundwater is the principal pathway for contaminants leaving the waste units. The main flow and contaminant transport pathways in groundwater at the waste units are along strike with the discharge points at tributaries to Bear Creek. Fluxes in flow paths at the waste units (overland flow, soil interflow, and groundwater flow) have not been quantified but recharge followed by groundwater flow to tributaries constitutes the main water flux pathway. During a 10-month surface water monitoring program, an estimated 97% of water available for flow (precipitation and evapotranspiration) exited the section of the valley above BCK 9.47 as surface water flow.

ES-7

Figure ES.4. Hydrogeological conceptual model for Bear Creek Valley.

ES.3 NATURE AND EXTENT OF CONTAMINATION

ES.3.1 Environmental Database

The environmental database used for the BCV RI includes 75,000 soil, sediment, groundwater, surface water, and biota analyses obtained during the RI field projects conducted during 1994 and 1995, and 20,000 soil, sediment, groundwater, and surface water analyses obtained from historical field studies conducted in the 1980s and early 1990s. A detailed data quality assessment review demonstrated that the quality of both the recent and historical chemical data is adequate: <1% of the recent data were considered unacceptable, and only 1.3% of the historical chemical data were rejected. Historical radiological data for groundwater were deemed unacceptable for use in the RI and the Human Health Risk Assessment, therefore, additional groundwater samples were taken during the RI to complete the radiological database.

ES.3.2 Waste Sites

The primary waste sites characterized in this BCV RI report are the S-3 Site, OLF, BYBY, SL 1, and BCBG (Fig. ES.2). Three other primary waste sites within BCV — Spoil Area 1, Rust Spoil Area, and SY-200 Yard — are discussed in the BCV OU 2 RI (Energy Systems 1995). Although these sources were described in the BCV OU 2 RI Report, the watershed approach dictates that their impacts on the environment in BCV are considered in this report. In addition, numerous smaller waste disposal or storage areas throughout BCV, such as the OLF Storage Containment Pad, Bear Creek Road Debris Burial area, and Creekside Debris Burial area, are also considered as potential contaminant sources.

During the DQO process for BCV, the RI team decided that direct sampling to characterize the waste materials was not feasible (DQO meeting minutes). Instead, the physical and chemical characteristics of the contaminant sources were derived from interpretation of historical data and information in waste management records: pre-closure sampling data were used to quantify waste contamination at the S-3 Ponds and OLF sites; a detailed waste inventory was used for BCBG; and data from recent (1994) soil sampling were used for BYBY and SL 1. Where possible, current conditions within each source area were estimated to allow modeling of the potential future releases and assessment of current and future risks.

The waste areas in BCV are located in the upper 3.5 km (2.2 miles) of the valley (east of the IP) (Fig ES.2). Both solid and liquid wastes were disposed of at these sites. Most liquid waste has either infiltrated to groundwater below the waste sites or has migrated in groundwater and surface water away from the source areas. The following volumes of waste, contaminated soil, and contaminated groundwater are estimated to be present in BCV (Note: volume estimates for soils and wastes do not include materials in waste area caps):

S-3 Site	1,600 m ³ waste and contaminated soils 7.1 × 10 ⁶ m ³ (5740 acre-ft) contaminated groundwater
Oil Landfarm	25,000 m ³ waste and contaminated soils
BYBY	90,000 m ³ waste and contaminated soils 0.4 × 10 ⁶ m ³ (320 acre-ft) contaminated groundwater

SL 1	110,000 m ³ waste and contaminated soils
BCBG	190,000 m ³ waste and contaminated soils 4.0 × 10 ⁶ m ³ (3200 acre-ft) contaminated groundwater

In addition, there is an estimated 5.7×10^6 m³ (4600 acre-ft) of contaminated groundwater in the Maynardville Limestone, and < 1,000 m³ of contaminated soils and waste materials on the BCV floodplain.

ES.3.3 Nature and Extent of Contamination in Environmental Media and Wastes

The data available for the BCV CA were divided into four functional areas (FAs), each of which contains data that are logically interpreted together because of location and/or contaminant source. Three of the FAs — the S-3 FA, the OLF FA, and the BCBG FA — include data that relate to the three primary waste areas (Fig. ES.2). The fourth FA is the Maynardville Limestone and Bear Creek FA, which is located downgradient of the source FAs and acts as an integrated exit pathway for contaminants migrating away from the source units, via groundwater in the Maynardville Limestone or surface water flow in Bear Creek.

S-3 Functional Area

The S-3 FA includes the soils, groundwater, and surface water at and immediately downgradient of the S-3 Site.

Sources and contaminants. At the S-3 Site FA, primary contaminant sources are (1) a plume of contaminated groundwater derived from infiltration of nitric acid waste water and density-driven flow downward into bedrock, and (2) sludges remaining in place in the former ponds. Thirty years of disposal of concentrated (~1 molar) nitric acid solutions at the S-3 Site has resulted in a reservoir of contaminated groundwater with high (> 10,000 mg/L) total dissolved solids (TDS) in the Nolichucky Shale at this site. Discharge of groundwater from this contaminated plume results in contaminated surface water with elevated TDS (maximum > 1000 mg/L).

Contamination derived from the S-3 Site can be identified in the Maynardville Limestone as far west as Picket W and in surface water at BCK 4.55. Primary contaminants that have migrated away from the S-3 Site include (1) nitrate, uranium, ⁹⁹Tc, barium, boron, cadmium, strontium, acetone, and tetrachloroethene (PCE) in groundwater, and (2) nitrate, cadmium, uranium, and ⁹⁹Tc in surface water. Contaminant concentrations in groundwater at the S-3 Site exceed ARARs for inorganic and organic chemicals in drinking water.

S-3 Site conceptual model. At the S-3 Site, contaminated groundwater in the Nolichucky Shale is the main source of contaminants to downgradient receptors: more contaminant mass flux is discharging to the creek than is leaching from waste materials that remain in the former ponds. Historically, during operations at the S-3 Ponds, most of the acidic waste water probably migrated rapidly to the main stem of Bear Creek, NT-1, and Upper East Fork Poplar Creek via shallow groundwater flow. At the present time, contaminants in this plume are migrating in shallow and deep groundwater and discharging to Bear Creek, NT-1, and NT-2 (Fig. ES.5).

Figure ES.5. Conceptual model for Bear Creek Valley showing the main contaminant migration pathways.

Contaminants have undergone differential retardation that has resulted in different distributions and exit pathways for the primary contaminants: nitrate, metals, uranium, ^{99}Tc , and PCE. Uranium and some metals are made relatively immobile by geochemical reactions and have been held up in the residuum and shallow groundwater close to the S-3 Site. The exit pathway for these contaminants is via discharge of shallow groundwater to Bear Creek. Nitrate, ^{99}Tc , PCE, and the more mobile metals have contaminated bedrock groundwater. The main pathway for these contaminants is along strike flow in the intermediate and deep groundwater intervals, followed by upwelling and/or diffusion to the shallow groundwater interval and discharge to NT-1 and NT-2. Nitrate is least retarded and has traveled the farthest from the S-3 Site — its occurrence in groundwater marks the maximum extent of contamination resulting from the S-3 Site.

All contaminants in groundwater at the S-3 Site have been retarded by matrix diffusion. A reservoir of contaminants in the matrix porosity now exists at the S-3 Site, where these contaminants flow and/or diffuse from the rock matrix into the active flow fractures in each pathway.

The maximum concentrations of PCE found at S-3 Site ($> 1\%$ of PCE solubility) indicate the potential for PCE bearing DNAPL in the bedrock formations beneath the ponds.

The plume of contaminated groundwater derived from the S-3 Site can be traced in the Nolichucky Shale as far west as NT-2. However, although the extent west of the plume in shallow groundwater is well known, no data points exist until downgradient of SL 1 to identify the leading edge of the plume in intermediate and deep groundwater. Increasing concentrations of nitrate in shallow wells near the NT-2 catchment over the past 10 years suggest that the center of mass of the nitrate plume may be moving along strike to the west in groundwater below 30 m (100 ft) depth. The probable condition is that the plume in deep groundwater extends no further west than the plume in shallow groundwater and that much of the contaminant mass flux in the plume is discharged to NT-2.

Oil Landfarm Functional Area

The OLF FA encompasses the soils, groundwater, and surface water at and immediately downgradient of four sites: OLF, BYBY, Hazardous Chemicals Disposal Area (HCDA), and SL 1.

Sources and contaminants. Both solid and liquid wastes were disposed of at the OLF FA. There are three primary locations of solid wastes: (1) buried waste materials at BYBY, (2) buried waste materials in the SL 1 trench, and (3) contaminated soils on the former OLF plots. In addition, disposals of liquid wastes at BYBY, HCDA, and OLF have resulted in plumes of volatile organic compound (VOC) -contaminated groundwater.

Contamination at the OLF FA is diverse, including metal, radionuclide, and VOC contamination in groundwater, surface water, soils, and waste materials. Frequently detected contaminants in the OLF FA are as follows:

- At BYBY and HCDA: (1) mercury, beryllium, manganese, nickel, vanadium, PCE, trichloroethene (TCE), 1,2-dichloroethene (DCE), and uranium isotopes in groundwater; (2) mercury, lithium, and uranium isotopes in surface water; and (3) mercury, cadmium, copper, polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), phthalates, uranium isotopes, and ^{99}Tc in soils.

- At OLF: (1) PCBs and uranium in soils and wastes, and (2) 1,1,1-trichloroethane (TCA), 1,1-dichloroethane (DCA), 1,1-DCE, 1,2-DCE, PCE, and TCE in groundwater. There is no surface water contamination that can be attributed to OLF.
- At SL 1: (1) mercury, copper, nickel, PCB-1254, and ²³⁵U in soils and wastes, and (2) 1,1-DCA, 1,2-DCE, and vinyl chloride in groundwater. There is no surface water contamination that can be attributed to SL 1.

OLF FA conceptual model. The conceptual models for both OLF and SL 1 are that soils surrounding the waste sites are relatively uncontaminated. Groundwater below and immediately downgradient of each waste area is contaminated with VOCs as a result of liquid waste disposals.

At BYBY, uranium leaches from waste materials (some of which are most likely inundated with groundwater) and contaminated soils to groundwater, which subsequently discharges to surface water in NT-3. Uranium in groundwater that has leached from fill material in the southern portion of BYBY probably migrates directly to the Maynardville Limestone and Bear Creek via shallow groundwater flow (Fig. ES.5). Fate and transport modeling indicates that most inorganic and radiological contaminants in NT-3 have probably reached peak concentrations; however, the presence of a continuous source (leaching from waste materials) suggests that these peak values would be maintained over several hundred years.

The VOC plume at BYBY is partly located in residuum above the Maynardville Limestone and, like uranium, VOCs probably migrate directly into the Maynardville Limestone or Bear Creek. Although VOCs entering groundwater from HCDA or the Burnyard may discharge to surface water in NT-3, the extent of this discharge is low, hence, VOCs volatilize almost immediately.

Bear Creek Burial Grounds Functional Area

Sources and contaminants. At the BCBG FA, both solid and liquid wastes were disposed of in a series of unlined trenches. The waste trenches are grouped into areas BG-A, -B, -C, -D, -F, and Walk-in-Pits (WIP). Uranium dominates the wastes disposed of in each area with a total estimated mass of 18.6 million Kg. Disposals of liquid wastes have also resulted in DNAPL (PCE and TCE) in groundwater that may have reached depths of 180 m (600 ft). Dissolution of DNAPL results in plumes of VOC-contaminated groundwater.

Contamination in the BCBG FA includes VOCs and metals in groundwater, and VOCs, metals, and radionuclides in surface water, soils, waste materials, and leachate from waste trenches. In general, organic contamination of environmental media at BCBG is more widespread than inorganic and radionuclide contamination. Primary contaminants detected at the BCBG are: (1) boron, PCE, TCE, 1,1,1-TCA, and 1,2-DCE in groundwater; (2) beryllium, 1,1,2-TCA, 1,1-DCE, 1,2-DCA, vinyl chloride, 1,1-DCA, 1,1,1-TCA, chloroethane, and uranium isotopes in surface water; (3) arsenic, vanadium, PCBs, acetone, and toluene in soils surrounding the waste areas; and (4) uranium, beryllium, PCBs, TCE, and PCE in wastes. Contaminant concentrations in groundwater at BCBG exceed ARARs for inorganic and organic chemicals in drinking water at many locations.

Contamination of groundwater and surface water is dominated by VOCs at the BCBG FA. Three groundwater plumes were identified: (1) the BG-A plume is dominated by PCE, TCE, and 1,2-DCE, and includes DNAPL; (2) the WIP plume is dominated by PCE; and (3) the plume at the NT-8 catchment is dominated by 1,2-DCE, with lesser concentrations of vinyl chloride.

Radiological contamination is virtually absent from groundwater wells in the BCBG, but uranium is consistently detected in surface water. Collection of leachate in the NT-7 and NT-8 catchments has significantly reduced the concentration of radiological and other contaminants in surface water.

Radiological contamination occurs in soils in the NT-8 floodplain and is probably related to past deposition of contaminated sediments derived from drainage of the BG-B, -C, and -D areas.

BCBG conceptual model. The distribution of contaminants at BCBG reflects the type of waste materials that were disposed. The organic wastes were dense liquids and were disposed of directly into groundwater; uranium is in the solid form and is slowly leaching from trenches. The dominance of the hydrogeologic system by shallow flow restricts inorganic and radionuclide contamination to short flow paths in the shallow groundwater interval, whereas the density-driven flow of DNAPL provides a mechanism for organic contamination to enter the shallow, intermediate, and deep bedrock intervals (Fig. ES.5).

Oils and solvents were disposed of in the BG-A area by pouring the liquids into standpipes in debris- and waste-filled trenches. The bulk of these liquids migrated laterally to surface water and downward to groundwater, ultimately reaching depths of up to 180 m (600 ft) as DNAPL. Free-phase liquids occur in bedrock and probably remain in the trenches as residual droplets that have adhered to waste materials and minerals. Dissolved VOCs in the BG-A and NT-8 plumes have undergone limited chemical or biological degradation. A plume of dissolved PCE is migrating along strike in the Nolichucky Shale to the west of BG-A South. Fate and transport modeling suggests that a PCE plume may take a few hundred years to migrate along strike as far as NT-8.

Maynardville Limestone and Bear Creek Functional Area

The Maynardville Limestone and Bear Creek FA includes (1) soils and sediments in the Bear Creek floodplain, (2) groundwater in the Maynardville Limestone, and (3) surface water in the main stem of Bear Creek and in floodplain springs.

Sources and contaminants. The environmental media in this FA represent the downgradient pathways and receptors of contaminants migrating away from the sources on the Nolichucky Shale. The primary sources of contaminant input to Bear Creek and the Maynardville Limestone from the source sites are:

- S-3 Site: nitrate, radionuclides, and high TDS via discharge from NT-1 and NT-2, shallow groundwater discharges to Bear Creek, and shallow groundwater discharges directly to the Maynardville Limestone.
- BYBY: uranium via discharge from NT-3 and direct runoff to the Floodplain, and uranium and VOCs by shallow groundwater discharge into the Maynardville Limestone.
- SL 1: VOCs via shallow groundwater discharge into the Maynardville Limestone.
- BCBG: VOCs and uranium via discharge from NT-7 and NT-8.
- Past releases of TCE and 1,2-DCE from an unknown site east of BYBY FA or Rust Spoil Area.

- Past releases of TCE and 1,2-DCE from the Fire Training area in the neighboring Upper East Fork Poplar Creek (Fig. ES.1) hydrogeologic regime that may have migrated in karst in the Maynardville Limestone into the Bear Creek hydrogeologic regime at Spoil Area 1.

In addition, the Creekside Debris Burial area and the Bear Creek Road Debris Burial area are two waste areas, first identified during field operations for the BCV RI, with soil contamination on the Floodplain. These sites do not currently contribute to groundwater contamination but may have done so in the past. Primary contaminants in the Maynardville Limestone and Bear Creek FA are:

- nitrate, boron, uranium, strontium, barium, PCE, TCE, 1,2-DCE, and ^{99}Tc in groundwater; concentrations of these contaminants exceed ARARs for drinking water at many locations in the valley upgradient of BCK 9.47;
- barium, cadmium, manganese, uranium, boron, strontium, TCE, 1,2-DCE, and ^{99}Tc in springs and surface water upstream of BCK 9.47;
- nitrate, boron, strontium, and uranium in surface water downstream of BCK 9.47; and
- cadmium, uranium, and PCBs in Floodplain soils and sediments at a few locations [in general, contaminant concentrations are higher in sediments than in soils, and the highest concentrations in soils occur in the top 10 cm (4 in.) of soil].

Nitrate, uranium, and ^{99}Tc contamination occurs close to the S-3 Site and continues west as far as BCK 9.47 and Picket A. Nitrate contamination in groundwater occurs 2590 m (8500 ft) west of Picket A in Picket W, but uranium and ^{99}Tc have not reached this far west. TCE- and 1,2-DCE contaminated groundwater occurs in groundwater wells at the Spoil Area 1 and Rust Spoil Area. Concentrations of TCE and 1,2-DCE in groundwater increase downgradient of Rust Spoil Area at Picket C and adjacent to BYBY. The furthest west that TCE is detected in groundwater is in Picket B; however, discharge to SS-5 is contaminated with trace concentrations of TCE, which may indicate the presence of the leading edge of the TCE plume at Picket A.

Maynardville Limestone conceptual model. At monitoring points downgradient of BYBY (groundwater and surface water), the plumes from the S-3 Site and BYBY source areas are completely commingled (Fig. ES.5). It is only possible to identify BYBY as a contributor to the inorganic and organic Maynardville Limestone contaminant plumes because of the relative concentrations of contaminants in groundwater, surface water, and springs. Progressive changes in relative concentrations of contaminants in groundwater along the valley reflect the inputs to the Bear Creek/Maynardville Limestone system and suggest that after entering Bear Creek contaminants can migrate downward into the Maynardville Limestone (Fig. ES.5).

Surface water in Bear Creek and shallow groundwater in the Maynardville Limestone are closely interrelated and constitute 96% of water flowing along the valley. Contaminants in these media pathways are quickly diluted by rapid recharge of rainwater and inputs from noncontaminated tributaries. Concentrations of contaminants in the intermediate and deep groundwater pathways [30 to 90 m (100 to 300 ft) depth] are not attenuated as rapidly as those in shallow groundwater because this interval is somewhat isolated from inputs from recharge and tributaries. Plumes of groundwater contaminated above maximum contaminant levels in the 30 to 90 m (100 to 300 ft) depth interval are more continuous and extend further along the valley.

Groundwater contamination at Picket W is attributed both to diffuse contamination as a result of infiltration of contaminated surface water in Bear Creek and along strike migration of contaminated groundwater in intermediate and deep groundwater.

ES.4 CONTAMINANT FATE AND TRANSPORT PATHWAYS

The principal contaminant sources in BCV are located on the outcrop of the Nolichucky Shale (S-3 Site, BYBY, and BCBG), a carbonate-rich fractured shale with low permeability. Solid and liquid waste disposals have caused shallow groundwater contamination. Leaching of solid materials, particularly uranium, is a current source of shallow groundwater contamination. Where dense liquids were disposed of at the S-3 Site and BCBG, contamination of deep groundwater in the Nolichucky Shale has occurred. Contaminants migrate away from the waste disposal units using the following pathways (Fig. ES.5):

- Contaminated shallow groundwater at sources on the Nolichucky Shale migrates through fractures along geological strike and discharges to tributaries or directly to Bear Creek causing the tributaries and Bear Creek to become contaminated.
- Contaminants in deep groundwater in the Nolichucky Shale also migrate through fractures along strike and discharge to tributaries. However, contaminant pathways in the deep groundwater can underflow proximal tributaries and/or springs and be a source of contamination in neighboring tributary subwatersheds.
- After entering tributaries, contaminants migrate in surface water directly to Bear Creek. Bear Creek intermittently loses and gains water from groundwater in the Maynardville Limestone throughout the length of the valley. Losing reaches of Bear Creek cause groundwater contamination in the Maynardville Limestone. Gaining reaches of Bear Creek are associated with large springs at the base of Chestnut Ridge, some of which have contaminated discharge (SS-1, -4, -5, and -6).
- Surface water in Bear Creek and shallow groundwater in the Maynardville Limestone constitute 96% of water flowing along the valley. Contaminants in these media pathways are quickly diluted by rapid recharge of rainwater and inputs from noncontaminated tributaries.
- Deep groundwater in the Maynardville Limestone [30 to 90 m (100 to 300 ft) depth] constitutes <4% of water flowing along the valley. Concentrations of contaminants in this and in the deep groundwater pathway are not attenuated as rapidly as those in shallow groundwater; this pathway is an important source of long distance groundwater transport along the valley.
- Contaminant concentrations in shallow groundwater in the Nolichucky Shale and the Maynardville Limestone and in surface water are diluted by recharge during storm events and show seasonal trends of lower concentrations during periods of high rainfall.

Contaminants migrating from the waste sites in BCV converge at BCK 9.47/SS-5 — more than 99% of available water from the upper portion of the valley passes through this location as either surface water or groundwater.

ES.4.1 Integrator Point/Plane Assessment

To determine the contribution of each FA to the valley-wide contaminant flux migrating off site from the BCV CA, an IP assessment was completed at BCK 9.47/SS-5. Using a mass balance calculation, 69% of uranium measured at BCK 9.47 and SS-5 was measured at monitoring stations in tributaries to Bear Creek (gauged flux on Fig. ES.3). The remaining 31% was not measured in the RI (engaged flux) but is expected to be derived from migration of uranium directly to Bear Creek and the Maynardville Limestone via shallow groundwater at the BYBY and S-3 Site sources.

Assuming a similar distribution of the engaged flux as the gauged flux, then ~ 61% of the uranium found in surface water and groundwater at the IP is derived from BYBY. The S-3 Site is the second major contributor of uranium (26%), and this site contributes approximately 94% of the nitrate contamination at the IP. At the IP, 13% of the uranium is derived from BCBG. VOCs at the IP are mainly derived from BCBG; however, most VOCs (82%) discharged to surface water at source areas volatilize before reaching BCK 9.47. Boron was not measured in tributaries in the RI but is probably mostly derived from the BCBG where it was reported to be a contaminant in waste liquids that accompanied uranium tailings disposal and is found in the current leachate at BCBG.

Using these flux data, the portion of the total risk to human health and total hazard at the IP contributed by each waste site was calculated (Fig. ES.6). BYBY contributes most to the human health risk to the IP (38.5%), followed by BCBG (23.0%), and the S-3 Site (17.4%). Engaged uranium fluxes contribute 20.7% of risk at the IP. As discussed above, most of the engaged uranium flux originates in the BYBY (assumed 70%) and the S-3 Site (assumed 30%).

ES.4.2 Anticipated Future Changes

In the absence of remedial action and assuming maintenance of the current leachate collection system at BCBG, contaminant concentrations in most pathways are expected to remain at concentrations similar to those currently observed with four exceptions. These exceptions are:

- Concentrations of uranium and some metals in groundwater discharged to NT-1 are expected to increase in the foreseeable future (100 to 200 years). Concentrations of VOCs and nitrate may have peaked in this pathway but are expected to remain close to current levels for the next 100 years.
- Concentrations of nitrate, uranium, and some metals in groundwater discharged to NT-2 are expected to increase in the foreseeable future (100 to 1000 years).
- Along strike migration in the Nolichucky Shale of a plume of PCE-contaminated groundwater at BCBG may result in discharge of contaminated groundwater to NT-8 in the next 100 years. However, it is anticipated that volatilization of most of the VOCs in surface water, as is observed today, will lessen the impact of this discharge.
- Along strike migration in the Maynardville Limestone of a plume of TCE- and 1,2-DCE-contaminated groundwater at BCBG may result in discharge of increasingly contaminated groundwater at SS-5 and BCK 9.47 for the next 500 years. In addition, migration of this plume to BCK 9.47/SS-5 may result in unacceptable risk from use of groundwater at these locations and cause additional groundwater ARARs to be exceeded in the future.

Figure ES.6. Relative contributions from source areas to potential risks and hazards at the IP.

In the absence of remedial actions, the resulting effect of these changes on contaminant fluxes will be to increase the fluxes of uranium, nitrate, some metals, and VOCs at the IP during the foreseeable future. The leading edge of the nitrate plume in BCV has reached Picket W wells ~ 2.3 km west of BCK 9.47 (Fig ES.1). Increased fluxes of contaminants at the IP will most likely result in extension of the plumes of contaminated groundwater west of BCK 9.47 and increased concentrations of contaminants at Picket W.

ES.5 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

ARARs and to-be-considered guidance that may be applicable to BCV have been identified so that remedial actions planned for BCV can be fully protective of human health and the environment. Chemical-specific guidance for the BCV include:

- Environmental Protection Agency's (EPA's) insufficient yield criterion for groundwater classification;
- Safe Drinking Water Act maximum contaminant levels;
- National Secondary Drinking Water Standards secondary maximum contaminant levels;
- EPA rule for natural attenuation of contaminants in groundwater in cases where active remediation is not appropriate; and
- Tennessee Department of Environment and Conservation ambient water quality criteria.

Chemical-specific ARARs for soils and sediments and location- and action-specific ARARs applicable to sensitive resources are usually invoked during remedial action. Thus, these ARARs will be analyzed and discussed as remedial alternatives are screened in the BCV FS.

ES.6 BASELINE RISK ASSESSMENT

ES.6.1 Baseline Human Health Risk Assessment

Conclusions on potential human health risks in BCV are based on four hypothetical land uses for which risks to human health were calculated; these are current hypothetical "unprotected" site maintenance workers at the source areas, future industrial workers, future recreational receptors downstream of BCK 9.47, and future residential receptors (Figs. ES.7 and ES.8).

At BCBG, S-3 Site, and OLF, there is an important distinction between contamination due to buried waste materials and soil contamination resulting from mobilization of contaminants in wastes (secondary contamination). In general, although secondary contamination is present in soils immediately surrounding the wastes, the concentrations of contaminants in these soils are lower and pose potential risks that are orders of magnitude less than those from the neighboring waste materials. Soils surrounding waste units generally pose risks to potential future residents but little risks to potential future industrial or unprotected maintenance workers; whereas exposure to contaminants in wastes poses high risks for potential future residents and future industrial workers. With the exception of BYBY and BG-D, -E, and -J, waste materials are buried and covered with multilayer RCRA caps; therefore, the scenario for exposure of future residents and industrial workers assumes degradation of these caps and eventual uncovering of the wastes.

Figure ES.7. Distribution of risks posed to potential future residents and recreational users in Bear Creek Valley.

Figure ES.8. Distribution of risks posed to potential future industrial workers and unprotected maintenance workers in Bear Creek Valley.

Current "unprotected" maintenance worker. Risks from exposures to an unprotected maintenance worker (rather than a worker having the level of protection currently required for access at BCV sites) were evaluated to provide a conservative estimate of current risk. Assuming that existing caps at the waste areas are maintained, the only risks exceeding 10^{-4} identified for an unprotected maintenance worker at any of the BCV sites are through exposure to three chemicals of concern (COCs) (^{234}U , ^{235}U , and ^{238}U) found in hot spot soils, where waste material was exposed at the surface, at BYBY, and at BCBG (Fig. ES.8).

Future industrial worker. Risks/hazards to a future industrial worker can occur from exposure to 33 COCs:

- buried and capped wastes at the S-3 Site contain 12 COCs (beryllium, PCB-1248, and radionuclides);
- soils adjacent to the OLF cap contain 4 COCs (arsenic and radionuclides);
- soils at BYBY contain 12 COCs (metals, PAHs, and radionuclides);
- soils adjacent to caps, hot spot soils near BG-D East, and buried wastes at BCBG contain 12 COCs (metals, PCBs, VOCs, and radionuclides); and
- inventoried soils at the Disposal Area Remedial Action (DARA) Solids Storage Unit and the OLF Storage Pad contain 6 COCs (dioxins, PCB-1254, and uranium isotopes) and 4 COCs (beryllium, PCBs, and uranium isotopes), respectively.

Future recreational receptor. Risks to a future recreational user of BCV were evaluated for the BCV Floodplain, starting just west of the BCBG (BCK 9.47) and ending near Highway 95. Only one pathway was estimated to pose potential risks under this scenario: ingestion of fish that have bioaccumulated mercury (i.e., methylmercury) and PCBs (Fig. ES.7). However, there is uncertainty whether the fish analyzed in the assessment were exposed to contamination only from Bear Creek. No COCs associated with exposure to surface water, floodplain soils, and sediments were identified.

Future resident. Although a residential exposure scenario at the source areas is unlikely, it was evaluated to obtain a reasonable maximum exposure estimate of the risk to future human receptors in BCV.

West of BCK 9.47 and Picket A, total pathway risks from aggregated data do not exceed 10^{-4} (Fig. ES.7). Two individual locations have COCs associated with them. These are:

- 1 COC, PCB-1254, in soils at SP04 near Highway 95 in the BCV Floodplain;
- 4 COCs, arsenic, chromium, manganese, and PCB-1254 in sediments in Bear Creek near NT-9 and NT-11; and
- 2 COCs, boron and strontium, considered as naturally occurring and not related to activities in BCV, were identified for well GW-711 at Picket W.

In addition, low activities (< 7 pCi/L) of radium, ^{137}Cs , and ^{228}Th in groundwater at Picket W and arsenic, ^{137}Cs , and ^{238}U in surface water in Bear Creek downstream of BCK 9.47 pose risk between 10^{-6} and 10^{-4} . However, there is a high degree of uncertainty associated with these radiological data, and the lack of other radionuclides usually associated with contamination in BCV (e.g., U and ^{99}Tc) in these wells makes their occurrence at Picket W suspect.

At the IP, total pathway risks are between 10^{-4} and 10^{-6} . Specific risks and hazards are as follows:

- Ingestion of isotopic uranium in groundwater in GW-684 poses a risk between 10^{-6} and 10^{-4} to future residents. Nitrate and uranium in groundwater in this well also result in a potential HI = 1 for future residents.
- Ingestion of PCE, TCE, ^{99}Tc , ^{137}Cs , ^{237}Np , and isotopic uranium in surface water poses a potential risk between 10^{-6} and 10^{-4} to future residents. Ingestion of uranium in surface water at the IP also results in an HI > 1 for future residents with boron, fluoride, and nitrate also contributing to the hazard.
- Soils at transect TS4, located at the confluence of NT-8 and Bear Creek (Fig. ES.1), pose a potential risk > 10^{-4} to future residents via incidental ingestion or external exposure from beryllium, PCB-1260, or isotopic uranium.

East of BCK 9.47, risks and hazards posed to potential future residents are numerous, and at nearly all locations cumulative pathway risks exceed 10^{-4} and/or HIs exceed 1 via exposure to waste, soil, groundwater, or surface water (Fig. ES.7). Potential risks/hazards to future residents can occur from exposure to 94 COCs:

- at the S-3 Site FA: 34 COCs in groundwater, 13 COCs in surface water, 2 COCs in soils, and 17 COCs in buried/capped waste;
- at the OLF FA: 28 COCs in groundwater and 11 COCs in surface water, 10 COCs in OLF soils, 6 COCs in OLF Storage Pad soils, 12 COCs in SL 1 soils, and 22 COCs in BYBY soils;
- at the BCBG FA: 23 COCs in groundwater, 14 COCs in surface water, 41 COCs in leachate, 11 COCs in soils adjacent to caps and in hot spots, 16 COCs in buried waste, 7 COCs in DARA soils; an
- for the Maynardville Limestone and Bear Creek FA: 13 COCs in Bear Creek Road Debris Burial area, and 16 COCs in Creekside Debris Burial area.

In addition to the risk/hazard associated with exposure to chemicals in BCV, the BCBG site presents potential physical hazards associated with the burial of pyrophoric and explosive agents. An incompatibility study conducted in 1984 concluded that it is reasonable to expect that excavation at BCBG would foster additional reactions through re-exposure to air and unavoidable mixing as wastes are handled.

ES.6.2 Ecological Risk Assessment

Ecological risk was estimated for fish, benthic invertebrate, soil invertebrate, and plant communities and representative organisms of populations of small mammals (mice and shrew), piscivores (mink and kingfisher), large herbivores (deer), and predator/scavengers (hawks and fox). The baseline ecological risk assessment identified significant ecological risks from chemicals in water, sediment, soil, and shallow groundwater for one or more receptors. Metals and PCBs are the primary contaminants of potential ecological concern, and source area and floodplain soils, including transects west of 9.47, contribute to these risks (Fig. ES.9).

In characterizing risk to the assessment endpoints established for the BCV baseline ecological risk assessment (e.g. species richness and abundance), a 20% or greater reduction in one of the

Figure ES.9. Distribution of risks posed to aquatic and terrestrial biota in Bear Creek Valley.

endpoint properties measured in the field or a 20% reduction in survivorship, growth, or reproduction in a toxicity test was considered to be potentially significant. The assessment endpoints and their associated risks for the BCV are:

Reduction in species richness or abundance in fish communities resulting from toxicity. Risks to fish communities were evaluated for Bear Creek, which was divided into four reaches for the baseline ecological risk assessment (Fig. ES.1), and for tributaries NT-2 through NT-8. Both dissolved phase and total concentrations of metals were used in the exposure assessment for fish. The weight of evidence suggests that water from Bear Creek and NT-2 through NT-8 does not pose a significant risk of a 20% reduction in fish species richness or abundance or in the Tennessee dace population due to a toxic effect.

Reduction in species richness or abundance of benthic macroinvertebrate communities resulting from toxicity. Benthic invertebrates exposed primarily to surface water in erosional areas were evaluated separately from those exposed primarily to fine sediments in depositional areas. For benthic invertebrates in erosional areas, the weight of evidence suggests that water in Reaches 1 and 2, NT-2, SS-1, and SS-4 poses a significant risk of a 20% reduction in species richness and abundance due to a toxic effect from high concentrations of calcium, cadmium, manganese, nickel, and uranium. For benthic invertebrates in depositional areas, the weight of evidence suggests that sediment from 3 of 18 sites poses a significant risk due to a toxic effect, probably from manganese and, potentially, selenium and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). However, it is unlikely that the soft-sediment benthic invertebrate community as a whole is reduced by 20% in species richness or abundance.

Reduction in production of soil/litter invertebrates resulting from toxicity. Risk to soil invertebrates was evaluated for four source areas (S-3 Site, BYBY, combined SL 1 and OLF, and BCBG) and for the Bear Creek Floodplain. Risks of a toxic effect to soil invertebrates from mercury and, possibly, chromium, copper, and zinc, are estimated to be significant in the S-3 Site, SL 1/OLF, BYBY, Creekside Debris Burial area, and Bear Creek Road Debris Burial area.

Reduction in production of terrestrial plant communities resulting from toxicity. The plant communities in the BYBY area near HCDA are probably adversely affected by metals in shallow groundwater if they are exposed by root uptake. Soils at isolated locations along two Floodplain transects in Upper Bear Creek (transects TS3 and TS4, Fig. ES.1)) appear to pose a significant risk to plants.

Reduction in abundance or production of terrestrial wildlife populations resulting from toxicity. Risks to wide-ranging species were evaluated for the BCV as a whole. Risks to small mammals, which have more limited spatial requirements, were evaluated within the source areas and for BCV as a whole. Among the wide-ranging species, only fox were estimated to be significantly at risk of a 20% reduction in population production; this risk results from soil contamination by: antimony at BYBY; mercury at S-3 Site, BYBY, OLF, and Floodplain transect TS1; and PCBs in BCBG and Floodplain transects TS4 and TS10. Shrews are estimated to be significantly at risk of a 20% reduction in population production from high soil concentrations of metals at S-3 Site, BYBY, and OLF and PCBs at BCBG. Shrews are also estimated to be at risk from elevated chromium and PCBs in Floodplain soils in transects west of BCK 9.47. There were no risks to shrew, mouse, deer, hawk, and fox from uptake of radionuclides.

Reduction in abundance or production of piscivorous wildlife populations resulting from toxicity. Because piscivorous wildlife are highly mobile, risks to piscivores were evaluated for the BCV as a whole. Kingfishers inhabiting the watershed were estimated to be significantly at risk of a 20% reduction in population production because of mercury in fish.

ES.6.3 Conclusions about Potential Risk

At nearly all locations in BCV east of the IP, potential cumulative pathway risks posed to future residents exceed 10^{-4} and/or HIs exceed 1 via potential exposure to contaminants in waste, soil, groundwater, or surface water (Fig. ES.7). Cumulative pathway potential risks posed to future industrial workers or unprotected maintenance workers vary between 10^{-6} and 10^{-1} via exposure to buried waste and contaminated soil at hot spots (Fig. ES.8). Contamination both at the waste areas and in the floodplain poses risks to wide ranging predatory animals, fish-eating wildlife, small mammals, soil invertebrates, and plant communities (Fig. ES.9). Contaminants in surface water upstream of BCK 9.47 and in sediments in NT-2, NT-6, and reach 4 of Bear Creek pose risks to benthic invertebrates (Fig. ES.9). In addition, ARARs are exceeded in groundwater at many locations east of the IP.

At the IP, potential human health risks posed from use of groundwater or surface water exceed 10^{-6} or an HI > 1. The COCs at the IP are uranium, nitrate, boron, and fluoride. In addition, ARARs for nitrate, uranium, and VOCs are most likely exceeded in groundwater.

In the portion of the valley west of the IP, environmental media are contaminated as a result of releases from the waste areas east of the IP, but contamination is slight and poses relatively little risk (Figs. ES.7 to ES.8). West of the IP, the most prevalent contaminants in groundwater and surface water are chloride, fluoride, nitrate, boron, strontium, and uranium, but contamination does not exceed ARARs. For a potential future residential receptor, four COCs (As, Cr, Mn, and PCB-1254) were identified in sediments from Bear Creek at two locations, and one COC (PCB-1254) in soils at one location in the Bear Creek floodplain.

ES.7 REMEDIAL GOAL OPTIONS

Media- and chemical-specific RGOs have been developed for each chemical of concern in BCV. RGOs are target cleanup goals to be used in identifying effective remedial technologies. They are not proposed final cleanup levels. RGOs were calculated for the following three criteria:

- Chemicals of concern identified in the baseline human health risk assessment. For these chemicals of concern, RGOs were calculated to be protective of human health at target risk levels of 10^{-4} , 10^{-5} , and 10^{-6} and target HIs of 0.1, 1, and 3.
- Chemicals of concern identified in the baseline ecological risk assessment. For these chemicals of concern, RGOs represent benchmarks, probable effects levels, ambient water quality criteria, and naturally occurring background levels.
- Chemicals of concern identified as chemicals that exceed ARARs. For these COCs, RGOs represent the ARAR.

In addition, results of fate and transport modeling were used to identify chemicals that are likely to exceed ARARS or preliminary remediation goals as a result of leaching from soils to groundwater

or transport to surface water in the future. These chemicals are also considered chemicals of concern, and the RGOs for these chemicals are considered the maximum contaminant level or preliminary remediation goal in the receptor medium.

The ability to meet RGOs for primary risk drivers will be evaluated in the FS. Based on the results of the baseline risk assessments, primary risk drivers include uranium, nitrate, and VOCs in the upper third section of BCV.

ES.8 TECHNICAL CONSIDERATIONS FOR REMEDIAL ACTIONS

Contamination in groundwater and surface water at, and west of, the IP is derived from migration away from the source sites. A remedial strategy with the goal of reducing contaminant fluxes at the IP to acceptable levels will have two general options: (1) take actions at the IP to mitigate exposures downstream, or (2) take actions upstream and east of the IP that will result in achieving the remedial goals at the IP.

Actions taken at the IP would be groundwater and surface water capture/treatment type actions. Actions taken upstream of the IP would involve interception of contaminant pathways to tributaries (i.e., actions taken closer to the sources) that would result in remediation of nitrate and uranium in contaminated surface water in Bear Creek and groundwater in the Maynardville Limestone. These actions may also be groundwater and surface water treatment actions taken closer to the sources, but could also include source isolation/treatment/removal to mitigate three pathways. In addition, a plume of VOC-contaminated water in the Maynardville Limestone that has no apparent source would also need to be addressed.

The following physical, chemical, and hydrological parameters will need to be addressed to achieve the remedial action objectives for BCV.

ES.8.1 Considerations for Remedial Actions for Groundwater and Surface Water at the Sources

- Large volumes of contaminated groundwater exist in the Nolichucky Shale at the contaminant sources ($7.1 \times 10^6 \text{ m}^3$ at the S-3 Site, $0.4 \times 10^6 \text{ m}^3$ at BYBY, and $4.0 \times 10^6 \text{ m}^3$ at BCBG). Due to the fractured nature of the Nolichucky Shale, < 10% of this contaminated volume occurs in fractures that are accessible for withdrawal of water. More than 90% of this volume occurs in the very low permeability matrix and contains the highest concentrations of contaminants. The mechanism for migration of contaminants from the matrix to flowing fractures is by chemical diffusion and is termed matrix diffusion. The result of matrix diffusion is that, if pump and treat technology is used to remediate a plume in fractured bedrock, many times the contaminated volume of water will require pumping before acceptable concentrations can be achieved.
- DNAPL occurs at two locations in the Nolichucky Shale, the S-3 Site and BCBG (Fig. ES.5). The nature of migration of DNAPL in the subsurface means that small droplets of residual DNAPL exist rather than large and identifiable pools of liquids. Thus, identification and extraction of DNAPL is not possible. Dissolution of DNAPL at these sites will, therefore, act as a dispersed source of contamination to groundwater.

- Some of the solid waste at BYBY, BCBG, and most likely at the S-3 Site is inundated by shallow groundwater and will be a continuing source for groundwater contamination unless it is hydraulically isolated from groundwater.
- Contaminated shallow and deep groundwater in the Nolichucky Shale migrates rapidly through discrete fractures or preferential pathways along geological strike to discharge to tributaries or directly to Bear Creek. Most of the groundwater flux most likely flows through a few discrete fracture zones; however, the specific locations and depths of these fracture zones are not known at this time and may be difficult to ascertain.
- Flow in shallow groundwater and tributaries is "flashy." For example, flow in NT-3 varies from extremes of 0 L/s to over 150 L/s (2400 gpm). Average baseflow in NT-3 varies from 0 L/s in summer to almost 10 L/s (160 gpm) during winter months.

ES.8.2 Considerations for Remedial Actions for Groundwater and Surface Water in the Maynardville Limestone

- Water flows through a network of interconnected cavities and fractures up to 150 m (500 ft) deep in the Maynardville Limestone. Most of the groundwater flux most likely flows through a few discrete cavities, however, the flux through these cavities and the specific locations and depths of these cavities are not known at this time and may be difficult to ascertain.
- The total flux of groundwater flow at the IP was calculated as 54,000 m³ during the 10-month monitoring period for the RI (~65,000 m³/a or 52.5 acre ft/a).
- Flow in Bear Creek at BCK 9.47 is flashy and varies from extremes of < 1 L/s (~16 gpm) to over 10,000 L/s (16,000 gpm). Average baseflow varies from < 1 L/s in summer to 100 L/s (1,600 gpm) during winter months. Flow in SS-5 is more steady than in Bear Creek and varies from extremes of < 3 L/s (~48 gpm) to over 100 L/s (1600 gpm). Average baseflow varies from < 3 L/s in summer to 10 L/s (160 gpm) during winter months.
- Concentrations of contaminants in BCK 9.47 and SS-5 are relatively dilute. For example, at BCK 9.47, uranium ranges from 52 to 152 µg/L and nitrate ranges from < 1 mg/L to 46.2 mg/L.

ES.8.3 Considerations for Remedial Actions for Soils at Sources

- Large volumes of buried waste materials exist at the BCBG, some of which are potentially pyrophoric or explosive. In addition, large volumes of waste materials and contaminated fill exist at BYBY, SL 1, and the S-3 Site.
- At some locations in BCBG and BYBY, and probably at the S-3 Site, waste materials are inundated by shallow groundwater.
- At some locations in BYBY and BCBG, waste materials occur at the surface of the soil. These locations constitute the most likely areas where direct exposure to waste could occur with unrestricted use.
- Many of the source areas are covered with RCRA caps that limit the possibility of direct exposure to waste materials under the current land use.

ES.8.4 Consideration for Remedial Actions for Soils/Sediments in the Bear Creek Floodplain

- The sampling strategy for floodplain soils and sediments was, by intention, biased towards likely sediment accumulation areas. The relatively small number of samples for the area of land that constitutes the Bear Creek floodplain means that volumes of contaminated soils are not well defined. The data indicate that contaminant concentrations are low and soil volumes are small (most likely < 1000 m³).

ES.8.5 Relative Importance of Pathways

For actions taken close to the sources, the relative importance of the pathways with regard to the contaminant mass flux is a consideration for which remedial actions will be most effective from a watershed perspective. The following parameters, therefore, also need to be considered:

- Figure ES.3 shows the potential human health risk/hazard from surface water and groundwater at the IP posed by exposure to the individual COCs. Figure ES.3 also lists the relative proportions of the flux of the two principal COCs, nitrate and uranium, derived from sources in BCV. Based on this ranking of source contributions to the total potential risk/hazard at the IP (refer to Sect. 3.2.7 and Appendix E), most of the potential risk/hazard is from uranium migrating from BYBY and the S-3 Site. In addition, most of ungauged flux is most likely from BYBY and the S-3 Site, further increasing the proportion of uranium flux derived from these sites. Nitrate is the second most important COC at the IP and is 94% derived from the S-3 Site.
- Reduction of the contaminant mass flux through shallow groundwater and/or surface water discharge in tributaries at BYBY and S-3 Site will reduce the overall mass flux of uranium and nitrate at the IP and achieve a reduction of potential risks and hazards at this location. For example, a reduction of 70% in the uranium flux from NT-3 and a similar reduction in the ungauged flux derived from this site (assumed to be 70% of the total ungauged flux) would result in a 43% reduction in the total uranium flux at the IP. A reduction of 70% in the contaminant flux from S-3 Site (NT-1 and NT-2) and a similar reduction in the ungauged flux derived from this site (assumed to be 30% of the total ungauged flux) would result in an 18% reduction in the total uranium flux at the IP, and a 66% reduction in the total nitrate flux.
- COCs for ecological receptors in Bear Creek are mainly metals in reaches 1 and 2 that are derived from discharge in NT-1, -2, and -3 (with the exception of mercury for which no sources have been defined in BCV). It can be expected that actions taken to reduce the contaminant flux in any of these pathways will result in a reduction of ecological impacts in Bear Creek east of the IP and reduce impacts to piscivores in all of BCV.

ES.9 DOCUMENT LAYOUT

The BCV RI Report is contained in six volumes. Volume 1, the RI Report, summarizes the extensive data analysis and interpretation that have been completed for the RI. The eight chapters of the Report address (1) the strategy used to satisfy the regulatory requirements in BCV; (2) physical and hydrogeological properties of BCV; (3) results of environmental investigations conducted to determine the nature, extent, fate, and transportation of contamination; (4) ARARs; (5) results of baseline human health risk assessment; (6) results of baseline ecological risk assessment; (7) RGOs derived from the RI; and (8) conclusions.

The RI Report is supported by seven appendices (A through G), contained in five volumes, that provide detailed analysis and discussion corroborating the information provided and conclusions reached in Volume 1. Volume 2 contains three appendices addressing (A) the operational histories of BCV waste sites and detailed analysis of inventory records of the BCBG; (B) the historical database for BCV and a detailed description of the field activities conducted during 1994 and 1995; and (C) the valley-wide hydrogeological conceptual model for BCV. Volumes 3 through 6, each containing one appendix, address (D) nature and extent of contamination in BCV; (E) fate and transport of contaminants in BCV; (F) baseline human health risk assessment; and (G) baseline ecological risk assessment.

APPENDIX D

NATURE AND EXTENT OF CONTAMINATION

D.1 INTRODUCTION

The Bear Creek Valley (BCV) Characterization Area includes numerous contaminant sources and environmental media in BCV. To organize the data analysis and reporting in the Remedial Investigation (RI) report for this large and complex area, the data have been divided into four functional areas (FAs). Each FA contains data that are logically interpreted together on the basis of location and/or contaminant source. Chemical data within each FA are further organized into data aggregates on the basis of medium and location within the FA. All data aggregates are completely contained within one FA, and no aggregates span the boundaries of the FAs.

The FAs relate to the main groupings of waste sites and their locations with respect to the distribution of hydrogeologic units in BCV. Three FAs — the S-3 FA, the Oil Landfarm (OLF) FA, and the Bear Creek Burial Grounds (BCBG) FA — include data that relate to the main waste areas located within the Nolichucky Shale. These three FAs are generally interpreted as sources for contamination in the BCV and, therefore, are usually referred to as the *source FAs*.

The principal exit pathway for contaminants migrating in water away from the source FAs in BCV is via groundwater in the Maynardville Limestone or via surface water flow in Bear Creek (HSW 1995). Thus, the fourth FA — the Maynardville Limestone and Bear Creek FA — is located downgradient of the three source FAs and encompasses the integrated exit pathway for contaminants migrating away from the various source units in the source FAs. This FA also contains waste sites and potential sources that are located directly on the Maynardville Limestone and may contribute contaminants directly to the exit pathway. The Maynardville Limestone and Bear Creek FA is referred to as the *integrator FA*.

As demonstrated by the conceptual models for groundwater movement in BCV described in Appendix C, groundwater in source FAs acts both as a receptor medium and as a potential source for downgradient contamination of the integrator FA. Groundwater aggregates in the source FAs are restricted to wells with screened intervals in the Nolichucky Shale.

The data aggregates were formed to aid in statistical analysis of the data and in comparison of analyte concentrations to concentrations from background samples. Comparison with background samples is necessary to determine which analytes are site-related as the first step in determining the list of contaminants of concern (COCs) for the FA. The COCs are used to perform the risk assessment and, ultimately, to make remedial decisions for the site. For this reason, only data of known quality assurance have been allocated into aggregates; the data included in the aggregates include both recent data [data collected during the BCV RI field activities (RIFA)] and historic data (data obtained from investigations conducted in BCV before the BCV RIFA were initiated). In some cases, data with insufficient quality documentation have been used qualitatively to support the data interpretation for each FA. Instances in which qualitative data do not correlate with the aggregate data are identified as uncertainties, which may or may not need to be addressed prior to decision making.

D.2 DESCRIPTION OF FUNCTIONAL AREAS

Figure D.1 shows the distribution of the FAs in BCV; the following is a brief description of these groupings:

D.2.1 S-3 FUNCTIONAL AREA

The S-3 FA covers the soils, groundwater, and surface water at, and immediately downgradient from, the S-3 Site. It is composed of two soil, three surface water, and one groundwater data aggregates. Groundwater in this aggregate is restricted to groundwater in the siliceous dominant formations of the Conasauga Group or residuum overlying those formations. Groundwater in the Maynardville Limestone that is contaminated with contaminants derived from the S-3 Site, such as nitrate, is not considered in this FA. Groundwater wells that were included in the S-3 groundwater data aggregate were determined by using the Groundwater Quality Report (GWQR) (HSW 1995) and the Oak Ridge Y-12 Plant well construction database (Jones et al. 1995) to identify nitrate-contaminated wells in the clastic formations.

D.2.2 OIL LANDFARM FUNCTIONAL AREA

The OLF FA covers the soils, groundwater, and surface water at, and downgradient from, OLF, Sanitary Landfill 1 (SL 1), and Boneyard/Burnyard (BYBY). It is composed of three soil, three surface water, and one groundwater data aggregates. As in the S-3 FA, only groundwater wells within the siliceous dominant formations and overlying residuum were included in the OLF groundwater data aggregate.

D.2.3 BEAR CREEK BURIAL GROUNDS FUNCTIONAL AREA

The BCBG FA covers the soils, groundwater, and surface water at, and downgradient from, the BCBG. It is composed of seven soil, three surface water, and two groundwater data aggregates. As in the S-3 FA, only groundwater wells within the siliceous dominant formations and overlying residuum were included in the BCBG groundwater data aggregates.

D.2.4 MAYNARDVILLE LIMESTONE AND BEAR CREEK FUNCTIONAL AREA

The Maynardville Limestone and Bear Creek FA covers the soils, groundwater, and surface water in the Bear Creek floodplain and the outcrop of the Maynardville Limestone. It is composed of five floodplain soil, three surface water, four spring, and one groundwater data aggregates. Only groundwater wells within the Maynardville Limestone and Chestnut Ridge formations in BCV were included in the Maynardville Limestone and Bear Creek groundwater data aggregate.

D.3 VALLEY-WIDE DATA CONCERNS

Although division of the BCV database into the four FAs facilitates the presentation of chemical data for the RI report, a valley-wide approach is necessary to avoid repetition of data analysis and presentation in two instances: background data and contaminant plumes.

- **Background Data.** The data used for background reference as well as the methods used for background comparisons are common to all four FAs. Thus, the methods for establishing chemical background values for each medium and the methods for conducting the background screen are covered in Sect. D.4. The results of the background screen and identification of site-related contaminants, however, are described in the sections for each FA (Sects. D.6 through D.9).
- **Valley-Wide Contaminant Plume Maps.** Many of the contaminant plumes in groundwater have migrated from the source FAs into the integrator FA. To prevent repetition of figures depicting the extent of groundwater contamination, which is valley-wide, figures depicting the extent of these contaminants are presented together in Sect. D.5. Detailed discussions of the nature and extent of these contaminants are presented within the sections for each FA (Sects. D.6 through D.9), which refer back, as applicable, to the figures in Sect. D.5.

D.4 METHODS FOR IDENTIFYING SITE-RELATED CHEMICALS AND RADIONUCLIDES

Methods for identifying site-related chemicals and radionuclides are described in the following subsections by medium: (1) soils and sediments, (2) groundwater, and (3) surface water. The general process for identifying site-related chemicals and radionuclides follows four steps: data quality evaluation, data aggregation, comparison to background, and qualitative technical evaluation. This process is summarized in Figs. D.2 and D.3 for soil and water aggregates, respectively.

D.4.1 SOILS AND SEDIMENTS

Data for determining the nature and extent of soils and sediment contamination were obtained from two field investigations: the BCV Operable Unit (OU) 1 investigation, which produced 28,261 soil analytical results, and the BCV Floodplain Soils and Sediment (FPSS) investigation, which produced 13,187 soil analytical results. In most cases the BCV OU 1 data represent the characteristics of soils surrounding the major waste units within the valley; however, the samples collected in the area of the BYBY were taken from within the waste unit itself. FPSS soils data represent the soils in the floodplain of the creek; sediment data represent sediments in the stream bed of Bear Creek.

The process used to perform an initial evaluation of the soil and sediment data is summarized in Fig. D.2 and detailed below.

D.4.1.1 Data Validation Screens

Analytical data validation was performed on all soil and sediment samples, as summarized for all major data types in Table D.1. Validation results for soils are presented in Table D.2. For the BCV OU 1 investigation, 1.3% of the data were rejected for analytical quality control reasons. No single soils aggregate had more than 1.78% of the collected sample rejected. All rejected data were eliminated from the data sets. Most of the rejected results were non-detects, and most of the rejections resulted from poor surrogate sample recovery rates.

For the FPSS soils task, only 0.42% of the data were rejected. However, unlike the BCV OU 1 data, several of the rejected data were considered important for the RI. Of the 46 samples analyzed for uranium isotopes, 15% were rejected. The rejected uranium data were from samples collected throughout Bear Creek — not from a single location. The reason for the “R” qualifier was that radiological chemical recovery was <20%, indicating that the actual uranium activity concentrations at the site may be higher than the reported results. Samples were not re-analyzed because the laboratory criterion for re-analysis is a recovery of <10%. The uranium data were ultimately used in the RI because (1) recovery results were in the “gray” area (10 to 20%), suggesting that they are border-line useful, and (2) the available results, no matter how questionable from an analytical viewpoint, provide insight into the characterization of the extent of uranium in the floodplain soils.

The data validation results for both BCV OU 1 and the FPSS soils are discussed in detail in Appendix B.

One additional screen was performed on the soil data after formal validation. In some cases, a chemical was not detected, but the detection limit for the analysis was too high to conclude that the chemical was not present *at levels of concern* (e.g., the detection limit was above risk-based

preliminary remedial goals). This often occurs when a sample must be diluted due to the presence of high concentrations of a specific analyte. To prevent a potential “false negative” conclusion that the soil poses no risk, “non-detect” results where the detection limits were 5 times greater than the contract-required detection limits were excluded from the database. Only 0.9% of all soil data were eliminated from the database by applying this rule.

D.4.1.2 Data Aggregates

Data from soil borings were aggregated, or placed into subsets, based on two criteria: (1) proximity of the boring to a waste source and (2) sample depth. For example, all soil samples believed to represent the BYBY were placed into a subset and further aggregated by depth to meet risk assessment requirements. [The risk assessment evaluates potential contamination from 0 to 2.4 m (0 to 8 ft) to evaluate potential risks to a future resident who may contact soils while excavating a basement.] Soil boring samples were generally collected from 1.2-m (4-ft) intervals. Sample results from the top two intervals [0 to 2.4 m (0 to 8 ft)] were grouped together, and sample results from intervals deeper than 2.4 m (8 ft) were grouped together.

Tables D.3 and D.4 summarize the BCV soil samples and their associated aggregates. Two borings, SBY-27 (from the BYBY) and SBG-42 (from south of BCBG C-East), were not included in a soil aggregate. SBY-27 was collected from an exposed drum near the BYBY, and SBG-42 was collected from a noticeably yellowish-colored anomaly on the ground surface. Both samples had high levels of radioactivity and were handled and analyzed separately from other samples. Analytical results for these samples, which are assumed to represent “hot spots” of actual waste material, are presented separately. As indicated in the tables, only a subset of the samples collected during the OU 1 field effort was sent to a laboratory for full analysis. Bear Creek sediment data were evaluated as a single data set; floodplain soils were aggregated into three data sets based on sample depth: 0 to 1.2 m (0 to 4 ft), 1.2 to 4.9 m (4 to 16 ft), and 4.9 to 9.8 m (16 to 32 ft).

D.4.1.3 Comparison to Background Data

A major step in assessing soils and sediment data is to distinguish between chemicals that are likely related to past waste disposal practices and those that may be naturally occurring. The selected statistical method for determining which chemicals detected at the sites are present above background levels is to compare site sample results to background upper tolerance limits (UTLs). A tolerance limit is the concentration that contains a specified portion of the population with a specified confidence. For background comparison, the standard is to use the upper 95% tolerance limit with a 95% confidence on that limit.

Soils

Background data used to construct the UTLs for soil were taken from the Background Soil Characterization Project (BSCP), which characterizes background soils for the entire Oak Ridge Reservation (ORR) (DOE 1993). The study collected samples from six geologic formations: Dismal Gap (Maryville), Nolichucky, Copper Ridge, Chepultepec, Chickamauga-Bethel Valley, and Chickamauga-K-25.

The UTL method is best applied in situations where there is little variance in background concentrations (e.g., in areas of fairly homogeneous soil conditions). Thus, the background UTL values for the BCV RI were constructed using a subset of the background data for the ORR: those data representing the three horizons of the Dismal Gap (Maryville) and Nolichucky formations. These formations were selected because the waste sources in the BCV are located on them. Four

samples were collected from each horizon, resulting in a total of 24 data results available to construct the UTLs (2 formations $\times$ 3 horizons $\times$ 4 samples).

Sediments

Background sediment data were taken in three BL tributaries that are not flumed by waste disposal activities. Background samples were taken in NT11 (Station RD 18), NT13 (Station RD19), and NT15 (Station RD20).

Once the background dataset was established, background UTLs for the BCV RI were developed for each chemical using Draft ERWM/ER-P2000.017, the Lockheed Martin Energy Systems, Inc. (Energy Systems) procedure for performing background comparisons. This procedure includes five steps:

- (1) Group analytes into one of three frequencies of detection categories:
 - Frequency of detection $\geq 50\%$
 - Frequency of detection between $>0\%$ and 50%
 - Frequency of detection = 0% (all non-detects)
- (2) When frequency of detection $\geq 50\%$, determine the best fit distribution for each analyte using the Shapiro-Wilk test. Use normal data and log-transformed data to test the hypothesis that data are normally distributed; if one fit is statistically significant ($p > 0.05$), assign the distribution. If both fits have associated confidence of $p > 0.05$, select the fit based on the largest p-value. Calculate the 95% UTL using either the data or log-transformed data:

$$UTL = \bar{x} + k(STD_x) ,$$

where:

$\bar{x}$	=	arithmetic mean of the background data,
k	=	appropriate tolerance factor for one-sided tolerance interval,
STD_x	=	standard deviation of the background concentrations.

If the UTL is greater than the maximum detected background concentration, use the maximum detected background concentration for the background criteria.

If the distribution is neither normal or log-normal (where $p > 0.05$), calculate the nonparametric UTL as described by Walpole and Myers (1978).

- (3) If the frequency of detection is 0% to 50% , calculate a 99% nonparametric UTL, or the 99th percentile of the background data (following Energy Systems draft procedure ERWM/ER-P2000.017). For sample sizes ≤ 59 , the nonparametric UTL concentration equals the maximum detected values. Because the sample sizes for the background data set were all < 59 , all nonparametric UTLs used for the BCV soil screen represent the maximum detected background value.
- (4) If the frequency of detection is 0% (no detects), use the largest reported quantitation limit for the background screen.

- (5) If fewer than three results are available for a given chemical, use the maximum detected background concentration for the screen.

Table D.5 provides background criteria for soils constructed using the ORR background data and the Energy Systems Environmental Restoration procedure for background comparisons. Table 5a provides the background criteria for sediments. To apply the background UTLs to the site-related data, all results in a given soil or sediment aggregate were compared to the chemical-specific UTL. Analytes with no detections greater than the UTL were considered naturally occurring and not related to past waste disposal activities in BCV. If a single detection was greater than the UTL, the analyte was identified as “above background,” except for the few cases discussed in Sect. D.4.1.4.

D.4.1.4 Weight of Evidence Screens

Because of inherent problems in applying a single statistical tool to datasets that have different characteristics, an additional screening step was applied to the BCV data after they had been subjected to the background screen. This screening step is referred to as a weight of evidence screen; that is, multiple types of evidence are considered to determine whether a chemical is site-related or naturally occurring. This screen was applied to naturally occurring metals that were not screened out during the statistical screen, for whatever reason. The most common reasons for not passing the background screen were: (1) the chemical was not detected in the ORR background study, presumably because naturally occurring levels are near the detection limit used for that background analysis; or (2) the percent detects or skewedness of the background distribution made defining the UTL difficult. The weight of evidence screens applied to the inorganics are described below.

Ubiquitous Essential Elements

Naturally occurring essential elements include sodium, potassium, calcium, magnesium, and iron. These chemicals are an integral part of the country’s food supply, are often added to foods as supplements, and thus are not considered “contaminants” in most Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) studies. Thus, such chemicals are not addressed as contaminants in the RI unless they are found at extreme levels. However, data results are sometimes used for other purposes in the RI (e.g., geochemical analysis).

Frequency of Detection Above the UTL

Because the UTL represents the 95th percentile of the data (not the full range), one would expect hits above the UTL that are still within the range of background. In several cases a single sample result was greater than the background UTL, and the difference between the result and the UTL was considered small. For example, arsenic was detected in the S-3 Site soils [0 to 2.4 m (0 to 8 ft)] in 1/20 samples at 20.5 mg/kg, compared to an estimated background UTL of 20.2 mg/kg. In this case, arsenic is assumed to be naturally occurring. In a second example, beryllium was detected above the background UTL in a single sample in the deep soils at SL 1. The background UTL for beryllium is 2.12 mg/kg; the single detect in the SL 1 was 2.2 mg/kg. In this example, beryllium was considered to be within the range of background. All cases in which similar judgement was applied are clearly identified in the data summary tables.

Detection Limit Review

Experience with background comparisons at other locations in the country and at other sites within the ORR [e.g., the RI for the K1070 C/D Classified Burial Ground (DOE 1995)] has shown that statistical background comparisons are difficult to perform for cadmium and silver. The naturally

occurring concentrations of these chemicals are so close to analytical detection limit capabilities that the slight difference in analytical detection limits between the background study and the RI invalidates dataset comparisons. For example, cadmium was not detected in the ORR background study; however, the detection limits used for the background study (as high as 2.8 mg/kg) exceeded the concentrations detected in the BCV studies (e.g., 1.5 and 2 mg/kg in S-3 Site samples).

Data from U.S. Geological Service (USGS) studies of concentrations of background metals, conducted both on the ORR and at other locations in the country, also indicate that cadmium is naturally occurring at concentrations near the detection limit (Boerngen and Shacklette 1981; Pulliam 1985a and b). Background cadmium levels in these studies range from 1 to 10 mg/kg, with an average value of 2 mg/kg. Most of the cadmium detections in the BCV soils were near 1 mg/kg. Silver was similar in that most site-related concentrations were within the USGS background results of 0.7 to 5 mg/kg. Another analyte for which USGS data were used to evaluate background was tin (which was not analyzed for in the ORR background soil study). USGS analyzed 355 tin samples from the continental United States and found detections ranging from <0.1 to 10 mg/kg. BCV soil results for cadmium, silver, and tin are compared to USGS rather than ORR background criteria because (1) the ORR detection limits used for cadmium and silver were too high, and (2) tin was not included in the ORR background study. Data results for these metals that appear to be within the USGS range of naturally occurring levels are not identified as site-related contaminants.

D.4.1.5 Data Summaries

The screening process and screening results are summarized for each data aggregate in the tables presented in Sects. D.6 through D.9. Chemicals that are identified as “site-related” as opposed to naturally occurring are highlighted in the tables and discussed in text. All cases for which a weight of evidence screen was applied are documented.

D.4.2 GROUNDWATER

Three sources of groundwater data were used to help define the nature and extent of groundwater contamination in BCV: historic data obtained from annual GWQRs for BCV wells, Geoprobe™ data obtained during BCV OU 1 sampling, and a single sampling event for radiological analysis of groundwater during Fall 1995.

Groundwater wells in the valley were divided into three source FAs and one integrator FA (Table D.6) to (1) represent the sources from which contaminants in the wells were likely associated and (2) distinguish between “secondary source” plumes in the Nolichucky formation and the contaminants migrating through the Maynardville formation. The wells were also classified as either shallow wells [<30 m (100 ft)] or deep wells [>30 m (100 ft)] to better delineate the mechanisms of plume movement.

Statistical analysis of the groundwater data was performed by well rather than as an aggregate, as was the case with the soils data.

GWQR data are available for 1986 through 1994. A “rule of 4” was applied to all GWQR data, except for radionuclide data. The rule of 4 requires a minimum of four data points: if a well has four data points after 1990, use 1990 through 1994 data; otherwise, use data from 1986 through 1994. Radionuclides are excluded from the rule of 4 because changes in analytical procedures for radionuclides resulted in elimination of data generated before 1991. Application of the “rule of 4”

eliminated 16% of the total GWQR dataset from use in the BCV RI. Even after eliminating 16% of the data, 144,485 analytical records were available for use in the analysis.

The rule of 4 was applied because the most recent data best characterize the nature of existing conditions in BCV. Furthermore, the GWQR datasets are similar for all wells, no matter what year they were constructed; thus, use of GWQR from different years does not result in use of disparate datasets for the various wells. The GWQR data and data handling methods are presented in HSW (1995) (GWQR, Part 1).

The process used to identify the nature and extent of groundwater contamination is summarized in Fig. D.3 and detailed in the following subsections.

D.4.2.1 Data Validation Screens

GWQR data did not receive the same type of validation that was performed on BCV OU 1 and FPSS data; however, the GWQR data verification and validation efforts were reviewed to check that the data quality process was compatible with CERCLA goals. In addition to the data validation activities described below, two verification steps were performed on the data (Energy Systems 1996):

- (1) Data transferred from the laboratory were electronically checked for mistakes in the electronic file (e.g., unexpected character data).
- (2) Data in the database were visually checked against hardcopy reports for completeness and accuracy.

Data were blank validated [e.g., volatile organic compound (VOC) results were compared to corresponding sample blank results] to verify that detected analytes were not introduced during the sample collection and analysis process.

Radiological minimum detectable activities (MDAs) were not available for GWQR groundwater data; in lieu of sample-specific MDAs, data were screened against reasonable MDAs (e.g., current contract-required MDAs). Radiological data were also screened against the reported counting errors for each sample analysis.

BCV OU 1 groundwater data were validated using the same criteria as spelled out for OU 1 soils data (Table D.1). Table D.7 summarizes the results of the analytical validation effort. Most of the rejected results were “non-detects.” Because none of the questionable data were determined to be critical to the BCV RI, they were excluded from the data evaluation.

As with the soils data, an additional screen was performed on the groundwater data after formal validation. “Non-detect” results (i.e., the detection limit was five times greater than the project detection limits) were excluded from the database. Because sample-specific detection limits were not available in the GWQR dataset, Resource Conservation and Recovery Act (RCRA) SW846 detection limits were used to screen the GWQR data. Fewer than 1% of the groundwater data were screened from the database by applying this rule.

D.4.2.2 Additional Data Screens

Data screens applied to the inorganic results included (1) reviewing specific analytical methods in cases where results were available from two methods; (2) comparing filtered (dissolved) versus

unfiltered (total) data results; (3) performing a charge balance on data results; and (4) screening data on the basis of GWQR findings. These screens are described below.

For some metals, results are available from two different analytical methods: gas furnace atomic absorption (GFAA) and inductively coupled plasma (ICP). ICP results for arsenic, cadmium, chromium, lead, selenium, and silver were screened out of the dataset when GFAA results were available. For barium and beryllium, GFAA results were screened out if ICP results were available.

In most cases, both dissolved and total results were available for a single sampling event. A systematic screen is performed to compare dissolved concentrations to total concentrations; dissolved amounts, because they are a subset of the total amounts, should be the lower of the two. Thus, if the dissolved fraction exceeded the total fraction by more than 10%, the data were screened out of the BCV RI dataset. A total of 0.07% (114 of 172,039) of the GWQR analytical results were eliminated using this screen.

A third systematic screen that was applied to the GWQR data was a charge balance screen. This screen helps to identify questionable data by checking the internal consistency of results from a single well and single sampling event. The equation for calculating the charge balance is:

$$\frac{\text{total cations} - \text{total anions}}{\text{total cations} + \text{total anions}} \times 100 ,$$

where:

$$\begin{aligned} \text{Total cations (milliequivalents)} &= \text{Calcium} + \text{Magnesium} + \text{Potassium} + \text{Sodium} + \\ &\quad \text{Ammonium-N (converted to ammonium)} + \text{pH} \\ &\quad \text{(converted to H}^+) \\ \text{Total anions (milliequivalents)} &= \text{Fluoride} + \text{Sulfate} + \text{Nitrate-N (converted to nitrate):} \\ &\quad \text{Chloride} + \text{Alk-HCO}_3 \text{ (converted to bicarbonate)} + \\ &\quad \text{Alk CO}_3 \text{ (converted to carbonate)} + \text{pH (converted to} \\ &\quad \text{OH}^-) \end{aligned}$$

Although ideally the charge balance would fall between $\pm 10\%$, a more realistic goal of $\pm 20\%$ is used to screen the data. Only 2.65% of the analytical results in the GWQR dataset were screened out using the charge balance screen.

The final screen applied to the data was to incorporate the results of data evaluation experience gained over the past 8 years. Patterns detected in several wells suggest that well construction materials, anomalous geochemical conditions, or high total suspended solids (TSS) may result in questionable data. These findings, published in recent GWQRs (e.g., HSW 1995), are summarized in Table D.8. Specific analytical results for the wells listed in Table D.8 have been screened from the RI dataset as data inconsistencies. The screened analytical results represents only 0.19% of the dataset.

D.4.2.3 Background Comparison

The screening method used to determine if detected analytes are present in groundwater at naturally occurring levels differed from that used for soils. The background level of inorganics analyte was determined by using the GWQR data. The methods for defining background levels using

this historical data and for screening the BCV RI data using the calculated background levels are summarized in the following subsections.

Defining Background Levels

Historical data from a total of 423 GWQR wells at the Y-12 Plant were used to define naturally occurring levels of inorganic analytes (Energy Systems 1996). Of these wells, 32 were determined to be “contaminated,” “turbid,” or affected by well construction problems; therefore, data from these wells were not used to define background levels. Of the 423 wells, 261 provided sampling data used for the BCV RI.

In this study, background tolerance limits were calculated for each inorganic analyte by using a multi-variate cluster analysis technique. GWQR wells were “clustered” based on five geochemical parameters: nitrate, alkalinity, sodium, magnesium, and conductivity (see Fig. D.4). Ten well clusters were identified (Table D.9). Wells in four of the clusters — 5, 7, 8, and 9 — displayed characteristics of being impacted by nitrate contamination and thus were not used to calculate background levels. Data from the wells in the remaining six clusters (1, 2, 3, 4, 6 and 10) were used to calculate background values. A surrogate cluster analysis was used to determine which background values for the six “uncontaminated” geochemical clusters should be used when screening wells in the four “contaminated” clusters.

Data for calculating background values were censored in the following manner (Energy Systems 1996):

- Data with elevated detection limits (e.g., five times the contract laboratory procedure detection limit) were screened from each cluster dataset.
- Results reported as less than the detection limit were set equal to one-half the detection limit.
- A median value was calculated for each analyte in each well within a cluster.
- Kruskal-Wallis tests were run to compare analytes datasets among the clusters. Nonparametric multiple comparison tests were run to determine the groups of well clusters that could not be distinguished from each other. If analytes from different clusters could not be distinguished from each other, data from the clusters were combined to calculate a UTL.

Background UTLs were calculated using the following steps:

- (1) If >50% of median results from wells in a cluster or cluster group were “non-detects,” check for outliers, calculate percentiles, and determine a nonparametric UTL.
- (2) If the median values from all wells in a cluster or cluster group are detects, test for normality and check for outliers at the upper end of the distribution. If the dataset of median values does not differ significantly from “normal,” calculate a parametric UTL; if the dataset of median values appears to be “log-normal,” calculate a nonparametric UTL.
- (3) If 0 to 50% of the wells in a cluster have median values that are detects, test for normality and check for outliers at the upper end of the distribution. If no outliers, reconstruct the lower tail using the probability plot generated from the upper tail. Retest the normality of the distribution. If the dataset of median values does not differ significantly from “normal,” calculate a

parametric UTL; if the dataset of median values appears to be “log-normal,” calculate a nonparametric UTL.

All outliers detected, no matter the situation, were screened from the dataset.

Table D.7 lists the wells used in the RI and their cluster assignment. Table D.10 lists the UTLs for inorganics by analyte and by cluster.

Comparison to Background

To determine whether detected inorganics are present at naturally occurring levels, each RI well was assigned to a cluster. In cases where the well fell into clusters 1, 2, 3, 4, 6, or 10, the well was assigned to that cluster; however, when wells were assigned to clusters 5, 7, 8, or 9, the wells were assigned to their surrogate cluster (Fig. D.4). Usable data from each well (e.g., those data that pass the screens summarized in Sects. D.4.2.1 and D.4.2.2) were used to estimate a median value for each analyte in that well. The median value in each well was compared to the UTL for the assigned cluster. If the median value was less than the UTL, the analyte was assumed to be naturally occurring. Table D.7 summarizes the RI well cluster assignments.

D.4.2.4 Data Summaries

Groundwater data, summarized by well and by FA, are presented in the FA discussions (Sects. D.6 through D.9).

D.4.3 SURFACE WATER

Surface water data come from (1) the BCV OU 4 investigation, which focused primarily on delineating contaminant releases from tributaries into Bear Creek, and (2) data collected as part of the National Pollutant Discharge Elimination System (NPDES) compliance sampling effort at various stations along Bear Creek.

The process used to perform an initial evaluation of the surface water is the same as that shown for soils in Fig. D.2. The screening process used for surface water, which is similar to that for soils and groundwater, is summarized below, with reference, as applicable, to Sects. D.4.1 and D.4.2.

D.4.3.1 Validation

Surface water data collected as part of the NPDES program and the BCV OU 4 investigation were verified and validated as described in Sect. D.4.2.1. Rejected data were reviewed to determine the reason for the rejection and the potential usefulness of the rejected data. As a result of this review, three radiological surface water samples collected from North Tributary (NT)-3 were identified as rejected data that could impact BCV RI decision-making. High reported uranium activity concentrations in these samples were rejected because of chemical recovery and matrix spike problems:

- The chemical recovery reported for the samples was low, as low as 13%. The reported results therefore reflect measured results that have been mathematically adjusted to account for low recovery. It is questionable whether the method for adjusting the value is valid when recovery is so low as to be considered an unacceptable recovery by data validators (hence the “R” qualifier). Matrix interference (e.g., high iron in the water) may be the cause of the low

recovery. High concentrations of uranium could be causing the interference and, hence, low recovery, but the laboratory analysts indicated that they have had no recovery problems in the past with even higher concentrations.

- In one sample, matrix spike recovery was above the upper control limit, which is seemingly inconsistent with low chemical recovery.
- The rejected sample results reflect the highest detected concentrations at NT-3, almost double the other results. The October sample was taken in low-flow conditions, during which high concentrations would be expected. *However, the concentration was twice as high as other low-flow concentrations*, thus making the adjusted value suspect.

The RI team determined that the uranium concentrations in the sample are high; they should be used qualitatively to document the nature and extent of contamination in BCV, but too much uncertainty exists to use the data quantitatively.

As with the soils data, surface water results reflecting poor detection limits were screened from the dataset.

D.4.3.2 Background Comparison

Surface water and spring data were aggregated by sampling location (Table D.11.).

Background data for surface water are from samples collected in NT-13. Located west of the BCV waste disposal area and separated from it by four additional tributaries that drain Pine Ridge, NT-13 is isolated from any contaminant waste source. NT-13 has been sampled on a quarterly basis as part of the Y-12 Plant Groundwater Protection Program (GWPP), and sampling results have been reported in the GWQR. Chemical-specific surface water background UTLs were calculated using the same procedure used for soils (see Sect. D.4.1.3). Surface water background UTLs were developed for both filtered and unfiltered data. Filtered data are used primarily in the ecological assessment. Calculated UTLs are presented in Tables D.12 and D.13, respectively. Comparisons between site-related data and background levels were performed in the same manner as for soils data.

Several different background data sets were evaluated for use in screening seep data, including UTLs from NT-13 and background values from various shallow groundwater clusters, including Cluster 1 (shallow groundwater), Cluster 2 (shallow recharge), Cluster 3 (shallow groundwater), and Cluster 4 (Knox Group).

To determine which background dataset best represented the seep data, geochemical data results from the major seeps were run through the surrogate cluster assignment model. Results of these runs indicated that the geochemical makeup of the seep water most closely matched the geochemistry of Cluster 4, the Knox Group. This analysis is one line of evidence that suggests seep water primarily is recharge from the Maynardville formation, likely mixed with some shallow groundwater. For this reason, the Cluster 4 UTL was used to represent background for the seep aggregates.

D.4.4 SUMMARY

Data screening methods presented in the preceding sections were used to identify detected chemicals and radionuclides that are associated with past waste burial practices in BCV. Chemicals

present in the environment that are identified as naturally occurring or essential elements will not be addressed in discussions on the nature and extent of contamination.

Surface water data, summarized by aggregate and FA, are presented in each FA discussion (Sects. D.6 through D.9).

D.5 GROUNDWATER DATABASE AND VALLEY-WIDE MAPS FOR GROUNDWATER CONTAMINATION

The organization of this report into FAs allows the discussion to focus on the individual FAs and their associated contaminants and on the migration pathways within the Maynardville Limestone. However, the FAs have many contaminants in common; thus, the contaminant plume maps for all four FAs are presented in this section to avoid duplication. Presenting all the plume maps in one section also provides a BCV-wide perspective of the plumes, which is necessary to support the conclusions about the nature and extent of contamination in BCV (Sect. D.10).

The locations for groundwater wells in BCV and the valley-wide plumes for selected contaminants in groundwater are presented in Figs. D.5 and D.6 to D.11. The nature and extent of the contaminants shown in these plume maps is discussed in detail in the sections for each FA. A BCV-wide perspective of groundwater and surface water contamination, including potential pathways between the source and integrator FAs, is presented in Sect. D.10.

The groundwater data for the entire BCV were derived from a single source, the annual GWQRs for the Bear Creek Hydrogeologic Regime (BCHR) (e.g., HSW 1995). Part 2 of each GWQR describes the contaminant distributions in BCV for that year. Although each GWQR focuses on the preceding year's sampling efforts, interpretation of the sampling data is based on the cumulative knowledge gained from preparation of the previous reports. This knowledge base has been used in the BCV RI report; the reader is, therefore, referred to the GWQRs [especially the 1994 annual report (HSW 1995)] for additional details concerning the GWQR database.

The difference between previous analyses of the GWQR database and the current analysis presented here is that a rigorous comparison to background values was completed to develop a list of COCs for use in the Human Health Risk Assessment. Although the GWPP included background screens, the method used to establish the background values for the BCV RI is probably more representative of background values throughout BCV. Background values for the GWQRs were obtained from wells on Pine Ridge that are hydraulically upgradient of the waste areas. However, the water types in BCV vary along flowpath (Haase 1991; Toran and Saunders 1992); therefore, simply using values from upgradient wells may not be representative of groundwater at the waste sites. The BCV RI used cluster analysis to identify water types in the valley and then allocated background values to each water type by identifying uncontaminated wells in each cluster. The method for developing the background values for groundwater in this study (Sect. D.4.2) is based on previous knowledge from the GWQRs and is described in detail in *Determination of Reference Concentrations for Inorganic Analytes in Groundwater at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (Energy Systems 1996).

Figure D.5 shows the locations of the wells from the GWQR database that were used to analyze the distribution of contaminants in BCV (Table D.6). The wells on this map are color coded to distinguish well aggregates. Figures D.6 to D.11 show the mean concentrations of nitrate, gross α , gross β , tetrachloroethene (PCE), trichloroethene (TCE), and 1,2-dichloroethene (1,2-DCE) in these wells and the distribution of the contaminant plumes, as interpreted from these concentrations.

The following principles were applied in generating the values for these maps:

- Only data that were accepted for use in the background screen were used to calculate the mean values used on these plume maps, thus maintaining consistency between the risk assessment and the inferred plume distributions.
- Each well in BCV has been sampled multiple times, and the mean values for each analyte were used to represent the analyte concentration. Trends in concentration over time are known to occur in wells in BCV; such trends for nitrate are depicted for selected wells in Figs. D.12 and D.13.

Figures D.6 to D.11 each contain two plots of the groundwater contaminant plume in BCV: the upper and lower maps depict the distribution of a contaminant in wells that are screened <30 m (100 ft) and >30 m (100 ft) below the surface, respectively. For the purpose of this discussion, the two maps are referred to as “shallow” and “intermediate” groundwater plumes. The mean concentrations of analytes at surface water, seep, and spring sample sites are also included on the shallow interval (upper) maps. Although these data are not considered as groundwater values, they are used to support the plume distributions where groundwater data are sparse. Although groundwater in BCV is contaminated with a wide range of chemicals, the distributions of nitrate, gross α , gross β , PCE, TCE, and 1,2-DCE were chosen for depiction on the BCV-wide map because they are the most commonly occurring contaminants in the valley. Other groundwater contaminants are represented by site in each FA.

The 30-m (100-ft) depth distinction was made because changes functions in groundwater geochemistry have been observed at this depth in clastic formations in BCV (Haase 1991; Dreier, Early, and King 1993, Appendix C). These studies suggest that groundwater in the clastic formations at depths >30 m (100 ft) probably has considerably longer residence times than the shallower groundwater, which results in the different geochemical compositions (see Sect. 2). In addition, the shallow plume maps presented here correlate well with the water table and shallow bedrock intervals defined in the GWQRs, while the intermediate plume maps correlate with the intermediate and deep intervals defined in the GWQRs.

Figures D.14 to D.29 depict groundwater contaminant concentrations in cross-sections of BCV. These figures are consistent with the plume maps in that mean values for concentrations are used, and only data accepted for the risk assessment are included.

The hydrogeologic conceptual model for BCV (Appendix C) should be considered when reviewing these maps. Geology and hydrogeologic properties of rocks in BCV are heterogeneous. Thus, small-scale heterogeneities in the formations have probably resulted in small-scale heterogeneities in contaminant distributions within the plumes. The plume maps should, therefore, be considered as the maximum extent of contaminants in these plumes, with the plume colors indicating the average concentrations of the contaminants within those areas.

D.6 S-3 FUNCTIONAL AREA

The S-3 FA is composed of two soils, three surface water, and one groundwater chemical data aggregates encompassing these media at, and immediately downgradient of, the S-3 Site. Figure D.30 shows the distribution of groundwater wells, and surface water, soil, and sediment samples sites for data in the S-3 FA.

Groundwater in this aggregate is restricted to groundwater in the Nolichucky Shale. Groundwater in the Maynardville Limestone that is contaminated with S-3 derived contaminants, such as nitrate, is not considered in this FA and is discussed in the Maynardville Limestone and Bear Creek FA (Section D.8). Table D.6 lists the groundwater wells in the S-3 groundwater aggregate.

Table D.11 lists sample sites in the S-3 FA surface water aggregates and Table D.3 lists sites in the S-3 FA soil aggregates.

D.6.1 S-3 SITE – DETAILED SITE HYDROLOGY

Groundwater Hydrology

The S-3 Ponds are located just west of the groundwater divide between the Upper East Fork Poplar Creek (UEFPC) Hydrogeologic Regime and BCHR. A water table mound that was present below the S-3 Ponds while the ponds were accepting liquid wastes has diminished in size and is now almost indistinguishable in the shallow interval (Geraghty and Miller 1989). A nitrate plume that occurs in the groundwater of both the BCHR and UEFPC Hydrogeologic Regime is also found in groundwater below the S-3 Ponds, which indicates that, during the time this groundwater mound was present, the groundwater divide passed under the S-3 Ponds (Turner et al. 1991).

Dreier, Early, and King (1993) present detailed hydraulic head measurements from four deep coreholes (GW-132, -133, -134, and -135) that form a transect across BCV near the S-3 Site. A Westbay™ multiport sampler was installed in each corehole, and hydraulic head was measured at discrete intervals within the groundwater system. Figure D.31 is a hydrogeologic cross-section at the S-3 Site, as delineated by hydraulic head measurements (Dreier, Early, and King 1993). An isolated pressure bulge within the Nolichucky Shale bedrock was identified down dip of the S-3 Ponds and is attributed to contaminated water that infiltrated from the S-3 Site when the ponds were active. Dreier, Early, and King (1993) identified two factors that contributed to the pressure bulge: (1) the density contrast between waste water and natural groundwater and (2) the superposed water mound from the period of operation at the S-3 Ponds, which elevates the fluid pressure in the region surrounding the flow pathway. Because the hydraulic conductivity of the Nolichucky Shale is low [locally on the order of 1×10^{-7} to 1×10^{-8} cm/sec (King and Haase 1988)], the increased pressure is expected to dissipate very slowly. Because the source of the elevated fluid pressure no longer exists, the flow system is expected to ultimately return to a static, pre-S-3 Ponds configuration.

The range of groundwater levels recorded in wells at this site in relation to the waste unit is shown on Fig. D.32. These data show that waste materials located in the SW quadrant of the former S-3 Ponds are likely submerged when groundwater is at its highest elevations. Waste materials in the remaining quadrants are probably 2 to 6 ft above the water table year round. However, these data are based on water levels recorded in wells located at the edge of the S-3 Ponds cap; no data are available

to determine the water table elevation below the cap so the extent of inundation of the sludges in the former ponds is uncertain.

Surface Water Hydrology

The former S-3 Ponds are located in the catchment of two streams: NT-1 and the uppermost main stem of Bear Creek (Fig. D.30). Comparison of the current configuration of the channel of Upper Bear Creek to historic photographs shows that the main stem of Bear Creek above Bear Creek Kilometer (BCK) 12.38 has changed and is now located slightly south of its former location. During development of the Y-12 Plant, the topography of area was altered considerably by cut-and-fill activities, which resulted in redirection of the Bear Creek channel. Except for a change in the channel location at Bear Creek Road, the channel for NT-1 is in its natural location. One wetland, a 0.17 ha (0.42 acre) area located north of Bear Creek Road, was identified in the S-3 FA located along NT-1 (Rosensteel and Trettin 1993).

Continuous flow measurements were made at two surface water monitoring locations in the S-3 FA: BCK 12.38 and NT-2. In addition, instantaneous flow measurements were made periodically at BCK 12.46, BCK 12.38, and BCK 12.01 as part of the Y-12 Plant GWPP and NPDES monitoring.

The pattern of flow at BCK 12.38 and at NT-2 is typical of that observed for the second-order or tributary streams in BCV. The magnitude of flow varies greatly; however, maximum flow is maintained for only short periods of time during and immediately after precipitation events. Figure D.33 shows flow stream hydrographs showing daily maximum, minimum, and average flow for these two monitoring points. Baseflow at BCK 12.38 (best marked by the daily minimum flow) ranges from ~2.8 L/s [0.1 cubic foot/second (cfs)] during late spring, summer, and fall (low-flow periods) to 8.4 L/s (0.3 cfs) between December and April (high-flow periods). The maximum flow during storms ranges from 56 to 560 L/s (2 to 20 cfs), depending primarily on rainfall intensity. For NT-2, baseflow ranges from <0.3 L/s (0.01 cfs) during summer to 8.4 L/s (0.3 cfs) during high-flow periods. Maximum flow during storms ranges from 56 to 532 L/s (2 to 19 cfs).

Despite low flow in both streams during the lowest-flow periods, neither stream stopped flowing at the monitoring points between March 1994 and January 1995; however, the USGS spring and seep survey shows that, upstream of both monitoring locations, the channels of NT-1, NT-2, and Bear Creek were mostly dry.

The surface water monitoring point at BCK 12.38 was located just downstream of the confluence between the main stem of Bear Creek and NT-1. At this location Bear Creek passes through two culverts, backing up flow during high-flow periods in both the main stem and NT-1. In addition, NT-1 passes through a culvert to reach the main stem, which may cause additional flow backup in NT-1 during high-flow periods.

Of the 15 storms that were assessed for storm hydrographs at each site (refer to Appendix C), all 15 were evaluated for NT-2; for BCK 12.38, flow data are missing for only storms 6, 11, and 12. Figure D.34 shows representative storm hydrographs for the flow at these two monitoring points. The three component segments of the storm hydrograph described in Appendix C [surface runoff, soil interflow, and groundwater baseflow (Moore 1988)] can be identified at both sites. However, the slope of the initial regression hydrographs at BCK 12.38 is generally steeper than those at NT-2, whereas the later regression is steeper at NT-2 than at BCK 12.38. This trend reflects the nature of the two catchments: the catchment for BCK 12.38 contains a larger proportion of paved area than that for NT-2, which is almost free of pavement; therefore, proportionally more overland flow would be expected at BCK 12.38 than at NT-2.

D.6.2 RADIATION SURVEY DATA

Except for aerial surveys of the ORR, no comprehensive radiation survey has been conducted at the S-3 Site. Turner et al. (1991) report elevated activity in soils excavated at the West End Treatment Plant; slightly elevated β/γ radiation was recorded in soil boring S3-7 [400 to 2000 cpm at 0.6 to 3 m (2 to 10 ft)], located at the southwest corner of the former ponds, during the field investigation in 1995.

D.6.3 SOIL CHEMICAL DATA

Ten soil borings were augered to refusal at the S-3 area, and samples were collected at 4-ft depth intervals for chemical analysis (Table D.3). The depth to refusal of each S-3 soil boring is presented in Table D.14.

The soil borings at the S-3 area were divided into two areal aggregates based on geographic proximity and two depth aggregates based on sample collection depths. The two areal aggregates are S-3 Aggregate I, which comprises nine soil borings around the perimeter of the former S-3 Ponds (S3-1 through S3-9), and S-3 Aggregate II, which comprises a single distal soil boring (S3-10). The two depth aggregates include a shallow interval, ranging from 0 to 2.4 m (0 to 8 ft), and a deep interval, covering depths >2.4 m (8 ft). In the text that follows, discussion will generally refer to maximum concentrations from the samples collected from that depth aggregate. Specific sampling intervals within one of the depth aggregates will be referred to only when necessary to elucidate the discussion.

The S-3 soil samples were analyzed for inorganic elements and compounds, radionuclides, organic compounds, and polychlorinated biphenyls (PCBs)/pesticides.

D.6.3.1 S-3 Aggregate I Soils

Inorganic Elements and Compounds

Eight inorganic elements and compounds were detected in S-3 Aggregate I and classified as site-related contaminants (Tables D.15 and D.16): barium, copper, cyanide, lead, mercury, nickel, vanadium, and zinc. All eight occur in the shallow interval, and four — barium, copper, cyanide, and mercury — occur in the deep interval. Mercury concentrations above the background criterion of 0.34 mg/kg were detected in 16 samples in both depth aggregates; barium and copper concentrations above the background criteria were detected in 6 samples. The distribution of mercury, as a representative inorganic element or compound, is displayed on Fig. D.35. In the shallow interval, mercury occurs above background in every borehole except S3-5 and S3-9. The maximum mercury concentration in every borehole occurs in the shallow interval.

Barium concentrations above background were detected six times, of these six detections, four occurred in the deep interval, and three of these four occurred in borehole S3-6. Four of the six copper detections above background occurred in the shallow interval; the samples were distributed around the S-3 Site in boreholes S3-6, -7, -8, and -9 in the 1.2- to 2.4-m (4- to 8-ft) sampled interval. Samples in the 2.4- to 3.7 m (8- to 12-ft) interval also exceeded the background criterion for copper.

Lead was detected only once above its background criterion in the shallow interval of S3-6. Nickel was detected twice above its background criterion; both occurrences were in borehole S3-6 in the 1.2- to 2.4 m (4- to 8-ft) and 2.4- to 3.7-m (8- to 12-ft) intervals. Both vanadium and zinc

concentrations above background were detected twice in the shallow interval of boreholes S3-6 and S3-7. Cyanide was detected above its background criterion four times; two occurrences were in the deep interval of S3-6, and two were in the shallow intervals of S3-7 and S3-8.

Radionuclides

Eleven radionuclides occur at activity concentrations above their background criteria in S-3 Aggregate I: ^{241}Am , ^{237}Np , ^{238}Pu , $^{239/240}\text{Pu}$, ^{99}Tc , ^{228}Th , ^{230}Th , ^{232}Th , ^{234}U , ^{235}U , and ^{238}U . The distributions of radionuclide activity concentrations above background in the shallow and deep intervals are presented in Fig. D.35 for four representative radionuclides: ^{230}Th , ^{234}U , ^{235}U , and ^{238}U . Most of the radionuclide occurrences above background criteria are in soil borings S3-7 and S3-8, which correlates with the field radiation screening, which showed S3-7 as the only boring with elevated counts (Sect. D.6.2). The S-3 Aggregate I samples included 49 detections of radionuclides above background. Of these detections, 33 were from soil borings S3-7 and S3-8, and 9 were from borehole S3-1; thus, three boreholes account for more than 85% of the detections of radionuclides above their background criteria.

The shallow interval accounts for most of these detections (Fig. D.35); however, most of those radionuclides with excessive activity concentrations found in borehole S3-7, the deepest soil boring, are in the deep interval. The radionuclides in this borehole include the isotopes of uranium as well as the two S-3 Aggregate I occurrences of ^{241}Am , the two S-3 Aggregate I occurrences of ^{237}Np , the single S-3 Aggregate I occurrence of ^{238}Pu , one of the three ^{99}Tc occurrences (the other two are in the shallow intervals of S3-7 and S3-8), the single occurrence of ^{228}Th , two of the three occurrences of ^{230}Th (the other occurrence is in the shallow interval of S3-7), and the single occurrence of ^{232}Th .

Organic Compounds

Six organic compounds occur at concentrations above their detection limits (hereinafter referred to as “detects”) in samples from S-3 Aggregate I. All are VOCs and include toluene, PCE, methylene chloride, acetone, 2-butanone, and 4-methyl-2-pentanone; no semivolatile organic compounds (SVOCs) were detected in this aggregate. Because several of the detected VOCs have distinct physical and chemical characteristics, their distributions can be used to help define the hydrogeologic factors affecting their migration and transport. For example, chlorinated hydrocarbons such as PCE and methylene chloride have high densities relative to water and thus tend to sink when mixed with water. Acetone and 2-butanone have relatively low densities compared to water and will float when mixed with water. Acetone is also highly soluble in water and therefore can help delineate water pathways.

Acetone was detected in all but three of the S-3 Aggregate I soil borings. The distribution of maximum acetone concentrations in these borings for the shallow and deep intervals is shown in Fig. D.36. The greatest occurrence of maximum concentration for acetone in the S-3 Aggregate I borings ($4200\ \mu\text{g/kg}$) is in the 1.2- to 2.4-m (4- to 8-ft) sampled interval of boring S3-7, followed by the 0 to 1.2-m (0- to 4-ft) sampled interval of boring S3-3 ($1600\ \mu\text{g/kg}$) and the 1.2- to 2.4-m (4- to 8-ft) sampled interval of boring S3-3 ($1300\ \mu\text{g/kg}$). Acetone was also detected in boring S3-4, with a maximum concentration in the shallow interval of $410\ \mu\text{g/kg}$. All three borings are located adjacent to the southwest quadrant downgradient of the former S-3 Ponds (Fig. D.36). However, acetone is also disseminated in soils surrounding the former ponds and is found in the shallow interval of borings S3-1, -2, and -9 (Fig. D.36) and in the deep interval of borings S3-1, -2 and -6. Acetone concentrations in these borings are typically smaller than those observed near the southwest quadrant.

Toluene occurs in soil throughout S-3 Aggregate I in both the shallow and deep interval; detects range from 1 to 120 $\mu\text{g/kg}$. Maximum toluene concentrations from each depth interval are displayed on Fig. D.36. The maximum and second highest concentrations of toluene for the whole S-3 Aggregate I occur in the deep interval; specifically, the maximum concentration, 120 $\mu\text{g/kg}$, occurs at the bottom of S3-7 [7.3 to 8.5 m (24 to 27.9 ft)], and the second highest concentration, 36 $\mu\text{g/kg}$, occurs immediately above it in the 6.0- to 7.3-m (20- to 24-ft) depth interval of boring S3-7. Toluene was not detected in the deep interval of soil borings S3-3 and S3-4, adjacent to S3-7, but these borings met refusal at shallow depth [1.8 and 4.9 m (6 and 16 ft), respectively]. Other detects of toluene in the deep interval are at relatively low concentrations. In the shallow interval, toluene detects are widespread, with maximum concentrations ranging from 1 to 22 $\mu\text{g/kg}$. The distribution of toluene throughout S-3 Aggregate I in the shallow interval indicates that toluene was radially dispersed into the soils surrounding the former S-3 Ponds. High concentrations also occur at the southwest corner of the former ponds, except that toluene was not detected in the shallow interval soil boring S3-7 (Fig. D.36).

PCE detects occurred in both shallow and deep intervals in S-3 soil borings (Fig. D.39). Except for the 7.0- $\mu\text{g/kg}$ concentrations found in samples collected from the 2.4- to 3.7-m (8- to 12-ft) and 3.7- to 4.9-m (12- to 16-ft) intervals of S3-7, all analyses for PCE were flagged with the J qualifier, indicating the values were estimated. Similar to acetone, the PCE detects occur at the southwest corner of the former S-3 Ponds. The maximum concentration of PCE (24 $\mu\text{g/kg}$) occurs in the shallow interval in boring S3-7, and the second highest concentration (10 $\mu\text{g/kg}$) occurs in the shallow interval in boring S3-3 and in the deep interval of S3-7. All remaining PCE detects are <10 $\mu\text{g/kg}$; are all associated with the southern side of the former S-3 Ponds in the shallow interval and with the western side in the deep interval.

The three remaining organics with concentrations above detection limits — 2-butanone, 4-methyl-2-pentanone, and methylene chloride — do not occur as regularly in samples from around the former S-3 Ponds as do acetone and toluene (Fig. D.36): 2-butanone was detected once in the shallow depth interval of boring S3-2 (10 $\mu\text{g/kg}$; J qualifier); 4-methyl-2-pentanone detects (3 to 28 $\mu\text{g/kg}$; J qualifiers) are restricted to 2.4-m (8-ft) depth intervals in boring S3-7, with the maximum concentration occurring in the 0- to 1.2-m (0- to 4-ft) depth interval of boring S3-7; and methylene chloride (180 $\mu\text{g/kg}$) was detected once in the shallow interval of S3-7.

PCBs/pesticides

Three different PCBs — Aroclor-1248, -1254, and -1260 — and one pesticide — methoxychlor — were detected in soils from S-3 Aggregate I. The distribution of the maximum concentrations of total PCBs in the two sampling intervals is depicted on Fig. D.36. The single detect of methoxychlor in the shallow interval of borehole S3-9 is not depicted.

PCBs were detected in seven of the nine boreholes that constitute S-3 Aggregate I. Maximum total concentrations in the shallow interval range from 8 $\mu\text{g/kg}$ in borehole S3-4 to 370 $\mu\text{g/kg}$ in S3-1. PCBs (Aroclor-1254 only) were detected in only one S-3 Aggregate I borehole in the deep interval, S3-7, with a maximum concentration of 260 $\mu\text{g/kg}$. The PCBs detects included 1 detect of Aroclor-1248, 13 of Aroclor-1254, and 3 of Aroclor-1260. Concentrations range from 12 to 370 $\mu\text{g/kg}$ for Aroclor-1254 and from 16 to 170 $\mu\text{g/kg}$ for Aroclor-1260. The widespread presence of PCBs in the shallow interval is consistent with expected surface contamination at a large industrial plant; similar distributions have been observed elsewhere in BCV (Rust Spoil Area and SA-200), where spill material exists in the subsurface.

D.6.3.2 S-3 Aggregate II Soils

Inorganic Elements and Compounds

Mercury is the only inorganic element detected in concentrations above its background criterion in samples from S-3 Aggregate II (Tables D.17 and D.18). The distribution of mercury in the shallow and deep intervals is shown on Fig. D.35. Mercury concentrations ranging from 3.7 to 10.7 mg/kg occur in all three samples collected from borehole S3-10 (two in the shallow interval and one in the deep interval), which is located close to a soil pile generated during excavation of the West End Treatment Plant. Observations of mercury contamination of these soils by Turner et al. (1991) confirm the occurrence of mercury-contaminated soil at this location.

Radionuclides

The distribution of representative radionuclides in the shallow and deep intervals of the S-3 Aggregate II soil boring is shown on Fig. D.35. Three radionuclides were detected in activity concentrations above their background criteria in S-3 Aggregate II: ^{241}Am , ^{238}Pu , and ^{238}U . All three radionuclides were detected once; ^{241}Am and ^{238}Pu occurred in the deep interval of soil boring S3-10 and ^{238}U in the shallow interval.

Organic Compounds

Four VOCs were detected in soil boring S3-10: acetone, 2-butanone, PCE, and toluene. The distribution of organic compounds in the two depth intervals of S-3 Aggregate II is shown on Fig. D.36. No SVOCs were detected in S3-10.

Acetone and 2-butanone were not detected in the shallow interval of S3-10, but both were detected in the single sample from the deep interval of the borehole [2.4 to 3.7 m (8 to 12 ft)]. PCE was detected in two samples from the shallow and deep intervals, but the concentrations in both samples were very low (2 $\mu\text{g/kg}$ in both). Toluene was detected in all three samples from S3-10 with concentrations ranging from 7 to 19 $\mu\text{g/kg}$.

PCBs/pesticides

The same three PCBs that were detected in samples from the S-3 Aggregate I boring were detected in the S-3 Aggregate II boring: Aroclor-1248, -1254, and -1260. The distribution of total PCBs in both the shallow and deep depth intervals of S3-10 is shown on Fig. D.36. Unlike the S-3 Aggregate I distribution, where the maximum PCB concentration occurred in the shallow interval, the maximum concentration in S-3 Aggregate II (3300 $\mu\text{g/kg}$) occurs in the deep interval for Aroclor-1248.

D.6.3.3 Summary and Discussion

Mercury contamination at the S-3 Site is the most widespread of all inorganic contamination. Of the 24 total inorganic detects in the 37 samples collected from the S-3 Site, 17 had mercury concentrations exceeding its background criterion. Only two borings, S3-5 and S3-9, provided a sample in which the mercury concentration was below its background criterion.

PCBs, although fairly ubiquitous at the S-3 Site, were detected most frequently in the shallow interval in Aggregate I. This distribution of PCBs in Aggregate I and their relatively low concentrations (270 $\mu\text{g/kg}$, maximum) are consistent with contamination resulting from a spill or

other minor industrial accident at a major industrial plant. However, a high concentration of Aroclor-1248 (3300 $\mu\text{g/kg}$) in the deep interval of Aggregate II indicates possible burial of PCBs.

Contamination by VOCs, primarily acetone and toluene, is centered at the southwest corner of the former S-3 Ponds. These compounds were detected in both the shallow and deep intervals of borings S3-3, -4, and -7. The areal distribution of acetone and toluene suggests a migration pathway out of the former S-3 Ponds into surrounding soil. The vertical distribution of a low density compound such as acetone suggests possible redistribution with a fluctuating water table.

D.6.4 SEDIMENT DATA

Four sediment samples were taken from the Bear Creek stream channel in S-3 FA during the BCV OU 1 investigation (Fig. D.30) and screened in the field for radiological parameters. Based on the results of field screening, no additional analysis was performed. Historical sediment data from the S-3 FA consist of one background sample (UBC-BK) and four sediment samples identified as UBC-1 through UBC-4 (Geraghty and Miller 1988; Turner and Kamp 1984). These samples were analyzed for inorganic elements and compounds, as well as radiological and organic parameters. The analytical data from these samples are summarized in Table D.19, which shows comparison values for soils using the BSCP (DOE 1993) and for data derived from UBC-BK, which is located in the upper reaches of NT-2.

Except for zirconium, all analytes for which a background reference value is available (either from BSCP or from UBC-BK) have at least one sample that exceeds a background concentration. Barium concentrations ranged from 200 to 680 $\mu\text{g/kg}$, with all but one sample exceeding the background criterion of 212 $\mu\text{g/kg}$. In general, contaminant concentrations, particularly for radionuclides, are lower in UBC-1 and UBC-2, which are the two locations farthest from the S-3 Ponds, than in UBC-3 and UBC-4. Each sample shows elevated total uranium (ranging from 100 to 4900 $\mu\text{g/kg}$), gross α (ranging from 39 to 1500 pCi/g) and gross β (ranging from 99 to 2400 pCi/g). Isotopes of uranium account for the elevated gross α . The highest concentrations were generally found in sediments from UBC-3, which is located between the S-3 Site and NT-1. Uranium-238, in particular, shows elevated activity concentrations, with a maximum value of 2675 pCi/g detected in the sample from UBC-3, compared to background values of 0.5 pCi/g (UBC-BK) to 2.6 pCi/g (BSCP). These values indicate that sediments were contaminated with uranium and barium at the time of the historical studies.

D.6.5 SURFACE WATER CHEMICAL DATA

Surface water in the S-3 FA is contaminated with a wide range of chemicals consistent with the history of operations at the S-3 Ponds: metals, radionuclides, VOCs, and nitrate. The three streams considered in this FA are the uppermost reach of Bear Creek above its intersection with NT-1 and NT-2.

Over the past decade, since closure of the S-3 Site, concentrations of contaminants in surface water at this site have decreased markedly, and the quality of water in Bear Creek has improved significantly (Moore and Toran 1992). Because of the marked increase in the quality of surface water near the S-3 Site since closure of the former ponds, only the most recent data were used in the BCV RI to quantify current contaminant concentrations in surface streams. These data are from the BCV RI, the GWQR database for samples taken after 1990, and the NPDES database for samples taken after 1990. Although historical contamination of Bear Creek is discussed briefly, the text focuses on

current conditions of surface water at this site. This text includes a discussion of the nature and extent of contamination in surface water and an analysis of the relationship between flow and contaminant concentration in the surface water aggregates for S-3.

Recent data have been subdivided into three aggregates (Table D.11): Bear Creek at BCK 12.46, NT-1, and NT-2. Table B.12 in Appendix B summarizes the analytes for surface water in BCV. Tables D.20 through D.25 summarize the analytical results for each analyte that was detected in the S-3 Site FA aggregates and one sample taken at BCK 12.71 that was not aggregated. Results for unfiltered and filtered samples are summarized in separate tables. Included in these tables are the frequency of detection of the analytes; the background criteria; the frequency with which each analyte exceeded background; the minimum, maximum, and mean results; and the relative importance of this analyte as a site-related contaminant. Table D.26 presents the results of analyses for other parameters such as pH, alkalinity, total dissolved solids (TDS), TSS, and dissolved oxygen, for each surface water aggregate in the S-3 FA.

Each analytical result for a metal in unfiltered surface water was compared to background using the method for background screening outlined in Sect. D.4. The relative importance of this analyte as a site-related contaminant is determined through technical judgment based on the weight of evidence (e.g., the frequency of detection of an analyte or the concentrations at which an analyte is detected relative to regulatory benchmarks, refer to Sect. D.4). No background comparison was carried out for filtered results.

Contaminants identified in the S-3 surface water aggregates are also contaminants in groundwater within the S-3 FA. This finding is consistent with the site conceptual model, which shows that, except for peak flows during storm events, surface water flow is derived from groundwater discharge. Nitrate is the principal contaminant in both aggregates, and is accompanied by other anions, radionuclides, metals, and some organics. The extent of contamination in surface water is less than that in groundwater at the S-3 Site, in terms of number of contaminants as well as concentrations of these contaminants common to both media.

D.6.5.1 Historical Contamination – S-3 Surface Water

Historically, contamination in the upper reaches of Bear Creek and NT-1 is characterized by low pH (<pH 4.0), high concentrations of various metals (in particular, aluminum), and elevated radionuclide activity (Turner et al. 1991). Data available for surface water quality between December 1971 and October 1972 (during operation of the S-3 Ponds and prior to introduction of the nitrate recovery system) show that this section of the creek was highly contaminated during that period (Fig. D-36a). Regular monitoring of surface water started at the NPDES monitoring station at BCK 12.46 in August 1983, and additional historical data were derived from USGS monitoring (Pulliam 1985a and b; McCauley 1985).

Results of monitoring of surface water quality in upper Bear Creek between December 1971 and October 1972 show that the concentration of nitrate and uranium were closely related to flow in Bear Creek. Two periods of low flow occurred during this monitoring period during which the maximum concentrations of nitrate (>10,000 mg/L NO₃-N) and uranium (>30 mg/L U) were recorded (Fig. D-36a). These maximum values are similar to maximum values for these contaminants in groundwater in the S-3 aggregate and probably represent almost pure waste water from the S-3 Ponds that has reached Bear Creek with little or no dilution or attenuation.

Monitoring at BCK 12.46 shows that, after neutralization of liquids in the S-3 Ponds in 1983, the pH of surface water rose from <pH 4.0 to >pH 6.0 within a few months. This change in pH was

accompanied by equally rapid decreases in the concentrations of nitrate and uranium in surface waters (Moore and Toran 1992). The rapidity of this change indicates that, before closure of the ponds, contaminants traveled from the S-3 Ponds to the surface water via two primary pathways: one short-residence-time pathway, in which little or no attenuation of contaminants occurred, and a second, longer-residence-time pathway, in which the concentrations of contaminants were attenuated. The rapid pathway probably related to rapid migration of waste water from the active ponds to Bear Creek through the regolith at and above water table. Closure of the S-3 Ponds effectively shut off this direct pathway for low-pH waste water, resulting in a rapid improvement in water quality in the main stem at BCK 12.46 after 1983. The second pathway is probably via discharge of shallow groundwater to Bear Creek and to NT-1.

D.6.5.2 Inorganic Elements and Compounds – S-3 Surface Water

The background screen and weight of evidence analysis showed that site-related contaminants in surface water at the S-3 Site include six inorganic elements and compounds in the Bear Creek at BCK 12.46, 10 in the NT-1 aggregate, four in the NT-2 aggregate and five in the sample from BCK 12.71. The inorganic contaminants in these streams were as follows:

- **BCK 12.46.** Boron, cyanide, nitrate, phosphorous, strontium, and uranium.
- **BCK 12.71.** Chloride, fluoride, mercury, nitrate, and sulfate.
- **NT-1.** Barium, boron, cadmium, chloride, fluoride, nickel, nitrate, strontium, uranium, and sulfate.
- **NT-2.** Barium, chloride, fluoride, and nitrate.

Of the eleven elements or compounds listed above, 10 are also contaminants in groundwater at the S-3 Site, and barium, mercury, and nickel are contaminants in shallow soils at the S-3 Site (Sect. D.6.3). In addition, higher concentrations of the inorganic contaminants reported for NT-1 occurred in grab samples for two shallow piezometer and one stream sample close to an identified S-3 plume discharge point in NT-1 (Table D.27). The geochemistry of these elements is discussed in detail in Sect. D.6.6.2. The most likely explanation for their presence in surface water is that they enter via a discharge of contaminated groundwater.

Some inorganic elements detected in each aggregate were not considered important as site-related surface water contaminants because they occur only sporadically above background. These elements were aluminum, barium, beryllium, cerium, copper, mercury, nickel, thallium, titanium, vanadium, zinc, and zirconium at BCK 12.46, and aluminum and cyanide in NT-2. These analytes occurred above background in only one or two samples in either stream in a population of 72 samples in BCK 12.46 and 21 in NT-2 (less than 5% of samples). These inorganic elements also occur as contaminants in soils or groundwater, and their absence to any significant degree in surface water probably relates either to a relatively immobile chemistry or to a sporadic occurrence in soils or groundwater.

Additional weight of evidence analyses applied to those metals detected in Bear Creek and NT-2 that were not considered to be contaminants are described in the following paragraphs.

- **Aluminum.** The single elevated detection of aluminum in NT-2 (7.75 mg/L) exceeded background; however, this sample was taken during the peak flow from a large storm on April 12. This sample was unfiltered, and had a TSS that was at least an order of magnitude

greater than that for the other samples at this site (564 mg/L). The elevated concentrations of aluminum in this sample is assumed to be a result of the high TSS, which is a natural phenomenon resulting from high turbidity during peak flow.

- **Cyanide.** Cyanide was not considered an important contaminant in NT-2 because it was detected in only 2/21 samples (10 and 15 $\mu\text{g/L}$). These concentrations are also less than the Safe Drinking Water Act (SDWA) maximum contaminant level (MCL) for cyanide (200 $\mu\text{g/L}$).

D.6.5.3 Nitrate – S-3 Site Surface Water

Nitrate is the principal common anion contaminant in the S-3 Site surface water aggregates. Higher concentrations of nitrate occur in NT-1 and NT-2 than in the Bear Creek Main Stem aggregates at the S-3 FA indicating that the primary migration pathway for nitrate-contaminated water downgradient of the S-3 Site is currently along strike to NT-1 and NT-2 rather than directly to the main stem of Bear Creek. Supporting this hypothesis are the following observations:

- Concentrations of nitrate in NT-1 range from 31 to 286.1 mg/L with an average of 166.6 mg/L, whereas in the main stem of Bear Creek at BCK 12.46 concentrations range from 3.8 to 530.0 mg/L, with a considerably lower average of 38.8 mg/L. In addition, the average nitrate concentration in NT-2 is also greater than that recorded at BCK 12.46. In NT-2 the observed range of concentrations was 2.9 to 211 mg/L with an average concentration of 74.2 mg/L.
- During one sampling event on April 12, 1995, the concentration of nitrate at BCK 12.71 was only 2.2 mg/L, and a composite sample, collected at BCK 12.38 (just below the confluence with NT-1), had a concentration of 44.7 mg/L (Upper Bear Creek aggregate in the Maynardville Limestone and Bear Creek FA, Sect. D.9.3).
- NPDES monitoring at BCK 11.97 and BCK 12.48 between February 1989 to June 1992 showed that nitrate concentrations in the main stem of Bear Creek were consistently greater below the confluence with NT-1 (BCK 11.97) than above the confluence (BCK 12.46) (Bogle and Turner 1993, Fig. D.37). During this time period the mean concentration of nitrate was 38.8 mg/L at BCK 12.46 and 42 mg/L at BCK 11.97 (Upper Bear Creek aggregate in the Maynardville Limestone and Bear Creek FA, Sect. D.9.3).
- One grab sample from NT-1 ~150 m (500 ft) above the confluence with Bear Creek taken on December 14, 1995 had a concentration of nitrate of 230 mg/L (Table D.27). This grab sample is associated with a sample taken from a 1.6-m (5.4-ft) deep piezometer (P2) located <1 m (3 ft) east of NT-1 (Fig D.38) that had a concentration of 1919 mg/L nitrate. These data, and a field observation that specific conductance in NT-1 at this location was greater at the bed of the stream than at the surface, suggest that the sources of nitrate in NT-1 are discharges of contaminated groundwater.

In field screening data, samples of surface water in NT-1 contained concentrations of nitrate greater than 50 mg/L (method maximum) up to 250 feet upstream of the NT-1 sampling point (Fig. B.1) and nitrate concentrations greater than 10 mg/L up to 500 ft upstream of the NT-1 sample location (Fig. D.37a). In the same study, 13 samples of surface water from the were obtained from the main stem of Bear Creek between the top of the channel and the confluence with NT-1 and none of the samples exceeded 9 mg/L nitrate-N.

The observation that nitrate concentrations in NT-2 are greater than in Bear Creek adjacent to the former S-3 Ponds is notable because NT-2 is nearly 760 m (2500 ft) along strike from the former

S-3 Ponds, whereas the main stem of Bear Creek is located ~60 m (200 ft) across strike and downgradient. In determining the optimum location for the site of the flume and sampling device, a profile of specific conductivity of NT-2 was measured. Conductance of surface water in the stream was measured at 15.2-m (50-ft) intervals for 305 m (1000 ft) upstream of the flume location. The results of this profile, illustrated in Fig. D.39, show a marked increase in stream specific conductance between 192 (630) and 76 m (250 ft) upstream of the flume. This increase also corresponds to the location, at 183 m (600 ft) upstream, of the confluence of NT-2 with a small tributary in which a specific conductivity of 800 $\mu\text{mhos/cm}$ was measured. If higher-conductivity water is assumed to be associated with groundwater discharge, the zone over which the conductance of surface water increases probably corresponds to the location of the discharge zone for contaminated groundwater in the NT-2 catchment. Figure D.40 shows the relationship between nitrate concentration and specific conductance for samples from NT-2 and indicates an approximate linear relationship between these parameters. The location of the discharge in NT-2 is close to the location of well GW-537 (Fig. D.30), which is contaminated with nitrate (see Sect. D.6.6) interpreted to be derived from the S-3 Site. Nitrate contamination in NT-2 is therefore assumed to result also from the discharge from a contaminated groundwater plume derived from the S-3 Site.

Major Cations and Anions and Miscellaneous Parameters

Sulfate, chloride, and fluoride are also identified as site-related contaminants (SRCs) in both surface water aggregates at S-3, and, in general, concentrations of all major ions in these streams are elevated. TDS ranged from 130 to 1400 mg/L (mean 839 mg/L) at BCK 12.46, 538 to 1746 mg/L (mean 1147 mg/L), and 58 to 1240 mg/L (mean 560 mg/L) in NT-2 (Table D.26). In addition, results from the spring and seep survey conducted by the USGS show that surface water in streams close to the S-3 Site has elevated specific conductance relative to other tributaries in BCV (Fig. D.41). These elevated concentrations of major ions, which are a result of the high-TDS waste water disposed of in the former ponds and its interactions with bedrock, relate to the overall increase in dissolved load of groundwater and surface water downstream of the S-3 Site. The presence of these analytes as contaminants is consistent with the groundwater origin for surface water, and their source in groundwater is discussed in Sect. D.6.6.2.

D.6.5.4 Organic Compounds – S-3 Surface Water

In general, the concentration of organic contaminants in surface water at the S-3 FA is very low. Site-related organic contaminants in surface water at the S-3 Site include the following:

- **BCK 12.46.** Phenols (1 to 7 $\mu\text{g/L}$).
- **BCK 12.71.** 1,2-dichloroethane (1,2-DCA) (7 $\mu\text{g/L}$) and acetone (14 $\mu\text{g/L}$).
- **NT-1.** PCE (1 to 6 $\mu\text{g/L}$).
- **NT-2.** 1,2-DCA (9 to 18 $\mu\text{g/L}$), acetone (4 to 27 $\mu\text{g/L}$), and chloromethane (2 to 6 $\mu\text{g/L}$).

In addition, the grab sample taken from NT-1 ~150 m (500 ft) above the confluence with Bear Creek had a concentration of PCE at 19 $\mu\text{g/L}$ (Table D.27). This grab sample is associated with a sample taken from piezometer P2, located <1 m (3 ft) east of NT-1 (Fig. D.38), that had a concentration of 120 $\mu\text{g/L}$ PCE. These data indicate that the concentrations of organic contaminants in NT-1 decline rapidly below the discharge point of contaminated groundwater.

Acetone, PCE, and 1,2-DCA are the principal VOC contaminants in these aggregates; however, the concentrations of these organic contaminants, and of all organic contaminants in these two aggregates, are relatively low (the maximum value is for acetone in NT-2 at 27 $\mu\text{g/L}$); the principal compounds occur sporadically with no discernible pattern of distribution. This is probably the result of variable rates of volatilization of these compounds after discharge to the surface stream from groundwater.

D.6.5.5 Radioactivity – S-3 Surface Water

In the S-3 FA aggregates, total uranium, uranium isotopes, and gross α and β are elevated above background in most samples. The relative distribution of uranium between the surface water aggregates at the S-3 FA is opposite to that for nitrate; whereas, higher concentrations of nitrate occur in NT-1 and NT-2 than in the Bear Creek Main Stem. Higher concentrations or activities of uranium and its isotopes occur in the Main Stem samples compared to NT-1 and NT-2. This indicates that the primary migration pathway for uranium-contaminated water downgradient of the S-3 Site is currently to Bear Creek Main Stem rather than along strike to NT-1 and NT-2. Supporting this hypothesis are the following observations:

- Uranium occurs above background in all samples taken at BCK 12.46 and ranges in concentration from 0.129 to 1.04 mg/L (average 0.621 mg/L). Concentrations of uranium in NT-1 are an order of magnitude less and range from 0.012 to 0.185 mg/L with an average of 0.075 mg/L. Uranium isotopes were detected in only one sample in NT-2.
- The sample taken at BCK 12.71 recorded the highest value of gross α activity (237 pCi/L) for the S-3 FA surface water aggregates and also had elevated gross β activity (114 pCi/L). A composite sample collected on the same day from BCK 12.38, below the confluence with NT-1 had a lower activity of 60.5 pCi/L for gross α and higher activity for gross β of 125 pCi/L (Upper Bear Creek aggregate in the Maynardville Limestone and Bear Creek FA, Sect. D.9.3).
- NPDES monitoring at BCK 11.97 and BCK 12.48 between February 1989 to June 1992 showed that uranium concentrations and gross α activities in the main stem of Bear Creek were consistently greater above the confluence with NT-1 (BCK 11.97) than below the confluence (BCK 12.46) (Bogle and Turner 1993, Fig. D.42). During this period, the mean value for gross α activity was 282 pCi/L at BCK 12.46 and 152 pCi/L at BCK 11.97.
- The grab sample from NT-1 ~150 m (500 ft) above the confluence with Bear Creek taken on December 14, 1995 had low activities of uranium isotopes (^{235}U 3.9 pCi/L and ^{238}U 8.4 pCi/L) (Table D.27). A uranium concentration of 0.006 mg/L was recorded in piezometer P2, located <1 m (3 ft) east of NT-1 (Fig D.38) indicating that groundwater at this location is also relatively free of uranium.

In field screening data, 10 samples of surface water were obtained from the main stem of Bear Creek and analyzed for total uranium. The results ranged from 0.27 to 0.49 mg/L total uranium (Fig D.37a). In the same study, uranium was not detectable in 4 samples of surface water from NT-1.

These data indicate that uranium monitored at BCK 12.38, below the confluence of Bear Creek and NT-1, mainly from the upper reach of Bear Creek rather than from NT-1, whereas most nitrate appears to be derived from NT-1 discharge.

The NPDES data also show that the activity of gross β has a similar pattern to that of nitrate in that it is consistently lower in the main stem at BCK 12.46 (mean value 510 pCi/L) than at

BCK 11.97 (mean value 178 pCi/L) (Fig. D.37). The single grab sample from NT-1 (Fig D.38) had a ^{99}Tc (beta emitter) activity of 1000 pCi/L, and groundwater from P2 an activity of 15,000 pCi/L. In addition, gross β was detected in 95% of all samples in NT-2, with an activity concentration ranging 12 to 164 pCi/L and a mean activity of 59.7 pCi/L. These data indicate that, similar to nitrate, the pathway for ^{99}Tc from the S-3 Site groundwater plume is to NT-1 and NT-2.

Records indicate that a number of radioisotopes were disposed of in the S-3 Ponds during their operation (Appendix A). However, for the S-3 Site aggregates, isotopes of uranium (principally ^{238}U and ^{234}U) dominated the activity detected in the samples from BCK 12.47, and ^{99}Tc dominated in samples from NT-1 and NT-2. Other radioisotopes that have been detected in these aggregates but at low activities are ^{241}Am (maximum detected activity of 0.93 pCi/L), ^{237}Np (5.7 pCi/L maximum), ^{238}Pu and ^{239}Pu (0.41 maximum), and ^{228}Th (0.10 pCi/L maximum). All of these radioisotopes are considered contaminants in surface water at the S-3 Site because no background value is available.

D.6.5.6 Relationships Between Stream Flow, Groundwater, and Contaminant Concentrations

Continuous monitoring of flow and specific conductivity conducted at the sample point in NT-2 shows that the conductivity of surface water in this stream is controlled by flow. Stream conductivity, which is higher during low-flow periods, decreases for short periods during storm events (Fig. D.43) as a result of dilution of groundwater discharge to the creek by rain water. Figure D.43 shows specific conductivity (Ks) in NT-2 during three rainfall events plotted as a function of the discharge (Q) on log axes.

The general theoretical relationship relating concentration (C) of a contaminant in a stream and the discharge is $C = A \times Q^{-B}$, where A and B are empirical constants (Solomon et al. 1991). For the storms observed at NT-2, this relationship holds true for specific conductivity and discharge because each storm shows an almost linear relationship between log (Ks) and log (Q). For these storms, the value of B (slope of the linear relationship) ranges from 0.3 to 0.4.

If an empirical linear relationship between Ks and nitrate concentrations (Cn) (for NT-2 this is $C_n = 0.0945 \times K_s + 10.37$, $R^2 = 0.73$; Fig. D.40) is assumed, then the above equation also holds for the relationship between Cn and Q, where

$$C_n = 0.0945 \times A \times Q^{-B} + 10.37,$$

and on a log (Cn) vs log (Q) plot, the slope of the line (-B) remains the same and only the intercept varies.

The size of the value for B can be used to categorize the type of relationship between C and Q in the following way:

$B = 1$	<i>Simple dilution.</i> As discharge increases, the total mass flux remains the same. This type of relationship indicates that the contaminant source to a stream is constant and does not vary with changing hydrogeologic conditions.
$B = 0$	<i>Constant concentration.</i> The concentration of a contaminant does not change with flow; thus, the contaminant source to the stream increases with flow.
$0 < B < 1$	<i>Partial dilution.</i> As flow increases, the concentration decreases with dilution; however, dilution is insufficient to maintain a constant flux, and flux increases as flow increases. This relationship indicates that the input rate of a contaminant to the stream

increases as flow increases; this situation can occur, for example, if discharge of contaminated groundwater increases during the storm event.

B values for specific conductivity in NT-2 storms range from 0.3 to 0.4 (Fig. D.43), indicating that partial dilution of the contaminant source probably occurs during storm events. The source of contaminants in NT-2 is contaminated groundwater derived from along-strike flow from the S-3 Site in the Nolichucky Shale. The current site conceptual model includes rapid response of groundwater levels in the shallow water table interval during storm events, indicating quick flow occurring at the water table interval during storms. This effect means that discharge to streams during storm events increases rapidly, which is consistent with the observed partial dilution effect seen in the data from NT-2.

As a result of the relationships between contaminant concentrations and discharge, nitrate concentrations, gross β activities, and concentrations of other inorganic contaminants vary widely in relation to average stream flow stream for the period of sampling. Tables D.28 and D.29 list the sample results for the principal inorganic contaminants at BCK 12.38 and NT-2, respectively, and include the average discharge rate for each sample during the period over which the sample was obtained (sample periods are listed in Appendix B, Tables B.14 and B.15 for BCK 12.38 and NT-2, respectively; total flow was calculated from stream hydrographs in Figs. B.6 to B.13). Figure D.44 shows plots of the log concentration [$\log(C)$] vs the log of the average flow rate [$\log(Q_{av})$] for nitrate, gross α , and gross β at BCK 12.38, respectively. Figure D.45 shows plots of $\log(C)$ vs the $\log(Q_{av})$ for nitrate and gross β at NT-2. The best fit empirical curve for each of these relationships is also shown on these figures. Except for nitrate at BCK 12.38, negative slopes for these curves on $\log(C)$ vs $\log(Q_{av})$ space range from -0.6 to -0.75. Although slopes on these graphs for NT-2 are not directly related to those on Fig. D.43 because of the effect of averaging flow and of compositing the sample, both sets of data imply that partial dilution of groundwater discharge occurs. This dilution means that effects of contaminants increase with flow.

D.6.6 GROUNDWATER CHEMICAL DATA

Groundwater near the S-3 Site is contaminated with a wide range of chemicals consistent with the history of operations at the S-3 Ponds: metals, radionuclides, VOCs, and nitrate. Contamination originating at the S-3 Site can be identified in groundwater in the Maynardville Limestone as far west as Picket W and in surface water at BCK 9.47. The distribution of contaminants in the groundwater plume that has developed in BCV from the S-3 Ponds depends strongly on contaminant geochemistry and interaction with aquifer materials. Contaminants that are chemically mobile (e.g., nitrate) have migrated a long distance from the origin of the plume at the former S-3 Ponds. Conversely, contaminants that are generally geochemically immobile or particle reactive are detected only in wells close to the site.

The wells included in the S-3 aggregate are listed in Table D.6, and their locations are shown on Fig. D.5. These wells were selected because they met one or both of the following criteria:

- (1) The well is screened in the Nolichucky Shale or Maryville Limestone and located within the same drainage area as the S-3 Site (the area between NT-1 and the main stem of Bear Creek above its confluence with NT-1). Groundwater in these wells is the potential primary receptor of contaminants from the S-3 Site.

- (2) The well is screened in the Nolichucky Shale or Maryville Limestone, and past sampling results have indicated that groundwater at this well is contaminated with nitrate. The well is also located in the watershed of NT-1, NT-2, or NT-3.

Plumes of metals, radionuclides, VOCs, and nitrate are present in groundwater at the S-3 Site, up to 1067 m (3500 ft) downgradient to the west in the Nolichucky Shale, and downgradient to the east in UEFPC Hydrogeologic Regime. Contaminants are most concentrated in the subsurface at the S-3 Site, decreasing in concentration downgradient. In general, contaminant plumes in the Nolichucky Shale that are derived from the S-3 Site are elongate in shape and parallel to the strike of bedding.

Table B.2 in Appendix B summarizes the analytes for groundwater in BCV, and Tables D.30 and D.31 summarize the results for each analyte detected in unfiltered and filtered samples, respectively. Table D.30 includes the frequency of detection of the analytes, the frequency of wells that detect each analyte, the frequency at which the median value for an analyte in a well exceeds the background UTL, the aggregate minimum and maximum results, the mean of the well median results, and the relative importance of each analyte as an SRC. The background screening method outlined in Sect. D.4.2 was used to identify wells that have consistently elevated concentrations of metals in groundwater. Tables D.32 and D.33 present results of analysis for miscellaneous parameters such as pH, alkalinity, dissolved oxygen, and dissolved solids.

The following subsections describe the extent of the principal contaminants in the S-3 Site groundwater aggregate and the dynamics of changes in contaminant concentrations in the groundwater.

D.6.6.1 Nitrate – S-3 Groundwater Aggregate

The primary anionic contaminant at the S-3 Site is nitrate. Although sulfate, chloride, and fluoride also occur above UTLs, nitrate contamination is one of the overwhelming features of groundwater contamination at S-3. Because nitrate effectively acts as a tracer, its occurrence in groundwater in BCV marks the maximum extent of groundwater contamination resulting from activities at the former S-3 Ponds.

Figure D.6 depicts the BCV-wide distribution of nitrate as nitrogen. The minimum contour on this figure is the 10 mg/L SDWA MCL from nitrate as nitrogen; the subsequently higher contours are logarithmic (i.e., 100, 1,000, and 10,000 mg/L). Figures D.14 and D.15 depict the nitrate concentrations in cross sections of BCV oriented across geological strike, and Fig. D.16 depicts along strike cross sections of the upper section of BCV in the Nolichucky Shale. The locations of these cross sections are shown on Fig. D.5.

The nitrate plume extends along strike in the Nolichucky Shale, occurring downgradient of the S-3 Ponds, to both the east and the west and in both the shallow and deep intervals (Fig. D.6). Although the extent of nitrate contamination in the UEFPC Hydrogeologic Regime is not covered by this report, the nitrate plume in UEFPC is known to be contiguous with the plume in BCV, and concentrations of nitrate in both hydrogeologic regimes are similar in magnitude.

Interpretation of the distribution of nitrate in groundwater at the S-3 Site, as observed in the monitoring wells, is supported by the BCV hydrogeological conceptual model (see Appendix C). The following subsections describe the observed distributions of nitrate concentrations in wells in BCV and the interpretation of these observations to develop the plume maps.

Distribution of Nitrate in the S-3 Groundwater Aggregate

One of the main features of the nitrate plume in the Nolichucky Shale at the S-3 Site is that the highest concentrations of nitrate are generally found in the intermediate and deep intervals and that the zone of groundwater contaminated with >1000 mg/L is more extensive below 30 m (100 ft) depth than above. To the west of the S-3 Site, groundwater contaminated with >1000 mg/L nitrate has been observed in screening samples nearly 914 m (3000 ft) west of the former ponds in the intermediate interval (HSW 1995), whereas >1000 mg/L nitrate has only been observed up to 427 m (1400 ft) west of the former ponds in the shallow interval (GW-526). In addition, two well nests that are screened in the nitrate plume west of the former ponds record higher concentrations in the intermediate interval than in the shallow interval (GW-85 and GW-86, and GW-345 and GW-526).

The S-3 nitrate plume in shallow groundwater in BCV is well defined, with little uncertainty about its distribution or boundaries (Fig D.6). In shallow groundwater in the Nolichucky Shale in BCV, the plume extends ~1060 m (3500 ft) west (along strike) from the S-3 Site; however, the highest mean concentrations of nitrate within the shallow aquifer [<30 m (100 ft)] occur at wells located in the UEFPC Hydrogeologic Regime. Wells GW-274 [10.7 m (35 ft)] and GW-108 [18 m (59 ft)] have mean concentrations >10,000 mg/L and are located just east of the groundwater divide between UEFPC Hydrogeologic Regime and BCHR.

In BCV the highest mean concentrations in the shallow interval occur in wells adjacent to the former S-3 Ponds and at NT-1; for example, in wells GW-243 through GW-247, mean concentrations at 23.5 m (77 ft) range from 3265 to 6361 mg/L. Field screening data from shallow groundwater in the catchment area between the main stem of Bear Creek and NT-1 shows that the highest concentrations of nitrate contamination occur in shallow groundwater either directly adjacent to the S-3 Ponds cap or at NT-1 (Fig D-37a). Nitrate exceeded 50 mg/L (method maximum) in shallow piezometers adjacent to the S-3 Ponds cap and in a region close to the confluence between NT-1 and Bear Creek. One piezometer (P2) contained a nitrate concentration of 1919 mg/L. In the same study five piezometers located adjacent to the main stem of Bear Creek upstream of BCK 12.46 had nitrate concentrations ranging from 0 to 33 mg/L, and one shallow piezometer located along strike west of the S-3 Site had concentration of 6 mg/L (TPB-27).

Nitrate contamination is detected in shallow groundwater wells at three locations along strike west of the former ponds:

- At NT-1, GW-345 had a mean nitrate concentration of 48 mg/L at 7.9 m (26 ft), and GW-346 a mean nitrate concentration of 882 mg/L at 19.8 m (65 ft). A screening sample from piezometer P2 located at NT-1 had a concentration of 8500 mg/L nitrate (Table D.27).
- At NT-2, GW-537 had a mean nitrate concentration of 756 mg/L at 7.6 m (25 ft).
- At the furthest extent westward just east of BYBY, GW-085 had a mean nitrate concentration of 195 mg/L at 18.9 m (62 ft), and GW-086 a mean nitrate concentration of 3.3 mg/L at 10.4 m (34 ft).

Nitrate is not detected in wells further west along strike from GW-085: GW-087, GW-076, and GW-005 all showed nitrate to be <0.2 mg/L at depths of 5.8 m (19 ft), 24.7 m (81 ft), and 4.6 m (15 ft), respectively.

The extent of the nitrate plume in the Nolichucky Shale in the intermediate and deep intervals (>30 m or 100 ft) is defined by fewer wells, resulting in more uncertainty concerning its distribution.

The shape of the plume shown on Fig D.6 assumes that the strike of bedding in the Nolichucky Shale strongly controls nitrate migration. The plume in the Nolichucky Shale below 30 m (100 ft) is defined by four wells that are probably screened close to the zone of maximum concentration:

- GW-109 had a mean nitrate concentration of 9,760 mg/L at 44.8 m (147 ft);
- GW-615 had a mean nitrate concentration of 10,098 mg/L at 67.7 m (222 ft);
- GW-526 had a mean nitrate concentration of 902 mg/L at 30.8 m (101 ft); and
- GW-829 had a nitrate concentration of 54 and 59 mg/L at 51.5 m (169 ft) in the 3rd and 4th quarters of 1995 from usual sampling methods. However, the initial screening result for this well that was obtained during drilling operations was 2000 mg/L. This indicates that this well has probably intercepted a segment of the nitrate plume with concentrations >1000 mg/L nitrate. However, the depth at which the plume was intercepted is above the well screen and is isolated from groundwater sampled by this well.

These four wells are located along an approximate straight line parallel to strike that is 1060 m (3500 ft) long. GW-134, which is installed with multiport sampling equipment, also recorded a nitrate concentration of 5581 mg/L in sample zone 18 at a depth of 126.5 m (415 ft).

The distribution of nitrate in the Nolichucky Shale at the S-3 Site indicates that a continuous plume of nitrate contamination exists in the bedrock below 30 m (100 ft), which extends along strike underneath tributaries and catchment boundaries. Contamination in shallow groundwater wells [~10 m (30 ft deep)] located in the NT-2 catchment cannot be derived from along-strike flow in the shallow interval or water table interval because shallow groundwater is not likely to underflow tributaries. Contamination in these wells was probably derived from contaminated groundwater at the S-3 Site by way of along-strike flow in the intermediate and deep bedrock intervals of the Nolichucky Shale and upward movement of nitrate-contaminated groundwater from the bedrock into the water table interval and ultimately into NT-2. This hypothesis is supported by the fact that in each case where wells were screened at different depth intervals (GW-345, GW-346, and GW-537; GW-085 and GW-086), the deeper wells had higher concentrations of nitrate. In addition, the hydrogeologic conceptual model includes upward hydraulic gradients in the Nolichucky Shale that could drive upward migration of contaminants (Appendix C).

This hypothesis indicates that contaminant migration in the bedrock intervals of the Nolichucky Shale below 30 m (100 ft) at the S-3 Site is more rapid than would be suspected from the inferred rate of flow in this interval (Appendix C). However, contaminant migration along strike in this interval is probably by way of a limited number of stratabound pathways where fractures are better connected and have slightly wider apertures. The very small amount of flow along such pathways (relative to total water flow in BCV) could result in proportionally greater mass because of the high concentration of nitrate and other contaminants in that interval.

The westernmost sample of deep groundwater in the nitrate-contaminated zone (GW-829) is located close to NT-2; as a result, the western extent of the plume in intermediate groundwater cannot be bounded with certainty. The next wells located approximately along strike are GW-098 [31.7 m (104 ft)] and GW-120 [39.6 m (130 ft)], which are located west of SL 1, a further 850 m (2800 ft) along strike. Nitrate has not been detected in these wells. However, as discussed above, nitrate in the shallow groundwater interval is derived from upward migration of nitrate from the deeper interval. The absence of nitrate in the shallow interval at the BYBY (OU 1 grab samples and GW-087)

indicates that the nitrate plume probably does not extend further west than BYBY in the intermediate interval at this time.

The extent of nitrate contamination down dip in the deep interval of the aquifer is bounded by wells GW-125 and GW-123 in the Nolichucky Shale adjacent to the S-3 Site. GW-125 [167 m (550 ft deep)] sporadically recorded concentrations of nitrate above 10 mg/L before 1991; however, after January 1991, no samples with concentrations of nitrate >5 mg/L have been recorded. Nitrate has not been recorded in well GW-123 [159 m (522 ft)] (Fig. D.13). The maximum depth of nitrate concentration down dip in the Nolichucky Shale east and west of the former ponds is assumed to be no greater than that found at the S-3 Site; however, no bounding monitoring point exists to determine the likely depth. The maximum depth of the nitrate plume is probably strongly related to the mode of plume emplacement, as discussed in the following subsections.

Geochemistry of Nitrogen

Nitrogen may be present in aqueous solution in oxidation states from III- to V+. An important plant and animal nutrient, nitrogen has a redox chemistry that is closely linked with life cycles in the biosphere. In aqueous solutions, the most common forms of nitrogen are in the ammonium NH_4^+ cation and the anionic oxides NO_3^- and NO_2^- , although two other less stable oxide forms and the sparingly soluble, neutral nitrogen gas are also possible. A summary of nitrate redox geochemistry can be found in Drever (1988).

The form of nitrogen disposed at the S-3 Site was almost completely in the nitrate (NO_3^-) ion form as nitric acid. This anion species is normally considered as being highly mobile in aqueous systems, primarily because of its large size-to-charge ratio, and is stable in the absence of nitrate-reducing bacteria. The high mobility and lack of retardation of this ion explain its observed wide distribution in the subsurface in BCV. The distribution of nitrate, which acts as a tracer compound for dissolved contaminants, marks the maximum extent of site-related contamination in BCV.

