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

Volume 1

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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 1

Date Issued—September 1996

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Oak Ridge, Tennessee 37831-8169
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LOCKHEED MARTIN ENERGY SYSTEMS, INC.
for the
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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

2,4,5-T	2,4,5-trichlorophenoxyacetic acid
amsl	above mean sea level
ARAR	applicable or relevant and appropriate requirement
BCBG	Bear Creek Burial Grounds
BCK	Bear Creek Kilometer
BCV	Bear Creek Valley
BHHRA	Baseline Human Health Risk Assessment
BRA	baseline risk assessment
BYBY	Boneyard/Burnyard
CA	Characterization Area
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
COPC	chemical of potential concern
COPEC	contaminant of potential ecological concern
CWA	Clean Water Act
DARA	Disposal Area Remedial Action Solids Storage Unit
DCA	dichloroethane
DCE	dichloroethene
DNAPL	dense non-aqueous phase liquid
DOE	Department of Energy
DQO	data quality objective
EPA	Environmental Protection Agency
ER	Environmental Restoration
FA	functional area
FFA	Federal Facilities Agreement
FPSS	Floodplain soils and sediments
FS	Feasibility Study
GWQR	Groundwater Quality Report
HCDA	Hazardous Chemicals Disposal Area
HI	hazard index
HQ	hazard quotient
IP	integration point
LNAPL	light non-aqueous phase liquid
LOAEL	lowest observed adverse effect level
LOEC	lowest observed effect concentration
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NOAEL	no observed adverse effect level
NOEC	no observed effect concentration
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
NT	North Tributaries

OLF	Oil Landfarm
ORO	Oak Ridge Operations
ORP	Oil Retention Pond
ORR	Oak Ridge Reservation
OSHA	Occupational Safety and Health Administration
OU	operable unit
PAH	polyaromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
ppm	parts per million
PRG	preliminary remediation goal
RAGS	<i>Risk Assessment Guidance for Superfund</i>
RBRGO	risk-based remedial goal option
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RGO	remedial goal option
RI	Remedial Investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Water Drinking Act
SL 1	Sanitary Landfill 1
SMCL	secondary maximum contaminant level
SRC	site-related contaminant
SSNAEL	site-specific no adverse effect level
SVOC	semivolatile organic compound
TBC	to be considered
TCA	trichloroethane
TCE	trichloroethene
TDEC	Tennessee Department of Environment and Conservation
TSCA	Toxic Substances Control Act
UCL	upper confidence limit
UEFPC	Upper East Fork Poplar Creek
UTL	upper tolerance limit
VOC	volatile organic compound
WIP	Walk-In Pits
WQC	water quality criteria

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

BEAR CREEK VALLEY KEY MAP

Y-12 PLANT NORTH

BEAR CREEK VALLEY

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

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.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, ⁹⁹Tc, 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, ⁹⁹Tc, 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 ⁹⁹Tc 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 BCVA, 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.

1. INTRODUCTION

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), encompasses multiple waste units containing hazardous and radioactive wastes arising from operations at the adjacent Oak Ridge Y-12 Plant. 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, and 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 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.

1.1 OVERVIEW

1.1.1 Purpose, Scope, and Layout

The purpose of the RI Report is to characterize the nature and extent of contamination in BCV, to evaluate the fate and transport of contaminants, and to assess risk to human health and the environment.

The RI Report is contained in six volumes. The first volume is a summary of the extensive data analysis and interpretation that has been completed for the RI and is the RI Report. Chapters 2, 3, 5, and 6 of the RI Report are supported by appendices in the remaining five volumes that contain detailed analysis and discussion. The intent of this format is to provide the reader with a clear and concise presentation of the RI findings and conclusions in Volume 1. The first volume is then corroborated by detailed discussion of the approach to data analysis and the interpretation of the data that led to the conclusions in the appendices. The appendices, which are detailed and inclusive, are best used as reference documents while reading the RI Report (Volume 1).

Chapter 1 of the RI Report presents the strategy used to satisfy regulatory requirements in BCV. Chapter 2 describes the physical properties of the valley, as well as the demographics. The results of investigations of the environmental media (e.g., soil, water, and sediment) to determine the nature, extent, fate, and transport of contamination are presented in Chap. 3. The applicable or relevant and appropriate requirements (ARARs) are provided in Chap. 4. The results of the baseline human health risk assessment (BHHRA) are in Chap. 5, and the findings of the baseline ecological risk assessment are in Chap. 6. Chapter 7 presents the initial remedial goal options derived from this study, and Chap. 8 contains the conclusions. Tables for each chapter of the RI Report are located in the back of this volume.

The appendices relate to the RI Report in the following manner:

- **Appendix A.** Appendix A contains a discussion of the operational histories of waste sites in BCV and a detailed analysis of inventory records for the Bear Creek Burial Grounds (BCBG) waste area. This appendix supports Sect. 3.1.
- **Appendix B.** Appendix B is a listing of the historical database for BCV and a detailed description of the field activities completed in BCV during 1994 and 1995. Results of analyses are not presented in this appendix; rather, this appendix supports the discussions of data in Sect. 3.2 and in Appendices C, D, and E with a detailed description of the field activities and a review of the quality of these data.

- **Appendix C.** Appendix C presents the hydrogeological site conceptual model for BCV. This section combines the wealth of past knowledge of hydrogeology on the Oak Ridge Reservation (ORR) with data from recent field studies. The conceptual models for contaminant distribution in surface water and groundwater are developed within the framework of the hydrogeologic conceptual model; as such, this appendix supports Chap. 2 and Sect. 3.2.
- **Appendix D.** Appendix D is the detailed discussion of the nature and extent of contamination in BCV. This appendix supports Sect. 3.2.
- **Appendix E.** Appendix E is the detailed discussion of the fate and transport of contaminants in BCV. This appendix supports Sect. 3.2.
- **Appendix F.** Appendix F is the Baseline Human Health Risk Assessment (BHHRA) for BCV and supports Chap. 5.
- **Appendix G.** Appendix G is the Baseline Ecological Risk Assessment (BERA) for BCV and supports Chap. 6.

1.1.2 Site Location

BCV is mostly contained in the Department of Energy (DOE) ORR, which is located in east Tennessee, ~32 km (20 miles) northwest of Knoxville. The valley is ~16.7 km (10.4 miles) long and spans the distance from the eastern end of the Oak Ridge Y-12 Plant to the Clinch River on the west. This report deals with that portion of BCV constituting the Bear Creek watershed that extends from the western boundary of the Y-12 Plant near the S-3 Ponds to ~0.4 km (0.25 mile) west of Highway 95 and the remainder of the Bear Creek Watershed north of BCU (Fig. 1.1).

BCV is an operationally and hydrologically complex site. There are multiple individual waste units within the valley that contain various types of hazardous and radioactive wastes derived from the Y-12 Plant (Fig. 1.2). Groundwater is contaminated throughout the eastern 5 km (3 miles) of the valley; individual plumes from separate sources have commingled to produce seemingly continuous contamination of groundwater with multiple contaminants (HSW 1995).

1.1.3 Site History

During the operation of the Y-12 Plant since the 1940s, hazardous and radioactive materials were disposed of at the various sites in BCV (Energy Systems 1994a). Considerable volumes of solid hazardous and radioactive materials (particularly uranium) are known to be buried in trenches located at the BCBG and, probably, also at the Boneyard/Burnyard (BYBY). Hazardous liquids are known to have been disposed of at S-3 Ponds, Oil Landfarm (OLF), Hazardous Chemicals Disposal Area (HCDA), and BCBG. For the most part, soils, groundwater, and surface water at each of these sites and at the Rust Spoil Area are known to be contaminated.

Until 1992, prior to the formulation of the Federal Facilities Agreement (FFA), remedial investigation and remedial actions on the ORR were carried out under the Resource Conservation and Recovery Act (RCRA). The ORR is now listed on the National Priorities List (NPL), and investigations and actions in BCV are required to comply with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) regulations (Energy Systems 1992).

Fig. 1.1. Location map for BCV.

- ① ABANDONED NITRIC ACID PIPELINE
- ② S-3 TREATMENT FACILITY
- ③ S-3 SITE
- ④ WEST END TREATMENT FACILITY
- ⑤ INTERIM REACTIVE WASTE TREATMENT AREA
- ⑥ SPOIL AREA 1
- ⑦ RUST ENGINEERING STORAGE YARD
- ⑧ SY-200 YARD
- ⑨ WASTE OIL/SOLVENT STORAGE FAC.
AND TRANSFORMER FLUID STORAGE FAC.
- ⑩ RUST SPOIL AREA
- ⑪ LIQUID ORGANIC WASTE
STORAGE FACILITY (OD10)
- ⑫ HAZARDOUS CHEMICAL DISPOSAL AREA
- ⑬ OIL LANDFARM

- ⑭ OIL LANDFARM CONTAM.
- ⑮ SANITARY I
- ⑯ OIL RETENTION PO
- ⑰ BEAR CREEK BURIAL
- ⑱ OIL RETENTION PO
- ⑲ DARA LIQUID STORAGE AND TREAT
- ⑳ DARA SOLID STORAG
- ㉑ NaK BUR
- ㉒ M.K. FERGUSON LAYD
- ㉓ BEAR CR
DEBRIS BU
- ㉔ CREEKSIDE DEBRIS BU
- ㉕ MERCURY CONTAMINATED CON
- ㉖ BONEYARD/

Fig. 1.2. Locations of waste disposal sites and waste storage areas in BCV.

T PAD
FILL 1
NO. 2
OUNDS
NO. 1
UNIT
CILITY
CILITY
AREA
ROAD
AREA
AREA
SECTION
PILE
NYARD

BEAR CREEK VALLEY KEY MAP

Y-12 PLANT NORTH

LEGEND:

- ===== ROADS
- BEAR CREEK & TRIBUTARIES
- 900 20' CONTOUR
- ⓪ SITE IDENTIFIER

BEAR CREEK VALLEY
WASTE STORAGE AND
DISPOSAL AREAS

Since 1983, there have been five major site closures under RCRA in BCV, and engineered caps cover parts of BCBG (three RCRA closures), OLF, HCDA, and S-3 Ponds (Energy Systems 1994a). With the exception of a leachate collection system at the BCBG, groundwater remediation has not been implemented.

1.2 REGULATORY INITIATIVE

The ORR was placed on the NPL on November 21, 1989 (54 *FR* 48184), effective December 21, 1989. Remediation efforts at ORR, including individual sites in BCV, are governed by the FFA between DOE, Environmental Protection Agency (EPA) Region IV, and Tennessee Department of Environment and Conservation (TDEC) (EPA 1992a). This agreement became effective on January 1, 1992, and has been amended several times by agreement of the parties (DOE, EPA Region IV, and TDEC). The FFA defines various federal environmental statutes that are applicable to remedial efforts. One of the purposes of the FFA is to “establish a procedural framework and schedule for developing, implementing, and monitoring appropriate response actions at the Site in accordance with CERCLA, the National Contingency Plan (NCP), RCRA, the National Environmental Policy Act (NEPA), appropriate guidance and policy, and in accordance with Tennessee state law” (EPA 1992a). These requirements and potential ARARs are summarized in Table 1.1. (All tables are located at the back of the RI in Volume 1; also refer to Chap. 4).

Requirements of the Atomic Energy Act (42 *USC* 2011 et seq.) and all executive orders concerning the handling of restricted data and national security information, including “need to know” requirements, are applicable under CERCLA or the Superfund Amendments and Reauthorization Act (SARA). An operable unit (OU) assessment has been conducted specifically to determine if classified substances may be present in BCV and, if they are, which of those substances may cause risk and is documented separately from the RI.

1.3 ORR ENVIRONMENTAL RESTORATION

The ORR Environmental Restoration (ER) Program was established to manage the assessment, investigation, analysis, and specific closure activities to reduce adverse risk to health and environment and achieve regulatory compliance. The ORR ER Program addresses legal requirements in a series of integrated documents for each OU. The primary goals of the ORR ER Program are to (1) reduce/minimize the risks to public health and the environment from inactive disposal sites and (2) achieve regulatory compliance. Since the regulations protect health and the environment, achievement of the second goal should simultaneously achieve the first. To achieve the goals of the ER program, DOE maintains two prime contractors. Figure 1.3 depicts the roles and responsibilities of these prime DOE contractors.

1.4 Y-12 PLANT ER PROGRAM

Twelve OUs were previously defined at the Y-12 Plant and its surrounding environs that are grouped by hydrogeologic regime or watershed: Upper East Fork Poplar Creek (UEFPC), Chestnut Ridge, and BCV. Each hydrogeologic regime encompasses (1) a series of source OUs that include the locations of soil contamination, waste materials, and other potential contaminant sources, and

*These activities are carried with the support of LMES Subcontractors: Science Applications International Corporation, Foster Wheeler Environmental Corporation, and MK-Ferguson of Oak Ridge Corporation.

Figure 1.3. Roles and responsibilities of prime contractors at the ORR.

(2) an integrator OU that includes groundwater and surface water throughout the hydrogeologic regime. Since 1994, for the purposes of characterization, these OUs have been combined into three CAs, each area encompassing one of the hydrogeologic regimes. The BCV CA is the focus of this report. Figure 1.4 lists the OUs contained in the BCV CA.

Fig. 1.4. CAs at the Y-12 Plant with details of the OUs in the BCV CA.

The BCV RA is the subject of this RI Report and a previous RI Report for the waste sites in the former BCV OU2 (Rust Spoil Area, Spoil Area 1, and SY-200 Yard). Because the sites in BCV OU2 have been described elsewhere (Energy Systems 1995), a discussion of these waste areas is not included in this RI Report. However, the impacts of these waste areas on the environment in BCV is discussed in the context of the watershed approach to evaluating BCV.

1.5 SPECIAL PROBLEMS

From the perspective of conducting field work in BCV, special problems existed such as those associated with site access, security, and safety; these problems are discussed in the work plans for BCV OU 1 and BCV OU 4. In addition, special problems arise because, in accordance with the valley-wide strategy taken in BCV, the RI (1) relied on historical data to a great extent; (2) minimized and, in some cases, curtailed planned new data collection; and (3) accelerated data analysis schedules. The following special problems were considered when reviewing the data base:

Uncertainty

There will always be some degree of uncertainty associated with the characterization of environmental media, the site conceptual model, and the effectiveness of remedial actions— *even when extensive data collection is carried out. It is assumed that in BCV uncertainties will not prolong the selection of alternatives, the FS can move forward, and decisions can be made.* Inherent uncertainty cannot be eliminated, but will be managed by the FS such that decisions and actions taken in BCV will accommodate the likely impacts. If likely bounds can be estimated for an uncertainty, then reasonable contingent actions can be evaluated by the FS that will accommodate possible future variances from the site conceptual model or presumed technology effectiveness. For example, as a result of uncertainty, soil excavation at a site may not remove all contaminated soils. The contingency for this action would allow further excavation to remove all contamination. Where uncertainty is too great to be managed by contingent actions, then it is deemed unacceptable and is resolved before the RI is complete.

Data Consistency

The watershed characterization approach recognized that sufficient environmental data were available to proceed with the RI/FS without additional field studies and sampling (Appendix B). Sources of data to the RI were existing historical data (some captured into electronic format); data collected to characterize soils at the waste units (former OU 1); data collected to characterize surface water and groundwater (former OU 4 Phase I); data from the floodplain soil sampling effort [BCV Floodplain soils and sediments (FPSS)]; and data from the ecological sampling effort (BCV FPSS) (Fig. 1.5).

Using this approach, consistency between historic and recent data is a potential problem. There are three possible causes of inconsistency: historical analytical techniques that were either less sensitive or less accurate than today's, less rigorous quality control measures applied to historical data, and real changes in environmental quality in time between historical and recent data sampling events. These problems were surmounted by (1) using only those results for which the detection limits and accuracy of detection could be established; (2) using only data for which sufficient quality control in numerical analysis exists (data with less rigorous quality control were used only qualitatively); (3) identifying time trends in data that indicated real change; and (4) using only recent data (post-1990) where conditions had changed.

Adjacent Characterization Areas

To the east, the BCV CA borders on the UEFPC CA. The boundary between the two CAs is defined by the hydraulic divide between the two watersheds. During operations at the S-3 Ponds, the hydraulic divide passed directly under the ponds. Thus, groundwater contamination derived from the S-3 Site occurs in both CAs as an apparently continuous plume (HSW 1995). For the purposes of this RI, the plumes of groundwater contaminants that occur in both BCV and UEFPC regimes are mapped as continuous plumes; however, summary tables of data refer only to groundwater in the BCV CA. Future remedial activities will be coordinated between BCV and UEFPC.

SITE

	S-3 Ponds	Rust Spoil Area	S-3 Nolichucky Plume	Bear Creek Road Debris Burial Area	Creekside Debris Burial Area	BYBY	OLF	SL 1	OLF/BYBY Plume	BG-A (S) and -A (N)	BG-B through -J	BCBG Plume	Maynardville Plume	Bear Creek Floodplain Soils	Bear Creek Sediments	Bear Creek
Design and Operation	●	●	●	○	○	●	●	●	●	●	●	NA	NA	NA	NA	NA
Nature of Waste	●	●	NA	●	●	●	●	○	NA	○	○	NA	NA	NA	NA	NA
Ecological	●	●	NA	●	●	●	●	●	NA	●	○	NA	NA	●	○	○
Soil/Sediment	●	●	NA	●	●	●	●	●	NA	●	●	NA	NA	○	○	NA
Site Conceptual Model	●	●	●	○	○	●	●	●	●	●	●	●	●	●	●	●
Groundwater	●	●	●	○	○	●	●	●	●	●	●	●	○	NA	NA	NA
Surface Water	●	●	NA	○	○	●	●	●	NA	●	●	NA	NA	NA	NA	●

96-042MS/82096

Uncertainty

● Low

● Medium

○ High

NA = Not applicable

Fig. 1.5. Data completeness summary for the main sites in BCV.

1.6 OBJECTIVES

1.6.1 BCV Objectives

The ER Program objectives in BCV are: to eliminate or minimize risks to human health and the environment posed by inactive waste sites. The RI is one of the first steps in satisfying this goal by characterizing and quantifying the risks posed by this site. The objectives of the RI are to evaluate the nature and extent and the fate and transport of contaminants in BCV and to evaluate potential risks contaminants may pose to human health and the environment. Subsequently, in the FS, DOE will evaluate the best ways to eliminate or minimize risks at this site and will propose a plan for carrying this out. The objective is then to develop an agreement with regulatory agencies concerning the Proposed Plan and to garner public support for the actions it prescribes. Figure 1.6 shows the main components of the RI/FS process in BCV. Specific objectives of the components of the RI/FS are as follows:

95-118P.PPT/081696

Fig. 1.6. Main components of RI/FS process.

RI

The purpose of the BCV RI is to provide information on the physical characterization of the environment, characterization of the nature and extent of contaminants, characterization of the potential risks to human health and the environment, and an analysis of the fate and transport of contaminants. To accomplish this, the objectives of the BCV RI Report were to:

- capture historical data into a central database available to participants of the RI/FS process in BCV;
- characterize the nature of the waste materials in each source area using available historical information;
- characterize the nature and extent of secondary contamination in soils at each source site;
- characterize the environmental setting of waste materials and contaminated soils at each source site;
- define the nature and extent of contamination in groundwater and surface water and describe contaminant fate and transport in these media relative to the known sources;

- identify areas of technological uncertainty and attempt to quantify the magnitude of uncertainties and their impacts on the RA process;
- complete a ranking of source sites in BCV based on the relative risk posed by each source site to a human receptor located at a possible future residence site; and
- complete the baseline risk assessment (BRA).

The BRA has two parts: (1) to evaluate and document the potential risks to human health from exposures to site-related contaminants (SRCs) if no remedial action is taken (the BHHRA), and (2) to carry out the same evaluation for the environment (the BERA). This information provides a basis for determining whether remediation is necessary at the site. The risks determined in the BRA represent the risk for the no-action alternative in the FS risk assessment. In addition, the BRA provides a basis to determine acceptable levels of contaminants that can remain on site.

Human Health Risk Assessment. The process used to accomplish the objectives of the BHHRA is summarized in Fig. 1.7. This process is derived from EPA (1993). The following tasks are conducted:

- evaluate data to identify radionuclides and chemicals of potential concern (COPCs) at the site;
- conduct an exposure assessment for site-related radionuclides and COPCs;
- assess the toxicity of site-related radionuclides and COPCs;
- characterize the potential risks to human health;
- determine chemicals of concern (COCs); and
- identify what, if any, risk issues need to be addressed during the FS process.

The BHHRA should provide recommendations for supplemental investigations of the site and should support the development of preliminary remediation goals, remedial goal objectives, final remediation goals, and remedial action objectives.

Ecological Risk Assessment. The regulatory and scientific frameworks that guide the baseline ecological risk assessment for BCV are contained in EPA 1989a, EPA 1989b, and subsequent documents (EPA 1991 and 1992b). The objectives of the baseline ecological risk assessment are:

- to estimate the degree of risk to aquatic biota and terrestrial plants and small mammals from chemicals of potential ecological concern (COPECs) in surface water, surface soil, and shallow groundwater;
- to identify COCs
- to provide a qualitative evaluation of the potential threatened and endangered animal species present in BCV; and
- to provide input to the reservation-wide ecological risk assessment.

Fig. 1.7. BHHRA process. Source: Adapted from EPA 1993.

FS

The goal of the BCV FS is to evaluate potentially applicable remedial action technologies and approaches to compare risk reduction, technical feasibility, implementability, and cost associated with meeting the remedial objectives. The FS will support an analysis of all alternatives; however, when the available information does not support such a level of detail, the report will note the major assumptions but still will be focused on the detailed analysis. An initial set of site-wide alternatives is screened for technical feasibility, implementability, and relative cost; then the FS focuses on a limited number of discrete alternatives that address the range of remedial action objectives and evaluates them against a set of nine EPA-specified criteria. After analysis, the remaining alternatives also undergo a comparative evaluation. The final alternatives will be described in terms of base actions to address probable conditions, monitoring to detect reasonable deviations, and contingency plans to address those deviations to the probable conditions.

Post RI/FS - ROD

Following the completion of the FS, the Proposed Plan will be developed. The Proposed Plan and ROD will identify the preferred site-wide alternative. Portions of the site-wide alternative will have sufficient data to support the design of preferred site-specific remedial actions. Other portions of the site-wide alternative, where actions have been selected, will require additional parameter evaluation prior to taking action or to designing the remedial action (Fig. 1.6).

Demonstration Projects

During the RI/FS program, certain technologies may be identified that are most likely to be applicable to remediation in BCV. Where possible, demonstration of the application of these technologies in BCV will be conducted early in the RI/FS process. A waste grouting technology and in situ groundwater remediation using shallow trenches have been identified as suitable technologies to date.

1.6.2 Project Data Quality Objectives

The DQO process consists of three stages: identification of decision types, identification of data uses and needs, and design of the data collection program. The goal of this process is to guide the activities of the RI so that they identify and address data gaps, characterize the nature and extent of contamination, determine the human health and environmental risk from exposure to contamination, and determine if contamination at the site exceeds ARARs to support remedial action decisions. Ultimately, reliable decisions need to be made concerning protection of human health and the environment that will be based on the data collected in the RI.

The DQOs for the OU 1 and OU 4 field projects were established in the approved RI Work Plans for BCV OU 1 (Energy Systems 1994) and OU 4 (Energy Systems 1993) in accordance with developing EPA guidance for DQOs (EPA 1994). In addition, a BCV DQO Workshop was carried out after revision of the strategy to the valley-wide RI/FS ensuring that the DQOs would be met by the revised approach (DOE 1994—DQO meeting minutes).

The field investigations for BCV OU 1, OU 4, and the FPSS (SAIC 1995) met the project DQOs as specified in the approved RI Work Plans. One exception was radiological data from the historic database for groundwater that did not meet analytical DQOs and could not be used in the RI Report to assess risk to human receptors. This data gap was rectified by a sampling event in August and September 1995, when groundwater from selected wells and springs in BCV was analyzed for specific radionuclides. Appendix B contains a discussion of the quality of the data obtained in the field activities for the RI. Chapters 2 and 3 of this RI Report and Appendices C, D, and E contain analysis of these data and demonstrate that the database for BCV is sufficient to support reliable decisions in BCV.

1.7 SCHEDULE

Figure 1.8 depicts the current schedule for the BCV project through submittal of the ROD. The timetable for completion of the process has been accelerated compared to the previous OU strategy by reducing the extent of environmental data collection and by including extensive use of existing

data. The BCV RI will be available for public review September 1996 and the FS by April 1997. The revised schedule has the valley-wide ROD to be available for public review by October 1998.

Fig. 1.8. Schedule for the BCV ROD.

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2. CHARACTERIZATION OF ENVIRONMENTAL SETTING

This section of the RI Report summarizes the physical characteristics of BCV, including the geography, demography, climate, topography, BCV hydrogeologic conceptual model (geology, hydrology, and water balance), and ecology of the study area. Additional details on these topics can be found in Appendix C of this report.

2.1 GEOGRAPHY

BCV is located on the DOE ORR in eastern Tennessee [within both Anderson and Roane counties (Fig. 1.1)]. Oak Ridge and the ORR are ~32 km (20 miles) west-northwest of Knoxville, 19 km (12 miles) southwest of Clinton, and 11 km (6.8 miles) northeast of Kingston (Fig. 1.1). The area is linked by Interstates 40 and 75, which intersect in Knoxville.

BCV is ~16.7 km (10.4 miles) long, spanning the distance from the eastern end of the Y-12 Plant to the Clinch River on the west (Fig. 1.1). The eastern portion of the valley is on ORR land and the western portion (the Grassy Creek watershed) includes Tennessee Valley Authority and private land. This report deals with that portion of BCV constituting the Bear Creek watershed extending from the Y-12 Plant to the confluence of Bear Creek with East Fork Poplar Creek, which is wholly contained on the ORR. Bear Creek itself originates at the western boundary of the Y-12 Plant near the S-3 Ponds and empties into East Fork Poplar Creek 12.87 km (8 miles) downstream. The Bear Creek watershed has a drainage area of 1917 ha (4736 acres). The average gradient of the creek is 5.6 m/km (30 ft/mile), dropping from nearly 305 m (1000 ft) above mean sea level (amsl) at its headwaters to 232 m (760 ft) amsl at its confluence with East Fork Poplar Creek.

Bear Creek is used as reference for locating other features within the valley by referring to "creek kilometers;" locations are designated by Bear Creek Kilometer (BCK) plus the kilometer value measured from the confluence with East Fork Poplar Creek for the location (e.g., BCK 12.36). Tributaries and major springs in BCV are also labeled. There are 24 labeled tributaries to Bear Creek, 15 that drain into Bear Creek from the north, 4 east tributaries, 2 west tributaries, and 3 south tributaries (Fig. 2.1). These tributaries are numbered consecutively from the headwaters of Bear Creek. Eight major springs on the south side of Bear Creek have been identified and were also numbered consecutively (SS-1 to -8).

2.2 AREA DEMOGRAPHY AND LAND USE

The ORR encompasses all of the contiguous land owned by DOE in the Oak Ridge area. The residential section of Oak Ridge forms the northern boundary of the ORR and the Tennessee Valley Authority's Melton Hill and Watts Bar reservoirs on the Clinch and Tennessee rivers form the eastern, southern, and western boundaries (Fig. 1.1).

The population of the ten-county region surrounding the ORR is 717,880; ~5% of the labor force from this ten-county region is employed on the ORR (Energy Systems 1994a). The city

LEGEND:

- ROADS
- BEAR CREEK & TRIBUTARIES
- NT-1
- 900
- 100' CONTOUR
- MANAGEMENT AREA
- BCV SURFACE WATER
- △ NT-1
- ▽ SFT-1
- SS-1
- SS-2
- MAJOR SPRINGS NOT SAMPLED BY BCV RI

BEAR CREEK VALLEY

Fig. 2.1. Locations of geographic and hydrological features in BCV.

limits of the city of Oak Ridge (pop. ~27,300) about the Y-12 Plant boundaries. The approximate location and population of the other towns nearest the ORR are Oliver Springs (pop. ~3400), 11 km (6.8 miles) to the northwest; Clinton (pop. ~9000), 16 km (10 miles) to the northeast; Lenoir City (pop. 5500), 11 km (6.8 miles) to the southeast; Kingston (pop. ~4500), 11 km (6.8 miles) to the southwest; and Harriman (pop. ~8300), 13 km (8 miles) to the west. Population levels are based on 1990 U.S. census data. The nearest residential area of the city of Oak Ridge (Country Club Estates) is located on the north flank of Pine Ridge, ~1.5 km (0.9 miles) from Bear Creek Road.

Recreational uses of the surrounding area include fishing, boating, hunting, and camping. Melton Hill Lake, which delineates the southern boundary of the ORR, is the major water body for recreational uses. Major lake recreational areas within a 5-mile radius of BCV include Clark Center Park, Melton Hill Park, Solway Public Use Area, Haw Ridge Park, Oak Ridge Marina, and Guinn Road Park. Additional recreational areas include neighborhood parks and civic centers managed by the city of Oak Ridge. Controlled deer hunts are held annually on the ORR but are not allowed in areas immediately adjacent to the Y-12 Plant or its disposal areas in BCV.

2.3 CLIMATE

The climate of the region surrounding the Oak Ridge area is broadly classified as humid continental. The Cumberland Mountains to the northwest have a moderating influence on the climate of the area by shielding the region from cold air masses that frequently extend far south over the plains and prairies of the central United States during the winter months. In the summer months, tropical air masses from the south provide warm and humid conditions that often produce thunderstorms; however, anticyclonic circulation around high-pressure systems centered in the western Gulf of Mexico can bring dry air from the southwestern United States into the region, which causes occasional periods of drought (Energy Systems 1994a).

Temperature

The annual mean air temperature for the Oak Ridge area is 13.9°C (57.1°F) (1963 through 1992 base period). The coldest month is usually January, with temperatures averaging about 2.0°C (35.6°F) but occasionally falling as low as -27°C (-17°F). July is typically the hottest month of the year, with average temperatures of 24.7°C (76.5°F) but occasionally rising to 41°C (105°F) (Fig. 2.2). Diurnal temperature changes are relatively consistent from month to month having a range of 10 to 15°C (18 to 27°F) (Site and Facilities Planning Department 1994).

Precipitation

Detailed discussions of precipitation patterns for BCV can be found in Sect. 2.2 of the document, *Ecological Effects of Contaminants and Remedial Actions in Bear Creek*, prepared by Southworth et al. (1992). Average precipitation in the Oak Ridge area varies from place to place by as much as 30% depending on the location relative to local terrain. The 40-year annual average precipitation is 137 cm (53.75 in.), including about 26 cm (10.4 in.) of snowfall. Precipitation in the region is greatest in the winter and spring months (January through April) and least during the fall months (September through November), when high-pressure systems are most frequent (Fig. 2.2) (Energy Systems 1994a). Precipitation in 1994 measured by the National Oceanic and Atmospheric Administration was 165 cm (64.7 in.).

Fig. 2.2. Meteorological data for ORR.

Winds

The Oak Ridge area has relatively light winds compared to other parts of the United States. The Cumberland Mountains and Plateau to the northwest and west, and the local valley-and-ridge topography, divert severe storms and minimize air movement and local wind impact. Ridge-top and valley sites in the Oak Ridge area (excluding the Cumberland Plateau) experience wind speeds <5 m/s (11.2 mph) over 90% of the time, and many valley-bottom sites experience winds <2 m/s (4.5 mph) over 70% of the time. Prevailing wind directions in the Oak Ridge area are primarily oriented parallel to the direction of the local ridge and valley terrain (Fig. 2.3). Prevailing winds are either up-valley (northeasterly), day-time winds, or down-valley (southwesterly), night-time winds (Energy Systems 1994a).

2.4 TOPOGRAPHY

The ORR lies within the Valley and Ridge Physiographic Province, which is characterized by steep-sided parallel ridges with broad intervening valleys, generally oriented in a northeast-southwest direction. BCV is bordered by Pine Ridge on the northwest and by Chestnut Ridge on the southeast (Fig. 2.1). Topographic relief from the crest of Pine Ridge to the floor of BCV ranges from 260 to 300 ft; relief from the crest of Chestnut Ridge to the floor of BCV ranges from 85 to 122 m (280 to 400 ft). The average elevation of the ridges is ~ 335 m (1100 ft) amsl, with elevation of the floor of BCV ranging from 244 m (800 ft) to 305 m (1000 ft) amsl (Fig. 2.1).

ORNL-DWG 94M-5238
with 99.2 percent of possible data
Wind rose produced from 1993 data from the
eastern meteorological tower (MT5) at the Y-12 Plant.

Fig. 2.3. Wind data for ORR.

2.5 BCV HYDROGEOLOGICAL CONCEPTUAL MODEL

2.5.1 Geology

The hydrogeologic system in BCV is governed by the valley's geology: a lithology that is predominantly shale and limestone; a geologic structure characterized by tilted stratigraphy, faults, and fractures; and a geomorphology of parallel ridges and valleys. Listed below are the key geologic features that affect transmission of fluids in BCV. These points are elaborated in the ensuing discussion and presented in detail in Hatcher et al. (1992), Solomon et al. (1992), and Appendix C.

The geology of BCV displays an inclined layer-cake-style stratigraphy that is observed on a variety of scales: on a regional scale where limestone- and dolomite-dominated rock groups are interbedded with predominantly clastic shale groups, and on the scale of outcrops where clastic beds are interlayered with carbonate beds (Fig. 2.4). This layered structure results in anisotropy of permeability and hydraulic conductivity that, especially in the predominantly clastic formations, exerts a strong influence on flow directions.

BCV is underlain by rocks of three regionally important stratigraphic units: the Rome Formation, the Conasauga Group, and the Knox Group that typically dip 45° to the southeast (Figs. 2.4 and 2.5). For general descriptions of the stratigraphy of geological units in the ORR, refer to Hatcher et al. (1992) for an overview of the ORR geology; Haase, Walls, and Farmer

Fig. 2.4. Geology of BCV. (Photograph of the Nolichucky shale courtesy of P. Lemiski)

Fig. 2.5. Geologic map of BCV.

(1985) for the Conasauga Group and Rome Formation; and Lee and Ketelle (1987) for the Knox Group. These units can be grouped into those that are mainly clastic and generally have low permeability, and those that are mainly carbonates and are generally more permeable (Solomon et al. 1992).

The Rome Formation and the Conasauga Group crop out in BCV on Pine Ridge and dip beneath BCV. With the exception of the Maynardville Limestone, the Conasauga Group is a sequence of fractured shale, siltstone, and thin-bedded limestone. Some formations, however, include laterally continuous limestone beds that can be several meters thick and strike parallel high permeability zones may exist, especially where karstification has enlarged fractures in limestone beds. The Maynardville Limestone, the uppermost member of the Conasauga Group, is a massively bedded limestone and dolomite with extensive karstification. This formation forms the floor of BCV and contains the channel of Bear Creek along most of the valley.