Analyses of groundwater at the S-3 Site have been almost totally restricted to determining the concentration of the nitrate form of nitrogen. Nitrite was analyzed in eight samples from four wells [GW-103(1), GW-127(1), GW-276(4), and GW-277(2)] and was only detected in one sample in well GW-276. However, the detection limits for the remaining samples were relatively high; thus, the extent of nitrogen reduction in groundwater at the S-3 Site is uncertain. Nitrate-reducing bacteria, which were introduced to the S-3 Ponds during remediation, may have entered groundwater. The wide distribution of nitrate in groundwater in BCV indicates that biological reduction of nitrate cannot be occurring to any great extent.

D.6.6.2 Inorganic Elements and Compounds – S-3 Groundwater Aggregate

The background screen and the weight of evidence analysis identified 21 metals as contaminants in the S-3 groundwater aggregate. Figure D.46 shows the distribution of wells with metal contaminants in groundwater. The shaded area on this figure depicts a zone defined by those wells for which four or more metal analytes had median values greater than the background UTL. Four or more metals occur above background in 15 of 26 wells (58%) in the S-3 aggregate, and, of these, 14 wells occur in a group located within 305 m (1000 ft) of the former S-3 Ponds. In the portion of UEFPC close to the S-3 Site, 16 wells had four or more metals above background. Figure D.46 also shows a second group of four wells that have four or more median values greater than the UTL located in the vicinity of the former S-3 Ponds in UEFPC.

The contaminants were identified using only the results from unfiltered samples and, thus, may not represent the extent of dissolved metal contaminants. However, for comparison, the same background screen was conducted using results from the accompanying filtered samples (Table D.31). This screen identified 19 contaminants, two less than the screen using the unfiltered sample results; however, the mean of the median concentrations of analytes was generally lower in the filtered samples. The contaminants identified in both screens were the same, except that the screen of filtered results did not identify chromium or titanium as contaminants. This similarity implies that, for this aggregate, the metal plume is both in the dissolved and suspended phase.

The geographic proximity of wells with four or more metal contaminants close to the S-3 Ponds indicates that a plume of groundwater contaminated with metals exists in the vicinity of the former S-3 Ponds. However, no single metal has a median value that consistently occurs above UTL in all of the wells that define the plume; that is, the same contaminant suite does not occur in each well. Rather, the plume defines a volume of groundwater that is heterogeneously contaminated with a list of 16 metals (inset in Fig. D.46). Sampling any well within this zone will likely yield groundwater that is contaminated with four or more metals from this list.

Metal Contaminant Geochemistry

The shape of the plume of four or more site-related metal contaminants indicates that the primary cause of metal contamination in groundwater is the S-3 Site. Acidic solutions disposed of in the former ponds have enhanced the solubility of metals. The plume of metal contaminant groundwater at the S-3 Site is the result, primarily, of mobilization of metals by the acidic waste water disposed of in the former S-3 Ponds, which then infiltrated the Nolichucky Shale, creating a region of groundwater with low pH. Two likely sources of metal contamination in groundwater at this site are (1) the waste water from the S-3 Ponds and (2) dissolution from reactions of the acidic waste water with minerals in the Nolichucky Shale. Elements are considered as site-related contaminants under either scenario because, if the source is the Nolichucky Shale, then the elevated concentrations are the result of enhanced mineral reactions with the acidic solutions discharged in the S-3 Ponds.

Since closure of the S-3 Ponds, the pH of groundwater surrounding the former ponds has increased and has almost reached neutral conditions (pH 5 to 7) in most wells. Thus, the current elevated concentrations of metals in the groundwater at the S-3 Site cannot be explained by low-pH groundwater increasing solubility. Saunders and Toran (1995) modeled the mobility of metals at the S-3 Site using the MINTEQ3 computer code and incorporating an iron hydroxide adsorption model. They concluded that the current observed concentrations of metals in groundwater are consistent with modeled equilibrium with adsorbed metals. This reservoir of adsorbed metals probably developed during pond operation and now is able to maintain concentrations of metals at the observed concentrations.

In general, metal and semi-metal contaminants form positive valence states between +I and +IV. Except for metals in the +I and +II states that are commonly present in the hydrated free ion form (M^{n+}), most metals form complex ions with anionic species (most notably hydroxide, carbonate, sulfate, and organics). In addition, most metals ions have a tendency to sorb to mineral surfaces or coprecipitate with iron oxyhydroxide colloids and thus become immobile. The 1994 GWQR data (HSW 1995) show that an empirical relationship usually exists between total metal concentration and the TSS in most wells in BCV. They have demonstrated this relationship for chromium in well GW-063 and for lead in well GW-705 (both wells are located in the Maynardville groundwater aggregate) (Fig. D.5). The 1994 GWQR data (HSW 1995) also show that, except for wells in the S-3 area, only two wells in BCV have recorded concentrations of metals greater than MCLs in the filtered

samples. This finding implies that many of the metal analyses for groundwater are sampling artifacts resulting from mobilization of colloid particles, in either the well bore or the rock, that are subsequently acidified and analyzed in the total sample.

The geochemistry of a metal will, therefore, strongly affect its mobility and occurrence in the subsurface. The occurrence of individual metals in groundwater at the S-3 Site and the geochemistry of the main element groups are summarized in the following paragraphs. The geochemical attributes of metal contaminants for all the groundwater aggregates in BCV are discussed here because the metal contaminants in the S-3 aggregate far outnumber those in the remaining groundwater aggregates. For a more detailed discussion of the geochemistry of any of the COC metals, refer to Hem (1985), Drever (1988), or Garrels and Christ (1965).

Alkali and Alkali-earth Metals (Groups I and II)

[S-3 contaminants: barium (Ba), beryllium (Be), lithium (Li), and strontium (Sr)]

Both Ba and Sr have a +II valence state and are common minor constituents in carbonate minerals (calcite and dolomite); their sulfate minerals, barite (BaSO_4) and celestite (SrSO_4), have been observed in core samples from the Nolichucky Shale close to the S-3 Site (Dreier, Early, and King 1993). Ba concentrations in the S-3 aggregate range from 1.2 to 380,000 $\mu\text{g/L}$ (mean of medians 19,137 $\mu\text{g/L}$), and Sr concentrations range from 8.5 to 340,000 $\mu\text{g/L}$ (mean of medians 17,932 $\mu\text{g/L}$). The distribution of wells in which these metals occur as contaminants is similar: Ba occurs as a contaminant in 10 of 24 wells, and Sr in 11 of 22 wells. Both metals are found in nine wells, and both record their maximum value in well GW-615.

Both elements are usually present in solution as the free ion form (M^{2+}), and the close similarity of their distribution in groundwater suggests that they share the same source. Two likely sources of Ba and Sr in groundwater at this site could be the waste water from the S-3 Ponds or mobilization of these elements during dissolution of carbonates in the Nolichucky Shale. In addition, brines in deep [>305 m (1000 ft)] groundwater elsewhere on the ORR display high concentrations of Ba and Sr and could be a source of the elements if they are present in the underlying portions of BCV. Both Ba and Sr are sparingly soluble in the presence of sulfate in moderate- to high-alkalinity waters such as those in BCV. Concentrations above background of both Ba and Sr occur in wells along strike from S-3 (GW-345, -346, -526), indicating that these metals have migrated with nitrate as far as NT-1 along the bedrock groundwater pathway. Both Ba and Sr are also contaminants in surface water at BCK 12.38; surface water probably provides one pathway for these contaminants to NT-1.

Beryllium was detected in 11/22 wells and occurs above background in seven wells. The concentration of Be ranges in concentration from 0.3 to 110 $\mu\text{g/L}$ (mean of medians 12 $\mu\text{g/L}$) in the S-3 aggregate wells. Be also forms a +II valence ion; however, because of the small size of this ion, Be hydrates strongly in solution, and both the hydroxide and oxide forms have very low solubilities. Hem (1985) reported that Be concentrations in natural waters were a few tenths of $\mu\text{g/L}$ and were probably controlled by the scarcity of the element in rock as much as by the low solubility of Be. Similar to Ba and Sr, possible sources of Be in groundwater at this site include the rock matrix via enhanced leaching as well as the waste water; however, beryllium compounds were components in Y-12 Plant operations and are more likely to have originated in the waste water.

Lithium was detected in 7/7 wells in the S-3 aggregate and occurs above background in 6 wells, ranging in concentration from 13 to 3,500 $\mu\text{g/L}$ (mean of medians 882 $\mu\text{g/L}$). Li forms a Li^+ ion that is relatively soluble; however, it does not usually occur in natural waters at concentrations near its maximum solubility because it is rarely present in crustal materials. Similarly to Be, possible sources

of Li in groundwater at this site include the rock matrix via enhanced leaching as well as the waste water; however, Li is known to be a component in Y-12 Plant operations and is more likely to have originated in the waste water.

Group III Metals

[S-3 contaminants: aluminum (Al) and boron (B)]

Aluminum was detected in 23/23 wells and is a contaminant in 6 wells, ranging in concentration from 23 to 800,000 $\mu\text{g/L}$ (mean of medians 81,046 $\mu\text{g/L}$). The chemistry of aluminum is strongly influenced by the acidity of solution, and its solubility increases exponentially for each unit drop in pH below pH 6.0. The Al^{+3} ion predominates only in the most acidic solutions (pH <4.0); Al occurs mainly in its hydrated forms (AlOH^{+2} and AlOH_3) in most natural waters. The source of aluminum contamination in groundwater at the S-3 is both waste water, which contained high concentrations of aluminum nitrate (Appendix A), and dissolution of aluminum from aluminosilicate minerals in the Nolichucky Shale.

Boron was detected in 24/24 wells and is a contaminant in 10 wells, ranging in concentration from 4.1 to 4,400 $\mu\text{g/L}$ (mean of medians 294 $\mu\text{g/L}$). Boron is usually present in natural waters as borate [$\text{B}(\text{OH})_3$], which acts chemically as a weak acid but does not readily dissociate into charged ionic forms below pH 9.2 (Hem 1985). Boron is a common ingredient in industrial cleaning solutions, usually as Borax (sodium tetraborate). Naturally occurring boron is common in igneous rocks; however, it is usually relatively depleted in sedimentary rocks because of its high mobility in the borate form and is therefore unlikely to be derived from dissolution of minerals in the Nolichucky Shale. The likely source for boron at the S-3 Site is therefore the waste water.

Group IV and V Metals and Nonmetals

(S-3 contaminants: lead and vanadium)

Lead ranges in concentration from 4 to 660 $\mu\text{g/L}$ (mean of medians 11 $\mu\text{g/L}$) in the S-3 aggregate wells. In acidic solutions, lead readily forms a Pb^{2+} free ion; however, in neutral and slightly alkaline systems, like those encountered in much of BCV, Pb tends to form hydroxide and carbonate ion complexes, which reduce the solubility of this element. Sources for Pb at the S-3 Site could be the waste water and/or mobilization of Pb from the Nolichucky Shale.

Vanadium ranges in concentration from 5.2 to 36 $\mu\text{g/L}$ (mean of medians 4 $\mu\text{g/L}$) in the S-3 aggregate wells and is a COC in only one well in the metal-contaminated groundwater plume (GW-103). The source of vanadium contamination is probably mobilization of vanadium in the Nolichucky Shale or analysis of vanadium in the solid phase of turbid samples.

Transition Metals

[S-3 contaminants: cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), manganese (Mn), mercury (Hg), nickel (Ni), and zinc (Zn)]

Zinc and cadmium both tend to form a M^{2+} free ion in solution, with the limit of solubility possibly being the relatively insoluble carbonate. Zn ranges in concentration from 1.2 to 20,000 $\mu\text{g/L}$ (mean of medians 497 $\mu\text{g/L}$) in the S-3 aggregate wells, and Cd ranges from 2 to 4000 $\mu\text{g/L}$ (mean of medians 174 $\mu\text{g/L}$). Both elements are found in >50% of the wells in the metal-contaminated

groundwater plume. The source of these metals in groundwater could be either the waste water or mobilization from the rock.

Chromium ranges in concentration from 10 to 310 $\mu\text{g/L}$ (mean of medians 17.4 $\mu\text{g/L}$) in the S-3 aggregate wells. It has a complex chemistry, but in slightly oxidizing conditions and alkaline solutions the chromate anion (CrO_4^{2-} , Cr VI) is the most common form. Cr occurs only in two wells within the metal-contaminated groundwater plume, which suggests that chromium is not very mobile in groundwater at the S-3 Site. The source for Cr is most likely waste water in the S-3 Ponds.

Cobalt ranges in concentration from 5.1 to 2,300 $\mu\text{g/L}$ (mean of medians 268 $\mu\text{g/L}$) in the S-3 aggregate wells, and nickel ranges from 11 to 20,000 $\mu\text{g/L}$ (mean of medians 2,074 $\mu\text{g/L}$). Both occur in >50% of the wells in the metal-contaminated groundwater plume. Both elements form multiple oxidation states, and the hydroxide forms tend to be more stable in aqueous solutions. Solubility of both Co and Ni is commonly reduced by co-precipitation or sorption to manganese or iron oxides. Both potential sources of metal contamination in S-3 could be sources for these metals.

Manganese ranges in concentration from 1.1 to 220,000 $\mu\text{g/L}$ (mean of medians 24,162 $\mu\text{g/L}$) in the S-3 aggregate wells. Like iron, Mn can exist in multiple oxidation states and commonly undergoes redox reactions in the environment. Its most common form in natural aqueous solution is Mn^{2+} ion, and hydroxide complexes of this ion form only in alkaline conditions ($\text{pH} > 10.5$). The solubility of Mn is greatly increased in acidic solutions and will also be enhanced in solution by forming ion complexes with carbonate, hydroxide, sulfate, and organics. Mn oxide co-precipitates with iron oxide/hydroxide are fairly common on minerals in groundwater aquifers and streams. The surfaces of these oxides also provide good sites for sorption of a wide variety of metals; studies carried out on the ORR have shown that these oxides may form a trap for radionuclides and metals in natural waters (Cerling and Turner 1982). The source of Mn in groundwater at the S-3 Site is most probably remobilization of Mn oxide precipitates by the acidic waste water.

Copper ranges in concentration from 4.1 to 3,100 $\mu\text{g/L}$ (mean of medians 278 $\mu\text{g/L}$) in the S-3 aggregate wells. Cu is found in >50% of the wells in the metal-contaminated groundwater plume. The source of Cu in groundwater could be either the wastewater or mobilization of these metals from the rock.

Mercury ranges in concentration from 0.2 to 110 $\mu\text{g/L}$ (mean of medians 4.2 $\mu\text{g/L}$) in the S-3 aggregate wells. Hg may form hydroxide or chloride complexes in solution. In addition, organic complexes such as methyl mercury increase the solubility of Hg in natural waters. Hg is a common contaminant in soils at the Y-12 Plant, and the BCV RI found Hg concentrations in the subsurface of up to 2.3 mg/kg (see Sect. D.6.3). Thus, the source of Hg in groundwater at the S-3 Site is probably both waste water and mobilization of Hg from the subsurface formations.

Uranium

Refer to Sect. D.6.6.5: radionuclides

D.6.6.3 Common Anions and Cations – S-3 Groundwater Aggregate

Most major anions and cations have elevated concentrations above background UTL values in the S-3 aggregate as a result of the high TDS of the waste water. The major ions that are identified as contaminants are chloride, sulfate, and fluoride. Calcium, magnesium, sodium, and potassium, although occurring in elevated concentrations, are essential elements and thus are not regarded as contaminants. For chloride and sulfate, the highest mean concentrations tend to coincide with wells

with the highest mean concentrations of nitrate. As discussed in Sect. D.6.6.1, these elevated concentrations are probably derived directly from the waste water disposed of in the S-3 Ponds. Although elevated concentrations of sulfate are also usually associated with the highest mean concentration of nitrate, the distribution of wells with elevated sulfate is more sporadic. This pattern could indicate that sulfate is derived both from the S-3 Ponds and from dissolution of sulfate minerals in the rock matrix.

The pH of groundwater at the S-3 Site varies from 2.9 to 11.8 (Tables D.32 and D.33). In general, wells close to the former S-3 Ponds have the lowest pH groundwater: pH in well GW-243 ranges from 2.9 to 4.4 with a mean value of 3.7. In addition, well GW-276, a shallow well (5.6 m or 18.5 ft) located adjacent to the former S-3 Ponds and close to the main stem of Bear Creek, has groundwater with pH ranging from 3.3 to 5.4. These wells are all impacted by nitrate contamination and the low pH results from incomplete neutralization of the waste water. In addition, a screening sample from piezometer P1 located adjacent to NT-1 (Fig D.38) had a pH of 4.85, indicating that groundwater discharging at NT-1 has undergone only partial neutralization in the pathway from the former S-3 Ponds to NT-1.

Wells with the highest pH values are generally deep wells; for example, GW-125 (168.2 m or 552 ft) has groundwater pH ranging from 7.3 to 10.6. This is consistent with the geochemical model for groundwater chemical evolution in BCV presented in Appendix C. The only deep well with lower pH is GW-615 (pH range from 5.8 to 6.9), and this well is also impacted with nitrate.

D.6.6.4 Organic Compounds – S-3 Groundwater Aggregate

Although 21 VOCs have been detected in wells in the Nolichucky Shale close to the S-3 Site, their distribution varies greatly, in terms of both the suite of organics detected in different wells around the site and the concentrations found. The principal (i.e., >10% of detects) VOCs in the S-3 Site aggregate are 1,1,1-trichloroethane (TCA), acetone, chloroform, methylene chloride, PCE, and toluene. TCE, 1,2-DCE, 2-butanone, benzene, and total xylenes occur less commonly in the S-3 aggregate wells in BCV and were detected in <10% of all samples.

The BCV-wide distribution of PCE, TCE, and 1,2-DCE is shown on Figs. D.9, D.10, and D.11. These chemicals are common contaminants in groundwater throughout BCV and therefore have been depicted on site-wide contaminant maps. The distribution of acetone for the S-3 aggregate wells and Maynardville aggregate wells located adjacent to the S-3 Site is shown on Fig. D.47. The relative concentrations of the principal site-related organic contaminants at the S-3 Site are shown in Fig. D.48.

Except for acetone and PCE, the organic contaminants at the S-3 site do not form identifiable continuous plumes. The distributions of acetone and PCE in groundwater at the S-3 Site are similar, which may indicate the same source and a similar transport mechanism. The highest concentrations of both chemicals occur in well GW-243, located in the shallow bedrock interval in the southwest corner of the former S-3 Ponds, and in GW-615, located in the deep bedrock interval on the south side of the former ponds. In addition, PCE concentrations in screening samples of shallow groundwater at NT-1 range in concentration from 120 to 260 $\mu\text{g/L}$ (Table D.27). These wells and piezometers also recorded some of the highest concentrations of nitrate, gross α , and gross β in BCV groundwater and have been interpreted on the plume maps and cross sections as being in the central axis of the S-3 contaminant plume. Acetone and PCE contamination at the S-3 Site is assumed to have derived from infiltration from the active ponds. The maximum recorded concentration of PCE in well GW-243 is 9000 $\mu\text{g/L}$, whereas concentrations in the remaining wells in which PCE is detected are two orders of magnitude less. The maximum concentration of PCE in GW-243 is ~6%

of its maximum solubility (150,000 $\mu\text{g/L}$), which indicates that a free-phase DNAPL containing PCE probably occurs close to this well. Figure D.49 shows the conceptual model for dense non-aqueous phase liquid (DNAPL) and VOC-contaminated groundwater at the S-3 Site.

The groundwater data suggest that, instead of a single plume of organics at the S-3 Site, several isolated plumes, possibly resulting from sporadic disposal of organics in the S-3 Ponds, have commingled in some cases. The few organic analyses available for the pond waters during operation indicate that concentrations of organics in the ponds could have varied greatly over the period of operation (Appendix B). This variability, combined with the fact that organic compounds were not regularly disposed of in the S-3 Pond, would contribute to the sporadic nature of organic plumes in the Nolichucky Shale at the S-3 Site.

D.6.6.5 Radioactivity – S-3 Groundwater Aggregate

The distribution of radiological contamination in groundwater in BCV can be defined by the distribution of gross α and gross β . In the absence of suitable historical data for specific radionuclide activities, a single event for sampling and isotopic analysis of groundwater was conducted for samples collected from multiple locations, ranging from the most contaminated section of BCV to the plume perimeters, during Fall 1995 (Fig. B.5). Results of this sampling event confirmed that the principal radioactive isotopes that contaminate groundwater at the S-3 site are isotopes of uranium and ^{99}Tc . These isotopes can account for the gross α and gross β activities observed in groundwater.

The distributions of gross α and gross β in groundwater in BCV are shown in Figs. D.7 and D.8. For gross α , the minimum contoured value is 15 pCi/L, which is the MCL for gross α , and for gross β , the minimum contoured value is 50 pCi/L, the MCL for gross β . The subsequently higher contours shown are logarithmic: 100, 1,000, and 10,000 pCi/L. Figure D.19 depicts gross α in along strike cross sections of the upper section of BCV in the Nolichucky Shale, and Fig. D.17 depicts the gross α activities in two cross sections of BCV oriented across strike. Figure D.22 depicts gross β in along strike cross sections of the upper section of BCV in the Nolichucky Shale, and Fig. D.20 depicts the gross β activities in two cross sections of BCV oriented across strike. The locations of these cross sections are shown on Fig. D.5.

The distributions of gross α and gross β in groundwater in the S-3 aggregate closely resemble the distribution of nitrate. Most of the wells that define the nitrate plume are those that define the gross α and gross β plumes. The general shapes of the plumes are very similar, both in areal extent and in vertical distribution; this similarity probably reflects the fact that the plumes have the same source and mode of emplacement. However, some notable exceptions may indicate subtle variations in the timing of the contaminant influx to groundwater or in contaminant transport mechanisms.

Distribution of Gross α and Gross β Contamination in Groundwater at the S-3 FA

In shallow and deep groundwater in the Nolichucky Shale in BCV, the gross β plume extends east and west along strike to approximately the same boundaries as the nitrate plume and is bounded to the north, south, and at depth by the same wells as the nitrate plume. The primary differences between the gross β plume and the nitrate plume are in the distribution of maximum values. Unlike the plume of nitrate contamination close to the former S-3 Ponds, the gross β activities are greater in shallow wells than in the intermediate and deep wells.

The highest mean concentrations of gross β occur in the shallow (<30 m or 100 ft) aquifer at wells located adjacent to the former S-3 Ponds; well GW-243 [23.5 m (77 ft)] has the highest mean activity (42,896 pCi/L), with other wells located adjacent to the former ponds recording activities

between 800 and 1200 pCi/L. The results of radiological sampling in 1995 for GW-243 had a gross β activity of 9300 pCi/L that was attributable to ^{99}Tc , which had an activity of 23,108 pCi/L. This distribution differs from that of the nitrate plume, in that the highest concentrations of nitrate in shallow groundwater are located in UEFPC Hydrogeologic Regime, east of the S-3 Site, and that the highest nitrate concentration in BCV was well GW-615.

A similar difference in distribution of maximum values is observed between nitrate and gross α . The highest mean gross α activity from GWQR data (11,100 pCi/L) is recorded in well GW-243, adjacent to the former ponds. However, sampling of this well for radiological parameters in 1995 had a result of 550 pCi/L for gross α (in addition there are two low results from the GWQR data of 1060 pCi/L in 1991 and 3530 pCi/L in 1994). Uranium isotopes for the 1995 sampling event had activities of 88 pCi/L for ^{234}U , 5.2 for ^{235}U , and 230 pCi/L for ^{238}U . This is equivalent to a concentration of 0.69 mg/L for total uranium, whereas the mean result from GWQR data is equivalent to a concentration of 23.697 mg/L total U (assuming an identical isotopic ratio to the 1995 data). Modeling of uranium solubility using the Minteq model developed by Saunders and Toran (1995) shows a solubility for uranium of ~ 40 mg/L at pH 3.5, and ~ 10 mg/L at pH 4 in groundwater at the S-3 Site (Appendix E). This suggests that the higher values for gross α activity in GW-243 are reasonable.

Unlike the nitrate plume, the shallow groundwater plume for gross α does not extend significantly into the UEFPC Hydrogeologic Regime. For example, in well GW-108, gross α activity is 22.6 pCi/L, whereas the mean nitrate concentration is the highest at 13,100 mg/L. High gross α activities also appear to be restricted to the shallow bedrock interval. Well GW-615 in the deep bedrock at the S-3 Site had a mean activity of 430 pCi/L.

Field screening data from shallow groundwater in the catchment area between the main stem of Bear Creek and NT-1 shows that the highest concentrations of uranium contamination occur in shallow groundwater directly adjacent to the S-3 Ponds cap and in groundwater close to the main stem of Bear Creek (Fig D-37a). Concentrations of total uranium range from 1,300 $\mu\text{g/L}$ to 14,000 $\mu\text{g/L}$ in these wells. In this study uranium occurred in relatively low concentrations in wells close to NT-1 (7 - 77 $\mu\text{g/L}$). In general, shallow piezometers that had the highest concentrations of nitrate had the lowest concentrations of uranium and visa versa.

West of the S-3 Site in BCV, both the gross α and gross β plumes extend along strike west of the S-3 Site. Gross β contamination extends to approximately the same boundary as nitrate contamination; however, the plume cannot be bounded with certainty at the BYBY because the grab samples of groundwater from BYBY are also contaminated with gross β . Although this is interpreted as being derived from another source (refer to Sect. D.8), it is uncertain whether the two gross β plumes may coalesce to form a continuous plume of contaminated groundwater in the shallow groundwater at BYBY. West of the S-3 Site, the median activities of gross β are highest in wells GW-526 (69.1 pCi/L) and GW-537 (302.6 pCi/L).

The distribution of gross α contamination in shallow groundwater along strike west of the S-3 Site is much less extensive than that for gross β or nitrate. The furthest point of detectable gross α contamination in the Nolichucky Shale west of the former S-3 Ponds is at well GW-085; however, the mean activity is 8.5 pCi/L, which is below the groundwater MCL. The 15 pCi/L contour is interpreted to extend as far enough to the west to include GW-537 (16.6 pCi/L gross α). Samples of shallow groundwater from NT-1 taken from piezometers P1 and P2 had concentrations for total uranium of 0.01 and 0.006 mg/L, respectively (Table D.27). This indicates that uranium has not migrated west from the S-3 Site in shallow groundwater as far as NT-1. The source of gross α

contamination at NT-2 (GW-537) is probably from upward migration of uranium from the intermediate bedrock interval.

In the intermediate and deep intervals, the furthest extent of gross α and gross β contamination west of the S-3 Site is recorded in well GW-829. However, this detection was in a screening sample taken during the installation of this in this well. Later sampling in the 3rd and 4th quarters of 1996 resulted in almost no detectable radioactive contamination. Similarly to the nitrate contamination, this plume cannot be bounded east of NT-3 by any wells. The western extent of gross β contamination is assumed to have a distribution similar to that of nitrate. The gross α plume, however, probably does not extend as far west in the deep interval as the gross β plume and its furthest extent to the west is probably indicated by the presence of gross α contamination in shallow groundwater at NT-2.

Radioisotopic Analysis of Groundwater at the S-3 FA

Much of the radioactive contamination at the S-3 Site can be attributed to isotopes of uranium or their daughter products or to the ^{99}Tc isotope.

Uranium

The types and forms of uranium in aqueous solution are detailed by Langmuir (1978); the reader is referred to this text for a listing of the thermodynamic properties of uranium species. Uranium can occur in aqueous solution in a wide variety of oxidation states (commonly +IV to +VI) and species. In most aqueous solutions, uranium forms relatively stable oxides and complexes with carbonate, fluoride, and phosphate when these anions are present.

Uranium disposed of at the S-3 Site was probably in an oxidized form (IV+, V+, or VI+), which readily hydrate in aqueous solutions to form oxide and oxyhydroxide species, of which the uranyl (UO_2^{2+}) ion is usually the most prevalent form of dissolved uranium in oxidizing solutions. Reducing conditions are not likely to have developed extensively in the S-3 Ponds or shallow groundwater, and no subsequent reduction of uranium in the sludges and groundwater in BCV would be expected. Therefore, most dissolved uranium probably occurs in groundwater in BCV in the uranyl ion form. In natural waters (in the absence of phosphate), the uranyl ion is present predominantly as the free UO_2^{2+} . At pH >7.5, or at lower pH in solutions with elevated Pco_2 , the uranyl ion forms stable ion complexes with carbonate [UO_2CO_3^0 and $\text{UO}_2(\text{CO}_3)_2^{-2}$, refer to Appendix E] (Langmuir 1978). In addition, uranium solubility is controlled by adsorption of the uranyl ion onto the surfaces of aluminum and iron oxyhydroxide compounds at commonly coated mineral surfaces. In addition, a geochemical study of sludges in the S-3 Ponds before their remediation determined that uranium was present in the solid phase in aluminum oxyhydroxide compounds (Lee and Hyder 1987).

Figure D.50 shows the conceptual model for geochemical reactions at the S-3 Site that impact uranium solubility. Infiltrating waste water reacts with the bedrock minerals of the Nolichucky Shale resulting in changes to the geochemistry of the waste. The pH of the waste water is initially below pH 2, and dissolution of carbonate minerals and/or aluminum minerals buffers between 3.2 and 3.5. Further neutralization of the waste water by dissolution of carbonate minerals raises the pH above 5. In the presence of an iron oxyhydroxide mineral, as the pH of the infiltrating waste water increases, the solubility of uranium decreases. Above pH 4, the absolute solubility of uranium is controlled both by adsorption of uranium to the mineral's surface and by the tendency for uranium to form a nonsorbing uranyl carbonate species in solution. As the partial pressure of CO_2 (Pco_2) in solution increases as a result of carbonate dissolution, uranium will tend to form the uranyl carbonate species. The extent to which the Pco_2 is likely to increase is dependent on how easily the solution is

able to release CO₂ gas during the neutralization reaction. Conceptually, in shallow groundwater, the Pco₂ will be close to atmospheric Pco₂ (10^{-3.5} atm), whereas in intermediate and deep groundwater where dissolution of carbonate has occurred, the Pco₂ is expected to be elevated. Pco₂ was calculated for wells at the S-3 Site using conventional carbonate equilibrium methods (Freeze and Cherry 1976) and results of analysis for pH and alkalinity (Table D.33). The resulting range of Pco₂ for groundwater at the S-3 Site was 6.9 × 10⁻⁵ to 5.2 × 10⁻¹ atm. The graph of uranium solubility on Fig. D.50 represents the calculated range of uranium solubility based on these maxima and minima values for Pco₂ and an initial concentration of 111 mg/L (Jeter and Napier 1978).

Technetium-99

Although Tc can form a number of valence states, it is most common in either the IV or VII states. Tc rarely exists in cationic form, and in aqueous solutions, the TcO₄⁻ compound is the most common form of Tc (Cotton and Wilkinson 1972). Technetium-99 present in groundwater or surface water in BCV is assumed to be in this anionic oxide form, which is relatively mobile and not easily sorbed to mineral surfaces.

D.6.6.6 Plume Dynamics – Time Trends in Concentration Data in the Nolichucky Shale

During 10 years of groundwater monitoring, trends of concentration over time have been observed in many of the monitoring wells in BCV. These trends tend to fall into two categories: (1) cyclic variation in analyte concentrations over approximately annual periods and (2) long-term trends of increasing or decreasing concentration. In most cases, where a well shows a long-term trend in concentration change, an annual cyclic trend is superimposed on the longer-term trend. After comparing the concentrations of some selected analytes to piezometric head in BCV wells, HSW (1995) interpreted the annual cyclic variation in concentrations of analytes in wells as being related to the seasonal high- and low-flow periods. In the absence of long-term changes in hydraulic head, which might indicate changes in the hydraulic regime of a well, the long-term trends are assumed to be related to the migration of plumes in the subsurface.

Long-Term Trends

Nitrate, gross α, and gross β

The principal contaminants at the S-3 Site that occur in identifiable, extensive groundwater plumes are nitrate, gross α, and gross β. Groundwater in BCV has been comprehensively monitored for these parameters for nearly 10 years (the GWQR database dates from 1985). Although concentrations or activities of these three main contaminants have changed in some wells, changes observed over 10 years of monitoring have not been large enough to alter the interpreted distribution of the nitrate, gross α, and gross β plumes.

Figures D.12 and D.13 show the concentration vs time trends for nitrate in wells in BCV. In the deep interval close to the S-3 Site, GW-615, which is screened in the central axis of the nitrate plume, has recorded variations in nitrate and gross β concentrations; however, this well shows no systematic changes in values of these analytes over time. Two wells located in shallow and intermediate bedrock close to the S-3 Site, GW-616 and GW-243, both show long-term increasing trends in nitrate: nitrate in GW-243 increased from <6000 mg/L in 1988 to ~9000 mg/L in 1994; and, except for two samples with results >400 mg/L in 1990, nitrate concentrations in GW-616 increased from ~200 mg/L in 1st quarter 1990 to 320 mg/L in 3rd quarter 1992 (there are no samples from this well after 1992). Water table wells at the S-3 Site show decreasing trends in nitrate concentration and decreasing activities of gross α and gross β (Shevenell, Moore, and Dreier 1994). Well GW-276 recorded decreasing

nitrate, gross α , and gross β between 4th quarter 1986 and 3rd quarter 1994 (Figs. D.12 and D.51). GW-127 has also shown a decreasing trend in nitrate concentration (Shevenell, Moore, and Dreier 1994; Fig. D.12).

About 457 m (1500 ft) along strike west from the S-3 Site, well cluster GW-345/GW-346/GW-526 shows trends in nitrate concentrations over time similar to those in wells close to the former S-3 Ponds. At this cluster, the two shallower wells [GW-245 (8 m or 26.3 ft) and GW-246 (19.9 m or 65.3 ft)] show apparent decreasing trends in time between 4th quarter 1988 and 1st quarter 1994. The deepest well in the cluster [GW-526 (30.8 m or 101 ft)] shows an increase in nitrate concentration over the same period from <600 mg/L to ~1000 mg/L.

About 1067 m (3500 ft) along strike west from the S-3 Site, two wells west of NT-2 screened in the <30 m (100 ft) interval also show increasing trends in concentration. Nitrate in groundwater monitored by wells GW-085 [18.9 m (62 ft)] and GW-086 [10.2 m (33.5 ft)] has increased in concentration over the past 4 to 6 years. However, nitrate concentration in well GW-537 [7.5 m (24.5 ft)], located west of NT-2 but east of GW-085 and GW-086, has remained approximately the same over the past 4 years.

Although no monitoring data along strike from the S-3 Site in the Nolichucky Shale are available before 1984, the results from 1984 sampling (McCauley 1985) indicate that the nitrate plume was approximately in its current location in 1984. Observed changes in individual wells indicate that the concentration is decreasing in some parts of the plume and increasing in others. The following patterns are apparent:

- Nitrate concentrations in shallow, intermediate, and deep bedrock wells adjacent to the S-3 Site show slightly increasing trends (GW-243, -245, -277, and -616), whereas water table wells close to the S-3 Site show decreasing trends (GW-105, -107, and -276).
- Shallow bedrock and water table wells in the NT-1 catchment (GW-345 and GW-346) show decreasing trends, whereas the intermediate bedrock well in this cluster (GW-526) shows an increasing trend.
- Further west, in the NT-2 catchment, shallow wells show increasing concentrations (GW-085 and GW-086); however, no data are available for the interval >30 m (100 ft) deep.

VOCs

The extent of VOC contamination in groundwater at the S-3 Site is limited to fewer wells than that of inorganic contamination. However, the concentrations of PCE and TCE in groundwater show trends over time in wells GW-243 and GW-245, both screened at 23.5 m (77 ft) and located adjacent to the S-3 Site (Fig. D.52).

PCE and TCE in well GW-243 each show two distinct trends, with a change in slope (rate of change in concentration with time) between the 2nd quarter of 1989 and 3rd quarter 1990. Before 1990, TCE maintains an almost stable, or slightly increasing, concentration of <11 $\mu\text{g/L}$; this concentration subsequently increased from 11 $\mu\text{g/L}$ in the May 1990 to 150 $\mu\text{g/L}$ in October 1991. The concentration of PCE shows a similar increasing trend with two slopes: (1) the concentration of PCE increased from 630 $\mu\text{g/L}$ in March 1987 to 2300 $\mu\text{g/L}$ in May 1989 (an increase of ~110 $\mu\text{g/L}$ per month); and PCE in GW-243 increased from 2300 $\mu\text{g/L}$ in May 1989 to 9000 $\mu\text{g/L}$ in August 1992 (an increase of ~170 $\mu\text{g/L}$ per month). These changes in concentration over time are accompanied by a decrease in the hydraulic head in this well over time. Before 1990, the piezometric

head in GW-243 declined from 304.86 m (1000.2 ft) in March 1987 to 303.34 m (995.2 ft) in January 1990 [a decrease of ~6 cm (2.4 in.) per month]. However, after January 1990, this declining trend stopped; although groundwater head has varied by >30 cm (12 in.) from sample event to sample event, no long-term increasing or decreasing trend has been apparent since that time.

D.6.6.7 Mechanisms Affecting the Migration of Contaminants in the Nolichucky Shale at the S-3 Ponds

Emplacement of the S-3 Plume

During operation of the S-3 Ponds, a considerable volume of waste water was disposed of in the ponds, most of which probably infiltrated to groundwater. Influent rates varied throughout the period of operation: in 1983, the annual quantity of liquid waste entering the ponds was reported to be ~10.3 million L (2.7 million gal).

Based on the 50-year average rainfall for East Tennessee [135.5 cm (54.2 in.), Appendix C], average direct rainfall input to the S-3 Ponds was 20.1 million L/year (5.3 million gal/year) during this period, resulting in a total average liquid input to the ponds of 30.4 million L/year (8 million gal). The annual loss from the ponds to evaporation was estimated to be one-half to two-thirds the annual input from direct rainfall (10.1 to 13.4 million L/year) (Energy Systems 1987); the remainder, plus waste inputs into the ponds, is assumed to have infiltrated to the groundwater (17.0 to 20.3 million L/year or 114 to 137 cm/year). This value for total recharge for the ponds is 3 to 10 times greater than the average annual recharge estimated for the ORR [average annual recharge on the ORR is estimated at 14 to 37 cm (5.6 to 14.8 in.) (Moore 1988), compared to 114 to 137 cm (45.6 to 54.8 in.) for the S-3 Ponds during operation]. This increased flux of recharge associated with the active ponds resulted in elevated groundwater piezometric heads in the vicinity of the ponds during operation (Geraghty and Miller 1989).

Much of the waste water that infiltrated through the base of the ponds probably did not recharge to bedrock groundwater but migrated laterally to the main stem of Bear Creek and NT-1. That these sections of the creek and NT-1 were extensively contaminated is well recorded (Turner et al. 1991). Additional evidence supporting the hypothesis that much of the waste water exited the S-3 Site to surface water after relatively short flowpaths is that, after cessation of operations at the ponds, the concentrations of nitrate and uranium and the pH in Bear Creek increased dramatically over a few months, while considerable contamination (>10,000 mg/L nitrate) still remains in groundwater at the S-3 Site (Sect. D.6.5). The available records are not sufficient to quantify the total volume of waste water that has recharged to bedrock groundwater in the vicinity of S-3 Ponds.

The mechanisms that caused recharge of waste water from the ponds into intermediate and deep groundwater were unique to the environment during that period. Figure D.53 depicts a conceptualization of emplacement of the contaminated groundwater plume in the Nolichucky Shale at the S-3 Site. The relatively recent (<50 years old) infiltration of groundwater into the intermediate and deep interval of the aquifer is somewhat anomalous, as shown by the BCV hydrogeological conceptual model (Appendix C), for three reasons: (1) groundwater gradients in the Nolichucky Shale are generally upward and gradients tend to increase towards the axis of the valley; (2) geochemical modeling suggests that the flow system <30 m (100 ft) includes groundwater that is >500 years old; and (3) the conductivity of the Nolichucky Formation is very low, especially in the bedrock intervals (Solomon et al. 1992), which would tend to preclude relatively rapid emplacement of the waste water plume. Thus, other mechanisms were apparently operating at the time of operation of the S-3 Ponds to drive infiltrating waste water into the deep groundwater system.

Two mechanisms that contributed to driving the waste water plume into the deep groundwater interval are (Dreier, Early, and King 1993):

- The elevated head at the ponds, which resulted from rapid infiltration through the ponds, may have locally reversed the hydraulic gradients in the Nolichucky Shale to create a downward gradient.
- Waste water was more dense than ambient groundwater.

In the center portion of the nitrate plume (GW-615, -108, and -109), concentrations of nitrate $>10,000$ mg/L (~ 0.71 mol/L) are commonly recorded. This concentration would be equivalent to a nitric acid solution of $\text{pH} < 1$, and almost no dilution of the original waste water in the center of the plume can be assumed. The solutions disposed of in the S-3 Ponds were reported as having $\text{pH} < 2$ (Energy Systems 1987), which is approximately consistent with the observed concentrations in groundwater. Because of the concentration of nitrate in the center of the plume, recharged waste water solutions are assumed to have had a total molarity ~ 0.5 to 1.0 M. These solutions (densities 1.06 to 1.12) were denser than ambient groundwater (density ~ 1.0), and this density contrast would have been a driving force behind emplacement of the waste water plume in deep groundwater.

In addition to an increased driving force for recharge to the intermediate and deep groundwater interval, the corrosiveness of the waste water ($\text{pH} < 2.0$) provided a mechanism for increasing the formation conductivity and porosity such that waste water was able to infiltrate to the deep interval in a relatively short time.

Although siliceous lithologies dominate in the Nolichucky Shale, the formation contains considerable limestone (Hatcher et al. 1992) and has an approximate shale to limestone ratio of $1:1.75$ (36% limestone). The results of modeling reactions of infiltrating waste water using the Minteq model show that a maximum of 12 g of calcite will dissolve in 1 L of S-3 Pond waste water (Fig. D.50). This equates to ~ 4.4 cc of calcite per liter of waste water, or $230,000$ L of acid, to dissolve 1 m³ of carbonate. Using this gross estimate for the volume of carbonate that could have been dissolved by each liter of waste water, sufficient acid was disposed of in the S-3 Ponds each year to dissolve ~ 88 m³ of carbonate. Over the life of the ponds (31 years), this equates to 2728 m³ of carbonate or all the limestone out of ~ 7500 m³ of the Nolichucky Shale. This calculation includes several uncertainties: the main one being that not all the waste water is likely to have recharged to groundwater. Nevertheless, the volume of rock that could be dissolved by the waste water disposed of in the S-3 Ponds is probably representative of the order of magnitude of the true value.

Compared to the total extent of the plume, the total volume of rock from which carbonate could be removed (calculated above) is relatively small. However, dissolution of this volume of carbonate from the subsurface could increase porosity by 1 to 2% in a relatively large volume of rock ($100,000$ m³) and would probably increase conductivity of some individual fractures or limestone beds along strike for a considerable distance from the former ponds. This would be sufficient to create preferential flow paths along strike from the former ponds.

Migration of the S-3 Plume

The configuration of the plume directly after emplacement and the hydraulic gradients in the Nolichucky Shale control the current distribution and mass fluxes of contaminants in groundwater at the S-3 Site. In addition, two important mechanisms that affect contaminant migration in fractured bedrock probably dominate on the ORR: (1) advective transport through fractures and solution openings and (2) diffusive transport through fine and poorly connected fractures (or the matrix).

Figure D.54 shows a detailed conceptual model of the S-3 plume and the likely migration pathways operating today. The conceptual model for groundwater flow in the Nolichucky Shale in BCV (Appendix C) includes generally upward hydraulic gradients in the bedrock and downward hydraulic gradients in the water table interval that result in converging flow paths at the bedrock/residuum interface and at tributaries. Flow paths at the water table interval carry most of the groundwater flux, and the proportion of flow contributed to the shallow system from deep groundwater is probably small. The effect of this flow pattern on contaminant migration is to allow contaminated groundwater in the most concentrated part of the S-3 plume in the Nolichucky Shale [<30 m (100 ft) depth] to slowly migrate upwards into the shallow system, where it is diluted with shallow recharged water and then mostly discharged into tributaries. This effect is probably enhanced where vertical fracture zones cut through Nolichucky Shale. The following observations support this hypothesis:

- Groundwater in the shallow bedrock and water table intervals in the Nolichucky Shale is contaminated up to 914 m (3000 ft) along strike from the S-3 Ponds. The shallow plume apparently traverses two tributary catchments and one watershed. The BCV conceptual model for groundwater flow indicates that contaminants from the S-3 Site are not likely to migrate over catchment watersheds in the shallow bedrock and water table intervals; thus, migration of contaminants in the shallow interval alone cannot explain the current configuration of the S-3 plume in the Nolichucky Shale.
- The plume in the intermediate and deep intervals of the Nolichucky shale is an order of magnitude more concentrated than that in the shallow system, and in some zones, the concentration of nitrate indicates that solutions are almost pure, undiluted waste water.
- The rate of change of contaminant concentrations in the intermediate and deep intervals of the plume implies that most of the plume below 30 m (100 ft) was emplaced during pond operation. During operation, elevated heads at the ponds and the higher density and corrosive nature of the waste water probably resulted in the waste water migrating into the intermediate and deep intervals of the aquifer almost to the extent seen today.

The configuration of the nitrate plume at the S-3 Site defines the maximum extent of the distribution of contaminants derived from the S-3 Ponds. However, the configurations of the radionuclide and organic contaminant plumes differ significantly from that of the nitrate plume, implying that different mechanisms influence the migration of radionuclides and organics in the subsurface. The primary differences between the distribution of nitrates versus that of radionuclides and organics are:

- Although radionuclides (distributions of which are reflected in the configuration of gross α and gross β activities) are more concentrated in the deep intervals downgradient from the S-3 Ponds, the concentration gradients are reversed close to the former ponds, where higher activities have been recorded in the shallow intervals.
- The extent of gross α contamination along strike in the Nolichucky Shale is less than that for nitrate and gross β in both the shallow and deep intervals.
- The extent of organic contaminant plumes is much less than either the nitrate or radionuclide plumes. In addition, the nature of organic chemicals that occur in groundwater varies widely.

Possible mechanisms responsible for different plume configuration from the same source are:

- variability in the timing of inputs for the various contaminants, and
- greater retardation of more particle reactive species.

Waste waters disposed of in the S-3 Ponds were probably consistently contaminated with radionuclides, although the incidence of some radionuclides that have not been detected in groundwater was probably sporadic. Uranium isotopes have been identified as the principal α radiation emitters. Although uranium forms relatively soluble and negatively charged species in carbonate systems, uranium will be more retarded than nitrate in a fractured shale such as the Nolichucky. One reason for greater retardation would be the formation of the positively charged uranyl ion that coexists with the uranyl carbonate anion complex. Uranyl ions are highly particle reactive and will easily sorb to the bedrock minerals in the pH range observed in groundwater at the S-3 Site, thus removing uranium from solution. Greater retardation of uranium can explain the apparent lesser extent to which the gross α plume has migrated along strike from the S-3 Ponds compared to the extent of nitrate and ^{99}Tc .

D.6.7 HABITAT DESCRIPTION AND ECOLOGICAL SETTING OF THE S-3 SITE

Before 1983, the S-3 Ponds were open ponds containing nitric acid process wastes from Y-12 Plant operations. The waste solutions were highly toxic, and the ponds are presumed not to have had aquatic populations. After the wastes were neutralized and the nitric acid concentrations were reduced in 1983 through 1984, a thick layer of sludge formed at the bottom of the ponds. Active populations of protists (e.g., rotifers, *Stentor*, *Paramecium*) and bacteria (especially rosette-forming populations) developed in the bottom sediments; however, populations of aquatic vertebrates are assumed not to have formed in the ponds.

The populations of protists and bacteria are assumed to have been eliminated when the ponds were filled and paved in 1989. The S-3 Ponds source unit is currently paved and used as a parking lot, and the immediately surrounding area consists of paved roads and mowed grass. Figure D.55 shows the distribution of paved areas and mowed grass on the S-3 Ponds source unit. No jurisdictional wetlands occur within the source unit. Federal- and state-listed protected species are described in Supporting Information for Appendix D.

D.6.7.1 Potential Exposure to Contaminants

No surface water exposures occur within the S-3 Ponds source unit. Because the non-paved areas surrounding the source unit are assumed not to have been contaminated by the ponds, no significant exposures to site-related contaminants in surface soil are likely. Therefore, no surface soil samples were taken during the field sampling phase of the investigation. Similarly, because the S-3 Ponds source unit has no natural habitat and no assumed exposure to contaminants, no ecological sampling was performed.

S-3 Pond contaminants may impact shallow groundwater and surface soils west of the source unit itself. The area west of the S-3 Ponds includes the West End Treatment Facility, the Rust Spoil Area, the Bear Creek Road Debris Burial, the Creekside Debris Burial Area, and habitat north of Bear Creek and west to NT-2. The West End Treatment Facility is paved and provides no suitable habitat for ecological receptors. The Rust Spoil Area was included in BCV OU 2 (Energy Systems 1993). The Creekside Debris Burial Area and the area west of the S-3 Ponds, north of Bear Creek, and extending to NT-2, comprise predominantly pine and mixed hardwood forest and right-of-way for Bear Creek Road. The distribution of habitat types in the area from the S-3 Ponds to NT-2 and north of BCV is approximately:

- industrial 15.0 ha (37.2 acres)
- pine forest 1.0 ha (2.5 acres)
- hardwood forest 18.6 ha (46.0 acres)

The Creekside Debris Burial Area is currently in an area of mixed pine and hardwood forest.

D.6.7.2 Toxicity Testing at the S-3 Ponds Area

Ambient Water Toxicity

Two test organisms, fathead minnow (*Pimphales promelas*) and *Ceriodaphnia dubia*, were used in the tests, which were conducted at the ORNL Environmental Sciences Division Toxicology Laboratory. Standard Environmental Protection Agency protocols were used for all tests. Toxicity is defined in these tests as statistically significant reduction in (1) fathead minnow survival and growth or (2) *Ceriodaphnia* survival and reproduction. Briefly, for the fathead minnow test (Method 1000.0), 1-d-old fathead minnow larvae were placed in beakers containing either control water or water from a test or reference site (Hinds Creek). Four replicates of each sample were tested. The water in the test chambers was changed daily, using test water that had been stored for no more than 3 d. The summary report lists survival and growth after 7 d. For the *Ceriodaphnia* test (Method 1002.0), ten replicates were tested per site. The water in the test chambers was changed daily, using test water that had been stored for no more than 3 d. Survival and the number of offspring were scored daily. The summary report lists reproduction as average offspring per individual and as percentage of control and of the reference site. Each water sample was also analyzed for pH, conductance, alkalinity, hardness, and oxygen concentration.

Ambient water toxicity tests showed toxicity in surface water from BCK 12.36 and tributaries NT-1 and NT-2 (Hinzman 1995). For example, tests done in May 1994 showed significant reductions in survival of *Ceriodaphnia* in water from these locations, and reproduction was decreased in water from NT-1 and BCK 12.36. In August 1994, decreased reproduction was observed in a sample from BCK 12.36 but not at other sites related to the S-3 Ponds. However, dilution of the surface water by a recent rainfall had diluted site-related contaminants in the surface water. No significant toxicity to fathead minnows was seen in any sample during either test period.

Sediment Toxicity

Ambient sediment toxicity tests were done as part of the RI in May and June of 1995. In these tests, the freshwater scud *Hyaella azteca* is exposed to whole sediment and *Daphnia magna* is exposed to overlying water. Details of sediment toxicity tests were reported by Gonzalez (1995). Protocols for sediment toxicity testing are found in the ORNL/ESD *Toxicology Laboratory Quality Assurance Program Manual* (Kszos et al. 1989), which are in draft form. Whole-sediment toxicity to *H. azteca* was tested by SOP #21, which is based on U.S. EPA methods (EPA 1994). In this test, sediment is placed in beakers and equilibrated with clean water. Amphipods are added to each beaker and incubated under controlled temperature conditions, with daily feeding. After 10 days, organisms are recovered from each beaker, and live amphipods are counted. Toxicity of overlying water from the test chambers was measured using *D. magna* according to SOP #22, which is based on methods presented by the American Society for Testing and Materials (ASTM 1991). This test is similar to ambient water toxicity testing using *Ceriodaphnia*, except that the test water is a layer of water overlying the test sediment.

Sampling locations SD01 through SD17 are shown in Fig. B.50 in Appendix B. No statistically significant toxicity was demonstrated in samples taken at sites SD01, SD02, SD03, or SD14 near the S-3 Ponds, when compared to a composite reference sample taken from NT-11, NT-13, and NT-15.

D.6.7.3 Bioaccumulation Studies

A study of contaminant bioaccumulation by stonerollers in Bear Creek (Hinzman 1995) showed elevated concentrations of metals, especially mercury, nickel, and cadmium, in fish sampled at BCK 12.36, near the S-3 Ponds. Nickel and cadmium are thought to be derived from the S-3 groundwater plume (Hinzman 1995), but the source of mercury is not currently known.

D.6.8 S-3 SITE CONCLUSIONS

D.6.8.1 General Conclusions for Nature and Extent

Figures D.54 and D.56 show detailed conceptual models of the S-3 plume and the likely migration pathways operating today. Figure D.53 depicts a conceptualization of emplacement of the contaminated groundwater plume in the Nolichucky Shale at the S-3 Site. These two figures are key to understanding the conclusions of this chapter and are referred to often in this section.

Wastes

- Sludges remain in the former S-3 Ponds and are mixed with the material used to structurally stabilize the pond cap (Appendix A, Plate A.4). Photographs of the closure operations indicate that the material used to stabilize the cap was dolomite or limestone and that this material was mixed with the remaining sludges. The sludges contain or contained elevated concentrations of metals, volatiles, and radionuclides, particularly chromium, cadmium, acetone, PCE, uranium, and ^{99}Tc .
- A leaching study of the sludges showed that, when leached with water, the sludges yielded solutions up to 120 pCi/L uranium and 60,000 pCi/L ^{99}Tc (Lee and Hyder 1987). Modeling of leachate from the S-3 sludges supports these data.

Soils

- The concentrations of some chemicals in soils surrounding the S-3 Site are slightly elevated above background. Contaminants of note are mercury, acetone, PCE, and uranium. The highest concentrations of PCE and uranium occur in samples from borings close to the southwest quadrant of the S-3 Ponds.
- Contaminant concentrations in the soils surrounding the S-3 Site are one to three orders of magnitude less than the concentrations in the sludges.
- Contaminants that occur both in pond sludges and in soils above background criteria are uranium isotopes (^{234}U , ^{235}U , and ^{238}U) acetone, and PCE.

Groundwater

- Groundwater is contaminated with nitrate, radionuclides, 21 metal species, and 21 VOCs. In general, the contaminant plumes are strongly oriented parallel to geologic strike and exhibit the

highest concentrations in the Nolichucky Shale. The principal contaminants are nitrate, gross α (uranium), gross β (uranium and ^{99}Tc), barium, boron, cadmium, manganese, nickel, strontium, uranium, zinc, 1,1,1-TCA, acetone, methylene chloride, PCE, toluene, and TCE.

- The distribution of the contaminant plume is highly depth-dependent: below 30 m (100 ft), nitrate, gross β , gross α , and acetone contamination extends from the former S-3 Ponds east into UEFPC and west along geologic strike as far as the BYBY [~ 914 m (3000 ft)]. Above 30 m (100 ft), the contaminant plume extends westward, but only nitrate and gross β contamination extends as far as NT-1. The maximum depth at which contaminants have been detected close to the S-3 Ponds in the Nolichucky Shale is 129.5 m (425 ft). The maximum depth of contaminants downgradient of the S-3 Ponds at NT-1 and NT-2 is not known.
- The distribution of the principal contaminants exhibits distinct differences: close to the S-3 Ponds source, the highest concentrations of nitrate ($\sim 10,000$ mg/L) occur at depths >30 m (100 ft), whereas the highest activities of gross β and gross α occur at depths <30 m (100 ft). Downgradient west of the S-3 Ponds, the highest concentrations of all three contaminants occur at depths >30 m (100 ft). To the east in UEFPC, the highest nitrate concentrations occur at <30 m (100 ft), whereas gross α is almost absent at <30 m (100 ft).
- Time series trends for nitrate show that, in general, concentrations of nitrate in the Nolichucky Shale west of the former S-3 Ponds have steadily increased or remained stable over the past 10 years. The most significant increases have occurred in wells located close to the leading edge of the plume (GW-085, -086, and -537). However, wells located adjacent to the S-3 Ponds have also shown increases in nitrate concentration (GW-243).
- Concentrations of nitrate in shallow water table wells to the south and east of the S-3 Ponds have shown both stable and decreasing trends (GW-106 and GW-276).
- Activities of gross α and gross β show no consistent trend, but this lack of any trend could be an artifact of few data points. GW-276 is a shallow well that shows decreasing trends in both gross α and gross β consistent with a decreasing trend in nitrate in that well, and GW-085 is a shallow well near the BYBY that shows an increasing trend in gross β consistent with an increasing trend in nitrate.
- Well GW-243 shows a distinct trend over time for PCE, with concentrations having systematically increased over the past 5 years. The maximum concentration of PCE in GW-243 (9000 mg/L or $\sim 6\%$ of maximum solubility) indicates the potential for DNAPL close to the S-3 Ponds.

Surface Water

- Surface water in the uppermost reaches of Bear Creek, NT-1, and NT-2 is contaminated with nitrate, ten other inorganic species, radionuclides, and seven VOCs. The principal contaminants are nitrate, gross α (mainly uranium), gross β (mainly ^{99}Tc), barium, boron, cadmium, nickel, strontium, uranium, and PCE. All contaminants detected in surface water also occur as contaminants in groundwater at this site.
- The relative concentrations/activities of contaminants vary between stream reaches. The concentrations of nitrate in NT-1 and NT-2 are greater than those in the main stem of Bear Creek above the confluence with NT-1. However, uranium contamination of surface water at the S-3 FA occurs in the main stem of Bear Creek, and concentrations in NT-1 are almost an

order of magnitude lower. Gross α contamination was not detected in NT-2, whereas gross β activities and nitrate concentrations are similar to those recorded in NT-1.

- The most frequent organic contaminant was PCE and its maximum concentration was 19 $\mu\text{g/L}$ in a grab sample close to the contaminated groundwater discharge point in NT-1.
- Concentrations of contaminants vary, depending on total flow. As flow increases, concentrations of contaminant decrease; however, the relationship is not a simple dilution of contaminants discharging from groundwater by rainwater. The total flux of contaminants increases with flow, indicating that contaminant release rates are governed, in part, by flow rates.

D.6.8.2 Interpretive Conclusions and Working Hypotheses

Soils

The generally low concentrations of contaminants in the soils surrounding the S-3 Ponds (especially when compared to contaminant concentrations in the pond sludges) indicate that the source of contamination in groundwater and surface water at this site is the former pond basins and that, if leaching is a current source of contamination, the sludges that remain in the pond basins are the most likely source. The low concentrations in the soils also indicate that contaminants in the sludges have not migrated to surrounding soils and reprecipitated. This finding is consistent with the following conclusions: the shallow groundwater pathway from the S-3 Ponds to surface water is probably by way of preferential flow paths (probably fractures), and waste water migrating through the shallow subsurface close to the S-3 Ponds bypassed most of the rock body. Thus, most of contaminants probably passed through the shallow system and were not exposed sufficiently to mineral surfaces to sorb or precipitate.

All Media Organics

PCE. PCE is present as a contaminant in the S-3 sludges, soils close to the southwest quadrant, groundwater, and surface water. The concentration of PCE in GW-243 adjacent to the S-3 Ponds has been increasing over the past 5 years, and the maximum concentration of PCE attained indicates the potential for a DNAPL. The PCE plume is localized to the southwest quadrant of the former S-3 Ponds and along strike to NT-1; however, this localization could be an artifact of the monitoring well distribution because no samples have been obtained from beneath the S-3 Ponds.

The working hypothesis is that most PCE was emplaced in the ground during operations and that it probably included a free-phase DNAPL containing PCE. DNAPL is probably present in the formations beneath the S-3 Ponds and is responsible for the current concentrations of PCE in groundwater (Fig. D.49). The observed changes in PCE concentrations in GW-243 are probably a function of the slower migration rates of organics in the Nolichucky Shale and represent the breakthrough of the leading edge of the plume. The S-3 Ponds sludges may also be contributing PCE to groundwater via leaching; however, because the concentrations of PCE in groundwater that would result from this leaching are lower than those observed, this conclusion cannot be confirmed or denied.

Acetone. Unlike PCE, acetone was more likely to have dissolved completely in the pond waste water and, thus, is more likely to migrate as a dissolved phase. The observation of acetone as a co-contaminant with nitrate 610 m (2000 ft) downgradient to the west confirms this hypothesis. Most acetone was probably emplaced in the ground during operations and probably migrates in a similar manner to nitrate.

Inorganic Plume

TDS. TDS concentrations in groundwater in wells close to the S-3 Ponds have exceeded 20,000 mg/L or 20 g/L. These high values reflect the recharge of waste water solutions, with apparently little or no dilution by groundwater. TDS concentrations decrease downgradient, indicating that the plume becomes more diffuse and has mixed with groundwater; however, TDS concentrations >5000 mg/L occur in the deep system up to 610 m (2000 ft) downgradient of the S-3 Ponds. TDS in surface water reaches a maximum of 1520 mg/L in the main stem of Bear Creek at BCK 12.38.

Nitrate. Because nitrate was effectively removed from the S-3 sludges during treatment (denitrification), the sludges still in place are not expected to currently yield nitrate to groundwater via leaching. The migration pathways for nitrate in groundwater are complex and have changed over time from the pathways active during operations at the S-3 Ponds to current pathways. Nitrate defines the maximum distribution of contaminants from the S-3 Ponds because of its conservative chemical nature. The interpreted development of the nitrate plume in groundwater (considered as a tracer) in the Nolichucky Shale is discussed below. Although other contaminants in the waste water, such as metals and radionuclides, have migrated along the same pathways, different chemical reactions may have caused differential retardation of contaminants as well as differences in distributions of contaminants within the S-3 plume.

Emplacement of the nitrate plume took place during operations at the S-3 Ponds until denitrification (1951 through 1983). During emplacement, the following processes operated (Fig. D.53):

- The plume was driven by the elevated head in the S-3 Ponds and the higher density of the waste water. The corrosiveness of the waste water created the pathways for migration along carbonate-rich horizons in the Nolichucky Shale close to the S-3 Ponds by dissolving carbonate minerals, thereby increasing conductivity of the formation. Further downgradient of the S-3-Ponds, where waste water had been neutralized by mineral reactions, dissolution of carbonate was probably less important in increasing the conductivity of the formation, and flow through fractured shale and limestone beds in the Nolichucky Shale was the primary flow path. These factors combined to result in the downward migration of the plume to depths up to 122 m (400 ft) and along strike at depths >30 m (100 ft) for up to 914 m (3000 ft) west of S-3 (Fig. D.53).
- A shallow pathway for nitrate to Bear Creek is evidenced by the low pH of water in the uppermost sections of the creek during operations at the ponds. The shallow pathway was through preferential flow paths in the shallow subsurface and had a relatively short residence time (<6 months). Evidence for this conclusion is that within 6 months of neutralization of the pond liquids in 1983, the pH of water in the creek had increased from pH 3 to pH 6. This information also shows that shallow groundwater near the S-3 Ponds was effectively neutralized by mineral reactions even at this time. During operation of the S-3 Ponds, the primary pathway for nitrate to Bear Creek was the shallow, short-residence pathway to the main stem and NT-1.
- High concentrations of contaminants in the flow paths and higher piezometric head in the center of the plume drove contaminants from the flow system into the less conductive matrix of the rock formation. This action built up a reservoir of contaminants in the poorly connected matrix and also probably increased the piezometric head above the ambient head in the pore spaces.

Since cessation of activities at the S-3 Ponds, the shallow pathway has steadily ceased to be as significant a pathway for nitrate. This conclusion is evidenced by the reduction in nitrate concentrations in the main stem close to the S-3 Ponds and correlates with the reduction of nitrate concentrations in some shallow wells near the S-3 Ponds. Nitrate moves into the shallow active groundwater flow system and surface water from two principal sources: (1) upwelling and/or diffusion from the deep groundwater plume to the shallow system and then into tributaries NT-1 and NT-2 and (2) flow and/or diffusion from the reservoir of contaminants in the matrix to the shallow flow system close to the S-3 Ponds (Figs. D.54 and D.56):

- Migration from the deep plume into the shallow groundwater system is probably driven by upward hydraulic gradients, which may be locally more prominent at tributaries and may also include upward diffusion of nitrate. Unless a vertical fracture system exists, the migration pathway will not be directly upwards because of the anisotropy of the formations. However, the vertical upward gradients induce an upward component in the migration vector of the contaminants in the deep plume, which ultimately results in contaminants entering the shallow, more active flow system and, hence, into the tributaries to Bear Creek.
- The effects of matrix diffusion have resulted in a large body of nitrate-contaminated water in the groundwater system that is slowly releasing nitrate into the actively flowing system. In addition, the elevated pressure in the groundwater during the time of emplacement of the plume has not dissipated as quickly from the matrix as from the flow system. The likely existence of this hydraulic gradient from the matrix blocks to the flow system also drives contaminants into the flow system. The effects of diffusive and advective transport of contaminants from the matrix to the flow systems cannot be distinguished from one another; however, the effects are the same—a slow release of contaminants into the flow system from a large reservoir of contaminants.

In the shallow flow system, contaminated groundwater mixes with recent recharge in a convergent flow zone, probably located in the bedrock residuum interface and shallow bedrock intervals. Flow in this region is lateral, along strike to the tributaries.

Shallow wells (GW-085 and GW-086) at BYBY (NT-2 catchment) show increasing concentrations of nitrate over the past 10 years; the fact that the source of nitrate for these wells is by way of upwelling from the deep plume suggests that the center of mass of the deep plume is still moving westward along strike. The fate of the plume's leading edge is the most uncertain condition of the S-3 plume. The future distribution of the nitrate plume is probably governed by large-scale structure in the upper Nolichucky Shale and in the Maynardville Limestone. There are two possible hypotheses:

- The current plume is at its maximum extent, and the center of mass of the plume is moving slowly along strike towards NT-2. This hypothesis assumes that the geologic structure close to NT-2 causes large-scale upwelling of the nitrate plume and essentially removes the force driving plume further along strike. The presence of a structure may be indicated by large springs in Chestnut Ridge opposite NT-2. In addition, the concentration of nitrate in a shallow well close to NT-2 (GW-537) is almost as high as that in wells closer to the S-3 Ponds, possibly indicating a high rate of upward migration from the deep plume at this location. Head data from the most recent wells in this area also indicate that the upward hydraulic head is anomalously high in this area.
- The plume will continue to migrate along strike until a cross-cutting structure forces the plume either upwards to the shallow system or across strike into the Maynardville Limestone.

Cross-cutting structures have been observed in the upper Nolichucky Shale and the Maynardville Limestone in local quarries. The stratigraphic thickness of the Maynardville Limestone is known to change along strike in BCV at the expense of the thickness of the Nolichucky Shale (Goldstrand and Dreier 1993).

Both these hypotheses are likely working hypotheses, although a single working hypothesis for this aspect of the S-3 plume cannot be selected at this time.

Gross α . Gross α contamination is mostly derived from uranium. In the following discussion, the extent and activity of gross α in groundwater is presumed to reflect the relative total activity and extent of uranium isotopes in groundwater.

The relative distribution of gross α activity in the S-3 plume distinctly differs from that of nitrate concentrations. At the S-3 Ponds, the most elevated activities of gross α are in the shallow bedrock wells, and the extent to depth and along strike is much less for gross α than for nitrate. Three possible contributing processes may have resulted in the differences between the distribution of uranium relative to nitrate:

- Different disposal histories for nitrate and uranium. This hypothesis is not likely because the nitric acid solutions disposed in the S-3 Ponds were always contaminated with uranium.
- Relative retardation of uranium in the subsurface. The initial reaction of the acidic solutions on contact with rock during infiltration would be to neutralize the acidity and increase pH. The propensity for the stable uranium aqueous species in acidic solutions to sorb to minerals increases exponentially with increasing pH above pH 2. At pH 5, all uranium in solution would effectively precipitate. Figure D.50 shows the conceptualization of this reaction and shows how nitrate solutions may be effectively stripped of uranium during the neutralization reaction. Continued neutralization of the waste waters would eventually develop a $\text{Ca-NO}_3\text{-CO}_3$ -dominated solution with pH 5.5 to 7 (pH 6.2 is observed in GW-615). In such solutions, uranium may become mobile again as a neutral carbonate complex, enabling uranium to migrate in groundwater.
- The S-3 Ponds sludges are currently leaching uranium to groundwater. Modeling of the pond sludges (Appendix E) and leaching studies that were carried out on the sludges before closure of the S-3 Ponds (Lee and Hyder 1987) suggest that uranium and ^{99}Tc are likely to be released from the sludges.

The working hypothesis for the BCV RI is that uranium in waste water was considerably retarded by geochemical sorption reactions compared to nitrate (the effects of matrix diffusion apply to both). Most uranium in groundwater at S-3 is immobile, sorbed to mineral surfaces, and slowly being chemically mobilized as the pH of groundwater near the S-3 Ponds increases in response to neutralization reactions. However, even in this more mobile form, migration of uranium in the Nolichucky Shale is retarded relative to nitrate by geochemical sorption reactions. Although the high activities of gross α can be explained by chemical retardation effects, the possibility that the pond sludges are continuing to leach uranium to groundwater cannot be ruled out. Evidence from leaching studies and modeling suggests that leaching may still occur; however, because the activity of gross α in leachate is less than the activities in the shallow groundwater at the site, changes in the chemistry of shallow groundwater that result from leachate cannot be observed.

The exit pathway for uranium is different from that of nitrate. Whereas nitrate-contaminated groundwater migrates along strike with only a small amount of attenuation of nitrate, uranium is

effectively stripped from these solutions and does not occur in elevated concentrations in shallow groundwater at NT-1. Uranium does discharge from groundwater to surface water in the main stem of Bear Creek adjacent to the S-3 Ponds, indicating that the shallow groundwater pathway from the Ponds to Bear Creek still operates for uranium. This may be the result of retardation of uranium relative to nitrate where the peak nitrate concentrations this pathway have already discharged to Bear Creek. In addition, a reservoir of adsorbed uranium exists in the shallow subsurface that is now leaking to groundwater.

Gross β . Gross β contamination is mostly derived from ^{99}Tc . In the following discussion, the extent and activity of gross β in groundwater is presumed to reflect the relative total activity and extent of ^{99}Tc in groundwater.

The relative distribution of gross β activities in the S-3 Ponds plume differs slightly from that of nitrate concentration but also shows some similarities with that of gross α . At the S-3 Ponds the most elevated activities of gross β are in the shallow bedrock wells, as are those for gross α ; however, the extent of gross β contamination along strike is similar to that of nitrate. The similarity to the distribution of nitrate along strike can be explained by the chemistry of the two contaminants, in that both occur as relatively stable anions in aqueous solutions, NO_3^- and TcO_4^- . Retardation of ^{99}Tc (similar to that of uranium) may also have occurred during acid neutralization via precipitation of insoluble Tc oxides with increasing pH. However, the pH range of insolubility of Tc is much smaller than that for uranium, and Tc is probably soluble at pH >4 in groundwater, whereas uranium only becomes soluble at pH >7.

The working hypothesis is that the distribution of gross β can be explained following the same lines of reasoning used to explain the distributions of uranium and nitrate at the S-3 Site. The pH range for precipitation of Tc is much smaller than that for uranium, which explains why gross β contamination is apparently retarded but not to the extent that gross α is. The chemical nature of Tc means that, once remobilized in the neutralized solutions, it is almost as soluble and mobile as nitrate and thus has a similar distribution. Similarly to gross α , leaching of ^{99}Tc from the current pond sludges cannot be ruled out because modeling predicts leaching and its effects cannot be observed.

Another factor that probably has contributed to the distribution of gross β in groundwater at the S-3 Site is the disposal history of ^{99}Tc . Solutions containing ^{99}Tc were disposed of in the S-3 Ponds after delivery to Y-12 Plant from off-site facilities during a period of unknown duration. The time frame for disposal probably differed from that for nitrate and uranium, which were disposed of at the S-3 Ponds continuously during their use. This different history will almost certainly have resulted in some differences in distribution of ^{99}Tc relative to nitrate; however, this effect cannot be defined at this time.

Metals. A variety of metals occurs sporadically in groundwater close to the S-3 Ponds. The solubility of most metals is increased by acidic solutions, and the occurrence of metals in groundwater close to the S-3 Ponds is consistent with this principle. A considerable reservoir of metals has probably sorbed to mineral surfaces close to the S-3 Ponds; however, the high-TDS groundwater may enhance metals solubility over sorption by reducing the effect of surface charges at mineral surfaces.

Other metals that occur as contaminants, but for which solubility is less pH-controlled, are barium and strontium. Both metals occur in elevated concentrations accompanying nitrate contamination. They probably have similar flow paths and distributions in groundwater. These metals are minor constituents in carbonates and were probably mobilized during dissolution of the carbonate minerals by the S-3 Ponds acid solutions. This process is consistent with the conceptual models for emplacement of the S-3 plume described above.

D.7 OIL LANDFARM FUNCTIONAL AREA

The OLF FA is composed of three soils, three surface water, and two groundwater chemical data aggregates for these media at, and immediately downgradient of, the OLF, BYBY, and SL 1 sites. Figure D.57 shows the distributions of groundwater wells, surface water sample sites, and soil and sediment samples sites, respectively, for data in the OLF FA.

Groundwater in this FA is restricted to groundwater in the Nolichucky Shale. Groundwater in the Maynardville Limestone that is contaminated with the OLF-derived contaminants is not considered in this FA. Table D.6 lists the groundwater wells in the OLF groundwater aggregates.

D.7.1 OIL LANDFARM FA – DETAILED SITE HYDROLOGY

Groundwater

Detailed information about the site hydrology of the OLF FA is sparse, but the hydrology is assumed to be similar to that found elsewhere in the BCV (Appendix C). Figure D.58 shows a hydrogeologic cross section of the site developed from Y-12 Plant GWPP data. Little or no data exist to estimate the depth of buried waste materials or contaminated soils at BYBY SL 1; however, because of the shallow depth of the water table over most of this FA, waste materials are probably inundated at BYBY and SL 1, particularly those buried close to NT-3 at the BYBY.

Most of the OLF FA is located on the Nolichucky Shale, and most water recharged to the groundwater is discharged to surface water in the tributaries after short flow paths through soil or shallow groundwater (see Appendix C). However, the southern section of BYBY and about half of SL 1 are located on the outcrop of the Maynardville Limestone and the floodplain of Bear Creek. Recharge from these sections of the OLF FA, instead of discharging rapidly to surface water, may enter the Maynardville aquifer, becoming incorporated in the along-valley flow system in this formation. Thus, contaminants leaching from soils and waste materials in the sections of the OLF FA underlain by the Maynardville Limestone migrate directly into the Maynardville Limestone aquifer.

Surface Water

The OLF FA is contained within the catchment of two tributaries to Bear Creek: NT-3 and NT-4. In addition to these two tributaries, NT-5, which is not geographically encompassed by any of the FAs in BCV, is included in the OLF FA because of its location along strike and immediately downgradient of the OLF.

Continuous flow measurements were made at three surface water monitoring locations in the OLF FA: NT-3, NT-4, and NT-5 (Fig. B.5 in Appendix B). The pattern of flow at all three sites is typical of that observed for the second-order or tributary streams in BCV. The magnitude of flow varies greatly; however, maximum flow is only maintained for short periods during and immediately after precipitation events. Figure D.59 contains the daily flow stream hydrographs for NT-3 and NT-4 showing the maximum, minimum, and average flow for each day.

Baseflow at NT-3 (best marked by the daily minimum flow) ranges from 0.0 L/s during late spring, summer, and fall (low-flow period) to ~5 L/s (0.2 cfs) between December and April (high-flow period). Baseflow ranges from 0.0 to 0.84 L/s (0.03 cfs) for NT-4 and from 0.0 to 2.2 L/s

(0.08 cfs) for NT-5. The maximum flow during storms in these tributaries ranges from 28 to 532 L/s (1 to 19 cfs). Although the maximum individual flow recorded in these streams was in NT-3, NT-4 and NT-5 generally have greater maximum flows during storms, indicating that surface runoff in these catchments is more prominent than in NT-3.

During the lowest-flow periods, each stream in the OLF FA periodically stopped flowing at its monitoring point. The USGS spring and seep survey shows that, upstream of both monitoring locations, the channels of each stream were mostly dry in late September (Fig. D.41). Flow during the low-flow period primarily occurs during storm events, and flow is maintained for a few days after cessation of rainfall.

Figure D.60 shows representative storm hydrographs for the flow at these monitoring points. The shapes of the regression hydrographs for NT-4 and NT-5 are almost identical, probably because of the similar nature of the catchments. The storm hydrograph for NT-3 is similar to that for the other two catchments, except for lower peak flows; thus, although groundwater discharge for this catchment is similar to that for NT-4 and NT-5, the overland flow is relatively less prominent.

D.7.2 OIL LANDFARM FA – RADIATION AND GEOPHYSICAL SURVEY DATA

Geophysical and radiation surveys, covering the shaded areas on Fig. D.57, were conducted at the BYBY. The results of these surveys are shown on Figs. D.61 to D.65.

The radiation surveys were conducted using Ultra Sonic Ranging and Data System (USRADS) technology, which allows for taking a dense pattern of readings for each survey, thus delineating anomalies with a high degree of accuracy. The methods used for the radiation survey are described in Appendix B. Figure D.61 shows the floor monitor results (β/γ), and Fig. D.62 shows the sodium iodide (NaI) probe results (γ). As would be expected, the results of the two radiation survey instruments correlate over the anomalies identified at BYBY, except for anomalies to the south of the Hazardous Chemical Disposal Area (HDCA) cap, where the floor monitor survey was not conducted because of a problem with accessibility of the equipment. In addition, dense, irregular vegetation over much of the BYBY made it impossible to suspend the instruments close enough to the ground to obtain optimum signal response; however, readings were generally taken 15 to 30 cm (6 to 12 in.) above the ground surface. Although the area was mowed before surveying, the potential hazards from waste materials on the surface prevented surveyors from mowing sufficiently close to the ground. The relative magnitudes of these data can be used to identify anomalous areas; however, stronger emissions counts might be obtained if instruments could be held closer to the ground surface. Therefore, these data should be considered qualitative.

Figures D.63 to D.65 show the results of the geophysical surveys. Figures D.63 and D.64 show the results of the electromagnetic (EM)-31 survey: the EM-31 quadrature data that are measurements of bulk soil/groundwater conductivity to a depth of ~18 m (60 ft) and the in-phase data that provide limited insight into the presence of metallic objects (Sharma 1986). Like the radiation surveys, the EM-31 measurements are considered to be qualitative measurements of the ground conductivity. Elevated readings occur over buried metallic objects; however, other factors, such as groundwater elevation or changes in the composition of the soil, affect the magnitude of the results. In general, in-phase readings increase over buried metallic objects relative to the quadrature phase; thus, the comparison between the two fields can indicate the presence of buried metallic objects. Figure D.65 shows the results of the magnetometer survey, which can identify buried metallic objects, such as drums, to a depth of 10 m (30 ft).

Both the radiation and geophysical surveys identified a number of anomalous areas at BYBY, many of which coincide with each other. In general, the radiological data are indicative only of surface anomalies, whereas the geophysical data are indicative of both surface and subsurface anomalies. Therefore, where anomalies coincide, they indicate surface and possible subsurface anomalies. Radiological anomalies that occur alone indicate surface contamination that is not associated with metal objects on the surface or with buried anomalies. Geophysical anomalies that occur alone indicate buried anomalies with no surface expression.

An area that is bounded to the south by the old channel of Bear Creek, to the west by NT-3, and to the east by the HCDA cap and that reaches north as far as sample SBY-9 contains a number of anomalously high β/γ emissions and geophysical anomalies. Within this area, the radiological surface anomalies do not coincide exactly with the geophysical anomalies, indicating that surface contamination is somewhat separate from buried objects. Four primary anomalies were identified:

- An area of both radiological and geophysical anomalies located south of boring BYBY-3 and between the HDCA cap and NT-3. Surveys of this area showed radiation results of up to 6000 cpm and small EM anomalies that indicate elevated soil or groundwater conductivities. The EM-31 in-phase field deviates above the quadrature field at one point in the area, indicating buried metal; however, this point anomaly coincides with well GW-087, which explains the signal. All the anomalies in this area are, therefore, associated with surface contamination rather than buried objects.
- An area of radiological anomalies bounded by borings BYBY-8, BYBY-3, and SL 1 and by surface sample SBY-12, with the highest readings occurring at BYBY. The eastern boundary of this area stops very abruptly at the foot of the HDCA cap, whereas the boundaries to the north, south, and west are more gradual; the abrupt truncation of eastern boundary indicates that surface contamination continues below the HCDA cap to an unknown extent.
- An area of radiological anomalies bounded by boring BYBY-8 and by surface sample sites SBY-12, -8, -9, and -13.
- An area of geophysical anomalies best depicted by the EM-31 quadrature results. This area is bounded by the OLF cap and NT-3 to the west, by SBY-13 to the east, by SBY-17 and the HDCA cap to the south, and by BYBY-4 to the north. Within this area, the highest conductivity occurs in an approximately linear anomaly, which is oriented NE-SW and extends from boring OLF-2 in the northeast to the northeast corner of the HCDA cap. This anomaly is abruptly truncated at both ends by the OLF and HCDA caps, indicating that the anomaly runs beneath both caps. The high quadrature field conductivity measurements are associated with negative in-phase values, indicating that this region does not contain significant amounts of buried metal. The high conductivities may be associated more with fill materials or contaminated groundwater. The magnetic survey indicates some isolated anomalies within this area of elevated conductivity, which could indicate the presence of buried metal objects that are too small to be identified by the resolution of the EM survey.

In addition to the anomalies listed above, geophysical and radiological anomalies occur sporadically throughout the BYBY. Two linear geophysical anomalies, one located along Bear Creek Road and one along the Haul Road to the north, are related to cultural features (a pipeline and a fence, respectively) and can be discounted. Other anomalies of note are:

- Radiological and magnetic anomalies along the south side of the HDCA cap. These anomalies are in the location of a drum and of other metallic objects observed at the surface during field activities.
- West of SBY-5, a radiological anomaly on the bank of NT-3 indicates possible soil contamination.
- A linear geophysical and radiological anomaly at SBY-6 indicates both surface and subsurface contamination.

A number of other small magnetic anomalies distributed throughout the BYBY area indicate small metal objects, either on the surface or buried, that are too small to be detected by the resolution of the EM-31.

D.7.3 OIL LANDFARM FA – SOIL CHEMICAL DATA

The OLF FA comprises three soil sampling aggregates: those samples collected to characterize the OLF, those collected to characterize SL 1, and those collected to characterize the BYBY. Soil contamination in the OLF FA was characterized through a combination of radiation and geophysical surveys (Sect. D.7.2), field screening analysis of surface soil samples, laboratory analysis of surface soil samples and laboratory analysis of soil boring samples. Soil sample locations in the OLF FA are shown on Fig. D.57, and the samples contained in each soil aggregate are listed in Table D.3.

D.7.3.1 BYBY Aggregate Soils

The BYBY aggregate included 22 surface soil samples (0 ft to 1 ft depth maximum) (Fig. D.57), which were screened for inorganic elements and compounds, total uranium, ^{235}U , and PCBs at the Y-12 Laboratory; 5 of these samples were sent to an off-site laboratory for full analysis. An additional waste sample was collected from an open drum exposed at the surface south of the HCDA cap (sample SBY-27). This sample was screened for uranium, ^{235}U , and inorganics at the Y-12 Laboratory and is discussed separately in this section. Table D.3 lists the BYBY surface soil samples, and Table D.34 lists the sampling depths for the five samples sent for off-site analysis.

In addition to the surface soil samples, nine soil borings were augered to refusal [2.4 to 6.7 m (8 to 22 ft)] in the BYBY aggregate (Table D.34 and Fig. D.66). Samples were collected from the soil borings at 1.2-m (4-ft) depth intervals. The samples collected from 0- to 1.2-m (0- to 4-ft) and 1.2- to 2.4-m (4- to 8-ft) depth intervals plus the surface soil samples were combined to represent the shallow interval; samples collected from depth intervals >2.4 m (8 ft) represent the deep interval. Boring SL1-2 features prominently in the following discussions of contaminants at the SL1 Site. In that borehole actual waste materials (gauze, wire, etc.) were encountered. Also, methane gas from the borehole caused the geoprobe to be shut down for a period of time.

Results of the screening soil sample analyses are summarized in Table D.35. Analytical results for the soil boring samples plus the laboratory analyses for the five surface soil samples are summarized in Tables D.36 and D.37 for the shallow and deep intervals, respectively.

D.7.3.1.1 Inorganic elements and compounds in the BYBY aggregate soils

Eighteen inorganic elements or compounds were detected above their background criteria in soil samples collected from the BYBY aggregate: of these contaminants, 17 occur in the shallow interval

and 13 occur in the deep interval (Tables D.36 and D.37). The distributions of cadmium, copper, and mercury are shown in Fig. D.67 as representative of the distribution of inorganics in the BYBY aggregate. The three elements were selected to represent the inorganic group because they are most widespread, occur at the highest concentrations, and thus most clearly define the nature and extent of contamination by inorganics at the BYBY site. The data plotted on Fig. D.67 are the maximum concentrations of the analytes in each location for their respective depth intervals.

Shallow Interval. Contamination by inorganic elements and compounds in the shallow interval is widespread (Fig. D.67): at least one inorganic contaminant is recorded in every boring and surface sample.

Mercury exceeds its background criterion (0.34 mg/kg) in all samples and attains its maximum concentration in the shallow interval (77.7 mg/kg) in surface soil sample SBY-22. This maximum for the shallow interval is also the maximum mercury concentration for both intervals in the BYBY. The mercury concentration in the sample collected from the 0- to 1.2-m (0- to 4-ft) depth interval of borehole BY-04 (75 mg/kg) is nearly identical to the maximum observed concentration of the shallow interval (Table D.36).

Copper exceeds its background criterion (35.5 mg/kg) in 12 of the 15 samples collected from the shallow interval in the BYBY. Its maximum concentration (6220 mg/kg) occurs in the 0- to 1.2-m (0- to 4-ft) depth interval of borehole BY-03; this also constitutes the maximum copper concentration for all soil samples collected from the BYBY (Table D.36).

Cadmium exceeds its background criterion (0.31 mg/kg) in 11 of 15 samples collected from the shallow interval in the BYBY. Its maximum concentration (32.3 mg/kg) occurs in the sample collected from the 1.2- to 2.4-m (4- to 8-ft) interval of borehole BY-04; this is also the maximum cadmium concentration for all samples from the BYBY. A cadmium concentration of 31.3 mg/kg was recorded in surface soil sample SBY-17 (Table D.36).

Other inorganic elements or compounds that are widespread (i.e., >50% of samples are above background criterion) or occur at high concentrations (i.e., maximum concentration $>10 \times$ background criterion) in the shallow interval of the BYBY aggregate include: antimony (widespread and high concentration), barium (widespread), lead (widespread and high concentration), nickel (widespread and high concentration), selenium (high concentration), silver (widespread and high concentration), and zinc (widespread and high concentration).

Deep Interval. Inorganic contaminants are not as widespread in the deep interval as in the shallow interval, nor do they occur in as high concentrations (Fig. D.67). However, the fact that the shallow interval includes five additional sample locations (the surface soil sampling locations) that are not included in the deep interval may exaggerate the perception that inorganic contaminants are more widespread in the shallow interval.

Mercury is less widespread in the deep interval than in the shallow interval, having been detected in only 15 of the 20 samples collected from this interval; only 8 of these detects are greater than the background criterion for mercury (Table D.37). The maximum concentration of mercury in the deep interval (16.6 mg/kg) occurs in the 2.4- to 3.7-m (8- to 12-ft) sample of borehole BY-9; the next highest mercury concentration in the deep interval (3.1 mg/kg) occurs in the 2.4- to 3.7-m (8- to 12-ft) sample of borehole BY-4.

Copper was detected in 18 of the 20 samples collected from the deep interval at the BYBY; 11 of these 18 detects are at concentrations above its background criterion (Table D.37). The

maximum copper concentration in the deep interval (635 mg/kg), like that for mercury, occurs in the 2.4- to 3.7-m (8- to 12-ft) sample from borehole BY-9, and the second highest copper concentration (254 mg/kg), also like mercury, occurs in the 2.4- to 3.7-m (8- to 12-ft) sample from borehole BY-4.

Of the three representative elements for the inorganic elements and compounds, cadmium is the least widespread in the deep interval of the BYBY. Cadmium was detected only twice in the deep interval, and both detects are in concentrations greater than the background criterion for cadmium. The maximum cadmium concentration in the deep interval (6 mg/kg), like those for mercury and copper, occurs in the 2.4- to 3.7-m (8- to 12-ft) interval of borehole BY-9, and, also like mercury and copper, the second highest detect for cadmium is in the deep interval is in the 2.4- to 3.7-m (8- to 12-ft) sample from borehole BY-4.

Other inorganic elements or compounds considered as contaminants in the deep interval of the BYBY aggregate include barium, beryllium, cyanide, lead, manganese, nickel, selenium, silver, tin, and zinc (Table D.37). Of these 10 elements and compounds, 8 exceed their background criterion in the 2.4- to 3.7-m (8- to 12-ft) sample from borehole BY-9; the maximum concentrations of nickel, lead, selenium, tin, and zinc in the deep interval occur in this sample. The maximum concentration of barium occurs in the sample from the 3.7- to 4.9-m (12- to 16-ft) interval of borehole BY-9. Hence, the maximum concentrations of 6 of the 10 contaminants in the deep interval of the BYBY occur in a single borehole, BY-9.

D.7.3.1.2 Radionuclides in the BYBY aggregate

Eight radionuclides were detected in the samples collected from the BYBY aggregate, six of which occur above their background criteria (Tables D.34 and D.37). The distribution of radionuclides is portrayed on Fig. D.67 using ^{99}Tc and ^{238}U as representatives of the group. These two radionuclides were selected because they effectively demonstrate the distributions and ranges of activity concentrations for the group. In addition to its general representativeness, ^{238}U is specifically representative of the other two uranium isotopes, ^{234}U and ^{235}U .

Shallow Interval. Uranium-238 was detected in all 17 samples from the shallow interval that were analyzed for ^{238}U ; it exceeds its background criterion of 2.6 pCi/g in 16 of those samples. The maximum ^{238}U activity concentration (880 pCi/g) occurs in the sample from the 1.2- to 2.4-m (4- to 8-ft) interval in borehole BY-8; the next highest ^{238}U activity concentration (520 pCi/g) occurs in the sample from the 0- to 1.2-m (0- to 4-ft) interval in borehole BY-9. The two other isotopes of uranium tend to follow ^{238}U ; for example, the first and second highest activity concentrations of ^{235}U (17 pCi/g and 15 pCi/g) occur in the same sample as the first and second highest concentration for ^{238}U , respectively. The observed differences in activity concentration of ^{238}U and ^{235}U are consistent with the presence of depleted uranium. The first and second highest activity concentrations of ^{234}U occur in the same samples as the second and first highest activity concentrations of the two other isotopes, respectively.

Technetium-99 was detected in 6 of the 14 samples analyzed for ^{99}Tc in the shallow interval of the BYBY; all 6 detects exceed the background criterion for ^{99}Tc (4.07 pCi/g). The maximum activity concentration for ^{99}Tc (77 pCi/g) in the shallow interval occurs in the sample from the 1.2- to 2.4-m (4- to 8-ft) interval in borehole BY-8, along with the maximum ^{238}U and ^{235}U activity concentrations. The next highest activity concentration of ^{99}Tc (69 pCi/g) occurs in the sample from the 0- to 1.2-m (0- to 4-ft) interval in borehole BY-7, followed by the 0- to 1.2-m (0- to 4-ft) sample from borehole BY-8 (60 pCi/g). No ^{99}Tc was detected in borehole BY-9.

The other radionuclide contaminants in the shallow interval of the BYBY are ^{90}Sr and ^{230}Th . Each occurs as a contaminant only once; neither of the occurrences is associated with the four relatively high activity concentrations of the other radionuclides.

Deep Interval. Only four radionuclides are considered contaminants in the deep interval of the BYBY aggregate: the three isotopes of uranium and ^{99}Tc . The distribution of maximum activity concentrations of these nuclides in the deep interval of the BYBY is shown on Fig. D.67. As with the inorganic elements and compounds, the distribution of radionuclides and maximum activity concentrations are not as great in the deep interval as in the shallow interval. The maximum concentration of ^{238}U occurs in borehole BY-3, those for ^{234}U and ^{235}U occur in borehole BY-9, and that for ^{99}Tc occurs in borehole BY-7.

D.7.3.1.3 VOCs in the BYBY aggregate

VOCs considered to be contaminants in the BYBY aggregate are 1,2-DCE, 2-butanone, acetone, PCE, toluene, and TCE (Tables D.36 and D.37). The distributions of acetone and toluene are shown on Fig. D.68 as representatives of the VOCs. The two compounds were selected because they effectively demonstrate the distributions and ranges of concentrations for the remaining four VOCs.

Shallow Interval. Three of the six BYBY VOC contaminants occurred in the shallow interval: acetone, PCE, and toluene. Acetone and toluene are the most prevalent, with 7 detections and 12 detections, respectively, out of a total of 16 samples. PCE was detected only once. The maximum concentration of acetone ($110\ \mu\text{g/kg}$) was detected in the 0- to 1.2-m (0- to 4-ft) sample in borehole BY-05. The maximum concentration of toluene ($590\ \mu\text{g/kg}$), which is significantly higher than that for acetone, was detected in the surface soil sample SBY-22. In fact, all of the surface soil samples in the BYBY aggregate have high concentrations of toluene (SBY-13: $84\ \mu\text{g/kg}$; SBY-17: $300\ \mu\text{g/kg}$; SBY-20: $560\ \mu\text{g/kg}$; SBY-21: $340\ \mu\text{g/kg}$). The single detection of PCE in the shallow interval ($5\ \mu\text{g/kg}$) occurs in the 0- to 1.2-m (0- to 4-ft)-deep sample from borehole BY-02.

Deep Interval. All six of the BYBY VOC contaminants occur above background in the deep interval. The most prevalent VOC is acetone, with 14 detections in 21 samples, followed by toluene, with 11 detections in 23 samples. The maximum concentration of acetone in the deep interval of the BYBY aggregate ($180\ \mu\text{g/kg}$) occurs in the 2.4- to 3.7-m (8- to 12-ft)-deep sample from borehole BY-06. The maximum concentration of toluene in the deep interval ($190\ \mu\text{g/kg}$) occurs in the 4.3- to 5.9-m (14- to 18-ft)-deep sample from borehole BY-05. Compared to acetone and toluene, the remaining four VOCs in the deep interval occur in low concentrations; thus, the distributions of acetone and toluene encompass the distributions of all other VOCs.

D.7.3.1.4 SVOCs in the BYBY aggregate

Most of the 26 SVOCs detected in the BYBY aggregate (Tables D.36 and D.37) fall into one of two major groups: polyaromatic hydrocarbons (PAHs) and phthalates. The individual compounds detected are listed in Table D.38. The distributions of total PAHs and total phthalates are shown on Fig. D.68 as representative of the distribution of all SVOCs.

Shallow Interval. Figure D.68 shows that the contamination by SVOCs in the BYBY aggregate is dominated by total PAHs. Of all the PAHs, fluoranthene occurs at the highest concentration; its maximum concentration ($270,000\ \mu\text{g/kg}$) occurs in the surface soil sample from SBY-21. All of the PAHs occur in relatively high concentrations in all five of the surface soil samples in the BYBY aggregate, except for acenaphthylene, which was not detected in the sample collected from SBY-13. Samples collected from soil borings also show some high PAH concentrations although, typically,

these are not as high as those observed in the surface soil samples. The one exception is the maximum total PAH concentration in the shallow interval of borehole BYBY-8, which is 151,580 $\mu\text{g/kg}$.

Phthalates, although nearly ubiquitous in the shallow interval of the BYBY aggregate, do not occur in concentrations as high as the PAHs. Four phthalates are SRCs in the shallow interval of the BYBY: butylbenzylphthalate, di-n-butylphthalate, diethylphthalate, and bis(2-ethylhexyl)phthalate. Bis(2-ethylhexyl)phthalate is the most widespread of the phthalates, having been detected in 11 of the 14 samples that were collected. The maximum concentration for a phthalate (2500 $\mu\text{g/kg}$ di-n-butylphthalate) occurs in the 0- to 1.2-m (0- to 4-ft) interval of borehole BYBY-3. Only bis(2-ethylhexyl)phthalate was detected in the five surface soil samples.

SVOCs other than PAHs and phthalates that are SRCs in the shallow interval of the BYBY include 2,4-dimethylphenol, 2-methylnaphthalene, methylphenol, carbazole, and dibenzofuran. The distribution of these organic compounds in the shallow interval is reflected by those of the PAHs and phthalates. Each of these SVOCs was detected in every surface soil sample.

Deep Interval. SVOCs are not as widespread in the deep interval of the BYBY aggregate as they are in the shallow interval, nor are their concentrations as high (Fig. D.68); for example, PAHs were detected in only five of the nine boreholes, with a maximum total PAH concentration of 6285 $\mu\text{g/kg}$ in borehole BYBY-9. Phthalates, on the other hand, were detected in eight of the nine boreholes, but with a maximum total phthalate concentration of only 1088 $\mu\text{g/kg}$. The other SVOCs in the deep interval of the BYBY are also sparsely distributed and occur in low concentrations. In addition to the fewer numbers of detections and lower concentrations of SVOCs in the deep interval, as compared to the shallow interval, SVOC concentrations tend to decrease with sampling interval. For example, the highest concentrations of all SVOCs in the deep interval occur in the 2.4- to 3.7-m (8- to 12-ft) interval. In those boreholes that go deeper than 3.7 m (12 ft), concentrations decrease with depth and some compounds are no longer detected.

D.7.3.1.5 PCBs and pesticides in the BYBY aggregate

The distribution of PCBs and pesticides in the BYBY aggregate is represented by total PCBs in Fig. D.68. Two PCBs, Aroclor-1254 and -1260, and one pesticide, 2378-TCDD, are SRCs. In general, the PCBs and pesticides detected in the BYBY aggregate behave similarly to the SVOCs; that is, they are more widespread and occur at higher concentrations in the shallow interval than in the deep interval. Of the PCBs, Aroclor-1254 is the more prevalent, occurring in every surface soil sample and in the shallow interval of every borehole; it also occurs in higher concentrations than Aroclor-1260.

D.7.3.1.6 Waste sample SBY-27

As described above, a sample of waste was collected at SBY-27 from the mouth of an open drum exposed in the BYBY. Initially, the material associated with the drum was of interest because it registered high activity on hand-held, radiometric instruments. The results of the analyses performed on sample SBY-27 at the Y-12 Laboratory show the sample to have high gross α (143,000 pCi/g) and gross β (32,000 pCi/g) activities and high concentrations of uranium and ^{235}U . The data from the Y-12 Laboratory presented uranium as total uranium in units of $\mu\text{g/kg}$ and presented ^{235}U as weight % of total uranium (data for ^{234}U were not reported). The actual analytical results of 142,000 $\mu\text{g/g}$ and 0.24 weight %, respectively, were converted to activity units to give the following results: $^{238}\text{U} = 46,750$ pCi/g and $^{235}\text{U} = 725$ pCi/g. These values clearly exceed the background criteria for ^{238}U and ^{235}U (2.6 and 0.24 pCi/g, respectively).

In addition to total uranium and percent ^{235}U , waste sample SBY-27 was analyzed for inorganic elements and compounds. Inorganic element concentrations/background criteria, in mg/kg, for those elements whose concentrations exceed their background criteria in sample SBY-27 are silver (108/2.8), barium (491/212), beryllium (11/2.12), cadmium (3/0.31), cobalt (60/40.1), chromium (83.5/80.1), copper (705/35.5), molybdenum (110/12.8), nickel (175/56.7), lead (705/49.6), and zinc (1070/108).

D.7.3.2 Oil Landfarm Aggregate

Five surface soil samples were collected from the OLF aggregate (Table D.3) and were screened for inorganic elements and compounds, total uranium, ^{235}U , and PCBs at the Y-12 Laboratory. None of the surface soil samples were sent to the off-site laboratory for full-suite analysis. In addition to the surface soil samples, five soil borings were augered to refusal [3.7 to 8.5 m (12 to 28 ft)] (Table D.39). Samples were collected from the soil borings at depth intervals of 1.2 m (4 ft); the samples collected from 0- to 1.2-m (0- to 4-ft) and 1.2- to 2.4-m (4- to 8-ft) depth intervals, plus the surface soil samples, were combined for the shallow interval, and samples collected from depths >2.4 m (8 ft) represent the deep interval.

Results for the screening soil sample analyses are summarized in Table D.40. Analytical results for the soil boring samples are summarized in Tables D.41 and D.42.

D.7.3.2.1 Inorganic elements and compounds in the Oil Landfarm aggregate

Eight inorganic elements or compounds were detected above their background criteria in soil samples collected from the OLF aggregate; six of these inorganics occur in the shallow interval, and four in the deep interval (Tables D.41 and D.42). The distributions of copper and barium in the OLF aggregate are shown in Fig. D.69 as representative of the organics distribution. These elements were chosen because they are the most widespread and occur at the highest concentrations. The data plotted on Fig. D.69 are the maximum concentrations of the analytes in each borehole for their respective depth intervals.

Shallow Interval. Copper was detected in concentrations above its background criteria (35.5 mg/kg) in OLF-1 and OLF-2 (Fig. D.69). The 1.2- to 2.4-m (4- to 8-ft)-deep sample from OLF-1 had a copper concentration of 43.3 mg/kg, and the 0- to 1.2-m (0- to 4-ft) deep sample from OLF-2 had a copper concentration of 120 mg/kg, which is the maximum copper concentration for the OLF aggregate.

Barium, the other element used to represent inorganic elements and compounds in the OLF aggregate, is not an SRC in the shallow interval.

Other inorganic elements detected in the shallow interval of the OLF aggregate include arsenic, lead, mercury, silver, and zinc. As shown in Table D.41, the concentrations of these elements do not greatly exceed their respective background criteria.

Deep Interval. Barium, copper, nickel, and silver were detected in concentrations above their background criteria in the deep interval of the OLF aggregate. The distributions of barium and copper are plotted on Fig. D.69 as representative of inorganic contamination in the deep interval of the OLF. Barium concentrations exceed background criteria in 7 of 13 samples from the deep interval. The maximum concentration detected (883 mg/kg) occurs in the 2.4- to 3.7-m (8- to 12-ft)-deep sample of OLF-1. Barium also exceeds background in OLF-2, OLF-3, and OLF-5.

Copper exceeds its background criterion in 2 of 12 samples, both in OLF-3. The maximum concentration of 41.6 mg/kg occurs in the 6.7- to 8.5-m (22- to 28-ft)-depth sample (Fig. D.69). The 3.0- to 3.7-m (10- to 12-ft) sample has a concentration of 35.9 mg/kg, which is nearly equal to its background criterion (35.5 mg/kg) (Table D.42).

Nickel and silver were also detected above background in the deep interval (Table D.42).

D.7.3.2.2 Radionuclides in the Oil Landfarm aggregate

A total of six radionuclides were detected at activity concentrations above their background criteria in the OLF aggregate: ^{60}Co , ^{212}Pb , ^{208}Tl , ^{234}U , ^{235}U , and ^{238}U . All six occur in the shallow interval, while three are contaminants in the deep interval (Table D.42). The distribution of ^{238}U , ^{60}Co , and ^{208}Tl in the OLF aggregate is shown on Fig. D.69 as representative of the radionuclides distribution. In addition to its general representativeness, ^{238}U is specifically representative of the other two uranium isotopes, ^{234}U and ^{235}U .

Shallow Interval. Cobalt-60 occurs in active concentrations above its background criterion in three borings in the shallow interval: OLF-3, OLF-4, and OLF-5 (Fig. D.69). The maximum value of 1.7 pCi/g occurs in the 0- to 1.2-m (0- to 4-ft)-deep sample of OLF-4, which also has a ^{60}Co activity concentration of 0.7 pCi/g in the 1.2- to 2.4-m (4- to 8-ft) sample.

Thallium-208 was detected once in the shallow interval (no background criterion is available for ^{208}Tl) in OLF-3, with an activity concentration of 4.6 pCi/g.

Uranium-234, ^{235}U , and ^{238}U each had one detection above background (Table D.41). The distribution of ^{238}U is shown on Fig. D.69 as representative of uranium contamination. The activity concentration of 5.9 pCi/g occurs in the 0- to 1.2-m (0- to 4-ft) depth interval of boring OLF-2, as do all activity concentrations of the uranium isotopes that exceed their background criteria.

Deep Interval. Cobalt-60, ^{212}Pb , and ^{208}Tl were each detected in activity concentrations above their background criteria in the deep interval of the OLF aggregate (Table D.42). The distribution of ^{60}Co , ^{208}Tl , and ^{238}U in the deep interval of the OLF aggregate is shown on Fig. D.69 as representative of the radionuclide distribution.

Cobalt-60 was detected above its background criterion one time, in the 3.0- to 4.3-m (10- to 14-ft)-deep sample from OLF-3, with an activity concentration of 0.67 pCi/g.

Thallium-208 was detected three times, once each in OLF-2, OLF-3, and OLF-5. The activity concentrations for these detections are 3.3 pCi/g in the 3.0- to 4.3-m (10- to 14-ft) sample of OLF-2, 7.5 pCi/g in the 1.8- to 3.0-m (6- to 10-ft) sample of OLF-3, and 1.7 pCi/g in the 2.4- to 3.7-m (8- to 12-ft) sample of OLF-5 (Fig. D.69).

D.7.3.2.3 Organic compounds in the Oil Landfarm aggregate

Seven organic compounds (including VOCs, SVOCs, PCBs, and pesticides) were detected in soils from the OLF aggregate (Tables D.41 and D.42): PCB-1254, PCB-1260, 2-butanone, acetone, carbon disulfide, methylene chloride, and toluene. The distributions of total PCBs, acetone, methylene chloride, and toluene are shown on Fig. D.70 as representative of the organics distribution. These compounds were selected because they effectively demonstrate the distributions and ranges of all of the organic compounds.

Shallow Interval. Four of the seven OLF organic contaminants occur in the shallow interval: PCB-1260, acetone, methylene chloride, and toluene. Acetone and toluene are the most prevalent, with seven detections out of eight samples for both compounds. PCB-1260 was detected in three samples, and methylene chloride in two samples (Table D.41).

Acetone occurs in all five borings, with concentrations ranging from 7 to 590 $\mu\text{g/kg}$. The maximum concentration for acetone, 590 $\mu\text{g/kg}$, occurs in the 1.2- to 2.4-m (4- to 8-ft)-deep sample of boring OLF-5 (Fig. D.70).

Toluene also occurs in all five borings in the shallow interval, with concentrations ranging from 1 to 24 $\mu\text{g/kg}$. The maximum concentration, 24 $\mu\text{g/kg}$, occurs in the 0- to 1.2-m (0- to 4-ft)-deep sample of OLF-4 (Fig. D.70).

PCB-1260 was detected in two different boreholes in the shallow interval: OLF-2 and OLF-5. The maximum concentration of 220 $\mu\text{g/kg}$ occurs in the 0- to 1.2-m (0- to 4-ft)-deep sample of OLF-5 (Fig. D.70). Methylene chloride also was detected in two boreholes in the shallow interval: OLF-1 and OLF-2. Its maximum concentration, 4 $\mu\text{g/kg}$, occurs in the 1.2- to 2.4-m (4- to 8-ft)-deep sample of OLF-1.

Deep Interval. All seven organic contaminants occur in the deep interval of the OLF aggregate. Acetone is the most prevalent, with 13 detections out of 13 samples (Table D.42). As in the shallow interval, acetone occurs in all five borings, ranging in concentration from 10 to 200 $\mu\text{g/kg}$. The maximum, 200 $\mu\text{g/kg}$, occurs in the 2.4- to 3.7-m (8- to 12-ft)-deep sample of OLF-4. Figure D.70 shows the maximum concentrations for the deep interval in each boring.

Toluene occurs in four of the five borings (Fig. D.70). Concentrations range from 2 to 14 $\mu\text{g/kg}$, with the maximum occurring in the 2.4- to 3.7-m (8- to 12-ft)-deep sample of OLF-5. Toluene was not detected in OLF-1.

Methylene chloride was detected three times, all from boring OLF-2. The maximum value of 5 $\mu\text{g/kg}$ occurred in the 5.5- to 6.7-m (18- to 22-ft)-deep interval. Methylene chloride was also detected in the 3.0- to 4.3-m (10- to 14-ft) (4 $\mu\text{g/kg}$) and 4.3- to 5.5-m (14- to 18-ft) (3 $\mu\text{g/kg}$) deep samples of OLF-2.

PCB-1254 and PCB-1260 each were detected once in the deep interval, with PCB-1254 occurring at a concentration of 12 $\mu\text{g/kg}$ in the 2.4- to 3.7-m (8- to 12-ft)-deep sample of OLF-1 and PCB-1260 occurring at a concentration of 69 $\mu\text{g/kg}$ in the 1.2- to 3.0-m (4- to 10-ft)-deep interval of OLF-2 (Fig. D.70).

2-Butanone and carbon disulfide were each detected once. 2-Butanone occurs in the 1.2- to 3.0-m (4- to 10-ft)-deep sample of OLF-2 at a concentration of 19 $\mu\text{g/kg}$, and carbon disulfide occurs in the 1.2- to 3.0-m (4- to 10-ft)-deep sample of OLF-2 at a concentration of 6 $\mu\text{g/kg}$ (Table D.42).

D.7.3.3 SL 1 Aggregate

Sixteen surface soil samples were collected from within the SL-1 aggregate (Table D.3) and were screened for inorganic elements and compounds, total uranium, ^{235}U , and PCBs at the Y-12 Laboratory. Two of the samples (SSL-13 and SBY-16) were sent to an off-site laboratory for full-suite analysis. In addition to the surface soil samples, two borings were augered to refusal in the SL 1 aggregate, with refusal occurring at 4.9 m (16 ft) for SL1-1 and 8.5 m (28.0 ft) for SL1-2. Samples were collected from the soil borings at depth intervals of 1.2 m (4 ft); the samples collected

from 0- to 1.2-m (0- to 4-ft) and 1.2- to 2.4-m (4- to 8-ft) depth intervals, plus the surface soil samples, were combined to represent the shallow interval, while all samples collected from depth intervals >2.4 m (8 ft) represent the deep interval. Boring SL1-2 features prominently in the following discussions of contaminants at the SL1 site. In that borehole, actual waste materials (gauze, wire, etc.) were encountered. Also, methane gas from the borehole caused the geoprobe to be shut down for a period of time.

Results for the screening soil sample analyses are summarized in Table D.43. Analytical results for the soil boring samples plus the laboratory analyses for the two surface soil samples are summarized in Tables D.44 and D.45.

D.7.3.3.1 Inorganic elements and compounds in the SL 1 aggregate

Eight inorganic elements or compounds were detected above their background criteria in soil samples collected from the SL 1 aggregate: six of these occur in the shallow interval, and seven occur in the deep interval (Tables D.44 and D.45). The distributions of copper, mercury, and nickel in the SL 1 aggregate are shown on Fig. D.71 as representative of the inorganics distribution. These three elements were selected because they are the most widespread and occur at the highest concentrations. The data plotted on Fig. D.71 are the maximum concentrations of the analytes in each boring for their respective depth intervals.

Shallow Interval. Six of the eight inorganic elements or compounds are classified as SRCs in the shallow interval of the SL 1 aggregate.

Copper concentrations exceed their background criteria (35.3 mg/kg) in three of four samples collected from the shallow interval of the SL 1 aggregate. The maximum copper concentration (252 mg/kg) occurs in surface soil sample SBY-16.

Mercury is the most widespread of the inorganic elements in the shallow interval, with detections above its background criterion (0.34 mg/kg) in four of five samples. All four sampling stations in the SL 1 aggregate (surface soil samples and soil borings) record mercury above its background criterion. The maximum mercury concentration (41.5 mg/kg), like that of copper, occurs in surface soil sample SBY-16 (Fig. D.71). Both mercury detections exceeding their background criteria in the two boreholes in the shallow interval of the SL 1 aggregate were from the 0- to 1.2-m (0- to 4-ft) deep samples.

Nickel is not an SRC in the shallow interval of the SL 1 aggregate.

Other inorganic elements that exceed their background criteria in the shallow interval of the SL 1 aggregate are barium, lead, silver, and zinc. Silver exceeds its background criterion in three samples, lead in two samples, barium in one sample, and zinc in one sample. The maximum concentrations of silver (7.6 mg/kg) and lead (201 mg/kg) occur in surface soil sample SBY-16, as do the two occurrences of barium and zinc.

Deep Interval. Seven of the eight site-related inorganic contaminants of the SL 1 aggregate occur in the deep interval. These include barium, copper, lead, manganese, mercury, nickel, and zinc. The distributions of copper, mercury, and nickel are shown on Fig. D.71.

Copper exceeds its background criterion (35.3 mg/kg) in two of six samples from the deep interval, both from boring SL1-1. The maximum value of 56.7 mg/kg was detected in the 2.4- to 3.7-m (8- to 12-ft)-deep sample (Table D.45, Fig. D.71).

Mercury was detected above background criterion (0.34 mg/kg) in the deep interval in two of six samples. Both detections occur in boring SL1-2, with the maximum concentration of 2.0 mg/kg occurring in the 1.8- to 3.7-m (6- to 12-ft)-deep sample.

Nickel does not exceed its background criterion (35.5 mg/kg) in the shallow interval; however, it exceeds background in three of six samples in the deep interval (Table D.45), with one detection above background occurring in the 2.4- to 3.7-m (8- to 12-ft)-deep sample of SL1-1 and two occurring in SL1-2. The maximum copper concentration (231 mg/kg) occurs in the 4.9- to 6.1-m (16- to 20-ft)-deep sample in borehole SL1-2. (Fig. D.71).

Other inorganic elements detected above their background criteria are barium, lead, manganese, and zinc. Barium occurs above background in four of six samples, all from boring SL1-2. The maximum barium concentration from this boring occurs in the 6.1- to 7.3-m (20- to 24-ft)-deep sample, with a value of 486 mg/kg.

Lead was detected above its background criterion (49.6 mg/kg) once, occurring at concentration of 65.4 mg/kg in the 6.1- to 7.3-m (20- to 24-ft)-deep sample of boring SL1-2 (Table D.45).

Manganese occurs above its background criterion in three of six samples, again all in boring SL1-2.

Zinc had one detection above its background criterion in the deep interval, from the 1.8- to 3.7-m (6- to 12-ft)-deep sample of SL1-2.

D.7.3.3.2 Radionuclides in the SL 1 aggregate

Six radionuclides are site-related contaminants in the SL 1 aggregate (Tables D.44 and D.45): ^{60}Co , ^{134}Cs , ^{208}Tl , ^{234}U , ^{235}U , and ^{238}U . The distribution of ^{238}U is shown on Fig. D.71 as representative of the radionuclides distribution. In addition to its general representativeness for the group as a whole, ^{238}U is specifically representative of the other two uranium isotopes, ^{234}U and ^{235}U .

Shallow Interval. Four of the six radionuclide contaminants at the SL 1 aggregate occur in the shallow interval: ^{60}Co , ^{234}U , ^{235}U , and ^{238}U (Table D.44).

Uranium-238 exceeds its background criterion (2.6 pCi/g) in four of five samples in the shallow interval of the SL 1 aggregate. The maximum activity concentration of ^{238}U (22 pCi/g) occurs in the 1.2- to 2.4-m (4- to 8-ft)-deep sample from borehole SL 1. Uranium-238 was detected above its background criterion in all sample locations (surface soil and borehole) within the shallow interval at the SL 1 aggregate. Both ^{234}U and ^{235}U also exceed their background criteria in the 1.2- to 2.4-m (4- to 8-ft)-deep sample from borehole SL 1, but do not exceed background in any other locations within the shallow interval of the SL 1 aggregate.

Cobalt-60 was also detected above its background criterion (0.01 pCi/g) in the 1.2- to 2.4-m (4- to 8-ft)-deep sample of SL1-1 (1.3 pCi/g).

Deep Interval. Four of the six site-related radionuclide contaminants in the SL 1 aggregate occur in the deep interval: ^{134}Cs , ^{208}Tl , ^{234}U , and ^{238}U (Table D.45).

Uranium-238 exceeds its background criterion (2.6 pCi/g) in one of seven samples collected from the deep interval of the SL 1 aggregate. This 2.4- to 3.7-m (8- to 12-ft)-deep sample from borehole SL1-1 shows an activity concentration of 6 pCi/g ^{238}U . Uranium-234 exceeds its background

criterion (3.2 pCi/g) in the same sample, with an activity concentration of 4.3 pCi/g. Uranium-234 also exceeds background in one other sample in the deep interval, from the 1.8- to 3.7-m (6- to 12-ft)-deep sample from borehole SL1-2, with an activity concentration of 5.2 pCi/g.

Cesium-134 and ^{208}Tl were detected in one of seven samples from the deep interval of the SL 1 aggregate (neither radionuclide has a background criterion). Both were detected in borehole SL1-2: ^{134}Cs (1.2 pCi/g) in the 3.7- to 4.9-m (12- to 16-ft)-deep sample and ^{208}Tl (2.9 pCi/g) in the 4.9- to 6.1-m (16- to 20-ft)-deep sample.

D.7.3.3.3 VOCs in the SL 1 aggregate

Ten VOCs were detected in the SL 1 aggregate (Tables D.44 and D.45): 2-butanone, 2-hexanone, 4-methyl-2-pentanone, acetone, carbon disulfide, chlorobenzene, chloroform, dimethylbenzene, ethylbenzene, and toluene. The distributions of acetone and 2-butanone are shown on Fig. D.72 as representative of VOCs distribution. Acetone and 2-butanone were selected because they effectively demonstrate the distributions and ranges of concentrations for all 10 VOCs.

Shallow Interval. Three of the ten SL 1 VOC contaminants occur in the shallow interval: acetone, chloroform, and toluene. Acetone and toluene are the most prevalent, with four and three detections, respectively, in five samples (Table D.44). Chloroform was detected only once. The maximum concentration of acetone (230 $\mu\text{g/kg}$) occurs in the 1.2- to 2.4-m (4- to 8-ft)-deep sample of boring SL1-1. Acetone was also detected in the 0- to 1.8-m (0- to 6-ft)-deep sample of SL1-2 (33 $\mu\text{g/kg}$), as well as in surface soil samples SSL-13 (18 $\mu\text{g/kg}$) and SSL-16 (48 $\mu\text{g/kg}$) (Fig. D.72).

The maximum concentration of toluene (110 $\mu\text{g/kg}$) occurs in surface soil sample SSL-13. Toluene also occurs in the 1.2- to 2.4-m (4- to 8-ft)-deep sample of boring SL1-1 (1 $\mu\text{g/kg}$) and in surface soil sample SSL-16 (21 $\mu\text{g/kg}$). The single detection of chloroform in the shallow interval occurs in surface soil sample SSL-16, with a concentration of 1 $\mu\text{g/kg}$.

Deep Interval. Nine of the ten SL 1 VOC contaminants occur in the deep interval of the SL 1 aggregate (Table D.45). The most prevalent VOC in this interval is acetone, with six detections in six samples. Acetone also occurs at the highest concentrations, with a maximum of 1100 $\mu\text{g/kg}$ in the 1.8- to 3.7-m (6- to 12-ft)-deep interval of boring SL1-2. Acetone is found at all depths in the deep interval of boring SL1-1 and all but the deepest [7.3 to 8.5 m (24 to 28 ft)] of boring SL1-2. The maximum acetone concentration in the deep interval for each boring is shown on Fig. D.72.

2-Butanone is the third most prevalent VOC in the deep interval of the SL 1 aggregate, with two detections in six samples (2-hexanone is second, with three detections in six samples). 2-Butanone was chosen to be plotted on Fig. D.72 because of its high concentrations, the maximum being 1000 $\mu\text{g/kg}$ in the 3.7- to 4.9-m (12- to 16-ft)-deep sample of boring SL1-2. The 4.9- to 6.1-m (16- to 20-ft)-deep sample also has a concentration of 93 $\mu\text{g/kg}$ 2-butanone.

Carbon disulfide and toluene were each detected in two of six samples in the deep interval of the SL 1 aggregate. Carbon disulfide concentrations range from 2 $\mu\text{g/kg}$ in the 3.7- to 4.9-m (12- to 16-ft)-deep sample of boring SL1-2 to 12 $\mu\text{g/kg}$ in the 1.8- to 3.7-m (6- to 12-ft)-deep sample of that boring. Toluene was detected both in boring SL1-1 [2 $\mu\text{g/kg}$ in the 2.4- to 3.7-m (8- to 12-ft)-deep sample] and boring SL1-2 [1 $\mu\text{g/kg}$ in the 1.8- to 3.7-m (6- to 12-ft)-deep sample].

The remainder of the VOCs detected in the deep interval — 4-methyl-2-pentanone, chlorobenzene, dimethylbenzene, and ethylbenzene — were each detected in one of six samples (Table D.45).

D.7.3.3.4 SVOCs in the SL 1 aggregate

A total of 24 SVOCs were detected in the SL 1 aggregate (Tables D.44 and D.45). Most of these compounds fall into two major groups: PAHs and phthalates. Table D.38 lists the individual compounds by group. The distributions of PAHs and phthalates are shown on Fig. D.72 as representative of the SVOCs distribution.

Shallow Interval. PAH and phthalate contamination is widespread in the SL 1 aggregate, with 20 SVOCs detected in soil samples from the shallow interval (Fig. D.72). Total PAHs do not dominate the SVOC contaminants in this aggregate, as they do in the BYBY aggregate; however, in surface soil sample SBY-16, the concentrations of PAHs are on the same order of magnitude as in the BYBY (Fig. D.72). All the PAHs detected occur in this surface soil sample and at concentrations several orders of magnitude greater than elsewhere in this aggregate. Almost all of the detected PAHs also occur in the 0- to 1.2-m (0- to 4-ft)-deep sample of boring SL1-1 and the 0- to 1.8-m (0- to 6-ft)-deep sample of boring SL1-2. No PAHs were detected in deeper samples from the shallow interval. In surface soil sample SSL-13, only the PAHs chrysene, fluoranthene, phenanthrene, and pyrene were detected. Fig. D.72 shows the sum of the maximum concentrations of each PAH in the shallow interval.

Of the phthalates, only bis(2-ethylhexyl)phthalate and di-n-butylphthalate were detected in the shallow interval (Table D.44). Bis(2-ethylhexyl)phthalate occurs in both surface soil samples and in the 0- to 1.8-m (0- to 6-ft)-deep sample of boring SL1-2, while di-n-butylphthalate occurs in the 0- to 1.2-m (0- to 4-ft) and 1.2- to 2.4-m (4- to 8-ft)-deep samples of boring SL1-1 but in neither of the surface soil samples. The sum of the maximum concentrations in the shallow interval is shown on Fig. D.72.

Deep Interval. Of the 24 SVOCs detected at the SL-1 aggregate, 23 occur in the deep interval (Table D.45). Again, these compounds are mostly members of either the PAH or phthalate groups (Table D.38). Total PAHs and total phthalates are shown on Fig. D.72. PAHs are entirely absent from boring SL1-1. Phthalates present in the deep interval include bis(2-ethylhexyl)phthalate, di-n-butylphthalate, di-n-oxyphthalate, and diethylphthalate. The maximum concentrations for the PAHs and phthalates always occur in the 1.8- to 3.7-m (6- to 12-ft)-deep sample of boring SL1-2.

D.7.3.3.5 PCBs and pesticides in the SL 1 aggregate

Three PCBs — PCB-1232, -1254, and -1260 — and four pesticides — 4-4'-DDE, aldrin, endosulfan II, and endosulfan sulfate — were detected in samples from the SL 1 aggregate (Tables D.44 and D.45). The distribution of PCBs is shown on Fig. D.72 using total PCBs.

Shallow Interval. All three PCBs were detected in the shallow interval of the SL 1 aggregate. PCB-1232, although detected in only one of five samples, has the highest concentration (1300 $\mu\text{g/kg}$); this concentration occurs in the 0- to 1.8-m (0- to 6-ft)-deep sample from boring SL1-2. PCB-1254 was detected in two of five samples, with a maximum concentration of 1700 $\mu\text{g/kg}$ in surface soil sample SBY-16. The 0- to 1.8-m (0- to 6-ft)-deep sample from boring SL1-2 has a concentration of 750 $\mu\text{g/kg}$ for PCB-1254. PCB-1260 was detected in one of five sample (surface soil sample SL1-13) at a concentration of 98 $\mu\text{g/kg}$.

Deep Interval. PCB-1254 and PCB-1260 were both detected in soil samples from the deep interval (Table D.45). PCB-1254 was detected once, at a concentration of 3000 $\mu\text{g/kg}$ in the 1.8- to 3.7-m (6- to 12-ft)-deep interval of boring SL1-2. PCB-1260 was detected at three different depths from SL1-2, with the maximum value of 660 $\mu\text{g/kg}$ occurring in the 1.8- to 3.7-m (6- to 12-ft)-deep

sample (Fig. D.72) and the other two detections occurring at 3.7 to 4.9 m (12 to 16 ft) and at 4.9 to 6.1 m (16 to 20 ft).

Although pesticides were detected in the deep interval in the SL 1 aggregate (Table D.45), they are not plotted on the figures for this aggregate because of their limited extent. Except for endosulfan II, all pesticides were detected only in the 1.8- to 3.7-m (6- to 12-ft)-deep sample of boring SL1-2. Endosulfan II was detected in both the 1.8- to 3.7-m (6- to 12-ft)-deep and 3.7- to 4.9-m (12- to 16-ft)-deep samples of boring SL1-2. The maximum detected concentrations for pesticides are listed in Table D.45.

D.7.3.4 Discussion

The nature and extent of contamination in the OLF FA range from minimal in the OLF aggregate to extensive in the BYBY aggregate. In all aggregates, contamination occurs more extensively and at higher concentrations in the shallow interval than in the deep interval.

In the BYBY aggregate, the main contaminants include metals (especially copper and mercury), uranium isotopes, ^{99}Tc , PAHs, PCBs, and phthalates. Inorganic contamination is widespread in this FA, with copper concentrations two orders of magnitude above the background criterion. Although concentrations of inorganic elements in the shallow interval are lower, copper and mercury levels remain high. The highest concentrations of organic compounds occur in the surface soil samples on the western and southern edge of the HCDA. Radiological contamination in the BYBY aggregate is delineated by the isotopes of uranium and ^{99}Tc , which, like the inorganics, are more extensive and occur at higher activity concentrations in the shallow interval. The highest concentrations of these radionuclides occur on the western edge of the HCDA. Organic contamination is widespread, with numerous PCB, PAH, and phthalate compounds in addition to acetone, toluene, and several other organic compounds.

There is little historical information available about the nature of the fill material or wastes disposed of in the BYBY (Appendix A). Conclusions concerning the nature and extent of fill material and contaminants in the fill (including wastes) are based on five lines of evidence: (1) geophysical anomalies (Figs. D.63 and D.65); (2) soil sample results (Figs. D.67 to D.72); (3) a single, identified, and analyzed sample of waste and observed waste and debris in exposed fill material on the Bear Creek floodplain; (4) the knowledge that disposals were relatively uncontrolled during the 1940s and 1950s; and (5) associated groundwater and surface water contamination (e.g., Figs. D.7 and D.8). Based on the thickness of the fill material observed in soil borings and the above lines of evidence, it is assumed that the fill material is sporadically contaminated throughout BYBY. Contamination is assumed to occur mainly in isolated hot spots where waste is present rather as diffuse contamination throughout the fill. Geophysical anomalies indicate that the largest hot spots occur in the western portion of BYBY adjacent to the NT-3 stream channel (Figs. D.63 to D.65). In addition, hot spots may extend underneath the HCDA cap, and small hot spots occur on the BC floodplain.

In the OLF aggregate, sampling was limited to five borings around the perimeter of the OLF boundary. No surface soil samples were taken from this aggregate. Inorganic elements occur at slightly higher concentrations in the deep interval, but even here, the concentrations do not greatly exceed background. Cobalt-60 and ^{208}Tl have slightly higher concentrations in the shallow interval than the deep, but again, their activity concentrations are not greatly elevated above background. Organic compounds were detected in all borings, with slightly higher concentrations in the shallow interval. PCBs were detected in OLF-1 (deep only), OLF-2 (shallow and deep), and OLF-5 (shallow only), with total concentrations ranging from 12 to 220 $\mu\text{g/kg}$. This area has been remediated for PCB contamination in the past.

The SL 1 aggregate is characterized by two surface soil samples and two soil borings. The nature of contamination is more varied in this aggregate than in the OLF. Inorganic contaminants include mercury, copper, and nickel. Concentrations of mercury and copper are higher in the shallow interval, while concentrations of nickel are higher in the deep interval. Concentrations of all contaminants are highest in the shallow interval of surface soil sample SBY-16 and boring SL1-1. The distribution and concentrations of organics in SBY-16 more closely match that of the BYBY aggregate than the SL 1, particularly when considering the concentrations of total PAHs and PCBs. The maximum concentrations for organic compounds occur on the eastern and western edge of the SL 1, suggesting a preference for along-strike migration away from the disposal area. In SL1-2, the concentrations of organic compounds are higher in the deep interval, suggesting vertical migration of contaminants, at least on that end of the waste disposal area.

D.7.4 OIL LANDFARM FA – SEDIMENT DATA

Sediment data from the OLF FA are derived from two historical investigations: the Bechtel study (BNI 1984) and the 1984 tributary study (McCauley 1984) and the 1995 RI investigation of floodplain soils and sediments. These sets of historical data are reported in McCauley (1985). In the McCauley (1985) study, sediment was sampled all along tributaries NT-3 and NT-4, as well as from an upstream and downstream location near the confluence of the tributary with Bear Creek. The 1984 tributary study was more limited in sample extent, essentially resampling the lowermost tributary site, and the Bear Creek sample sites on either side of the confluence of each tributary with Bear Creek. The sample locations are shown on Fig. B.1, and the analytical data are summarized in Tables D.46 and D.47. Also included as part of these investigations were two reference samples from Grassy Creek (Tables D.46 and D.47).

The maximum concentrations for most of the inorganic elements and compounds occurred in sediments from the sites near the confluence of the tributaries with the creek. However, uranium (both total and isotopic) and barium peak in NT-3 at Station 3, which is located between the southeast corner of the OLF and the HCDA cap in the BYBY. This area roughly coincides with geophysical and radiological anomalies noted during a ChemRad radiation survey that was conducted as part of the BCV RI. These data indicate that sediments in NT-3 were contaminated with uranium and barium downstream of the anomalous area at the time of sampling in 1984. Although the historical data is more than 10 years old and sediment is thought to be somewhat mobile, NT-3 and NT-4 have not been disturbed by processes or operations since data were collected, and the results likely reflect current conditions within these tributaries.

Oil Landfarm FA sediment samples (SD04, SD05, SD07) were collected from Bear Creek at the confluence of NT-3 and NT-4 as part of the 1995 Floodplain Soils and Sediment investigation of the current RI. These samples were sent off site for radiological and chemical (inorganic, semivolatile, PCB/pesticide, and herbicide) analysis. The results of the sediment analysis are summarized in Table D. 101, and illustrated on Figs. D.112 through D.120. The distribution of contaminants in floodplain sediments is discussed in more detail in Sect. D. 9.2.

D.7.5 OIL LANDFARM FA – SURFACE WATER CHEMICAL DATA

The OLF FA contains three surface water aggregates: NT-3, NT-4, and NT-5. Prior to the BCV RI, NT-3 and NT-4 had been sampled during two studies (BNI 1984; McCauley 1984), with the data reported in McCauley (1985). Because NT-5 had not been sampled before the BCV RI, no historical data are available for this stream. Samples from NT-3 and NT-4 taken near the confluence with Bear

Creek were analyzed for a wide range of priority pollutants, including metals, VOCs, radionuclides, and base/neutral and acid extractable (BNAE) organics. The historic data for NT-3 and NT-4, which are generally consistent with data from the BCV OU 4 field investigation, are discussed in conjunction with the BCV OU 4 data. The current conditions of surface water at the OLF, based on data obtained from the BCV OU 4 investigation, are subdivided into three aggregates: NT-3, NT-4, and NT-5.

Table B.12 in Appendix B summarizes the analytes in surface water in BCV. Tables D.48, D.49, D.50, D.51, D.52, and D.53 summarize the analytical results for each analyte that was detected for unfiltered and filtered samples in the NT-3, NT-4, and NT-5 aggregates, respectively. Included in Tables D.48 through D.52 are the frequency of detection of the analytes; background criteria; frequency with which each analyte exceeds background; minimum, maximum, and mean results; and the relative importance of each analyte as a contaminant related to the OLF FA. The relative importance of an analyte as a contaminant at the OLF FA is determined by applying technical judgment based on the weight of evidence from a series of criteria (e.g., the frequency of detection of an analyte or the concentrations at which an analyte is detected relative to regulatory benchmarks). In addition, Table D.54 summarizes the results of analysis of miscellaneous parameters in NT-3, NT-4, and NT-5.

D.7.5.1 Inorganic Elements and Compounds – Oil Landfarm Surface Water

Surface water draining the OLF FA is relatively free of metal contaminants. Two metals, lithium and mercury, occur above background in NT-3, but no metals in NT-4 or -5 occur above background. Historic data from NT-3 and NT-4 identify no metal contaminants in these two streams.

Lithium was detected in all seven samples from NT-3 that were analyzed for lithium. Of these seven detections, six have a higher concentration of lithium than the background value (71 $\mu\text{g/L}$). Mercury was detected in 10 of 21 samples in NT-3. Although all 10 detections are greater than the background value (0.2 $\mu\text{g/L}$), the concentrations are generally low, with a maximum concentration of 0.51 $\mu\text{g/L}$.

Both lithium and mercury were used in the manufacturing process at the Y-12 Plant, and mercury is a contaminant in soils at BYBY. The source of these contaminants in NT-3 is assumed to be waste materials in the BYBY. However, the concentrations of these elements in surface water do not exceed SDWA MCLs (2 $\mu\text{g/L}$ for mercury).

D.7.5.2 Common Anions and Cations – Oil Landfarm Surface Water

In the tributaries draining the OLF FA, two anions, fluoride and chloride, occur regularly above background. Nitrate occurs above background in only one sample in NT-3 and in two in NT-5; sulfate occurs above background only in NT-3; and cyanide occurs in one sample in NT-4. Except for one sample of nitrate in NT-5, none of these anions occur in concentrations greater than SDWA MCLs or other regulatory benchmarks.

Cyanide was detected in only one of twelve samples in NT-4. The detected concentration (13 $\mu\text{g/L}$) in this sample is less than both the SDWAs MCL (200 $\mu\text{g/L}$). Because cyanide in NT-4 is both highly sporadic (8% of samples) and occurs at low concentrations compared to the regulatory benchmark for human health, it is not considered a contaminant in NT-4.

Because of the sporadic occurrence of nitrate and its generally low concentrations (a total of three samples above background), it is not considered as a contaminant in either of the streams

draining the OLF FA. Sulfate concentrations above background in NT-3 are probably the result of drainage from the BYBY, where uncontrolled waste is present; however, sulfate concentrations (maximum concentration 114 mg/L) are less than the federal and state SDWA MCLs (250 mg/L).

Chloride and fluoride occur in concentrations above background in all of the tributaries draining the OLF FA. Facilities or waste areas now exist, or have existed, in each of the NT-3, NT-4, and NT-5 catchments, and access roads are used continually by light and heavy duty vehicles. In contrast, NT-13 (the background catchment) is essentially untouched, except for one, infrequently used road. Although the activities in the NT-3 and NT-4 catchments have affected the major ion chemistry of the impacted catchments, the concentrations of chloride and fluoride in these streams (maximum values of 58 and 2.6 mg/L, respectively) do not exceed regulatory benchmarks.

D.7.5.3 Organic Compounds – Oil Landfarm Surface Water

Although two facilities in the OLF FA received disposal of organic chemicals (OLF and HCDA), the concentrations of organic chemicals in surface water are low. Seven organic compounds were detected in NT-3, one was detected in NT-4, and four were detected in NT-5. These data are consistent with historical data from NT-3 and NT-4 (McCauley 1985), which show that very few organics were detected in samples taken between October 1983 and August 1984. The historical data, which were obtained before the sites in these catchments were capped, include analytical results for VOCs and BNAE organics; these results suggest that little or no organic contamination in surface water has resulted from activities at the OLF FA.

Of the seven detected organic compounds in NT-3, four were detected at a frequency of 1/20 and at concentrations that were relatively low: 2-butanone (8 $\mu\text{g/L}$), 2-hexanone (6 $\mu\text{g/L}$), 4-methyl-2-pentanone (4 $\mu\text{g/L}$), and toluene (2 $\mu\text{g/L}$). The concentration of toluene is almost three orders of magnitude below the SDWA MCL (1,000 $\mu\text{g/L}$), and the other three contaminants are common laboratory contaminants. Because of their sporadic occurrence and low concentrations, none of the four compounds are considered contaminants in NT-3.

Three organic compounds were detected in NT-3: 1,2-DCA, acetone, and chloromethane. However, the occurrence of one of these compounds, 1,2-DCA, is highly suspect. During the BCV OU 4 investigation, elevated concentrations of 1,2-DCA were found in early samples from BCK 12.38, NT-2, NT-3, and NT-7, but were suspected to have resulted from sample contamination during handling in the field or in the laboratory. A rigorous investigation of the likely causes of contamination in the field or laboratory did not yield a source; however, after completion of the investigation, elevated concentrations of 1,2-DCA in NT-2, NT-3, and BCK 12.3 did not occur in the remaining samples. Although no causal effect can be determined for these elevated values in these streams, they remain suspect.

Acetone and chloromethane, which are common contaminants in BCV groundwater and surface water, were also detected in shallow groundwater at BYBY and OLF. Their occurrence in NT-3 is consistent with these observations, and their likely origin is contaminated shallow groundwater.

In NT-4, the only detected organic compound is 1,2-DCE, which is consistent with its occurrence as a contaminant in groundwater at the OLF. However, 1,2-DCE occurs in only 1 of 13 samples at a concentration of 2 $\mu\text{g/L}$, which is below the reported detection limit and almost two orders of magnitude less than the SDWA MCL. Thus, 1,2-DCE is not considered a contaminant in NT-4.

The organic compounds 1,2-DCE, methylene chloride, toluene, and TCE were each detected once in 13 samples at NT-5. Concentrations of methylene chloride, toluene, and 1,2-DCE are estimated as occurring at or below their reported detection limits; because these limits are less than the SDWA MCLs, these three compounds are not considered contaminants. TCE occurs in 1 of 13 samples, at a concentration of 7 $\mu\text{g/L}$, which is above the SDWA MCL; however, the source of TCE in this tributary is not known.

D.7.5.4 Radioactivity – Oil Landfarm Surface Water

Radioactive contamination is the principal form of contamination in surface water in NT-3, which yielded the highest activities for gross α and gross β in surface water for the BCV OU 4 project. Each sample in NT-3 exceeds background for gross α and gross β . Gross α ranges from 64.6 to 1350 pCi/L, with a mean activity of 455.4 pCi/L, and gross β ranges from 55.8 to 603 pCi/L, with a mean activity of 221.8 pCi/L.

Isotopes of uranium (^{238}U , ^{235}U , and ^{234}U), thorium (^{232}Th , ^{230}Th , and ^{228}Th), and strontium (^{90}Sr) were detected in NT-3. However, the frequency of detection and the activities at which they occur indicate that the isotopes of Th and Sr are not the principal radioactive contaminants in NT-3. Because occurrence of these isotopes is consistent with groundwater data and with operations at the Y-12 Plant, they are considered contaminants in NT-3; however, the activity of uranium isotopes is up to two orders of magnitude greater than that of the other radionuclides. These data are consistent with a sample taken in 1983 from NT-3 close to the confluence with Bear Creek (3-3 or 5 in McCauley 1985), which had activities for ^{234}U , ^{235}U , and ^{238}U of 235, 26.5, and 478 pCi/L, respectively (these data have no MDAs reported with them).

The activities of uranium radioisotopes can explain the observed gross α and gross β activities, which are of the same magnitude as the sum of the ^{238}U , ^{235}U , and ^{234}U activities in all samples from NT-3 (Fig D.73). Alpha activity is associated with decay of the ^{238}U , ^{235}U , and ^{234}U isotopes, whereas β activity is derived from decay of the daughter isotopes of ^{238}U (^{234}Th and ^{234}Pa), which are assumed to be in secular equilibrium with the parent ^{238}U .

Uranium isotopes were detected in 1 of 12 samples in surface water in NT-4. The maximum activities for ^{234}U (1.77 pCi/L) and ^{238}U (2.51 pCi/L) in NT-4 occur in the lowest-flow sample (SN4010), taken in October 1994. These activities are an order of magnitude below the proposed SDWA MCL activity of 30 pCi/L for natural uranium (corresponds approximately to 20 $\mu\text{g/L}$ total uranium). The occurrence of detected uranium only in the lowest flow sample indicates that the uranium originates in groundwater, and these very low values may represent reasonable background values for these uranium isotopes in BCV; thus, uranium isotopes are not considered a contaminant in NT-4.

In NT-5, gross β activity exceeds background in one sample (SN5004), with an activity of 11.4 pCi/L; however, this activity is below the SDWA MCL of 4 mrem/year (relates approximately to an activity of 50 pCi/L) and is not considered indicative of contamination.

D.7.5.5 Relationships Between Streamflow and Contaminant Concentrations

Continuous monitoring of flow and specific conductivity conducted at the sample point in NT-3 shows that the conductivity of surface water in this stream is controlled by flow (conductivity measured in 30-min. intervals). Conductivity is higher during low-flow periods and decreases for short periods during storm events (Fig. D.74) because of dilution of groundwater discharge to the creek by runoff. On Fig. D.74 specific conductivity (Ks) in NT-3 during a single rainfall event is

plotted as a function of the discharge (Q) plotted on log axes. As discussed in Sect. D.6.5, the slope relationship between $\log(C)$ and $\log(Q)$ indicates the type of dilution by rainwater in the stream during a storm. A slope of 1 indicates simple dilution, whereas a slope <1 indicates that contaminants are released at a greater rate during storms. For the storms observed at NT-3, slopes of the linear relationship (the value of B) are ~ 0.3 , indicating that the rate of release of dissolved load to the stream increases during a storm.

Table D.55 lists the sample results for the principal inorganic contaminants at NT-3 and the average discharge rate for each sample during the period over which the sample was obtained (sample periods are listed in Table B.16 in Appendix B; total flow was calculated from stream hydrographs in Figs. B.17 to B.19). Figure D.75 shows plots of the log activity [$\log(C)$] vs the log of the average flow rate [$\log(Q_{av})$] for gross α , gross β , and uranium isotopes at NT-3, respectively. The best fit empirical curve for each of these relationships is also shown on these figures. Slopes of these curves on axes of $\log(C)$ vs $\log(Q_{av})$ range from 0.16 to 0.24, which are slightly smaller than the B values observed for conductivity for NT-3. These values are also much lower than those observed for contaminants in NT-2 and BCK 12.38 (Sect. D.6.5.6).

Similarly to the C vs Q relationship for conductivity (Fig. D.74), the values for B derived from plots of $\log(C)$ vs $\log(Q_{av})$ indicate that a simple dilution of contaminants does not occur during storm events in NT-3; rather, the range of values (0.16 to 0.24) indicates that, as flows increase, so does the total flux of contaminants. This response can be attributed to an increase in the rate of release of contaminants from the subsurface in NT-3 catchment during storm events, which in turn is a function of the solubility of the chemicals and the discharge rate.

D.7.6 OIL LANDFARM FA – GROUNDWATER CHEMICAL DATA

Groundwater in the vicinity of the OLF, BYBY, and SL 1 sites is contaminated with a wide range of chemicals — radionuclides, VOCs, and metals — consistent with the history of operations at these sites. In addition, contaminants derived from the BYBY site can be identified in groundwater in the Maynardville Limestone.

The wells included in the OLF aggregates are listed in Table D.6, and their locations are shown on Fig. D.5. The two OLF groundwater aggregates are defined by the sampling methods used to obtain the data: the OLF aggregate contains wells from the GWQR database that were sampled as part of the Y-12 Plant GWPP, and the OLF OU 1 aggregate contains wells that were sampled during the RI field activities. The samples taken in the RI field activities were obtained as groundwater grab samples using a direct push sampling method and, thus, may not be directly comparable to samples taken in the GWPP. Hence, data from the two sources were analyzed as separate aggregate. Wells from the GWQR database to be included in the analysis were selected on the basis of two criteria: the well is screened in the Nolichucky Shale and is located within the watersheds of NT-3 or NT-4.

Tables B.2 and B.7 in Appendix B summarize the analytes for groundwater at the OLF aggregates. Tables D.56, D.57, D.58, D.59, and D.60 summarize the analytical results for each detected analyte from the GWQR database and RI database, respectively. Included in Tables D.56 through D.60 are the frequency of detection of the analytes; frequency of wells that detect each analyte; frequency at which the median value for an analyte in a well exceeds the background UTL; aggregate minimum and maximum results; mean of the well median results; and relative importance of each analyte as a contaminant related to the OLF FA.

As described in the background screening method outlined in Sect. D.4.2, the median concentration of a chemical in groundwater from wells in the OLF aggregate was used to identify wells that have consistently elevated concentrations of metals in groundwater. The extent of the principal contaminants in the OLF groundwater aggregates is described in the following subsections.

D.7.6.1 Organic Compounds – Oil Landfarm Groundwater Aggregates

Eighteen VOCs were detected in groundwater in the GWQR OLF groundwater aggregate, and 19 VOCs were detected in the OLF OU 1 groundwater aggregate. The primary VOCs in the OLF FA are 1,1,1-TCA, 1,1-DCA, 1,1-DCE, 1,2-DCA, 1,2-DCE, acetone, 2-butanone, benzene, chloroform, methylene chloride, PCE, TCE, trans-1,2-DCE, and vinyl chloride. 1,1,2,2-Tetrachloroethane, 1,1,2-trichloroethane, bis(2-ethylhexyl)phthalate, chloroethane (CE), and toluene occur less frequently or at lower concentrations. The distribution of VOCs at OLF FA is shown in Fig. D.76.

Because no background values exist for VOCs in groundwater, a detected chemical is considered a contaminant. However, nine organic chemicals occur only at concentrations below their detection limit (reported as estimated values) and at low frequencies: phenol and total phenols occur in the GWQR OLF aggregate, and Aroclor-1254, bis(2-ethylhexyl)phthalate, di-n-butylphthalate, fluoranthene, phenanthrene, pyrene, and toluene occur in the OU 1 OLF aggregate. None of the estimated concentrations of these chemicals exceed regulatory drinking water criteria. These nine chemicals are not considered as contaminants in groundwater because of their extremely low concentrations and sporadic occurrence.

PCE, TCE, and 1,2-DCE are common contaminants in groundwater throughout BCV, as shown in Figs. D.9 to D.11. The relative concentrations of the principal organic contaminants at the OLF site are shown in Fig. D.76. Figures D.24 through D.29 depict the distribution of TCE and 1,2-DCE concentrations in cross sections of the BCV oriented across strike and along strike. The location of this cross section is shown on Fig. D.5.

Organic contamination in the OLF FA occurs in three locations associated with the OLF, BYBY, and possibly SL 1, respectively, as described in the following subsections.

Oil Landfarm

Organic contamination at OLF occurs mainly in wells screened in the shallow bedrock and water table intervals located close to the OLF cap. In GW-003, located on the northeast side of the cap, the principal organic contaminants are 1,1,1-trichloroethane (240 to 510 $\mu\text{g/L}$), 1,1-DCA (1900 to 2000 $\mu\text{g/L}$), and 1,1-DCE (620 $\mu\text{g/L}$). In the shallow interval south of the OLF cap (GW-007 and GW-010), the principal contaminants are 1,2-DCE (16 to 150 $\mu\text{g/L}$), trans-1,2-DCE (5 to 270 $\mu\text{g/L}$), PCE (3 to 100 $\mu\text{g/L}$), and TCE (4 to 20 $\mu\text{g/L}$).

Organic contaminants have been detected in one well screened in the intermediate bedrock groundwater interval south of the OLF cap (GW-073). However, the concentrations of these contaminants (1,2-DCE, 4 to 13 $\mu\text{g/L}$; trans-1,2-DCE, 1 to 13 $\mu\text{g/L}$; PCE, 0.9 to 6 $\mu\text{g/L}$; and TCE, 0.7 to 2 $\mu\text{g/L}$) are considerably lower than those detected in the shallow interval.

The distributions and concentrations of organic contaminants at OLF suggest that no DNAPL is present in the subsurface at this site. The highest concentrations of organic contaminants are <1% of the solubility of the chemicals and occur in the shallowest intervals. In addition, the concentrations of the parent chemicals (PCE and TCE) are the lowest, whereas chemicals that are potentially degradation products of these parent chemicals (1,2-DCE and 1,1-DCA) are the highest. Elsewhere

in BCV, where DNAPL is indicated (BCBG and S-3), the concentrations of parent organic chemicals predominate, and contaminant concentrations in the shallow, intermediate, and deep intervals are of a similar order of magnitude. The absence of this pattern at OLF supports the conclusion that DNAPL is probably not present here. This conclusion is also supported by information about the mode of emplacement of these chemicals at the OLF. The liquids were spread over the ground by spraying, and soil was tilled over to promote breakdown or volatilization of the chemicals. The occurrence of mostly breakdown products in groundwater is probably consistent with this operation.

BYBY

The highest concentration of VOCs in the OLF FA occurs in shallow groundwater at the BYBY. Data from the BCV OU 1 investigation delineate a plume of organics in the water table interval, as well as data from one GWQR well screening in the shallow bedrock interval (GW-087) are consistent with these data. Two distinct contaminant suites have been identified at BYBY: (1) boring BY-02, which shows 1,2-DCE at a concentration of 1,100 $\mu\text{g/L}$ ($<0.1\%$ of maximum solubility), PCE at 620 $\mu\text{g/L}$ (0.3% of maximum solubility), and TCE at 210 $\mu\text{g/L}$ ($<0.1\%$ of maximum solubility); and (2) boring BY-03, which shows TCE at 2,000 $\mu\text{g/L}$ (0.18% of maximum solubility), 1,2-DCE at 78 $\mu\text{g/L}$, and PCE at 15 $\mu\text{g/L}$. Borings BY-02 and BY-03 are both located directly adjacent to the HCDA cap, 60 m (200 ft) apart, and are screened in the residuum.

Well GW-087, located about half-way between borings BY-02 and BY-03, is screened at 2.7 to 5.8 m (9 to 19 ft) in the residuum. Mean concentrations of 1,2-DCE, PCE, and TCE in GW-087 are 143, 676, and 383 $\mu\text{g/L}$, respectively. These concentrations indicate that the two distinct contaminant suites observed in BY-02 and BY-03 coalesce to form a single plume of organic-contaminated groundwater in this well.

Both BY-02 and BY-03 are located directly adjacent to the HCDA cap, and activities at the HCDA are a likely source of contamination in these wells. However, the HCDA cap is also located above the BYBY landfill, which is also a likely source of the organic contamination. Photographs of the HCDA during operations (Appendix A, Plate A.6) show that a percolation pond was located in the southwest corner of the facility (close to the location of BY-02); this pond is another likely source of the groundwater contamination at BY-02. A similar source for the TCE-dominated organic contaminant suite at BY-03 is not known; however, various organic liquids have been handled at HCDA or were used to initiate burning at the BYBY. The distribution and concentrations of VOC contaminants suggest that, although contaminant plumes in the residuum are very localized, the plumes coalesce downgradient in the residuum, resulting in an observation of the combined contaminant suites in GW-087.

No data are available to determine the extent of VOC contamination in bedrock intervals at BYBY; however, because one mode of disposal for chemicals at HCDA was for liquids to percolate directly to groundwater (through the percolation pond), the existence of DNAPL in the subsurface cannot be discounted. DNAPL, if present, would likely have resulted in elevated concentrations of VOCs in the bedrock; however, the lack of data for the bedrock groundwater means that the presence of DNAPL cannot be determined.

SL 1

Three Nolichucky bedrock wells located along strike from SL 1 contain low concentrations of organic contaminants (GW-097 and GW-098), and one well screened in the Maynardville Limestone (GW-229) contains a similar suite of contaminants. The detected chemicals are 1,1-DCA (2 to 17 $\mu\text{g/L}$ in the Nolichucky Shale and 4 to 20 $\mu\text{g/L}$ in the Maynardville Limestone); 1,2-DCE (6 to

35 $\mu\text{g/L}$ in the Nolichucky Shale and 1 to 38 $\mu\text{g/L}$ in the Maynardville Limestone); trans-1,2-DCE (7 to 27 $\mu\text{g/L}$ in the Nolichucky Shale and 1 to 54 $\mu\text{g/L}$ in the Maynardville Limestone); and vinyl chloride (14 to 35 $\mu\text{g/L}$ in the Maynardville Limestone only).

The occurrence of this organic contamination in wells GW-097, -098, and -229 may be associated with the plumes of organic contaminants upgradient in the Nolichucky Shale or Maynardville Limestone. However, in the case of GW-229 in the Maynardville Limestone, the contaminant suite differs slightly from those in the wells immediately upgradient; that is, 1,1-DCA and vinyl chloride are not significant contaminants in wells GW-225, -226, -227, and -228. In GW-097 and GW-098, the contaminant suites are similar to those in shallow groundwater wells close to the OLF cap; however, as demonstrated by the BCV conceptual hydrogeologic model, a pathway allowing migration from shallow groundwater at the OLF to shallow groundwater in this well is not likely. A more likely hypothesis is that organic contamination described in GW-097 and GW-098 is derived from SL 1; however, with no direct evidence to suggest that SL 1 is the source of this contamination, this conclusion is tentative. The concentrations that occur in these wells preclude the presence of DNAPL.

D.7.6.2 Radioactivity – Oil Landfarm Groundwater Aggregates

The distributions of gross α and gross β in groundwater in BCV are shown in Figs. D.7 and D.8. For gross α , the minimum contoured value is 15 pCi/L, which is the MCL for gross α ; and for gross β , the minimum contoured value is 50 pCi/L, the MCL for gross β . The subsequently higher contours on the figures are logarithmic: 100, 1,000, and 10,000 pCi/L. Figures D.17 through D.22 depict the distribution of gross α and gross β activities in cross sections of BCV oriented across and along strike. The locations of these cross sections are shown on Fig. D.5.

Radiological contamination of groundwater in the OLF FA is restricted to groundwater in the catchment of NT-3, particularly that underlying BYBY. Elevated gross α and gross β activities occur in the water table and shallow bedrock intervals in a plume adjacent to the NT-3 stream channel. The highest activities in this plume occur in samples from the RI field activities grab samples, in which elevated gross α activity coincides with elevated gross β activity. The maximum activities, recorded in boring BY-09, are 2200 pCi/L for gross α and 2800 pCi/L for gross β . The plume of radioactively contaminated groundwater extends approximately along NT-3 from boring BY-04, located in the northwest corner of BYBY, to the confluence of NT-3 with Bear Creek. Borings BY-03 and BY-02, adjacent to the HCDA cap, and SL1-1, adjacent to NT-3 and SL 1, also show elevated activities of gross α and gross β ; this distribution implies that the contaminant plume may also extend under the HCDA and SL 1 caps.

Isotopes of uranium (^{238}U , ^{235}U , and ^{234}U), thorium (^{232}Th , ^{230}Th , and ^{228}Th), lead (^{210}Pb), and potassium (^{40}K) were detected in shallow groundwater in the RI field activity borings. However, the frequency of detection and the activities at which they occur indicate that the isotopes of Th, Pb, and K are not the principal radioactive contaminants in groundwater at BYBY. Because occurrence of these isotopes is consistent with surface water data for NT-3 and with operations at the Y-12 Plant, these radionuclides are considered contaminants in shallow groundwater. However, the activity of uranium isotopes exceeds that of other radionuclides by up to two orders of magnitude. The maximum activities of uranium isotopes are 1300 pCi/L for ^{234}U (equivalent to 0.2 $\mu\text{g/L}$ ^{234}U), 53 pCi/L for ^{235}U (24 $\mu\text{g/L}$ ^{235}U), and 1800 pCi/L for ^{238}U (5382 $\mu\text{g/L}$ ^{238}U) compared to the maximum activities for the other radionuclides of 2.6 pCi/L for ^{230}Th , 16 pCi/L for ^{210}Pb , and 170 pCi/L for ^{40}K .

The activities of uranium radioisotopes can explain the observed gross α and gross β activities in shallow groundwater, which are consistent with the data for surface water. The observed α and β activities are of the same magnitude as the sum of the ^{238}U , ^{235}U , and ^{234}U activities. Alpha activity is associated with decay of the ^{238}U , ^{235}U , and ^{234}U isotopes, whereas β activity is derived from decay of the daughter isotopes of ^{238}U , ^{234}Th , and ^{234}Pa , which are assumed to be in secular equilibrium with the parent ^{238}U .

The most likely source for uranium contamination in groundwater at BYBY is leaching of uranium waste and uranium-contaminated waste materials. The highest activities of uranium isotopes in groundwater coincide with the locations of the radiological and geophysical anomalies at BYBY, which likely occur at the location of buried wastes at BYBY; thus, the uranium contamination in groundwater is probably derived from the leaching of these waste materials. No data are available to determine the extent of contamination in bedrock intervals at BYBY. However, in other locations where radiological contamination is derived from leaching of waste materials (BCBG), little or no contamination has been observed in the bedrock intervals. In the BCV conceptual hydrogeological model (Appendix C), >95% of the groundwater flow is through the shallow bedrock and water table intervals; thus, deeper groundwater contamination is not likely to occur unless contaminants are driven downward by density contrasts (such as at S-3 and in DNAPL).

D.7.6.3 Common Anions and Cations – Oil Landfarm Groundwater Aggregates

Chloride is the only anion consistently above background in the GWQR OLF groundwater data aggregate; however, chloride, fluoride, sulfate, and cyanide are all consistently above their background criteria in the eight groundwater grab samples taken from the BYBY and SL 1 areas during the BCV OU 1 investigation. Concentrations of sulfate are particularly high in the shallow groundwater at BYBY, and all eight groundwater samples exceed the background criteria. The maximum concentration of sulfate was 300 mg/L in well BYBY-06, with an average value for the aggregate of 101 mg/L. None of the detected anion concentrations exceed applicable or relevant and appropriate requirements (ARARs), SDWA MCLs, or ambient water quality criteria.

D.7.6.4 Inorganic Elements and Compounds – Oil Landfarm Groundwater Aggregates

A total of 14 inorganic elements (not including essential elements) occur above their background criteria in one or more wells in the OLF FA GWQR groundwater aggregate. Similarly, the background screen of the OLF OU 1 groundwater aggregate identified 11 inorganic elements above background. Figure D.77 shows these wells in the OLF GWQR aggregate that have one or more metal contaminants. As shown by the figure, relatively few wells have contamination related to inorganic elements, and no distinct plume of contaminated groundwater can be delineated by the wells in the OLF GWQR aggregate. Most contaminated groundwater is associated with older wells located close to the OLF (GW-007 and GW-010) or close to the BYBY (GW-005 and GW-087). These wells are screened in the water table interval or shallow bedrock; wells screened in the intermediate and deep bedrock intervals show no inorganic contamination.

The data from the shallow grab samples in the OU 1 OLF aggregate appear to be consistent with those from the GWQR database. Well GW-087 is screened in the shallow bedrock in the area where the groundwater grab samples were obtained and, of the 11 inorganic elements that occur above background in GW-087, 7 are in the shallow groundwater at BYBY. Also, uranium, although not analyzed for, was detected in elevated activities in shallow groundwater through isotopic analysis.

Because only unfiltered sample results were used to identify the contaminants (filtered samples were not available for the OLF OU 1 aggregate), the contaminants may not represent the extent of

dissolved metals. For comparison, the same background screen was conducted for the GWQR aggregate using results from the accompanying filtered samples. This screen identified only four contaminants, ten less than those identified using only unfiltered samples. Both screens identified boron, cadmium, lead, and uranium as occurring in the same wells: GW-005, -007, and -087. However, except for boron, the frequency of detection was greatly reduced for all inorganic analytes. These results imply that, except for the four metals identified in both screens, most of the inorganic contamination is in the suspended rather than the dissolved phase.

In the unfiltered OLF GWQR aggregate, cadmium (GW-007), chromium (GW-010), lead (GW-007, -010, -087, and -531), and uranium (GW-005 and -087) exceed SDWA MCLs in at least one sample. In the OLF OU 1 aggregate, antimony (BY-06), lead (BY-03 and -09), and mercury (BY-06) exceed SDWA MCLs in at least one sample.

The conclusions from these data are that shallow groundwater at the OLF FA has sporadic metals contamination, which in some cases exceeds drinking water ARARs for groundwater. The worst contamination occurs in the shallow groundwater system at the BYBY and close to the channel of NT-3. Metal concentrations in shallow groundwater samples from these two locations are generally higher and exceed background and ARARs.

D.7.7 OIL LANDFARM FA – ECOLOGICAL SETTING

The OLF FA has been subdivided into three aggregates: BYBY, SL 1, and OLF proper. The distributions of habitat types in the OLF groups were estimated by using an overlay grid to measure areas on Fig. D.78 and D.79 and are summarized in Table D.61.

D.7.7.1 Potential Exposure to Contaminants

Potential surface water and sediment exposures in the OLF area occur in tributaries NT-3 and NT-4. Capped areas and roadways offer little or no high-quality habitat for terrestrial biota, but habitat between the capped areas offers shelter and food in the grassy brushy and wooded areas for small mammals, reptiles, amphibians, and birds.

D.7.7.2 Habitat Description

Although the BYBY site contains small wooded areas, old-field, and brushy areas, it is predominantly covered with mowed grass (Fig. D.78). The northwest corner of BYBY contains a small wooded area along NT-3 (Fig. D.78), primarily supporting mainly hardwoods 15 to 35 cm (6 to 14 in.) in diameter at breast height (DBH) and ~15 to 18 m (~50 to 60 ft) high. Most of the rest of the area north of the HCDA is covered with mowed grass, except for low brush or gravel along the haul road right-of-way. The area from the western edge of the HCDA to NT-3 is predominantly covered with grass.

The HCDA cap is covered with mowed grass. Its southern edge, which slopes sharply to the former channel of Bear Creek (Fig. D.78), is covered with dense brush and mixed hardwoods, which provide good cover for a variety of small mammals and birds. Bear Creek has been rerouted away from the HCDA on the lower part of BYBY. The southern edge of BYBY is densely wooded, with mixed pine and hardwoods ranging up to ~10 to 15 m (~35 to 50 ft) tall and up to ~15 to 20 cm (6 to 8 in.) DBH. East of the HCDA and south of its access road is a stand of pines and mixed hardwoods. Old field has developed between the HCDA and NT-3.

The grassy areas provide little cover because the grass has been kept mowed. However, some habitat is provided in the grassy areas, and particularly in the brushy and wooded areas, for small mammals, reptiles, amphibians, and birds.

The Bear Creek floodplain adjacent to SL 1 is heavily wooded with a dense stand of mixed hardwoods ~12 to 25 cm (5 to 10 in.) DBH. A border of planted pines separates the floodplain and SL 1; otherwise, SL 1 is predominantly mowed grass and gravel roads (Fig. D.79).

A dense patch of small planted pine trees borders the OLF cap to the north, but most of the site is mowed grass. The northwest corner of the area, west of NT-4, contains a stand of pines, oaks, and maples ~15 to 40 cm (6 to 16 in.) DBH. NT-4 flows through an area of riparian vegetation containing willow, alder, and elm, as well as smaller vegetation. East of NT-4, a graveled storage area is bordered to the south by an open stand of pines ~20 to 25 cm (8 to 10 in.) DBH and ~10 to 13 m (33 to 43 ft) tall. A branch of NT-4 extends between OLF and SL 1 (Fig. D.79); it is also bordered by riparian vegetation containing willow, alder, and elm, as well as smaller vegetation. Federal- and state-listed protected species are described in Supporting Information for Appendix D.

Wetlands

Wetlands have been identified on NT-3 and NT-4 (Rosensteel and Trettin 1993), but they are all north of the haul road and therefore outside the boundaries of the OLF group.

D.7.7.3 Toxicity Testing at the BYBY Area

Ambient Water Toxicity

Ambient water toxicity testing has not shown toxicity of water from NT-4 (Southworth et al. 1992). Fathead minnow (*Pimphales promelas*) toxicity testing was performed using water from NT-4 in October 1984, April 1985, and June 1985. No toxicity (statistically significant reduction in growth of survival compared to controls or reference samples) was observed in these tests.

Ambient water toxicity testing was also performed as part of BCV RI in May and August 1994 at sites in Bear Creek, tributaries NT-1 through NT-8, and springs SS-1, -4, -5, -6, and -8. Because contaminants from the BYBY migrate to tributary NT-3, the results of toxicity tests in NT-3 may reflect contaminants from the BYBY area.

Two test organisms, fathead minnow (*Pimphales promelas*) and *Ceriodaphnia dubia*, were used in the tests, which were conducted at the Oak Ridge National Laboratory (ORNL) Environmental Sciences Division Toxicology Laboratory.

Results for BCK 11.83, NT-3, NT-4, and BCK 11.09 are shown in Table D.62. None of the samples significantly reduced survival or growth of fathead minnows. Water from NT-3 and NT-4 reduced reproduction of *Ceriodaphnia* less than did samples from the main stem above and below the tributaries. Reproduction was significantly inhibited (Dunnett's t-test, $\alpha=0.05$) in NT-3 and NT-4 compared to that at the reference site but not compared to the control. This inhibition was seen in May 1994 but not in August 1994.

Sediment Toxicity

Ambient sediment toxicity tests were done as part of the RI in May and June of 1995. In these tests, the freshwater scud *Hyalella azteca* is exposed to whole sediment and *Daphnia magna* is

exposed to overlying water (details are presented in Appendix G). Sampling locations SD01 through SD17 are shown in Fig. B.50 in Appendix B. No statistically significant toxicity was demonstrated in samples taken at sites SD05 or SD07, sites near the BYBY area, when compared to a composite reference sample taken from NT-11, NT-13, and NT-15.

Soil Toxicity

No historical population and community data exist for plants, birds, or mammals specific to the OLF grouping. Studies of contaminant body burdens and biomarkers of exposure of terrestrial biota have not been conducted for this portion of BCV, nor is there a historic record of toxicity testing for terrestrial media.

D.7.7.4 Bioaccumulation Studies

Studies of contaminant bioaccumulation in Bear Creek (Hinzman 1995) have not recently used sample sites near the BYBY area. Therefore, no conclusions can be drawn about the potential effects of BYBY contaminants on the body burdens of fish in Bear Creek.

D.7.8 CONCLUSIONS

Figures D.80 and D.81 show detailed conceptual models of the OLF FA and the likely migration pathways for contaminants operating today. This figure is key to understanding the conclusions of this chapter.

D.7.8.1 General Conclusions for Nature and Extent

Wastes

- Waste materials have been observed at the surface in many places in the BYBY. A rusted drum, metal, and concrete pieces can be seen in the soil in the southwest section of this area, particularly along the southern side of the HCDA cap, where the edge of the fill material is interpreted to be located. A 3.0- to 3.7-m (10- to 12-ft) step-up from the floodplain marks the southernmost extent of fill. Soil borings show that 3.0- to 3.7-m (10- to 12-ft)-thick fill material covers most of BYBY, except for the southwest corner.
- Geophysical and radiological surveys of this area reveal numerous anomalies throughout the BYBY. The main radiological anomalies are located to the south of HCDA and in the southwest section of BYBY, particularly in a region close to the channel of NT-3 at the northwest corner of the HCDA cap. Both conductivity (EM-31) and magnetic anomalies outline an anomalous area [45×45 m (150×150 ft)] located between the northeast corner of the HCDA cap and the southwest corner of the OLF cap. Other magnetic and conductive anomalies occur sporadically throughout the BYBY over the area interpreted as fill.
- A sample of waste material from inside a drum located at the surface in BYBY has a total uranium activity of more than 48,000 pCi/g.
- The composition of waste materials at SL 1 is almost unknown but is expected to be fairly consistent with that found at other sanitary landfills for industrial complexes similar to the Y-12 Plant. One sample of what is apparently sanitary waste (cloth materials) contains no chemicals that are inconsistent with this assumption.

- Soils under the OLF cap are contaminated with metals and PCBs, but the soils most heavily contaminated with BCVs have been excavated and placed in the OLF storage area. The contamination in soil underneath the cap is <0.3 m (1 ft) deep and is well characterized.

Soils

- In the OLF FA, soils are contaminated with metals (especially copper and mercury), uranium, ⁹⁹Tc, PAHs, PCBs, and phthalates. However, except for some PAH compounds, concentrations are generally low throughout the FA. The most heavily contaminated area is the BYBY.
- At BYBY, the main contaminants include metals (especially copper and mercury), uranium, ⁹⁹Tc, PAHs, PCBs, and phthalates. Inorganic contamination is widespread, with copper concentrations two orders of magnitude above background. Inorganic concentrations in the shallow zone are much lower, but copper and mercury levels are still high. The highest concentrations of organic compounds occur in the surface soil samples on the western and southern edges of the HCDA. Radiological contamination in the BYBY is represented by uranium and ⁹⁹Tc, which are more extensive and occur at higher activity concentrations in the shallow zone. The highest concentrations for these radionuclides occur on the western edge of the HCDA. Organic contamination is very widespread, with numerous PCB, PAH, and phthalate compounds in addition to acetone, toluene, and several other organic compounds.
- At OLF, inorganic elements occur at slightly higher concentrations in the deep interval, but even here, the concentrations detected are only slightly above background. Radionuclides ⁶⁰Co and ²⁰⁸Tl have slightly higher concentrations in the shallow interval, but again, the activity concentrations detected are not elevated much above background. Organic compounds were detected in all the borings, with slightly higher concentrations in the shallow interval. The area under the OLF cap has been remediated for PCB contamination in the past; PCBs sporadically were detected at concentrations ranging from 12 to 220 µg/kg (total PCBs) in soils surrounding the OLF cap.
- The SL 1 was characterized by two surface soil samples and two soil borings. The nature of contamination is more varied in this aggregate than in the OLF. Inorganic contaminants include mercury, copper, and nickel, with the highest concentrations of mercury and copper occurring in the shallow interval but the highest concentrations of nickel occurring in the deep interval. Concentrations of all contaminants are highest in the shallow interval of surface soil sample SBY-16 and boring SL1-1. The distribution and concentrations of organics in SBY-16, particularly the concentration of total PAHs and PCBs, more closely match those of the BYBY aggregate than the SL 1. The maximum concentrations for organic compounds occur on the eastern and western edges of the SL 1, again suggesting a slight preference for along strike migration away from the disposal area. In SL1-2, the concentrations of organic compounds are higher in the deep interval, suggesting vertical migration of contaminants, at least on this end of the waste disposal area.

Groundwater

- Groundwater is contaminated with radionuclides (principally uranium isotopes), 14 metal species, and 19 VOCs. The most severely contaminated groundwater is in the vicinity of BYBY, where groundwater is contaminated with radionuclides, metals, and VOCs. Groundwater immediately downgradient from the OLF and SL 1 is contaminated primarily with VOCs.

- Groundwater contamination at BYBY has been well defined in the water table interval in the residuum; however, because no wells are screened in the bedrock at this site, the extent of groundwater contamination in bedrock cannot be determined. Two distinct contaminant plumes occur at BYBY: a VOC plume associated with the HCDA (BY-02 and BY-03) and a radionuclide/metal plume that is oriented parallel to the channel of NT-3.

Groundwater in the VOC plume is contaminated with PCE (maximum 620 $\mu\text{g/L}$), TCE (2000 $\mu\text{g/L}$), and 1,2-DCE (1100 $\mu\text{g/L}$). Concentrations are <1% of maximum solubility for each chemical (maximum 0.3% for PCE), indicating that DNAPL is not present in the subsurface close to the soil borings; however, the presence of DNAPL at BYBY cannot be discounted. The relative concentrations of each chemical vary within the plume: TCE and 1,2-DCE predominate in the northwest corner of the HCDA, whereas PCE and 1,2-DCE predominate in the southwest corner of the HCDA cap.

The principal contaminants in the radionuclide/metal plume are isotopes of uranium (^{238}U and ^{234}U), beryllium, lead, and mercury.

- Groundwater close to the OLF cap is contaminated with two separate suites of VOCs: (1) 1,1,1-TCA (240 to 510 $\mu\text{g/L}$), 1,1-DCA (1900 to 2000 $\mu\text{g/L}$), and 1,1-DCE (620 $\mu\text{g/L}$) to the northeast of the cap; and (2) 1,2-DCE (16 to 150 $\mu\text{g/L}$), trans-1,2-DCE (5 to 270 $\mu\text{g/L}$), PCE (3 to 100 $\mu\text{g/L}$), and TCE (4 to 20 $\mu\text{g/L}$) to the south of the cap. Restriction of this contamination to the shallow interval, combined with the occurrence of these chemicals in <0.1% of their solubility, suggest that the presence of DNAPL in the subsurface is unlikely.
- Two borings in the Nolichucky Shale (GW-097 and GW-098) and one in the Maynardville Limestone (GW-229) located downgradient of SL 1 are contaminated with 1,1-DCA (2 to 17 $\mu\text{g/L}$ in the Nolichucky and 4 to 20 $\mu\text{g/L}$ in the Maynardville Limestone); 1,2-DCE (6 to 35 $\mu\text{g/L}$ in the Nolichucky and 1 to 38 $\mu\text{g/L}$ in the Maynardville Limestone); trans-1,2-DCE (7 to 27 $\mu\text{g/L}$ in the Nolichucky and 1 to 54 $\mu\text{g/L}$ in the Maynardville Limestone); and vinyl chloride (14 to 35 $\mu\text{g/L}$ in the Maynardville Limestone only). The source of this contamination is uncertain. Possible upgradient sources are the OLF in the Nolichucky Shale, the upgradient VOC plume in the Maynardville Limestone, and SL 1. Because the suite of contaminants differs slightly from those of upgradient sources at OLF and Maynardville Limestone, the contaminants were attributed to SL 1 through a process of elimination.

Shallow groundwater at the OLF FA has sporadic contamination with metals and in some cases exceeds drinking water ARARs for groundwater. The worst contamination is focused on the shallow groundwater system at the BYBY and close to the channel of NT-3. Here, metal concentrations in shallow groundwater are generally higher and exceed background and ARARs in many of the shallow groundwater samples.

Surface Water

- Of the three streams draining the OLF FA, only NT-3 is contaminated above background to any significant extent. The principal contaminants in NT-3 are isotopes of uranium, lithium, and mercury. The lack of organic contamination in any of the tributary streams draining OLF FA is conspicuous because VOC contamination in shallow groundwater is present in the catchments of NT-3 and NT-4. Radiological contamination in NT-3 is the most extreme recorded in BCV: each sample in NT-3 exceeds background for gross α and gross β ; gross α ranges from 64.6 to 1350 pCi/L, with a mean activity of 455.4 pCi/L, and gross β ranges from 55.8 to 603 pCi/L with a mean activity of 221.8 pCi/L.

Ecological Habitat

- Terrestrial habitats provide potential exposure of biota to contaminants in soil and soil pore water. No toxicity in water from NT-3 or NT-4 was demonstrated.

D.7.8.2 Interpretive Conclusions and Working Hypotheses

The three main locations of groundwater contamination in the OLF FA can be associated with either operations at a site and/or soil contamination determined during the RI characterization of the site.

BYBY

Radioactive Contamination. At BYBY, uranium isotopes are the principal contaminants; they are present in soils, groundwater, and surface water, indicating that conditions are suitable for mobilization and off-site migration of uranium. The activities of uranium isotopes can explain the gross activities of α and β observed in each medium. The highest activities of uranium isotopes in both soil and groundwater both occur in boring BY-09 and coincide with the primary geophysical and radiological anomalies located northwest of the HCDA cap (Fig. D.82). NT-3 also flows through this anomalous zone.

Inorganic contaminants were detected in soils at the BYBY in relatively low concentrations, despite the reports of uncontrolled waste materials at this site. The low level of inorganic contamination in soils probably means that metals and radionuclides migrating away from waste by leaching have not contaminated surrounding soils significantly; the same observation has been made at each of the other waste sites in BCV (S-3 and BCBG). Waste materials are randomly distributed on the surface throughout the area southwest of HCDA. The low level of contamination in soil samples simply means that the soil samples did not include waste. The potential for uranium waste, similar to the samples in the rusted drum south of the HCDA (SBY-27), to occur in fill materials throughout BYBY is assumed. However, the most likely location for waste materials to occur is in the area of most concentrated radiological and geophysical anomalies between the HCDA cap and NT-3.

The contaminant suite in groundwater at BYBY is distinct from that in the S-3 plume. Although the S-3 plume contains considerable radiological contamination, the leading edge of the plume (currently near NT-2) consists of nitrate and ^{99}Tc (Sect. D.6.6). At BYBY, groundwater is not contaminated with either of these chemicals and so cannot be considered as a continuation of the S-3 plume.

The combination of information from soil and groundwater indicates that the BYBY and HCDA are the source of the contaminant plume at BYBY. The focus of inorganic contamination appears to be close to the channel of NT-3 and associated with the geophysical anomaly located northwest of the HCDA cap (Fig. D.82). This area is probably the source of much of the radiological contamination in groundwater and surface water. Groundwater upgradient of this anomalous zone is also contaminated (BY-04), which indicates that groundwater below the areas where fill has been identified can potentially be radiologically contaminated (Fig. D.80).

Although uranium contamination is observed in soils, the activities of uranium isotopes are relatively low and would not in themselves indicate extensive contamination of soils. However, the potential for buried uranium waste materials exists throughout the area of fill at BYBY, even though the soil borings did not intercept waste materials. The presence of buried uranium waste, primarily

in the areas of geophysical and radiological anomalies, is supported by the elevated activities of uranium isotopes in groundwater.

VOCs are present in groundwater at BYBY; however, VOC contamination does not occur in NT-3 and the groundwater plume is separate from that for inorganic materials. VOC contamination probably resulted from operations at the HCDA or from operations in the Burnyard. The absence of observations of VOCs in soils probably reflects the location of soil borings, which were drilled at the edges of the HCDA cap and not directly into the probable waste areas. Two distinct plumes of VOCs are present close to the cap; however, further downgradient, these plumes appear to have coalesced.

The working hypothesis for BYBY is that much of the site is covered with above-grade fill up to 3.0 to 3.7 m (10 or 12 ft) thick. This fill contains mostly noncontaminated or slightly contaminated construction rubble or other relatively stable materials (Fig. D.80). However, this fill also may contain some radioactively contaminated items or uranium waste materials. The main focus of radioactive contamination is close to the NT-3 channel; which is assumed to be the locus of most radioactive waste disposal. Groundwater in this area is very shallow, and uranium wastes are probably in contact with groundwater. In this scenario, uranium is leaching from the waste materials to groundwater, which subsequently discharges to surface water (Fig. D.81). VOCs in groundwater are derived from direct infiltration at the HCDA or from activities at the Burnyard. These contaminants may discharge to surface water; however, the extent of this discharge is so low that any VOCs volatilize almost immediately. The VOC plume, however, is in part located in residuum above the Maynardville Limestone and probably migrates directly into the Maynardville Limestone. Although DNAPLs are not indicated by the concentrations observed in the residuum, they could have migrated down dip in both the Nolichucky Shale or the Maynardville Limestone and be present at depth.

Oil Landfarm

Historical data and data from soils at the OLF pad (Appendix A) indicate that soils below the OLF cap are probably contaminated with organics (PCBs and SVOCs) and metals. Although the most contaminated soils were excavated and are currently located at the OLF storage pad, the remaining soils were probably contaminated at a similar (although slightly less) level, and contamination is restricted to the upper 0.3 m (1 ft) of soil. Very little contamination was observed in borings around the edges of the OLF cap, indicating that soils outside the OLF were not affected by operations at this site. Groundwater is contaminated with organics, and the suite of chemicals observed in groundwater consists primarily of breakdown products of the types of chemicals used at the Y-12 Plant. The concentrations of these chemicals and the fact that the highest concentrations occur in shallow wells indicate that DNAPL is not present in groundwater at this site. The groundwater data indicate that the landfarming operation successfully removed most volatile chemicals from the liquids spread on the soils there, leaving behind poorly volatilized organic chemicals, principally PCBs, in the soils.

SL 1

Very little data exist for SL 1. The one sample of waste materials from this site indicates that the usual type of contaminants from a municipal landfill are present (PAHs and SVOCs). SVOCs are the most common contaminants, and no radiological contamination has been observed at this site. Groundwater wells downgradient of SL 1 are contaminated with a VOC suite similar to that at OLF; however, a pathway from OLF to these wells is not likely. The working hypothesis is that SL 1 contains various semivolatile and nonvolatile organic contaminants and has impacted groundwater to a small extent downgradient of this site with some VOCs. This conclusion, however, is very uncertain because of the small database for this site and its location downgradient of sites that produce similar contaminant suites in groundwater.

D.8 BEAR CREEK BURIAL GROUNDS FUNCTIONAL AREA

The BCBG FA is composed of seven soil, three surface water, and two groundwater data aggregates and seven waste media groupings covering these media at and immediately downgradient of the BCBG. Groundwater in this aggregate is restricted to groundwater in the clastic formations of the Conasauga group. Groundwater in the Maynardville Limestone that is contaminated with BCBG-derived contaminants is not considered in this FA. Table D.6 lists the groundwater wells in the BCBG groundwater aggregates, and Fig. D.83 shows the distributions of groundwater wells, surface water sample sites, and soil and sediment samples sites.

D.8.1 BEAR CREEK BURIAL GROUNDS FA – DETAILED SITE HYDROLOGY

Groundwater

Much of the detailed information concerning the BCV site hydrology has been derived from data obtained in the BCBG FA. This area of BCV contains numerous wells screened at various depths in the Nolichucky Shale. In addition, five deep borings (GW-726, -727, -729, -730, and -790) equipped with multi-port monitoring devices monitor groundwater in both the Maynardville Limestone and the Nolichucky Shale.

In general, groundwater movement at the BCBG is adequately described by the BCV hydrogeologic conceptual model. Of most interest to the BCV RI is the movement of groundwater relative to the trenches and buried waste at BCBG. Figure D.84 shows hydrogeologic cross sections of the water table and shallow bedrock intervals at the BCBG, which were assembled using data from the Y-12 Plant GWPP. The range of water table elevations between 1988 and 1994, shown on Fig. D.84 as a shaded zone, represents the likely range of groundwater elevations at the BCBG. No data are available for the elevation of groundwater below the caps at the BCBG; however, because of the upward hydraulic gradients common in the Nolichucky Shale, the caps are not likely to have changed the water table elevation significantly.

Little data exist to estimate the depth of buried waste materials at BCBG; however, interviews with waste management personnel suggest that the depth of trenches may vary between 3 and 6 m (10 and 20 ft), depending on the mode of construction of each trench (Appendix A). In general, long trenches, which were generally dug using a drag line, may be deeper than shorter trenches, which were dug using a backhoe (Figs. A.6 and A.7). A comparison of the historic groundwater monitoring data and the probable depth of trenches (Fig. D.84) shows that trenches in some areas of the BCBG are saturated (i.e., the base of the trench is below the water table), while those in others are wholly contained in the vadose zone. The level of uncertainty associated with the data and trench depth information causes, in some cases, a high degree of uncertainty in this determination. The probable condition of the trenches, by area, are summarized in the following paragraphs.

BG-A South. Trenches in BG-A South are located in a relatively low-lying area at the foot of Pine Ridge. Groundwater table elevation data from wells in this area suggest that the depth to water ranges from 0 to 2.1 m (6 ft) below ground surface (bgs) (GW-046). Thus, the trenches, which are at least 3.0 to 4.6 m (10 to 15 ft) deep, are probably almost completely saturated.

BG-A North. These trenches are located on slightly higher ground than those in BG-A South, on a small hill underlain by the Maryville Limestone. Although little information is available on the

depth to groundwater in this area, the depth to groundwater at BG-B, which is located on a neighboring hill underlain by the same geological formation, ranges from 4.0 to 10.7 m (13 to 35 ft) bgs (GW-027 and -039). Thus, many of the trenches in BG-A North probably do not intercept the water table. Although this determination is made with a high degree of uncertainty, the possibility of groundwater intercepting the trenches in BG-A North is less for the trenches located higher on the ridge.

Waste areas BG-A 16, 17, and 18 were not constructed as trenches but as horizontal benches excavated into the sides of the ridge. Thus, the waste in these trenches is not buried deeply and does not contact groundwater. However, these trenches are not capped and probably collect soil interflow or stormflow. A significant seep has recently developed in the side of BG-A 17, and the cap of this area appears to be slumping downslope; this seep and associated slump are probably the result of stormflow collection.

BG-B. Located in a relatively high area, on a small hill underlain by the Maryville Limestone, the trenches in BG-B are probably all above the water table. Depth to groundwater in wells close to BG-B ranges from 4.0 to 10.7 m (13 to 35 ft) (GW-249 and -037). The narrow width [0.9 m (3 ft)] of the trenches at BG-B probably restricted their maximum depth. All trenches, as well as the Walk-In Pits (WIP), which remained open for a long period of time, are unlikely to be saturated. Seeps, probably of leachate from BG-B, have been identified in the slopes downgradient of BG-B and in the walls of the WIP. This area is now capped, and the cap will probably restrict the extent of water table variation below BG-B as well as preventing water from infiltrating into the unsaturated trenches. Because of the cap's location at the top of a hill, trenches below it will be unaffected by stormflow.

BG-C East and BG-D East. BG-C East is located in a relatively low-lying area between Pine Ridge and BG-B. This area is the location of seep 2, and depth to groundwater is very shallow. Trenches in BG-C East are probably at least 3 m (10 ft) deep, and although this is relatively shallow compared to BG-A, the shallow nature of the groundwater results in almost complete saturation of trenches in BG-C East.

Because BG-D East is located slightly higher up on Pine Ridge than BG-C East, its trenches may not be completely saturated. Depths to groundwater in well GW-242 range from 0 to 1.8 m (0 to 5 ft) bgs; thus, the trenches, which are probably ~3 m (10 ft) deep, are likely saturated. In addition, the location of these trenches at the foot of Pine Ridge probably results in collection of stormflow in these trenches. Photographs of trenches that are probably located in the D Area show them half full of water, suggesting that they do intercept groundwater.

BG-C West. No data are available for groundwater below the BG-C West cap, and groundwater wells located around the cap are not representative of the areas below the cap. Historically, seeps have been present around the edges of BG-C West, which may indicate some degree of saturation in these trenches. The most probable condition for trenches in BG-C West is that they are periodically saturated during high-flow periods and dry during low-flow periods.

BG-D West, BG-E, and BG-J. Trenches in these areas are located on a bench at the foot of Pine Ridge. No groundwater wells are located in the vicinity of these trenches; however, one of the branches of NT-8 that flows between BG-C West and BG-E and -J has cut a ravine in the residuum 3 m (10 ft) deep. Thus, groundwater must be at least this deep, and probably deeper most of the time, in the immediate vicinity of this stream. The most likely condition for these trenches is that they are above the water table most of the time; however, their location at the foot of Pine Ridge may result in collection of stormflow in these trenches.

As in the BCV conceptual hydrogeological model, flow parallel to geological strike probably dominates flow at the BCBG. Where trenches exist, they probably have a higher hydraulic conductivity than the surrounding formation resulting from soil disturbance and the hydraulic properties of the debris. Trenches undoubtedly exert some local influence on the flow path of groundwater. Trenches parallel to strike will enhance along strike flow; this hypothesis is confirmed by the occurrence of seeps along strike from trenches in BG-A South but not across strike. Where trenches cut across strike (such as BG-D East), they probably promote across-strike, and down-slope, flow of groundwater.

Surface Water

The BCBG FA is contained within the catchment of three tributaries to Bear Creek: NT-6, -7, and -8. Except for some sections at their headwaters, NT-6 and NT-8 are located in natural drainage channels. NT-7, however, is located almost entirely in an engineered channel that was developed during construction of the caps on BG-A and Oil Retention Pond (ORP)-1 (Appendix A, Fig. A.5). The natural channel of NT-7 is located beneath a cap for most of its length. The constructed channel is lined with medium-sized aggregate.

Continuous flow measurements were made at three surface water monitoring locations in the BCBG FA: NT-6, -7, and -8. The pattern of flow at all three sites is typical of that observed for the second-order or tributary streams in BCV. Although the magnitude of flow varies greatly, maximum flow is maintained for only short periods during and immediately after precipitation events. Figure D.85 shows flow stream hydrographs showing the daily maximum, minimum, and average flow for the monitoring points at NT-7 and NT-8.

All three streams are usually dry during the low-flow periods in the late summer and early fall. Baseflow at NT-6 (best marked by the daily minimum flow) ranges from 0 L/s during late spring, summer, and fall to ~2.8 L/s (0.1 cfs) between December and April. For NT-7, baseflow ranges from 0 to 2.8 L/s (0.1 cfs), and for NT-8, baseflow ranges from 0 to 3.2 L/s (0.15 cfs). The maximum flow during storms in these tributaries ranges from 56 to 1680 L/s (2 to 60 cfs). The highest flows are recorded in NT-7; during many storms, the flow in this stream and in NT-6 overflows the banks of the stream. During overflow periods, flow measurements are estimates. Peak flows in NT-7 during March reached more than 1680 L/s (60 cfs), in some cases damaging the monitoring equipment. During low flow in NT-7, no flow was sometimes recorded in the flume; however, flow was probably maintained below the flume in the aggregate bed of the stream, where it was not measurable.

During the lowest-flow periods, all streams in the BCBG FA periodically stopped flowing at the monitoring points. The USGS spring and seep survey shows that, upstream of both monitoring locations, the channels of all streams were mostly dry (Fig. C.23 in Appendix C). Flow during the low-flow period primarily occurs during storm events, and flow is maintained for a few days after cessation of rainfall.

Figure D.86 shows representative storm hydrographs for the flow at NT-6, -7, and -8. The shapes of the regression hydrographs for NT-6 and NT-8 are almost identical, except that the peak flows in NT-6 are delayed relative to both NT-7 and NT-8. This similarity probably reflects the similar nature of these catchments: for both NT-6 and NT-8, most of the catchment is native wooded terrain, with ~25 to 30% of the catchment falling within the BCBG. The relative delay in reaching peak flow in NT-6 signifies greater water storage in the catchment than in NT-7 and NT-8. The storm hydrograph for NT-7 is similar in its peak flow magnitude to those for NT-6 and NT-8; however, the regression slopes for the stormflow and groundwater discharge segments of the hydrograph are steeper. This trend probably reflects the greater proportion of the NT-7 catchment that is covered by

caps; the caps enhance runoff during precipitation events and prevent recharge to groundwater over much of the catchment, resulting in less effective storage capacity in the catchment.

D.8.2 BEAR CREEK BURIAL GROUNDS FA – RADIATION SURVEY DATA

A radiological survey was conducted at the BCBG using the USRADS technology. This technology is capable of taking a dense pattern of readings, thus delineating anomalies with a high degree of accuracy. Survey methods used are described in Appendix B. The areas surveyed are shown on Fig. D.83, and survey results are shown on Figs. D.87 and D.88.

Figure D.87 shows the pancake probe results (β/γ), and Fig. D.88 shows the NaI probe results (γ). As is discussed in Sect. D.7.2, these data can be used to qualitatively identify areas of soil contamination at the surface. However, because of the irregularity of vegetation cover that results in readings being taken from variable heights above the surface, these results should not be used quantitatively. As would be expected, the results of the two radiation survey instruments agree as to the anomalies identified in the BCBG.

Two areas of elevated radiation emissions were identified at the BCBG:

- An area adjacent to the BG-B cap located on the east side of the cap. Elevated readings were obtained from soils close to GW-037 and further south near the banks of NT-7. Some elevated readings were obtained at the foot of the BG-G cap, indicating that soil contamination continues under the cap.
- The second area of elevated readings occurs along the banks of the south fork of NT-8 and along the banks of NT-8 below the confluence of the north and south forks of this stream. Between the BCBG and the confluence of NT-8 with Bear Creek, four areas of elevated readings were identified. This soil contamination is probably related to soils in the NT-8 floodplain, which is derived from drainage of the BG-B, BG-C, and BG-D areas.

Elsewhere in the BCBG, radiological emissions were not elevated above 200 cpm; however, the uncapped areas of BG-C and BG-D were not surveyed, but are likely contaminated.

D.8.3 SOIL CHEMICAL DATA

The BCBG FA comprises seven soil sampling aggregates, with samples collected to characterize the soil surrounding various features of the BCBG, as shown in Table D.4. Soil contamination in the BCBG FA was characterized by conducting radiological and geophysical surveys, surface soil sampling for field screening analysis, surface soil sampling for laboratory analysis, and soil boring sampling for laboratory analysis.

A total of 44 surface soil samples [0- to 0.46-m (0- to 1.5-ft)-depth maximum] were collected from within the various aggregates and screened for inorganic elements and compounds, total uranium, ^{235}U , and PCBs at the Y-12 Laboratory. Eight of these samples were sent to an off-site laboratory for full analysis. One of the surface soil samples, SBG-42, is a waste sample, consisting of soil and yellowish material scraped from the soil surface; it has been designated a separate “hot spot” aggregate.

In addition to the surface soil samples, a total of 15 soil borings were augered to refusal in soil surrounding the BCBG disposal areas. The depths of these borings varied from 2.3 to 11.6 m (7.5 to 38 ft), as summarized in Table D.63. Samples were collected from the soil borings at depth intervals of 1.2 m (4 ft) in most cases; the samples collected from the 0- to 1.2-m (0- to 4-ft) and 1.2- to 2.4-m (4- to 8-ft) intervals were combined to represent the shallow interval, and samples collected from depth intervals >2.4 m (8 ft) represent the deep interval.

D.8.3.1 BG-A North Aggregate I

Three surface soil samples [0- to 0.46-m (0- to 1.5-ft)-depth maximum] were collected from BCBG Aggregate I: SBG-40, -41, and -44. All three samples were screened for inorganic elements and compounds, total uranium, ^{235}U , and PCBs at the Y-12 Laboratory, and one (SBG-44) was sent off site for full-suite analysis (Table D.4). In addition to the surface soil samples, four soil borings were augered to refusal [2.3 to 8.5 m (7.5 to 28 ft)] in BCBG Aggregate I: BG-5, -6, -7, and -16 (Table D.63). Results for the screening surface soil sample analyses are summarized in Table D.64, and analytical results for the soil boring samples plus the laboratory analyses for the surface soil sample are summarized in Tables D.65 and D.66.

D.8.3.1.1 Inorganic elements and compounds in Aggregate I

Five inorganic elements or compounds were detected in concentrations above their background criteria in soil samples collected from Aggregate I (Tables D.65 and D.66). In the shallow interval, only tin exceeded its background criterion. No ORR background criterion is available for tin, but the concentration detected (6.4 mg/kg) is slightly above the USGS background value; therefore, tin is considered to be an SRC in the shallow interval of Aggregate I.

In the deep interval, barium, copper, cyanide, and nickel were detected at least once above their background criterion. Concentrations of these elements and compounds are generally low, with average results for all except cyanide being below their background criteria. Although the average concentration of cyanide is above its background criterion, cyanide was detected in only one of eight samples. Because of relatively low concentrations of inorganic elements and compounds, the distribution of inorganic contamination in soils surrounding BG-A North was not plotted.

D.8.3.1.2 Radionuclides in Aggregate I

No radionuclides in excess of their background criteria were detected in the soil surrounding BG-A North in either the shallow or deep intervals (Table D.65 or D.66).

D.8.3.1.3 Organic compounds in Aggregate I

Fifteen organic compounds (including VOCs, SVOCs, PCBs, and pesticides) are considered SRCS in Aggregate I (Tables D.65 and D.66): 4,4'-DDE, 4,4'-DDT, PCB-1254, PCB-1260, Bis(2-ethylhexyl)phthalate, 1,1,1-TCE, 1,1-DCA, 1,1-DCE, 1,2-DCA, 1,2-DCE, CE, toluene, vinyl chloride, benzene, and methylene chloride. The distributions of total aroclor (PCB-1254 plus PCB 1260), 1,1,1-TCA, 1,1-DCA, and toluene are shown on Fig. D.89 as representative of the organics distribution. The four compounds were selected because they are the most extensively occurring organic compounds in this aggregate.

Shallow Interval. Of the 15 Aggregate I site-related organics, 13 were detected in the shallow interval; however, except for those shown in Fig. D.89, all were detected in only one out of nine samples. PCBs were detected in six samples, toluene in four samples, and 1,1,1-TCA and 1,1-DCA

in two samples. Both of the 1,1,1-TCA and 1,1-DCA detections occur in boring BG-16. Organic compounds were detected in only three of the four soil borings (BG-6, -7, and -16). The surface soil sample in this aggregate, SBG-44, has relatively low concentrations and numbers of organic contaminants detected; however, the only occurrences of 4,4'-DDE, and 4,4'-DDT are in SBG-44. Also present in this surface soil sample is bis(2-ethylhexyl)phthalate and toluene (Fig. D.89).

Deep Interval. Of the 15 Aggregate I site-related organics, 6 were detected in the deep interval. Only benzene and toluene were detected more than once in the 10 samples collected (Table D.66). Organic compounds occur in the deep interval in BG-5, -6, and -7; because BG-16 reached refusal at 2.3 m (7.5 ft), no samples were collected from this boring in the deep interval (Fig. D.89). 1,1,1-TCA and 1,1-DCA, which occur in the shallow interval, do not occur in any of the deep interval samples. PCBs occur only in BG-5, at a concentration of 49 $\mu\text{g/kg}$, from the 4.9- to 6.1-m (16- to 20-ft)-deep sample. Toluene also occurs in this boring, both at 6.1 to 7.3 m (20 to 24 ft) and at 7.3 to 8.5 m (24 to 28 ft), with the maximum concentration (12 $\mu\text{g/kg}$) occurring in the 6.1- to 7.3-m (20- to 24-ft) sample. Toluene occurs in BG-6 in both the 4.9- to 6.1-m (16- to 20-ft) and 6.7- to 7.9-m (22- to 26-ft) samples, with the maximum concentration (6 $\mu\text{g/kg}$) occurring in the 6.7- to 7.9-m (22- to 26-ft) sample. The maximum concentration of toluene for Aggregate I in the deep interval (71 $\mu\text{g/kg}$) occurs in the 2.4- to 3.7-m (8- to 12-ft) sample of BG-7; BG-7 reached refusal at 3.7 m (12 ft) (Table D.63).

D.8.3.2 BG-A South Aggregate II

Four soil borings were augered to refusal [4.3 to 11.6 m (14 to 38 ft)] in BCBG Aggregate II: BG-1, -2, -3, and -4 (Tables D.4 and D.63). No surface soil samples were taken from this aggregate. Analytical results for the soil boring samples are summarized in Tables D.67 and D.68.

D.8.3.2.1 Inorganic elements and compounds in Aggregate II

Nine inorganic elements or compounds were detected in concentrations above their background criteria in soil samples collected from Aggregate II: barium, beryllium, cobalt, copper, lead, manganese, nickel, silver, and tin. All occur in the deep interval. Mercury was detected above its background criterion in one of seven samples in the shallow interval; however, the concentration detected, 0.4 mg/kg, only barely exceeds the background criterion of 0.34 mg/kg.

The distributions of barium and nickel in the Aggregate II deep interval are shown on Fig. D.90 as representative of the inorganics distribution. Barium and nickel were selected to represent the inorganic elements and compounds because they were detected most frequently, with barium exceeding its background criterion in 10 of 18 samples and nickel exceeding its background criterion in 6 of 18 samples (Tables D.67 and D.68). Beryllium, copper, manganese, silver, and tin exceed their background criteria in 3 of 18 samples, but their maximum concentrations are only slightly above the background criteria (Tables D.67 and D.68). No ORR background criterion is established for tin, but the observed concentrations are slightly above the USGS background value for tin. Cobalt exceeds its background criterion in 2 of 18 samples, and lead in 1 of 18 samples.

Barium concentrations greater than background criterion (212 mg/kg) in the deep interval range from 213 to 640 mg/kg, with the maximum detected in the 9.8- to 11.0-m (32- to 36-ft) sample from boring BG-1. The second highest concentration was from the 3.7- to 4.9-m (12- to 16-ft) sample from the same boring. Barium was detected at least once in the deep interval of all four borings (Fig. D.90).

Nickel was detected in concentrations greater than its background criterion (56.7 mg/kg) in three of four soil borings (BG-1, -2, -4) (Fig. D.90). Concentrations range from 60.2 to 85.8 mg/kg. The maximum concentration occurs in the 9.8- to 11.0-m (32- to 36-ft) sample of boring BG-1, and the second highest concentration (79.3 mg/kg) occurs in the 2.4- to 3.7-m (8- to 12-ft) sample of boring BG-2.

D.8.3.2.2 Radionuclides in Aggregate II

No radionuclides were detected above their background criteria in the shallow interval. In the deep interval, ^{208}Tl was detected in 2 of 18 samples, with concentrations ranging from 3.4 to 3.8 pCi/g (Tables D.67 and D.68, Fig. D.90). No reported background value is available for ^{208}Tl .

D.8.3.2.3 Organic compounds in Aggregate II

A total of 12 organic compounds (including VOCs, SVOCs, PCBs, and pesticides) were detected in Aggregate II (Tables D.67 and D.68): acetone, PCE, toluene, TCE, methoxychlor, 1,1,1-TCA, 1,1-DCA, 1,1-DCE, 1,2-DCA, 1,2-DCE, benzene, and vinyl chloride. The distributions of acetone, PCE, TCE, and toluene are shown on Fig. D.91 as representative of the organics distribution. The four compounds were selected as representative of the organic group because they are the most widespread and occur at the highest concentrations.

Shallow Interval. Of the 12 Aggregate II site-related organic compounds, 4 were detected in the shallow interval: acetone, PCE, TCE, and toluene (Table D.67). Acetone is the most widespread in this interval, occurring in four of seven samples. PCE and toluene occur in two of the seven samples, and TCE occurs in one. In the shallow interval, organic compounds occur only in borings BG-1 and BG-3 (Fig. D.91). The only organic compound detected in BG-1 is acetone, with concentrations of 18 $\mu\text{g/kg}$ in the 0- to 1.2-m (0- to 4-ft) sample and 23 $\mu\text{g/kg}$ in the 1.2- to 2.4-m (4- to 8-ft) sample. All four organic compounds detected in the shallow interval occur in boring BG-3, with the highest concentrations occurring in the 1.2- to 2.4-m (4- to 8-ft) interval.

Deep Interval. Contamination by organic compounds in the deep interval is widespread (Fig. D.91). All 12 of the site-related organic compounds identified in Aggregate II soils occur in the deep interval, with at least one organic compound occurring in every soil sample. Acetone is the most widespread, occurring in 9 of 19 samples in the deep interval. Acetone concentrations range from 17 to 160 $\mu\text{g/kg}$, with the maximum concentration occurring in the 2.4- to 3.7-m (8- to 12-ft) sample of BG-3 (Fig. D.91). Acetone was detected in borings BG-1 and BG-3, with no particular pattern of distribution with depth.

PCE was detected in 8 of 19 samples, with detections in all four soil borings (Fig. D.91). Concentrations range from 1 to 220 $\mu\text{g/kg}$, with the maximum occurring in the 9.8- to 11.0-m (32- to 36-ft) deep sample of boring BG-1.

Toluene was detected in 5 of 19 samples, with concentrations ranging from 1 to 17 $\mu\text{g/kg}$. Toluene occurs in borings BG-2 and BG-4 (Fig. D.91), with the maximum concentration occurring in the 9.8- to 11.6-m (32- to 38-ft) deep sample of boring BG-2.

TCE was detected in 4 of 19 samples in borings BG-1, BG-2, and BG-4. Concentrations range from 2 $\mu\text{g/kg}$ in the 3.0- to 4.3-m (10- to 14-ft)-deep sample of boring BG-4 to a maximum of 85 $\mu\text{g/kg}$ in the 9.8- to 11.0-m (32- to 36-ft)-deep sample of boring BG-1.

Other organic compounds detected in the deep interval of Aggregate II include 1,2-DCE (4 of 19 samples); methoxychlor (3 of 19 samples); 1,1-DCA (2 of 19 samples); and 1,1,1-TCA, 1,1-DCE, 1,2-DCA, benzene, and vinyl chloride (1 of 19 samples) (Table D.68).

D.8.3.3 BG-A-16, -17, and -18 Aggregate III

Seven surface soil samples were collected from BCBG Aggregate III: SBG-24, -25, -26, -27, -36, -37, and -38. All samples were screened for inorganic elements and compounds, total uranium, ^{235}U , and PCBs at the Y-12 Laboratory, and one surface soil sample, SBG-25, was sent off site for full-suite analysis. In addition to the surface soil samples, one boring, BG-8, was augered to refusal [4.3 m (14 ft)] in BCBG Aggregate III. Results for screening surface soil sample analyses are presented in Table D.69, and analytical results for the soil boring samples plus the laboratory results for the surface soil sample are summarized in Tables D.70 and D.71.

D.8.3.3.1 Inorganic elements and compounds in Aggregate III

Three inorganic elements were detected in concentrations above their background criteria in soil samples collected from Aggregate III: selenium, barium, and manganese. Two of these elements (selenium and barium) occur in the shallow interval, and two (barium and manganese) occur in the deep interval (Tables D.70 and D.71). In the shallow interval, selenium occurs in one of three samples, with a concentration of 2.1 mg/kg, which exceeds its background criterion of 1.2 mg/kg. Barium also occurs in one of three samples, with a concentration of 224 mg/kg, only slightly above its background criterion of 212 mg/kg. In the deep interval, barium and manganese occur in the single sample collected from that interval, at concentrations barely higher than their background criteria. Because of the limited extent of inorganic contamination in this aggregate and the low concentrations of detected elements, the distribution of inorganic elements was not plotted.

D.8.3.3.2 Radionuclides in Aggregate III

No radionuclides were detected above their background criteria in the soil surrounding BG-A-16, -17, and -18 in either the shallow or deep intervals (Tables D.70 and D.71).

D.8.3.3.3 Organic compounds in Aggregate III

Thirteen organic compounds (including VOCs, SVOCs, and PCBs) were detected in Aggregate III (Tables D.70 and D.71): acetone, toluene, 2-butanone, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, fluoranthene, pyrene, pesticides, PCB-1248, and PCB-1254. For the distribution of organic compounds presented on Fig. D.92, the SVOCs are divided into total PAHs and total phthalates. Other compounds plotted on these figures include total PCBs, 2-butanone, and toluene.

Shallow Interval. Most of the organic compounds occur in the shallow interval, primarily in the surface soil sample (SBG-25). This sample contains the only detected phthalates, PAHs, and 2-butanone. Pesticides also occur in the surface soil sample and in the 0- to 1.2-m (0- to 4-ft)-deep sample of boring BG-8. PCB-1254 occurs only in SBG-25, and PCB-1248 and PCB-1254 both occur in the upper 1.2 m (4 ft) of BG-8. Toluene occurs in both the shallow interval of boring BG-8 and in the SBG-25, with the maximum concentration in SBG-25 (63 $\mu\text{g/kg}$) significantly higher than that in BG-8 (2 $\mu\text{g/kg}$ in the shallow interval). Acetone does not occur in the surface soil sample, but does occur in both samples taken from BG-8, with a maximum value of 31 $\mu\text{g/kg}$ in the 1.2- to 3.0-m (4- to 10-ft)-deep sample.

Deep Interval. Only two organic compounds — acetone and toluene — were detected in the one deep interval [3.0- to 4.3-m (10- to 14-ft)] sample taken from BG-8 (Table D.71). The concentrations for acetone and toluene, respectively, are 28 and 8 $\mu\text{g/kg}$ (Fig. D.92).

D.8.3.4 Walk-in Pits (North and South), BG-B, BG-D (South) Aggregate IV

Fourteen surface soil samples were collected from BCBG Aggregate IV: SBG-1, -2, -3, -4, -5, -6, -7, -14, -15, -16, -18, -19, -23, -39 (Table D.4). All samples were screened for inorganic elements and compounds, total uranium, ^{235}U , and PCBs at the Y-12 Laboratory, and one sample, SBG-7, was sent off site for full-suite analysis. In addition to the surface soil samples, two soil borings (BG-11 and BG-12) were augered to refusal [5.5 to 11.0 m (18 to 36 ft), respectively] in BCBG Aggregate IV (Table D.63). Results for the screening surface soil sample analyses are summarized in Table D.72, and analytical results for the soil boring samples plus the laboratory analyses for the surface soil sample are summarized in Tables D.73 and D.74.

D.8.3.4.1 Inorganic elements and compounds in Aggregate IV

Seven inorganic elements or compounds were detected above their background criteria in soil samples collected from Aggregate IV; four of these occur in the shallow interval, and four occur in the deep interval (Tables D.73 and D.74).

Cyanide was detected above its background criterion in two of four samples in the shallow interval (Fig. D.93) and in three of eight samples in the deep interval (Fig. D.93). In the shallow interval, both detections occur in the 0- to 1.2-m (0- to 4-ft)-deep samples from BG-11 and BG-12. The cyanide concentration (1.7 mg/kg) detected in BG-11 is only slightly above its background criterion (0.63 mg/kg), but that in BG-12 (142 $\mu\text{g/kg}$) is substantially elevated. In the deep interval, cyanide concentrations range from 1.1 to 1.3 mg/kg.

Arsenic and zinc were each detected one time in the shallow interval at concentrations barely exceeding their background criteria (Tables D.73 and D.74). Tin was detected in one of four samples in the shallow interval. The tin concentration detected in the shallow interval (5.7 mg/kg) is slightly above the USGS background value (Tables D.73 and D.74).

Barium was detected above its background criterion (212 $\mu\text{g/kg}$) in four of eight samples in the deep interval, with concentrations ranging from 260 to 301 mg/kg (Fig. D.93). Manganese was detected above its background criterion in two of eight deep interval samples, and lead was detected above its background criterion in one of eight samples. Overall, inorganic elements and compounds, while detected above background in Aggregate IV, do not occur at high concentrations or with wide distribution.

D.8.3.4.2 Radionuclides in Aggregate IV

Two radioisotopes, ^{234}U and ^{238}U , were detected at activity concentrations above their background criteria in the shallow and deep intervals of Aggregate IV (Tables D.73 and D.74). The distribution of ^{238}U is shown on Fig. D.93 and D.93 as representative of the distribution of both uranium isotopes.

In the shallow interval, both ^{234}U and ^{238}U were detected in one of four samples at activity concentrations above their background criteria (3.2 and 2.6 pCi/g, respectively). Surface soil sample SBG-7 shows an activity concentration of 5.8 pCi/g for ^{234}U and 11.0 pCi/g for ^{238}U .

In the deep interval, ^{238}U was detected in one of ten samples (7.0 pCi/g) in the 4.9- to 6.1-m (16- to 20-ft)-deep sample from boring BG-12.

D.8.3.4.3 Organic compounds in Aggregate IV

A total of 10 organic compounds (including VOCs, SVOCs, and PCBs) were identified in soils in Aggregate IV (Tables D.73 and D.74): PCB-1254, PCB-1260, 1,4-dichlorobenzene, bis(2-ethylhexyl)phthalate, di-n-octylphthalate, phenanthrene, pyrene, acetone, methylene chloride, and toluene. The distributions of total PCBs, toluene, and methylene chloride are shown on Fig. D.94 as representative of the organics distribution. The compounds were selected because they have the highest rate of detection, with PCBs and toluene detected in three of four samples in the shallow interval and methylene chloride detected in four of nine samples in the deep interval.

Shallow Interval. PCBs were detected in surface soil sample SBG-7 and in the 0- to 1.8-m (0- to 6-ft)-deep sample from boring BG-11. The maximum concentration of 46,000 $\mu\text{g/kg}$ total PCBs occurs in SBG-7; (Fig. D.94). Toluene was detected in surface soil sample SBG-7 (250 $\mu\text{g/kg}$), the 0- to 1.8-m (0- to 6-ft)-deep sample of boring BG-11 (1 $\mu\text{g/kg}$), and the 0- to 1.2-m (0- to 4-ft)-deep sample of boring BG-12 (23 $\mu\text{g/kg}$). Other organic compounds occurring in the shallow interval, with one detection each, are 1,4-dichlorobenzene, bis(2-ethylhexyl)phthalate, di-n-octylphthalate, phenanthrene, and pyrene (Table D.73).

Deep Interval. Methylene chloride was detected in the deep interval of boring BG-12, in the 3.7- to 4.9-m (12- to 16-ft), 4.9- to 6.1-m (16- to 20-ft), 6.1- to 7.3-m (20- to 24-ft), and 7.3- to 8.5-m (24- to 28-ft)-deep samples. Concentrations range from 51 to 86 $\mu\text{g/kg}$, with the maximum concentration occurring in both the 3.7- to 4.9-m (12- to 16-ft) and 7.3- to 8.5-m (24- to 28-ft)-deep samples. Acetone was detected once (180 $\mu\text{g/kg}$) in the 3.7- to 4.9-m (12- to 16-ft)-deep sample of boring BG-12, and bis(2-ethylhexyl)phthalate was detected once (8700 $\mu\text{g/kg}$) in the 1.8- to 3.0-m (6- to 10-ft)-deep sample of boring BG-11.

D.8.3.5 BG-C West Aggregate V

Seven surface soil samples were collected from BCBG Aggregate V: SBG-8, -9, -10, -11, -17, -29, and -43 (Table D.4). All samples were screened for inorganic elements and compounds, total uranium, ^{235}U , and PCBs at the Y-12 Laboratory, and two of the samples, SBG-11 and SBG-43, were sent off site for full-suite analysis. In addition to the surface soil samples, four boreholes were augered to refusal [2.4 to 9.1 m (8 to 30 ft)] in BCBG Aggregate V: BG-10, -13, -14, and -15 (Table D.63). Samples were collected from the boreholes at 1.2-m (4-ft) depth intervals and sent off site for laboratory analysis. Results from the screening surface soil sample analyses are summarized in Table D.75, and analytical results for the soil boring samples plus the laboratory analyses for the surface soil samples are summarized in Table D.78.

D.8.3.5.1 Inorganic elements and compounds in Aggregate V

Eight inorganic elements and compounds were detected above their background criteria in Aggregate V; five of these occur in the shallow interval, and six occur in the deep interval (Table D.76). The distributions of arsenic, copper, and zinc are plotted on Fig. D.95 as representative of the inorganics distribution. The three elements were chosen because of the number of detections above their background criteria and their presence in both shallow and deep intervals.

Shallow Interval. In the shallow interval, arsenic and zinc were detected above their background criteria in two of ten samples (Table D.76). The maximum arsenic concentration is

42.3 mg/kg, about twice the background criteria of 20.2 mg/kg. Both detections of arsenic occur in boring BG-10 (Fig. D.95), with the maximum concentration occurring in the 0- to 1.2-m (0- to 4-ft)-deep sample of that boring. Zinc was detected above its background criterion (108 mg/kg) in the 0- to 1.2-m (0- to 4-ft) and 1.2- to 2.4-m (4- to 8-ft)-deep samples of BG-10, with a maximum value of 199 mg/kg in the 1.2- to 2.4-m (4- to 8-ft)-deep sample. Copper, mercury, and nickel were detected above their background criteria one time in the shallow interval, all at relatively low concentrations (Table D.76).

Deep Interval. In the deep interval, arsenic, copper, zinc, barium, cobalt, and cyanide were detected (Table D.77). Barium is the most widespread element, with detections above its background criterion (212 mg/kg) in 4 of 12 samples. The maximum concentration of barium (728 mg/kg) occurs in the 4.9- to 6.1-m (16- to 20-ft)-deep sample of boring BG-14 (Fig. D.95). Barium was also detected above its background criterion in the 3.7- to 4.9-m (12- to 16-ft) and 7.3- to 9.1-m (24- to 30-ft)-deep samples from boring BG-10 and in the 2.4- to 3.7-m (8- to 12-ft)-deep sample of boring BG-13. Copper and zinc both occur above their background criteria in 2 of 12 samples (Table D.77). Zinc occurs in the 2.4- to 3.7-m (8- to 12-ft) and 3.7- to 4.9-m (12- to 16-ft)-deep samples from boring BG-19, with its maximum concentration of 399 mg/kg occurring in the 3.7- to 4.9-m (12- to 16-ft)-deep sample. Arsenic, cobalt, and cyanide were detected at concentrations above background criteria in 1 of 12 samples (Table D.79). Arsenic was detected in the 2.4- to 3.7-m (8- to 12-ft)-deep sample of boring BG-10 (52.6 mg/kg); cobalt was detected in the 3.7- to 4.9-m (12- to 16-ft)-deep sample of boring BG-10 (44.6 mg/kg); and cyanide was detected in the 7.3- to 9.1-m (24- to 30-ft)-deep sample of boring BG-10 (1 mg/kg).

D.8.3.5.2 Radionuclides in Aggregate V

Radionuclides occurring above their background criteria — ^{60}Co , ^{99}Tc , ^{234}U , and ^{238}U — were detected only in the shallow interval in Aggregate V. The distributions of three of these radionuclides, ^{99}Tc , ^{234}U , and ^{238}U , are plotted on Fig. D.95. ^{60}Co was detected above its background criterion (0.01 pCi/g) in one of ten samples, with a concentration of 1.2 pCi/g in the 1.2- to 2.4-m (4- to 8-ft)-deep sample of boring BG-14. ^{99}Tc , ^{234}U , and ^{238}U were detected above their background criteria in two surface soil samples, SBG-11 and SBG-43 (Table D.76).

D.8.3.5.3 Organic compounds in Aggregate V

A total of 15 site-related organic compounds (including VOCs, SVOCs, and PCBs) were identified in Aggregate V (Table D.76): PCB-1254, PCB-1260, bis(2-ethylhexyl)phthalate, pyrene, 1,1-DCE, 1,2-DCE, 2 butanone, 4-methyl-2-pentanone, acetone, benzene, chlorobenzene, methylene chloride, PCE, toluene, and TCE. Of these 15 organics, 7 were identified in the shallow interval, and 13 were identified in the deep interval (Table D.77). The distributions of acetone, toluene, PCE, total PCBs, and 4-methyl-2-pentanone are shown on Fig. D.96 as representative of the organics distribution in Aggregate V.

Shallow Interval. Toluene was detected in five of ten samples in Aggregate V. Concentrations range from 2 $\mu\text{g/kg}$ in both the 0- to 1.2-m (0- to 4-ft)-deep sample of boring BG-10 and the 1.2- to 2.4-m (4- to 8-ft)-deep sample of boring BG-13 to 360 $\mu\text{g/kg}$ in SBG-11 (Table D.76 and Fig. D.96). 4-Methyl-2-pentanone was detected in three of ten samples, but at low concentrations ranging from 2 $\mu\text{g/kg}$ in the 1.2- to 2.4-m (4- to 8-ft)-deep sample from BG-10 to 5 $\mu\text{g/kg}$ in the 1.2- to 2.4-m (4- to 8-ft)-deep sample from BG-13. 4-Methyl-2-pentanone was also detected in BG-15 in the 0- to 1.2-m (0- to 4-ft)-deep sample, with a concentration of 3 $\mu\text{g/kg}$. PCBs were detected only in surface soil sample SBG-43 (Fig. D.96). Acetone was detected once in the shallow interval in the 1.2- to 2.4-m (4- to 8-ft)-deep sample of boring BG-14.

Other organics detected in the shallow interval but not plotted on Fig. D.96 are bis(2-ethylhexyl)phthalate and pyrene, each of which was detected once (Table D.76).

Deep Interval. Acetone was detected in 7 of 12 samples in the deep interval, including the 2.4- to 3.7-m (8- to 12-ft), 3.7- to 4.9-m (12- to 16-ft), 4.9- to 6.1-m (16- to 20-ft), 6.1- to 7.3-m (20- to 24-ft), and 7.3- to 8.5-m (24- to 28-ft)-deep samples of boring BG-14 and the 3.7- to 4.9-m (12- to 16-ft) and 7.3- to 9.1-m (24- to 30-ft)-deep samples of boring BG-10. The maximum concentration (150 $\mu\text{g/kg}$) was detected in the 4.9- to 6.1-m (16- to 20-ft)-deep sample of BG-14 (Fig. D.96). Toluene was detected in 5 of 12 samples, in concentrations ranging from 2 $\mu\text{g/kg}$ in the 2.4- to 3.7-m (8- to 12-ft)-deep sample of BG-13 to a maximum of 27 $\mu\text{g/kg}$ in the 3.7- to 4.9-m (12- to 16-ft)-deep sample of the same boring. Toluene was also detected in BG-10 and BG-14 (Fig. D.96). 4-Methyl-2-pentanone was detected in four samples in the deep interval, with the maximum concentration (15 $\mu\text{g/kg}$) occurring in the 3.7- to 4.9-m (12- to 16-ft)-deep sample of boring BG-10. 4-Methyl-2-pentanone was also detected in BG-13 in the 2.4- to 3.7-m (8- to 12-ft)-deep sample. PCE was detected in two samples: the 7.3- to 8.5-m (24- to 28-ft)-deep sample of BG-14 and the 7.3- to 9.1-m (24- to 30-ft)-deep sample of BG-10 (Fig. D.96). The only detection of PCBs in the deep interval was in the 3.7- to 4.9-m (12- to 16-ft)-deep sample of BG-10 (Fig. D.96).

Other organic compounds detected but not plotted on Fig. D.96 are 1,2-DCE, 1,1-DCE, 2-butanone, benzene, bis(2-ethylhexyl)phthalate, chlorobenzene, methylene chloride, and TCE (Table D.77).

D.8.3.6 BG-C East and BG-D East Aggregate VI

Six surface soil samples were collected from BCBG Aggregate VI: SBG-20, -32, -33, -34, -35, and -42 (Table D.4). All samples were screened for inorganic elements and compounds, total uranium, ^{235}U , and PCBs at the Y-12 Laboratory, and two (SBG-20 and SBG-33) were sent off site for full-suite analysis. No soil borings were installed in this aggregate; thus, all data represent the shallow interval [0 to 0.3 m (0 to 1 ft)]. Results for the screening surface soil sample analyses are summarized in Table D.78, and analytical results for the off-site laboratory analyses for the surface soil samples are summarized in Table D.79. Additionally, SBG-42, a sample of yellowish material scraped off the ground surface in the vicinity of BG-D East, was sent to the Y-12 Laboratory to be analyzed for inorganic elements and compounds, gross α , gross β , ^{234}U , ^{235}U , and ^{238}U . Results of the SBG-42 analysis are discussed separately in Sect. D.8.3.6.4.

D.8.3.6.1 Inorganic elements and compounds in Aggregate VI

Four inorganic elements — arsenic, beryllium, selenium, and vanadium — were detected at concentrations above their background criteria in Aggregate VI. Of the two samples that received full-suite analyses, arsenic was detected above its background criteria (20.2 mg/kg) in one sample (39.4 mg/kg) (SBG-20). Beryllium was also detected above its background criterion (2.12 mg/kg) in one sample, with a concentration of 2.77 mg/kg (SBG-20). Selenium exceeds its background criterion (1.20 mg/kg) in both samples, with a maximum value of 2.8 mg/kg in SBG-20. Vanadium exceeds its background criterion (60.1 mg/kg) in SBG-20 (68.8 mg/kg).

D.8.3.6.2 Radionuclides in Aggregate VI

Three radionuclides were detected at activity concentrations exceeding their background criteria in Aggregate VI surface soils: ^{99}Tc , ^{234}U , and ^{238}U (Table D.79). The distributions of these radionuclides are shown on Fig. D.97. ^{99}Tc was detected above its background criterion (4.07 pCi/g) in both surface soil samples, with a maximum activity concentration of 130 pCi/g in SBG-33.

Uranium-234 was detected above its background criterion (3.2 pCi/g) in SBG-33 (4.7 pCi/g). Uranium-238 was detected above its background criterion (2.6 pCi/g) in both SBG-20 and SBG-33, with a maximum value of 36.0 pCi/g in SBG-33.

D.8.3.6.3 Organic compounds in Aggregate VI

Four organic compounds were detected in the surface soil samples from Aggregate VI: PCB-1254, bis(2-ethylhexyl)phthalate, CE, and toluene. The distributions of PCBs and toluene are shown on Fig. D.98 as representative of the organics distribution in Aggregate VI. PCB-1254 was detected in both surface soil samples, with a maximum concentration of 93 $\mu\text{g/kg}$ in SBG-20. Toluene was detected in SBG-33, with a concentration of 110 $\mu\text{g/kg}$. Also detected but not plotted on Fig. D.98 were bis(2-ethylhexyl)phthalate, which had a concentration of 860 $\mu\text{g/kg}$ in SBG-20, and CE, which had a concentration of 26 $\mu\text{g/kg}$ in SBG-20.

D.8.3.6.4 Waste sample SBG-42

As described above, a sample of waste was collected at surface sample location SBG-42. The results of the analyses performed on this sample at the Y-12 Laboratory show the sample to have high gross α (134,000 pCi/g) and gross β (245,800 pCi/g) activities and high concentrations of uranium, ^{235}U , and ^{234}U . The data from the Y-12 Laboratory presented uranium as total uranium units of $\mu\text{g/kg}$ and presented ^{235}U and ^{234}U as weight % of total uranium. The actual results from the laboratory are 623,000 $\mu\text{g/g}$ uranium, 0.19 weight % ^{235}U , and 0.004 weight % ^{234}U . These data were converted to activity units to give the following results: ^{238}U = 205,000 pCi/g, ^{235}U = 2,500 pCi/g, and ^{234}U = 154,000 pCi/g. These values clearly exceed the background criteria for ^{238}U , ^{235}U , and ^{234}U (2.6 pCi/g, 0.24 pCi/g, and 3.2 pCi/g, respectively).

In addition to total uranium and percent ^{235}U and ^{234}U , waste sample SBG-42 was analyzed for inorganic elements and compounds. Arsenic, beryllium, and vanadium were detected in the sample, with no concentrations exceeding background criteria.

D.8.3.7 BG-D West, BG-E, and BG-J Aggregate VII

Seven surface soil samples [0- to 0.3-m (0- to 1-ft)-depth maximum] were collected from BCBG Aggregate VII: SBG-12, -13, -21, -22, -28, -30, and -31 (Table D.4). These samples were screened for inorganic elements and compounds, total uranium, ^{235}U , and PCBs at the Y-12 Laboratory. No additional analysis was performed on these samples. No borings were installed within Aggregate VII. Results for the screening surface soil samples are summarized in Table D.80.

D.8.3.8 Discussion

A number of chemicals were detected in soils surrounding the BCBG trenches. Inorganic contamination appears limited in both nature and extent: when inorganic elements or compounds are detected, they tend to occur at concentrations at or just above background. Radionuclide contamination in the soils surrounding the BCBG is similarly noteworthy by its absence, particularly in BG-A North and South and in the A-16, -17, and -18 disposal areas. Radionuclides, particularly uranium and ^{99}Tc , are slightly more prevalent in the western portion of the BCBG, in the area of Aggregates IV, V, and VI. Despite the vast mass of radionuclides, primarily uranium, known to have been disposed of in the BCBG, the soil data seem to indicate that soils are not affected by secondary contamination.

Organic contaminants are more widespread and occur at higher concentrations in the BCBG than the other analyte groups. Although the distribution of organic contamination appears somewhat random with regard to depth, it does appear that suites of organic contaminants are associated with different disposal areas. For example, Aggregate I, BG-A North, is dominated by toluene, PCBs, 1,1,1 TCA, and 1,1 DCA. Aggregate II, BG-A South, is characterized by acetone, toluene, PCE, and TCE. Aggregate III, which comprises BG-A-16, -17, and -18, is unique in that PAHs and phthalates are present in addition to toluene, PCBs, and 2-butanone. Aggregate IV, located west of NT-7 in the region of the WIP North and South, BG-B, and BG-D South, is mostly characterized by toluene and PCBs. Aggregate V, BG-C West, displays a variety of organic contaminants, with acetone, toluene, PCE, PCBs, and 4-methyl-2-pentanone dominating. Aggregate VI, comprising BG-D East and BG-C East, is dominated by PCBs and toluene.

The absence of extreme contamination in the soils surrounding the waste disposal units in the BCBG does not necessarily mean that the BCBG do not contain extensive contamination, but rather that soils surrounding the trenches are not contaminated and that no active pathway allows for the lateral migration of contamination from trenches to surrounding soils. In addition, very few soil samples, either surface soil or soil borings, were taken from the along-strike ends of the disposal trenches, especially along strike between the disposal areas and the tributaries.

D.8.4 SEDIMENT DATA

Sediment data for the streams in the BCBG FA are derived from historical data (McCauley 1985; Turner and Kamp 1984), a 1984 comprehensive study of sediments in Bear Creek and its tributaries and the 1995 investigation of floodplain soils and sediments. Extensive and detailed characterization of sediments in the NT-6, -7, and -8 streams was carried out prior to remediation of those sites in the late 1980s and early 1990s (Herbes 1988; Bogle, Turner, and Easterling 1991). Because much of the contaminated sediment was removed from these tributaries during remediation and the contaminated areas were subsequently capped, these historical data do not reflect current conditions. The reader is referred to these documents for details of the characterization effects.

Burial Grounds FA sediment samples (SD08, SD09, SD10) were collected from Bear Creek at the confluence of NT-6, near the confluence of the two upper arms of NT8 and just downstream of the confluence of NT-8 and BC, respectively, as part of the 1995 Floodplain Soils and Sediment investigation of the current RI. These samples were sent off site for radiological and chemical (inorganic, semivolatile, PCB/pesticide, and herbicide) analysis. The results of the sediment analyses are summarized in Table D. 101 and illustrated in Figs. D.112 through D.120. The distribution of contaminants in floodplain sediments is discussed in more detail in Sect. D.9.2.

D.8.5 BEAR CREEK BURIAL GROUNDS FA – SURFACE WATER CHEMICAL DATA

Surface water in the BCBG FA is contaminated with a wide range of chemicals consistent with the history of operations at the BCBG. Surface water contamination is dominated by VOCs; radionuclides and metals, although present in surface water, do not occur in the same magnitude as VOCs. Three streams are considered in the BCBG FA: NT-6, -7, and -8.

During the past decade, considerable effort has been directed to removing contaminated soils and wastes from contact with water bodies at BCBG by excavating the most heavily contaminated soils and sediments, capping the main waste areas, and collecting waste leachate. Because these remediation activities have successfully improved the quality of surface water draining the BCBG,

only the most recent data are used in the BCV RI to quantify current contaminant concentrations in surface streams. These data include BCV OU 1 and BCV OU 4 field investigation results and GWQR data for samples taken after 1990. All other data for surface water are considered as historical data that may not reflect current conditions and are thus discussed qualitatively.

Recent data are subdivided into three aggregates — NT-6, -7, and -8 — each of which contains samples from these streams taken during the BCV OU 1 and BCV OU 4 field activities. Although VOCs are the principal contaminants in these surface water aggregates, they are accompanied by uranium isotopes and sporadic metal contamination. Before the BCV RI, surface water in NT-6, -7, and -8 had not been monitored regularly. Most historical data for these tributaries were derived from grab samples of surface water taken during studies of sediment contamination in the streams.

Table B.12 in Appendix B summarizes the analytes for surface water in BCV. Tables D.81, D.82, D.83, D.84, D.85, and D.86 summarize the results of these analyses for each analyte that was detected in the NT-6, -7, and -8 aggregates, respectively. Included in Tables D.81 through D.86 are the frequency of detection of the analytes; background criteria; frequency with which each analyte exceeded background; minimum, maximum, and mean results; and the relative importance of each analyte as a contaminant related to the BCBG FA. The relative importance of each analyte as a contaminant at the OLF FA is determined by applying technical judgment based on the weight of evidence from a series of criteria (e.g., the frequency of detection of an analyte or the concentrations at which an analyte is detected relative to regulatory benchmarks). In addition, Table D.87 summarizes the results of analysis for miscellaneous parameters in NT-6, -7, and -8.

D.8.5.1 Organic Compounds – Bear Creek Burial Grounds Surface Water

Each of the three streams draining the BCBG is contaminated with a variety of VOCs, which is consistent with the operations at this site and the elevated concentrations of VOCs in groundwater. The concentrations of total VOCs and the variety of chemicals detected are greater in NT-7 and -8 (mean total VOCs at 352 and 391 $\mu\text{g/L}$, respectively) than in NT-6 (mean 35 $\mu\text{g/L}$).

Of the 13 organic compounds detected in NT-6, 4 (carbon disulfide, chlorobenzene, methylene chloride, and toluene) were detected in only 1/21 samples and at estimated values (concentration less than detection limit), and 5 (1,1,1-TCA, 1,1-DCA, 1,2-DCE, PCE, and TCE) were detected more than once but at concentrations less than the detection limit. None of these nine chemicals were detected above SDWA MCLs. Of the remaining four chemicals, all occur at low concentrations, and only 1,2-DCA (11 to 24 $\mu\text{g/L}$) exceeds its SDWA MCL. 2-Butanone (5 to 6 $\mu\text{g/L}$), acetone (17 to 34 $\mu\text{g/L}$), and chloromethane (4 to 14 $\mu\text{g/L}$) were all detected sporadically. Only 1,2-DCA, 2-butanone, acetone, and chloromethane are considered as contaminants in NT-6.

Fifteen organic compounds were detected in NT-7. The principal contaminants are 1,2-DCE (33 to 290 $\mu\text{g/L}$), PCE (16 to 120 $\mu\text{g/L}$), and TCE (8 to 82 $\mu\text{g/L}$). In addition, 1,1,1-TCA (3 to 35 $\mu\text{g/L}$), 1,1-DCA (3 to 25 $\mu\text{g/L}$), 1,1-DCE (2 to 16 $\mu\text{g/L}$), chloroform (1 to 8 $\mu\text{g/L}$), and vinyl chloride (6 to 33 $\mu\text{g/L}$) were detected at a frequency of >90%. Of the 15 chemicals detected in NT-7, 13 are considered contaminants; the occurrence of carbon disulfide (one detect at 6 $\mu\text{g/L}$) and toluene (one detect at 1 $\mu\text{g/L}$) is too sporadic, and their concentrations are too low for these two compounds to be considered contaminants.

Fifteen organic compounds were detected in NT-8. The principal contaminants are similar to those for NT-7: 1,1-DCA (9 to 27 $\mu\text{g/L}$), 1,2-DCE (4 to 410 $\mu\text{g/L}$), PCE (26 to 58 $\mu\text{g/L}$), and TCE (13 to 29 $\mu\text{g/L}$). In addition, 1,1,1-TCA (2 to 11 $\mu\text{g/L}$), 1,1-DCE (5 to 11 $\mu\text{g/L}$), and vinyl chloride (3 to 21 $\mu\text{g/L}$) were detected at a frequency of >90%. Of the 15 chemicals detected in NT-8, 14 are

considered contaminants; the occurrence of trichlorofluoromethane (one detect at 1 $\mu\text{g/L}$) is too sporadic and its concentration too low for it to be considered a contaminant.

The wide range of concentrations observed for the principal chemicals in both NT-7 and NT-8 is partially a function of the total flow and the effects of volatilization. Figure D.99 shows the relationship between flow (Q) and concentration (C) for the three principal organic chemicals in NT-7 plotted on logarithmic axes. Although the relationship between flow and concentrations is not a simple one, lower concentrations generally occur at higher flow rates. However, straightforward dilution effects (as observed in NT-2 for inorganic contaminants) do not apply to these data, probably because of volatilization of the chemicals as well as dilution during storms.

Historical data for surface water from NT-7 and NT-8 (McCauley 1985) are generally consistent with the recent data. The primary contaminants in the historic database are PCE, TCE, and 1,2-DCE. In addition, 1,1-DCA, 1,1,1-TCA, and vinyl chloride are also detected in relatively high concentrations in both tributaries.

Historic data samples also provide information about the distribution of VOCs within each tributary catchment because they were taken from locations along the tributaries from their headwaters to the confluence with Bear Creek (McCauley 1985). However, because these data were obtained before capping of the BCBG, they may not reflect current conditions. In NT-7, the highest concentrations of VOCs were observed in samples adjacent to BG-A South. The suite of VOCs in these samples is consistent with that observed in NT-7 today: 1,2-DCE predominates, with lower concentrations of PCE and TCE. These data also reflect the contamination observed in groundwater at this site; the most likely origin for contaminated water in NT-7 is discharge of contaminated groundwater.

A second suite of VOCs may be present in NT-7; detected in one historical sample taken from NT-7 adjacent to BG-A North (5A) (McCauley 1985), this VOC suite is dominated by 1,1-DCA, and TCE and PCE are absent. These data are consistent with data from the leachate collection system in seep 1 (Table D.88), in which 1,1-DCA occurs at a concentration of 400 $\mu\text{g/L}$. 1,1-DCA is the breakdown product of 1,1,1-TCA. These surface water data are consistent with groundwater data; together they indicate that BG-A North may be the source of this chemical and its breakdown products in NT-7.

In NT-8, the historical data are consistent with the data from samples in BCV OU 4 in that 1,2-DCE dominates the VOC contaminant suite. However, samples from BCV OU 1 taken in the uppermost section of NT-8 in 1995 and leachate collection data from samples in March 1993 are not consistent with the historical data from 1983 or with the data from the BCV OU 4 monitoring location.

Historical data show that the highest concentration of VOCs in NT-8 occur in the south branch of the stream, close to seep 2 (sample 8-7 with 1,2-DCE at 210 $\mu\text{g/L}$ and sample 8-8 with 1,2-DCE at 740 $\mu\text{g/L}$) (McCauley 1985). The VOC suite in these samples consists of CE, 1,1-DCA, and 1,2-DCE in approximately equal amounts. A sample taken from this location during the (SW-02) BCV OU 1 investigation shows 1,2-DCE at a concentration of 4 $\mu\text{g/L}$; the principal detected VOC in this sample is CE at 93 $\mu\text{g/L}$. In addition, the VOC suite in samples from the Seep 2 leachate collection system are dominated by CE (640 $\mu\text{g/L}$; Table D.89), with only 2 $\mu\text{g/L}$ 1,2-DCE and no detectable TCE or PCE. A sample for the C-West Toe leachate collection system has a similar VOC suite to that for Seep 2, with CE at 890 $\mu\text{g/L}$, 1,2-DCE at 2 $\mu\text{g/L}$, and no detectable PCE and TCE. Thus, the BCV OU 1 surface water data are consistent with the leachate collection data from Seep 2 and C-West Toe, but these three VOC suites differ significantly from those recorded in 1983 and

found during the BCV OU 4 investigation. A third VOC suite is observed in the Seeps 3 and 4 leachate collection system. Samples from these seeps are dominated by CE (1770 $\mu\text{g/L}$), but also contain high concentrations of 1,1-DCA (410 $\mu\text{g/L}$), 1,1-DCE (30 $\mu\text{g/L}$), 1,1,1-TCA (120 $\mu\text{g/L}$), vinyl chloride (180 $\mu\text{g/L}$), and benzene (53 $\mu\text{g/L}$).

Although the various VOC suites observed in the headwaters of NT-8 differ, they are all composed of possible breakdown products derived from parent compounds PCE, TCE, or 1,1,1-TCA or are common contaminants in PCE, TCE, and TCA products. In recent data, the dominating chemical in samples from the headwaters of NT-8 and in the leachate collection systems is CE, which is towards the end of the breakdown chain for the parent chemicals (Fig. D.100). The 1983 VOC suite is also composed primarily of breakdown products; however, the concentrations of 1,2-DCE (a chemical higher up the breakdown chain) are more prominent in these samples than in recent data. These findings may indicate that breakdown of organics is occurring in shallow groundwater sources for VOCs in NT-8 and that, on the whole, the contamination in this area may have progressed further along the reaction path over the past 10 years.

The source of 1,2-DCE in surface water at the monitoring point in NT-8 close to the confluence with Bear Creek is not known. As is discussed above, neither recent samples from the headwaters of NT-8 nor samples from the leachate collection system contain concentrations of 1,2-DCE that are consistent with their occurrence at this OU 4 monitoring point. The most likely conclusion is that groundwater discharge into NT-8 between the headwaters and the OU 4 monitoring point is contaminated with 1,2-DCE and that the section of NT-8 parallel to the C-West cap is the most likely location for this discharge.

D.8.5.2 Radioactivity – Bear Creek Burial Grounds Surface Water

The results for gross α and gross β analysis indicate that all three streams draining the BCBG are radioactively contaminated. In NT-6, gross α and gross β were detected in ~50% of the samples, with maximum recorded activities of 22.5 and 22.9 pCi/g, respectively (mean activities are 10 and 9 pCi/L for gross α and gross β , respectively). The activities of uranium isotopes can explain the gross α and gross β activities in NT-6. Although this stream has radioactive contaminants elevated above background, the uranium activities are below the proposed SDWA MCL activity of 30 pCi/L for natural uranium (corresponds approximately to 20 $\mu\text{g/L}$ total U).

In NT-7, gross α was detected in ~60% of samples, with activities ranging from 11 to 41 pCi/L (mean 14.7 pCi/L). In NT-8, gross α ranges from 28 to 135 pCi/L (mean 55 pCi/L). Only one sample in NT-7 exceeds the 30 pCi/L SDWA MCL, whereas 11/12 samples in NT-8 exceeds this benchmark. Gross β activities in these two tributaries range from 10 to 117 pCi/L (mean 24 pCi/L) in NT-7 and from 20 to 66 pCi/L (mean 37 pCi/L) in NT-8.

Isotopes of uranium (^{238}U , ^{235}U , and ^{234}U), thorium (^{232}Th , ^{230}Th , and ^{228}Th), and plutonium (^{238}Pu) were detected in the tributaries draining the BCBG. Because occurrence of these isotopes is potentially consistent with operations at the Y-12 Plant, these radionuclides are considered as SRCs in surface water. However, the activities at which the isotopes of Th and Pu occur indicate that they are not the principal radioactive contaminants in either tributary (Pu activity in NT-7 is 0.223 pCi/L); the activity of uranium isotopes is two orders of magnitude greater than that of the other radionuclides. The activities of uranium radioisotopes can explain the observed gross α activities. Gross β activities in these tributaries are explained by secular equilibrium of β emitting daughter isotopes of uranium.

Available data on radiological contamination at the BCBG include both recent and historical data. Data from the BCV OU 4 investigation, which focused on estimating the contaminant loading to Bear Creek from each tributary, are drawn from samples taken at a monitoring point located close to the confluence. Historical data, data from two samples taken in BCV OU 1, and data from analysis of leachate from seeps in the BCBG can be used to isolate the primary areas of discharge of uranium-contaminated water in the headwaters of NT-8. The BCV OU 1 samples (SW01 and SW02) were taken in the streams draining the BG-C, BG-D, BG-E, and BG-F areas (Fig. D.83). Eight surface water samples were taken along NT-8 in 1984 (McCauley 1985) (refer also to Appendix A), and leachate in the leachate collection systems at Seeps 2, 3, and 4 was analyzed in 1993 (Table D.89), and in 1995 (Table D.90).

The activities of uranium isotopes in the BCV OU 1 samples are considerably higher than those in samples from the BCV OU 4 monitoring point. The activities of uranium in these samples and for historical samples from BCBG are shown in Fig. D.101. These data, although not conclusive, indicate that the highest activities of uranium occur in the southern branch of NT-8, which drains the Seep 2 and BG-C East area. The highest activities occur at the very top of this stream, almost at Seep 2, and probably decrease very rapidly downstream. The samples taken closest to Seep 2 in 1984 have similar activities to those seen today in the BCV OU 1 samples (sample 8-8, total uranium of 434 pCi/L; sample SW-02, total uranium of 502 pCi/L). However, the activities of uranium in NT-8 are strongly controlled by the flow in the stream, and flow data are not available for these samples. The similarity of activities over time is not surprising because conditions in the BCBG upgradient of this sampling point (BG-C and BG-D East) did not change between the two sampling events. In addition, the activity of uranium in discharging groundwater is probably more strongly controlled by the solubility of uranium in the soils rather than availability (excess uranium is available).

D.8.5.3 Inorganic Elements and Compounds – Bear Creek Burial Grounds Surface Water

Surface water draining the BCBG FA is relatively free of metal contaminants: detections above background were limited to one metal (mercury) in NT-6; five metals (aluminum, mercury, nickel, vanadium, and zinc) in NT-7; and five metals (aluminum, beryllium, lithium, mercury, and vanadium) in NT-8.

Mercury was detected above background in all three tributaries draining the BCBG: 3/21 samples in NT-6, 2/21 samples in NT-7, and 2/14 samples in NT-8. Although seven detects for mercury were greater than the background value ($0.2 \mu\text{g/L}$), the concentrations were generally low, with a range of 0.1 to $0.5 \mu\text{g/L}$. However, the samples in which mercury was detected were all baseflow samples; these samples were taken on August 11, 1994 (summer baseflow), October 13, 1994 (summer baseflow), and January 24, 1995 (winter baseflow). The occurrence of elevated concentrations only in baseflow suggests that mercury is derived from groundwater discharge and that, during periods when flow in these streams includes components of runoff and soil interflow, the concentrations of mercury are too diluted to detect.

In NT-7, aluminum, vanadium, and zinc occur above background in five samples, all of which are stormflow samples. NT-7 is typically a very turbid stream during storm events; it was especially turbid during the time frame of monitoring for BCV OU 4 because of the ongoing construction of the BG-B and WIP cap. The TSS of these five samples were approximately an order of magnitude greater than TSS during normal flow ($> 100 \text{ mg/L}$ for stormflow compared to 10 to 30 mg/L for baseflow). The occurrence of aluminum, vanadium, and zinc above background only in the five most turbid samples indicates that these metals are transported in this watershed as suspended load rather than dissolved.

D.8.5.4 Common Anions and Cations – Bear Creek Burial Grounds Surface Water

In general, the tributaries draining the BCBG FA are contaminated with elevated concentrations of common anions. Nitrate, fluoride, and chloride occur regularly above background in NT-6, -7, and -8. Cyanide was detected in two samples, one from NT-7 and one from NT-8. Except for two samples of nitrate (NT-6, sample 9 and NT-7, sample 16), none of these anions occur in concentrations greater than SDWA MCLs.

Nitrate was detected in most samples from the tributaries draining the BCBG (~60% of samples in NT-6 and NT-8 and all samples in NT-7). However, the concentrations at which nitrate occurs are generally low; only 8% of the samples in NT-6 and NT-8 are >1 mg/L, and although 52% in NT-7 are >1 mg/L, all but one are <5 mg/L.

Cyanide was detected in only 1 of 21 samples in NT-7 and 1 of 14 samples in NT-8. The concentration of detected cyanide was 14 µg/L in NT-7 and 21.5 µg/L in NT-8. These concentrations are less than both the SDWA MCL of 200 µg/L. These data indicate that cyanide in NT-7 and NT-8 is highly sporadic (6% of samples) and occurs at low concentrations relative to the regulatory benchmark for protection of human health; thus, cyanide is not considered as a contaminant in NT-7 or NT-8.

Chloride and fluoride occur in concentrations above background concentrations in all three tributaries draining the BCBG FA. Facilities now exist, or have existed, in each of the NT-6, -7, and -8 catchments, and access roads are used continually by light- and heavy-duty vehicles. In contrast, NT-13 (the background catchment) is essentially untouched, except for one, infrequently used road. The activities in the NT-6, -7, and -8 catchments have resulted in changes in the concentration of the major ion chemistry of surface waters, including the presence of chloride and fluoride.

Concentrations of sulfate are generally low in these tributaries, with only one detection above background. In NT-6 sulfate has a mean concentration of 7.2 mg/L, in NT-7 a mean of 17.29 mg/L, and in NT-8 a mean of 10.49 mg/L, compared to a background concentration of 57 mg/L in NT-13. Elsewhere in BCW, the concentration of sulfate in impacted catchments is generally above background (e.g., NT-2, NT-3, and BCK 12.38). The very low sulfate concentrations in the tributaries draining the BCBG may indicate enhanced activity of sulfate-reducing bacteria that are involved in biological breakdown of organic contaminants. In addition, the low sulfate concentrations coincide with the observed concentrations of breakdown products of the parent organic chemicals disposed of at the BCBG.

D.8.6 BEAR CREEK BURIAL GROUNDS FA – GROUNDWATER CHEMICAL DATA

Groundwater contamination in the vicinity of the BCBG is dominated by VOCs, with minor concentrations of metals and radionuclides. These contaminants are consistent with the operations at this site, which involved pouring solvents and oils into unlined trenches. Historical data indicate the presence of free-phase DNAPL and light non-aqueous phase liquid (LNAPL) formations in the vicinity of BCBG.

The wells included in the BCBG aggregates are listed in Table D.6, and their locations are shown on Fig. D.5. The two aggregates are defined by the sampling methods used to obtain the data: the BCBG aggregate contains wells from the GWQR database that were sampled as part of the Y-12 Plant GWPP, and the BCBG OU 1 aggregate contains wells sampled during the BCW OU 1 field activities. Because the samples taken in the BCW OU 1 field activities were obtained as

groundwater grab samples using a direct-push sampling method, they may not be directly comparable to the GWPP samples, which were all taken from installed wells that had been properly developed and purged. Hence, these data were separated into two aggregates for analysis. The GWPP wells used for the BCVR RI were selected on the basis of two criteria: the well is screened in clastic functions of the Conasauga Group and it is located within the watershed of NT-6, -7, or -8. Groundwater in these wells is the potential primary receptor of contaminants from the sites in the OLF FA.

Tables B.2 and B.7 in Appendix B summarize the analytes for groundwater in the BCBG aggregates. Tables D.91, D.92, D.93, D.94, and D.95 summarize the analytical results for each analyte that was detected in data from the GWQR database and the BCVR OU 1 database, respectively. Included in Tables D.91 through D.95 are the frequency of detection of the analytes; frequency of wells that detect each analyte; frequency at which the median value for an analyte in a well exceeds the background UTL; aggregate minimum and maximum results; mean of the well median results; and the relative importance of each analyte as a contaminant related to the BCBG FA.

As described in the background screening method outlined in Sect. D.4.2, the median concentration of a chemical in groundwater from wells in the BCBG aggregate was used to identify wells that have consistently elevated concentrations of metals in groundwater. The following sections describe the extent of the principal contaminants in the BCBG site groundwater aggregates.

D.8.6.1 Organic Compounds – Bear Creek Burial Grounds Groundwater Aggregates

The contaminant geochemistry of the BCBG groundwater is dominated by organic chemicals. One drilling and groundwater sampling study has sampled DNAPL from one boring (Haase and King 1990) and may have encountered DNAPL in two other borings. In addition, the concentrations of dissolved organics in many of the BCBG area wells have concentrations of volatile organic chemicals >5% of their solubility, indicating that DNAPL is present in the subsurface. These data are consistent with the history of the BCBG where oils and solvents were discharged into standpipes in the unlined trenches, particularly in the BG-A and BG-B areas.

The occurrence, distribution, and migration of DNAPL at the BCBG have been studied by Haase and King (1990), Kueper, Haase, and King (1992), and Dreier and Davidson (1994). Most of the drilling and sampling programs investigating DNAPLs have been conducted in the area south of BG-A South. The conclusions of these studies are that solvents (primarily PCE and TCE) placed in the BCBG trenches have migrated away from the trenches down geological dip in the Nolichucky Shale as DNAPL. Because of the fractured nature of the Nolichucky Shale bedrock, the migration and occurrence of pools of DNAPL large enough to detect and sample are sporadic (Kueper, Haase, and King 1992). However, DNAPL from BG-A South appears to have migrated down dip preferentially in a zone at the base of the middle Nolichucky Shale (Fig. D.102). This may be a function of (1) the location of BG-A South at the outcrop of the middle Nolichucky Shale and (2) fracture spacings in the middle and lower Nolichucky Shale, which restrict the DNAPL to this zone (Dreier and Davidson 1994). The maximum depth of DNAPL at the BCBG is not known; however, in theory, a maximum depth of migration is likely to occur at a depth where fracture apertures become too small to allow entry of the liquid [a function of entry pressure and surface tension of the liquid (Kueper, Haase, and King 1992)]. Dreier and Davidson (1994) and Kueper, Haase, and King (1992) both suggest that the maximum depth for DNAPL at the BCBG may be as deep as 152 m (500 ft).

Dissolved Organics

Twenty-four VOCs were detected in groundwater in the BCBG GWQR groundwater aggregate, and 15 VOCs were detected in the BCBG OU 1 groundwater aggregate. The primary VOCs in the BCBG FA are 1,1,1-TCA, 1,1-DCA, 1,1-DCE, 1,2-DCA, 1,2-DCE, CE, PCE, TCE, trans-1,2-DCE, and vinyl chloride.

The BCV-wide distributions of PCE, TCE, and 1,2-DCE are shown on Figs. D.9 to D.11. These chemicals are common contaminants in groundwater throughout BCV and therefore have been depicted on BCV-wide contaminant maps. Figures D.23 to D.29 depict the distributions of PCE, TCE, and 1,2-DCE concentrations in a BCV cross section oriented across strike. The location of this cross section is shown on Fig. D.5.

Two distinct VOC plumes with slightly differing suites of chemicals are associated with the BG-A and WIP areas. A third distinct suite of organic contaminants, detected in wells in the NT-8 catchment, is associated with BG-C East and BG-C West. Figure D.103 depicts the suites of organics detected in selected wells at the BCBG and the changes in the proportions of those chemicals over time. In general, these organic chemicals can be subdivided into groups of parent and daughter chemicals based on the known chemical and biological breakdown pathways (Fig. D.100). The presence of daughter chemicals (such as 1,2-DCE) may indicate that breakdown of a parent chemical has occurred; however, daughter chemicals are also common contaminants of the parent product and, thus, may be primary contaminants rather than breakdown products.

BG-A Area Plume

The most widespread plume is intercepted in wells screened around the BG-A area. The suite of organic contaminants in wells located close to BG-A is a mix of most of the organic contaminants identified at the BCBG, except for carbon tetrachloride, which is almost absent from this area. The wells that define this plume are GW-014 (4 m or 13.2 ft), GW-027 (9.3 m or 30.5 ft), GW-039 (6.9 m or 22.5 ft), GW-046 (6.2 m or 20.5 ft), GW-068 (25.9 m or 85 ft), GW-071 (67.2 m or 220.6 ft), GW-623 (106.4 m or 349 ft), GW-624 (8.3 m or 27.2 ft), GW-626 (23.8 m or 78.0 ft), GW-627 (82.3 m or 270 ft), and GW-629 (95.1 m or 312 ft) and the BCV OU 1 grab samples from BG-02 and BG-03. Parent chemicals in the suite for the BG-A plume are 1,1,1-TCA, TCE, and PCA; other chemicals in the organic contaminant suite, mainly DCE, DCA, vinyl chloride, and CE, are either daughter products or common contaminants in the parent product (Fig. D.100). This plume is also associated with the occurrence of DNAPL in the subsurface, which was detected in GW-625 (86.3 m or 283 ft) and GW-628 (87.7 m or 288 ft) and which probably has a widespread occurrence down dip of BG-A as small droplets of DNAPL in ganglia left by migrating liquid pools (Kueper, Haase, and King 1992).

Although the contaminant suites detected in these wells are similar, subtle differences among the wells provide some insight into the geochemistry of the organic chemicals in the subsurface at BG-A. The contaminant suite in well GW-039 and in Seep 1 (Table D.88) is dominated by 1,1,1-TCA and its daughter products 1,1-DCE and 1,1-DCA. This contaminant suite is chemically distinct from the rest of the BG-A plume, suggesting a different source in BG-A for this suite of contaminants. 1,1,1-TCA is present in most of the other wells defining this plume; however, it always makes up <10% of the contaminants suite.

The only other well located at BG-A North (GW-027), along with wells located at BG-A South, has contaminant suites more typical of the BG-A area, a mix of TCE and PCE as parent compounds and 1,2-DCE dominating the daughter compounds. The proportions of these chemicals vary among

wells. In GW-624 and GW-626, the proportion of daughter products (DCE, DCA, and vinyl chloride) is more than 80% of the total organic suite; in wells GW-627 and GW-629, located nearby, the proportion of parent chemicals is between 50% and 60%; and in well GW-623, parent chemicals constitute more than 90% of the total organic suite. This variation of parent-to-daughter chemicals does not appear to have any systematic distribution; in the shallow intervals, however, all deep bedrock wells are dominated by parent compounds and have few daughter products. The variable distributions may be the result of variable breakdown rates or separate sources; however, in all cases, the daughter products in a well [146.3 to 161.5 m (480 to 530 ft)] are consistent with the decay pathway for the detected parent chemicals in that well.

GW-117 is a deep borehole (146.3 to 161.5 m or 480 to 530 ft) screened in the Nolichucky Shale located close to BG-A South. Samples taken from this boring before 1989, when the well was purged for the first time (Haase and King 1990), exhibit a contaminant suite dominated by PCE, with little or no daughter products and a maximum concentration of 1400 $\mu\text{g/L}$ (Fig. D.104). After 1989, the concentrations of VOCs in this well declined dramatically and did not revert to their original values. PCE was detected with a range of 9 to 22 $\mu\text{g/L}$ in the BCBG data aggregate, and because of the four or more rule, none of the pre-1990 data for this well were included in the aggregate. These findings have two likely explanations:

- When this well was drilled, DNAPL from formations higher up in the boring accumulated at the bottom of the well, remaining there until the well was purged in 1989. After purging, DNAPL did not accumulate because the well construction prevented migration of the liquids into the well.
- The conductivity of the Nolichucky Shale at this depth is so low that this well is still recovering today from the purging in 1989.

Time Trends in the BG-A Area Plume

Systematic changes in PCE concentrations have been observed in GW-623, -627, and -629 (Fig. D.103). In both GW-627 and GW-629, PCE dominates the organic contaminant suite. In GW-627 (79.8 m or 262 ft), the PCE concentration has increased from non-detect in 1990 to >30 $\mu\text{g/L}$ in 1994; and in GW-296 (29 m or 95 ft), PCE was not detected before 1991, but was detected at >70 $\mu\text{g/L}$ in two samples in 1991. In the absence of possible interference effects (such as changes in sampling or analysis protocols) to explain these changes, the increase in PCE concentrations over time are explained by migration of this compound to the well in question. Both wells are screened in the Nolichucky Shale bedrock and are located along strike, west of BG-A South. Groundwater down dip of BG-A South is contaminated with PCE and contains DNAPL. The most likely source for the changes in concentration observed in these wells is along strike migration of PCE from contaminated groundwater at BG-A South.

Changes in PCE and TCE concentrations have also been observed in GW-623. The organic contaminant suite in this well is dominated by these two parent compounds in approximately equal amounts (PCE 2,900 to 29,000 $\mu\text{g/L}$; and TCE 1,800 to 24,000 $\mu\text{g/L}$), and the concentrations are indicative of DNAPL close to the well (2% to 19% of PCE solubility, and 0.2% to 2% of TCE solubility). GW-623 is screened in the Nolichucky bedrock in the intermediate interval (74.3 to 83.5 m or 244 to 274 ft) located down dip of BG-A South. The changes in concentration in this well indicates down dip migration of contaminants.

WIP Area Plume

Five wells located south of WIP have a unique, PCE-dominated suite of organic contaminants, which define a distinct plume. In GW-257 (10.3 m or 33.7 ft), GW-259 (10.2 m or 33.7 ft), GW-288 (18.3 m or 60 ft), GW-289 (12.4 m or 40.8 ft), and GW-291 (5.2 m or 16.9 ft), PCE constitutes over 95% of the organic contaminants in groundwater. The likely source for these contaminants is WIP South or North, both of which are located directly up dip from these wells. The predominance of PCE in these wells indicates that little or no breakdown of the parent compound has occurred. The concentrations of PCE in three of these wells (GW-259, -288, and -289) are similar, ranging from 570 to 2100 $\mu\text{g/L}$. These concentrations are $\sim 1\%$ of the maximum solubility of PCE, suggesting that DNAPL is present in this area. The concentrations in GW-257 are substantially lower, ranging from 130 to 210 $\mu\text{g/L}$.

The lack of daughter compounds in the WIP plume could be a function of a number of possible parameters, two of which are (1) a slower rate of breakdown in this section of the Nolichucky Shale than elsewhere or (2) introduction of the parent chemical into the groundwater in this area at a later date than in BG-A. The operational history of the BCBG suggests that the latter could be true because the WIP was still operating during the 1980s, whereas oil and solvent disposal ceased at BG-A in 1979. However, this hypothesis suggests only a 10-year differential in time in the ground between these two plumes, which would be unlikely to cause the difference in breakdown that is observed. Therefore, other factors affecting organics in this section of the BCBG may be causing the slower breakdown.

NT-8 Catchment

Wells GW-082 (10.7 m or 35 ft) and GW-242 (5.2 m or 17 ft) and Seep 2 (Table D.89) show VOC contamination, primarily 1,2-DCE (19 to 90 $\mu\text{g/L}$ in GW-082 and 62 to 130 $\mu\text{g/L}$ in GW-242), with lower concentrations of vinyl chloride (maximum concentration of 71 $\mu\text{g/L}$). Although the contaminant suite in these two wells is almost identical, they are geographically separate; therefore, they probably do not define a continuous plume of contamination. The likely sources of the plume in GW-082 and GW-242 are BG-C East and BG-C West, respectively.

D.8.6.2 Radioactivity – Bear Creek Burial Grounds Groundwater Aggregates

Despite the extensive amounts of radioactively contaminated materials disposed of in the trenches at BCBG, the extent of radioactive contamination of groundwater is small. Gross α was detected above background in only 8 of 47 GWPP wells and in only 2 of 6 grab samples of groundwater during the BCV OU 1 sampling. The overall frequency of detection was 10 of 408 samples (2%), and only three wells (GW-040, -643, and -655) had more than one detect of gross α between 1991 and 1994. Gross β has a frequency of detection of 26 of 408 (6%), with gross β activities above background occurring in 16 wells. Elevated gross β occurs in four of six groundwater grab samples.

The sporadic nature of detection and the low activities detected imply that groundwater at BCBG is not radioactively contaminated. The highest activities for gross α and gross β occur in a grab sample of shallow groundwater from BG-13 located at the toe of the BG-C West Cap and from analyses of leachate captured in Seep 2 and C-West Toe (Table D.90). No wells show consistent contamination from year to year, and no plume of contaminated groundwater can be defined. However, surface water, particularly NT-8, is contaminated with isotopes of uranium and, as mentioned above, leachate in Seeps 1, 2, and C-West Toe is contaminated with radionuclides. Thus, the probable source for surface water contamination is shallow groundwater discharge to the streams.

This apparent inconsistency can be resolved if radiological contamination is assumed to be restricted to the shallow groundwater flow paths in the water table interval and is sampled in BG-13. This restriction of the radiological contamination within shallow groundwater would localize it close to the trench areas; however, no monitoring well sampling points are located in the contaminated areas in the shallow system to enable confirmation. This hypothesis is consistent with the likely sources for uranium contamination to surface water: (1) trenches in the BG-C East and D East area drained by Seep 2 (closest wells GW-040 and GW-291) and (2) trenches in BG-A South [closest well (GW-021) now plugged]. This hypothesis is also consistent with the site conceptual hydrogeologic model, which shows that most flow through the water table interval discharges rapidly to streams after short flow paths and does not recharge to groundwater.

D.8.6.3 Inorganic Elements and Compounds – Bear Creek Burial Grounds Groundwater Aggregates

Contamination of groundwater with inorganic elements at BCBG is very sporadic with generally low concentrations. In addition to essential elements, 15 metals or semi-metals occur above background values in one or more wells in the BCBG FA GWQR groundwater aggregate, and 10 in the background screen for the BCBG OU 1 groundwater aggregate. Figure D.105 shows wells in the BCBG GWQR aggregate that have one or more metal contaminants.

The frequency of detection above background concentrations of most metal contaminants at BCBG is low, and except for boron (detected above background in 10 wells), contaminants were detected in four wells or less. Of the 14 metals or semi-metals that occur above background in the BCBG groundwater aggregate, 11 occur above background in more than two wells: barium, boron, cadmium, copper, lead, lithium, manganese, nickel, niobium, vanadium, and zinc. Relatively few wells contain metals or semi-metals contamination, and no distinct plume of contaminated groundwater can be delineated. Most contaminated groundwater is associated with older, shallow bedrock and water table interval wells located close to the BG-A North and South (most notably GW-014, -021, -027, and -039).

The data from the shallow grab samples in the BCBG OU 1 aggregate appear to be consistent with those from the GWQR database in that BCBG OU 1 groundwater grab samples contaminated with metals or semi-metals were taken from borings BG-1, -2, and -3, adjacent to BG-A South, and from BG-12, located close to WIP South.

Because the BCBG OU 1 investigation used results from unfiltered samples only, the results may not represent the extent of dissolved metal contaminants. For comparison, the same background screen was conducted using results for the accompanying filtered samples from the BCBG GWQR aggregate (filtered samples were not available for the BCBG OU 1 aggregate). This screen identified 12 contaminants, 2 less than the screen using the BCBG OU 1 unfiltered sample results.

These data indicate that shallow groundwater at the BCBG FA is sporadically contaminated with metals, which, in some cases, exceed drinking water ARARs for groundwater. The worst contamination occurs within the shallow groundwater system at BG-A South.

D.8.6.4 Common Anions – Bear Creek Burial Grounds Groundwater Aggregates

Chloride, sulfate, and fluoride were detected in wells in the BCBG aggregates at concentrations greater than background. Concentrations of chloride were particularly elevated in the shallow groundwater at BG-A South, where six of the seven wells with chloride above background were located. Except for three wells, the concentrations of sulfate are notably low, with most wells in the

BCBG area having mean concentrations <10 mg/L. The three wells in which sulfate is elevated above background are GW-248, -249, and -250, which are located close to BG-B and WIP; none of the wells with elevated sulfate is contaminated with organic compounds. No detected anion concentrations exceed ARARs, SDWA MCLs, or ambient water quality criteria.

D.8.7 BEAR CREEK BURIAL GROUNDS – ECOLOGICAL SETTING

The BCBG comprise a variety of waste disposal areas, designated A, B, C, D, E, and J. BG-A North and South, in the eastern portion of the BCBG area, consisted of a series of trenches in which contaminated water and oil were placed and burned. ORPs were constructed at the west end of BG-A South to contain oil seeping into NT-7 and at the northeast corner of BG-A North to contain oil seeping from the trenches into NT-6. In 1989, BG-A North and South were closed in place as landfills and covered with engineered caps; the ORPs were cleaned out and covered with engineered caps, and NT-7 was rerouted to the west of its original location.

BG-B and BG-D were used for disposal of depleted uranium metal and oxides. BG-C West, which was used for disposal of beryllium, thorium, and wastes contaminated with beryllium, thorium, and uranium, has been closed in place with an engineered cap. BG-C East and the associated WIP, where chemicals and uranium saw fines were disposed of, have been closed and covered with a concrete cap. Therefore, most waste areas in the BCBG have been covered or capped. Because they are subject to various levels of maintenance, they have not reverted significantly to old field or forest. Federal- and state-listed protected species are described in Supporting Information for Appendix D.

D.8.7.1 Potential Exposure to Contaminants

Potential surface water and sediment exposures in the BCBG area occur in tributaries NT-6, -7, and -8. Capped areas and roadways offer little or no high-quality habitat other than feeding areas for terrestrial biota, but habitat between the capped areas offers shelter and food in the grassy and wooded areas for small mammals, reptiles, amphibians, and birds. The terrestrial biota are potentially exposed to contaminants in soil, drinking water, and food. Habitats in which these biota may be exposed are described in the following section.

D.8.7.2 Habitat Description

BG-A Group

The BG-A aggregate, located in the eastern portion of the BCBG area, mostly east of NT-7, comprises BG-A South, BG-A North, ORP-1 and -2 (at the east end of BG-A North and the west end of BG-A South, respectively), BG-A-16, -17, and -18 (Fig. D.106). The approximate distribution of habitats displayed in Fig. D.106 was estimated by using an overlay grid and is presented in Table D.96.

Most of the BG-A aggregate, including BG-A South, BG-A North, and the ORPs, is covered with mowed grass. BG-A-16, -17, and -18 are not maintained and have reverted to old field, as has the area between BG-A-16 and -17 (Fig. D.106). Just north of BG-A North is a small dense stand of mixed hardwoods up to ~25 cm (10 in.) DBH, which is located near the top of a rise whose north side is mowed grass. An area east of BG-A-18 and between the main access road and a small spur road that leads north of BG-A-18 is also mowed grass, whereas the area north and east of the access road is a forest of mixed hardwoods and open understory. South of BG-A South, the land slopes gently to Bear Creek and is covered with mowed grass and occasional individual hardwoods. The lower

portion of NT-6, from the haul road between BG-A South and BG-A North, runs through a forest of bottomland hardwoods.

Bear Creek Burial Grounds West Group

The remainder of the BCBG area includes BG-B, the WIP, BG-C East, BG-C West, BG-D South, BG-D East, BG-D, BG-E, and BG-J (Fig. D.107). BG-B and the WIP have been covered with a constructed concrete cover. BG-C West and BG-D are covered with grass. BG-D East, which contains shock-sensitive wastes and cannot be maintained, BG-C East, BG-D, BG-E, and BG-J have reverted to old field. The area north of BG-J, BG-D, and BG-E is a hillside with patchy old field and sparse forest of mixed pines and hardwoods with an open to bare-soil understory. The west branch of NT-8 runs through a dense forest of mixed hardwoods [10 to 30 cm (4 to 12 in.) DBH] and open understory. The forested areas provide suitable habitat for a variety of mammals, birds, reptiles, and invertebrates. The area from the south end of BG-C West to Bear Creek is dense forest of mixed hardwoods and open understory. Table D.96 lists the habitat type and area covered by each for the BG-A and BG-West groups.

Buildings used to store solid and liquid wastes are located south of the WIP (Fig. D.107). These facilities are inside an asphalt-paved yard that is bordered to the north and west by roadways. NT-7 runs from north of the northern access road, northwest of BG A-17, and between the BG-A waste areas and the BG-B and WIP grouping (Fig. D.107). The slope northeast of BG-B down to NT-7 and the access road are densely wooded, grading from mixed hardwoods on the upper slope to bottomland hardwood and typical wetland vegetation along NT-7.

Wetlands

Wetlands have been identified on NT-6 and NT-8 (Rosensteel and Trettin 1993). A wetland extends from the confluence of NT-6 with Bear Creek to the haul road that runs between BG-A North and BG-A South (Fig. D.106). This wetland is classified C1A (Palustrine forested wetland in tributary bottoms: open understory, with broad, level bottoms). Another narrow wetland extends from the origin of the east branch of NT-6 to ~N31,000. Its upper reaches are classified C3A (Palustrine emergent wetland in forested areas in upstream reaches, groundwater seeps on slight slopes). Further downstream, the wetland grades into category C1A outside the boundaries of the BCBG area. The west branch of NT-6 is entirely within a wetland. The south end of the wetland is formed by the haul road right-of-way (Fig. D.106) and is classified C4A (disturbed area wetland, road and utility rights-of-way). The remainder, which parallels the access road that forms the eastern perimeter of the BCBG (Fig. D.106), is classified C1B (Palustrine forested wetlands in tributary bottoms: open understory, benches or depressions in narrow bottoms).

A wetland extends from just west of BG-C West to the haul road right-of-way (Fig. D.107). The south end of this wetland is formed by the road right-of-way and is classified C4A, and the remainder of the wetland is classified C1A. Another wetland, classified C1A, extends from slightly south of sample point SBG-11 to the confluence of NT-8 with Bear Creek (Fig. D.107).

D.8.7.3 Toxicity Testing at the Bear Creek Burial Grounds Area

Ambient Water Toxicity

Although ambient water toxicity testing has not clearly shown toxicity in tributaries draining the BCBG, toxicity at levels are not statistically significant has been indicated (Southworth et al. 1992). Fathead minnow (*Pimphales promelas*) toxicity testing was performed using water from NT-7

and NT-8 in October 1984, April 1985, and June 1985. No significant toxicity (statistically significant reduction in survival or growth) was demonstrated in the samples from NT-7 during the April 1985 and October 1984 tests. In June 1985 test, survival in the NT-7 sample averaged 2.5%, or 3.2% of the mean control survival. Because of variability in the control test, the test of NT-7 was not definitive, but the sample was likely toxic to fathead minnows on the date. No significant toxicity was demonstrated in the NT-8 samples.

Ambient water toxicity testing was performed as part of the BCBG RI in May and August 1994 at sites in Bear Creek, tributaries NT-1 through NT-8, and springs SS-1, -4, -5, -6, and -8. Because contaminants from the BCBG area migrate to tributaries NT-6, -7 and -8, which drain the BCBG area, the results of toxicity tests in those tributaries may reflect BCBG-related contaminants. Results for NT-6, -7, and -8 are shown in Table D.97, along with results for BCK 9.91, which lies between NT-6 and NT-7 and therefore includes contributions from NT-6.

None of the water samples significantly reduced survival or growth of fathead minnows. Samples from NT-6 and NT-7 (along with samples from BCK 9.91) reduced reproduction of *Ceriodaphnia*. The reductions were statistically significant (Dunnett's t-test, $\alpha=0.05$) in the May 1994 test but not in the August 1994 test and were significant only when compared with the reference site but not with the control.

Sediment Toxicity

Ambient sediment toxicity tests were done as part of the RI in May and June of 1995. In these tests, the freshwater scud *Hyalella azteca* is exposed to whole sediment and *Daphnia magna* is exposed to overlying water (details are presented in Appendix G). Sampling locations SD01 through SD17 are shown in Fig. B.50 in Appendix B. No statistically significant toxicity was demonstrated in samples taken at sites SD08, SD09, or SD10, sites located in the BCBG area, when compared to a composite reference sample taken from NT-11, NT-13, and NT-15.

Soil Toxicity

No historical population and community data are available for plants, birds, or mammals specific to the BCBG grouping. Contaminant body burdens and biomarkers of exposure of terrestrial biota have not been studied for this portion of BCBG RI, nor is there a historic record of toxicity testing for terrestrial media.

D.8.8 BEAR CREEK BURIAL GROUNDS – BIOMONITORING DATA

Surface soil samples were screened by comparing them to background soil concentrations and toxicity benchmarks for white-footed mice and short-tailed shrews. Because surface contamination levels were below the screening benchmarks in portions of the BCBG area where habitat was suitable for small mammals, no sampling and analysis of biota was performed. Instead, bioaccumulation factors derived from floodplain and BYBY samples were used to estimate contaminant body burdens in BCBG biota.

Studies of contaminant bioaccumulation in Bear Creek (Hinzman 1995) have used a sample site at BCK 9.47, near the BCBG area. Concentrations of mercury, nickel, and cadmium in central stonerollers were lower at BCK 9.47 than at BCK 12.36 and higher than at downstream and reference sites. However, concentrations of lithium, uranium, and PCBs were high at BCK 9.47 than at the

reference site and at sites upstream or downstream of BCK 9.47. This suggests that the BCBG area is a source of lithium, uranium, and PCB exposure to aquatic biota in Bear Creek.

D.8.9 GENERAL CONCLUSIONS FOR NATURE AND EXTENT

Figures D.108 and D.109 show detailed conceptual models of the BCBG FA and the likely contaminant migration pathways operating today. These figures are key to understanding the conclusions of this chapter.

Wastes

- Trenches in the BCBG contain a wide range of radioactively contaminated materials and waste uranium metal. In general, contaminated debris is located in the BG-A area, whereas metal parts and chips are located in the BG-B, -C, -D, -E, and -J areas. BCBG wastes are further detailed in Appendix B.
- Oils and solvents were disposed of at the BCBG by pouring the liquids into standpipes in debris- and waste-filled trenches. The relatively high hydraulic conductivity of the trenches allow the liquids to percolate away from the standpipes relatively easily. The bulk of these liquids is assumed to have migrated away from the trenches and to now contaminate groundwater. Small quantities of free-phase liquids probably remain in the trenches as small droplets that have adhered to waste materials and minerals.

Soils

- A number of chemicals were detected in soils surrounding the BCBG trenches. Inorganic contamination appears limited in both nature and extent; when detected, inorganic elements or compounds tend to occur at concentrations at or just above background. Radionuclide contamination in the soils surrounding the BCBG is similarly noteworthy by its absence, particularly in BG-A North and South and the BG-A-16, -17, and -18 disposal areas. Radionuclides, in particular uranium and ⁹⁹Tc, are slightly more prevalent in the western portion of the BCBG (Aggregates IV, V, and VI).
- Organic contaminants are more widespread in BCBG soils, occurring in higher concentrations than the other analyte groups. Although the distribution of organic contamination appears somewhat random with regard to depth, suites of organic contaminants appear to be associated with different disposal areas. Aggregate I, BG-A North, is dominated by toluene, PCBs, 1,1,1-TCA and 1,1-DCA; Aggregate II, BG-A South, is characterized by acetone, toluene, PCE, and TCE; Aggregate III, comprising BG-A-16, -17, and -18, is unique in that PAHs and phthalates are present in addition to toluene, PCBs, and 2-butanone. Aggregate IV, located west of NT-7 in the region of WIP North and South, BG-B, and BG-D South, is characterized primarily by toluene and PCBs. Aggregate V, BG-C West, is characterized by a variety of organic contaminants, dominated by acetone, toluene, PCE, PCBs, and 4-methyl-2-pentanone. Aggregate VI, comprising BG-D East and BG-C East, is dominated by PCBs and toluene.

Groundwater

- Groundwater contamination in the vicinity of the BCBG is dominated by VOCs, containing only minor concentrations of metals and radionuclides. This suite of contaminants reflects BCBG

operations, which involved pouring solvents and oils into unlined trenches. Historical data indicate the presence of free-phase DNAPL and LNAPL.

- Metals contamination in groundwater is highly sporadic: relatively few wells are contaminated with metals or semi-metals, and no distinct plume of contaminated groundwater can be delineated. Most contaminated groundwater is associated with older, shallow bedrock and water table interval wells located close to the BG-A North and South (most notably, GW-014, -021, -027, and -039).
- Almost no radioactively contaminated groundwater has been detected at BCBG. Despite the extensive amounts of radioactively contaminated materials disposed of in the trenches at BCBG, the extent of radioactive contamination of groundwater is surprisingly small. Gross α activity is detected above background in only 8 of 47 wells. The overall frequency of detection is 10 of 408 samples (2%), and only 3 wells (GW-040, -643, and -655) have more than one detect of gross α between 1991 and 1994. Gross β has a frequency of detection of 26 of 408 (6%), with activities above background occurring in 16 wells.
- Groundwater contamination in the BCBG FA is dominated by VOCs, which occur in three separate plumes associated with BG-A, WIP, and BG-C East and West.
- **BG-A.** Groundwater contamination at this site is dominated by PCE, TCE, and 1,2-DCE, and 1,1,1-TCA, 1,1-DCA, and 1,2-DCA are commonly found in lower concentrations. The presence of DCE, DCA, vinyl chloride, and CE indicates that breakdown of parent compounds PCE, TCE, and 1,1,1-TCA has occurred. In all cases where daughter products are present, the suite of daughter products is consistent with breakdown of the parent products detected in that well.

In some wells, the maximum concentrations of total VOCs is >60,000 ppb, with many samples showing concentrations of VOCs >1% of solubility, indicating pervasive DNAPL in the subsurface. DNAPLs have been detected between 24.4 and 30.5 m (80 and 100 ft) down dip and have probably migrated to depths of 152 m (500 ft) in the Nolichucky Shale.

- **WIP South.** Four wells adjacent to WIP South are contaminated with PCE and almost no other VOCs; this lack of diversity is the defining feature of this contaminant suite. Concentrations of PCE reach a maximum of 2100 ppb (~1% of solubility), which indicates the presence of DNAPL.
- **NT-8 catchment.** Wells GW-082 and GW-242 both have VOC contamination, primarily 1,2-DCE (130 $\mu\text{g/L}$) with minor concentrations of vinyl chloride. PCE and TCE are absent from this plume. Although the contaminant suites in these two wells are almost identical, the wells are geographically separate; therefore, these wells probably do not define a continuous plume of contamination. The likely sources of the plumes in GW-082 and GW-242 are BG-C East and BG-C West, respectively.
- Parent chemicals, PCE and TCE, are apparently migrating west in bedrock along strike west of BG-A. During 1990 to 1991, two wells (GW-627 and GW-629) both recorded breakthrough of PCE into the well. The most likely source of PCE in these wells, which are located between 152 and 229 m (500 and 750 ft) along strike from BG-A South, is along strike migration of a dissolved PCE plume.

Surface Water

- Surface water contamination at BCBG is also dominated by VOCs, with lower concentrations of radioactivity and metals. All three streams draining the BCBG are contaminated with a variety of VOCs consistent with BCBG operations and with the elevated VOC concentrations in groundwater. The concentrations of total VOCs and the variety of chemicals detected are greater in NT-7 and NT-8 (mean total VOCs of 352 $\mu\text{g/L}$ and 391 $\mu\text{g/L}$, respectively) than in NT-6 (mean of 35 $\mu\text{g/L}$).
- The primary VOC contaminants in NT-7 are 1,2-DCE, PCE, and TCE, with minor concentrations of vinyl chloride and CE. The contaminant suite in NT-8 is dominated by 1,2-DCE, with lower concentrations of PCE and vinyl chloride.
- Historical data for 1984 indicate that VOC contamination to surface water in NT-7 was derived from BG-A South.
- Data from the leachate collection systems and from two samples taken at the headwaters of NT-8 indicate that, in Seep 2 and adjacent to BG-C East, the principal VOC contaminant in NT-8 is CE, with little or no PCE and 1,2-DCE contamination. These data indicate that 1,2-DCE contamination enters NT-8 downstream from Seep 2, probably in the reach alongside the BG-C West cap.

Ecological Habitat

- Terrestrial habitats provide potential exposures of biota to contaminants in soil and soil pore water, especially where contaminants occur close to the surface.
- Wetlands on NT-6 and NT-8 create potential exposures of amphibians and insects to contaminants in soil, surface water, and sediment.
- Toxicity has not been demonstrated in water from NT-6, -7, or -8.

D.8.10 INTERPRETIVE CONCLUSIONS AND WORKING HYPOTHESES

D.8.10.1 Inorganics and Radionuclides

Despite the large mass of radionuclides and metals (uranium in particular) known to have been disposed of in the BCBG, soil and groundwater are relatively free of contamination by metals and radionuclides. However, surface water is radiologically contaminated and sporadically contaminated with metals.

Soils

The relatively small extent of inorganic and radiological contamination in BCBG soils indicates that few or no metals or radionuclides have migrated laterally across strike out of the trenches to areas that were sampled during the BCVR RI. However, a number of contaminated seeps occur in the NT-7 and NT-8 catchments (Bogle, Turner, and Easterling 1991; Herbes 1988), which have been considerably impacted by BCBG activities. These seeps are located along strike from the trenches in the neighboring BCBG, indicating that the primary migration route for inorganic and radionuclide

contamination away from the trenches prior to capping was along strike. The seeps were remediated during capping of the BCBG.

The lack of apparent lateral migration of metals and radionuclide can also be attributed, in part, to their lack of mobility in the BCBG environment. Shallow groundwater is slightly acidic to neutral alkaline, and the clay-rich residuum provides a large potential for adsorption of dissolved ions. Therefore, few metal species are likely to partition into solution and become mobile.

The working hypothesis for soils is that, outside of the burial areas and around the caps, soils at the BCBG are relatively free of secondary metal and radiological contamination.

Groundwater and Surface Water

For groundwater, the apparent lack of radiological contamination is somewhat inconsistent with the high activity concentrations present in surface waters. This inconsistency can be best explained by the hypothesis that radiological contamination of groundwater occurs only in the shallowest water table interval of the subsurface and, consistent with the BCV hydrogeologic conceptual model, the shallow groundwater discharges rapidly to the surface water. Thus, radiological contamination of groundwater remains shallow and localized near the contamination source (the trenches containing uranium). This hypothesis cannot be confirmed because no groundwater monitoring points at BCBG are located within the correct depth ranges to detect the radiological contamination if it exists.

The most likely regions for radionuclide contamination of shallow groundwater are the BG-C East and BG-A South areas, with BG-C East probably having higher concentrations. Surface water in the headwaters of NT-8 and in Seep 2 is radiologically contaminated, primarily by isotopes of uranium. The BG-C East area was used to dispose of uranium chips; this set of trenches is inundated with groundwater most of the time. The maximum activity of uranium in this reach of NT-8 has apparently changed little since samples were taken in 1984, suggesting that the concentration of uranium isotopes is primarily a function of the solubility of uranium in the BG-C East area and is not a function of availability.