The Knox Group underlies and forms Chestnut Ridge, the southern boundary of BCV, and is composed of a series of medium- to thick-bedded, massive, grey, green, and pink dolomite. Although the carbonate lithologies have little matrix porosity, extensive karst formation in the Knox Group has resulted in substantial secondary porosity and high permeability (Shevenell and Beauchamp 1994). Sinkholes are common at outcrop, and springs and seeps are common features at the upper and lower geologic contacts.

Overlying the bedrock on the ORR is unconsolidated material that consists of weathered bedrock (referred to as residuum), man-made fill, alluvium, and colluvium. Residuum comprises a majority of the unconsolidated material in this area. The depths to unweathered bedrock differ throughout the ORR because of the different thicknesses of fill and alluvium and the particular weathering characteristics of the bedrock units. The total thickness of these materials typically ranges from 3 to 15 m (10 to 50 ft) (Hoos and Bailey 1986).

The primary permeability of the rocks underlying BCV is very low. However, diagenesis, fracturing, and solution weathering of bedrock have resulted in secondary porosity and increased permeability through which most fluid movement occurs (Solomon et al. 1992; Shevenell 1994; Goldstrand, Menefee, and Dreier 1995). The formations are extensively fractured and, in the case of carbonate formations, extensively karstified, thereby enhancing their permeability. It is only in the Knox Group and the Maynardville Limestone that cavity systems are highly developed and extensive; however, many of the smaller limestone or dolomite beds within the predominantly clastic formations exhibit solution openings and cavities at shallow depth.

The orientations of well-connected fractures or solution conduits are predominantly parallel to geological strike and enhance the effect of anisotropy caused by layering. This results in dominance of strike-parallel groundwater flow paths. Fracture aperture width generally decreases with depth in all formations and thus restricts the depth of active groundwater circulation hydrology. Active (or open) fractures occur at greater depths in the Knox Group and the Maynardville Limestone than in the siliceous members of the Conasauga Group, and active groundwater circulation is deeper in these formations.

2.5.2 Hydrology

The hydraulic component of the hydrogeological conceptual model for BCV is presented here as the hypothesis that best describes the main observations of hydraulic parameters in BCV. Figure 2.6 depicts the hydrologic conceptual model for BCV.

Fig. 2.6. Conceptual model for groundwater flow in BCV.

BC-125a

One of the main points raised by the conceptual model is that 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. For the 10-month monitoring period of BCV RI field activities, it is estimated that 97% of water available for flow (precipitation - evapotranspiration) exited the upper section of the valley [above Bear Creek Kilometer (BCK) 9.47] as surface water flow (Fig. 2.7). In addition, of water available for flow in the predominantly clastic formations outcropping on Pine Ridge, 94% exited these formations via surface water in tributaries, and 6% via subsurface flow. Fluxes in flow paths at the waste units (overland flow, soil interflow, and groundwater flow) have not been quantified; however, hydraulic monitoring data show that overland flow and soil interflow are only important during storm events, and recharge followed by groundwater flow to tributaries constitutes the main water flux pathway.

Exhibit 2.1. Water balance model for BCV above BCV 9.47 during the 10-month period April 1994–January 1995

Water balance component	10-month water volume (L)	Reference ^a
Precipitation (P)	4.8×10^9	National Oceanic and Atmospheric Administration
Evapotranspiration (ET)	2.8×10^9	Unknown parameter in water balance equation (Fig. 2.7)
Available Water (P-ET)	2×10^9	
Gaged Surface Water Flow (SWG)	1.6×10^9	Gaged flow at BCK 9.4
Gaged Subsurface Flow (SSG)	3.2×10^8	Gaged flow at SS-5
Ungaged Subsurface Flow (SSU)	6.0×10^7	Groundwater flow model for BCV (Jacobs Engineering, in preparation)

^aRefer to Fig. 2.7.

Hydrogeology differs significantly between mainly clastic formations (such as the Nolichucky Shale) and mainly carbonate formations (such as the Maynardville Limestone), to the extent that they can almost be treated as separate hydraulic entities. In BCV, the contact between the Maynardville Limestone and the Nolichucky Shale roughly corresponds to the axis of the valley (Fig. 2.4) and marks a major transition from predominantly clastic formations in the Conasauga Group to carbonate dominant formations in the overlying Knox Group.

Groundwater movement in the predominantly clastic formations is mainly by way of fracture flow (Solomon et al. 1992; Moline and Schreiber 1995) and more than 95% of flow occurs through the shallow intervals of the formations, principally in the water table interval at the bedrock – residuum interface. In this interval of the groundwater regime, flow rates can be very rapid (up to 40 m/d; Sanford and Solomon 1995; McKay et al. 1995) and may be even greater during transient storm events. The transient response of surface water streams to precipitation shows that both interflow through soils and groundwater flow through the water table interval are probably major components of the total flow during storm events.

Fig. 2.7. Water balance model for BCV above 9.47 for the 10-month period April 1994 - January 1995.
 Values refer to total water volumes in millions m³

Groundwater movement in the carbonate dominant formations has components of both fracture flow and flow through solution-enlarged cavities and conduits (Shevenell 1994). Although most flow in the carbonate dominant formations probably occurs in the shallow intervals [< 30 m (100 ft) depth], a component of groundwater flow occurs in deeper intervals [> 30 m (100 ft) depth] (Solomon et al. 1992). The shallowest intervals of the Maynardville Limestone in BCV are dominated by a maze-like system of interconnected cavities and solution-enlarged fracture. Bear Creek can be considered as one of the primary conduits for flow in this cavity system.

The dynamic nature of the hydrology of BCV is extremely important, both for clastic- and carbonate-dominated formations. The nature, rate, and direction of groundwater flow are transient and vary based on the climatological conditions. Variations occur on different scales: an annual cyclic variation resulting from seasonal climate changes and short-term variation resulting from the response to individual storm events. Piezometric head in groundwater wells and baseflow in streams relate both to the amount of precipitation and the rate of evapotranspiration. In general, flow in streams as well as groundwater elevations peak during late winter and early spring because annual precipitation is greatest during this time period and moisture demand from plants is at a minimum. Conversely, during the summer and fall, precipitation is usually relatively low and evapotranspiration is high. During this time, flow in most tributaries to Bear Creek ceases and groundwater elevations fall to a minimum.

Additional key features of the hydraulic component of the hydrogeological conceptual model are as follows:

Flow in Predominantly Clastic Formations

- Although there are no clearly defined abrupt hydrogeologic changes in the clastic formations with depth, a general hydrogeologic stratigraphy can be defined that separates these formations into shallow, intermediate, and deep flow regimes (Fig. 2.5, Solomon et al. 1992). The boundary between shallow and intermediate intervals is defined by a consistent change in groundwater geochemistry at ~ 30 m (100 ft) depth that indicates flow is considerably slower below this depth (Haase 1991; Dreier, Early, and King 1993). The boundary between intermediate and deep intervals is poorly defined and is indicated by a change in groundwater geochemistry that has been observed between ~ 100 and 150 m (328 and 492 ft) depth (Solomon et al. 1992; Haase 1991; Dreier, Early, and King 1993). The deep interval probably relates to the base of effective flow in the siliceous formations.
- Most flow in siliceous formations occurs in the shallow interval. This interval includes the water table interval that usually occurs close to the bedrock/residuum interface. Most flow in the shallow interval is probably through high conductivity zones that may exist at the bedrock/residuum interface (Soloman et al. 1992) or through other preferential flow pathways in the bedrock. Flow in the shallow interval is oriented predominantly along geological strike, with discharge occurring at the tributaries to Bear Creek.
- Geochemistry indicates that greater groundwater residence times and, thus, slower flow generally occur below 30 m (100 ft) in the intermediate interval (Sect. C.4.2). However, the distribution of contaminant plumes in BCV indicates that more rapid flow than predicted by major ion geochemistry may occur in an along-strike direction along preferential pathways in this interval and may occur up to 200 ft in depth [nitrate from the S-3 Site has migrated ~ 1 km (0.62 mi) or more since 1950, refer to Appendix D].

- An upward hydraulic gradient occurs almost everywhere in the bedrock of the siliceous dominant formations that crop out on the southern flank of Pine Ridge. This upward hydraulic gradient is a function of the anisotropy of the geological formations and the average 45° dip of the beds. Transmissivity along bedding planes may be on order of magnitude greater than that across bedding planes. Groundwater in deep formations is hydraulically connected along the bedding planes to recharge areas located up dip at higher elevations up on Pine Ridge. As a result, deeper formations tend to have recharge zones farther up-slope than shallow formations; therefore, the hydraulic head in successively deeper formations generally increases.
- During rainfall events, the hydrological system in the siliceous dominant formations responds in changing ways to the influx of water (Fig. 2.8):
 - The shallow portions of the soil profile become saturated, transmitting water laterally downslope to springs and seeps in the banks of streams as interflow.
 - Fractures in the residuum also become saturated, transmitting water rapidly to the shallow groundwater table. As a result, the elevation of the water table rises rapidly during rainfall events.
 - The elevated water table increases the rate of groundwater flow in the water table interval and, subsequently, groundwater discharge to streams increases.
 - During the heaviest precipitation events, flow in streams increases very rapidly as overland flow enters the stream channels.
 - After precipitation has ceased, flow in streams reflects the rate of drainage from three reservoirs of water: overland flow, soil interflow, and groundwater flow. These components of the hydrologic system drain at varying rates: overland flow is the most rapid, stormflow is intermediate, and groundwater discharge declines at the slowest rate and reaches near pre-precipitation levels within a few days.
- Although flow through the porous matrix constitutes a minor component of flow volume through all formations, it probably plays an important role in contaminant migration because matrix diffusion will significantly slow down transport rates.

Flow in Carbonate Dominant Formations

- The Maynardville Limestone crops out along the southern side of the BCV floor. This formation and Copper Ridge Dolomite act as a hydraulic drain for the valley. Flow in these formations is predominantly along strike and parallel to the maximum hydraulic gradient.
- The hydrostratigraphy in the carbonate formations is less well defined than that in the siliceous formations (Fig. 2.5, Solomon et al. 1992). The definitions of shallow, intermediate, and deep regimes are not rigid and rely on cumulative evidence from cavity occurrence (Shevenell, Dreier, and Jago 1992; Shevenell and Beauchamp 1994), hydraulic and geochemical responses during storms (Shevenell 1994; Sect. C.6.2.3 in Supporting Information for Appendix C), and the distribution of contaminant plumes (Appendix D).
- The shallow interval includes groundwater to ~30 m (100 ft) depth. Flow in this interval occurs through a maze of interconnected fractures and solution conduits and cavities (Sect. C.3.3) and is closely associated with flow in Bear Creek (Sect C.4.5). The channel of Bear Creek can be considered conceptually as one of the main hydraulic conduits in this conduit system. In this interval, groundwater flow is relatively rapid and, during storm

Fig. 2.8. Monitoring of changes in soil saturation, stream flow, and groundwater at the BCBG for a storm on April 15, 1994.

events, recharge to this interval occurs as a quickflow. Contaminants are easily flushed through this interval, and dilution effects that arise from rainfall/recharge and quickflow mean that contaminant concentrations attenuate rapidly along strike.

- The intermediate interval occurs between ~30 m and 100 m (100 and 328 ft) depth. Solution cavities and solutionally enlarged fractures exist in the Maynardville Limestone in this interval and are probably well connected by fractures. Because of its depth, this zone is isolated from dilution effects seen in shallower zones, thus flow rates are probably slower

than those in the shallow interval, but contaminant plumes are more persistent and extend farther along the valley. This zone constitutes an important contaminant transport pathway.

- In the deep interval [>100 m (328 ft) depth] flow through fractures dominates groundwater movement and, as fracture density decreases with depth, flow zones become less frequent.
- Bear Creek displays losing and gaining reaches where groundwater is recharged and discharged to the surface, respectively (Fig. 2.9). Major gaining reaches along strike are associated with large springs in the floodplain of Bear Creek (SS-2, -5, -6, -7, and -8), which may be sites of upwelling groundwater from deep flowpaths in the Maynardville Limestone and Knox Group. The locations of these springs may be controlled by large-scale geologic structure, such as across-strike faults, or thinning of the Maynardville Limestone due to stratigraphic changes or faulting.

2.6 ECOLOGY

Most of the Bear Creek floodplain lies outside the main Y-12 Plant complex and, as such, includes or is in close proximity to areas of potential ecological sensitivity. Ecological studies of the Bear Creek watershed were initiated in May 1984 and are continuing at the present time (Southworth et al. 1992; Energy Systems 1992, 1993, 1994b). An initial characterization of the benthic invertebrate and fish communities in Bear Creek and potential sources of toxicity to biota was followed by a monitoring phase that relates to the long-term goal of identifying and prioritizing contaminant sources and assessing the effectiveness of remedial actions. The following subsections describe the ecological setting for BCV as a background for the detailed ecological descriptions of source units and the floodplain that are presented in Appendix D. Threatened and endangered flora and fauna found within the ORR are also listed in Appendix D.

2.6.1 Flora

Before 1940, most of BCV was cleared and used for agriculture (Southworth et al. 1992). Currently, about 65% of the BCV watershed is wooded (McMaster 1967), predominantly in oak, oak-hickory associations on the upper slopes and ridgetops, with mixed hardwoods and planted pine along the creek and floodplain area. More detailed information is available for portions of the Bear Creek watershed area on forest compartment maps and in various other documents (Bradburn and Rosenbalm 1984; Parr and Pounds 1987).

Rare plants occurring on the Y-12 Plant site have been characterized by Hardy, Pounds, and Cook (1992) and Ayl et al. (1996). Several areas in BCV contain rare plant populations, (Table 2.1) and these have been designated National Environmental Research Park Natural Areas (Ayl et al. 1996). One site has also been registered as a State Natural Area in an agreement between DOE and TDEC (Howell 1986).

2.6.2 Terrestrial Fauna

BCV contains old field, grassland, and forest habitat zones, elements of the majority of wildlife habitat types found on the ORR; therefore, the expected terrestrial fauna is that described for the entire reservation (Welch 1989). Hardwood and mixed hardwood/conifer habitats are the most abundant habitat types in the Bear Creek watershed, followed by pine plantation and grassland habitats, with considerable riparian habitat along the length of Bear Creek. Species

Fig. 2.9. Results of spring and seep surveys in BCV at low- and high-flow periods.

commonly found in these habitats are described in the ecological risk assessment in Appendix G. State and federally listed species are presented in Table 2.1.

2.6.3 Aquatic Fauna

Nineteen species of fish have been found in Bear Creek in recent quantitative monitoring efforts conducted at seven sites along virtually the entire length of Bear Creek (Southworth et al. 1992; see Sect. D.9.5 in Appendix D). Conclusions of the recent fish-monitoring studies were that much of Bear Creek had limited fish fauna (low species richness) characterized by robust population parameters (high densities and biomass). Fish communities at BCK 12.4, just below the S-3 Ponds, have shown signs of recovery from the effects of contaminants in the S-3 Ponds. Both total abundance and numbers of species have increased since fall of 1989 (Energy Systems 1992), implying that toxic effects on aquatic populations have been reduced at that site.

Quantitative sampling of benthic invertebrates showed a pattern of increasing density, biomass, and taxonomic diversity and richness with increasing distance downstream from the uppermost sampling site (BCK 12.36) (Southworth et al. 1992). Unlike the fish data, which provide evidence of ecological recovery in Bear Creek since 1984, the benthic macroinvertebrate fauna do not appear to have changed in a manner indicative of either improving or degrading water quality since 1984 (Southworth et al. 1992).

The Tennessee dace, a major constituent of the fish population above the weir at BCK 4.55, is listed as a species in need of management. Its habitat is protected by the state of Tennessee (Starnes and Etnier 1980). Other species listed in Appendix D may occur in the vicinity of the ORR but have not been verified in BCV. No threatened or endangered species of aquatic macroinvertebrates have been collected in Bear Creek.

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3. SITE HISTORY AND CURRENT CONDITIONS

This section provides a summary of the site history and current conditions for BCV. Section 3.1 describes the site, including geographic information, background and operational information, a review of contaminant releases, and source term characterization (waste inventory). Further details on these topics may be found in Appendix A of this report.

Section 3.2 summarizes existing data for BCV, including both historical data and data obtained during the recent field investigations. Included is a summary of the data quality assessment for the BCV environmental database, the methods for identifying site-related chemicals and radionuclides, and the discussion of the integrated nature and extent of contamination. Section 3.2 is supported by detailed information given in Appendices B, C, and D of this report.

3.1 SITE DESCRIPTION

3.1.1 Geographic Information

The Y-12 Plant and its supporting facilities are located in BCV; detailed geographical information concerning the Plant, its facilities, and the surrounding area is given in Welch (1989) and Chap. 2 of this report. The main facilities of the Y-12 Plant lie on the BCV floor, mostly within the UEFPC watershed. Auxiliary facilities, including the main disposal areas for the Plant, are located in the Bear Creek watershed in BCV and along Chestnut Ridge. The principal waste disposal sites, which are located in the Bear Creek Hydrogeologic Regime, are the S-3 Site, the Spoil Area 1, the Rust Spoil Area, the SY-200 Yard, the OLF, the BYBY, the Sanitary Landfill 1 (SL 1), and the BCBG (Table 3.1 and Fig. 1.2). In addition, there are numerous smaller sites in BCV that are known waste disposal or storage areas and are also potential contaminant sources (Table 3.1).

3.1.2 Background Information

The Y-12 Plant was built by the U.S. Army Corps of Engineers in 1943 as part of the Manhattan Project. The original mission of the Plant was to separate the fissionable isotope of uranium (^{235}U) using an electromagnetic separation process. After World War II, this process was discontinued in favor of a more economical gaseous diffusion process conducted at the nearby Oak Ridge K-25 Site (Welch 1989).

Since its inception, the Y-12 Plant has developed into a sophisticated manufacturing and developmental engineering facility. The mission of the Y-12 Plant is to serve as a key manufacturing technology center for the development and demonstration of unique materials, components, and services of importance to DOE and the nation. This is accomplished through the reclamation and storage of nuclear materials, manufacture of nuclear materials, manufacture of components for the nation's defense capabilities, support to national security programs, and services provided to other customers as approved by DOE.

Much of the background information pertaining to the Y-12 Plant (and the ORR in general) has remained classified since the beginning of the Manhattan Project. The current agreement with

DOE is that classified material will be declassified to the extent possible. In some cases, declassified summaries of classified material prepared in an appropriately secure way will be issued (e.g., such a summary has been completed for the BCBG waste inventory). Material that remains classified will be available for review by appropriately cleared personnel and will be entered into the on-site record. Classified material will not be entered into the off-site record. This report is intended as a nonclassified analysis of data in BCV.

3.1.3 Operational Information and Description of Waste Areas

This section contains the information that defines the main sources for contaminants in BCV. During the DQO process for BCV, the RI team decided that direct sampling of the waste materials for the purpose of characterization was not feasible (Energy Systems 1994, BCV OU 1 Work Plan). Instead, the physical and chemical characteristics of the contaminant sources are described based on interpretation of historical inventory data. Where possible, current conditions in the source areas were estimated to facilitate modeling of the potential future releases from these sources (Appendix E) and on-site risk assessment (Appendices F and G). For the S-3 Site and OLF, pre-closure sampling data were used to quantify contamination in the waste that remains in place (Tables A.3 and A.8 in Appendix A, respectively). For BCBG, where there are no sampling results for waste materials, a detailed waste inventory was used (Supporting Information to Appendix A). For BYBY and SL 1, there are no historical sample results or inventory. For these sites, data from recent (1994) soil sampling were used to estimate waste composition; these data are discussed in Sect. 3.2 with the soil sampling results. A more detailed review of historical waste information is contained in Appendix A of this report.

The S-3 Ponds, Spoil Area 1, SY-200 Yard, Rust Spoil Area, BYBY, OLF, SL 1, and BCBG are considered the primary contaminant sources in BCV (Fig. 1.2). Wastes and secondary contamination at the S-3 Ponds, BYBY, OLF, SL 1, and BCBG are subjects of this report; contamination at Spoil Area 1, SY-200 Yard, and Rust Spoil Area has been described in the BCV OU 2 RI (Energy Systems 1995) and is not described further in this report. In addition, much of the debris disposal carried out in BCV prior to establishment of disposal areas has not been documented and so will not be discussed further here. However, this unrecorded debris disposal in the section of upper BCV between the Y-12 Plant boundary and what is now Rust Spoil Area, is seen in one photograph of the Y-12 Plant circa 1947 (Fig. 3.1). The impacts of sources that are not discussed in this report (the OU 2 RI sources) are included in the integrator point assessment. Although these source parameters are described elsewhere, the watershed approach to BCV dictates that their impacts on the environment are considered relative to the other sources in BCV.

A chronological list of the main events at the waste sites in BCV is provided in Table 3.2; Fig. 3.2 depicts the schedule of operations at sites in BCV. Tables 3.3 and 3.4 list waste streams known to have been managed in the following primary contaminant sources as well as information about their generation, disposal methods, and any subsequent treatment or clean-up activities that have been carried out:

- **S-3 Ponds.** Located adjacent to the west end of the Y-12 Plant, the former S-3 Ponds were a part of the S-3 Waste Management Area (Figs. 1.2 and 3.3). Sludges and contaminated sediments remain in place, and the site is covered with a multilayer RCRA cap (Energy Systems 1992).

Fig. 3.1. Upper BCV and the Y-12 Plant, circa 1947.

Fig 3.2. Approximate schedule of operations in BCV.

- **OLF.** The OLF is located ~2.4 km (1.5 miles) west of the Y-12 Plant, and north of SL 1 and Bear Creek Road (Figs. 1.2 and 3.4). Soils contaminated with <25 mg/kg polychlorinated biphenyls (PCBs), metals, and uranium remain in place (Bohrman 1989). The site is covered

with a multilayer RCRA cap (Energy Systems 1994). Excavated soils were placed on a concrete pad at the OLF site.

Fig. 3.3. Ponds during neutralization and bionitrification, circa 1983.

- **Boneyard/Burnyard.** The BYBY consists of three sites: the Boneyard, the Burnyard, and the HCDA located adjacent to the OLF (Figs. 1.2 and 3.4). This site was one of the earliest used waste areas in BCV and information concerning operations, obtained primarily from unsubstantiated verbal reports, is sparse (Energy Systems 1987).
- **Sanitary Landfill 1.** SL 1 is located adjacent to the OLF (Fig. 1.2 and 3.4). SL 1 accepted materials such as paper and cardboard, plastics, rubber, wood, brush, animal bedding, organic garbage, textile products, and asphalt roofing materials. Although administrative controls were used to exclude the disposal of toxic chemicals and other contaminated materials, it is possible that some of these materials were disposed of in the landfill (Energy Systems 1987).
- **Bear Creek Burial Grounds.** The BCBG are located ~3.2 km (2 miles) west of the Y-12 Plant (Fig. 1.2). Their primary purpose was disposal of industrial wastes composed of or contaminated with uranium or thorium. The BCBG consist of several, principal waste-disposal units designated as BG-A, -B, -C, -D, -E, and -J; the Walk-In Pits (WIP); the Uranium Vaults; and Oil Retention Ponds (ORPs) (ORP-1 and -2) (Figs. 3.5 and 3.6). Each waste-disposal unit consists of a series of trenches used for disposal of liquid and solid wastes (Fig. 3.7) (Energy Systems 1988).

Fig. 3.4. Aerial photograph of OLF FA. Foreground: HCDA while active (note small percolation pond in SW corner), circa late 1970s. Background: OLF, SL 1, and NT-3.

3.1.4 Bear Creek Burial Grounds Waste Inventory Information

The DQO process for BCV determined that direct sampling of the waste materials for the purpose of characterization was not feasible (BCV OU 1 RI Work Plan; Energy Systems 1994). Thus, the waste materials in BCBG were characterized to the extent possible by reviewing waste inventory records. A detailed waste inventory has been compiled by Energy Systems (Bailey 1983): Appendix A summarizes the detailed inventory that is available for general use.

Table 3.5 includes an estimated inventory mass (Kg) for the known and quantifiable uranium disposals for each area. For the purposes of risk assessment, average concentrations were calculated from these data (Fig. 3.5). To complete the review, a number of assumptions were made that should be considered when using these data. The main assumptions are:

- Concentrations were derived based on the assumption that the quantity of contaminant is distributed equally throughout the trenched area of each location.
- The total weight for trench material for each area was calculated from the volume of the trench: an assumed density of 2.2 g/cc and an assumed void volume of 40%. The assumed weight of uranium was then added to this mass to obtain the total mass.

Fig. 3.6. Aerial photograph of the BCBG site looking approximately North (date unknown). (Note possible uranium fire in the BG-D area.)

Fig. 3.7. Unidentified trench in BG-A South. (Note construction area in foreground with firebricks may be a solvent burn area.)

- A liquid density of 8 lb/gal was assumed (instances in which specific compound densities were used and differ from the assumption have been noted).
- For risk assessment purposes, a natural uranium isotopic distribution was assumed for all uranium forms in the BCBG.

A comparison to disposal estimates acquired and reported under the SWIMS (Mynatt 1991) program provides a level of confidence to the order of magnitude estimated through this review. Figure 3.5 shows the total uranium estimated for each area by this review (18.6×10^6 Kg as uranium), and Table 3.5 contains a comparison of these data to a 1989 historical release report total (17.3×10^6 Kg) (DOE 1988).

3.1.5 Releases

For liquid wastes, the operations for disposal of wastes in BCV were essentially designed to release the waste materials to the environment. Liquid wastes were put into unlined trenches or ponds with the intention that they would percolate downward and out of the pond. These releases were the result of either working practices that were approved at the time (such as injection of waste oils into standpipes in the BCBG) or accidental releases. The instances of releases through working practices have mostly been described in the preceding paragraphs of Sect. 3.1 and in Appendix A, and the nature and extent of released contaminants are described in detail in Sect. 3.2 and Appendix D.

Solid wastes were buried in trenches with the intention that they would not be released to the environment beyond the trench boundaries. There are no recorded instances of solid wastes being released accidentally outside of the trenches. Releases from leaching of the solid materials are discussed in Sect. 3.2 and in Appendices D and E of this report.

3.2 SUMMARY OF EXISTING DATA

The discussion of the nature and extent of contamination in BCV presented in this section is supported by detailed presentation and analysis of the data in Appendix D of this report. The reader is referred to Appendix D for confirmation of the interpretations described here.

3.2.1 BCV Environmental Database and Background Screens

3.2.1.1 Database description and data quality assessment

An extensive database of environmental data for BCV was derived from recent RI (1994 and 1995) and historical (1980s and early 1990s) field studies. Appendix B summarizes the extent and quality of the environmental database for BCV. Analyses from over 20,000 historic soil, sediment, groundwater, and surface water samples were included (refer to Table B.1 in Appendix B), and over 75,000 discrete recent soil, sediment, groundwater, and surface water analyses were accumulated.

A data quality assessment review was conducted for both the Ground Water Quality Report (GWQR) dataset and the recent BCV RI dataset. The details of these reviews are in Appendix B,

Sects. B.7 and B.8, respectively. The purpose of the data quality assessment was to determine the level of confidence associated with these datasets. This involved reviewing the level of data quality and uncertainty to determine data usability. Data of known quality assurance have been used quantitatively in the RI (i.e., compared to background data), while data with insufficient quality documentation have been used qualitatively within data interpretation. Those cases, in which quantitative data do not correlate with qualitative data, are identified as uncertainties.

In general, the 1986 through 1994 GWQR dataset is adequate for use in the BCV RI. Some specific areas of uncertainty exist, such as holding times, reporting units, and reporting analytical method types. In addition, very few analyses for specific radionuclides had minimum detectable activity (MDA) values low enough to be useful for the human health risk assessment. Thus, all of these data for specific radionuclides in the GWQR dataset were discarded. Apart from radionuclide data, only 1.3% of data from this database were rejected for use in the RI. Data were rejected based mainly on elevated quantitation limits, but also because of preferences of methodology, elevated concentrations of interferant, unacceptable charge balance information, and unacceptable total comparisons with dissolved analyses. The quality of recent BCV RI data (OU 4, OU 1, and FPSS) are also adequate with <1% (672 out of 78,455) considered unacceptable.

3.2.1.2 Methods for identifying site-related chemicals and radionuclides

The first step in interpreting environmental data is to differentiate between those chemicals that are likely related to past waste disposal practices and those that are naturally occurring. The selected statistical method for determining which chemicals detected at the sites are present above background levels is a comparison of 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 used was the upper 95% tolerance limit with a 95% confidence on that limit.

Figure 3.8 summarizes the process of initial evaluation of the soil, groundwater, and surface water data in BCV that determines SRCs. In summary, a contaminant is considered site-related if it occurs above a background criteria and additional factors (i.e., weight of evidence criteria, which are also taken into account to evaluate whether it is reasonable to consider a chemical as a contaminant) do not discount it being an SRC. Weight of evidence criteria allow for input of reasonable scientific judgement to the decision process for determining SRCs.

Background criteria were developed using the following data:

Soils. The background UTL values for the BCV RI soils were constructed using a subset of the background data for the ORR from the Background Soil Characterization Project (Energy Systems 1993). Those data representing the three horizons of the Maryville Limestone (Dismal Gap) and Nolichucky formations were selected because the waste sources in the BCV are located on the Maryville and Nolichucky formations. 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).

Once the background dataset was established, background UTLs for the BCV RI were developed for each chemical using Draft ERWM/ER-P2000.017, the Energy Systems procedure for performing background comparisons (Appendix D, Chap. D.4).

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Fig. 3.8. Screening process for soil and groundwater data.

Groundwater. The background UTL values for BCV groundwater were calculated by analysis of historical groundwater data. Data from a total of 423 GWQR wells at the Y-12 Plant were used to define naturally occurring levels of inorganic analytes in groundwater (Energy Systems 1996). Background tolerance limits were calculated for each inorganic analyte using multi-variate cluster analysis technique where GWQR wells were “clustered” based on five geochemical parameters: nitrate, alkalinity, sodium, magnesium, and conductivity. Ten well clusters were identified in BCV (refer to Table D.9 in Appendix D), and background values for each analyte were calculated for each cluster (refer to Table D.10 in Appendix D). The median value for each analyte in each well was calculated from the “usable data” and was compared to the UTL for that analyte in the assigned cluster. If the median value is less than the UTL, it is assumed that the analyte is naturally occurring.

Surface Water. The background UTL values for BCV for surface water were calculated from samples collected in North Tributary (NT)-13. NT-13 is west of the BCV waste disposal area and separated from disposal areas by four additional tributaries that drain Pine Ridge. NT-13 is isolated from any contaminant waste source and is considered uncontaminated. NT-13 was sampled on a quarterly basis as part of the Groundwater Protection Program sampling effort; these sampling results have been reported in the GWQR (e.g., HSW 1995). Chemical-specific surface water background UTLs were calculated using the same procedure as used for soils.

Site-related data in tributaries and in the upper section of Bear Creek were compared to the background UTLs calculated from NT-13 data. Data for spring water in the floodplain of Bear Creek were compared to data from cluster 4 of the groundwater background data. Groundwater background data were used for these sites because surface water here is chemically more similar to groundwater in the Maynardville Limestone than to surface water in tributaries draining Pine Ridge. The background comparisons for surface water were performed in the same manner as used for soils data.

3.2.1.3 Functional areas and data aggregates

The BCV CA includes numerous contaminant sources and environmental media. In order to organize the data analysis and reporting in the RI Report for this large and complex area, the data have been divided into four functional areas (FAs) (Fig. 3.9). Each FA contains data that are logically interpreted together due to location and/or contaminant source. Chemical data within each group are further organized into data aggregates based on media and location within the FA. All data aggregates are completely contained within one FA, and no aggregates cross over 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. In forming these groups, it is recognized that the principal exit pathway for contaminants migrating in water away from the source areas in BCV is via groundwater in the Maynardville Limestone or via surface water flow in Bear Creek (HSW 1995). Three FAs — the S-3 FA, the OLF FA, and the BCBG FA — include data that relate to the main waste areas that are located on the Nolichucky Shale. These FAs are generally interpreted as sources for contamination in the valley. The fourth FA is the Maynardville Limestone and Bear Creek FA (MNV FA), which is located downgradient of the three source FAs and acts as an integrated exit pathway for contaminants migrating away from the source units. In

LEGEND:

- BEAR CREEK & TRIBUTARIES
- MONITORING WELL LOCATIONS
- S-3 AREA AGGREGATE
- ... OIL LANDFARM AGGREGATE
- ◇ BURIAL GROUNDS AGGREGATE
- MAYNARDVILLE
- ⊗ LIMESTONE AGGREGATE
- WESTBAY WELLS
- △ SPRINGS

FUNCTIONAL AREAS BEAR CREEK VALLEY

addition, the MNV FA contains waste sites and potential sources that are located directly on the Maynardville Limestone and may contribute contaminants directly to the exit pathway.

3.2.2 Valley-Wide Contaminant Fluxes

A sampling strategy for this RI was to monitor contaminant concentrations in surface water at key locations in BCV with the aim of estimating mass fluxes of contaminants being transported away from sources (Appendix B, Sect. B.4). This strategy was based on the hydrogeologic conceptual model (Chap. 2 and Appendix C), which demonstrates that ~95% of water draining the source areas passes through tributary streams to Bear Creek and ~96% of water that drains the section of BCV containing the waste units passes through Bear Creek at BCK 9.47 or SS-5 (Fig. 2.6). An additional 3% of available water passes through the Maynardville Limestone at BCK 9.47 as groundwater. Coupling these data with contaminant distributions in groundwater derived from GWQR data provides the basis for calculating total mass fluxes of contaminants draining the section of BCV that contains the waste areas (above BCK 9.47). In this section the total mass fluxes of contaminants from tributaries draining the waste areas (NT-1 through -8) and at BCK 9.47 and SS-5 (termed the *integrator plane*) are calculated for the 10-month monitoring period of the BCV RI field activities (March 1994 – January 1995).

The primary groundwater and surface water contaminants in BCV are nitrate (Fig. 3.10), uranium, technetium (the extent of which is represented by gross α and β contamination, Figs. 3.11 and 3.12), and volatile organic compounds (VOCs) [principal VOCs are trichloroethene (TCE) and tetrachloroethene (PCE), Figs. 3.13 and 3.14]. Concentrations of these contaminants often exceed maximum contaminant levels (MCLs) in both media. These releases can be associated with individual sources with a fairly high degree of certainty based on groundwater plume distributions and contaminant footprints (Table 3.6). One exception is the source of TCE in the intermediate and deep intervals of the Maynardville Limestone adjacent to BYBY. A small percentage of the contaminants detected in the various environmental media in upper BCV have migrated down the valley in surface water and groundwater and currently pass through the integrator plane at BCK 9.42 (Fig. E.10, Table E.9 in Appendix E).

Uranium contamination is present in tributaries that drain waste areas, with the highest activities of gross α detected at BCK 12.36/SS-1, NT-3, and -8 (Fig. 3.11). Frequent detectable VOC concentrations in surface water occur in NT-6, -7, and -8 and SS-1 and -4 in the floodplain of BCV (Figs. 3.13 and 3.14). Nitrate, a third major contaminant, is derived from a single primary source, the S-3 Site. Nitrate has been detected in BCK 12.36/NT-1, SS-1, and NT-2 (Fig. 3.10); no other waste area appears to be a source of nitrate.

At the integrator plane, uranium and nitrate are present in surface water and groundwater. These contaminants in groundwater are derived mainly from recharge of contaminated surface water from Bear Creek and along strike transport to the integrator plane. Recharge from Bear Creek to shallow groundwater probably occurs at many locations in upper BCV. Locations where recharge of contaminated water to intermediate and deep groundwater intervals occurs are probably associated with losing reaches of Bear Creek of which there are two in Upper BCV: one adjacent to BYBY and SL-1 and one adjacent to the BCBG (Fig 2.8).

The distribution of the 10-month fluxes of some of the major contaminants in the valley is presented in Fig. 3.15. Flux estimates for the integrator plane were calculated for each

Fig. 3.10. Distribution of nitrate-contaminated groundwater in BCV.

Fig. 3.13. Distribution of TCE-contaminated groundwater in BCV.

Fig. 3.14. Distribution of PCE-contaminated groundwater in BCV.

Fig. 3.15. Distribution of mass fluxes in NT-1 to NT-8 for uranium, nitrate, and VOCs.

contaminant of concern (COC) that was detected frequently at BCK 9.47 or SS-5; however, flux estimates for several contaminants (mainly VOCs and trace metals) have a high degree of uncertainty associated with them because of the low frequency of detection for those contaminants. Detailed information on fluxes is contained in Table E.11, Appendix E. Uranium fluxes are greatest at NT-3 and BCK 12.38/SS-1. Based on groundwater data and the radiological walkover survey data, the source of uranium at NT-3 is the BYBY. The source of uranium at BCK 12.38/SS-1 is the contaminated groundwater underlying the S-3 Site. The only major source of nitrate in the valley is the plume of nitrate-contaminated groundwater at the S-3 Site. Elevated concentrations of nitrate were not detected in tributaries past NT-2. VOCs are detected at low levels in groundwater and surface water throughout the valley; however, the greatest mass fluxes emanate from the BCBG.

A contaminant mass balance was performed for the section of Bear Creek above the integrator plane by equating the following 10-month fluxes:

$$\begin{array}{ccc} \text{Outflux} & = & \text{Influx} \\ \\ F10^i_{\text{BCK 9.47}} + F10^i_{\text{SS-5}} + F10^i_{\text{outung}} & = & F10^i_{(\text{BCK 12.38} + \text{NT-1})} + F10^i_{\text{SS-1}} + F10^i_{\text{NT-2}} + F10^i_{\text{NT-3}} + \\ & & F10^i_{\text{NT-4}} + F10^i_{\text{NT-5}} + F10^i_{\text{NT-6}} + F10^i_{\text{NT-7}} + F10^i_{\text{NT-8}} + \\ & & F10^i_{\text{inung}} \end{array}$$

Where $F10^i_{\text{XX}}$ represents the 10-month mass flux of a contaminant i at site XX , and $F10^i_{\text{outung}}$ and $F10^i_{\text{inung}}$ represent outflux and influx to the mass balance via engaged pathways. Ungauged pathways in BCV are those where flow from the waste areas on the Nolichucky Shale does not pass through the BCV RI monitoring points on each tributary or where flow over the integrator plane does not pass through either Bear Creek at BCK 9.47 or SS-5. Based on the hydrogeological conceptual model, the main ungauged pathways are: mass outflux in groundwater flowing in the Maynardville Limestone through the integrator plane; mass influx in shallow groundwater flowing directly from the Nolichucky Shale and its residuum to the Maynardville Limestone; and mass influx in ungauged runoff from waste site directly into Bear Creek.

The results of this mass balance provide information on the relative contaminant influx from the waste sources via gaged tributaries compared to the gaged flux at the integrator plane. Figure 3.16 summarizes the results of the contaminant mass balance for uranium, nitrate, and total VOCs (Table E.11 in Appendix E contains results for each contaminant).

- For nitrate, gaged mass influxes exceeded outflow by 4,916 Kg in the 10-month period (35%) indicating a net excess of ungauged outflux over ungauged influx ($F10^{\text{N}}_{\text{outung}} > F10^{\text{N}}_{\text{inung}}$) for nitrate. The excess ungauged outflux is probably accounted for by three possible sinks for nitrate: (1) ungauged subsurface flow at BCK 9.47; (2) denitrification in groundwater and surface water; and (3) uptake by plants. Assuming an average concentration for nitrate in groundwater at the integrator plane of 11 mg/L (Fig 3.10) and using the calculated 10-month water flux for ungauged groundwater flow at this location (Fig 2.6, 54,000 m³), subsurface flow could account for 590 kg (~12 %) of the ungauged outflux.
- The balance for uranium in the valley differs from nitrate, in that the net influx of uranium is less than the outflow indicating a net excess of ungauged influx over ungauged outflux ($F10^{\text{U}}_{\text{inung}} > F10^{\text{U}}_{\text{outung}}$) for uranium. The 22.5 mCi of excess uranium flux measured at the

integrator plane is from an ungauged source(s) (30.8%). This ungauged influx is probably the uranium flux flowing directly from the Nolichucky Shale to the Maynardville Limestone at the BYBY and S-3 Site where shallow groundwater is contaminated with uranium (refer to Sects. 3.2.3 and 3.2.4). In addition, a small component of this excess is a mass influx in ungauged runoff from BYBY directly into Bear Creek.

Fig. 3.16. Results of mass balance calculations for nitrate, uranium, and VOCs for BCV east of BCK 9.47 during the 10-month period March 1994 to January 1995.

- The 83% (55 Kg over the 10-month period) of VOCs detected at tributary monitoring points volatilize prior to reaching BCK 9.47. This volatilization mass flux probably represents only a portion of the total mass of VOCs that volatilizes in BCV each year because these figures do not represent compounds that volatilize in the headwaters of each tributary before they reach the tributary monitoring point.

3.2.3 S-3 Functional Area

The S-3 FA covers the soils, groundwater, and surface water at, and immediately downgradient of, the S-3 Site. In the following sections, the nature and extent of contamination in environmental media at the S-3 Site by each of the main chemical types (inorganics, VOCs, and radionuclides) is described. In addition, conceptual models are developed that show the nature and extent of contamination and past and present mechanisms of contaminant migration that have resulted in the configuration observed today.

3.2.3.1 Detailed site hydrology

The S-3 Ponds are located just west of the groundwater divide between the Upper East Fork Poplar Creek and Bear Creek hydrogeologic regimes (e.g., Fig. 3.9). During operations, the groundwater divide passed underneath the S-3 Ponds; this is made evident by the presence of the nitrate plume in groundwater below the S-3 Ponds that occurs in both the Bear Creek and Upper East Fork Poplar Creek hydrogeologic regimes (Turner et al. 1991). Dreier, Early, and King (1993) identified an isolated pressure bulge within the Nolichucky Shale down dip of the S-3 Ponds (Fig. C.13 in Appendix C) that was attributable to slow dissipation of elevated hydraulic head caused by the operations at the former ponds.

Water level data from GWQR monitoring of wells located at the edge of the S-3 Ponds cap (no data are available to determine the water table elevation below the cap) indicate that waste materials located in the southern quadrants of the former S-3 Ponds may be submerged when groundwater is at its highest elevations (Fig. D.32 in Appendix D). Waste materials in the remaining quadrants are probably 0.6 to 1.8 m (2 to 6 ft) above the water table year round.

The former S-3 Ponds are located in the catchment of two streams: NT-1 and the uppermost main stem of Bear Creek. The S-3 Site FA also includes flow in NT-2 (Fig. 3.9). The pattern of flow in these streams is typical of that observed for the second order or tributary streams in BCV. The range in magnitude of flow is great, for example, flow varies from ~2.8 L/s (0.1 cfs) to 560 L/s (20 cfs) in Bear Creek Main Stem at BCK 12.38; however, high flow is maintained for only short periods of time (12 to 24 hours) during and immediately following precipitation events (Fig. D.34 Appendix D). Although flow in both streams is low during the lowest flow periods, none of the streams in the S-3 Site FA stopped flowing at the monitoring points during the 10-month monitoring period.

3.2.3.2 Chemical data

Table 3.7 lists the results of analyses of soils, surface water, and groundwater at the S-3 Site. Those chemicals considered to be SRCs are noted in a column for each medium. The data in this table represent the following:

- Soil sampling from the BCV RI at the S-3 Site. These data are the combined results from aggregates I and II, shallow and deep (refer to Appendix D, Tables D.15 to D.18).
- Surface water sampling from GWQR surface water samples for NT-1 combined with NPDES monitoring from BCK 12.46 (refer to Appendix D, Tables D.20 and D.22).
- Groundwater samples of wells in the S-3 aggregate (Fig. 3.9) (refer to Appendix D, Table D.30).

In general, SRCs are more numerous in groundwater and surface water at the S-3 Site (totals of 54 groundwater SRCs and 23 surface water SRCs) than in soils (26 SRCs). This reflects one of the main features of the nature and extent of contamination at the S-3 Site in that the highest degree of contamination occurs in groundwater. This relative distribution of contaminants is attributable to the type of operations at the former S-3 Ponds, in the mode of emplacement of the contaminants, and in the history of this site prior to construction of the ponds. In brief, as is

described in Sect. 3.1, disposals at the S-3 Site were mainly liquid and were mostly contained within the pond boundaries (only one recorded breach of the ponds). Contamination at the S-3 Site is derived from dispersal of contaminants from waste liquids that have infiltrated into groundwater through the former S-3 Ponds (Fig. 3.17). Soil contamination is derived both from fill material deposited at this site prior to construction of the S-3 Ponds and from contaminated groundwater.

Soils

Compared to concentrations of the same contaminants in the sludges in the former ponds, contaminant concentrations in the soils surrounding the S-3 Site are one to three orders of magnitude lower (Table 3.7). Contaminants that frequently occur above background are the following:

- **Mercury.** Mercury is a COC in soils at the S-3 Site (Table 5.4). It was detected in 24 of 37 samples (mean concentration of 7.8 mg/kg) with 17 detects exceeding background. The highest concentrations typically occurred in the 0- to 2.4-m (0- to 8-ft) interval (ranging from 58.7 to 82.9 mg/kg) in three borings situated close to the south side of the former ponds (S3-3, S3-4, and S3-8; Fig. 3.18).
- **PCBs.** PCBs were detected most frequently in the 0- to 2.4-m (0- to 8-ft) interval; however, there is no apparent pattern to their distribution. With the exception of one sample located near the confluence of NT-1 and Bear Creek (Fig. 3.18) that had a concentration of 3300 µg/kg, PCB concentrations in the S-3 soils are relatively low (270 µg/kg, maximum).
- **VOCs.** Soil contamination by VOCs in the S-3 Area is centered at the southwest corner of the former ponds (Fig. 3.18). The most frequently occurring chemicals are acetone and toluene (2 to 4,224 µg/Kg total VOCs).
- **Radionuclides.** Most radionuclide occurrences in soils above background criteria were in the 0- to 2.4-m (0- to 8-ft) interval from borings located on the east and south side of the former ponds (Fig. 3.18). The maximum recorded activities of most of the radionuclides listed in Table 3.7 were low (e.g., maximum activity of ²³⁷Np was 0.27 pCi/g; Table 3.7) and none are COCs. Uranium isotopes occur most frequently in soil samples with maximum activities of 17 pCi/g for ²³⁴U, 0.99 pCi/g for ²³⁵U, and 43 pCi/g for ²³⁸U.

A photograph of this Site (Fig. 3.1) shows that the area was probably used to dispose of debris from the Y-12 Plant prior to construction of the ponds. It is consistent with known operations at the plant and other studies that have sampled soils at Y-12 Plant that this type of "fill" material was sporadically contaminated with low concentrations of mercury, PCBs, and uranium (Energy Systems 1994; Rothschild et al. 1984). The data from this RI suggest that operations at the S-3 Ponds have not caused soil contamination outside the pond boundaries that is distinguishable from that which would be anticipated from fill material and that this type of sporadic and low-level contamination is probably present in the subsurface throughout the area of the S-3 Site underlain by fill material.

BC-79 Rev 0 8.5 x 11

Fig. 3.17. Conceptual model for emplacement of contaminated groundwater at S-3 Site.

Fig. 3.18. Distribution of mercury, uranium, PCBs, and VOCs in soils at the S-3 Site.

Groundwater and Surface Water

Groundwater at the S-3 Site contains the following SRCs: nitrate, radionuclides, inorganic chemical species, and VOCs (Table 3.7, Figs. 3.19 and 3.20). Surface water in the uppermost reaches of Bear Creek, NT-1, and NT-2 contains these SRCs: nitrate, radionuclides, 11 inorganic chemical species, and 5 VOCs. Each of the contaminants detected in surface water also occurs as a contaminant in groundwater at this site.

Contamination of groundwater and surface water with nitrate and radionuclides is the overwhelming feature of contamination at the S-3 Site. Nitrate effectively acts as a tracer for the plume of contaminated groundwater, and the occurrence of nitrate in groundwater in BCV marks the maximum extent of groundwater contamination resulting from activities at the former S-3 Ponds. In general, the contaminant plumes are strongly oriented parallel to geologic strike and exhibit the highest concentrations in the Nolichucky Shale. Contamination derived from 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 4.55 (Fig. 2.1).

The distribution of contaminants in the groundwater plume that has developed in BCV from the S-3 Ponds is also strongly dependent on the contaminant geochemistry and the contaminant reactions with aquifer materials. Contaminants that are chemically mobile at the S-3 Site (nitrate, ^{99}Tc , barium, strontium, PCE, and acetone) have migrated long distances from the origin of the plume and occur extensively in surface water (e.g., Fig. 3.10). Conversely, contaminants that are generally geochemically immobile, as is the case for most metals, are only detected in wells close to the source (Fig. 3.19) and occur only sporadically as contaminants in surface water. Uranium is considered as intermediate between mobile and immobile chemicals at the S-3 Site.

Nitrate. The plume of nitrate-contaminated groundwater extends in the Nolichucky Shale along strike in both directions east and west downgradient of the S-3 Ponds, in both the shallow and deep intervals (Fig. 3.10). The nitrate plume in UEFPC is contiguous with the plume in BCV, and concentrations of nitrate in both hydrogeologic regimes are similar in magnitude.

One of the main features of the nitrate plume in the Nolichucky Shale formations is that the highest concentrations of nitrate are generally found in the intermediate and deep bedrock intervals [>30 m (100 ft)], and the zone of groundwater contaminated with >1000 mg/L nitrate is more extensive below 30 m (100 ft) depth than above (Figs. 3.10 and 3.21). The highest concentrations of nitrate in BCV occur in the deep interval directly below the S-3 Ponds (GW-615 with 10,099 mg/L). 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 deep interval (HSW 1995). The shape of the plume (as depicted on Fig. 3.10) has been interpreted assuming strong control of migration of nitrate by the strike of bedding in the Nolichucky Shale following the site conceptual hydrogeological model (Chap. 2). Although available data (four well control points) are sparse, they indicate that a continuous plume of nitrate contamination exists in the bedrock below 30 m (100 ft) depth that extends along strike underneath tributaries and catchment boundaries.

The westernmost sample of deep groundwater in the nitrate-contaminated zone (GW-829) is located close to NT-2, and the western extent of the plume in deep groundwater cannot be bounded with certainty. However, nitrate in the shallow groundwater interval west of NT-1 is interpreted as being derived from upward migration of nitrate from the deeper interval. The

LEGEND:

- ROADS
- BEAR CREEK & TRIBUTARIES
- PLUME OF METAL CONTAMINATED GROUNDWATER

- S-3 AGGREGATE
- GW-101.....GROUNDWATER WELL
- GW-135.....GROUNDWATER WELL
- WESTDAY
- MAYNARDVILLE AGGREGATE
- ⊗ GW-122.....GROUNDWATER WELL

BEAR CREEK VALLEY KEY MAP

	101	103	127	243	244	245	246	247	276	277	345	346	526	615	P1	P2
Al		690.0	24.0	760.0		13.0	99.0		270.0						90.3	81.3
Ba	6.1			7.1		21.0	26.5	30.5	4.8	9.5		1.8	9.5	340.0	5.5	20.1
Be		0.064	0.0007	0.066		0.008	0.035		0.084						0.02	0.01
B	0.190		0.17	1.55		0.13	0.28	0.14	0.097	0.09	0.029			1.1	0.2	
Cd	0.005		0.0057	2.3	1.01	0.18	0.49	0.1	0.15					0.0850	0.68	0.79
Cr				0.26											0.08	0.08
Co		2.3		1.6		0.14	0.48		1.2					0.36	0.62	0.6
Cu	0.095	3.1	0.12	1.06					0.36				0.044	0.98		
Pb		0.16			0.011				0.026							
Mn	6.9	110.0	2.7	210.0		43.0	88.0	24.0	67.0	6.8				20.0	115.0	100.0
Hg	0.0044	0.016			0.0016		0.0029		0.0009							
Ni	0.063	18.0	0.056	18.5		1.5	5.0	0.47	5.8					0.25	3.5	3.2
Sr	11.5	1.7		12.0		13.0	9.4	13.0	2.0	7.3	0.082		12.5	310.0	42	
Th		0.28														
U	0.045	32.6	0.44	35.4	0.015	0.115	0.6	0.029	5.54	0.013				0.43		
V			0.023												0.04	0.05
Zn		5.1	0.076	3.4		0.18	0.28	0.049	1.6	0.15			0.06	0.73	0.19	0.23
#	9	12	10	14	4	11	12	8	14	6	2	1	4	10

Fig. 3.19. Distribution of metal-contaminated groundwater at the S-3 Site.

Fig. 3.20. Relative concentrations of VOCs in groundwater at S-3 Site.

BC-130 a, b2, c & f nitrate

Fig. 3.21. Cross sections of BCV showing distribution of nitrate-contaminated groundwater.

absence of nitrate in the shallow interval at the BYBY (BCV RI grab samples and GW-087, Sect. 3.2.3) indicates that the nitrate plume does not extend further west than BYBY in the deep interval.

In shallow groundwater in the Nolichucky Shale in BCV, the plume is effectively bounded by the locations of NT-1 and Bear Creek; an additional lobe of nitrate-contaminated groundwater occurs at NT-2 interpreted as a result of upwelling of contaminated groundwater from below 30 m (100 ft) depth. The highest mean concentrations in the shallow interval occur in wells adjacent to the former ponds; e.g., GW-243 through GW-247 [23.5 m (77 ft)] (3265 through 6361 mg/L).

Time-series trends for nitrate concentrations in groundwater 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 (Fig. 3.22). The most significant increases occur in wells located close to the leading edge of the plume (GW-085, GW-086, and GW-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 interval wells to the south and east of the S-3 Ponds have shown both stable and decreasing trends (GW-106 and GW-276).

Nitrate, which is the principal common anion contaminant in the S-3 Site surface water aggregates, was detected in all surface water samples at BCK 12.46, in NT-1, and in NT-2 (Tables D.20, D.22, and D.24 in Appendix D). Nitrate shows a wide range in concentrations in each stream dependent on flow (e.g., concentrations range from 2.9 to 211 mg/L). Higher concentrations of nitrate occur in NT-1 (mean 166.6 mg/L) and NT-2 (mean 74.2 mg/L) than in the Bear Creek Main Stem aggregates (mean 38.8 mg/L). In addition, a screening sample from shallow groundwater (0.755 m or 2.5 ft) adjacent to NT-1 had a concentration of 1991 mg/L (P2, Table D.27 in Appendix D). This indicates 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.

Radioactivity. The distribution of radiological contamination in groundwater and surface water in BCV is best defined by the distribution of gross α and gross β , for which there is an extensive database of suitable analyses; whereas suitable analyses of specific radioisotopes are sporadic. Recent radioisotopic analyses and historical information suggest that a diverse population of radioisotopes may be present in groundwater at the S-3 Site, including isotopes of uranium, thorium, ^{90}Sr , and ^{237}Np (Table 3.7). However, away from the former S-3 Ponds in the downgradient plumes, radiological contamination is dominated by isotopes of uranium and ^{99}Tc . These isotopes can account for the observed activities of gross α and gross β . It is assumed that the distribution of gross α and gross β in BCV delineates the distributions of these isotopes (Figs. 3.11 and 3.12).

The distribution of the gross β in groundwater and surface water in the S-3 FA closely resembles the distribution of nitrate (Fig. 3.12). However, some notable differences between the distribution of the gross α plume and that of nitrate indicate subtle variations in contaminant transport mechanisms and timing of the contaminant influx to groundwater.

Close to the S-3 Ponds source, the highest concentrations of nitrate ($\sim 10,000$ mg/L) occur at depths >30 m (100 ft) (Fig. 3.21) whereas the highest activities of gross α and gross β occur

Fig. 3.22. Temporal trends in the concentration of nitrate in groundwater in BCV.

at <30 m (100 ft) depth (Fig. 3.23). In addition, the extent of the gross α plume is less than that of both the nitrate and gross β plumes. Differences between distributions of radiological and nitrate contamination also occur in surface water; the relative concentrations of contaminants vary between stream reaches. Gross α contamination was not detected in NT-2, whereas gross β and nitrate occur in that stream (12 to 164 pCi/L for gross β). At BCK 12.46 where concentrations of nitrate were lower than those below NT-1, the activities of gross α and gross β are higher than those in NT-1 (a mean of 270 pCi/L for gross α at BCK 12.46 and a mean of 26 pCi/L for gross α in NT-1). A screening sample of shallow groundwater at NT-1 that had a nitrate concentration of 1919 mg/L (P2) had a uranium concentration of 6 μ g/L. In addition to 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 (Appendix D, Fig D.37a) and correlated with elevated uranium concentrations (1.2 to 14 mg/L) in groundwater adjacent to Bear Creek. In the same study, uranium was not detectable in four samples of surface water from NT-1 and was detected at concentrations < 10 μ g/L in groundwater adjacent to NT-1. This indicates that the primary pathway for uranium from groundwater at the S-3 Site to surface water, unlike that for nitrate, is currently directly to Bear Creek adjacent to the former ponds and not via along strike flow. This is due to the effects of differential retardation of uranium and nitrate. Although uranium and nitrate have migrated along the same pathways away from the former S-3 Ponds, uranium is retarded in these pathways by greater adsorption at mineral surfaces than nitrate. Thus, flushing by shallow groundwater since cessation of operations at the S-3 Ponds has resulted in a considerable decrease in the concentrations of nitrate in the shallow pathways (Shevenell et al. 1994) whereas the concentrations of uranium remain elevated. The elevated uranium concentrations are maintained by the reservoir of adsorbed uranium. Conversely, nitrate concentrations are highest in the intermediate and deep groundwater at the S-3 Site because the volume of groundwater flowing through these intervals is less and thus has not reduced nitrate concentrations by flushing. Uranium concentrations in the intermediate and deep intervals at the S-3 Site are relatively low because uranium is retarded in this pathway and remains mostly in the shallow intervals as adsorbed uranium.

Activities of gross α and gross β in groundwater do not show consistent temporal trends as do those observed for nitrate, but this could be an artifact of a few data points. Exceptions are GW-276, a shallow well that shows decreasing trends in both gross α and gross β consistent with a decreasing trend in nitrate in that well (Fig. D.51 in Appendix D), and GW-085, a shallow well near the BYBY that shows an increasing trend in gross β consistent with an increasing trend in nitrate (Fig. 3.22).

Inorganic species. With the exception of barium, boron, and strontium, which are relatively mobile in groundwater at the S-3 Site, most metal species have not migrated away from the vicinity of the former ponds (Fig. 3.19). 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. The geographic grouping 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. 3.19). Grad samples of groundwater from two piezometers (P1 and P2) close to S-3 plume discharge points in NT-1 also had elevated concentrations of metal contaminants (Table D.27 in Appendix D).

BC-129 a, b2, c & f alpha

VOCs. A number of wells close to the S-3 Ponds are contaminated with VOCs. The distribution of VOC chemical species is highly varied: the suite of organics detected in wells differs around the site, and the concentrations vary widely (Fig. 3.20). Acetone and PCE are the most common organic contaminants and form continuous plumes. The plume of PCE extends along strike in the shallow interval as far as NT-1, where shallow groundwater contains up to 260 $\mu\text{g/L}$ PCE. The maximum concentration of PCE in groundwater (9000 $\mu\text{g/L}$ in GW-243) is ~6% of its maximum solubility (150,000 $\mu\text{g/L}$), indicating that a PCE-bearing DNAPL is probably present close to this well.

Acetone, chloromethane, and PCE are the most commonly occurring VOCs in surface water; however, concentrations of all VOCs in surface water are much lower than groundwater. The most frequent organic contaminant was PCE, which attained a maximum concentration of 18 $\mu\text{g/L}$ in NT-1.

Water salinity. In general, concentrations of all major ions (sodium, calcium, magnesium, potassium, sulfate, and chloride) in groundwater and surface water at the S-3 Site are elevated. Total dissolved solids concentrations in the center of the S-3 groundwater plume in excess of 20,000 mg/L have been recorded. Total dissolved solids in surface water range from 58 to 1520 mg/L. The elevated concentrations of major ions relates to the overall increase in dissolved load of groundwater and surface water down stream of the S-3 Site, both of which are a result of the high total dissolved solids waste water disposed of in the former ponds and the interactions of this waste with bedrock.

3.2.3.3 S-3 Site conceptual model

The site conceptual model for the S-3 Site is an interpretation of the data described above that shows the nature and extent of contamination and past and present mechanisms of contaminant migration that have resulted in the configuration observed today (Figs. 3.17 and 3.24). This conceptual model also describes the past and future fate and transport of contaminants at the S-3 Site.

Contaminant Sources

The type of waste disposed of at the S-3 Site and the history of remediation since operations ceased have resulted in two potential sources of contamination for downgradient environmental media: (1) sludges remaining in place in the former ponds and (2) waste water that recharged to groundwater and formed a plume in the Nolichucky Shale below the ponds. The groundwater plume is the principal source at the S-3 Site for most contaminants. Modeling of leachate formation from the remaining sludges shows that only uranium and ^{99}Tc are likely to be released to shallow groundwater (Appendix E), and both these at concentrations comparable to those already occurring in the waste water plume.

Emplacement of the groundwater plume took place during operations at the S-3 Ponds (1951 through 1983). The Nolichucky Shale exhibits relatively low hydraulic conductivity; it is likely that most waste water disposed of in the ponds migrated rapidly to the main stem of Bear Creek and NT-1 via shallow groundwater flow in the residuum. However, an unknown portion of the waste water that infiltrated through the base of the ponds recharged to bedrock groundwater (Fig. 3.17). The higher relative density of the waste solutions compared to ambient groundwater,

Fig. 3.24. Representative along strike cross sections showing the distributions of nitrate- and uranium-contaminated groundwater at the S-3 Site.

combined with the influx of waste water that maintained an elevated hydraulic head in the ponds, created a downward driving force for infiltration. The corrosiveness of the waste water (~5% nitric acid solutions) created the pathways for migration along carbonate-rich horizons in the Nolichucky Shale close to the S-3 Ponds by dissolving carbonate minerals. These two effects resulted in movement of waste water up to 122 m (400 ft) deep in the Nolichucky Shale bedrock.

High concentrations of contaminants in fractures and 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 creating a secondary source of contamination to downgradient media.

Contaminant Movement

The rate of contaminant migration in groundwater and surface water at the S-3 Site is strongly dependent on the geochemistry of the contaminant. This has resulted in differentiation of contaminants in the groundwater plume and variable predictions of the future transport of contaminants at this site. The following is a discussion of the main contaminants at the S-3 Site (nitrate, uranium, technetium, VOCs, and metals):

Nitrate. Nitrate defines the maximum distribution of contaminants from the S-3 Ponds because of its nonsorbing chemical nature. The S-3 Ponds themselves are no longer a source of nitrate contamination, and the main source for contamination to downgradient media is the plume of nitrate-contaminated groundwater in the Nolichucky Shale.

There are two main pathways for nitrate-contaminated groundwater at the S-3 Site to reach the Maynardville Limestone and Bear Creek: by direct migration in the shallow groundwater to Bear Creek or by along strike flow to NT-1 and NT-2.

Between cessation of activities at the S-3 Ponds and today, the direct pathway from the S-3 Ponds to Bear Creek has ceased to be as significant a pathway for nitrate. This is evidenced by the reduction of nitrate concentrations in the main stem close to the S-3 Ponds, which correlates with a reduction of nitrate concentrations in some shallow wells near the S-3 Ponds (GW-276; Fig. 3.22). The main pathways for nitrate operating today are (1) flow and/or diffusion from the reservoir of contaminants in the matrix to the flow system close to the S-3 Ponds followed by discharge to NT-1 and (2) upwelling and/or diffusion from the intermediate and deep groundwater plume in the Nolichucky Shale to the shallow interval and then into tributaries NT-1 and NT-2 (Fig. 3.24):

- 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 probably not dissipated as quickly from the matrix as from the flow system; the resulting hydraulic gradient from the matrix to the flow system may also drive contaminants into the flow system. The effects of diffusive and advective transport of contaminants from the matrix to the flow system 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.

- Migration from contaminated groundwater in the intermediate and deep intervals to the shallow groundwater interval is probably driven by upward hydraulic gradients that may be locally more prominent at tributaries and may also include upward diffusion of nitrate. In the absence of vertical fractures, the migration pathway may not be directly upwards due to the anisotropy of the formations, but the vertical upward hydraulic gradients induce an upward component in the migration vector of the contaminants in the deep plume. This ultimately results in contaminants entering the shallow, and more active, flow system and, hence, moving into the tributaries to Bear Creek.

Shallow wells at BYBY (NT-2 catchment) show increasing concentrations of nitrate over the past 10 years (GW-085 and GW-086; Fig. 3.22). This trend suggests that the center of mass of the plume may currently be moving along strike to the west. Fate and transport modeling shows that nitrate concentrations in shallow groundwater at NT-1 and NT-2 are expected to continue to increase in the future (Fig. 3.25). Concentrations of nitrate at NT-1 have either peaked (1919 mg/L in groundwater at NT-1) or are approaching peak concentrations within 50 years. Concentrations will also probably remain close to the elevated concentrations observed today for over 500 years. Concentrations of nitrate at NT-2 are expected to increase in the near future with peak values less than an order magnitude greater than current concentrations expected within the next 300 to 800 years (Table 3.8). Concentrations of nitrate in Bear Creek above BCU 12-46 have decreased dramatically since cessation of operations at the S-3 Ponds and are expected to continue to decline (Fig. 3.26 and Table 3.9).

Fig. 3.25. Modeled breakthrough of nitrate from the S-3 Site at NT-1.

The fate of the plume's leading edge in intermediate and deep bedrock intervals is the most uncertain condition of the S-3 plume. The future distribution of the nitrate plume is probably

governed by the presence of large-scale geological structure in the upper Nolichucky Shale and in the Maynardville Limestone, such as fault zones. 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 the plume further along strike.
- 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.

Fig. 3.26. Modeled breakthrough curves for nitrate and uranium in groundwater at the main stem of Bear Creek adjacent to the S-3 Ponds.

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

Uranium. Gross α contamination is mostly derived from uranium. The relative distribution of gross α activity in the S-3 groundwater plume differs from the relative distribution of nitrate concentrations. At the S-3 Ponds, the most elevated activities of gross α are in the shallow

bedrock wells, and the vertical and along strike extent of gross α is much less than that of nitrate (Fig. 3.24). As well as the processes and pathways outlined above to explain the distribution of nitrate, there are three possible contributing processes that may have resulted in the differences between the distribution of uranium relative to that of nitrate. These are as follows:

- Different disposal histories for nitrate and uranium. This explanation is not very likely because the nitric acid solutions disposed of in the S-3 Ponds were probably always contaminated with uranium.
- Relative retardation of uranium in the subsurface. Conceptually, this is a very likely process. Modeling predicts that, during the initial neutralization reaction of the acidic solutions on contact with bedrock, the propensity for the stable uranium aqueous species in acidic solutions to sorb to minerals increases exponentially (Fig. 3.27). At pH 5, all uranium in solution would effectively be sorbed to mineral surfaces and, only with continued neutralization of the waste waters, would uranium desorb and return to solution.
- The S-3 Ponds sludges are currently leaching uranium to groundwater. Modeling of the pond sludges (Sect. 3.3 and Appendix E) suggest that uranium and ^{99}Tc may leach from the sludges, so this is a possible pathway.

The working hypothesis is that 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, geochemical reactions have removed most uranium from these solutions (Fig. 3.27). Uranium does discharge from groundwater to surface water in the main stem of Bear Creek adjacent to the S-3 Ponds, which probably indicates that the shallow groundwater pathway from the ponds to Bear Creek still operates for uranium. Modeling of this pathway indicates that this may be the result of retardation of uranium relative to nitrate (Fig. 3.25). The peak nitrate and uranium concentrations have already discharged to Bear Creek from this pathway; however, the concentrations of uranium are declining more slowly. In addition, the finding that the pond sludges may continue to act as a source to uranium contamination in shallow groundwater cannot be ruled out. The same fate and transport modeling shows that uranium is expected to breakthrough into shallow groundwater at NT-1 and NT-2, reaching peak values of 0.8 to 2.0 mg/L within 50 to 150 years (Fig. 3.28 and Table 3.8).

Technetium. The similar distributions of Tc and nitrate along strike can be explained by the chemistry of these contaminants; that is, both are present as relatively stable anions in aqueous solutions, NO_3^- and TcO_4^- . Retardation of Tc may also have occurred during acid neutralization, in a way similar to that for uranium, by precipitation of insoluble Tc oxides as pH increases.

The working hypothesis is that the distribution of Tc can be explained following the same lines of reasoning that were used to explain the distributions of uranium and nitrate at S-3. The pH range for precipitation of Tc is smaller than that for uranium, probably explaining why Tc contamination, although apparently retarded, is not retarded to the same extent as uranium. The chemical nature of Tc means that, once remobilized in the neutralized solutions, it is almost as mobile as nitrate and so has a similar distribution. As for uranium, leaching of ^{99}Tc from the current pond sludges cannot be ruled out.

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 Pco₂.