The working hypothesis for radionuclide movement in the BCBG is that uranium leaching out of trenches migrates to surface water streams along short pathways in the residuum. The concentrations of uranium in groundwater are controlled by the solubility of uranium, as discussed in Appendix E. Trenches in BG-C East and BG-A South that are inundated with groundwater appear to have a greater impact on groundwater and surface water contamination.

D.8.10.2 Organics

Organic contamination of environmental media at BCBG is more widespread than inorganic contamination. The predominance of organic contamination probably reflects the type of waste materials disposed of in the BCBG: organic wastes were disposed of as liquids, which have migrated more easily in their pure form.

Soils

Soils sampled during the BCV RI were generally contaminated with small quantities of VOCs and PCB. Except for soils at BG-A-16, -17, and -18, soils are not contaminated with PAHs. Extensive soil contamination with PCBs at the BCBG has been documented in the past and, for the most part, has been remediated by excavation and capping. PCBs were detected in relatively low concentrations in the soils around the BCBG but show no distinct distribution. The working hypothesis is that, like

most of the waste sites in BCV, soils at the BCBG are sporadically contaminated with PCBs. Historical data indicate that PCB contamination inside trench areas, particularly BG-A and BG-B, is extensive and occurs at relatively high concentrations. Detection of PCBs in DNAPL samples from wells adjacent to of BG-A indicates that free-phase oils and solvents containing high concentrations (27,000 $\mu\text{g/g}$) of PCBs exist in the trenches and in the ground down dip from the trenches.

Groundwater and Surface Water

Organic contamination of groundwater is extensive and is closely related to the presence of DNAPL, which probably occurs widespread in the subsurface. DNAPL is probably associated with each of the defined plumes in the BCBG and is the apparent reason why the organic plumes differ. Although the dominance of the hydraulic system by shallow flow restricts inorganic contamination to the shallow groundwater intervals, density-driven flow of DNAPL provides a mechanism for organic contamination to enter the shallow-, intermediate-, and deep-bedrock intervals. This mechanism is comparable to that hypothesized for the S-3 Ponds, where density-driven recharge for contaminated pond waters is believed to cause contamination of the deep system, and constitutes a primary feature of contaminant distribution in BCV as a whole.

In addition, along-strike migration of PCE appears to be occurring west of BG-A South. Two wells screened in bedrock have detected breakthrough of dissolved PCE into the well during 1990 to 1991. This moving plume of dissolved PCE is contained in the bedrock; however, the extent along strike to which this plume has migrated is not known.

The presence of daughter products in the PCE, TCE, and 1,1,1-TCA breakdown pathway may indicate that the original parent chemicals have undergone breakdown to some extent. The extent of breakdown differs substantially between the plumes. In BG-A, variable amounts of daughter products indicate that breakdown is variable; however, the concentrations of breakdown products in shallow groundwater are generally greater than in the deep bedrock. WIP is marked by an almost complete absence of breakdown products, whereas BG-C is marked by an almost complete absence of parent compounds. The reasons for these variations are speculative at best. Likely, parameters affecting the extent of breakdown are the timing of chemicals disposals, the availability of other organic compounds to act as energy sources to microbes, and, possibly, the presence of zero-valent metal (uranium) in trenches.

The suite of VOCs contaminating surface water is consistent with that in groundwater. Surface water contamination in NT-7 has a similar suite of VOCs to that in the BG-A plume, which is probably the primary source of VOCs to NT-7. The WIP plume is located in shallow-bedrock groundwater, but may not discharge extensively to surface water. Surface water contamination in NT-8 has a similar suite of VOCs to that in the BG-C East and West plumes. However, discharge from the BG-C East plume at Seep 2 is dominated by CE, with almost no 1,2-DCE; therefore, the primary source of 1,2-DCE (the main contaminant in NT-8) is probably the BG-C West plume. The apparent lack of 1,2-DCE contamination in Seep 2 and the NT-8 headwaters is somewhat unusual because groundwater in GW-242 directly upgradient of Seep 2 is contaminated with 1,2-DCE with no detectable CE. However, the flow path from GW-242 to Seep 2 in shallow groundwater passes through a series of trenches containing zero-valent uranium, which has possibly promoted breakdown of the 1,2-DCE to CE in a similar manner to that observed for zero-valent iron (Gillham and O'Hannesin 1992).

The working hypothesis for organic contamination at the BCBG is that three areas of contamination exist: BG-A, where VOC contamination is at all depths; WIP, where contamination is mainly in the bedrock interval; and BG-C, where contamination is in the shallow interval only. At

BG-A and WIP, the dissolved organic plumes are maintained by DNAPL in the subsurface. Whether DNAPL is present at BCBG is not known. A certain amount of breakdown of parent chemicals has occurred; however, close to the DNAPL sources in the subsurface, dissolved plumes are composed primarily of the parent compounds. In general, the extent of breakdown is greater in the NT-8 catchment than in the NT-7 catchment.

D.9 MAYNARDVILLE LIMESTONE AND BEAR CREEK FUNCTIONAL AREA

The Maynardville Limestone and Bear Creek FA is composed of seven surface water and one groundwater data aggregates as well as the BCV FPSS investigation database, which cover the soils and sediments in the Bear Creek floodplain, groundwater in the Maynardville Limestone, and surface water in the main stem of Bear Creek. These environmental media represent the downgradient pathways and receptors of contaminants migrating away from the source sites in BCV. Table D.6 lists the groundwater wells in the Maynardville Limestone groundwater aggregate, and Fig. D.5 shows their locations.

D.9.1 HYDROGEOLOGY OF THE MAYNARDVILLE LIMESTONE AND BEAR CREEK

The Maynardville Limestone forms the central axis of BCV; in general, hydraulic head in the Maynardville Limestone is lower than those in the underlying Conasauga Group formations of Pine Ridge and in the overlying Copper Ridge dolomite (Figs. C.14 and C.15 in Appendix C). This configuration means that the Maynardville Limestone and Bear Creek constitute the hydraulic low point of the valley and, therefore, a drain for BCV. The detailed hydrogeology of the Maynardville Limestone and Bear Creek is discussed in Appendix C as part of the BCV conceptual hydrogeological model. This section summarizes the primary points that are pertinent to contaminant migration.

One principal feature affecting contaminant migration in the Maynardville Limestone is the solution cavity system that occurs above 30-m (100-ft) depth (Shevenell, Dreier, and Jago 1992). The distribution of this cavity system is widespread in the Maynardville Limestone and Copper Ridge Dolomite. The occurrence of dissolution features and cavities in the Maynardville Limestone shows a qualitative relationship to stratigraphic height in the formation; in general, cavities and solution features are most common in the upper stratigraphic section of the Maynardville, followed by shallow intervals of Zone 2 in the lower stratigraphic sections (Fig. C.8 in Appendix C; Goldstrand and Dreier 1993). In some cases, the shallow interval of the Maynardville Limestone is so cavernous that the Maynardville Pathway Program had great difficulty installing wells through this interval (Shevenell, Dreier, and Jago 1992).

Shevenell, Moore, and Dreier (1994) identify quickflow occurrence in shallow wells in the Maynardville Limestone based on well hydrograph analysis, which is attributed to rapid flow in the cavity system. The cavity system in the Maynardville Limestone in BCV apparently has good interconnectivity and is able to transmit water rapidly along strike in the shallow interval. The occurrence of this cavity system and the evidence that supports quickflow in shallow wells suggest that this interval is the focus for the major portion of westward flow in groundwater in BCV.

Below 30 m (100 ft), solution cavities are less common; however, Dreier, Solomon, and Beaudoin (1987) identify numerous water-bearing zones that relate to fractures observed in core materials. As is described in later sections, continuous plumes of contaminated groundwater occur in the interval of the Maynardville Limestone between ~30 m (100 ft) and 150 m (500 ft). In addition, hydrograph analysis of groundwater wells screened in this interval in the Maynardville Limestone (Appendix C, Fig. C.25) shows that water bearing fractures up to 150 m (500 ft) depth are hydraulically well connected. The 30 m (100 ft) and 150 m (500 ft) interval in the Maynardville Limestone provides an important pathway for contaminants to migrate along strike in groundwater.

The cavity system, which conducts flow westward under Bear Creek, plays an important role in the surface water hydrology of BCV. Thus, the system probably constitutes an important avenue for contaminant transport because contaminants in the surface water can be lost within the system, which extends outside the BCHR. In 1988 tracers placed in Bear Creek and BCK 10.41 were observed to break through in SS-5 ~5.5 d later (Geraghty and Miller 1989). This observation demonstrates that a component of flow at SS-5 comes from BCV surface water flow, which is presumably recharged from a losing reach of Bear Creek into the shallow groundwater in the Maynardville. Flow in the shallow Maynardville Limestone interval subsequently transported the tracer to SS-5 ~914 m (3000 ft) in 132 h (~6.9 m/h or 22 ft/h), demonstrating that contaminants can migrate rapidly along BCV in either surface water or groundwater. This study also concludes that, although the tracer was not detected in SS-4 (because the tracer was injected into the creek too far downstream to be captured in SS-4), the similar chemistry of SS-4 and SS-5 suggests that a component of flow at SS-4 might also be derived from shallow groundwater and, ultimately, from Bear Creek.

In some of the upper sections of BCV, flow in Bear Creek is ephemeral. During the dry months in summer and fall, the creek channel is commonly dry in a reach between NT-3 and NT-8. Below BCK 9.47, Bear Creek is a perennial stream. Both the low- and high-flow periods exhibit similar patterns along BCV.

Figure D.110 shows the hydrographs for BCK 9.47 and SS-5 from March 1994 to January 1995. The hydrograph for BCK 12.38 is contained on Fig. D.33, and the hydrographs for SS-1, -4, and -6 are shown on Fig. D.111. The volume of stream flow at BCK 9.47 is the highest recorded during flow monitoring for BCV OU 4, as is expected from its location at a point where the flows from all upstream tributaries to Bear Creek coalesce. Like flows in the tributary streams, flow at BCK 9.47 is "flashy," reflecting conditions in this section of the drainage system in BCV. The maximum flow at this site exceeded 10,000 L/s on three occasions during Spring 1994. BCK 9.47 is located in a rock pool between two small rapids; between September and December 1994, stream stage at BCK 9.47 was usually at its minimum value, reflecting the height of water in the rock pool. Small variations in flow were difficult to measure at this stage; however, the stream at the exit to the pool never stopped flowing, and the values recorded for flow are probably a good representation of actual flow.

Variability of the flow in the monitored springs (SS-1, -4, -5, and -6) is much less than that in the stream channels, as would be expected from the groundwater origin of these flows. Only SS-6 is an ephemeral spring; no flow, other than storm flow, was recorded at this site between September and December 1994. However, ~100 m west of the SS-6 spring monitored during the BCV OU 4 field activities is a second spring, which flows year round. In general, flow in SS-5 is ~2 to 3 times that in SS-4 and an order of magnitude greater than that in SS-1. During storm events, each spring showed brief maxima in the hydrographs, which probably relate to either overland flow or storm flow in the immediate catchment of the spring.

The data indicate that these sites are hydraulically connected via a surface water pathway during high-flow periods (winter and spring) and that, consequently, contaminant concentrations in these reaches of the stream react similarly. However, during low-flow periods, the direct pathway is not available for contaminant migration because some reaches of Bear Creek are dry. Contaminant concentrations in Bear Creek at BCK 9.47 during low-flow periods are governed more by groundwater than by surface water.

Flow in the creek varies in an alternating, step-wise fashion down BCV in response to gaining and losing reaches (Fig. C.25, Appendix C). A major spring or spring appears to be associated with each increase in flow (SS-2 and SS-3 at 48,500E; SS-4 at 43,500E; SS-5 at 41,250E; SS-6 at

35,250E; and SS-7 and SS-8 at 30,000E) and, in at least one case (SS-5), is probably associated with additional groundwater discharge to the creek. This pattern may indicate that the major springs in the floodplain of BCV are associated with general groundwater discharge zones, not just the discharge from the individual spring.

D.9.2 FLOODPLAIN SOILS AND SEDIMENTS

Floodplain soils and sediments were collected and analyzed in several phases, as detailed in Appendix C, Sect. C.5. Floodplain soil samples were collected from 13 transects oriented perpendicular to Bear Creek. Each transect consisted of six sampling stations with three stations on either side of the creek. Soil samples were taken from three depth intervals — 0 to 10 cm (0 to 4 in.), 10 to 41 cm (4 to 16 in.), and 41 to 81 cm (16 to 32 in.) — or to sampler refusal, whichever came first. These samples were homogenized and field screened for (1) γ radiation using an NaI scintillation detector and (2) VOCs using a MiniRAE to detect head-space concentrations. Aliquots of each sample were also sent to the Y-12 Laboratory for PCB screening. Stations whose screening samples had PCB concentrations >0.5 mg/kg, β/γ activity >247 cpm, and/or VOC levels >5 mg/kg were classified as areas for further investigation (AFIs). The AFIs were subjected to a second round of sampling in which samples were collected from those depth intervals that had yielded samples exceeding any of the sampling action levels for PCBs, radioactivity, or VOCs. The AFI samples were sent for laboratory radiological and chemical (inorganic, semivolatile, PCB/pesticide, and herbicide) analysis. The analytical results for the floodplain soils are summarized in Table D.98.

Floodplain sediment samples were collected from the BCV floodplain and stream channel, and sent off site for radiological and chemical (inorganic, semivolatile, PCB/pesticide, and herbicide) analysis. The results of the sediment analyses are summarized in Table D.101.

Soil samples collected from the AFIs and sent for laboratory analysis included 16 samples from the 0- to 10-cm (0- to 4-in.) depth interval, 16 from the 10- to 41-cm (4- to 16-in.) depth interval, and 5 from the 41- to 81-cm (16- to 32-in.) depth interval. Table D.102 presents the transect and station identifiers, sample numbers, and depth increments for these AFI samples. A total of 18 sediment grab samples were taken at the sediment-surface water interface. The floodplain soil and sediment analyses are discussed below, aggregated by depth interval, with sediment data included in the 0- to 10-cm (0- to 4-in.) aggregate.

D.9.2.1 Inorganic Elements and Compounds in BCV Floodplain Soils and Sediments

A total of 10 inorganic elements or compounds (beryllium, cadmium, copper, cyanide, lead, lithium, mercury, nickel, selenium, and thallium) were detected in concentrations above their background criteria (Tables D.98, D.99, and D.100), and 15 inorganic elements or compounds (antimony, barium, beryllium, cadmium, chromium, cobalt, copper, lead, lithium, manganese, mercury, nickel, selenium, vanadium, and zinc) were detected above their background criteria in floodplain sediments (Table D.101). The distributions of cadmium, lithium, mercury, and selenium within each depth interval are shown on Figs. D.112 to D.115 as representative of inorganics distribution in the BCV floodplain. These four elements were selected because of their frequency of detection and ranges in concentration. Figures D.112 to D.115 show the maximum concentration of each element in each depth interval.

0- to 10-cm (0- to 4-in.) depth interval. Eight of the ten site-related inorganic elements and compounds in the floodplain soils (all except lead and nickel) exceed their background criteria in the 0- to 10-cm (0- to 4-in.) depth interval.

Cadmium was detected above its background criterion (0.31 mg/kg) in 9/16 samples in the 0- to 10-cm (0- to 4-in.) interval, with a maximum concentration of 9.3 mg/kg (Table D.98). Cadmium was detected above its background criterion in 8/18 floodplain sediment samples, with a maximum concentration of 21.7 mg/kg. As shown in Fig. D.112, three of the four highest cadmium concentrations in the BCV floodplain occur in sediments from SD-02, -07, and -14. SD-02 is located just upstream of the confluence of NT-1 in the S-3 FA. SD-07 is located just downstream of the confluence of NT-4, immediately below the OLF FA. SD-14 is located at the confluence of NT-3 with Bear Creek in the OLF FA. The highest reported concentration of cadmium in the 0- to 10-cm (0- to 4-in.) floodplain soils (9.3 mg/kg) occurs in TS-01, which is located downstream of the confluence of NT-1 with Bear Creek near the S-3 FA (Fig. D.112).

Lithium was detected in soils and sediments at concentrations above its background criterion (33 mg/kg) four times in the 0- to 10-cm (0- to 4-in.) depth interval (Tables D.98 and D.101). These detects occur in transects TS-01 and -04 (maximum values of 41.0 and 55.2 mg/kg, respectively) and in sediment samples SD-09 and -12 (45.0 and 69.0 mg/kg, respectively). TS-01 meets Bear Creek downstream from the S-3 Site, and TS-04 includes the lowermost portion of NT-8 as it joins Bear Creek (Fig. D.113). SD-09 is located on NT-8, just below the confluence of the two branches of this tributary. SD-12 is located south of Bear Creek proper between NT-12 and -13 (Fig. D.113).

Mercury was detected in concentrations above its background criterion (0.34 mg/kg) in the 0- to 10-cm (0- to 4-in.) interval in 11 floodplain soil samples and 3 sediment samples (Tables D.98 and D.101). Maximum concentrations in soil samples from this interval range from 0.36 mg/kg in TS-13 to 7.3 mg/kg in TS-01 (Fig. D.114). The 7.3-mg/kg detection is the highest mercury concentration in any floodplain soil or sediment sample and occurs at soil location. Mercury concentrations in the sediment samples range from 0.53 mg/kg in SD-07 to 6.9 mg/kg in SD-04.

Selenium was detected in concentrations above its background criterion (1.2 mg/kg) in 12 floodplain soil samples (TS-01 through -08, -10 and -13) and at 14 sediment sampling stations (SD-01 through -14) (Tables D.98 and D.101 and Fig. D.115). The highest concentrations occur in sediments, with a maximum reported value of 6.7 mg/kg. Selenium concentrations in all floodplain soils samples in which selenium is an SRC range between 1.2 and 3.2 mg/kg, which barely exceeds the background criterion (Fig. D.115).

Other inorganic elements and compounds detected in floodplain soils at concentrations above their background criteria in the 0- to 10-cm (0- to 4-in.) depth interval, but not plotted on Figs. D.112 through D.115, include (Table D.101) beryllium (2/16 samples), copper (1/16 samples), cyanide (1/16 samples), and thallium (1/16 samples) (Table D.98). Other inorganic elements and compounds detected in concentrations above their background criteria in sediments, but not plotted on Figs. D.112 through D.115, include antimony (1/17 samples), barium (6/18 samples), beryllium (1/18 samples), chromium (2/18 samples), cobalt (2/18 samples), copper (1/18 samples), lead (4/18 samples), manganese (5/18 samples), nickel (4/18 samples), vanadium (2/18 samples), and zinc (4/18 samples).

10- to 41-cm (4- to 16-in.) depth interval. Concentrations of seven inorganic elements or compounds exceed their background criteria in the 10- to 41-cm (4- to 16-in.) depth interval of floodplain soil samples (Table D.99). The maximum cadmium concentration in this depth interval (11.1 mg/kg) occurs in TS-03, which is located between NT-6 and NT-7 in the vicinity of the BCBG FA. Cadmium also occurs in concentrations above background in TS-01, -05, -06, and -07 (Fig. D.112). Cadmium does not occur in concentrations above background in any transect downstream from TS-07.

Lithium was detected in concentrations above its background criterion in this depth interval at two transects (Fig. D.113), with maximum concentrations of 33.4 mg/kg in TS-03 and 39.1 mg/kg in TS-04.

Mercury was detected in concentrations above its background criterion in the 10- to 41-cm (4- to 16-in.) depth interval in TS-01 through -04. Mercury is not an SRC in this depth interval downstream from TS-04 (Fig. D.114). Selenium occurs in concentrations above its background criterion in the 10- to 41-cm (4- to 16-in.) depth interval of TS-01 through -10 and TS-13 (Fig. D.115). Maximum selenium concentrations in samples from these transects range from 1.2 to 2.8 mg/kg, which do not greatly exceed the background criterion for selenium.

Other inorganic elements and compounds detected in concentrations above their background criteria in the 10- to 41-cm (4- to 16-in.) depth interval, but not shown on Figs. D.112 through D.115, include (Table D.98) beryllium (1/16 samples), lead (1/16 samples), and nickel (2/16 samples).

41- to 81-cm (16- to 32-in.) depth interval. Cadmium, mercury, and selenium are the only inorganic elements detected in the 41- to 81-cm (16- to 32-in.) depth interval at concentrations exceeding their background criteria (Table D.100 and Figs. D.112 to D.115). The maximum cadmium concentration (0.31 mg/kg) in TS-12 is equal to the background criterion for cadmium. Mercury was detected in TS-12 at a concentration of 0.47 mg/kg, which is slightly above its background criteria of 0.34 mg/kg. Selenium was detected in concentrations above its background criterion in this depth interval in TS-6, -11, and -12 at concentrations ranging from 1.6 to 2.7 mg/kg.

D.9.2.2 Radionuclides in BCV Floodplain Soils and Sediments

Six radionuclides were detected at activity concentrations above their background criteria in floodplain soils (Tables D.98, D.99, and D.100): ^{241}Am , ^{243}Cm , ^{99}Tc , ^{234}U , ^{235}U , and ^{238}U . Except for ^{243}Cm , the same radionuclides were also detected at activity concentrations above background in floodplain sediments (Table D.101). The distributions of ^{99}Tc and ^{238}U are shown on Figs. D.116 and D.117 as representative of radionuclides distribution in floodplain soils and sediments. These two radionuclides were selected because of the frequency of their detections and their ranges of activity concentrations. Maximum activity concentrations are shown on Figs. D.116 and D.117.

A substantial number of radiological values for the FPSS investigation were rejected, primarily because of low sample recovery (<20%), which caused the reported value to be lower than the actual activity concentration in the sample (see Sect. B.7). These data are included in the data summary Tables D.98, D.99, D.100, and D.101 and on Figs. D.116 and D.117, with the caveat that actual activity concentrations are somewhat higher.

0- to 10-cm (0- to 4-in.) depth interval. All six of the site-related radionuclides occur in the 0- to 10-cm (0- to 4-in.) interval of floodplain soils, and all except ^{243}Cm occur in floodplain sediment samples (Tables D.98 and D.101). Technetium-99 occurs at activity concentrations above its background criterion (4.07 pCi/g) in the upper portion of BCV between tributaries NT-1 and NT-8. The elevated ^{99}Tc activity concentrations occur in 6/16 floodplain soil samples from the 0- to 10-cm (0- to 4-in.) interval, with a maximum activity concentration of 11.98 pCi/g, and in 3/18 sediment samples, with a maximum activity concentration of 8.74 pCi/g (Fig. D.116). Technetium-99 is an SRC in sediment samples only in the vicinity of NT-1, -2, and -8 (SD-02, -14, and -09) (Fig. D.116).

Uranium-238 was detected in activity concentrations above its background criterion (2.6 pCi/g) in 14/16 floodplain soil samples, with a maximum activity concentration of 67 pCi/g (Tables D.98 and D.101). In floodplain sediment samples, activity concentrations of ^{238}U exceed background in

11/18 samples, with a maximum detected activity concentration of 36.53 pCi/g (Tables D.98 and D.101). Uranium-238 is an SRC in floodplain soils and/or sediments in the 0- to 10-cm (0- to 4-in.) depth interval along the entire length of BCV (Fig. D.117).

Other radionuclides detected at activity concentrations above their background criteria in the 0- to 10-cm (0- to 4-in.) depth interval (Tables D.98 and D.101), but not plotted on Figs. D.116 and D.117, include ^{241}Am , ^{243}Cm , ^{234}U , and ^{235}U . Americium-241 activity concentrations exceed background (0.06 pCi/g) in 6/15 floodplain soil samples (0.16 pCi/g maximum) and in 3/18 floodplain sediment samples (0.07 pCi/g). Curium-243 activity concentrations exceed background (0.08 pCi/g) in 1/15 floodplain soil samples (0.14 pCi/g).

Uranium-234 and ^{235}U are widespread SRCs in the 0- to 10-cm (0- to 4-in.) depth interval of the Bear Creek floodplain. Uranium-234 activity concentrations exceed background (3.2 pCi/g) in 13/16 floodplain soil samples (25.36 pCi/g maximum) and in 11/18 floodplain sediment samples (36.53 pCi/g maximum). Uranium-235 activity concentrations exceed background (0.24 pCi/g) in 13/16 floodplain soil samples (2.66 pCi/g maximum) and in 6/18 floodplain sediment samples (1.24 pCi/g maximum).

10- to 41-cm (4- to 16-in.) depth interval. Six radionuclides were detected at activity concentrations above their background criteria in the 10- to 41-cm (4- to 16-in.) depth interval of the floodplain soils (Fig. D.117 and Table D.99). These radionuclides are the same site-related radionuclides identified in the 0- to 10-cm (0- to 4-in.) depth interval of the floodplain soils (see above).

Of the 16 floodplain soil samples from the 10- to 41-cm (4- to 16-in.) depth interval, ^{99}Tc occurs as an SRC only in TS-04, with an activity concentration of 6.45 pCi/g. Uranium-238 is an SRC in 7/16 floodplain soil samples from this depth interval, with a maximum detected activity concentration of 94.35 pCi/g in TS-04. Transects TS-03 and TS-04 both have maximum activity concentrations >50 pCi/g (51.94 and 94.35 pCi/g, respectively). Both transects are located in the vicinity of the BCBG: TS-03 is located just upstream of NT-7, and TS-04 is located at the confluence of NT-8 and BCV (Fig. D.117).

Other radionuclides detected in floodplain soils at activity concentrations above their background criteria, but not shown on Figs. D.116 and D.117, include ^{241}Am [2/16 samples, with a maximum of 0.06 pCi/g (equal to background)], ^{243}Cm (1/16 samples, maximum 0.19 pCi/g), ^{235}U (5/16 samples, maximum 2.04 pCi/g), and ^{234}U (7/16 samples, maximum 32.81 pCi/g).

41- to 81-cm (16- to 32-in.) depth interval. Four radionuclides were detected at activity concentrations above their background criteria in the 41- to 81-cm (16- to 32-in.) depth interval of the Bear Creek floodplain: ^{241}Am occurs in 1/5 samples, with a maximum of 0.07 pCi/g in TS-06; ^{238}U occurs in 1/5 samples, with a maximum of 4.32 pCi/g in TS-12; ^{235}U occurs in 1/5 samples, with a maximum of 0.41 pCi/g in TS-12; and ^{234}U occurs in 1/5 samples, with a maximum of 4.08 pCi/g in TS-12 (Table D.100).

D.9.2.3 PCBs/Pesticides in BCV Floodplain Soils and Sediments

A total of 3 herbicides, 18 pesticides, and 2 PCBs were detected in BCV floodplain soils, and 2 herbicides, 20 pesticides and 2 PCBs were detected at least once in floodplain sediments (Tables D.98, D.99, D.100, and D.101). The distribution of total PCBs (Aroclor-1254 and Aroclor-1260) is shown on Fig. D.118 as representative of the PCBs/pesticides distribution in the BCV floodplain.

0- to 10-cm (0- to 4-in.) depth interval. PCBs and pesticides are prevalent in the 0- to 10-cm (0- to 4-in.) depth interval of the Bear Creek floodplain soils and sediments. The most commonly detected compounds in this depth interval of the floodplain soils are the pesticides alpha-chlordane (12/16 samples), dieldrin and endrin aldehyde (11/16 samples), and PCBs (17/16 samples). Concentrations are generally low ($<1 \mu\text{g/kg}$), except for most frequently detected compounds (Table D.98). The maximum total floodplain concentration for total PCBs in the 0- to 10-cm (0- to 4-in.) depth interval is $1300 \mu\text{g/kg}$ at transect TS-07 (Fig. D.118), followed by total PCB values $>1000 \mu\text{g/kg}$ at transect TS-10 (Fig. D.118).

The most commonly detected compounds in floodplain sediments are the pesticides 4,4'-DDE (12/17 samples), endrin aldehyde (13/17 samples), and total PCBs (16/18 samples). Concentrations for most of the compounds listed on Table D.101 are low, except for those detected most frequently. The maximum total PCB concentration in floodplain sediments was $2500 \mu\text{g/kg}$, which occurs in sediment sample SD-09, located just upstream of transect TS-04 (Fig. D.118). Average total PCB concentrations $>1000 \mu\text{g/kg}$ were also detected in sediment samples SD-04 and -10 (Fig. D.118).

10- to 41-cm (4- to 16-in.) depth interval. PCBs and pesticides were detected less frequently and at lower concentrations in floodplain soils in the 10- to 41-cm (4- to 16-in.) depth interval than in the 0- to 10-cm (0- to 4-in.) interval (Table D.99 and Fig. D.118). The maximum total PCB concentration detected in this depth interval ($1700 \mu\text{g/kg}$) occurs in transect TS-04 (Fig. D.118). The maximum total concentration of PCBs in the other transects is $<500 \mu\text{g/kg}$.

41- to 81-cm (16- to 32-in.) depth interval. PCBs and pesticides were detected in floodplain soils even less frequently and at lower concentrations in the 41- to 81-cm (16- to 32-in.) depth interval than in the shallower intervals (Table D.100 and Fig. D.118). As seen on Fig. D.118, PCBs were detected only at transects TS-06 and TS-12; all average total concentrations by transect for PCBs were $<50 \mu\text{g/kg}$.

D.9.2.4 Semivolatiles in BCV Floodplain Soils and Sediments

A total of 12 SVOCs were detected in the Bear Creek floodplain soil samples, and 20 SVOCs were detected in the Bear Creek floodplain sediment samples (Tables D.98, D.99, D.100, and D.101). These compounds mostly fall into two groups of organic compounds: phthalates and PAHs. The distributions of total PAHs and total phthalates are shown on Figs. D.119 and D.120 as representative of the SVOCs distribution in the BCV floodplain. Table D.38 lists the specific chemicals included in each group. In addition, three of the SVOCs were each detected one time in the floodplain sediments: 4-methylphenol, carbazole, and dibenzofuran (Table D.101).

0- to 10-cm (0- to 4-in.) depth interval. Maximum total PAH concentrations in the 0- to 10-cm (0- to 4-in.) depth interval range from 46 to $1195 \mu\text{g/kg}$ in the floodplain soil samples and from 380 to $65,878 \mu\text{g/kg}$ in the floodplain sediment samples (Fig. D.119). The maximum concentration for total PAHs occurs in sediment sample SD-04, which is near the confluence of NT-3 with Bear Creek. The other soil transects and sediment samples show fairly consistent concentrations of PAHs (on the order of 100 to $1000 \mu\text{g/kg}$) all along BCV (Fig. D.119). Phthalates show an equally consistent distribution along BCV, with maximum total concentrations ranging from 40 to $920 \mu\text{g/kg}$ (Fig. D.120).

10- to 41-cm (4- to 16-in.) depth interval. Like PCBs, PAHs and phthalates become less important with depth in the Bear Creek floodplain. For example, PAHs were detected in only two transect borings in the 10- to 41-cm (4- to 16-in.) interval, compared to five detections in the 0- to 10-cm (0- to 4-in.) interval. The maximum concentration of total PAHs is $1163 \mu\text{g/kg}$, significantly

less than that observed in the overlying interval. Phthalates were detected in eight transect borings in the 10- to 41-cm (4- to 16-in.) interval, compared to 10 detections in the 0- to 10-cm (0- to 4-in.) interval, with a maximum concentration (420 $\mu\text{g/kg}$), substantially less than that observed in the overlying interval.

41- to 81-cm (16- to 32-in.) depth interval. The trend of decreasing detections and concentrations of PAHs and phthalates with depth in the Bear Creek floodplain continue into the deepest sampling interval. PAHs were detected only one time in the 41- to 81-cm (16- to 32-in.) interval, and phthalates were detected three times. The concentration of the single PAH detection is 363 $\mu\text{g/kg}$, significantly less than that observed in the maximum concentration in the overlying interval. The maximum phthalate concentration is 430 $\mu\text{g/kg}$, slightly greater than that observed in the 10- to 41-cm (4- to 16-in.) interval.

D.9.2.5 Floodplain Waste Samples

During the course of the OU 4 RIFA, two previously unidentified waste areas in the BCV Floodplain were recognized and sampled. These were named the Creekside Debris Burial Area, located between the Rust Spoil Area and Bear Creek Road, and the Bear Creek Road Debris Burial Area, located between Bear Creek Road, Old Bear Creek Road, and the Rust Spoil Area (Fig. A.2 in Appendix A).

Both areas appear to consist of the surface disposal of miscellaneous wastes and had radioactive contamination (based on screening with field instruments). There is no information on the operational history of these sites. One early photograph of the Y-12 Plant [Plate A.1 (circa. 1947) in Appendix A] shows that the area in Upper Bear Creek adjacent to the Y-12 Plant boundary was probably used as a debris disposal area at this time. Burnt or incinerated material had been disposed of at the Bear Creek Road Debris Burial Area. Pieces of broken glass vessels suggest that this waste stream also included discarded laboratory equipment.

Table D.103 lists the concentrations for all detected analytes for each waste area. The sample from the Bear Creek Road Debris Burial Area was diluted by 4 times with clean soil when sampled to allow for transport of the sample off site (Sect. B.5.3.1 in Appendix B). Table D.103 lists the results of analysis of this sample and the corrected results based on this dilution (Note however, that this dilution factor does not apply to some analytes such as aluminum and manganese that would have been present in the eluant soil). Elements or compounds at concentrations greater than background criteria used in BCV for soils and sediments were as follows:

- for the Creekside Debris Burial Area: cadmium, copper, mercury, selenium, silver, zinc, SVOCs (in particular PAHs and phthalates), and ^{234}U , ^{235}U , and ^{238}U ; and
- for the Bear Creek Road Debris Burial Area: barium, cadmium, copper, lead, mercury, nickel, silver, ^{99}Tc , and ^{234}U , ^{235}U , and ^{238}U .

The uranium isotope ratio at the Bear Creek Road Debris Burial Area is of particular interest. Elsewhere in BCV the isotopic ratio of ^{234}U to ^{238}U is $\sim 1:1$, while at this site, it is 6:5. There is no explanation for this elevated $^{234}\text{U}:$ ^{238}U ratio, however, the presence of laboratory waste at this site suggests that this waste was derived from a laboratory and was not part of the main uranium waste stream from the Y-12 Plant. Such evidence may explain the unique uranium isotope ratios. Uranium in samples from both these areas was depleted of ^{235}U relative to the other isotopes.

D.9.2.6 Discussion and Conclusions

- The greatest variety and highest concentrations of site-related chemicals and radionuclides in FPSS occur in the upper portion of BCV, proximal to the source units.
- Where contaminants are noted in the downstream soil transects, they occur above background more frequently at depth [41 to 81 cm (16 to 32 in.)] than at the surface. This trend may indicate that contaminants that were being deposited this far downstream in the past are no longer reaching this point. However, several chemicals were noted in the shallow intervals of TS-13: mercury, selenium, and PCBs.
- The points along BCV showing the highest concentrations of SRCs are in the vicinity of tributaries draining the source areas. These include sediment samples SD-02 (adjacent to NT-1), SD-04 (adjacent to NT-3), SD-07 (adjacent to NT-4), SD-08 (along NT-6), SD-09 (NT-8), SD-10 (just downstream of NT-8), and SD-14 (adjacent to NT-2); and transects TS-01 (adjacent to NT-2), TS-03 (adjacent to NT-7), TS-04 (along NT-8), and TS-06 and TS-07 (downstream from the BCBG, adjacent to NT-10 and NT-11).
- Some chemicals and radionuclides, particularly cadmium, selenium, ²³⁸U, PCBs, and phthalates, occur in concentrations above their background criteria along all of BCV. Others, such as lithium, mercury, ⁹⁹Tc, and PAHs, are more limited in their distribution. All chemicals and radionuclides seem to be more abundant in the shallow zone [0 to 10 cm (0 to 4 in.)] than in deeper intervals [10 to 41 cm (4 to 16 in.) and 41 to 81 cm (16 to 32 in.)].

D.9.3 MAYNARDVILLE LIMESTONE AND BEAR CREEK FA – SURFACE WATER AND GROUNDWATER DATA

Groundwater in the Maynardville Limestone and surface water in Bear Creek are closely connected hydrologically. Flow in various sections of Bear Creek is, in part, a function of the rate of discharge from or recharge to the Maynardville Limestone aquifer. This relationship is described further in Appendix C. As a result of this interaction between groundwater and Bear Creek, the contaminant chemistries of the surface water and groundwater streams are very similar. For this reason, the contamination of surface water and groundwater is discussed together in this FA, rather than separately as in the source FA.

D.9.3.1 Maynardville Limestone and Bear Creek FA Database and Data Summaries

Surface water and groundwater in the Maynardville Limestone and Bear Creek FA are contaminated with a wide range of chemicals (VOCs, radionuclides, metals, and nitrate) consistent with the history of operations in BCV.

During the past decade, waste disposal operations at waste sites in BCV have ceased. Considerable effort has been directed to removing contaminated soils and wastes from contact with water bodies in the source areas by excavating the worst contaminated soils and sediments, capping the main waste areas, and collecting waste leachate. Because these remediation activities have improved the quality of surface water in Bear Creek, they have been used in the BCV RI to quantify current contaminant concentrations in surface streams. These recent data include surface water data from the BCV RI field activities and groundwater data from the GWQR database for samples taken after 1990. All other data are considered as historical data that may not reflect current conditions and are discussed qualitatively.

In general, recent surface water data cover contaminants in five BCV springs and at three locations in Bear Creek: between BCK 11.97 and BCK 12.38, at BCK 9.47, and at BCK 4.55 (Tables D.104 and D.105 and D.106 through D.120). Recent samples from Bear Creek between these sites are not available; however, historical data published in McCauley (1985) provide a snapshot of the distribution of contaminants along Bear Creek.

Recent surface water data have been subdivided into three aggregates: Bear Creek between BCK 11.97 and BCK 12.38 (Upper Bear Creek), Bear Creek between BCK 9.4 and 9.47 (Mid Bear Creek), and Bear Creek between BCK 4.55 and 4.67 (Lower Bear Creek). Flow in Bear Creek above BCK 12.38 is probably derived primarily from discharge off the Nolichucky Shale in the S-3 FA; data for this portion of Bear Creek are included in the S-3 FA and are summarized in Table D.21. Recent data from BCV springs are contained in five additional aggregates: SS-1, -4, -5, -6, and -8. Tables B.2 and B.12 in Appendix B summarize the analytes for surface water in BCV. Tables D.104 and D.105 and D.106 through D.120 summarize the analytical results for each analyte that was detected in the Upper, Mid, and Lower Bear Creek, SS-1, -4, -5, -6, and -8 aggregates, respectively. Included in Tables D.104 and D.105 and D.106 through D.120 are the frequency of detection of the analytes; background criteria; frequency with which each analyte exceeded background; minimum, maximum, and mean results; and relative importance of each analyte as a contaminant related to the Maynardville Limestone and Bear Creek FA. The relative importance of each analyte as a contaminant at the Maynardville Limestone and Bear Creek FA is determined by applying technical judgment based on the weight of evidence from a series of criteria (e.g., the frequency of detection of an analyte or the concentrations at which an analyte is detected relative to regulatory benchmarks). Table D.121 contains results of analyses for miscellaneous surface water parameters.

Groundwater data have been included into a single aggregate for wells in BCV screened in the Maynardville Limestone and Copper Ridge formations. The wells included in the Maynardville Limestone aggregate are listed in Table D.6, and their locations are shown on Fig. D.5. Table B.2 in Appendix B summarizes the analytes for groundwater in the Maynardville Limestone aggregate. Tables D.122 and D.123 summarize the analytical results for each analyte that was detected in GWQR data for unfiltered and filtered groundwater, respectively. Included in Table D.122 are the frequency of detection of the analytes; frequency of wells that detect each analyte; frequency at which the median value for an analyte in a well exceeds the background UTL; aggregate minimum and maximum results; mean of the well median results; and relative importance of each analyte as a contaminant related to the Maynardville Limestone and Bear Creek FA. Tables D.124 and D.125 contain results of analyses for miscellaneous groundwater parameters.

As described in the background screening method outlined in Sect. D.4.2, the median concentration of a chemical in groundwater from wells in the Maynardville Limestone aggregate was used to identify wells that have consistently elevated concentrations of metals in groundwater. The following sections describe the extent of the principal contaminants in the Maynardville Limestone site groundwater aggregates, referring, as appropriate, to the site-wide plume maps and cross sections presented in Sect. D.5. Figures D.6 to D.11 show the site-wide distributions of nitrate, gross α , gross β , PCE, TCE, and 1,2-DCE in shallow (<30 m or 100 ft) and deep (>30 m or 100 ft) groundwater in BCV between BCK 9.47 and the headwaters of Bear Creek. Figures D.14 to D.29 show these distributions in cross sections of BCV.

D.9.3.2 Organic Compounds – Maynardville Limestone and Bear Creek FA

VOC contamination has been detected both in surface water and groundwater in the Maynardville Limestone and Bear Creek FA. Eight organic compounds, principally, 1,2-DCA, acetone, and PCE were detected in surface water in the Upper Bear Creek aggregate; twelve,

including 1,2-DCA and 1,2-DCE, were detected in the Mid Bear Creek aggregate; and only one, acetone, was detected in the Lower Bear Creek aggregate. Springs in BCV were contaminated with a total of 11 organic compounds, primarily TCE; groundwater was contaminated with 12 compounds, with TCE being the most widespread and occurring at elevated concentrations.

Groundwater. A total of 12 organic analytes were detected in groundwater in the Maynardville Limestone aggregate, each detected in 20% or more of the wells: 1,1,1-TCA, 1,1-DCA, 1,1-DCE, 1,2-DCA, 1,2-DCE, acetone, carbon tetrachloride, chloroform, methylene chloride, PCE, TCE, and trans-1,2-DCE. Except for phenols, all detected analytes were detected in at least one well at concentrations greater than the respective detection limits and, consequently, are considered contaminants. However, only PCE, TCE and 1,2-DCE occur in more than two wells at concentrations greater than detection limits. The most common organic compound contaminating groundwater in the Maynardville Limestone and Bear Creek FA is TCE. The distributions of PCE, TCE, and 1,2-DCE in BCV are shown on Figs. D.9, D.10, and D.11 as representative of organics distribution. Plumes of organic contamination occur throughout BCV but are primarily associated with three areas: in the uppermost section of BCV adjacent to the S-3 ponds, between Rust Spoil Area and SS-4, and in the mid section of BCV adjacent to the BCBG.

Uppermost Section Adjacent to S-3 Ponds

At the uppermost section of BCV, a plume of 1,2-DCE, PCE, and TCE associated with the Fire Training Area (UEFPC) and SA-1 (BCV) is defined in wells GW-313 (34.4 m or 113 ft), GW-314 (35.1 m or 115 ft), GW-315 (31.7 m or 104 ft), GW-619 (12.4 m or 40.8 ft), and GW-620 (22.9 m or 75 ft). The contaminant suite in this plume is dominated by 1,2-DCE, occurring in concentrations three times those of TCE (e.g., GW-313 has a mean 1,2-DCE concentration of 17.5 $\mu\text{g/L}$ and a mean TCE concentration of 5.4 $\mu\text{g/L}$). Although this plume is detected in the shallow bedrock and residuum intervals in UEFPC, it is located only in the bedrock at depths >30 m (100 ft) in BCV. PCE occurs in similar concentrations to TCE in the Fire Training Area plume. PCE occurs in well GW-124 (45.7 m or 150 ft) at a mean concentration of 14.1 $\mu\text{g/L}$, which is higher than those of TCE and 1,2-DCE (mean concentrations 8.4 $\mu\text{g/L}$ and 6.5 $\mu\text{g/L}$, respectively); thus, the origin of contamination in this well may be associated with a different source, possibly the S-3 Site.

Section Adjacent to BYBY (Rust Spoil Area and SS-4)

The most extensive plume of organics-contaminated groundwater in the Maynardville Limestone and Bear Creek FA occurs downgradient of the Rust Spoil Area. TCE has the highest concentrations in this plume [e.g., mean concentrations of 368 $\mu\text{g/L}$ in GW-225 (61 m or 200 ft)], with 1,2-DCE generally occurring in lower concentrations [e.g., mean concentrations of 27 $\mu\text{g/L}$ in GW-226 (16.7 m or 55 ft)]. However, the relative distributions of TCE and 1,2-DCE differ significantly: the highest concentrations of TCE occur at depths >30 m (100 ft), whereas those for 1,2-DCE occur in the shallow bedrock interval. The two examples above (GW-225 and GW-226) highlight this situation: whereas the maximum value for TCE occurs in GW-225 (deep bedrock interval), 1,2-DCE has a mean concentration of 11 $\mu\text{g/L}$; conversely, whereas 1,2-DCE records its maximum mean value in GW-226 (shallow interval), the mean concentration for TCE is 9 $\mu\text{g/L}$.

The distributions of concentrations in this plume suggest more than one source for both contaminants. Elevated concentrations of TCE and 1,2-DCE occur in the groundwater wells screened in the shallow bedrock at the Rust Spoil Area. In this area, TCE concentrations are 2 to 3 times those of 1,2-DCE, and concentrations steadily increase in the shallow bedrock downgradient from GW-310 (8.3 m or 27.1 ft; mean TCE 35 $\mu\text{g/L}$) to GW-063 (10.7 m or 35 ft; mean TCE 98 $\mu\text{g/L}$) (Figs. D.10 and D.11). No monitoring wells are available to determine the extent of groundwater contamination

at the Rust Spoil Area in the deep bedrock interval; however, downgradient of Rust Spoil Area, the mean concentration in well GW-724 (91.7 m or 301 ft) in Picket C is 72 $\mu\text{g/L}$, indicating that contamination may exist in deeper bedrock below the Rust Spoil Area.

Downgradient of Picket C, TCE concentrations in the deep interval increase adjacent to the location of the BYBY, which is a second potential source for TCE and 1,2-DCE in the Maynardville Limestone. Elevated concentrations of TCE (2000 $\mu\text{g/L}$) and 1,2-DCE (1100 $\mu\text{g/L}$) occur in the residuum at BYBY close to the Maynardville/Nolichucky contact. As discussed in Sect. D.7.6, the migration of a dissolved plume of organics and/or DNAPL from the BYBY area directly to the Maynardville is possible. The maximum TCE concentration in the Maynardville Limestone occurs in GW-225 (mean 365 $\mu\text{g/L}$), which is screened in the lower-most stratigraphic section of the Maynardville Limestone, close to the contact with the Nolichucky Shale immediately downgradient of BYBY (Figs. D.10 and D.25). Thus, this maximum TCE concentration occurs at approximately the same stratigraphic interval as the contamination observed in the residuum at BYBY. In addition, the reach of Bear Creek immediately downgradient of BYBY is a losing reach until the confluence with NT-5. Thus, dissolved contamination in the shallow system and residuum is likely to migrate downward in this section of the Maynardville Limestone, as suggested by the distribution of concentrations of TCE in the Maynardville Limestone in wells downgradient of the BYBY.

1,2-DCE, which is also present in the dissolved plume at the BYBY, apparently does not migrate to the deep interval in the Maynardville Limestone to the extent that TCE has. The relative distributions of TCE and 1,2-DCE, with TCE predominating in the deep bedrock interval and TCE and 1,2-DCE both occurring in similar concentrations in the shallow intervals, are similar to those seen at the BCBG (Sect. D.6), where parent chemicals (PCE and TCE) predominate in the deep plume. The differences in the distributions of TCE and 1,2-DCE in this section of the Maynardville Limestone may tentatively be explained by hypothesizing that free-phase TCE is present in the bedrock or that TCE has migrated into the deep bedrock as DNAPL and since dissolved. This explanation, however, must be considered tentative and uncertain.

Well GW-365 (45.7 m or 150 ft) contains an organic contaminant suite that differs from those elsewhere in the Maynardville Limestone; that is, in addition to TCE (44 $\mu\text{g/L}$) and 1,2-DCE (35 $\mu\text{g/L}$), three other organic compounds — 1,1,1-TCA (mean 6 $\mu\text{g/L}$), 1,1-DCE (17 $\mu\text{g/L}$), and 1,1-DCA (5 $\mu\text{g/L}$) — are also detected in a high proportion of samples. 1,1-DCA was also detected at elevated concentrations in GW-229 (16.8 m or 55 ft; 8 $\mu\text{g/L}$), which is located upgradient of GW-365 at the SL 1 site, and in wells at the SL 1 site screened in the Nolichucky Shale. These compounds have not been detected consistently in any other Maynardville Limestone well, except for the detection of 1,1,1-TCA in GW-236 (5.6 m or 18.5 ft), which is geographically separate from GW-365. In Sect. D.7.6, the source of this organic contamination in the Nolichucky wells (GW-097 and GW-098) is tentatively concluded to be SL 1; if this conclusion is correct, the organic contamination in 1,1,1-TCA and 1,1-DCA in GW-365 could be derived from the same source. However, a more likely explanation is that this contamination, if derived from SL 1, has commingled with the TCE and 1,2-DCE plume in the Maynardville Limestone, and SL 1 is not necessarily the source of TCE and 1,2-DCE in this well.

Mid Section Adjacent to BCBG

Organic contamination in the Maynardville Limestone adjacent to the BCBG is slight compared to that observed in the Nolichucky Shale at the BCBG and in the Maynardville Limestone upgradient adjacent to BYBY. In the shallow system, 1,2-DCE and 1,2-DCA were consistently detected in well GW-053 (12.1 m or 39.7 ft; 21 $\mu\text{g/L}$ and 13 $\mu\text{g/L}$, respectively). The most likely source of contamination in GW-053, which is a shallow well located close to the confluence of NT-7 and Bear

Creek, is either contaminated shallow groundwater in the NT-7 catchment or surface water discharging from the NT-7 catchment.

In the deep aquifer adjacent to BCBG, TCE was detected at a low concentration ($1\text{ }\mu\text{g/L}$) in Zone 21 [190.5 m (625 ft) above mean sea level (amsl)] in GW-790 in association with nitrate. The association with nitrate indicates that, in the deep bedrock, this detection is a continuation of the TCE plume in the Maynardville Limestone further upgradient adjacent to SL 1.

Acetone and methylene chloride were detected sporadically in groundwater throughout the Maynardville Limestone and Bear Creek FA in concentrations above their detection limits. However, neither compound was detected in any well continuously, and the distribution of wells in which these analytes were detected shows no distinct pattern. This apparently random nature of detection, coupled with the knowledge that these two compounds are common laboratory contaminants that have been identified as such in many samples from BCV (HSW 1995), suggests that these detects may be laboratory contaminants rather than evidence of groundwater contamination.

Upper Bear Creek and SS-1. Of the eight organic compounds detected in the Upper Bear Creek aggregate, only 1,2-DCA, acetone, and PCE were detected at concentrations greater than $5\text{ }\mu\text{g/L}$. Detection of all organic compounds was sporadic with the exception of 1,2-DCA (7/31), acetone (5/31), phenols (51/72), and PCE (18/31). PCE is a contaminant in groundwater in the Nolichucky Shale at the S-3 Site and occurs in NT-1. The likely source for organics in this aggregate is groundwater discharge to NT-1 or the upper main stem of Bear Creek.

Of the seven organic compounds detected in SS-1, all were detected at concentrations $<5\text{ }\mu\text{g/L}$, except for acetone (maximum detection at $9\text{ }\mu\text{g/L}$). Detection of organic compounds was sporadic (1 to 2 detections in 27 samples), except for PCE (13/27) and TCE (6/27). Both TCE and PCE occur in bedrock groundwater in the uppermost section of BCV, PCE occurs in well GW-124 adjacent to the S-3 Site, and TCE occurs in wells surrounding the Rust Spoil Area (closest to SS-1 being GW-310). Therefore, contamination of SS-1 with TCE and PCE is consistent with bedrock groundwater data; however, the concentrations detected in SS-1 indicate that the contaminated bedrock groundwater is substantially diluted, possibly by shallow groundwater from Chestnut Ridge or by runoff, before discharge.

SS-4. Five organic compounds were detected in SS-4; however, only TCE and 1,2-DCE occur in more than 90% of the samples, with the remaining three compounds, 1,1,1-TCA, 1,1-DCE, and carbon disulfide, occurring at a frequency of $\leq 10\%$. In addition, the latter three compounds occur only in concentrations below their detection limits.

The concentrations of TCE and 1,2-DCE in SS-4 are almost identical for each sample (mean TCE is $8.7\text{ }\mu\text{g/L}$ and mean 1,2-DCE is $7.7\text{ }\mu\text{g/L}$), and concentrations in the samples vary similarly over time (Fig. D.121). Although the source for this contamination in SS-4 is contaminated groundwater, the depth from which contamination is derived is uncertain. Directly upgradient from SS-4, groundwater is contaminated with both TCE and 1,2-DCE; however, the relative concentrations of contaminants are not consistent with those observed for SS-4. In deep groundwater, the concentrations of TCE are almost always 2 to 3 times greater than those for 1,2-DCE. However, in the shallow system, although the concentrations of 1,2-DCE and TCE are similar in magnitude, the concentrations of these compounds in wells upgradient from SS-4 [e.g., GW-621 (13.1 m or 43 ft) has mean concentrations of $5.1\text{ }\mu\text{g/L}$ TCE and $5.1\text{ }\mu\text{g/L}$ 1,2-DCE] are much lower than the concentrations observed in SS-4. However, because contaminants are probably able to migrate rapidly through discrete pathways in the shallow cavity system, the shallow wells upgradient of SS-4

may not necessarily intersect the discrete pathway of these contaminants. The source of contamination in SS-4 is discussed further in Sect. D.9.8.

SS-5. Six organic compounds were detected in SS-5. TCE and 1,2-DCE occur in 20 to 30% of samples, and the remaining four compounds, 4-methyl-2-pentanone, acetone, carbon disulfide, and methylene chloride, occur at a frequency of <10%. In addition, all compounds occur in concentrations less than their detection limits. Similarly to SS-4, although the source of contamination in SS-5 is contaminated groundwater, whether this groundwater is from a deep source in the aquifer or is shallow groundwater associated with Bear Creek has not been determined. The source of contamination in SS-5 is discussed further in Sect. D.9.8.

Mid Bear Creek. Of the 12 chemicals detected at Mid Bear Creek, three (1,1,1-TCA, 4-methyl-2-pentanone, and toluene) were detected in only 1/35 samples; in addition, 1,1,1-TCA and toluene occur at concentrations less than detection limit. Four other chemicals (1,1-DCA, methylene chloride, PCE, and TCE) were detected more than once but at concentrations less than the detection limit. None of these seven chemicals were detected above SDWA MCLs and, except for PCE and TCE, these chemicals are not considered contaminants in Bear Creek at this location.

PCE and TCE, although detected in low concentrations, were detected in more than 20% of samples and are considered contaminants. Of the remaining five chemicals that are considered as contaminants at this location, all were detected at low concentrations, and only two — 1,2-DCA (12 to 20 $\mu\text{g/L}$) and 1,2-DCE (1 to 28 $\mu\text{g/L}$) — were detected above the SDWA MCL. Chloromethane (2 to 7 $\mu\text{g/L}$), 2-butanone (8 to 24 $\mu\text{g/L}$), and acetone (6 to 23 $\mu\text{g/L}$) were all detected in more than 20% of samples.

All VOC contaminants in the Mid Bear Creek aggregate have been detected as contaminants in NT-8. NT-8 discharges into Bear Creek ~6 m (20 ft) upstream from the Mid Bear Creek monitoring point; therefore, the VOCs detected at Mid Bear Creek are probably derived primarily from NT-8. Other potential sources for these contaminant may be NT-7 and SS-4; however, these streams are located 457 and 610 m (1500 and 2000 ft) upstream from the Mid Bear Creek monitoring point, and most of the VOCs contributed by these sources probably volatilize before reaching BCK 9.47.

SS-6, SS-8, and Lower Bear Creek. Two organic contaminants (2-hexanone and methylene chloride) were detected in SS-6 and one (acetone) in SS-8. Each was detected at a low frequency (4 to 8%) and in concentrations less than detection limits. All of these contaminants are common laboratory contaminants, suggesting that contamination during samples handling is the most likely origin of these detects. At BCK 4.55, acetone, which is the only detected organic, occurs in only 1 of 28 samples (at a concentration of 1 $\mu\text{g/L}$). Because acetone is a common contaminant derived from handling samples in the field and in the laboratory, this single detection probably does not indicate contamination at BCK 4.55.

D.9.3.3 Radioactivity – Maynardville Limestone and Bear Creek FA

Radioactive contamination has been detected both in surface water and groundwater in the Maynardville Limestone and Bear Creek FA, and elevated activities of gross α and gross β have been detected in surface water as far downstream as BCK 4.55 and in spring water at SS-6.

Groundwater. Radiological contamination of groundwater occurs from the uppermost section of BCV adjacent to the S-3 Site to the section adjacent to the BCBG. Elevated gross α activity was detected in 30% of the wells, and elevated gross β in 75%. No monitoring points for groundwater are located below BCK 9.47 until Picket W, where no radiological contamination has been identified.

Although gross α activity in most wells in the uppermost section of BCV is slightly elevated, only GW-314 (35.1 m or 115 ft) has a mean gross α activity >15 pCi/L (15.8 pCi/L). Similarly, although gross β activities are elevated in this area, no wells have gross β activities >50 pCi/L. In addition, although the wells at the northern end of Picket C, located adjacent to NT-2, have elevated gross β activities, none has a mean activity >50 pCi/L [mean activities in GW-725 (43.3 m or 142 ft), GW-736 (32 m or 105 ft), GW-737 (27.1 m or 89 ft) are 36, 39, and 40 pCi/L, respectively]. Gross α activities are not significantly elevated in the Picket C wells (mean activities in GW-725, -736, and -737 are 4.6, 3.9, and 5.8 pCi/L, respectively), which may reflect the nearby NT-2 source, which is contaminated with gross β but not gross α .

Adjacent to SL 1, wells screened in the shallow bedrock are contaminated with gross α and gross β . Gross α activities exceed 15 pCi/L in GW-226 (16.7 m or 55 ft; mean 28 pCi/L) and GW-227 (12.2 m or 40 ft; mean 17 pCi/L), and gross β activities exceed 50 pCi/L in GW-227 (mean 52 pCi/L) and are elevated in GW-226 (mean 37 pCi/L). Both wells are located adjacent to the losing reach of Bear Creek immediately downgradient of NT-3. The most likely source of this contamination is the contaminated discharge from NT-3 or the migration of contaminated shallow groundwater in the NT-3 catchment.

Further along strike, radiologically contaminated groundwater occurs in a deep bedrock plume that is first detected in Picket B wells. GW-694 (62.2 m or 204 ft) and GW-706 (55.5 m or 182 ft), both screened in Zone 4 of the Maynardville Limestone (Figs. D.19 and D.22, the Lower Chances Branch Member) and located at about the same depth, are contaminated with elevated gross α and gross β . GW-694 has a mean activity for gross α of 50 pCi/L and for gross β of 94 pCi/L, and GW-706 has a mean activity for gross α of 42 pCi/L and for gross β of 87 pCi/L. These activities are higher than those in wells of similar depth located immediately upgradient in the Maynardville Limestone [e.g., wells in Picket C, GW-601 (108.5 m or 356 ft), GW-368 (74.7 m or 245 ft), GW-365 (45.7 m or 150 ft), and GW-367 (46.1 m or 151.4 ft)]. Thus, along-strike flow in the Maynardville Limestone is not a likely source of this contamination.

Few isotopic analyses for groundwater from GW-706 and -694 have activities exceeding MDAs or available counting errors. However, ^{99}Tc was detected more than once in each well above MDAs and errors, indicating that ^{99}Tc is a β emitter in groundwater in these wells. Although not detected, uranium isotopes are probably the main α emitters in groundwater here.

This plume in the deep bedrock apparently continues along strike to at least BCK 9.47, where elevated gross α and gross β occur in GW-684 (37.5 m or 129.6 ft). This well, however, is not screened in the same stratigraphic interval as GW-694 and -706; therefore, groundwater with higher activities than those detected in Picket A wells may be present here, probably at greater depths than in Zone 4 of the Maynardville Limestone (GW-684 is screened in Zone 4).

The source of this deep plume is uncertain. The presence of ^{99}Tc indicates that one ultimate source is the S-3 Site because the S-3 Site is the only location upgradient at which ^{99}Tc has been detected in either groundwater or surface water. However, uncertainties about the contaminant migration pathway that has resulted in this plume and as to whether all the uranium isotopes are derived from the S-3 Site are noted:

- NT-3, a second potential source for uranium isotopes in groundwater, has concentrations substantially higher than those seen in the other tributary streams to Bear Creek. Uranium from this source would be likely to enter groundwater because a losing reach of Bear Creek is located immediately downgradient of NT-3. In addition, the distribution of the gross α and gross β

plumes at BYBY indicates the presence of contaminated groundwater in the Maynardville Limestone at BYBY.

- In both shallow and deep groundwater upgradient from Picket B in the Maynardville Limestone, gross β is elevated in a number of wells where gross α is not (e.g., Picket C wells). Gross α activities in groundwater subsequently increase downgradient of NT-3.
- Migration of gross α in the S-3 plume is generally retarded in comparison with that of nitrate and gross β , and uranium isotopes were not detected in NT-2, where both elevated nitrate and gross β were detected. Groundwater adjacent to the confluence of NT-2 and Bear Creek has a similar contaminant suite, with elevated gross β and nitrate and little or no gross α .

These facts suggest that the source of radiological contamination in groundwater at, and west of, Picket B could be a mix of the two upgradient sources. Further discussion is presented in Sect. D.9.8.

Upper Bear Creek and SS-1. Gross α and gross β occur above background in almost 100% of the samples in the Upper Bear Creek aggregate. Gross α ranges from 0.07 to 520 pCi/L, with a mean activity of 110 pCi/L; gross β ranges from 0.13 to 1,200 pCi/L, with a mean activity of 343 pCi/L. Isotopic analysis of the BCV OU 4 samples shows that gross α emissions can be attributed to isotopes of uranium, ^{234}U (5.13 to 54 pCi/L), ^{235}U (1.04 to 4.66 pCi/L), and ^{238}U (8.72 to 135 pCi/L). Other than uranium daughter isotopes, the only β emitter that was frequently detected was ^{99}Tc with a range of 139 to 477 pCi/L and a mean activity of 27 pCi/L. Other isotopes that were detected in Upper Bear Creek and their maximum detected activity were as follows: ^{90}Sr (2.15 pCi/L), ^{228}Th (0.25 pCi/L), ^{230}Th (0.23 pCi/L), and ^{232}Th (0.13 pCi/L).

SS-1 is contaminated with both gross α and gross β ; gross α is elevated in 85% of samples, and gross β in 100%. In general, the activities of gross β (mean 66.7 pCi/L) are ~3 times greater than those of gross α (mean 17.6 pCi/L). These data are consistent with both those from the Upper Bear Creek surface water aggregate where mean gross β is ~3 times mean gross α , and data from nearby wells (e.g., GW-310 has detected gross β but not gross α). This situation is also similar to that observed in the Nolichucky Shale adjacent to SS-1 where gross α is retarded relative to nitrate and gross β . Although uranium isotope activities can account for the observed gross α , not all of the gross β can be accounted for. Technetium-99 has not been analyzed for at this site; because the S-3 Ponds are the most likely source, ^{99}Tc is likely a β -emitting radionuclide in this spring.

SS-4. SS-4 is contaminated with both gross α and gross β , which were detected in 100% of samples. In general, the activities of gross β (mean 82.3 pCi/L) are ~1.5 times greater than those of gross α (mean 52.9 pCi/L). Uranium isotope activities can account for the observed gross α , and detection of ^{99}Tc in two samples indicates that gross β is likely contributed by uranium daughter products and ^{99}Tc .

The gross α and gross β data are nearly consistent with those for groundwater in the Picket B wells directly upgradient [GW-706 (55.6 m or 182.5 ft): gross β = 87.6 and gross α = 42.4]; however, comparison of the mean activity concentrations between these wells and SS-4 (mean gross β in SS-4 is 82.3 and mean gross β in GW-706 is 87.6) suggests that (1) little or no dilution of groundwater discharge occurs at SS-4 or (2) the deep groundwater plume is more contaminated than has been detected in the Picket B wells, and dilution does occur. The presence of ^{99}Tc indicates that the S-3 Site is a source of contamination in SS-4 because it is the only known upgradient source for ^{99}Tc . However, although the gross β concentrations in SS-4 are generally lower than those in surface water at BCK 12.38 (Fig. D.122), as would be expected from natural dilution and attenuation in a migration

pathway almost 1980 m (6500 ft) long, gross α has almost the same activities at these two sites. This inconsistency suggests a second source for gross α at SS-4; this observation is consistent with that for deep groundwater in Picket B. The most likely source for gross α is the BYBY via discharge in NT-3 or subsurface flow. Further discussion is presented in Sect. D.9.8.

SS-5 and Mid Bear Creek. SS-5 is contaminated with both gross α and gross β , which were detected in more than 80% of samples. At both sites, the activities of gross β are generally the same as those for gross α (Fig. D.123). Uranium isotope activities can account for the observed gross α and gross β in samples from BCV OU 4; ^{99}Tc was analyzed for in three samples from SS-5 and seven samples from BCK 9.47 that had the most elevated gross β but only detected once.

The radionuclides observed in SS-5 and BCK 9.47 could be derived from any of the BCV sources because these sites are downgradient of all of them. The source for elevated radiological contamination is uncertain, and the proportional contributions of each potential source in BCV to contaminant flux at SS-5 and BCK 9.47 are calculated by mass balance in Appendix E. The migration pathways from the BCV sources to these two locations are also discussed further in Sect. D.9.6.

SS-6 and SS-8. Isotopes of uranium were detected at very low activities in SS-6, and no radioactivity was detected in SS-8. The activities of uranium isotopes detected in SS-6 range from 1.0 to 1.3 pCi/L for ^{234}U and 1.1 to 2.1 pCi/L for ^{234}U ; ^{235}U was not detected. Overall, the activities of uranium in SS-6 are low enough to be considered as background values; however, in comparison to SS-8, the activities are slightly elevated, which may imply diffuse contamination.

Lower Bear Creek. Surface water at BCK 4.55 is radiologically contaminated in more than 75% of samples. In general, the activities of gross β (mean 19.7 pCi/L) are about the same magnitude as those of gross α (mean 13.7 pCi/L). Activities at BCK 4.55 range from 10.8 to 27.3 pCi/L for gross α and 10.2 to 37.6 for gross β . These activities are about one-fifth those at BCK 9.47; if no significant source of surface water contamination occurs between these sites, this difference in activity concentration indicates a dilution factor of about 0.2 for uranium isotopes in this stream reach. Contaminated surface water in this reach also provides a potential source for contamination of shallow groundwater via recharge from Bear Creek at losing reaches of the creek that are located downstream of BCK 9.47.

D.9.3.4 Inorganic Elements and Compounds – Maynardville Limestone and Bear Creek FA

Groundwater. The background screen shows that, in addition to essential elements, 17 inorganic elements occur above background values in one or more wells in the Maynardville Limestone and Bear Creek FA groundwater aggregate. Figures D.47, D.77, and D.105 show those wells in the S-3, OLF, BCBG, and Maynardville Limestone aggregates that have one or more metal contaminants. Relatively few wells are contaminated with inorganic elements, and no distinct plume of contaminated groundwater can be delineated by wells in the Maynardville Limestone aggregate.

In general, metal-contaminated groundwater in the Maynardville Limestone is associated with wells located adjacent to the S-3 Site. In this area, contamination occurs in both shallow and intermediate bedrock wells. Wells GW-100 (4.3 m or 14 ft), GW-122 (43.3 m or 142 ft), and GW-236 (5.5 m or 18 ft) are particularly impacted, with elevated concentrations of barium, boron, cadmium, copper, lead, mercury, strontium, and uranium. This distribution and list of contaminant metals is consistent with that of metal-contaminated groundwater at the S-3 Site (Sect. D.4), indicating that the most likely source of metal contamination in the Maynardville Limestone here is the S-3 Site.

Three metals, boron, strontium, and uranium, are fairly widespread contaminants in the Maynardville Limestone aggregate. Boron occurs above background criteria in 30% of the wells in the Maynardville Limestone, from the uppermost sections (GW-100 and GW-122) to Picket W [GW-710 (226.9 m or 744.5 ft), GW-711 (203.1 m or 666.2 ft), GW-712 (139.4 m or 457.5 ft), and GW-714 (44.2 m or 145 ft)] and including wells in between [e.g., GW-053 (12.1 m or 39.7 ft) and GW-054 (12.2 m or 40 ft) at BCBG, GW-310 (8.3 m or 27.1 ft) at Rust Spoil Area, and GW-228 (30.8 m or 100 ft) and GW-229 (16.8 m or 55 ft) at SL 1]. Uranium occurs above background in 16 wells, with concentrations ranging from 1 to 300 $\mu\text{g/L}$ (mean 9.2 $\mu\text{g/L}$). GW-706 (55.6 m or 182.5 ft) and GW-694 (62.3 m or 204.5 ft) have the highest median values of total uranium, which is consistent with the elevated activities of gross α and gross β in these wells. As discussed above, the uranium in groundwater in the Maynardville Limestone probably originates at both the S-3 Site and BYBY (via NT-3).

The widespread distribution of these elements also indicates that they occur in groundwater in relatively mobile species. Both boron and uranium probably exist as anionic species. Boron is usually present in natural waters as the borate $[\text{B}(\text{OH})_3]$ ion, which acts chemically as a weak acid that does not readily dissociate into charged ionic forms below pH 9.2 (Hem 1985). Uranium is probably present in its oxidized form (V+ or VI+) and most probably occurs as an oxide, the uranyl (UO_2^{2+}) ion being the most prevalent form of dissolved uranium in oxidizing solutions. In natural waters (in the absence of phosphate), the uranyl ion forms stable ion complexes with carbonate $[\text{UO}_2\text{CO}_3^0$ and $\text{UO}_2(\text{CO}_3)^{-1}]$ above pH 7.5 (Langmuir 1978).

Strontium has a +II valence state and has common minor constituents in carbonate minerals (calcite and dolomite); its sulfate mineral, celestite (SrSO_4), has been observed in core samples from the Nolichucky Shale close to the S-3 Site (Dreier, Early, and King 1993). Therefore, elevated strontium is probably derived from mineral dissolution in the bedrock rather than the source sites.

SS-1, SS-4, and SS-5. Eleven metals were detected above background in springs in upper BCV; however, the concentrations and frequency of occurrence for metal contaminants are greater at SS-1, close to the S-3 Ponds, than at SS-5, adjacent to the BCBG. SS-1 has 11 metal contaminants, SS-4 has 7 metal contaminants, and SS-5 has 4 metal contaminants. Boron, strontium, and uranium occur in all three springs. This pattern of contaminant distribution in springs is consistent with that for groundwater, where metal contamination is more prevalent close to the S-3 Site; boron, strontium, and uranium are common contaminants throughout BCV.

Another notable metal that occurs in elevated concentrations in SS-4 is lithium, which behaves similarly to boron in this spring. Both metals are slightly more elevated in SS-4 than in SS-1 (mean values for lithium of 29 $\mu\text{g/L}$ compared to 4 $\mu\text{g/L}$ and for boron of 110 $\mu\text{g/L}$ compared to 51 $\mu\text{g/L}$). These metals act as possible tracers of contamination from NT-3, where these metals are considerably elevated, as opposed to S-3 Site, where only boron is found in elevated concentrations.

SS-6 and SS-8. Metal contamination in SS-6 and SS-8 is very sporadic. Only zinc in SS-6 and boron in SS-8 were detected above background more than once, and six other metals were detected only once in either spring. Because of the lack of a distinct pattern of contamination, combined with low concentrations detected, these occurrences above background are not considered as contamination.

Bear Creek. Contamination of surface water with metals is more prevalent in the Upper Bear Creek aggregate than in both the Mid and Lower Bear Creek aggregates. This is consistent with the likely source of metal contamination, discharge of contaminated groundwater, in these surface streams. In Upper Bear Creek, 8 metals were detected above background, however, only 5 of these

occur above background in more than 25% of samples: boron (27 to 289 $\mu\text{g/L}$), cadmium (2 to 8 $\mu\text{g/L}$), nickel (9 to 100 $\mu\text{g/L}$), strontium (143 to 1270 $\mu\text{g/L}$), and uranium (55 to 848 $\mu\text{g/L}$). The remaining metals that occur above background are cyanide (2 to 21 $\mu\text{g/L}$, 10 of 93 samples), mercury (<0.1 to 6 $\mu\text{g/L}$, 8 of 100 samples above background), and phosphorous (50 to 110 $\mu\text{g/L}$, 18 of 72 samples).

Ten metals were detected at concentrations greater than background at both BCK 9.47 and BCK 4.55. However, except for boron, strontium, and uranium at both sites, and lithium at BCK-9.4, detection of metals above background at these sites was sporadic. At BCK 9.47, boron (100 to 4,100 $\mu\text{g/L}$), strontium (79 to 220 $\mu\text{g/L}$), and uranium (52 to 152 $\mu\text{g/L}$) were detected above background in 75% of all samples; at BCK 4.55 boron (9 to 310 $\mu\text{g/L}$) was above background in 43%, uranium (15 to 67 $\mu\text{g/L}$) in 93%, and strontium (34 to 149 $\mu\text{g/L}$) in 8% of samples. The occurrence of these elements above background in surface water in the Maynardville Limestone aggregate is consistent with their widespread distribution above background in groundwater and in springs in Upper Bear Creek.

The remaining metals detected in Mid and Lower Bear Creek have a frequency of detection of <5%, except for aluminum (2/35), nickel (2/35), vanadium (3/35), and zinc (2/35).

D.9.3.5 Nitrate and Common Anions – Maynardville Limestone and Bear Creek FA

The primary contaminating anionic species in the Maynardville Limestone is nitrate; contamination of groundwater with nitrate is one of the overwhelming features of groundwater contamination in BCV. Nitrate effectively acts as a tracer for the contaminant plume derived from operations at the former S-3 Ponds. The occurrence of nitrate in groundwater in BCV marks the maximum extent of groundwater contamination resulting from activities at the S-3 site. The nature and extent of nitrate contamination of groundwater in the Maynardville Limestone aggregate wells and springs are detailed in this section.

Groundwater. Nitrate contamination of groundwater occurs from the uppermost section of BCV adjacent to the S-3 Site to the BCBG. Of wells in the Maynardville Limestone aggregate, 53% are contaminated with nitrate above background. Below BCK 9.47, no groundwater monitoring points exist until Picket W, where nitrate contamination has been identified in shallow, intermediate, and deep groundwater. Both chloride and sulfate also occur above background in ~10% of wells in the Maynardville Limestone.

As might be expected, the wells closest to the S-3 Site have the highest nitrate concentrations. Nitrate contamination at the S-3 Site occurs in both shallow and deep wells: GW-100 (6.3 m or 20.7 ft) has a mean concentration of 362 mg/L; GW-122 (43.3 m or 142 ft) has a mean of 749 mg/L; GW-124 (45.7 m or 150 ft) has a mean of 261 mg/L; and GW-236 (5.6 m or 18.5 ft) has a mean of 373 mg/L. Further along strike in the Maynardville Limestone, the concentration of nitrate in wells decreases rapidly, and only two wells in the rest of BCV, GW-227 (12.2 m or 40 ft) and GW-725 (43.4 m or 145 ft), have mean nitrate concentrations >50 mg/L (84 mg/L and 57 mg/L, respectively).

Between the S-3 Site and Picket C, the nitrate plume appears to occur only in the lower-most zone of the Maynardville Limestone in both the shallow and deep intervals. Only wells screened on the northern side of Rust Spoil Area detected nitrate >10 mg/L [e.g., GW-308 (11.4 m or 37.7 ft) and GW-309 (11.6 m or 38 ft)]. However, at Picket C, nitrate contamination with mean values >10 mg/L occurs at <30-m (100-ft) depth across the Maynardville in Zones 2 to 6 [GW-738 (27.5 m or 90.1 ft) and GW-737 (27.3 m or 89.5 ft)]. At depths >30 m (100 ft) the plume of contamination >10 mg/L is apparently restricted to Zones 2 and 3 [GW-724 (91.9 m or 301.6 ft) and GW-723 (135.5 m or

444.5 ft)]; however, GW-740 (57.9 m or 190 ft), screened in the uppermost section of Zone 6, records concentrations of 4.8 mg/L nitrate, which exceeds the background criterion (2.7 mg/L), suggesting that this well is located on the edge of the current nitrate plume at Picket C.

Along strike from Picket C, the distribution of the nitrate plume is almost identical to that of the gross β plume, and a continuous plume of nitrate-contaminated water appears to extend at >30-m (100-ft) depth from Picket C to Picket A at the BCBG and further down BCW. At the SL 1, nitrate contamination >10 mg/L is observed in GW-225 (61 m or 200 ft), GW-226 (16.8 m or 55 ft), and GW-227 (12.2 m or 40 ft); and at Picket B, wells GW-694 (62.2 m or 204 ft) and GW-706 (55.5 m or 182 ft) show the highest concentrations of nitrate (mean values of 28 and 30 mg/L, respectively). Well GW-225 is screened in the lower-most zone of the Maynardville, whereas the two wells in Picket B, GW-294 and GW-706, are screened in Zone 4. At Picket A, nitrate contamination is observed in GW-684 (39.5 m or 129.6 ft; mean 11.1 mg/L), screened in Zone 6, and in GW-683 (60.2 m or 197.5 ft; mean 11 mg/L), screened in the Copper Ridge Dolomite; concentrations of nitrate in GW-685 (42.2 m or 138.3 ft), screened in Zones 4 and 5, are not significantly elevated (mean value 2.3 mg/L).

The distribution of contamination in the subsequent along-strike picket wells may indicate that, along strike from Picket C to Picket A, the nitrate plume steadily moves up the stratigraphic section in the Maynard Limestone and Copper Ridge Dolomite. Because no monitoring well is located in the deep section of the Maynardville Limestone at Picket A, nitrate-contaminated groundwater could exist in this interval and go undetected. Between Picket A and Picket B, nitrate was detected at a concentration of 68 mg/L at 187.4 m (615 ft) amsl in one of multiple sampling ports at GW-790. This elevation corresponds with a strike-parallel fracture observed in the core for this well (Dreier and Davidson 1994). No data are available to determine whether this contamination continues along strike beneath BCK 9.47, where the deepest well at Picket A has an elevation of 228.9 m (751 ft). However, because the contamination in GW-790 can probably be associated with nitrate migration in a discrete, strike-parallel fracture, this pathway probably continues further along strike and underneath BCK 9.47 without being intersected by the Picket A wells.

At Picket W, nitrate has been detected in wells GW-712 (134.6 m or 441.5 ft, 0.3 to 0.3 mg/L), GW-713 (73 m or 305 ft, 0.47 mg/L), GW-714 (44.2 m or 145 ft, 3.2 to 4.8 mg/L), and GW-715 (13.6 m or 44.5 ft, 0.4 to 1.1 mg/L). The highest concentrations in GW-714 occur in Zone 5 of the Maynardville Limestone; however, the remaining wells at Picket W screened at >30-m (100-ft) depth are screened in Zones 2, 3, and 4. Because the nitrate plume at Pickets A and B is probably located in Zones 5 and 6 and in the Copper Ridge Dolomite, the center of the plume may not be intersected by the wells at Picket W. Thus, although nitrate has been detected in these wells, the extent of contamination with nitrate at Picket W is uncertain.

Long-Term Time Trends – Nitrate Concentrations

Some wells that are screened in the nitrate plume show trends in concentrations over time (Figs. D.12 and D.13). GW-276 (5.6 m or 18.5 ft) and GW-127 (7.3 m or 24 ft) both show nitrate decreasing in concentrations in the water table interval close to the S-3 Site; however, in the bedrock aquifer, two wells — GW-122 (43.3 m or 142 ft) in the intermediate interval and GW-277 (23.4 m or 77 ft) in the shallow bedrock interval — show approximately steady concentrations of nitrate over time. These data indicate that, close to the former S-3 Ponds in the Maynardville Limestone, nitrate concentration in shallow groundwater has decreased since closure of the S-3 Site, whereas those in bedrock groundwater have shown little change.

Further along strike, a similar pattern of changes in nitrate concentration over time can be observed. Wells screened in the water table and in shallow groundwater intervals show decreasing nitrate concentrations since 1986, whereas wells screened below 30-m (100-ft) depth generally have steady or increasing concentrations. Wells GW-064 (17.4 m or 57 ft), GW-309 (11.6 m or 38 ft), GW-063 (10.7 m or 35 ft), GW-227 (12.2 m or 40 ft), and GW-226 (16.8 m or 55 ft) all show decreasing concentrations over time; in particular, GW-064 shows an exponential decline in nitrate concentration from 25 mg/L in 1989 to ~10 mg/L in 1994. However, wells GW-225 (61 m or 200 ft), GW-228 (30 m or 100 ft), and GW-601 (108.5 m or 356 ft), screened below 30-m (100-ft) depth, show slightly increasing trends; for example, GW-225 from an annual average of 64 mg/L in 1986 to an annual average of 93 mg/L in 1990 before decreasing again to an annual average of 73 mg/L in 1992. The contrast between the shallow and deep systems is shown in wells GW-227 and GW-228 (Fig. D.124). During the same period, 1986 to 1990, the concentration of nitrate in GW-227 increased from <20 mg/L to almost 40 mg/L, whereas that in GW-228 decreased from between 60 and 80 mg/L to <20 mg/L.

Further along strike downgradient, the long-term trends in nitrate concentrations are overshadowed by annual variations in nitrate concentrations (Figs. D.12 and D.13). In general, wells show lower concentrations during high-flow periods (winter and early spring) and higher concentrations during low-flow periods (summer and fall).

The apparent inconsistency between long-term concentration changes in the shallow and the deep intervals of the Maynardville may be explained by the distribution of cavities and water-bearing fractures in the Maynardville Limestone. Most cavities that were intersected during drilling of the exit pathway monitoring program occur above 30-m (100-ft) depth (Shevenell, Dreier, and Jago 1992). If the cavity system is assumed to represent the zone of most groundwater circulation, then contaminants would be expected to be flushed from shallow groundwater more quickly than from groundwater below 30 m (100 ft). The nitrate concentrations in the shallow Maynardville wells probably decreased in response to the improving quality of surface water in BCV after remediation of the S-3 Ponds. The quality of water recharging to the Maynardville has improved since remediation, and contaminants are being flushed from the shallow interval. Nitrate concentrations in surface water decreased over a 6-month period after use of the S-3 Ponds stopped (Sect. D.6.5). Groundwater trend data indicate that the concentration of nitrate in groundwater has declined over the past 10 years and has only recently reached steady concentrations in some wells (e.g., GW-064) (Fig. D.12).

SS-1, SS-4, and SS-5. SS-1, -4, and -5 are all contaminated with nitrate, with more than 90% of samples from each spring having nitrate concentrations above background. Both SS-1 and SS-5 have higher concentration than SS-4 (11 mg/L), with concentrations in SS-1 (mean 39 mg/L) being slightly higher than those in SS-4 (mean 32 mg/L).

The concentrations of nitrate in BCV OU 4 data from SS-4 vary widely (3.1 to 68 mg/L, Fig. D.125) in an inverse relation to flow in the spring; the concentrations of nitrate in BCV OU 4 data from SS-1 (11.6 to 38 mg/L) and SS-5 (0.1 to 16.8 mg/L), however, are generally less variable and span a smaller range. The variability of concentrations in SS-4 is similar to that in Upper Bear Creek (Fig. D.126), indicating that these locations share a related pathway or that the process causing the variability is so similar at both sites that the result is the same.

SS-6 and SS-8. Only one sample in SS-6 and no samples in SS-8 have nitrate concentrations above background. In SS-8, the nitrate concentrations range from 0.14 to 1.2 mg/L; in SS-6, they range from 0.15 to 2.6 mg/L, except for one sample from the BCV OU 4 database taken during July 1994 with a concentration of 6.6 mg/L. These data, which are consistent with the groundwater data,

which show nitrate concentrations of ~4 mg/L in wells in Picket W, indicate that shallow groundwater is contaminated with nitrate as far west as Picket W. The absence of nitrate in SS-8 indicate that nitrate contamination may not have reached as far west as BCK 4.55 at this time; however, the lack of groundwater monitoring points precludes confirmation of this hypothesis.

Bear Creek. Bear Creek is contaminated with nitrate for most of the year throughout its length from the S-3 Site to BCK 4.55. Nitrate concentrations generally decrease downgradient, as shown by mean concentrations in the three aggregates that include flow in Bear Creek: Upper Bear Creek has a mean concentration of 126 mg/L, Mid Bear Creek a mean concentration of 14 mg/L, and Lower Bear Creek a mean concentration of 9 mg/L. The mean concentration for Lower Bear Creek would probably be less if not for five samples, in which nitrate occurs at >40 mg/L, and two samples, in which nitrate occurs at 440 and 500 mg/L. Except for these seven unusually high samples, nitrate concentrations in Lower Bear Creek are generally <10 mg/L.

At Mid Bear Creek the concentration of nitrate varies from <1 to 46.2 mg/L. In a plot of concentration vs time, the variation in concentration at BCK 9.47 is similar to that observed at BCK 12.38 between April and June 1994 (Fig. 126). However, after January 1, the concentration of nitrate at BCK 9.47 is generally less variable than that at BCK 12.38, and the ratio of concentration between the two sites is also smaller.

Samples taken along the upper section of Bear Creek by McCauley (1985) show that, during the wet season (March 1984), concentrations of nitrate steadily decline in the creek between BCK 12.3 and BCK 9.47 (Fig. D.127), whereas, during dry, low-flow periods, the concentrations decline rapidly in the upper section of the creek (probably because of clean flow from SS-2) but remain relatively steady down the creek where flow occurs. When compared to the difference in the discharge along the creek measured during 1995 (USGS spring and seep survey), the amount of dilution of nitrate is almost proportional to the increase in flow downgradient from NT-2. These data imply that, during high flow, the concentration of nitrate in the upper section of Bear Creek is controlled by discharge into Bear Creek from NT-2 and NT-1, whereas in the section below NT-2, it is controlled by dilution with nitrate-free inputs from the tributaries. In the dry season, the concentrations of nitrate in Bear Creek are probably controlled primarily by the concentration of nitrate in groundwater discharge rather than dilution.

Annual Cyclic Variation in Contaminant Concentrations

In addition to the long-term changes in concentrations observed, many wells also show shorter term, annual variations in contaminant concentrations that have a cyclic nature. Figure D.128 shows examples of this cyclic variation from two representative wells: GW-537 screened in the Nolichucky Shale and GW-684 screened in the Maynardville Limestone. In general, the highest contaminant concentrations in groundwater occur during the periods of lowest head, and vice versa for low concentrations. This association with groundwater elevations indicates that during periods of high flow (elevated heads) that usually occur during late winter and spring, contaminant plumes in groundwater are diluted relative to low-flow periods.

Wells in the shallow, intermediate, and deep intervals show these types of cyclic changes (Figs. D.12 and D.13). These phenomena are most likely the result of matrix diffusion. In this conceptual model, where concentrations of contaminants are greater in the matrix of the formation than in the hydraulically active fractures due to past waste operations, the source of contaminants in hydraulically active fractures is diffusion of contaminants from the matrix. Dilution of contaminants by circulating groundwater is greater during high flow periods than during low-flow periods. Because

wells sample the hydraulically active fractures, the changes in concentrations due to the extent of dilution are observed in the samples.

D.9.4 BEAR CREEK FLOODPLAIN – ECOLOGICAL SETTING

The numerous tributaries and springs of Bear Creek have a significant impact on the ecology of Bear Creek and its floodplain. Both the hydrogeologic flow regime and waterborne chemicals in the main stem, tributaries, and springs are important to ecological conditions in the creek. Ecological studies of Bear Creek are reviewed by Southworth et al. (1992), and additional studies are being conducted as part of the Bear Creek Biological Monitoring Program. Federal- and state-listed protected species are described in Supporting Information for Appendix D.

D.9.4.1 Potential Exposure to Contaminants

Potential surface water and sediment exposures occur in Bear Creek, which has a variety of stream and bottom habitats. Relatively natural areas of the floodplain offer shelter and food in the grassy areas and, particularly, in the brushy and wooded areas for small mammals, reptiles, amphibians, and birds. The terrestrial biota are potentially exposed to contaminants in soil, drinking water, and food. The habitats in which these biota may be exposed are described in the following section.

D.9.4.2 Habitat Description

The ecology of Bear Creek and its floodplain is influenced by both past and current land uses. Before the Y-12 Plant was constructed, the predominant land use was agricultural; much of BCKV was cleared, with only a narrow strip of riparian vegetation along the creek. Many previously cleared areas are now planted in pine forest, and waste disposal areas occupy a portion of the open land.

Construction activities have altered the main channel of Bear Creek several times. The channel between NT-5 and BCK 11.83 was relocated south of its original location when a sanitary landfill was constructed there in 1968. The channel between SS-4 and BCK 10.36 was moved north of its original location to accommodate construction of a utility corridor and alterations to Bear Creek Road. The creek channel was also relocated to the south for the construction and operation of the HCDA at the BYBY. Other construction activities, including operation of the waste areas, may have affected water quality and stream habitat.

D.9.4.2.1 Bear Creek Channel

As do most streams, Bear Creek changes in size and form throughout its length. Although much of the creek is relatively natural, portions are channeled or run through culverts, weirs, or other artificial structures. Because of the variability of the stream's properties, multiple reference streams were used in the ecological studies to provide the best match of ecological setting for each task. In the following discussion, surface water and sediment are discussed separately.

Surface Water

Two primary factors impact biological populations found in BCKV: (1) the hydrogeologic setting of Bear Creek, which defines water flow and sources of water to the creek; and (2) the distribution of contaminants in the water, which impacts lotic biota.

Hydrogeologic setting. The hydrogeologic setting and its potential ecological effects on Bear Creek biota are reviewed by Southworth et al. (1992), and detailed data on Bear Creek hydrogeology are presented in Appendix C.

The flow pattern of Bear Creek has important effects on the ecological setting. During droughts, flow in Bear Creek decreases and temperatures increase. Typically, surface water in Bear Creek receives enough solar heating in the summer to raise the temperature significantly. Moderate temperatures are maintained by cool discharges from springs, which are fed by groundwater discharges. During these periods the contribution of springs and seeps is very important in maintaining flow and keeping temperatures below levels that are potentially lethal to aquatic biota.

Southworth et al. (1992), who studied potential ecological effects of proposed remedial activities in BCV, state that three potential remedies would disrupt or destroy habitat for threatened and endangered species:

- Treatment of groundwater contaminated by leachate from the S-3 Ponds, with subsequent discharge to EFPC, could dewater parts of Bear Creek upstream of SS-5, thus destroying spawning habitat for the endangered Tennessee dace.
- Groundwater removal would also alter the temperature regime in Bear Creek by decreasing the groundwater's cooling effect, endangering and destroying the habitat of species that cannot tolerate warm water.
- The increased runoff associated with capping waste areas would likely increase siltation of the creek, potentially covering gravel beds that are essential spawning grounds for Tennessee dace and other species.

Contaminants. Historic studies of contaminants in Bear Creek surface water are reviewed by Turner et al. (1991) and Southworth et al. (1992). Before neutralization, conditions in the S-3 Ponds were toxic to fish and sensitive aquatic invertebrates. The pH of water in Upper Bear Creek ranged, at different times, from 3.5 to 6.8, from 3.9 to 7.5, or from 4.0 to 4.5. High concentrations of aluminum were present in the acidic water. Several kilometers downstream, where the acidity had been neutralized, conditions were more conducive to survival of biota.

After the S-3 Ponds were neutralized in 1983, the pH in Upper Bear Creek rose to neutrality, and the concentration of aluminum fell more than an order of magnitude (Southworth et al. 1992). Detailed chemical and biological monitoring began after this time. Studies show that conductivity and dissolved solids levels in Upper Bear Creek were 10 to 20 times those at reference sites. Data from 1984 through 1986 show a general decrease in inorganic contaminants with distance downstream; however, lithium and boron were reported to be highest below the BCBG, and alkalinity did not change significantly from Upper Bear Creek to its confluence with East Fork Poplar Creek (Southworth et al. 1992).

Studies of organic contaminants in the Bear Creek Main Stem from 1983 through 1986 detected only VOCs. Trace levels of PCE, toluene, and TCE were detected at BCK 12.36, but much higher levels were detected at BCK 9.91, just downstream of NT-7, which drains the BCBG. VOCs decreased dramatically at BCK 9.43, presumably because of volatilization (Southworth et al. 1992). Although PCBs were not detected in surface water, they were found in fish in 1982 and 1987 and in caged clams in 1987; PCB concentrations in the clams were 20-fold those in controls. Thus, biologically available PCBs were present in Bear Creek surface water.

Current data on surface water contaminants are presented in Sects. D.6.5, D.7.5, D.8.5, and D.9.3.

Sediment

Instream sediment provides important habitat for benthic invertebrates, a major dietary item of aquatic and some terrestrial predators. Although sediment typically accumulates in pools and other slow-moving parts of streams, it is also quite mobile, being easily carried downstream via stormflow and redeposited at other locations. Both the distribution and contaminant load of sediment affect benthic populations.

Distribution. Fine sediment typically accumulates in pools and behind barriers, while coarser particles may be deposited also in runs and riffles. The distribution of Bear Creek sediment was evaluated at fish sampling sites (Southworth et al. 1992). Most of the sites were dominated by coarse sediment to gravel, with fine sediment dominating only at BCK 12.36. The heterogeneity of sediments varied from site to site, with no clear spatial trend other than the influence of pools, runs, riffles, and barriers. Sediment was not mapped in detail for the BCV RI, in part because mobility of sediment would make such information of little value to cleanup performed months to years after the measurements were made.

Contaminants. Although levels of many inorganic analytes have historically been high in Bear Creek sediments, they are also high in reference stream sediments, indicating that the sediments are naturally high in metals, probably because of high clay content. Because much of the inorganic content of clay (either structural or sorbed) is not biologically available, measurements of metal concentrations may not be an accurate indicator of toxicity.

Cadmium, copper, lithium, nickel, uranium, and zinc were found to be elevated in Upper Bear Creek, with concentrations decreasing further downstream. All of these analytes, except for lithium, sorb to sediment, potentially reducing their toxicity. Mercury concentrations in Bear Creek sediments (up to 20 mg/kg) have historically been as much as 100 times the levels found in uncontaminated sediments.

The distribution of VOCs in sediments sampled during 1984 through 1986 was similar to that in surface water, although significant sorption of VOCs was not observed (Southworth et al. 1992). Significant accumulations of PAHs have not been observed in historical studies. PCBs have been found downstream of the BCBG, especially in NT-7. PCB concentrations in fish decreased from 1986 to 1989 (Southworth et al. 1992), suggesting that concentrations in sediment might have decreased in that time. Recent sediment data are discussed in Sect. D.9.3.

Canopy was evaluated as part of the historical fish sampling studies (Southworth et al. 1992). Sites ranged from BCK 3.25, which is relatively undisturbed, to BCK 12.36, which is highly disturbed. At most sites, the surrounding habitat contained mixed hardwood and pine forest. Bank cover consisted of honeysuckle, Virginia creeper, poison ivy, wingstem, sedge, blackberry, fescue, panic grass and other grasses, and other shrubs and vines. The percent of canopy cover ranged from ~55% at BCK 12.36 to ~60% at BCK 11.83 and BCK 11.09 to ~80% at BCK 9.91, BCK 7.87, and BCK 3.25.

D.9.4.2.2 Bear Creek floodplain

Terrestrial Habitats

The Bear Creek floodplain provides a variety of habitats. Much of the creek has maintained or redeveloped a natural riparian edge, although portions of the creek are channeled and edged with riprap. The floodplain varies in width from very narrow, at those points where the creek is bounded by steep slopes, to broad, at those points where the valley widens and tributaries enter in flat areas.

Wetlands

Wetlands upstream of BCK 9.40 have been identified on SS-2, -3, and -4 (Rosensteel and Trettin 1993); these wetlands are south of Bear Creek Road and outside the floodplain. Wetlands at NT-1, -2, -3, -4, and -5 are also outside the floodplain. NT-6 and NT-8 have wetlands that fall both within and outside the Bear Creek floodplain; these wetlands, which extend upstream along the tributaries, are described in the discussion of wetlands at BCBG (Sect. D.8.7.2). Wetlands also occur downstream of BCK 9.4 and within the floodplain at ST-2, NT-12, SS-8 and as a forested backwater just upstream of SS-8, between WT-1 and WT-2, and from ET-3 to near BCK 4.55, including parts of WT-3; these wetlands are described in Rosensteel and Trettin (1993).

D.9.4.3 Toxicity Testing

D.9.4.3.1 Surface water toxicity

Toxicity testing has been performed both in the laboratory and in situ. Ambient water toxicity tests used standard tests on fathead minnows and *Ceriodaphnia*, and in situ tests used the snail *Elimia clavaeformis* (Southworth et al. 1992). These tests are described in the following sections.

Ambient Toxicity Testing

Historical data on ambient water toxicity show high toxicity in the upper reaches of Bear Creek, with decreasing toxicity further downstream (Southworth et al. 1992). Fathead minnow (*Pimephales promelas*) toxicity testing of water from some or all of sites at BCK 12.36, BCK 11.83, BCK 11.09, BCK 10.32, BCK 9.91, and BCK 9.40 was conducted in June, July, and October 1984; April, June, and October 1985; April 1986; March 1988; and May 1989. Other samples were also taken at locations further downstream, in four tributaries, and at two reference stream sites in Grassy Creek. Toxicity testing of samples from NT-7 and NT-8 is described in Sect. D.8.7.3.

In the main-stem tests from 1984 through 1989, fathead minnow toxicity was always greatest in the sample from BCK 12.36. Reduction in survival at the other main-stem sites was not as high as that at BCK 12.36 and was statistically significant only occasionally. The survival data show no clear spatial trend, except for a general implication that toxicity increases slightly with distance upstream (Southworth et al. 1992). Growth data show similar variability, with a general trend of decreased growth with distance upstream, beginning at BCK 11.09. A general trend of increased growth occurs for the period from 1984 through 1986, with the March 1988 test growth lower at all sites than the April 1986 test growth; however, growth of the control was also lower in 1988 than in 1986. In fact, in the 1988 test, growth was greater in all Bear Creek samples than in the control. The 1989 test shows no statistically significant evidence for toxicity in any sample, although an inhibition of growth is found in samples taken upstream of BCK 11.09.

The combined test data of *Ceriodaphnia* from 1984 through 1989 show decreasing toxicity from BCK12.36 through BCK11.83 and BCK11.09 to BCK 9.91. Even 20% dilutions of surface water were toxic at BCK12.36. In contrast, reproduction but not survival was significantly reduced in the 100% concentration tests for samples from BCK 9.91 and BCK 9.40 but not for samples from BCK 7.87 (Southworth et al. 1992).

In Situ Toxicity Testing

In situ toxicity tests with snails (*Elimia*) showed toxicity in the upper reach of Bear Creek, with lower toxicity farther downstream. In situ toxicity tests were conducted in two ways (Southworth et al. 1992):

- In a series of tests from August 1986 through January 1987, *Elimia* were placed in plastic cages into Bear Creek at BCK 5.15, BCK 7.87, BCK 9.40, and BCK 12.36. The snails had no access to food. After 7 to 30 d of exposure, the snails were evaluated for signs of stress or morbidity, and some were subjected to chemical analysis.
- In a series of tests from December 1986 through February 1987, *Elimia* were placed in Bear Creek in trays containing natural cobble substrate. The snails had free access to food and could leave the trays. After 24 or 48 h, both the position and condition (alive, stressed, or dead) of each snail was recorded.

In all caged-snail tests, toxicity was highest at BCK 12.36, with intermediate levels at BCK 9.40 and BCK 7.87. In the test in which snails were free to move about, the snails in uncontaminated reference streams consistently moved upstream [maximum of 4 m (13 ft) in 24 h] during the test period and showed no evidence of stress or morbidity. In contrast, at all Bear Creek sites the snails either moved downstream, implying an attempt to escape toxic conditions, or remained at the site of release. At the BCK 12.36 site, snails moved as much as 16 m (52.5 ft) downstream in 24 h in one test; in the other two an average of 15% died and 64% were stressed.

Chemical analysis of the exposed snails showed that they had accumulated aluminum, cadmium, cobalt, and strontium but not barium, lithium, magnesium, manganese, or nickel. Results of feeding tests with contaminated filamentous algae suggest that the metals were taken up directly from the water and not significantly from food.

Conclusions About Surface Water Toxicity

Southworth et al. (1992) conclude that the upper reaches of Bear Creek are toxic to most species of aquatic biota. Toxicity at BCK 12.36 is attributed to contaminants leaching from the S-3 Ponds waste area. The reduction in toxicity downstream is attributed to dilution by input from tributaries and springs and/or immobilization or chemical conversion of waterborne contaminants, with dilution thought to be the more important process. Conductivity, which appears to be correlated with survival, is probably associated with contaminant releases.

The combined ambient toxicity data show a trend in toxicity, increasing with distance upstream above BCK 9.40. This trend implies that discharges from the west end of the Y-12 Plant and/or the waste disposal areas have contributed to toxicity in Bear Creek. Another, temporal trend indicates that toxicity in the main stem of Bear Creek decreased from 1984 to 1988. This trend implies that releases from plant operations and/or the waste sites may have been reduced during that period.

Ambient Water Toxicity

Ambient water toxicity tests done in May 1994 showed significant reductions in survival of *Ceriodaphnia* in water from BCK 12.36, SS1, and BCK 11.83; reproduction was decreased in water from BCK 12.36, SS1, and BCK 11.83. In August 1994, decreased reproduction of *Ceriodaphnia* was observed in a sample from BCK 12.36, SS1, and SS4 but not at other sites. No significant toxicity to fathead minnows was seen in any sample during either test period.

Sediment Toxicity

Ambient sediment toxicity tests were done as part of the RI in May and June of 1995. In these tests, the freshwater scud *Hyalella azteca* is exposed to whole sediment and *Daphnia magna* is exposed to overlying water (details are presented in Appendix G). Sampling locations SD01 through SD17 are shown in Fig. B.50 in Appendix B. No statistically significant toxicity was demonstrated in samples taken at sites SD01, SD02, SD03, SD04, SD05, SD06, SD07, SD08, SD09, SD10, SD11, SD12, SD13, SD14, SD15, or SD16 when compared to a composite reference sample taken from NT-11, NT-13, and NT-15. Toxicity is suspected at site SD17 in Lower Bear Creek, where Bear Creek passes under Highway 58.

D.9.5 BIOMONITORING DATA

Biomonitoring studies in Bear Creek have been conducted since 1984 and are ongoing. Southworth et al. (1992) summarize results up to 1987, and more recent results are presented in Hinzman (1995).

D.9.5.1 Population Studies

D.9.5.1.1 Surface water

Studies of ecological populations, conducted since neutralization of the S-3 Ponds, are summarized in Turner et al. (1991), Southworth et al. (1992), and Hinzman (1995). Historical data indicate that aquatic populations in Bear Creek were more diverse in 1941 than in the 1980s (Southworth et al. 1992); however, the Bear Creek biological monitoring program results (Hinzman 1995) show an increase in species richness and abundance since 1987, especially at BCK 12.36. An increasing trend in biomass since 1987 is also indicated.

Eight quantitative surveys, conducted between 1984 and 1987 (Southworth et al. 1992), identified 14 fish species in Bear Creek. All species were found at least once at BCK 3.25, but only seven species were found upstream of the weir at BCK 4.55. Only four species were found at BCK 11.09 to BCK 12.36. Four additional species were found in qualitative surveys in 1984 through 1988. In general, species richness increased with increasing stream size; however, the weir at BCK 4.55 provided a physical barrier to some species, and the thermal impacts of cool springs, especially at SS-5, altered the population distributions expected from stream size alone. Species classified as intolerant of ecological disturbance (poor water quality or habitat degradation) were rarely observed except at BCK 3.25.

Studies of contaminant bioaccumulation in Bear Creek (Hinzman 1995) reported that concentrations of metals and PCBs in central stonerollers were lower at BCK 3.3, in lower Bear Creek, than at all upstream sites. However, this study reported a steady increase in mercury concentration in the tissues of rock bass at BCK 0.6. This increase was speculated to result from

increased bioavailability of mercury as water quality improves in Upper Bear Creek (Hinzman 1995). Concentrations of PCBs in rock bass show considerable variability over time. PCB concentrations in rock bass at BCK 4.5 approached or exceeded 1 mg/kg on four of eight sampling dates since 1990, possibly coincidently with remedial activities in BCV (Hinzman 1995).

Measurements of biomass made during 1984 through 1987 show no clear spatial pattern. In Upper Bear Creek (BCK 11.09, BCK 11.83, and BCK 12.36), biomass increased from 1984 to 1985 (April 1986 at BCK 11.83) and then generally decreased through 1987. Further downstream biomass measurements vary considerably, but show no clear temporal trend (Southworth et al. 1992).

Condition factors were also evaluated during sampling from 1984 through 1987 (Southworth et al. 1992). The studies show clear differences between seasons, with higher condition factors in the spring, when the fish are ready for spawning and less healthy fish have died over the winter. No other trends, neither spatial nor temporal, are apparent.

D.9.5.1.2 Sediment

Population studies of benthic invertebrates during 1984 through 1987 are summarized by Southworth et al. (1992). Generally, these studies show a trend of increasing biomass and density with distance from the Y-12 Plant. Density and biomass at BCK 3.25 are similar to those in reference streams. Density and biomass are lower upstream of SS-5 than downstream of SS-5 and are lowest at BCK 12.36. Biomass generally increases from 1984 to 1987, although not always to a statistically significant degree.

Taxonomic richness also generally increases with distance downstream. Stoneflies, caddisflies, and mayflies are typical indicators of good ecological conditions in sediment. Bear Creek sediments are depauperate of mayflies at all sites except BCK 3.25, and stoneflies and caddisflies show a trend of decreasing frequency with distance upstream. Taxonomic richness of all taxa increases after 1984 at all sites except BCK 12.36.

D.9.5.1.3 Terrestrial populations

No historical population and community data are available for plants, birds, or mammals specific to the Bear Creek floodplain. Population data gathered during the BCV RI are described in Sect. D.9.5.2.

D.9.5.2 Terrestrial Biota Sampling and Analysis

The sampling and analysis plan for terrestrial biota sampling for the BCV RI (DOE 1994a) states that the primary objective of biota sampling and analysis is to determine the degree to which contaminants have bioaccumulated in small mammals and the potential for accumulation or biomagnification in higher trophic levels. This objective required that plants and earthworms also be analyzed as potential sources of exposure by ingestion. The biota sampling locations and the chemical analyses to be performed on biota were selected after analyzing the results of a screening study on floodplain soils (Sect. D.9.3).

D.9.5.2.1 Screening rationale

A series of transects were established across the BCV floodplain at 13 locations from BCK 12.6 to BCK 4.5. Shallow soil samples were analyzed for metals, PCBs, and radionuclides. Analytical results were screened against background and against toxicity benchmarks for ingestion of soil and

food by short-tailed shrews (*Blarina brevicauda*) and white-footed mice (*Peromyscus leucopus*), using data from Sample and Suter (1994) and Opresko, Sample, and Suter (1994). All analytes exceeding toxicity benchmarks were candidates for analysis in biota sampled at the chosen sites.

Sites for small mammal sampling were chosen from transects where contaminants exceeded small mammal toxicological benchmarks. No more than a single array of small mammal traps was established per sampling transect. Up to two sites for earthworm sampling were also chosen from transects where analytes exceeded small mammal toxicological benchmarks. Vegetation was sampled near the earthworm sampling locations.

The results of chemical analyses of surface soil, small mammals, depurated earthworms, and vegetation were expected to provide a range of concentrations that would allow determination of bio-uptake rates of contaminants from soil to biota. Bio-uptake factors were then to be used to calculate potential exposures from soil and food ingestion at other locations. The derivation and use of bio-uptake factors are discussed in Appendix G, Ecological Risk Assessment.

Site Selection

Sampling locations, which are designated by TSXX, are shown in Fig. B.50 in Appendix B. Small mammals were sampled near Transect 1, Station 2; Transect 3, Station 3; Transect 4, Stations 1 and 2; and Transect 7, Stations 1 and 3. Earthworms and vegetation were sampled at Transect 1, Stations 2 and 6; Transect 3, Stations 3 and 4; Transect 4, Stations 1 and 2; and Transect 7, Stations 1 and 3. Radionuclides were analyzed in the samples closest to the small mammal sampling locations. Additional confirmatory locations were established for small mammals at Transect 2, Station 3, and for earthworms and vegetation at Transect 2, Station 3, and Transect 9, Station 2.

Reference samples were collected from three locations near those where soil background samples were taken.

Analytes

Small mammals were analyzed for metals (using ICP/mass spectrometry), PCBs, and radionuclides (uranium isotopes, thorium, americium, curium, and gamma emitters). Earthworms were analyzed for metals and PCBs at all sampling sites and for radionuclides at the reference sites and at five other sampling locations. Plants were analyzed for metals at all sampling sites and for radionuclides at the reference sites and at five other sampling locations.

Results of chemical analyses were evaluated for analytes whose concentrations in surface soil exceed toxicity benchmarks for soil ingestion by shrews and white-footed mice. Cadmium is the only detected analyte that exceeds background and the screening toxicological benchmark for mice. At seven sites on five transects, cadmium concentrations range from 11.1 to 0.2 mg/kg, with a general decrease in concentration with distance downstream. Because cadmium appears to be an SRC, it was included as an analyte for evaluation. Although mercury does not exceed toxicological benchmarks for mice and only slightly exceeds the benchmark for shrews at one site, it was included as an analyte for evaluation because of its status as a contaminant of special interest. Selenium was included as an analyte for evaluation because it exceeds background and shrew-screening benchmarks, although it shows no clear spatial trend and the shrew benchmark is an order of magnitude below background. PCBs were included as an analyte for evaluation in small mammals and earthworms because Aroclor-1260 exceeds the Aroclor-1254 toxicological benchmark for shrews at two locations. Arsenic does not exceed background but does show a spatial gradient; because it is included in the ICP/mass spectrometry suite of analytes, it was analyzed in biota. Lithium does not exceed

toxicological screening benchmarks for mice or shrews, but it is a contaminant of special interest and, thus, was evaluated in biota. Radionuclides were analyzed and evaluated because of uncertainty about screening benchmarks for radionuclides.

D.9.5.3 Results of Biota Sampling and Analysis

Small mammals, earthworms, and plant samples were taken at several locations in the BC floodplain and at two locations in the BYBY. Sampling is described in Sect. B.6. The numbers and locations of biota sampled for the RI are presented in Table B.35. Summary results are presented in Table G.38 through Table G.43. Biota contaminant concentrations were used along with soil contaminant concentrations to derive biological uptake factors for the three classes of biota (Table G.34).

Elevated concentrations (UCL or mean concentrations above the reference UCL or mean) of various metals were found in small mammals, earthworms, and vegetation at BY17, BY22 and floodplain transects TS1, TS2, TS3, TS4, TS7, and TS9. There was no consistent spatial distribution of contamination. Different metals were predominant at different locations. PCB concentrations were elevated in earthworms at TS7 and in small mammals at TS4. The lack of clear patterns of contaminant concentrations in biota most likely reflects local variations in soil contaminant concentrations, soil composition, and many other factors related to the life histories of the individual biota sampled.

D.9.6 CONCLUSIONS – MAYNARDVILLE LIMESTONE AND BEAR CREEK FA

D.9.6.1 General Conclusions for Nature and Extent

Figure D.129 shows a detailed conceptual model of the Maynardville Limestone and Bear Creek FA with contaminant plumes and the likely migration pathways operating today. This figure is key to understanding the conclusions of this chapter and is referred to often in the following section.

Floodplain Soils Ecological Habitat

- Terrestrial biota may be exposed to contaminants in floodplain soil and soil pore water. Wetlands create exposure environments for terrestrial biota, amphibians, and aquatic insects at the confluence of NT-6 and NT-8 as well as at locations downstream of BCK 9.4.

Surface Water and Groundwater

- Groundwater and surface water in the Maynardville Limestone and Copper Ridge Dolomite are contaminated with nitrate, VOCs, radionuclides, and metals. In general, these contaminants occur in groundwater and in surface water in similar proportions and concentrations, indicating that these two media are closely connected throughout BCV.
- Groundwater contamination occurs in two main plumes in BCV: (1) a groundwater plume contaminated with nitrate and radionuclides (uranium isotopes and ^{99}Tc), which originates close to the S-3 Site and continues west along BCV past Picket A as far as Picket W, ~2590 m (8500 ft) further west; and (2) a groundwater plume contaminated with VOCs (TCE and 1,2-DCE), which originates in groundwater wells at Rust Spoil Area. Although the VOC-contaminated plume has been detected along strike in Pickets B and C, no VOC

contamination has been detected at Picket A. Both contaminant plumes are detected in the shallow and deep intervals of the Maynardville Limestone.

- In wells upgradient of Picket B, at Picket B, and in the Westbay well GW-790 (located adjacent to the BCBG), the inorganic plume (nitrate and uranium) is detected in highest concentrations in the lower zones of the Maynardville Limestone. Further along strike, at Picket A, nitrate concentration has been detected only in the upper-most zone of the Maynardville Limestone and in the Copper Ridge Dolomite; however, no wells are screened in the lower zones of the Maynardville Limestone at depths >30 m (100 ft) in Picket A, which is the most likely location of the plume at this point along BCV.
- The relative distributions of nitrate, gross α , and gross β vary along strike. All three contaminants are observed in groundwater and surface water close to the S-3 Site in relatively high concentrations. At Picket C, however, nitrate and gross β are detected, but gross α contamination is absent; this finding is consistent with the location of Picket C adjacent to NT-2, which shows a similar distribution (nitrate and gross β with no gross α).

Further along strike, from the wells located adjacent to SL 1 to BCK 9.47, all three contaminants occur in similar proportions in the deep groundwater and in SS-4 and SS-5. In this section of the plume, however, gross α and gross β have approximately the same activity concentrations, whereas at the head of BCV (SS-1 and BCK-12.38), gross β activities are greater than gross α activities. This distribution of radioactive contaminants, along with the knowledge that gross α is generally more retarded in gradients than gross β , suggests two sources of contamination for this plume, one at the S-3 Site and the second at BYBY. Downgradient of BYBY, the contaminant plumes are intermingled.

- The relative distributions of individual VOCs in the VOC plume also indicate two sources of contamination: one at BYBY and one unknown source at the Rust Spoil Area. Although the VOC plume originates close to Rust Spoil Area and contains both TCE and 1,2-DCE at this site, concentrations of TCE increase downgradient, reaching a maximum in wells screened below 30 m (100 ft) located adjacent to SL 1 (GW-225). Concentrations of 1,2-DCE, however, are highest in the shallow intervals, and 1,2-DCE is almost absent from wells screened in the intermediate and deep intervals.

The increase in concentrations of TCE along strike in the deep interval in the Maynardville Limestone is coincident with the occurrence of TCE-contaminated groundwater in shallow groundwater at BYBY. However, the shallow plumes at BYBY also contain PCE and 1,2-DCE; why these compounds do not also occur in the Maynardville Limestone at depth is not known.

In addition to increasing concentrations downgradient, the distribution of the VOC plume in the Maynardville Limestone changes. At Picket C, the plume is located fairly evenly throughout the zones of the Maynardville Limestone. Adjacent to SL 1, the plume is more concentrated in the lower zones; this distribution is consistent with contamination from BYBY, which is partially located on the outcrop of the lowest zone in the Maynardville Limestone.

- Adjacent to SL-1 the relative distribution of radiological and VOC contamination may reflect the nature of the radionuclide and VOC contributions from BYBY. Radionuclides and 1,2-DCE occur in shallow wells GW-226 and GW-227, whereas TCE occurs in the deep wells GW-225 and GW-228. This distribution would be consistent with (1) TCE input from a DNAPL and depth in the Maynardville Limestone and (2) 1,2-DCE and radiological input from surface water in NT-3 and/or shallow groundwater.

- Boron, uranium, and strontium occur in concentrations elevated above background throughout BCV. Apart from these three contaminants, metal contamination is restricted to groundwater and surface water close to the S-3 Site: SS-1, BCK 12.38, and GW-124.
- Concentrations of contaminants in the major plumes vary in the wells, springs, and surface water monitoring points, depending on flow. During high flow associated with storms, the concentrations of nitrate, TCE, 1,2-DCE, gross α , and gross β are low; the concentrations of these contaminants are highest during baseflow periods. For groundwater, the resolution of sampling is not sufficient to define the changes in concentrations in relation to individual storms; however, the concentrations vary on an approximate annual basis and are probably related to semi-annual high- and low-flow periods. Specific conductivity data from shallow wells in the Maynardville Limestone indicate that concentrations can also vary greatly in shallow groundwater during storms; however, this variation does not occur in deep groundwater.
- Concentrations of nitrate have also varied in some wells over the past 10 years. In general, concentrations of nitrate in wells screened in the shallow bedrock interval have decreased since 1986, whereas concentrations in wells screened below 30 m (100 ft) have either remained approximately steady or in some cases have increased slightly.

Surface Water Ecological Habitat

- The quality of aquatic habitats in Bear Creek depends primarily on land use and the resulting modification of the stream channel. Aquatic populations that were previously reduced by exposure to water-borne contaminants appear to be increasing. Integrity of aquatic habitats in the upper reaches depends on recharge of groundwater to tributaries.
- Ambient water toxicity tests show a gradient of toxicity, with the highest observed toxicity at BCK 12.36, near the former S-3 Ponds. Toxicity decreases with distance downstream as toxicants are diluted. Toxicity in the upper reaches has decreased since 1984.

D.9.6.2 Interpretive Conclusions and Working Hypotheses – Migration Pathways in the Maynardville Limestone and Bear Creek FA

The working hypothesis is that the contamination in the Maynardville Limestone and in Bear Creek can be traced to inputs from sources at S-3 and BYBY (the exception being TCE and 1,2-DCE in groundwater at Rust Spoil Area). In interpreting these data, changes in the rate of contaminant input from these sources to the Maynardville Limestone over the past 20 years are also considered. Although BYBY is probably a source that has remained relatively unchanged since the 1950s, the rate of contamination flux from the S-3 Site has changed dramatically since remediation of that site in the 1980s; for example, concentrations of nitrate in Bear Creek at BCK 12.46 exceeded 1000 mg/L in 1983 and were probably greater in previous years, whereas the maximum concentration during 1994 monitoring was 171 mg/L. Thus, a residual plume of contamination derived from the former S-3 Ponds is probably present in groundwater in the Maynardville Limestone; identifying current contaminant fluxes from fluxes derived from residual contamination may be complicated by this relict contamination.

The main sources of contaminant input to Bear Creek and the Maynardville Limestone, as identified in previous sections and shown on Fig. D.129, are:

- S-3 Site: nitrate and radionuclides via discharge from NT-1 and NT-2, shallow groundwater discharge to Bear Creek, and shallow groundwater discharge into the Maynardville Limestone shallow groundwater.
- BYBY: radionuclides via discharge from NT-3, shallow groundwater discharge to Bear Creek, and shallow groundwater discharge into the Maynardville Limestone shallow groundwater; and VOCs via shallow groundwater discharge to Bear Creek and via shallow groundwater discharge into the Maynardville Limestone shallow groundwater.
- SL 1: VOCs via shallow groundwater discharge into the Maynardville Limestone shallow groundwater.
- BCBG: VOCs and radionuclides via surface water discharge from NT-7 and NT-8 and via shallow groundwater discharge into the Maynardville Limestone shallow groundwater.
- Unknown site or Rust Spoil Area: VOCs by direct recharge to Maynardville Limestone.

At monitoring points downgradient of BYBY (groundwater and surface water), the plumes from the S-3 Site and BYBY source areas appear to be completely commingled. BYBY can be identified as a contributor to the inorganic and organic Maynardville Limestone contaminant plumes only because of the relative concentrations of nitrate, gross α , gross β , TCE, and 1,2-DCE in groundwater and surface water.

Contaminants discharging from the S-3 Site pathways into the Maynardville Limestone are nitrate, uranium isotopes, and ^{99}Tc ; nitrate provides a nonreactive tracer that can be used to trace the fate and transport of contaminants from the S-3 Site. The distributions of the gross α and gross β plumes relative to that of the nitrate plume suggest that uranium and ^{99}Tc follow the same contamination pathways in the Maynardville Limestone. However, as in the Nolichucky Shale, uranium is probably retarded relative to nitrate and ^{99}Tc , resulting in a lesser extent.

Surface water in NT-1, in the main stem of Bear Creek, and in SS-1 is also contaminated with nitrate, uranium isotopes, and ^{99}Tc ; surface water is undoubtedly an active pathway for contaminant migration into the Maynardville Limestone at this site. In addition, surface water in NT-2 discharges nitrate and ^{99}Tc into Bear Creek. Shallow groundwater in the Maynardville Limestone close to the Nolichucky contact (GW-100 and GW-236) is contaminated with nitrate at concentrations almost twice those in surface water; concentrations in these wells showed no decrease in concentrations between 1986 and 1990. Elsewhere in the Maynardville Limestone, shallow groundwater has been flushed of nitrate contamination, resulting in generally decreasing concentrations. Therefore, the shallow groundwater discharge into the Maynardville Limestone pathway appears to be active in the vicinity of these wells (NT-1) and, possibly, at other locations where contaminated shallow groundwater occurs close to the Maynardville Limestone – Nolichucky Shale contact.

Along strike in the Maynardville Limestone, nitrate has been detected only at concentrations <10 mg/L in shallow groundwater wells; however, the mean concentration in SS-4 and in shallow groundwater wells downgradient of SS-4 is >10 mg/L. Over the same section of BCV, plumes of nitrate-, uranium-, and VOC-contaminated groundwater below 30-m (100-ft) depth are continuous. This pattern of contaminant distribution is interpreted as resulting from the relatively rapid rate of flushing in the shallow Maynardville Limestone, which has rapidly reduced the concentrations of contaminants in shallow groundwater by dilution. The close association of the creek and the shallow groundwater conduit system means that, as the concentrations in surface water decline, so do those in the groundwater as they are flushed out of the system.

In the groundwater interval below 30 m (100 ft), contaminant flushing is slower because the flux of groundwater is considerably less in this interval. In this interval contaminant plumes occur in the lowest zone of the Maynardville Limestone. The plumes were also more continuous and the nitrate plume extends all the way from S-3 Site to Picket A and beyond. The extent to which contaminated groundwater from the Nolichucky Shale migrates into the Maynardville Limestone is unknown; however, although concentrations are high, the flow rate is probably very low. Contaminated groundwater from the shallow system also appears to recharge into the deep system in some parts of BCV. The reach of Bear Creek adjacent to SL 1 is a losing reach, and this is accompanied by downward hydraulic gradients in the Maynardville Limestone. Coincident with this losing reach of Bear Creek is an increase in the concentrations of nitrate and TCE in deep groundwater; further downgradient at Picket B, concentrations of gross α and gross β increase. The losing reach of Bear Creek near SL 1 is probably important in transferring contaminants from Bear Creek and the shallow systems into the deep groundwater flow path. However, much of the contamination observed in the deep system is probably derived from past years, when contamination in the creek was more elevated; thus, the flux in this system may not be consistent with the current contaminant flux from the source unit into the Maynardville Limestone.

The distribution of organics in the Maynardville Limestone suggests two sources for this contamination. TCE and 1,2-DCE occur in similar concentrations in bedrock groundwater at Rust Spoil Area; however, downgradient, the concentrations of TCE increase along strike and at Picket C. Adjacent to the SL 1, the concentrations of TCE in bedrock at depths >30 m (100 ft) increase dramatically, whereas concentrations of 1,2-DCE decrease. This indicates a source for TCE close to Picket C; possible sources are Rust Spoil Area (or a waste site located nearby, such as the Bear Creek Road Site Debris Burial Area) and BYBY. Because the Rust Spoil Area is the most likely source for the contamination observed at this site, contamination downgradient of this location is likely. Additional input from BYBY can then explain the increase in concentrations of TCE adjacent to and downgradient of this site; however, PCE occurs in shallow groundwater at BYBY in elevated concentrations and does not appear in groundwater in the Maynardville Limestone. This pattern may indicate that the source of TCE in deep groundwater from BYBY is the result of free-phase TCE from BYBY or HCDA that has migrated into the Maynardville Limestone and that the PCE is held up in the residuum. This conclusion, however, is tentative and would need additional data for confirmation.

Springs SS-4 and SS-5 both have concentrations of nitrate, gross α , gross β , TCE, and 1,2-DCE that exceed those in shallow groundwater directly upgradient of them; however, the springs show concentrations of contaminants similar to those in deep groundwater. This distribution may indicate that the source of contamination in these springs is deep groundwater; this hypothesis is generally supported by the fact that flow in these springs is continuous year-round at a fairly consistent rate. However, the chemistry of the springs is similar to that of Bear Creek (Turner et al. 1991). A tracer test conducted in 1989 (Geraghty and Miller 1989) shows that SS-5 receives a component of its flow from surface water flow in Bear Creek upgradient of BCBG. Thus, the working hypothesis of the BCV RI is that SS-4 and SS-5 tap groundwater from many levels in the Maynardville Limestone and may represent the surface expression of a vertical, across-valley fault or fracture at this location. These springs, therefore, serve to bring contamination from deep groundwater into the shallow groundwater systems and Bear Creek. This effect can be seen downgradient of SS-4, where nitrate, gross α , and gross β concentrations in shallow groundwater increase.

Little information about groundwater and surface water contamination downgradient from Picket A and BCK 9.47 is available. Two wells at Picket W — one shallow and the other 42.7 m (140 ft) deep — are contaminated with low concentrations of nitrate. SS-6 has a slightly elevated

nitrate concentration, as does Bear Creek at BCK 4.55; however, SS-8 at BCK 4.55 is not contaminated with nitrate. This distribution may be explain in two ways:

- (1) Groundwater is diffusely contaminated throughout BCV as a result of (1) the interaction of previously contaminated surface water flow in Bear Creek with shallow groundwater and (2) a small amount of recharge from shallow groundwater to deep groundwater.
- (2) The plume of contaminated groundwater in the deep system that is detected in GW-790 extends along strike as far as Picket W and may extend further, although not as far as SS-8; and deep groundwater discharge results in shallow groundwater contamination.

No data are available to confirm either hypothesis; likely both hypotheses are probably correct in part, and the true situation may contain aspects of both. This remains a major uncertainty.

D.10 CONCLUSIONS

Text and figures describing the interpreted nature and extent of contamination in BCV are contained in the concluding sections to each FA (Sects. D.6.8, D.7.8, D.8.9, and D.9.6) and are not repeated here. This section provides a brief synopsis of contamination in BCV and re-emphasizes some of the distribution patterns that are seen in the source FAs. The relationships between patterns of contaminant distributions in groundwater and surface water, the interpretation of the physical setting of BCV (Appendix C), and the knowledge of the wastes (Appendix A) is discussed. This section also contains a list of the main users where the technical interpretation of the data contains a high degree of uncertainty.

The volume of waste materials disposed of at the waste sites in BCV have included more than 18.6 million kg of uranium metal, more than 1 million gal of chlorinated solvents, and at least 2.7 million gal/year of metal- and radionuclide-contaminated nitric acid. In addition, contaminated media at BYBY indicate that unrecorded amounts of uranium and chlorinated solvents were disposed of at this site. Along with these primary waste constituents are other contaminants associated with operations at the Y-12 Plant (e.g., mercury, beryllium, lithium, and boron) or that might be expected at a large industrial facility operating from the 1940s to 1980s (e.g., SVOCs, PCBs, and benzene, ethylbenzene, toluene, and xylene compounds).

Soils

Although these waste constituents were detected above background concentrations in soils, their concentrations in source area soils sampled during the BCV RIFA are relatively low. They are especially low at the BCBG and S-3 Sites, where the source areas and primary shallow groundwater discharge areas have been remediated and the areas containing waste have been capped. At BYBY, where the cap does not completely cover the waste areas, concentrations of contaminants in soils were the most elevated of all sites in BCV. In addition, relatively high concentrations of contaminants were recorded at previously unknown waste sites in the BCV floodplain. The conclusion from these observations is that, in general, activities at waste sites have not contaminated the surrounding soils to any great extent and, where soils or sediments have been impacted (such as in NT-7 or at the headwaters of Bear Creek), soils at these sites have either been excavated or covered with a cap. Groundwater and surface water contamination implies that contaminants are leaching from waste areas; however, once leached from the waste, these contaminants are discharged to groundwater rapidly and do not appear to cause extensive secondary soil contamination.

Migration Pathways at the Waste Sources

Groundwater contamination in the Nolichucky Shale. Groundwater and surface water in (and on) the Nolichucky Shale at the BCV source sites have been considerably impacted by contaminants migrating away from the waste sites. The principal contaminants in these media reflect closely the primary waste constituents: nitrate, uranium, and chlorinated solvents. According to the BCV hydrogeological conceptual model, the hydrogeology of the Nolichucky Shale is dominated by shallow flow (surface runoff, stormflow, and rapid shallow groundwater flow). More than 95% of the water that enters the hydrogeology system on the Nolichucky Shale and lower formations in the Conasauga Group moves rapidly to surface water exit points at tributaries and, hence, to Bear Creek. Only ~5% of the water in the Nolichucky Shale and lower formations in the Conasauga Group recharges to bedrock; geochemical studies have shown that average groundwater flow at depths >30 m (100 ft) in the clastic formations is very slow (path lengths exceed 400 years).

Contaminant distributions at the source sites are consistent with the hydrogeological conceptual model if the mode of emplacement of contaminants is taken into account. Where contaminants were placed in the waste areas in liquid form that was denser than the ambient groundwater, contamination occurs in both shallow and deep groundwater intervals; however, where contaminants were disposed of as non-dense liquids or in solid form and the mechanism of release is leaching with percolating rainwater, then groundwater contamination remains in the shallow system only and does not occur in bedrock.

These contrasting patterns of distribution are especially apparent at the BCBG. At this site, large volumes of chlorinated solvents were disposed of in unlined trenches along with uranium metal. The solvents, driven by the density difference, have migrated down geological dip; groundwater contamination from VOCs (principally PCE, TCE, and 1,2-DCE) occurs in both shallow and deep intervals of the Nolichucky Shale and in surface water. Uranium contamination occurs in tributaries and in leachate collection systems but not in groundwater. Despite the 18.6 million kg of uranium disposed of at BCBG, uranium contamination has not been observed in groundwater, even though the extensive groundwater contamination from chlorinated solvents demonstrates that migration pathways exist from the trenches to groundwater. However, uranium contamination of aqueous media at this site is from leaching of uranium from the metal by percolating rainwater, and, consistent with the hydrogeologic conceptual model in the absence of a density contrast leachate in shallow groundwater, it migrates laterally to tributary discharge points and does not recharge bedrock to any great extent.

This conceptual model for explaining contaminant distributions in BCV is also consistent with that observed at the S-3 Site, where contaminants were disposed of in nitric acid solutions (density >1.1). The contaminants in this waste stream (principally uranium, nitrate, and ^{99}Tc) occur in both shallow and deep intervals of the Nolichucky Shale as a result of the density difference. Applying these principles can also explain the lack of deep contamination at the OLF and suggests that, at the BYBY (where there is no information for bedrock groundwater), groundwater contamination by radionuclides may be restricted to the shallow interval, although the organic contamination at this site may occur in bedrock as a result of DNAPL migration.

The flux of contaminants is greatest in the shallow system and in surface water; this observation is consistent with the hydrogeologic conceptual model, where 95% of flow occurs through the shallow intervals. However, flow occurs along geologic strike in the deeper groundwater intervals in the clastic formations (below 30 m or 100 ft), which has resulted in along strike migration of contaminants in the bedrock interval below 30 m (100 ft) at the S-3 Site and at BCBG. Although the total flux of contaminants in this pathway is probably small, the importance of this migration pathway is increased considerably because, where density-driven flow has occurred, concentrations of contaminants that occur in this interval are generally the greatest. In addition, this migration pathway is not limited to tributary catchments, but is able to pass under the shallow hydraulic divides between tributaries and thus contaminates groundwater over a large areal extent. At the S-3 Site, where nitrate and radionuclides have migrated along strike for over 914 m (3000 ft) at depths >30 m (100 ft), the discharge mechanism is by upward migration to the shallow flow system, driven by upward hydraulic gradients and, hence, discharge to the tributaries and Bear Creek.

Rate of Contaminant Flushing

In both the Maynardville Limestone and the Nolichucky Shale, concentrations of contaminants in the shallow intervals are generally less than those seen at depth. The difference in concentrations is probably a function of two processes: matrix diffusion and rate of flushing of contaminants. If the concentrations of contaminants in shallow and deep intervals are assumed to have been comparable

during operation of the waste sites, the differences in concentration have developed primarily since cessation of waste disposal. Contaminant plumes are maintained at high concentrations in the subsurface because the bulk of contamination is held in small pore spaces. Flow in these formations is principally through fractures in the rock, and contaminants migrate by diffusion from the rock matrix to the fractures. The net result is that concentrations of contaminants in most active flow systems are generally lower than in the less active systems; thus, concentrations are generally higher in the deep intervals of the bedrock than in the active shallow intervals. This effect is also observed on an annual basis, where contaminant concentrations in groundwater tend to be higher during the less active, low-flow periods during the summer and fall and lower during the high-flow periods in winter and spring.

Migration Pathways in the Maynardville Limestone

The distribution of contaminants in the Maynardville Limestone contrasts somewhat to that in the clastic formations. Contamination exists at all depths in the Maynardville Limestone; however, contaminants have migrated to depth primarily along deep flow paths in the aquifer. Some of the organic contamination observed in the Maynardville Limestone may have been emplaced as DNAPL by discharges from BYBY or an unknown site on the Bear Creek floodplain; however, both nitrate and uranium that occur at depths >30 m (100 ft) in the Maynardville Limestone are derived from contaminated groundwater and surface water in the Nolichucky Shale.

The Maynardville Limestone and Bear Creek act as a hydraulic drain for BCV, making them the principal migration route for contaminants moving along strike down the valley. These two entities are hydraulically connected and can be considered as a single hydraulic regime within the BCHR. The tributaries that drain catchments containing source areas act as contaminant sources to this Maynardville Limestone/BCHR. Once in this regime, however, the plumes of contaminants become commingled; distinguishing between the ultimate sources is complicated by the fact that the contaminant suites in the sources are similar. This effect is seen particularly well in SS-4, where contaminants in this spring can be attributed to S-3 (nitrate, uranium, and ⁹⁹Tc), BYBY (uranium, TCE, and 1,2-DCE), and an unknown source for VOCs within the BCV floodplain (TCE and 1,2-DCE).

Summary of Uncertainties in Data Interpretation

There will always be some degree of uncertainty associated with interpreting environmental data for characterization of the nature and extent and fate and transport of contaminants — *even if extensive data collection is carried out*. This is especially true for large and diverse sites such as BCV. In BCV, the likelihood of data gaps, and the degree of uncertainty associated with them, was minimized by adherence to the data quality objective (DQO) process (EPA 1987) during planning of the characterization phase. This approach is documented in work plans for soils, surface water, and groundwater sampling (Energy Systems 1993 and DOE 1994b) and in meeting minutes from the BCV RI DQO meeting (DOE 1994c).

The existence of uncertainty in the interpretation of the BCV database does not halt the progress towards developing remedial strategies for the valley. These uncertainties have been identified during the development of the RI and fall into two categories: those where uncertainty was too great to complete a meaningful RI report, and those where it is not too great.

During development of the RI only one situation arose where the uncertainty was too great to complete the RI: this was the case for historical radiological data from the GWQR database that did not meet the quality objectives for the human health risk assessment. The identification of this

uncertainty resulted in an additional round of groundwater and surface water sampling specifically for radiological parameters needed to complete the human health risk assessment. The uncertainty was reduced to reasonable levels by this sampling effort, and the RI could be completed.

In most cases, uncertainty in data interpretation was not considered too great to complete the RI. In these situations, the conceptual model for BCV included the probable condition for the uncertainty based on reasonable scientific evaluation of the existing data. Likely deviations from the site conceptual model are also identified to enable users of the RI to evaluate the potential effects of the uncertainty. The following is a list of the main uncertainties that arose during interpretation of the BCV database. The existence of these uncertainties does not prevent completing the RI or continuing with the remediation effort in BCV.

- **S-3 Site Groundwater – Extent of contamination in the Nolichucky Shale.** The plume of contaminated groundwater derived from the S-3 Site can be traced as far west as NT-2 below 30 m (100 ft) depth; however, no data points exist until downgradient of SL 1 to identify the leading edge of the plume. The probable condition is that the plume in deep groundwater extends no further west than the plume in shallow groundwater and that much of the contaminant mass flux in the plume is discharge to NT-2. The most likely deviation is that the plume of nitrate-contaminated groundwater extends further west in the Nolichucky Shale than NT-2 and will eventually reach NT-3 and further down the valley. Under this scenario, the plume of nitrate-contaminated groundwater will at some point reach a cross-cutting structure and discharge to surface water or the Maynardville Limestone.
- **S-3 Site Groundwater – Uranium pathways.** Recent grab samples from NT-1 show that the main pathway for uranium to surface water at the S-3 Site currently is not to NT-1, as is the case for nitrate, but directly to the main stem of Bear Creek. The combination of field observations and fate and transport modeling suggests that uranium will migrate via the same pathways as nitrate but is relatively retarded in those pathways. The probable condition is that in the pathway to Bear Creek from the S-3 Ponds the concentrations of nitrate reached maximum values during pond operations and have since declined; whereas uranium concentrations, although they have also reached maximum values, have not declined as much. In the pathway to NT-1, uranium has not yet broken through, or is on the verge of breaking through (concentration = 6 $\mu\text{g/L}$), in the groundwater flow pathway.
- **S-3 Site Waste – Potential for leaching uranium.** It is uncertain whether uranium leachate from the waste in place at the S-3 Site is causing groundwater contamination. There are two main components to this uncertainty: (1) does the waste remaining in place at the S-3 Site contact groundwater, and (2) will uranium leach from the waste if it does? The most probable condition is that the waste materials are periodically inundated (during high-flow periods) and that the waste materials will leach uranium to groundwater. The solubility of uranium in this shallow groundwater could reach concentrations of 0.08 mg/L, which is low relative to concentrations already present in the S-3 Site plume (maximum = 33.4 mg/L).
- **S-3 Site Groundwater – DNAPL.** It is uncertain if DNAPL exists in groundwater at the S-3 Site. Concentrations of dissolved phase PCE in GW-243 are ~6% of the maximum solubility, which indicates that DNAPL may be present close to this well. However, DNAPL has not been identified in any soil borings at this site, and PCE is recorded in the waste stream for the S-3 Site only at much lower concentrations (Jeter 1983). The probable condition is that DNAPL is present in the bedrock below the S-3 Ponds.

- **BYBY Wastes – Extent of hot spots.** The extent of the volumes of “hot spots” of buried waste materials at BYBY is uncertain. The presence of uranium waste materials in fill at BYBY is indicated by small amounts of waste observed at the surface, uranium-contaminated groundwater, and geophysical and radiological anomalies. The probable condition is that most of the waste materials are delineated by a geophysical anomaly located between the HCDA cap and NT-3. In addition, uranium waste material is present below the HCDA cap. Waste materials close to NT-3 are inundated most of the time, those farther away from NT-3 are periodically inundated by shallow groundwater or perched water tables. Likely deviations are that the extent of buried uranium waste has been overestimated and only occurs sporadically in fill material.
- **BYBY Groundwater – DNAPL.** It is uncertain whether DNAPL is present in residuum or bedrock at BYBY. Concentrations of dissolved phase VOCs in shallow borings are <1% of the maximum solubility, and DNAPL has not been identified in any soil borings at this site. The probable condition is that DNAPL is not present in the bedrock below the S-3 Ponds. The likely deviation is that DNAPL is present in bedrock in the Nolichucky Shale.
- **BYBY Groundwater – Uranium and VOC pathways.** The extent of ungaged migration of uranium and VOCs ranges from shallow groundwater at BYBY to the Maynardville Limestone. It is well established that BYBY is a source for uranium contamination in the Maynardville Limestone via NT-3; however, additional pathways to the Maynardville Limestone for uranium from this source are indicted by the mass balance in Appendix E. The plumes of uranium and VOCs that are present in shallow groundwater at BYBY are almost on the Bear Creek floodplain. The most probable condition is that uranium- and VOC-contaminated groundwater migrates directly to the Maynardville Limestone and Bear Creek at the BYBY. The likely deviation is that they do not and that the pathway for uranium from the S-3 Site to Bear Creek provides more uranium mass than is currently indicated by the data.
- **BCBG Groundwater – VOC migration.** The VOC contaminant plume derived from BG-A at BCBG extends west in groundwater in the Nolichucky Shale. There are no well points to trace the plume of VOC-contaminated groundwater past GW-629 and GW-627. The most probable condition is that this plume will continue to migrate west along strike and will eventually reach NT-8. Fate and transport modeling indicates that a maximum concentration of PCE in surface water that would result from this plume eventually discharging to NT-8 is 160 to 280 $\mu\text{g/L}$. A likely deviation from this scenario is that the cause of the VOC increase observed in GW-629 and GW-627 is due to drawing contaminants to these wells during purging and sampling. In this situation, the plume is not migrating west.
- **Maynardville Limestone Groundwater – Source of the VOC plumes.** The source of plumes of TCE and 1,2-DCE between the Rust Spoil Area and Picket B in the Maynardville Limestone is uncertain. The probable condition is that there are two sources: an unidentified point source close to what is now Rust Spoil Area, and BYBY. Concentrations of TCE progressively increase downgradient of Rust Spoil Area; this plume configuration suggests that the upgradient source no longer exists (highest concentration would be expected close to the source if it did exist). Likely deviations are that BYBY does not contribute to this plume or that a source, smaller than historically present, remains close to Rust Spoil Area.
- **Maynardville Limestone Groundwater – Extent of contamination beyond Picket A.** Nitrate and uranium contamination is detected in groundwater in two wells at Picket A, which indicates that the contaminant plume in the Maynardville Limestone has reached BCK 9.47. The next monitoring point along strike in BCV is Picket W, ~2.1 km further west, where nitrate has been detected in four wells at low concentrations (maximum concentration = 4.8 mg/L). The source

of nitrate contamination at Picket W is uncertain. Two likely sources are along strike migration in groundwater, and diffuse groundwater contamination from past infiltration from Bear Creek. The probable condition is that both sources provide input, i.e., the nitrate plume in groundwater has started to arrive at wells in Picket W, and groundwater in much of BCK downgradient of BCK 9.47 is contaminated with low concentrations (<1 mg/L) of nitrate derived from infiltration from Bear Creek.