Bedrock can potentially release uranium as waste water is neutralized. High Pco₂ 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 Pco₂. This reaction releases H₂CO₃ into solution and, in a partially closed system, Pco₂ increases as this reaction proceeds.

Fig. 3.27. A geochemical model for waste water neutralization and uranium solubility in groundwater at the S-3 Ponds.

Fig. 3.28. Modeled breakthrough of uranium at NT-1.

VOCs. The maximum concentration of PCE attained indicates the potential for dense non-aqueous phase liquid (DNAPL), which may be present in the bedrock formations beneath the S-3 Ponds. The elevated concentrations of PCE in shallow groundwater at NT-1 indicate that the primary pathway for VOCs from the S-3 Ponds to surface water is via along strike flow in the shallow groundwater.

Metals. A variety of metals occur 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 concept. A considerable reservoir of metals is probably sorbed to mineral surface close to the S-3 Ponds, and the high total dissolved solids in groundwater may enhance metal solubility by reducing the effect of surface charges at mineral surfaces. Modeling predicts that concentrations of metal COCs in NT-1 and NT-2 are likely to increase in the future (Table 3.8). Barium and strontium occur as contaminants, but their solubility is less pH controlled, and they are relatively mobile. It is likely that these metal species have similar migration 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.

Soils

The generally low concentrations of contaminants in the soils surrounding the S-3 Ponds (especially when compared to the concentrations of contaminants 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 there is a current source of contamination via leaching, the sludges remaining 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.

3.2.4 Oil Landfarm Functional Area

The OLF FA covers the soils, groundwater, and surface water at, and immediately downgradient of, the OLF, BYBY, and SL 1 sites (Fig. 1.2). In the following section, the nature and extent of contamination in environmental media at the OLF, SL 1, and BYBY sites by each of the main chemical types (inorganics, VOCs, and radionuclides) are described. In addition, conceptual models are developed that show the nature and extent of contamination and past and present mechanisms of contaminant migration that have resulted in the configuration observed today.

3.2.4.1 Detailed site hydrology

There is little detailed information concerning the site hydrology of the OLF FA; it is therefore assumed that the hydrology of this section of BCV is similar to that elsewhere in the valley, as described in Chap. 2 and Appendix C. The water table is relatively shallow over most of the OLF FA because most of the site is located close to the floor of BCV. This is particularly the case for parts of BYBY and SL 1, which are located on the floodplain of Bear Creek. Soil borings from BCV RI sampling indicate that fill material ranges from 0 to 4.6 m (0 to 15 ft) depth at BYBY and is sporadically saturated (Appendix B). Waste materials at SL 1 and BYBY are probably inundated for all or part of the year.

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 (NT-3 and NT-4) after short flow paths through soil or shallow groundwater (see Appendix C). However, the southern section of BYBY and approximately 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 may not discharge to tributaries and probably flows directly to the Maynardville Limestone aquifer.

3.2.4.2 Radiation and geophysical survey data

Geophysical (magnetometry and EM-31) and radiological (β/γ) surveys were conducted at the BYBY (Appendix B). Results of these surveys are included on Figs. 3.29 and 3.30; a more complete depiction of the data is shown on Figs. D.61 to D.65 in Appendix D. These data are used to qualitatively identify areas of soil radiological contamination or buried waste materials. In general, EM-31 quadrature readings (Fig. 3.29) increase over areas of elevated soil conductance and may indicate buried metallic objects or contaminated groundwater. The magnetometer survey (Fig. D.65 in Appendix D) identifies buried metallic objects, such as drums, to depths of 10 m (30 ft).

Both the radiological 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. 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 main anomalies can be identified:

Fig. 3.29. Results of the EM-31 survey, the area underlain by fill material and the distribution of the plume of gross α -contaminated groundwater.

SHALLOW (0-8 ft.)

DEEP (>8 ft.)

Fig. 3.30. Map of BYBY showing results of the radiological survey (NaI probe) and the concentration of uranium in soil samples.

- An area of both radiological and geophysical anomalies located south of boring BYBY-3 and between the HCDA cap and NT-3, which indicate mostly surface contamination.
- An area of radiological anomalies north of BYBY-3 between the HCDA cap and NT-3. The highest radiological anomalies at BYBY occur in this area and probably continue to an unknown extent below the HCDA cap.
- An area of radiological anomalies north of the HCDA cap and south of BYBY-4.
- An area of geophysical anomalies bounded by the OLF cap, NT-3, HCDA cap, and BYBY-4 that is best depicted by the EM-31 quadrature results and indicates elevated ground conductivity. This anomaly is abruptly truncated at both ends by the OLF and HCDA caps, indicating that the anomaly runs beneath both caps. Elevated ground conductivity in this region may be associated with fill materials or contaminated groundwater.

In addition to the anomalies listed above, other geophysical and radiological anomalies occur sporadically throughout the BYBY. In particular, a suite of radiological and magnetic anomalies occurs along the south side of the HCDA cap that marks the location of a corroded drum (refer to discussion of sample SBY-27 below) and of other radiologically contaminated metal objects observed at the surface during field activities.

3.2.4.3 Chemical data for BYBY and HCDA

Table 3.10 lists the results of analysis of soils, surface water, and groundwater at the BYBY site. The data in this table represent the following:

- Soil sampling data from BCV RI at the BYBY site. These data are the combined results from the BYBY aggregate shallow and deep intervals (refer to Appendix D, Tables D.36 to D.37).
- Surface water sampling data from BCV RI at NT-3 (refer to Appendix D, Table D.46).
- Groundwater samples of wells in the BCV RI BYBY groundwater aggregate (refer to Appendix D, Table D.60).

More complete summaries of these data are presented in Appendix D. In Table 3.10, those chemicals considered to be SRCs are noted in a column for each medium.

SRCs at BYBY are numerous in groundwater (38 SRCs), surface water (17 SRCs), and soils (68 SRCs). There are SRCs from each analyte group (inorganics, organics, and radionuclides) in each medium. Disposals at BYBY and HCDA were in the form of both liquids and solid materials and, although few details are known, the waste streams were probably diverse. Contamination at BYBY is derived from dispersal of contaminants from leaching of buried waste materials and from waste liquids that have infiltrated into groundwater.

Wastes

Debris and waste materials have been observed at the surface in many places in the BYBY. A rusted drum and 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 a 3.0- to 3.7-m (10- to 12-ft) step-up from the floodplain level marks the southernmost extent of fill. Soil borings show that 3.0- to 3.7-m (10- to 12-ft)-thick fill material (shown on Figs. 3.29, 3.30, and 3.31 as a shaded area) covers most of BYBY with the exception of the southwest corner.

A single sample of uranium waste was collected from a corroded drum exposed at the surface south of the HCDA cap (SBY-27). The results of the analyses performed on sample SBY-27 show the sample to have high gross α (143,000 pCi/g) and gross β (32,000 pCi/g) activities and 142,000 $\mu\text{g/g}$ total uranium with 0.24 weight % ^{235}U . These data, converted to activity units, give the following results: $^{238}\text{U} = 46,750$ pCi/g and $^{235}\text{U} = 725$ pCi/g. In addition, inorganic elements that exceeded the soil background criteria in this sample are silver, barium, beryllium, cadmium, cobalt, chromium, copper, molybdenum, nickel, lead, and zinc.

Soils

The main contaminants in soils at BYBY include inorganic chemicals (including cadmium, copper, and mercury), radionuclides (uranium isotopes and ^{99}Tc), and organic compounds [polyaromatic hydrocarbons (PAHs), PCBs, and phthalates] (Figs. 3.30 and 3.31).

Inorganic chemicals. Seventeen inorganic elements or compounds were detected above their background criteria in soil samples collected from the BYBY aggregate (Table 3.10), and 10 of these are COCs (Table 5.4). Most (16) occur in the shallow interval [0 to 2.4 m (0 to 8 ft)] and cadmium and mercury are representative of the distributions of contaminants in this chemical group (Fig. 3.31).

- Mercury exceeds its background criterion (0.34 mg/kg) in every soil sample in the 0- to 2.4-m (0- to 8-ft) interval and attains its maximum concentration (77.7 mg/kg) in surface soil sample SBY-22. Mercury is less widespread in the deep interval [>2.4 m (8 ft)] than in the shallow interval, having been detected in only 15 of the 20 samples with a maximum concentration of 16.6 mg/kg that occurs in the 2.4- to 3.7-m (8- to 12-ft) sample of borehole BY-9.
- Cadmium exceeds its background criterion (0.31 mg/kg) in 11 of 15 samples collected from the 0- to 2.4-m (0- to 8-ft) interval with a maximum concentration of 32.3 mg/kg. Cadmium was detected only twice in borings below 2.4 m (8 ft) at concentrations greater than background.

Organics. Organic SRCs at BYBY are mainly PCBs and pesticides and semivolatile organic compounds (SVOCs), falling into two major groups: PAHs and phthalates (Table 3.10). Although fourteen VOCs were detected in a number of samples, none are COCs (Table 5.4).

- Twenty-six SVOCs were detected in the BYBY aggregate (their distribution is represented by total PAHs on Fig. 3.31). Contamination by SVOCs in the BYBY aggregate is dominated by total PAHs. The highest concentrations occur in surface soil samples in the 0- to 2.4-m (0- to 8-ft) interval; e.g., fluoranthene with a maximum concentration of 270,000 $\mu\text{g/kg}$ in surface soil sample SBY-21. 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.

Fig. 3.31. Concentration of mercury, cadmium, PCBs, and total PAH in soils at BYBY.

- The distribution of PCBs and pesticides in the BYBY aggregate is represented by total PCBs in Fig. 3.31. Two PCBs, Aroclor-1254 and -1260, and one dioxin 2,3,7,8-TCDD [0- to 1.2-m (0- to 4-ft) interval of BY-03], are COCs (Table 5.4). In general, the PCBs and pesticides detected in the BYBY aggregate have similar distributions to the SVOCs; that is, they are widespread and 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.

Radionuclides. Eight radionuclides were detected in the samples collected from the BYBY aggregate; six of these eight occur above their background criteria (Table 3.10), but only two, isotopes ^{234}U and ^{238}U , are COCs (Table 5.4). The distribution of ^{238}U in soils is portrayed on Fig. 3.30 with the results of the radiological survey. Uranium isotopes were detected in nearly all samples from BYBY and exceeded background in 34 samples. Like the inorganic chemicals, the highest activities occur in the 0- to 2.4-m (0- to 8-ft) interval with the maximum ^{238}U activity concentration (880 pCi/g) occurring in a sample from 1.2 to 2.4 m (4 to 8 ft) in borehole BY-8. The relative activities of ^{238}U and ^{235}U are consistent with depleted uranium.

Groundwater and Surface Water

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. Surface water contamination in NT-3 was recorded by the BCV RI field activities. However, southern sections of BYBY lie on the Bear Creek floodplain and are outside of the NT-3 drainage area (refer to Fig. E.1 in Appendix E). Thus, not all surface water contamination derived from BYBY is gaged or recorded, and because of its location, there is likely to be contaminant transport from BYBY directly to the Maynardville Limestone and Bear Creek.

There are two distinct groundwater contaminant plumes at BYBY: a VOCs plume associated with borings close to the HCDA (BY-02, BY-03, and GW-087) and a radionuclide plume that is oriented parallel to the channel of NT-3 (BYBY-6, BYBY-9, and SL1-1). Contamination of surface water in NT-3 is dominated by radionuclides; there are no inorganic or organic COCs in NT-3.

Radioactivity. The distributions of gross α and gross β in groundwater in BCV are shown in Figs. 3.11, 3.12, and 3.29. The radiologically contaminated plume at BYBY is distributed almost coincident with the NT-3 stream channel and extends from boring BY-04 located in the northwest corner of BYBY to the confluence of NT-3 with Bear Creek. The maximum recorded activities were 2200 pCi/L for gross α and 2800 pCi/L for gross β (BY-09). Borings adjacent to the HCDA cap and to SL 1 also show elevated activities of gross α and gross β , implying that the contaminant plume may also extend under the HCDA and SL 1 caps. The activity of uranium isotopes dominates the radioactive contaminant suite in groundwater at BYBY: the maximum activity of ^{234}U was 1300 pCi/L, that of ^{235}U 53 pCi/L, and that of ^{238}U 1800 pCi/L.

Radiological contamination in NT-3 surface water is the most extreme recorded in surface water in BCV. Like groundwater at BYBY, the principal contaminants are isotopes of uranium (^{238}U and ^{234}U). Other radionuclides, also detected in groundwater, were also detected in surface

water at low activities and are not COCs (Table 3.10). Activities of ^{234}U range from 34.2 to 217 pCi/L, with a mean of 130.8 pCi/L; ^{235}U ranges from 1.3 to 17.7 pCi/L, with a mean of 6.6 pCi/L; and ^{238}U ranges from 64 to 543 pCi/L, with a mean of 304.7 pCi/L.

The activities of uranium radioisotopes can explain the observed gross α and gross β activities in shallow groundwater and surface water. In each sample, the observed α and β activities are of the same magnitude as the sum of the ^{238}U , ^{235}U , and ^{234}U activities (Fig. D.73 in Appendix D). Alpha activity is associated with decay of the ^{238}U , ^{235}U , and ^{234}U isotopes, whereas β activity is derived from decay of their daughter isotopes.

Inorganic species. Figure 3.32 shows the distribution of inorganic contaminants in groundwater at the OLF FA. Eleven inorganic elements occur above background values in one or more shallow borings at BYBY, and nine inorganic elements occur above background in GW-087. Twelve metal species are SRCs in groundwater at BYBY and five are COCs (Table 5.4): beryllium, manganese, mercury, nickel, and vanadium. The metals that occur above background and the COCs are distributed sporadically throughout BYBY, and there is no apparent continuous plume of metal-contaminated shallow groundwater.

Surface water in NT-3 is relatively free of inorganic contaminants: two metals, lithium and mercury, occur above background, but neither is considered a COC. Lithium was detected in all seven samples analyzed for lithium, six of which exceeded the background value (71 $\mu\text{g/L}$). Mercury was detected in 10 out of 21 samples in NT-3. Although all 10 detects for mercury exceeded the background value (0.2 $\mu\text{g/L}$), the concentrations were generally low, and the maximum detected value was 0.51 $\mu\text{g/L}$.

Organics. There are 10 organic COCs for groundwater in borings at BYBY that were detected principally in three borings (Table 5.4): BYBY-1, BYBY-2, and BYBY-3. The most common contaminants in the VOC plume are PCE (maximum 620 $\mu\text{g/L}$), TCE (2000 $\mu\text{g/L}$), and 1,2-dichloroethene (DCE) (1100 $\mu\text{g/L}$) (Fig. 3.33). Other organic COCs detected in this plume are PCB-1254 (0.45 $\mu\text{g/L}$), 1,1,2-trichloroethane (TCA), 1,1-DCE, 1,2-dichloroethane (DCA), benzene, chloroform, and vinyl chloride. Concentrations of PCE and TCE are <1% of maximum solubility for each chemical (maximum 0.3% for PCE). Although equivocal, these calculations suggest that DNAPL may not be present at this site (a 1% "rule-of-thumb" is suggested as a reasonable measure for the presence of DNAPL by Pankow and Cherry, 1996). The composition of the VOC plume varies: at the northwest corner of the HCDA cap, TCE and 1,2-DCE are the dominant contaminants, whereas at the southwest corner of the HCDA cap, PCE and 1,2-DCE dominate.

Organic contamination is almost completely absent in NT-3. Only acetone and chloroethane were detected more than once in 20 samples. There are no organic COCs for this stream (Table 5.4); none of the organic COCs in groundwater were detected in NT-3.

3.2.4.4 Chemical data for OLF

Contamination at OLF occurs to a lesser extent than at BYBY. Organic chemicals in groundwater constitute the majority of contamination, and there is apparently little or no impact on surface water. There are three COCs in soils, 14 COCs in groundwater, and no COCs in surface water that can be attributed to OLF.

Fig. 3.32. Distribution of metal-contaminated groundwater at the OLF FA.

Fig. 3.33. Relative concentrations of VOCs in groundwater at OLF FA.

Soils

OLF soil sampling was limited to five borings around the perimeter of the OLF cap, and no surface soil samples were taken. Concentrations of contaminants in soils surrounding the OLF cap were generally low: only three analytes are COCs, and all three are radionuclides [^{60}Co , ^{212}Pb , ^{208}Tl (Table 5.4)]. Inorganic elements occur at slightly higher concentrations in the deep interval, but even here, the concentrations do not greatly exceed background. Organic compounds were detected in all borings, with slightly higher concentrations in the shallow interval. This site has been remediated for PCB contamination in the past (Sect 3.1 and Appendix A), and total PCB concentrations in borings ranged from 12 to 220 $\mu\text{g/kg}$.

Groundwater and Surface Water

Groundwater close to the OLF cap is contaminated with two separate suites of VOCs (Fig. 3.33) and sporadically with metals (Fig. 3.32). Organic contamination at OLF occurs mainly in wells screened in the shallow bedrock and water table intervals located close to the OLF cap. The volatile suites are composed of: 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 $\mu\text{g/L}$) in GW-003 to the northeast of the cap; and 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 $\mu\text{g/L}$) in GW-007 and GW-010 to the south of the cap. Contamination is mainly restricted to the shallow interval, and the concentrations indicate that these chemicals are present in $<0.1\%$ of their solubility. Although there is no clear evidence to discount DNAPL at this site, the distribution and concentrations of organic contaminants at OLF suggest that DNAPL is not present in the subsurface at this site.

In NT-4, the only detected organic compound was 1,2-DCE, which is consistent with its occurrence as a contaminant in groundwater at the OLF. However, 1,2-DCE occurs in only one sample out of 13 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 Safe Drinking Water Act (SDWA) maximum contaminant level. This discounts 1,2-DCE as a contaminant in NT-4.

3.2.4.5 Chemical data for SL 1

Soils

SL 1 was characterized by two surface soil samples and two soil borings. The nature of contamination is more varied in this aggregate than at OLF; four analytes are COCs (Table 5.4): mercury, PCB-1254, ^{60}Co , and ^{235}U . Concentrations of all contaminants are highest in the surface soil sample SBY-16 and the shallow interval of boring SL1-1 (Fig. D.71 in Appendix D). Since both these sample points are located on the western end of SL 1 close to BYBY, contaminants in these samples may be derived from operations at BYBY. Inorganic contaminants include mercury, copper, and nickel. Concentrations of mercury and copper are higher in the shallow soil interval, while concentrations of nickel are higher in the deep interval.

Groundwater

Characterization of groundwater contamination at SL 1 is uncertain because only four wells exist close to the site, and these wells are also downgradient of other potential sources such as BYBY. In addition, almost half of the footprint of SL 1 is located on the outcrop of the

Maynardville Limestone. Contaminants from this site will probably migrate directly into groundwater in the Maynardville Limestone and become difficult to distinguish.

Wells screened in the Nolichucky Shale and Maynardville Limestone located along strike from SL 1 (GW-097, GW-098, and GW-229) detected low concentrations of 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 (only in the Maynardville Limestone with 14 to 35 $\mu\text{g/L}$). The source of this contamination is uncertain; however, the suite of contaminants differs from upgradient sources (OLF and the Maynardville Limestone plume) and this contamination may be derived from SL 1.

3.2.4.6 OLF FA site conceptual models

BYBY

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, and this fill consists mostly of noncontaminated or slightly contaminated construction rubble and other relatively stable materials. 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, (2) soil sample results, (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.

At BYBY there are apparently two separate plumes of contaminated groundwater with slightly different distributions that may reflect different sources: one for radionuclides and inorganic chemicals and one for VOCs.

Radionuclides and inorganics. Uranium isotopes are the principal contaminants and are present in soils, groundwater, and surface water, indicating that conditions are suitable for mobilization and off-site migration of uranium. The highest activities of uranium isotopes in both soil and groundwater coincide with the main geophysical and radiological anomalies located northwest of the HCDA cap (Figs. 3.29 and 3.30). Groundwater in this area is very shallow, and uranium wastes are probably located in contact with groundwater. This combined information indicates that waste materials buried at BYBY are the source of the radiological contamination in groundwater and surface water.

The focus of radiological contamination appears to be close to the channel of NT-3, suggesting that there is a relatively short pathway for contaminated groundwater to this surface water body. Uranium leaches from waste materials to groundwater, which subsequently discharges to surface water in NT-3. In the southern section of BYBY, fill material is located over the outcrop of the Maynardville Limestone and on the floodplain of Bear Creek (Fig. 3.29). Fill material is located within 10 m (30 ft) of the current channel of Bear Creek; it is also probable that a former channel of Bear Creek underlies the fill material. 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. 3.34). This could contribute to the ungauged influx of uranium to the Maynardville Limestone and Bear Creek identified in Sect. 3.2.2. In addition, uranium contamination at the soil surface results in contaminated runoff directly to Bear Creek.

Comparing the results of fate and transport modeling (Appendix E) to today's plume configuration suggests that most inorganic and radioactive contaminants in NT-3 have almost reached maximum concentrations or, if they have not, will show no discernable increase in the future. It is assumed that there is a continuous source for these contaminants (leaching from waste materials) and, therefore, that these current values will be maintained at an approximately steady state for the foreseeable future (Fig. 3.35 and Table 3.11).

Like the pathway to NT-3, uranium concentration in the pathway to the Maynardville Limestone has also almost reached peak concentrations (3.5 to 4.9 mg/L) and, likewise, will remain at these concentrations for over 1000 years (Table E.39 in Appendix E).

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, it is assumed that there is the potential for buried uranium waste materials to exist throughout the area of fill at BYBY and that the soil borings apparently did not intercept waste materials. Assuming buried uranium waste, mainly in the areas of geophysical and radiological anomalies, the elevated activities of uranium isotopes in groundwater appear reasonable. The relatively low concentrations of other inorganic contaminants in soils, anomalous considering the reports of poorly controlled waste materials at this site, can also be explained by the sample borings not intercepting waste materials.

The contaminant suite in groundwater at BYBY is distinct from that in the S-3 plume. The S-3 plume contains considerable radiological contamination and, at the leading edge of the plume (interpreted to be near NT-2), the contaminant suite consists of nitrate and ^{99}Tc (Sect. 3.2.3). At BYBY, groundwater is not contaminated with either of these chemicals and so cannot be considered as a continuation of the S-3 plume.

VOCs. VOCs are present in groundwater at BYBY, but do not occur in NT-3. The organic plume in groundwater is aligned more with the location of the HCDA cap (Fig. 3.33), which suggests VOCs in groundwater are probably derived from infiltration at the HCDA or from activities at the Burnyard. Although these contaminants may discharge to surface water in NT-3, the extent of this discharge is so low that any VOCs volatilize before they reach the downstream monitoring location. The VOC plume is partly located in residuum above the Maynardville Limestone and, like uranium, probably migrate directly into the Maynardville Limestone or Bear Creek. Although DNAPLs are not indicated by the concentrations observed in the residuum, DNAPL could have migrated down dip in the Nolichucky Shale.

Oil Landfarm

Historical data and data from soils at the OLF pad (Appendix A) indicate that soil remaining in place below the OLF cap are contaminated with organics (PCBs and SVOCs) and metals. Soils surrounding OLF apparently were not affected by operations at this site. The three radionuclide COCs in soils at this site (^{60}Ci , ^{212}Pb , and ^{208}Tl) were detected at low activities and are unlikely

3-55
BYBY

Fig. 3.34. Site conceptual model for the BYBY.

to be SRCs. Groundwater is contaminated with organics and the suite of chemicals observed in groundwater mainly consists of breakdown products of the 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 the subsurface at this site. The groundwater data indicated that the landfarming operation successfully removed most volatile chemicals, leaving behind poorly volatilized organic chemicals, principally PCBs, in soils on the landfarm plots.

Fig. 3.35. Modeled future concentrations for uranium in groundwater discharging to NT-3.

SL 1

Very little data exist concerning SL 1. The one sample of waste materials from this site indicated that the usual type of contaminants from a municipal landfill are present (PAHs and SVOCs). SVOCs were the most common contaminants, and radiological contamination observed at this site can be attributed to secondary contamination from BYBY. SL 1 probably 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 due to the small database for this site and its location downgradient of sites producing similar contaminant suites in groundwater.

3.2.5 Bear Creek Burial Grounds Functional Area

The BCBG FA is composed of seven soil, three surface water, and two groundwater chemical data aggregates, and seven waste media groupings. In the following section, the nature and extent of contamination in environmental media at the BCBG by each of the main chemical types (inorganics, VOCs, and radionuclides) are described. In addition, conceptual models are developed that show the nature and extent of contamination and past and present mechanisms of contaminant migration that have resulted in the configuration observed today.

3.2.5.1 Detailed site hydrology

Much of the detailed information concerning the BCBG site hydrology has been derived from data obtained in the BCBG FA. This area of BCBG contains numerous wells screened at various depths in the Nolichucky Shale. In general, groundwater movement at BCBG is adequately described by the site-wide hydrogeologic conceptual model (Chap. 2). Of most interest to the RI at BCBG is the movement of groundwater relative to trenches and buried waste. Figure 3.36 shows a schematic hydrogeologic cross section of the water table and shallow bedrock interval at BCBG, assembled using data from the groundwater monitoring program at Y-12 Plant. Interviews with waste management personnel from the Y-12 Plant suggest that the depth of trenches may vary between 3 m (10 ft) and 6 m (20 ft) depending on the mode of construction of each trench (Appendix A). In general, long trenches were dug using a drag line and may be deeper than shorter trenches that were dug using a backhoe (Fig. A.10 in Appendix A). Figure 3.36 summarizes the probable condition of the trenches in each Burial Ground relative to the water table.

As in the site-wide conceptual model, flow parallel to geological strike probably dominates flow at the BCBG. Trenches probably have a higher hydraulic conductivity than the surrounding formation due to disruption of the soil and the hydraulic properties of the debris; as a result, they exert 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), and trenches that cut across strike (such as BG-D East) probably promote across strike flow of groundwater.

The BCBG FA is contained in the catchment of three tributaries to Bear Creek: NT-6, NT-7, and NT-8. With the exception of some sections of the channel at their headwaters, NT-6 and NT-8 are located in natural drainage channels. NT-7, however, is almost wholly located in an engineered channel that was developed during construction of the caps on BG-A and ORP-1 (Sect. 3.1, Fig. 3.5). Each of these streams is usually dry during the low-flow periods in the late summer and early fall. Baseflow in each stream reaches a maximum of ~3.2 L/s (0.15 cfs) between December and April, and peak stormflow ranges from 56 to 1680 L/s (2 to 60 cfs).

3.2.5.2 Radiation survey data

Radiological (β/γ) surveys were conducted at the BCBG and covered some of the floodplain of Bear Creek adjacent to BCBG (Figs. D.87 and D.88 in Appendix D). As was the case for BYBY, radiological survey data were used to qualitatively identify areas of soil contamination. At the BCBG, two areas of elevated radiation emissions were identified: one adjacent to the BG-B cap located on the east side of the cap and a second along the banks of NT-8 between BG-C West and the confluence of Bear Creek and NT-8.

Radiological soil contamination in the NT-8 floodplain is probably related to past deposition of contaminated sediments derived from drainage of the BG-B, BG-C, and BG-D areas. Contamination at BG-B is probably related to past operations at this Burial Ground. 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, and surface contamination probably occurs in these areas.

Fig. 3.36. A cross section of shallow groundwater at the BCBG and the conceptual model for trench hydrology.

3.2.5.3 Chemical data

Table 3.12 lists the results of analysis of soils, surface water, and groundwater at the BCBG. The data in this table represent the following:

- Soil sampling from the BCBG RI. These data are the combined results from the BCBG aggregates shallow and deep intervals (refer to Appendix D, Tables D.65, D.66, D.67, D.68, D.70, D.71, D.73, D.74, D.76, D.77, and D.79).
- Combined surface water sampling from the BCBG RI at NT-6, -7, and -8 (refer to Appendix D, Tables D.81, D.83, and D.85).
- Groundwater samples of wells in the BCBG groundwater aggregate (refer to Appendix D, Table D.91).

More complete summaries of these data are presented in Appendix D. In Table 3.12, those chemicals considered to be SRCs are indicated in a column for each medium.

SRCs at BCBG are numerous in groundwater (35 SRCs), surface water (37 SRCs), and soils (52 SRCs). There are SRCs from each analyte group (inorganics, organics, and radionuclides) in each medium. Disposals at BCBG were in the form of both liquids and solid materials. Contamination at BCBG is derived from dispersal of contaminants from leaching of buried waste materials and from waste liquids that have infiltrated into groundwater.

Waste Sample SBG-42

A sample of probable waste material was collected at surface sample location SBG-42 in the BG-D East area. Due to the heterogeneity of the trench fill material at the burial grounds, this sample is not representative of the bulk chemical make-up of the waste. This sample does, however, indicate the composition of some of the waste material in the BCBG trenches. The results of the analyses show this sample to have high gross α (134,000 pCi/g) and gross β (245,800 pCi/g) activities and high concentrations of uranium (623,000 $\mu\text{g/g}$) with 0.19 weight % ^{235}U and 0.004 weight % ^{234}U . These data, converted to activity units, give the following results: $^{238}\text{U} = 205,000 \text{ pCi/g}$, $^{235}\text{U} = 2,500 \text{ pCi/g}$, and $^{234}\text{U} = 154,000 \text{ pCi/g}$. Arsenic, beryllium, and vanadium were also detected in this sample but not at concentrations exceeding the soil background criteria.

Soils

Soil contamination of all chemical types is limited in both nature and extent in soils surrounding the BCBG trenches and, when contamination is detected, contaminants tend to occur at concentrations at or only slightly above background (Table 3.12). It must be emphasized in this discussion that absence of extreme contamination in the soils surrounding the waste disposal units in BCBG does not necessarily mean that the BCBG do not contain extensive contamination, but rather that there is little or no secondary contamination of soils surrounding the trenches.

Inorganic chemicals. Fourteen inorganic chemicals occurred above background values and only two are COCs, arsenic and vanadium (Table 5.4). In general, metal contamination of soil is

more prevalent in the western BCBG, BG-B, BG-C, and BG-D (Figs. D.90, D.93, and D.95 in Appendix D). Arsenic was detected above background in five samples (three in boring BG-10, Fig. 3.37). The maximum detected arsenic concentration was 52.6 mg/kg (background = 20.2 mg/kg). Vanadium occurred above background in only one sample, SBG-20 (68.8 mg/kg), close to BG-C East. Other inorganic chemicals that occurred above background relatively frequently in BCBG soils were barium, beryllium, copper, cyanide, and nickel.

Organics. Organic contaminants are more widespread in BCBG soils than the other analyte groups (Fig. 3.37). Thirty-two organic compounds were detected in soils at the BCBG; however, only PCB-1254 and -1260 are COCs (Table 5.4). Of the detected organic contaminants, acetone and toluene are most frequently detected (29% and 37% of samples, respectively).

While the distribution of organic contamination appears somewhat random with regard to depth, characteristic suites of organic contaminants seem to be associated with disposal areas:

- At BG-A North – toluene, PCBs, 1,1,1-TCA, and 1,1-DCA.
- At BG-A South – acetone, toluene, PCE, and TCE.
- At BG-A-16, -17, and -18 – PAHs and phthalates.
- West of NT-7 at WIP North and South, BG-B, BG-C, and BG-D – toluene and PCBs.

Although soil contamination by PCBs is relatively widespread (16% of samples), PCB contamination was detected mainly in the surface and 0- to 2.4-m (0- to 8-ft) soil intervals. The highest concentrations are associated with surface soil samples in the floodplain of NT-8: the maximum concentration of total PCBs (46,000 µg/kg) occurred in surface soil sample SBG-7 located immediately south of the BG-C West cap (Fig. 3.37).

Radionuclides. Radionuclide contamination in the soils surrounding the BCBG is noteworthy by its virtual absence (Fig. 3.37), particularly in the BG-A North and South, and A-16, -17, and -18 disposal areas. Eight radionuclides occur above background values; however, the detected activities were low (e.g., maximum ^{238}U was 36 pCi/g) and only one is a COC [^{60}Co (Table 5.4)]. Radionuclides, in particular, uranium and ^{99}Tc , are slightly more prevalent in the western portion of the BCBG; the two samples with elevated PCBs in the NT-8 floodplain also had slightly elevated activities of ^{238}U (Fig. 3.37).

Groundwater and Surface Water

Groundwater in the vicinity of BCBG is contaminated mainly with VOCs and contains minor concentrations of metals and radionuclides (Table 3.12). This suite of contaminants reflects the operations at this site where solvents and oils were poured into unlined trenches, and free-phase DNAPL and light non-aqueous phase liquid (LNAPL) have been reported in historical data. Inorganic contamination of groundwater and surface water at the BCBG is relatively slight and sporadic, and radioactive contamination is conspicuous by its virtual absence.

Inorganic chemicals. Fifteen inorganic chemicals occurred above background values in one or more wells in the BCBG (Table 3.12, Fig. 3.38), and four of those metals are COCs (Table 5.4). The frequency of detection above background concentrations of most metal contaminants at BCBG is low and, with the exception of boron (detected above background in 10 wells), each contaminant was detected in four wells or less. Most inorganic contamination is

Fig. 3.37. Distribution of arsenic, PCBs, VOCs, and ^{238}U in soils at BCBG.

Fig. 3.38. Distribution of metal-contaminated groundwater at BCBG.

associated with older, shallow bedrock and water table interval wells located close to the BG-A North and South (most notably GW-014, GW-021, GW-027, and GW-039). The data from the shallow grab samples in the BCVR BCBG aggregate are consistent with that from the GWQR database in that groundwater grab samples from the BCVR RI that were contaminated with inorganic compounds were taken from borings BG-1, -2, and -3 adjacent to BG-A South, and from BG-12 located close to WIP South (Table D.95 in Appendix D).

Like groundwater, surface water draining the BCBG FA is relatively free of metal contaminants. 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 were detected above background. However, concentrations of inorganic contaminants were relatively low, and only beryllium in NT-8 is a COC. Beryllium was detected in 4 of 14 samples in NT-8 (maximum concentration = $8.6 \mu\text{g/L}$). Beryllium was detected in NT-8 at both high-flow and low-flow conditions, and concentrations had no apparent relationship to flow.

Organics. Contamination of groundwater with VOCs dominates the BCBG FA. There are three separate plumes of VOC contamination that can be identified, one associated with BG-A, a second with WIP, and the third in the NT-8 catchment associated with BG-C East and BG-C West (Fig. 3.39). The three streams draining BCBG, NT-6, NT-7, and NT-8 are contaminated with a variety of VOCs that reflect the VOC suites contaminating the groundwater. The concentrations of total VOCs and the variety of chemicals detected are greater in NT-7 and NT-8 (mean total VOCs $> 350 \mu\text{g/L}$) than in NT-6 (mean $35 \mu\text{g/L}$). Seventeen organic compounds were considered SRCs in surface water draining BCBG, and nine compounds are COCs (Table 5.4 in Sect. 5.5), 1,1,2-TCA (maximum = $2 \mu\text{g/L}$), 1,1-DCE (maximum = $16 \mu\text{g/L}$), 1,2-DCA (maximum = $24 \mu\text{g/L}$), and vinyl chloride (maximum = $33 \mu\text{g/L}$).

BG-A Plume. Groundwater at BG-A is contaminated with a diverse VOC contaminant suite and includes DNAPL. Almost 2 million gallons of oils and coolants have been disposed of at the BG-A trenches (Sect. 3.1 and Appendix A). Migration and occurrence of free-phase liquids in the subsurface is difficult to predict, and pools of DNAPL large enough to detect and sample are sporadic (Kueper, Haase, and King 1992). DNAPLs have been detected between 80 and 100 m (260 to 330 ft) down dip (Haase and King 1990; Dreier and Davidson 1994) and appear to have migrated down dip preferentially in a zone at the base of the middle Nolichucky Shale (Dreier and Davidson 1994, Fig. D.102 in Appendix D). The maximum depth of DNAPL at BCBG is not known; however, in theory, there will be a maximum depth of migration that is likely to occur at a depth where fracture apertures become too small to allow entry 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 BCBG may be as deep as 152 m (500 ft). In addition, DNAPL samples from wells downgradient of BG-A indicated that the free-phase oils and solvents contain PCBs (maximum 27 mg/g).

The dissolved organic contaminant suite typical of wells in the BG-A South area is dominated by PCE, TCE, and 1,2-DCE that are present in concentrations $>5\%$ of their solubility. In addition, 1,1,1-TCA, 1,1-DCA, and 1,2-DCA are commonly found in lesser concentrations. The proportions of parent (PCE and TCE) to daughter chemicals (mainly 1,2-DCE) varies between wells but does not appear to have any systematic distribution with the exception that daughter products occur mainly in shallow groundwater, and all intermediate and deep bedrock wells are dominated by

parent compounds. In all cases, the daughter products in a well are consistent with the decay pathway for the detected parent chemicals in that well.

Systematically increasing concentrations of PCE, since 1990, have been observed in GW-627 and GW-629 (Fig. 3.39). Both these wells are screened in the Nolichucky Shale, and are located along strike and downgradient from BG-A South, where groundwater is contaminated with PCE and DNAPL. In the absence of possible interference effects (such as changes in sampling or analysis protocols), the increase of concentrations of PCE in GW-627 and GW 629 may be explained by breakthrough in these wells of a plume of PCE-contaminated groundwater moving along strike in bedrock from BG-A South. A similar increase in concentrations of PCE and TCE in GW-623 may indicate down-dip migration of contaminants from BG-A South.

Shallow groundwater at BG-A North exhibits a contaminant suite that is chemically distinct from the remainder of the BG-A plume, suggesting a different source in BG-A North. Contamination in GW-039 and seep 1 is dominated by 1,1,1-TCA and its daughter products, 1,1-DCE and 1,1-DCA. 1,1,1-TCA is present in most of the other wells in the BG-A plume but constitutes <10% of the contaminant suite.

The VOC contaminant suite from NT-7 reflects the suite found in shallow groundwater at BG-A South, with PCE, TCE, and 1,2-DCE pre-dominating. Historical data for NT-7 (McCauley 1985; Table D.75 in Appendix D) also show that the highest concentrations of VOCs were observed in samples adjacent to BG-A South, suggesting that this is the main contaminant source for VOCs in NT-7.

WIP Plume. Five wells located south of WIP define a distinct plume where PCE comprises over 95% of the dissolved organic contaminants (GW-257, -259, -288, -289, and -291, Fig. 3.39). Concentrations of PCE in groundwater range from 570 to 2100 $\mu\text{g/L}$, which are ~1% of the maximum solubility of PCE, suggesting that DNAPL is present in this area.

NT-8 catchment. Shallow groundwater and surface water in the NT-8 catchment exhibit a chemically diverse contaminant suite. Seeps 2, 3, and 4 have contaminant suites containing 1,1,1-TCA (maximum 120 $\mu\text{g/L}$) but dominated by its breakdown daughter products 1,1-DCE (maximum 30 $\mu\text{g/L}$), 1,1-DCA (maximum 410 $\mu\text{g/L}$), and chloroethane (maximum 1,770 $\mu\text{g/L}$). Groundwater in GW-082 and -142 is dominated by 1,2-DCE (maximum 130 $\mu\text{g/L}$), with lesser concentrations of vinyl chloride (maximum 71 $\mu\text{g/L}$). The sources of the contamination in NT-8 are BG-C and BG-D, and the variability of the plume probably represents a number of sources within these areas.

Surface water in NT-8 for the most part is consistent with groundwater and leachate data in that the contaminant suite in the upper reaches of the south fork of NT-8 is dominated by chloroethane. The north fork contains almost no VOC contamination. However, the dominant organic contaminant in NT-8 further downstream at the BCVR RI monitoring point is 1,2-DCE, which does not occur extensively in groundwater in the NT-8 catchment. It is, therefore, probable that there is an additional source for 1,2-DCE in the NT-8 catchment.

Radionuclides. Almost no radiologically contaminated groundwater has been detected at BCBG. Considering that extensive amounts of radiologically contaminated materials were disposed of in the trenches at BCBG, the extent of radioactive contamination of groundwater is surprisingly

small. Gross α was detected above background in only 8 of 47 wells. The overall frequency of detection was 10 of 408 samples (2%), and only 3 wells had more than one detect of gross α between 1991 and 1994 (GW-040, -643, and -655). Beta activity occurs greater than background in 16 wells and had a frequency of detection of 26 of 408 (6%). Elevated gross β occurred in four out of six groundwater grab samples from the BCG RI.

Unlike groundwater, each of the three streams draining the BCBG is radiologically contaminated. The highest activities of gross α occur in NT-8 (range from 28 to 135 pCi/L, mean 55 pCi/L). Only one sample in NT-7 exceeded the 30 pCi/L SDWA MCL, whereas 11/12 samples in NT-8 exceeded this benchmark. Gross β in these tributaries ranges in NT-7 from 10 to 117 pCi/L (mean 24 pCi/L) and in NT-8 from 20 to 66 pCi/L (mean 37 pCi/L). The activities of uranium isotopes are two orders of magnitude greater than the other radionuclides detected in these streams (isotopes of Th and Pu), and uranium radioisotopes can explain the observed gross α and gross β activities in these tributaries. The activity of uranium isotopes in the BCG RI samples in NT-8 and in seeps 2, 3, and 4 (Fig. 3.39) indicate that the highest activities of uranium occur in the southern branch of NT-8 that drains BG-C and BG-D. The highest activities occur at the very top of this stream and in seep 2.

3.2.5.4 BCBG site conceptual model

Inorganics and Radionuclides

Considering the large mass of radionuclides and metals (uranium in particular) known to have been disposed of in BCBG, soil and groundwater are relatively free of contamination with metals and radionuclides. However, surface water is radiologically contaminated and sporadically contaminated with metals.

For soils, the lack of secondary contamination indicates that little or no metals or radiological contaminants have migrated laterally across strike out of the trenches. However, a number of contaminated seeps have been reported along strike from trenches in the NT-7 and NT-8 catchments (Bogle, Turner, and Easterling 1991; Herbes 1988). This indicates that the primary migration route for inorganic and radionuclide contamination away from the trenches prior to capping was along strike.

For groundwater, the apparent lack of contamination with radionuclides is somewhat inconsistent in that surface water is radioactively contaminated. This can be best explained if radiological contamination of groundwater occurs only in the shallowest water table interval of the subsurface via leaching of uranium in trenches. Consistent with the hydrogeologic conceptual model, the shallow groundwater discharges rapidly to the surface water (Fig. 3.40). In this way, radiological contamination of groundwater remains shallow and localized to the source of the contamination (the trenches containing uranium) (Fig. 3.40). The most likely areas for shallow groundwater radionuclide contamination to occur are BG-A South, BG-C East, and BG-D East, where trenches containing uranium are inundated with groundwater for at least part of the year. These areas appear to have a greater impact on surface water contamination. The maximum activity of uranium in this reach of NT-8 has apparently changed little since samples were taken in 1984, suggesting that the activity of uranium isotopes is mainly a function of the solubility of uranium in the BG-C East area.

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Fig. 3.40. Site conceptual model for the BCBG.

Results of fate and transport modeling (Appendix E) combined with the conceptual model for contaminant migration suggest that most inorganic and radioactive contaminants in NT-7 and NT-8 are close to reaching maximum concentrations. It is assumed that there is a continuous source for these contaminants (leaching from waste materials) and, therefore, modeling predicts that the concentrations of these chemicals at the discharge points in NT-7 and NT-8 will continue to increase imperceptibly for the foreseeable future. Considering the uncertainty associated with the calculations, it is assumed that, maximum values, once attained, will be maintained for the foreseeable future (Tables 3.13 and 3.14).

Predicted maximum concentrations for the headwaters of NT-8 where leachate from Burial Grounds B, C and D discharges are an order of magnitude greater than those currently observed (Table 3.13). This can be explained by the fact that modeling of these pathways does not account for the leachate collection system at the BCBG. This system prevents the leachate entering NT-8 and improves the quality of water in that stream.

Organics

In general, organic contamination of environmental media at BCBG is more widespread than the inorganic and radionuclide contamination. This probably reflects liquid organic wastes disposed of at BCBG that have migrated more easily in their pure form. Oils and solvents were disposed of in the BG-A area by pouring the liquids into standpipes in debris- and waste-filled trenches. The relatively high hydraulic conductivity of the debris-filled trenches allowed the liquids to percolate away from the standpipes relatively easily. It is assumed that the bulk of these liquids has migrated laterally to surface water and downward to groundwater. Small quantities of free-phase liquids probably remain in the trenches as residual droplets that have adhered to waste materials and soils.

As is the case for inorganic compounds, soils outside waste areas sampled during this RI were contaminated only with small quantities of VOCs and PCBs. Extensive soil contamination with PCBs associated with the oil retention ponds and sediments in NT-7 at BCBG has been documented in the past (Bogle, Turner, and Easterling 1991; Herbes 1988), and for the most part, has been remediated by excavation and capping. Based on historical data and the waste inventory, it is assumed that PCB contamination inside trench areas, particularly BG-A and BG-B, is extensive and at relatively high concentrations.

Organic contamination of groundwater is extensive and is closely related to the presence of DNAPL, which occurs in the subsurface. DNAPL is probably associated with the plumes at BG-A South and WIP (Fig. 3.40). 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. In addition, along strike migration of dissolved PCE appears to be occurring west of BG-A South. The extent along strike to which this plume has migrated is not known; fate and transport modeling suggests that a PCE plume may take between 300 and 600 years to migrate along strike as far as NT-8 (Table 3.13). Fate and transport modeling predicts that, like metals and radionuclides, maximum concentrations via other pathways to NT-7 and NT-8 have already been achieved (Table 3.13).

The presence of daughter products of PCE, TCE, and 1,1,1-TCA may indicate that the original parent chemicals have undergone chemical or biological breakdown. At BG-A, breakdown has occurred mainly in shallow groundwater and not in intermediate and deep bedrock. At WIP, there is an almost complete absence of breakdown products, whereas in BG-C, there is 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 disposal of chemicals, 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, and discharge of contaminated groundwater is the source. Surface water in NT-6 and NT-7 has a suite of VOCs similar to that in the BG-A plume, which is probably the primary source of VOCs to these streams. Surface water contamination in NT-8 has a suite of VOCs similar to that in the BG-C East and West plumes.

3.2.6 Maynardville Limestone and Bear Creek Functional Area

The Maynardville Limestone and Bear Creek FA includes the soils and sediments in the Bear Creek floodplain, groundwater in the Maynardville Limestone, and surface water in the main stem of Bear Creek and springs on the floodplain. These environmental media represent the downgradient pathways and receptors of contaminants migrating away from the source sites located on the Nolichucky Shale.

3.2.6.1 Hydrology of the Maynardville Limestone and Bear Creek

The Maynardville Limestone crops out in the axis of BCV; in general, hydraulic head in the Maynardville Limestone is lower than hydraulic head in the underlying Conasauga Group formations of Pine Ridge and lower than that in the overlying Copper Ridge dolomite (Figs. C.11 and C.12 in Appendix C). This configuration means that the Maynardville Limestone/Bear Creek system is the hydraulic low point of the valley.

One of the features affecting contaminant migration in the Maynardville Limestone and Copper Ridge Dolomite is the solution cavity system that occurs mainly above 30 m (100 ft) depth (Shevenell, Dreier, and Jago 1992). Shevenell (1994) has identified quickflow occurrence in shallow wells in the Maynardville Limestone based on well hydrograph analysis and has attributed this to rapid flow in the cavity system. It appears that the cavity system in the Maynardville Limestone in BCV has good interconnectivity and is able to transmit water rapidly along strike in the 0- to 30-m (0- to 100-ft) depth interval.

Below 30 m (100 ft), solution cavities are less common; however, Dreier, Soloman, and Beaudoin (1987) identify numerous water-bearing zones that relate to fractures observed in core materials. As 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 shallow cavity system, which conducts flow westward under Bear Creek, plays an important role in the surface water hydrology of BCV and is likely an important avenue for contaminant transport. A tracer study conducted in 1988 (Geraghty and Miller 1989) revealed that a component of flow at SS-5 comes from BCV surface water flow further up the valley. In this tracer study, the combination of flow in the surface stream and flow in the shallow interval of the Maynardville Limestone transported the tracer to SS-5 at an average rate of ~6.9 m/h (22 ft/h). This demonstrates that it is possible for contaminants to migrate rapidly along the valley in either surface water or groundwater.

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 (see Fig. 2.8 in Sect. 2.5). Below BCK 9.47, Bear Creek is a perennial stream. Like flows in the tributary streams, flow at BCK 9.47 is "flashy," reflecting this character of the drainage system in BCV (a maximum flow at this site of over 10,000 L/s was recorded on three occasions during Spring 1994). Flow in the monitored springs (SS-1, -4, -5, and -6) is much less variable than that in the stream channels as would be expected from the groundwater origin of these flows.

Flow in the creek varies in an alternating step-wise fashion down the valley with gaining and losing reaches (Fig. 2.8 in Sect. 2.5). A major spring or seepage area 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), additional (ungauged) groundwater discharge to Bear Creek also occurs over this section of the stream. This suggests that the large springs in the floodplain of BCV are associated with general groundwater discharge zones and not just the discharge from the individual spring.

3.2.6.2 Groundwater and surface water chemical data

As a result of the close association between shallow groundwater and Bear Creek, the contaminant chemistries of the surface water and groundwater are very similar. Groundwater and surface water in the Maynardville Limestone and Bear Creek FA are contaminated with nitrate, VOCs, radionuclides, and metals. Contamination occurs in two main plumes in BCV: one containing nitrate and radiologically contaminated groundwater (uranium isotopes and ⁹⁹Tc) starting close to the S-3 Site and continuing west along the valley past Picket A, possibly as far as Picket W, ~2590 m (8500 ft) further west. The second contaminant plume contains VOC-contaminated groundwater (TCE and 1,2-DCE) and originates in groundwater wells at Rust Spoil Area. This plume has been detected along strike in Pickets B and C; however, organic contamination has not been detected at Picket A. Low concentrations of TCE in SS-5 indicates that the TCE plume has probably not advanced as far as BCK 9.47 and Picket A at concentrations exceeding ARARs at this time.

The surface water database includes data for springs in BCV and at five stream locations in Bear Creek: BCK 12.38, 11.97, 9.47, 4.55, and 0.63. Groundwater data have been combined into a single aggregate for wells in BCV screened in the Maynardville Limestone and Copper Ridge formations. Tables 3.15 and 3.16 summarize the results of these analyses for each analyte that was detected in data from the GWQR database.

Nitrate

Nitrate effectively acts as a tracer for the contaminant plume derived from operations at the former S-3 Ponds and is only derived from this source in BCV. Contamination of groundwater with nitrate occurs from the uppermost section of the valley adjacent to the S-3 Site to the section adjacent to BCBG. Of wells in the Maynardville Limestone aggregate, 53% are contaminated with nitrate above background.

As might be expected, wells closest to the S-3 Site are those in which nitrate occurs in the highest concentrations (Fig. 3.10). Further along strike in the Maynardville Limestone, the concentration of nitrate in wells decreases rapidly, and only two wells further downgradient (GW-227 and GW-725) have mean nitrate concentrations >50 mg/L (84 mg/L and 57 mg/L, respectively). The plume of nitrate-contaminated groundwater (> 10 mg/L) in the 30- to 150- m depth interval of the Maynardville Limestone is continuous from the S-3 Site to Picket A, whereas the plume in the shallow interval is not continuous. This is a result of the greater influence of recharge and the greater flux of groundwater through the shallow interval (< 30 m depth) that causes rapid attenuation of contaminant concentrations along strike in this interval by dilution. Although wells in the deep and intermediate intervals of the Maynardville Limestone are hydraulically well connected to the shallow interval, the effects of recharge are lessened and the groundwater flux is smaller. This results in the observed lower attenuation of contaminant concentrations along strike in the deep and intermediate intervals of the Maynardville Limestone.

The stratigraphic location of the nitrate-contaminated plume changes progressively along strike in BCV (Fig. 3.21, refer to Chap. 2 and Fig. C.5 in Appendix C for a discussion of stratigraphic zones in the Maynardville Limestone):

- Between the S-3 Site and Picket C, the nitrate plume is restricted to the lowest zone of the Maynardville Limestone (refer to Fig. 3.9 for location of well pickets).
- At Picket C, nitrate contamination with mean values >10 mg/L occurs at <30 m (100 ft) depth across the Maynardville Limestone (GW-738, GW-737).
- Adjacent to SL 1, the highest concentrations of nitrate are observed in GW-225, which is screened in the lowest zone of the Maynardville Limestone.
- At Picket B, the highest concentrations are recorded in wells screened in Zone 4 (GW-294 and GW-706).
- At Picket A, nitrate contamination is observed in GW-684, screened in Zone 6 and GW-683, and screened in the Copper Ridge Dolomite.

No monitoring well is located in the deep section of the Maynardville Limestone at Picket A, and nitrate-contaminated water could exist undetected in this interval. Between Picket A and Picket B, nitrate was detected at a concentration of 68 mg/L at 187.4 m (615 ft) amsl in a single port of GW-790, a multi-sampling port-equipped well (Dreier and Davidson 1994). This contamination probably continues along strike beneath BCK 9.47, where the deepest well at Picket A has a screen elevation of 228.9 m (751 ft), and is sporadically contaminated with nitrate. Because contamination in GW-790 can probably be associated with migration of nitrate in a

discrete, strike-parallel fracture, it is likely that this pathway continues further along strike and underneath BCK 9.47 and Picket A and is not intersected by wells at this picket.

At Picket W, nitrate has been detected in wells GW-712 (0.3 mg/L), GW-713 (0.47 mg/L), GW-714 (3.2 to 4.8 mg/L), and GW-715 (0.4 to 1.1 mg/L). The highest concentrations occur in Zone 5 of the Maynardville Limestone (GW-714); however, the remaining wells at Picket W are screened at more than 30 m (100 ft) depth in Zones 2, 3, and 4. Considering that the nitrate plume at Pickets A and B is probably located in Zones 5 and 6 and in the Copper Ridge Dolomite, this may mean that the center of the plume is not intersected by the wells at Picket W. Thus, although nitrate has been detected in these wells, the extent of nitrate contamination at Picket W is uncertain.

Long-term time trends in nitrate concentrations. Some wells that are screened in the nitrate plume in the Maynardville Limestone show trends in concentrations over time (Fig. 3.22). In general, wells screened in the water table and in shallow groundwater intervals show decreasing concentrations of nitrate since 1986, whereas wells screened below 30 m (100 ft) depth generally have steady or increasing concentrations. This contrast between the shallow and deep systems is shown in the well nest composed of GW-227 and GW-228 (Fig. D.124 in Appendix D). During the same time period from 1986 to 1990, the concentration of nitrate in GW-227 has increased from <20 mg/L to almost 40 mg/L, whereas that in GW-228 has 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 the concentrations of nitrate (Fig. 3.22). In general, wells show lower concentrations during high-flow periods (winter and early spring) and the highest concentrations during low-flow periods (summer and fall).

Springs. Nitrate concentrations were above background in over 90% of samples from SS-1, -4, and -5. In general, concentrations in SS-1 (mean 39 mg/L) are slightly higher than those in SS-4 (mean 32 mg/L), and both springs have greater concentration than SS-5 (mean 11 mg/L). BCV RI data indicate that the concentrations of nitrate in SS-4 show wide variations (3.1 to 68 mg/L, Fig. 3.41) that are inversely related to flow in the spring, whereas the concentrations of nitrate in SS-1 (11.6 to 38 mg/L) and SS-5 (0.1 to 16.8 mg/L) generally vary within a more narrow range. The variation of concentrations in SS-4 is closely related to that in Upper Bear Creek (Fig. 3.41). This may indicate either that these locations occupy a related pathway, or that the processes causing the variations in concentrations at both sites are so similar that the resulting effect is the same.

Surface water. Bear Creek is contaminated with nitrate throughout its length from the S-3 Site to BCK 4.55. Mean concentrations in the three aggregates that include flow in Bear Creek show that the concentration of nitrate generally decreases downgradient: Upper Bear Creek has a mean concentration of 97 mg/L (Table D.104 in Appendix D), Mid Bear Creek has a mean concentration of 14 mg/L (Table 3.15), and Lower Bear Creek has a mean concentration of 9 mg/L (Table 3.16). Specific conductance data from the U.S. Geological Survey spring and seep survey clearly show that high total dissolved solids surface water in the upper reaches of Bear Creek is progressively diluted downstream away from the S-3 Site during high-flow periods. During low-flow periods, the extent of dilution is less and, overall, total dissolved solids concentrations in Bear Creek are higher. During low-flow periods, the concentrations of

contaminants in Bear Creek is probably controlled more by the concentrations of contaminants in groundwater discharge than by dilution in the channel.

Fig. 3.41. Concentration of nitrate in Bear Creek or in springs on Bear Creek floodplain during 1994.

Inorganic Chemicals

Groundwater. A total of 17 inorganic elements occurred above background values in one or more wells in the Maynardville Limestone and Bear Creek FA (Figs. 3.19, 3.32, and 3.38), and ten are COCs (Table 5.4). In general, metal-contaminated groundwater in the Maynardville Limestone is associated with wells located adjacent to the S-3 Site. In this area, contamination by barium, boron, cadmium, copper, lead, mercury, strontium, and uranium occurs in both shallow

and intermediate bedrock wells. In the remainder of the Maynardville Limestone downgradient, boron, strontium, and uranium are fairly widespread contaminants:

- Boron concentrations above background values occur in 30% of the wells in the Maynardville Limestone.
- Uranium occurs at concentrations above background in 16 wells, and was detected with a range of 1 to 300 $\mu\text{g/L}$ (mean 9.2 $\mu\text{g/L}$). GW-706 and GW-694 have the highest median values of total uranium, which is consistent with the elevated activities of gross α and gross β in these wells.
- Strontium occurs at concentrations above background values in 11 of 77 wells in the Maynardville Limestone aggregate.

The widespread distribution of boron and uranium also indicates that they are present in groundwater in relatively mobile forms. Both boron and uranium probably exist as complexed species: borate $[\text{B}(\text{OH})_3]$ and uranyl carbonate complexes $[\text{UO}_2(\text{CO}_3)]^0$ and $[\text{UO}_2(\text{CO}_3)_2]^{-2}$, respectively. Strontium is a common minor constituent in carbonate minerals (calcite and dolomite) and 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). It is likely, therefore, that elevated strontium is derived from dissolution of natural minerals but is associated with contamination in the S-3 plume.

Springs. Eleven metals have been detected in springs in upper BCV above background. The concentrations and frequency of occurrence for metal contaminants are greater in SS-1 close to the S-3 Ponds than in SS-4 and SS-5. There are no inorganic COCs in SS-5, and two in SS-4. At SS-1, there are four COCs: barium, cadmium, manganese, and uranium. Like groundwater, boron, strontium, and uranium are common contaminants to each of the springs in Upper Bear Creek. Another notable metal that occurs in elevated concentrations in SS-4 is lithium, which has a similar behavior to boron in this spring. Both these metals are slightly more elevated in SS-4 than in SS-1 (mean values, lithium 29 $\mu\text{g/L}$ compared to 4 $\mu\text{g/L}$, and boron 110 $\mu\text{g/L}$ compared to 51 $\mu\text{g/L}$), and these metals may be a tracer of contamination from NT-3, where they occur in elevated concentrations.

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 a further six metals were detected only once in either spring (Table 3.16). There are no metal COCs in either spring.

Surface water. Ten metals were detected at concentrations greater than background at BCK 9.47, and 10 at BCK 4.55. With the exception of boron, strontium, and uranium at both sites, and lithium at BCK 9.47, detection of metals above background at these sites was sporadic. Boron and uranium are COCs at BCK 9.47, and arsenic, antimony, beryllium, and uranium are COCs at BCK 4.55. 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.

Radionuclides

Radioactive contamination has been detected in both surface water and groundwater in the Maynardville Limestone and Bear Creek FA; 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. Radioactive contamination of groundwater occurs from the uppermost section of the valley adjacent to the S-3 Site to the section adjacent to BCBG (Figs. 3.11 and 3.12). Elevated gross α was detected in 30% of the wells in the Maynardville Limestone groundwater aggregate, and elevated gross β was detected in 75% of those wells. Below BCK 9.47, there are no monitoring points for groundwater until Picket W, and radiological contamination has not been identified in these wells with the exception of radionuclides that were detected sporadically and at low activities and are not considered SRCs (^{137}Cs 8.8 pCi/L, ^{228}Ra 7.8 pCi/L, ^{228}Th 0.92 pCi/L, and ^{238}U 1.5 pCi/L). In general, the distribution of radiological contamination is similar to that of nitrate contamination in the Maynardville Limestone.

The distribution of radiological contamination of groundwater in the Maynardville Limestone reflects the location of the main inputs from the source areas (BYBY and the S-3 Site) and the location of a losing reach of Bear Creek adjacent to SL-1. Adjacent to NT-2, wells at the northern end of Picket C have elevated gross β (although neither well has a mean activity >50 pCi/L) (Fig. 3.12). Gross α is not significantly elevated in these wells (mean activities in GW-725, -736, and -737 were 4.6, 3.9, and 5.8 pCi/L, respectively), which may be a reflection of surface water in NT-2 that is contaminated with gross β but not gross α (Sect. 3.2.3). The highest gross α and gross β activities occur in wells adjacent to SL 1 (GW-226 and GW-227) screened in the shallow bedrock and in wells at Picket B downgradient of both NT-3 and the S-3 Site screened in intermediate bedrock depths. These wells probably intersect the combined plume from BYBY and S-3 Site.

Few isotopic analyses for groundwater from GW-706 and GW-694 are available; however, ^{99}Tc was detected more than once in each at activities well above minimum detectable activities and errors. This plume in the deep bedrock apparently continues along strike to at least BCK 9.47, where elevated gross α and gross β have been detected in groundwater in GW-684. As with nitrate, it is possible that groundwater with higher activities than have been detected in Picket A wells is present here.

Springs. SS-1 and SS-4 are contaminated with both gross α and gross β ; gross α is elevated in more than 90% of the samples and gross β in 100% (Table 3.15) (Fig. D.122 in Appendix D). Isotopes of uranium (^{234}U , ^{235}U , and ^{238}U) account for the elevated activities at both springs and are COCs at SS-4. The relative activities of radiological contamination in these springs reflect those in nearby groundwater, which, in turn, are a function of the location relative to contaminant sources. Radiological contamination in SS-1 is consistent with that both in Upper Bear Creek surface water and in groundwater from nearby wells. In SS-4, gross α and gross β data are nearly consistent with that those for groundwater in Picket B wells directly upgradient [GW-706 (55.6 m or 182.5 ft): gross β = 87.6 and gross α = 42.4]. However, comparing 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) implies that little or no dilution of groundwater discharge occurs at SS-4 or that the deep groundwater plume is more contaminated than has been detected in the wells at Picket B.

Uranium isotope activity can account for the observed gross α in these springs. Technetium-99 has been detected in two samples from SS-4; it is likely that gross β is contributed from uranium daughter products (^{234}Pa and ^{234}Th) and ^{99}Tc . The presence of ^{99}Tc at SS-4 indicates that the S-3 Site is a source of contamination in SS-4; however, the relative ratios of gross α to gross β activities in SS-4 compared to those in SS-1 suggest an additional source for gross α in SS-4. Although gross β activities in SS-4 are generally lower than those in surface water at BCK 12.38 [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 between these two sites. The source for gross α downgradient of NT-1 is the BYBY via discharge in NT-3 or subsurface flow.

Discharge at SS-5 is contaminated with both gross α and gross β ; these analytes were detected in more than 80% of samples (Fig. D.123 in Appendix D). In general, activities are lower than those at SS-4 (at SS-5 mean gross α is 29 pCi/L and mean gross β is 82 pCi/L). Isotopes of uranium were detected at very low activities in SS-6, and no radioactivity was detected in SS-8.

Surface water. Surface water at BCK 12.38, BCK 9.47, and BCK 4.55 is contaminated with both gross α and gross β . Activities are progressively lower downgradient, reflecting dilution (mean gross α is 110.4 pCi/L at BCK 12.38, 68 pCi/L at BCK 9.47, and 13.7 pCi/L at BCK 4.55). Assuming that there is no significant source of surface water contamination between BCK 9.47 and BCK 4.55, this indicates a dilution factor of about 0.2 for uranium isotopes in this stream reach.

Organics

The most common organic compounds contaminating groundwater and surface water in the Maynardville Limestone and Bear Creek FA are TCE (Fig. 3.13) and 1,2-DCE. A total of 12 organic analytes were detected in groundwater in the Maynardville Limestone aggregate, each detected in 20% or more of wells (Table 3.15). Other VOCs detected in the Maynardville Limestone and Bear Creek FA are 1,1,1-TCA, 1,1-DCA, 1,1-DCE, 1,2-DCA, acetone, carbon tetrachloride, chloroform, methylene chloride, and PCE. However, only PCE, TCE, and 1,2-DCE occur in more than two wells at concentrations greater than detection limits, and seven VOCs are COCs.

In the uppermost section of the valley, a plume of TCE, 1,2-DCE, and PCE occurs at SA-1 (Fig. 3.20) and has been tentatively associated with the Fire Training Area in UEFPC (Energy Systems 1994). The contaminant suite in this plume is composed of primarily 1,2-DCE with an ~3:1 ratio between the concentrations of 1,2-DCE and that of TCE (e.g., GW-313 mean TCE concentration of 5.4 $\mu\text{g/L}$ and mean 1,2-DCE of 17.5 $\mu\text{g/L}$). Whereas this plume is detected in the shallow bedrock and residuum intervals in UEFPC, in BCV, it is located only in the bedrock at depths >30 m (100 ft). PCE also occurs in the uppermost section of the valley in well GW-124 (45.7 m or 150 ft) at a mean concentration of 14.1 $\mu\text{g/L}$. PCE occurs in this well in greater concentrations than TCE and 1,2-DCE (mean concentrations 8.4 $\mu\text{g/L}$ and 6.5 $\mu\text{g/L}$, respectively), and the origin of contamination in this well may be associated with a different source, possibly the S-3 Site.

The most extensive plume of organic-contaminated groundwater in the Maynardville Limestone and Bear Creek FA starts downgradient of the Rust Spoil Area (Fig. 3.42). The highest contaminant concentrations in this plume are for TCE (e.g., mean concentrations of 368 $\mu\text{g/L}$ in

Fig. 3.42. Cross section of BCV showing the distribution of TCE-contaminated groundwater.

GW-225), with 1,2-DCE generally occurring in lower concentrations (e.g., mean concentrations of 27 $\mu\text{g/L}$ in GW-226). 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 (Fig. D.29 in Appendix D). The two examples above (GW-225 and GW-226) highlight this situation; the maximum value for TCE occurs in GW-225, whereas this well has a mean concentration of 11 $\mu\text{g/L}$ for 1,2-DCE. Conversely for GW-226, where 1,2-DCE recorded its maximum mean value in the Maynardville Limestone, the mean concentration for TCE was 9 $\mu\text{g/L}$.

From the distributions of concentrations in this plume, more than one source for both contaminants seems likely. Elevated concentrations of TCE and 1,2-DCE occur in the groundwater wells screened in the shallow bedrock at the Rust Spoil Area, and concentrations increase downgradient past Picket C. The likely source(s) of this contamination are one or both of the following:

- BYBY where elevated concentrations of TCE (2000 $\mu\text{g/L}$) and 1,2-DCE (1100 $\mu\text{g/L}$) occur in the residuum close to the Maynardville/Nolichucky contact (Sect. 3.2.4). In addition, the maximum concentration of TCE in the Maynardville Limestone occurs in GW-225 (mean 365 $\mu\text{g/L}$), which is screened in the lowest stratigraphic section of the Maynardville Limestone immediately downgradient of BYBY.
- Wells upgradient of BYBY are contaminated, and a past release of TCE from an unidentified site close to the current location of Rust spoil Area is likely.

Adjacent to BCBG, organic contamination in the Maynardville Limestone is slight compared to concentrations observed in the Nolichucky Shale and in the Maynardville Limestone adjacent to BYBY. In the shallow system, 1,2-DCE and 1,2-DCA have been 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). This well is a shallow well located close to the confluence of NT-7 and Bear Creek, and the most likely source of contamination in this well is 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 in zone 21 [190.5 m (625 ft) amsl] in GW-790 in association with nitrate; however, the detected concentration was low (1 $\mu\text{g/L}$; Fig. 3.42). 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. No TCE has been detected in Picket A; however, TCE occurs sporadically in SS-5, which suggests that the TCE plume has reached as far as Picket A.

Springs. Seven organic compounds were detected in SS-1, -4, and -5. Organic contamination occurred most frequently in SS-4, with TCE and 1,2-DCE occurring in more than 90% of the samples in that spring with mean concentrations of 8.7 $\mu\text{g/L}$ and 7.7 $\mu\text{g/L}$, respectively. In SS-5, TCE and 1,2-DCE occurred in 20 to 30% of samples and in low concentrations, less than their detection limits (both compounds with a maximum detected concentration of 2 $\mu\text{g/L}$).

In general, the distribution of VOCs in springs reflects that in groundwater. In SS-4, concentrations of TCE and 1,2-DCE in SS-4 are almost identical for each sample (mean TCE is 8.7 $\mu\text{g/L}$ and mean 1,2-DCE is 7.7 $\mu\text{g/L}$), and over time the concentrations vary similarly between

samples (Fig. D.121 in Appendix D). 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 (Fig. 3.13) 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 two to three times greater than those for 1,2-DCE.