- **Floodplain Soils – “Hot spot” identification.** The strategy for FPSS sampling is concentrated on identifying and analyzing contaminant “hot spots” on the floodplain. The assumption was made that these data are representative of soil and sediment contamination in the floodplain of Bear Creek, i.e., that no “hot spots” exist with significantly greater contamination than those identified by this study. In addition, sampling outside the identified “hot spots” is representative of most of the floodplain. Thus, the probable condition is that the ecological risk assessment based on these data is representative.
- **Surface Water – Concentrations in tributaries.** Water sampling from tributary streams represents the concentrations of contaminants at the confluence of the streams with Bear Creek. These data may not represent the highest concentrations of contaminants in the tributaries because of dilution in the stream between the discharge point and the monitoring point. The probable condition is that the highest concentrations observed at the tributary confluences during baseflow are representative of the highest concentration in the tributary stream. The likely deviation is that there are some localized tributary reaches, close to discharge points, where contaminant concentrations are higher than at the sampling point.
- **Groundwater – Solubility of uranium.** The solubility of uranium in groundwater at the S-3 Site, BYBY, and BCBG is a complex geochemical problem and depends on a number of site-specific parameters. The probable condition is that uranium is sparingly soluble at each site (0.08 to 12 mg/L). Use of the Minteq model, including adsorption of uranium on a pH-dependent adsorption complex, is a reliable way to predict future site-specific maximum concentrations of uranium.
- **Groundwater – Effects of storm flow.** The effects on contaminant migration of the rapid changes in flow during storm events are not fully understood. The probable condition is that as groundwater levels rise during storms additional waste materials become inundated and potentially release contaminants. In addition, where a groundwater plume is the source (as at the S-3 Site), the overall mass flux of contaminants increases during storms. Under storm-flow conditions, these contaminants will probably migrate rapidly to surface water. At the same time, as contaminant fluxes increase, the additional flow in surface water bodies dilutes the concentrations. This results in the overall concentrations decreasing during storms.
- **Groundwater – Future concentration.** Future concentrations of contaminants at discharge points in tributaries for the S-3, BCBG, and BYBY contaminant plumes are probable. Contaminant fate and transport modeling is been used in Appendix E to predict possible future concentration of contaminants at discharge points in NT-1, -2, -3, -7, and -8. As with any modelling exercise, there is a high degree of uncertainty associated with the absolute values; however, the modeling is based on a well-established conceptual model. The most probable condition is that results listed in Appendix E represent orders of magnitude for breakthrough timing and maximum concentrations.

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D.12 FIGURES

Fig. D.1. Map of BCV showing waste units and the extent of the four functional areas.

Fig. D.2. Soil data screening process.

Fig. D.3. Groundwater data screening process.

**Cluster
assignment
model**

**Surrogate cluster
assignment model for
clusters 5, 7, 8, and 9**

Fig. D.4. Cluster assignment and surrogate cluster assignment models for groundwater in BCV.
Source: HSW 1995.

LEGEND:

- GW-105 • S-3 AGGREGATE WELLS
 OIL LANDFARM
 GW-087 ○ AGGREGATE WELLS
 BURIAL GROUNDS
 GW-374 • AGGREGATE WELLS
 MAYNARDVILLE
 GW-645 • AGGREGATE WELLS
 GW-135 • WEST BAY WELLS

SCALE: 1" = 700'

BEAR CREEK VALLEY RI

CROSS-SECTION LOCATION

REVISION	DRAWN BY:	CHKD. BY:	DATE
0	P. HOLM	D. MOSS	08/24/95

XREFERENCES	PLOT FILES
94020\XREF\XRCVS-14 94020\data\NEWEL700	94020\PLT\256SECT

94020/DWGS/256SECT
SAIC CAD FILE #

Fig.D.5. Groundwater wells in BCV identified by FA; also showing locations of cross sections of BCV.

LEGEND:

- 77 ● AGGREGATED SHALLOW WELLS <100 ft DEEP
- 32 ○ AGGREGATED DEEP WELLS >100 ft DEEP
- 28.9 ▲ SURFACE WATER SAMPLE LOCATION
- WESTBAY WELL
- 54 ⊗ 1995 FOURTH QUARTER DATA ONLY
- 6.7 ■ OU1 GEOPROBE GRAB SAMPLE
- NOLICHUCKY/MAYNARDVILLE GEOLOGIC CONTACT

NOTE: Value of the numbers plotted represent the mean Nitrate concentration for a well.

NITRATE CONTOURS (mg/L)

DATA SOURCE: GWQRS e.g., HSW 1995.

BEAR CREEK VALLEY RI

NITRATE (mg/L)

REVISION	DRAWN BY:	CHKD. BY:	DATE
0	P. HOLM	D. MOSS	03/22/95
1	P. HOLM	D. MOSS	08/11/96

XREFERENCES	PLOT FILES
94020\XREF\XRBVC9,10,11,12,13 14,15 DATA/ NEWELLS,2D, SURH2OC, DSUBS, NITR-3, WESTBAY, NOLUSHAL, NOLUDEEP	94020\LOT\061NIT2 PLOT ORIGIN = X -25

94020/DWGS/061NIT2
SAIC CAD FILE #

Fig. D.6. Distribution of nitrate in groundwater in BCV and the interpreted plume of contaminated groundwater for shallow and deep groundwater intervals. Source: data source from GWQRS, e.g., HSW 1995.

DATA SOURCE: GWQRS e.g., HSW 1995.

BEAR CREEK VALLEY RI

ALPHA ACTIVITY (pCi/L)

REVISION	DRAWN BY	CHKD. BY:	DATE
0	P. HOLM	D MOSS	03/22/95
1	P. HOLM	D MOSS	08/11/96

XREFERENCES	PLOT FILES
94020\XREF\XRBCV9,10,11,12,13,14,15, DATA\NEWELL25,20, SURH20C, DSUBS, ALPHA, WESTBAY, XREF/ NOUSHAL, NOLUDEEP	94020\PLOT\061ALPHA PLOT ORIGIN = X -25

94020/DWGS/061ALPHA
SAIC CAD FILE #

Fig. D.7. Distribution of gross alpha contamination in groundwater in BCV and the interpreted plume of contaminated groundwater for shallow, intermediate, and deep groundwater intervals. Source: data source from GWQRs, e.g., HSW 1995.

LEGEND:

- 20 ● AGGREGATED SHALLOW WELLS <100 ft DEEP
- 11 ● AGGREGATED DEEP WELLS >100 ft DEEP
- 60.0 ▲ SURFACE WATER SAMPLE LOCATION
- WESTBAY WELL
- 1995 FOURTH QUARTER
- 6 ⊗ DATA ONLY
- OU1 GEOPROBE
- 82.3 ■ GRAB SAMPLE
- NOLICHUCKY/MAYNARDVILLE
- GEOLOGIC CONTACT

BETA CONTOURS (pCi/L) **NOTE:**

- (1) Value of the numbers plotted represent the mean Beta activity for a well.
- (2) The plume configuration for the deep interval in UEFPC was based on data before 1990. These data have no MDA associated with them and were therefore not used in this RI. The configuration of this portion of the plume must be considered a quantitative estimate.

DATA SOURCE: GWQRS e.g., HSW 1995.

**BEAR CREEK VALLEY
RI****BETA ACTIVITY (pCi/L)**

REVISION	DRAWN BY:	CHKD. BY:	DATE
0	P. HOLM	D. MOSS	03/22/95
1	P. HOLM	D. MOSS	08/12/96

XREFERENCES	PLOT FILES
94020\XREF\XRCVS,10,11,12,13 14,15, DATA\NEWELL2S,20, SURHZOC, DSUBS, BETA-3, WESTBAY, XREF/ NOLUSHAL, NOLUDEEP	94020\LOT\061BETA PLOT ORIGIN = X: -25

94020/DWGS/061BETA
SAIC CAD FILE #

Fig. D.8. Distribution of gross beta contamination in groundwater in BCV and the interpreted plume of contaminated groundwater for shallow, intermediate, and deep groundwater intervals. Source: data source from GWQRs, e.g., HSW 1995.

LEGEND:

- AGGREGATED SHALLOW
WELLS <100 ft DEEP
- AGGREGATED DEEP
WELLS >100 ft DEEP
- SURFACE WATER
- 30.46 ▲ SAMPLE LOCATION
- WESTBAY WELL
- 1995 FOURTH QUARTER
- ⊗ DATA ONLY
- OU1 GEOPROBE
- 15.00 ■ GRAB SAMPLE
- NOLICHUCKY/MAYNARDVILLE
- GEOLOGIC CONTACT
- ⊠ 1995 PIEZOMETER

NOTE: Value of the numbers plotted represent the mean PCE concentration for a well.

**TETRACHLOROETHENE
CONTOURS (ug/L)**

DATA SOURCE: GWQRS e.g., HSW 1995.

**BEAR CREEK VALLEY
RI**

TETRACHLOROETHENE

REVISION	DRAWN BY:	CHKD BY:	DATE
0	P. HOLM	S. REID	03/29/95
1	P. HOLM	D. MOSS	08/12/96

XREFERENCES	PLOT FILES
94020\XREF\XRCV9,10,11,12,13 14,15 DATA\NEWELL25,20, DSUBS, TETRA, WESTBAY XRE\NOLISHAL, NOLUDEEP	94020\LOT\061TET PLOT ORIGIN X -25

94020/DWGS/061TET
SAIC CAD FILE #

Fig. D.9. Distribution of PCE in groundwater in BCV and the interpreted plume of contaminated groundwater for shallow, intermediate, and deep groundwater intervals. Source: data source from GWQRs, e.g., HSW 1995.

NOTE: Value of the numbers plotted represent the mean TCE concentration for a well.

> 5
 > 50
 > 100
 > 1000
 > 10,000

Geological map of the Y-12 Plant North area. The map shows the approximate location of the BC-UEFPC hydraulic divide and the approximate subcrop of the Maynardville Limestone/Nolichucky Shale contact at 200 ft depth. The map includes a grid with Easting coordinates (E 52000, E 53000, E 54000) and a north arrow. Key features include the S-3 Area, NT-1, and various contour lines and shaded regions.

BEAR CREEK VALLEY
RI

TRICHLOROETHENE (μg/L)

REVISION	DRAWN BY:	CHKD BY:	DATE
0	P. HOLM	S. REID	03/29/95
1	P. HOLM	D. MOSS	08/12/96

XREFERENCES	PLOT FILES
94020\XREF\XRCVS,10,11,12,13 14, NOLSHAL, NOLDEEP, DATA\DSUBS,NEWELL20,NEWELL25,	94020\PLOT\061TCE PLOT ORIGIN = X. - 25

94020/DWGS/061TCE
SAIC CAD FILE #

Fig. D.10. Distribution of TCE in groundwater in BCV and the interpreted plume of contaminated groundwater for shallow, intermediate, and deep groundwater intervals. Source: data source from GWQRs, e.g., HSW 1995.

LEGEND:

- 4 ● AGGREGATED SHALLOW WELLS <100 ft DEEP
 20 ○ AGGREGATED DEEP WELLS >100 ft DEEP
 78.00 ▲ SURFACE WATER SAMPLE LOCATION
 ○ WESTBAY WELL
 ⊗ 1995 FOURTH QUARTER DATA ONLY
 16.00 ■ OU1 GEOPROBE GRAB SAMPLE
 - - - - - NOLICHUCKY/MAYNARDVILLE GEOLOGIC CONTACT
 ⊠ 1995 PIEZOMETER LOCATION

NOTE: Value of the numbers plotted represent the mean 1,2-DCE concentration for a well.

**1,2 DICHLOROETHENE
CONTOURS (µg/L)**

DATA SOURCE: GWQRS e.g., HSW 1995.

**BEAR CREEK VALLEY
RI**

1, 2 DICHLOROETHENE

REVISION	DRAWN BY:	CHKD. BY:	DATE
0	P. HOLM	S. RED	03/29/95
1	P. HOLM	D. MOSS	08/12/96

XREFERENCES	PLOT FILES
94020\XREF\XRBVC9.10.11.12.13 14.15 DATA\NEWELL2S.20. DSUBS. 1-20CH. WESTBAY XREF/ NOLISHAL. NOLIDEEP	94020\PILOT\061DE2 PLOT ORIGIN = X: -25

94020/DWGS/061DE2
SAIC CAD FILE #

Fig. D.11. Distribution of 1,2-DCE in groundwater in BCV and the interpreted plume of contaminated groundwater for shallow, intermediate, and deep groundwater intervals. Source: data source from GWQRs, e.g., HSW 1995.

LEGEND:

- AGGREGATED SHALLOW WELLS <100 ft DEEP
- ▲ SURFACE WATER SAMPLE LOCATION
- OU1 GEOPROBE
- GRAB SAMPLE
- NOLICHUCKY/MAYNARDVILLE GEOLOGIC CONTACT

NITRATE CONTOURS (mg/L)

DATA SOURCE: GWQRS e.g., HSW 1995.

**BEAR CREEK VALLEY
RI****NITRATE IN
SHALLOW GROUNDWATER**

REVISION	DRAWN BY:	CHKD. BY:	DATE
0	P. HOLM	D. MOSS	08/24/95
1	P. HOLM	D. MOSS	08/11/96

XREFERENCES	PLOT FILES
94020\XREF\XRCV9-14 NEWELL2S, NOLISHAL DATA\SURH20, DSUBS, WESTBAY, NITRAT-3 NITRSHAL, NITRSHAZ,	94020\PILOT\202SHAL

94020/DWGS/202SHAL
SAIC CAD FILE #

Fig. D.12. Distribution of the plume of nitrate-contaminated groundwater in BCV and time trends of nitrate concentration for shallow groundwater interval. Source: data source from GWQRS, e.g., HSW 1995.

OIL LANDFARM
STORAGE PAD

OIL LANDFARM

BONEYARD/
BURNYARD

SANITARY LANDFILL 1

LEGEND:

- AGGREGATED DEEP WELLS >100 ft DEEP
- ▲ SURFACE WATER SAMPLE LOCATION
- OU1 GEOPROBE GRAB SAMPLE
- ⊗ 1995 FOURTH QUARTER DATA ONLY
- NOLICHUCKY/MAYNARDVILLE GEOLOGIC CONTACT

NITRATE CONTOURS (mg/L)

DATA SOURCE: GWQRs e.g., HSW 1995.

**BEAR CREEK VALLEY
RI****NITRATE IN
INTERMEDIATE AND DEEP
GROUNDWATER**

REVISION	DRAWN BY:	CHKD BY:	DATE:
0	P. HOLM	D. MOSS	08/24/95
1	P. HOLM	D. MOSS	08/11/96

XREFERENCES	PLOT FILES
94020\XREF\XRCV9-14 NEWELL2S, NOLUSHAL DATA/SURH2O, DSUBS, WESTBAY, NITRAT-3 NITPLUMD	94020\PL0T\202SHAL

94020/DWGS/202DEEP
SAIC CAD FILE #

Fig. D.13. Distribution of plume of nitrate-contaminated groundwater in BCV and time trends of nitrate concentration for intermediate and deep groundwater intervals. Source: data source from GWQRs, e.g., HSW 1995.

Fig. D.14. Across strike cross sections of BCV, A-A' and B₂-B₂, showing nitrate concentrations in groundwater.

Fig. D.15. Across strike cross sections of BCV, B-B' and C-C' showing nitrate concentrations in groundwater.

Fig. D.16. Strike parallel cross sections of BCV, E-E' and F-F', showing nitrate concentrations in groundwater.

Fig. D.17. Across strike cross sections of BCV, A-A' and B₂-B₂', showing gross α activities in groundwater.

Fig. D.18. Across strike cross sections of BCV, B-B' and C-C', showing gross α activities in groundwater.

Fig. D.19. Strike parallel cross sections of BCV, E-E' and F-F', showing gross α activities in groundwater.

Fig. D.20. Across strike cross sections of BCV, A-A' and B₂-B₂, showing gross β activities in groundwater.

Fig. D.21. Across strike cross sections of BCV. B-B' and C-C', showing gross β activities in groundwater.

Fig. D.23. Across strike cross sections of BCV, A-A' and C-C', showing PCE concentrations in groundwater.

BC-89 A & B2 TCE

Fig. D.24. Across strike cross sections of BCV, A-A' and B₁-B₂, showing TCE concentrations in groundwater.

Fig. D.25. Across strike cross sections of BCV, B-B' and C-C', showing TCE concentrations in groundwater.

Fig. D.26. Strike parallel cross sections of BCV, E-E' and F-F', showing TCE concentrations in groundwater.

Fig. D.27. Across strike cross sections of BCV, A-A' and B₁-B₂, showing 1,2-DCE concentrations in groundwater.

BC-86A & B2 DCH

Fig. D.28. Across strike cross sections of BCV, B-B' and C-C', showing 1,2-DCE concentrations in groundwater.

Fig. D.29. Strike parallel cross sections of BCV, E-E' and F-F', showing 1,2-DCE concentrations in groundwater.

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Fig. D.32. Sketch of hydrogeologic cross section of the water table interval at the S-3 Site.

Fig. D.33. Hydrographs for BCK 12.38 and NT-2 between March 24, 1994 and January 31, 1995 showing maximum, minimum, and average flows for each day.

Fig. D.34. Representative storm hydrographs for BCK 12.38 and NT-2 for storm 9 (April 16, 1994). (For definition of λ , refer to Appendix C)

Y-12 PLANT NORTH

SHALLOW

Fig. D.35. S-3 area shallow (0 to 8 ft) and deep (> 8 ft) intervals in soil sampling. Results for mercury (Hg), thorium (^{230}Th), ^{234}U , ^{235}U , and ^{238}U .

400 800
SCALE: 1" = 800'

S-3 AREA

SHALLOW (0-8 ft.) and DEEP (>8 ft.)

MERCURY (Hg) (mg/Kg), THORIUM 230 (Th-230),
URANIUM 234, 235, 238, (U-234),
(U-235), (U-238) (pCi/g)

SHALLOW

Fig. D.36. S-3 area shallow (0 to 8 ft) and deep (>8 ft) intervals in soil sampling. Results for total PCBs, acetone (ace), toluene (tol), and tetrachloroethene (PCE).

400 800
SCALE: 1" = 800'

S-3 AREA

SHALLOW (0-8 ft.) and DEEP (>8 ft.)

TOTAL PCBs, ACETONE (Ace),
TOLUENE (Tolu),
TETRACHLOROETHENE (PCE) (ug/Kg)

DEEP

Fig. D.36a. Results of monitoring for nitrate and uranium in surface water at BCK 12.46 between December 1971 and October 1972.

Fig. D.37. Temporal trends in nitrate concentrations and gross β activities at BCK 12.46 and BCK 11.97.

Fig. D.37a. Results of field screening analysis of shallow groundwater and surface water at the S-3 site.

BEAR CREEK VALLEY KEY MAP

LEGEND:

- ROADS
- BEAR CREEK & TRIBUTARIES
- WASTE AREA BOUNDARY

TPB-19	
Conductivity	mS/cm
pH	
Nitrate	ppm
Total Uranium Fluorimetric	ppm
Gross α	pCi/L
Gross β	pCi/L

S-3 AREA
BEAR CREEK VALLEY

Fig. D.38. Location map for temporary piezometers P1 and P2.

D12-72

Fig. D.39. Profile of specific conductivity in the lower reaches of NT-2.

Fig. D.40. Relationship between nitrate concentration and specific conductivity for samples from NT-2.

OAK RIDGE ADMIN. GRID

0 900 1800
SCALE: 1" = 1800'

STREAM MEASUREMENT SITE
SEEP SITES

NO FLOW (missing or zero)
FLOW LESS THAN 0.07 cfs
FLOW GREATER THAN 0.07 cfs

SAIC CAD DWG. 94020\DWGS\268BCV

Fig. D.41. USGS spring and seep survey for BCV.

BEAR CREEK VALLEY WET SEASON AND DRY SEASON SEEP AND SPRING SURVEY (U.S.G.S.)

BLACK = NO CONDUCTIVITY MEASURED
BLUE = CONDUCTIVITY LESS THAN 75 $\mu\text{S}/\text{cm}$
GREEN = CONDUCTIVITY BETWEEN 75 AND 300 $\mu\text{S}/\text{cm}$
RED = CONDUCTIVITY BETWEEN 300 AND 600 $\mu\text{S}/\text{cm}$
MAGENTA = CONDUCTIVITY GREATER THAN 600 $\mu\text{S}/\text{cm}$

Fig. D.42. Temporal trends in gross α activities and uranium concentrations at BCK 12.46 and BCK 11.97.

Fig. D.43. Relationship between surface water specific conductivity and flow at the NT-2 sample point.

Fig. D.44. Relationships between flow and nitrate concentration, gross α activity, and gross β activity at BCK 12.38.

Fig. D.45. Relationships between flow and nitrate concentration and gross β activity at NT-2.

LOCATED TO THE
F THIS LINE ARE
RED UEFPC WELLS.

	UEFPC Aggregate Wells - GW well number													
	105	106	107	108	109	270	273	275	505	508	631	632	633	634
Al	4				41	8	3		6				6	
Ba	6.90			150	54	1.0	2.2	110					29	
Be				0.03	0.01				<0.01	<0.01	<0.01			
B	0.07	0.07		0.36	0.44	0.08			0.05	0.07	0.06		0.62	0.07
Cd	0.02		0.01		4.10			0.04						
Cr									0.01					
Co	0.03			0.06	1.20			0.05		0.13	0.04	0.1		0.05
Cu						0.03	0.03	0.02					1.40	
Pb				0.02										
Mn			4.70	73	200	3.8		4.6		4.95		6.4	4.70	3.1
Hg				0.13										
Ni	0.07			0.0	8.20		0.07		0.04	0.06	0.03	0.03	0.39	
Sr	2.6	7.4		41.0	28.0	5.2	1.1	39.0					14.0	
V					0.01			0.01						
Zn	0.07		0.12	0.12	0.33		0.05	0.10		0.09	0.08	0.06	0.33	0.07
#	8	2	3	8	12	7	6	7	6	6	5	4	8	4

GW-263	
Cr	0.07
Ni	0.21

GW-267	
Al	4.10
Be	0.01

GW-266	
Al	12.35
B	0.04
Be	0.01
Cu	0.01
Mn	2.01
Pb	0.03
Sb	0.07
V	0.01
Zn	0.05

GW-272	
Cu	0.02

GW-195	
Al	9.2
Cu	0.03
V	0.01

GW-335	
Cu	0.01
Hg	2.01
No	0.03
Ni	0.07
Zn	0.05

GW-336	
Cu	0.01

	S-2 PONDS		
	251	254	256
Al		3.6	2.9
Ag			
Be	<0.01		0.01
Cd	0.16	0.04	0.65
Co	0.84		0.61
Cu	0.63	0.29	8.3
Pb	0.02		
Mn	4.85		7.7
Hg		<0.01	<0.01
Ni			0.33
Zn	0.11		0.67
#	7	4	9

LEGEND:

ROADS
BEAR CREEK &
 TRIBUTARIES
WASTE AREA BOUNDARY
PLUME OF METAL CONTAMINATED
 GROUNDWATER
 S-3 AGGREGATE
GW-101 GROUNDWATER WELL
 WESTDAY
GW-135 GROUNDWATER WELL
 MAYNARDVILLE AGGREGATE
GW-122 GROUNDWATER WELL

GW-122	
Ba	9.1
B	0.38
Sr	19.5

—WELL NUMBER

— MEDIAN
CONCENTRATION
OF ANALYTES
(mg/L)

- INORGANIC CONTAMINANTS > BACKGROUND

S-3 SITE
GROUNDWATER
AGGREGATE
Wells with metals
(median concentration) > UTL

S-3 AREA **ACETONE**

Fig. D.47. Distribution of acetone in groundwater at the S-3 Site.

SAC CAD DWG: 94020\DWG5\06153
REV: 1 / 08-11-96

S:\CADD\DWG_94020\DWG\S\201SUM53
REV 1 / 08-12-96

Fig. D.48. Principal organic contaminants in groundwater at the S-3 FA and part of the Maynardville Limestone and Bear Creek FA. Color bars show relative concentrations of individual VOCs.

LEGEND:

- ROADS
- BEAR CREEK & TRIBUTARIES
- WASTE MANAGEMENT BOUNDARY
- S-3 AGGREGATE GROUNDWATER WELL
- MAYNARDVILLE AGGREGATE GROUNDWATER WELL

COLOR BAR REPRESENTS 100% VOCs

GW-243 (groundwater well)
ug/L
(total mean VOCs)

NOTE:
RELATIVE CONCENTRATIONS OF VOCs
ARE BASED ON MEAN OF CONCENTRATIONS FROM HISTORIC SAMPLES.

SYMBOL SHAPE REPRESENTS:

SYMBOL COLOR REPRESENTS:

Y-12 PLANT NORTH

S-3 AREA

D12-87

Fig. D.49. Conceptual model for the current configuration of DNAPL and the dissolved VOC plume at the S-3 Site.

BC-81 Rev 0

Uranium Solubility

Uranium is readily adsorbed during neutralization of S-3 Pond waters by bedrock reaction. This graph depicts the concentration of uranium in solution in the presence of a strong sorber as a function of pH and P_{CO_2} .

Bedrock can potentially release uranium as waste water is neutralized. High P_{CO_2} induces release by promoting formation of mobile uranyl carbonate complexes.

Neutralization

Reactions with aluminosilicate minerals such as illite and kaolinite buffers pH at pH 3.5 to 4.2

Complete neutralization of waste water by dissolution of limestone raises pH of waste water from pH 4.2 to between pH 5 and 7 depending on P_{CO_2} . This reaction releases H_2CO_3 into solution and, in a partially closed system, P_{CO_2} increases as this reaction proceeds.

Fig. D.50. Conceptual model for geochemical reactions during emplacement of contaminated groundwater at the S-3 Site.

Fig. D-51. Changes in gross α and gross β activities in well GW-276 between 1987 and 1990.

Fig. D.52. Changes in PCE, TCE, and nitrate concentrations in well GW-243 between 1988 and 1994 in relation to changes in water level.

Fig. D.53. Conceptual model for emplacement of contaminated groundwater at the S-3 Site.

BC-75 rev 1

Fig. D.54. Conceptual model showing current configuration of the S-3 nitrate plume in the Nolichucky Shale.

Fig. D.55. Distribution of paved areas and mowed grass in S-3 Ponds source unit.

NITRATE

URANIUM

Fig. D.56. Conceptual cross sections showing the current distributions of nitrate and uranium at the S-3 Site.

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Fig. D.58. Schematic hydrogeologic cross section showing the water table interval at the OLF FA.

Fig. D.59. Hydrographs for NT-3 and NT-4 between March 24, 1994 and January 31, 1995 showing maximum, minimum, and average flows for each day.

Fig. D.60. Representative storm hydrographs for NT-3, NT-4, and NT-5 for storm 9 (August 21, 1994).

NOTE:

THIS MAP IS BASED ON CURRENT GEOPHYSICAL INFORMATION AND SURVEYS, AND NONGEOMETRICALLY RESOLVED AERIAL PHOTOGRAPHS. CRITICAL DIMENSIONS SHOULD BE VERIFIED BY FIELD SURVEY.

LEGEND:

- ROADS
- BEAR CREEK & TRIBUTARIES
- 10' CONTOUR
- 900
- ⊕ SBY-11 SURFACE SOIL SAMPLE
- △ BYBY-7 SOIL BORING LOCATION
- ▲ BYBY-9 .. WITH GROUNDWATER SAMPLE
- GW-005 GROUNDWATER WELL LOCATION

BONEYARD/BURNYARD
FLOOR MONITOR**FLOOR MONITOR**

Near surface Beta/Gamma detection.
(cpm)

- 0 - 2000
- 2000 - 3000
- 3000 - 4000
- 4000 - 5000
- 5000 - 6000

Fig. D.61. Radiological survey data for BYBY - Floor monitor.

NOTE:

THIS MAP IS BASED ON CURRENT GEOPHYSICAL INFORMATION AND SURVEYS, AND NONGEOMETRICALLY RESOLVED AERIAL PHOTOGRAPHS. CRITICAL DIMENSIONS SHOULD BE VERIFIED BY FIELD SURVEY.

LEGEND:

- ROADS
- BEAR CREEK & TRIBUTARIES
- 900 10' CONTOUR
- ⊕ SBY-11 SURFACE SOIL SAMPLE
- △ BYBY-7 SOIL BORING LOCATION
- ▲ BYBY-9 .. WITH GROUNDWATER SAMPLE
- GW-005 GROUNDWATER WELL LOCATION

**BONEYARD/BURNYARD
SODIUM IODIDE PROBE****SODIUM IODIDE PROBE**

Near surface gamma detection.
(cpm)

- 0 - 4000
- 4000 - 8000
- 8000 - 12000
- 12000 - 16000
- 16000 - 27000

Fig. D.62. Radiological survey data for BYBY - NaI probe.

**BONEYARD/BURNYARD
EM-31 QUADRATURE** **NOTE:**

THIS MAP IS BASED ON CURRENT GEOPHYSICAL INFORMATION AND SURVEYS, AND NONGEOMETRICALLY RESOLVED AERIAL PHOTOGRAPHS. CRITICAL DIMENSIONS SHOULD BE VERIFIED BY FIELD SURVEY.

LEGEND:

- ROADS
- BEAR CREEK & TRIBUTARIES
- 10' CONTOUR
- ⊕ SBY-11 SURFACE SOIL SAMPLE
- △ BYBY-7 SOIL BORING LOCATION
- ▲ BYBY-9 .. WITH GROUNDWATER SAMPLE
- GW-005 GROUNDWATER WELL LOCATION

EM-31 QUADRATURE

Ground conductivity
to 18m (60 ft.)
(millimhos/m)

- 0 - -80
- 0 - 60
- 60 - 100
- 100 - 160
- 160 - 200

Fig. D.63. Geophysical survey data for BYBY - EM-31 results, Quadrature field.

NOTE:

THIS MAP IS BASED ON CURRENT GEOPHYSICAL INFORMATION AND SURVEYS, AND NONGEOMETRICALLY RESOLVED AERIAL PHOTOGRAPHS. CRITICAL DIMENSIONS SHOULD BE VERIFIED BY FIELD SURVEY.

LEGEND:

- ROADS
- BEAR CREEK & TRIBUTARIES
- 900 10' CONTOUR
- ⊕ SBY-11 SURFACE SOIL SAMPLE
- △ BYBY-7 SOIL BORING LOCATION
- ▲ BYBY-9 .. WITH GROUNDWATER SAMPLE
- GW-005 GROUNDWATER WELL LOCATION

***BONEYARD/BURNYARD
IN-PHASE CONTOURS***

IN-PHASE CONTOUR
Ground conductivity
to 18m (60 ft.)

- -50 - 0
- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20

Fig. D.64. Geophysical survey data for BYBY - EM-31 results, in-phase field.

NOTE:

THIS MAP IS BASED ON CURRENT GEOPHYSICAL INFORMATION AND SURVEYS, AND NONGEOMETRICALLY RESOLVED AERIAL PHOTOGRAPHS. CRITICAL DIMENSIONS SHOULD BE VERIFIED BY FIELD SURVEY.

LEGEND:

- ROADS
- BEAR CREEK & TRIBUTARIES
- 10' CONTOUR
- ⊕ SBY-11 SURFACE SOIL SAMPLE
- △ BYBY-7 SOIL BORING LOCATION
- ▲ BYBY-9 .. WITH GROUNDWATER SAMPLE
- GW-005 GROUNDWATER WELL LOCATION

**BONEYARD/BURNYARD
MAGNETOMETER****MAGNETOMETER**

Earth magnetic field
nano Tesla (nT)

- -20000 - 500
- 500 - 3000
- 3000 - 5000
- 5000 - 7000
- 7000 - 8000

Fig. D.66. Estimated distribution of fill at the BYBY.

SHALLOW

NT-3

SAIC CAD FILE: 94020/DWGS/166BY2-1.DWG

Fig. D.67. BYBY shallow (0 to 8 ft) and deep (> 8 ft) intervals in soil sampling. Results for Cd, Cu, Hg, ⁹⁹Tc, and ²³⁸U.

400 800
SCALE: 1" = 800'

BONEYARD/BURNYARD
SHALLOW (0-8 ft.) and DEEP (>8 ft.)

CADMIUM (Cd), COPPER (Cu)
MERCURY (Hg) (mg/Kg),
TECHNETIUM 99 (Tc-99),
URANIUM 238 (U238) (pCi/g)

SHALLOW

Fig. D.68. BYBY shallow (0 to 8 ft) and deep (> 8 ft) intervals in soil sampling. Results for total PAHs, total PCBs, total phthalates (PHTH), acetone (ace), and toluene (tol).

BONEYARD/BURNYARD
SHALLOW (0-8 ft.) and DEEP (>8 ft.)

TOTAL PAHs, TOTAL PCBs,
TOTAL PHTHALATES (PHTH),
ACETONE (ace) AND TOLUENE (tol),
(ug/Kg)

BEAR CREEK VALLEY KEY MAP

Fig. D.69. OLF shallow (0 to 8 ft) and deep (>8 ft) intervals in soil sampling. Results for Cu, Ba, ^{238}U , ^{60}Co , and ^{208}Tl .

OIL LANDFARM

SHALLOW (0-8 ft.) and DEEP (>8 ft.)

COPPER (Cu), BARIUM (Ba) (mg/Kg),
URANIUM 238 (U238), COBALT-60 (Co-60)
THALLIUM-208 (TI-208) (Pci/g)

Fig. D.70. OLF shallow (0 to 8 ft) and deep (>8 ft) intervals in soil sampling. Results for total PCBs, acetone (ace), methylene chloride (mchl), and toluene (tol).

400 800
SCALE: 1" = 800'

OIL LANDFARM
SHALLOW (0-8 ft.) and DEEP (>8 ft.)

TOTAL PCBs, ACETONE (ace),
METHYLENE CHLORIDE (mchl),
TOLUENE (tol) (ug/Kg)

SHALLOW

Fig. D.71. SL 1 shallow (0 to 8 ft) and deep (>8 ft) intervals in soil sampling. Results for Cu, Hg, Ni, and ^{238}U .

400 800
SCALE: 1" = 800'

SANITARY LANDFILL
SHALLOW (0-8 ft.) and DEEP (>8 ft.)

COPPER (Cu), MERCURY (HG),
NICKEL (Ni) (mg/Kg),
URANIUM 238 (U238) (pCi/g)

D-301

D12-125

BEAR CREEK VALLEY KEY MAP

Y-12 PLANT NORTH

SHALLOW

SAIC CAD FILE: 94020/DWGS/166SL211.DWG

Fig. D.72. SL 1 shallow (0 to 8 ft) and deep (>8 ft) intervals in soil sampling. Results for total PAHs, total PCBs, total phthalate (PHTH), acetone (ace), 2-butanone (2-but).

400 800
SCALE: 1" = 800'

SANITARY LANDFILL

SHALLOW (0-8 ft.) and DEEP (>8 ft.)

TOTAL PAHs, TOTAL PCBs,
TOTAL PHTHALATE (PHTH),
ACETONE (ace), 2-BUTANONE (2-but)
(ug/Kg)

Fig. D.73. Comparison of total isotopic uranium activity to gross α activity in NT-3.

Fig. D.74. Relationship between surface water specific conductivity and flow at the NT-3 sample point.

Fig. D.75. Relationships between activities of gross α and gross β , and flow at NT-3.

Fig. D.76. Relative concentrations of principal organic contaminants in groundwater at the OLF FA and part of the Maynardville Limestone aggregate.

LEGEND:

-ROADS
-BEAR CREEK & TRIBUTARIES
-WASTE AREA BOUNDARY
- BYBY-31995 RI PIEZOMETER
- OIL LANDFARM AGGREGATE
- GW-533GROUNDWATER WELL
- MAYNARDVILLE AGGREGATE
- ⊗ GW-052GROUNDWATER WELL

COLOR BAR REPRESENTS 100% VOCs

GW-307 (groundwater well)
69
(total mean VOCs)

NOTE:
RELATIVE CONCENTRATIONS OF VOCs
ARE BASED ON MEAN OF CONCENTRATIONS FROM HISTORIC SAMPLES.

SYMBOL SHAPE REPRESENTS:

SYMBOL COLOR REPRESENTS:

Y-12 PLANT NORTH

OIL LANDFARM

BEAR CREEK VALLEY KEY MAP

- mixed hardwoods
- pine
- riparian
- old field
- mowed grass
- 1995 RI soil boring
- 1995 RI soil boring with piezometer
- RI surface soil sample
- waste area boundary

Fig. D.78. Habitat description map for BYBY.

Fig. D.79. Habitat description map for OLF and SL 1.

Fig. D.80. Conceptual model for the distribution of contaminants at the BYBY.

BYBY

Fig. D.81. Conceptual model showing waste/groundwater interactions explaining the distribution of contamination in groundwater and surface water at BYBY.

HC-74 rev 1

Fig. D.82. Map showing the distribution of fill material at BYBY relative to geophysical anomalies and groundwater contamination.

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BC-73 rev 0

Fig. D.84. Schematic hydrogeologic cross sections of the water table and shallow bedrock intervals of the Nolichucky Shale at the BCBG FA.

Fig. D.85. Hydrographs for NT-7 and NT-8 between March 24, 1994 and January 31, 1995 showing maximum, minimum, and average flows for each day.

Fig. D.86. Representative storm hydrographs for NT-6, NT-7, and NT-8 for storm 14 (January 19, 1995).

SOURCE:

TOPOGRAPHIC MAP WAS DIGITIZED BY SAIC FROM MMES MAPS I.D. NO. SY4007-00 PREPARED BY CONTINENTAL AERIAL SURVEY, MARCH 7, 1984.

MANAGEMENT AREA ROADS WERE DIGITIZED FROM AERIAL PHOTOGRAPHS, 1991. PHYSICAL FEATURES WERE REVISED BY SAIC FIELD TEAMS, BEAR CREEK VALLEY OU1 & RI FIELD ACTIVITIES, 1995.

NOTE:

THIS MAP IS BASED ON CURRENT GEOPHYSICAL INFORMATION AND SURVEYS, AND NONGEOMETRICALLY RESOLVED AERIAL PHOTOGRAPHS. CRITICAL DIMENSIONS SHOULD BE VERIFIED BY FIELD SURVEY.

Fig. D.87. Radiological survey of BCBG - Pancake probe.

LEGEND:

- ===== ROADS
- BEAR CREEK & TRIBUTARIES
- 900 ----- 10' CONTOUR
- ⊕ SBB-25 SURFACE SOIL SAMPLE
- △ BG-7 SOIL BORING LOCATION
- ▲ BG-3 .. WITH GROUNDWATER SAMPLE
- SW-02 SURFACE WATER SAMPLE
- SF-9 STORM FLOW TUBES

PANCAKE PROBE

(cpm)

- 0 - 200
- 200 - 400
- 400 - 600
- 700 - 900
- 900 - 1000

BURIAL GROUNDS
GM PANCAKE PROBE

SOURCE:

TOPOGRAPHIC MAP WAS DIGITIZED BY
SAIC FROM MMES MAPS I.D. NO.
SY4007-00 PREPARED BY CONTINENTAL
AERIAL SURVEY, MARCH 7, 1984.

MANAGEMENT AREA ROADS WERE
DIGITIZED FROM AERIAL PHOTOGRAPHS,
1991. PHYSICAL FEATURES WERE RE-
VISED BY SAIC FIELD TEAMS, BEAR
CREEK VALLEY 0U1 & RI FIELD
ACTIVITIES, 1995.

NOTE:

THIS MAP IS BASED ON CURRENT
GEOPHYSICAL INFORMATION AND SURVEYS,
AND NONGEOMETRICALLY RESOLVED AERIAL
PHOTOGRAPHS. CRITICAL DIMENSIONS SHOULD
BE VERIFIED BY FIELD SURVEY.

Fig. D.88. Radiological survey of BCBG - NaI probe.

LEGEND:

- ROADS
- BEAR CREEK & TRIBUTARIES
- 10' CONTOUR
- ⊕ SBB-25 SURFACE SOIL SAMPLE
- △ BG-7 SOIL BORING LOCATION
- ▲ BG-3 .. WITH GROUNDWATER SAMPLE
- SW-02 SURFACE WATER SAMPLE
- SF-9 STORM FLOW TUBES

SODIUM IODIDE

(cpm)

- 3000 - 6000
- 6000 - 9000
- 9000 - 12000
- 12000 - 15000
- 15000 - 27000

BURIAL GROUNDS SODIUM IODIDE

400 800
SCALE: 1" = 800'

AGGREGATE I:
BURIAL GROUNDS - A NORTH
SHALLOW (0-8 ft.) and DEEP (>8 ft.)

TOTAL PCBs
1,1,1 TRICHLOROETHANE (111TCA)
1,1 DICHLOROETHANE (11DCA)
TOLUENE (TOL)
(ug/Kg)

DEEP

D12-157

BEAR CREEK VALLEY KEY MAP

SHALLOW-NOT DETECTED
ABOVE BACKGROUND

SAIC CAD FILE: 94020/DWGS/166B2S4.DWG

Fig. D.90. Aggregate II - Burial Grounds (A South) shallow (0 to 8 ft) and deep (> 8 ft) intervals in soil sampling. Results for Ba, Ni, and ²⁰⁸Pb.

AGGREGATE II
BURIAL GROUNDS - A SOUTH
 SHALLOW (0-8 ft.) and DEEP (>8 ft.)

BARIUM, (Ba)
 NICKEL, (Ni) (mg/Kg)
 THALLIUM 208 (TI208) (pCi/g)

DEEP

BEAR CREEK VALLEY KEY MAP

Y-12 PLANT NORTH

SHALLOW

SAIC CAD FILE: 94020/DWGS/166B2S5.DWG

Fig. D.91. Aggregate II - Burial Grounds (A North) shallow (0 to 8 ft) and deep (> 8 ft) intervals in soil sampling. Results for acetone (ace), PCE, TCE, and toluene (tol).

400 800
SCALE: 1" = 800'

AGGREGATE II:
BURIAL GROUNDS - A SOUTH
SHALLOW (0-8 ft.) and DEEP (>8 ft.)

ACETONE (ACE)
TETRACHLOROETHENE (PCE)
TRICHLOROETHENE (TCE)
TOLUENE (TOL) (ug/Kg)

DEEP

0 400
SCALE: 1" =

SAIC CAD FILE: 94020/DWGS/166B2S6.DWG

Fig. D.92. Aggregate III - Burial Grounds (A-16, -17, -18) shallow (0 to 8 ft) and deep (>8 ft) intervals in soil sampling. Results for total PCBs, total PAHs, bis(2-ethylhexyl)phthalate (PHTH), 2-butanone (2BUT), and toluene (tol).

AGGREGATE III:
BURIAL GROUNDS - A16, 17, 18
SHALLOW (0-8 ft.) and DEEP (>8 ft.)

TOTAL PCBs, TOTAL PAHs,
Bis(2-ethylhexyl)phthalate (PHTH)
2-BUTANONE (2BUT)
TOLUENE (TOL) (ug/Kg)

800
0'

DEEP

SHALLOW

Fig. D.93. Aggregate IV - Burial Grounds (WIP North and South, BG-B, BG-D South) shallow (0 to 8 ft) and deep (>8 ft) intervals in soil sampling. Results for CN, Ba, and ^{238}U .

400 800
SCALE: 1" = 800'

AGGREGATE IV:
BURIAL GROUNDS - WIP NORTH
AND SOUTH, BG-B, BG-D SOUTH

SHALLOW (0-8 ft.) and DEEP (>8 ft.)

CYANIDE (CN)
BARIUM (Ba) (mg/Kg),
URANIUM 238 (U238) (pCi/g)

DEEP

D12-165

**AGGREGATE IV
BURIAL GROUNDS - WIP NORTH
AND SOUTH, BG-B, BG-D SOUTH**

SHALLOW (0-8 ft.)

TOTAL PCBs
TOLUENE (TOL)
(ug/Kg)

SAIC CAD FILE: 94020/DWGS/166B2S9.DWG

Fig. D.94. Aggregate IV - Burial Grounds (WIP North and South, BG-B, BG-D South) shallow (0 to 8 ft) interval in soil sampling. Results for total PCBs and toluene (tol).

Fig. D.95. Aggregate V - Burial Grounds (C West) shallow (0 to 8 ft) and deep (> 8 ft) intervals in soil sampling. Results for As, Cu, Zn, ⁹⁹Tc, ²³⁸U, and ²³⁴U.

400 800
SCALE: 1" = 800'

**AGGREGATE V:
BURIAL GROUNDS - C WEST
SHALLOW (0-8 ft.) and DEEP (>8 ft.)**

ARSENIC (As), COPPER (Cu),
ZINC (Zn) (mg/Kg), TECHNETIUM 99 (Tc99),
URANIUM 238 (U238),
URANIUM 234 (U234) (pCi/g)

BEAR CREEK VALLEY KEY MAP

SHALLOW

SAIC CAD FILE: 94020/DWGS/166B2S13.DWG

Fig. D.96. Aggregate V - Burial Grounds (C West) shallow (0 to 8 ft) and deep (> 8 ft) intervals in soil sampling. Results for acetone (ace), toluene (tol), PCE, total aroclors (PCBs), and 4-methyl-2-pentanone (4M2P).

400 800
SCALE: 1" = 800'

AGGREGATE V
BURIAL GROUNDS - C WEST
SHALLOW (0-8 ft.) and DEEP (>8 ft.)

ACETONE (ACE), TOLUENE (TOL),
TETRACHLOROETHENE (PCE),
TOTAL AROCLORS (PCB),
4-methyl-2-pentanone (4M2P)
(ug/Kg)

**AGGREGATE VI:
BURIAL GROUNDS - C, D EAST
SHALLOW (0-8 ft.)**

**TECHNETIUM 99 (Tc99),
URANIUM 238 (U238),
URANIUM 234 (U234)
(pCi/g)**

Fig. D.97. Aggregate VI - Burial Grounds (C, D East) shallow (0 to 8 ft) interval in soil sampling. Results for ^{99}Tc , ^{238}U , and ^{234}U .

D12-172

AGGREGATE VI
BURIAL GROUNDS - C, D EAST
SHALLOW (0-8 ft.)

TOTAL AROCLORS (PCB),
TOLUENE (TOL)
(ug/Kg)

BEAR CREEK VALLEY KEY MAP

SHALLOW

Fig. D.98. Aggregate VI - Burial Grounds (C, D East) shallow (0 to 8 ft) interval in soil sampling. Results for total aroclors (PCBs) and toluene (tol).

Fig. D.99. Relationship between concentrations of 1,2-DCE, PCE, and TCE, and flow at NT-7.

Fig. D.100. Chemical and biologically mediated breakdown pathways for organic chemicals in the BCBG FA.

D12-175

BURIAL GROUND

OIL LANDFARM

S-3 SITE

BEAR CREEK VALLEY KEY MAP

LEGEND:

- ROADS
- BEAR CREEK & TRIBUTARIES
- McCAULEY, 1985 DATA
 ∇ 3A 88 TOTAL URANIUM ACTIVITY pCi/L
- BOGLE & TURNER (1991),
 $\blacklozenge$ 3A (210) GROSS ALPHA ACTIVITY (pCi/L)

0 250 500
 SCALE: 1" = 500'

Y-12 PLANT NORTH

Fig. D.101. Historical activities of radiological contamination of surface water in NT-8.

Fig. D.14/. Conceptual model for the distribution of DNAPL in the subsurface at the BCBG.
Source: Dreier and Davidson 1994.

LEGEND:

..... ROADS
 BEAR CREEK & TRIBUTARIES
 .. WASTE AREA BOUNDARY

APPROXIMATE BOUNDARY OF PLUMES
 .. DISCUSSED IN THE TEXT

BURIAL GROUND AGGREGATE
 ○ GW-373..... GROUNDWATER WELL
 BG-3..... 1995 RI PIEZOMETER
 MAYNARDVILLE AGGREGATE
 ⊗ GW-052..... GROUNDWATER WELL

COLOR BAR REPRESENTS 100% VOCs

GW-046 (groundwater well)
 2272 ug/L
 (total mean VOCs)

..... 1,1,1 trichloroethane
 trichloroethene
 tetrachloroethene
 1,2 dichloroethene
 1,1 dichloroethane
 & 1,1 dichloroethane
 sum: vinyl chloride,
 chloroform & chloroethane

NOTE:
 RELATIVE CONCENTRATIONS OF VOCs
 ARE BASED ON MEAN OF CONCENTRATIONS FROM HISTORIC SAMPLES.

SYMBOL SHAPE REPRESENTS:

BEDROCK SHALLOW
 WATER TABLE
 BEDROCK DEEP
 5-50 ug/L
 50-100 ug/L
 100-1000 ug/L
 >1000 ug/L

SYMBOL COLOR REPRESENTS:

SOIL BORING
 .. WITH GROUNDWATER SAMPLE
 BURIAL GROUND AGGREGATE
 GROUNDWATER WELL
 MAYNARDVILLE AGGREGATE
 GROUNDWATER WELL

NOTE:
 HISTOGRAM INSETS SHOW TRENDS
 IN ABSOLUTE CONCENTRATIONS IN
 INDIVIDUAL WELLS. (COLOR CODE
 IS CONSISTENT WITH RELATIVE
 CONCENTRATION PLOTS)

0 150 300
 SCALE: 1" = 300'

BURIAL GROUNDS

Fig. D.104. Historic VOC concentrations in well GW-117.

☐ mixed hardwoods	☐ wetland	☒ 1995 RI soil boring with piezometer
☐ gravel	☐ old field	☒ RI surface soil sample
☐ mowed grass	☐ 1995 RI soil boring	☒ waste area boundary

Fig. D.106. Habitat description map for BCBG.

Fig. D.107. Description of BG West group for BCBG.

Fig. D.103. Conceptual model for the distribution of contaminants at the BCBG FA.

Conceptual Model for Contamination at the Burial Grounds

Fig. D.109. Conceptual model showing waste and groundwater interactions explaining the distribution of contamination in groundwater in surface water at the BCBG.

Fig. D.110. Hydrograph for BCK 9.47 and SS-5 between March 24, 1994 and January 31, 1995 showing maximum, minimum, and average flows for each day.

Fig. D.111. Hydrograph for SS-1, SS-4, and SS-6 between March 24, 1994 and January 31, 1995 showing maximum, minimum, and average flows for each day.

SAIC CAD DWG: 94020\DWGS\263CAD

Fig. D.112. Distribution of cadmium on floodplain soils and sediments.

LEGEND:

- BEAR CREEK & TRIBUTARIES
- MANAGEMENT AREA BOUNDARIES
- TS01 BCV FLOODPLAIN SOIL TRANSECT
- SD01BCV FLOODPLAIN SEDIMENT SAMPLE

CADMIUM
background = 0.31
range = .31 to 21.7 mg/kg

- SEDIMENT SOIL
- △ <1 mg/kg
 - △ 1-10 mg/kg
 - △ >10 mg/kg

Maximum Cadmium Values > Background (mg/kg)			
STATION	0 - 4 in	4 - 16 in	16 - 32 in
SD01	4.00		
SD02	21.70		
SD04	9.20		
SD07	10.60		
SD10	4.50		
SD11	5.10		
SD14	16.20		
SD15	0.53		
TS01	9.30	2.90	
TS02	0.96		
TS03	8.70	11.10	
TS05		0.51	
TS06	1.40	0.50	
TS07	3.50	0.62	
TS10	0.37		
TS12			0.31

Y-12 PLANT NORTH

SCALE: 1" = 2500'

BEAR CREEK VALLEY
CADMIUM

Fig. D.113. Distribution of lithium on floodplain soils and sediments.

Maximum Lithium Values > Background (mg/kg)			
STATION	0 – 4 in	4 – 16 in	16 – 32 in
SD09	45.00		
SD12	69.00		
TS01	41.00		
TS03		33.40	
TS04	55.20	39.10

Y-12 PLANT NORTH

SCALE: 1" = 2500'

BEAR CREEK VALLEY
LITHIUM

SAIC CAD DWG: 94020\DWGS\263MER

Fig. D.114. Distribution of mercury on floodplain soils and sediments.

LEGEND:

..... BEAR CREEK & TRIBUTARIES

..... MANAGEMENT AREA BOUNDARIES

TS01 BCV FLOODPLAIN SOIL TRANSECT

SD01BCV FLOODPLAIN SEDIMENT SAMPLE

MERCURY

background = .34 mg/Kg
range = 0.36 - 7.3 mg/Kg

SEDIMENT SOIL

▲<1 mg/Kg
▲1 - 5 mg/Kg
▲>5 mg/Kg

Maximum Mercury Values > Background (mg/kg)			
STATION	0 - 4 in	4 - 16 in	16 - 32 in
SD02	3.00		
SD04	6.90		
SD07	0.53		
TS01	7.30	1.60	
TS02	1.60	0.41	
TS03	1.70	2.50	
TS04		0.43	
TS06	0.67		
TS07	1.14		
TS08	0.42		
TS12			0.47
TS13	0.36

SCALE: 1" = 2500'

BEAR CREEK VALLEY
MERCURY

DEPTH: 0-4"

DEPTH: 4-16"

DEPTH: 16-32"

Fig. D.115. Distribution of selenium on floodplain soils and sediments.

LEGEND:

..... BEAR CREEK & TRIBUTARIES

..... MANAGEMENT AREA BOUNDARIES

TS01 BCV FLOODPLAIN SOIL TRANSECT

SD01BCV FLOODPLAIN SEDIMENT SAMPLE

SELENIUM

background = 1.20 mg/Kg

range = 1.3 – 6.7 mg/Kg

SEDIMENT SOIL

▲<5 mg/Kg

●>5 mg/Kg

Maximum Selenium Values > Background (mg/kg)			
STATION	0 – 4 in	4 – 16 in	16 – 32 in
SD01	3.60		
SD02	3.90		
SD03	2.40		
SD04	5.50		
SD05	2.20		
SD06	2.70		
SD07	4.20		
SD08	6.70		
SD09	3.50		
SD10	3.10		
SD11	3.90		
SD12	2.50		
SD13	2.00		
SD14	6.60		
TS01	2.50	2.40	
TS02	3.20	2.20	
TS03	2.10	2.10	
TS04	2.70	2.50	
TS05	1.30	1.70	
TS06	1.20	1.40	2.10
TS07	2.60	2.80	
TS08	1.20	2.00	
TS09		1.20	
TS10	1.40	1.40	
TS11			1.60
TS12			1.70
TS13	1.50	1.30

SCALE: 1" = 2500'

BEAR CREEK VALLEY
SELENIUM

DEPTH: 0-4' **DEPTH: 4-16'** **DEPTH: 16-32'**

(no TC-99 detected at activity
concentrations greater than
background in this depth interval.)

Fig. D.116. Distribution of ^{99}Tc on floodplain soils and sediments.

LEGEND:

..... BEAR CREEK & TRIBUTARIES

..... MANAGEMENT AREA BOUNDARIES

TS01 BCV FLOODPLAIN SOIL TRANSECT

SD01BCV FLOODPLAIN SEDIMENT SAMPLE

TC-99

background = 4.07 pCi/g
range = 4.55 - 11.98 pCi/g

SEDIMENT SOIL

▲ <5 pCi/g

● >5 pCi/g

Maximum Tc-99 Values > Background (pCi/g)			
STATION	0 - 4 in	4 - 16 in	16 - 32 in
SD02	8.74		
SD09	5.43		
SD14	4.93		
TS01	10.81		
TS02	8.38		
TS03	11.98		
TS04	4.55	6.45

SCALE: 1" = 2500'

BEAR CREEK VALLEY
TC 99

DEPTH: 0-4"

DEPTH: 4-16"

DEPTH: 16-32"

SAC CAD DWG: 94020\DWGS\2630238

Fig. D.117. Distribution of ^{238}U on floodplain soils and sediments.

LEGEND:

..... BEAR CREEK & TRIBUTARIES

..... MANAGEMENT AREA BOUNDARIES

TS01 BCV FLOODPLAIN SOIL TRANSECT

SD01BCV FLOODPLAIN SEDIMENT SAMPLE

U-238

background = 2.6 pCi/g
range = 2.69 to 94.35 pCi/g

SEDIMENT SOIL

▲<10 pCi/g
●10 - 50 pCi/g
▲>50 pCi/g

Maximum U-238 Values > Background (pCi/g)			
STATION	0 - 4 in	4 - 16 in	16 - 32 in
SD01	7.35		
SD02	27.38		
SD04	34.39		
SD07	14.83		
SD08	13.32		
SD09	21.56		
SD10	9.36		
SD11	7.98		
SD14	36.53		
SD17	4.75		
SD18	5.28		
TS01	67.00	10.11	
TS02	5.45		
TS03	39.55	51.94	
TS04	63.41	94.35	
TS06	60.72	4.02	
TS07	52.66	6.93	
TS08	6.17		
TS09	2.69		
TS10	13.14		
TS12			4.32

Y-12 PLANT NORTH
SCALE: 1" = 2500'

BEAR CREEK VALLEY
URANIUM 238

Fig. D.118. Distribution of PCBs (total) on floodplain soils and sediments.

LEGEND:

..... BEAR CREEK & TRIBUTARIES

..... MANAGEMENT AREA BOUNDARIES

TS01 BCV FLOODPLAIN SOIL TRANSECT

SD01BCV FLOODPLAIN SEDIMENT SAMPLE

PCBs (TOTAL)

range = 17 - 2500 ug/Kg

SEDIMENT SOIL

▲ <100 ug/Kg
 ● 100 - 1000 ug/Kg
 ▲ >1000 ug/Kg

Maximum Total PCB Values (ug/kg)			
STATION	0 - 4 in	4 - 16 in	16 - 32 in
SD02	120.00		
SD04	1180.00		
SD05	98.00		
SD06	25.00		
SD07	59.00		
SD08	430.00		
SD09	2500.00		
SD10	1200.00		
SD11	520.00		
SD14	24.00		
SD15	38.00		
SD16	39.00		
SD17	110.00		
SD18	17.00		
TS01	780.00	190.00	
TS02	28.00		
TS03	170.00	212.00	
TS04	870.00	1700.00	
TS06	510.00	62.00	41.00
TS07	1300.00	56.00	
TS08	150.00	6.40	
TS09	30.00		
TS10	1000.00	57.00	
TS12			48.00
TS13	78.00

SCALE: 1" = 2500'

BEAR CREEK VALLEY **PCBs (TOTAL)**

Fig. D.119. Distribution of PAHs (total) on floodplain soils and sediments.

LEGEND:

..... BEAR CREEK & TRIBUTARIES

..... MANAGEMENT AREA BOUNDARIES

TS01 BCV FLOODPLAIN SOIL TRANSECT

SD01BCV FLOODPLAIN SEDIMENT SAMPLE

PAH (TOTAL)

range = 46-65, 878 ug/Kg

SEDIMENT SOIL

- ▲<1000 ug/Kg
- 1000 - 10,000 ug/Kg
- ▲>10,000 ug/Kg

Maximum Total PAH Values (ug/kg)			
STATION	0 - 4 in	4 - 16 in	16 - 32 in
SD02	1970.00		
SD04	65878.00		
SD07	230.00		
SD11	1591.00		
SD12	863.00		
SD14	745.00		
SD15	380.00		
SD16	1124.00		
SD17	477.00		
TS01	1195.00	86.00	
TS02	199.00		
TS03	1083.00	1163.00	
TS07	68.00		
TS10	46.00		
TS12			363.00

SCALE: 1" = 2500'

BEAR CREEK VALLEY
PAH (TOTAL)

Fig. D.120. Distribution of phthalates (total) on floodplain soils and sediments.

LEGEND:

- BEAR CREEK & TRIBUTARIES
- MANAGEMENT AREA BOUNDARIES
- TS01 BCV FLOODPLAIN SOIL TRANSECT
- SD01BCV FLOODPLAIN SEDIMENT SAMPLE

PHTHALATES (TOTAL)
range = 33 - 920 ug/Kg

SEDIMENT SOIL

▲ ● <100 ug/Kg

▲ ● 100-500 ug/Kg

▲ ● >500 ug/Kg

Maximum Total Phthalate Values (ug/kg)			
STATION	0 - 4 in	4 - 16 in	16 - 32 in
SD02	920.00		
SD03	86.00		
SD04	86.00		
SD05	85.00		
SD06	74.00		
SD07	122.00		
SD08	88.00		
SD09	191.00		
SD10	130.00		
SD11	82.00		
SD13	120.00		
SD14	130.00		
SD15	152.00		
SD16	150.00		
SD17	150.00		
TS01	410.00	420.00	
TS02	40.00		
TS03	184.00	204.00	
TS04	138.00	120.00	
TS05	76.00	150.00	
TS06	57.00	158.00	430.00
TS07	120.00	82.00	
TS08	38.00	40.00	
TS09	160.00		
TS10	92.00	160.00	
TS11			85.00
TS12			33.00

Y-12 PLANT NORTH

SCALE: 1" = 2500'

BEAR CREEK VALLEY
PHTHALATES (TOTAL)

Fig. D.121. Concentrations of TCE and 1,2-DCE in SS-4 during sampling in OU 4.

Fig. D.122. Comparison of gross β and gross α activities in SS-4 and BCK 12.38 during sampling at OU 4.

Fig. D.123. Comparison of gross β and gross α activities in SS-5 and BCK 9.47 during sampling at OU 4.

Fig. D.124. Comparison of historical nitrate concentrations in wells GW-227 and GW-228.

Fig. D.125. Comparison of nitrate concentrations in SS-1, SS-4, and SS-5 during sampling at OU 4.

Fig. D.126. Comparison of nitrate concentrations in SS-4, BCK 12.38, and BCK 9.47 during sampling at OU 4.

Fig. D.127. Nitrate concentrations in Bear Creek in April 1984 and August 1984.

BEAR CREEK VALLEY KEY MAP

LEGEND:

- ===== ROADS
- BEAR CREEK & TRIBUTARIES
- 900--- 10' CONTOUR
- ⊙ 1984 TRIB. STUDY
- ▽ BECHTEL DATA (McCAULEY, 1985)
- SAMPLING ON 3/2/84 AND 3/3/84
- 82** (values in mg/L)
- SAMPLING ON 8/21/84 AND 8/22/84
- 48** (values in mg/L)

BEAR CREEK VALLEY
NITRATE CONCENTRATION
APRIL 1984 - AUGUST 1984

Fig. D.128. Examples of cyclic contaminant concentrations from wells GW-537 and GW-684.

Fig. D.129. Conceptual model for the current configuration of plumes in the Maynardville Limestone.

Plume of nitrate-contaminated groundwater ($>10\text{mg/L}$ and $<100\text{ mg/L}$)

TCE Plume

TCE contamination at SS-4

Gaining reaches of Bear Creek with year-round flow

Gaining reaches of Bear Creek that are periodically dry during summer

Losing reaches of Bear Creek

Indicates pathways from intermediate and deep groundwater to springs SS-4 and SS-5

B wells

D.13 TABLES

Table D.1. Data validation process used in BCV

Validation qualifier	Analytical group		
	Organics	Inorganics	Radiological
U	Not detected	Not detected	Activity < MDA ^a
UJ	Not detected above estimated quantitation level	Not detected above estimated quantitation level	Estimated activity < MDA
J	Detected concentration is estimated value	Detected concentration is estimated value	Estimated activity > MDA; or activity > MDA and counting error is within 50%-100 % of activity ^b
R	Results fail analytical quality control criteria	Results fail analytical quality control criteria	Results fail analytical quality control criteria; or activity > MDA and counting error > 100% of activity ^b
N	Tentatively identified compound (TIC)	NA ^c	NA
NJ	TIC with estimated value	NA	NA
=	Positively identified, concentration is accurate	Positively identified, concentration is accurate	Activity > MDA, no quality control issues

^a MDA = minimal detectable activity.

^b These criteria were used only during validation of Floodplain soils data; the radiological validation process was undergoing transition. New criteria were added between the BCV OU 1 and Floodplain soils projects.

^c Qualifier not applicable to this analytical group.

Table D.2. Soils data validation results

Location	Rejected analytes/ total analytes	Percent rejected	Major analytes rejected	Reason for rejection
Burial Grounds	195/ 12,169	1.60	PCBs/pesticides (4 samples)	Surrogate recovery < 10 %
			Thorium isotopes (5 samples)	Radiological chemical recovery < 20 %
Boneyard/Burnyard	32/ 6818	0.47	Antimony (22 samples)	Concentration < CRQL
Sanitary Landfill 1	36/ 1830	1.97	Antimony (8 samples)	MS recovery < 30 %
Oil Landfarm	34/ 2552	1.33	Antimony (21 samples)	MS recovery < 30 %
S-3 Ponds	69/ 4892	1.41	Antimony (40 samples)	Concentration < CRQL; MS recovery < 30 %
Floodplain soils	35/ 8229	0.43	Antimony (8 samples)	MS recovery < 30 %
			Uranium isotopes (7 samples)	Radiological recovery < 20 %
Floodplain soils reference location	0/ 24	0.00		
Floodplain sediments	2/ 3481	0.06	Antimony (2 samples)	MS recovery < 30 %
Floodplain sediments reference location	3/ 1026	0.29	Antimony (3 samples)	MS recovery < 30 %

CRQL = contract required quantitation level

MS = mass spectrometry

Table D.3. OLF, BYBY, and SL 1 soil boring aggregates

S-3 Site	BYBY	OLF	SL 1	Drum Sample
S3-01 ^a	SBY-1 ^b	OLF-1 ^a	SSL-1 ^b	SBY-27 ^b
S3-02 ^a	SBY-2 ^b	OLF-2 ^a	SSL-2 ^b	
S3-03 ^a	SBY-3 ^b	OLF-3 ^a	SSL-3 ^b	
S3-04 ^a	SBY-5 ^b	OLF-4 ^a	SSL-4 ^b	
S3-05 ^a	SBY-6 ^b	OLF-5 ^a	SSL-5 ^b	
S3-06 ^a	SBY-7 ^b	SOL-1 ^b	SSL-6 ^b	
S3-07 ^a	SBY-9 ^b	SOL-2	SSL-7 ^b	
S3-08 ^a	SBY-10 ^b	SBY-4 ^b	SSL-8 ^b	
S3-09 ^a	SBY-11 ^b	SBY-8 ^b	SSL-9 ^b	
S3-10 ^a	SBY-13 ^c	SBY-12 ^b	SSL-10 ^b	
	SBY-14 ^b		SSL-11 ^b	
	SBY-15 ^b		SSL-12 ^b	
	SBY-17 ^c		SSL-13 ^c	
	SBY-18 ^b		SSL-14 ^b	
	SBY-19 ^b		SL1-1 ^a	
	SBY-20 ^c		SL1-2 ^a	
	SBY-21 ^c		SBY-16 ^c	
	SBY-22 ^c		SBY-24 ^b	
	SBY-23 ^b			
	SBY-25 ^b			

Table D.3 (continued)

S-3 Site	BYBY	OLF	SL 1	Drum Sample
	SBY-26 ^b			
	SBY-28 ^b			
	BYBY-1 ^a			
	BYBY-2 ^a			
	BYBY-3 ^a			
	BYBY-4 ^a			
	BYBY-5 ^a			
	BYBY-6 ^a			
	BYBY-7 ^a			
	BYBY-8 ^a			
	BYBY-9 ^a			

^a Subsurface soil, full laboratory analytical data

^b Surface soil, field screening data only (metals, PCBs, Total Uranium, and % U²³⁵)

^c Surface soil, full laboratory analytical data

Table D.4. BCBG soil boring aggregates

Aggregate I BG-A North	Aggregate II BG-A South	Aggregate III A-16, 17, 18	Aggregate IV WIP (N&S), BG-B, BG-D (S)	Aggregate V BG-C (W)	Aggregate VI BG-C (E), BG-D (E)	Aggregate VII BG-D (W), BG-E, BG-J	Waste Sample
BG-5 ^a	BG-1 ^a	BG-8 ^a	BG-11 ^a	BG-10 ^a	SBG-20 ^c	SBG-12 ^b	SGB-42
BG-6 ^a	BG-2 ^a	SBG-24 ^b	BG-12 ^a	BG-13 ^a	SBG-32 ^b	SBG-13 ^b	
BG-7 ^a	BG-3 ^a	SBG-25 ^c	SBG-1 ^b	BG-14 ^a	SBG-33 ^c	SBG-21 ^b	
BG-16 ^a	BG-4 ^a	SBG-26 ^b	SBG-2 ^b	BG-15 ^a	SBG-34 ^b	SBG-22 ^b	
SBG-40 ^b		SBG-27 ^b	SBG-3 ^b	SBG-8 ^b	SBG-35 ^b	SBG-28 ^b	
SBG-41 ^b		SBG-36 ^b	SBG-4 ^b	SBG-9 ^b		SBG-30 ^b	
SBG-44 ^c		SBG-37 ^b	SBG-5 ^b	SBG-10 ^b		SBG-31 ^b	
		SBG-38 ^b	SBG-6 ^b	SBG-11 ^c			
			SBG-7 ^c	SBG-17 ^b			
			SBG-14 ^b	SBG-29 ^b			
			SBG-15 ^b	SBG-43 ^c			
			SBG-16 ^b				
			SBG-18 ^b				
			SBG-19 ^b				
			SBG-23 ^b				
			SBG-39 ^b				

^a Subsurface soil, full laboratory analytical data^b Surface soil, field screening data only (metals, PCBs) - no analytical data^c Surface soil, full laboratory analytical data

Table D.5. BCV background soil data

Analyte (units)	Results > detection limit	%Results > detection limit	Average result	Coefficient of variation (%)	Min detect	Max detect	Dist. ^a	95% upper tolerance limit	Nonparametric 95% UTL	99th percentile	Background criteria
<i>Inorganics</i>											
Aluminum (mg/Kg)	24/ 24	100	31900	28	16900	46700	N	53000	46700	46700	46700
Antimony (mg/Kg)	9/ 24	37.5	0.3	84	0.49	1	D	.	1	1	1
Arsenic (mg/Kg)	21/ 22	95.5	8.4	57	4	20.2	X	.	20.2	20.2	20.2
Barium (mg/Kg)	24/ 24	100	94.9	32	59.7	212	X	.	212	212	212
Beryllium (mg/Kg)	24/ 24	100	0.97	39	0.4	2.2	L	2.1	2.2	2.2	2.1
Boron (mg/Kg)	9/ 23	39.1	13.5	86	13.9	34	D	.	34	34	34
Cadmium (mg/Kg)	0/ 24	0	0.1	8	.	.	O	.	0.3	0.3	0.3
Calcium (mg/Kg)	15/ 15	100	1010	37	370	1860	N	1980	1860	1860	1860
Chromium (mg/Kg)	22/ 22	100	39.3	38	19.4	80.1	L	82.5	80.1	80.1	80.1
Cobalt (mg/Kg)	24/ 24	100	15	60	6.3	40.1	L	42.4	40.1	40.1	40.1
Copper (mg/Kg)	23/ 23	100	21.2	36	11	35.5	L	47.1	35.5	35.5	35.5
Cyanide (mg/Kg)	1/ 23	4.3	0.08	108	0.46	0.46	D	.	0.63	0.63	0.63
Iron (mg/Kg)	24/ 24	100	37900	22	23000	52000	N	57000	52000	52000	52000
Lead (mg/Kg)	22/ 22	100	18.5	62	8.4	49.6	X	.	49.6	49.6	49.6
Lithium (mg/Kg)	23/ 23	100	21.6	32	7.6	33	N	37.9	33	33	33
Magnesium (mg/Kg)	24/ 24	100	3230	38	1730	7430	L	6630	7430	7430	6630
Manganese (mg/Kg)	24/ 24	100	563	80	85	2220	L	2590	2220	2220	2220
Mercury (mg/Kg)	11/ 24	45.8	0.1	69	0.0	0.3	D	.	0.3	0.3	0.3
Molybdenum (mg/Kg)	1/ 24	4.1	2.8	71	2	2	D	.	12.8	12.8	12.8
Nickel (mg/Kg)	24/ 24	100	24	35	15.2	56.7	X	.	56.7	56.7	56.7
Osmium (mg/Kg)	0/ 8	0	7.6	13	.	.	O	.	19.9	19.9	19.9
Potassium (mg/Kg)	24/ 24	100	3390	32	1890	5560	L	6680	5560	5560	5560
Selenium (mg/Kg)	9/ 24	37.5	0.5	62	0.5	1.1	D	.	1.2	1.2	1.2
Silicon (mg/Kg)	24/ 24	100	400	44	185	868	L	996	868	868	868
Silver (mg/Kg)	0/ 24	0	0.8	30	.	.	O	.	2.8	2.8	2.8
Strontium (mg/Kg)	23/ 23	100	6.9	44	3.2	16.8	L	16.8	16.8	16.8	16.8

D13-8

Table D.5 (continued)

Analyte (units)	Results > detection limit	%Results > detection limit	Average result	Coefficient of variation (%)	Min detect	Max detect	Dist. ^a	95% upper tolerance limit	Nonparametric 95% UTL	99th percentile	Background criteria
Sulfate (mg/Kg)	23/ 23	100	85.9	90	14.1	344	L	443	344	344	344
Thallium (mg/Kg)	10/ 24	41.6	0.3	60	0.3	0.7	D	.	0.7	0.7	0.7
Vanadium (mg/Kg)	23/ 23	100	41	19	27.9	60.1	L	62.7	60.1	60.1	60.1
Zinc (mg/Kg)	24/ 24	100	50.1	30	33.9	108	X	.	108	108	108
<i>Radionuclides</i>											
Americium-241 (pCi/g)	0/ 22	0	0.03	36	.	.	O	.	0.06	0.06	0.06
Barium-133 (pCi/g)	0/ 22	0	0.01	32	.	.	O	.	0.01	0.01	0.01
Cesium-137 (pCi/g)	15/ 22	68.2	0.34	122	0.01	1.4	X	.	1.4	1.4	1.4
Chromium-51 (pCi/g)	0/ 22	0	0.06	33	.	.	O	.	0.089	0.089	0.089
Cobalt-57 (pCi/g)	0/ 22	0	0.01	31	.	.	O	.	0.01	0.01	0.01
Cobalt-60 (pCi/g)	0/ 22	0	0.01	32	.	.	O	.	0.01	0.01	0.01
Curium-243 (pCi/g)	0/ 12	0	0.05	27	.	.	O	.	0.08	0.08	0.08
Curium-244 (pCi/g)	0/ 4	0	1.4	117	.	.	O	.	3.5	3.5	3.5
Curium-245 (pCi/g)	0/ 12	0	0.08	38	.	.	O	.	0.11	0.11	0.11
Curium-247 (pCi/g)	2/ 12	16.7	0.01	57	0.01	0.01	D	.	0.03	0.03	0.03
Europium-152 (pCi/g)	0/ 22	0	0.04	27	.	.	O	.	0.07	0.07	0.07
Europium-154 (pCi/g)	0/ 22	0	0.01	31	.	.	O	.	0.02	0.02	0.02
Hafnium-181 (pCi/g)	0/ 10	0	0.01	15	.	.	O	.	0.01	0.01	0.01
Iridium-192 (pCi/g)	0/ 10	0	0.01	16	.	.	O	.	0.01	0.01	0.01
Neptunium-237 (pCi/g)	2/ 2	100	0.15	70	0.08	0.23	N	0.23	0.23	0.23	0.23
Niobium-95 (pCi/g)	0/ 9	0	0.01	18	.	.	O	.	0.01	0.01	0.01
Plutonium-238 (pCi/g)	3/ 12	25	0.08	29	0.08	0.1	D	.	0.12	0.12	0.12
Plutonium-239/240 (pCi/g)	2/ 12	16.7	0.03	46	0.03	0.03	D	.	0.07	0.07	0.07
Potassium-40 (pCi/g)	21/ 21	100	18.7	26	12	28	L	32.8	28	28	28
Radium-226 (pCi/g)	23/ 24	95.8	0.86	30	0.35	1.4	N	1.47	1.4	1.4	1.4
Ruthenium-103 (pCi/g)	0/ 22	0	0.01	193	.	.	O	.	0.11	0.11	0.11
Strontium-90 (pCi/g)	1/ 12	8.3	0.88	17	1.1	1.1	D	.	1.1	1.1	1.1

Table D.5 (continued)

Analyte (units)	Results > detection limit	%Results > detection limit	Average result	Coefficient of variation (%)	Min detect	Max detect	Dist. ^a	95% upper tolerance limit	Nonparametric 95% UTL	99th percentile	Background criteria
Technetium-99 (pCi/g)	1/ 12	8.3	2.13	34	2.79	2.79	D	.	4.07	4.07	4.07
Thorium-228 (pCi/g)	23/ 24	95.8	1.33	51	0.5	3.4	N	2.88	3.4	3.4	2.88
Thorium-230 (pCi/g)	24/ 24	100	0.85	46	0.19	2.3	X	.	2.3	2.3	2.3
Thorium-232 (pCi/g)	24/ 24	100	1.27	50	0.18	3.2	N	2.75	3.2	3.2	2.75
Thorium-234 (pCi/g)	23/ 24	95.8	1.25	28	0.94	1.9	N	2.05	1.9	1.9	1.9
Tritium (pCi/g)	5/ 9	55.6	0.04	38	0.04	0.06	N	0.09	0.06	0.06	0.06
Uranium (pCi/g)	12/ 12	100	1.46	119	0.07	6.5	L	26.7	6.5	6.5	6.5
Uranium-234 (pCi/g)	12/ 24	50	1.72	50	0.52	3.2	X	.	3.2	3.2	3.2
Uranium-235 (pCi/g)	9/ 24	37.5	0.09	55	0.03	0.24	D	.	0.24	0.24	0.24
Uranium-236 (pCi/g)	2/ 24	8.3	0.03	101	0.02	0.17	D	.	0.17	0.17	0.17
Uranium-238 (pCi/g)	12/ 24	50	1.8	50	0.53	2.6	X	.	3.5	3.5	2.6
Zinc-65 (pCi/g)	0/ 22	0	0.02	34	.	.	O	.	0.03	0.03	0.03
Zirconium-95 (pCi/g)	0/ 22	0	0.01	33	.	.	O	.	0.02	0.02	0.02

^a The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because few than 50% detects.

Table D.5a. BCV background sediment data Background Sediment Data from RD18, RD19, and RD20

Analyte (units)	Results > detection limit	% Results > detection limit	Average result	Coefficient of variation (%)	Min detect	Max detect	Dist. ^a	95% upper tolerance limit	Nonparametric 95% UTL	99th percentile	Background criteria
<i>Inorganics</i>											
Aluminum (mg/kg)	6/6	100.00	8960.00	19	6860.00	11500.00	L	17400.00	11500.00	11500.00	11500.00
Antimony (mg/kg)	0/3	0.00	0.38	29			O		1.00	1.00	1.00
Arsenic (mg/kg)	5/6	83.33	2.70	80	1.40	6.60	L	29.70	6.60	6.60	6.60
Barium (mg/kg)	6/6	100.00	154.00	24	117.00	206.00	L	363.00	206.00	206.00	206.00
Beryllium (mg/kg)	5/6	83.33	0.74	39	0.62	1.20	N	1.81	1.20	1.20	1.20
Cadmium (mg/kg)	1/6	16.67	0.10	52	0.13	0.13	D		0.36	0.36	0.36
Calcium (mg/kg)	6/6	100.00	1890.00	8	1690.00	2050.00	N	2420.00	2050.00	2050.00	2050.00
Chromium (mg/kg)	6/6	100.00	19.00	16	16.30	23.70	L	33.20	23.70	23.70	23.70
Cobalt (mg/kg)	6/6	100.00	15.20	33	8.80	23.30	L	50.20	23.30	23.30	23.30
Copper (mg/kg)	6/6	100.00	9.80	20	7.60	11.70	L	20.50	11.70	11.70	11.70
Cyanide (mg/kg)	0/6	0.00	0.49	26			O		1.40	1.40	1.40
Iron (mg/kg)	6/6	100.00	24900.00	39	14800.00	42100.00	L	91000.00	42100.00	42100.00	42100.00
Lead (mg/kg)	6/6	100.00	12.20	24	8.60	15.10	L	29.80	15.10	15.10	15.10
Lithium (mg/kg)	4/6	66.67	11.40	36	12.60	15.80	L	19.30	15.80	15.80	15.80
Magnesium (mg/kg)	6/6	100.00	1610.00	23	1080.00	2050.00	L	3810.00	2050.00	2050.00	2050.00
Manganese (mg/kg)	6/6	100.00	957.00	52	176.00	1570.00	N	2790.00	1570.00	1570.00	1570.00
Mercury (mg/kg)	1/6	16.67	0.24	149	0.97	0.97	D		0.97	0.97	0.97
Nickel (mg/kg)	6/6	100.00	17.90	12	15.10	21.00	L	28.20	21.00	21.00	21.00
Potassium (mg/kg)	6/6	100.00	1540.00	18	1120.00	1970.00	N	2540.00	1970.00	1970.00	1970.00
Selenium (mg/kg)	5/6	83.33	2.47	51	2.00	4.30	N	7.16	4.30	4.30	4.30
Silver (mg/kg)	0/6	0.00	0.10	26			O		0.27	0.27	0.27
Sodium (mg/kg)	6/6	100.00	270.00	23	214.00	374.00	L	593.00	374.00	374.00	374.00
Thallium (mg/kg)	0/6	0.00	0.88	26			O		2.30	2.30	2.30
Vanadium (mg/kg)	6/6	100.00	18.80	22	15.30	26.90	L	39.30	26.90	26.90	26.90
Zinc (mg/kg)	6/6	100.00	36.70	15	29.40	42.40	L	64.80	42.40	42.40	42.40

Table D.5a (continued)

Analyte (units)	Results > detection limit	% Results > detection limit	Average result	Coefficient of variation (%)	Min detect	Max detect	Dist. ^a	95% upper tolerance limit	Nonparametric 95% UFL	99th percentile	Background criteria
Radionuclides											
Am-241 (pCi/g)	0/6	0.00	0.02	100			O		0.06	0.06	0.06
Cm-243 (pCi/g)	1/6	16.67	0.12	69	0.12	0.12	D		0.28	0.28	0.28
Cm-244 (pCi/g)	0/6	0.00	0.01	245			O		0.05	0.05	0.05
Cs-137 (pCi/g)	5/6	83.33	0.15	53	0.07	0.28	L	0.80	0.28	0.28	0.28
Pu-238 (pCi/g)	0/6	0.00	0.01	200			O		0.05	0.05	0.05
Pu-239/240 (pCi/g)	1/6	0.00	0.00	245			O		0.02	0.02	0.02
Sr-90 (pCi/g)	0/6	0.00	0.23	90			O		0.60	0.60	0.60
Tc-99 (pCi/g)	0/6	0.00	0.17	212			O		0.90	0.90	0.90
Th-228 (pCi/g)	6/6	100.00	1.12	31	0.57	1.60	N	2.42	1.60	1.60	1.60
Th-230 (pCi/g)	6/6	100.00	0.66	34	0.29	0.90	N	1.49	0.90	0.90	0.90
Th-232 (pCi/g)	6/6	100.00	0.88	26	0.52	1.14	N	1.71	1.14	1.14	1.14
U-234 (pCi/g)	6/6	100.00	1.32	82	0.77	3.54	X		3.54	3.54	3.54
U-235 (pCi/g)	3/6	50.00	0.03	79	0.04	0.06	N	0.12	0.06	0.06	0.06
U-238 (pCi/g)	6/6	100.00	0.89	8	0.81	1.02	L	1.19	1.02	1.02	1.02

^a The distribution of the data was determined using EPAWATER-P2000.017. Rev. 0. L = distribution most similar to lognormal, N = distribution most similar to normal, X = distribution significantly different from normal or lognormal, D = distribution not determined because few than 50% detects.

Table D.6. Summary of BCV groundwater sampling from 1986-1994

Station	Depth (ft)	Clust. ^a	Rule of 4 applies ^b	Pre-1986 ^c	1986 ^d	1987 ^d	1988 ^d	1989 ^d	1990 ^d	1991 ^d	1992 ^d	1993 ^d	1994 ^d	Status ^e
<i>S-3 Site Functional Area</i>														
GW-085	62.0	3	Y	4/84, 8/84		4	2,3	3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-086	35.5	3	Y	4/84, 8/84					2,3,4	1,2		1,2,3,4		
GW-101	17.5	3	Y	10/84	1,2				2,3,4	1,2				
GW-103	25.0	10	N	10/84	1,2									P&A
GW-104	74.0	10	N	10/84	1,2									P&A
GW-123	572.0	6	Y		4	1,2,3,4	2,3,4	1,2,4	1,2,3,4	1,2,3,4	1,2,3			
GW-125	552.0	6	Y		4	1,2,3,4	1,2,3,4	1,2,4	1,2,3,4	1,2,3,4	1,2,3			
GW-127	24.0	3	N		4		2,3,4	1,2,3,4	1					
GW-243	77.0	3	Y		4	1,2,3,4	1,2,3,4	1,2,3,4	1,4	1,2,3,4	1,2,3		1	
GW-244	77.0	3	N			1,2,3,4	1,2,3,4	1,2,3,4	1					
GW-245	76.0	3	N			1,2,3,4	1,2,3,4	1,2	1					
GW-246	76.0	3	N			1,2,3,4	1,2,3,4	1,2	1					
GW-247	78.0	3	N			1,2,3,4	1,2,3,4	1,2	1					
GW-276	18.5	3	Y		4	1,2,3,4	1,2,3,4	1,2,3,4	1				1,3	
GW-277	77.4	2	Y		4	1,2,3,4	1,2,3,4	1,2,3,4	1					
GW-324	80.0	3	Y			4	1,2,3,4	1,2,3,4	1,2,3,4	1,2		1,2,3,4	1	
GW-325	17.9	2	Y			4	1,2,3,4	1,2,3,4	1,2,3,4	1,2		1,2,3,4	1	
GW-345	26.3	2	Y				3,4	1,2,3,4	1,2,3,4	1,2		1,2,3,4	1	
GW-346	65.3	3	N				3,4	1,2,3,4	1					
GW-526	123.0	10	Y				3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4		
GW-537	24.5	3	Y					4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	

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Table D.6 (continued)

Station	Depth (ft)	Clust. ^a	Rule of 4 applies ^b	Pre-1986 ^c	1986 ^d	1987 ^d	1988 ^d	1989 ^d	1990 ^d	1991 ^d	1992 ^d	1993 ^d	1994 ^d	Status ^e
GW-613	42.0	2	Y						1,2,3,4	1,2,3,4	1,2,3	1	1,3	
GW-614	90.2	3	Y						1,2,3,4	1,2,3,4	1,2,3	1	1,3	
GW-615	245.0	3	Y						2,3,4	1,2,3,4	1,2,3			
GW-616	269.0	10	Y						2,3,4	1,2,3,4	1,2,3			
GW-649	20.8	2	Y							1,2,3,4	1,2,3			
<i>Oil Landfarm Functional Area</i>														
GW-003	35.2	3	N	11/83, 3/84, 8/84			2,3							P&A
GW-005	12.5	1	Y	11/83, 3/84					2,3,4	1,2				D13-14
GW-007	16.5	2	N	11/83, 3/84, 8/84		1,2,3,4	2,3	3,4	1					
GW-010	15.0	1	N	11/83, 3/84		1,2,3,4	2,3	3,4	1					
GW-013	33.8	3	Y	11/83, 3/84, 8/84					2,3,4	1,2,3,4	1,2,3,4	1,2,3,4		
GW-043	40.0	2	Y	11/83, 3/84, 4/84, 8/84		1,2,3	2		1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-044	70.0	3	Y	11/83, 3/84, 4/84, 8/84					2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-073	81.0	3	N	4/84, 8/84		1,2,3,4	2,3,4	1,3,4	1					
GW-074	207.42	10	Y	4/84, 8/84					2,3,4	1,2,3,4	1,2,3			
GW-075	200.0	10	Y	4/84, 8/84					2,3,4	1,2,3,4	1,2,3			

Table D.6 (continued)

Station	Depth (ft)	Clust. ^a	Rule of 4 applies ^b	Pre-1986 ^c	1986 ^d	1987 ^d	1988 ^d	1989 ^d	1990 ^d	1991 ^d	1992 ^d	1993 ^d	1994 ^d	Status ^e
GW-076	81.0	3	Y	4/84, 8/84					2,3,4	1,2				
GW-084	34.0	3	Y	4/84, 8/84		1,2,3,4	2,3,4	1,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-087	19.0	3	N	4/84, 8/84		1,2,3,4	2,3,4	1,4	1					
GW-097	19.2	1	N	10/84		1,2,3,4	2,3,4	1,3,4	1					
GW-098	104.0	1	N	10/84		1,2,3,4	2,3,4	1,3,4	1					
GW-120	180.0	10	N			1,2,3,4	2,3,4	1,3,4	1					
GW-363	75.0	10	Y				3,4	1,3,4	1				1,2,3,4	
GW-364	60.3	1	Y				3,4	1,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4		
GW-376	218.0	3	N				4	1,4	1					
GW-531	39.5	2	Y				4	1,4	1,2,3,4	1,2				
GW-532	29.7	3	Y					1,4	1,2,3,4	1,2				
GW-533	30.1	2	N						4	1,2				
GW-534	47.0	3	N						4	1,2				
GW-535	19.5	3	Y					4	1,2,3,4	1,2				
GW-536	19.7	3	N					4	1					Dest.
GW-538	42.5	3	N						4	1,2				
GW-630	28.6	3	Y						2,3,4	1,2,3,4	1,2,3			
GW-636	117.0	3	Y							1,2,3,4	1,2,3	1,2,3,4		
GW-637	27.5	3	Y							1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-638	12.0	1	Y							1,2,3,4	1,2,3,4	1,2,3,4		
GW-644	23.4	2	Y							1,2,3,4	1,2,3,4	1,2,3,4		
GW-793	29.0	3	Y								2,3,4		1,2,3,4	

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Table D.6 (continued)

Station	Depth (ft)	Clust. ^a	Rule of 4 applies ^b	Pre-1986 ^c	1986 ^d	1987 ^d	1988 ^d	1989 ^d	1990 ^d	1991 ^d	1992 ^d	1993 ^d	1994 ^d	Status ^e
GW-794	39.3	3	Y								2,3,4		1,2,3,4	
GW-795	20.1	3	Y								2,3,4		1,2,3,4	
<i>Burial Grounds Functional Area</i>														
GW-014	13.2	1	N	3/84, 8/84		1,2,3,4	2,3		1					
GW-018	20.8	2	N	12/83, 3/84						1,2				
GW-021	15.0	1	N	3/84		1,3,4								P&A
GW-027	30.5	1	N	3/84, 8/84		1,2,3,4								P&A
GW-037	70.0	3	Y	3/84					2,3,4	1,2				P&A
GW-039	22.5	10	N	3/84		1,2,3,4	2,3,4							P&A
GW-040	35.0	3	Y	3/84		1,3,4	2,3,4	1,3,4	1	4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-042	30.0	2	Y	12/83, 3/84, 4/84, 8/84		1,2,3,4	2,3,4	1,3,4	1,2,3,4	1,2,3,4	1,2,3	1	1,2,3,4	
GW-046	20.5	2	N	12/83, 4/84, 8/84		1,2,3,4	2,3		1					
GW-047	25.5	2	Y	12/83, 4/84, 8/84		1,2,3,4	2,3,4	1,3,4	1				1,2,3,4	
GW-068	85.0	1	N	4/84, 8/84		1,2,3,4		3	1					
GW-069	100.0	10	Y	4/84, 8/84					2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-071	220.6	10	Y	4/84, 10/84		1,2,3,4		3	1,2,3,4	1,2				
GW-072	101.4	10	Y	4/84, 8/84		12,3,4		3	1,2,3,4	1,2				
GW-077	100.5	3	Y	4/84					2,3,4	1,2				

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Table D.6 (continued)

Station	Depth (ft)	Clust. ^a	Rule of 4 applies ^b	Pre-1986 ^c	1986 ^d	1987 ^d	1988 ^d	1989 ^d	1990 ^d	1991 ^d	1992 ^d	1993 ^d	1994 ^d	Status ^e
GW-078	21.1	3	Y	4/84					2,3,4	1,2				
GW-079	65.0	3	Y	4/84, 8/84					2,3,4	1,2		1	1,2,3,4	
GW-080	30.0	2	Y	4/84, 8/84					2,3,4	1,2,3,4	1,2,3	1	1,2,3,4	
GW-082	35.0	3	Y	4/84, 8/84		1,2,3,4	2,3,4		1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4		
GW-083	30.0	3	Y	4/84, 8/84					2,3,4	1,2,3,4	1,2,3			
GW-089	25.0	3	Y						2,3,4	1,2,3,4	1,2,3			
GW-117	530.0	6	Y			2,3,4	2,3,4	2,3,4	1,2,3,4	1,2,3,4	1,2,3			
GW-118	575.0	6	Y			2,3,4	2,3,4	2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4		
GW-119	510.0	6	Y			1,3,4	2,3,4	2,3,4	1,2,3,4	1,2,3,4	1,2,3			
GW-126	155.0	10	N			1,3,4	2,3,4	1,3,4	1					
GW-162	125.0	3	Y			1,3,4	2,3,4	1,3,4	1,2,3,4	1,2		1	1,2,3,4	
GW-163	225.0	10	Y			1,2,3			2,3,4	1,2				
GW-164	405.0	3	Y						2,3,4	1,2				
GW-237	13.7	0	N				2							
GW-242	17.0	1	N			4	2,3,4	1,3,4	1					
GW-248	62.0	3	N				1,2,3,4	2,3,4	1					
GW-249	35.1	3	N						1					
GW-250	61.7	1	N			4	2,3,4	1,3,4	1					
GW-257	33.7	3	N				2	2,3,4	1					
GW-258	50.0	3	N				1,2,3,4	2,3,4	1					
GW-259	33.5	3	N				1,2,3,4	2,3,4	1					
GW-286	32.3	3	Y			1,2,3,4	1,2,3,4	1,3,4	1	3,4	1,2,3,4	1,2,3,4		

Table D.6 (continued)

Station	Depth (ft)	Clust. ^a	Rule of 4 applies ^b	Pre-1986 ^c	1986 ^d	1987 ^d	1988 ^d	1989 ^d	1990 ^d	1991 ^d	1992 ^d	1993 ^d	1994 ^d	Status ^e
GW-287	12.5	3	Y			1,2,3,4	1,2,3,4	1,3,4	1	3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-288	60.0	3	N				1,2,3,4	1,3,4	1					
GW-289	40.8	2	N				1,2,3,4	1,3,4	1					
GW-290	35.5	3	N				1,2,3,4		1	1,2				
GW-291	17.0	3	N				1,2,3,4		1	1,2				
GW-342	75.0	2	Y						2,3,4	1,2,3,4	1,2,3	1		
GW-343	185.0	3	Y				3	4	1,2,3,4	1,2,3,4	1,2,3			
GW-344	316.0	3	Y						2,3,4	1,2,3,4	1,2,3			
GW-370	33.1	3	Y				3,4	1,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-371	125.0	3	Y				3,4	1,3,4	1	3,4	1,2,3,4	1,2,3,4		
GW-372	51.6	3	Y				3,4	1,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-373	158.0	10	Y				3,4	1,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-374	150.1	10	N				3,4	1,3,4	1					
GW-502	260.0	10	N				4	2,3,4	1					P&A
GW-622	20.5	3	Y						1,2,3,4	1,2,3,4	1,2,3			
GW-623	349.0	6	Y						2	1,2,3,4	1,2,3			
GW-624	27.2	1	Y						2,3,4	1,2				
GW-626	78.0	3	Y						1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4		
GW-627	270.0	10	Y						1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-629	312.0	10	Y											
GW-639	125.5	10	Y						4	1,2,3,4	1,2,3,4	1,2,3,4		
GW-640	945.38	2	Y						4	1,2,3,4	1,2,3,4	1,2,3,4		

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Table D.6 (continued)

Station	Depth (ft)	Clust. ^a	Rule of 4 applies ^b	Pre-1986 ^c	1986 ^d	1987 ^d	1988 ^d	1989 ^d	1990 ^d	1991 ^d	1992 ^d	1993 ^d	1994 ^d	Status ^e
GW-641	24.3	2	Y						4	1,2,3,4	1,2,3,4	1,2,3,4		
GW-642	36.9	2	Y						4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-643	29.3	2	Y							1,2,3,4	1,2,3,4	1,2,3,4		
GW-653	39.0	2	Y							1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-654	15.5	3	Y							1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-655	65.0	2	Y							1,2,3,4	1,2,3,4	1,2,3,4		
GW-705	307.0	10	Y							2,3,4	1,2,3,4			
<i>Maynardville Limestone Functional Area</i>														
<i>Maynardville Limestone FA - S-3 Site Locality</i>														
GW-100	20.7	2	Y	10/84	1,2		3,4	1,2,3,4	1					
GW-122	142.0	1	Y		4		1,2,3,4	1,2,3,4	1,2,3,4	1,2				
GW-124	150.0	1	N		4		1,2,3,4	1,2,3,4	1					
GW-236	18.5	1	N				2,3,4	1,2	1					
GW-313	113.0	4	Y				1,2,3		1,2,3,4	1,2,3,4				
GW-314	115.0	1	Y				1,2,3,4		1,2,3,4	1,2,3,4				
GW-315	104.0	1	Y				1,2,3,4		1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-316	80.0	4	Y				1,2,3,4		1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4		
GW-317	132.0	4	Y				1,2,3,4	2	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-323	108.0	4	Y				1,2,3,4		1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4		
GW-347	27.8	3	Y				3,4	2	2,3,4	2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-348	80.9	2	Y				3,4	2	2,3,4	2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-811	67.5	NA ^f	N									4		

Table D.6 (continued)

Station	Depth (ft)	Clust. ^a	Rule of 4 applies ^b	Pre-1986 ^c	1986 ^d	1987 ^d	1988 ^d	1989 ^d	1990 ^d	1991 ^d	1992 ^d	1993 ^d	1994 ^d	Status ^e
GW-812	48.0	NA	N									4		
GW-813	27.8	NA	N									4		
GW-814	26.1	NA	N									4		
GW-815	23.5	NA	N									4		
<i>Maynardville Limestone FA - Rust Spoil Locality</i>														
GW-306	179.6	1	Y				1,2,3,4	2,4	1,2,3,4	1,2				
GW-307	58.5	1	Y				1,2,3,4	4	1,2,3,4	1,2				
GW-308	41.6	1	Y				1,2	2,3,4	1,2,3,4	1,2	1,2,3			
GW-309	37.7	1	Y				1,2	2,3,4	1,2,3,4	1,2,3,4	1,2,3			
GW-310	38.0	1	Y				1,2,3,4	2,3,4	1,2,3,4	1,2				
GW-311	27.1	3	Y				1,2,4	2,3,4	1,2,3,4	1,2		1,2,3,4	1,2,3,4	
GW-312	40.3	1	Y				1,2,4	2,3,4	1,2,3,4	1,2		1,2,3,4	1,2,3,4	
GW-648	80.1	4	Y							1,2,3,4	1,2,3			
<i>Maynardville Limestone FA - Oil Landfarm Locality and Picket C</i>														
GW-063	35.0	1	Y	4/84, 8/84		1,2,3,4	2,3,4	1,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1		P&A
GW-064	57.0	1	Y	4/84, 8/84		4	2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	
GW-067	16.5	1	N	4/84		1,2,3,4	2,3,4	1,4	1					
GW-225	200.0	1	Y		1,2,3,4	1,2,3,4		1,3,4	1,2,3,4	1,2,3,4	1,2,3			
GW-226	55.0	1	Y		1,2,3,4	1,2,3,4	2,3,4	1,3,4		1,2				
GW-227	40.0	1	Y		1,2,3,4	1,2,3,4		1,3,4		1,2,3,4	1,2,3			
GW-228	100.0	1	N		1,2,3,4	1,2,3,4	2,3,4	1,3,4	1					
GW-229	55.0	1	N		1,2,3,4	1,2,3,4	2,3,4	1,3,4	1					

Table D.6 (continued)

Station	Depth (ft)	Clust. ^a	Rule of 4 applies ^b	Pre-1986 ^c	1986 ^d	1987 ^d	1988 ^d	1989 ^d	1990 ^d	1991 ^d	1992 ^d	1993 ^d	1994 ^d	Status ^e
GW-365	150.0	1	Y				3,4	1,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4		
GW-366	102.5	4	Y				3,4	1,3,4	1,2,3,4	1,2,3,4	1,2,3			
GW-367	151.4	4	Y				3,4	1,3,4	1,2,3,4	1,2				
GW-368	245.0	1	N				3,4	1,3,4	1					
GW-369	150.2	1	Y				3,4	1,3,4	1,2,3,4	1,2				
GW-520	80.3	1	Y				3,4	1	2,3,4	1,2,3,4	1,2,3			
GW-601	356.0	1	Y						1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1	
GW-602	212.0	1	Y						1,2,3,4	1,2,3,4	1,2,3			
GW-645	85.8	4	Y							1,2,3,4	1,2,3			
GW-646	75.9	1	Y							1,2,3,4	1,2,3			
GW-647	91.0	1	Y							1,2,3,4	1,2,3,4	1,2,3,4		
GW-723	444.5	1	Y								2,3,4	1,2,3,4	1,4	
GW-724	301.6	1	Y								2,3,4	1,2,3,4	1,4	
GW-725	142.5	1	Y								2,3,4	1,2,3,4	1,4	
GW-736	105.0	1	Y								2,3,4	1,2,3,4	1,4	
GW-737	89.5	1	Y								2,3,4	1,2,3,4	1,4	
GW-738	90.1	1	Y								2,3,4	1,2,3,4	1,4	
GW-739	320.0	1	Y								2,3,4	1,2,3,4	1,4	
GW-740	190.0	4	Y								2,3,4	1,2,3,4	1,4	
GW-800	32.0	4	Y									2,3,4	1,2,3,4	
<i>Maynardville Limestone FA - Picket B</i>														
GW-621	43.0	3	Y						1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,4	

Table D.6 (continued)

Station	Depth (ft)	Clust. ^a	Rule of 4 applies ^b	Pre-1986 ^c	1986 ^d	1987 ^d	1988 ^d	1989 ^d	1990 ^d	1991 ^d	1992 ^d	1993 ^d	1994 ^d	Status ^e
GW-694	204.5	1	Y							2,3,4	1,2,3,4	1,2,3,4	1,4	
GW-695	62.5	1	Y							2,3,4	1,2,3,4	1,2,3,4	1,4	
GW-703	182.0	1	Y							2,3,4	1,2,3,4	1,2,3,4	1,4	
GW-704	256.0	1	Y							2,3,4	1,2,3,4	1,2,3,4	1,4	
GW-706	182.5	1	Y							2,3,4	1,2,3,4	1,2,3,4	1,4	
<i>Maynardville Limestone FA - Burial Grounds Locality and Picket A</i>														
GW-045	15.2	3	N	12/83, 3/84,		1	2	1,3,4	1					
GW-052	19.5	2	Y	12/83, 3/84					2	1	4	1,2		
GW-053	39.7	1	Y	12/83, 3/84					2,3,4	1,2,3,4	1,2,3		1,2,3,4	
GW-054	40.0	3	Y	12/83, 3/84					2,3,4	1,2,3,4	1,2,3			
GW-056	55.2	1	Y	4/84, 8/84					2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,3	
GW-057	25.0	1	Y	4/84, 8/84					2,3,4	1,2		1,2,3,4	1,3	
GW-058	45.2	1	Y	4/84, 8/84		4	2,3,4	1,3,4	1,2,3,4	1,2,3,4	1,2,3			
GW-061	25.0	1	Y	4/84					1,2,3,4	1,2,3,4	1,2,3		1,2,3,4	
GW-094	131.0	10	N	10/84		1,3,4	2,3,4		1					
GW-095	156.0	10	Y	10/84		1,2,3,4	2,3,4	1,3,4	1,2,3,4	1,2,3,4	1,2,3		1,2,3,4	
GW-375	161.5	10	N				3,4	1,3,4	1					
GW-651	52.0	3	Y							1,2,3,4	1,2,3,4	1,2,3,4		
GW-652	31.2	3	Y							1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	

Table D.6 (continued)

Station	Depth (ft)	Clust. ^a	Rule of 4 applies ^b	Pre-1986 ^c	1986 ^d	1987 ^d	1988 ^d	1989 ^d	1990 ^d	1991 ^d	1992 ^d	1993 ^d	1994 ^d	Status ^e
GW-683	197.5	4	Y							2,3,4	1,2,3,4	1,2,3,4	1,3	
GW-684	129.6	4	Y							2,3,4	1,2,3,4	1,2,3,4	1,3	
GW-685	138.3	1	Y							2,3,4	1,2,3,4	1,2,3,4	1,3	
<i>Maynardville Limestone FA - Picket W</i>														
GW-710	744.5	1	Y							4	1,2,3,4	1,2,3,4	1,3	
GW-711	666.2	1	Y							4	1,2,3,4	1,2,3,4	1,3	
GW-712	457.5	1	Y							4	1,2,3,4	1,2,3,4	1,3	
GW-713	315.2	1	Y								2,3,4	1,2,3,4	1,3	
GW-714	145.0	3	Y								3,4	1,2,3,4	1,3	
GW-715	44.6	1	Y								3,4	1,2,3,4	1,3	
<i>Maynardville Limestone FA - Other Sites</i>														
GW-165	405.0	4	Y											
GW-166	325.0	4	Y											
GW-209	48.1	2	Y											
GW-210	124.0	3	Y											
GW-211	410.0	1	Y											

^a Cluster number defined by *Determination of Reference Concentrations for Inorganic Analytes in Groundwater at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (Energy Systems 1996).

^b For a definition of the rule of 4 refer to section D.4.2.

^c The month and year in which each pre-1985 sample was taken is represented in this column.

^d The quarters that were sampled for this well are represented in these columns.

^e P&A = Well has been plugged and abandoned, and Dest. = Well has been destroyed.

^f NA = No background cluster assigned. These data not used in the risk assessment. Refer to the RI report for BCV OU 2.

Table D.7. BCV OU 1 groundwater validation results

Location	Rejected samples/ total samples	Percent rejected	Major analytes rejected	Reason for rejection
BCBG	0/ 818	0.00		
BYBY	92/ 1520	6.05	PCBs/pesticides; SVOCs	Surrogate recovery is <10%
SL 1	0/ 190	0.00		
OLF	No groundwater samples collected			
S-3 Ponds	No groundwater samples collected			

Table D.8. Screening based on GWQR data interpretation^a

Well	Analyte	Reason for screening result		
		Sodium-rich groundwater more than 200 ft bgs	High TSS — metal ions mobilized from solids during acid preservation	Corrosion of steel casing due to high chloride (> 8 mg/L) and static water levels
GW-071	Boron	✓		
GW-075	Boron	✓		
GW-117	Molybdenum	✓		
GW-118	Iron, strontium	✓		
GW-119	Molybdenum, strontium	✓		
GW-211	Strontium	✓		
GW-344	Strontium	✓		
GW-371	Strontium	✓		
GW-623	Boron	✓		
GW-705	Boron	✓		
GW-705	Copper, iron, lead, manganese, zinc	✓		
GW-005	Aluminum, iron		✓	
GW-040	Aluminum, iron		✓	
GW-086	Aluminum, iron		✓	
GW-343	Aluminum, iron		✓	
GW-531	Aluminum, iron		✓	
GW-537	Barium			✓
GW-005	Cadmium, lead, mercury, strontium, uranium			✓
GW-042	Cadmium			✓
GW-085	Strontium			✓
GW-537	Strontium			✓

^a Source: HSW 1995

Table D.9. Summary of groundwater well clusters

Formation	Cluster 1 "Shallow Groundwater" ^a		Cluster 2 "Shallow Recharge Groundwater" ^a		Cluster 3 "Shallow Groundwater" ^a		Cluster 4 "Knox Group Groundwater" ^a		Cluster 5 "Shallow Industrial Impacted Groundwater" ^a	
	No.	%	No.	%	No.	%	No.	%	No.	%
Chickamauga Group	5	5.3	0	0.0	1	1.0	0	0.0	0	0.0
Knox Group	9	9.5	1	3.8	2	2.1	84	89.4	0	0.0
Maynardville Limestone	41	43.2	0	0.0	18	18.8	10	10.6	1	5.3
Nolichucky Shale	23	24.2	11	42.3	29	30.2	0	0.0	14	73.7
Maryville (Dismal Gap) Limestone	7	7.4	8	30.8	34	35.4	0	0.0	2	10.5
Rogersville Shale	3	3.2	2	7.7	5	5.2	0	0.0	0	0.0
Rutledge Limestone	1	1.1	0	0.0	1	1.0	0	0.0	0	0.0
Pumpkin Valley Shale	2	2.1	3	11.5	2	2.1	0	0.0	2	10.5
Rome Formation	4	4.2	1	3.8	4	4.2	0	0.0	0	0.0
Total:	95		26		96		94		19	
Mean depth (ft bgs)	87		34		52		156		15	

Table D.9 (continued)

Formation	Cluster 6 "Deep Aquitard Groundwater" ^a		Cluster 7 "Nitrate Impacted Groundwater" ^a		Cluster 8 "Nitrate Impacted Groundwater" ^a		Cluster 9 "Nitrate Impacted Groundwater" ^a		Cluster 10 "Intermediate Depth Aquitard Groundwater" ^a	
	No.	%	No.	%	No.	%	No.	%	No.	%
Chickamauga Group	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Knox Group	0	0.0	0	0.0	1	2.9	0	0.0	0	0.0
Maynardville Limestone	0	0.0	6	33.3	32	91.4	0	0.0	4	19.0
Nolichucky Shale	7	100.0	12	66.7	2	5.7	12	100	15	71.4
Maryville (Dismal Gap) Limestone	0	0.0	0	0.0	0	0.0	0	0.0	1	4.8
Rogersville Shale	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rutledge Limestone	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Pumpkin Valley Shale	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rome Formation	0	0.0	0	0.0	0	0.0	0	0.0	1	4.8
Total:	7		18		35		12		21	
Mean depth (ft bgs)	470		43		120		71		180	

^a Cluster labels from *Determination of Reference Concentrations for Inorganic Analytes in Groundwater at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (Energy Systems 1996).

**Table D.10. Groundwater background upper tolerance limits for the BCV RI
by analyte and cluster**

Analyte (mg/L)	Cluster					
	1	2	3	4	6	10
Aluminum	2.4	6.1	2.4	2.4	2.4	2.4
Antimony	0.05	0.05	0.05	0.05	0.05	0.05
Arsenic	0.078	0.078	0.078	0.078	0.078	0.078
Barium	0.71	0.68	0.79	0.34	0.34	0.35
Beryllium	0.00045	0.00045	0.00045	0.00045	0.00045	0.00045
Boron	0.12	0.028	0.041	0.028	3.1	3.1
Cadmium	0.002	0.0028	0.0025	0.0025	0.0025	0.0025
Calcium	203	66	89	60	10	10
Chloride	100	2	26	21	100000	26
Chromium	0.029	0.041	0.041	0.029	0.043	0.029
Cobalt	0.019	0.019	0.019	0.019	0.019	0.019
Copper	0.012	0.012	0.012	0.012	0.012	0.012
Fluoride	2.3	0.55	0.22	0.55	12	25
Iron	8.7	8.7	8.7	4.6	11	6.9
Lead	0.0096	0.0096	0.0096	0.0096	0.0096	0.009
Magnesium	49	13	19	36	11	1.8
Manganese	1.7	1.7	1.7	0.13	1.7	0.13
Mercury	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Molybdenum	0.018	0.018	0.018	0.018	0.018	0.018
Nickel	0.06	0.06	0.02	0.02	0.06	0.02
Nitrate-N	6.9	6.9	5.3	2.7	5.3	5.3
Potassium	14	4.2	5.5	5	100	5.5
Selenium	0.05	0.05	0.05	0.05	0.05	0.05
Silicon	16	15	15	9	17	9
Silver	0.006	0.006	0.006	0.006	0.006	0.006
Sodium	64	22	22	9.7	5200	530
Strontium	4.4	0.079	0.92	0.079	0.92	0.92
Sulfate	170	19	37	19	170	170
Thorium	0.2	0.2	0.2	0.2	0.2	0.2
Uranium	0.012	0.004	0.005	0.005	0.004	0.005
Vanadium	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044
Zinc	0.041	0.043	0.041	0.041	0.041	0.04

Table D.11. Surface water aggregates for BCV

Data Aggregate	Components
Bear Creek at BCK 12.46	BCK 12.46
Bear Creek between BCK 11.47 and BCK 12.36	BCK 11.47, BCK 12.38
Middle Bear Creek	BCK 9.47
Lower Bear Creek	BCK 4.55, BCK 0.63
NT-1	NT-1
NT-2	NT-2
NT-3	NT-3
NT-4	NT-4
NT-5	NT-5
NT-6	NT-6
NT-7	NT-7
NT-8	NT-8
SS-1	SS-1
SS-4	SS-4
SS-5	SS-5
SS-6	SS-6

BCK - Bear Creek Kilometer

NT - North Tributary

SS - South Spring

Table D.12. BCV background surface water data from NT-13, unfiltered results

Analyte (units)	Results > detection limit	%Results > detection limit	Average result	Coefficient of variation (%)	Minimum detect	Maximum detect	Dist. ^a	95% upper tolerance limit	Nonparametric 95% UTL	99th percentile	Selected background criteria
<i>Inorganics</i>											
Aluminum (mg/L)	15/ 16	93.75	1.54	157	0.031	7.4	L	32.6	7.4	7.4	7.4
Antimony (mg/L)	0/ 16	0	0.025	0	.	.	O	.	0.05	0.05	0.05
Arsenic (mg/L)	0/ 16	0	0.025	0	.	.	O	.	0.05	0.05	0.05
Barium (mg/L)	16/ 16	100	0.0814	69	0.034	0.21	X	.	0.21	0.21	0.21
Beryllium (mg/L)	3/ 16	18.75	0.0003	74	0.0004	0.00072	D	.	0.00072	0.00072	0.00072
Boron (mg/L)	16/ 16	100	0.026	53	0.0043	0.062	L	0.104	0.062	0.062	0.062
Cadmium (mg/L)	0/ 14	0	0.001	0	.	.	O	.	0.002	0.002	0.002
Calcium (mg/L)	16/ 16	100	18.4	60	4.2	36	L	84.4	36	36	36
Chloride (mg/L)	12/ 16	75	1.11	43	1	2	N	2.31	2	2	2
Chromium (mg/L)	2/ 14	14.3	0.0069	70	0.016	0.02	D	.	0.02	0.02	0.02
Cobalt (mg/L)	3/ 16	18.75	0.0048	106	0.012	0.017	D	.	0.017	0.017	0.017
Copper (mg/L)	4/ 16	25	0.0030	63	0.0043	0.0072	D	.	0.0072	0.0072	0.0072
Fluoride (mg/L)	2/ 16	12.5	0.0563	30	0.1	0.1	D	.	0.1	0.1	0.1
Iron (mg/L)	16/ 16	100	5.24	186	0.37	30	X	.	30	30	30
Lead (mg/L)	4/ 14	28.6	0.0044	113	0.0068	0.02	D	.	0.02	0.02	0.02
Magnesium (mg/L)	16/ 16	100	3.35	53	1.2	7.2	L	11.5	7.2	7.2	7.2
Manganese (mg/L)	16/ 16	100	1.31	147	0.03	6.1	L	23.7	6.1	6.1	6.1
Mercury (mg/L)	0/ 13	0	0.0001	0	.	.	O	.	0.0002	0.0002	0.0002
Molybdenum (mg/L)	0/ 16	0	0.005	0	.	.	O	.	0.01	0.01	0.01

Table D.12 (continued)

Analyte (units)	Results > detection limit	%Results > detection limit	Coefficient Average of variation result	(%)	Minimum detect	Maximum detect	Dist. ^a	95% upper tolerance limit	Nonparametr ic 95% UTL	99th percentile	Selected background criteria
Nickel (mg/L)	1/ 16	6.25	0.0054	28	0.011	0.011	D	.	0.011	0.011	0.011
Nitrate as N (mg/L)	0/ 16	0	0.1	0	.	.	O	.	0.2	0.2	0.2
Potassium (mg/L)	16/ 16	100	1.86	41	1	3.5	L	4.51	3.5	3.5	3.5
Selenium (mg/L)	1/ 16	6.25	0.0276	37	0.066	0.066	D	.	0.066	0.066	0.066
Silicon (mg/L)	5/ 5	100	9.08	73	4.3	19	N	37.1	19	19	19
Silver (mg/L)	0/ 16	0	0.003	0	.	.	O	.	0.006	0.006	0.006
Sodium (mg/L)	16/ 16	100	3.76	52	1.4	7.6	L	12.1	7.6	7.6	7.6
Strontium (mg/L)	16/ 16	100	0.0604	59	0.017	0.12	L	0.253	0.12	0.12	0.12
Sulfate (mg/L)	16/ 16	100	11.9	106	4	57	X	.	57	57	57
Thorium (mg/L)	0/ 16	0	0.1	0	.	.	O	.	0.2	0.2	0.2
Vanadium (mg/L)	3/ 16	18.75	0.0042	87	0.01	0.013	D	.	0.013	0.013	0.013
Zinc (mg/L)	13/ 16	81.25	0.0146	143	0.0029	0.066	L	0.15	0.066	0.066	0.066
Total uranium (fluorometric) (mg/L)	1/ 16	6.25	0.0010	180	0.001	0.001	D	.	0.015	0.015	0.015
<i>Organics</i>											
1,1,1-Trichloroethane (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
1,1,2,2-Tetrachloro-ethane (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
1,1,2-Trichloroethane (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
1,1-Dichloroethane (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
1,1-Dichloroethene (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10

Table D.12 (continued)

Analyte (units)	Results > detection limit	%Results > detection limit	Average result	Coefficient of variation (%)	Minimum detect	Maximum detect	Dist. ^a	95 % upper tolerance limit	Nonparametr ic 95% UTL	99th percentile	Selected background criteria
1,2-Dichloroethane (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
1,2-Dichloroethene (total) (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
1,2-Dichloropropane (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
2-Butanone (µg/L)	0/ 16	0	5	0	.	.	O	.	10	10	10
2-Hexanone (µg/L)	0/ 16	0	5	0	.	.	O	.	10	10	10
4-Methyl-2-pentanone (µg/L)	0/ 16	0	4.16	50	.	.	O	.	16	16	16
Acetone (µg/L)	2/ 16	12.5	4.28	34	1	4	D	.	10	10	10
Benzene (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
Bromodichloromethane (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
Bromoform (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
Bromomethane (µg/L)	0/ 16	0	5	0	.	.	O	.	10	10	10
Carbon disulfide (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
Carbon tetrachloride (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
Chlorobenzene (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
Chloroethane (µg/L)	0/ 16	0	5	0	.	.	O	.	10	10	10
Chloroform (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
Chloromethane (µg/L)	0/ 16	0	5	0	.	.	O	.	10	10	10
Cis-1,3-dichloro-propene (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
Dibromochloro-methane (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
Ethylbenzene (µg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10

Table D.12 (continued)

Analyte (units)	Results > detection limit	%Results > detection limit	Average result	Coefficient of variation (%)	Minimum detect	Maximum detect	Dist. ^a	95% upper tolerance limit	Nonparametr ic 95% UTL	99th percentile	Selected background criteria
Methylene chloride (μg/L)	0/ 16	0	1.97	62	.	.	O	.	10	10	10
Styrene (μg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
Tetrachloroethene (μg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
Toluene (μg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
Total xylenes (μg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
Trans-1,3-dichloro-propene (μg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
Trichloroethene (μg/L)	0/ 16	0	2.66	24	.	.	O	.	10	10	10
Vinyl acetate (μg/L)	0/ 16	0	5	0	.	.	O	.	10	10	10
Vinyl chloride (μg/L)	0/ 16	0	5	0	.	.	O	.	10	10	10
<i>Radioactivity</i>											
Alpha activity (pCi/L)	16/ 16	100	0.589	111	0	2.11	L	3.95	2.11	2.11	2.11
Beta activity (pCi/L)	16/ 16	100	1.36	97	0	3.75	L	14.3	3.75	3.75	3.75

^a The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because few than 50% detects.

Table D.13. Summary of NT-13 surface water data, filtered results

Analyte	Freq of detect	Freq of detect (%)	Avg result	Coef. of variation (%)	Min detect	Max detect	Dist ^a	95% UTL	Nonp 95% UTL	99th Percentile	Background criteria
Aluminum (mg/l)	12/ 16	75.00	0.238	322	0.025	3.1	X	.	3.1	3.1	3.1
Antimony (mg/l)	0/ 16	0.00	0.025	0	.	.	O	.	0.05	0.05	0.05
Arsenic (mg/l)	0/ 16	0.00	0.025	0	.	.	O	.	0.05	0.05	0.05
Barium (mg/l)	16/ 16	100.00	0.061	67	0.025	0.17	L	0.219	0.17	0.17	0.17
Beryllium (mg/l)	1/ 16	6.25	0.0002	31	0.0004	0.0004	D	.	0.0004	0.0004	0.0004
Boron (mg/l)	15/ 16	93.75	0.029	67	0.013	0.081	L	0.138	0.081	0.081	0.081
Cadmium (mg/l)	0/ 14	0.00	0.001	0	.	.	O	.	0.002	0.002	0.002
Calcium (mg/l)	16/ 16	100.00	18.4	60	4.1	36.0	L	83.6	36.0	36.0	36.0
Chromium (mg/l)	0/ 14	0.00	0.005	0	.	.	O	.	0.01	0.01	0.01
Cobalt (mg/l)	1/ 16	6.25	0.003	89	0.014	0.014	D	.	0.014	0.014	0.014
Copper (mg/l)	2/ 16	12.50	0.003	60	0.0063	0.0067	D	.	0.0067	0.0067	0.0067
Iron (mg/l)	16/ 16	100.00	1.76	337	0.017	24.0	L	14.5	24.0	24.0	14.5
Lead (mg/l)	0/ 14	0.00	0.002	0	.	.	O	.	0.004	0.004	0.004
Magnesium (mg/l)	16/ 16	100.00	3.21	51	1.1	6.2	L	10.9	6.2	6.2	6.2
Manganese (mg/l)	16/ 16	100.00	0.977	172	0.029	6.6	L	14.5	6.6	6.6	6.6
Mercury (mg/l)	1/ 14	7.14	0.0001	27	0.0002	0.0002	D	.	0.0002	0.0002	0.0002
Molybdenum (mg/l)	0/ 16	0.00	0.005	0	.	.	O	.	0.01	0.01	0.01
Nickel (mg/l)	2/ 16	12.50	0.006	47	0.011	0.015	D	.	0.015	0.015	0.015
Potassium (mg/l)	15/ 16	93.75	1.42	35	1.0	2.3	N	2.67	2.3	2.3	2.3
Selenium (mg/l)	0/ 16	0.00	0.025	0	.	.	O	.	0.05	0.05	0.05
Silicon (mg/l)	5/ 5	100.00	5.88	36	4.3	9.4	L	22.0	9.4	9.4	9.4

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Table D.13 (continued)

Analyte	Freq of detect	Freq of detect (%)	Avg result	Coef. of variation (%)	Min detect	Max detect	Dist ^a	95% UTL	Nonp 95% UTL	99th Percentile	Background criteria
Silver (mg/l)	0/ 16	0.00	0.003	0	.	.	O	.	0.006	0.006	0.006
Sodium (mg/l)	16/ 16	100.00	3.81	54	1.5	8.3	L	12.3	8.3	8.3	8.3
Strontium (mg/l)	16/ 16	100.00	0.061	63	0.017	0.14	L	0.262	0.14	0.14	0.14
Thorium (mg/l)	0/ 16	0.00	0.1	0	.	.	O	.	0.2	0.2	0.2
Vanadium (mg/l)	0/ 16	0.00	0.0025	0	.	.	O	.	0.005	0.005	0.005
Zinc (mg/l)	14/ 16	87.50	0.012	145	0.0035	0.071	L	0.099	0.071	0.071	0.071
Total uranium (fluorometric) (mg/l)	3/ 16	18.75	0.0007	60	0.001	0.002	D	.	0.002	0.002	0.002

^a The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because few than 50% detects.

Table D.14. Depth to refusal in soil borings at the S-3 Site

Soil boring	Depth (ft)
S3-01	11.5
S3-02	15.4
S3-03	6.0
S3-04	22.9
S3-05	12.0
S3-06	18.8
S3-07	27.9
S3-08	20.0
S3-09	13.4
S3-10	12.0

Table D.15. Summary of selection of site-related chemicals and radionuclides, S-3 Site, shallow soils, borings 1-9

Analyte ^a	Freq of detect	Bkgd ^b criteria	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	18/ 18	46700	0/ 18	1600	29000	14600	N	No	Below background
Antimony (mg/kg)	1/ 1	1	0/ 1	0.25	0.25	0.25	X	No	Below background
Arsenic (mg/kg)	18/ 18	20.2	1/ 18	0.82	20.5	5.2	L	No	1 detect > bkgd; 20.5 (site) vs. 20.2
Barium (mg/kg)	18/ 18	212	2/ 18	13.2	277	106	L	Yes	> 5% detect above background
Beryllium (mg/kg)	16/ 18	2.12	0/ 18	0.6	1.5	0.81	N	No	Below background
Cadmium (mg/kg)	1/ 18	0.31	2/ 18	2.0	2	0.26	D	No	Detection limit differences ^e ; within USGS background
Calcium (mg/kg)	17/ 17	1860	13/ 17	189	318000	38200	L	No	Essential element
Chromium (mg/kg)	18/ 18	80.1	0/ 18	5.4	43.3	28.5	N	No	Below background
Cobalt (mg/kg)	18/ 18	40.1	0/ 18	2.9	27.6	14.8	N	No	Below background
Copper (mg/kg)	17/ 18	35.5	4/ 18	5.3	50.8	24.2	N	Yes	> 5% detect above background
Cyanide (mg/kg)	2/ 18	0.63	2/ 18	1.2	1.4	0.40	D	Yes	> 5% detect above background
Iron (mg/kg)	18/ 18	52000	0/ 18	4610	48300	26500	N	No	Essential element
Lead (mg/kg)	18/ 18	49.6	1/ 18	5.5	82.3	20.7	L	Yes	> 5% detect above background
Magnesium (mg/kg)	18/ 18	6630	6/ 18	401	33900	7400	L	No	Essential element
Manganese (mg/kg)	18/ 18	2220	0/ 18	116	2000	604	L	No	Below background
Mercury (mg/kg)	15/ 18	0.34	13/ 18	0.08	82.9	15.6	L	Yes	> 5% detect above background
Molybdenum (mg/kg)	1/ 18	12.8	0/ 18	3.7	3.7	0.68	D	No	Below background
Nickel (mg/kg)	18/ 18	56.7	2/ 18	5.7	128	26.10	X	Yes	> 5% detect above background
Potassium (mg/kg)	18/ 18	5560	0/ 18	413	3100	1620	N	No	Essential element
Silver (mg/kg)	12/ 18	2.8	5/ 18	0.85	4.3	2.01	L	No	Detection limit difference; within USGS background

Table D.15 (continued)

Analyte ^a	Freq of detect	Bkgd ^b criteria	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Sodium (mg/kg)	12/ 18	.		40.1	214	87.20	L	No	Essential element
Thallium (mg/kg)	1/ 18	0.79	0/ 18	0.75	0.75	0.23	D	No	Below background
Tin (mg/kg)	3/ 18	.		5.6	7.7	2.15	D	No	No site bkgd; within USGS background
Vanadium (mg/kg)	18/ 18	60.1	2/ 18	3.9	91.9	28.70	X	Yes	> 5% detect above background
Zinc (mg/kg)	18/ 18	108	3/ 18	18.3	163	53.10	L	Yes	> 5% detect above background
<i>Organics</i>									
Methoxychlor (μg/kg)	1/ 4	.		5.9	5.9	8.85	D	Yes	No background available
PCB-1248 (μg/kg)	1/ 18	.		20	20	19.50	D	Yes	No background available
PCB-1254 (μg/kg)	10/ 18	.		12	370	64.10	X	Yes	No background available
PCB-1260 (μg/kg)	3/ 18	.		16	170	31.40	D	Yes	No background available
2-Butanone (μg/kg)	1/ 17	.		10	10	6.18	D	Yes	No background available
4-Methyl-2-pentanone (μg/kg)	2/ 18	.		28	28	7.17	D	Yes	No background available
Acetone (μg/kg)	11/ 17	.		14	4200	477	L	Yes	No background available
Methylene chloride (μg/kg)	1/ 16	.		180	180	15.10	D	Yes	No background available
Tetrachloroethene (μg/kg)	3/ 18	.		2	24	4.42	D	Yes	No background available
Toluene (μg/kg)	10/ 17	.		1	22	7.94	L	Yes	No background available

Table D.15 (continued)

Analyte ^a	Freq of detect	Bkgd ^b criteria	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Radioactivity</i>									
Americium-241 (pCi/g)	1/ 19	0.06	2/ 19	0.11	0.12	0.0203	D	Yes	> 5% detect above background
Beta activity (pCi/g)	11/ 18	.		9.3	47	14.7	L	NA	Total activity of all radionuclides
Gross Alpha (pCi/g)	9/ 18	.		5.7	23.0	7.67	L	NA	Total activity of all radionuclides
Neptunium-237 (pCi/g)	5/ 18	0.23	1/ 18	0.03	0.13	0.03	D	No	1 detect > bkgd; within "error"
Plutonium-239/240 (pCi/g)	1/ 18	0.07	0/ 18	0.02	0.02	0.02	D	No	Below background
Technetium-99 (pCi/g)	3/ 18	4.07	2/ 18	4.6	6.8	2.27	D	Yes	> 5% detect above background
Thorium-228 (pCi/g)	13/ 18	2.88	0/ 18	0.4	1.7	0.681	L	No	Below background
Thorium-230 (pCi/g)	13/ 18	2.3	1/ 18	0.21	2.7	0.57	L	No	1 detect > bkgd; within "error"
Thorium-232 (pCi/g)	12/ 18	2.75	0/ 18	0.2	1.5	0.42	L	No	Below background
Uranium-234 (pCi/g)	18/ 18	3.2	5/ 18	0.1	7.70	1.95	L	Yes	> 5% detect above background
Uranium-235 (pCi/g)	9/ 18	0.24	4/ 18	0.05	0.54	0.11	L	Yes	> 5% detect above background
Uranium-238 (pCi/g)	18/ 18	2.6	8/ 18	0.15	18	3.88	L	Yes	> 5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCV RI.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects; R = distribution with negative results and therefore treated as normal.

^e Differences in the detection limits between the background study and the BCV sampling effort make statistical comparison between background and site data difficult for cadmium and silver.

Table D.16. Summary of selection of site-related chemicals and radionuclides, S-3 Site, deep soils, borings 1-9

Analyte ^a	Freq of detect	Bkgd ^b criteria	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	19/ 19	46700	0/ 19	1720	24600	16900	X	No	Below background
Antimony (mg/kg)	1/ 1	1	0/ 1	0.34	0.34	0.34	X	No	Below background
Arsenic (mg/kg)	19/ 19	20.2	0/ 19	1	3.8	1.88	L	No	Below background
Barium (mg/kg)	19/ 19	212	4/ 19	62.3	712	179	X	Yes	>5% detect above background
Beryllium (mg/kg)	17/ 19	2.12	0/ 19	0.85	1.8	1.18	N	No	Below background
Cadmium (mg/kg)	1/ 19	0.31	1/ 19	0.58	0.58	0.188	D	No	Detection limit differences ^e ; within USGS background
Calcium (mg/kg)	19/ 19	1860	10/ 19	307	281000	17000	X	No	Essential element
Chromium (mg/kg)	19/ 19	80.1	0/ 19	5.7	69.6	34.1	X	No	Below background
Cobalt (mg/kg)	19/ 19	40.1	0/ 19	1.9	31.1	17.8	N	No	Below background
Copper (mg/kg)	18/ 19	35.5	2/ 19	9	40.1	20.9	N	Yes	>5% detect above background
Cyanide (mg/kg)	2/ 19	0.63	2/ 19	1.7	7.8	0.767	D	Yes	>5% detect above background
Iron (mg/kg)	19/ 19	52000	0/ 19	3210	33700	24900	X	No	Essential element
Lead (mg/kg)	19/ 19	49.6	0/ 19	3.9	31	10.6	L	No	Below background
Magnesium (mg/kg)	19/ 19	6630	2/ 19	1460	60400	6740	X	No	Essential element
Manganese (mg/kg)	19/ 19	2220	0/ 19	178	2000	775	L	No	Below background
Mercury (mg/kg)	8/ 18	0.34	3/ 18	0.086	2.3	0.29	D	Yes	>5% detect above background
Nickel (mg/kg)	19/ 19	56.7	1/ 19	3.8	57.9	34.6	N	No	1 detect > bkgd; 57.9(site) vs. 56.7
Potassium (mg/kg)	19/ 19	5560	0/ 19	455	3990	2620	N	No	Essential element

Table D.16 (continued)

Analyte ^a	Freq of detect	Bkgd ^b criteria	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Selenium (mg/kg)	2/ 19	1.2	0/ 19	0.64	0.66	0.336	D	No	Below background
Silver (mg/kg)	14/ 19	2.8	1/ 19	0.61	3.7	1.8	N	No	Detection limit differences; within USGS bkgd
Sodium (mg/kg)	17/ 19	.		43.3	313	148	L	No	Essential element
Thallium (mg/kg)	1/ 19	0.79	0/ 19	0.42	0.42	0.215	D	No	Below background
Vanadium (mg/kg)	19/ 19	60.1	0/ 19	5.5	24.7	20.8	X	No	Below background
Zinc (mg/kg)	19/ 19	108	0/ 19	11.4	72.9	47.8	N	No	Below background
<i>Organics</i>									
Endrin aldehyde (µg/kg)	1/ 7	.		5.4	5.4	2.54	D	Yes	No background available
PCB-1254 (µg/kg)	2/ 18	.		22	260	33.3	D	Yes	No background available
4-Methyl-2-pentanone (µg/kg)	4/ 19	.		3	7	5.82	D	Yes	No background available
Acetone (µg/kg)	5/ 13	.		12	230	39.8	D	Yes	No background available
Tetrachloroethene (µg/kg)	5/ 19	.		1	10	3.66	D	Yes	No background available
Toluene (µg/kg)	6/ 19	.		1	120	11.3	D	Yes	No background available
<i>Radioactivity</i>									
Americium-241 (pCi/g)	2/ 19	0.058	2/ 19	0.11	0.12	0.0238	D	Yes	>5% detect above background
Beta activity (pCi/g)	15/ 19	.		9	180	30.7	L	NA	Total activity of all radionuclides
Gross Alpha (pCi/g)	11/ 19	.		6.2	92	14.6	L	NA	Total activity of all radionuclides
Neptunium-237 (pCi/g)	4/ 19	0.23	1/ 19	0.04	0.27	0.0527	D	No	1 detect > bkgd; within "error"

Table D.16 (continued)

Analyte ^a	Freq of detect	Bkgd ^b criteria	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Plutonium-238 (pCi/g)	1/ 19	0.12	1/ 19	0.36	0.36	0.0303	D	Yes	>5% detect above background
Technetium-99 (pCi/g)	2/ 19	4.07	2/ 19	5.8	36	3.79	D	Yes	>5% detect above background
Thorium-228 (pCi/g)	18/ 19	2.88	1/ 19	0.16	3.5	0.924	L	No	1 detect > bkgd; within "error"
Thorium-230 (pCi/g)	19/ 19	2.3	2/ 19	0.22	3.4	0.83	X	Yes	>5% detect above background
Thorium-232 (pCi/g)	18/ 19	2.75	1/ 19	0.22	3.6	0.746	L	No	1 detect > bkgd; within "error"
Uranium-234 (pCi/g)	19/ 19	3.2	3/ 19	0.059	17	2.45	L	Yes	>5% detect above background
Uranium-235 (pCi/g)	10/ 19	0.24	3/ 19	0.017	0.99	0.143	L	Yes	>5% detect above background
Uranium-238 (pCi/g)	19/ 19	2.6	6/ 19	0.078	43	5.73	L	Yes	>5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCV RI.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

^e Differences in the detection limits between the background study and the BCV sampling effort make statistical comparison between background and site data difficult for cadmium and silver.

Table D.17. Summary of selection of site-related chemicals and radionuclides, S-3 Site, shallow soil, boring 10

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site Related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	2/ 2	46700	0/ 2	13000	16000	14500	N	No	Below background
Arsenic (mg/kg)	2/ 2	20.2	0/ 2	1.8	2.7	2.25	N	No	Below background
Barium (mg/kg)	2/ 2	212	0/ 2	151	196	174	N	No	Below background
Beryllium (mg/kg)	2/ 2	2.12	0/ 2	0.86	0.93	0.895	N	No	Below background
Calcium (mg/kg)	2/ 2	1860	2/ 2	10600	24000	17300	N	No	Essential element
Chromium (mg/kg)	2/ 2	80.1	0/ 2	21.9	25.9	23.9	N	No	Below background
Cobalt (mg/kg)	2/ 2	40.1	0/ 2	15.5	22.2	18.9	N	No	Below background
Copper (mg/kg)	2/ 2	35.5	0/ 2	14.7	21.7	18.2	N	No	Below background
Iron (mg/kg)	2/ 2	52000	0/ 2	24300	26200	25300	N	No	Essential element
Lead (mg/kg)	2/ 2	49.6	0/ 2	11.6	13.8	12.7	N	No	Below background
Magnesium (mg/kg)	2/ 2	6630	0/ 2	3290	4760	4030	N	No	Essential element
Manganese (mg/kg)	2/ 2	2220	0/ 2	615	793	704	N	No	Below background
Mercury (mg/kg)	2/ 2	0.34	2/ 2	5.8	10.7	8.25	N	Yes	> 5% detect above background
Nickel (mg/kg)	2/ 2	56.7	0/ 2	17.8	22.1	20	N	No	Below background
Potassium (mg/kg)	2/ 2	5560	0/ 2	1740	2270	2010	N	No	Essential element
Sodium (mg/kg)	2/ 2	.		97.3	104	101	N	No	Essential element
Vanadium (mg/kg)	2/ 2	60.1	0/ 2	19.5	21.5	20.5	N	No	Below background
Zinc (mg/kg)	2/ 2	108	0/ 2	38.9	47.4	43.2	N	No	Below background

Table D.17 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site Related?	Justification
<i>Organics</i>									
PCB-1248 (µg/kg)	2/ 2	.		65	140	103	N	Yes	No background available
PCB-1254 (µg/kg)	2/ 2	.		69	190	130	N	Yes	No background available
PCB-1260 (µg/kg)	2/ 2	.		73	210	142	N	Yes	No background available
Tetrachloroethene (µg/kg)	1/ 2	.		2	2	2.5	N	Yes	No background available
Toluene (µg/kg)	2/ 2	.		12	19	15.5	N	Yes	No background available
<i>Radioactivity</i>									
Gross Alpha (pCi/g)	2/ 2	.		5	8.4	6.7	N	NA	Total activity of all radionuclides
Gross Beta (pCi/g)	1/ 2	.		9.7	9.7	8.3	N	NA	Total activity of all radionuclides
Thorium-228 (pCi/g)	2/ 2	2.88	0/ 2	0.46	0.92	0.69	N	No	Below background
Thorium-230 (pCi/g)	2/ 2	2.3	0/ 2	0.31	0.47	0.39	N	No	Below background
Thorium-232 (pCi/g)	1/ 2	2.75	0/ 2	0.36	0.36	0.29	N	No	Below background
Uranium-234 (pCi/g)	2/ 2	3.2	0/ 2	0.84	1.4	1.12	N	No	Below background
Uranium-235 (pCi/g)	2/ 2	0.24	0/ 2	0.042	0.092	0.067	N	No	Below background
Uranium-238 (pCi/g)	2/ 2	2.6	1/ 2	2	2.9	2.45	N	No	1 detect above bkgd; 2.9(site) vs. 2.6 (bkgd)

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCV RI.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.18. Summary of selection of site-related chemicals and radionuclides, S-3 Site, deep soils, boring 10

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	1/ 1	46700	0/ 1	13300	13300	13300	X	No	Below background
Arsenic (mg/kg)	1/ 1	20.2	0/ 1	7	7	7	X	No	Below background
Barium (mg/kg)	1/ 1	212	0/ 1	137	137	137	X	No	Below background
Beryllium (mg/kg)	1/ 1	2.12	0/ 1	0.91	0.91	0.91	X	No	Below background
Calcium (mg/kg)	1/ 1	1860	1/ 1	32700	32700	32700	X	No	Essential element
Chromium (mg/kg)	1/ 1	80.1	0/ 1	22	22	22	X	No	Below background
Cobalt (mg/kg)	1/ 1	40.1	0/ 1	20.2	20.2	20.2	X	No	Below background
Copper (mg/kg)	1/ 1	35.5	0/ 1	24.6	24.6	24.6	X	No	Below background
Iron (mg/kg)	1/ 1	52000	0/ 1	25000	25000	25000	X	No	Essential element
Lead (mg/kg)	1/ 1	49.6	0/ 1	22.1	22.1	22.1	X	No	Below background
Magnesium (mg/kg)	1/ 1	6630	1/ 1	7870	7870	7870	X	No	Essential element
Manganese (mg/kg)	1/ 1	2220	0/ 1	1260	1260	1260	X	No	Below background
Mercury (mg/kg)	1/ 1	0.34	1/ 1	3.7	3.7	3.7	X	Yes	> 5% detect above background
Nickel (mg/kg)	1/ 1	56.7	0/ 1	18.3	18.3	18.3	X	No	Below background
Potassium (mg/kg)	1/ 1	5560	0/ 1	1820	1820	1820	X	No	Essential element
Sodium (mg/kg)	1/ 1	.		89.4	89.4	89.4	X	No	Essential element
Vanadium (mg/kg)	1/ 1	60.1	0/ 1	21.8	21.8	21.8	X	No	Below background
Zinc (mg/kg)	1/ 1	108	0/ 1	53.6	53.6	53.6	X	No	Below background

Table D.18 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Organics</i>									
PCB-1248 (µg/kg)	1/ 1	.	.	3300	3300	3300	X	Yes	No background available
PCB-1254 (µg/kg)	1/ 1	.	.	290	290	290	X	Yes	No background available
PCB-1260 (µg/kg)	1/ 1	.	.	280	280	280	X	Yes	No background available
2-Butanone (µg/kg)	1/ 1	.	.	17	17	17	X	Yes	No background available
Acetone (µg/kg)	1/ 1	.	.	170	170	170	X	Yes	No background available
Tetrachloroethene (µg/kg)	1/ 1	.	.	2	2	2	X	Yes	No background available
Toluene (µg/kg)	1/ 1	.	.	7	7	7	X	Yes	No background available
<i>Radioactivity</i>									
Americium-241 (pCi/g)	1/ 1	0.058	1/ 1	0.077	0.077	0.077	X	Yes	> 5% detect above background
Plutonium-238 (pCi/g)	1/ 1	0.12	1/ 1	0.14	0.14	0.14	X	Yes	> 5% detect above background
Thorium-228 (pCi/g)	1/ 1	2.88	0/ 1	0.26	0.26	0.26	X	No	Below background
Thorium-230 (pCi/g)	1/ 1	2.3	0/ 1	0.26	0.26	0.26	X	No	Below background
Thorium-232 (pCi/g)	1/ 1	2.75	0/ 1	0.15	0.15	0.15	X	No	Below background
Uranium-234 (pCi/g)	1/ 1	3.2	0/ 1	1.1	1.1	1.1	X	No	Below background
Uranium-235 (pCi/g)	1/ 1	0.24	0/ 1	0.041	0.041	0.041	X	No	Below background
Uranium-238 (pCi/g)	1/ 1	2.6	0/ 1	1.3	1.3	1.3	X	No	Below background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCV RI.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects; R = distribution with negative results and therefore treated as normal.