Surface water. Fourteen organic chemicals were detected in surface water at Upper Bear Creek, and twelve in Mid Bear Creek. In general, all organic chemicals were detected sporadically and at low concentrations, reflecting the tendency for these chemicals to volatilize in surface water.

3.2.6.4 Floodplain soils and sediments chemical data

Inorganic Chemicals

A total of 10 inorganic elements or compounds were detected in floodplain soils at concentrations above their background criteria, and 15 were detected in floodplain sediments (Table 3.17). None of the inorganic elements detected in floodplain soils or sediments in BCV west of BCK 9.47 were COCs (Table 5.4).

The distribution of cadmium and mercury is shown on Fig. 3.43 as representative of the relative distributions of metals that were detected above background in the FPSS. In general, concentrations of inorganic compounds are higher in sediments than in soils, and in soils the highest concentrations occur in the shallow interval [0 to 10 cm (0 to 4 in.)]. In addition, there is a progressive decrease in the concentrations of contaminants along the valley downgradient from the source areas; for example, three of the four highest cadmium concentrations in the BCV floodplain occur in sediments from SD-02, -07, and -14, each of which is located upgradient of the confluence of Bear Creek with NT-4.

Cadmium was detected above its background criterion in 9 of 16 soil samples in the shallow interval, with a maximum concentration of 9.3 mg/kg, and in 8 of 18 floodplain sediment samples, with a maximum concentration of 21.7 mg/kg. Mercury was detected in concentrations above its background criterion in the 0- to 10-cm (0- to 4-in.) interval in 11 floodplain soil samples and 3 sediment samples. Maximum concentrations of mercury in soil samples from this interval ranged from 0.36 mg/kg in TS-13 to 7.3 mg/kg in TS-01. Mercury concentrations in the sediment samples ranged from 0.53 mg/kg in SD-07 to 6.9 mg/kg in SD-04.

Radionuclides. Six radionuclides were detected at activity concentrations above their background criteria in floodplain soils and, with one exception, were also detected at activity concentrations above their background criteria in floodplain sediments (Table 3.17). None of the radionuclides in floodplain soils or sediments is a COC. The distribution of elevated uranium activities in soils is similar to that for the inorganic contaminants in that the highest concentrations occurred in sediments and in shallow soil intervals; concentrations generally decrease along the valley downgradient of the S-3 Site (Fig. 3.43).

PCBs/pesticides. 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

DEPTH: 4-16"

DEPTH: 16-32'

Fig. 3.43. Distribution of PCBs, cadmium, mercury, and ^{238}U in BCV floodplain soils.

LEGEND:

..... BEAR CREEK & TRIBUTARIES

..... MANAGEMENT AREA BOUNDARIES

TS01 BCV FLOODPLAIN SOIL TRANSECT

SD01BCV FLOODPLAIN SEDIMENT SAMPLE

..... SEDIMENT SAMPLE

.....SOIL SAMPLE

MERCURY (mg/kg)
PCBs (ug/kg)
CADMIUM (mg/Kg)
U-238 (pCi/g)

1.0
10
100
1000

Y-12 PLANT NORTH

SCALE: 1" = 3500'

BEAR CREEK VALLEY

floodplain sediments (Table 3.17). Aroclor-1254 is the only organic COC. Although PCBs occur at most sample sites, Aroclor-125 is a COC only at two sites: sediment sample (SD-04) and soil sample (SP-04) (Fig. 3.43). Like inorganics and radionuclides, contamination with PCBs and pesticides is most prevalent in the shallow FPSS. The maximum concentration for total PCBs in the 0- to 10-cm (0- to 4-in.) soil depth interval was 1300 $\mu\text{g/kg}$ at transect TS-07 (Fig. 3.43). A maximum total of PCB values >1000 $\mu\text{g/kg}$ was also detected at transect TS-10. In addition, a sample taken from a 1- to 3-cm (0.4- to 1.2-in.)-thick, organic-rich layer located in a trench at BCK 4.70 (SP-04) had an Aroclor-1254 concentration of 5100 mg/kg and is a COC. The maximum total PCB concentration in floodplain sediments was 2500 $\mu\text{g/kg}$, which occurred in sediment sample SD-09, located just upstream of transect TS-04 (Fig. 3.43).

3.2.6.5 Floodplain waste samples

During the course of the BCV RI, two previously unidentified waste areas in the BCV floodplain were sampled: the Creekside Debris Burial Area and the Bear Creek Road Site Debris Burial Area (Fig. 1.2). Compared to the background criteria used in the BCV RI for soils and sediments, various metals and uranium isotopes occur in elevated concentrations at these waste areas (Table D.103 in Appendix D). Soils at the Bear Creek Road Site Debris Burial Area had the highest radiological contamination (1908 pCi/g total uranium) and had an unusual uranium isotopic ratio compared to other samples in BCV, with a ^{234}U activity about 6.5 times greater than the ^{238}U activity.

3.2.6.6 Maynardville Limestone and Bear Creek conceptual model

The working hypothesis is that most of the contamination in the Maynardville Limestone and in Bear Creek can be traced to inputs from sources at S-3, BYBY, and an undefined source close to the 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 should also be considered. Although BYBY has probably been 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. Concentrations of nitrate in Bear Creek at BCK 12.46 were in excess of 1000 mg/L in 1983 (Turner et al. 1991) and were probably greater in preceding years, whereas the maximum concentration during 1994 monitoring was 171 mg/L . Thus, it is likely that a residual plume of contamination derived from the S-3 Ponds remains in groundwater in the Maynardville Limestone. Differentiating current contaminant fluxes from fluxes derived from residual contamination may be complicated by this plume.

The conceptual model for contaminant distribution in BCV is shown in Fig. 3.44, and the conceptual model for contaminant movement on Fig. 3.45. The main sources of contaminant input to Bear Creek and the Maynardville Limestone from the source sites that have been identified in previous sections are identified on Fig. 3.45 and are as follows:

- 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

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Fig. 3.44. Site conceptual model for contaminant distribution in BCV.

st B wells

- Plume of nitrate-contaminated groundwater (>10mg/L and <100 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

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Fig. 3.45. Site conceptual model for contaminant movement in BCV.

ort

Historical Plumes act as secondary source

**OIL/LAND FARM AREA:
BONEYARD/BURNYARD**

Picket C
wells

**Polichukky
Shale**

Maynardville Limestone

NT-3

groundwater; and VOCs by shallow groundwater discharge to Bear Creek and 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 discharge from NT-7 and NT-8, and 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. 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 nitrate, gross α , gross β , TCE, and 1,2-DCE in groundwater, surface water, and springs. Progressive changes in relative concentrations of contaminants in groundwater along the valley in many ways reflect the inputs to the Bear Creek/Maynardville Limestone system. For example, radiological contamination in groundwater adjacent to NT-2 is higher in gross β than in gross α , reflecting the lack of gross α contamination in NT-2. This suggests that, after contaminants enter Bear Creek via tributaries, pathways exist to transport the contaminants downward into the Maynardville Limestone. This observation is consistent with the presence of downward hydraulic gradients in parts of the Maynardville Limestone (Chap. 2) and losing reaches of Bear Creek. One losing reach of particular importance is located immediately downgradient of NT-3. The main contaminant pathways from S-3 Site and BYBY pass through this reach of Bear Creek and probably provide much of the groundwater contamination that occurs downgradient of Picket C.

Although the greater fluxes of contaminants move through surface water in Bear Creek and the shallow interval (< 30 m deep) of the Maynardville Limestone, the intermediate interval (30 to 150 m deep) also acts as an important contaminant transport pathway. The resulting effect of the greater influence of recharge and the greater flux of groundwater through the shallow interval (< 30 m depth) is that contaminant concentrations are more quickly attenuated along strike in the shallow interval than in the intermediate interval. Thus, although the greater flux of contaminants is through the shallow interval and surface water, concentrations of contaminants in the intermediate interval are higher and may result in greater risk. In addition, shallow groundwater contamination downgradient of contaminated springs in BCV (SS-4 and SS-5) appears to be derived from the spring discharge rather than from along-strike migration of contaminants in the shallow interval. Contaminated spring discharge is derived in part from groundwater in the intermediate and deep groundwater intervals. This effect, combined with the greater extent of contaminant plumes in the intermediate interval, provides a mechanism for shallow groundwater and surface water further downgradient to be contaminated via along-strike migration of contaminants in the intermediate and deep groundwater intervals.

Downgradient from Picket A and BCK 9.47, there is little information concerning groundwater and surface water contamination. Two wells at Picket W, one a shallow well and the second, 42.7 m (140 ft) deep, are contaminated with low concentrations of nitrate. SS-6 has slightly elevated nitrate concentration, and so does Bear Creek at BCK 4.55; however, SS-8 at BCK 4.55 is not contaminated with nitrate. This distribution may be explained in two ways:

- (1) Groundwater is diffusely contaminated throughout BCV as a result of past contaminated surface water flow in Bear Creek interacting with shallow groundwater and 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.

There are no data available to predict which hypothesis is correct, however, it is most likely that both hypotheses are true to some degree, and that the actual situation is somewhere between the two. The issue of the extent of groundwater contamination west of Picket A remains an uncertainty.

Using results of modeling for future concentrations at the tributaries feeding Bear Creek, the ranges of possible future concentrations of COCs at BCK 9.47 were calculated. Concentrations were calculated using a mass balance model assuming that the current water balance in upper BCV will remain unchanged in the future. The results of these calculations (Table 3.18) provide a conceptual idea of likely changes in contaminant concentrations at BCK 9.47; however, the inherent uncertainty in numerical modeling of a natural system as complex as BCV means that there is a high degree of uncertainty associated with these results. In Table 3.18, ranges of potential future concentrations are present for both a model including input from NT-8 and excluding input from NT-8. The model that included NT-8 input represents likely concentrations in the future for BCK 9.47 if the leachate collection system is not maintained; the model that excludes NT-8 input represents likely conditions if the leachate collection system is maintained.

The results show that although many of the inorganic and organic contaminants at BCK 9.47 may increase in concentration in the foreseeable future, the predicted impact is less if the NT-8 leachate collection system is maintained. Most metals are predicted to increase in time, with uranium and nitrate expected to increase up to three times the current maximum values. This increase is derived mainly from increase in the contaminant loading from NT-1 and NT-2. Although many organic chemicals are predicted to increase, the effect of volatilization on these modeled concentrations is not known and is likely to have a large negative impact. After allowing for in-stream volatilization of VOCs, actual future concentrations of organic chemicals may not vary from current values.

3.2.7 Site-wide Contaminant Source Ranking

As discussed in Sect. 3.2.2, contaminant fluxes from various sources were calculated from the 10-month monitoring period for the BCV RI between April 1994 and January 1995. The relative importance of these fluxes can be directly compared to each other by evaluating them in terms of their contribution to total risk at the integrator point (IP) at BCK 9.47. Use of relative risk factors is critical in this comparison since, for example, uranium fluxes cannot be directly compared to nitrate fluxes, but the risk associated with uranium can be compared to the risk associated with nitrate.

Risk estimates used in the IP/integrator plane assessment are calculated using methods presented in the BHHRA (Appendix F). Risks associated with exposure to surface water have been estimated as part of the BHHRA and details on the exposure scenarios, exposure parameters, and toxicity information are presented in Appendix F. The IP assessment differs from the risk

assessment in that the IP assessment uses a flow-weighted average concentration as the concentration in surface water for calculating the risk values (Appendix E). **The values presented in the BHHRA (Appendix F, Chap. 5) should be used as the estimate of the absolute risk value for BCK 9.47 and SS-5. The values estimated using the flow-weighted concentrations should only be used as a step in estimating the relative risk/hazard associated with contaminant fluxes across the IP in the valley.**

As with the BHHRA, cancer-causing substances and chemical toxicants are treated separately in the IP assessment, since the hazard associated with the two primary human health endpoints cannot be compared.

Figure 3.46 and Table 3.19 summarize the results of the IP assessment (also refer to Figs. E.12 and E.13 in Appendix E). The results of the IP assessment suggest the following:

- Uranium appears to pose the greatest human health hazard, contributing 98% of the total risk at BCK 9.47/SS-5 and 64% to total toxic effects.
- Most of the uranium migrating off site via surface water appears to come from BYBY via NT-3. The second greatest identified source is BCK 12.38/NT-1, which captures fluxes coming from the S-3 Site and the S-3 groundwater plume.
- A significant percentage of the uranium flux measured at BCK 9.47/SS-5 (~31%) is derived from an input pathway that was not gaged during the BCV RI. The likely sources for this ungaged input include the groundwater plumes underlying BYBY and the S-3 Site and runoff from BYBY directly to Bear Creek. Based on the site conceptual models for these sites, especially since BYBY is partly located on the outcrop of the Maynardville Limestone and the Bear Creek floodplain, BYBY is probably the contributor for most of this ungaged flux.
- Nitrate, which has been the focus of many studies in BCV in the past, does not contribute a high proportion of the toxic hazard associated with surface water migration. However, based on the nitrate mass balance for the various flow paths in the valley, nitrate has moved past the integrator plane via the intermediate/deep groundwater.
- VOCs are detected in most of the tributaries in the valley, with the greatest amounts entering Bear Creek at NT-7 (27%) and NT-8 (71%). The primary VOCs in these tributaries are: 1,1-DCE (with concentrations ranging from 33 to 410 µg/L), PCE (16 to 120 µg/L), 1,1,1-TCA, 1,1-DCA, 1,2-DCE, TCE, and vinyl chloride. Shallow groundwater results show that the primary waste source for these VOCs is BG-A South and BG-A North.
- Large amounts of VOCs have not been detected at BCK 9.47, and it is estimated that >80% (or 55 Kg) of the VOC mass detected in the tributaries during the 10-month monitoring period for the BCV RI volatilized prior to reaching BCK 9.47/SS-5.

3.2.8 Conclusions

Text and figures describing the interpreted nature and extent of contamination in each FA are contained in the preceding sections. These sections are not repeated here; rather, this section

Fig. 3.46. Relative contribution from BCV sources to the IP assessment.

contains a brief synopsis of contamination in BCV and re-emphasizes some of the distribution patterns that are seen in the source FAs. These are as follows:

- **Wastes.** Large volumes of waste materials have been disposed of at the waste sites in BCV; disposal of over 18.6 million kg of uranium metal, more than 1 million gal of liquid containing chlorinated solvents, and at least 2.7 million gal/year of metal- and radionuclide-contaminated nitric acid has been recorded at the BCBG and S-3 Site. In addition, contaminated media at BYBY indicate that unrecorded amounts of uranium and chlorinated solvents have been disposed at this site. Associated with these main waste constituents are other contaminants that are associated with operations at the Y-12 Plant (such as mercury, beryllium, lithium, and boron) or that might be expected at a large industrial facility operating during the 1940s to 1980s (such as SVOCs, PCBs, and benzene, ethylbenzene, toluene, and xylene compounds).
- **Soils.** Concentrations of contaminants in soils are relatively low. This is especially true of the BCBG and S-3 Site, where the source areas and main shallow groundwater discharge areas have been remediated and the areas containing waste have been capped. 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 contamination in the Nolichucky Shale.** The principal contaminants in groundwater and surface water at the source areas reflect the main waste constituents: nitrate, uranium, and chlorinated solvents. Contamination in groundwater at source areas occurs in both the shallow and deep intervals of the Nolichucky Shale, which would appear to be inconsistent with the conceptual flow model (<5% of available water is recharged to bedrock). However, contaminant distributions at the source sites are consistent with the hydrogeological conceptual model when the mode of emplacement of contaminants is taken into account. Where contaminants were placed in the waste areas in liquid form, and that liquid was denser than the ambient groundwater, contamination occurs in both shallow and deep groundwater intervals. 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.
- **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. This is probably a function of two processes: matrix diffusion and rate of flushing of contaminants. Assuming that, during operations at the waste sites, the concentrations of contaminants in shallow and deep intervals were comparable, the concentration differences have mainly developed 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 those 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 Nolichucky Shale. Contamination exists at all depths in the Maynardville Limestone; however, contaminants have migrated to depth principally along deep flow paths in the aquifer. Both nitrate and uranium occur at >30 m (100 ft) depth in the Maynardville Limestone and are derived from contaminated groundwater and surface water in the Nolichucky Shale. The principal contaminant migration pathway from Bear Creek and the shallow groundwater intervals to deeper groundwater occurs approximately adjacent to SL 1, where a losing reach of Bear Creek and downward hydraulic gradients in the Maynardville Limestone that promote downward migration are located.

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 Bear Creek Hydrogeologic Regime. The tributaries that drain catchments containing source areas act as contaminant sources to this Maynardville Limestone/Bear Creek Hydrogeologic Regime. Once in this regime, however, the plumes of contaminants become commingled, complicating attempts to isolate the ultimate sources, which have similar contaminant suites. This effect is seen particularly well in SS-4, where contaminants in this spring can be attributed to S-3 (nitrate, uranium, and ^{99}Tc), BYBY (uranium, TCE, and 1,2-DCE), and an unknown source for VOCs on the floodplain (TCE and 1,2-DCE).

3.2.9 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 when extensive data collection is carried out*. This is especially true for large and diverse sites such as BCV and the likelihood of data gaps in the BCV RI was minimized by adherence to the DQO process during planning of the characterization phase.

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 BHHRA. Additional groundwater sampling was carried out to fill this data gap. In the remaining cases, uncertainty in data interpretation was not considered too great to complete the RI. In these situations, the conceptual model for BCV includes the probable condition 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 uncertainties in the BCV conceptual model. 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 discharged 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 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.
- **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 free phase 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 not recorded in the waste stream for the S-3 Site. 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 BYBY. The likely deviation is that DNAPL is present in bedrock in the Nolichucky Shale at this site.
- **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 indicated by the mass balance in Appendix E. 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. 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 9.4. 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 BCV 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 contaminant concentrations.** Contaminant fate and transport modeling has been used to predict possible future concentration of contaminants at discharge points in NT-1, -2, -3, -7, and -8. As with any modeling 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 this report (and in Appendix E) represent orders of magnitude for breakthrough timing and maximum concentrations.

3.3 REFERENCES

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4. APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

CERCLA was passed by Congress and signed into law on December 11, 1980 [Public Law (Pub. L.) 96-510]. SARA, adopted on October 17, 1986 (Pub. L. 99-499), did not substantially alter the original structure of CERCLA but did provide extensive amendments. In particular, §121 of CERCLA specifies that remedial actions for clean up of hazardous substances must comply with requirements or standards under federal or more stringent state environmental laws and regulations that are applicable or relevant and appropriate to the hazardous substances or particular circumstances at a site. Inherent in the interpretation of ARARs is the assumption that protection of human health and the environment is ensured [§121(d)(1)]. In the absence of federal or state ARARs, there are many criteria, advisories, guidance values, and proposed standards that serve as guidance for setting protective cleanup levels. These are not ARARs, but are "to be considered" (TBC) guidance [40 *CFR* 300.400(g)(3)].

CERCLA on-site remedial response actions must comply only with the substantive requirements of a regulation and not the administrative requirements to obtain federal, state, or local permits [CERCLA §121(e) and FFA §XXII]. To ensure that CERCLA response actions proceed as rapidly as possible, EPA has reaffirmed this position in the final NCP (55 *FR* 8756, March 8, 1990). Substantive requirements pertain directly to the actions or conditions at a site; administrative requirements facilitate their implementation.

In an effort to limit the size of the document, this section of the report presents tables (Tables 4.1 and 4.2) of chemical-specific ARARs for COCs present in groundwater and surface water only, as well a limited discussion of major water ARARs and issues for BCV. A full discussion of potential chemical-, location-, and action-specific ARARs will be included in the BCV FS. A more complete discussion of ARARs applicable to the ORR CAs can be found in the document, "*Applicable or Relevant and Appropriate Requirements for Remedial Action at the Oak Ridge Reservation*" (ES/ER/TM-1/R3, Etnier et al. 1996).

4.1 CHEMICAL-SPECIFIC ARARs

Chemical-specific requirements provide health- or risk-based concentration limits or discharge limitations in various environmental media for specific hazardous substances, pollutants, or contaminants (53 *FR* 51437, 55 *FR* 8741). These requirements generally provide protective clean-up levels for the COCs in the designated media or indicate a safe level of discharge that may be incorporated when considering a specific remedial activity.

4.1.1 Groundwater

4.1.1.1 Classification

As stated in the NCP (55 *FR* 8666), EPA's goal for contaminated groundwater is to return usable groundwater to its beneficial use within a given time frame that is reasonable for the particular circumstances at a CERCLA site. The beneficial use to which the groundwater needs

to be restored depends on how the groundwater has been classified by the state or federal regulating bodies.

Although not an ARAR unless promulgated, the EPA guidance on groundwater classification (EPA 1986) could be used to determine whether groundwater at BCV falls within Class I, II, or III. Classes I and IIA represent current sources of drinking water of varying quality, Class IIB represents potential sources of drinking water, and Class III groundwater is not considered to be a potential source of drinking water and is of limited beneficial use. Class III groundwater includes groundwater that is not a potential source of drinking water due to (1) salinity (i.e., >10,000 mg/L total dissolved solids); (2) insufficient yield (it is not available in sufficient quantity (i.e., > 150 gallons/day) at any depth to meet the needs of an average household); or (3) contamination that cannot be cleaned up using treatment methods reasonably used in public water supply systems (or economically treated). Class IIIA groundwaters are defined as having a high to intermediate degree of interconnection to adjacent groundwater units of a higher class or to surface waters. Class IIIB is restricted to groundwater characterized by a low degree of interconnection to higher class groundwater or surface waters within the area of concern.

To meet the EPA definition for a Class IIIA aquifer, there must be no wells or springs used as a source of drinking water in the area regardless of yield. In addition, all water-bearing units must meet the insufficient yield criterion, which EPA has set at 150 gal/day, achievable throughout the year, to support basic household needs. EPA has codified this definition of insufficient yield in the final rule for groundwater protection at DOE-owned inactive uranium processing plants (40 *CFR* 192.11); this may be relevant and appropriate for groundwater classification at the BCV OU.

Under the TDEC Underground Injection Control regulations, all groundwater in the state of Tennessee is classified for domestic and industrial water supply, livestock watering and wildlife, and irrigation. However, these regulations [TDEC 1200-4-6-.02(4)] define an underground source of drinking water as meaning “an aquifer or its part that: (a) currently supplies any public water system; or (b) contains a sufficient quantity of groundwater to supply a public water system; *and* (b1) currently supplies drinking water for human consumption; *or* (b2) contains fewer than 10,000 mg/L total dissolved solids; and (c) which is not classified for underground injection use pursuant to Rule 1200-4-6-.05(3).” If these criteria are not met, the groundwater would not meet TDEC’s definition as an underground source of drinking water and, thus, would not be subject to MCLs as the clean-up standard (see Sect. 2.1.2 below).

The TDEC Water Well Construction regulations also address the state’s definition of an underground source of drinking water, albeit indirectly. The regulations apply to wells constructed solely for the production of water for the purpose of “developing a groundwater supply from any aquifer of beneficial use” [TDEC 1200-4-9-.01(26)]. An aquifer is defined as “a geologic formation, a group of such formations, or a part of a formation that will yield usable quantities of water to wells” [TDEC 1200-4-9-.01(2)]. The source of water for any production well shall be at least 6 m (20 ft) below the surface of the ground [TDEC 1200-4-9-.10(3)(a)]. All water-bearing units must meet the sufficient yield criterion, which EPA has set at 150 gal/day, achievable throughout the year, to support basic household needs. EPA has codified this definition of insufficient yield in the final rule for groundwater protection at DOE-owned inactive uranium processing plants (40 *CFR* 192.11). Based on these definitions, and on the requirement for depth

to the source of water, the use of SDWA MCLs as groundwater clean-up standards may have limited applicability for groundwater remediation at BCV.

TDEC is currently writing a proposed general groundwater classification rule for Tennessee groundwaters, to be included in Rules of the Chapter 1200-4-3 (*General Water Quality Criteria*), that will affect CERCLA cleanups. The new rule will propose issuing a site-specific permit and variance allowing the groundwater to be cleaned up to risk-based correction action levels rather than MCLs. The national CWA allows the issuance of such a variance (40 *CFR* § 131.13). The proposed rule will be issued for public comment later this year.

4.1.1.2 Cleanup standards

CERCLA §121(d)(2)(A) specifies that remedial actions must require a level or standard of control that at least attains maximum contaminant level goals (MCLGs) where such goals are relevant and appropriate under the circumstances of the release. Although MCLGs are nonenforceable guidelines, Congress elevated them to a higher status by specifically mentioning them in CERCLA. If the groundwater in BCV is classified, using any of the criteria discussed in Sect. 4.1.1.1, as a current or potential source of drinking water, the NCP requires use of the SDWA MCLs as clean-up levels for carcinogens that have a zero value MCLG and any nonzero value MCLG for remedial action compliance for systemic toxicants [40 *CFR* 300.430(e)(2)]. Alternate concentration limits may also be used when active restoration of the groundwater to MCLs or non-zero MCLGs is not practical [40 *CFR* 300.430(e)(2)]. For Class III groundwaters, EPA establishes remediation levels based on specific site conditions, the beneficial use of the groundwater, and the environmental receptors (55 *FR* 8732). CERCLA § 121(d)(2)(B)(i) refers to "the designated or potential use" of the groundwater in determining clean-up levels, reflecting Congress' intent to apply varying clean-up standards to different kinds of groundwater (55 *FR* 8733).

MCLs are legally applicable to water "at the tap" but are not applicable to clean up of groundwater or surface water. However, they may be considered as relevant and appropriate in situations where groundwater or surface water may be used for drinking water. Chapter 1200-5-1 of the Rules of the TDEC, as amended in January 1993, lists MCLs for public water systems that are identical to the federal MCLs. EPA has proposed MCLs/MCLGs for a variety of contaminants (54 *FR* 38668, July 29, 1994) that will be ARARs when promulgated; until that time, they may be considered TBC guidance. Table 4.1 lists current and proposed MCLs for COCs in BCV groundwater, based on groundwater being classified as a potential source of drinking water.

MCLs for radionuclides appear in two forms: concentration limits for certain alpha-emitting radionuclides (40 *CFR* 141.15) and an annual dose limit for ingestion of certain beta- and gamma-emitting radionuclides (40 *CFR* 141.16). MCLs and MCLGs were promulgated for radon and uranium and repropoed for ²²⁶Ra and ²²⁸Ra and beta and photon emitters on July 18, 1991, and are included and footnoted as such in Table 4.1. Final action to promulgate the limits is currently on hold. In Appendix B of the proposed rule, EPA lists estimated concentrations of beta particle and photon emitters in pCi/L that correspond to an effective equivalent dose (EDE) of 4 mrem/yr (the current MCL for beta and photon emitters).

A 4 mrem EDE/yr corresponds to a lifetime cancer risk of approximately 10⁻⁴. The proposed rule also lists, in Appendix C, levels of alpha emitters representing 10⁻⁴ lifetime risk in drinking water

(assuming ingestion of 2 liters daily). These values are listed on Table 4.1 as TBC guidance, not ARARs.

National Secondary Drinking Water Standards regulate contaminants that affect the aesthetic qualities related to public acceptance of drinking water and are implemented in 40 *CFR* 143.3 as secondary maximum contaminant levels (SMCLs). These regulations are not federally enforceable, but rather are intended to serve as guidelines for use by states in regulating water supplies and, thus, would be considered TBC guidance. Tennessee, however, has promulgated SMCLs in Chap. 1200-5-1.12 of the Rules of the TDEC and considers these SMCLs as enforceable rather than aesthetic guidelines. In that context, they may be considered as relevant and appropriate where groundwater meets the state classification as a current or potential drinking water source, and there is no MCL available for the COC. SMCLs are listed in Table 4.1 for COCs in BCV groundwater.

The postclosure maintenance, groundwater monitoring, and reporting requirements of the Y-12 RCRA post-closure permit (Permit number TNHW-087) apply to the areas listed in the permit. However, corrective actions in the BCV OU have been deferred until completion of remedial actions under CERCLA that address risk to individuals and the environment from contaminated groundwater and surface water (Permit Condition IVD). Since the permit states that groundwater protection standards shall be developed under CERCLA (Permit condition IVC), the CERCLA MCLs/MCLGs for remediation of contaminated groundwater will be cited as potential ARARs for cleanup of S-3 Ponds and OLF groundwater, rather than the RCRA maximum concentrations for constituents (MCCs) listed under 40 *CFR* 264.94.

In addition to groundwater classification, point(s) of compliance and restoration time periods will need to be established if groundwater contamination mandates remedial action be taken. EPA's guidance for these issues, as established in the NCP, including the preambles to the proposed and final rules establishing the NCP, and other EPA preambles and rules, is discussed below.

4.1.1.3 Point of compliance

EPA believes that remediation levels should generally be attained throughout a contaminated groundwater plume or at and beyond the edge of the waste management area when the waste is left in place (55 *FR* 8753). However, EPA acknowledges there may be certain circumstances where a plume of groundwater contamination is caused by releases from several distinct sources that are in close geographical proximity. In such cases, the most feasible and effective groundwater clean-up strategy may be to address the problem as a whole, rather than source by source, and to draw the point of compliance to encompass the sources of release. In determining where to draw the point of compliance, the lead agency shall consider factors such as the proximity of the sources, the technical practicability of groundwater remediation at that specific site, the vulnerability of the groundwater and its possible uses, exposure, and likelihood of exposure and similar considerations (55 *FR* 8753). EPA, in the preamble to the final NCP (55 *FR* 8734), states that in situations where there would be little likelihood of exposure due to the remoteness of the site, alternate points of compliance may be considered, provided contamination in the aquifer is controlled from further migration.

For groundwater classified as Class III based on EPA's groundwater classification scheme, the beneficial use of the groundwater (e.g., agricultural or industrial use), if any, should be determined, and the remediation approach should be tailored for returning the groundwater to that designated use (55 *FR* 8732). In general, alternatives for Class III groundwaters will be relatively limited, and the focus may be, for example, on preventing adverse spread of the significant contamination or source control to prevent exposure to waste materials or contamination (55 *FR* 8732). The expectation concerning groundwater remediation is that, when groundwater restoration is not practicable, remedial action will focus on plume containment to prevent contaminant migration and further contamination of the groundwater, prevention of exposures, and evaluation of further risk reduction (55 *FR* 8734).

Based on this EPA guidance, the designated land uses in Bear Creek Valley may impact the decision regarding point of compliance for any needed groundwater remediation. Specifically, the point of compliance for attainment of MCLs/MCLGs might logically be set at the edge of, or within, the areas designated for recreational or residential land use, rather than within the area designated as industrial land use.

4.1.1.4 Restoration time periods

In the preamble to the final NCP (55 *FR* 8732), EPA states that its preference is for rapid restoration, when practicable, of Class I groundwaters and contaminated groundwaters that are currently, or likely in the near-term to be, the source of a drinking water supply. Reasonable restoration time periods, however, may range from very rapid (1 to 5 years) to relatively extended (perhaps several decades) periods (55 *FR* 8732). If there are other readily available drinking water sources, the necessity for rapid restoration is reduced. Such factors as location, proximity to population, and likelihood of exposure may allow much more extended timeframes for remediating groundwater.

EPA's final rule for groundwater protection at DOE-owned inactive uranium processing plants (40 *CFR* 192.11) allows for natural attenuation of contaminants in groundwater in cases where active remediation of groundwater is not appropriate. A discrete time limit of 100 years is specified with implementation of institutional controls. Such controls must have a high degree of permanence, effectively protect human health and the environment, and satisfy beneficial uses of the groundwater during the extended period. Groundwater remediated in this fashion must not currently be, or be projected to be, a source of public drinking water supply regulated under the SDWA [40 *CFR* 192.12(c)(2)]. Although not legally applicable to the DOE ORR site, this rule could be potentially relevant and appropriate or TBC guidance for setting restoration time periods if it is determined that the groundwater in BCV must be remediated or may be cleaned up through natural attenuation.

4.1.2 Surface Water

CERCLA §121(d)(2)(A) specifically states that remedial actions shall at least attain federal ambient water quality criteria (WQC) established under the CWA if they are relevant and appropriate. In determining whether any WQC are relevant and appropriate, one must consider the "designated or potential use of the surface, the environmental media affected, the purposes for which the criteria were developed, and the latest information available" [CERCLA §121(d)(2)(B)]. EPA has derived WQC for ingestion of drinking water and aquatic organisms and for the ingestion

of aquatic organisms alone. WQC for certain toxic pollutants were withdrawn and others revised in the "National Toxics Rule" (57 *FR* 60848, December 22, 1992), and the EPA Region IV Water Quality Standards Unit has adopted these criteria.

The purpose of the Tennessee Water Quality Control Act [Tennessee Code Annotated (TCA) 69-3-102(b)] is "to abate existing pollution of the waters of Tennessee, to reclaim polluted waters, to prevent the future pollution of waters and to plan for the future use of the waters" The Tennessee Water Quality Control Act (TCA 69-3-103(33)) defines "waters" of the State as "any and all water, public or private, on or beneath the surface of the ground, which are (sic) contained within, flow through, or border upon Tennessee or any portion thereof" Thus, all surface waters, including all tributaries, in BCV would be considered waters of the State.

Tennessee has promulgated implementing regulations to fully protect existing uses of all surface waters as established under the Water Quality Control Act. Chapter 1200-4-3 of the Rules of the TDEC lists seven use-designation categories for Tennessee's surface waters. Specific water quality standards are promulgated for each use category. Under the Tennessee Water Quality Control Act, the Tennessee Water Quality Control Board has classified Bear Creek for fish and aquatic life, recreation, irrigation, and livestock watering and wildlife uses (Chap. 1200-4-4 of the Rules of the TDEC). None of the tributaries to Bear Creek are specifically named and given a use classification in the regulations, but the regulations do state that "all other streams, named and unnamed, which have not been specifically noted shall be classified for fish and aquatic life, recreation, irrigation, and livestock watering and wildlife uses." It should be noted that none of the streams on the ORR are classified for domestic water supply; therefore, the SDWA MCLs, as incorporated into TDEC's standards for surface waters classified for domestic water supply, are not ARARs for any of the surface waters on ORR.

As part of the federal requirement for a triennial review of state water quality standards, the TDEC Division of Water Pollution Control has promulgated amendments to Chaps. 1200-4-3 and 1200-4-4 of the Rules of the TDEC that incorporate all of the current EPA Region IV WQC for noncarcinogens (effective date July 1995). The TDEC WQC for carcinogens differ from those of EPA Region IV in that they are based on a risk of 10^{-5} rather than the 10^{-6} risk. Additional criteria for protection of recreational uses include a WQC for consumption of aquatic organisms alone. EPA Region IV has also revised WQC for the protection of freshwater aquatic life based on current toxicity and bioaccumulation data for aquatic organisms, and TDEC has adopted these WQC. Table 4.2 lists TDEC ambient WQC for the use classifications given to Bear Creek and its tributaries; these levels are potential ARARs for the clean up of regulated surface waters in the BCV OU. When the designated use classification requires protection of aquatic life or when environmental factors rather than human health are being considered at a remedial action site, a WQC for the protection of aquatic life that is more stringent than the WQC for human health may be relevant and appropriate for CERCLA clean up.

EPA's criteria for metals were administratively stayed (60 *FR* 22228, May 4, 1995) because EPA has decided to change the way the metals standards were established, from basing standards on "total recoverable metal" to basing them on "dissolved metals" in a surface water body. When this revised approach is promulgated by TDEC, the WQC for aquatic life will more closely approximate the bioavailable fraction of metal in the water column. Until that time, EPA has presented freshwater criteria conversion factors for the calculation of dissolved freshwater aquatic life criteria for metals (60 *FR* 22229). The EPA Region IV Water Quality Standards Unit does

have available factors for converting the "total recoverable" criteria to the "dissolved" criteria. Aquatic WQC for metals calculated by this method might be considered as potential ARARs, rather than metals criteria based on the total recoverable method (the method TDEC used in setting its current WQC), based on TDEC Rules Chap. 1200-4-3-.05(9), which states "The criteria shall be applied using the total recoverable method, unless otherwise specified, or the Division conducts or approves a chemical speciation study which determines the bioavailable or toxic fraction of a specific chemical."

There is also a narrative, but not numeric, AWQC for recreation that protects humans from body contact with toxic substances (TDEC 1200-4-3-.03(4)(h)); this could include contact with contaminated sediments during capture and subsequent consumption of fish or shellfish.

However, there are no numeric criteria set in the TDEC regulations for body contact to contaminants in either water or sediments, nor is there a method presented to derive concentrations protective for body contact, thus there are no chemical-specific ARARs for body contact.

4.1.3 Soil/sediment

There are no chemical-specific ARARs specifically for contaminants in soil or sediment. Chemical-specific ARARs and TBC guidance for soil are usually invoked as action is taken to remediate the soil. The particular action itself invokes the ARAR/TBC guidance. Thus, ARARs for soil/sediment will be analyzed and discussed as remedial alternatives are screened in the feasibility study.

4.2 LOCATION- AND ACTION-SPECIFIC ARARs

A number of sensitive resources (i.e., wetlands, floodplains, endangered/threatened plants and wildlife and their habitats, undiscovered archaeologic resources) may be or have been identified in BCV, and remedial actions that would impact those resources will invoke a number of ARARs. These location-specific ARARs, as well as the action-ARARs specific to each remedial alternative will be analyzed and discussed as alternatives are screened in the feasibility study.

4.3 REFERENCES

- Environmental Protection Agency (EPA). 1986. *Guidelines for Groundwater Classification under the EPA Groundwater Protection Strategy*, Final Draft, EPA Office of Groundwater Protection, Office of Water, November.
- Etnier, E.L., L.M. Houlberg, A.M. Vance and L.B. Cobb. 1996. *Applicable or Relevant and Appropriate Requirements for Remedial Action at the Oak Ridge Reservation, a Compendium of Major Environmental Laws*, ES/ER/TM-1/R3, Lockheed Martin Energy Systems, Inc., Environmental Restoration Division, January.

5. BASELINE HUMAN HEALTH RISK ASSESSMENT SUMMARY

This section of the RI Report provides a summary of the results of the BHHRA including the selection of COPCs, the exposure assessment, the toxicity assessment, and the risk characterization (and identification of chemicals of concern). Details on each of these areas can be found in Appendix F of this report.

5.1 INTRODUCTION

The overall objective of the BHHRA evaluation process is to characterize potential risks and provide information necessary for making remediation decisions. A quantitative analysis of the SRCs found in various media is used to characterize the potential risks to human health associated with exposure to these contaminants. The results of the BHHRA are used to (1) document and evaluate risks to human health, (2) determine the need for remedial action, (3) determine chemical concentrations protective of current and future human receptors, and (4) support the FS selection and comparison of various remedial alternatives (Energy Systems 1993a).

This report follows the organization of the standard risk assessment processes described in *Risk Assessment Guidance for Superfund* (RAGS) (EPA 1989a) and in the *Supplemental Guidance to RAGS: Region 4 Bulletins; Human Health Risk Assessment* (EPA 1995). First, the data for the various media are evaluated to determine data useability for risk assessment, then SRCs to be considered in the BHHRA are identified. This process is referred to as the selection of COPCs, and at this point, the representative concentrations for those contaminants to be included in the risk assessment are determined. Next, an assessment of the exposure potential is performed, and exposure pathways/routes are identified. Subsequently, exposure is estimated quantitatively, and the toxicity of the COPCs is appraised. The results of the exposure and toxicity assessments are combined to quantify potential risks, which are summarized in the risk characterization section (Sect. 5.5).

5.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

The following discussion addresses the data evaluation steps necessary to (1) aggregate the data to best represent the BHHRA source areas/FAs in BCV, in terms of the human health risk assessment; (2) identify a set of SRCs that may significantly contribute to human health risks/hazards for each FA in BCV; and (3) report analyte concentrations that are representative of the COPCs and of acceptable quality for use in this quantitative BHHRA.

5.2.1 Data Collection and Compilation Considerations

For purposes of this BHHRA, six FAs were considered; an FA encompasses all media in and immediately downgradient of an area. The six FAs include: (1) the S-3 Pond area, (2) the BYBY area, (3) the OLF area, (4) the SL 1 area, (5) the BCBG area, and (6) the Floodplain (western BCV) area (i.e., the area starting just west of BCBG and ending near Hwy. 95). For the evaluation of groundwater and surface water, the BYBY, OLF, and SL 1 areas are considered as a single FA. The Disposal Area Remedial Action Solids Storage Unit (DARA), OLF Storage Pad, Bear Creek Road Debris Burial, and Creekside Debris Burial areas are evaluated separately from the six FAs listed in this paragraph (because of their locations and because they contain only one potentially contaminated medium, soil). In addition to the source areas/FAs listed previously, this BHHRA also evaluates surface water, FPSS,

and groundwater on a valley-wide basis (i.e., location-by-location and well-by-well). Detailed source area descriptions, history, operational information, and current conditions are provided in Sect. 3 and Appendix F, Sect. F.3.1.

The data and information presented and used in this BHHRA include an extensive database of environmental data derived from historical analytical data, historical inventories, and recent RI field activities (Energy Systems 1993b, 1994, 1995). A summary of the current and historical data available and the data quality assessments for the BCV data is provided in Sect. 3.2; specifics in terms of the data used in the BHHRA are provided in Appendix F, Sect. F.2.1. In brief, groundwater, surface water, spring water, BCBG leachate, fish, soil, floodplain soil, sediment, and historical inventoried soil and waste inventory data were available and evaluated in this BHHRA.

5.2.2 Data Evaluation Considerations and Preparation

All data (soils, surface water, groundwater, etc.) were aggregated in this BHHRA to best represent the source areas in terms of a human health risk evaluation. Some data (surface water, groundwater, and FPSS) were also evaluated on a location-by-location/well-by-well basis to provide the reader and the FS with valley-wide (and location-specific) risk information.

SRCs for the BCV RI, including the BHHRA, were determined for each medium for each sampling location in BCV; the details of this process (i.e., identifying SRCs) are described in Sect. 3.2. In general, SRCs are determined by collecting available historical and new data, evaluating the quality of the data, identifying detected analytes, screening the analyte concentrations against appropriate background concentrations, and applying additional sample-specific weight-of-evidence (e.g., best professional judgment) criteria. The identified BCV SRCs (refer to Sect. 3.2) were evaluated in this BHHRA.

5.2.3 Data Evaluation and Preparation

Appendix F (Sect. F.2.3) provides specific information on how this BHHRA addresses (1) essential nutrients (Ca, Mg, Fe, K, Na, Cl, P, and I), (2) detection criteria, (3) detection limits (e.g., one-half of the detection limit used for nondetected nonradionuclides; minimum detectable activities and uncertainties considered for radionuclides), (4) statistical calculations, (5) tentatively identified compounds, and (6) specific chemical and radiological assumptions and assignments (e.g., Cr was evaluated as Cr-VI). Note: gross alpha and gross beta data were used to depict extent of contamination in this RI (refer to Sect. 3.2); however, these data were not evaluated in the BHHRA. Measured isotopic radiological data were evaluated quantitatively in this BHHRA and were used to define the nature of the radiological contamination in this RI.

Section F.2.3 in Appendix F also provides specific details on how the various data were aggregated for each of the source areas/FAs in the BHHRA. For example, groundwater data were selected and aggregated to best represent each FA based on high SRC concentrations (i.e., groundwater data from the most contaminated wells were used to represent each source area). For example, the S-3 Ponds groundwater aggregate included data from GW-100, -101, -103, -122, -127, -236, -243, -244, -245, -246, -247, -276, -277, -309, -346, -526, -537, -615, and -618; the S-3 Ponds BHHRA surface water aggregate used data from SS-1, BCK-12.36, BCK-S3, and NT-1.

5.2.4 Screening Site-related Contaminants Against Preliminary Remediation Goals

A preliminary remediation goal (PRG) is a concentration derived from a specific excess cancer risk level (carcinogenic PRG) or a hazard quotient (HQ) (noncarcinogenic PRG). PRGs are (1) chemical-specific concentration goals for a specific land use and medium (e.g., residential use of groundwater) and (2) risk-based screening levels (i.e., initial concentration guidelines protective of human health) that are based on readily available information and comply with ARARs (EPA 1991a).

The objective of the PRG screen is to identify those SRCs most likely to contribute significantly to human health carcinogenic risks and noncarcinogenic hazards (EPA 1995, 1989a). For this BHHRA, SRCs with maximum detected concentrations less than the chemical-specific PRG for residential uses of water and soil (i.e., risks $< 1.0\text{E-}06$ and/or HQ < 0.1) are not considered to be COPCs in accordance with EPA guidance (EPA 1995). PRGs were taken from *Preliminary Remediation Goals for Use at the U.S. Department of Energy Oak Ridge Operations Office* (Energy Systems 1996a). In addition, if an analyte was detected $< 5\%$ of the time (e.g., frequency of detection $< 1/20$) at a particular sampling location, it was not considered a COPC in this BHHRA (EPA 1989a, Energy Systems 1996b).

5.2.5 Summary of Chemicals of Potential Concern

Approximately 182 SRCs were identified as COPCs in this BHHRA. Appendix F, Tables F.14–F.39, provides the lists of human health COPCs and summary statistics for each COPC in each medium for all BCV source areas/FAs and for each groundwater and surface water sampling location. The quantitative COPCs have EPA-approved or -suggested toxicity values and therefore can be evaluated quantitatively in terms of risks/hazards to human health in this BHHRA. Approximately 84 of the COPCs could not be evaluated quantitatively in this BHHRA due to the unavailability of EPA-approved toxicity values for these analytes. The 95% upper confidence limit (UCL) on the mean concentrations were calculated for the COPCs and used as the representative concentrations in this BHHRA (EPA 1989a), except where specifically noted in Appendix F.

5.2.6 Identification of Uncertainties in the Selection of COPCs and Estimation of Representative Exposure Concentrations

The data evaluation process associated with the selection of COPCs involves compliance with established procedures and guidance as well as the development of decisions and assumptions based on historical information, disposal records, and best professional judgment concerning the data; uncertainties are associated with each of these factors. Uncertainty can be introduced in the data aggregation process of estimating representative exposure concentrations in the BCV media; frequency of detection, detection limits, and data distribution type can contribute to this uncertainty. Background concentrations and PRGs used to screen the data are subject to uncertainty, and uncertainties exist in the SRC concentrations in the BCBGs, for example, because they are based on historical and potentially incomplete inventory records and personnel interviews. Appendix F, Sect. F.2.6, provides a detailed discussion of the uncertainties associated with the selection of human health COPCs.

5.3 EXPOSURE ASSESSMENT

The exposure assessment combines information concerning site characteristics and site-related data/information to develop the exposure assumptions and quantify exposures (i.e., intakes) to be used in characterizing potential human health risks and hazards in this BHHRA. The objectives of the exposure assessment include determining/estimating the magnitude, frequency, and duration of potential human exposure to site-related COPCs by (1) characterizing the exposure setting, (2) identifying potential receptors, (3) identifying exposure pathways, and (4) quantifying exposures. Appendix F, Sect. F.3, presents more detailed discussion on the BCV BHHRA Exposure Assessment. The following text provides a brief summary of the BCV BHHRA Exposure Assessment.

5.3.1 Characterization of Exposure Setting

Appendix F, Sect. F.3.1, provides a characterization of the BCV source area/FA exposure settings.

5.3.2 Identification of Exposure Pathways and Scenarios

As indicated in the BCV Conceptual Site Model for Human Health (Fig. 5.1), several exposure scenarios were selected for evaluation in this BHHRA. The exposure scenarios are designated as either current or future land use. The current exposure scenario evaluates those exposure pathways that are considered to occur or have the potential to occur; the future exposure scenarios evaluate exposure pathways that are not currently occurring but have the potential to occur at a later date. In this BHHRA, current measured (or estimated) contaminant concentrations were used to represent concentrations in the evaluation of both current and future exposures.

Four hypothetical land use scenarios were evaluated in this BHHRA: (1) a current “unprotected” maintenance worker, (2) a future industrial worker, (3) a future resident, and (4) a future recreational receptor [evaluated for the Floodplain (western BCV) area only]. For the actual current land use conditions in BCV, no completed exposure pathways (nor receptors) have been identified for exposure to the BCV media for these four land uses.

Currently, most areas in BCV are auxiliary facilities and historical Y-12 Plant disposal sites/areas. Therefore, personnel visiting or working in BCV have limited exposures and include “maintenance” or “sampler” workers, fully protected from exposure to contamination via adherence to Health and Safety Plans, the use of protective equipment when necessary, and Occupational Safety and Health Administration (OSHA)/SARA training. To be conservative in terms of protecting human health, and upon request of EPA Region IV (as a means of evaluating a current worst case scenario), potential risks from exposures to an “unprotected” maintenance worker were evaluated in this BHHRA. The exposure pathways/routes evaluated for this receptor included incidental ingestion of soil, inhalation of dust/particulates and VOCs in soil, dermal contact with the soil, and external exposure to radionuclides in the soil. The exposure parameters used in this site-specific BCV maintenance worker assessment can also be considered representative of other potential short-term exposures in BCV (e.g., a trespasser).

Risks from exposure to BCV COPCs were evaluated for future industrial land use. The exposure pathways/routes evaluated included incidental ingestion of soils, inventoried soils, and inventoried wastes; inhalation of dust/particulates and VOCs in soils, inventoried soils, and inventoried wastes;

Fig. 5.1. BCV conceptual site model for human receptors.

dermal contact with the soils, inventoried soils, and inventoried wastes; and external exposure to radionuclides in the soils and inventoried wastes and soils.

Risks were evaluated for a future recreational land use for the Floodplain (western BCV) area only (i.e., the area starting just west of BCBG and ending near Hwy 95). Exposure pathways/routes evaluated for the future recreational land use included incidental ingestion of soil (including sediment), incidental ingestion of surface water (including spring water) while swimming, inhalation of dust/particulates and VOCs in soil, dermal contact with soil, dermal contact with surface water while swimming, external exposure to radionuclides in the soil, inhalation of VOCs in surface water while swimming, and ingestion of fish.

A reasonable maximum exposure estimate of the risk to future human receptors in BCV was determined using a residential exposure scenario. Because the BCV CA is within the Y-12 Plant boundaries of the ORR and because the area between the BCBG and the S-3 Ponds will be evaluated in the BCV FS as industrial land use only (for current and for future land uses), such a conservative residential scenario is unlikely. However, the intent of this residential evaluation is to (1) provide managers with a conservative estimate of potential risks to future receptors from exposure to contaminants in BCV media, (2) be consistent with the NCP, and (3) provide for comparisons across DOE facilities. The routes/pathways of exposure evaluated for the residential exposure scenario included dermal contact with the soil/sediments, inventoried soils, and inventoried wastes; dermal contact with groundwater, leachate, and surface water (including spring water) while showering; incidental ingestion of the soil/sediments, inventoried soils, and inventoried wastes; ingestion of groundwater, leachate, and surface water/spring water; inhalation of dust/particulates and VOCs in soil, sediments, inventoried soils, and inventoried wastes; inhalation of VOCs from groundwater, leachate, and surface water for all indoor uses; external exposure to radionuclides in the soil/sediments, inventoried soils, and inventoried wastes; and ingestion of homegrown leafy vegetables.

5.3.3 Quantification of Exposure

In the context of risk to human health, exposure is defined as the direct contact of a person with a chemical or physical agent. To quantify exposure, one must determine exposure concentrations (refer to Sect. 5.2.5) and calculate chemical intakes for the various exposure pathways identified for the site. The exposure concentrations and potential exposure pathways for the BCV media are considered quantitatively in this section.

Exposure to contaminants can be evaluated quantitatively by developing the chronic daily intake of a chemical, also termed “intake” (or “dose” for exposure to radionuclides). The intake is the amount of a contaminant that an individual takes into his/her body per day via ingestion, inhalation, or dermal contact, and it is the total exposure to a radionuclide. To calculate the intake, one evaluates the exposure concentration in the context of the scenario, exposure pathway, and chemical-specific exposure variables, such as duration of exposure and intake rate. Specific information regarding the quantification of exposure and calculation of the intake for the four land uses evaluated in this BHHRA is presented in Appendix F, Sect. F.3.3. In general, the intake is determined using the following equations:

$$\text{Intake (nonradionuclides)} = (\text{CS} \times \text{IR} \times \text{EF} \times \text{ED}) / (\text{BW} \times \text{AT}),$$

$$\text{Intake (radionuclides)} = \text{CS} \times \text{IR} \times \text{EF} \times \text{ED},$$

where:

Intake	=	chronic daily intake (for nonradionuclides) and = intake or dose (for radionuclides),
CS	=	contaminant concentration in the medium,
IR	=	intake rate,
EF	=	exposure frequency,
ED	=	exposure duration,
BW	=	body weight,
AT	=	averaging time.

The quantification of exposures to the hypothetical future industrial, recreational, and residential receptors uses EPA-approved default parameters (EPA 1989a, 1989b, 1991b, 1995). The quantification of exposure to the hypothetical "unprotected" maintenance worker uses site-specific information (specific to current ongoing activities in BCV) to determine the appropriate exposure parameters to use in estimating potential risks (and hazards) in BCV for this receptor. The majority of the current activities in BCV include groundwater well maintenance, repairs, drilling, and inspection; quarterly groundwater sampling; Biological Monitoring and Abatement Program sampling activities; mowing; cap repairs; surface water (including tributaries) sampling; biota sampling; and site inspections. Personal communications with representatives from these different organizations resulted in estimated exposure frequencies from 24 to 1000 hours per year. An average of all the exposure frequencies for these activities of 286 hours/year (i.e., 36 days/year) was used to represent the exposure frequency of the "unprotected" maintenance worker in this BHHRA. The exposure parameters used in the maintenance worker assessment will also be considered representative of other potential short-term exposures in BCV (e.g., a trespasser).

5.3.4 Identification of Exposure Assessment Uncertainties

Quantification of exposure provides an estimate of the chemical intake for various exposure pathways identified at the site. Several uncertainties associated with the various components of the exposure assessment include uncertainties about the exposure pathway equations, the applicable routes of exposure, exposure parameters (e.g., intake rates), land use scenarios, and sampling and analysis of the media. In this BHHRA, the assumptions used are consistent with EPA-approved parameters, which are assumed to be representative of the potentially exposed populations (EPA 1989a). For the site-specific BCV risk analyses, uncertainty is associated with the estimation of the frequency of exposure for the potential site-specific maintenance worker scenario; this exposure frequency parameter is variable (it depends on what specific BCV activity is being performed, e.g., cap maintenance or groundwater sampling). The reader should refer to Appendix F, Sect. F.3.4, for a more detailed discussion of the uncertainties associated with quantification of exposure to the human health COPCs in BCV.

5.4 TOXICITY ASSESSMENT

The purpose of the toxicity assessment is to evaluate the potential for the COPCs to cause adverse health effects in exposed individuals. Where possible, it provides an estimate of the relationship between the extent of exposure to a particular COPC and the increased likelihood of severity of adverse health effects as a result of that exposure, relative to a baseline. The toxicity assessment generally involves two steps: (1) determining whether exposure to an agent can cause an increase in the incidence of a particular health effect (and whether that health effect will occur in humans) and

(2) characterizing the relationship between the received dose of the contaminant and the incidence of adverse health effects in exposed populations.

5.4.1 Toxicity Information and EPA Guidance for Noncarcinogens

Noncarcinogenic effects are evaluated by comparing an exposure experienced over a specified time period (e.g., 30 years) with a reference dose (RfD) [or reference concentration (RfC)] derived for a similar exposure period. To evaluate the noncarcinogenic effects from exposure to COPCs in the BCV media, an HQ [the ratio of the exposure dose (i.e., intake) to the RfD] is calculated for each COPC. To estimate the potential hazards to human health from exposure to all COPCs in a particular exposure pathway, a total pathway hazard index (HI) is determined by summing the individual analyte HQs within a pathway (EPA 1989a). In addition, an overall cumulative HI can be determined for each medium (for each land use scenario) by summing the HQs from all COPCs across all pathways.

The noncarcinogenic HQ assumes that, below a given level of exposure (i.e., the RfD), even sensitive populations are unlikely to experience adverse health effects. If the exposure dose exceeds this threshold [i.e., if intake/RfD exceeds one (1.0)], there may be concern for potential noncarcinogenic health effects. The level of concern does not necessarily increase linearly as the HQ approaches or exceeds unity because the HQ is not a percentage or probability. The RfDs used in this BHHRA are provided in Appendix F, Table F.44.

5.4.2 Toxicity Information and EPA Guidance for Carcinogens

For carcinogens, risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the carcinogen (i.e., the term “incremental” refers to excess individual lifetime cancer risk). Cancer risk from exposure to contamination is expressed as excess cancer risk—cancer incurred in addition to normally expected rates of cancer development. An excess cancer risk of $1.0\text{E-}06$ indicates that each person has a one in one million excess chance to incur cancer from exposure to this contamination level over a 70-year lifetime.

To evaluate the carcinogenic risk from exposure to BCV COPCs in the various media, the risk is calculated for each COPC by multiplying the exposure dose (i.e., intake and/or dose) by the slope factor, which is a chemical-specific value based on carcinogenic dose-response data. To estimate the potential risk to human health from exposure to all COPCs in a particular exposure pathway, a total pathway risk is determined by summing the individual analyte risks within a pathway (EPA 1989a). In addition, an overall cumulative risk can be determined for each medium (for each land use scenario) by summing the risks from all COPCs across all pathways.

Excess cancer risks between $1.0\text{E-}06$ and $1.0\text{E-}04$ are considered to be within EPA’s range of concern (also referred to as the EPA target risk range) (EPA 1989a); risks within this target risk range are consistent with the clean-up goals of CERCLA; and risks above $1.0\text{E-}04$ are considered regulatorily unacceptable by the EPA (EPA 1989a). The slope factors used in this BHHRA are provided in Appendix F, Tables F.45 and F.46. (Appendix F, Sects. F.4.3 and F.4.4 provide specific information concerning the toxicity values used in the evaluation of dermal exposures, and for exposures to PAHs and dioxins.)

5.4.3 Chemicals Without EPA Toxicity Values

Slope factors and RfDs are not currently available for all COPCs in BCV because their carcinogenic and/or noncarcinogenic effects have not yet been determined. These chemicals may

contribute to carcinogenic and noncarcinogenic effects from exposure to the contaminated BCV media, but their effect cannot be quantified at the present time. In addition, epidemiological studies have indicated that several chemicals are not carcinogenic; consequently, these species do not have slope factors. A qualitative summary of the available information for many of these COPCs can be found in *Toxicity Profiles for Use in Hazardous Waste Risk Assessment and Remediation* (BEIAS 1995). EPA Region IV approved the use of previously withdrawn toxicity values for the following chemicals: 1,1,1-TCA, TCE, and PCE; therefore, these COPCs were evaluated quantitatively in this BHHRA.

5.4.4 Toxicity Information/Profiles for BCV Chemicals of Concern

The chemical-specific information in Appendix F, Sects. F.4.7.1–F.4.7.4, provides general information as well as a chemical-specific discussion about health effects related to the chemicals of concern identified in the BHHRA; both carcinogenic and noncarcinogenic health effects are considered. In addition, toxicity profiles are also provided for a selection of BCV COPCs that can be evaluated only qualitatively due to the absence of toxicity values. The majority of the information pertaining to specific contaminants was taken from *Toxicity Profiles for Use in Hazardous Waste Risk Assessment and Remediation* (BEIAS 1995).

5.4.5 Methodology and Uncertainties Related to Toxicity Information

The methodology used in developing a noncarcinogenic toxicity value (RfD or RfC) involves identifying a threshold level below which adverse health effects are not expected to occur. The uncertainty associated with the toxicity factors for noncarcinogens is measured by the uncertainty factor, the modifying factor, and the confidence level. A two-part evaluation exists for assessing the carcinogenic potential of a chemical: (1) the likelihood that a chemical is a carcinogen (i.e., a weight-of-evidence assessment) and (2) the quantitative dose-response relationship (i.e., SF). Uncertainties occur with each evaluation, are chemical-specific, and are embedded in the carcinogenic toxicity values. In addition, uncertainties exist in evaluating the carcinogenic and noncarcinogenic effects for COPCs for which toxicity values are not yet available. These chemicals may contribute to human health risks and hazards, but their effects cannot be quantified at the present time. Details of the methodologies and uncertainties associated with the toxicity information can be found in Appendix F, Sect. F.4.6.

5.5 RISK CHARACTERIZATION

The purpose of the risk characterization is to integrate the information presented in the exposure and toxicity assessments summarizing the potential risks to human health. Potential carcinogenic effects are characterized by estimating the probability that an individual will develop cancer over a lifetime from projected intakes (and exposure) and chemical-specific dose-response data. Potential noncarcinogenic effects are characterized by comparing projected intakes of contaminants to toxicity threshold values. The numerical risk and HQ estimates presented in this section must be interpreted in the context of the uncertainties and assumptions associated with the risk assessment process and with the data upon which the risk estimates are based (refer to Sects. 5.2.6, 5.3.4, 5.4.5, and 5.5.5).

This section provides the reader with a summary of the BCV BHHRA results. Complete details (i.e., risk and HQ results for all source areas/FAs, exposure media, exposure pathways/routes, sampling locations, and land uses) are provided in Appendix F, Sects. F.5 and F.6 (Tables F.47–F.88).

5.5.1 General Considerations for Evaluating Risks/Hazards to Human Health

5.5.1.1 EPA guidance for carcinogens and noncarcinogens

The constituents detected in the BCV media were evaluated within the context of EPA-approved guidelines (EPA 1989a, 1995), which specify three categories for carcinogenic risk [risk < 1.0E-06, no concern; risk between 1.0E-06 and 1.0E-04, range of concern (or target risk range); and risk $\geq$ 1.0E-04, regulatorily unacceptable] and two categories in terms of noncarcinogenic toxicity (HI < 1.0, no concern; and HI $\geq$ 1.0, concern). Sections 5.4.1 and 5.4.2 provide additional EPA guidance concerning the calculations of risks and HQs.

5.5.1.2 Criteria for identification of chemicals of concern

Chemicals of concern are defined (EPA 1995) for a given medium as contaminants with individual risks $\geq$ 1E-06 and/or individual HQs $\geq$ 0.1 within a land use scenario with a total cumulative risk $\geq$ 1E-04 and/or a total cumulative HI $\geq$ 1.0, respectively. In this BHHRA, an exposure pathway is identified as being of concern if the total pathway risk is $\geq$ 1E-04 or if the total pathway HI is $\geq$ 1.0. Based on this guidance, specific COCs are identified in this assessment for each source area/FA, medium, and land use scenario.

5.5.2 Current Land Use Conditions

5.5.2.1 “Unprotected” maintenance worker

The current hypothetical “unprotected” maintenance worker scenario was evaluated for each of the source areas/FAs in BCV. EPA Region IV has requested that this “unprotected” worker be evaluated as part of the BCV BHHRA, although current workers are fully protected from exposure to contamination via adherence to Health and Safety Plans, the use of protective equipment when necessary, and OSHA/SARA training. Risks to this receptor are also considered to be representative of other short-term exposures in BCV (e.g., a trespasser).

Exposures to COPCs in uncapped soils (e.g., BCV RI soil samples taken adjacent to capped areas), hot-spot soils (e.g., soils identified in the BYBY as highly contaminated soils), DARA and OLF storage pad inventoried soils, and creek floodplain soils were evaluated for this receptor using current contaminant concentrations. Section 5.3.2 discusses the exposure pathways/routes evaluated for this receptor.

The COCs identified for the current “unprotected” maintenance worker are listed by source area/FA in Table 5.1. The table also presents the frequency of detection for each COC, the 95% UCL exposure concentration, and the risk and HQ results for only those exposure pathways/routes for which the COC is a COC.

Three COPCs were identified as COCs ($^{234,235,238}\text{U}$) for this receptor. The exposure pathways/routes of concern include incidental ingestion of soil, inhalation of dust/soil, and external exposure to the radionuclides in the soil. The only medium of concern is hot-spot soil in the BYBY and in the BCBG D-East areas.

In addition to the source area/FA evaluations, because of the large distances between floodplain soil transects (i.e., soil sampling locations), an evaluation of the risks/HQs for each transect was performed; no COCs were identified in this location-specific evaluation.

5.5.3 Future Land Use Conditions

5.5.3.1 Industrial worker

The future hypothetical industrial worker scenario was evaluated for each of the source areas/FAs in BCV using current measured (and estimated) contaminant concentrations. Exposures to COPCs in uncapped soils, hot-spot soils, DARA and OLF storage pad inventoried soils, creek floodplain soils, OLF soils-in-place capped soils, and capped waste inventories (i.e., the BCBG waste inventory and the S-3 Ponds soil/sediment/sludge waste inventory) were evaluated for this receptor. Section 5.3.2 provides a discussion of the exposure pathways/routes evaluated for this receptor. (Note, any exposure to the contaminants in the buried waste in the BCBG is considered to be unacceptable in terms of risks/hazards to human health. The uncertainty in the estimations of the contaminant concentrations in the BCBG wastes is high, although unquantifiable; therefore, the accuracy of the risks/HQs is difficult to quantitate. An attempt to quantitate risks/HQs has been made for future hypothetical industrial exposures to the buried wastes in the BCBG.)

The COCs identified for the future industrial worker are listed by source area/FA in Table 5.2. Thirty-three COCs were identified for this receptor. The exposure pathways/routes of concern include incidental ingestion of soil (including inventoried wastes/soils), inhalation of dust/soil (and VOCs), dermal contact with soils, and external exposure to the radionuclides in the soil. Several soil-type media of concern [e.g., waste inventory (soils) and hot-spot soils] were identified (refer to Table 5.2 for details). No COCs were identified in the location-specific floodplain soils evaluation for this receptor.

5.5.3.2 Recreational receptor

The future hypothetical recreational scenario was evaluated for the Floodplain (western BCV) area (i.e., the area starting just west of the BCBG and ending at Hwy 95) using current contaminant concentrations. Creek floodplain soils and sediments, surface/spring water, and fish were the media evaluated for the recreational receptor. Section 5.3.2 provides a discussion of the exposure pathways/routes evaluated for this receptor.

The COCs identified for the future recreational receptor for the Floodplain (western BCV) area are listed in Table 5.3. Three COCs (mercury, PCB-1254, and PCB-1260 in the BCV fish fillets) were identified for the ingestion of fish exposure pathway/route. No COCs were identified in the location-specific floodplain soils and sediments evaluation for this receptor.

5.5.3.3 Resident

The reasonable maximum exposure scenario for a future hypothetical resident was evaluated for each of the source areas/FAs in BCV using current measured (and estimated) contaminant concentrations. Exposures to COPCs in the uncapped soils, hot-spot soils, DARA and OLF Storage Pad inventoried soils, creek floodplain soils and sediments, OLF soils-in-place capped soils, capped waste inventories, BCBG leachate, BCV groundwater (for each source area/FA aggregate and well-by-well), and BCV surface/spring water (for each source area/FA aggregate and location-by-location) were evaluated for this receptor. Section 5.3.2 presents a discussion of the exposure pathways/routes evaluated. (Note, any exposure to the contaminants in the buried waste in the BCBG is considered to be unacceptable in terms of risks/hazards to human health. The uncertainty in the estimations of the contaminant concentrations in the BCBG wastes is high, although unquantifiable; therefore, the

accuracy of the risk/HQs is difficult to quantitate. An attempt to quantitate risks/HQs has been made for future hypothetical residential exposures to the buried wastes in the BCBG.)

Source areas/functional areas. The COCs identified for the future resident are listed by source area/FA in Table 5.4. A total of 94 COCs were identified for this receptor. All exposure pathways/routes and media evaluated are of concern for this receptor (refer to Table 5.4). Section 5.5.6 presents additional risk characterization information concerning the BCV source areas/FAs.

In addition, for each of the source areas/FAs in BCV, risks, HQs, and COCs from consumption of contaminated homegrown leafy vegetables were evaluated, using estimated vegetable concentrations modeled from the current measured (and estimated) contaminant concentrations in soil and water. Seventy-nine quantitative COPCs could be evaluated for the vegetable ingestion exposure pathway/route, and 70 of the 79 were identified as COCs for this pathway. Appendix F, Sect. F.5.3.4 and Table F.84, provides details of this evaluation.

Floodplain soil and sediment (by location). Several COCs were identified in the location-specific FPSS for the residential receptor. For the floodplain soils, beryllium, PCB-1260, and $^{234,235,238}\text{U}$ were identified as COCs for Transect-04 (located along NT-8 and across Bear Creek at BCBG) and PCB-1254 was identified as a COC for sampling location SP04 (located near Hwy 95). For the Bear Creek sediments: As, Be, Cd, Mn, Hg, Ni, benzo(a)pyrene, PCB-1260, and $^{235,238}\text{U}$ were identified as COCs for sampling location SD02 (in Bear Creek near NT-1); Sb, As, Cd, Cr, Mn, Hg, V, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, PCB-1254, PCB-1260, and $^{234,235,238}\text{U}$ were identified as COCs for SD04 (in tributary NT-3); As, Cd, Cr, and Mn were identified as COCs for SD07 (near NT-4); As, Ba, and Mn were identified as COCs for SD08 (in NT-6); beryllium, PCB-1260, and $^{235,238}\text{U}$ were identified as COCs for SD09 (in NT-8); As, Mn, and PCB-1254 were identified as COCs for SD10 (between NT-8 and NT-9); As, Cr, Mn, and PCB-1254 were identified as COCs for SD11 (near NT-11); and As, Be, Cd, Mn, ^{228}Th , and $^{234,235,238}\text{U}$ were identified as COCs for SD14 (near NT-2) for this receptor. The reader should note that only two of these sediment sampling locations, SD10 (in Bear Creek between NT-8 and NT-9) and SD11 (in Bear Creek near NT-11), are located in the Floodplain (western BCV) area (i.e., are west of the BCBG).