Table D.19. Summary of analysis of sediments from the main stem of BCV at the S-3 Site

Parameter	Units	Soil background ^a	Sample site results				
			UBC-1	UBC-2	UBC-3	UBC-4	UBC-BK
Inorganics							
Aluminum	wt %		5.2	9.6	15	12	2.4
Antimony	µg/g						
Arsenic	µg/g	20.2	14	155	210	102	4.6
Barium	µg/g	212.0	680	310	200	550	200
Beryllium	µg/g	2.1	3	6	10	7	1
Boron	µg/g	34.0	40	43	46	70	13
Cadmium	µg/g	0.3	14	2.2		1.9	
Calcium	wt %		2.8	0.24	0.52	0.58	0.09
Cerium	µg/g		120	91	190	130	51
Chromium	µg/g	80.1	56	86	100	97	30
Cobalt	µg/g	40.1	42	30	19	33	10
Copper	µg/g	35.5	29	100	140	180	9
Cyanide	µg/g			2	1.5	6.5	
Gallium	µg/g		74				60
Iron	wt %		3.9	2.7	2.4	3.8	1.6
Lanthanum	µg/g		43	40	56	48	23
Lead	µg/g	49.6	38	127	220	119	
Magnesium	wt %		0.86	0.43	0.46	0.91	0.14
Manganese	µg/g	2220.0	3500	340	330	600	380
Mercury	µg/g	0.3	1.5	16	20	12	
Molybdenum	µg/g	12.8					
Nickel	µg/g	56.7	130	71	69	170	13
Niobium	µg/g		8	9		9	6
Percent Moisture	wt %		39.4	85.8	90.1	58.9	34
Phosphorus	µg/g		320	450	530	590	260
Potassium	wt %		1.4	1.3	1.1	2.1	0.62
Scandium	µg/g		5	7	8	11	4
Selenium	µg/g	1.2		4.4			2.9
Sodium	wt %		0.1	0.15	0.21	0.17	0.06
Strontium	µg/g	16.8	77	56	47	73	33
Thallium	µg/g	0.7		15	0.5		
Thorium	µg/g			35	43	70	29
Titanium	µg/g		0.28	0.35	0.26	0.36	0.23
Uranium	µg/g		100	1600	4900	1800	1.45
Vanadium	µg/g	60.1	53	57	45	77	28

Table D.19 (continued)

Parameter	Units	Soil background ^a	Sample site results				
			UBC-1	UBC-2	UBC-3	UBC-4	UBC-BK
Yttrium	µg/g		53	43	96	51	15
Zinc	µg/g	108.0	100	160	180	240	25
Zirconium	µg/g		110	130	75	110	170
<i>Organics</i>							
4-Nitrophenol	µg/kg					1400	
Benzo(a)pyrene	µg/kg			320			
Benzo(b)fluoranthene	µg/kg			340		280	
Benzo(k)fluoranthene	µg/kg			340		280	
Bis(2-ethylhexyl) phthalate	µg/kg					560	
Chrysene	µg/kg			320			
Di-n-buthyphthalate	µg/kg		320				
Fluoranthene	µg/kg		300	300		460	
Methylene chloride	µg/kg			11	22		
Naphthalene	µg/kg					220	
Phenanthrene	µg/kg					360	
Pyrene	µg/kg		240	280		360	
Tetrachloroethene	µg/kg					89	
<i>Radioactivity</i>							
Alpha activity	pCi/g		39	770	1500	1200	5.1
Beta activity	pCi/g		99	1200	2600	2400	
Lead-212	pCi/g		1.8	3.8	7.5	4.9	
Neptunium-237	pCi/g	0.2	2.6	2.5	1.5	1.2	
Plutonium-239/240	pCi/g	0.1			1.3	1.9	
Technetium-99	pCi/g	4.1		56	91		
Thallium-208	pCi/g		2.4	9		2.1	
Uranium-234	pCi/g	3.2	15	246	755	280	0.5
Uranium-235	wt %	0.2	0.38	0.32	0.34	0.3	0.76
Uranium-238	pCi/g	3.1	55	880	2675	980	0.5
Zr95/Nb95	pCi/g			2.3	20	3.4	

^a Soil background data taken from Table D.5.

Table D.20. Summary of selection of site-related chemicals and radionuclides, Upper Bear Creek at BCK 12.46, unfiltered samples

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. ^c result	Dist ^d	Comment
<i>Inorganics</i>								
Nitrate (mg/L)	71/ 71	0.2	71/ 71	3.8	530.0	38.8	X	> 5% detect above background
Aluminum (mg/L)	64/ 72	7.4	1/ 72	0.04	21.8	0.51	X	Below background
Barium (mg/L)	71/ 72	0.21	1/ 72	0.044	0.928	0.092	X	Below background
Beryllium (mg/L)	1/ 72	0.00072	1/ 72	0.001	0.001	0.0000	D	< = 5% detects
Boron (mg/L)	72/ 72	0.062	59/ 72	0.04	0.291	0.086	X	> 5% detect above background
Calcium (mg/L)	72/ 72	36	72/ 72	57.2	230.0	164.5	X	Essential element
Cerium (mg/L)	1/ 72	.		0.08	0.08	0.012	D	< = 5% detects
Cobalt (mg/L)	1/ 72	0.017	0/ 72	0.014	0.014	0.001	D	< = 5% detects
Copper (mg/L)	3/ 72	0.0072	3/ 72	0.02	0.052	0.005	D	< = 5% detects
Cyanide (mg/L)	6/ 72	.		0.002	0.003	0.001	D	Background < Detection Limit
Iron (mg/L)	41/ 72	30	1/ 72	0.06	42.6	0.74	X	Essential element
Lithium (mg/L)	33/ 72	.		0.02	0.02	0.02	D	No detects > WOE UTL
Magnesium (mg/L)	72/ 72	7.2	72/ 72	7.63	37.4	23.4	N	Essential element
Manganese (mg/L)	72/ 72	6.1	0/ 72	0.005	0.571	0.046	L	Below background
Mercury (mg/L)	18/ 72	0.0002	3/ 72	0.0	0.001	0.0000	D	> 5% background
Nickel (mg/L)	2/ 72	0.011	1/ 72	0.009	0.03	0.005	D	< = 5% detects
Phosphorous (mg/L)	41/ 72	.		0.05	0.4	0.06	X	No background data available
Potassium (mg/L)	72/ 72	3.5	69/ 72	2.5	7.5	5.1	N	Essential element
Scandium (mg/L)	1/ 72	.		0.012	0.012	0.000	D	< = 5% detects

Table D.20 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. ^c result	Dist ^d	Comment
Selenium (mg/L)	1/ 72	0.066	0/ 72	0.002	0.002	0.0010	D	< = 5% detects
Sodium (mg/L)	72/ 72	7.6	72/ 72	18.6	179.0	57.0	X	Essential element
Strontium (mg/L)	72/ 72	0.12	72/ 72	0.155	0.578	0.4230	X	> 5% detect above background
Thallium (mg/L)	2/ 72	.		0.001	0.005	0.001	D	< = 5% detects
Thorium (mg/L)	2/ 72	0.2	0/ 72	0.01	0.01	0.006	D	< = 5% detects
Titanium (mg/L)	3/ 72	.		0.01	0.19	0.01	D	< = 5% detects
Total uranium (fluorometric) (mg/L)	72/ 72	0.015	72/ 72	0.129	1.04	0.621	N	> 5% detect above background
Vanadium (mg/L)	1/ 72	0.013	1/ 72	0.09	0.09	0.003	D	< = 5% detects
Zinc (mg/L)	24/ 72	0.066	1/ 72	0.007	0.2	0.013	D	> 95% below background
Zirconium (mg/L)	1/ 71	.		0.016	0.016	0.002	D	< = 5% detects
Organics								
Phenols (mg/L)	54/ 72	.		0.001	0.007	0.002	X	No background data available
Radioactivity								
Alpha activity (pCi/L)	72/ 72	2.11	71/ 72	0.17	750.0	270.5	X	> 5% detect above background
Americium-241 (pCi/L)	54/ 72	.		0.0	0.93	0.18	L	No background data available
Beta activity (pCi/L)	72/ 72	3.75	70/ 72	0.06	360.0	164.1	X	> 5% detect above background
Neptunium-237 (pCi/L)	70/ 72	.		0.20	5.7	0.8	X	No background data available
Plutonium-238 (pCi/L)	31/ 69	.		0.0	0.41	0.08	D	No background data available

Table D.20 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. ^c result	Dist ^d	Comment
Plutonium-239 (pCi/L)	39/ 69			0.0	0.2	0.03	L	No background data available
Technetium-99 (pCi/L)	70/ 72			0.0	0.67	0.12	X	No background data available

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For surface water, background criteria have been established using data from NT-13 published in the GWQRs (e.g., HSW 1995). Only results for unfiltered samples were used.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects; R = distribution with negative results and therefore treated as normal.

^e No background value for cyanide was available from NT-13 (Energy Systems 1996). Cyanide was not detected in any samples from NT-5, the least contaminated catchment on BCV. The background value for cyanide was, therefore, assumed to be less than the detection limit and any detection of cyanide is considered as above background.

^f No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCV. See text for further details.

Table D.21. Summary of selection of site-related chemicals and radionuclides, Bear Creek Main Stem at BCK 12.71 (Sample BCK S-3), unfiltered and filtered samples

Analyte ^a	Bkgd criteria ^b	Detects > bkgd	Unfiltered result	Filtered result
<i>Inorganics</i>				
Chloride (mg/L)	2	1/ 1	1220.0	
Fluoride (mg/L)	0.1	1/ 1	0.43	
Nitrate (mg/L)	0.2	1/ 1	2.2	
Sulfate (mg/L)	57	1/ 1	68.8	
Antimony (mg/L)	0.05	0/ 1	0.0018	0.0015
Arsenic (mg/L)	0.05	0/ 1	0.0017	
Barium (mg/L)	0.21	0/ 1	0.1350	0.135
Calcium (mg/L)	36	1/ 1	115.0	113.0
Magnesium (mg/L)	7.2	1/ 1	14.10	14.0
Manganese (mg/L)	6.1	0/ 1	0.11	0.105
Mercury (mg/L)	0.0002	1/ 1	0.0003	
Potassium (mg/L)	3.5	1/ 1	4.4200	4.47
Sodium (mg/L)	7.6	1/ 1	670.0	668.0
Zinc (mg/L)	0.066	0/ 1	0.0081	
<i>Organics</i>				
1,2-Dichloroethane (µg/L)			7	
Acetone (µg/L)			14	
Chloromethane (µg/L)			2	
<i>Radioactivity</i>				
Alpha Activity (pCi/L)	2.11	1/ 1	237	103
Beta Activity (pCi/L)	3.75	1/ 1	114	84.2
Thorium-228 (pCi/L)			0.1030	
Uranium-233/234 (pCi/L)			52.8	57.8
Uranium-235 (pCi/L)			4.7	2.12
Uranium-238 (pCi/L)			127.0	125.0

^a Only detected analytes are listed. Results reflect data validation and data usability screens.

^b For surface water, background criteria have been established using data from NT-13 published in the GWQRs (e.g., HSW 1995). Only results for unfiltered samples were screened against background.

Table D.22. Summary of selection of site-related chemicals and radionuclides, NT-1, unfiltered samples

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. result ^c	Dist ^d	Comment
<i>Inorganics</i>								
Chloride (mg/L)	6/ 6	2	6/ 6	9.9	44.0	27.4	N	> 5% detect above background
Fluoride (mg/L)	6/ 6	0.1	5/ 6	0.1	1.8	1.0	N	> 5% detect above background
Nitrate (mg/L)	6/ 6	0.2	6/ 6	31.0	286.1	166.6	N	> 5% detect above background
Sulfate (mg/L)	6/ 6	57	3/ 6	19.9	74.0	46.8	N	> 5% detect above background
Aluminum (mg/L)	6/ 6	7.4	0/ 6	0.13	0.79	0.56	N	Below background
Barium (mg/L)	6/ 6	0.21	5/ 6	0.084	1.100	0.554	N	> 5% detect above background
Beryllium (mg/L)	2/ 6	0.00072	0/ 6	0.0003	0.0005	0.0002	D	Below background
Boron (mg/L)	6/ 6	0.062	3/ 6	0.041	0.120	0.073	L	> 5% detect above background
Cadmium (mg/L)	3/ 4	0.002	3/ 4	0.017	0.024	0.015	N	> 5% detect above background
Calcium (mg/L)	6/ 6	36	6/ 6	120.0	340.0	228.30	L	Essential element
Cobalt (mg/L)	4/ 6	0.017	0/ 6	0.0071	0.0130	0.0068	N	Below background
Copper (mg/L)	1/ 6	0.0072	0/ 6	0.0042	0.0042	0.0024	D	Below background
Iron (mg/L)	5/ 6	30	0/ 6	0.0064	0.7500	0.2332	L	Essential element
Lead (mg/L)	1/ 4	0.02	0/ 4	0.0073	0.0073	0.0033	D	Below background
Magnesium (mg/L)	6/ 6	7.2	6/ 6	16.0	44.0	29.8	L	Essential element
Manganese (mg/L)	6/ 6	6.1	0/ 6	0.1	5.9	3.0	N	Below background
Nickel (mg/L)	5/ 6	0.011	5/ 6	0.0480	0.1200	0.0678	N	> 5% detect above background
Potassium (mg/L)	6/ 6	3.5	3/ 6	1.9	8.1	4.5	L	Essential element
Sodium (mg/L)	6/ 6	7.6	6/ 6	14.0	50.0	29.5	N	Essential element
Strontium (mg/L)	6/ 6	0.12	6/ 6	0.3300	1.0000	0.6917	L	> 5% detect above background
Zinc (mg/L)	6/ 6	0.066	0/ 6	0.0069	0.0210	0.0138	N	Below background
Total Uranium (fluorometric) (mg/L)	6/ 6	0.015	4/ 6	0.012	0.185	0.075	L	> 5% detect above background

Table D.22 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. result ^c	Dist ^d	Comment
<i>Organics</i>								
Acetone (µg/L)	1/ 6	.		3	3	5	D	All detects < detection limit
Tetrachloroethene (µg/L)	6/ 6	.		1	6	3	N	No background available
<i>Radioactivity</i>								
Alpha Activity (pCi/L)	3/ 6	2.11	3/ 6	16.3	72.8	26.3	L	> 5% detect above background
Beta Activity (pCi/L)	6/ 6	3.75	6/ 6	63.6	384.0	226.7	N	> 5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For surface water, background criteria have been established using data from NT-13 published in the GWQRs (e.g., HSW 1995). Only results for unfiltered samples were used.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects; R = distribution with negative results and therefore treated as normal.

^e No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCV. See text for further details.

Table D.23. Summary of chemical and radionuclide results for filtered samples, NT-1

Analyte ^a	Freq. of detect	Min detect	Max detect	Avg. result ^b
Aluminum (mg/l)	6/ 6	0.047	0.91	0.375
Barium (mg/l)	6/ 6	0.088	0.91	0.505
Beryllium (mg/l)	3/ 6	0.0003	0.0006	0.0003
Boron (mg/l)	6/ 6	0.036	0.095	0.068
Cadmium (mg/l)	3/ 4	0.013	0.022	0.013
Calcium (mg/l)	6/ 6	120	330	223.3
Chromium (mg/l)	1/ 4	0.019	0.019	0.009
Cobalt (mg/l)	4/ 6	0.0075	0.02	0.0085
Copper (mg/l)	1/ 6	0.044	0.044	0.009
Iron (mg/l)	3/ 6	0.047	11	1.879
Lead (mg/l)	1/ 4	0.018	0.018	0.006
Magnesium (mg/l)	6/ 6	16	49	29.67
Manganese (mg/l)	6/ 6	0.011	4.8	2.835
Nickel (mg/l)	6/ 6	0.012	0.24	0.09
Potassium (mg/l)	6/ 6	1.9	7.7	4.3
Sodium (mg/l)	6/ 6	14	50	28.5
Strontium (mg/l)	6/ 6	0.33	1	0.66
Zinc (mg/l)	6/ 6	0.0076	0.082	0.0247
Total uranium (fluorometric) (mg/l)	6/ 6	0.012	0.207	0.070

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals.

Table D.24. Summary of selection of site-related chemicals and radionuclides, NT-2

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
<i>Inorganics</i>								
Chloride (mg/L)	21/ 21	2	15/ 21	1.2	10	4.676	L	> 5% detect above background
Fluoride (mg/L)	8/ 21	0.1	7/ 21	0.1	0.14	0.0757	D	5% detect above background
Nitrate-N (mg/L)	21/ 21	0.2	21/ 21	2.9	211	74.24	L	5% detect above background
Sulfate (mg/L)	11/ 21	57	0/ 21	5.4	31.5	9.038	X	Below background
Aluminum (mg/L)	18/ 21	7.4	1/ 21	0.0613	7.75	1.15	L	≤ 5% below background
Antimony (mg/L)	3/ 21	0.05	0/ 21	0.0016	0.0023	0.0010	D	Below background
Barium (mg/L)	21/ 21	0.21	12/ 21	0.0596	0.682	0.3067	L	5% detect above background
Beryllium (mg/L)	1/ 21	0.0007	0/ 21	0.0005	0.0005	0.0002	D	Below background
Calcium (mg/L)	21/ 21	36	15/ 21	13.6	259	109.1	L	Essential element
Cobalt (mg/L)	1/ 21	0.017	0/ 21	0.0024	0.0024	0.0014	D	Below background
Cyanide (mg/L)	2/ 21	.	.	0.0101	0.0148	0.0057	D	Background < detection limit ^e
Iron (mg/L)	20/ 21	30	0/ 21	0.112	9.65	1.575	L	Essential element
Lithium (mg/L)	7/ 7	.	.	0.0037	0.0092	0.0072	N	No detects > WOE UTL ^f
Magnesium (mg/L)	21/ 21	7.2	12/ 21	2.42	26.2	11.88	L	Essential element
Manganese (mg/L)	21/ 21	6.1	0/ 21	0.0208	0.392	0.1183	L	Below background
Nickel (mg/L)	3/ 21	0.011	0/ 21	0.0044	0.0104	0.0034	D	Below background
Potassium (mg/L)	21/ 21	3.5	0/ 21	1.25	3.26	2.108	L	Essential element
Sodium (mg/L)	20/ 21	7.6	7/ 21	1.21	14.8	6.915	L	Essential element
Vanadium (mg/L)	4/ 21	0.013	0/ 21	0.0028	0.0116	0.0020	D	Below background
Zinc (mg/L)	11/ 21	0.066	0/ 21	0.0076	0.063	0.0149	L	Below background
<i>Organics</i>								
1,2-Dichloroethane (µg/L)	7/ 21	.	.	9	18	6.048	D	No background available
2-Butanone (µg/L)	1/ 21	.	.	10	10	2.857	D	≤ 5% detects

Table D.24 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
4-Methyl-2-pentanone (µg/L)	1/ 21	.		3	3	2.524	D	≤5% detects
Acetone (µg/L)	5/ 21	.		4	27	7.31	D	No background available
Carbon disulfide (µg/L)	1/ 21	.		2	2	2.476	D	≤5% detects
Chloromethane (µg/L)	6/ 21	.		2	6	3.071	D	No background available
Methylene chloride (µg/L)	1/ 21	.		1	1	2.381	D	≤5% detects
Toluene (µg/L)	1/ 21	.		1	1	2.429	D	≤5% detects
<i>Radioactivity</i>								
Beta Activity (pCi/L)	19/ 20	3.75	19/ 20	12	164	59.67	L	5% detect above background
Technetium-99 (pCi/L)	2/ 2	.		121	290	205.5	N	No background data available
Uranium-233/234 (pCi/L)	1/ 21	.		24.7	24.7	1.554	D	≤5% detects
Uranium-238 (pCi/L)	1/ 21	.		49.5	49.5	2.675	D	≤5% detects

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For surface water, background criteria have been established using data from NT-13 published in the GWQRs (e.g., HSW 1995). Only results for unfiltered samples were used.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

^e No background value for cyanide was available from NT-13 (Energy Systems 1996). Cyanide was not detected in any samples from NT-5, the least contaminated catchment on BCV. The background value for cyanide was, therefore, assumed to be less than the detection limit and any detection of cyanide is considered as above background.

^f No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCV. See text for further details.

Table D.25. Summary of chemical and radionuclide results for filtered samples, NT-2

Analyte ^a	Freq of detect	Min detect	Max detect	Average result
Aluminum (mg/l)	7/ 21	0.023	1.96	0.159
Antimony (mg/l)	12/ 21	0.0014	0.0095	0.0022
Barium (mg/l)	21/ 21	0.0245	0.705	0.3049
Beryllium (mg/l)	1/ 21	0.0004	0.0004	0.0002
Calcium (mg/l)	21/ 21	13.6	270.0	98.1
Iron (mg/l)	4/ 21	0.112	1.12	0.095
Lithium (mg/l)	6/ 7	0.0042	0.0071	0.0059
Magnesium (mg/l)	21/ 21	1.67	27.1	11.81
Manganese (mg/l)	21/ 21	0.012	0.17	0.063
Potassium (mg/l)	21/ 21	1.09	2.4	1.79
Sodium (mg/l)	20/ 21	1.01	15.2	6.91
Zinc (mg/l)	7/ 21	0.0086	0.0569	0.0086
Beta Activity (pCi/l)	17/ 20	12.2	141.0	56.3
Uranium-233/234 (pCi/l)	1/ 21	1.21	1.21	0.37
Uranium-238 (pCi/l)	1/ 21	1.76	1.76	0.27

^a Analytes detected at least once are summarized. Results reflect data validation and usability screens.

Table D.26. Summary of miscellaneous parameters for surface water aggregates in the S-3 FA

Parameter	Min	Max	Mean	n ^a	Min	Max	Mean	n ^a	Min	Max	Mean	n ^a	Min	Max	Mean	n ^a
	<i>BCK 12.71</i>				<i>BCK 12.46</i>				<i>NT-1</i>				<i>NT-2</i>			
Alkalinity (HCO ₃) (mg/L)	205	205	205	1					90	328	190	6	21.9	148	79.1	21
Specific conductance (μmhos/cm)	2300	2300	2300	1					105	2330	948	19	47.5	1800	845	17
Dissolved oxygen (mg/L)					44.5	11.4	8.1	312	6.6	11.2	8.2	6				
Total dissolved solids (mg/L)	2180	2180	2180	1	130	1400	839	326	538	1746	1147	6	58	1240	521	21
pH	7.7	7.7	7.7	1	6.7	8.7	7.4	310	6.9	7.7	7.3	19	7	7.9	7.4	17
Total suspended solids (mg/L)	4.8	4.8	4.8	1	0.5	380	9.6	326	4	8	6	6	4.8	564	56.7	21
Temperature (°C)	17.9	17.9	17.9	1					2.9	25.6	11.9	13	1.9	21.1	15.8	17
Turbidity (NTU)	3.5	3.5	3.5	1					1.3	8.4	4.0	6	1.6	155	20.0	21

^a n = total number of samples analyzed.

Table D.27. Results of analysis for water samples from temporary piezometers P1 and P2, and the adjacent reach of NT-1, unfiltered samples

Parameter	Units	P1 (2/26/96) ^a	Lab qual. ^b	P2 (3/6/96) ^c	Lab qual. ^b	NT-1 (12/14/95)	Lab qual. ^b
<i>Inorganics</i>							
Aluminum	mg/L	90.3		81.3		1.9	
Alkalinity (total)	mg/L			160		120	
Antimony	mg/L	0.2	<				
Arsenic	mg/L	0.2	<	0.1	<	0.005	<
Barium	mg/L	5.45		20.1		0.824	
Beryllium	mg/L	0.02		0.0103		0.0007	
Boron	mg/L	0.2				0.02	
Cadmium	mg/L	0.68		0.788		0.038	
Calcium	mg/L	184		1000	>	279	
Cerium	mg/L	0.58	Z			0.02	Z
Chloride	mg/L			180		23	
Chromium	mg/L	0.08		0.0758		0.006	<
Cobalt	mg/L	0.62		0.598		0.018	
Copper	mg/L	0.03	<	0.03	<	0.006	<
Fluoride	mg/L			30.0		1.2	
Iron	mg/L	37.7		37.4		0.06	<
Lead	mg/L	0.1	<	0.2	<		
Lithium	mg/L	0.1				0.02	<
Magnesium	mg/L	262.0		334.0		37.9	
Manganese	mg/L	115.0		100.0	>	6.93	
Mercury	mg/L			0.0002		0.0002	<
Molybdenum	mg/L	0.03	<	0.04	<	0.006	<
Nickel	mg/L	3.45		3.18		0.151	
Nitrate	mg/L			1919		230	
Nitrite	mg/L			16		1	
o-Phosphate	mg/L			0.12	<		
Potassium	mg/L	47.0		48.2		4.3	
Selenium	mg/L	0.5	<			0.005	<
Silver	mg/L	0.03	<	0.02	<Z	0.006	<
Sodium	mg/L	329.0		379.0		36.3	
Strontium	mg/L	4.16	Z			0.806	Z
Sulfate	mg/L			12			
Thallium	mg/L	0.2	<	0.135		0.03	<
Thorium	mg/L	0.05	<Z			0.01	<Z
Titanium	mg/L	0.41	Z			0.02	<Z
Uranium	mg/L	0.01		0.006			

Table D.27 (continued)

Parameter	Units	P1 (2/26/96) ^a	Lab qual. ^b	P2 (3/6/96) ^c	Lab qual. ^b	NT-1 (12/14/95)	Lab qual. ^b
Vanadium	mg/L	0.04		0.0514		0.004	<
Zinc	mg/L	0.19		0.225		0.01	<
Zirconium	mg/L	0.02	<Z				
<i>Organics</i>							
1,1,1-Trichloroethane	µg/L	2	J	2	J		
1,1,2-Trichloro-1,2,2-trifluoroethane	µg/L			65	B		
1,1-Dichloroethene	µg/L	3	J	2	J		
cis-1,2-Dichloroethene	µg/L			19			
2-Butanone	µg/L			3	BJ		
Acetone	µg/L			6	BJ	4	JB
Chloroform	µg/L	17		17		1	J
Bromomethane	µg/L			4	J		
Methylene chloride	µg/L	27		18		2	J
Tetrachloroethene	µg/L	260		120	B	19	
Toluene	µg/L	1	J				
Trichloroethene	µg/L	2	J	2	J		
<i>Radioactivity</i>							
Alpha Activity	pCi/L					24 ± 10	(12)
Beta Activity	pCi/L					310 ± 42	(8.3)
Total Strontium	pCi/L			27 ± 4.5	(13)		
Technitium-99	pCi/L			15000 ± 1500	(12)	1000 ± 110	(12)
Tritium	pCi/L			950 ± 190	(420)		
Uranium-235	wt %	0.35		0.37			
Uranium-234	pCi/L					3.9 ± 1.1	(0.13)
Uranium-235	pCi/L					0.18 ± 0.21	(0.16)
Uranium-236	pCi/L					0.14 ± 0.17	(0.13)
Uranium-238	pCi/L					8.4 ± 1.8	(0.32)
<i>Other</i>							
pH		4.82					
Total suspended solids	mg/L			370		8	
Total dissolved solids	mg/L			13000	270		

^a Metals by method EPA 200.7^b < indicates that less than detection limit and detection limit reported; Z indicates that the analyte was not included in method EPA SW846 prep method 3010; a number in parenthesis represents a counting error^c Metal by method EPA SW846

Table D.28. C vs Q relationship data for surface water contaminants in Bear Creek at BCK 12.38

Sample	Date	Q (L/s)	Barium	Chloride	Fluoride	Nitrate	Sulfate	Gross α	Gross β	^{99}Tc	$^{233/234}\text{U}$	^{235}U	^{238}U
SB1001	29-Mar-94	32.89	0.2	96.6	0.6	45.9	38.0	19.6	108.0	165.0	21.9	1.5	47.8
SB1002	05-Apr-94	15.14	0.2	83.3	0.5	41.5	38.1		109.0		23.4		46.2
SB1003	07-Apr-94	58.16	0.1	72.4	0.3	13.8	13.5		46.1		9.3		16.4
SB1004	12-Apr-94	12.76	0.2	23.9	0.5	44.7	84.5	60.5	125.0	186.0	24.7	1.3	51.2
SB1005	14-Apr-94	105.02	0.2	1220.0	0.2	2.9		17.2	38.9		5.1		8.7
SB1006	20-Apr-94	16.40	0.2	65.2	0.5	57.3	34.3	32.2	93.4	139.0			
SB1007	22-Apr-94	10.15	0.3	65.6	0.7	98.0	45.3	57.2	158.0	194.0	30.3	1.0	63.1
SB1008	26-Apr-94	7.96	0.4	71.6	0.7	93.6	47.1	57.8	196.0	359.0	36.3	1.8	71.6
SB1009	24-May-94	3.57	0.5	133.0	1.3	129.0	55.2	129.0	314.0	477.0	49.8	1.8	108.0
SB1010	31-May-94	4.70	0.5	102.0	1.0	126.0	47.2	80.5	290.0	394.0	35.9	2.0	76.8
SB1011	07-Jun-94	3.43	0.6	130.0	1.0	171.0	55.3	150.0	364.0		54.0	2.0	110.0
SB1012	16-Jun-94	1.57	0.5	86.2	0.9	118.0	49.4	108.0	240.0		44.1		86.1
SB1013	21-Jun-94	3.81	0.5	87.4	1.0	136.0	56.8	97.0	303.0		42.7	4.2	104.0
SB1014	28-Jun-94	7.31	0.3	50.5	0.7	71.2	43.2	61.7	183.0		24.6	1.5	56.9
SB1015	07-Jul-94	3.25	0.4	71.0	0.8	92.0	66.0	118.0	236.0		31.7	3.8	93.5
SB1016	12-Jul-94	1.69	0.5	27.1	0.9	138.0	45.3	90.8	350.0		43.5	1.5	62.8
SB1017	19-Jul-94	7.37	0.3	52.9	0.7	57.1	45.0	102.0	151.0	210.0	29.6	1.7	64.5
SB1018	11-Aug-94	2.85	0.4	67.0	0.9	115.0	57.1	148.0	302.0		51.4	3.1	111.0
SB1019	03-Oct-94	2.39	0.5	61.4	1.0	151.0	57.5	148.0	355.0		49.9	4.3	135.0
SB1020	25-Jan-95	6.14	0.3	38.4	0.8	74.7	43.9	50.0			34.0	2.2	64.0
SB1021	29-Jan-95	24.97	0.1	18.5	0.3	26.7	25.0	29.0	120.0		9.1		16.0

Table D.29. C vs Q relationship data for surface water contaminants in NT-2

Sample	Date	Q (L/s)	Barium	Chloride	Fluoride	Nitrate	Gross β	^{99}Tc
SN2001	29-Mar-94	12.24	0.0955	1.7		5.9	12	
SN2002	05-Apr-94	13.24	0.0893	1.7		14.5	17.1	
SN2003	07-Apr-94	76.79	0.0596	1.2		6.7		
SN2004	12-Apr-94	29.21	0.1	1.8		17.8	18.3	
SN2005	14-Apr-94	158.44	0.111	1.8		2.9	12.8	
SN2006	20-Apr-94	10.07	0.11	1.8		29.2	23.7	
SN2007	22-Apr-94	5.04	0.177	2.7		52.3	35.5	
SN2008	26-Apr-94	4.03	0.249	3.5		51.8	42.7	
SN2009	24-May-94	0.52	0.509	7.1	0.11	124	89.2	121
SN2010	31-May-94	1.99	0.326	4.9	0.12	76.3	45.7	
SN2011	07-Jun-94	0.74	0.682	9.6		185	138	
SN2012	16-Jun-94	1.29	0.315	4.2		62.5	58.4	
SN2013	21-Jun-94	0.60	0.479	6.7		125	80.3	290
SN2014	28-Jun-94	1.67	0.237	3.8	0.14	47.7	34.2	
SN2015	07-Jul-94	0.08	0.637	9.3	0.12	159	130	
SN2016	12-Jul-94	0.20	0.602	9.1	0.12	168	164	
SN2017	19-Jul-94	5.82	0.228	3.8	0.11	48.2	35.7	
SN2018	11-Aug-94	0.16	0.538	8.1		137	102	
SN2019	03-Oct-94	0.11	0.677	10	0.12	168	164	
SN2020	25-Jan-95	1.86	0.134	2.8	0.1	26.7		
SN2021	29-Jan-95	12.41	0.086	2.6		7.5	13	

Table D.30. Summary of selection of site-related chemicals and radionuclides, S-3 Site groundwater aggregate

Analyte ^a	Freq of detect	Freq of wells w. detects	Wells w. median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Comment
<i>Inorganics</i>							
Aluminum (mg/L)	130/ 160	23/ 23	6	0.0230	800	81.05	>5% of wells with median > UTL
Antimony (mg/L)	0/ 149	0/ 20	0	0	0	0.025	≤5% of wells with median > UTL
Arsenic (mg/L)	1/ 26	1/ 9	0	0.0090	0.0090	0.003	≤5% of wells with median > UTL
Barium (mg/L)	192/ 192	24/ 24	10	0.0012	380	19.137	>5% of wells with median > UTL
Beryllium (mg/L)	26/ 152	11/ 22	7	0.0003	0.1100	0.0119	>5% of wells with median > UTL
Boron (mg/L)	161/ 175	24/ 24	10	0.0041	4.4000	0.29	>5% of wells with median > UTL
Cadmium (mg/L)	64/ 231	10/ 25	9	0.0020	4	0.1734	>5% of wells with median > UTL
Calcium (mg/L)	235/ 235	26/ 26	15	0.6200	10,000	1,665.6	Mean concentration > 1,000 mg/L ^d
Chromium (mg/L)	34/ 235	13/ 25	2	0.0100	0.3100	0.017	>5% of wells with median > UTL
Cobalt (mg/L)	32/ 160	11/ 23	6	0.0051	2.3000	0.268	>5% of wells with median > UTL
Copper (mg/L)	96/ 161	20/ 21	8	0.0041	3.1000	0.278	>5% of wells with median > UTL
Iron (mg/L)	164/ 167	23/ 23	4	0.0051	28	3.59	Essential element
Lead (mg/L)	80/ 244	21/ 26	4	0.0040	0.6600	0.0106	>5% of wells with median > UTL
Lithium (mg/L)	13/ 13	7/ 7	NA ^e	0.0130	3.5000	0.88	6/7 wells with median > WOE UTL ^e
Magnesium (mg/L)	235/ 235	26/ 26	14	0.0610	2,500	263.3	Essential element
Manganese (mg/L)	173/ 176	24/ 24	10	0.0011	220	24.162	>5% of wells with median > UTL
Mercury (mg/L)	48/ 243	15/ 26	6	0.0002	0.1100	0.0042	>5% of wells with median > UTL
Molybdenum (mg/L)	17/ 149	3/ 19	0	0.0110	0.0230	0.006	≤5% of wells with median > UTL
Nickel (mg/L)	43/ 160	22/ 24	10	0.0110	20	2.07	>5% of wells with median > UTL
Niobium (mg/L)	6/ 10	4/ 5	NA ^e	0.0075	0.1000	0.027	4/7 wells with detects ^e

Table D.30 (continued)

Analyte ^a	Freq of detect	Freq of wells w. detects	Wells w. median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Comment
Potassium (mg/L)	208/ 228	26/ 26	13	0.6400	200	30.95	Essential element
Selenium (mg/L)	3/ 50	3/ 10	0	0.0100	0.0140	0.003	≤5% of wells with median > UTL
Silicon (mg/L)	88/ 88	24/ 24	2	0.1800	39	9.99	> UTL in 2 wells; component of minerals
Silver (mg/L)	0/ 17	0/ 6	0	0	0	0	≤5% of wells with median > UTL
Sodium (mg/L)	235/ 235	26/ 26	14	1.2000	3,200	357.6	Essential element
Strontium (mg/L)	150/ 150	22/ 22	11	0.0085	340	17.93	>5% of wells with median > UTL
Thallium (mg/L)	1/ 14	1/ 8	NA ^e	0.0100	0.0100	0.005	1 detect at the detection limit ^e
Thorium (mg/L)	1/ 149	1/ 20	1	0.2800	0.2800	0.109	≤5% of wells with median > UTL
Tin (mg/L)	3/ 6	3/ 6	0	0.0110	0.0180	0.01	≤5% of wells with median > UTL
Titanium (mg/L)	10/ 13	7/ 7	NA ^e	0.0097	0.8500	0.237	3/7 wells with median > WOE UTL ^e
Total uranium (fluorometric)(mg/L)	124/ 243	22/ 26	11	0.0010	44	2.90	>5% of wells with median > UTL
Vanadium (mg/L)	9/ 149	5/ 20	2	0.0052	0.0360	0.004	>5% of wells with median > UTL
Zinc (mg/L)	159/ 172	24/ 24	12	0.0012	20	0.497	>5% of wells with median > UTL
Zirconium (mg/L)	4/ 9	3/ 4	0	0.0170	0.0510	0.018	≤5% of wells with median > UTL
<i>Common Anions</i>							
Ammonia nitrogen (mg/L)	5/ 10	2/ 4	NA ^e	1.5000	4.7600	1.19	No background UTL; nitrate = SRC
Chloride (mg/L)	205/ 216	26/ 26	13	0.8000	1,341	106.2	>5% of wells with median > UTL
Fluoride (mg/L)	118/ 233	23/ 25	7	0.1000	110	1.32	>5% of wells with median > UTL
Kjeldahl nitrogen (mg/L)	6/ 10	4/ 4	NA ^e	0.2000	1.8000	0.73	No background UTL; nitrate = SRC

Table D.30 (continued)

Analyte ^a	Freq of detect	Freq of wells w. detects	Wells w. median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Comment
Nitrate (mg/L)	151/ 235	19/ 26	17	0.6400	13,400	1,659	>5% of wells with median > UTL
Nitrite (mg/L)	1/ 8	1/ 4	NA ^e	6.7000	6.7000	20.2	No background UTL
Sulfate (mg/L)	171/ 174	23/ 23	5	2	2,204	204.7	>5% of wells with median > UTL
<i>Organics</i>							
1,1,1-Trichloroethane (µg/L)	36/ 290	9/ 27		0.4000	28	3.8	>5% of wells with detects
1,1,2-Trichloroethane (µg/L)	1/ 288	1/ 26		1	1	2.5	<= 5% of wells with detects
1,1-Dichloroethene (µg/L)	11/ 288	3/ 26		1	5	2.5	<= 5% of detects
1,2-Dichloroethane (µg/L)	1/ 288	1/ 26		4	4	2.5	<= 5% of wells with detects
1,2-Dichloroethene (µg/L)	10/ 240	3/ 25		1	100	5.0	>5% of wells with detects
2,4-Dinitrophenol (µg/L)	2/ 11	1/ 3		11	77	20.8	>5% of wells with detects
2-Butanone (µg/L)	19/ 288	9/ 26		2	32	5.0	>5% of wells with detects
2-Chloroethylvinyl ether (µg/L)	1/ 53	1/ 10		4	4	5	<= 5% detects
2-Hexanone (µg/L)	4/ 288	3/ 26		1	4	5	<= 5% detects
2-Nitrophenol (µg/L)	5/ 11	1/ 3		18	71	20.3	>5% of wells with detects
4-Methyl-2-pentanone (µg/L)	1/ 289	1/ 27		97	97	8.4	≤5% of wells with detects
4-Nitrophenol (µg/L)	5/ 11	1/ 3		22	120	30.3	>5% of wells with detects
Acetone (µg/L)	62/ 294	19/ 27		2	6,000	51.8	>5% of wells with detects
Benzene (µg/L)	17/ 288	4/ 26		0.2000	3	2.5	>5% of wells with detects
Benzenemethanol (µg/L)	2/ 11	1/ 3		2	2	4.2	All detects < detection limit
Benzoic acid (µg/L)	2/ 11	2/ 3		6	58	25.0	> 5% of wells with detects

Table D.30 (continued)

Analyte ^a	Freq of detect	Freq of wells w. detects	Wells w. median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Comment
Bis(2-ethylhexyl)phthalate (µg/L)	6/ 11	2/ 3		1	32	6.3	> 5% of wells with detects
Bromodichloromethane (µg/L)	3/ 288	2/ 26		2	3	2.5	<= 5% detects
Bromoform (µg/L)	1/ 288	1/ 26		2	2	2.5	<= 5% of wells with detects
Butylbenzylphthalate (µg/L)	2/ 11	2/ 3		1	1	3.3	All detects < detection limit
Carbon disulfide (µg/L)	7/ 288	5/ 26		0.7	2	2.5	<= 5% detects
Carbon tetrachloride (µg/L)	1/ 288	1/ 26		0.7	0.7	2.5	<= 5% of wells with detects
Chlorobenzene (µg/L)	2/ 288	2/ 26		0.6	3	2.5	<= 5% detects
Chloroform (µg/L)	90/ 292	14/ 27		0.4000	69	7.0	> 5% of wells with detects
Chloromethane (µg/L)	1/ 288	1/ 26		10	10	5	<= 5% of wells with detects
Dibromochloromethane (µg/L)	1/ 288	1/ 26		1	1	2.5	<= 5% of wells with detects
Di-n-butylphthalate (µg/L)	1/ 11	1/ 3		2	2	4.2	All detects < detection limit
Di-n-octylphthalate (µg/L)	2/ 11	2/ 3		2	3	3.5	All detects < detection limit
Dimethylbenzene (µg/L)	15/ 288	5/ 26		1	16	2.5	> 5% of wells with detects
Ethylbenzene (µg/L)	7/ 288	3/ 26		0.6	4	2.5	<= 5% detects
Methylene chloride (µg/L)	88/ 296	19/ 27		1	560	17.3	> 5% of wells with detects
Naphthalene (µg/L)	4/ 11	1/ 3		1	1	3.7	All detects < detection limit
Phenols (mg/L)	2/ 15	2/ 7		0.0010	0.0020	0.003	> 5% of wells with detects
Tetrachloroethene (µg/L)	79/ 296	12/ 27		0.5000	9,000	269.9	> 5% of wells with detects
Toluene (µg/L)	44/ 290	11/ 27		0.4000	35	3.2	> 5% of wells with detects
trans-1,2-Dichloroethene (µg/L)	2/ 61	2/ 13		2	2	2.8	<= 5% detects

Table D.30 (continued)

Analyte ^a	Freq of detect	Freq of wells w. detects	Wells w. median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Comment
Trichloroethene (µg/L)	21/ 289	6/ 27		0.8000	16	2.9	> 5% of wells with detects
Vinyl acetate (µg/L)	1/ 288	1/ 26		1	1	5	< = 5% of wells with detects
<i>Radioactivity</i>							
Alpha activity (pCi/L)	50/ 156	14/ 18		5.1	24400	615.7	> 5% detects
Americium-241 (pCi/L)	5/ 9	1/ 4		27	38	7.5	> 5% detects
Beta activity (pCi/L)	75/ 156	17/ 18		11.09	75000	2620.8	> 5% detects
Cesium-137 (pCi/L)	2/ 4	2/ 4		6	9.7	5.3	> 5% detects
Iodine-125/129 (pCi/L)	. / 2	. / 1		.	.	2.7	No detects
Iodine-129 (pCi/L)	. / 1	. / 1		.	.	2.7	No detects
Iodine-131 (pCi/L)	. / 1	. / 1		.	.	0	No detects
Neptunium-237 (pCi/L)	7/ 11	1/ 4		40	1090	106.3	> 5% detects
Plutonium-238 (pCi/L)	. / 6	. / 3		.	.	0.14	No detects
Plutonium-239/240 (pCi/L)	. / 7	. / 4		.	.	0	No detects
Radium (pCi/L)	1/ 1	1/ 1		35.139	35.139	35.14	> 5% detects
Radium-228 (pCi/L)	. / 1	. / 1		.	.	0	No detects
Strontium-90 (pCi/L)	7/ 9	3/ 4		147	254	194	> 5% detects
Technetium-99 (pCi/L)	10/ 11	3/ 4		50	80400	17538	> 5% detects
Thorium-228 (pCi/L)	1/ 4	1/ 4		3.2	3.2	1	> 5% detects
Thorium-230 (pCi/L)	2/ 4	2/ 4		0.41	0.59	0.36	> 5% detects
Thorium-232 (pCi/L)	. / 3	. / 3		.	.	0	No detects
Tritium (pCi/L)	9/ 12	2/ 4		620	5406	1245	> 5% detects

Table D.30 (continued)

Analyte ^a	Freq of detect	Freq of wells w. detects	Wells w. median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Comment
Uranium-234 (pCi/L)	10/ 11	3/ 4		1.5	4650	660	> 5% detects
Uranium-235 (pCi/L)	8/ 11	2/ 4		3.6	547	68.8	> 5% detects
Uranium-238 (pCi/L)	10/ 11	3/ 4		0.52	13600	1601	> 5% detects

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established by *Determination of Reference Concentrations for Inorganic Analytes in Groundwater at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (Energy Systems 1996). The background value for an analyte varies depending upon the groundwater cluster that a well has been assigned to so no single background value applies to each analyte. Refer to Sect. C.2 and the above referenced document for a discussion of the approach to evaluating groundwater background, the groundwater background values, and the well cluster assignments.

^c The mean of the medians is the arithmetic mean of the median concentration of an analyte for each well. In calculating the mean of the medians it was assumed that nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d High concentrations of calcium in solution may be harmful to the environment (see Appendix G for details).

^e No background value was available from the above referenced source. Values for lithium and titanium UTLs were calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995). The values are 0.071 mg/L for lithium and 0.12 mg/L for titanium. See text for further details. Niobium and thallium were not detected in 13 groundwater wells that were previously considered as reasonable background wells and the background UTL values was, therefore, assumed to be less than the detection limit and detected values are considered as above background.

Table D.31. Summary of chemical and radionuclide results from filtered samples,
S-3 Site groundwater aggregate

Analyte ^a	Freq of detect	Freq of wells w. detects	Min detect	Max detect	Mean of the medians ^b
Aluminum (mg/L)	119/ 186	25/ 25	0.02	1700.0	121.04
Antimony (mg/L)	1/ 175	1/ 21	0.5	0.5	0.04
Arsenic (mg/L)	3/ 31	2/ 10	0.01	0.047	0.007
Barium (mg/L)	228/ 228	26/ 26	0.0012	390.0	27.8636
Beryllium (mg/L)	28/ 182	14/ 25	0.0004	0.26	0.0196
Boron (mg/L)	195/ 207	25/ 25	0.0044	10.0	0.3012
Cadmium (mg/L)	83/ 274	10/ 25	0.0028	2.8	0.1740
Calcium (mg/L)	278/ 278	27/ 27	0.56	14000.0	1764.84
Chromium (mg/L)	18/ 278	9/ 25	0.011	0.32	0.016
Cobalt (mg/L)	32/ 188	11/ 26	0.0054	3.5	0.3508
Copper (mg/L)	91/ 189	22/ 22	0.0043	3.2	0.2407
Iron (mg/L)	149/ 186	25/ 25	0.0054	22.0	1.0539
Lead (mg/L)	54/ 291	19/ 27	0.004	1.3	0.008
Lithium (mg/L)	18/ 19	8/ 9	0.083	3.5	1.127
Magnesium (mg/L)	282/ 282	27/ 27	0.086	2600.0	277.186
Manganese (mg/L)	196/ 208	26/ 26	0.0011	220.0	34.5263
Mercury (mg/L)	35/ 290	12/ 27	0.0002	0.113	0.0063
Molybdenum (mg/L)	22/ 175	4/ 22	0.01	2.3	0.11
Nickel (mg/L)	49/ 188	23/ 26	0.011	22.0	2.689
Niobium (mg/L)	4/ 15	2/ 5	0.0079	0.027	0.0050
Potassium (mg/L)	250/ 273	27/ 27	0.64	220.0	32.92
Selenium (mg/L)	4/ 66	4/ 11	0.006	0.018	0.003
Silicon (mg/L)	107/ 110	25/ 25	0.18	34.0	8.34
Silver (mg/L)	. / 19	. / 7	.	.	0.0050
Sodium (mg/L)	282/ 282	27/ 27	1.2	3700.0	368.3
Strontium (mg/L)	177/ 177	24/ 24	0.0089	360.0	20.2067
Thallium (mg/L)	. / 20	. / 10	.	.	0.0050
Thorium (mg/L)	2/ 174	2/ 21	0.23	0.23	0.11
Tin (mg/L)	1/ 7	1/ 7	0.014	0.014	0.006
Titanium (mg/L)	12/ 19	7/ 9	0.011	0.33	0.093
Total uranium (fluorometric) (mg/L)	149/ 287	23/ 27	0.001	159.0	8.34
Vanadium (mg/L)	2/ 175	2/ 22	0.0089	2.1	0.0978
Zinc (mg/L)	180/ 201	25/ 25	0.001	8.6	0.58
Zirconium (mg/L)	7/ 15	3/ 5	0.0081	0.047	0.0168

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b The mean of the medians is the arithmetic mean of the median concentration of an analyte for each well. In calculating the mean of the medians it was assumed that nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

Table D.32. Summary of miscellaneous parameters for the S-3 groundwater aggregate

Parameter	Min	Max	Mean	n ^a
Alkalinity (CO ₃) (mg/L)	.	590	15	929
Alkalinity (HCO ₃) (mg/L)	.	927	203	929
Specific conductance (μmhos/cm)	33	230750	7137	3229
Dissolved oxygen (mg/L)	0.04	19.4	4.0	993
Total dissolved solids (mg/L)	.	86914	6251	828
pH	2.9	11.8	6.7	3422
Redox (eV)	-237	684	205	984
Total suspended solids (mg/L)	.	30312	146	945
Temperature (°C)	6.3	28.7	17.3	998
Total coliform	.	13	0	166
Total organic carbon (mg/L)	.	176	7	648
Total organic chloride (mg/L)	5	9779	242	776
Turbidity (NTU)	0.23	17200	101.9	737

^a n = frequency of analysis.

Table D.33. Summary of pH and alkalinity results for wells in the S-3 FA

Well	pH				Alkalinity (HCO ₃) (mg/L)				Alkalinity (CO ₃) (mg/L)			
	min	max	mean	n	min	max	mean	n	min	max	mean	n
GW-085	5.7	8.1	7.2	73	105	142	119	26	.	.	.	26
GW-086	5.5	6.9	6.2	18	91	142	107	9	.	.	.	9
GW-101	6.1	7.2	6.6	13	158	576	375	6	.	.	.	6
GW-103	3.3	4	3.7	3	.	.	.	1	.	.	.	1
GW-104	3.3	4.1	3.8	3	.	.	.	1	.	.	.	1
GW-123	6.2	11	9.9	85	273	927	586	21	185	534	315	21
GW-125	7.3	10.6	9.7	85	.	904	487	22	51	590	268	22
GW-127	5.6	7.8	6.6	50	261	410	325	10	.	2	1	10
GW-243	2.9	4.4	3.7	69	.	.	.	16	.	.	.	16
GW-244	5.2	6.3	5.7	49	212	317	246	8	.	.	.	8
GW-245	5.3	6.6	5.8	51	213	309	265	9	.	.	.	9
GW-246	3.8	5.5	4.3	51	11	31	22	9	.	.	.	9
GW-247	4	6.7	6.0	51	283	376	325	9	.	.	.	9
GW-276	3.3	5.4	3.8	74	.	.	.	16	.	.	.	16
GW-277	4.5	6.9	6.2	70	.	422	328	14	.	138	11	14
GW-324	6.3	8.8	7.5	66	84	109	98	20	.	2	1	20
GW-325	3.5	7.8	5.7	70	.	19	9	20	.	.	.	20
GW-345	4.6	6.4	5.7	55	17	382	103	17	.	.	.	17
GW-346	6.1	7.9	6.7	35	123	151	135	7	.	.	.	7
GW-526	5.9	8.7	7.5	65	42	74	57	22	.	2	1	22
GW-537	6.4	7.6	6.9	52	204	276	236	23	.	.	.	23
GW-613	3.4	7.4	6.7	31	79	95	89	14	.	.	.	14
GW-614	6.7	8.2	7.4	31	161	176	171	14	.	.	.	14
GW-615	5.8	6.9	6.2	20	157	224	194	10	.	5	1	10
GW-616	7.2	9.6	9.0	20	139	189	159	10	.	56	34	10
GW-649	6	7.5	6.7	14	80	105	95	7	.	.	.	7

Table D.34. Surface soil sampling depths and depth to refusal in BYBY boreholes

Soil boring (BY) or surface sample (SBY)	Depth (ft)
BY-1	18
BY-2	18
BY-3	18
BY-4	16
BY-5	18
BY-6	16
BY-7	22
BY-8	8
BY-9	16
SBY-13	1
SBY-17	1
SBY-20	0.5
SBY-21	0.5
SBY-22	1
SBY-27	0.3

Table D.35. Field screening data for BYBY

Analyte (units)	Results > detect limit ^a	Bkgd criteria	Detects > bkgd criteria	Min detect	Max detect	Avg result	Dist ^b	Site related?	Justification
<i>Media=Soil Location=BYBY Group=Surface (0 to 1 ft) Analysis Type=Metals</i>									
Aluminum (mg/kg)	17/ 17	46700	9/ 17	6730	65900	43142.94	N	Yes	> 5% detect above background
Barium (mg/kg)	17/ 17	212	10/ 17	47.7	317	217.21	N	Yes	> 5% detect above background
Beryllium (mg/kg)	16/ 17	2.12	0/ 17	0.6	1.9	1.18	N	No	Below background
Calcium (mg/kg)	17/ 17	1860	11/ 17	500	225000	37388.24	L	No	Essential element
Cerium (mg/kg)	16/ 17	.		30	80	42.35	X	Yes	No background data available
Chromium (mg/kg)	17/ 17	80.1	2/ 17	10	210	57.71	L	Yes	> 5% detect above background
Cobalt (mg/kg)	17/ 17	40.1	0/ 17	3	18	11.42	N	No	Below background
Copper (mg/kg)	16/ 17	35.5	5/ 17	8	127	35	L	Yes	> 5% detect above background
Gallium (mg/kg)	2/ 5	.		20	20	14	D	Yes	No background data available
Iron (mg/kg)	17/ 17	52000	0/ 17	4380	42200	24187.06	N	No	Essential element
Lead (mg/kg)	8/ 8	49.6	5/ 8	30	80	52.5	L	Yes	> 5% detect above background
Lithium (mg/kg)	16/ 17	33	4/ 17	20	50	28.82	L	Yes	> 5% detect above background
Magnesium (mg/kg)	17/ 17	6630	7/ 17	1400	20600	7547.06	L	No	Essential element
Manganese (mg/kg)	17/ 17	2220	1/ 17	100	2980	658.42	L	Yes	> 5% detect above background
Nickel (mg/kg)	16/ 17	56.7	1/ 17	10	125	31.03	L	Yes	> 5% detect above background
Niobium (mg/kg)	5/ 17	.		9	20	6.76	D	Yes	No background data available
Potassium (mg/kg)	17/ 17	5560	17/ 17	6900	30900	14929.41	L	No	Essential element

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Table D.35 (continued)

Analyte (units)	Results > detect limit ^a	Bkgd criteria	Detects > bkgd criteria	Min detect	Max detect	Avg result	Dist ^b	Site related?	Justification
Sodium (mg/kg)	17/ 17	.		330	2720	1006.47	L	No	Essential element
Strontium (mg/kg)	17/ 17	16.8	17/ 17	22.8	303	79.64	L	Yes	> 5% detect above background
Thorium (mg/kg)	3/ 17	.		9	11	5.53	D	Yes	No background data available
Titanium (mg/kg)	17/ 17	.		370	3110	2134.12	N	Yes	No background data available
Vanadium (mg/kg)	17/ 17	60.1	2/ 17	8	97	48.06	N	Yes	> 5% detect above background
Zinc (mg/kg)	17/ 17	108	7/ 17	11	207	88.94	L	Yes	> 5% detect above background
Zirconium (mg/kg)	17/ 17	.		5	153	90.71	N	Yes	No background data available
<i>Media=Soil Location=BYBY Group=Surface (0 to 1 ft) Analysis Type=Radionuclides</i>									
Uranium (pCi/g)	21/ 21	6.5	0/ 21	0.000018	0.026	0.00188	L	No	Below background
Uranium-235 (pCi/g)	21/ 21	0.24	0/ 21	7.0299E-6	0.00278	0.000355	L	No	Below background

^a Results less than the detection limit were set to 1/2 the reported detection limit (except for radioisotopes).

^b Dist. Codes: L = distribution most similar to lognormal
 N = distribution most similar to normal
 X = distribution significantly different from normal and lognormal
 D = distribution not determined because fewer than 50% detects

Table D.36. Summary of selection of site-related chemicals and radionuclides, BYBY, shallow soils

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	15/ 15	46700	0/ 15	8400	23100	14900	L	No	Below background
Antimony (mg/kg)	12/ 12	1	6/ 12	0.27	1650	139	X	Yes	>5% detect above background
Arsenic (mg/kg)	15/ 15	20.2	5/ 15	2.1	32.5	13.3	L	Yes	>5% detect above background
Barium (mg/kg)	15/ 15	212	8/ 15	54.5	1100	312	L	Yes	>5% detect above background
Beryllium (mg/kg)	14/ 15	2.12	2/ 15	0.6	3.3	1.14	L	Yes	>5% detect above background
Cadmium (mg/kg)	11/ 15	0.31	11/ 15	0.87	32.3	10.5	X	Yes	>5% detect above background
Calcium (mg/kg)	15/ 15	1860	15/ 15	5130	75300	31100	L	No	Essential element
Chromium (mg/kg)	15/ 15	80.4	5/ 15	20.7	140	65.7	N	Yes	>5% detect above background
Cobalt (mg/kg)	15/ 15	40.1	2/ 15	10.4	131	27.9	X	Yes	>5% detect above background
Copper (mg/kg)	15/ 15	35.5	12/ 15	18.2	6220	2030	X	Yes	>5% detect above background
Cyanide (mg/kg)	1/ 14	0.63	1/ 14	0.69	0.69	0.334	D	No	1 detect > bkgd; 0.69(site) vs 0.63
Iron (mg/kg)	15/ 15	52000	4/ 15	23000	10200	41600	L	No	Essential element
Lead (mg/kg)	15/ 15	49.6	11/ 15	16.2	1870	625	X	Yes	>5% detect above background
Magnesium (mg/kg)	15/ 15	6630	4/ 15	793	15000	6780	L	No	Essential element
Manganese (mg/kg)	15/ 15	2220	2/ 15	416	2680	1210	L	Yes	>5% detect above background
Mercury (mg/kg)	15/ 15	0.34	15/ 15	2.4	77.7	31.7	N	Yes	>5% detect above background
Molybdenum (mg/kg)	3/ 11	12.8	3/ 11	36	50.3	12.9	D	Yes	>5% detect above background
Nickel (mg/kg)	15/ 15	56.7	11/ 15	6.9	10600	849	L	Yes	>5% detect above background
Potassium (mg/kg)	15/ 15	5560	0/ 15	669	3250	2150	N	No	Essential element
Selenium (mg/kg)	4/ 13	1.2	2/ 13	0.76	132	10.9	D	Yes	>5% detect above background
Silver (mg/kg)	14/ 15	2.8	10/ 15	0.62	61.5	22	L	Yes	>5% detect above background

Table D.36 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Sodium (mg/kg)	14/ 15	.		34.9	960	241	L	No	Essential element
Thallium (mg/kg)	1/ 15	0.79	1/ 15	0.87	0.87	0.25	D	No	1 detect > bkgd; 0.87(site) vs 0.79
Tin (mg/kg)	10/ 14	.		3.3	102	34.3	N	Yes	No background data available
Vanadium (mg/kg)	15/ 15	60.1	0/ 15	17.4	57.9	32	L	No	Below background
Zinc (mg/kg)	15/ 15	108	12/ 15	46.8	4380	1210	L	Yes	>5% detect above background
<i>Organics</i>									
2378-TCDD (pCi/g)	2/ 3	.		0.91	7.72	3.3	L	Yes	No background available
PCB-1254 (µg/kg)	11/ 11	.		190	5800	1660	L	Yes	No background available
PCB-1260 (µg/kg)	3/ 10	.		360	1600	267	D	Yes	No background available
2,4-Dimethylphenol (µg/kg)	1/ 13	.		110	110	193	D	Yes	No background available
2-Methylnaphthalene (µg/kg)	10/ 14	.		53	2600	364	L	Yes	No background available
4-Methylphenol (µg/kg)	1/ 13	.		140	140	195	D	Yes	No background available
Acenaphthene (µg/kg)	13/ 14	.		110	6700	1030	L	Yes	No background available
Acenaphthylene (µg/kg)	8/ 12	.		53	490	175	L	Yes	No background available
Anthracene (µg/kg)	13/ 14	.		220	53000	5570	L	Yes	No background available
Benzo(a)anthracene (µg/kg)	14/ 14	.		92	120000	14400	L	Yes	No background available
Benzo(a)pyrene (µg/kg)	14/ 14	.		100	76000	9860	L	Yes	No background available
Benzo(b)fluoranthene (µg/kg)	14/ 14	.		120	86000	11800	L	Yes	No background available
Benzo(ghi)perylene (µg/kg)	14/ 14	.		58	30000	4480	L	Yes	No background available
Benzo(k)fluoranthene (µg/kg)	14/ 14	.		120	80000	10100	L	Yes	No background available
Bis(2-ethylhexyl)phthalate (µg/kg)	11/ 12	.		71	600	238	L	Yes	No background available
Butylbenzylphthalate (µg/kg)	2/ 10	.		43	87	173	D	Yes	No background available

Table D.36 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Carbazole (µg/kg)	13/ 14	.		120	25000	2840	L	Yes	No background available
Chrysene (µg/kg)	14/ 14	.		96	120000	14500	L	Yes	No background available
Di-n-butylphthalate (µg/kg)	1/ 12	.		2500	2500	411	D	Yes	No background available
Dibenzo(a,h)anthracene (µg/kg)	13/ 14	.		54	12000	2060	L	Yes	No background available
Dibenzofuran (µg/kg)	13/ 14	.		68	10000	1140	L	Yes	No background available
Diethylphthalate (µg/kg)	1/ 12	.		65	65	209	D	Yes	No background available
Fluoranthene (µg/kg)	14/ 14	.		230	270000	31800	L	Yes	No background available
Fluorene (µg/kg)	13/ 14	.		180	17000	2040	L	Yes	No background available
Indeno(1,2,3-cd)pyrene (µg/kg)	14/ 14	.		63	31000	4620	L	Yes	No background available
Naphthalene (µg/kg)	13/ 14	.		57	5000	552	X	Yes	No background available
Phenanthrene (µg/kg)	14/ 14	.		120	180000	20300	L	Yes	No background available
Phenol (µg/kg)	9/ 12	.		41	280	127	L	Yes	No background available
Pyrene (µg/kg)	14/ 14	.		200	210000	25500	L	Yes	No background available
Acetone (µg/kg)	7/ 15	.		23	110	33.2	D	Yes	No background available
Tetrachloroethene (µg/kg)	1/ 16	.		5	5	3.13	D	Yes	No background available
Toluene (µg/kg)	12/ 16	.		2	590	124	X	Yes	No background available
Radioactivity									
Gross Alpha (pCi/g)	17/ 17	.		8	710	198	L	NA	Total activity of all radionuclides
Gross Beta (pCi/g)	16/ 17	.		9.6	1600	279	L	NA	Total activity of all radionuclides
Strontium-90 (pCi/g)	3/ 14	1.1	1/ 14	0.58	1.9	0.322	D	Yes	> 5% detect above background
Technetium-99 (pCi/g)	6/ 14	4.07	6/ 14	10	77	21.9	D	Yes	> 5% detect above background
Thorium-228 (pCi/g)	12/ 16	2.88	0/ 16	0.23	2.4	0.544	L	No	Below background

Table D.36 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Thorium-230 (pCi/g)	16/ 16	2.3	1/ 16	0.13	7.1	1.01	X	Yes	>5% detect above background
Thorium-232 (pCi/g)	10/ 16	2.75	0/ 16	0.26	1.9	0.413	L	No	Below background
Uranium-234 (pCi/g)	17/ 17	3.2	16/ 17	1.4	260	95.2	L	Yes	>5% detect above background
Uranium-235 (pCi/g)	15/ 17	0.24	14/ 17	0.085	17	5.03	L	Yes	>5% detect above background
Uranium-238 (pCi/g)	17/ 17	2.6	16/ 17	1.8	880	149	L	Yes	>5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCV RI.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.37. Summary of selection of site-related chemicals and radionuclides, BYBY, deep soils

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	20/ 20	46700	0/ 20	7780	19000	14700	N	No	Below background
Antimony (mg/kg)	3/ 3	1	0/ 3	0.22	0.42	0.307	L	No	Below background
Arsenic (mg/kg)	20/ 20	20.2	0/ 20	1.1	16.3	4.98	L	No	Below background
Barium (mg/kg)	20/ 20	212	8/ 20	36.7	481	176	L	Yes	> 5% detect above background
Beryllium (mg/kg)	18/ 20	2.12	5/ 20	0.61	3.2	1.54	N	Yes	> 5% detect above background
Cadmium (mg/kg)	2/ 20	0.31	2/ 20	4	6	0.655	D	Yes	> 5% detect above background
Calcium (mg/kg)	20/ 20	1860	17/ 20	1370	51300	8110	L	No	Essential element
Chromium (mg/kg)	20/ 20	80.1	0/ 20	18.6	58.6	33.4	L	No	Below background
Cobalt (mg/kg)	20/ 20	40.1	0/ 20	5.1	34.9	19.3	N	No	Below background
Copper (mg/kg)	18/ 20	35.5	11/ 20	10.4	635	78.4	L	Yes	> 5% detect above background
Cyanide (mg/kg)	3/ 19	0.63	3/ 19	2.1	7.4	0.898	D	Yes	> 5% detect above background
Iron (mg/kg)	20/ 20	52000	3/ 20	17700	68400	35200	L	No	Essential element
Lead (mg/kg)	20/ 20	49.6	4/ 20	5.2	314	51.8	X	Yes	> 5% detect above background
Magnesium (mg/kg)	20/ 20	6630	1/ 20	1270	7730	3250	L	No	Essential element
Manganese (mg/kg)	20/ 20	2220	2/ 20	120	3120	750	L	Yes	> 5% detect above background
Mercury (mg/kg)	15/ 20	0.34	8/ 20	0.065	16.6	1.43	L	Yes	> 5% detect above background
Nickel (mg/kg)	20/ 20	56.7	4/ 20	8.3	179	44.3	L	Yes	> 5% detect above background
Potassium (mg/kg)	20/ 20	5560	0/ 20	1060	5070	2680	L	No	Essential element
Selenium (mg/kg)	6/ 20	1.2	3/ 20	0.71	1.9	0.595	D	Yes	> 5% detect above background
Silver (mg/kg)	17/ 20	2.8	8/ 20	1.2	18.3	3.99	X	Yes	> 5% detect above background
Sodium (mg/kg)	20/ 20	.		44.5	176	86	L	No	Essential element
Tin (mg/kg)	4/ 20	.		10.7	30	5.29	D	Yes	No background data available

Table D.37 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Vanadium (mg/kg)	20/ 20	60.1	0/ 20	18.1	35.3	24.5	X	No	Below background
Zinc (mg/kg)	20/ 20	108	4/ 20	18.4	843	123	X	Yes	> 5% detect above background
<i>Organics</i>									
2378-TCDD (pCi/g)	4/ 8	.	.	0.32	0.99	1.2	L	Yes	No background available
PCB-1254 (µg/kg)	4/ 19	.	.	12	2800	312	D	Yes	No background available
PCB-1260 (µg/kg)	1/ 19	.	.	2500	2500	152	D	Yes	No background available
Acenaphthene (µg/kg)	1/ 19	.	.	48	48	200	D	Yes	No background available
Anthracene (µg/kg)	2/ 19	.	.	40	120	196	D	Yes	No background available
Benzo(a)anthracene (µg/kg)	4/ 19	.	.	73	490	204	D	Yes	No background available
Benzo(a)pyrene (µg/kg)	4/ 19	.	.	49	550	204	D	Yes	No background available
Benzo(b)fluoranthene (µg/kg)	4/ 19	.	.	79	820	222	D	Yes	No background available
Benzo(ghi)perylene (µg/kg)	2/ 19	.	.	47	420	212	D	Yes	No background available
Benzo(k)fluoranthene (µg/kg)	4/ 19	.	.	67	580	209	D	Yes	No background available
Bis(2-ethylhexyl)phthalate (µg/kg)	11/ 19	.	.	51	880	220	L	Yes	No background available
Butylbenzylphthalate (µg/kg)	2/ 19	.	.	48	52	192	D	Yes	No background available
Carbazole (µg/kg)	1/ 19	.	.	79	79	202	D	Yes	No background available
Chrysene (µg/kg)	5/ 19	.	.	53	570	201	D	Yes	No background available
Di-n-butylphthalate (µg/kg)	1/ 19	.	.	610	610	233	D	Yes	No background available
Dibenzo(a,h)anthracene (µg/kg)	1/ 19	.	.	160	160	206	D	Yes	No background available
Dibenzofuran (µg/kg)	1/ 19	.	.	49	49	200	D	Yes	No background available
Fluoranthene (µg/kg)	6/ 19	.	.	74	730	224	D	Yes	No background available
Fluorene (µg/kg)	1/ 19	.	.	70	70	201	D	Yes	No background available
Indeno(1,2,3-cd)pyrene (µg/kg)	2/ 19	.	.	46	340	208	D	Yes	No background available

Table D.37 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Naphthalene (µg/kg)	1/ 19	.		67	67	201	D	Yes	No background available
Phenanthrene (µg/kg)	6/ 19	.		50	510	196	D	Yes	No background available
Phenol (µg/kg)	1/ 19	.		60	60	201	D	Yes	No background available
Pyrene (µg/kg)	6/ 19	.		60	810	218	D	Yes	No background available
1,1,2,2-Tetrachloroethane (µg/kg)	1/ 23	.		4	4	3.2	D	No	≤ 5% detects
1,1,2-Trichloroethane (µg/kg)	1/ 23	.		2	2	3.11	D	No	≤ 5% detects
1,2-Dichloroethane (µg/kg)	1/ 23	.		2	2	3.11	D	No	≤ 5% detects
1,2-Dichloroethene (µg/kg)	2/ 23	.		2	6	3.24	D	Yes	No background available
2-Butanone (µg/kg)	2/ 23	.		12	18	7.43	D	Yes	No background available
2-Hexanone (µg/kg)	1/ 23	.		14	14	6.63	D	No	≤ 5% detects
4-Methyl-2-pentanone (µg/kg)	1/ 23	.		13	13	6.24	D	No	≤ 5% detects
Acetone (µg/kg)	14/ 21	.		11	180	52.9	L	Yes	No background available
Bromoform (µg/kg)	1/ 23	.		4	4	3.2	D	No	≤ 5% detects
Carbon disulfide (µg/kg)	1/ 23	.		2	2	3.13	D	No	≤ 5% detects
Dibromochloromethane (µg/kg)	1/ 23	.		2	2	3.11	D	No	≤ 5% detects
Tetrachloroethene (µg/kg)	3/ 23	.		4	13	3.67	D	Yes	No background available
Toluene (µg/kg)	11/ 23	.		1	190	12	D	Yes	No background available
Trichloroethene (µg/kg)	2/ 23	.		2	6	3.22	D	Yes	No background available
Radioactivity									
Gross Alpha (pCi/g)	15/ 20	.		1.8	150	16.8	L	NA	Total activity of all radionuclides
Gross Beta (pCi/g)	10/ 20	.		9.3	73	15.8	L	NA	Total activity of all radionuclides
Lead-212 (pCi/g)	1/ 20	.		1.9	1.9	2.11	D	No	≤ 5% detects
Technetium-99 (pCi/g)	2/ 12	4.07	2/ 12	9.3	12	2.69	D	Yes	> 5% detect above background

Table D.37 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Thorium-228 (pCi/g)	19/ 20	2.88	0/ 20	0.31	1.9	0.719	L	No	Below background
Thorium-230 (pCi/g)	18/ 20	2.3	0/ 20	0.17	0.89	0.452	L	No	Below background
Thorium-232 (pCi/g)	20/ 20	2.75	1/ 20	0.19	44	2.68	X	No	Below background
Uranium-234 (pCi/g)	17/ 20	3.2	7/ 20	0.11	100	9.78	L	Yes	>5% detect above background
Uranium-235 (pCi/g)	11/ 20	0.24	8/ 20	0.048	3.1	0.443	L	Yes	>5% detect above background
Uranium-238 (pCi/g)	19/ 20	2.6	8/ 20	0.077	44	6.47	L	Yes	>5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCVR.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.38. SVOCs belonging to the PAH and phthalate groups

Polyaromatic hydrocarbons (PAHs)		Phthalates
2-methylnaphthalene	chrysene	butylbenzylphthalate
acenaphthene	dibenzo(a,h)anthracene	di-n-butylphthalate
acenaphthylene	fluoranthene	di-n-octylphthalate
anthracene	fluorene	diethylphthalate
benzo(a)anthracene	indeno(1,2,3-cd)pyrene	dimethylphthalate
benzo(a)pyrene	naphthalene	bis(2-ethylhexyl)phthalate
benzo(b)fluoranthene	phenanthrene	
benzo(g,h,i)perylene	pyrene	
benzo(k)fluoranthene		

Table D.39. Depth to refusal in OLF boreholes

Soil boring	Depth (ft)
OLF-1	16.0
OLF-2	22.0
OLF-3	28.0
OLF-4	12.0
OLF-5	12.0

Table D.40. Field screening data for OLF

Analyte (units)	Results > detect limit ^a	Bkgd criteria	Detects > bkgd criteria	Min detect	Max detect	Avg result	Dist ^b	Site related?	Justification
<i>Media=Soil Location=BYBY Group=Surface 8 ft Analysis Type=Metals</i>									
Aluminum (mg/kg)	5/5	46700	2/5	39600	63300	47780	L	Yes	> 5% detect above background
Barium (mg/kg)	5/5	212	0/5	81.8	183	139.16	N	No	Below background
Beryllium (mg/kg)	5/5	2.12	1/5	1.1	2.5	1.54	L	Yes	> 5% detect above background
Calcium (mg/kg)	5/5	1860	2/5	1400	19400	8120	X	No	Essential element
Cerium (mg/kg)	5/5	.		30	200	74	L	Yes	No background data available
Chromium (mg/kg)	5/5	80.1	0/5	39	51	43.8	L	No	Below background
Cobalt (mg/kg)	5/5	40.1	1/5	9	406	92.4	X	Yes	> 5% detect above background
Copper (mg/kg)	5/5	35.5	1/5	13	148	45	X	Yes	> 5% detect above background
Iron (mg/kg)	5/5	52000	0/5	21100	31800	25720	L	No	Essential element
Lead (mg/kg)	4/4	49.6	0/4	20	40	30	X	No	Below background
Lithium (mg/kg)	5/5	33	3/5	20	120	58	L	Yes	> 5% detect above background
Magnesium (mg/kg)	5/5	6630	2/5	2690	7400	4952	L	No	Essential element
Manganese (mg/kg)	5/5	2220	1/5	283	4900	1307	X	Yes	> 5% detect above background
Nickel (mg/kg)	5/5	56.7	1/5	16	123	42.2	L	Yes	> 5% detect above background
Niobium (mg/kg)	1/5	.		7	7	5.1	D	Yes	No background data available
Potassium (mg/kg)	5/5	5560	5/5	5900	13400	10400	N	No	Essential element
Sodium (mg/kg)	5/5	.		200	1090	682	N	No	Essential element
Strontium (mg/kg)	5/5	16.8	4/5	12.8	36.7	26.76	N	Yes	> 5% detect above background

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Table D.40 (continued)

Analyte (units)	Results > detect limit ^a	Bkgd criteria	Detects > bkgd criteria	Min detect	Max detect	Avg result	Dist ^b	Site related?	Justification
Titanium (mg/kg)	5/5	.		1480	2280	1926	N	Yes	No background data available
Vanadium (mg/kg)	5/5	60.1	1/5	39	75	57.6	N	Yes	> 5% detect above background
Zinc (mg/kg)	5/5	108	4/5	48	322	149.6	L	Yes	> 5% detect above background
Zirconium (mg/kg)	5/5	.		58	98	77.6	N	Yes	No background data available
<i>Media=Soil Location=BYBY Group=Surface 8 ft Analysis Type=Radionuclides</i>									
Uranium (pCi/g)	6/6	6.5	0/6	0.00012	0.00104	0.000366	L	No	Below background
Uranium-235 (pCi/g)	6/6	0.24	0/6	0.00005	0.00038	0.000126	L	No	Below background

^a Results less than the detection limit were set to 1/2 the reported detection limit (except for radioisotopes).

^b Dist. Codes: L = distribution most similar to lognormal
 N = distribution most similar to normal
 X = distribution significantly different from normal and lognormal
 D = distribution not determined because fewer than 50% detects

Table D.41. Summary of selection of site-related chemicals and radionuclides, OLF, shallow soils

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	8/ 8	46700	0/ 8	10700	19000	14400	N	No	Below background
Antimony (mg/kg)	1/ 1	1	0/ 1	0.34	0.34	0.34	X	No	Below background
Arsenic (mg/kg)	8/ 8	20.2	1/ 8	1.1	31.8	6.08	X	Yes	>5% detect above background
Barium (mg/kg)	8/ 8	212	1/ 8	31.2	228	112	L	No	1 detect > bkgd; 228 (site) v. 212
Beryllium (mg/kg)	3/ 8	2.12	0/ 8	0.72	1.3	0.651	D	No	Below background
Calcium (mg/kg)	6/ 8	1860	5/ 8	672	13100	4350	L	No	Essential element
Chromium (mg/kg)	8/ 8	80.1	0/ 8	22	32.3	28.4	X	No	Below background
Cobalt (mg/kg)	8/ 8	40.1	0/ 8	5	33.5	18.5	N	No	Below background
Copper (mg/kg)	8/ 8	35.5	2/ 8	7.1	120	31.2	L	Yes	>5% detect above background
Iron (mg/kg)	8/ 8	52000	0/ 8	10900	35900	24300	N	No	Essential element
Lead (mg/kg)	8/ 8	49.6	1/ 8	5.9	74.2	20.5	L	Yes	>5% detect above background
Magnesium (mg/kg)	8/ 8	6630	0/ 8	1480	5840	3170	L	No	Essential element
Manganese (mg/kg)	8/ 8	2220	0/ 8	45.3	1470	478	L	No	Below background
Mercury (mg/kg)	3/ 8	0.34	1/ 8	0.13	2.2	0.338	D	Yes	>5% detect above background
Molybdenum (mg/kg)	2/ 8	12.8	0/ 8	1.3	4.4	1.19	D	No	Below background
Nickel (mg/kg)	8/ 8	56.7	0/ 8	12	40.7	27	N	No	Below background
Potassium (mg/kg)	8/ 8	5560	0/ 8	1050	2630	1920	N	No	Essential element
Silver (mg/kg)	7/ 8	2.8	3/ 8	0.57	4.3	2.12	N	Yes	>5% detect above background
Sodium (mg/kg)	5/ 8	.		22.2	74.7	44	N	No	Essential element
Vanadium (mg/kg)	8/ 8	60.1	0/ 8	14.4	46	25.5	L	No	Below background
Zinc (mg/kg)	8/ 8	108	2/ 8	26.5	162	72	L	Yes	>5% detect above background
<i>Organics</i>									
PCB-1260 (µg/kg)	3/ 8			36	220	55.6	D	Yes	No background available

Table D.41 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Acetone (µg/kg)	7/ 8	.	.	7	590	136	L	Yes	No background available
Methylene chloride (µg/kg)	2/ 8	.	.	3	4	3.19	D	Yes	No background available
Toluene (µg/kg)	7/ 8	.	.	1	24	8.13	L	Yes	No background available
Cobalt-60 (pCi/g)	4/ 8	0.014	4/ 8	0.7	1.7	1.09	N	Yes	> 5% detect above background
Gross Alpha (pCi/g)	7/ 8	.	.	1.8	30	6.98	L	No	Total activity of all radionuclides
Gross Beta (pCi/g)	4/ 8	.	.	7.6	17	8.65	N	No	Total activity of all radionuclides
Lead-212 (pCi/g)	1/ 8	.	.	6.2	6.2	1.19	D	Yes	No background data available
Potassium-40 (pCi/g)	2/ 8	28	0/ 8	18	20	15.9	D	No	Below background
<i>Radioactivity</i>									
Thallium-208 (pCi/g)	1/ 8	.	.	4.6	4.6	3.21	D	Yes	No background data available
Thorium-228 (pCi/g)	7/ 8	2.88	0/ 8	0.41	1.1	0.66	L	No	Below background
Thorium-230 (pCi/g)	6/ 8	2.3	0/ 8	0.24	0.76	0.355	L	No	Below background
Thorium-232 (pCi/g)	5/ 8	2.75	0/ 8	0.29	0.72	0.378	N	No	Below background
Uranium-234 (pCi/g)	8/ 8	3.2	1/ 8	0.067	10	1.4	X	Yes	> 5% detect above background
Uranium-235 (pCi/g)	2/ 8	0.24	1/ 8	0.021	0.36	0.0511	D	Yes	> 5% detect above background
Uranium-238 (pCi/g)	8/ 8	2.6	1/ 8	0.066	5.9	0.853	X	Yes	> 5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment." Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCVR RI.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.42. Summary of selection of site-related chemicals and radionuclides, OLF, deep soils

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	13/ 13	46700	0/ 13	7680	20100	15300	N	No	Below background
Arsenic (mg/kg)	13/ 13	20.2	0/ 13	0.61	7.1	2.44	L	No	Below background
Barium (mg/kg)	13/ 13	212	7/ 13	68.6	883	247	L	Yes	> 5% detect above background
Beryllium (mg/kg)	6/ 13	2.12	0/ 13	0.87	1.4	0.916	D	No	Below background
Calcium (mg/kg)	13/ 13	1860	8/ 13	52.9	12000	3920	L	No	Essential element
Chromium (mg/kg)	13/ 13	80.1	0/ 13	19.9	49.8	35.2	N	No	Below background
Cobalt (mg/kg)	13/ 13	40.1	0/ 13	8.7	29	19.3	N	No	Below background
Copper (mg/kg)	11/ 12	35.5	2/ 12	10.4	41.6	21.9	N	Yes	> 5% detect above background
Iron (mg/kg)	13/ 13	52000	0/ 13	15700	47100	27400	L	No	Essential element
Lead (mg/kg)	13/ 13	49.6	0/ 13	4.6	19	7.85	X	No	Below background
Magnesium (mg/kg)	13/ 13	6630	2/ 13	1850	10200	5100	L	No	Essential element
Manganese (mg/kg)	13/ 13	2220	1/ 13	107	2410	848	L	No	1 detect > bkgd; 2410 (site) v. 2220
Nickel (mg/kg)	13/ 13	56.7	3/ 13	19.6	68	48.2	N	Yes	> 5% detect above background
Potassium (mg/kg)	13/ 13	5560	0/ 13	1920	4150	3270	X	No	Essential element
Silver (mg/kg)	13/ 13	2.8	2/ 13	1.4	4.2	2.21	L	Yes	> 5% detect above background
Sodium (mg/kg)	8/ 13	.		66.3	122	61.8	N	No	Essential element
Vanadium (mg/kg)	13/ 13	60.1	0/ 13	12.8	36.3	20.6	X	No	Below background
Zinc (mg/kg)	13/ 13	108	0/ 13	27.8	77.8	56.5	N	No	Below background
<i>Organics</i>									
PCB-1254 (µg/kg)	1/ 13			12	12	18.6	D	Yes	No background available
PCB-1260 (µg/kg)	1/ 13			69	69	23	D	Yes	No background available
2-Butanone (µg/kg)	1/ 13			19	19	6.96	D	Yes	No background available
Acetone (µg/kg)	13/ 13			10	200	63.3	L	Yes	No background available

Table D.42 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Carbon disulfide (μg/kg)	1/ 13	.	.	6	6	3.35	D	Yes	No background available
Methylene chloride (μg/kg)	3/ 13	.	.	3	5	3.65	D	Yes	No background available
Toluene (μg/kg)	4/ 12	.	.	2	24	5.71	D	Yes	No background available
Radioactivity									
Cesium-137 (pCi/g)	1/ 13	1.4	0/ 13	1.1	1.1	0.588	D	No	Below background
Cobalt-60 (pCi/g)	1/ 13	0.014	1/ 13	0.67	0.67	1.16	D	Yes	>5% detect above background
Gross Alpha (pCi/g)	12/ 13	.	.	2.4	6.4	4.01	N	No	Total activity of all radionuclides
Gross Beta (pCi/g)	7/ 13	.	.	8.2	19	8.63	L	No	Total activity of all radionuclides
Lead-212 (pCi/g)	2/ 13	.	.	1.6	1.7	1.18	D	Yes	No background data available
Potassium-40 (pCi/g)	4/ 13	28	0/ 13	11	16	21.1	D	No	Below background
Thallium-208 (pCi/g)	3/ 13	.	.	1.7	7.5	3	D	Yes	No background data available
Thorium-228 (pCi/g)	12/ 12	2.88	0/ 12	0.39	1.1	0.695	L	No	Below background
Thorium-230 (pCi/g)	8/ 12	2.3	0/ 12	0.14	0.74	0.316	L	No	Below background
Thorium-232 (pCi/g)	12/ 12	2.75	0/ 12	0.32	0.74	0.518	L	No	Below background
Uranium-234 (pCi/g)	13/ 13	3.2	0/ 13	0.062	0.2	0.121	L	No	Below background
Uranium-235 (pCi/g)	2/ 13	0.24	0/ 13	0.014	0.018	0.0066	D	No	Below background
Uranium-238 (pCi/g)	13/ 13	2.6	0/ 13	0.05	0.15	0.0935	L	No	Below background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCV RI.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.43. Field screening data for SL 1

Analyte (units)	Results > detect limit ^a	Bkgd criteria	Detects > bkgd criteria	Min detect	Max detect	Avg result	Dist ^b	Site related?	Justification
<i>Media=Soil Location=BYBY Group=Surface 8 ft Analysis Type=Metals</i>									
Aluminum (mg/kg)	14/ 14	46700	9/ 14	18800	77500	55900	N	Yes	> 5% detect above background
Barium (mg/kg)	14/ 14	212	10/ 14	85.8	353	238.27	N	Yes	> 5% detect above background
Beryllium (mg/kg)	14/ 14	2.12	0/ 14	0.6	2	1.39	N	No	Below background
Calcium (mg/kg)	14/ 14	1860	7/ 14	900	20900	5097.86	L	No	Essential element
Cerium (mg/kg)	14/ 14	.		40	70	55	X	Yes	No background data available
Chromium (mg/kg)	14/ 14	80.1	0/ 14	27	76	56.5	N	No	Below background
Cobalt (mg/kg)	14/ 14	40.1	0/ 14	5	20	14.36	N	No	Below background
Copper (mg/kg)	14/ 14	35.5	4/ 14	9	174	39.07	L	Yes	> 5% detect above background
Iron (mg/kg)	14/ 14	52000	0/ 14	14300	47600	32335.71	N	No	Essential element
Lead (mg/kg)	12/ 12	49.6	2/ 12	20	100	35.83	X	Yes	> 5% detect above background
Lithium (mg/kg)	14/ 14	33	5/ 14	20	50	33.57	X	Yes	> 5% detect above background
Magnesium (mg/kg)	14/ 14	6630	3/ 14	820	7340	4427.14	N	No	Essential element
Manganese (mg/kg)	14/ 14	2220	0/ 14	118	1420	698.29	N	No	Below background
Nickel (mg/kg)	14/ 14	56.7	0/ 14	9	49	28.86	N	No	Below background
Niobium (mg/kg)	2/ 14	.		9	10	5.43	D	Yes	No background data available
Potassium (mg/kg)	14/ 14	5560	12/ 14	2700	43400	21042.86	N	No	Essential element
Sodium (mg/kg)	14/ 14	.		350	1210	640.71	L	No	Essential element
Strontium (mg/kg)	14/ 14	16.8	12/ 14	11.9	61.6	38.69	N	Yes	> 5% detect above background

Table D.43 (continued)

Analyte (units)	Results > detect limit ^a	Bkgd criteria	Detects > bkgd criteria	Min detect	Max detect	Avg result	Dist ^b	Site related?	Justification
Thorium (mg/kg)	8/ 14	.		9	12	7.82	X	Yes	No background data available
Titanium (mg/kg)	14/ 14	.		1510	2800	2357.14	X	Yes	No background data available
Vanadium (mg/kg)	14/ 14	60.1	4/ 14	30	90	56.36	N	Yes	> 5% detect above background
Zinc (mg/kg)	14/ 14	108	3/ 14	39	279	80.86	X	Yes	> 5% detect above background
Zirconium (mg/kg)	14/ 14	.		65	168	100.5	L	Yes	No background data available
<i>Media=Soil Location=BYBY Group=Surface 8 ft Analysis Type=Radionuclides</i>									
Uranium (pCi/g)	18/ 18	6.5	0/ 18	0.0001	0.004	0.00079	X	No	Below background
Uranium-235 (pCi/g)	18/ 18	0.24	0/ 18	0.00003	0.0011	0.00025	X	No	Below background

^a Results less than the detection limit were set to 1/2 the reported detection limit (except for radioisotopes).

^b Dist. Codes: L = distribution most similar to lognormal
 N = distribution most similar to normal
 X = distribution significantly different from normal and lognormal
 D = distribution not determined because fewer than 50% detects

Table D.44. Summary of selection of site-related chemicals and radionuclides, SL 1, shallow soils

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	5/ 5	46700	0/ 5	11600	17100	14300	N	No	Below background
Arsenic (mg/kg)	5/ 5	20.2	0/ 5	6.3	18.8	11.4	L	No	Below background
Barium (mg/kg)	5/ 5	212	1/ 5	69.3	380	179	L	Yes	> 5% detect above background
Beryllium (mg/kg)	5/ 5	2.12	0/ 5	0.84	1.3	1.07	N	No	Below background
Cadmium (mg/kg)	1/ 5	0.31	1/ 5	3.2	3.2	0.779	D	No	Detection limit differences; within USGS background
Calcium (mg/kg)	5/ 5	1860	2/ 5	1440	7880	3480	N	No	Essential element
Chromium (mg/kg)	5/ 5	80.1	0/ 5	22	49.3	33.6	L	No	Below background
Cobalt (mg/kg)	5/ 5	40.1	0/ 5	14.2	28.3	22	L	No	Below background
Copper (mg/kg)	4/ 4	35.5	3/ 4	23.7	252	90.6	L	Yes	> 5% detect above background
Iron (mg/kg)	5/ 5	52000	0/ 5	23000	49400	38300	N	No	Essential element
Lead (mg/kg)	5/ 5	49.6	2/ 5	13	201	64.9	L	Yes	> 5% detect above background
Magnesium (mg/kg)	5/ 5	6630	0/ 5	983	3790	1930	L	No	Essential element
Manganese (mg/kg)	5/ 5	2220	0/ 5	620	1690	971	L	No	Below background
Mercury (mg/kg)	5/ 5	0.34	4/ 5	0.09	41.5	9.85	L	Yes	> 5% detect above background
Nickel (mg/kg)	5/ 5	56.7	1/ 5	17.2	61.8	37.2	L	No	1 detect > bkgd; 61.8 (site) v. 56.7
Potassium (mg/kg)	5/ 5	5560	0/ 5	1310	2340	1710	L	No	Essential element
Silver (mg/kg)	3/ 5	2.8	3/ 5	4	7.6	3.83	L	Yes	> 5% detect above background; > USGS bkgd
Sodium (mg/kg)	5/ 5	.		14.9	111	76.2	N	No	Essential element
Thallium (mg/kg)	1/ 5	0.79	0/ 5	0.48	0.48	0.277	D	No	Below background
Tin (mg/kg)	3/ 5	.		2.6	4.8	3.89	N	No	Within USGS bkgd
Vanadium (mg/kg)	5/ 5	60.1	0/ 5	24.9	39	33.1	N	No	Below background

Table D.44 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Zinc (mg/kg)	5/ 5	108	1/ 5	36.2	470	150	L	Yes	>5% detect above background
Organics									
PCB-1232 (µg/kg)	1/ 5	.	.	1300	1300	277	D	Yes	No background available
PCB-1254 (µg/kg)	2/ 5	.	.	750	1700	502	D	Yes	No background available
PCB-1260 (µg/kg)	1/ 4	.	.	98	98	40.6	D	Yes	No background available
Acenaphthene (µg/kg)	1/ 5	.	.	320	320	237	D	Yes	No background available
Acenaphthylene (µg/kg)	1/ 5	.	.	49	49	183	D	Yes	No background available
Anthracene (µg/kg)	3/ 5	.	.	49	1100	331	L	Yes	No background available
Benzo(a)anthracene (µg/kg)	3/ 5	.	.	130	5700	1300	X	Yes	No background available
Benzo(a)pyrene (µg/kg)	3/ 5	.	.	110	4200	985	X	Yes	No background available
Benzo(b)fluoranthene (µg/kg)	3/ 5	.	.	110	5800	1310	X	Yes	No background available
Benzo(g,h,i)perylene (µg/kg)	3/ 5	.	.	54	1700	449	L	Yes	No background available
Benzo(k)fluoranthene (µg/kg)	3/ 5	.	.	140	3900	929	X	Yes	No background available
Bis(2-ethylhexyl)phthalate (µg/kg)	3/ 5	.	.	51	3200	742	L	Yes	No background available
Carbazole (µg/kg)	2/ 5	.	.	71	310	198	D	Yes	No background available
Chrysene (µg/kg)	4/ 5	.	.	44	5300	1190	L	Yes	No background available
Di-n-butylphthalate (µg/kg)	2/ 5	.	.	100	110	182	D	Yes	No background available
Dibenzo(a,h)anthracene (µg/kg)	1/ 5	.	.	1000	1000	373	D	Yes	No background available
Dibenzofuran (µg/kg)	1/ 5	.	.	130	130	199	D	Yes	No background available
Fluoranthene (µg/kg)	4/ 5	.	.	100	11000	2410	L	Yes	No background available
Fluorene (µg/kg)	2/ 5	.	.	83	410	221	D	Yes	No background available
Indeno(1,2,3-cd)pyrene (µg/kg)	3/ 5	.	.	67	1500	412	L	Yes	No background available

Table D.44 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Phenanthrene (µg/kg)	4/ 5	.		52	4900	1160	L	Yes	No background available
Phenol (µg/kg)	1/ 5	.		50	50	183	D	Yes	No background available
Pyrene (µg/kg)	4/ 5	.		77	9000	2000	L	Yes	No background available
Acetone (µg/kg)	4/ 5	.		18	230	67	L	Yes	No background available
Chloroform (µg/kg)	1/ 5	.		1	1	2.8	D	Yes	No background available
Toluene (µg/kg)	3/ 5	.		1	110	27.8	L	Yes	No background available
Radioactivity									
Cobalt-60 (pCi/g)	1/ 5	0.014	1/ 5	1.3	1.3	1.08	D	Yes	>5% detect above background
Gross Alpha (pCi/g)	4/ 5	.		6.7	35	13	L	NA	Total activity of all radionuclides
Gross Beta (pCi/g)	3/ 5	.		12	51	19.3	L	NA	Total activity of all radionuclides
Thorium-228 (pCi/g)	5/ 5	2.88	0/ 5	0.23	0.68	0.474	L	No	Below background
Thorium-230 (pCi/g)	4/ 5	2.3	0/ 5	0.19	0.82	0.356	L	No	Below background
Thorium-232 (pCi/g)	4/ 5	2.75	0/ 5	0.14	0.52	0.342	N	No	Below background
Uranium-234 (pCi/g)	5/ 5	3.2	1/ 5	1.1	14	4.38	L	Yes	>5% detect above background
Uranium-235 (pCi/g)	4/ 5	0.24	1/ 5	0.053	0.7	0.225	L	Yes	>5% detect above background
Uranium-238 (pCi/g)	5/ 5	2.6	4/ 5	1.1	22	7.34	L	Yes	>5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCVR RI.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.45. Summary of selection of site-related chemicals and radionuclides, SL 1, deep soils

Analyte ^a	Freq of detect	Bkgd ^b criteria	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	6/ 6	46700	0/ 6	7560	14300	11700	N	No	Below background
Antimony (mg/kg)	2/ 2	1	0/ 2	0.33	0.72	0.525	N	No	Below background
Arsenic (mg/kg)	6/ 6	20.2	0/ 6	2.7	14.5	8.27	N	No	Below background
Barium (mg/kg)	6/ 6	212	4/ 6	49	486	247	N	Yes	>5% detect above background
Beryllium (mg/kg)	6/ 6	2.12	1/ 6	0.62	2.2	1.24	L	No	1 detect > bkgd; 2.2 (site) vs. 2.12
Calcium (mg/kg)	6/ 6	1860	4/ 6	267	103000	19100	L	No	Essential element
Chromium (mg/kg)	6/ 6	80.1	0/ 6	19.3	74.6	33.9	L	No	Below background
Cobalt (mg/kg)	6/ 6	40.1	0/ 6	16.5	31.9	23.5	L	No	Below background
Copper (mg/kg)	6/ 6	35.5	2/ 6	14.7	56.7	31.2	L	Yes	>5% detect above background
Iron (mg/kg)	6/ 6	52000	0/ 6	14500	40500	28800	N	No	Essential element
Lead (mg/kg)	6/ 6	49.6	1/ 6	5.9	65.4	29.9	N	Yes	>5% detect above background
Magnesium (mg/kg)	6/ 6	6630	0/ 6	683	4090	1900	L	No	Essential element
Manganese (mg/kg)	6/ 6	2220	3/ 6	376	3150	1740	N	Yes	>5% detect above background
Mercury (mg/kg)	3/ 6	0.34	2/ 6	0.12	2	0.513	L	Yes	>5% detect above background
Nickel (mg/kg)	6/ 6	56.7	3/ 6	34.3	231	82.3	L	Yes	>5% detect above background
Potassium (mg/kg)	6/ 6	5560	0/ 6	1150	3750	2120	L	No	Essential element
Silver (mg/kg)	1/ 6	2.8	1/ 6	4.1	4.1	1.77	D	No	Detection limit difference; within USGS background ^e
Sodium (mg/kg)	3/ 6	.		90.5	283	92.6	L	No	Essential element
Tin (mg/kg)	2/ 6	.		3.3	3.8	2	D	No	No site bkgd; within USGS bkgd

Table D.45 (continued)

Analyte ^a	Freq of detect	Bkgd ^b criteria	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Vanadium (mg/kg)	6/ 6	60.1	0/ 6	11	34.4	26.5	N	No	Below background
Zinc (mg/kg)	6/ 6	108	1/ 6	22.9	128	69.4	L	Yes	> 5% detect above background
<i>Organics</i>									
4,4'-DDE (µg/kg)	1/ 5	.	.	13	13	4.25	D	Yes	No background available
Aldrin (µg/kg)	1/ 5	.	.	19	19	4.63	D	Yes	No background available
Endosulfan II (µg/kg)	2/ 5	.	.	8.3	27	8.29	D	Yes	No background available
Endosulfan sulfate (µg/kg)	1/ 5	.	.	5.5	5.5	2.75	D	Yes	No background available
PCB-1254 (µg/kg)	1/ 5	.	.	3000	3000	617	D	Yes	No background available
PCB-1260 (µg/kg)	3/ 5	.	.	74	660	191	L	Yes	No background available
2,4-Dimethylphenol	1/ 6	.	.	730	730	294	D	Yes	No background available
4-Methylphenol (µg/kg)	1/ 6	.	.	2400	2400	573	D	Yes	No background available
Acenaphthene (µg/kg)	1/ 6	.	.	85	85	187	D	Yes	No background available
Anthracene (µg/kg)	1/ 6	.	.	210	210	208	D	Yes	No background available
Benzo(a)anthracene	3/ 6	.	.	45	410	194	L	Yes	No background available
Benzo(a)pyrene (µg/kg)	2/ 6	.	.	70	320	202	D	Yes	No background available
Benzo(b)fluoranthene	3/ 6	.	.	44	340	180	N	Yes	No background available
Benzo(ghi)perylene	1/ 6	.	.	140	140	196	D	Yes	No background available
Benzo(k)fluoranthene	2/ 6	.	.	76	300	199	D	Yes	No background available
Bis(2-ethylhexyl)phthalate	5/ 6	.	.	84	2200	517	L	Yes	No background available
Carbazole (µg/kg)	2/ 6	.	.	49	180	175	D	Yes	No background available

Table D.45 (continued)

Analyte ^a	Freq of detect	Bkgd ^b criteria	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Chrysene (µg/kg)	3/ 6	.		45	410	194	L	Yes	No background available
Di-n-butylphthalate	2/ 6	.		49	100	165	D	Yes	No background available
Di-n-octylphthalate	1/ 6	.		220	220	209	D	Yes	No background available
Dibenzo(a,h)anthracene	1/ 6	.		70	70	184	D	Yes	No background available
Dibenzofuran (µg/kg)	1/ 6	.		51	51	181	D	Yes	No background available
Diethylphthalate (µg/kg)	1/ 6	.		61	61	183	D	Yes	No background available
Fluoranthene (µg/kg)	3/ 6	.		120	940	325	L	Yes	No background available
Fluorene (µg/kg)	1/ 6	.		110	110	191	D	Yes	No background available
Indeno(1,2,3-cd)pyrene	1/ 6	.		140	140	196	D	Yes	No background available
Phenanthrene (µg/kg)	3/ 6	.		80	810	283	L	Yes	No background available
Phenol (µg/kg)	1/ 6	.		230	230	211	D	Yes	No background available
Pyrene (µg/kg)	3/ 6	.		90	900	302	L	Yes	No background available
2-Butanone (µg/kg)	2/ 6	.		93	1000	186	D	Yes	No background available
2-Hexanone (µg/kg)	3/ 6	.		3	140	29	X	Yes	No background available
4-Methyl-2-pentanone	1/ 6	.		15	15	7.75	D	Yes	No background available
Acetone (µg/kg)	6/ 6	.		59	1100	378	L	Yes	No background available
Carbon disulfide (µg/kg)	2/ 6	.		2	12	4.33	D	Yes	No background available
Chlorobenzene (µg/kg)	1/ 6	.		2	2	2.83	D	Yes	No background available
Dimethylbenzene (µg/kg)	1/ 6	.		27	27	7	D	Yes	No background available
Ethylbenzene (µg/kg)	1/ 6	.		3	3	3	D	Yes	No background available
Toluene (µg/kg)	2/ 6	.		1	2	2.5	D	Yes	No background available

Table D.45 (continued)

Analyte ^a	Freq of detect	Bkgd ^b criteria	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Radioactivity</i>									
Cesium-134 (pCi/g)	1/ 7	.		1.2	1.2	0.179	D	Yes	No background data available
Gross Alpha (pCi/g)	5/ 7	.		4.1	9.3	6.03	L	NA	Total activity of all radionuclides
Gross Beta (pCi/g)	2/ 7	.		10	18	9.31	D	NA	Total activity of all radionuclides
Potassium-40 (pCi/g)	1/ 7	28	0/ 7	9.3	9.3	2.82	D	No	Below background
Thallium-208 (pCi/g)	1/ 7	.		2.9	2.9	1.22	D	Yes	No background data available
Thorium-228 (pCi/g)	7/ 7	2.88	0/ 7	0.52	1.7	0.837	L	No	Below background
Thorium-230 (pCi/g)	6/ 7	2.3	0/ 7	0.34	0.61	0.42	N	No	Below background
Thorium-232 (pCi/g)	6/ 7	2.75	0/ 7	0.25	0.84	0.526	N	No	Below background
Uranium-234 (pCi/g)	7/ 7	3.2	2/ 7	0.19	5.2	2.02	L	Yes	> 5% detect above background
Uranium-235 (pCi/g)	4/ 7	0.24	0/ 7	0.045	0.2	0.0817	L	No	Below background
Uranium-238 (pCi/g)	7/ 7	2.6	1/ 7	0.085	6	1.33	L	Yes	> 5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCV RI.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.46. Results of chemical analysis of sediments in NT-3^a

Sample site Old sample label	Background site		2	3	4 (7)	3-1 (7)	NT-3 sites		3-1 (6)	3-2 (6)	3-2 (6)	3-2 (5)	3-3 (5)	3-3 (5)	3-3 (5)
	GCK-1.4	GCK-2.4					3-1 (7)	3-1 (6)							
Date sampled	08/21/84	08/21/84	10/14/83	10/24/83	10/24/83	10/24/83	03/03/84	08/22/84	10/24/83	03/03/84	08/22/84	10/24/83	03/03/84	08/22/84	08/22/84
<i>Metals (mg/kg)</i>															
Aluminum	36000	40000	28300	10200	17500	58900	43000	34000	14700	51000	39000	22000	47000	39000	
Antimony	<10	11	19	12	14	24	19	<10	4	9	<10	16	10	<10	
Arsenic	120	130	81	31	55	166	200	85	46	210	100	54	160	120	
Barium	210	280	87	513	121	208	330	310	87	820	350	141	320	350	
Beryllium	6	7	<1	<1	<1	2	4	7	<1	5.9	7	<1	1.9	7	
Boron	52	44	7	3	<2	8	15	18	<2	11	21	<2	46	10	
Cadmium	2.8	3.4	3	3	2	6	11	11	6	32	16	3	5	13	
Calcium	1600	1600	5500	2740	1140	2590	2200	7300	1700	6600	11000	913	2100	7100	
Chromium	76	88	39	21	20	49	80	53	12	66	55	26	47	87	
Cobalt	22	29	<10	15	11	19	37	38	16	100	46	9	22	43	
Copper	<2	<2	7	102	16	23	14	15	10	37	20	3	21	25	
Iron	43000	53000	26500	15100	15200	30700	76000	51000	8700	65000	57000	18200	36000	55000	
Lead	130	220	57	138	54	192	210	200	33	250	180	64	160	230	
Lithium	31	<20	26	18	20	65	67	47	20	79	51	43	50	91	
Magnesium	3300	3700	3800	1160	1520	3900	2700	2600	830	2900	3600	1620	3000	2800	
Manganese	1800	2300	244	3100	450	914	2300	2900	800	8700	3500	377	790	4000	
Molybdenum	<6	<6	<2	2	<2	<2	<2	<6	<2	<2	<6	<2	<2	<6	
Nickel	22	27	12	34	11	48	60	90	57	230	130	21	28	100	
Selenium	<20	21	<20	<20	<20	<20	<20	55	<20	<20	55	<20	<20	58	
Silicon	110	96	619	78	240	2240	710	74	87	380	57	302	630	54	
Silver	<3	<3	<1	2	<1	<1	<1	<3	<1	<1	<3	<1	<1	<3	
Sodium	480	570	186	130	158	161	870	490	102	640	400	256	1200	630	
Strontium	19	23	27	30	18	25	43	27	10	35	35	23	36	39	
Thallium	<100	<100	<50	<50	<50	5	<30	<100	<50	<30	<100	21	<30	<100	
Tin	99	77	54	51	47	103	62	<50	37	56	<50	53	<20	<50	
Titanium	790	1100	250	189	307	375	1000	850	151	1400	930	148	890	950	
Vanadium	51	63	34	14	21	70	72	53	85	57	58	24	46	58	

Table D.46 (continued)

Sample site Old sample label Date sampled	Background site		2	3	4 (7)	3-1 (7)	NT-3 sites							
	GCK-1.4	GCK-2.4					3-1 (7)	3-1 (6)	3-2 (6)	3-2 (6)	3-2 (5)	3-3 (5)	3-3 (5)	3-3 (5)
	08/21/84	08/21/84	10/14/83	10/24/83	10/24/83	10/24/83	03/03/84	08/22/84	10/24/83	03/03/84	08/22/84	10/24/83	03/03/84	08/22/84
Zinc	52	66	34	193	41	122	83	86	5	140	99	63	70	98
Uranium	<200	<200	<200	635	262	250	<200	<200	315	<200	<200	303	<200	<200
Cerium														
Gallium														
Germanium														
Gold														
Lanthanum														
Potassium														
Zirconium														
Cyanide			<0.5	<0.5	<0.5	<0.5			0.58				<0.5	
Mercury	<0.1	0.5	6.7	60	7.5	<0.2	0.33	0.3	<0.1	1	0.9	2.7	1	0.7
<i>Radioactivity (pCi/L)</i>														
234 Uranium														
233+4 Uranium	0.59	10.3	9.52	89.4	21.7	3.25	15.4	20.5	5.84	37.5	27.2	23.3	8.98	21.6
235 Uranium	0.08	0.907	0.528	4.88	1.64	0.224	0.87	1.72	0.528	3.42	2.9	1.73	0.995	1.81
238 Uranium	0.657	16.2	8.75	101	47.4	5.42	20.3	39	11.8	76.7	56.8	48.8	9.55	45.7
232 Thorium	0.752	1.05					1.22	0.477		1.26	1.23		1.24	1.31
230 Thorium	0.706	1.02					1.09	0.487		0.993	1.04		0.819	1.14
238 Plutonium	<0.07	0.017					0	0.02		0.017	<0.03		0	<0.03
239+240 Plutonium	0.042	0.011					0	<0.013		0.0043	<0.03		0	<0.03
241 Americium	<0.04	0.061						0.054			<0.05			<0.11
242+3 Curium	<0.02	<0.01						<0.01			<0.01			<0.02
244 Curium	<0.04	<0.01						<0.04			<0.02			<0.05
237 Neptunium	0.036	0.667						1.32			2.54			1.19
137 Cesium	0.073	0.083					0.064	0.099		0.16	0.11		0	<0.1

^a Source: McCauley 1985.

Table D.47. Results of chemical analysis of sediments in NT-4^a

Sample site Old sample label	Background site		8	9	10	11	12 (15)	NT-4 sites								
	GCK-1.4	GCK-2.4						4-1 (15)	4-1 (15)	4-1 (14)	4-2 (14)	4-2 (14)	4-2 (13)	4-3 (13)	4-3 (13)	4-3 (13)
Date sampled	08/21/84	08/21/84	10/14/83	10/14/83	10/14/83	09/22/83	09/22/83	09/22/83	03/02/84	08/22/84	09/22/83	03/02/84	08/22/84	10/26/83	03/02/84	08/22/84
Metals (µg/L)																
Aluminum	36000	40000	14400	29000	28000	39000	46000	31000	48000	34000	56000	39000	27000	42200	39000	52000
Antimony	<10	11	<10	20	<10	10	20	20	7	<10	20	<5	<10	42	16	<10
Arsenic	120	130	38	95	76	110	120	90	200	83	150	160	61	121	210	130
Barium	210	280	136	162	103	190	210	200	460	450	230	840	500	200	280	270
Beryllium	6	7	<1	<1	7.3	2	4	3	3	6	3	5.4	5	2	2.2	6
Boron	52	44	<2	5	6	<2	<2	88	12	18	10	23	15	22	35	19
Cadmium	2.8	3.4	2	4	2.7	3.2	3.6	6.4	17	23	7.7	65	35	5	4	3.7
Calcium	1600	1600	320	11100	6600	3000	8700	3400	4100	6600	2600	5300	5600	2800	2600	3300
Chromium	76	88	13	31	30	36	41	36	67	81	46	71	36	65	58	76
Cobalt	22	29	<10	13	<10	11	11	23	45	47	34	82	42	35	19	31
Copper	<2	<2	2	2	7	4	9	6	12	12	16	32	24	8	8	<2
Iron	43000	53000	9400	29400	17200	26000	25000	35000	50000	49000	32000	50000	29000	45400	34000	59000
Lead	130	220	29	67	55	80	70	80	220	190	110	190	150	101	105	220
Lithium	31	<20	24	42	32	50	40	50	61	60	70	100	76	72	66	28
Magnesium	3300	3700	800	7350	3540	3100	6300	3300	4000	2500	4000	2700	2000	5200	3400	5100
Manganese	1800	2300	212	650	260	200	480	2200	4100	5700	1600	12000	6500	2300	1600	2800
Molybdenum	<6	<6	<2	<2	<2	<2	<2	<2	<2	10	<2	5	<6	<2	<2	<6
Nickel	22	27	7	13	10	15	16	37	110	150	47	440	210	32	21	31
Selenium	<20	21	<20	<20	<20	<20	<20	<20	<20	49	<20	<20	21	<20	<20	62
Silicon	110	96	93	750	360	1400	240	1400	650	13	1900	480	15	1970	170	29
Silver	<3	<3	<1	<1	<1	<1	<1	<1	<1	<3	<1	<1	<3	<1	<1	<3
Sodium	480	570	340	374	316	780	430	290	1100	360	160	670	340	236	1100	840
Strontium	19	23	15	29	20	16	18	11	32	28	14	33	26	30	30	33
Thallium	<100	<100	<50	<50	<50	<50	<50	<50	<30	<100	<50	<30	<100	<50	<30	<100
Tin	99	77	87	57	<50	60	60	70	29	<50	50	62	<50	153	160	<50
Titanium	790	1100	32	219	230	730	610	280	870	800	400	710	830	235	960	1400
Vanadium	51	63	14	27	23	40	39	32	62	52	48	35	37	42	44	57
Zinc	52	66	15	25	36	30	40	46	78	91	87	160	100	64	42	61
Uranium	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200
Cerium																
Gallium																
Germanium																

Table D.47 (continued)

Sample site Old sample label	Background site		8	9	10	11	12	NT-4 sites								
	GCK-1.4	GCK-2.4						4-1 (15)	4-1 (15)	4-1 (14)	4-2 (14)	4-2 (14)	4-2 (13)	4-3 (13)	4-3 (13)	4-3 (13)
Date sampled	08/21/84	08/21/84	10/14/83	10/14/83	10/14/83	09/22/83	09/22/83	09/22/83	03/02/84	08/22/84	09/22/83	03/02/84	08/22/84	10/26/83	03/02/84	08/22/84
Gold																
Lanthanum																
Potassium																
Zirconium																
Cyanide			<0.5	<0.5	<0.5	<0.5	<0.5	<0.5			<0.5				<0.5	
Mercury	<0.1	0.5	<0.1	<0.1	0.2	<0.1	0.1	0.1	0.31	0.4	0.1	1.8	1.1	<0.2	0.26	<0.1
<i>Radioactivity (pCi/L)</i>																
234 Uranium																
233+4 Uranium	0.59	10.3	1.2	1.66	22.3	0.986	1.48	11.1	12.5	18.1	11.5	22.8	15.1	2.92	3.67	2.63
235 Uranium	0.08	0.907	0.065	0.125	1.56	0.08	0.078	0.946	0.947	1.49	0.948	1.65	1.36	0.21	0.218	0.326
238 Uranium	0.657	16.2	1.29	2.33	24.7	1.3	2.17	21.9	22.8	34.1	23.3	46.7	30.2	3.85	5.16	3.23
232 Thorium	0.752	1.05							1.23	1.1		1.07	0.6		1.35	0.938
230 Thorium	0.706	1.02							1	0.792		0.858	1.08		0.905	0.594
238 Plutonium	<0.07	0.017							0	0.089		0	0.102		0	0.096
239+240 Plutonium	0.042	0.011							0	<0.042		0.005	0.013		0	<0.03
241 Americium	<0.04	0.061								<0.09			0.043			0.1
242+3 Curium	<0.02	<0.01								<0.03			<0.02			<0.01
244 Curium	<0.04	<0.01								<0.06			<0.01			<0.01
237 Neptunium	0.036	0.667								1.86			1.82			0.023
137 Cesium	0.073	0.083							0.057	<0.07		0	0.078		0.051	<0.12

^a Source: McCauley 1985.

Table D.48. Summary of selection of site-related chemicals and radionuclides, NT-3 surface water

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	AvgC result	Dist ^d	Justification
<i>Inorganics</i>								
Chloride (mg/L)	21/ 21	2	13/ 21	1	5.8	2.367	L	> 5% detect above background
Fluoride (mg/L)	21/ 21	0.1	21/ 21	0.28	2.6	1.602	N	> 5% detect above background
Nitrate (mg/L)	7/ 21	0.2	3/ 21	0.12	1.2	0.1476	D	≤ 5% below background
Sulfate (mg/L)	20/ 21	57	15/ 21	9.9	114	65.81	N	> 5% detect above background
Aluminum (mg/L)	18/ 21	7.4	0/ 21	0.18	3.8	1.166	L	Below background
Antimony (mg/L)	4/ 21	0.05	0/ 21	0.0017	0.0049	0.0011	D	Below background
Arsenic (mg/L)	4/ 21	0.05	0/ 21	0.0018	0.0036	0.0012	D	Below background
Barium (mg/L)	21/ 21	0.21	0/ 21	0.0325	0.105	0.0675	L	Below background
Beryllium (mg/L)	1/ 21	0.0007	0/ 21	0.0004	0.00035	0.0002	D	Below background
Calcium (mg/L)	21/ 21	36	17/ 21	19.5	110	68.84	N	Essential element
Cobalt (mg/L)	1/ 21	0.017	0/ 21	0.0039	0.0039	0.0013	D	Below background
Copper (mg/L)	1/ 21	0.0072	0/ 21	0.003	0.003	0.0047	D	Below background
Iron (mg/L)	18/ 21	30	0/ 21	0.355	4.97	1.69	X	Essential element
Lithium (mg/L)	7/ 7			0.0569	0.175	0.1352	X	6/7 detects > WOE UTL ^c
Magnesium (mg/L)	21/ 21	7.2	14/ 21	3.1	16.4	10.16	N	Essential element
Manganese (mg/L)	21/ 21	6.1	0/ 21	0.021	1.19	0.2727	L	Below background
Mercury (mg/L)	10/ 21	0.0002	10/ 21	0.0002	0.00053	0.0002	D	> 5% detect above background
Nickel (mg/L)	4/ 21	0.011	0/ 21	0.0042	0.0086	0.0036	D	Below background
Potassium (mg/L)	20/ 21	3.5	12/ 21	2.45	6.85	3.987	N	Essential element
Sodium (mg/L)	20/ 21	7.6	0/ 21	0.985	6.03	3.538	N	Essential element
Vanadium (mg/L)	5/ 21	0.013	0/ 21	0.0032	0.0083	0.0022	D	Below background
Zinc (mg/L)	9/ 21	0.066	0/ 21	0.0096	0.0449	0.0137	D	Below background
<i>Organics</i>								
1,2-Dichloroethane (µg/L)	7/ 20			11	22	7.575	D	No background available

Table D.48 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	AvgC result	Dist ^d	Justification
2-Butanone (µg/L)	1/ 20	.		8	8	2.775	D	≤5% detects
2-Hexanone (µg/L)	1/ 20	.		6	6	2.675	D	≤5% detects
4-Methyl-2-pentanone (µg/L)	1/ 20	.		6	6	2.675	D	≤5% detects
Acetone (µg/L)	6/ 20	.		2	26	8.525	D	No background available
Chloromethane (µg/L)	7/ 20	.		4	12	4.3	D	No background available
Toluene (µg/L)	1/ 20	.		2	2	2.475	D	≤5% detects
<i>Radioactivity</i>								
Alpha Activity (pCi/L)	20/ 20	2.11	20/ 20	64.6	1350	455.4	N	>5% detect above background
Beta Activity (pCi/L)	20/ 20	3.75	20/ 20	55.8	603	221.8	L	>5% detect above background
Strontium-90 (pCi/L)	3/ 11	.		1.012	1.94	0.7204	D	No background data available
Thorium-228 (pCi/L)	4/ 11	.		0.104	0.31	0.1314	D	No background data available
Thorium-230 (pCi/L)	6/ 11	.		0.136	19.5	1.939	X	No background data available
Thorium-232 (pCi/L)	7/ 11	.		0.103	1.79	0.2782	X	No background data available
Uranium-233/234 (pCi/L)	18/ 18	.		34.2	217	130.8	X	No background data available
Uranium-235 (pCi/L)	17/ 18	.		1.27	17.7	6.6	N	No background data available
Uranium-238 (pCi/L)	18/ 18	.		64	543	304.7	N	No background data available

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For surface water, background criteria have been established using data from NT-13 published in the GWQRs (e.g., HSW 1995). Only results for unfiltered samples were used.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

^e No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCV. See text for further details.

**Table D.49. Summary of chemical and radionuclide results for filtered samples,
NT-3 surface water**

Analyte ^a	Freq of detect	Min detect	Max detect	Average result
Aluminum (mg/L)	6/ 21	0.0348	2.26	0.2
Antimony (mg/L)	9/ 21	0.0017	0.0053	0.0018
Arsenic (mg/L)	1/ 21	0.002	0.002	0.001
Barium (mg/L)	20/ 21	0.0227	0.0964	0.057
Beryllium (mg/L)	1/ 21	0.0003	0.0003	0.0002
Calcium (mg/L)	21/ 21	17.3	115.0	68.24
Cobalt (mg/L)	1/ 21	0.0024	0.0024	0.0012
Iron (mg/L)	7/ 21	0.0127	1.53	0.1353
Lithium (mg/L)	7/ 7	0.0535	0.171	0.1337
Magnesium (mg/L)	21/ 21	2.45	16.8	10.09
Manganese (mg/L)	21/ 21	0.017	0.668	0.168
Mercury (mg/L)	7/ 21	0.0001	0.0004	0.0001
Nickel (mg/L)	1/ 21	0.0067	0.0067	0.0029
Potassium (mg/L)	21/ 21	1.6	6.58	3.92
Sodium (mg/L)	20/ 21	0.813	5.93	3.46
Zinc (mg/L)	4/ 21	0.0091	0.0286	0.0064
Alpha activity (pCi/L)	21/ 21	62.3	1490.0	458.0
Beta activity (pCi/L)	20/ 20	15.7	603.0	208.0
Uranium-233/234 (pCi/L)	20/ 20	30.0	436.0	134.8
Uranium-235 (pCi/L)	19/ 20	1.61	97.6	15.88
Uranium-238 (pCi/L)	20/ 20	68.8	957.0	310.8

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

Table D.50. Summary of selection of site-related chemicals and radionuclides, NT-4 surface water

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg result ^c	Dist ^d	Justification
<i>Inorganics</i>								
Chloride (mg/L)	12/ 12	2	12/ 12	2.8	5.2	4.167	N	>5% detect above background
Fluoride (mg/L)	8/ 12	0.1	8/ 12	0.11	0.14	0.0983	X	>5% detect above background
Nitrate (mg/L)	2/ 12	0.2	1/ 12	0.18	0.3	0.0817	D	Below background
Sulfate (mg/L)	6/ 12	57	0/ 12	5.5	26.1	8.65	X	Below background
Aluminum (mg/L)	11/ 12	7.4	0/ 12	0.188	5.19	1.562	L	Below background
Antimony (mg/L)	1/ 12	0.05	0/ 12	0.0036	0.0036	0.0011	D	Below background
Arsenic (mg/L)	1/ 12	0.05	0/ 12	0.0025	0.0025	0.0012	D	Below background
Barium (mg/L)	12/ 12	0.21	0/ 12	0.0397	0.102	0.0626	L	Below background
Calcium (mg/L)	12/ 12	36	8/ 12	22.4	52	37.78	N	Essential element
Cobalt (mg/L)	2/ 12	0.017	0/ 12	0.0025	0.0026	0.0014	D	Below background
Cyanide (mg/L)	1/ 12	.		0.0131	0.0131	0.0057	D	Background < detection limit ^e
Iron (mg/L)	11/ 12	30	0/ 12	0.646	7.12	2.417	X	Essential element
Lithium (mg/L)	6/ 7	.		0.0018	0.0056	0.003	N	No detects > WOE UTL ^f
Magnesium (mg/L)	12/ 12	7.2	0/ 12	3.75	6.85	5.341	N	Essential element
Manganese (mg/L)	12/ 12	6.1	0/ 12	0.0523	0.249	0.1243	L	Below background
Mercury (mg/L)	1/ 12	0.0002	0/ 12	0.0002	0.00018	0.0001	D	Below background
Potassium (mg/L)	12/ 12	3.5	3/ 12	1.21	3.94	2.35	L	Essential element
Sodium (mg/L)	12/ 12	7.6	0/ 12	1.1	4.79	3.561	N	Essential element
Vanadium (mg/L)	5/ 12	0.013	0/ 12	0.0022	0.0098	0.0035	D	Below background

Table D.50 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg result ^c	Dist ^d	Justification
Zinc (mg/L)	1/ 12	0.066	0/ 12	0.0071	0.0071	0.0075	D	Below background
<i>Organics</i>								
1,2-Dichloroethene (µg/L)	1/ 12	.		2	2	2.458	D	No background available
<i>Radioactivity</i>								
Uranium-233/234 (pCi/L)	1/ 12			1.77	1.77	7197	D	No background data available
Uranium-238 (pCi/L)	1/ 12			2.51	2.51	0.75	D	No background data available

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For surface water, background criteria have been established using data from NT-13 published in the GWQRs (e.g., HSW 1995). Only results for unfiltered samples were used.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

^e No background value for cyanide was available from NT-13. Cyanide was not detected in any samples from NT-5 and it was, therefore, assumed that the background value for cyanide is < the detection limit.

^f No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCV. See text for further details.

**Table D.51. Summary of chemical and radionuclide results for filtered samples,
NT-4 surface water**

Analyte ^a	Freq of detect	Min detect	Max detect	Average result
Aluminum (mg/L)	3/ 12	0.0338	1.29	0.1312
Antimony (mg/L)	1/ 12	0.0034	0.0034	0.0011
Arsenic (mg/L)	1/ 12	0.002	0.002	0.001
Barium (mg/L)	11/ 12	0.0211	0.0695	0.0488
Calcium (mg/L)	12/ 12	22.3	49.4	35.9
Iron (mg/L)	5/ 12	0.0607	0.407	0.0956
Lithium (mg/L)	3/ 7	0.0015	0.0027	0.0014
Magnesium (mg/L)	12/ 12	3.4	6.55	5.05
Manganese (mg/L)	12/ 12	0.0186	0.192	0.0614
Mercury (mg/L)	2/ 12	0.0001	0.0002	0.0001
Potassium (mg/L)	12/ 12	1.18	3.15	2.00
Sodium (mg/L)	12/ 12	1.03	5.01	3.49
Zinc (mg/L)	3/ 12	0.0072	0.0086	0.0043
Uranium-233/234 (pCi/L)	2/ 12	1.09	1.66	0.55
Uranium-238 (pCi/L)	1/ 12	1.97	1.97	0.62

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

Table D.52. Summary of selection of site-related chemicals and radionuclides, NT-5 surface water

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Justification
<i>Inorganics</i>								
Chloride (mg/L)	13/ 13	2	10/ 13	1.6	15.2	3.346	X	>5% detect above background
Fluoride (mg/L)	4/ 13	0.1	4/ 13	0.11	0.35	0.0885	D	>5% detect above background
Nitrate (mg/L)	7/ 13	0.2	4/ 13	0	12.2	1.103	X	>5% detect above background
Sulfate (mg/L)	4/ 13	57	0/ 13	7	24.7	6.662	D	Below background
Aluminum (mg/L)	12/ 13	7.4	0/ 13	0.0999	5.78	1.455	L	Below background
Arsenic (mg/L)	1/ 13	0.05	0/ 13	0.0039	0.0039	0.0013	D	Below background
Barium (mg/L)	13/ 13	0.21	0/ 13	0.0428	0.12	0.0731	L	Below background
Calcium (mg/L)	13/ 13	36	2/ 13	15.2	69.5	32.42	X	Essential element
Cobalt (mg/L)	1/ 13	0.017	0/ 13	0.0037	0.0037	0.0015	D	Below background
Iron (mg/L)	13/ 13	30	0/ 13	0.256	8.12	2.229	L	Essential element
Lithium (mg/L)	7/ 7	.		0.0014	0.0063	0.0031	L	No detects > WOE UTL ^e
Magnesium (mg/L)	13/ 13	7.2	1/ 13	2.44	14.4	4.804	X	Essential element
Manganese (mg/L)	13/ 13	6.1	0/ 13	0.0146	0.495	0.1709	L	Below background
Potassium (mg/L)	13/ 13	3.5	3/ 13	1.21	3.84	2.184	X	Essential element
Sodium (mg/L)	13/ 13	7.6	1/ 13	2.17	9.14	4.173	L	Essential element
Vanadium (mg/L)	3/ 13	0.013	0/ 13	0.006	0.0081	0.0025	D	Below background
Zinc (mg/L)	3/ 13	0.066	0/ 13	0.0068	0.0107	0.0069	D	Below background
<i>Organics</i>								
1,2-Dichloroethene (µg/L)	1/ 13	.		5	5	2.692	D	No background available

Table D.52 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Justification
Methylene chloride ($\mu\text{g/L}$)	1/ 13	.		4	4	2.538	D	No background available
Toluene ($\mu\text{g/L}$)	1/ 13	.		2	2	2.462	D	No background available
Trichloroethene ($\mu\text{g/L}$)	1/ 13	.		7	7	2.846	D	No background available
Radioactivity								
Beta Activity (pCi/L)	1/ 12	3.75	1/ 12	11.4	11.4	3.812	D	> 5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For surface water, background criteria have been established using data from NT-13 published in the GWQRs (e.g., HSW 1995). Only results for unfiltered samples were used.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

^e No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCV. See text for further details.

**Table D.53. Summary of chemical and radionuclide results for filtered samples,
NT-5 surface water**

Analyte ^a	Freq of detect	Min detect	Max detect	Average result
Aluminum (mg/L)	5/ 13	0.0174	2.18	0.2684
Antimony (mg/L)	2/ 13	0.0019	0.0024	0.0010
Arsenic (mg/L)	2/ 13	0.0017	0.0027	0.0012
Barium (mg/L)	12/ 13	0.0343	0.0886	0.0562
Calcium (mg/L)	13/ 13	13.6	71.9	32.1
Copper (mg/L)	1/ 13	0.0023	0.0023	0.0015
Iron (mg/L)	9/ 13	0.064	0.294	0.12
Lithium (mg/L)	3/ 7	0.0017	0.0021	0.0014
Magnesium (mg/L)	13/ 13	2.18	14.8	4.62
Manganese (mg/L)	12/ 13	0.0131	0.0914	0.0469
Potassium (mg/L)	13/ 13	1.07	3.12	1.86
Sodium (mg/L)	13/ 13	2.22	9.11	4.13
Zinc (mg/L)	3/ 13	0.004	0.0221	0.0053

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

Table D.54. Summary of miscellaneous parameters for surface water aggregates in the OLF FA

Parameter	Min	Max	Mean	n ^a	Min	Max	Mean	n ^a	Min	Max	Mean	n ^a
	<i>NT-3</i>				<i>NT-4</i>				<i>NT-5</i>			
Alkalinity (HCO ₃) (mg/L)	35.6	273	142.7	21	51.1	144	104.4	12	40.2	165	89.9	13
Specific conductance (μmhos/cm)	0	610	375	24	75	290	203	14	50	230	155	15
Total dissolved solids (mg/L)	45	446	277	21	104	201	153	12	54	299	132	13
pH	0	7.7	7.2	24	7.3	7.9	7.7	14	6.9	8.1	7.5	15
Total suspended solids (mg/L)	4	112	33	21	2	234	40	12	10	224	37	13
Temperature (°C)	0	21.1	14.4	24	2.5	22.2	16.9	14	3.1	20.9	16.7	15
Turbidity (NTU)	0.78	60	18	21	4.7	171	33.0	12	2.3	105	21.8	13

^a n = frequency of analysis.

Table D.55. C vs Q relationship data for surface water contaminants in NT-3

Sample	Date	Q (L/s)	Chloride	Fluoride	Gross α	Gross β	Lithium	Sulfate	^{233/234} U	²³⁵ U	²³⁸ U
SN3001	29-Mar-94	9.78	1.8	0.9	115	125		36.5	53.6	2.58	107
SN3002	05-Apr-94	13.73	1.2	1.2		344		67	139		325
SN3003	07-Apr-94	24.82	1.6	0.68	131	99.2		19	56.4	3.01	132
SN3004	12-Apr-94	11.54	1.2	1.2	446	244		60.3	140	5.43	325
SN3005	14-Apr-94	107.70	1.6	0.28	75.2	55.8			34.2	1.27	75
SN3006	20-Apr-94	14.06	1	1	399	135		62.8	149	5.68	358
SN3007	22-Apr-94	3.83	1.4	1.9	747	294		79.4	217	11.5	543
SN3008	26-Apr-94	2.87	1.7	2	713	233		82.5	191	11.5	464
SN3009	24-May-94	0.33	2.2	2.6	719	259		89.2	162	8.82	369
SN3010	31-May-94	0.28	2.7	2.1	619	213		74.4	176	7.38	400
SN3011	07-Jun-94	0.02	3.5	1.9	531	220		78.5	185	9.65	404
SN3012	16-Jun-94	1.35	2.1	2.2	602	186		88.8	159	5.24	338
SN3013	21-Jun-94	0.71	2.2	2.2	477	312	0.148	84.7	192	17.7	507
SN3014	28-Jun-94	0.78	2.9	1.1	146	115	0.0727	25.3	70.7	3.7	154
SN3015	07-Jul-94	0.43	2.3	2.2	433	244	0.175	92.3	192	9.14	424
SN3016	12-Jul-94	0.28	2.9	2.3	766	214	0.168	84.2			
SN3017	19-Jul-94	2.32	5.8	0.86	64.6	79.3	0.0569	9.9	47.3	2.72	97.1
SN3018	11-Aug-94	0.38	2.4	2.5	304	351	0.167	99.3	155	12.1	399
SN3019	03-Oct-94	0.06	4.4	1.9	1350	603	0.159	114			
SN3020	25-Jan-95	3.25	2.1	2	370			97.2			
SN3021	29-Jan-95	11.25	2.7	0.62	100	110		34.2	35	1.4	64

Table D.56. Summary of selection of site-related chemicals and radionuclides, OLF groundwater aggregate

Analyte ^a	Freq of detect	Freq of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Justification
<i>Inorganics</i>							
Aluminum (mg/L)	192/ 234	30/ 31	4	0.0240	43.	2.0573	> 5% of wells with median > UTL
Antimony (mg/L)	0/ 241	0/ 33	0	0.	0.	0.0250	No detects
Arsenic (mg/L)	1/ 32	1/ 11	0	0.0060	0.0060	0.0025	No wells with median > UTL
Barium (mg/L)	241/ 241	33/ 33	1	0.0120	1.2000	0.2288	≤ 5% of wells with median > UTL
Beryllium (mg/L)	27/ 241	15/ 33	3	0.0003	0.0031	0.0003	> 5% of wells with median > UTL
Boron (mg/L)	215/ 230	31/ 32	8	0.0046	0.6200	0.0965	> 5% of wells with median > UTL
Cadmium (mg/L)	20/ 253	7/ 32	1	0.0020	0.0300	0.0013	≤ 5% of wells with median > UTL
Calcium (mg/L)	300/ 300	34/ 34	2	0.6900	230.	57.1931	Essential element
Chromium (mg/L)	57/ 287	18/ 34	3	0.0100	0.4100	0.0105	> 5% of wells with median > UTL
Cobalt (mg/L)	17/ 241	10/ 33	1	0.0052	0.0910	0.0052	≤ 5% of wells with median > UTL
Copper (mg/L)	114/ 241	28/ 33	3	0.0040	0.1000	0.0069	> 5% of wells with median > UTL
Iron (mg/L)	233/ 238	31/ 31	1	0.0050	83.	3.5287	Essential element
Lead (mg/L)	107/ 284	26/ 33	6	0.0040	0.6400	0.0056	> 5% of wells with median > UTL
Lithium (mg/L)	7/ 8	7/ 8	NA ^d	0.0120	0.0500	0.0236	No wells with median > WOE UTL ^d
Magnesium (mg/L)	293/ 293	34/ 34	1	0.13	22.	6.614	Essential element
Manganese (mg/L)	239/ 245	33/ 33	1	0.0011	6.9000	0.3946	≤ 5% of wells with median > UTL
Mercury (mg/L)	6/ 232	5/ 31	1	0.0002	0.0006	0.0001	≤ 5% of wells with median > UTL
Molybdenum (mg/L)	3/ 241	3/ 33	0	0.01	0.02	0.005	≤ 5% of wells with median > UTL
Nickel (mg/L)	49/ 241	21/ 33	2	0.0100	0.2100	0.0137	> 5% of wells with median > UTL
Niobium (mg/L)	0/ 8	0/ 8	NA ^d	0.	0.	0.0035	No wells with median > UTL
Potassium (mg/L)	281/ 294	33/ 34	1	0.600	17.	2.6860	Essential element
Selenium (mg/L)	2/ 32	2/ 11	0	0.0050	0.0070	0.0027	No wells with median > UTL
Silicon (mg/L)	96/ 96	29/ 29	2	0.7600	24.	9.2690	> 5% of wells with median > UTL
Silver (mg/L)	0/ 30	0/ 11	0	0.	0.	0.005	No detects

Table D.56 (continued)

Analyte ^a	Freq of detect	Freq of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Justification
Sodium (mg/L)	300/ 300	34/ 34	2	1.9000	270.	24.1574	Essential element
Strontium (mg/L)	236/ 236	32/ 32	0	0.019	0.85	0.239	No wells with median > UTL
Thallium (mg/L)	0/ 8	0/ 4	NA ^d	0.	0.	0.005	No detects
Thorium (mg/L)	0/ 241	0/ 33	0	0.	0.	0.1000	No detects
Titanium (mg/L)	3/ 8	3/ 8	NA ^d	0.0250	0.2900	0.0478	1/8 wells with median > WOE UTL ^d
Total uranium (fluorometric) (mg/L)	106/ 301	25/ 34	2	0.0010	0.5220	0.0157	>5% of wells with median > UTL
Vanadium (mg/L)	23/ 241	10/ 33	4	0.0051	0.0710	0.0042	>5% of wells with median > UTL
Zinc (mg/L)	223/ 241	33/ 33	3	0.0016	1.2000	0.0196	>5% of wells with median > UTL
Zirconium (mg/L)	0/ 8	0/ 8	0	0.	0.	0.0025	No detects
<i>Common Anions</i>							
Chloride (mg/L)	258/ 300	33/ 34	4	1.	74.	8.9868	>5% of wells with median > UTL
Fluoride (mg/L)	119/ 268	27/ 34	0	0.1000	5.7000	0.2819	No wells with median > UTL
Nitrate (mg/L)	60/ 300	10/ 34	0	0.1000	10.2000	0.1905	No wells with median > UTL
Sulfate (mg/L)	292/ 300	34/ 34	0	1.	178.	12.7338	No wells with median > UTL
<i>Organics</i>							
1,1,1-Trichloroethane (µg/L)	59/ 327	10/ 34		0.5000	510.	13.5	>5% of wells with detects
1,1,2-Trichloroethane (µg/L)	3/ 327	1/ 34		7	10	2.6	<= 5% of wells with detects
1,1,2,2-Tetrachloroethane (µg/L)	2/ 327	2/ 34		1.	41.	2.6	>5% of wells with detects
1,1-Dichloroethane (µg/L)	71/ 327	8/ 34		1.	2,000.	60.8	>5% of wells with detects
1,1-Dichloroethene (µg/L)	56/ 327	7/ 34		1.	620.	21.0	>5% of wells with detects
1,2-Dichloroethane (µg/L)	10/ 327	2/ 34		2.	27.	3.0	>5% of wells with detects
1,2-Dichloroethene (µg/L)	42/ 280	8/ 33		1.	190.	11.5	>5% of wells with detects
2-Butanone (µg/L)	25/ 327	10/ 34		3	91.	5.	>5% of wells with detects
2-Hexanone (µg/L)	6/ 327	6/ 34		1	2	5	> 5% of wells with detects

Table D.56 (continued)

Analyte ^a	Freq of detect	Freq of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Justification
4-Methyl-2-pentanone (µg/L)	11/ 327	8/ 34		1	3	5	> 5% of wells with detects
Acetone (µg/L)	36/ 327	15/ 34		1.	86	4.9	> 5% of wells with detects
Benzene (µg/L)	20/ 327	11/ 34		0.2000	53.	3.5	> 5% of wells with detects
Bis(2-ethylhexyl)phthalate (µg/L)	1/ 7	1/ 5		17.	17.	6.2	> 5% of wells with detects
Carbon disulfide (µg/L)	3/ 327	3/ 34		1	1	2.6	> 5% of wells with detects
Chlorobenzene (µg/L)	2/ 327	2/ 34		0.2	0.3	2.6	> 5% of wells with detects
Chloroethane (µg/L)	13/ 327	3/ 34		3	20	5.3	> 5% of wells with detects
Chloroform (µg/L)	22/ 327	8/ 34		0.5000	84.	3.4	> 5% of wells with detects
Dimethylbenzene (µg/L)	10/ 327	6/ 34		1	1	2.6	> 5% of wells with detects
Ethylbenzene (µg/L)	7/ 327	5/ 34		0.8	2	2.6	> 5% of wells with detects
Methylene chloride (µg/L)	57/ 327	19/ 34		0.4000	3,400.	2.6	> 5% of wells with detects
Phenol (µg/L)	1/ 7	1/ 5		2.	2.	4.4	All detects < detection limit
Phenols (mg/L)	3/ 25	3/ 12		0.0020	0.0030	0.0063	All detects < detection limit
Styrene (µg/L)	1/ 327	1/ 34		0.4	0.4	2.6	< = 5% of wells with detects
Tetrachloroethene (µg/L)	45/ 327	9/ 34		0.3000	1,600.	16.3	> 5% of wells with detects
Toluene (µg/L)	25/ 327	12/ 34		0.2000	3.	2.5	> 5% of wells with detects
Trichloroethene (µg/L)	65/ 327	9/ 34		0.5000	800.	13.4	> 5% of wells with detects
Trans-1,2-Dichloroethene (µg/L)	36/ 47	6/ 8		1.	270.	49.4	> 5% of wells with detects
Vinyl acetate (µg/L)	4/ 327	4/ 34		2	3	5	> 5% of wells with detects
Vinyl chloride (µg/L)	10/ 327	4/ 34		2	9	5.1	> 5% of wells with detects
Radioactivity							
Alpha activity (pCi/L)	18/ 196	7/ 25		4.82	360	16.2	> 5% detects
Americium-241 (pCi/L)	. / 4	. / 4		.	.	0.03	No detects
Beta activity (pCi/L)	19/ 196	9/ 25		12	330	17.1	> 5% detects

Table D.56 (continued)

Analyte ^a	Freq of detect	Freq of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	
Cesium-137 (pCi/L)	2/ 4	2/ 4		4.6	7.6	3.40	> 5% detects
Neptunium-237 (pCi/L)	1/ 4	1/ 4		0.24	0.24	0.11	> 5% detects
Plutonium-238 (pCi/L)	. / 4	. / 4		.	.	0.11	No detects
Plutonium-239/240 (pCi/L)	. / 4	. / 4		.	.	0.01	No detects
Radium-228 (pCi/L)	. / 3	. / 3		.	.	0.20	No detects
Technetium-99 (pCi/L)	1/ 4	1/ 4		36	36	9	> 5% detects
Thorium-228 (pCi/L)	. / 4	. / 4		.	.	0.17	No detects
Thorium-230 (pCi/L)	3/ 4	3/ 4		0.29	0.74	0.41	> 5% detects
Thorium-232 (pCi/L)	. / 4	. / 4		.	.	0.06	No detects
Total radioactive strontium (pCi/L)	. / 1	. / 1		.	.	0	No detects
Tritium (pCi/L)	. / 4	. / 4		.	.	100	No detects
Uranium-234 (pCi/L)	3/ 3	3/ 3		0.26	130	46.69	> 5% detects
Uranium-235 (pCi/L)	1/ 4	1/ 4		8.4	8.4	2.18	> 5% detects
Uranium-238 (pCi/L)	2/ 4	2/ 4		3.5	380	95.9	> 5% detects

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established by *Determination of Reference Concentrations for Inorganic Analytes in Groundwater at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (Energy Systems 1996). The background value for an analyte varies depending upon the groundwater cluster that a well has been assigned to so no single background value applies to each analyte. Refer to Sect. C.2 and the above referenced document for a discussion of the approach to evaluating groundwater background, the groundwater background values, and the well cluster assignments.

^c The mean of the medians is the arithmetic mean of the median concentration of an analyte for each well. In calculating the mean of the medians it was assumed that nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d No background value was available from the above referenced source. Values for lithium and titanium UTLs were calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995). The values are 0.071 mg/L for lithium and 0.12 mg/L for titanium. See text for further details. Niobium and thallium were not detected in 13 groundwater wells that were previously considered as reasonable background wells. The background UTL values were, therefore, assumed to be less than the detection limit, and detected values are considered as above background.

**Table D.57. Summary of chemical and radionuclide results from filtered samples,
OLF groundwater aggregate**

Analyte ^a	Freq of detect	Freq of wells w. detects	Min detect	Max detect	Mean of the medians ^b
Aluminum (mg/L)	122/ 237	25/ 31	0.02	0.54	0.02
Antimony (mg/L)	. / 250	. / 33	.	.	0.0250
Arsenic (mg/L)	1/ 37	1/ 12	0.005	0.005	0.003
Barium (mg/L)	249/ 249	33/ 33	0.0074	0.72	0.1804
Beryllium (mg/L)	5/ 247	4/ 33	0.0003	0.0007	0.0002
Boron (mg/L)	221/ 238	32/ 32	0.0048	0.65	0.0952
Cadmium (mg/L)	16/ 272	6/ 32	0.0021	0.03	0.0011
Calcium (mg/L)	316/ 316	34/ 34	0.63	220.0	55.68
Chromium (mg/L)	11/ 307	8/ 34	0.01	0.047	0.005
Cobalt (mg/L)	1/ 249	1/ 33	0.0068	0.0068	0.0025
Copper (mg/L)	91/ 249	25/ 33	0.004	0.046	0.003
Iron (mg/L)	179/ 245	29/ 31	0.0042	2.6	0.0709
Lead (mg/L)	32/ 304	14/ 33	0.004	0.096	0.002
Lithium (mg/L)	6/ 7	6/ 7	0.0074	0.05	0.0195
Magnesium (mg/L)	306/ 306	34/ 34	0.11	19.0	6.20
Manganese (mg/L)	226/ 257	32/ 33	0.0011	3.0	0.1469
Mercury (mg/L)	4/ 245	3/ 31	0.0002	0.0003	0.0001
Molybdenum (mg/L)	4/ 249	2/ 33	0.011	0.022	0.005
Nickel (mg/L)	28/ 249	16/ 33	0.01	0.34	0.01
Niobium (mg/L)	. / 7	. / 7	.	.	0.0035
Potassium (mg/L)	283/ 307	33/ 34	0.6	11.0	2.3
Selenium (mg/L)	. / 37	. / 12	.	.	0.0025
Silicon (mg/L)	101/ 101	29/ 29	2.1	19.0	7.9
Silver (mg/L)	. / 35	. / 12	.	.	0.0050
Sodium (mg/L)	315/ 315	34/ 34	1.6	270.0	24.6
Strontium (mg/L)	244/ 244	32/ 32	0.016	0.91	0.241
Thallium (mg/L)	. / 9	. / 5	.	.	0.0050
Thorium (mg/L)	. / 249	. / 33	.	.	0.1000

Table D.57 (continued)

Analyte ^a	Freq of detect	Freq of wells w. detects	Min detect	Max detect	Mean of the medians ^b
Titanium (mg/L)	3/ 7	3/ 7	0.0032	0.01	0.0035
Total uranium (fluorometric) (mg/L)	99/ 319	23/ 34	0.001	0.63	0.012
Vanadium (mg/L)	3/ 249	3/ 33	0.0053	0.012	0.0025
Zinc (mg/L)	214/ 249	31/ 33	0.0012	0.43	0.0081
Zirconium (mg/L)	. / 7	. / 7	.	.	0.0025

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

Table D.58. Summary of miscellaneous parameters for the OLF groundwater aggregate

Parameter	Min	Max	Mean	n ^a
Alkalinity (mg/L)	130	360	287	9
Alkalinity (CO ₃) (mg/L)	.	88	6	359
Alkalinity (HCO ₃) (mg/L)	7	831	189	359
Specific conductance (μmhos/cm)	50	3500	424	1127
Dissolved oxygen (mg/L)	0.2	16.5	3.3	370
Total dissolved solids (mg/L)	.	1742	282	340
pH	3.9	9.6	7.2	1128
Redox (eV)	-241	446	165	368
Total suspended solids (mg/L)	.	5520	150	368
Temperature (°C)	7.2	25.4	15.7	370
Total coliform	.	8	0	35
Total organic carbon (mg/L)	.	11.3	2.1	164
Total organic chloride (mg/L)	10	26	11	60
Turbidity (NTU)	0.2	5800	79.7	301

^a n = frequency of analysis.

Table D.59. Summary of pH and alkalinity results for wells in the OLF FA

Well	pH				Alkalinity (HCO ₃) (mg/L)				Alkalinity (CO ₃) (mg/L)			
	min	max	mean	n ^a	min	max	mean	n ^a	min	max	mean	n ^a
GW-003	7.1	8.4	7.8	10	109	110	110	2	.	.	.	2
GW-005	6.4	7.7	7.2	10	204	319	256	5	.	.	.	5
GW-007	4.7	6.9	5.6	50	7	55	24	9	.	.	.	9
GW-010	6.3	7.8	6.9	50	253	714	327	9	.	.	.	9
GW-013	6.3	7.4	6.8	30	72	329	277	15	.	.	.	15
GW-043	3.9	8	6.6	63	26	86	60	23	.	.	.	23
GW-044	6.1	8.1	7.3	38	125	143	134	19	.	.	.	19
GW-073	6.1	9	7.5	65	146	185	164	12	.	.	.	12
GW-074	6.7	9.6	9.1	20	177	200	190	10	62	74	71	10
GW-075	7.1	9.6	9.0	20	406	444	421	10	64	88	73	10
GW-076	6.2	8.4	7.5	10	146	164	158	5	.	.	.	5
GW-084	6.1	8.3	7.4	10 3	130	174	151	31	.	.	.	31
GW-087	5.5	7.7	6.5	47	58	239	155	8	.	.	.	8
GW-097	6.2	7.3	6.7	65	256	831	482	12	.	.	.	12
GW-098	6.4	8	7.1	65	223	319	260	12	.	.	.	12
GW-120	6	9	8.0	65	163	208	181	12	3	15	7	12
GW-363	7.8	9.6	8.9	47	187	217	198	13	13	40	27	13
GW-376	6.6	7.6	7.1	20	183	213	198	4	.	.	.	4
GW-531	4.9	6.6	5.9	30	20	39	26	9	.	.	.	9
GW-532	6.5	7.7	7.1	25	150	173	167	8	.	.	.	8
GW-533	6	7.1	6.5	6	61	68	64	3	.	.	.	3
GW-534	7	8	7.3	6	179	255	229	3	.	.	.	3
GW-535	6.9	7.7	7.2	20	190	241	208	7	.	.	.	7
GW-536	7.1	7.8	7.4	10	182	190	186	2	.	.	.	2
GW-538	6.9	8.1	7.3	6	162	174	170	3	.	.	.	3
GW-630	6.8	8.2	7.3	20	175	220	190	10	.	.	.	10
GW-636	6.2	8.6	8.2	24	156	179	171	12	.	16	3	12
GW-637	6.3	7.9	7.5	32	197	222	210	16	.	.	.	16
GW-638	6.5	7.7	7.2	24	164	250	205	12	.	.	.	12
GW-644	4.1	7.1	6.4	24	58	136	88	12	.	.	.	12
GW-793	6.6	7.7	7.3	20	147	164	153	10	.	.	.	10
GW-794	6.8	7.8	7.6	18	206	239	224	9	.	.	.	9
GW-795	6.5	7.6	7.2	20	178	215	200	10	.	.	.	10

^a n = frequency of analysis.

Table D.60. Summary of selection of site-related chemicals and radionuclides, OLF OU 1 groundwater aggregate

Analyte ^a	Freq of detect	Freq of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Avg ^c result	Justification
<i>Inorganics</i>							
Aluminum (mg/L)	9/ 9	8/ 8	4	0.7670	19.2	7.32	>5% of wells with median > UTL
Antimony (mg/L)	1/ 9	1/ 8	0	0.0339	0.033	0.004	≤5% of wells with median > UTL
Arsenic (mg/L)	5/ 9	4/ 8	0	0.0020	0.013	0.003	≤5% of wells with median > UTL
Barium (mg/L)	9/ 9	8/ 8	0	0.0676	0.57	0.214	≤5% of wells with median > UTL
Beryllium (mg/L)	4/ 9	3/ 8	3	0.0005	0.0017	0.0005	>5% of wells with median > UTL
Calcium (mg/L)	9/ 9	8/ 8	7	42.1000	413.	157.3	Essential element
Cobalt (mg/L)	6/ 9	5/ 8	3	0.0049	0.035	0.014	>5% of wells with median > UTL
Copper (mg/L)	3/ 9	3/ 8	4	0.0137	0.12	0.03	>5% of wells with median > UTL
Iron (mg/L)	9/ 9	8/ 8	5	1.5600	44.2	16.8	Essential element
Lead (mg/L)	8/ 9	7/ 8	5	0.0012	0.118	0.027	>5% of wells with median > UTL
Magnesium (mg/L)	9/ 9	8/ 8	2	8.3700	33.5	15.19	Essential element
Manganese (mg/L)	9/ 9	8/ 8	2	0.1470	7.58	1.88	>5% of wells with median > UTL
Mercury (mg/L)	9/ 9	8/ 8	7	0.0002	0.078	0.009	>5% of wells with median > UTL
Molybdenum (mg/L)	2/ 9	2/ 8	2	0.0155	0.129	0.02	>5% of wells with median > UTL
Nickel (mg/L)	9/ 9	8/ 8	6	0.0062	0.08	0.04	>5% of wells with median > UTL
Potassium (mg/L)	9/ 9	8/ 8	3	1.4800	13.7	6.39	Essential element
Selenium (mg/L)	2/ 9	2/ 8	0	0.0025	0.004	0.002	≤5% of wells with median > UTL
Sodium (mg/L)	9/ 9	8/ 8	0	4.0800	15.8	9.67	Essential element
Thallium (mg/L)	0/ 9	0/ 8	NA ^d	0.	0.	0.001	No detects
Tin (mg/L)	0/ 9	0/ 8	0	0.	0.	0.005	No detects
Vanadium (mg/L)	6/ 9	5/ 8	3	0.0027	0.03	0.01	>5% of wells with median > UTL
Zinc (mg/L)	5/ 9	4/ 8	3	0.0234	0.32	0.069	>5% of wells with median > UTL

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Table D.60 (continued)

Analyte ^a	Freq of detect	Freq of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Avg ^c result	Justification
<i>Common Anions</i>							
Chloride (mg/L)	9/9	8/8	1	1.8000	35.	10.3	>5% of wells with median > UTL
Cyanide (mg/L)	1/9	1/8	NA ^d	0.0336	0.04	0.008	1/8 Wells with detects ^d
Fluoride (mg/L)	4/9	4/8	3	0.1500	4.	1.04	>5% of wells with median > UTL
Nitrate (µg/L)	5/9	5/8	0	0.1100	6.7	0.82	≤5% of wells with median > UTL
Sulfate (mg/L)	9/9	8/8	7	33.	300.	101.4444	>5% of wells with median > UTL
<i>Organics</i>							
1,1,2-Trichloroethane (µg/L)	2/9	2/8		3.	5.	2.8	>5% of wells with detects
1,1-Dichloroethane (µg/L)	4/9	4/8		2.	9.	3.3	>5% of wells with detects
1,1-Dichloroethene (µg/L)	2/9	2/8		5.	110.	14.7	>5% of wells with detects
1,2-Dichloroethane (µg/L)	2/9	2/8		6.	23.	5.2	>5% of wells with detects
1,2-Dichloroethene (µg/L)	3/9	3/8		3.	1,100.	132.9	>5% of wells with detects
Acetone (µg/L)	2/9	2/8		15.	64.	16.4	>5% of wells with detects
Aroclor-1254 (µg/L)	1/8	1/7		0.4500	0.4500	0.54	all detects < detection limit
Benzene (µg/L)	3/9	3/8		1.	10.	3.8	>5% of wells with detects
Bis(2-Ethylhexyl)phthalate (µg/L)	2/8	2/7		1.	2.	4.69	1 detect < detection limit
Chloroethane (µg/L)	1/9	1/8		17.	17.	6.	>5% of wells with detects
Chloroform (µg/L)	1/9	1/8		140.	140.	17.8	>5% of wells with detects
Di-N-Butylphthalate (µg/L)	2/8	2/7		1.	1.	4.5	All detects < detection limit
Fluoranthene (µg/L)	4/8	4/7		1.	4.	4.2	All detects < detection limit
Phenanthrene (µg/L)	3/8	3/7		1.	3.	4.3	All detects < detection limit
Pyrene (µg/L)	4/8	4/7		1.	3.	3.9	All detects < detection limit
Tetrachloroethene (µg/L)	2/9	2/8		15.	620.	72.5	>5% of wells with detects

Table D.60 (continued)

Analyte ^a	Freq of detect	Freq of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Avg ^c result	Justification
Toluene (µg/L)	3/ 9	3/ 8		1.	1.	2.	All detects < detection limit
Trichloroethene (µg/L)	3/ 9	3/ 8		3.	2,000.	247.6	>5% of wells with detects
Vinyl chloride (µg/L)	2/ 9	2/ 8		9.	73.	13.	>5% of wells with detects
<i>Radionuclides</i>							
Alpha activity (pCi/L)	6/ 9	6/ 8		23.	2,200.	295.	>5% of wells with detects
Antimony-125 (pCi/L)	0/ 9	0/ 8		0.	0.	4.3	No detects
Beta activity (pCi/L)	7/ 9	7/ 8		22.	2,800.	378.2	>5% of wells with detects
Bismuth-212 (pCi/L)	0/ 9	0/ 8		0.	0.	32.	No detects
Cerium-144 (pCi/L)	0/ 9	0/ 8		0.	0.	10.6	No detects
Cesium-134 (pCi/L)	0/ 9	0/ 8		0.	0.	2.4	No detects
Cesium-137 (pCi/L)	0/ 9	0/ 8		0.	0.	5.	No detects
Chromium-51 (pCi/L)	0/ 9	0/ 8		0.	0.	14.9	No detects
Cobalt-57 (pCi/L)	0/ 9	0/ 8		0.	0.	1.3	No detects
Cobalt-58 (pCi/L)	0/ 9	0/ 8		0.	0.	0.2	No detects
Cobalt-60 (pCi/L)	0/ 9	0/ 8		0.	0.	6.3	No detects
Iron-59 (pCi/L)	0/ 9	0/ 8		0.	0.	5.2	No detects
Lead-212 (pCi/L)	1/ 9	1/ 8		16.	16.	10.7	>5% of wells with detects
Manganese-54 (pCi/L)	0/ 9	0/ 8		0.	0.	0.3	No detects
Niobium-95 (pCi/L)	0/ 9	0/ 8		0.	0.	2.3	No detects
Potassium-40 (pCi/L)	1/ 9	1/ 8		170.	170.	106.	>5% of wells with detects
Ruthenium-106 (pCi/L)	0/ 9	0/ 8		0.	0.	24.9	No detects
Sodium-22 (pCi/L)	0/ 9	0/ 8		0.	0.	0.74	No detects
Strontium-90 (pCi/L)	0/ 9	0/ 8		0.	0.	0.3	No detects

Table D.60 (continued)

Analyte ^a	Freq of detect	Freq of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Avg ^c result	Justification
Technetium-99 (pCi/L)	0/ 9	0/ 8		0.	0.	4.1	No detects
Thallium-208 (pCi/L)	0/ 9	0/ 8		0.	0.	12.9	No detects
Thorium-228 (pCi/L)	6/ 9	6/ 8		1.2000	2.3000	1.2	> 5% of wells with detects
Thorium-230 (pCi/L)	6/ 9	6/ 8		1.1000	2.6000	1.4	> 5% of wells with detects
Thorium-232 (pCi/L)	2/ 9	2/ 8		1.	1.2000	0.57	> 5% of wells with detects
Uranium-234 (pCi/L)	8/ 9	8/ 8		2.9000	1,300.	207.9	> 5% of wells with detects
Uranium-235 (pCi/L)	4/ 9	4/ 8		4.6000	53.	8.1	> 5% of wells with detects
Uranium-238 (pCi/L)	9/ 9	8/ 8		1.5000	1,800.	246.	> 5% of wells with detects
Zinc-65 (pCi/L)	0/ 9	0/ 8		0.	0.	2.2	No detects
Zirconium-95 (pCi/L)	0/ 9	0/ 8		0.	0.	4.8	No detects

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established by *Determination of Reference Concentrations for Inorganic Analytes in Groundwater at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (Energy Systems 1996). The background value for an analyte varies depending upon the groundwater cluster that a well has been assigned to so no single background value applies to each analyte. Refer to Sect. C.2 and the above referenced document for a discussion of the approach to evaluating groundwater background, the groundwater background values, and the well cluster assignments.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d No background value was available from the above referenced source. Values for lithium and titanium UTLs were calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995). The values are 0.071 mg/L for lithium and 0.12 mg/L for titanium. See text for further details. Niobium and thallium were not detected in 13 groundwater wells that were previously considered as reasonable background wells and the background UTL values was, therefore, assumed to be less than the detection limit and detected values are considered as above background.

Table D.61. Distribution of habitat types in the OLF area^a

Habitat type	BYBY group		OLF group		SL 1 group		Total area	
	ha	(acres)	ha	(acres)	ha	(acres)	ha	(acres)
Aquatic	0.2	(0.4)	0.1	(0.3)	0.02	(0.05)	0.32	(0.8)
Riparian	0.4	(0.9)	0.2	(0.6)	0.04	(0.1)	0.64	(1.6)
Wetland	0	(0)	0	(0)	0	(0)	0	(0)
Paved and right-of-way	0.1	(0.2)	0.8	(2.0)	0.2	(0.4)	1.1	(2.6)
Mowed grass	4.8	(12.0)	6.0	(14.8)	5.4	(13.2)	16.2	(40.0)
Old field	0.7	(1.7)	0	(0)	0	(0)	0.7	(1.7)
Mixed hardwood forest	0.7	(1.7)	0.4	(0.9)	0	(0)	1.1	(2.6)
Mixed pine and hardwood forest	0	(0)	0.2	(0.5)	0	(0)	0.2	(0.5)
Total	7.9	(19.3)	8.3	(20.5)	5.9	(14.4)	22.1	(54.2)

^a Areas estimated from Figs. D.78 and D.79 using a polygon grid overlay.

Table D.62. BYBY area ambient water toxicity test results

Parameter	Control	Reference	BCK 11.83	NT-3	NT-4	BCK 11.09
May 19-26, 1994						
Fathead minnow						
Survival (%)	92.5	87.5	87.5	77.5	82.5	92.5
Difference in growth (% of control)	NA	7.56	3.56	13.78	19.11	17.78
Difference in growth (% of reference)	NA	NA	-3.72	5.79	10.74	9.50
<i>Ceriodaphnia</i>						
Reproduction (offspring/ individual)	18.7	23.4	8.4	16.2	17.3	15.7
Difference in reproduction (% of control)	NA	25.13 ^a	-55.08 ^a	-13.37	-7.49	-16.04
Difference in reproduction (% of reference)	NA	NA	-64.1 ^a	-30.77 ^a	-26.07 ^a	-32.91 ^a
August 4-11, 1994						
Fathead minnow						
Survival (%)	97.5	80.0	85.0	95.0	97.5	97.5
Difference in growth (% of control)	NA	8.08	12.32	5.99	7.04	0.70
Difference in growth (% of reference)	NA	NA	3.24	-2.59	-1.62	-7.44
<i>Ceriodaphnia</i>						
Reproduction (offspring/individual)	20.9	26.1	21.7	22.5	26.1	25.9
Difference in reproduction (% of control)	NA	24.95	3.88	7.71	24.95	23.99
Difference in reproduction (% of reference)	NA	NA	-16.86	-13.79	0.0	-0.77

^a Significantly different ($\alpha = 0.05$)

NA = Not applicable

Table D.63. Depth to refusal for soil borings at the BCBG

Soil boring	Depth (ft)
BG-01	36.0
BG-02	38.0
BG-03	20.0
BG-04	14.0
BG-05	28.0
BG-06	26.0
BG-07	12.0
BG-08	14.0
BG-10	30.0
BG-11	18.0
BG-12	36.0
BG-13	16.0
BG-14	28.0
BG-15	8.0
BG-16	7.5

Table D.64. Field screening data for BG-A North

Analyte (units)	Results > detect limit ^a	Bkgd criteria	Detects > bkgd criteria	Min criteria	Max criteria	Avg result	Dist ^b	Site related?	Justification
<i>Media=Soil Location=BYBY Group=Surface (0 to 1 ft) Analysis Type=Metals</i>									
Aluminum (mg/kg)	2/ 2	46700	1/ 2	39800	55900	47850	N	Yes	> 5% detect above background
Barium (mg/kg)	2/ 2	212	1/ 2	207	222	214.5	N	Yes	> 5% detect above background
Beryllium (mg/kg)	2/ 2	2.12	0/ 2	0.9	1.4	1.15	N	No	Below background
Calcium (mg/kg)	2/ 2	1860	2/ 2	2000	2120	2060	N	No	Essential element
Cerium (mg/kg)	2/ 2	.		40	45	42.5	N	Yes	No background data available
Chromium (mg/kg)	2/ 2	80.1	0/ 2	38	54	46	N	No	Below background
Cobalt (mg/kg)	2/ 2	40.1	0/ 2	8	13	10.5	N	No	Below background
Copper (mg/kg)	2/ 2	35.5	0/ 2	10	14	12	N	No	Below background
Iron (mg/kg)	2/ 2	52000	0/ 2	21900	28000	24950	N	No	Essential element
Lead (mg/kg)	1/ 1	49.6	0/ 1	10	10	10	X	No	Below background
Lithium (mg/kg)	2/ 2	33	0/ 2	20	28	24	N	No	Below background
Magnesium (mg/kg)	2/ 2	6630	0/ 2	2110	5930	4020	N	No	Essential element
Manganese (mg/kg)	2/ 2	2220	0/ 2	493	1100	796.5	N	No	Below background
Nickel (mg/kg)	2/ 2	56.7	0/ 2	10	24	17	N	No	Below background
Potassium (mg/kg)	2/ 2	5560	2/ 2	11400	17700	14550	N	No	Essential element
Sodium (mg/kg)	2/ 2	.		360	590	475	N	No	Essential element
Strontium (mg/kg)	2/ 2	16.8	2/ 2	27.4	35	31.2	N	Yes	> 5% detect above background
Titanium (mg/kg)	2/ 2	.		1570	1770	1670	N	Yes	No background data available

Table D.64 (continued)

Analyte (units)	Results > detect limit ^a	Bkgd criteria	Detects > bkgd criteria	Min criteria	Max criteria	Avg result	Dist ^b	Site related?	Justification
Vanadium (mg/kg)	2/ 2	60.1	0/ 2	36	50	43	N	No	Below background
Zinc (mg/kg)	2/ 2	108	0/ 2	45	85	65	N	No	Below background
Zirconium (mg/kg)	2/ 2	.		70	83	76.5	N	Yes	No background data available
<i>Media=Soil Location=BYBY Group=Surface (0 to 1 ft) Analysis Type=Radionuclides</i>									
Uranium (pCi/g)	2/ 2	6.5	0/ 2	0.00006	0.00048	0.00027	N	No	Below background
Uranium-235 (pCi/g)	2/ 2	0.24	0/ 2	0.00002	0.00012	0.00007	N	No	Below background

^a Results less than the detection limit were set to 1/2 the reported detection limit (except for radioisotopes).

^b Dist. Codes: L = distribution most similar to lognormal
 N = distribution most similar to normal
 X = distribution significantly different from normal and lognormal
 D = distribution not determined because fewer than 50% detects

Table D.65. Summary of selection of site-related chemicals and radionuclides, BG-A North, shallow soils

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	9/ 9	46700	0/ 9	11200	25000	18100	N	No	Below background
Antimony (mg/kg)	3/ 3	1	0/ 3	0.23	0.56	0.35	L	No	Below background
Arsenic (mg/kg)	9/ 9	20.2	0/ 9	1.5	5.7	2.84	L	No	Below background
Barium (mg/kg)	9/ 9	212	0/ 9	41	126	96.2	N	No	Below background
Beryllium (mg/kg)	8/ 9	2.12	0/ 9	0.38	1.4	0.811	L	No	Below background
Calcium (mg/kg)	8/ 9	1860	1/ 9	28.9	3070	833	L	No	Essential element
Chromium (mg/kg)	9/ 9	80.1	0/ 9	18.8	41	30	N	No	Below background
Cobalt (mg/kg)	9/ 9	40.1	0/ 9	5.5	20.6	14.6	N	No	Below background
Copper (mg/kg)	9/ 9	35.5	0/ 9	11	24.3	17.2	L	No	Below background
Iron (mg/kg)	9/ 9	52000	0/ 9	18700	4550	29600	N	No	Essential element
Lead (mg/kg)	9/ 9	49.6	0/ 9	5	20.3	11.8	N	No	Below background
Magnesium (mg/kg)	9/ 9	6630	0/ 9	1350	6480	4040	N	No	Essential element
Manganese (mg/kg)	9/ 9	2220	0/ 9	53.4	1170	669	N	No	Below background
Mercury (mg/kg)	4/ 9	0.34	0/ 9	0.12	0.19	0.0854	D	No	Below background
Nickel (mg/kg)	9/ 9	56.7	0/ 9	9.5	41	25.4	N	No	Below background
Potassium (mg/kg)	9/ 9	5560	0/ 9	1260	2380	1750	L	No	Essential element
Selenium (mg/kg)	4/ 9	1.2	0/ 9	0.57	1	0.521	D	No	Below background
Silver (mg/kg)	4/ 9	2.8	3/ 9	2.2	3.8	1.88	D	No	Within USGS bkgd
Tin (mg/kg)	1/ 9			6.4	6.4	1.76	D	Yes	No background data available; slightly > USGS bkgd

Table D.65 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Vanadium (mg/kg)	9/ 9	60.1	0/ 9	18.7	34.5	27.6	N	No	Below background
Zinc (mg/kg)	9/ 9	108	0/ 9	27	83.3	51.7	L	No	Below background
<i>Organics</i>									
4,4'-DDE (µg/kg)	1/ 9	.	.	0.92	0.92	1.95	D	Yes	No background available
4,4'-DDT (µg/kg)	1/ 9	.	.	1	1	1.96	D	Yes	No background available
PCB-1254 (µg/kg)	4/ 9	.	.	20	89	29.6	D	Yes	No background available
PCB-1260 (µg/kg)	2/ 9	.	.	31	37	23.7	D	Yes	No background available
Bis(2-ethylhexyl)phthalate	1/ 3	.	.	66	66	160	D	Yes	No background available
1,1,1-Trichloroethane	2/ 9	.	.	3	19	4.83	D	Yes	No background available
1,1-Dichloroethane (µg/kg)	2/ 9	.	.	2	72	10.6	D	Yes	No background available
1,1-Dichloroethene (µg/kg)	1/ 9	.	.	5	5	3.28	D	Yes	No background available
1,2-Dichloroethane (µg/kg)	1/ 9	.	.	3	3	3.06	D	Yes	No background available
1,2-Dichloroethene (µg/kg)	1/ 9	.	.	7	7	3.5	D	Yes	No background available
Chloroethane (µg/kg)	1/ 9	.	.	170	170	24.3	D	Yes	No background available
Toluene (µg/kg)	4/ 9	.	.	10	200	32.3	D	Yes	No background available
Vinyl chloride (µg/kg)	1/ 9	.	.	6	6	6.11	D	Yes	No background available
<i>Radioactivity</i>									
Gross Alpha (pCi/g)	8/ 9	.	.	1.8	140	19.6	X	NA	Total activity of all radionuclides
Gross Beta (pCi/g)	6/ 9	.	.	4.8	55	10.8	L	NA	Total activity of all radionuclides
Thorium-228 (pCi/g)	9/ 9	2.88	0/ 9	0.17	1.3	0.662	N	No	Below background

Table D.65 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Thorium-230 (pCi/g)	9/ 9	2.3	0/ 9	0.15	1	0.526	N	No	Below background
Thorium-232 (pCi/g)	9/ 9	2.75	0/ 9	0.16	1.1	0.401	L	No	Below background
Uranium-234 (pCi/g)	7/ 9	3.2	0/ 9	0.11	0.57	0.286	N	No	Below background
Uranium-235 (pCi/g)	1/ 9	0.24	0/ 9	0.027	0.027	0.0103	D	No	Below background
Uranium-238 (pCi/g)	8/ 9	2.6	0/ 9	0.061	1.2	0.435	L	No	Below background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCV RI.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.66. Summary of selection of site-related chemicals and radionuclides, BG-A North, deep soils

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	8/ 8	46700	0/ 8	18000	24200	20500	L	No	Below Background
Antimony (mg/kg)	5/ 5	1	0/ 5	0.19	0.34	0.264	N	No	Below background
Arsenic (mg/kg)	8/ 8	20.2	0/ 8	1.5	4.2	2.61	L	No	Below background
Barium (mg/kg)	8/ 8	212	3/ 8	157	376	209	X	Yes	>5% detect above background
Beryllium (mg/kg)	8/ 8	2.12	0/ 8	0.91	1.5	1.26	N	No	Below background
Calcium (mg/kg)	8/ 8	1860	4/ 8	146	4760	1830	L	No	Essential element
Chromium (mg/kg)	8/ 8	80.1	0/ 8	28.5	51.1	36.9	L	No	Below background
Cobalt (mg/kg)	8/ 8	40.1	0/ 8	18.8	23.9	21	L	No	Below background
Copper (mg/kg)	8/ 8	35.5	1/ 8	13.7	46.7	25.3	L	Yes	> 5% detect above background
Cyanide (mg/kg)	1/ 8	0.63	1/ 8	44.2	44.2	5.77	D	Yes	>5% detect above background
Iron (mg/kg)	8/ 8	5200	0/ 8	28900	3540	3200	N	No	Essential element
Lead (mg/kg)	8/ 8	49.6	0/ 8	4	45.8	12.2	L	No	Below background
Magnesium (mg/kg)	8/ 8	6630	4/ 8	4680	8910	6770	N	No	Essential element
Manganese (mg/kg)	8/ 8	2220	1/ 8	161	2330	1090	N	No	1 detect > bkgd; 2330 (site) vs. 2220
Nickel (mg/kg)	8/ 8	56.7	1/ 8	34.3	61.9	48	N	Yes	>5% detect above background
Potassium (mg/kg)	8/ 8	5560	0/ 8	1400	3520	2540	N	No	Essential element
Selenium (mg/kg)	4/ 8	1.2	0/ 8	0.54	0.82	0.481	N	No	Below background
Silver (mg/kg)	7/ 8	2.8	1/ 8	2.3	2.9	2.45	X	No	1 detect > bkgd; 2.9 (site) vs 2.8 bkgd; within USGS
Sodium (mg/kg)	1/ 8	.		111	111	50.2	D	No	Essential element
Vanadium (mg/kg)	8/ 8	60.1	0/ 8	18.9	30.8	24.1	L	No	Below background
Zinc (mg/kg)	8/ 8	108	0/ 8	61.6	93	75.7	L	No	Below background

Table D.66 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Organics</i>									
PCB-1254 (µg/kg)	1/ 8	.		49	49	22.7	D	Yes	No background available
Bis(2-ethylhexyl)phthalate	1/ 3	.		2400	2400	922	D	Yes	No background available
Benzene (µg/kg)	2/ 10	.		84	180	28.8	D	Yes	No background available
Chloroform (µg/kg)	1/ 10	.		15	15	4.2	D	Yes	No background available
Methylene chloride (µg/kg)	1/ 9	.		7	7	3.72	D	Yes	No background available
Toluene (µg/kg)	5/ 10	.		1	71	10.7	X	Yes	No background available
<i>Radioactivity</i>									
Beta activity (pCi/g)	4/ 10	.		9.2	13	7.25	D	No	Total activity of all radionuclides
Gross Alpha (pCi/g)	5/ 10	.		4.5	7.6	4.5	N	No	Total activity of all radionuclides
Thorium-228 (pCi/g)	8/ 10	2.88	0/ 10	0.43	0.97	0.6	N	No	Below background
Thorium-230 (pCi/g)	7/ 10	2.3	0/ 10	0.48	1.2	0.493	L	No	Below background
Thorium-232 (pCi/g)	8/ 10	2.75	0/ 10	0.17	0.87	0.467	N	No	Below background
Uranium-234 (pCi/g)	10/ 1	3.2	0/ 10	0.044	0.46	0.192	L	No	Below background
Uranium-235 (pCi/g)	1/ 10	0.24	0/ 10	0.009	0.009	0.0073	D	No	Below background
Uranium-238 (pCi/g)	10/ 10	2.6	0/ 10	0.03	0.45	0.164	L	No	Below background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCV RI.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.67. Summary of selection of site-related chemicals and radionuclides, shallow soil surrounding BG-A South

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	7/ 7	46700	0/ 7	6900	16600	13000	N	No	Below background
Antimony (mg/kg)	2/ 2	1	0/ 2	0.23	0.28	0.255	N	No	Below background
Arsenic (mg/kg)	7/ 7	20.2	0/ 7	0.57	4.1	2.05	L	No	Below background
Barium (mg/kg)	7/ 7	212	0/ 7	35.3	60.7	48.3	L	No	Below background
Beryllium (mg/kg)	7/ 7	2.12	0/ 7	0.28	1.2	0.686	N	No	Below background
Calcium (mg/kg)	6/ 7	1860	1/ 7	74.3	2050	514	L	No	Essential element
Chromium (mg/kg)	7/ 7	80.1	0/ 7	11.8	47	29.7	N	No	Below background
Cobalt (mg/kg)	7/ 7	40.1	0/ 7	3.8	17.7	9.44	L	No	Below background
Copper (mg/kg)	7/ 7	35.5	0/ 7	3.8	31.7	15.4	N	No	Below background
Iron (mg/kg)	7/ 7	52000	0/ 7	6940	38300	25200	N	No	Essential element
Lead (mg/kg)	7/ 7	49.6	0/ 7	6.5	18.4	13	N	No	Below background
Magnesium (mg/kg)	7/ 7	6630	0/ 7	824	2380	1620	N	No	Essential element
Manganese (mg/kg)	7/ 7	2220	0/ 7	61.7	618	262	L	No	Below background
Mercury (mg/kg)	3/ 7	0.34	1/ 7	0.094	0.4	0.119	D	No	1 detect > bkgd; 0.4 (site) v. 0.34
Nickel (mg/kg)	7/ 7	56.7	0/ 7	6.4	23.5	13	L	No	Below background
Potassium (mg/kg)	7/ 7	5560	0/ 7	606	3960	2290	N	No	Essential element
Selenium (mg/kg)	1/ 7	1.2	0/ 7	0.69	0.69	0.347	D	No	Below background
Silver (mg/kg)	5/ 7	2.8	2/ 7	1.1	4	2.14	N	No	Within USGS bkgd
Sodium (mg/kg)	2/ 7	.		46.3	71	33	D	No	Essential element
Tin (mg/kg)	1/ 7	.		9.4	9.4	2.4	D	No	Within USGS bkgd
Vanadium (mg/kg)	7/ 7	60.1	0/ 7	14.8	32.3	22.9	L	No	Below background
Zinc (mg/kg)	7/ 7	108	0/ 7	14.1	36.3	25.7	N	No	Below background

Table D.67 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Organics</i>									
Acetone (µg/kg)	4/ 7	.		18	110	41	L	Yes	No background available
Tetrachloroethene (µg/kg)	2/ 7	.		2	82	14.1	D	Yes	No background available
Toluene (µg/kg)	2/ 7	.		2	2	2.71	D	Yes	No background available
Trichloroethene (µg/kg)	1/ 7	.		6	6	3.43	D	Yes	No background available
<i>Radioactivity</i>									
Beta activity (pCi/g)	4/ 7	.		13	18	10.2	N	NA	Total activity of all radionuclides
Gross Alpha (pCi/g)	4/ 7	.		4.2	7	4.59	L	NA	Total activity of all radionuclides
Technetium-99 (pCi/g)	1/ 7	4.07	1/ 7	5.9	5.9	1.94	D	No	1 detect > bkgd; 5.9 (site) v. 4.1 ^e
Thorium-228 (pCi/g)	7/ 7	2.88	0/ 7	0.4	1.3	0.757	L	No	Below background
Thorium-230 (pCi/g)	5/ 7	2.3	0/ 7	0.3	0.5	0.37	N	No	Below background
Thorium-232 (pCi/g)	5/ 7	2.75	0/ 7	0.35	0.76	0.462	N	No	Below background
Uranium-234 (pCi/g)	7/ 7	3.2	0/ 7	0.053	0.61	0.229	L	No	Below background
Uranium-235 (pCi/g)	1/ 7	0.24	0/ 7	0.035	0.035	0.0107	D	No	Below background
Uranium-238 (pCi/g)	7/ 7	2.6	1/ 7	0.075	3.9	0.689	X	No	1 detect > bkgd; 3.9 (site) v. 2.6

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCV RI.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects;

^e Values close to background, and gross alpha, gross beta results suggest background activity.

Table D.68. Summary of selection of site-related chemicals and radionuclides, deep soil surrounding BG-A South

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	18/ 18	46700	0/ 18	9910	17500	14100	N	No	Below background
Antimony (mg/kg)	3/ 3	1	0/ 3	0.23	0.33	0.293	N	No	Below background
Arsenic (mg/kg)	17/ 18	20.2	0/ 18	0.71	18.6	2.99	X	No	Below background
Barium (mg/kg)	18/ 18	212	10/ 18	54.2	640	247	L	Yes	>5% detect above background
Beryllium (mg/kg)	18/ 18	2.12	3/ 18	0.63	2.5	1.55	L	Yes	>5% detect above background
Calcium (mg/kg)	17/ 18	1860	12/ 18	118	11700	3610	X	No	Essential element
Chromium (mg/kg)	18/ 18	80.1	0/ 18	22.3	46.5	33.3	L	No	Below background
Cobalt (mg/kg)	18/ 18	40.1	2/ 18	6.7	83.2	24.5	X	Yes	>5% detect above background
Copper (mg/kg)	18/ 18	35.5	3/ 18	11.5	101	29.7	L	Yes	>5% detect above background
Iron (mg/kg)	18/ 18	52000	2/ 18	21900	66800	29700	X	No	Essential element
Lead (mg/kg)	18/ 18	49.6	1/ 18	3.9	93.3	14.8	X	Yes	>5% detect above background
Magnesium (mg/kg)	18/ 18	6630	1/ 18	1690	6890	4340	N	No	Essential element
Manganese (mg/kg)	18/ 18	2220	3/ 18	85.7	7120	1790	L	Yes	>5% detect above background
Molybdenum (mg/kg)	3/ 18	12.8	0/ 18	3.5	5	1.25	D	No	Below background
Nickel (mg/kg)	18/ 18	56.7	6/ 18	22.4	85.8	52.6	N	Yes	>5% detect above background
Potassium (mg/kg)	18/ 18	5560	0/ 18	1590	3760	3030	N	No	Essential element
Silver (mg/kg)	9/ 18	2.8	3/ 18	1.7	6.4	2.26	L	Yes	>5% detect above background; slightly > USGS bkgd
Sodium (mg/kg)	12/ 18	.		29.6	115	61.5	L	No	Essential element

Table D.68 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Tin (mg/kg)	3/ 18	.	.	8.7	15.5	2.83	D	Yes	Slightly > USGS bkgd
Vanadium (mg/kg)	18/ 18	60.1	0/ 18	16.2	26.1	19.2	L	No	Below background
Zinc (mg/kg)	18/ 18	108	0/ 18	31.7	66.5	55.9	X	No	Below background
<i>Organics</i>									
Methoxychlor (µg/kg)	3/ 17	.	.	2.9	6	8.93	D	Yes	No background available
1,1,1-Trichloroethane (µg/kg)	1/ 19	.	.	5	5	3.16	D	Yes	No background available
1,1-Dichloroethane (µg/kg)	2/ 19	.	.	2	20	3.89	D	Yes	No background available
1,1-Dichloroethene (µg/kg)	1/ 19	.	.	6	6	3.21	D	Yes	No background available
1,2-Dichloroethane (µg/kg)	1/ 19	.	.	2	2	3.05	D	Yes	No background available
1,2-Dichloroethene (µg/kg)	4/ 19	.	.	3	470	30.9	D	Yes	No background available
Acetone (µg/kg)	9/ 19	.	.	17	160	35.2	D	Yes	No background available
Benzene (µg/kg)	1/ 19	.	.	2	2	3	D	Yes	No background available
Tetrachloroethene (µg/kg)	8/ 19	.	.	1	220	18.7	D	Yes	No background available
Toluene (µg/kg)	5/ 19	.	.	1	17	3.84	D	Yes	No background available
Trichloroethene (µg/kg)	4/ 19	.	.	2	85	9.32	D	Yes	No background available
Vinyl chloride (µg/kg)	1/ 19	.	.	19	19	6.61	D	Yes	No background available
<i>Radioactivity</i>									
Beta activity (pCi/g)	13/ 18	.	.	6.3	16	9.48	N	NA	Total activity of all radionuclides
Gross Alpha (pCi/g)	5/ 18	.	.	5.1	9.8	4.58	D	NA	Total activity of all radionuclides

Table D.68 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Thallium-208 (pCi/g)	2/ 18			3.4	3.8	3.25	D	Yes	No background data available
Thorium-228 (pCi/g)	18/ 18	2.88	0/ 18	0.48	1.2	0.755	L	No	Below background
Thorium-230 (pCi/g)	16/ 18	2.3	0/ 18	0.17	0.78	0.382	L	No	Below background
Thorium-232 (pCi/g)	17/ 18	2.75	0/ 18	0.24	0.92	0.541	L	No	Below background
Uranium-234 (pCi/g)	18/ 18	3.2	0/ 18	0.038	0.31	0.138	L	No	Below background
Uranium-235 (pCi/g)	1/ 18	0.24	0/ 18	0.16	0.16	0.0133	D	No	Below background
Uranium-238 (pCi/g)	18/ 18	2.6	0/ 18	0.038	0.22	0.118	L	No	Below background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCV RI.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.69. Field screening data for BG-A-16, -17, and -18

Analyte (units)	Results > detect limit ^a	Bkgd criteria	Detects > bkgd criteria	Min criteria	Max criteria	Avg result	Dist ^b	Site related?	Justification
<i>Media=Soil Location=BYBY Group=Surface (0 to 1 ft) Analysis Type=Metals</i>									
Aluminum (mg/kg)	6/ 6	46700	2/ 6	17400	66900	36800	L	Yes	>5% detect above background
Barium (mg/kg)	6/ 6	212	3/ 6	68	298	184.167	N	Yes	>5% detect above background
Beryllium (mg/kg)	6/ 6	2.12	0/ 6	0.4	1.6	0.9833	L	No	Below background
Calcium (mg/kg)	6/ 6	1860	3/ 6	600	90500	18461.667	L	No	Essential element
Cerium (mg/kg)	6/ 6	.		20	50	38.33	L	Yes	No background data available
Chromium (mg/kg)	6/ 6	80.1	0/ 6	16	64	35.33	L	No	Below background
Cobalt (mg/kg)	6/ 6	40.1	0/ 6	5	16	9.33	L	No	Below background
Copper (mg/kg)	6/ 6	35.5	0/ 6	6	21	11.833	L	No	Below background
Iron (mg/kg)	6/ 6	52000	0/ 6	14500	33300	22633.33	L	No	Essential element
Lead (mg/kg)	2/ 2	49.6	0/ 2	20	20	20	X	No	Below background
Lithium (mg/kg)	5/ 6	33	1/ 6	20	40	25	N	Yes	>5% detect above background
Magnesium (mg/kg)	6/ 6	6630	3/ 6	1220	8930	4815	L	No	Essential element
Manganese (mg/kg)	6/ 6	2220	0/ 6	356	885	558.667	L	No	Below background
Nickel (mg/kg)	5/ 6	56.7	0/ 6	9	31	15.41667	L	No	Below background
Potassium (mg/kg)	6/ 6	5560	6/ 6	6600	21400	11533.33	X	No	Essential element
Sodium (mg/kg)	6/ 6	.		280	2520	968.33	L	No	Essential element
Strontium (mg/kg)	6/ 6	16.8	6/ 6	20.4	88.5	44.0833	L	Yes	>5% detect above background
Titanium (mg/kg)	6/ 6	.		700	2440	1596.667	N	Yes	No background data available

Table D.69 (continued)

Analyte (units)	Results > detect limit ^a	Bkgd criteria	Detects > bkgd criteria	Min criteria	Max criteria	Avg result	Dist ^b	Site related?	Justification
Vanadium (mg/kg)	6/ 6	60.1	1/ 6	18	61	35.667	L	Yes	> 5% detect above background
Zinc (mg/kg)	6/ 6	108	0/ 6	18	82	49.667	N	No	Below background
Zirconium (mg/kg)	6/ 6	.		28	111	77.667	N	Yes	No background data available
<i>Media=Soil Location=BYBY Group=Surface (0 to 1 ft) Analysis Type=Radionuclides</i>									
Uranium (pCi/g)	8/ 8	6.5	0/ 8	0.000164	0.00048	0.0002985	L	No	Below background
Uranium-235 (pCi/g)	8/ 8	0.24	0/ 8	0.000044	0.000116	0.0000709	L	No	Below background

^a Results less than the detection limit were set to 1/2 the reported detection limit (except for radioisotopes).

^b Dist. Codes: L = distribution most similar to lognormal

N = distribution most similar to normal

X = distribution significantly different from normal and lognormal

D = distribution not determined because fewer than 50% detects

Table D.70. Summary of selection of site-related chemicals and radionuclides, BG-A-16, shallow soil borings

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. result ^c	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	2/ 2	46700	0/ 2	8480	13800	11100	N	No	Below background
Arsenic (mg/kg)	2/ 2	20.2	0/ 2	2.4	5.8	4.1	N	No	Below background
Barium (mg/kg)	2/ 2	212	1/ 2	166	224	195	N	Yes	Single detect > bkgd; 224 vs 212
Beryllium (mg/kg)	2/ 2	2.12	0/ 2	0.69	0.82	0.755	N	No	Below background
Calcium (mg/kg)	2/ 2	1860	2/ 2	2340	75500	38900	N	No	Essential element
Chromium (mg/kg)	2/ 2	80.1	0/ 2	17.5	19.4	18.5	N	No	Below background
Cobalt (mg/kg)	2/ 2	40.1	0/ 2	9.8	13.7	11.8	N	No	Below background
Copper (mg/kg)	2/ 2	35.5	0/ 1	15.1	15.1	15.1	X	No	Below background
Iron (mg/kg)	2/ 2	52000	0/ 2	20700	21300	21000	N	No	Essential element
Lead (mg/kg)	2/ 2	49.6	0/ 2	11.9	13.9	12.9	N	No	Below background
Magnesium (mg/kg)	2/ 2	6630	1/ 2	1350	21700	11500	N	No	Essential element
Manganese (mg/kg)	2/ 2	2220	0/ 2	929	952	941	N	No	Below background
Mercury	2/ 2	0.34	0/ 2	0.19	0.19	0.19	X	No	Below background
Nickel (mg/kg)	2/ 2	56.7	0/ 2	12.9	21.7	17.3	N	No	Below background
Potassium (mg/kg)	2/ 2	5560	0/ 2	1350	1620	1490	N	No	Essential element
Selenium (mg/kg)	1/ 2	1.2	1/ 2	2.1	2.1	1.19	N	Yes	> 5% detect above background
Sodium (mg/kg)	1/ 2	.		57.4	57.4	47.9	N	No	Essential element
Vanadium (mg/kg)	2/ 2	60.1	0/ 2	18.4	21.8	20.1	N	No	Below background
Zinc (mg/kg)	2/ 2	108	0/ 2	38.6	42.5	40.6	N	No	Below background

Table D.70 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. result ^c	Dist ^d	Site related?	Justification
<i>Organics</i>									
PCB-1248 (µg/kg)	1/ 2	.		400	400	215	N	Yes	No background available
PCB-1254 (µg/kg)	2/ 2	.		43	370	207	N	Yes	No background available
Benzo(a)anthracene (µg/kg)	1/ 1	.		87	87	87	X	Yes	No background available
Benzo(b)fluoranthene (µg/kg)	1/ 1	.		90	90	90	X	Yes	No background available
Benzo(k)fluoranthene (µg/kg)	1/ 1	.		94	94	94	X	Yes	No background available
Bis(2-ethylhexyl) phthalate	1/ 1	.		91	91	91	X	Yes	No background available
Chrysene (µg/kg)	1/ 1	.		93	93	93	X	Yes	No background available
Fluoranthene (µg/kg)	1/ 1	.		230	230	230	X	Yes	No background available
Phenanthrene (µg/kg)	1/ 1	.		150	150	150	X	Yes	No background available
Pyrene (µg/kg)	1/ 1	.		220	220	220	X	Yes	No background available
2-Butanone (µg/kg)	1/ 2	.		42	42	24	N	Yes	No background available
Acetone (µg/kg)	1/ 1	.		30	30	30	X	Yes	No background available
Toluene (µg/kg)	2/ 2	.		2	63	32.5	N	Yes	No background available
<i>Radioactivity</i>									
Gross alpha (pCi/g)	1/ 2	.		3.9	3.9	2.65	N	No	Total activity of all radionuclides
Gross beta (pCi/g)	1/ 2	.		11	11	7.05	N	No	Total activity of all radionuclides
Potassium-40 (pCi/g)	1/ 2	28	0/ 2	16	16	17	N	No	Below Background

Table D.70 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. result ^c	Dist ^d	Site related?	Justification
Thallium-208 (pCi/g)	1/ 2			3.7	3.7	6.35	N	Yes	No background data available
Thorium-228 (pCi/g)	2/ 2	2.88	0/ 2	0.2	0.74	0.47	N	Yes	Below background
Thorium-230 (pCi/g)	2/ 2	2.3	0/ 2	0.36	0.63	0.495	N	No	Below background
Thorium-232 (pCi/g)	2/ 2	2.75	0/ 2	0.22	0.35	0.285	N	No	Below background
Uranium-234 (pCi/g)	2/ 2	3.2	0/ 2	0.53	1.6	1.07	N	No	Below background
Uranium-235 (pCi/g)	1/ 2	0.24	0/ 2	0.037	0.037	0.199	N	No	Below background
Uranium-238 (pCi/g)	2/ 2	0.24	0/ 2	1.6	2	1.8	N	No	Below background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0 *Background Comparison for Human Health Risk Assessment*. Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the Bear Creek Valley RI.

^c Average result reflects the arithmetic mean of the data set, assuming non-detects are equal to one-half of the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.71. Summary of selection of site-related chemicals and radionuclides, BG-A-16, deep soil borings

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg result ^c	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	2/ 2	46700	0/ 2	8960	14700	11800	N	No	Below background
Arsenic (mg/kg)	2/ 2	20.2	0/ 2	1.9	3.1	2.5	N	No	Below background
Barium (mg/kg)	2/ 2	212	1/ 2	85.1	416	251	N	Yes	> 5% detect above background
Beryllium (mg/kg)	2/ 2	2.12	0/ 2	0.63	1.1	0.865	N	No	Below background
Calcium (mg/kg)	2/ 2	1860	2/ 2	4420	16300	10400	N	No	Essential element
Chromium (mg/kg)	2/ 2	80.1	0/ 2	22.2	32.2	27.2	N	No	Below background
Cobalt (mg/kg)	2/ 2	40.1	0/ 2	14.7	20.1	17.4	N	No	Below background
Copper (mg/kg)	2/ 2	35.5	0/ 2	10.8	24.8	17.8	N	No	Below background
Iron (mg/kg)	2/ 2	52000	0/ 2	21600	41700	31700	N	No	Essential element
Lead (mg/kg)	2/ 2	49.6	0/ 2	9	11.6	10.3	N	No	Below background
Magnesium (mg/kg)	2/ 2	6630	0/ 2	5210	5800	5510	N	No	Essential element
Manganese (mg/kg)	2/ 2	2220	1/ 2	876	2250	1560	N	No	Single detect > bkgd; 2250 vs 2220
Nickel (mg/kg)	2/ 2	56.7	0/ 2	26.4	56.3	41.4	N	No	Below background
Potassium (mg/kg)	2/ 2	5560	0/ 2	1250	3000	2130	N	No	Essential element
Silver (mg/kg)	2/ 2	2.8	1/ 2	1.2	3.1	2.15	N	No	Detection limit differences; within USGS background
Tin (mg/kg)	1/ 2	.		2.9	2.9	1.98	N	No	Within USGS background
Vanadium (mg/kg)	2/ 2	60.1	0/ 2	19.9	21.4	20.7	N	No	Below background
Zinc (mg/kg)	2/ 2	108	0/ 2	22.2	71	46.6	N	No	Below background
<i>Organics</i>									
1,1-Dichloroethane (µg/kg)	1/ 2			3	3	3	X	Yes	No background available

Table D.71 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg result ^c	Dist ^d	Site related?	Justification
Acetone (µg/kg)	2/ 2	.		28	31	29.5	N	Yes	No background available
Toluene (µg/kg)	2/ 2	.		2	8	5	N	Yes	No background available
Radioactivity									
Cobalt-60 (pCi/g)	1/ 2	0.014	1/ 2	1.6	1.6	0.955	N	Yes	> 5% detect above background
Gross alpha (pCi/g)	2/ 2	.		4.3	4.3	4.3	X	No	Total activity of all radionuclides
Gross beta (pCi/g)	2/ 2	.		8.3	11	9.65	N	No	Total activity of all radionuclides
Potassium-40 (pCi/g)	2/ 2	28	0/ 2	8.5	27	17.8	N	No	Below background
Thallium-208 (pCi/g)	1/ 2	.		2.3	2.3	2.3	X	Yes	No background data available
Thorium-230 (pCi/g)	1/ 1	2.3	0/ 1	0.59	0.59	0.59	X	No	Below background
Uranium-234 (pCi/g)	2/ 2	3.2	0/ 2	0.074	0.26	0.167	N	No	Below background
Uranium-238 (pCi/g)	2/ 2	2.6	0/ 2	0.14	0.18	0.16	N	No	Below background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established by *Determination of Reference Concentrations for Inorganic Analytes in Groundwater at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (Energy Systems 1996). The background value for an analyte varies depending upon the groundwater cluster that a well has been assigned to so no single background value applies to each analyte. Refer to Sect. C.2 and the above referenced document for a discussion of the approach to evaluating groundwater background, the groundwater background values, and the well cluster assignments.

^c The mean of the medians is the arithmetic mean of the median concentration of an analyte for each well. In calculating the mean of the medians, it was assumed that non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.72. Field screening data for BG-B, BG-D(S)

Analyte (units)	Results > detect limit ^a	Bkgd criteria	Results > bkgd criteria	Min detect	Max detect	Avg result	Dist ^b	Site related?	Justification
<i>Metals</i>									
Aluminum (mg/kg)	13/ 13	46700	8/ 13	20700	85800	54146.153846	N	Yes	> 5% detect above background
Arsenic (mg/kg)	1/ 1	20.2	1/ 1	30	30	30	X	Yes	> 5% detect above background
Barium (mg/kg)	13/ 13	212	6/ 13	32.9	454	200.207692	N	Yes	> 5% detect above background
Beryllium (mg/kg)	13/ 13	2.12	0/ 13	0.5	2.1	1.2	L	No	Below background
Calcium (mg/kg)	13/ 13	1860	6/ 13	500	183000	27931.538462	L	No	Essential element
Cerium (mg/kg)	12/ 13	.		20	60	40.769230	X	Yes	No background data available
Chromium (mg/kg)	13/ 13	80.1	1/ 13	19	84	50.846153	N	Yes	> 5% detect above background
Cobalt (mg/kg)	13/ 13	40.1	0/ 13	2	37	12.461538	L	No	Below background
Copper (mg/kg)	13/ 13	35.5	0/ 13	10	34	18.769230	L	No	Below background
Iron (mg/kg)	13/ 13	52000	0/ 13	10400	42000	26884.615385	N	No	Essential element
Lead (mg/kg)	1/ 1	49.6	0/ 1	20	20	20	X	No	Below background
Lithium (mg/kg)	13/ 13	33	1/ 13	20	40	26.923076	X	Yes	> 5% detect above background
Magnesium (mg/kg)	13/ 13	6630	7/ 13	1880	35700	8433.846153	L	No	Essential element
Manganese (mg/kg)	13/ 13	2220	1/ 13	52	2450	590.615384	L	Yes	> 5% detect above background
Nickel (mg/kg)	13/ 13	56.7	0/ 13	9	37	22.230769	N	No	Below background
Niobium (mg/kg)	2/ 13	.		7	10	5.26923	D	Yes	No background data available
Potassium (mg/kg)	13/ 13	5560	13/ 13	6400	31500	16030.769231	L	No	Essential element
Sodium (mg/kg)	13/ 13	.		90	9300	1226.92308	X	No	Essential element

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Table D.72 (continued)

Analyte (units)	Results > detect limit ^a	Bkgd criteria	Results > bkgd criteria	Min detect	Max detect	Avg result	Dist ^b	Site related?	Justification
Strontium (mg/kg)	13/ 13	16.8	12/ 13	7.3	167	58.215384	L	Yes	> 5% detect above background
Thorium (mg/kg)	2/ 13	.		8	10	5.307692	D	Yes	No background data available
Titanium (mg/kg)	13/ 13	.		758	2950	2218.307692	N	Yes	No background data available
Vanadium (mg/kg)	13/ 13	60.1	6/ 13	28	82	54.76923	N	Yes	> 5% detect above background
Zinc (mg/kg)	13/ 13	108	1/ 13	39	169	67.615384	L	Yes	> 5% detect above background
Zirconium (mg/kg)	13/ 13	.		33	124	86.076923	N	Yes	No background data available
<i>Radionuclides</i>									
Uranium (pCi/g)	16/ 16	6.5	0/ 16	0.000084	0.00344	0.000353	X	No	Below background
Uranium-235 (pCi/g)	16/ 16	0.24	0/ 16	0.000030	0.000478	0.000071	X	No	Below background

^a Results less than the detection limit were set to 1/2 the reported detection limit (except for radioisotopes).

^b Dist. Codes: L = distribution most similar to lognormal.

N = distribution most similar to normal.

X = distribution significantly different from normal and lognormal.

D = distribution not determined because fewer than 50% detects.

Table D.73. Summary of selection of site-related chemicals and radionuclides,
WIP (N and S), BG-B, and BG-D (S), shallow soils

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	4/ 4	46700	0/ 4	7660	29100	17600	N	No	Below background
Arsenic (mg/kg)	4/ 4	20.2	1/ 4	1.1	32.3	9.88	L	Yes	>5% detect above background
Barium (mg/kg)	4/ 4	212	0/ 4	56.7	201	117	N	No	Below background
Beryllium (mg/kg)	3/ 4	2.12	0/ 4	1.4	1.7	1.2	N	No	Below background
Calcium (mg/kg)	4/ 4	1860	3/ 4	1430	14400	5160	L	No	Essential element
Chromium (mg/kg)	4/ 4	80.1	0/ 4	16.5	34.8	26.7	L	No	Below background
Cobalt (mg/kg)	4/ 4	40.1	0/ 4	6.8	21.6	12.9	L	No	Below background
Copper (mg/kg)	3/ 4	35.5	0/ 4	14.3	20.6	13.8	N	No	Below background
Cyanide (mg/kg)	2/ 4	0.63	2/ 4	1.7	142	36.1	L	Yes	>5% detect above background
Iron (mg/kg)	4/ 4	52000	0/ 4	10700	33600	26700	X	No	Essential element
Lead (mg/kg)	4/ 4	49.6	0/ 4	5.9	18	11.2	L	No	Below background
Magnesium (mg/kg)	4/ 4	6630	2/ 4	654	9830	4770	L	No	Essential element
Manganese (mg/kg)	4/ 4	2220	0/ 4	79.3	932	455	N	No	Below background
Mercury (mg/kg)	2/ 4	0.34	0/ 4	0.099	0.32	0.119	L	No	Below background
Nickel (mg/kg)	4/ 4	56.7	0/ 4	7.6	42.5	24.1	N	No	Below background
Potassium (mg/kg)	4/ 4	5560	0/ 4	879	2870	1850	L	No	Essential element
Silver (mg/kg)	4/ 4	2.8	1/ 4	0.79	3.1	1.95	N	No	Detection limit problems ^e ; within USGS bkgd

Table D.73 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Sodium (mg/kg)	2/ 4	.		65.9	70.5	39.6	L	No	Essential element
Tin (mg/kg)	1/ 4	.		5.7	5.7	2.34	D	Yes	Slightly > USGS bkgd
Vanadium (mg/kg)	4/ 4	60.1	0/ 4	15	45.2	30.4	N	No	Below background
Zinc (mg/kg)	4/ 4	108	1/ 4	30.5	139	76.5	L	Yes	> 5% detect above background
<i>Organics</i>									
PCB-1254 (µg/kg)	2/ 4	.		52	10000	2520	X	Yes	No background available
PCB-1260 (µg/kg)	1/ 4	.		36000	36000	9010	D	Yes	No background available
1,4-Dichlorobenzene (µg/kg)	1/ 2	.		92	92	146	N	Yes	No background available
Bis(2-ethylhexyl)phthalate (µg/kg)	1/ 2	.		1700	1700	950	N	Yes	No background available
Di-n-octylphthalate (µg/kg)	1/ 2	.		63	63	132	N	Yes	No background available
Phenanthrene (µg/kg)	1/ 2	.		99	99	150	N	Yes	No background available
Pyrene (µg/kg)	1/ 2	.		240	240	220	N	Yes	No background available
Toluene (µg/kg)	3/ 4	.		1	250	69.3	L	Yes	No background available
<i>Radioactivity</i>									
Gross Alpha (pCi/g)	1/ 4	.		7.7	7.7	4.23	D	NA	Total activity of all radionuclides
Gross Beta (pCi/g)	3/ 4	.		13	17	12.1	N	NA	Total activity of all radionuclides
Technetium-99 (pCi/g)	1/ 4	4.07	1/ 4	40	40	10	D	Yes	> 5% detect above background
Thorium-228 (pCi/g)	4/ 4	2.88	0/ 4	0.34	0.7	0.565	N	No	Below background
Thorium-230 (pCi/g)	3/ 4	2.3	0/ 4	0.27	0.59	0.403	L	No	Below background

Table D.73 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Thorium-232 (pCi/g)	4/ 4	2.75	0/ 4	0.19	0.45	0.345	N	No	Below background
Uranium-234 (pCi/g)	4/ 4	3.2	1/ 4	0.17	5.8	1.59	X	Yes	>5% detect above background
Uranium-235 (pCi/g)	2/ 4	0.24	0/ 4	0.015	0.018	0.055	X	No	Below background
Uranium-238 (pCi/g)	4/ 4	2.6	1/ 4	0.13	11	2.9	L	Yes	>5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCV RI.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

^e Detections limits in the background and site studies were slightly different; in both cases background is close to the detection limit. In this situation calculating the background criteria is difficult.

Table D.74. Summary of selection of site-related chemicals and radionuclides,
WIP (N and S), BG-B, and BG-D (S), deep soils

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Organics</i>									
Aluminum (mg/kg)	8/ 8	46700	0/ 8	14700	25100	20800	N	No	Below background
Arsenic (mg/kg)	8/ 8	20.2	0/ 8	1.6	5.3	2.68	L	No	Below background
Barium (mg/kg)	8/ 8	212	4/ 8	105	301	226	N	Yes	> 5% detect above background
Beryllium (mg/kg)	7/ 8	2.12	0/ 8	0.87	1.7	1.1	L	No	Below background
Calcium (mg/kg)	6/ 8	1860	4/ 8	1080	4660	1840	N	No	Essential element
Chromium (mg/kg)	8/ 8	80.1	0/ 8	24.9	43.3	32.7	L	No	Below background
Cobalt (mg/kg)	8/ 8	40.1	0/ 8	14.3	24.3	19.2	L	No	Below background
Copper (mg/kg)	7/ 8	35.5	1/ 8	11.7	39.7	22.6	N	No	1 detect > bkgd; 39(site)vs. 35
Cyanide (mg/kg)	3/ 8	0.63	3/ 8	1.1	1.3	0.648	D	Yes	> 5% detect above background
Iron (mg/kg)	8/ 8	52000	0/ 8	24300	34000	29100	L	No	Essential element
Lead (mg/kg)	8/ 8	49.6	1/ 8	5.5	124	26.6	L	Yes	> 5% detect above background
Magnesium (mg/kg)	8/ 8	6630	3/ 8	4040	8170	5950	N	No	Essential element
Manganese (mg/kg)	8/ 8	2220	2/ 8	323	3400	1530	L	Yes	> 5% detect above background
Nickel (mg/kg)	8/ 8	56.7	0/ 8	29.4	44.8	36.3	L	No	Below background
Potassium (mg/kg)	8/ 8	5560	0/ 8	1660	2860	2100	L	No	Essential element
Silver (mg/kg)	8/ 8	2.8	0/ 8	1.6	2.7	2.2	N	No	Below background
Sodium (mg/kg)	8/ 8	.		50.8	107	82	N	No	Essential element
Vanadium (mg/kg)	8/ 8	60.10	0/ 8	19.2	31.3	25.5	L	No	Below background

Table D.74 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Zinc (mg/kg)	8/ 8	108	0/ 8	45.2	87.3	67.8	N	No	Below background
<i>Inorganics</i>									
Bis(2-ethylhexyl)phthalate	1/ 2			8700	8700	4450	N	Yes	No background available
Acetone (μg/kg)	1/ 10			180	180	33.4	D	Yes	No background available
Methylene chloride (μg/kg)	4/ 9			51	86	34.1	D	Yes	No background available
<i>Radioactivity</i>									
Beta activity (pCi/g)	3/ 10			9.5	9.9	7.55	D	Yes	No background data available
Thorium-228 (pCi/g)	9/ 10	2.88	0/ 10	0.42	1.7	0.705	L	No	Below background
Thorium-230 (pCi/g)	10/ 10	2.3	0/ 10	0.18	1	0.506	L	No	Below background
Thorium-232 (pCi/g)	8/ 10	2.75	0/ 10	0.22	0.87	0.368	L	No	Below background
Uranium-234 (pCi/g)	10/ 10	3.2	0/ 10	0.11	2.8	0.46	X	No	Below background
Uranium-235 (pCi/g)	4/ 10	0.24	0/ 10	0.016	0.11	0.0204	D	No	Below background
Uranium-238 (pCi/g)	10/ 10	2.6	1/ 10	0.098	7	0.836	X	Yes	> 5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCVR I.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.75. Field screening data for BG-C(W)

Analyte (units)	Results > detect limit ^a	Bkgd criteria	Detects > bkgd criteria	Min detect	Max detect	Avg result	Dist ^b	Site related?	Justification
<i>Metals</i>									
Aluminum (mg/kg)	3/ 3	46700	3/ 3	62100	68000	65933	N	Yes	> 5% detect above background
Barium (mg/kg)	3/ 3	212	3/ 3	235	267	249	L	Yes	> 5% detect above background
Beryllium (mg/kg)	3/ 3	2.12	0/ 3	1.1	1.4	1.2	N	No	Below background
Calcium (mg/kg)	3/ 3	1860	1/ 3	200	2590	1030	L	No	Essential element
Cerium (mg/kg)	3/ 3	.		60	80	66	X	Yes	No Background data available
Chromium (mg/kg)	3/ 3	80.1	0/ 3	63	68	64	X	No	Below background
Cobalt (mg/kg)	3/ 3	40.1	0/ 3	4	8	6	X	No	Below background
Copper (mg/kg)	3/ 3	35.5	0/ 3	14	17	15	L	No	Below background
Iron (mg/kg)	3/ 3	52000	0/ 3	32000	39800	36733	N	No	Essential element
Lithium (mg/kg)	3/ 3	33	2/ 3	30	40	36	X	Yes	> 5% detect above background
Magnesium (mg/kg)	3/ 3	6630	0/ 3	2360	3480	2800	L	No	Essential element
Manganese (mg/kg)	3/ 3	2220	0/ 3	72	233	166	N	No	Below background
Nickel (mg/kg)	3/ 3	56.7	0/ 3	11	17	13	L	No	Below background
Potassium (mg/kg)	3/ 3	5560	3/ 3	16700	17200	16966	N	No	Essential element
Sodium (mg/kg)	4/ 4	.		350	550	460	N	N	Essential element
Strontium (mg/kg)	3/ 3	16.8	3/ 3	44.5	56.1	51	N	Yes	> 5% detect above background
Thorium (mg/kg)	2/ 3	.		9	9	7	X	Yes	No Background data available
Titanium (mg/kg)	3/ 3	.		1960	2640	2336	N	Yes	No Background data available

Table D.75 (continued)

Analyte (units)	Results > detect limit ^a	Bkgd criteria	Detects > bkgd criteria	Min detect	Max detect	Avg result	Dist ^b	Site related?	Justification
Vanadium (mg/kg)	3/ 3	60.1	2/ 3	57	63	60	N	Yes	> 5% detect above background
Zinc (mg/kg)	3/ 3	108	0/ 3	36	45	40	N	No	Below background
Zirconium (mg/kg)	3/ 3	.		95	106	100	L	No	Background data available
<i>Radionuclides</i>									
Uranium (pCi/g)	3/ 3	6.5	0/ 3	0.00012	0.0004	0.000241	L	No	Below background
Uranium-235 (pCi/g)	3/ 3	0.24	0/ 3	0.00002	0.00007	0.000047	L	No	Below background

^a Results less than the detection limit were set to 1/2 the reported detection limit (except for radioisotopes).

^b Dist. Codes: L = distribution most similar to lognormal.

N = distribution most similar to normal.

X = distribution significantly different from normal and lognormal.

D = distribution not determined because fewer than 50% detects.

Table D.76. Summary of selection of site-related chemicals and radionuclides, BG-C (W), shallow soils

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	10/ 10	46700	0/ 10	3050	27500	14400	L	No	Below background
Antimony (mg/kg)	4/ 4	1	0/ 4	0.24	0.39	0.315	L	No	Below background
Arsenic (mg/kg)	10/ 10	20.2	2/ 10	0.64	42.3	10.1	X	Yes	> 5% detect above background
Barium (mg/kg)	10/ 10	212	0/ 10	16.4	148	77.9	N	No	Below background
Beryllium (mg/kg)	10/ 10	2.12	0/ 10	0.42	1.5	0.891	L	No	Below background
Calcium (mg/kg)	10/ 10	1860	1/ 10	54.5	2860	952	L	No	Essential element
Chromium (mg/kg)	10/ 10	80.1	0/ 10	9.7	30.3	22.2	N	No	Below background
Cobalt (mg/kg)	10/ 10	40.1	0/ 10	3.5	24.8	12.1	N	No	Below background
Copper (mg/kg)	7/ 10	35.5	1/ 10	15	45	17.8	N	Yes	> 5% detect above background
Iron (mg/kg)	10/ 10	52000	0/ 10	6860	39700	23800	N	No	Essential element
Lead (mg/kg)	10/ 10	49.6	0/ 10	4.8	30.7	12.8	L	No	Below background
Magnesium (mg/kg)	10/ 10	6630	0/ 10	295	3930	2210	X	No	Essential element
Manganese (mg/kg)	10/ 10	2220	0/ 10	113	900	325	L	No	Below background
Mercury (mg/kg)	4/ 10	0.34	1/ 10	0.12	0.47	0.109	D	Yes	> 5% detect above background
Molybdenum (mg/kg)	1/ 10	12.8	0/ 10	3.4	3.4	0.856	D	No	Below background
Nickel (mg/kg)	10/ 10	56.7	1/ 10	5.2	206	39.6	L	Yes	> 5% detect above background
Potassium (mg/kg)	10/ 10	5560	0/ 10	546	2680	1550	N	No	Essential element
Selenium (mg/kg)	2/ 10	1.2	0/ 10	0.61	1.2	0.421	D	No	Below background
Silver (mg/kg)	8/ 10	2.8	0/ 10	1	2.7	1.64	N	No	Below background

Table D.76 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Sodium (mg/kg)	2/ 10	.		36.1	66.3	26.6	D	No	Essential element
Tin (mg/kg)	3/ 10	.		3.6	4.2	1.99	D	No	Within USGS bkgd
Vanadium (mg/kg)	10/ 10	60.1	0/ 10	12	51.2	26.3	L	No	Below background
Zinc (mg/kg)	9/ 10	108	2/ 10	27.1	199	66.2	L	Yes	>5% detect above background
<i>Organics</i>									
PCB-1254 (µg/kg)	1/ 9	.		670	670	92.7	D	Yes	No background available
PCB-1260 (µg/kg)	1/ 9	.		2300	2300	274	D	Yes	No background available
Bis(2-ethylhexyl)phthalate (µg/kg)	1/ 4	.		80	80	179	D	Yes	No background available
Pyrene (µg/kg)	1/ 4	.		69	69	179	D	Yes	No background available
4-Methyl-2-pentanone (µg/kg)	3/ 10	.		2	5	5.5	D	Yes	No background available
Acetone (µg/kg)	1/ 10	.		65	65	16.7	D	Yes	No background available
Toluene (µg/kg)	5/ 10	.		2	360	45.8	X	Yes	No background available
<i>Radioactivity</i>									
Cobalt-60 (pCi/g)	1/ 10	0.014	1/ 10	1.2	1.2	1.67	D	Yes	>5% detect above background
Gross Alpha (pCi/g)	4/ 10	.		4.3	18	5.44	D	NA	Total activity of all radionuclides
Gross Beta (pCi/g)	6/ 10	.		5.2	35	11.1	L	NA	Total activity of all radionuclides
Potassium-40 (pCi/g)	1/ 10	28	0/ 10	20	20	21.2	D	No	Below background
Technetium-99 (pCi/g)	2/ 7	4.07	2/ 7	13	44	8.55	D	Yes	>5% detect above background
Thorium-228 (pCi/g)	7/ 8	2.88	0/ 8	0.33	0.82	0.491	N	No	Below background

Table D.76 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Thorium-230 (pCi/g)	8/ 8	2.3	0/ 8	0.25	1.2	0.586	L	No	Below background
Thorium-232 (pCi/g)	7/ 8	2.75	0/ 8	0.21	0.56	0.351	L	No	Below background
Uranium-234 (pCi/g)	10/ 10	3.2	2/ 10	0.1	5.2	1.2	L	Yes	> 5% detect above background
Uranium-235 (pCi/g)	1/ 10	0.24	0/ 10	0.021	0.021	0.0838	D	No	Below background
Uranium-238 (pCi/g)	10/ 10	2.6	2/ 10	0.084	23	3.5	X	Yes	> 5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCV RI.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.77. Summary of selection of site-related chemicals and radionuclides, BG-C (W), deep soils

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	12/ 12	46700	0/ 12	6730	21600	15200	N	No	Below background
Antimony (mg/kg)	4/ 4	1	0/ 4	0.2	0.33	0.268	N	No	Below background
Arsenic (mg/kg)	12/ 12	20.2	1/ 12	0.98	52.6	8.02	L	Yes	>5% detect above background
Barium (mg/kg)	12/ 12	212	4/ 12	34.4	728	207	L	Yes	>5% detect above background
Beryllium (mg/kg)	12/ 12	2.12	0/ 12	0.36	1.3	0.898	N	No	Below background
Calcium (mg/kg)	12/ 12	1860	6/ 12	86.6	11700	3790	L	No	Essential element
Chromium (mg/kg)	12/ 12	80.1	0/ 12	16.1	33.6	27.4	N	No	Below background
Cobalt (mg/kg)	12/ 12	40.1	1/ 12	4.9	44.6	18.3	X	Yes	>5% detect above background
Copper (mg/kg)	11/ 12	35.5	2/ 12	11.3	38.5	22.8	N	Yes	>5% detect above background
Cyanide (mg/kg)	1/ 12	0.63	1/ 12	2.1	2.1	0.432	D	Yes	>5% detect above background
Iron (mg/kg)	12/ 12	52000	0/ 12	20700	32200	27700	N	No	Essential element
Lead (mg/kg)	12/ 12	49.6	0/ 12	2.4	44.1	11.9	L	No	Below background
Magnesium (mg/kg)	12/ 12	6630	4/ 12	915	9550	4840	N	No	Essential element
Manganese (mg/kg)	12/ 12	2220	0/ 12	107	1900	598	X	No	Below background
Mercury (mg/kg)	1/ 12	0.34	0/ 12	0.21	0.21	0.0431	D	No	Below background
Nickel (mg/kg)	12/ 12	56.7	0/ 12	6.4	54.8	34.5	N	No	Below background
Potassium (mg/kg)	12/ 12	5560	0/ 12	679	3110	2410	N	No	Essential element
Silver (mg/kg)	12/ 12	2.8	0/ 12	1.3	2.7	2.03	N	No	Below background
Sodium (mg/kg)	4/ 12	.		75.2	116	52.1	D	No	Essential element

Table D.77 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Tin (mg/kg)	1/ 12	.		3.5	3.5	1.29	D	No	Within USGS bkgd
Vanadium (mg/kg)	12/ 12	60.1	0/ 12	17.8	39.5	24.1	L	No	Below background
Zinc (mg/kg)	12/ 12	108	2/ 12	20.5	399	97.2	L	Yes	>5% detect above background

Organics

PCB-1254 (µg/kg)	1/ 11	.		10	10	18.7	D	Yes	No background available
Bis(2-ethylhexyl)phthalate (µg/kg)	1/ 4	.		59	59	159	D	Yes	No background available
1,1-Dichloroethene (µg/kg)	1/ 12	.		4	4	3.04	D	Yes	No background available
1,2-Dichloroethene (µg/kg)	4/ 12	.		2	19	4.96	D	Yes	No background available
2-Butanone (µg/kg)	1/ 12	.		72	72	11.4	D	Yes	No background available
4-Methyl-2-pentanone (µg/kg)	4/ 12	.		5	15	7.46	D	Yes	No background available
Acetone (µg/kg)	7/ 12	.		39	150	50.7	L	Yes	No background available
Benzene (µg/kg)	1/ 12	.		4	4	3.04	D	Yes	No background available
Chlorobenzene (µg/kg)	2/ 12	.		1	4	2.88	D	Yes	No background available
Methylene chloride (µg/kg)	1/ 11	.		68	68	9.32	D	Yes	No background available
Tetrachloroethene (µg/kg)	2/ 12	.		2	18	4.17	D	Yes	No background available
Toluene (µg/kg)	5/ 12	.		2	27	5.83	D	Yes	No background available

Table D.77 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
Trichloroethene (µg/kg)	1/ 12	.	.	4	4	3.04	D	Yes	No background available
<i>Radioactivity</i>									
Cesium-137 (pCi/g)	1/ 12	1.4	1/ 12	1.6	1.6	1.22	D	No	1 detect > bkgd; 1.6(site) vs. 1.4
Gross Alpha (pCi/g)	4/ 12	.	.	3	7.7	4.15	D	NA	Total activity of all radionuclides
Gross Beta (pCi/g)	7/ 12	.	.	7.5	15	8.95	L	NA	Total activity of all radionuclides
Potassium-40 (pCi/g)	2/ 12	28	0/ 12	13	18	19.9	D	No	Below background
Thorium-228 (pCi/g)	8/ 11	2.88	0/ 11	0.35	1.4	0.619	L	No	Below background
Thorium-230 (pCi/g)	9/ 11	2.3	0/ 11	0.29	0.9	0.425	N	No	Below background
Thorium-232 (pCi/g)	6/ 11	2.75	0/ 11	0.28	0.73	0.366	L	No	Below background
Uranium-234 (pCi/g)	11/ 12	3.2	0/ 12	0.11	1.2	0.401	L	No	Below background
Uranium-235 (pCi/g)	5/ 12	0.24	0/ 12	0.019	0.056	0.02	D	No	Below background
Uranium-238 (pCi/g)	11/ 12	2.6	0/ 12	0.093	1.1	0.314	L	No	Below background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the BCVR.

^c Average result reflects the arithmetic mean of the dataset, assuming nondetects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as nondetect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.78. Field screening data for BG-C(E), BG-D(E)

Analyte (units)	Results > detection limit ^a	Bkgd criteria	Detects > bkgd criteria	Min detect	Max detect	Ave result	Dist. ^b	Site related?	Justification
<i>Metals</i>									
Aluminum (mg/kg)	3/ 3	46700	3/ 3	62100	68000	65933	N	Yes	> 5% detect above background
Barium (mg/kg)	3/ 3	212	3/ 3	235	267	249	L	Yes	> 5% detect above background
Beryllium (mg/kg)	3/ 3	2.12	0/ 3	1.1	1.4	1.2	N	No	Below background
Calcium (mg/kg)	3/ 3	1860	1/ 3	200	2590	1030	L	No	Essential element
Cerium (mg/kg)	3/ 3	.		60	80	66	X	Yes	No background data available
Chromium (mg/kg)	3/ 3	80.1	0/ 3	63	68	64	X	No	Below background
Cobalt (mg/kg)	3/ 3	40.1	0/ 3	4	8	6	X	No	Below background
Copper (mg/kg)	3/ 3	35.5	0/ 3	14	17	15	L	No	Below background
Iron (mg/kg)	3/ 3	52000	0/ 3	32000	39800	36733	N	No	Essential element
Lithium (mg/kg)	3/ 3	33	2/ 3	30	40	36	X	Yes	> 5% detect above background
Magnesium (mg/kg)	3/ 3	6630	0/ 3	2360	3480	2800	L	No	Essential element
Manganese (mg/kg)	3/ 3	2220	0/ 3	72	233	166	N	No	Below background
Nickel (mg/kg)	3/ 3	56.7	0/ 3	11	17	13	L	No	Below background
Potassium (mg/kg)	3/ 3	5560	3/ 3	16700	17200	16966	N	No	Essential element
Sodium (mg/kg)	4/ 4	.		350	550	460	N	N	Essential element
Strontium (mg/kg)	3/ 3	16.8	3/ 3	44.5	56.1	51	N	Yes	> 5% detect above background
Thorium (mg/kg)	2/ 3	.		9	9	7.5	X	Yes	No background data available
Titanium (mg/kg)	3/ 3	.		1960	2640	2336	N	Yes	No background data available
Vanadium (mg/kg)	3/ 3	60.1	2/ 3	57	63	60	N	Yes	> 5% detect above background
Zinc (mg/kg)	3/ 3	108	0/ 3	36	45	40	N	No	Below background
Zirconium (mg/kg)	3/ 3	.		95	106	100	L	No	Background data available

Table D.78 (continued)

Analyte (units)	Results > detection limit ^a	Bkgd criteria	Detects > bkgd criteria	Min detect	Max detect	Ave result	Dist. ^b	Site related?	Justification
<i>Radionuclides</i>									
Uranium (pCi/g)	3/ 3	6.5	0/ 3	0.00012	0.0004	0.0002	L	No	Below background
Uranium-235 (pCi/g)	3/ 3	0.24	0/ 3	0.00002	0.00007	0.0000	L	No	Below background

^a Results less than the detection limit were set to 1/2 the reported detection limit (except for radioisotopes).

^b Dist. Codes: L = distribution most similar to lognormal.
 N = distribution most similar to normal.
 X = distribution significantly different from normal and lognormal.
 D = distribution not determined because fewer than 50% detects.

Table D.79. Summary of selection of site-related chemicals, BG-C (E) and BG-D (E), shallow soils

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	2/ 2	46700	0/ 2	11500	11800	11700	N	No	Below background
Arsenic (mg/kg)	2/ 2	20.2	1/ 2	5.3	39.4	22.4	N	Yes	> 5% detect above background
Barium (mg/kg)	2/ 2	212	0/ 2	38.2	185	112	N	No	Below background
Beryllium (mg/kg)	2/ 2	2.12	1/ 2	0.73	4.8	2.77	N	Yes	> 5% detect above background
Calcium (mg/kg)	2/ 2	1860	1/ 2	284	16500	8390	N	No	Essential element
Chromium (mg/kg)	2/ 2	80.1	0/ 2	22.9	28.7	25.8	N	No	Below background
Cobalt (mg/kg)	2/ 2	40.1	0/ 2	6.6	19.8	13.2	N	No	Below background
Copper (mg/kg)	2/ 2	35.5	0/ 2	26.2	26.8	26.5	N	No	Below background
Iron (mg/kg)	2/ 2	52000	0/ 2	33800	35800	34800	N	No	Essential element
Lead (mg/kg)	2/ 2	49.6	0/ 2	11.8	25.2	18.5	N	No	Below background
Magnesium (mg/kg)	2/ 2	6630	0/ 2	912	2470	1690	N	No	Essential element
Manganese (mg/kg)	2/ 2	2220	0/ 2	315	774	545	N	No	Below background
Mercury (mg/kg)	1/ 2	0.34	0/ 2	0.23	0.23	0.13	N	No	Below background
Nickel (mg/kg)	2/ 2	56.7	0/ 2	8.8	13.5	11.2	N	No	Below background
Potassium (mg/kg)	2/ 2	5560	0/ 2	1410	1730	1570	N	No	Essential element
Selenium (mg/kg)	2/ 2	1.2	2/ 2	1.3	2.8	2.05	N	Yes	> 5% detect above background
Silver (mg/kg)	2/ 2	2.8	0/ 2	1.4	2.8	2.1	N	No	Below background
Vanadium (mg/kg)	2/ 2	60.1	1/ 2	21.2	68.8	45	N	Yes	> 5% detect above background
Zinc (mg/kg)	2/ 2	108	0/ 2	36.2	98.8	67.5	N	No	Below background

Table D.79 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Site related?	Justification
<i>Organics</i>									
PCB-1254 (µg/kg)	2/ 2	.		22	93	57.5	N	Yes	No background available
Bis(2-ethylhexyl)phthalate	1/ 2	.		860	860	528	N	Yes	No background available
Chloroethane (µg/kg)	1/ 2	.		26	26	16	N	Yes	No background available
Toluene (µg/kg)	1/ 2	.		110	110	58	N	Yes	No background available
<i>Radioactivity</i>									
Beta activity (pCi/g)	2/ 2	.		14	71	42.5	N	NA	Total activity of all radionuclides
Gross Alpha (pCi/g)	2/ 2	.		11	40	25.5	N	NA	Total activity of all radionuclides
Technetium-99 (pCi/g)	2/ 2	4.07	2/ 2	11	130	70.5	N	Yes	> 5% detect above background
Thorium-228 (pCi/g)	1/ 1	2.88	0/ 1	0.78	0.78	0.78	X	No	Below background
Thorium-230 (pCi/g)	1/ 1	2.3	0/ 1	0.45	0.45	0.45	X	No	Below background
Uranium-234 (pCi/g)	2/ 2	3.2	1/ 2	2.2	4.7	3.45	N	Yes	> 5% detect above background
Uranium-238 (pCi/g)	2/ 2	2.6	2/ 2	8	36	22	N	Yes	> 5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the Bear Creek Valley RI.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.80. Field screening data for BG-D(W), BG-E, BG-J

Analyte (units)	Results > detection limit ^a	Bkgd criteria	Detects > bkgd criteria	Min detect	Max detect	Avg result	Dist. ^b	Site related?	Justification
<i>Metals</i>									
Aluminum (mg/kg)	7/ 7	46700	4/ 7	22000	76900	50357	N	Yes	> 5% detect above background
Barium (mg/kg)	7/ 7	212	6/ 7	206	336	261	L	Yes	> 5% detect above background
Beryllium (mg/kg)	7/ 7	2.12	0/ 7	0.4	1.8	1.1	N	No	Below background
Calcium (mg/kg)	7/ 7	1860	0/ 7	190	1010	498	L	No	Essential element
Cerium (mg/kg)	7/ 7	.		30	80	55	N	Yes	No background data available
Chromium (mg/kg)	7/ 7	80.1	0/ 7	18	73	48	N	No	Below background
Cobalt (mg/kg)	7/ 7	4.1	0/ 7	3	19	10	N	No	Below background
Copper (mg/kg)	7/ 7	35.5	0/ 7	5	19	12	N	No	Below background
Iron (mg/kg)	7/ 7	52000	0/ 7	7480	40500	26682	N	No	Essential element
Lead (mg/kg)	1/ 1	49.6	0/ 1	20	20	20	X	No	Below background
Lithium (mg/kg)	7/ 7	33	3/ 7	20	50	32	N	Yes	> 5% detect above background
Magnesium (mg/kg)	7/ 7	6630	0/ 7	970	4240	2351	L	No	Essential element
Manganese (mg/kg)	7/ 7	2220	0/ 7	127	1790	471	L	No	Below background
Nickel (mg/kg)	7/ 7	56.7	0/ 7	6	26	13	L	No	Below background
Niobium (mg/kg)	2/ 7	.		9	11	5	D	Yes	No background data available
Potassium (mg/kg)	7/ 7	5560	7/ 7	8300	22700	14214	L	No	Essential element
Sodium (mg/kg)	7/ 7	.		270	600	470	N	No	Essential element
Strontium (mg/kg)	7/ 7	16.8	7/ 7	28.9	51.3	42	N	Yes	> 5% detect above background

Table D.80 (continued)

Analyte (units)	Results > detection limit ^a	Bkgd criteria	Detects > bkgd criteria	Min detect	Max detect	Avg result	Dist. ^b	Site related?	Justification
Thorium (mg/kg)	3/ 7	.		8	10	6	D	Yes	No background data available
Titanium (mg/kg)	7/ 7	.		1290	3150	2355	N	Yes	No background data available
Vanadium (mg/kg)	7/ 7	60.1	2/ 7	20	65	47	N	Yes	> 5% detect above background
Zinc (mg/kg)	7/ 7	108	0/ 7	15	64	37	N	No	Below background
Zirconium (mg/kg)	7/ 7	.		86	175	117	L	Yes	No background data available
<i>Radionuclides</i>									
Uranium (pCi/g)	8/ 8	6.5	0/ 8	0.00012	0.002	0.00059	L	No	Below background
Uranium-235 (pCi/g)	8/ 8	0.24	0/ 8	0.00003	0.0002	0.00008	L	No	Below background

^a Results less than the detection limit were set to 1/2 the reported detection limit (except for radioisotopes).

^b Dist. Codes: L = distribution most similar to lognormal.
 N = distribution most similar to normal.
 X = distribution significantly different from normal and lognormal.
 D = distribution not determined because fewer than 50% detects.

Table D.81. Summary of selection of site-related chemicals and radionuclides, NT-6 surface water

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
<i>Inorganics</i>								
Chloride (mg/L)	21/ 21	2	21/ 21	2.2	7.5	4.2	L	> 5% detect above background
Fluoride (mg/L)	12/ 21	0.1	12/ 21	0.11	0.2	0.1033	X	> 5% detect above background
Nitrate (mg/L)	12/ 21	0.2	7/ 21	0.11	24.8	1.456	X	> 5% detect above background
Sulfate (mg/L)	9/ 21	57	0/ 21	6.7	25.8	7.248	D	Below background
Aluminum (mg/L)	18/ 21	7.4	0/ 21	0.138	6.33	1.658	L	Below background
Antimony (mg/L)	1/ 21	0.05	0/ 21	0.0016	0.0016	0.0008	D	Below background
Arsenic (mg/L)	4/ 21	0.05	0/ 21	0.0016	0.0034	0.0012	D	Below background
Barium (mg/L)	21/ 21	0.21	0/ 21	0.0347	0.109	0.0531	L	Below background
Calcium (mg/L)	21/ 21	36	8/ 21	16.8	46.6	31.79	N	Essential element
Cobalt (mg/L)	2/ 21	0.017	0/ 21	0.0035	0.0071	0.0017	D	Below background
Iron (mg/L)	21/ 21	30	0/ 21	0.338	12	2.728	L	Essential element
Lithium (mg/L)	7/ 7	.		0.0074	0.0198	0.0132	N	No detects > WOE UTL ^e
Magnesium (mg/L)	21/ 21	7.2	0/ 21	2.97	7.02	5.01	L	Essential element
Manganese (mg/L)	21/ 21	6.1	0/ 21	0.109	1.65	0.4792	L	Below background
Mercury (mg/L)	3/ 21	0.0002	3/ 21	0.0003	0.0004	0.0001	D	> 5% detect above background
Nickel (mg/L)	2/ 21	0.011	0/ 21	0.0032	0.0086	0.0031	D	Below background
Potassium (mg/L)	21/ 21	3.5	0/ 21	1.1	3.45	1.92	L	Essential element
Selenium (mg/L)	1/ 21	0.066	0/ 21	0.0029	0.0029	0.0013	D	Below background
Sodium (mg/L)	20/ 21	7.6	0/ 21	0.851	4.79	2.949	N	Essential element

Table D.81 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
Vanadium (mg/L)	6/ 21	0.013	0/ 21	0.0047	0.0108	0.003	D	Below background
Zinc (mg/L)	5/ 21	0.066	0/ 21	0.008	0.0269	0.008	D	Below background
<i>Organics</i>								
1,1,1-Trichloroethane (µg/L)	2/ 21	.	.	1	1	2.357	D	No background available
1,1-Dichloroethane (µg/L)	5/ 21	.	.	1	2	2.19	D	No background available
1,2-Dichloroethane (µg/L)	7/ 21	.	.	11	24	6.762	D	No background available
1,2-Dichloroethene (µg/L)	10/ 21	.	.	1	3	2.214	D	No background available
2-Butanone (µg/L)	2/ 21	.	.	5	6	2.786	D	No background available
Acetone (µg/L)	4/ 21	.	.	17	34	8.071	D	No background available
Carbon disulfide (µg/L)	1/ 21	.	.	3	3	2.524	D	< = 5% detects
Chlorobenzene (µg/L)	1/ 21	.	.	1	1	2.429	D	< = 5% detects
Chloromethane (µg/L)	6/ 21	.	.	4	14	4.048	D	No background available
Methylene chloride (µg/L)	1/ 21	.	.	2	2	2.643	D	< = 5% detects
Tetrachloroethene (µg/L)	4/ 21	.	.	1	2	2.262	D	No background available
Toluene (µg/L)	1/ 21	.	.	1	1	2.429	D	< = 5% detects
Trichloroethene (µg/L)	5/ 21	.	.	1	2	2.143	D	No background available
<i>Radioactivity</i>								
Alpha Activity (pCi/L)	10/ 20	2.11	10/ 20	10.2	22.5	10.5	N	> 5% detect above background
Beta Activity (pCi/L)	9/ 20	3.75	9/ 20	10	22.9	9.12	D	> 5% detect above background
Thorium-228 (pCi/L)	1/ 3	.	.	0.15	0.15	0.0933	D	No background data available

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Table D.81 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
Uranium-233/234 (pCi/L)	21/ 21	.		1.2	6.66	3.564	X	No background data available
Uranium-235 (pCi/L)	1/ 21	.		1.72	1.72	0.2417	D	< = 5% detects
Uranium-238 (pCi/L)	21/ 21	.		1.81	14.6	6.825	L	No background data available

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For surface water, background criteria have been established using data from NT-13 published in the GWQRs (e.g., HSW 1995). Only results for unfiltered samples were used.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

^e No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCV. See text for further details.

Table D.82. Summary of chemical and radionuclide results for filtered samples, NT-6 surface water

Analyte ^a	Freq of detect	Min detect	Max detect	Average result
Aluminum (mg/L)	3/ 21	0.0486	2.02	0.1290
Antimony (mg/L)	6/ 21	0.0015	0.005	0.0014
Arsenic (mg/L)	1/ 21	0.0016	0.0016	0.0010
Barium (mg/L)	20/ 21	0.0171	0.063	0.0361
Calcium (mg/L)	21/ 21	16.6	49.3	31.1
Iron (mg/L)	7/ 21	0.0272	0.195	0.0522
Lithium (mg/L)	7/ 7	0.0074	0.0134	0.0111
Magnesium (mg/L)	21/ 21	2.13	7.46	4.80
Manganese (mg/L)	21/ 21	0.019	0.93	0.293
Mercury (mg/L)	3/ 21	0.0002	0.0004	0.0001
Potassium (mg/L)	21/ 21	1.06	2.18	1.53
Sodium (mg/L)	20/ 21	0.735	4.87	3.0
Zinc (mg/L)	3/ 21	0.005	0.013	0.005
Alpha activity (pCi/l)	8/ 21	10.1	30.8	8.1
Beta activity (pCi/l)	3/ 20	10.9	15.3	6.0
Uranium-233/234 (pCi/L)	17/ 21	1.03	7.5	3.18
Uranium-238 (pCi/L)	20/ 21	1.28	16.1	6.63

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

Table D.83. Summary of selection of site-related chemicals and radionuclides, NT-7 surface water

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
<i>Inorganics</i>								
Chloride (mg/L)	21/ 21	2	21/ 21	3.4	36.3	17.86	L	> 5% detect above background
Fluoride (mg/L)	14/ 21	0.1	13/ 21	0.1	0.33	0.1152	X	> 5% detect above background
Nitrate (mg/L)	21/ 21	0.2	19/ 21	0.13	19.1	2.462	L	> 5% detect above background
Sulfate (mg/L)	19/ 21	57	1/ 21	6.1	78.8	17.29	X	< = 5% below background
Aluminum (mg/L)	12/ 21	7.4	5/ 21	0.0409	30.1	3.547	X	> 5% detect above background
Antimony (mg/L)	2/ 21	0.05	0/ 21	0.0023	0.003	0.001	D	Below background
Arsenic (mg/L)	7/ 21	0.05	0/ 21	0.0023	0.0324	0.0056	D	Below background
Barium (mg/L)	21/ 21	0.21	0/ 21	0.0377	0.157	0.0717	L	Below background
Beryllium (mg/L)	2/ 21	0.0007	1/ 21	0.0004	0.0013	0.0002	D	< = 5% below background
Calcium (mg/L)	21/ 21	36	14/ 21	20.7	75	47.89	L	Essential element
Cobalt (mg/L)	4/ 21	0.017	0/ 21	0.0038	0.0145	0.0024	D	Below background
Copper (mg/L)	1/ 21	0.0072	1/ 21	0.0306	0.0306	0.0044	D	< = 5% below background
Cyanide (mg/L)	1/ 21	.		0.0139	0.0139	0.0054	D	< = 5% detects
Iron (mg/L)	17/ 21	30	1/ 21	0.0631	42.7	5.703	L	Essential element
Lithium (mg/L)	7/ 7	.		0.0283	0.057	0.0499	X	No detects > WOE UTL ^e
Magnesium (mg/L)	21/ 21	7.2	12/ 21	4.01	11	7.509	L	Essential element
Manganese (mg/L)	20/ 21	6.1	0/ 21	0.0085	1.01	0.2401	X	Below background
Mercury (mg/L)	3/ 21	0.0002	2/ 21	0.0001	0.0004	0.0001	D	> 5% detect above background
Nickel (mg/L)	5/ 21	0.011	2/ 21	0.0031	0.022	0.0046	D	> 5% detect above background
Potassium (mg/L)	21/ 21	3.5	18/ 21	2.47	115	14.84	L	Essential element
Sodium (mg/L)	20/ 21	7.6	8/ 21	1.46	18.1	6.28	L	Essential element
Vanadium (mg/L)	6/ 21	0.013	5/ 21	0.009	0.0698	0.011	D	> 5% detect above background

Table D.83 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
Zinc (mg/L)	8/ 21	0.066	5/ 21	0.0073	0.132	0.0244	D	> 5% detect above background
<i>Organics</i>								
1,1,1-Trichloroethane (µg/L)	21/ 21	.	.	3	35	16.48	N	No background available
1,1-Dichloroethane (µg/L)	21/ 21	.	.	3	25	12.95	N	No background available
1,1-Dichloroethene (µg/L)	20/ 21	.	.	2	16	8.405	N	No background available
1,2-Dichloroethane (µg/L)	10/ 21	.	.	1	19	6.286	D	No background available
1,2-Dichloroethene (µg/L)	21/ 21	.	.	33	290	157.3	N	No background available
Acetone (µg/L)	4/ 21	.	.	17	27	8.571	D	No background available
Benzene (µg/L)	5/ 21	.	.	1	2	2.357	D	No background available
Carbon disulfide (µg/L)	1/ 21	.	.	6	6	2.786	D	< = 5% detects
Chloroform (µg/L)	20/ 21	.	.	1	8	3.929	N	No background available
Chloromethane (µg/L)	6/ 21	.	.	3	10	3.857	D	No background available
Methylene chloride (µg/L)	4/ 21	.	.	1	4	3.19	D	No background available
Tetrachloroethene (µg/L)	21/ 21	.	.	16	120	65.52	N	No background available
Toluene (µg/L)	1/ 21	.	.	1	1	2.548	D	< = 5% detects
Trichloroethene (µg/L)	21/ 21	.	.	8	82	41.95	N	No background available
Trichlorofluoromethane (µg/L)	3/ 21	.	.	4	4	3.024	D	No background available
Vinyl chloride (µg/L)	21/ 21	.	.	6	33	15.24	L	No background available
<i>Radioactivity</i>								
Alpha Activity (pCi/L)	12/ 19	2.11	12/ 19	11	41.3	14.7	L	> 5% detect above background
Beta Activity (pCi/L)	16/ 20	3.75	16/ 20	10.4	117	23.72	X	> 5% detect above background
Plutonium-238 (pCi/L)	1/ 3	.	.	0.223	0.223	0.078	D	No background data available
Thorium-232 (pCi/L)	1/ 3	.	.	0.474	0.474	0.1763	D	No background data available

Table D.83 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
Thorium-230 (pCi/L)	2/ 3	.		0.148	0.411	0.1863	L	No background data available
Thorium-232 (pCi/L)	1/ 3	.		0.38	0.38	0.133	D	No background data available
Uranium-233/234 (pCi/L)	21/ 21	.		2.22	25.6	7.627	X	No background data available
Uranium-235 (pCi/L)	4/ 21	.		1.17	1.83	0.4257	D	No background data available
Uranium-238 (pCi/L)	21/ 21	.		3.62	50.7	12.54	X	No background data available

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For surface water, background criteria have been established using data from NT-13 published in the GWQRs (e.g., HSW 1995). Only results for unfiltered samples were used.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

^e No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCV. See text for further details.

**Table D.84. Summary of chemical and radionuclide results for filtered samples,
NT-7 surface water**

Analyte ^a	Freq of detect	Min detect	Max detect	Average result
Aluminum (mg/L)	4/ 21	0.0285	1.94	0.1858
Antimony (mg/L)	7/ 21	0.0018	0.0051	0.0015
Arsenic (mg/L)	3/ 21	0.0018	0.0067	0.0013
Barium (mg/L)	20/ 21	0.0123	0.108	0.0509
Calcium (mg/L)	21/ 21	16.3	79.2	44.8
Iron (mg/L)	5/ 21	0.0299	0.296	0.0449
Lithium (mg/L)	7/ 7	0.0178	0.0603	0.0477
Magnesium (mg/L)	21/ 21	2.06	11.7	6.99
Manganese (mg/L)	18/ 21	0.0045	0.131	0.0309
Mercury (mg/L)	2/ 21	0.0003	0.0004	0.0001
Potassium (mg/L)	21/ 21	2.38	115.0	14.37
Sodium (mg/L)	20/ 21	1.42	17.9	6.3
Thallium (mg/L)	1/ 21	0.0023	0.0023	0.0011
Vanadium (mg/L)	3/ 21	0.0021	0.0029	0.0018
Zinc (mg/L)	3/ 21	0.0036	0.0228	0.0051
Alpha activity (pCi/L)	14/ 21	10.0	71.3	14.6
Beta activity (pCi/L)	13/ 20	11.0	109.0	18.5
Uranium-233/234 (pCi/L)	20/ 21	1.22	37.7	7.33
Uranium-235 (pCi/L)	1/ 21	1.17	1.17	0.32
Uranium-238 (pCi/L)	20/ 21	2.25	88.2	12.93

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

Table D.85. Summary of selection of site-related chemicals and radionuclides, NT-8 surface water

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
<i>Inorganics</i>								
Chloride (mg/L)	14/ 14	2	13/ 14	1.7	18.7	12.4	N	> 5% detect above background
Fluoride (mg/L)	13/ 14	0.1	13/ 14	0.12	0.87	0.2089	X	> 5% detect above background
Nitrate (mg/L)	9/ 14	0.2	7/ 14	0.11	1.6	0.2786	L	> 5% detect above background
Sulfate (mg/L)	10/ 14	57	0/ 14	5.3	23.4	10.49	N	Below background
Aluminum (mg/L)	7/ 14	7.4	1/ 14	0.0696	8.3	1.289	L	1 detect > UTL. Turbidity 100× mean turbidity. See text.
Antimony (mg/L)	1/ 14	0.05	0/ 14	0.0029	0.0029	0.0009	D	Below background
Arsenic (mg/L)	3/ 14	0.05	0/ 14	0.0024	0.0143	0.0022	D	Below background
Barium (mg/L)	14/ 14	0.21	0/ 14	0.031	0.102	0.0774	N	Below background
Beryllium (mg/L)	4/ 14	0.0007	1/ 14	0.0004	0.0086	0.0008	D	> 5% detect above background
Calcium (mg/L)	14/ 14	36	11/ 14	22.8	51.6	43.35	X	Essential element
Cobalt (mg/L)	1/ 14	0.017	0/ 14	0.0036	0.0036	0.0013	D	Below background
Cyanide (mg/L)	1/ 14	.		0.0215	0.0215	0.0062	D	Background < detection limit
Iron (mg/L)	12/ 14	30	0/ 14	0.0742	15	2.452	L	Essential element
Lithium (mg/L)	7/ 7			0.134	0.188	0.1563	L	7/7 detects > WOE UTL
Magnesium (mg/L)	14/ 14	7.2	0/ 14	3.26	5.51	4.875	X	Essential element
Manganese (mg/L)	13/ 14	6.1	0/ 14	0.0259	0.425	0.1293	L	Below background
Mercury (mg/L)	3/ 14	0.0002	2/ 14	0.0001	0.0005	0.0001	D	> 5% detect above background
Nickel (mg/L)	1/ 14	0.011	0/ 14	0.0046	0.0046	0.0025	D	Below background
Potassium (mg/L)	14/ 14	3.5	12/ 14	2.11	23.2	8.699	L	Essential element
Sodium (mg/L)	14/ 14	7.6	0/ 14	0.654	6.79	4.472	N	Essential element
Vanadium (mg/L)	4/ 14	0.013	1/ 14	0.004	0.0286	0.0043	D	1 detect > UTL. Turbidity 100× mean turbidity. See text.

Table D.85 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
Zinc (mg/L)	2/ 14	0.066	0/ 14	0.0069	0.0474	0.0113	D	Below background
<i>Organics</i>								
1,1,1-Trichloroethane (µg/L)	12/ 13	.	.	2	11	6.577	N	No background available
1,1,2-Trichloroethane (µg/L)	5/ 13	.	.	1	2	2.077	D	No background available
1,1-Dichloroethane (µg/L)	12/ 13	.	.	9	27	17.81	N	No background available
1,1-Dichloroethene (µg/L)	11/ 13	.	.	5	11	6.231	N	No background available
1,2-Dichloroethane (µg/L)	10/ 13	.	.	2	4	2.962	X	No background available
1,2-Dichloroethene (µg/L)	12/ 13	.	.	4	410	223.6	N	No background available
Acetone (µg/L)	2/ 13	.	.	7	9	3.346	D	No background available
Benzene (µg/L)	2/ 13	.	.	1	3	2.423	D	No background available
Chloroethane (µg/L)	1/ 13	.	.	93	93	9.654	D	No background available
Chloroform (µg/L)	11/ 13	.	.	1	3	2.308	X	No background available
Methylene chloride (µg/L)	4/ 13	.	.	1	3	2.538	D	No background available
Tetrachloroethene (µg/L)	11/ 13	.	.	26	58	30.46	X	No background available
Trichloroethene (µg/L)	11/ 13	.	.	13	29	16.15	X	No background available
Trichlorofluoromethane (µg/L)	1/ 13	.	.	1	1	2.769	D	No background available
Vinyl chloride (µg/L)	11/ 13	.	.	3	21	8	L	No background available
<i>Radioactivity</i>								
Alpha Activity (pCi/L)	12/ 12	2.11	12/ 12	28	135	54.87	L	> 5% detect above background
Beta Activity (pCi/L)	11/ 11	3.75	11/ 11	20.3	66	37.05	L	> 5% detect above background
Potassium-40 (pCi/L)	1/ 2	.	.	130	130	82	N	No background data available
Thallium-208 (pCi/L)	1/ 2	.	.	21	21	13.1	N	No background data available
Thorium-228 (pCi/L)	2/ 5	.	.	0.157	0.48	0.1714	D	No background data available

Table D.85 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
Thorium-230 (pCi/L)	4/ 5	.		0.209	0.57	0.318	N	No background data available
Thorium-232 (pCi/L)	2/ 5	.		0.173	0.32	0.1326	D	No background data available
Uranium-233/234 (pCi/L)	14/ 14	.		6.6	56.0	15.99	L	No background data available
Uranium-235 (pCi/L)	3/ 14	.		1.07	6.2	1.013	D	No background data available
Uranium-238 (pCi/L)	14/ 14	.		21.5	440	63.31	X	No background data available

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For surface water, background criteria have been established using data from NT-13 published in the GWQRs (e.g., HSW 1995). Only results for unfiltered samples were used.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

^e No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCW. See text for further details.

^f No background value for cyanide was available from NT-13. cyanide was not detected in any samples from NT-5 and it was, therefore, assumed that the background value for cyanide is < the detection limit.

**Table D.86. Summary of chemical and radionuclide results for filtered samples,
NT-8 surface water**

Analyte ^a	Freq of detect	Min detect	Max detect	Average result
Aluminum (mg/L)	6/ 14	0.028	0.338	0.062
Antimony (mg/L)	3/ 14	0.002	0.0026	0.0011
Arsenic (mg/L)	2/ 14	0.0018	0.0021	0.0012
Barium (mg/L)	13/ 14	0.0222	0.0991	0.0658
Beryllium (mg/L)	1/ 14	0.0072	0.0072	0.0007
Calcium (mg/L)	14/ 14	22.8	57.7	41.9
Copper (mg/L)	2/ 14	0.0031	0.0052	0.0021
Iron (mg/L)	7/ 14	0.0124	1.24	0.1599
Lithium (mg/L)	7/ 7	0.134	0.186	0.154
Magnesium (mg/L)	14/ 14	2.81	5.95	4.74
Manganese (mg/L)	14/ 14	0.0012	0.298	0.0647
Mercury (mg/L)	3/ 14	0.0002	0.0013	0.0002
Potassium (mg/L)	14/ 14	2.04	22.0	8.42
Selenium (mg/L)	2/ 14	0.0028	0.003	0.0015
Sodium (mg/L)	14/ 14	0.486	6.65	4.393
Zinc (mg/L)	2/ 14	0.012	0.0451	0.0067
Alpha activity (pCi/L)	12/ 12	26.1	59.7	42.4
Beta activity (pCi/L)	11/ 11	17.3	39.3	29.3
Uranium-233/234 (pCi/L)	12/ 12	4.5	28.9	14.4
Uranium-235 (pCi/L)	3/ 12	1.07	1.72	0.77
Uranium-238 (pCi/L)	12/ 12	21.3	51.3	34.5

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

Table D.87. Summary of miscellaneous parameters for surface water aggregates in the BCBG FA

Parameter	Min	Max	Mean	n	Min	Max	Mean	n	Min	Max	Mean	n
	<i>NT-6</i>				<i>NT-7</i>				<i>NT-8</i>			
Alkalinity (HCO ₃) (mg/L)	16.3	145	83.0	21	61.5	235	135.8	21	55.8	144	118.7	12
Specific conductance (μmhos/cm)	50	310	176	23	132	500	361	22	110	350	270	13
Total dissolved solids (mg/L)	99	209	151	21	138	422	234	21	116	222	189	12
pH	6.7	8	7.5	23	7.1	7.9	7.5	22	7	8.2	7.7	13
Total suspended solids (mg/L)	5.6	420	54.1	21	2	948	104	21	10	232	44	12
Temperature (°C)	1.4	23.1	16.4	23	3	27	19	22	4.4	21.5	17.7	13
Turbidity (NTU)	2.5	120	23.2	21	0.65	350	55.3	21	1.3	192	30.6	12

Table D.88. Results of analysis for organic compounds in water from Seep 1 at BCBG

Parameter ($\mu\text{g/L}$)	Seep 1	
1,1,1-Trichloroethane	50	
1,1,2-Trichloroethane	3	J
1,1-Dichloroethane	400	
1,1-Dichloroethene	13	
1,2,4-Trichlorobenzene	7	J
1,2-Dichloroethane	7	J
1,3-Dichlorobenzene	10	U
1,4-Dichlorobenzene	10	U
2,4-Dimethylphenol	210	
2,4-Dinitrotoluene	1	J
2,6-Dinitrotoluene	2	J
4-Bromophenyl phenyl ether	1	J
4-Chloro-3-methylphenol	10	U
Benzene	19	
Benzidine	5	J
Bis(2-ethylhexyl)phthalate	33	B
Chloroethane	10	U
Chloroform	4	J
Di-n-butylphthalate	2	J
Di-n-octylphthlate	4	J
Dibromochloromethane	4	J
Diethylphthalate	10	U
Ethylbenzene	10	U
Methylene chloride	10	U
Naphthalene	10	U
Pentachlorophenol	6	J
Phenol	1	J
Tetrachloroethene	10	U
Toluene	8	J
Trichloroethene	2	J
Vinyl chloride	990	
trans-1,2-Dichloroethene	22	

Table D.89. Chemical analysis of water from leachate collection systems in Seeps 2, 3, and 4 at BCBG

Parameter	Seeps 3 & 4 3/9/93	Seeps 3 & 4 3/18/93	C-West Toe 3/9/93	C-West Toe 3/18/93	Seep 2 3/18/93	Seep 2 3/9/93
<i>Inorganics (mg/l)</i>						
Aluminum	17.0	6.	0.3	2. U	2. U	159.
Arsenic	0.2 U	2. U	0.2 U	2. U	2. U	0.8
Barium	2.22	1.28	0.524	0.38	0.11	2.89
Beryllium	0.033	0.02	0.003	0.02 U	0.02 U	1.11
Boron	126	121.	63.3	56.0	12.1	17.5
Cadmium	0.02 U	0.2 U	0.02 U	0.2 U	0.2 U	0.02 U
Calcium	67.4	67.	116.	120.	92.	531
Cerium	0.08	0.8 U	0.08 U	0.8 U	0.8 U	1.22
Chromium	0.03 U	0.3 U	0.03 U	0.3 U	0.3 U	0.28
Cobalt	0.06	0.1 U	0.02	0.1 U	0.1 U	0.21
Copper	0.04	0.3 U	0.03 U	0.3 U	0.3 U	0.64
Gallium	0.09 U	0.9 U	0.09 U	0.9 U	0.9 U	0.09 U
Iron	350.	107.	84.1	15.	3. U	1290.
Lead	0.1 U	1. U	0.1 U	01. U	01. U	0.8
Lithium	32.4	31.7	14.8	12.8	9.0	11.9
Magnesium	23.1	23.	21.2	21.	15.	50.9
Manganese	13.5	10.6	10.1	8.83	0.27	18.7
Mercury	0.0002 U	0.0002 U	0.0003	0.0002 U	0.0002 U	0.0002 U
Molybdenum	0.14	0.3 U	0.03	0.3 U	0.3 U	0.07
Nickel	0.05	0.4 U	0.04 U	0.4 U	0.4 U	0.36
Niobium	0.05 U	0.5 U	0.05 U	0.5 U	0.5 U	0.05 U
PCB	0.0026	0.0095	0.018	0.0049	0.0005 U	0.0005 U

Table D.89 (continued)

Parameter	Seeps 3 & 4 3/9/93	Seeps 3 & 4 3/18/93	C-West Toe 3/9/93	C-West Toe 3/18/93	Seep 2 3/18/93	Seep 2 3/9/93
Phosphorus	10.9	4.	1.1	3. U	3. U	9.1
Potassium	18.	30. U	10.	30. U	30. U	18.
Selenium	0.5 U		0.5 U			0.5 U
Silver	0.03 U	0.3 U	0.03 U	0.3 U	0.3 U	0.03 U
Sodium	34.0	34.	21.4	19.	4.	5.1
Strontium	0.364	0.34	0.362	0.36	0.41	0.954
Thallium	0.2 U	2. U	0.2 U	2. U	2. U	0.2 U
Thorium	0.05 U	0.5 U	0.05 U	0.5 U	0.5 U	0.11
Titanium	0.17	0.6 U	0.06 U		0.6 U	1.02
Uranium	0.010	0.010	0.034	0.044	1.45	1.49
Vanadium	0.06	0.2 U	0.02 U	0.2 U	0.2 U	0.89
Zinc	0.27	0.5 U	0.05 U	0.5 U	0.5 U	3.20
Zirconium	0.02 UB19	0.2 U	0.02 U	0.2 U	0.2 U	0.16
<i>Organics (µg/L)</i>						
1,1,1-Trichloroethane	120	62	3 J	20	1 J	5 J
1,1,2-Trichloroethane	1 J	16	.010 U	.010 U	.010 U	.010 U
1,1-Dichloroethane	410	170	68	130	31	81
1,1-Dichloroethene	30	15	.010 U	8 J	.010 U	.010 U
1,2-Dichloroethane	8 J	6 J	2 J	7 J	1 J	2 J
Benzene	53	.010 U	3 J	39	.010 U	4 J
Chloroethane	1770	700	890	580	160	640
Ethylbenzene	2 J	.010 U	.010 U	.010 U	.010 U	.010 U
Methylene chloride	33	15	47	8 J	20	56

Table D.89 (continued)

Parameter	Seeps 3 & 4 3/9/93	Seeps 3 & 4 3/18/93	C-West Toe 3/9/93	C-West Toe 3/18/93	Seep 2 3/18/93	Seep 2 3/9/93
Tetrachloroethene	9 J	.010 U	.010 U	8 J	.010 U	.010 U
Toluene	20	.010 U	5 J	2 J	1 J	7 J
Trichloroethene	6 J	.010 U	.010 U	23	.010 U	.010 U
Vinyl chloride	180	84	9 J	56	3 J	10 J
trans-1,2-Dichloroethene	8 J	3 J	1 J	2 J	10 U	2 J
1,2,4-Trichlorobenzene	10 U		5 J			10 U
1,4-Dichlorobenzene	17		11			10 U
2,4-Dimethylphenol	30 U		52			6 J
Bis(2-ethylhexyl)phthalate	6 J		7 J			10 U
Naphthalene	10 U		3 J			10 U
<i>Radionuclides (pCi/L)</i>						
Alpha activity	38 ± 17	45 ± 21	49 ± 19	180 ± 86	650 ± 80	730 ± 96
Beta activity	67 ± 13	67 ± 14	57 ± 12	150 ± 48	140 ± 20	260 ± 33
Gross Gamma	67 ± 16	41 ± 91	47 ± 16	270 ± 27	52 ± 45	80 ± 16
Uranium-235 (wt %)	0.40	0.36	0.45	0.44	0.22	0.23
<i>Other (mg/L)</i>						
Oil and Grease	15	10	3.4	2 U	2 U	2.5
Total Organic Carbon	78	100	100	110	37	76
Total Suspended Solids	340	62	100	15	5 U	36

Table D.90. Results of 1995 radiological analysis of groundwater at Seep 1, Seep 2, and C-West Toe in BCBG

Analyte	Result	Detect. Limit	Error	Qual.	Result	Detect. Limit	Error	Qual.
<i>Seep 1</i>								
		<i>Filtered</i>				<i>Unfiltered</i>		
Alpha activity	8.4	7.8	5.2	J	10	8	5.5	J
Beta activity					13	8.3	5.8	J
Cesium-137					6.1	3.3	4.1	J
Neptunium-237	0.56	0.23	0.29	J	0.75	0.097	0.33	J
Technetium-99					23	6.5	5.4	J
Thorium-230	0.54	0.24	0.27	J	0.32	0.31	0.25	J
Thorium-232					0.11	0.1	0.13	R
Total radium alpha	0.48	0.47	0.37	J				
Tritium					-95	430	150	r
Uranium-234	4.9	0.093	1.1	=	6.3	0.19	1.2	=
Uranium-235	0.26	0.12	0.21	J				
Uranium-238	4.7	0.28	1	=	4.7	0.23	0.96	=
<i>Seep 2</i>								
		<i>Filtered</i>				<i>Unfiltered</i>		
Alpha activity	320	8.7	44	J	330	8.8	45	J
Beta activity	190	8.4	27	J	230	8.4	32	J
Cesium-137	4.4	4.2	2.4	J				
Neptunium-237	2.2	0.1	0.59	J	0.85	0.28	0.39	J
Technetium-99	36	6	5.9	J	110	6.5	12	J
Thorium-230	0.34	0.1	0.23	J				
Total rad sr	6.3	5.9	1.4	J				
Tritium	4200	430	480	j	4200	430	480	j
Uranium-234	50	0.59	10	J	58	0.36	16	R
Uranium-235	5.5	0.24	1.7	J	3.9	0.45	1.9	R
Uranium-238	310	0.59	61	J	350	0.37	90	R
<i>C-West Toe</i>								
		<i>Filtered</i>				<i>Unfiltered</i>		
Alpha activity	13	9	6.4	J				
Beta activity	26	8.4	7.2	J	22	8.4	6.8	J
Neptunium-237	0.41	0.22	0.24	J	0.52	0.078	0.25	J

Table D.90 (continued)

Analyte	Result	Detect. Limit	Error	Qual.	Result	Detect. Limit	Error	Qual.
Technetium-99	9	6	4.2	J	11	6	4.5	J
Thorium-228	0.18	0.081	0.15	J				
Thorium-230	0.24	0.08	0.17	J				
Total radium alpha					0.65	0.48	0.41	J
Tritium	2400	430	310	j	2400	430	310	j
Uranium-234	5.3	0.38	1.3	=	3.9	0.12	1	=
Uranium-235					0.34	0.15	0.28	J
Uranium-238	6.7	0.38	1.5	=	6.1	0.3	1.4	=

Table D.91. Summary of selection of site-related chemicals and radionuclides, BCBG groundwater aggregate

Analyte ^a	Freq. of detect	Freq. of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Comment
<i>Inorganics</i>							
Aluminum (mg/L)	405/ 496	59/ 59	1	0.0200	27.	0.417	<= 5% of wells with median > UTL
Antimony (mg/L)	5/ 517	4/ 61	1	0.0510	0.1600	0.026	<= 5% of wells with median > UTL
Arsenic (mg/L)	1/ 75	1/ 16	0	0.0100	0.0100	0.003	No wells with median > UTL
Barium (mg/L)	524/ 524	61/ 61	4	0.0047	1.6000	0.188	> 5% of wells with median > UTL
Beryllium (mg/L)	57/ 512	30/ 61	0	0.0003	0.0038	0.0002	No wells with median > UTL
Boron (mg/L)	470/ 500	57/ 57	10	0.0040	31.	0.796	> 5% of wells with median > UTL
Cadmium (mg/L)	49/ 574	18/ 64	4	0.0020	0.0520	0.0014	> 5% of wells with median > UTL
Calcium (mg/L)	624/ 624	65/ 65	1	0.6000	190.	33.7	Essential element
Chromium (mg/L)	103/ 592	36/ 65	1	0.0100	0.5100	0.008	<= 5% of wells with median > UTL
Cobalt (mg/L)	39/ 517	17/ 61	1	0.0050	0.0990	0.004	<= 5% of wells with median > UTL
Copper (mg/L)	256/ 510	56/ 60	4	0.0040	6.6000	0.008	> 5% of wells with median > UTL
Iron (mg/L)	486/ 492	57/ 57	1	0.0047	43.	1.38	Essential element
Lead (mg/L)	227/ 603	58/ 64	9	0.0040	0.7000	0.0057	> 5% of wells with median > UTL
Lithium (mg/L)	36/ 37	16/ 16	NA ^d	0.0019	0.9900	0.107	4/16 wells with median > WOE UTL ^d
Magnesium (mg/L)	617/ 617	65/ 65	3	0.0410	34.	6.54	Essential element
Manganese (mg/L)	516/ 525	60/ 60	3	0.0012	19.	0.59	<= 5% of wells with median > UTL
Mercury (mg/L)	14/ 518	12/ 60	0	0.0002	0.0007	0.0001	No wells with median > UTL
Molybdenum (mg/L)	7/ 507	7/ 59	0	0.0110	0.0710	0.005	No wells with median > UTL
Nickel (mg/L)	114/ 517	41/ 61	2	0.0100	1.7000	0.016	<= 5% of wells with median > UTL
Niobium (mg/L)	9/ 37	8/ 16	NA ^d	0.0077	0.0170	0.005	8/16 wells with detects ^d
Potassium (mg/L)	585/ 614	65/ 65	0	0.6100	31.	2.9052	Essential element
Selenium (mg/L)	0/ 105	0/ 20	0	0.	0.	0.003	No detects
Silicon (mg/L)	218/ 218	56/ 56	1	0.0760	30.	7.758	<= 5% of wells with median > UTL
Silver (mg/L)	0/ 87	0/ 20	0	0.	0.	0.005	No wells with median > UTL
Sodium (mg/L)	625/ 625	65/ 65	1	1.1000	2,100.	105.	Essential element
Strontium (mg/L)	492/ 492	57/ 57	1	0.0110	1.5000	0.1958	<= 5% of wells with median > UTL

Table D.91 (continued)

Analyte ^a	Freq. of detect	Freq. of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Comment
Thallium (mg/L)	0/ 50	0/ 9	0	0.	0.	0.005	No detects
Thorium (mg/L)	0/ 517	0/ 61	0	0.	0.	0.1	No detects
Titanium (mg/L)	25/ 37	12/ 16	NA ^d	0.0037	0.1300	0.0198	No wells with median > WOE UTL ^d
Total uranium (fluorometric) (mg/L)	156/ 613	54/ 65	0	0.001	0.174	0.001	No wells with median > UTL
Vanadium (mg/L)	35/ 517	14/ 61	2	0.0050	0.0400	0.0027	<= 5% of wells with median > UTL
Zinc (mg/L)	465/ 505	60/ 60	4	0.0012	1.6000	0.017	> 5% of wells with median > UTL
Zirconium (mg/L)	3/ 37	3/ 16	0	0.0066	0.0200	0.002	No wells with median > UTL
<i>Common Anions</i>							
Chloride (mg/L)	539/ 625	65/ 65	7	0.8000	3.910.	104.	> 5% of wells with median > UTL
Fluoride (mg/L)	380/ 534	57/ 61	3	0.1000	14.	0.814	<= 5% of wells with median > UTL
Nitrate (mg/L)	69/ 583	26/ 65	0	0.1100	5.1	0.153	No wells with median > UTL
Sulfate (mg/L)	599/ 616	65/ 65	3	1.	344.	19.74	<= 5% of wells with median > UTL
<i>Organics</i>							
1,1,1-Trichloroethane (µg/L)	89/ 655	18/ 65		0.4000	13,000.	93.0	> 5% of wells with detects
1,1,2-Trichloroethane (µg/L)	14/ 644	4/ 65		2.	300.	6.2	> 5% of wells with detects
1,1,2,2-Tetrachloroethane (µg/L)	2/ 643	2/ 65		5	24	2.8	<= 5% of wells with detects
1,1-Dichloroethane (µg/L)	148/ 655	23/ 65		0.6000	7,800.	133.4	> 5% of wells with detects
1,1-Dichloroethene (µg/L)	69/ 654	12/ 65		1.	13,000.	82.4	> 5% of wells with detects
1,2-Dichloroethane (µg/L)	47/ 645	10/ 65		0.8000	102.	5.0	> 5% of wells with detects
1,2-Dichloroethene (µg/L)	77/ 588	15/ 63		0.7000	5,400.	157.6	> 5% of wells with detects
2-Butanone (µg/L)	31/ 645	15/ 65		2.	3,600.	5.8	> 5% of wells with detects
2-Hexanone (µg/L)	12/ 645	9/ 65		1.	220.	5.6	> 5% of wells with detects
4-Methyl-2-pentanone (µg/L)	20/ 647	16/ 65		1.	320.	5.5	> 5% of wells with detects
Acetone (µg/L)	72/ 645	42/ 65		1.	850.	5.8	> 5% of wells with detects
Benzene (µg/L)	68/ 647	21/ 65		0.7000	420.	7.9	> 5% of wells with detects
Bromodichloromethane (µg/L)	1/ 642	1/ 65		2	2	2.8	<= 5% of wells with detects

Table D.91 (continued)

Analyte ^a	Freq. of detect	Freq. of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Comment
Bromoform (µg/L)	6/ 643	1/ 65		2	20	2.8	<= 5% of wells with detects
Carbon disulfide (µg/L)	7/ 643	5/ 65		0.4000	36.	2.8	> 5% of wells with detects
Carbon tetrachloride (µg/L)	8/ 643	6/ 65		1.	190.	2.8	> 5% of wells with detects
Chlorobenzene (µg/L)	2/ 642	2/ 65		0.7	1	2.8	<= 5% of wells with detects
Chloroethane (µg/L)	38/ 644	10/ 65		1.	740.	17.2	> 5% of wells with detects
Chloroform (µg/L)	52/ 647	17/ 65		0.3000	1,700.	3.2	> 5% of wells with detects
Chloromethane (µg/L)	2/ 643	2/ 65		2	8	5.5	<= 5% of wells with detects
cis-1,3-Dichloropropene (µg/L)	2/ 642	2/ 65		1	4	2.8	<= 5% of wells with detects
Dimethylbenzene (µg/L)	33/ 645	15/ 65		0.8000	130.	3.4	> 5% of wells with detects
Ethylbenzene (µg/L)	18/ 643	14/ 65		1.	33.	2.9	> 5% of wells with detects
Methylene chloride (µg/L)	83/ 646	30/ 65		0.8000	490.	4.8	> 5% of wells with detects
Phenols (mg/L)	22/ 90	12/ 23		0.0010	0.2000	0.009	> 5% of wells with detects
Styrene (µg/L)	1/ 643	1/ 65		12	12	2.8	<= 5% of wells with detects
Tetrachloroethene (µg/L)	190/ 660	28/ 65		0.5000	63,000.	453.2	> 5% of wells with detects
Toluene (µg/L)	50/ 645	16/ 65		0.3000	670.	3.9	> 5% of wells with detects
Trans-1,2-Dichloroethene (µg/L)	38/ 64	9/ 14		4,000	50,000.	1049.	> 5% of wells with detects
trans-1,3-Dichloropropene (µg/L)	1/ 642	1/ 65		15	15	2.8	<= 5% of wells with detects
Trichloroethene (µg/L)	159/ 659	27/ 65		0.6000	24,000.	286.4	> 5% of wells with detects
Vinyl acetate (µg/L)	5/ 643	3/ 65		1	6	5.5	<= 5% of wells with detects
Vinyl chloride (µg/L)	80/ 652	14/ 65		0.8000	3,400.	65.8	> 5% of wells with detects
Radioactivity							
Alpha activity (pCi/L)	41/ 418	18/ 52		4.88	330	7.7	> 5% detects
Americium-241 (pCi/L)	. / 10	. / 10		.	.	0.01	No detects
Beta activity (pCi/L)	28/ 418	18/ 52		11.6	300	7.55	> 5% detects
Cesium-137 (pCi/L)	4/ 10	4/ 10		6.1	11	4.59	> 5% detects
Neptunium-237 (pCi/L)	3/ 10	3/ 10		0.52	0.85	0.23	> 5% detects
Plutonium-238 (pCi/L)	. / 9	. / 9		.	.	0.07	No detects

Table D.91 (continued)

Analyte ^a	Freq. of detect	Freq. of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Comment
Plutonium-239/240 (pCi/L)	. / 10	. / 10		.	.	0.01	No detects
Radium-228 (pCi/L)	. / 9	. / 9		.	.	0.12	No detects
Technetium-99 (pCi/L)	4/ 10	4/ 10		11	110	16.55	> 5% detects
Thorium-228 (pCi/L)	2/ 9	2/ 9		0.38	0.96	0.25	> 5% detects
Thorium-230 (pCi/L)	6/ 9	6/ 9		0.28	0.51	0.34	> 5% detects
Thorium-232 (pCi/L)	2/ 9	2/ 9		0.27	0.38	0.09	> 5% detects
Total radioactive strontium (pCi/L)	. / 4	. / 4		.	.	1.01	No detects
Tritium (pCi/L)	3/ 10	3/ 10		620	4200	781	> 5% detects
Uranium-234 (pCi/L)	9/ 10	9/ 10		0.15	58	7.19	> 5% detects
Uranium-235 (pCi/L)	3/ 9	3/ 9		0.15	3.9	0.49	> 5% detects
Uranium-238 (pCi/L)	6/ 10	6/ 10		0.46	350	36.30	> 5% detects

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established by *Determination of Reference Concentrations for Inorganic Analytes in Groundwater at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (Energy Systems 1996). The background value for an analyte varies depending upon the groundwater cluster that a well has been assigned to so no single background value applies to each analyte. Refer to Sect. C.2 and the above referenced document for a discussion of the approach to evaluating groundwater background, the groundwater background values, and the well cluster assignments.

^c The mean of the medians is the arithmetic mean of the median concentration of an analyte for each well. In calculating the mean of the medians it was assumed that non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d No background value was available from the above referenced source. Values for lithium and titanium UTLs were calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995). The values are 0.071 mg/L for lithium and 0.12 mg/L for titanium. See text for further details. Niobium and Thallium were not detected in 13 groundwater wells that were previously considered as reasonable background wells and the background UTL values was, therefore, assumed to be less than the detection limit and detected values are considered as above background.

**Table D.92. Summary of chemical and radionuclide results for filtered samples,
BCBG groundwater aggregate**

Analyte ^a	Freq of detect	Freq of wells w. detects	Min detect	Max detect	Mean of the medians ^b
Aluminum (mg/L)	255/ 523	57/ 61	0.02	5.3	0.03
Antimony (mg/L)	6/ 546	6/ 63	0.051	0.24	0.029
Arsenic (mg/L)	2/ 80	2/ 18	0.005	0.012	0.003
Barium (mg/L)	554/ 555	63/ 63	0.0012	1.4	0.1686
Beryllium (mg/L)	33/ 542	27/ 63	0.0003	0.0025	0.0002
Boron (mg/L)	500/ 530	59/ 59	0.0035	29.0	0.7546
Cadmium (mg/L)	43/ 615	15/ 64	0.002	0.043	0.001
Calcium (mg/L)	665/ 665	65/ 65	0.51	190.0	32.84
Chromium (mg/L)	7/ 630	6/ 65	0.01	0.048	0.0050
Cobalt (mg/L)	10/ 546	7/ 63	0.005	0.07	0.004
Copper (mg/L)	197/ 538	50/ 62	0.004	0.15	0.005
Iron (mg/L)	419/ 519	57/ 59	0.0041	6.7	0.1565
Lead (mg/L)	75/ 641	37/ 64	0.004	0.049	0.002
Lithium (mg/L)	35/ 39	17/ 18	0.0032	0.96	0.0985
Magnesium (mg/L)	653/ 653	65/ 65	0.035	35.0	6.3
Manganese (mg/L)	521/ 551	62/ 62	0.001	18.0	0.558
Mercury (mg/L)	15/ 555	14/ 62	0.0002	0.0007	0.0001
Molybdenum (mg/L)	12/ 531	7/ 61	0.01	0.054	0.006
Nickel (mg/L)	93545	41/ 63	0.01	0.7	0.02
Niobium (mg/L)	6/ 39	6/ 18	0.0076	0.019	0.0051
Potassium (mg/L)	599/ 654	65/ 65	0.61	34.0	2.61
Selenium (mg/L)	. / 114	. / 20	.	.	0.0025
Silicon (mg/L)	231/ 231	58/ 58	0.12	19.0	7.38
Silver (mg/L)	. / 96	. / 20	.	.	0.0050
Sodium (mg/L)	664/ 664	65/ 65	1.1	2000	102.9
Strontium (mg/L)	514/ 514	59/ 59	0.0073	1.5	0.1911
Thallium (mg/L)	. / 50	. / 9	.	.	0.0050
Thorium (mg/L)	. / 546	. / 63	.	.	0.1000

Table D.92 (continued)

Analyte ^a	Freq of detect	Freq of wells w. detects	Min detect	Max detect	Mean of the medians ^b
Titanium (mg/L)	11/ 39	9/ 18	0.0038	0.07	0.0028
Total uranium (fluorometric) (mg/L)	132/ 654	45/ 65	0.001	0.07	0.001
Vanadium (mg/L)	3/ 546	1/ 63	0.0058	0.028	0.0025
Zinc (mg/L)	442/ 530	60/ 62	0.0013	0.44	0.0107
Zirconium (mg/L)	1/ 39	1/ 18	0.0083	0.0083	0.0024

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b The mean of the medians is the arithmetic mean of the median concentration of an analyte for each well. In calculating the mean of the medians it was assumed that non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

Table D.93. Summary of miscellaneous parameters for the BCBG groundwater aggregate

Parameter	Min	Max	Mean	n ^a
Alkalinity (mg/L)	7	410	171	6
Alkalinity (CO ₃) (mg/L)	.	678	28	834
Alkalinity (HCO ₃) (mg/L)	.	749	167	834
Specific Conductance (μmhos/cm)	25	14800	938	2741
Dissolved oxygen (mg/L)	0.1	19.1	3.6	852
Total dissolved solids (mg/L)	18	11622	534	793
pH	3	12.6	7.6	2746
Redox (eV)	-591	413	131	845
Total suspended solids (mg/L)	.	13200	132	846
Temperature (°C)	4.5	32	16.1	853
Total coliform	.	30	1	106
Total organic carbon (mg/L)	.	36	3	478
Total organic chloride (mg/L)	10	6010	435	231
Turbidity (NTU)	0.15	10000	67	699

^a n = frequency of analysis.

Table D.94. Summary of pH and alkalinity results for wells in the BCBG FA

Well	pH				Alkalinity (HCO ₃) (mg/L)				Alkalinity (CO ₃) (mg/L)			
	min	max	mean	n ^a	min	max	mean	n ^a	min	max	mean	n ^a
GW-014	6.3	8.3	7.1	35	292	383	349	6	.	.	.	6
GW-018	5.8	6.8	6.3	4	18	19	19	2	.	2	2	2
GW-021	6.8	7.7	7.2	20	303	333	314	3	.	.	.	3
GW-027	5.7	7.4	6.5	30	232	292	270	5	.	.	.	5
GW-037	6.3	8.2	6.9	10	166	172	167	5	.	2	1	5
GW-039	6.6	8	7.1	40	227	295	257	7	.	.	.	7
GW-040	5.5	8.4	6.4	91	18	44	35	25	.	.	.	25
GW-042	3	7.8	6.1	95	6	32	25	27	.	2	1	27
GW-046	4.9	6.6	5.5	50	25	50	40	9	.	.	.	9
GW-047	5.1	8.4	6.4	73	21	43	30	16	.	.	.	16
GW-068	6	8.4	7.5	40	134	164	148	7	.	.	.	7
GW-069	7.4	9.2	8.6	40	110	147	123	20	.	20	10	20
GW-071	9.9	11.5	10.5	50	93	749	409	12	224	678	398	12
GW-072	9.4	10.9	9.9	50	31	243	148	12	59	176	97	12
GW-077	6	8	7.3	10	132	148	141	5	.	.	.	5
GW-078	6	8	7.3	10	130	136	133	5	.	.	.	5
GW-079	5.9	8.4	7.6	20	100	196	113	10	.	2	1	10
GW-080	3.1	8.4	6.1	30	20	43	30	15	.	2	1	15
GW-082	5	8.6	7.4	95	127	208	167	27	.	2	1	27
GW-083	5.3	8.4	7.4	20	111	181	120	10	.	2	1	10
GW-089	5.9	7.7	7.1	20	139	180	156	10	.	2	1	10
GW-117	7.1	10.6	9.6	84	142	732	555	22	78	494	160	22
GW-118	7.9	12.6	9.7	94	1	570	176	27	12	333	141	27
GW-119	8.2	10.3	9.4	84	233	549	356	22	20	214	123	22
GW-126	8.4	9.1	8.8	65	90	375	302	12	15	40	27	12
GW-162	5.3	8.6	7.6	87	93	125	111	23	.	4	1	23
GW-163	5.9	9.7	9.1	25	126	179	151	7	.	40	21	7
GW-164	6	8	7.6	20	174	202	182	6	.	2	1	6
GW-237	6.5	6.6	6.6	5	100	100	100	1	.	.	.	1
GW-242	6.1	7.3	6.6	50	107	139	120	10	.	.	.	10
GW-248	5.8	7.9	7.2	40	185	238	205	8	.	.	.	8
GW-249	5.5	7.4	6.1	25	44	77	56	5	.	.	.	5
GW-250	6.7	7.9	7.3	50	1	354	254	10	.	.	.	10

Table D.94 (continued)

Well	pH				Alkalinity (HCO ₃) (mg/L)				Alkalinity (CO ₃) (mg/L)			
	min	max	mean	n ^a	min	max	mean	n ^a	min	max	mean	n ^a
GW-257	5.6	7.7	6.5	25	94	128	110	5	.	.	.	5
GW-258	5.7	8.6	7.5	40	104	136	119	8	.	.	.	8
GW-259	5.4	7.9	6.6	40	63	91	76	8	.	.	.	8
GW-286	6.3	8.5	7.6	92	117	151	134	24	.	.	.	24
GW-287	5.9	8.1	7.0	100	66	137	105	28	.	.	.	28
GW-288	6.2	7.8	6.9	50	81	134	94	10	.	.	.	10
GW-289	5.8	6.9	6.2	50	36	73	48	10	.	.	.	10
GW-290	6.5	8.6	7.6	44	128	232	191	10	.	11	2	10
GW-291	6.1	7.6	6.8	44	157	201	181	10	.	.	.	10
GW-370	5.3	8.1	6.8	75	58	120	96	27	.	.	.	27
GW-371	6.2	7.9	7.2	55	251	304	286	17	.	.	.	17
GW-372	5.8	8	7.3	77	157	188	179	28	.	2	1	28
GW-373	6.3	9.6	8.9	73	170	490	196	26	.	36	24	26
GW-374	8.5	9.4	9.0	35	398	427	408	7	25	68	46	7
GW-502	7.7	9.2	8.6	25	390	460	435	5	11	72	44	5
GW-622	5.9	7.7	7.0	25	141	182	164	11	.	.	.	11
GW-623	8.9	10.2	9.7	16	172	570	387	8	104	342	244	8
GW-624	6.9	7.9	7.2	10	173	262	218	5	.	.	.	5
GW-626	6.7	8.9	7.9	35	83	112	101	16	.	10	2	16
GW-627	8.6	9.8	9.0	47	447	541	480	22	.	86	68	22
GW-629	8.8	9.6	9.1	10	371	400	390	5	72	96	85	5
GW-639	8.9	9.4	9.2	26	320	352	342	13	58	102	73	13
GW-640	5.4	7.3	6.3	26	37	52	46	13	.	.	.	13
GW-641	4.7	6.5	5.6	26	10	22	17	13	.	.	.	13
GW-642	5.7	7.1	6.4	34	50	104	63	17	.	.	.	17
GW-643	3	7.2	5.8	24	10	82	24	12	.	.	.	12
GW-653	4.8	7.1	5.6	32	10	86	17	16	.	.	.	16
GW-654	6.7	7.8	7.4	32	94	132	116	16	.	.	.	16
GW-655	5.7	7.9	6.5	24	31	37	34	12	.	.	.	12
GW-705	7.6	9.4	8.8	15	248	298	272	7	.	50	29	7

^a n = frequency of analysis

Table D.95. Summary of selection of site-related chemicals and radionuclides, BCBG OU 1 groundwater aggregate

Analyte ^a	Freq. of detect	Freq. of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Avg ^c result	Comment
<i>Inorganics</i>							
Aluminum (mg/L)	6/ 6	6/ 6	5	2.1600	30.6000	14.1383	> 5% of wells with median > UTL
Antimony (mg/L)	0/ 6	0/ 6	0	0.	0.	0.0004	No detects
Arsenic (mg/L)	3/ 6	3/ 6	0	0.0034	0.0068	0.0030	< = 5% of wells with median > UTL
Barium (mg/L)	6/ 6	6/ 6	0	0.0846	0.6770	0.3273	< = 5% of wells with median > UTL
Beryllium (mg/L)	2/ 5	2/ 5	3	0.0012	0.0026	0.0010	> 5% of wells with median > UTL
Calcium (mg/L)	6/ 6	6/ 6	3	3.6400	135.	67.3567	Essential element
Cobalt (mg/L)	5/ 6	5/ 6	2	0.0034	0.0580	0.0207	> 5% of wells with median > UTL
Copper (mg/L)	2/ 6	2/ 6	3	0.0398	0.0534	0.0201	> 5% of wells with median > UTL
Iron (mg/L)	6/ 6	6/ 6	4	6.8800	51.8000	24.5583	Essential element
Lead (mg/L)	6/ 6	6/ 6	3	0.0036	0.0323	0.0148	> 5% of wells with median > UTL
Magnesium (mg/L)	6/ 6	6/ 6	0	1.9100	15.3000	9.5633	Essential element
Manganese (mg/L)	6/ 6	6/ 6	4	0.2260	5.6500	2.7925	> 5% of wells with median > UTL
Mercury (mg/L)	3/ 6	3/ 6	2	0.0003	0.0010	0.0004	> 5% of wells with median > UTL
Molybdenum (mg/L)	1/ 6	1/ 6	0	0.0069	0.0069	0.0027	< = 5% of wells with median > UTL
Nickel (mg/L)	6/ 6	6/ 6	4	0.0098	0.0965	0.0463	> 5% of wells with median > UTL
Potassium (mg/L)	6/ 6	6/ 6	2	3.1100	13.8000	6.0117	Essential element
Selenium (mg/L)	1/ 6	1/ 6	0	0.0034	0.0034	0.0016	< = 5% of wells with median > UTL
Sodium (mg/L)	6/ 6	6/ 6	0	1.4100	14.6000	7.0817	Essential element
Thallium (mg/L)	0/ 6	0/ 6	NA ^d	0.	0.	0.0009	No detects
Tin (mg/L)	0/ 6	0/ 6	0	0.	0.	0.0049	No detects
Vanadium (mg/L)	6/ 6	6/ 6	5	0.0039	0.0446	0.0203	> 5% of wells with median > UTL
Zinc (mg/L)	5/ 6	5/ 6	3	0.0081	0.1430	0.0553	> 5% of wells with median > UTL

Table D.95 (continued)

Analyte ^a	Freq. of detect	Freq. of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Avg ^c result	Comment
<i>Common Anions</i>							
Chloride (mg/L)	6/ 6	6/ 6	1	2.3000	38.	13.8833	> 5% of wells with median > UTL
Cyanide (mg/L)	1/ 6	1/ 6	NA ^d	0.0220	0.0220	0.0078	1/6 wells with detects ^d
Fluoride (mg/L)	2/ 6	2/ 6	0	0.0500	0.0700	0.0367	<= 5% of wells with median > UTL
Nitrate (µg/L)	3/ 6	3/ 6	0	0.1000	0.2500	0.1067	<= 5% of wells with median > UTL
Sulfate (mg/L)	6/ 6	6/ 6	0	2.6000	13.	6.5167	<= 5% of wells with median > UTL
<i>Organics</i>							
1,1,1-Trichloroethane (µg/L)	2/ 7	2/ 7		140.	2,200.	336.0714	> 5% of wells with detects
1,1,2-Trichloroethane (µg/L)	1/ 7	1/ 7		9.	9.	3.4286	> 5% of wells with detects
1,1-Dichloroethane (µg/L)	3/ 7	3/ 7		93.	820.	160.4286	> 5% of wells with detects
1,1-Dichloroethene (µg/L)	2/ 7	2/ 7		78.	1,700.	255.7857	> 5% of wells with detects
1,2-Dichloroethane (µg/L)	3/ 7	3/ 7		5.	300.	52.2857	> 5% of wells with detects
1,2-Dichloroethene (µg/L)	3/ 7	3/ 7		16.	2,000.	503.7143	> 5% of wells with detects
1,2-Dichloropropane (µg/L)	1/ 7	1/ 7		1.	1.	2.2857	1 detect < detection limit
Benzene (µg/L)	4/ 7	4/ 7		2.	1,000.	173.2143	> 5% of wells with detects
Chloroethane (µg/L)	2/ 7	2/ 7		13.	25.	9.	> 5% of wells with detects
Chloroform (µg/L)	2/ 7	2/ 7		13.	24.	7.0714	> 5% of wells with detects
Tetrachloroethene (µg/L)	4/ 7	4/ 7		3.	2,800.	454.3571	> 5% of wells with detects
Toluene (µg/L)	2/ 7	2/ 7		4.	5.	3.0714	> 5% of wells with detects
Trichloroethene (µg/L)	4/ 7	4/ 7		1.	3,200.	575.7857	> 5% of wells with detects
Trichlorotrifluoromethane (µg/L)	2/ 7	2/ 7		120.	1,600.	249.2857	> 5% of wells with detects
Vinyl chloride (µg/L)	3/ 7	3/ 7		5.	290.	72.1429	> 5% of wells with detects
Xylene, total (µg/L)	3/ 7	3/ 7		1	3	2.429	

Table D.95 (continued)

Analyte ^a	Freq. of detect	Freq. of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Avg ^c result	Comment
<i>Radionuclides</i>							
Alpha activity (pCi/L)	2/ 6	2/ 6		29.	280.	59.5000	> 5% of wells with detects
Beta activity (pCi/L)	4/ 6	4/ 6		22.	270.	69.3333	> 5% of wells with detects
Antimony-125 (pCi/L)	0/ 6	0/ 6		0.	0.	2.2333	No detects
Bismuth-212 (pCi/L)	0/ 6	0/ 6		0.	0.	18.	No detects
Cerium-144 (pCi/L)	0/ 6	0/ 6		0.	0.	9.0333	No detects
Cesium-134 (pCi/L)	0/ 6	0/ 6		0.	0.	0.7552	No detects
Cesium-137 (pCi/L)	0/ 6	0/ 6		0.	0.	3.67	No detects
Chromium-51 (pCi/L)	0/ 6	0/ 6		0.	0.	19.9333	No detects
Cobalt-57 (pCi/L)	0/ 6	0/ 6		0.	0.	0.8717	No detects
Cobalt-58 (pCi/L)	0/ 6	0/ 6		0.	0.	0.9667	No detects
Cobalt-60 (pCi/L)	0/ 6	0/ 6		0.	0.	5.6333	No detects
Iron-59 (pCi/L)	0/ 6	0/ 6		0.	0.	2.4167	No detects
Lead-212 (pCi/L)	0/ 6	0/ 6		0.	0.	9.4	No detects
Manganese-54 (pCi/L)	0/ 6	0/ 6		0.	0.	2.2667	No detects
Niobium-95 (pCi/L)	0/ 6	0/ 6		0.	0.	2.2333	No detects
Potassium-40 (pCi/L)	1/ 6	1/ 6		160.	160.	88.8333	> 5% of wells with detects
Ruthenium-106 (pCi/L)	0/ 6	0/ 6		0.	0.	10.3333	No detects
Sodium-22 (pCi/L)	0/ 6	0/ 6		0.	0.	0.4433	No detects
Strontium-90 (pCi/L)	0/ 6	0/ 6		0.	0.	0.0167	No detects
Technetium-99 (pCi/L)	0/ 6	0/ 6		0.	0.	3.	No detects
Thallium-208 (pCi/L)	0/ 6	0/ 6		0.	0.	7.5	No detects
Thorium-228 (pCi/L)	5/ 6	5/ 6		1.1000	2.	1.3750	> 5% of wells with detects
Thorium-230 (pCi/L)	1/ 6	1/ 6		1.2000	1.2000	0.7617	> 5% of wells with detects
Thorium-232 (pCi/L)	3/ 6	3/ 6		1.2000	1.4000	0.8067	> 5% of wells with detects

Table D.95 (continued)

Analyte ^a	Freq. of detect	Freq. of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Avg ^c result	Comment
Uranium-234 (pCi/L)	1/ 6	1/ 6		1.6000	1.6000	0.8683	> 5% of wells with detects
Uranium-235 (pCi/L)	0/ 6	0/ 6		0.	0.	0.0205	No detects
Uranium-238 (pCi/L)	3/ 6	3/ 6		1.100	1.600	0.945	> 5% of wells with detects
Zinc-65 (pCi/L)	0/ 6	0/ 6		0.	0.	2.95	No detects
Zirconium-95 (pCi/L)	0/ 6	0/ 6		0.	0.	0.8167	No detects

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established by *Determination of Reference Concentrations for Inorganic Analytes in Groundwater at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (Energy Systems 1996). The background value for an analyte varies depending upon the groundwater cluster that a well has been assigned to so no single background value applies to each analyte. Refer to Sect. C.2 and the above referenced document for a discussion of the approach to evaluating groundwater background, the groundwater background values, and the well cluster assignments.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d No background value was available from the above referenced source. Values for lithium and titanium UTLs were calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995). The values are 0.071 mg/L for lithium and 0.12 mg/L for titanium. See text for further details. Niobium and Thallium were not detected in 13 groundwater wells that were previously considered as reasonable background wells and the background UTL values was, therefore, assumed to be less than the detection limit and detected values are considered as above background.

Table D.96. Distribution of habitat types in the BCBG^a

Habitat type	BG-A group ha (acres)		BG West group ha (acres)		Total BCBG ha (acres)	
Aquatic	0.02	(0.05)	0.1	(0.3)	0.12	(0.35)
Riparian	0.04	(0.09)	0.3	(0.7)	0.34	(0.8)
Wetland	1.0	(2.5)	0.8	(2.0)	1.8	(4.5)
Paved and right-of-way	1.7	(4.1)	4.8	(11.9)	6.5	(16.0)
Mowed grass	20.7	(51.3)	5.1	(12.5)	25.8	(63.8)
Old field	3.3	(8.2)	3.7	(9.1)	7.0	(17.3)
Mixed hardwood forest	5.4	(13.3)	15.4	(38.0)	20.8	(51.3)
Pine forest	0	(0)	0.8	(2.0)	0.8	(2.0)
Mixed pine and hardwood forest	0	(0)	0	(0)	0	(0)
Total	32.2	(79.5)	31.0	(76.5)	63.2	(156.0)

^a Areas estimated from Figs. D.78 and D.79 using a polygon grid overlay.

Table D.97. Analysis of miscellaneous parameters in water for streams draining the BCBG^a

Location	Date	pH ^b	Conductivity (μ S/cm)	Alkalinity as mg/mL CaCO ₃	Hardness as mg/mL CaCO ₃	O ₂ conc. ^b (mg/L)
Control	8/4/94	8.20	193	80	112	8.3
	8/6/94	8.08	206	82	110	8.6
	8/9/94	8.22	204	87	96	8.0
HCK ^c 12.9 (reference)	8/4/94	8.33	329	161	184	8.2
	8/6/94	8.17	270	136	148	8.2
	8/9/94	8.39	332	165	164	8.1
NT-6	8/4/94	8.15	279	126	132	7.9
	8/6/94	7.72	258	109	134	7.7
	8/9/94	8.03	311	133	142	8.3
NT-7	8/4/94	8.20	461	176	204	7.9
	8/6/94	8.08	263	102	118	7.7
	8/9/94	8.17	478	184	200	7.8
NT-8	8/4/94	8.20	321	130	176	7.9
	8/6/94	7.96	235	93	100	7.8
	8/9/94	8.14	331	134	144	8.0
BCK ^d 9.91	8/4/94	8.31	764	225	348	7.8
	8/6/94	7.98	325	102	154	7.6
	8/9/94	8.26	697	110	280	8.5

^a Results for testing during August 4 through August 11, 1994.^b Initial values, taken on fresh samples.^c Hinds Creek kilometer^d Bear Creek kilometer

Table D.98. Summary of selection of site-related chemicals and radionuclides, Floodplain soils, 0 to 4 in.

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. result ^c	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	16/ 16	46700	0/ 16	4090	27800	8820	L	No	Below background
Arsenic (mg/kg)	16/ 16	20.2	0/ 16	1.1	15.8	5.01	L	No	Below background
Barium (mg/kg)	16/ 16	212	0/ 16	55.9	146	87.5	L	No	Below background
Beryllium (mg/kg)	16/ 16	2.12	2/ 16	0.37	3	0.976	X	Yes	> 5% detect above background
Cadmium (mg/kg)	11/ 16	0.31	9/ 16	0.12	9.3	2.21	L	Yes	> 5% detect above background
Calcium (mg/kg)	16/ 16	1860	11/ 16	561	9590	2670	L	No	Essential element
Chromium (mg/kg)	16/ 16	80.1	0/ 16	8.2	27.1	14.9	L	No	Below background
Cobalt (mg/kg)	16/ 16	40.1	0/ 16	5.1	18.4	11.7	L	No	Below background
Copper (mg/kg)	16/ 16	35.5	1/ 16	4.6	42.7	14.4	L	Yes	> 5% detect above background
Cyanide (mg/kg)	1/ 16	0.63	1/ 16	1.1	1.1	0.4	D	Yes	> 5% detect above background
Iron (mg/kg)	16/ 16	52000	0/ 16	7790	24500	13400	L	No	Essential element
Lead (mg/kg)	16/ 16	49.6	0/ 16	10.5	46.1	21.2	L	No	Below background
Lithium (mg/kg)	14/ 16	33	2/ 16	4.3	55.2	17.1	L	Yes	> 5% detect above background
Magnesium (mg/kg)	16/ 16	6630	0/ 16	527	2150	1000	X	No	Essential element
Manganese (mg/kg)	16/ 16	2220	0/ 16	376	1610	961	N	No	Below background
Mercury (mg/kg)	13/ 13	0.34	11/ 13	0.28	7.3	1.28	L	Yes	> 5% detect above background
Nickel (mg/kg)	16/ 16	56.7	0/ 16	6.9	46.1	18.1	L	No	Below background
Potassium (mg/kg)	16/ 16	5560	0/ 16	425	2000	913	L	No	Essential element
Selenium (mg/kg)	14/ 16	1.2	12/ 16	1.2	3.2	1.72	N	Yes	> 5% detect above background
Silver (mg/kg)	4/ 16	2.8	0/ 16	0.17	0.4	0.123	D	No	Below background
Sodium (mg/kg)	14/ 16	.	0/ 16	136	286	174	L	No	Essential element

Table D.98 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. result ^c	Dist ^d	Site related?	Justification
Thallium (mg/kg)	1/ 16	0.79	1/ 16	1.9	1.9	0.706	D	Yes	> 5% detect above background
Vanadium (mg/kg)	16/ 16	60.1	0/ 16	9.7	29	17.8	L	No	Below background
Zinc (mg/kg)	16/ 16	108	0/ 16	22.1	103	46.5	L	No	Below background
<i>Organics</i>									
2,4,5-T (µg/kg)	8/ 16			1.9	9.9	11.5	N	Yes	No background available
2,4-D (µg/kg)	7/ 16			5.7	120	56.5	D	Yes	No background available
Silvex (µg/kg)	4/ 16			1.7	9.5	13.7	D	Yes	No background available
4,4'-DDD (µg/kg)	4/ 16			0.34	0.83	1.94	D	Yes	No background available
4,4'-DDE (µg/kg)	8/ 16			0.084	4.5	1.92	N	Yes	No background available
4,4'-DDT (µg/kg)	4/ 16			0.17	1.6	1.94	D	Yes	No background available
Aldrin (µg/kg)	1/ 16			0.22	0.22	1.12	D	Yes	No background available
Dieldrin (µg/kg)	11/ 16			0.32	13	2.85	L	Yes	No background available
Endosulfan I (µg/kg)	1/ 16			0.76	0.76	1.18	D	Yes	No background available
Endosulfan II (µg/kg)	2/ 16			0.76	3	2.3	D	Yes	No background available
Endosulfan sulfate (µg/kg)	2/ 16			0.34	1.7	2.17	D	Yes	No background available
Endrin aldehyde (µg/kg)	11/ 16			0.47	38	7.63	L	Yes	No background available
Endrin ketone (µg/kg)	1/ 16			0.1	0.1	2.19	D	Yes	No background available
Heptachlor epoxide (µg/kg)	2/ 16			0.1	1.6	1.16	D	Yes	No background available
Methoxychlor (µg/kg)	7/ 16			0.64	7.4	7.73	D	Yes	No background available
PCB-1254 (µg/kg)	3/ 16			280	780	110	D	Yes	No background available
PCB-1260 (µg/kg)	14/ 16			28	1300	341	L	Yes	No background available

Table D.98 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. result ^c	Dist ^d	Site related?	Justification
alpha-BHC ($\mu\text{g/kg}$)	3/ 16	.		0.054	0.1	0.992	D	Yes	No background available
alpha-Chlordane ($\mu\text{g/kg}$)	12/ 16	.		0.13	6.9	1.72	L	Yes	No background available
beta-BHC ($\mu\text{g/kg}$)	2/ 16	.		0.56	0.98	1.14	D	Yes	No background available
delta-BHC ($\mu\text{g/kg}$)	2/ 16	.		0.19	0.41	1.08	D	Yes	No background available
gamma-BHC ($\mu\text{g/kg}$)	1/ 16	.		0.071	0.071	1.12	D	Yes	No background available
gamma-Chlordane ($\mu\text{g/kg}$)	6/ 16	.		0.13	2.1	1.01	D	Yes	No background available
Benzo(a)anthracene ($\mu\text{g/kg}$)	4/ 16	.		61	150	196	D	Yes	No background available
Benzo(a)pyrene ($\mu\text{g/kg}$)	3/ 16	.		51	100	198	D	Yes	No background available
Benzo(b)fluoranthene ($\mu\text{g/kg}$)	4/ 16	.		61	190	206	D	Yes	No background available
Benzo(k)fluoranthene ($\mu\text{g/kg}$)	4/ 16	.		37	160	198	D	Yes	No background available
Bis(2-ethylhexyl)phthalate ($\mu\text{g/kg}$)	9/ 16	.		38	180	152	X	Yes	No background available
Chrysene ($\mu\text{g/kg}$)	4/ 16	.		65	140	197	D	Yes	No background available
Di-n-butylphthalate ($\mu\text{g/kg}$)	7/ 16	.		57	260	179	D	Yes	No background available
Diethylphthalate ($\mu\text{g/kg}$)	1/ 16	.		57	57	220	D	Yes	No background available
Fluoranthene ($\mu\text{g/kg}$)	7/ 16	.		46	180	175	D	Yes	No background available
Phenanthrene ($\mu\text{g/kg}$)	4/ 16	.		60	85	187	D	Yes	No background available
Pyrene ($\mu\text{g/kg}$)	5/ 16	.		54	190	192	D	Yes	No background available
Radioactivity									
Americium-241 (pCi/g)	6/ 15	0.058	6/ 15	0.06	0.16	0.0473	D	Yes	> 5% detect above background
Cesium-137 (pCi/g)	15/ 16	1.4	0/ 16	0.23	1.33	0.578	L	No	Below background
Curium-243 (pCi/g)	2/ 15	0.075	1/ 15	0.07	0.14	0.05	D	Yes	> 5% detect above background

Table D.98 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. result ^c	Dist ^d	Site related?	Justification
Curium-244 (pCi/g)	2/ 15	3.5	0/ 15	0.14	0.17	0.054	D	No	Below background
Plutonium-238 (pCi/g)	1/ 16	0.12	0/ 16	0.03	0.03	0.0106	D	No	Below background
Plutonium-239/240 (pCi/g)	6/ 16	0.065	0/ 16	0.02	0.03	0.0163	D	No	Below background
Technetium-99 (pCi/g)	9/ 16	4.07	6/ 16	2.47	11.98	4.05	L	Yes	> 5% detect above background
Thorium-228 (pCi/g)	16/ 16	2.88	0/ 16	0.71	1.92	1.16	L	No	Below background
Thorium-230 (pCi/g)	16/ 16	2.3	0/ 16	0.48	1.72	0.996	L	No	Below background
Thorium-232 (pCi/g)	16/ 16	2.75	0/ 16	0.6	1.91	0.964	L	No	Below background
Uranium-234 (pCi/g)	16/ 16	3.2	13/ 16	1.33	44.13	13.7	L	Yes	> 5% detect above background
Uranium-235 (pCi/g)	16/ 16	0.24	13/ 16	0.03	2.66	0.876	L	Yes	> 5% detect above background
Uranium-238 (pCi/g)	16/ 16	2.6	14/ 16	1.38	67	25.9	L	Yes	> 5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the Bear Creek Valley RI.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.99. Summary of selection of site-related chemicals and radionuclides, Floodplain soils, 4 to 16 in.

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. result ^c	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	5/ 5	46700	0/ 5	5270	8210	6640	L	No	Below background
Arsenic (mg/kg)	5/ 5	20.2	0/ 5	2.5	5.6	3.46	L	No	Below background
Barium (mg/kg)	5/ 5	212	0/ 5	66.4	148	91.7	L	No	Below background
Beryllium (mg/kg)	5/ 5	2.12	0/ 5	0.48	0.6	0.568	X	No	Below background
Cadmium (mg/kg)	1/ 5	0.31	0/ 5	0.31	0.31	0.091	D	No	Below background
Calcium (mg/kg)	5/ 5	1860	0/ 5	312	1410	990	N	No	Essential element
Chromium (mg/kg)	5/ 5	80.1	0/ 5	12.9	19.4	15.9	L	No	Below background
Cobalt (mg/kg)	5/ 5	40.1	0/ 5	8.1	14.9	10.7	L	No	Below background
Copper (mg/kg)	5/ 5	35.5	0/ 5	3.8	9	5.48	L	No	Below background
Iron (mg/kg)	5/ 5	52000	0/ 5	12200	17100	13900	L	No	Essential element
Lead (mg/kg)	5/ 5	49.6	0/ 5	9.3	13.7	10.9	L	No	Below background
Magnesium (mg/kg)	5/ 5	6630	0/ 5	567	1070	798	L	No	Essential element
Manganese (mg/kg)	5/ 5	2220	0/ 5	577	1760	964	L	No	Below background
Mercury (mg/kg)	1/ 1	0.34	1/ 1	0.47	0.47	0.47	X	Yes	> 5% detect above background
Nickel (mg/kg)	5/ 5	56.7	0/ 5	6.7	11.6	9.42	N	No	Below background
Potassium (mg/kg)	5/ 5	5560	0/ 5	536	1130	707	L	No	Essential element
Selenium (mg/kg)	3/ 5	1.2	3/ 5	1.6	1.7	1.2	X	Yes	> 5% detect above background
Sodium (mg/kg)	2/ 5	.		209	209	139	D	No	Essential element
Vanadium (mg/kg)	5/ 5	60.1	0/ 5	13.7	21.5	16.3	L	No	Below background
Zinc (mg/kg)	5/ 5	108	0/ 5	20	35.6	25.9	L	No	Below background

Table D.99 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. result ^c	Dist ^d	Site related?	Justification
<i>Organics</i>									
2,4,5-T (µg/kg)	3/ 5	.		1.4	8.3	9.52	N	Yes	No background available
2,4-D (µg/kg)	3/ 5	.		35	83	112	L	Yes	No background available
Silvex (µg/kg)	3/ 5	.		4.5	10	23	L	Yes	No background available
Dieldrin (µg/kg)	2/ 5	.		0.15	0.21	1.31	D	Yes	No background available
Endosulfan I (µg/kg)	1/ 5	.		0.3	0.3	0.91	D	Yes	No background available
Endosulfan sulfate (µg/kg)	1/ 5	.		0.23	0.23	1.67	D	Yes	No background available
Endrin aldehyde (µg/kg)	2/ 5	.		0.93	1	1.63	D	Yes	No background available
PCB-1254 (µg/kg)	1/ 5	.		13	13	19.2	D	Yes	No background available
PCB-1260 (µg/kg)	2/ 5	.		41	48	30.2	D	Yes	No background available
alpha-Chlordane (µg/kg)	1/ 5	.		0.19	0.19	0.888	D	Yes	No background available
Benzo(b)fluoranthene (µg/kg)	1/ 5	.		72	72	179	D	Yes	No background available
Benzo(k)fluoranthene (µg/kg)	1/ 5	.		69	69	179	D	Yes	No background available
Bis(2-ethylhexyl)phthalate (µg/kg)	3/ 5	.		33	170	143	N	Yes	No background available
Chrysene (µg/kg)	1/ 5	.		44	44	174	D	Yes	No background available
Diethylphthalate (µg/kg)	1/ 5	.		260	260	218	D	Yes	No background available
Fluoranthene (µg/kg)	1/ 5	.		100	100	185	D	Yes	No background available
Pyrene (µg/kg)	1/ 5	.		78	78	181	D	Yes	No background available

Table D.99 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. result ^c	Dist ^d	Site related?	Justification
<i>Radioactivity</i>									
Americium-241 (pCi/g)	2/ 5	0.058	1/ 5	0.04	0.07	0.036	D	Yes	> 5% detect above background
Cesium-137 (pCi/g)	1/ 5	1.4	0/ 5	0.19	0.19	0.084	D	No	Below background
Curium-244 (pCi/g)	2/ 5	3.5	0/ 5	0.08	0.14	0.07	D	No	Below background
Thorium-228 (pCi/g)	5/ 5	2.88	0/ 5	0.29	0.86	0.666	N	No	Below background
Thorium-230 (pCi/g)	5/ 5	2.3	0/ 5	0.24	1.11	0.802	N	No	Below background
Thorium-232 (pCi/g)	5/ 5	2.75	0/ 5	0.23	0.97	0.694	N	No	Below background
Uranium-234 (pCi/g)	5/ 5	3.2	1/ 5	0.76	4.08	1.61	L	Yes	> 5% detect above background
Uranium-235 (pCi/g)	4/ 5	0.24	1/ 5	0.03	0.41	0.112	L	Yes	> 5% detect above background
Uranium-238 (pCi/g)	5/ 5	2.6	1/ 5	0.69	4.32	1.8	L	Yes	> 5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the Bear Creek Valley RI.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.100. Summary of selection of site-related chemicals and radionuclides, Floodplain soils, deep interval (> 16 in.)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. result ^c	Dist ^d	Site related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	16/ 16	46700	0/ 16	4060	10900	7360	L	No	Below background
Arsenic (mg/kg)	16/ 16	20.2	0/ 16	0.93	14.2	3.59	L	No	Below background
Barium (mg/kg)	16/ 16	212	0/ 16	45.2	146	86.2	L	No	Below background
Beryllium (mg/kg)	14/ 16	2.12	1/ 16	0.39	2.7	0.727	L	Yes	> 5% detect above background
Cadmium (mg/kg)	8/ 16	0.31	6/ 16	0.28	11.1	1.73	X	Yes	> 5% detect above background
Calcium (mg/kg)	16/ 16	1860	3/ 16	546	3850	1410	L	No	Essential element
Chromium (mg/kg)	16/ 16	80.1	0/ 16	9.7	21.7	13.9	L	No	Below background
Cobalt (mg/kg)	16/ 16	40.1	0/ 16	5	20.2	11.9	L	No	Below background
Copper (mg/kg)	16/ 16	35.5	0/ 16	4.3	20.8	8.16	X	No	Below background
Iron (mg/kg)	16/ 16	52000	0/ 16	7660	19400	12900	L	No	Essential element
Lead (mg/kg)	16/ 16	49.6	1/ 16	9.3	52.3	18.2	X	Yes	> 5% detect above background
Lithium (mg/kg)	13/ 16	33	2/ 16	4.1	39.1	10.9	L	Yes	> 5% detect above background
Magnesium (mg/kg)	16/ 16	6630	0/ 16	370	1390	822	L	No	Essential element
Manganese (mg/kg)	16/ 16	2220	0/ 16	270	2040	941	L	No	Below background
Mercury (mg/kg)	10/ 11	0.34	5/ 11	0.13	2.5	0.755	L	Yes	> 5% detect above background
Nickel (mg/kg)	16/ 16	56.7	2/ 16	6.6	62.8	16	X	Yes	> 5% detect above background
Potassium (mg/kg)	16/ 16	5560	0/ 16	265	1670	809	L	No	Essential element
Selenium (mg/kg)	15/ 16	1.2	14/ 16	1.2	2.5	1.68	N	Yes	> 5% detect above background
Silver (mg/kg)	3/ 16	2.8	0/ 16	0.17	0.3	0.0994	D	No	Below background
Sodium (mg/kg)	13/ 16	.		123	265	155	N	No	Essential element
Vanadium (mg/kg)	16/ 16	60.1	0/ 16	11	32.8	16.7	L	No	Below background

Table D.100 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. result ^c	Dist ^d	Site related?	Justification
Zinc (mg/kg)	16/ 16	108	0/ 16	15.3	66.2	31.4	X	No	Below background
<i>Organics</i>									
2,4,5-T (µg/kg)	6/ 16			0.9	14	12.8	D	Yes	No background available
2,4-D (µg/kg)	5/ 16			19	95	60	D	Yes	No background available
Silverx (µg/kg)	5/ 16			2.3	15	13.5	D	Yes	No background available
4,4'-DDE (µg/kg)	6/ 15			0.067	7	1.96	D	Yes	No background available
4,4'-DDT (µg/kg)	3/ 15			0.22	0.38	1.78	D	Yes	No background available
Dieldrin (µg/kg)	7/ 15			0.088	3.4	1.59	D	Yes	No background available
Endosulfan I (µg/kg)	1/ 15			0.15	0.15	1.06	D	Yes	No background available
Endosulfan II (µg/kg)	1/ 15			0.46	0.46	2.06	D	Yes	No background available
Endosulfan sulfate (µg/kg)	2/ 15			0.26	0.98	1.97	D	Yes	No background available
Endrin (µg/kg)	2/ 15			0.2	0.41	1.93	D	Yes	No background available
Endrin aldehyde (µg/kg)	8/ 15			0.27	23	3.19	X	Yes	No background available
Methoxychlor (µg/kg)	4/ 15			0.32	5.9	8.7	D	Yes	No background available
PCB-1254 (µg/kg)	2/ 15			130	190	40.2	D	Yes	No background available
PCB-1260 (µg/kg)	11/ 15			6.4	1700	222	X	Yes	No background available
alpha-BHC (µg/kg)	1/ 15			0.036	0.036	1.04	D	Yes	No background available
alpha-Chlordane (µg/kg)	7/ 15			0.082	5.9	1.26	D	Yes	No background available
delta-BHC (µg/kg)	3/ 15			0.072	0.14	0.91	D	Yes	No background available
gamma-BHC (µg/kg)	1/ 15			0.044	0.044	1.04	D	Yes	No background available
gamma-Chlordane (µg/kg)	4/ 15			0.087	1.6	0.955	D	Yes	No background available

Table D.100 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. result ^c	Dist ^d	Site related?	Justification
Benzo(a)anthracene (μg/kg)	1/ 16			120	120	208	D	Yes	No background available
Benzo(a)pyrene (μg/kg)	1/ 16			92	92	206	D	Yes	No background available
Benzo(b)fluoranthene (μg/kg)	2/ 16			54	180	201	D	Yes	No background available
Benzo(k)fluoranthene (μg/kg)	2/ 16			43	150	199	D	Yes	No background available
Bis(2-ethylhexyl)phthalate (μg/kg)	8/ 16			40	420	159	L	Yes	No background available
Chrysene (μg/kg)	1/ 16			150	150	209	D	Yes	No background available
Di-n-butylphthalate (μg/kg)	7/ 16			58	200	171	D	Yes	No background available
Fluoranthene (μg/kg)	3/ 16			42	170	187	D	Yes	No background available
Indeno(1,2,3-cd)pyrene (μg/kg)	1/ 16			55	55	203	D	Yes	No background available
Phenanthrene (μg/kg)	1/ 16			86	86	205	D	Yes	No background available
Pyrene (μg/kg)	3/ 16			44	160	187	D	Yes	No background available
Chloroform (μg/kg)	1/ 16			60	60	6.75	D	Yes	No background available

Radioactivity

Americium-241 (pCi/g)	5/ 16	0.058	2/ 16	0.02	0.06	0.0313	D	Yes	> 5% detect above background
Cesium-137 (pCi/g)	11/ 16	1.4	0/ 16	0.06	0.77	0.198	L	No	Below background
Curium-243 (pCi/g)	3/ 16	0.075	1/ 16	0.03	0.19	0.0625	D	Yes	> 5% detect above background
Curium-244 (pCi/g)	3/ 16	3.5	0/ 16	0.05	0.21	0.0263	D	No	Below background
Plutonium-239/240 (pCi/g)	1/ 16	0.065	0/ 16	0.04	0.04	0.00688	D	No	Below background
Technetium-99 (pCi/g)	3/ 16	4.07	1/ 16	2.25	6.45	1.05	D	Yes	> 5% detect above background
Thorium-228 (pCi/g)	16/ 16	2.88	0/ 16	0.77	1.38	1.07	N	No	Below background
Thorium-230 (pCi/g)	16/ 16	2.3	0/ 16	0.67	1.36	0.92	L	No	Below background

Table D.100 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. result ^c	Dist ^d	Site related?	Justification
Thorium-232 (pCi/g)	16/ 16	2.75	0/ 16	0.66	1.02	0.925	X	No	Below background
Uranium-234 (pCi/g)	16/ 16	3.2	7/ 16	0.95	32.81	8.22	X	Yes	> 5% detect above background
Uranium-235 (pCi/g)	15/ 16	0.24	5/ 16	0.02	2.04	0.509	L	Yes	> 5% detect above background
Uranium-238 (pCi/g)	16/ 16	2.6	7/ 16	0.99	94.35	17	X	Yes	> 5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established using ERWM/ER-P2000.017, Rev. 0, "Background Comparison for Human Health Risk Assessment". Soils background data are from *Annual Report on the Background Soil Characterization Project on the Oak Ridge Reservation, Oak Ridge, Tennessee, Results of Phase I Investigation* (DOE 1993). Data from three horizons in the Nolichucky and Dismal Gap (Maryville) formations have been used to establish soil background values for the Bear Creek Valley RI.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.101. Summary of selection of site-related chemicals and radionuclides, Floodplain sediments

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. ^c Result	Dist ^d	Site Related?	Justification
<i>Inorganics</i>									
Aluminum (mg/kg)	18/ 18	11500	6/18	2790	20900	10400	N	Yes	> 5% detect above background
Antimony (mg/kg)	2/ 17	1	1/17	0.68	4.6	0.587	D	Yes	> 5% detect above background
Arsenic (mg/kg)	16/ 18	6.6	10/18	2.1	17.5	8.7	N	Yes	> 5% detect above background
Barium (mg/kg)	18/ 18	206	6/18	5.4	571	194	L	Yes	> 5% detect above background
Beryllium (mg/kg)	15/ 18	1.2	9/18	0.59	3.4	1.16	N	Yes	> 5% detect above background
Cadmium (mg/kg)	8/ 18	0.36	8/18	0.53	21.7	4.13	D	Yes	> 5% detect above background
Calcium (mg/kg)	18/ 18	2050	14/18	505	25600	6410	L	No	Essential element
Chromium (mg/kg)	18/ 18	23.7	9/18	3.1	1040	85.9	X	Yes	> 5% detect above background
Cobalt (mg/kg)	18/ 18	23.3	7/18	0.37	60.1	23.1	N	Yes	> 5% detect above background
Copper (mg/kg)	18/ 18	11.7	10/18	3.7	241	27	X	Yes	> 5% detect above background
Iron (mg/kg)	18/ 18	42100	4/18	2160	61400	29500	N	No	Essential element
Lead (mg/kg)	18/ 18	15.1	12/18	11.1	107	31.4	L	Yes	> 5% detect above background
Lithium (mg/kg)	17/ 18	15.8	7/18	4.5	69	19.5	X	Yes	> 5% detect above background
Magnesium (mg/kg)	18/ 18	2050	5/18	50.1	8260	2090	X	No	Essential element
Manganese (mg/kg)	17/ 18	1570	8/18	101	9280	2260	X	Yes	> 5% detect above background
Mercury (mg/kg)	14/ 14	0.97	2/14	0.16	6.9	0.923	X	Yes	> 5% detect above background
Nickel (mg/kg)	18/ 18	21	12/18	1.1	160	39.9	L	Yes	> 5% detect above background
Potassium (mg/kg)	18/ 18	1970	1/18	117	2070	1170	N	No	Essential element
Selenium (mg/kg)	14/ 18	4.3	3/18	2	6.7	3.08	N	Yes	> 5% detect above background

Table D.101 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. ^c Result	Dist ^d	Site Related?	Justification
Silver (mg/kg)	7/ 18	0.27	4/18	0.16	2.8	0.287	D	Yes	Below background
Sodium (mg/kg)	11/ 18	374	1/18	167	479	204	L	No	Essential element
Vanadium (mg/kg)	18/ 18	26.9	11/18	5.3	249	43.5	L	Yes	> 5% detect above background
Zinc (mg/kg)	18/ 18	42.4	13/18	8.8	408	87.4	L	Yes	> 5% detect above background
<i>Organics</i>									
2,4,5-T (µg/kg)	6/ 18	.	.	2.8	50	20.7	D	Yes	No background available
2,4-D (µg/kg)	1/ 18	.	.	82	82	87.9	D	Yes	No background available
4,4'-DDD (µg/kg)	5/ 17	.	.	0.12	1.4	2.18	D	Yes	No background available
4,4'-DDE (µg/kg)	12/ 17	.	.	0.08	6.2	1.62	L	Yes	No background available
4,4'-DDT (µg/kg)	6/ 17	.	.	0.099	2.8	2.08	D	Yes	No background available
Aldrin (µg/kg)	3/ 16	.	.	0.11	0.21	1.14	D	Yes	No background available
Dieldrin (µg/kg)	2/ 17	.	.	3	12	3.29	D	Yes	No background available
Endosulfan I (µg/kg)	3/ 16	.	.	0.09	0.75	1.2	D	Yes	No background available
Endosulfan II (µg/kg)	2/ 16	.	.	1.2	20	3.66	D	Yes	No background available
Endosulfan sulfate (µg/kg)	7/ 16	.	.	0.43	4.2	2.38	D	Yes	No background available
Endrin (µg/kg)	4/ 16	.	.	0.21	0.9	2.12	D	Yes	No background available
Endrin aldehyde (µg/kg)	13/ 17	.	.	0.21	15	3.73	L	Yes	No background available
Endrin ketone (µg/kg)	1/ 16	.	.	0.51	0.51	2.61	D	Yes	No background available
Heptachlor (µg/kg)	1/ 16	.	.	0.38	0.38	1.32	D	Yes	No background available

Table D.101 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. ^c Result	Dist ^d	Site Related?	Justification
Heptachlor epoxide (µg/kg)	5/ 16	.		0.2	1.1	1.15	D	Yes	No background available
Methoxychlor (µg/kg)	7/ 16	.		0.38	2.4	8.25	D	Yes	No background available
PCB-1254 (µg/kg)	4/ 16	.		17	1200	159	D	Yes	No background available
PCB-1260 (µg/kg)	12/ 18	.		24	2500	240	X	Yes	No background available
alpha-BHC (µg/kg)	3/ 16	.		0.059	0.29	1.15	D	Yes	No background available
alpha-Chlordane (µg/kg)	6/ 16	.		0.066	0.58	0.937	D	Yes	No background available
beta-BHC (µg/kg)	1/ 16	.		0.29	0.29	1.3	D	Yes	No background available
delta-BHC (µg/kg)	1/ 16	.		3.5	3.5	1.51	D	Yes	No background available
gamma-BHC (µg/kg)	1/ 16	.		0.3	0.3	1.33	D	Yes	No background available
gamma-Chlordane (µg/kg)	9/ 16	.		0.093	2.4	0.903	N	Yes	No background available
4-Methylphenol (µg/kg)	1/ 18	.		260	260	270	D	Yes	No background available
Acenaphthene (µg/kg)	1/ 18	.		190	190	268	D	Yes	No background available
Anthracene (µg/kg)	1/ 18	.		1100	1100	318	D	Yes	No background available
Benzo(a)anthracene (µg/kg)	8/ 18	.		38	5800	506	D	Yes	No background available
Benzo(a)pyrene (µg/kg)	7/ 18	.		26	4800	462	D	Yes	No background available
Benzo(b)fluoranthene (µg/kg)	9/ 18	.		56	9100	695	X	Yes	No background available
Benzo(ghi)perylene (µg/kg)	4/ 18	.		61	960	278	D	Yes	No background available

Table D.101 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. ^c Result	Dist ^d	Site Related?	Justification
Benzo(k)fluoranthene (µg/kg)	9/ 18	.	.	59	8300	653	X	Yes	No background available
Bis(2-ethylhexyl)phthalate (µg/kg)	7/ 18	.	.	32	920	241	D	Yes	No background available
Carbazole (µg/kg)	1/ 18	.	.	520	520	286	D	Yes	No background available
Chrysene (µg/kg)	7/ 18	.	.	36	5800	516	D	Yes	No background available
Di-n-butylphthalate (µg/kg)	12/ 18	.	.	71	150	163	X	Yes	No background available
Dibenzo(a,h)anthracene (µg/kg)	1/ 18	.	.	350	350	276	D	Yes	No background available
Dibenzofuran (µg/kg)	1/ 18	.	.	200	200	268	D	Yes	No background available
Fluoranthene (µg/kg)	9/ 18	.	.	45	12000	861	X	Yes	No background available
Fluorene (µg/kg)	1/ 18	.	.	290	290	273	D	Yes	No background available
Indeno(1,2,3-cd)pyrene (µg/kg)	4/ 18	.	.	65	1600	312	D	Yes	No background available
Naphthalene (µg/kg)	1/ 18	.	.	88	88	262	D	Yes	No background available
Phenanthrene (µg/kg)	6/ 18	.	.	72	6900	584	D	Yes	No background available
Pyrene (µg/kg)	9/ 18	.	.	44	8600	669	X	Yes	No background available
1,2-Dichloroethene (µg/kg)	1/ 18	.	.	3	3	4.03	D	Yes	No background available
Acetone (µg/kg)	1/ 17	.	.	20	20	6.12	D	Yes	No background available

Table D.101 (continued)

Analyte ^a	Freq of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. ^c Result	Dist ^d	Site Related?	Justification
<i>Radionuclides</i>									
Americium-241 (pCi/g)	4/ 18	0.06	2/18	0.05	0.07	0.0367	D	Yes	> 5% detect above background
Cesium-137 (pCi/g)	13/ 18	0.028	0/ 18	0.07	0.18	0.112	L	No	Below background
Curium-244 (pCi/g)	1/ 18	0.05	1/ 18	0.3	0.3	0.03	D	Yes	> 5% detect above background
Technetium-99 (pCi/g)	3/ 18	0.9	3/18	4.93	8.74	1.98	D	Yes	> 5% detect above background
Thorium-228 (pCi/g)	18/ 18	1.6	1/18	0.55	2.17	1.14	L	Yes	> 5% detect above background
Thorium-230 (pCi/g)	18/ 18	0.9	4/ 18	0.48	1.3	0.787	L	Yes	> 5% detect above background
Thorium-232 (pCi/g)	18/ 18	1.14	2/ 18	0.49	1.65	0.867	L	Yes	> 5% detect above background
Uranium-234 (pCi/g)	18/ 18	3.54	10/ 18	1.02	25.36	7.04	L	Yes	> 5% detect above background
Uranium-235 (pCi/g)	16/ 18	0.06	13/18	0.04	1.24	0.339	L	Yes	> 5% detect above background
Uranium-238 (pCi/g)	18/ 18	1.02	18/18	1.27	36.53	10.8	L	Yes	> 5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For springs, background criteria have been established by *Determination of Reference Concentrations for Inorganic Analytes in Groundwater at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (Energy Systems 1996). Geochemistry of uncontaminated springs (SS-8 and SS-6) was allocated into cluster 4 in this study using the surrogate cluster analysis technique (see text). Background values from cluster 4 were therefore used as a background for spring water.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

Table D.102. Transects, station, sample, and depth of AFI samples

Transect	Station	Sample ID	Depth(s)
TS01	TS012	G01214	0 to 4 in.
		G01215	4 to 16 in.
	TS016	G01614	0 to 4 in.
		G01615	4 to 16 in.
TS02	TS023	G02314	0 to 4 in.
		G02315	4 to 16 in.
TS03	TS033	G03314	0 to 4 in.
		G03315	4 to 16 in.
	TS034	G03414	0 to 4 in.
		G03415	4 to 16 in.
TS04	TS041	G04114	0 to 4 in.
		G04115	4 to 16 in.
	TS042	G04214	0 to 4 in.
		G04215	4 to 16 in.
TS05	TS051	G05114	0 to 4 in.
		G05115	4 to 16 in.
TS06	TS063	G06314	0 to 4 in.
		G06315	4 to 16 in.
		G06316	16 to 32 in.
	TS064	G06414	0 to 4 in.
		G06415	4 to 16 in.
		G06416	16 to 32 in.
TS07	TS071	G07114	0 to 4 in.
		G07115	4 to 16 in.
	TS073	G07314	0 to 4 in.
		G07315	4 to 16 in.
TS08	TS086	G08614	0 to 4 in.
		G08615	4 to 16 in.
TS09	TS092	G09214	0 to 4 in.
		G09215	4 to 16 in.
TS10	TS103	G10314	0 to 4 in.
		G10315	4 to 16 in.
	TS105	G10516	16 to 32 in.
TS11	TS111	G11116	16 to 32 in.
TS12	TS123	G12316	16 to 32 in.
TS13	TS132	G13214	0 to 4 in.
		G13215	4 to 16 in.

Table D.103. Creekside and Bear Creek Road Site Debris Burial Areas sampling results

Analyte	Value		Corrected for 1:4 dilution
	Creekside	Bear Creek Road	
Inorganics (mg/kg)			
Aluminum	15900.00	5970.00	23880
Antimony	0.49	1.00	4
Arsenic	7.90	10.70	42.8
Barium	99.70	633.00	2532
Beryllium	1.40	0.88	3.52
Cadmium	1.70	15.60	62.4
Calcium	13900.00	5580.00	22320
Chromium	107.00	78.10	312.4
Cobalt	17.70	8.20	32.4
Copper	52.00	1650.00	6600
Iron	25500.00	15200.00	60800
Lead	47.30	516.00	2064
Lithium	32.50	10.80	43.2
Magnesium	5050.00	887.00	3548
Manganese	797.00	334.00	1336
Mercury	33.00	5.40	21.6
Nickel	43.00	86.50	346
Potassium	2030.00	908.00	3632
Selenium	2.50	2.20	8.8
Silver	8.70	32.70	130.8
Sodium	217.00	403.0	1612
Vanadium	27.00	18.60	74.4
Zinc	151.00	875.00	3500
Organics (µg/kg)			
2,4,5-T	14.00	6.00	24
Silvex	19.00	ND	—
2,4-D	14.00	ND	—
2,4-Dimethylphenol	140.00	ND	—

Table D.103 (continued)

Analyte	Value		Corrected for 1:4 dilution
	Creekside	Bear Creek Road	
2-Methylnaphthalene	1200.00	73.00	292
2-Methylphenol	37.00	ND	—
4-Methylphenol	110.00	ND	—
Acenaphthene	4200.00	ND	—
Anthracene	5300.00	ND	—
Benzo (A) Anthracene	10000.00	58.00	232
Benzo (A) Pyrene	8000.00	52.00	208
Benzo (B) Fluoranthene	14000.00	190.00	760
Benzo (GHI) Perylene	1800.00	ND	—
Benzo (K) Fluoranthene	13000.00	180.00	720
Bis (2-Ethylhexyl) Phthalate	240.00	150.00	600
Carbazole	4100.00	ND	—
Chrysene	9100.00	60.00	240
Dibenzo (A,H) Anthracene	350.00	ND	—
Di-N-Butylphthalate	ND	69.00	276
Dibenzofuran	2900.00	ND	—
Fluoranthene	28000.00	92.00	368
Gamma-BHC	ND	0.28	1.12
Fluorene	4300.00	ND	—
Indeno (1,2,3-CD) Pyrene	2200.00	ND	—
Naphthalene	9200.00	70.00	280
Phenanthrene	30000.00	63.00	252
Phenol	90.00	ND	—
Pyrene	20000.00	120.00	482
<i>Pesticides/PCBs (µg/kg)</i>			
PCB-1254	1200.00	3600.00	14400
<i>Radionuclides (pCi/g)</i>			
Americium-241	0.15	ND	—
Cesium-137	0.21	1.19	4.76

Table D.103 (continued)

Analyte	Value		Corrected for 1:4 dilution
	Creekside	Bear Creek Road	
Curium-243	0.16	0.33	1.32
Plutonium-238	0.51	ND	—
Plutonium-239/240	0.10	0.05	0.20
Technetium-99	3.43	18.74	74.96
Thorium-232	1.51	0.67	2.68
Thorium-228	2.20	0.88	3.52
Thorium-230	1.22	1.09	4.36
Uranium-234	27.90	411.39	1645.56
Uranium-235	1.45	1.81	7.24
Uranium-238	24.79	63.75	255.0

ND - Analyte not detected

Table D.104. Summary of selection of site-related chemicals and radionuclides, Upper Bear Creek between BCK 11.97 and BCK 12.36, unfiltered samples

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. ^c result	Dist ^d	Comment
<i>Inorganics</i>								
Chloride (mg/L)	30/ 31	2	30/ 31	18.5000	133.0000	59.9800	N	> 5% detect above background
Fluoride (mg/L)	31/ 31	0.1	31/ 31	0.2000	1.3000	0.7410	N	> 5% detect above background
Nitrate (mg/L)	102/ 102	0.2	102/ 102	2.9000	600.0000	126.0000	X	> 5% detect above background
Sulfate (mg/L)	30/ 31	57	5/ 31	13.5000	84.5000	46.5900	N	> 5% detect above background
Aluminum (mg/L)	96/ 103	7.4	1/ 103	0.0340	17.8000	0.5196	X	> 95% below background
Antimony (mg/L)	4/ 21	0.05	0/ 21	0.0014	0.0023	0.0010	D	Below background
Arsenic (mg/L)	5/ 94	0.05	1/ 94	0.0018	0.0560	0.0028	D	> 95% below background
Barium (mg/L)	103/ 103	0.21	92/ 103	0.0880	1.1600	0.4392	L	> 5% detect above background
Beryllium (mg/L)	3/ 103	0.00072	1/ 103	0.0003	0.0010	0.0001	D	< = 5% detects
Boron (mg/L)	82/ 82	0.062	41/ 82	0.0270	0.2890	0.0769	X	> 5% detect above background
Cadmium (mg/L)	5/ 8	0.002	5/ 8	0.0021	0.0086	0.0035	L	> 5% detect above background
Calcium (mg/L)	103/ 103	36	103/ 103	48.7000	454.0000	211.5000	X	Essential element
Cobalt (mg/L)	55/ 103	0.017	0/ 103	0.0020	0.0116	0.0028	X	Below background
Copper (mg/L)	6/ 103	0.0072	4/ 103	0.0043	0.0120	0.0033	D	> 95% below background
Cyanide (mg/L)	10/ 93			0.0020	0.0212	0.0022	D	Background < detection limit ^e
Iron (mg/L)	60/ 103	30	0/ 103	0.0130	20.8000	0.5075	X	Essential element
Lithium (mg/L)	7/ 79	.		0.0060	0.0098	0.0102	D	No detects > WOE UTL ^f
Magnesium (mg/L)	103/ 103	7.2	101/ 103	6.4700	59.8000	28.2800	X	Essential element
Manganese (mg/L)	103/ 103	6.1	0/ 103	0.1010	3.8800	1.4910	X	Below background
Mercury (mg/L)	14/ 100	0.0002	8/ 100	0.0000	0.0060	0.0001	D	> 5% detect above background
Nickel (mg/L)	100/ 103	0.011	98/ 103	0.0090	0.1000	0.0368	X	> 5% detect above background
Phosphorous (mg/L)	18/ 72	.		0.0500	0.1100	0.0372	D	No background data available
Potassium (mg/L)	103/ 103	3.5	66/ 103	2.1000	7.9000	4.3590	X	Essential element

Table D.104 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. ^c result	Dist ^d	Comment
Scandium (mg/L)	2/ 72	.		0.0000	0.0010	0.0000	D	< = 5% detects
Selenium (mg/L)	1/ 94	0.066	1/ 94	0.0710	0.0710	0.0018	D	< = 5% detects
Silicon (mg/L)	3/ 3	19	0/ 3	2.9000	3.4000	3.1330	L	Below background
Silver (mg/L)	2/ 103	0.006	2/ 103	0.0061	0.0068	0.0030	D	< = 5% detects
Sodium (mg/L)	103/ 103	7.6	103/ 103	12.6000	70.9000	38.9900	X	Essential element
Strontium (mg/L)	82/ 82	0.12	82/ 82	0.1430	1.2700	0.6495	L	> 5% detect above background
Thallium (mg/L)	1/ 92	.		0.0041	0.0041	0.0008	D	< = 5% detects
Thorium (mg/L)	3/ 82	0.2	0/ 82	0.0100	0.0100	0.0170	D	< = 5% detects
Titanium (mg/L)	1/ 72	.		0.0200	0.0200	0.0056	D	< = 5% detects
Total Uranium (Fluorometric) (mg/L)	82/ 82	0.015	82/ 82	0.0550	0.8480	0.1992	L	> 5% detect above background
Vanadium (mg/L)	4/ 103	0.013	1/ 103	0.0056	0.0319	0.0024	D	< = 5% detects
Zinc (mg/L)	35/ 103	0.066	1/ 103	0.0024	0.1360	0.0107	D	Below background
<i>Organics</i>								
1,1,1-Trichloroethane (µg/L)	1/ 31	.		0.4	0.4	2.5	D	< = 5% detects
1,2-Dichloroethane (µg/L)	7/ 31	.		8	20	5	D	No background available
1,2-Dichloroethene (µg/L)	1/ 31	.		1	1	2.5	D	< = 5% detects
2-Butanone (µg/L)	1/ 31	.		9	9	3.5	D	< = 5% detects
2-Hexanone (µg/L)	2/ 31	.		3	8	3.5	D	No background available
4-Methyl-2-pentanone (µg/L)	2/ 31	.		3	7	3.3	D	No background available
Acetone (µg/L)	5/ 31	.		4	24	6.0	D	No background available
Carbon disulfide (µg/L)	1/ 31	.		1	1	2.5	D	< = 5% detects
Chloromethane (µg/L)	6/ 31	.		2	11	3.9	D	No background available
Methylene chloride (µg/L)	2/ 31	.		2	5	2.6	D	No background available
Phenols (mg/L)	51/ 72	.		0.0010	0.0060	0.0018	X	No background data available

Table D.104 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg. ^c result	Dist ^d	Comment
Tetrachloroethene (µg/L)	18/ 31	.		1	6	2.8	X	No background available
Toluene (µg/L)	1/ 31	.		1	1	2.5	D	< = 5% detects
Trichloroethene (µg/L)	1/ 31	.		1	1	2.5	D	< = 5% detects
Radioactivity								
Alpha Activity (pCi/L)	101/ 101	2.11	100/ 101	0.07	520.0	110.4	X	> 5% detect above background
Beta Activity (pCi/L)	102/ 102	3.75	101/ 102	0.13	1200.0	343.0	X	> 5% detect above background
Strontium-90 (pCi/L)	7/ 11	.		1.05	2.152	1.095	N	No background data available
Technetium-99 (pCi/L)	8/ 9	.		139	477	239.9	N	No background data available
Thorium-228 (pCi/L)	5/ 10	.		0.103	0.25	0.1107	N	No background data available
Thorium-230 (pCi/L)	3/ 10	.		0.136	0.23	0.0985	D	No background data available
Thorium-232 (pCi/L)	3/ 10	.		0.126	0.132	0.0577	D	No background data available
Uranium-233/234 (pCi/L)	21/ 22	.		5.13	54	32.01	N	No background data available
Uranium-235 (pCi/L)	16/ 22	.		1.04	4.66	1.875	X	No background data available
Uranium-238 (pCi/L)	21/ 22	.		8.72	135	69.12	N	No background data available

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For surface water, background criteria have been established using data from NT-13 published in the GWQRs (e.g., HSW 1995). Only results for unfiltered samples were used.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects; R = distribution with negative results and therefore treated as normal.

^e No background value for cyanide was available from NT-13 (Energy Systems 1996). Cyanide was not detected in any samples from NT-5, the least contaminated catchment on BCV. The background value for cyanide was, therefore, assumed to be less than the detection limit and any detection of cyanide is considered as above background.

^f No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCV. See text for further details.

**Table D.105. Summary of chemical and radionuclide results for filtered samples,
Upper Bear Creek between BCK 11.97 and BCK 12.36**

Analyte ^a	Freq of detect	Min detect	Max detect	Average result
Aluminum (mg/L)	16/ 31	0.0251	0.401	0.0744
Antimony (mg/L)	11/ 21	0.0014	0.0095	0.0023
Arsenic (mg/L)	1/ 21	0.0021	0.0021	0.0010
Barium (mg/L)	31/ 31	0.0278	0.68	0.3259
Boron (mg/L)	10/ 10	0.033	0.57	0.119
Cadmium (mg/L)	5/ 8	0.0022	0.0087	0.0034
Calcium (mg/L)	31/ 31	20.2	390.0	166.8
Chromium (mg/L)	1/ 8	0.01	0.01	0.01
Cobalt (mg/L)	8/ 31	0.0024	0.0049	0.0025
Copper (mg/L)	6/ 31	0.0038	0.02	0.0033
Iron (mg/L)	11/ 31	0.0062	0.154	0.0235
Lead (mg/L)	1/ 8	0.0099	0.0099	0.0030
Lithium (mg/L)	6/ 7	0.0053	0.0077	0.0062
Magnesium (mg/L)	31/ 31	2.15	48.0	21.43
Manganese (mg/L)	31/ 31	0.0327	3.15	1.3330
Mercury (mg/L)	6/ 29	0.0002	0.0009	0.0002
Nickel (mg/L)	26/ 31	0.0122	0.0784	0.0321
Potassium (mg/L)	31/ 31	1.34	8.1	3.66
Silicon (mg/L)	3/ 3	2.8	3.3	3.1000
Silver (mg/L)	1/ 31	0.0077	0.0077	0.0024
Sodium (mg/L)	31/ 31	8.0	69.5	40.17
Strontium (mg/L)	10/ 10	0.17	1.2	0.49
Thallium (mg/L)	1/ 21	0.0031	0.0031	0.0012
Zinc (mg/L)	14/ 31	0.0067	0.018	0.0063
Total uranium (fluorometric) (mg/L)	10/ 10	0.073	0.31	0.1750
Alpha activity (pCi/L)	20/ 21	27.6	160.0	77.0
Beta activity (pCi/L)	20/ 20	12.5	372.0	196.7
Uranium-233/234 (pCi/L)	21/ 21	3.16	146.0	37.18
Uranium-235 (pCi/L)	17/ 21	1.06	8.75	2.35
Uranium-238 (pCi/L)	21/ 21	5.39	349.0	80.21

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

Table D.106. Summary of selection of site-related chemicals and radionuclides, Bear Creek Main Stem between BCK 9.40 and BCK 9.47

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
<i>Inorganics</i>								
Chloride (mg/L)	34/ 34	2	34/ 34	5.6	34.4	17.1	L	> 5% detect above background
Fluoride (mg/L)	35/ 35	0.1	35/ 35	0.12	0.4	0.2623	N	> 5% detect above background
Nitrate (mg/L)	35/ 35	0.2	34/ 35	0	46.2	14.47	L	> 5% detect above background
Sulfate (mg/L)	33/ 35	57	0/ 35	5.1	29.6	21.24	X	Below background
Aluminum (mg/L)	26/ 35	7.4	2/ 35	0.031	29.8	1.677	X	> 5% detect above background
Antimony (mg/L)	4/ 22	0.05	0/ 22	0.0016	0.0027	0.0011	D	Below background
Arsenic (mg/L)	5/ 22	0.05	0/ 22	0.0017	0.0226	0.0027	D	Below background
Barium (mg/L)	33/ 35	0.21	0/ 35	0.055	0.204	0.0992	L	Below background
Beryllium (mg/L)	1/ 35	0.0007	1/ 35	0.0015	0.0015	0.0002	D	< = 5% below background
Boron (mg/L)	13/ 13	0.062	13/ 13	0.1	4.1	0.8046	L	> 5% detect above background
Calcium (mg/L)	35/ 35	36	31/ 35	31	101	64.67	N	Essential element
Chromium (mg/L)	1/ 11	0.02	0/ 11	0.01	0.01	0.0055	D	Below background
Cobalt (mg/L)	3/ 35	0.017	0/ 35	0.0044	0.0139	0.0023	D	Below background
Copper (mg/L)	1/ 35	0.0072	0/ 35	0.005	0.005	0.0026	D	Below background
Iron (mg/L)	34/ 35	30	1/ 35	0.059	38	2.39	X	Essential element
Lithium (mg/L)	7/ 7			0.0282	0.091	0.0603	N	2/7 detects > WOE UTL ^e
Magnesium (mg/L)	35/ 35	7.2	28/ 35	5.2	18.1	11.44	N	Essential element
Manganese (mg/L)	34/ 35	6.1	0/ 35	0.025	0.708	0.1263	X	Below background
Mercury (mg/L)	3/ 32	0.0002	1/ 32	0.0002	0.0002	0.0001	D	< = 5% below background
Nickel (mg/L)	6/ 35	0.011	2/ 35	0.0037	0.0213	0.0049	D	> 5% detect above background
Potassium (mg/L)	35/ 35	3.5	15/ 35	1.3	12.2	4.155	L	Essential element
Selenium (mg/L)	1/ 22	0.066	0/ 22	0.0029	0.0029	0.0013	D	Below background
Silicon (mg/L)	3/ 3	19	0/ 3	3.3	3.7	3.533	N	Below background

Table D.106 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
Sodium (mg/L)	34/ 35	7.6	23/ 35	1.79	17.1	9.502	N	Essential element
Strontium (mg/L)	13/ 13	0.12	10/ 13	0.079	0.22	0.1638	N	> 5% detect above background
Vanadium (mg/L)	6/ 35	0.013	3/ 35	0.0051	0.0575	0.0048	D	> 5% detect above background
Zinc (mg/L)	19/ 35	0.066	2/ 35	0.0029	0.223	0.0181	X	> 5% detect above background
Total Uranium (Fluorometric) (mg/L)	13/ 13	0.015	13/ 13	0.052	0.152	0.1027	N	> 5% detect above background
<i>Organics</i>								
1,1,1-Trichloroethane (µg/L)	1/ 35	.		0.4	0.4	2.511	D	< = 5% detects
1,1-Dichloroethane (µg/L)	3/ 35	.		1	2	2.471	D	No background available
1,2-Dichloroethane (µg/L)	7/ 35	.		12	20	5.1	D	No background available
1,2-Dichloroethene (µg/L)	34/ 35	.		1	28	7.129	X	No background available
2-Butanone (µg/L)	2/ 35	.		8	24	4.2	D	No background available
4-Methyl-2-pentanone (µg/L)	1/ 35	.		86	86	5.386	D	< = 5% detects
Acetone (µg/L)	6/ 35	.		6	23	6.657	D	No background available
Chloromethane (µg/L)	6/ 35	.		2	7	3.871	D	No background available
Methylene chloride (µg/L)	3/ 35	.		3	4	2.357	D	No background available
Tetrachloroethene (µg/L)	14/ 35	.		0.5	4	2.1	D	No background available
Toluene (µg/L)	1/ 35	.		1	1	2.529	D	< = 5% detects
Trichloroethene (µg/L)	7/ 35	.		0.6	2	2.249	D	No background available
<i>Radioactivity</i>								
Alpha Activity (pCi/L)	32/ 32	2.11	32/ 32	18.9	138	54.64	L	> 5% detect above background
Beta Activity (pCi/L)	34/ 34	3.75	34/ 34	18.7	119.8	59.62	N	> 5% detect above background
Technetium-99 (pCi/L)	1/ 7	.		110	110	43.86	D	No background data available
Thorium-228 (pCi/L)	1/ 3	.		0.126	0.126	0.0527	D	No background data available
Thorium-230 (pCi/L)	1/ 3	.		0.2	0.2	0.0953	D	No background data available

Table D.106 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
Uranium-233/234 (pCi/L)	21/ 21			7.57	29.2	18.74	N	No background data available
Uranium-235 (pCi/L)	6/ 21			1.16	1.69	0.9	D	No background data available
Uranium-238 (pCi/L)	21/ 21			18.7	64.5	40.29	N	No background data available

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For surface water, background criteria have been established using data from NT-13 published in the GWQRs (e.g., HSW 1995). Only results for unfiltered samples were used.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

^e No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCV. See text for further details.

**Table D.107. Summary of chemical and radionuclide results for filtered samples,
Mid Bear Creek surface water**

Analyte ^a	Freq of detect	Min detect	Max detect	Average result
Aluminum (mg/L)	15/ 35	0.021	0.561	0.06
Antimony (mg/L)	5/ 22	0.0017	0.0053	0.0014
Arsenic (mg/L)	1/ 23	0.1	0.1	0.01
Barium (mg/L)	34/ 35	0.0141	0.29	0.0911
Boron (mg/L)	13/ 13	0.065	4.4	0.75
Cadmium (mg/L)	1/ 11	0.0051	0.0051	0.0014
Calcium (mg/L)	35/ 35	17.2	180.0	64.1
Cobalt (mg/L)	1/ 35	0.0025	0.0025	0.0017
Copper (mg/L)	7/ 35	0.0035	0.012	0.0027
Iron (mg/L)	15/ 35	0.0084	0.579	0.0514
Lithium (mg/L)	6/ 7	0.0432	0.0927	0.0554
Magnesium (mg/L)	35/ 35	2.02	20.0	11.61
Manganese (mg/L)	35/ 35	0.0016	1.1	0.0765
Mercury (mg/L)	2/ 33	0.0002	0.0003	0.0001
Nickel (mg/L)	2/ 35	0.014	0.026	0.004
Potassium (mg/L)	35/ 35	0.72	11.9	3.67
Selenium (mg/L)	1/ 22	0.0027	0.0027	0.0013
Silicon (mg/L)	3/ 3	2.9	3.8	3.4
Sodium (mg/L)	34/ 35	0.72	30.0	9.59
Strontium (mg/L)	13/ 13	0.022	0.51	0.175
Zinc (mg/L)	15/ 35	0.0022	0.034	0.0069
Total uranium (fluorometric) (mg/L)	13/ 13	0.001	0.24	0.107
Alpha activity (pCi/L)	22/ 22	16.5	109.0	56.1
Beta activity (pCi/L)	21/ 21	18.6	82.1	45.8
Uranium-233/234 (pCi/L)	22/ 22	5.18	28.9	17.36
Uranium-235 (pCi/L)	5/ 22	1.02	3.04	0.84
Uranium-238 (pCi/L)	22/ 22	9.9	57.7	36.4

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

Table D.108. Summary of selection of site-related chemicals and radionuclides, Bear Creek Main Stem at BCK 4.55 and BCK 4.67

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
<i>Inorganics</i>								
Chloride (mg/L)	82/ 83	2	80/ 83	2	15	7.318	X	> 5% detect above background
Fluoride (mg/L)	73/ 84	0.1	47/ 84	0.01	0.66	0.1295	X	> 5% detect above background
Nitrate (mg/L)	206/ 206	0.2	206/ 206	0.28	500	9.729	X	> 5% detect above background
Sulfate (mg/L)	48/ 84	57	0/ 84	7.8	26	10.23	X	Below background
Aluminum (mg/L)	79/ 84	7.4	0/ 84	0.035	4.21	0.5718	X	Below background
Antimony (mg/L)	1/ 28	0.05	1/ 28	0.057	0.057	0.026	X	< = 5% below background
Arsenic (mg/L)	2/ 84	0.05	1/ 84	0.05	0.06	0.022	N	< = 5% below background
Barium (mg/L)	84/ 84	0.21	0/ 84	0.0377	0.0905	0.0613	X	Below background
Beryllium (mg/L)	3/ 84	0.0007	2/ 84	0.0004	0.0072	0.0003	D	< = 5% below background
Boron (mg/L)	84/ 84	0.062	36/ 84	0.009	0.31	0.071	L	> 5% detect above background
Calcium (mg/L)	84/ 84	36	53/ 84	16.3	71	41.39	N	Essential element
Chromium (mg/L)	2/ 24	0.02	0/ 24	0.012	0.014	0.0057	D	Below background
Cobalt (mg/L)	8/ 84	0.017	0/ 84	0.002	0.0083	0.0018	D	Below background
Copper (mg/L)	5/ 84	0.0072	2/ 84	0.0046	0.014	0.0030	D	< = 5% below background
Gallium (mg/L)	1/ 56	.		0.02	0.02	0.0102	D	< = 5% detects
Iron (mg/L)	78/ 84	30	0/ 84	0.035	5.85	0.7593	L	Essential element
Lead (mg/L)	4/ 24	0.02	0/ 24	0.0044	0.011	0.0028	D	Below background
Lithium (mg/L)	8/ 56	.		0.02	0.03	0.0118	D	No detects > WOE UTL ^e
Magnesium (mg/L)	84/ 84	7.2	71/ 84	4.15	18.9	11.49	X	Essential element
Manganese (mg/L)	84/ 84	6.1	0/ 84	0.0089	0.447	0.0619	X	Below background
Mercury (mg/L)	1/ 78	0.0002	1/ 78	0.0003	0.0003	0.0001	D	< = 5% below background
Nickel (mg/L)	4/ 84	0.011	0/ 84	0.009	0.011	0.0046	D	Below background
Potassium (mg/L)	84/ 84	3.5	0/ 84	0.7	3.5	1.768	L	Essential element
Silicon (mg/L)	6/ 6	19	0/ 6	1.3	3.7	2.817	N	Below background
Silver (mg/L)	1/ 84	0.006	1/ 84	0.0061	0.0061	0.0030	D	< = 5% below background

Table D.108 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
Sodium (mg/L)	84/ 84	7.6	7/ 84	1.9	11.9	4.679	L	Essential element
Strontium (mg/L)	84/ 84	0.12	7/ 84	0.034	0.149	0.0775	L	> 5% detect above background
Thallium (mg/L)	1/ 56	.		0.03	0.03	0.0153	D	< = 5% detects
Titanium (mg/L)	16/ 56	.		0.01	0.05	0.015	D	Background < detection limit ^f
Vanadium (mg/L)	9/ 84	0.013	0/ 84	0.005	0.008	0.0026	D	Below background
Zinc (mg/L)	36/ 84	0.066	0/ 84	0.0032	0.04	0.0084	D	Below background
Total Uranium (Fluorometric) (mg/L)	27/ 28	0.015	26/ 28	0.015	0.067	0.0302	N	> 5% detect above background
Organics								
Acetone (µg/L)	1/ 28	.		1	1	4.446	D	< = 5% detects
Radioactivity								
Alpha Activity (pCi/L)	21/ 28	2.11	21/ 28	10.8	27.3	13.71	L	> 5% detect above background
Beta Activity (pCi/L)	25/ 28	3.75	25/ 28	10.2	37.56	19.66	L	> 5% detect above background

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For surface water, background criteria have been established using data from NT-13 published in the GWQRs (e.g., HSW 1995). Only results for unfiltered samples were used.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

^e No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCV. See text for further details.

^f No background value for titanium was available from NT-13. Titanium was not detected in any samples from NT-5 and it was, therefore, assumed that the background value for titanium is < the detection limit.

**Table D.109. Summary of chemical and radionuclide results for filtered samples,
Lower Bear Creek surface water**

Analyte ^a	Freq of detect	Min detect	Max detect	Average result
Aluminum (mg/L)	16/ 28	0.02	0.53	0.05
Arsenic (mg/L)	1/ 1	0.065	0.065	0.065
Barium (mg/L)	28/ 28	0.034	0.073	0.054
Beryllium (mg/L)	2/ 28	0.0006	0.0007	0.0002
Boron (mg/L)	28/ 28	0.046	0.29	0.111
Calcium (mg/L)	28/ 28	22.0	58.0	40.6
Copper (mg/L)	7/ 28	0.0044	0.021	0.0035
Iron (mg/L)	19/ 28	0.0081	0.42	0.0352
Lead (mg/L)	1/ 24	0.0071	0.0071	0.0022
Magnesium (mg/L)	28/ 28	3.9	17.0	10.9
Manganese (mg/L)	28/ 28	0.0065	0.04	0.0143
Potassium (mg/L)	27/ 28	0.76	2.2	1.42
Silicon (mg/L)	6/ 6	3.0	4.2	3.4
Silver (mg/L)	1/ 28	0.0067	0.0067	0.0031
Sodium (mg/L)	28/ 28	2.0	8.5	4.3
Strontium (mg/L)	28/ 28	0.043	0.13	0.076
Zinc (mg/L)	20/ 28	0.0025	0.03	0.0069
Total uranium (fluorometric) (mg/L)	28/ 28	0.012	0.067	0.031

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

Table D.110. Summary of selection of site-related chemicals and radionuclides, SS-1

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
<i>Inorganics</i>								
Chloride (mg/L)	27/ 27	21	26/ 27	14	98.6	55.09	N	> 5% detect above background
Fluoride (mg/L)	27/ 27	0.55	1/ 27	0.1	0.8	0.2115	X	< = 5% below background
Nitrate (mg/L)	27/ 27	2.7	27/ 27	11.6	142	39.35	L	> 5% detect above background
Sulfate (mg/L)	27/ 27	19	25/ 27	14	99	51.17	N	> 5% detect above background
Aluminum (mg/L)	20/ 27	2.4	1/ 27	0.0361	3.28	0.3369	L	< = 5% below background
Antimony (mg/L)	2/ 13	0.05	0/ 13	0.0019	0.0036	0.0011	D	Below background
Arsenic (mg/L)	2/ 13	0.078	0/ 13	0.0028	0.006	0.0015	D	Below background
Barium (mg/L)	27/ 27	0.34	1/ 27	0.0537	0.66	0.1127	X	< = 5% below background
Boron (mg/L)	14/ 14	0.028	14/ 14	0.031	0.09	0.0514	L	> 5% detect above background
Cadmium (mg/L)	1/ 12	0.0025	1/ 12	0.024	0.024	0.0029	D	> 5% detect above background
Calcium (mg/L)	27/ 27	60	27/ 27	101	240	185	X	Essential element
Copper (mg/L)	5/ 27	0.012	0/ 27	0.0043	0.0086	0.0028	D	Below background
Iron (mg/L)	23/ 27	4.6	1/ 27	0.0169	5.34	0.4997	L	Essential element
Lead (mg/L)	1/ 12	0.0096	1/ 12	0.026	0.026	0.0041	D	> 5% detect above background
Lithium (mg/L)	7/ 7	.		0.0032	0.0061	0.0041	L	No detects > WOE UTL ^e
Magnesium (mg/L)	27/ 27	36	0/ 27	9.75	29	17.67	X	Essential element
Manganese (mg/L)	26/ 27	0.13	3/ 27	0.0106	4	0.1934	X	> 5% detect above background
Mercury (mg/L)	3/ 24	0.0003	2/ 24	0.0001	0.0003	0.0001	D	> 5% detect above background
Nickel (mg/L)	1/ 27	0.02	1/ 27	0.08	0.08	0.0066	D	< = 5% detects
Potassium (mg/L)	27/ 27	5	0/ 27	2.82	4.5	3.713	N	Essential element
Silicon (mg/L)	3/ 3	9	0/ 3	5.7	5.9	5.8	N	Below background
Silver (mg/L)	1/ 27	0.006	1/ 27	0.0069	0.0069	0.0026	D	< = 5% detects
Sodium (mg/L)	27/ 27	9.7	25/ 27	8.57	26	17.02	L	Essential element
Strontium (mg/L)	14/ 14	0.079	14/ 14	0.36	0.6	0.4957	N	> 5% detect above background
Vanadium (mg/L)	2/ 27	0.0044	2/ 27	0.0075	0.0138	0.0025	D	> 5% detect above background

Table D.110 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
Zinc (mg/L)	16/ 27	0.041	1/ 27	0.0028	0.066	0.0108	L	< = 5% below background
Total Uranium (Fluorometric) (mg/L)	14/ 14	0.005	14/ 14	0.016	0.047	0.0366	N	> 5% detect above background
Organics								
1,2-Dichloroethene (µg/L)	2/ 27	.	.	0.7	2	2.507	D	No background available
4-methyl-2-pentanone (µg/L)	1/ 27	.	.	3	3	3.5	D	< = 5% detects
Acetone (µg/L)	2/ 27	.	.	4	9	4	D	No background available
Carbon disulfide (µg/L)	2/ 27	.	.	1	2	2.519	D	No background available
Chloroform (µg/L)	1/ 27	.	.	0.7	0.7	2.526	D	< = 5% detects
Tetrachloroethene (µg/L)	13/ 27	.	.	1	3	2.167	D	No background available
Trichloroethene (µg/L)	6/ 27	.	.	0.6	3	2.337	D	No background available
Radioactivity								
Alpha Activity (pCi/L)	23/ 27	.	.	11.74	29.5	17.57	N	No background data available
Beta Activity (pCi/L)	26/ 26	.	.	23.1	178	66.66	L	No background data available
Uranium-233/234 (pCi/L)	13/ 13	.	.	5.9	11	8.95	N	No background data available
Uranium-238 (pCi/L)	13/ 13	.	.	5.83	10.4	8.798	X	No background data available

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For springs, background criteria have been established by *Determination of Reference Concentrations for Inorganic Analytes in Groundwater at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (Energy Systems 1996). Geochemistry of uncontaminated springs (SS-8 and SS-6) was allocated into cluster 4 in this study using the surrogate cluster analysis technique (see text). Background values from cluster 4 were therefore used as a background for spring water.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

^e No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCV. See text for further details.

Table D.111. Summary of chemical and radionuclide results for filtered samples, SS-1 surface water

Analyte ^a	Freq of detect	Min detect	Max detect	Average result
Aluminum (mg/L)	15/ 27	0.0194	1.45	0.0846
Antimony (mg/L)	3/ 13	0.0018	0.0049	0.0014
Arsenic (mg/L)	1/ 13	0.0016	0.0016	0.0011
Barium (mg/L)	26/ 27	0.0522	0.61	0.1100
Boron (mg/L)	13/ 14	0.039	0.1	0.054
Cadmium (mg/L)	1/ 12	0.022	0.022	0.003
Calcium (mg/L)	27/ 27	107.0	260.0	184.3
Cobalt (mg/L)	1/ 27	0.0068	0.0068	0.0020
Copper (mg/L)	6/ 27	0.0042	0.018	0.0031
Iron (mg/L)	7/ 27	0.0052	0.124	0.0127
Lithium (mg/L)	6/ 7	0.0029	0.0042	0.0033
Magnesium (mg/L)	27/ 27	10.2	28.0	17.7
Manganese (mg/L)	26/ 27	0.003	3.7	0.155
Mercury (mg/L)	3/ 25	0.0001	0.0006	0.0001
Nickel (mg/L)	3/ 27	0.013	0.09	0.008
Potassium (mg/L)	27/ 27	2.74	4.6	3.68
Silicon (mg/L)	3/ 3	4.9	6.4	5.6
Sodium (mg/L)	27/ 27	8.85	28.0	16.89
Strontium (mg/L)	14/ 14	0.39	0.65	0.50
Zinc (mg/L)	16/ 27	0.0021	0.059	0.0088
Total uranium (fluorometric) (mg/L)	14/ 14	0.019	0.056	0.038
Alpha activity (pCi/L)	10/ 13	11.5	127.0	22.6
Beta activity (pCi/L)	12/ 12	28.0	241.0	65.1
Uranium-233/234 (pCi/L)	13/ 13	4.4	40.6	11.1
Uranium-235 (pCi/L)	1/ 13	2.09	2.09	0.45
Uranium-238 (pCi/L)	13/ 13	5.4	89.1	15.0

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

Table D.112. Summary of selection of site-related chemicals and radionuclides, SS-4

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
<i>Inorganics</i>								
Chloride (mg/L)	26/ 26	21	17/ 26	2.3	41.5	25.91	N	> 5% detect above background
Fluoride (mg/L)	26/ 27	0.55	2/ 27	0.2	0.6	0.3619	N	> 5% detect above background
Nitrate (mg/L)	26/ 27	2.7	26/ 27	3.12	67.6	31.58	N	> 5% detect above background
Sulfate (mg/L)	26/ 27	19	21/ 27	11.3	45	27.7	N	> 5% detect above background
Aluminum (mg/L)	19/ 27	2.4	1/ 27	0.028	2.98	0.3362	L	< = 5% below background
Antimony (mg/L)	1/ 13	0.05	0/ 13	0.0028	0.0028	0.0010	D	Below background
Barium (mg/L)	27/ 27	0.34	0/ 27	0.0545	0.24	0.1482	N	Below background
Boron (mg/L)	14/ 14	0.028	13/ 14	0.015	0.26	0.1104	N	> 5% detect above background
Calcium (mg/L)	27/ 27	60	24/ 27	16.3	140	100.2	X	Essential element
Copper (mg/L)	4/ 27	0.012	0/ 27	0.0044	0.0066	0.0024	D	Below background
Iron (mg/L)	23/ 27	4.6	0/ 27	0.035	3.72	0.4613	L	Essential element
Lead (mg/L)	1/ 12	0.0096	0/ 12	0.0047	0.0047	0.0022	D	Below background
Lithium (mg/L)	7/ 7	.		0.0214	0.0356	0.0293	N	No detects > WOE UTL ^e
Magnesium (mg/L)	27/ 27	36	0/ 27	2.94	26	20.27	X	Essential element
Manganese (mg/L)	26/ 27	0.13	7/ 27	0.0075	0.809	0.1371	L	> 5% detect above background
Mercury (mg/L)	3/ 24	0.0003	0/ 24	0.0001	0.0002	0.0001	D	Below background
Nickel (mg/L)	3/ 27	0.02	1/ 27	0.003	0.022	0.0048	D	< = 5% below background
Potassium (mg/L)	26/ 27	5	1/ 27	1.6	5.4	2.996	N	Essential element
Silicon (mg/L)	3/ 3	9	0/ 3	3.6	4.1	3.867	N	Below background
Silver (mg/L)	1/ 27	0.006	1/ 27	0.0065	0.0065	0.0026	D	< = 5% detects
Sodium (mg/L)	27/ 27	9.7	21/ 27	1.32	25	15.79	X	Essential element
Strontium (mg/L)	14/ 14	0.079	14/ 14	0.093	0.42	0.2329	L	> 5% detect above background
Vanadium (mg/L)	1/ 27	0.0044	0/ 27	0.0044	0.0044	0.0019	D	Below background
Zinc (mg/L)	12/ 27	0.041	0/ 27	0.0022	0.02	0.0056	D	Below background

Table D.112 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
Total Uranium (Fluorometric) (mg/L)	14/ 14	0.005	14/ 14	0.04	0.285	0.1356	N	> 5% detect above background
Organics								
1,1,1-Trichloroethane (µg/L)	2/ 27	.		1	1	2.481	D	No background available
1,1-Dichloroethene (µg/L)	3/ 27	.		2	3	2.574	D	No background available
1,2-Dichloroethene (µg/L)	21/ 27	.		1	21	7.704	L	No background available
Carbon disulfide (µg/L)	1/ 27	.		2	2	2.574	D	< = 5% detects
Trichloroethene (µg/L)	26/ 27	.		3	23	8.759	X	No background available
Radioactivity								
Alpha Activity (pCi/L)	27/ 27	.		15.3	130	52.94	L	No background data available
Beta Activity (pCi/L)	26/ 26	.		20.6	143	82.29	N	No background data available
Technetium-99 (pCi/L)	2/ 3	.		102	220	136.6	L	No background data available
Thorium-230 (pCi/L)	1/ 3	.		0.114	0.114	0.0581	D	No background data available
Uranium-233/234 (pCi/L)	13/ 13	.		6.76	37.3	27.26	N	No background data available
Uranium-235 (pCi/L)	10/ 13	.		1.04	3.62	1.568	N	No background data available
Uranium-238 (pCi/L)	13/ 13	.		12.2	82.6	57.59	N	No background data available

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For springs, background criteria have been established by *Determination of Reference Concentrations for Inorganic Analytes in Groundwater at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (Energy Systems 1996). Geochemistry of uncontaminated springs (SS-8 and SS-6) was allocated into cluster 4 in this study using the surrogate cluster analysis technique (see text). Background values from cluster 4 were therefore used as a background for spring water.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

^e No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCV. See text for further details.

**Table D.113. Summary of chemical and radionuclide results for filtered samples,
SS-4 surface water**

Analyte ^a	Freq of detect	Min detect	Max detect	Average result
Aluminum (mg/L)	15/ 27	0.024	0.36	0.06
Antimony (mg/L)	3/ 13	0.0029	0.0036	0.0014
Arsenic (mg/L)	1/ 13	0.0026	0.0026	0.0011
Barium (mg/L)	26/ 27	0.0289	0.24	0.1412
Boron (mg/L)	14/ 14	0.014	0.29	0.122
Calcium (mg/L)	27/ 27	15.9	160.0	101.1
Copper (mg/L)	7/ 27	0.0047	0.0084	0.0029
Iron (mg/L)	12/ 27	0.0065	0.470	0.0429
Lead (mg/L)	1/ 12	0.0078	0.0078	0.0025
Lithium (mg/L)	7/ 7	0.0203	0.0364	0.0291
Magnesium (mg/L)	27/ 27	2.51	29.0	20.33
Manganese (mg/L)	25/ 27	0.0013	0.23	0.0316
Mercury (mg/L)	3/ 25	0.0001	0.0002	0.0001
Nickel (mg/L)	3/ 27	0.018	0.031	0.006
Potassium filtered (mg/L)	27/ 27	1.2	5.3	2.9
Silicon (mg/L)	3/ 3	3.4	4.0	3.7
Sodium (mg/L)	27/ 27	1.23	26.0	15.72
Strontium (mg/L)	14/ 14	0.092	0.48	0.241
Zinc (mg/L)	12/ 27	0.0026	0.014	0.0046
Total uranium (fluorometric) (mg/L)	14/ 14	0.038	0.285	0.119
Alpha activity (pCi/L)	13/ 13	28.3	119.0	71.7
Beta activity (pCi/L)	12/ 12	71.1	118.0	90.5
Uranium-233/234 (pCi/L)	13/ 13	21.9	35.8	29.0
Uranium-235 (pCi/L)	8/ 13	1.22	2.97	1.49
Uranium-238 (pCi/L)	13/ 13	43.0	73.9	59.5

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

Table D.114. Summary of selection of site-related chemicals and radionuclides, SS-5

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
<i>Inorganics</i>								
Chloride (mg/L)	26/ 26	21	3/ 26	3	23.9	13.5	N	> 5% detect above background
Fluoride (mg/L)	24/ 27	0.55	0/ 27	0.1	0.44	0.2048	N	Below background
Nitrate (mg/L)	26/ 27	2.7	21/ 27	0.65	27	11.04	N	> 5% detect above background
Sulfate (mg/L)	27/ 27	19	10/ 27	4	29	16.75	N	> 5% detect above background
Aluminum (mg/L)	17/ 27	2.4	0/ 27	0.032	0.813	0.0980	L	Below background
Antimony (mg/L)	1/ 13	0.05	0/ 13	0.003	0.003	0.0010	D	Below background
Barium (mg/L)	27/ 27	0.34	0/ 27	0.036	0.12	0.0829	N	Below background
Beryllium (mg/L)	1/ 27	0.0005	0/ 27	0.0003	0.0003	0.0002	D	Below background
Boron (mg/L)	13/ 14	0.028	10/ 14	0.017	0.18	0.0754	N	> 5% detect above background
Calcium (mg/L)	27/ 27	60	18/ 27	26	87	62.73	X	Essential element
Copper (mg/L)	2/ 27	0.012	0/ 27	0.0061	0.0065	0.0021	D	Below background
Iron (mg/L)	20/ 26	4.6	0/ 26	0.0063	1.13	0.111	L	Essential element
Lead (mg/L)	1/ 12	0.0096	1/ 12	0.012	0.012	0.0028	D	1 detect > bkgd.; 0.012 (site) vs. 0.0096 (bkgd.)
Lithium (mg/L)	7/ 7	.		0.0085	0.014	0.0103	L	No detects > WOE UTL ^e
Magnesium (mg/L)	27/ 27	36	0/ 27	10	20	15.34	N	Essential element
Manganese (mg/L)	21/ 27	0.13	0/ 27	0.0023	0.0478	0.0074	L	Below background
Nickel (mg/L)	1/ 27	0.02	0/ 27	0.01	0.01	0.0039	D	Below background
Potassium (mg/L)	26/ 27	5	0/ 27	0.79	3.2	1.767	N	Essential element
Silicon (mg/L)	3/ 3	9	0/ 3	3.5	3.6	3.533	X	Below background
Sodium (mg/L)	27/ 27	9.7	6/ 27	2.3	14	7.781	N	Essential element
Strontium (mg/L)	14/ 14	0.079	8/ 14	0.025	0.2	0.1146	N	> 5% detect above background
Vanadium (mg/L)	1/ 27	0.0044	0/ 27	0.0037	0.0037	0.0019	D	Below background
Zinc (mg/L)	13/ 27	0.041	0/ 27	0.0024	0.02	0.0047	D	Below background

Table D.114 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
Total Uranium (Fluorometric) (mg/L)	14/ 14	0.005	13/ 14	0.005	0.117	0.0581	N	> 5% detect above background
<i>Organics</i>								
1,2-Dichloroethene (µg/L)	8/ 27	.		0.9	2	2.33	D	No background available
4-Methyl-2-pentanone (µg/L)	1/ 27	.		4	4	3.278	D	< = 5% detects
Acetone (µg/L)	2/ 27	.		2	6	3.574	D	No background available
Carbon Disulfide (µg/L)	1/ 27	.		1	1	2.537	D	< = 5% detects
Methylene Chloride (µg/L)	2/ 27	.		3	4	2.741	D	No background available
Trichloroethene (µg/L)	6/ 27	.		0.9	2	2.404	D	No background available
<i>Radioactivity</i>								
Alpha Activity (pCi/L)	22/ 27	.		10.6	75.8	29.35	N	No background data available
Beta Activity (pCi/L)	24/ 26	.		12.5	81.75	37.83	N	No background data available
Thorium-230 (pCi/L)	1/ 3	.		0.213	0.213	0.1357	D	No background data available
Uranium-233/234 (pCi/L)	13/ 13	.		5.9	26.6	13.97	L	No background data available
Uranium-235 (pCi/L)	3/ 13	.		1.1	2.98	0.8364	D	No background data available
Uranium-238 (pCi/L)	13/ 13	.		9.9	58.4	26.71	L	No background data available

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For springs, background criteria have been established by *Determination of Reference Concentrations for Inorganic Analytes in Groundwater at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (Energy Systems 1996). Geochemistry of uncontaminated springs (SS-8 and SS-6) was allocated into cluster 4 in this study using the surrogate cluster analysis technique (see text). Background values from cluster 4 were therefore used as a background for spring water.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

^e No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCV. See text for further details.

**Table D.115. Summary of chemical and radionuclide results for filtered samples,
SS-5 surface water**

Analyte ^a	Freq of detect	Min detect	Max detect	Average result
Aluminum (mg/L)	13/ 27	0.02	0.941	0.069
Antimony (mg/L)	2/ 13	0.0021	0.0056	0.0013
Arsenic (mg/L)	2/ 14	0.0019	0.059	0.0052
Barium (mg/L)	26/ 27	0.038	0.13	0.081
Beryllium (mg/L)	2/ 27	0.0004	0.0004	0.0002
Boron (mg/L)	14/ 14	0.011	0.17	0.064
Calcium (mg/L)	27/ 27	27.0	96.0	62.8
Copper (mg/L)	5/ 27	0.0044	0.016	0.0028
Iron (mg/L)	11/ 27	0.0076	0.4	0.0299
Lithium (mg/L)	6/ 7	0.0068	0.014	0.0093
Magnesium (mg/L)	27/ 27	11.0	21.0	15.6
Manganese (mg/L)	22/ 27	0.001	0.033	0.006
Mercury (mg/L)	1/ 25	0.0004	0.0004	0.0001
Nickel (mg/L)	2/ 27	0.01	0.024	0.005
Potassium (mg/L)	26/ 27	0.75	7.2	1.84
Silicon (mg/L)	3/ 3	3.2	3.5	3.3
Sodium (mg/L)	27/ 27	2.5	14.0	7.8
Strontium (mg/L)	14/ 14	0.026	0.24	0.119
Zinc (mg/L)	12/ 27	0.0036	0.019	0.0055
Total uranium (fluorometric) (mg/L)	14/ 14	0.005	0.115	0.059
Alpha activity (pCi/L)	13/ 13	21.0	63.1	42.5
Beta activity (pCi/L)	12/ 12	14.0	52.5	35.1
Uranium-233/234 (pCi/L)	13/ 13	7.7	18.3	13.4
Uranium-235 (pCi/L)	1/ 13	1.19	1.19	0.65
Uranium-238 (pCi/L)	13/ 13	18.0	38.0	26.6

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

Table D.116. Summary of selection of site-related chemicals and radionuclides, SS-6 unfiltered samples

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
<i>Inorganics</i>								
Chloride (mg/L)	15/ 22	21	0/ 22	1.5	5.8	2.6	X	Below background
Fluoride (mg/L)	2/ 23	0.55	0/ 23	0.1	0.11	0.0548	D	Below background
Nitrate (mg/L)	11/ 22	2.7	0/ 22	0.15	2.6	0.4477	X	Below background
Sulfate (mg/L)	22/ 23	19	0/ 23	2.3	14.5	8.435	N	Below background
Aluminum (mg/L)	17/ 23	2.4	1/ 23	0.025	3.77	0.2567	X	Below background
Antimony (mg/L)	1/ 12	0.05	0/ 12	0.0023	0.0023	0.001	D	Below background
Barium (mg/L)	23/ 23	0.34	0/ 23	0.023	0.0834	0.0489	X	Below background
Boron (mg/L)	10/ 11	0.028	0/ 11	0.0067	0.02	0.0119	N	Below background
Calcium (mg/L)	23/ 23	60	0/ 23	18	53.5	32.78	N	Essential element
Cobalt (mg/L)	1/ 23	0.019	0/ 23	0.0042	0.0042	0.002	D	< = 5% detects
Copper (mg/L)	2/ 23	0.012	1/ 23	0.0046	0.049	0.004	D	Below background
Iron (mg/L)	21/ 23	4.6	0/ 23	0.031	4.27	0.359	L	Essential element
Lithium (mg/L)	6/ 6	.		0.0033	0.0057	0.0043	N	0/7 detects > WOE UTL ^e
Magnesium (mg/L)	23/ 23	36	0/ 23	6.7	19.3	14.82	X	Essential element
Manganese (mg/L)	22/ 23	0.13	1/ 23	0.0044	0.352	0.0434	L	Below background
Nickel (mg/L)	1/ 23	0.02	0/ 23	0.0039	0.0039	0.0039	D	< = 5% detects
Potassium (mg/L)	19/ 23	5	0/ 23	0.532	1.3	0.777	N	Essential element
Silicon (mg/L)	3/ 3	9	0/ 3	3.2	3.4	3.3	X	Below background
Silver (mg/L)	1/ 23	0.006	1/ 23	0.0071	0.0071	0.0026	D	< = 5% detects
Sodium (mg/L)	23/ 23	9.7	0/ 23	0.2	3.27	1.35	X	Essential element
Strontium (mg/L)	11/ 11	0.079	0/ 11	0.016	0.028	0.021	L	Below background
Vanadium (mg/L)	2/ 23	0.0044	1/ 23	0.003	0.009	0.002	D	Below background

Table D.116 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
Zinc (mg/L)	12/ 23	0.041	3/ 23	0.009	0.078	0.019	L	> 5% detect above background
<i>Organics</i>								
2-Hexanone (µg/L)	1/ 23	.		3	3	4	D	< = 5% detects
Methylene chloride (µg/L)	2/ 23	.		2	4	2	D	No background available
<i>Radioactivity</i>								
Uranium-233/234 (pCi/L)	6/ 12			1.02	1.34	0.96	N	No background data available
Uranium-238 (pCi/L)	8/ 12			1.11	2.07	1.21	L	No background data available

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For surface water, background criteria have been established using data from NT-13 published in the GWQRs (e.g. HSW 1995). Only results for unfiltered samples were used.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects; R = distribution with negative results and therefore treated as normal.

^e No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCV. See text for further details.

**Table D.117. Summary of chemical and radionuclide results for filtered samples,
SS-6 surface water**

Analyte ^a	Freq of detect	Min detect	Max detect	Average result
Aluminum (mg/L)	14/ 26	0.02	0.438	0.056
Antimony (mg/L)	4/ 14	0.0017	0.0023	0.0012
Barium (mg/L)	25/ 26	0.021	0.13	0.052
Beryllium (mg/L)	1/ 26	0.0004	0.0004	0.0002
Boron (mg/L)	11/ 12	0.0094	0.25	0.0394
Calcium (mg/L)	26/ 26	17.0	100.0	35.7
Copper (mg/L)	5/ 26	0.0044	0.0105	0.0029
Iron (mg/L)	11/ 26	0.0078	0.184	0.0209
Lithium (mg/L)	6/ 7	0.0021	0.005	0.0030
Magnesium (mg/L)	26/ 26	6.3	20.3	15.1
Manganese (mg/L)	24/ 26	0.0031	0.336	0.0335
Nickel (mg/L)	3/ 26	0.013	0.017	0.005
Potassium (mg/L)	23/ 26	0.554	3.0	0.816
Silicon (mg/L)	3/ 3	3.1	3.3	3.2
Sodium (mg/L)	25/ 26	0.44	17.0	2.49
Strontium (mg/L)	12/ 12	0.016	0.28	0.044
Zinc (mg/L)	15/ 26	0.0059	0.046	0.0131
Total uranium (fluorometric) (mg/L)	4/ 12	0.001	0.17	0.015
Uranium-233/234 (pCi/L)	5/ 14	1.11	1.52	0.85
Uranium-238 (pCi/L)	7/ 14	1.24	2.33	1.19

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

**Table D.118. Summary of selection of site-related chemicals and radionuclides,
SS-6 unfiltered and filtered samples**

Analyte ^a	Bkgd criteria ^b	Detects > bkgd	Unfiltered result	Filtered result
<i>Inorganics</i>				
Chloride (mg/L)	21	0/ 1	5.1	
Nitrate (mg/L)	2.7	0/ 1	0.59	
Sulfate (mg/L)	19	0/ 1	10.9	
Barium (mg/L)	0.34	0/ 1	0.0637	0.066
Calcium (mg/L)	60	0/ 1	39.6	40.8
Iron (mg/L)	4.6	0/ 1	0.197	
Magnesium (mg/L)	36	0/ 1	16.1	16.6
Manganese (mg/L)	0.13	0/ 1	0.0216	0.0231
Potassium (mg/L)	5	0/ 1	0.791	0.855
Sodium (mg/L)	9.7	0/ 1	2.92	2.73
<i>Radioactivity</i>				
Uranium-233/234 (pCi/L)	.		1.3	
Uranium-238 (pCi/L)	.		1.7	1.5

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For surface water, background criteria have been established using data from NT-13 published in the GWQRs (e.g., HSW 1995). Only results for unfiltered samples were screened against background.

Table D.119. Summary of selection of site-related chemicals and radionuclides, SS-8

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
Chloride (mg/L)	24/ 24	21	0/ 24	1.5	6	2.817	L	Below background
Fluoride (mg/L)	1/ 25	0.55	0/ 25	0.1	0.1	0.052	D	Below background
Nitrate (mg/L)	20/ 24	2.7	0/ 24	0.14	1.2	0.2933	L	Below background
Sulfate (mg/L)	12/ 25	19	0/ 25	2	11	3.68	D	Below background
Aluminum (mg/L)	23/ 25	2.4	0/ 25	0.025	1.87	0.3116	L	Below background
Antimony (mg/L)	1/ 13	0.05	0/ 13	0.0015	0.0015	0.0009	D	Below background
Arsenic (mg/L)	1/ 13	0.078	0/ 13	0.0019	0.0019	0.0011	D	Below background
Barium (mg/L)	25/ 25	0.34	0/ 25	0.029	0.0604	0.0428	N	Below background
Boron (mg/L)	11/ 12	0.028	2/ 12	0.0081	0.036	0.0175	N	2 detects > bkgd.; max result 0.036 (site) vs 0.028 (bkgd.). Mean < bkgd.
Calcium (mg/L)	25/ 25	60	0/ 25	20	43.8	33.42	N	Essential element
Copper (mg/L)	1/ 25	0.012	0/ 25	0.0094	0.0094	0.0020	D	Below background
Iron (mg/L)	24/ 25	4.6	0/ 25	0.02	2.76	0.4323	L	Essential element
Lithium (mg/L)	3/ 7	NA ^e		0.0015	0.0019	0.0011	D	0/7 wells with median > WOE UTL ^e
Magnesium (mg/L)	25/ 25	36	0/ 25	8.1	16	11.88	X	Essential element
Manganese (mg/L)	25/ 25	0.13	0/ 25	0.0016	0.12	0.0233	L	Below background
Nickel (mg/L)	1/ 25	0.02	0/ 25	0.017	0.017	0.0041	D	Below background
Potassium (mg/L)	25/ 25	5	0/ 25	0.67	1.4	0.9823	L	Essential element
Silicon (mg/L)	3/ 3	9	0/ 3	3.4	3.7	3.567	N	Below background
Silver (mg/L)	1/ 25	0.006	1/ 25	0.0079	0.0079	0.0026	D	< = 5% detects
Sodium (mg/L)	25/ 25	9.7	0/ 25	1.2	3.8	1.898	L	Essential element
Strontium (mg/L)	12/ 12	0.079	0/ 12	0.018	0.052	0.0324	L	Below background

Table D.119 (continued)

Analyte ^a	Freq. of detect	Bkgd criteria ^b	Detects > bkgd	Min detect	Max detect	Avg ^c result	Dist ^d	Comment
Vanadium (mg/L)	2/ 25	0.0044	1/ 25	0.0023	0.0046	0.0020	D	< = 5% below background
Zinc (mg/L)	9/ 25	0.041	0/ 25	0.004	0.033	0.0066	D	Below background
Total Uranium (Fluorometric) (mg/L)	1/ 12	0.005	0/ 12	0.001	0.001	0.0005	D	Below background
Acetone (µg/L)	1/ 24	.		7	7	3.625	D	< = 5% detects

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b For springs, background criteria have been established by *Determination of Reference Concentrations for Inorganic Analytes in Groundwater at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (Energy Systems 1996). Geochemistry of uncontaminated springs (SS-8 and SS-6) was allocated into cluster 4 in this study using the surrogate cluster analysis technique (see text). Background values from cluster 4 were therefore used as a background for spring water.

^c Average result reflects the arithmetic mean of the dataset, assuming non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d The distribution of the data was determined using ERWM/ER-P2000.017, Rev. 0. L = distribution most similar to lognormal; N = distribution most similar to normal; X = distribution significantly different from normal or lognormal; D = distribution not determined because fewer than 50% detects.

^e No background value for lithium was available from NT-13 (Energy Systems 1996). The value of the lithium UTL was calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995) and is 0.071 mg/L. These data were used as background for surface water as the best available data that represent background for lithium in BCV. See text for further details.

**Table D.120. Summary of chemical and radionuclide results for filtered samples,
SS-8 surface water**

Analyte ^a	Freq of detect	Min detect	Max detect	Average result
Aluminum (mg/L)	12/ 25	0.0172	0.446	0.0593
Antimony (mg/L)	2/ 13	0.0018	0.0022	0.0010
Arsenic (mg/L)	2/ 14	0.0022	0.052	0.0047
Barium (mg/L)	24/ 25	0.027	0.0741	0.043
Beryllium (mg/L)	1/ 25	0.0004	0.0004	0.0002
Boron (mg/L)	12/ 12	0.0056	0.06	0.0197
Calcium (mg/L)	25/ 25	20.0	54.3	34.1
Copper (mg/L)	2/ 25	0.0093	0.07	0.0049
Iron (mg/L)	10/ 25	0.0073	0.662	0.0517
Lithium (mg/L)	1/ 7	0.0222	0.0222	0.0038
Magnesium (mg/L)	25/ 25	6.23	16.0	11.65
Manganese (mg/L)	19/ 25	0.0016	0.13	0.0174
Nickel (mg/L)	4/ 25	0.011	0.016	0.005
Potassium (mg/L)	24/ 25	0.62	7.12	1.11
Silicon (mg/L)	3/ 3	0.75	4.8	3.12
Sodium (mg/L)	24/ 25	1.3	5.61	2.0
Strontium (mg/L)	12/ 12	0.017	0.065	0.036
Vanadium (mg/L)	2/ 25	0.0023	0.0128	0.0023
Zinc (mg/L)	13/ 25	0.0025	0.1	0.0094
Total uranium (fluorometric) (mg/L)	5/ 12	0.001	0.014	0.002

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

**Table D.121. Summary of miscellaneous parameters for surface water aggregates
in the Maynardville Limestone and Bear Creek FA**

Parameter	Min	Max	Mean	n ^a	Min	Max	Mean	n ^a	Min	Max	Mean	n ^a
	<i>SS-1</i>				<i>SS-4</i>				<i>SS-5</i>			
Total alkalinity (mg/L)	198	332	265	13	34.9	238	.	13	132	194	167	13
Alkalinity (CO ₃) (mg/L)	.	.	.	16	.	4	1	16	.	.	.	16
Alkalinity (HCO ₃) (mg/L)	126	361	312	16	168	246	214	16	101	208	162	16
Specific conductance (μmhos/cm)	490	1540	1047	46	305	993	641	46	175	657	401	47
Dissolved oxygen (mg/L)	6.2	11.2	.	16	2.4	10.4	.	16	4.3	11.8	7.1	16
Total dissolved solids (mg/L)	365	1174	775	29	97	788	485	29	119	494	292	29
pH	6.3	8.2	.	46	6.2	8.3	.	46	6.1	8.3	7.3	47
Total suspended solids (mg/L)	1	117	19	29	1	42	13	29	1	55	7	29
Temperature (°C)	8	22.4	.	30	10	17.4	.	30	10.1	15.9	13.2	31
Turbidity (NTU)	0.32	94	.	29	0.06	35	.	29	0.58	26	3.1	29
	<i>SS-6</i>				<i>SS-8</i>							
Total alkalinity (mg/L)	106	198	155	14	118	151	140	11				
Alkalinity (CO ₃)(mg/L)	.	1	.	14	.	.	.	14				
Alkalinity (HCO ₃)(mg/L)	63	197	124	14	79	162	127	14				
Specific conductance (μmhos/cm)	100	728	233	43	19.5	317	217	41				
Dissolved oxygen (mg/L)	7.8	11.8	9.5	14	6	9.6	8.0	14				
Total dissolved solids (mg/L)	80	580	167	28	54	280	148	25				
pH	6	8.6	7.7	43	5.8	8.1	7.4	41				
Total suspended solids (mg/L)	1	60	9	28	1	46	9	25				
Temperature (°C)	8	20.5	13.9	29	11	17	13	27				
Turbidity (NTU)	0.74	180	10.2	28	1.1	13.2	4.8	25				
	<i>Upper BC</i>				<i>Mid BC</i>				<i>Lower BC</i>			
Total alkalinity (mg/L)	78.2	294	186.2	21	43.5	198	136.7	20				
Alkalinity (CO ₃) (mg/L)	.	.	.	12	.	4	1	16	.	.	.	32
Alkalinity (HCO ₃) (mg/L)	117	247	189	12	67	192	141	16	56	191	128	32
Specific conductance (μmhos/cm)	180	2892	1211	65	21.8	700	412.4	55	120	457	281	64

Table D.121 (continued)

Parameter	Min	Max	Mean	n ^a	Min	Max	Mean	n ^a	Min	Max	Mean	n ^a
Dissolved oxygen (mg/L)	4.6	14.1	9.6	334	6.2	12	9.6	15	6	11.4	9.2	32
Total dissolved solids (mg/L)	22	3000	1253	369	167	492	316	36	104	384	205	32
pH	6.2	8.8	7.6	387	6	8.4	7.8	55	6	8.5	7.7	64
Total suspended solids (mg/L)	1	1100	14	369	1	258	23	36	1	99	10	32
Temperature (°C)	3.1	26.5	15.6	52	4.8	24.7	15.3	39	5.7	20.9	12.5	32
Turbidity (NTU)	0.51	290	17.2	33	1.3	220	20.3	36	1.2	110	11.7	32

^a n = frequency of analysis.

Table D.122. Summary of selection of site-related chemicals and radionuclides, Maynardville Limestone groundwater aggregate

Analyte ^a	Freq. of detect	Freq. of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Comment
<i>Inorganics</i>							
Aluminum (mg/L)	606/ 756	78/ 78	0	0.020	68.	0.3	No wells with median > UTL
Antimony (mg/L)	1/ 756	1/ 78	2	0.130	0.1300	0.027	<= 5% of wells with median > UTL
Arsenic (mg/L)	1/ 38	1/ 17	0	0.005	0.005	0.003	No wells with median > UTL
Barium (mg/L)	770/ 769	78/ 78	2	0.0068	10.	0.23	<= 5% of wells with median > UTL
Beryllium (mg/L)	69/ 753	40/ 78	0	0.0003	0.0039	0.0002	No wells with median > UTL
Boron (mg/L)	727/ 760	78/ 78	24	0.0042	3.	0.16	> 5% of wells with median > UTL
Cadmium (mg/L)	59/ 756	21/ 82	4	0.0021	1.0200	0.008	<= 5% of wells with median > UTL
Calcium (mg/L)	856/ 856	82/ 82	11	1.	880.	119.52	Essential element
Chromium (mg/L)	118/ 779	39/ 82	2	0.010	0.710	0.007	<= 5% of wells with median > UTL
Cobalt (mg/L)	37/ 756	17/ 78	1	0.0051	0.1400	0.003	<= 5% of wells with median > UTL
Copper (mg/L)	294/ 754	70/ 78	8	0.004	0.190	0.005	> 5% of wells with median > UTL
Iron (mg/L)	735/ 765	78/ 78	5	0.0043	170.	1.82	Essential element
Lead (mg/L)	189/ 786	61/ 82	8	0.004	0.230	0.0046	> 5% of wells with median > UTL
Lithium (mg/L)	11/ 13	5/ 6	NA ^d	0.0047	0.0850	0.029	1/6 wells with median > WOE UTL ^d
Magnesium (mg/L)	848/ 848	82/ 82	10	0.1500	250.	28.58	Essential element
Manganese (mg/L)	706/ 767	78/ 78	4	0.0010	16.	0.37	> 5% of wells with median > UTL
Mercury (mg/L)	14/ 722	11/ 79	1	0.0002	0.0019	0.0001	<= 5% of wells with median > UTL
Molybdenum (mg/L)	9/ 757	6/ 78	0	0.0100	3.5000	0.0052	No wells with median > UTL
Nickel (mg/L)	182/ 756	57/ 78	1	0.0100	0.2300	0.0087	<= 5% of wells with median > UTL
Niobium (mg/L)	4/ 13	3/ 6	NA ^d	0.0081	0.0290	0.0073	3/6 wells with detects ^d
Potassium (mg/L)	836/ 845	82/ 82	5	0.620	44.	3.9916	Essential element
Selenium (mg/L)	2/ 55	2/ 20	0	0.005	0.005	0.0025	No wells with median > UTL
Silicon (mg/L)	253/ 253	63/ 63	1	0.810	18.	5.1238	<= 5% of wells with median > UTL

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Table D.122 (continued)

Analyte ^a	Freq. of detect	Freq. of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Comment
Silver (mg/L)	0/ 41	0/ 19	0	0.	0.	0.005	No detects
Sodium (mg/L)	856/ 856	82/ 82	4	0.550	1,300.	33.279	Essential element
Strontium (mg/L)	762/ 762	77/ 77	11	0.0097	23.	0.9129	> 5% of wells with median > UTL
Thallium (mg/L)	0/ 23	0/ 15	0	0.	0.	0.005	No detects
Thorium (mg/L)	0/ 756	0/ 78	1	0.	0.	0.1045	No detects
Tin (mg/L)	0/ 1	0/ 1	0	0.	0.	0.005	No detects
Titanium (mg/L)	7/ 13	5/ 6	NA ^d	0.0074	0.0520	0.0183	No wells with median > WOE UTL ^d
Total uranium (fluorometric) (mg/L)	529/ 830	71/ 82	13	0.0010	0.3000	0.0092	> 5% of wells with median > UTL
Vanadium (mg/L)	38/ 756	20/ 78	3	0.005	0.130	0.006	<= 5% of wells with median > UTL
Zinc (mg/L)	675/ 755	73/ 78	5	0.0013	5.1000	0.0452	> 5% of wells with median > UTL
Zirconium (mg/L)	2/ 13	2/ 6	0	0.0055	0.0081	0.0030	No wells with median > UTL
Common Anions							
Ammonia nitrogen (mg/L)	1/ 7	1/ 4	NA ^d	2.90	2.90	0.10	No background UTL; Nitrate is an SRC
Chloride (mg/L)	816/ 851	81/ 82	7	0.700	2,180.	49.3805	> 5% of wells with median > UTL
Fluoride (mg/L)	442/ 799	70/ 80	0	0.100	1.900	0.234	No wells with median > UTL
Kjeldahl nitrogen (mg/L)	5/ 7	3/ 4	NA ^d	0.3400	4.9000	1.3781	No background UTL; Nitrate is an SRC
Nitrate (mg/L)	587/ 829	64/ 82	34	0.1000	918.	29.5311	> 5% of wells with median > UTL
Nitrite (mg/L)	0/ 7	0/ 4	NA ^d	0.	0.	1.6250	No background UTL; Nitrate is an SRC
Sulfate (mg/L)	845/ 848	82/ 82	9	1.	2,833.	95.9244	> 5% of wells with median > UTL
Organics							
1,1,1-Trichloroethane (µg/L)	117/ 929	25/ 83		0.5000	43.	2.7199	> 5% of wells with detects
1,1,2,2-Tetrachloroethane (µg/L)	1/ 928	1/ 83		1	1	2.5	<= 5% of wells with detects

Table D.122 (continued)

Analyte ^a	Freq. of detect	Freq. of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Comment
1,1,2-Trichloroethane (µg/L)	1/928	1/83		1	1	2.5	<= 5% of wells with detects
1,1-Dichloroethane (µg/L)	95/928	16/83		0.5000	21	2.753	> 5% of wells with detects
1,1-Dichloroethene (µg/L)	81/929	18/83		0.5000	36	2.7108	> 5% of wells with detects
1,2-Dichloroethane (µg/L)	8/928	4/83		0.4	2	2.5	All detects < detection limit
1,2-Dichloroethene (µg/L)	312/870	44/83		0.7000	140	5.6627	> 5% of wells with detects
2-Butanone (µg/L)	25/929	15/83		2	16	5.1	All detects < detection limit
2-Hexanone (µg/L)	6/929	5/83		1	5	5.1	All detects < detection limit
4-Methyl-2-pentanone (µg/L)	9/929	9/83		2	8	5.1	All detects < detection limit
Acetone (µg/L)	76/928	44/83		1	180	5.0602	> 5% of wells with detects
Benzene (µg/L)	39/928	17/83		0.3	10	2.5	All detects < detection limit
Bromodichloromethane (µg/L)	6/928	1/83		1	4	2.5	<= 5% of wells with detects
Bromoform (µg/L)	2/928	2/83		1	1	2.5	<= 5% of wells with detects
Carbon disulfide (µg/L)	6/928	6/83		1	2	2.5	All detects < detection limit
Carbon tetrachloride (µg/L)	123/929	25/83		0.4000	9	2.5693	> 5% of wells with detects
Chlorobenzene (µg/L)	19/928	4/83		1	8	2.5	<= 5% of wells with detects
Chloroethane (µg/L)	13/929	5/83		0.9	8	5.1	All detects < detection limit
Chloroform (µg/L)	154/927	34/83		0.3000	11	2.4548	> 5% of wells with detects
Dimethylbenzene (µg/L)	11/928	8/83		1	6	2.5	All detects < detection limit
Ethylbenzene (µg/L)	10/928	7/83		0.8	2	2.5	All detects < detection limit
Methylene chloride (µg/L)	60/927	32/83		0.6000	23	2.5211	> 5% of wells with detects
Phenols (mg/L)	6/35	4/21		0.0020	0.0060	0.0075	All detects < detection limit
Styrene (µg/L)	3/928	3/83		0.8	1	2.5	<= 5% of wells with detects

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Table D.122 (continued)

Analyte ^a	Freq. of detect	Freq. of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Comment
Tetrachloroethene (µg/L)	227/929	35/83		0.4000	55	3.1325	> 5% of wells with detects
Toluene (µg/L)	35/928	19/83		0.3	4	2.5	All detects < detection limit
Trichloroethene (µg/L)	463/929	57/83		0.3000	460	21.8916	> 5% of wells with detects
Trans-1,2-Dichloroethene (µg/L)	29/70	5/16		0.6000	86	7.8281	> 5% of wells with detects
Vinyl acetate (µg/L)	15/929	15/83		1	10	5.1	All detects < detection limit
Vinyl chloride (µg/L)	43/929	4/83		2	35	5.3	<= 5% of wells with detects
Radioactivity							
Alpha activity (pCi/L)	147/667	43/73		4.73	108	4.69	> 5% detects
Americium-241 (pCi/L)	. /8	. /8		.	.	0.03	No detects
Beta activity (pCi/L)	275/667	53/73		8.6	197	16.7	> 5% detects
Cesium-137 (pCi/L)	3/7	3/7		5.6	8.8	4.3	> 5% detects
Neptunium-237 (pCi/L)	. /8	. /8		.	.	0.05	No detects
Plutonium-238 (pCi/L)	. /8	. /8		.	.	0.03	No detects
Plutonium-239/240 (pCi/L)	. /8	. /8		.	.	0.01	No detects
Radium-228 (pCi/L)	2/7	2/7		2.4	7.8	1.46	> 5% detects
Technetium-99 (pCi/L)	3/8	3/8		8	39	9.38	> 5% detects
Thorium-228 (pCi/L)	2/8	2/8		0.26	0.92	0.24	> 5% detects
Thorium-230 (pCi/L)	6/8	6/8		0.17	0.65	0.35	> 5% detects
Thorium-232 (pCi/L)	. /5	. /5		.	.	0.02	No detects
Total radioactive strontium (pCi/L)	. /8	. /8		.	.	0.69	No detects
Tritium (pCi/L)	. /8	. /8		.	.	14.8	No detects
Uranium-234 (pCi/L)	5/8	5/8		0.58	22	4.06	> 5% detects

Table D.122 (continued)

Analyte ^a	Freq. of detect	Freq. of wells w. detects	Wells with median > bkgd ^b	Min detect	Max detect	Mean of the medians ^c	Comment
Uranium-235 (pCi/L)	1/7	1/7	1	0.89	0.89	0.16	> 5% detects
Uranium-238 (pCi/L)	4/8	4/8	4	0.34	42	7.24	> 5% detects

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b Background criteria have been established by *Determination of Reference Concentrations for Inorganic Analytes in Groundwater at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee* (Energy Systems 1996). The background value for an analyte varies depending upon the groundwater cluster that a well has been assigned to so no single background value applies to each analyte. Refer to section C.2 and the above referenced document for a discussion of the approach to evaluating groundwater background, the groundwater background values, and the well cluster assignments.

^c The mean of the medians is the arithmetic mean of the median concentration of an analyte for each well. In calculating the mean of the medians it was assumed that non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

^d No background value was available from the above referenced source. Values for lithium and titanium UTLs were calculated using data from 13 groundwater wells that were previously considered as reasonable background wells in the GWQRs (HSW 1995). The values are 0.071 mg/L for lithium and 0.12 mg/L for titanium. See text for further details. Niobium and Thallium were not detected in 13 groundwater wells that were previously considered as reasonable background wells and the background UTL values was, therefore, assumed to be less than the detection limit and detected values are considered as above background.

**Table D.123. Summary of chemical and radionuclide results for filtered samples,
Maynardville Limestone groundwater aggregate**

Analyte ^a	Freq of detect	Freq of wells w. detects	Min detect	Max detect	Mean of the medians ^b
Aluminum (mg/L)	460/ 805	78/ 79	0.02	4.2	0.07
Antimony (mg/L)	4/ 803	4/ 79	0.07	0.11	0.03
Arsenic (mg/L)	1/ 48	1/ 19	0.007	0.007	0.003
Barium (mg/L)	818/ 820	80/ 80	0.0033	9.9	0.2322
Beryllium (mg/L)	27/ 804	23/ 79	0.0003	0.0027	0.0002
Boron (mg/L)	777/ 813	78/ 79	0.0041	6.2	0.1602
Cadmium (mg/L)	44/ 815	9/ 83	0.002	0.14	0.001
Calcium (mg/L)	921/ 922	83/ 83	0.45	890.0	117.34
Chromium (mg/L)	27/ 839	14/ 83	0.01	0.036	0.005
Cobalt (mg/L)	22/ 806	6/ 79	0.0052	0.031	0.0029
Copper (mg/L)	271/ 804	72/ 79	0.004	0.05	0.003
Iron (mg/L)	569/ 822	79/ 80	0.0041	40.0	0.5646
Lead (mg/L)	63/ 849	31/ 83	0.004	0.11	0.002
Lithium (mg/L)	14/ 17	5/ 6	0.004	0.13	0.031
Magnesium (mg/L)	909/ 910	83/ 83	0.0054	260.0	27.8938
Manganese (mg/L)	653/ 823	78/ 80	0.001	16.0	0.328
Mercury (mg/L)	7/ 785	7/ 81	0.0002	0.0004	0.0001
Molybdenum (mg/L)	14/ 808	7/ 79	0.011	4.1	0.005
Nickel (mg/L)	157/ 807	53/ 79	0.01	0.2	0.01
Niobium (mg/L)	2/ 17	2/ 6	0.0092	0.015	0.0054
Potassium (mg/L)	900/ 909	83/ 83	0.6	85.0	4.0
Selenium (mg/L)	3/ 71	2/ 21	0.002	0.006	0.003
Silicon (mg/L)	278/ 278	64/ 64	0.084	13.0	4.578
Silver (mg/L)	. / 47	. / 20	.	.	0.0050
Sodium (mg/L)	922/ 924	83/ 83	0.32	1300.0	33.23
Strontium (mg/L)	812/ 812	78/ 78	0.0009	24.0	0.8881
Thallium (mg/L)	. / 28	. / 16	.	.	0.005
Thorium (mg/L)	. / 806	. / 79	.	.	0.1019
Tin (mg/L)	. / 2	. / 2	.	.	0.005
Titanium (mg/L)	5/ 17	4/ 6	0.0055	0.021	0.005
Total uranium (fluorometric) (mg/L)	551/ 894	75/ 83	0.001	0.31	0.009
Vanadium (mg/L)	20/ 806	7/ 79	0.0051	0.014	0.0027
Zinc (mg/L)	683/ 807	79/ 79	0.001	0.6	0.009
Zirconium (mg/L)	. / 17	. / 6	.	.	0.0025

^a Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^b The mean of the medians is the arithmetic mean of the median concentration of an analyte for each well. In calculating the mean of the medians it was assumed that non-detects are equal to one-half the detection limit for chemicals. Radionuclide data qualified as non-detect based on comparison to minimal detectable activities or counting errors are set equal to the reported value.

Table D.124. Summary of miscellaneous parameters for the Maynardville Limestone groundwater aggregate

Parameter	Min	Max	Mean	n ^a
Alkalinity (CO ₃) (mg/L)	.	920	7	1304
Alkalinity (HCO ₃) (mg/L)	.	987	216	1304
Specific conductance (μmhos/cm)	5.83	8850	1034.5	3958
Dissolved oxygen (mg/L)	0.1	18.5	4.0	1329
Total dissolved solids (mg/L)	10	20056	606	1238
pH	3	12.7	7.3	3958
Redox (eV)	-357	570	158	1328
Total suspended solids (mg/L)	.	12355	52	1317
Temperature (°C)	5	32.6	15.3	1333
Total coliform	.	100	2	176
Total organic carbon (mg/L)	.	61	4	588
Total organic chloride (mg/L)	9	8490	294	644
Turbidity (NTU)	0.09	3500	30.7	1162

^a n = frequency of analysis.

Table D.125. Summary of pH and alkalinity results for wells in the Maynardville Limestone and Bear Creek FA

Well	pH				Alkalinity (HCO ₃) (mg/L)				Alkalinity (CO ₃) (mg/L)			
	min	max	mean	n ^a	min	max	mean	n ^a	min	max	mean	n ^a
GW-045	6.4	7.8	7.0	30	157	206	177	5	.	.	.	5
GW-052	6.6	7.4	7.1	10	105	151	121	5	.	.	.	5
GW-053	6	7.9	7.3	28	180	325	265	14	.	.	.	14
GW-054	6.6	7.73	7.4	20	242	261	252	10	.	.	.	10
GW-056	6.4	8	7.3	34	197	314	260	17	.	2	1	17
GW-057	6.6	7.9	7.1	22	208	319	269	11	.	.	.	11
GW-058	6.3	8.2	7.1	70	84	322	255	20	.	.	.	20
GW-061	3.5	7.6	7.0	48	155	241	198	18	.	.	.	18
GW-063	6.3	7.6	7.0	90	151	380	269	24	.	16	2	24
GW-064	6.3	8	7.1	90	171	302	271	30	.	2	1	30
GW-067	6.6	7.5	7.1	55	308	384	341	10	.	.	.	10
GW-094	7	9.9	9.0	65	258	333	280	12	19	60	35	12
GW-095	6.11	9.7	8.9	95	203	276	234	27	4	58	33	27
GW-100	6.1	7.8	6.9	58	138	348	191	11	.	.	.	11
GW-122	5.9	7.8	6.7	80	242	351	306	18	.	2	1	18
GW-124	6.1	8.4	6.7	70	202	262	233	13	.	.	.	13
GW-165	5.9	7.8	7.2	10	128	153	140	5	.	2	1	5
GW-166	5.9	8.3	7.5	10	122	140	131	5	.	2	1	5
GW-209	3	6.1	5.3	10	2	16	10	5	.	2	1	5
GW-210	5.2	11.6	8.6	10	0	194	114	5	.	54	24	5
GW-211	5.6	7.7	6.9	10	111	121	115	5	.	2	1	5
GW-225	5.4	8.4	7.2	101	176	435	216	26	.	2	1	26
GW-226	5.9	7.8	6.7	86	284	552	488	20	.	4	1	20
GW-227	5.4	8.1	6.9	101	177	490	275	26	.	2	1	26
GW-228	5.8	10.8	7.5	76	212	952	364	15	.	248	18	15
GW-229	5.8	7.56	6.6	76	166	632	489	15	.	4	1	15
GW-236	3.5	5.1	4.1	35	1	11	5	7	.	.	.	7
GW-306	6.3	7.4	7.0	45	238	316	284	12	.	.	.	12
GW-307	6.4	6.9	6.7	40	30	350	286	11	.	.	.	11

Table D.125 (continued)

Well	pH				Alkalinity (HCO ₃) (mg/L)				Alkalinity (CO ₃) (mg/L)			
	min	max	mean	n ^a	min	max	mean	n ^a	min	max	mean	n ^a
GW-308	6.3	7	6.7	40	107	417	329	11	.	.	.	11
GW-309	6	7.4	6.6	50	352	464	410	16	.	.	.	16
GW-310	6	6.9	6.4	50	167	239	217	13	.	.	.	13
GW-311	6.4	8.3	7.3	61	171	227	206	20	.	.	.	20
GW-312	6.5	12.7	11.7	57	1	987	125	20	4	920	160	20
GW-313	6.3	7.6	6.9	40	283	354	316	14	.	.	.	14
GW-314	6.5	7.8	7.2	45	215	298	257	15	.	.	.	15
GW-315	6.2	7.8	7.1	65	179	249	220	25	.	11	1	25
GW-316	6.8	8.1	7.5	55	182	262	200	20	.	.	.	20
GW-317	6.5	8.2	7.7	68	164	244	201	25	.	3	1	25
GW-323	6.6	8.1	7.5	55	181	215	203	20	.	.	.	20
GW-347	6.3	7.8	7.1	51	68	175	113	21	.	2	1	21
GW-348	5.8	7.9	7.3	57	182	248	228	24	.	2	1	24
GW-365	6.4	8.3	7.0	65	218	348	300	22	.	.	.	22
GW-366	6.5	10.4	7.4	55	57	322	240	17	.	14	2	17
GW-367	6.2	7.9	7.2	45	142	167	159	12	.	.	.	12
GW-368	6.6	7.8	7.2	35	150	199	174	7	.	.	.	7
GW-369	5.1	10	7.5	45	77	175	147	12	.	2	1	12
GW-375	8.4	9.6	9.1	35	230	281	253	7	28	79	53	7
GW-520	6.9	12.7	11.1	35	0	620	96	13	.	593	115	13
GW-601	6.3	9.2	7.8	37	72	196	185	17	.	40	3	17
GW-602	6	9.2	7.9	25	118	154	135	11	.	4	1	11
GW-621	6.8	8.2	7.5	41	137	171	155	19	.	.	.	19
GW-645	6.5	7.7	7.4	14	200	249	225	7	.	.	.	7
GW-646	6.3	9.5	7.3	14	202	253	226	7	.	.	.	7
GW-647	6.2	8.04	7.5	24	165	185	176	12	.	.	.	12
GW-648	5.8	7.9	7.2	14	174	200	187	7	.	.	.	7
GW-651	7.1	8.3	7.7	24	115	203	180	12	.	.	.	12
GW-652	7	7.9	7.4	32	185	208	197	16	.	.	.	16

Table D.125 (continued)

Well	pH				Alkalinity (HCO ₃) (mg/L)				Alkalinity (CO ₃) (mg/L)			
	min	max	mean	n ^a	min	max	mean	n ^a	min	max	mean	n ^a
GW-683	6.2	7.9	7.3	28	109	214	170	14	.	.	.	14
GW-684	6.2	8.4	7.6	26	124	182	152	13	.	.	.	13
GW-685	6.5	7.8	7.4	26	245	266	252	13	.	.	.	13
GW-694	6.6	7.8	7.1	26	188	288	227	13	.	.	.	13
GW-695	7.6	8.7	8.3	26	144	196	169	13	.	20	3	13
GW-703	7.2	8.4	8.0	26	158	212	185	13	.	.	.	13
GW-704	7.3	8.4	7.7	28	125	200	182	14	.	2	1	14
GW-706	5.2	8.6	7.4	26	93	303	216	13	.	8	2	13
GW-710	6.4	7.6	7.2	22	143	168	160	11	.	.	.	11
GW-711	6.6	7.8	7.3	22	138	157	149	11	.	.	.	11
GW-712	7.3	8.1	7.7	25	164	190	180	12	.	.	.	12
GW-713	7.3	8	7.6	20	177	194	184	10	.	.	.	10
GW-714	7.1	8.2	7.7	16	180	202	193	8	.	.	.	8
GW-715	6.4	8	7.2	16	203	252	222	8	.	.	.	8
GW-723	6.7	9.2	7.9	18	80	223	190	9	.	6	2	9
GW-724	6.3	8.4	7.5	20	116	282	205	10	.	12	2	10
GW-725	6.8	7.6	7.1	18	284	307	295	9	.	.	.	9
GW-736	6.8	7.4	7.0	18	299	330	315	9	.	.	.	9
GW-737	6.5	7.4	7.0	18	307	328	315	9	.	.	.	9
GW-738	6.2	7.8	7.2	20	201	297	278	10	.	.	.	10
GW-739	7.2	7.9	7.6	18	219	240	228	9	.	.	.	9
GW-740	7.3	7.8	7.5	18	237	261	249	9	.	.	.	9
GW-800	6.9	7.7	7.2	16	121	276	214	8	.	.	.	8

^a n = frequency of analysis.

**D.14 SUPPORTING INFORMATION
FOR APPENDIX D—RARE SPECIES
ON THE OAK RIDGE RESERVATION**

THREATENED AND ENDANGERED SPECIES

Several state- and federally-listed threatened and endangered species occur and potentially occur on the ORR (Parr 1984; Kroodsma 1987). Table D.126 lists rare plant and animal species that occur on the ORR. The federally listed mammal that is known to occur on the ORR is the gray bat (*Myotis grisescens*), which prefers roosting habitat near water. Another rare mammal known to occur on the ORR is the state-listed southeastern shrew (*Sorex longirostris*), which prefers floodplains and wetlands. A number of state- and federal-listed bird species, including several raptors, have been found on the ORR. The federally listed birds are the bald eagle (*Haliaeetus leucocephalus*) and peregrine falcon (*Falco peregrinus*). The state-listed birds include Cooper's (*Accipiter cooperi*) and Sharp-shinned (*Accipiter striatus*) hawks. A state-listed fish, the Tennessee dace (*Phoxinus tennesseensis*), is known to occur in Bear Creek. In addition, a number of species that are candidates for federal listing (designated C2 in Table D.126) have been found on the ORR.

Because of the numerous activities conducted on the ORR, informal consultation with the Tennessee Heritage Program, Tennessee Wildlife Resources Agency, and the U.S. Fish and Wildlife Service concerning listed species is performed as a continuous function. Consultation and correspondence with state and federal agencies with respect to rare species is coordinated through the ORNL Area Manager and U.S. Department of Energy, Oak Ridge Operations Office. The ORNL Area Manager also coordinates a team of biologists who conduct surveys for listed species on the ORR. These surveys include site-specific surveys for proposed projects and habitat-specific surveys for species with high likelihood of occurrence. Occurrence of any listed species is reported to the state Heritage Program and to the U.S. Fish and Wildlife Service by ORNL.

Table D.126. Status of rare species reported from the ORR^a

Species name	Common name	Legal status ^b	
		Federal	State
<i>Plants</i>			
<i>Aureolaria patula</i>	Spreading false foxglove	C2	T
<i>Carex gravida</i>	Heavy Sedge		S
<i>Carex oxylepis</i> var. <i>pubescens</i>	Hairy Sharp-scaled Sedge		S
<i>Cimicifuga rubifolia</i>	Appalachian Bugbane	C2	T
<i>Cypripedium acaule</i>	Pink Lady's-slipper		E
<i>Delphinium exaltatum</i>	Tall Larkspur	C2	E
<i>Diervilla lonicera</i>	Northern Bush-honeysuckle		T
<i>Draba ramosissima</i>	Branching Whitlow-grass		S
<i>Elodea nuttallii</i>	Nuttall's Waterweed		S
<i>Fothergilla major</i>	Mountain Witch-alder		T
<i>Hydrastis canadensis</i>	Goldenseal		T
<i>Juglans cinerea</i>	Butternut	C2	T
<i>Juncus brachycephalus</i>	Small-headed Sedge		S
<i>Lilium canadense</i>	Canada Lily		T
<i>Liparis loeselii</i>	Fen Orchis		E
<i>Panax quinquefolius</i>	American Ginseng		T
<i>Platanthera flava</i> var. <i>herbiola</i>	Tubercled Rein-orchid		T
<i>Platanthera peramoena</i>	Purple Fringeless Orchid		T
<i>Rhynchospora colorata</i>	White-topped Sedge		S
<i>Ruellia purshiana</i>	Pursh's Wild-petunia		S
<i>Saxifraga careyana</i>	Carey's Saxifrage		S
<i>Scirpus fluviatilis</i>	River Bulrush		S
<i>Spiranthes lucida</i>	Shining Ladies'-tresses		T
<i>Spiranthes ovalis</i>	Lesser Ladies'-tresses		S
<i>Fish</i>			
<i>Phoxinus tennesseensis</i>	Tennessee Dace		NM
<i>Polydon spathula</i>	Paddlefish	C2	
<i>Amphibians and Reptiles</i>			
<i>Aneides aeneus</i>	Green Salamander	C2	
<i>Cryptobranchus alleganiensis</i>	Hellbender	C2	NM
<i>Birds</i>			
<i>Accipiter cooperii</i> ^d	Cooper's Hawk		NM
<i>Accipiter striatus</i> ^d	Sharp-shinned Hawk		NM
<i>Aimophila aestivalis</i> ^d	Bachman's Sparrow	C2	E
<i>Ammodramus henslowi</i> ^f	Henslow's Sparrow	C2	
<i>Ammodramus savannarum</i> ^d	Grasshopper Sparrow		NM

Table D.126 (continued)

Species name	Common name	Legal status ^b	
		Federal	State
<i>Anhinga anhinga</i> ^c	Anhinga		NM
<i>Casmerodius albus</i> ^c	Great Egret		NM
<i>Chlidonias nigra</i> ^c	Black Tern	C2	
<i>Circus cyaneus</i> ^c	Northern Harrier		NM
<i>Contopus borealis</i> ^c	Olive-sided Flycatcher		NM
<i>Dendroica cerulea</i> ^d	Cerulean Warbler	C2	
<i>Egretta caerulea</i> ^d	Little Blue Heron		NM
<i>Falco peregrinus</i> ^c	Peregrine Falcon	T	E
<i>Grus canadensis</i> ^c	Sandhill Crane		NM
<i>Haliaeetus leucocephalus</i> ^c	Bald Eagle	T	T
<i>Pandion haliaetus</i>	Osprey		T
<i>Phalacrocorax auritus</i> ^c	Double-crested Cormorant		NM
<i>Sphyrapicus varius</i> ^c	Yellow-bellied Sapsucker		NM
<i>Thryomanes bewickii</i>	Bewick's Wren	C2	T
<i>Tyto alba</i>	Common Barn Owl		NM
Mammals			
<i>Myotis grisescens</i>	Gray Bat	E	E
<i>Sorex longirostris</i>	Southeastern Shrew		NM

^a From Parr and Evans (1992); Cunningham (1993); Kroodsmas (1987); Pounds, Parr, and Ryon (1993); King, Aul, and Gabrielson (1994); and ongoing environmental restoration field surveys.

^b E = endangered, T = threatened, C2 = candidate, NM = in need of management, S = special concern in Tennessee.

^c Uncommon visitor or migrant; not currently known to nest on the ORR.

^d Summer.

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