For the Bear Creek sediments: As, Be, Cd, Mn, Hg, Ni, benzo(a)pyrene, PCB-1260, and $^{235,238}\text{U}$ were identified as COCs for sampling location SD02 (in Bear Creek near NT-1); Sb, As, Cd, Cr, Mn, Hg, V, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, PCB-1254, PCB-1260, and $^{234,235,238}\text{U}$ were identified as COCs for SD04 (in tributary NT-3); As, Cd, Cr, and Mn were identified as COCs for SD07 (near NT-4); As, Ba, and Mn were identified as COCs for SD08 (in NT-6); beryllium, PCB-1260, and $^{235,238}\text{U}$ were identified as COCs for SD09 (in NT-8); As, Mn, and PCB-1254 were identified as COCs for SD10 (between NT-8 and NT-9); As, Cr, Mn, and PCB-1254 were identified as COCs for SD11 (near NT-11); and As, Be, Cd, Mn, ^{228}Th , and $^{234,235,238}\text{U}$ were identified as COCs for SD14 (near NT-2) for this receptor. The reader should note that only two of these sediment sampling locations, SD10 (in Bear Creek between NT-8 and NT-9) and SD11 (in Bear Creek near NT-11), are located in the Floodplain (western BCV) area (i.e., are west of the BCBG).

Groundwater and surface water (by location). Figures 5.2 through 5.7 include a graphical representation of the results of the location-specific residential risk and HQ evaluations of the BCV groundwater and surface water. COPC-specific percent contributions to the total residential risk and HII for each sampling location are provided in Appendix F, Tables F.85 – F.88. include a graphical representation of the results of the location-specific residential risk and HQ evaluations of the BCV

groundwater and surface water. COPC-specific percent contributions to the total residential risk and HI for each sampling location are provided in Appendix F, Tables F.85-F.88.

Figure 5.2 shows the BCV groundwater locations with a total cumulative risk (i.e., summed risks from all COPCs identified per sampling location across all appropriate exposure pathways) greater than $1.0\text{E-}06$; colors are provided to indicate whether the risk at each groundwater location is driven by inorganic, organic, or radiological COPCs. Figure 5.3 shows the BCV groundwater locations with a total risk greater than $1.0\text{E-}04$, and Fig. 5.4 shows the groundwater locations with a total HI greater than 1. Similarly, Fig. 5.5 shows the BCV surface water locations with a total risk greater than $1.0\text{E-}06$; Fig. 5.6 shows the surface water locations with a total risk greater than $1.0\text{E-}04$; and Fig. 5.7 shows the surface water locations with a total HI greater than 1.

From the results of the location-specific surface water/spring water residential risk characterization, of particular interest is the risk and HQ information at a potential exposure point (the integration point) in the Maynardville exit pathway just west of the most western BCV source area/FA (i.e., aggregate BCK-9.4/SS-5 just west of BCBG). For this surface water location (BCK-9.4/SS-5), boron, fluoride, nitrate, and uranium were identified as COCs for this receptor.

The location-specific groundwater risk characterization results for the data aggregate of wells in Picket A (i.e., the set of groundwater wells just west of BCBG) show no COCs (total risk = $2.6\text{E-}05$ and total HI = 0.30). However, for GW-684 (an individual well in the Picket A aggregate), two COCs were identified (nitrate and uranium metal: total well HI = 1.0). Furthermore, no COCs were identified for the data aggregate of Picket W wells (total risk = $5.5\text{E-}05$ and total HI = 0.82) located in the Maynardville exit pathway west of Picket A; however, for GW-711 (an individual well in the Picket-W aggregate), two COCs were identified (boron and strontium metal: total well HI = 1.0).

5.5.4 Pyrophoric and Explosive Agents Assessment for BCBG

The CERCLA process does not mandate that physical hazards be addressed as part of the BHHRA. However, the nature of the materials buried in the BCV BCBG and the history of uncontrolled and, at times, unexpected pyrophoric and explosive events there support the need for a discussion of the physical hazards associated with this site. The results of this qualitative assessment are presented in Appendix F, Sect. F.5.5; Exhibit F.5 in Appendix F illustrates the types of potential reactions considered and the areas in which the reactions might occur (Geraghty and Miller 1984).

In summary, conclusions of the incompatibility study are (1) it is reasonable to expect (according to the 1984 report) that excavation will foster additional reactions through re-exposure to air and unavoidable mixing as the wastes are handled; (2) incompatible wastes have been mixed together in all portions of BCBG; (3) essentially all types of hazards are possible in BG-A; (4) there is less likelihood of violent polymerization or toxic gas generation in BG-B; (5) essentially the same hazards, although with somewhat different likelihoods, are present in BG-C and the WIP as in BG-A; and (6) the potential exists for gas generation, pressure buildup, and the solubilization of metals in BG-D. Although an apparent potential exists for pyrophoric and explosive events at BCBG, estimates of the probability associated with these events are variable, depending upon the information source. In terms of evaluating the potential hazard to future human receptors (e.g., workers) at the site, the full range of probabilities should be considered.

VIEW A - Upper Bear Creek Valley

VIEW B - Picket W

VIEW C - Water Gap

Fig. 5.2. Groundwater locations with total (residential) human health risks greater than 1E-06.

VIEW C

BEAR CREEK VALLEY KEY MAP

VIEW B - Water Gap

VIEW C - Picket W

VIEW A - Upper Bear Creek Valley

Fig. 5.4. Groundwater locations with total (residential) human health hazard indexes greater than 1.

- LEGEND:
- BEAR CREEK & TRIBUTARIES
 - GW.....GWMP GROUNDWATER WELL
 - BURIAL GROUNDS LEACHATE
 - SEEP.....SEEPING LOCATION
 - BY, BG, & SL1. SAMPLING LOCATIONS
 - BLACK.....TOTAL HI < 1
 - GREEN.....INORGANIC HI DRIVER
 - RED.....ORGANIC HI DRIVER

Fig. 5.5. Surface water locations with total (residential) human health risks greater than 1E-06.

Fig. 5.6. Surface water locations with total (residential) human health risks greater than 1E-04.

Fig. 5.7. Surface water locations with total (residential) human health hazard indexes greater than 1.

5.5.5 Uncertainties and Assumptions in the Risk Characterization

Although the methodology used in this BHHRA follows EPA guidelines, risk assessment as a scientific activity is subject to uncertainty. The risk evaluation in this report is subject to uncertainty pertaining to sampling and analysis, selection of COPCs (Sect. 5.2.6), exposure assessment estimations (Sect. 5.3.4), and availability of toxicological data (Sect. 5.4.5); these uncertainties also affect the characterization of human health risks and HQs for BCV. Appendix F, Sect. F.5.6, provides detailed information regarding the uncertainties specifically associated with the BCV human health risk characterization; a brief summary follows.

Uncertainties related to the summations of risk and HQ estimates (i.e., cumulative risks/HQs) across chemicals and exposure pathways are a primary uncertainty in the risk characterization. Limitations of this approach include for example: for noncarcinogens, the effects of a mixture of chemicals is generally unknown (interactions could be synergistic or antagonistic); for carcinogens, the target organs of multiple chemicals may be different (risks may not be additive).

Uncertainties exist which could underestimate risks/hazards due to the 84 COPCs which could not be evaluated quantitatively in this BHHRA because of the unavailability of toxicity information for these chemicals. In addition, uncertainties exist in the toxicity values themselves which can effect risks and HQs. For three COPCs identified as COCs in this BHHRA (1,1,1-TCA, TCE, and PCE), withdrawn toxicity values were used; therefore, uncertainties with the risk and HQ estimates associated with these COCs are higher. In addition, for manganese, the EPA-approved RfD of 0.14 mg/kg-d was used for estimating hazards (HQs) from exposure to manganese in soil, water, and diet media; however, recent information in the Integrated Risk Information System suggests that it may be more appropriate to modify this manganese toxicity value (by a modifying factor of 3) when estimating HQs from exposure to manganese in water and soils. Therefore, HQs calculated for manganese in this BHHRA were potentially underestimated by a factor of 3. Furthermore, uncertainties are associated with the percent gastrointestinal absorption efficiencies used to modify the oral toxicity values used in the determination of dermal risks and HQs and similar uncertainties are associated with the toxicity equivalency factors values used to estimate risks from exposure to dioxins and PAHs.

Uncertainties are associated with the land use scenarios and the parameters within those scenarios. In particular, uncertainty is associated with the estimation of the exposure frequency for the BCV site-specific maintenance worker. The exposure frequency parameter is variable; it depends on what specific BCV activity is being performed (e.g., cap inspection versus mowing activities). The exposure frequency used in this BHHRA for this receptor (36 d/year) is the average of the exposure frequencies for the various BCV CA site-related activities.

Exposures to known DNAPLs in the BCBGs were not evaluated quantitatively in this BHHRA. Therefore, uncertainties (i.e., underestimations) are associated with the estimates of total risks and HQs from exposure to this medium; however, exposure to DNAPLs is considered to be unacceptable to human health. In addition, a high amount of uncertainty exists in identifying the SRCs and COPCs in the BCBGs waste inventory (buried wastes) and with estimating their representative exposure concentrations (refer to Sect. 5.2.6); these uncertainties are also reflected in the risk and HQ estimates for potential exposures to the BCBGs wastes. Additional uncertainties exist in the BCBGs because of the potential physical hazards associated with the site, due to its history of uncontrolled and unanticipated pyrophoric and explosive events (refer to Appendix F, Sect. F.5.5). This BHHRA

qualitatively evaluated this potential physical hazard to human health; the quantitative risks and HQs determined for the BCBGs functional area do not take this potential physical safety hazard into account and therefore may underestimate the health risks in the BCBGs.

Similar uncertainties exist for the SRCs, COPCs, representative concentrations, and estimated risks/HQs for the S-3 Ponds historical inventoried wastes/sludges. Furthermore, uncertainties are associated with the applicability of future residential and industrial exposures to the BCBGs, OLF, an S-3 Ponds capped buried wastes and soils; estimating exposures to such media are conservative in terms of protecting human health but may overestimate risks and HQs.

Furthermore, for the Bear Creek Road Debris Burial area, the hot-spot soil sample was diluted in the field to meet off-site laboratory radiological level requirements; therefore, the risk and HQ estimates for exposure to the COPCs in this area were potentially underestimated. The reader should refer to Appendix F, Sect. F.5.6, for additional discussion of uncertainties associated with the BCV human health risk characterization.

5.5.6 Summary and Conclusion of the Human Health Risk Characterization

Table 5.5 summarizes the results of the BHHRA for each source area/FA by medium of concern. A medium (e.g., groundwater) is considered to be of concern if COCs were identified for that medium. For example, many COCs were identified for residential use of S-3 Ponds groundwater; therefore, S-3 Ponds groundwater is a medium of concern for residential use. In Table 5.5, the character “Y” (for yes) is listed under those source areas (for each land use) that have COCs identified for each medium evaluated. Tables 5.1-5.4 present the specific COCs that contribute to each medium of concern identified in Table 5.5.

The total cumulative risks and HIs are summarized graphically for each of the source areas/FAs (for the four land uses considered in this BHHRA) in Figs. 5.8 and 5.9, respectively. (Note, the risk and HI results presented in the figures pertain to the representative aggregated data for each source area/FA; i.e., risks/HIs for individual sampling locations are not represented in these figures.)

S-3 Ponds. Numerous COCs (inorganics, organics, and radionuclides) were identified for a future hypothetical resident from exposure to the groundwater, surface water, and buried/capped waste associated with the S-3 Ponds. Only arsenic and mercury were identified as COCs for this receptor from exposure to the soils adjacent to the S-3 Ponds cap.

Many COCs (beryllium, PCB-1254, and many radionuclides) were identified for a future hypothetical industrial worker from exposure to the buried/capped waste associated with the S-3 Ponds. No COCs were identified for this receptor for exposure to the soils adjacent to the S-3 Ponds cap.

No COCs were identified for a hypothetical current “unprotected” maintenance worker from exposure to the soils adjacent to the S-3 Ponds cap.

Oil Landfarm. Numerous COCs (inorganics, organics, and radionuclides) were identified for a future hypothetical resident from exposure to the groundwater, surface water, soils (adjacent to cap), and inventoried soils (beneath the cap) associated with the OLF.

Fig. 5.8. Bear Creek Valley source area/functional area risk summary.

Fig. 5.8. (continued).

Fig. 5.9. Bear Creek Valley source area/functional area hazard index summary.

Fig. 5.9. (continued).

Four COCs (arsenic, ^{60}Co , ^{212}Pb , and ^{208}Tl) were identified for a future hypothetical industrial worker from exposure to the soils adjacent to the OLF cap. No COCs were identified for this receptor from exposure to the inventoried soils beneath the cap.

No COCs were identified for a hypothetical current “unprotected” maintenance worker from exposure to the soils adjacent to the OLF cap.

Boneyard/Burnyard. Numerous COCs (inorganics, organics, and radionuclides) were identified for a future hypothetical resident from exposure to the groundwater, surface water, and soils associated with the BYBY; $^{235,238}\text{U}$ are COCs identified for this receptor from exposure to the hot-spot soils in the BYBY.

Many COCs (antimony, arsenic, beryllium, various PAHs, and $^{234,235,238}\text{U}$) were identified for a future hypothetical industrial worker from exposure to the soils associated with the BYBY; $^{235,238}\text{U}$ are COCs identified for this receptor from exposure to the hot-spot soils in the BYBY.

No COCs were identified for a hypothetical current “unprotected” maintenance worker from exposure to the BYBY soils; $^{235,238}\text{U}$ are COCs identified for this receptor from exposure to the hot-spot soils in the BYBY.

Sanitary Landfill 1. Numerous COCs (inorganics, organics, and radionuclides) were identified for a future hypothetical resident from exposure to the groundwater, surface water, and soils (adjacent to cap) associated with the SL 1.

No COCs were identified for either the future hypothetical industrial worker or the hypothetical current “unprotected” maintenance worker from exposure to the soils adjacent to the SL 1 cap.

Burial Grounds. Numerous COCs (inorganics, organics, and radionuclides) were identified for a future hypothetical resident from exposure to the groundwater, surface water, soils (adjacent to caps), hot-spot soils (near D-East), and buried/capped wastes associated with BCBG. The primary COCs in the buried waste are beryllium, uranium, PCBs, VOCs, ^{232}Th , and $^{234,235,238}\text{U}$. VOCs comprise the majority of the COCs in the BCBG groundwater and surface water.

Numerous COCs (inorganics, organics, and radionuclides) were identified for a future hypothetical industrial worker from exposure to the soils adjacent to caps, hot-spot soils near BG-D East, and buried wastes associated with the BCBG. The only COC in the soils (adjacent to caps) is ^{208}Tl ; COCs in the BG-D East hot-spot soils are beryllium and $^{234,235,238}\text{U}$. The primary COCs in the buried waste for this receptor are beryllium, uranium, PCBs, VOCs, ^{232}Th , and $^{234,235,238}\text{U}$.

No COCs were identified for the hypothetical current “unprotected” maintenance worker from exposure to the soils adjacent to the BCBG caps; $^{234,235,238}\text{U}$ are COCs identified for this receptor from exposure to the BG-D East hot-spot soils.

DARA. COCs identified for a future hypothetical resident from exposure to the inventoried soils stored in the DARA are dioxins (HxCDD and 2,3,7,8-TCDD), PCB-1254, pentachlorobenzene, and $^{234,235,238}\text{U}$.

COCs identified for a future hypothetical industrial worker from exposure to the inventoried soils stored in the DARA are dioxins (HxCDD and 2,3,7,8-TCDD), PCB-1254, and $^{234,235,238}\text{U}$.

No COCs were identified for the hypothetical current "unprotected" maintenance worker from exposure to the inventoried soils stored in the DARA.

OLF Storage Pad. COCs identified for a future hypothetical resident from exposure to the inventoried soils stored in the OLF Storage Pad are arsenic, beryllium, PCBs, and ^{234,235,238}U.

Beryllium, PCBs, and ^{235,238}U are COCs identified for a future hypothetical industrial worker from exposure to the inventoried soils stored in the OLF Storage Pad.

No COCs were identified for the hypothetical current "unprotected" maintenance worker from exposure to the inventoried soils stored in the OLF Storage Pad.

Bear Creek Road Debris Burial. Numerous COCs (inorganics, PCB-1254, and radionuclides) were identified for a future hypothetical resident from exposure to the hot-spot soils associated with the Bear Creek Road Debris Burial area.

No COCs were identified for either the future hypothetical industrial worker or the hypothetical current "unprotected" maintenance worker from exposure to the hot-spot soils associated with the Bear Creek Road Debris Burial area.

Creekside Debris Burial. Numerous COCs [inorganics, organics (many PAHs), and radionuclides] were identified for a future hypothetical resident from exposure to the hot-spot soils associated with the Creekside Debris Burial area.

No COCs were identified for either the future hypothetical industrial worker or the hypothetical current "unprotected" maintenance worker from exposure to the hot-spot soils associated with the Creekside Debris Burial area.

Floodplain (western BCV) Area. No COCs were identified for a future hypothetical resident from exposure to the groundwater, surface water, and floodplain soils associated with the Floodplain (western BCV) area, with the exception of one floodplain soil location (SP04 near Hwy 95); PCB-1254 is a COC for location SP04. Four COCs (As, Cr, Mn, and PCB-1254) were identified for sediment locations SD10 (in Bear Creek between NT-8 and NT-9) and SD11 (in Bear Creek near NT-11) for the residential receptor.

No COCs were identified for either the future hypothetical industrial worker or the hypothetical current "unprotected" maintenance worker from exposure to the floodplain soils associated with the Floodplain (western BCV) area.

No COCs were identified for the future hypothetical recreational receptor from exposure to the surface water, floodplain soils, and sediments in the Floodplain (western BCV) area. Mercury, PCB-1254, and PCB-1260 are identified as COCs for this receptor from consumption of Bear Creek fish.

5.6 REFERENCES

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6. BASELINE ECOLOGICAL RISK ASSESSMENT

The purpose of this ecological risk assessment is to provide an estimate of ecological risks posed by contaminants in the BCV CA, which includes primary and secondary sources and aquatic and terrestrial habitats in BCV. The ecological risk assessment is structured in terms of the standard paradigm for risk assessment (Risk Assessment Forum 1992). It begins with a problem-formulation phase (Sect. 6.1) that defines the contaminant sources, the receiving environment, and the assessment endpoints. Then, for each endpoint, there is an analytical phase consisting of exposure assessment and effects assessment and a risk characterization that combines the components of the analysis phase by weighing all of the lines of evidence (Sects. 6.2–6.7). Finally, ecological risks are summarized (Sect. 6.8) and Remedial Goal Options are presented (Sect. 6.9). The components of the assessment are explained in detail in Appendix G.

6.1 FORMULATION OF THE ECOLOGICAL PROBLEM

This section describes the relevant features of the environment and the sources of contamination, identifies the ecological endpoints, and summarizes this information in terms of a conceptual model of the hazard posed by the contaminants to the endpoint biota.

6.1.1 Environment and Sources of Contamination

The environment considered in this assessment is the Bear Creek watershed, as described in Chap. 2 and in Appendix D. It consists of Bear Creek from the confluence with Lower East Fork Poplar Creek to the headwaters at the western edge of the Y-12 Plant, the associated floodplain and tributaries, and the source areas in upper BCV. The federally- and state-listed threatened and endangered species and other state-listed rare or declining species are listed in Chap. 2 and in Appendix D.

The proximate sources considered in this assessment are the contaminated media and biota in the BCV CA: water, sediment, soil, shallow groundwater, fish, soil invertebrates, vegetation, and small mammals. The ultimate sources of the contaminants are the DOE's operations of the Y-12 Plant, including waste disposal, spills, and the use of chemicals such as pesticides in the environment. The primary sources considered in this assessment are the waste and secondary contamination at the S-3 Ponds, BYBY, OLF, SL 1, and BCBG. Chapter 3 and Appendix D detail the sources and contaminants considered in this assessment.

6.1.2 Ecological Endpoints

Assessment endpoints are explicit statements of the environmental characteristics to be protected. Measurement endpoints are quantitative summaries of a measurement or series of measurements that are related to effects on an assessment endpoint. The assessment endpoints for this assessment were selected based on DQO meetings (DOE 1994) that included representatives of DOE, EPA Region IV, and TDEC. The rationale for selecting the following endpoints is discussed in Table 6.1.

- **Fish communities** - reduction in species richness or abundance resulting from toxicity
- **Benthic macroinvertebrate communities** - reduction in species richness or abundance resulting from toxicity

- **Piscivorous wildlife populations** - reduction in abundance or production resulting from toxicity
- **Terrestrial plant communities** - reduction in production resulting from toxicity
- **Soil/litter invertebrates** - reduction in production resulting from toxicity
- **Terrestrial wildlife populations** - reduction in abundance or production resulting from toxicity
- **Federally listed or state-listed threatened or endangered species** - reduction in viability or fecundity of individuals resulting from toxicity.

There is no specific endpoint for protection of wetlands. Under the baseline scenario, the only hazard to wetlands is that posed by the contaminants. These are covered by the other endpoints. The special protection of wetlands becomes a distinct issue in the feasibility study, where destruction of wetlands by remedial actions must be considered.

In addition to defining the assessment endpoints in terms of environmental entities (e.g., the fish community) and properties of those entities (e.g., species richness), it is necessary to identify a level of effect on those properties. A 20% or greater reduction in one of the endpoint properties measured in the field or a 20% reduction in survivorship, growth, or reproduction in a toxicity test is considered to be potentially significant. The figure 20% used in the definition of ecological assessment endpoints is based on an analysis of the EPA and Tennessee regulatory practice; it was adopted by the FFA parties in a DQO process and incorporated into the plan for ecological risk assessment for the ORR (Suter et al. 1995).

Three basic types of effects data were used, as available, as measurement endpoints: results of biological surveys, toxicity tests performed on media from the CA, and toxicity test endpoints for chemicals found in the CA. Section G.1 presents measurement endpoints for each assessment endpoint.

6.1.3 Ecological Conceptual Models

The ecological conceptual models graphically represent the relationships between the contaminant sources and the endpoint receptors. They are not intended to show all possible sources, routes of transport, modes of exposure, or effects. Rather, they concisely communicate the exposure assumptions made for this assessment. Further explanation of these assumptions (e.g., the distinction between benthic invertebrates in erosional and depositional areas) is provided in the assessment for the associated endpoint receptor (e.g., Sect. 6.3, "Risks to Benthic Invertebrates" and Appendix G). The RI assesses two baseline cases. The current baseline case is the state of the BCV CA as it now exists. That is, contaminants occur in the groundwater, surface water, sediment, and soil, but the existing caps prevent direct exposure to the primary sources. The hypothetical future case assumes exposure to the primary sources via degradation or removal of the existing caps and migration of contaminated groundwater plumes.

A conceptual model of current exposures of receptors inhabiting the BCV source areas is depicted in Fig. 6.1. The primary sources (e.g., pits and trenches) contaminate the secondary sources (e.g., shallow groundwater, surface water, sediment, soil) but are not considered as a source of exposure for current receptors in these areas. Plant communities and soil/litter invertebrates are directly exposed to contaminants in surface soil, and the plant community is exposed to contaminants in shallow groundwater. Contaminants are bioaccumulated in lower trophic levels (i.e., plants and invertebrates) and transferred to high trophic levels (omnivores and ground invertebrate feeders). Small omnivores and vermivores also are directly exposed to contaminants through consumption of surface water and incidental ingestion of soil and are externally exposed to radiation from

radionuclides in surface soil. Contaminated media in the source areas also serve as sources of contamination and exposure of the aquatic and terrestrial receptors inhabiting Bear Creek, its tributaries, and the floodplain. Contaminated media and biota in the CA are sources of exposure for the wide-ranging species inhabiting the Bear Creek watershed.

Fig. 6.1. Conceptual model for current exposures of receptors inhabiting BCV source areas. The dark-lined boxes indicate assessment endpoints.

A conceptual model of current exposures of receptors inhabiting Bear Creek, tributaries and seeps, and the Bear Creek floodplain is depicted in Fig. 6.2. Contaminants enter the system via surface water, groundwater, and eroded soil. Within the system, contaminants move among the abiotic components through erosional and depositional processes (e.g., erosion of floodplains and alluvial deposition of stream sediments) and adsorptive and desorptive processes. Exposure pathways for terrestrial receptors inhabiting the floodplain are the same as those for receptors in the source areas. Fish and benthic invertebrates in erosional areas are directly exposed to contaminants, and externally exposed to radiation from contaminants, in surface water. Benthic invertebrates in depositional areas are similarly exposed to contaminants in sediments. Contaminants are bioaccumulated in lower trophic levels (e.g., invertebrates) and transferred to higher trophic levels (e.g., fish).

A conceptual model of current exposures of wide-ranging receptors inhabiting the Bear Creek watershed is depicted in Fig. 6.3. Piscivores are directly exposed to contaminants in surface water and contaminants bioaccumulated in lower trophic levels (e.g., fish). They also are externally exposed to radiation from contaminants in surface water. Predators and large herbivores are directly exposed to contaminants in surface water and contaminants bioaccumulated in lower trophic levels

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Fig. 6.2. Conceptual model for current exposures of receptors inhabiting Bear Creek, tributaries, and seeps, and the Bear Creek Floodplain. The dark-lined boxes indicate assessment endpoints.

(e.g., small mammals or plants) through consumption and to contaminants in soil through incidental ingestion. They also are externally exposed to radiation from contaminants in surface soil.

Fig. 6.3. Conceptual model for current exposures of wide-ranging receptors inhabiting BCV. The dark-lined boxes indicate assessment endpoints.

A conceptual model of the additional exposure pathways evaluated for the future hypothetical case is depicted in Fig. 6.4. The inventoried primary sources (e.g., pits and trenches) are considered as a hypothetical source of direct exposure for future receptors inhabiting these areas. That is, existing caps are assumed to have been degraded or removed, and plant communities and soil/litter invertebrates are directly exposed to contaminants in wastes. Small mammals are assumed to be directly exposed to contaminants through incidental ingestion of waste. Also evaluated in the future case is migration of contaminated groundwater plumes. Additional conceptual models are not presented because the spatial distribution, intensity, and/or composition of contamination may change, but the exposure pathways are a subset of those evaluated in the current baseline case. Specifically, the exposure pathways include direct exposure of plants to shallow groundwater, direct exposure of aquatic biota to surface water, and direct exposure of piscivores through consumption of surface water.

6.2 RISKS TO FISH

Risks to the fish communities in Bear Creek and tributaries NT-2 through NT-8 were evaluated. Bear Creek was divided into four reaches (Fig. 6.5) based on contaminant sources and the availability of chemical and biological data. Reach 1 includes Bear Creek above NT-3 and NT-1, because the S-3 Ponds are the primary contaminant source to both channels and the location of the chemical sampling site for NT-1 precludes discriminating between the NT-1 and Bear Creek water chemistry. Reach 2 extends from NT-3 to BCK 9.4. Reach 3 encompasses BCK 9.4 to BCK 3.25. Reach 4 extends from BCK 3.25 to the confluence with EFPC. Seeps were evaluated for risks to benthic invertebrates in erosional areas, rather than fish, because of considerations of scale.

Fig. 6.4. Conceptual model for hypothetical exposures of receptors to inventoried wastes. The dark-lined boxes indicate assessment endpoints.

6.2.1 Exposure Assessment

Fish are exposed primarily to contaminants in water. Contaminants in water may come from upstream aqueous sources, exchange of materials between the surface water and contaminated sediments, or exchange of contaminants between the biota and the water column. The consensus of the scientific community and of the EPA Office of Water is that aquatic biota should be assumed to be exposed to the dissolved fraction of the chemicals in water, because that is the bioavailable form (HECD 1992; Prothro 1993). However, the EPA Region IV prefers to use total concentrations as conservative estimates of the exposure concentration. Therefore, both dissolved phase and total concentrations of metals are used in the exposure assessment for fish.

Although nearly all toxicity data for fishes are expressed in terms of aqueous concentrations, fish body burdens potentially provide an exposure metric that is more strongly correlated with effects (McCarty and Mackay 1993). This is particularly likely to be the case for chemicals that bioaccumulate in fish and other biota to concentrations greater than in water. For such chemicals, dietary exposure may be more important than direct aqueous exposures, and concentrations that are not detectable in water may result in high body burdens in fish. Sufficient toxicological data are available for two chemicals (mercury, PCBs) that bioaccumulate in such a manner and that were found to be significantly elevated in fish from Bear Creek (Hinzman 1995).

Exposures to radionuclides are expressed as the dose rate received by the organism. The total dose rate is the sum of the internal and external dose rates, which are a function of exposure to the radionuclide and the characteristics of the radiation. Because the radiation exposure rate is expressed as absorbed dose per unit time (rads per day), the dose rates for each isotope and pathway can be added to determine the total dose rate.

Fig. 6.5 Summary of risk characterization for fish in Bear Creek Valley.

The water toxicity tests include direct exposure of the standard test species *Ceriodaphnia dubia* and the fathead minnow (*Pimephales promelas*) to surface water. It is assumed that the form and bioavailability of chemicals are not altered by water collection and handling, so these tests represent exposures in the field.

Future exposure assessment is based on the range of predicted maximum surface water concentrations presented in Appendix E. These concentrations were derived using source terms for the known groundwater plumes, groundwater transport models; and surface water dilution ratios. These concentrations are assumed to be dissolved phase.

6.2.2 Effects Assessment

The sets of screening benchmarks for aquatic biota (presented in Table G.1 in Appendix G) are taken from Suter and Mabrey (1994). Ecotox Threshold values were issued by the EPA Office of Solid Waste and Emergency Response (OSWER 1996) subsequent to the screening of surface water data for this assessment and are not included herein. However, the OSWER values were either from, or consistent with, the Suter and Mabrey (1994) benchmarks. The benchmarks used in this assessment also are consistent with the EPA Region IV surface water screening values (Region IV 1995). Multiple benchmarks are included to provide greater assurance of detecting all COPECs.

There are no standard benchmarks for effects on fish from internal chemical exposures. The body burdens associated with effects in toxicity tests and field studies and body burdens found at other sites are discussed in Sect G.2 in Appendix G. To be consistent with EPA practices, thresholds for toxic effects are expressed as geometric means of body burdens measured at the NOEC and LOEC (lowest observed effect concentration).

The recommended acceptable radiation dose rate to natural populations of aquatic biota is 1 rad/d (NCRP 1991). Although there are no standard screening benchmarks for radionuclide concentrations in surface water, Blaylock, Frank, and O'Neal (1993) provide formulas and exposure factors estimating the dose rates to representative aquatic organisms. These formulas were used to calculate the water concentration that results in a total dose rate of 1 rad per day to a small fish for each radionuclide detected in the water samples from BCV (refer to Sect G.2 in Appendix G).

Methods and results of toxicity tests of ambient water are detailed in Hinzman (1995), summarized in Sect. D.9 in Appendix D, and evaluated in Sect G.2. The tests used include the standard 7-d tests of growth and survival in fathead minnow larvae and fecundity and survival of *C. dubia*. Because these subchronic tests were developed for testing effluents and ambient waters rather than pure chemicals, their relationship to levels of contaminant exposure must be related to the patterns of contamination in BCV and related to effects levels for individual contaminants in other tests reported in the literature.

Analysis of fish population and community survey data provides a direct measure of impacts of human activities on aquatic ecosystems. These data can provide an additional line of evidence relating to potential impacts of DOE operations on Bear Creek. Quantitative sampling of the fish population by electrofishing has been conducted biannually at seven locations in Bear Creek since 1984 [refer to Sects. D.9 in Appendix D and G.2 in Appendix G and Hinzman (1995)].

6.2.3 Risk Characterization

The weight of evidence suggests that water from Bear Creek and NT-2 through NT-8 does not pose a significant risk to the fish community or the Tennessee dace. Fig. 6.5 and Table 6.2

summarizes, for each site, the weighing of evidence for current risks presented in the following text. The risk characterization methods, results, and interpretation for each available line of evidence are presented in Sect G.2 in Appendix G. Although water from Reach 1 and NT-2 was consistently toxic to *Ceriodaphnia dubia* and metals occurred at concentrations likely to be toxic, the species richness and total density of the fish community in Reach 1 have increased since 1989 and are comparable to those of reference communities. The lower densities observed at some sites (e.g., BCK 11.09 and BCK 7.87) are likely to be attributable to poor habitat quality, including low stream flow and siltation from construction activities. The Tennessee dace population in Bear Creek does not appear to be degraded due to a toxic effect, given that the highest densities occur at the most highly contaminated site (BCK 12.36), and the lower densities observed in Reach 2 and upper Reach 3 are primarily attributable to poor habitat quality.

Current risks to fish are not considered significant primarily as a result of the toxicity and biosurvey data. However, the weight-of-evidence for future risks to fish is based solely on the screening of predicted future aqueous contaminant concentrations. The results of that screening (Table 6.3) suggest that exposures are expected to increase, and future risks to the fish community are expected to be significant, in NT-1, NT-2, NT-7, NT-8, and in Bear Creek at BCK 9.47. Significant risks are not expected in Bear Creek above NT-1. Chemical exposures in Bear Creek between BCK 9.47 and NT-1 have the potential to increase in the future and risks to the fish community may become significant, but the uncertainty in this is high because of the lack of model results for this stretch of Bear Creek. Chemical concentrations, and therefore risks to fish, in NT-1 and NT-2 are expected to peak in the next 50 to 350 years. Generally, risks in NT-7 and NT-8 are expected to increase slowly over the next 1000 years. The exception is that risks from cyanide are expected to peak in the next 50 years. The peak time for BCK 9.47 could not be estimated.

6.2.4 Uncertainties

The following issues constitute the major sources of uncertainty in the risk assessment for the fish community:

- **Water sampling locations** for most tributaries, Reach 2, and Reach 3 were not in the upstream areas and, therefore, may underrepresent the risks in these areas. Also, chemical analyses are available for only three sites below BCK 11.97 (Reach 1): BCKs 0.63, 4.55, and 9.4.
- **Concurrent chemical analyses** were available for only one set of aqueous toxicity tests. Hence, some uncertainty is associated with the causes of toxicity. This uncertainty is tempered by the strong relationships between the concentrations of calcium and manganese and the toxicity to *C. dubia*.
- **The ecological relevance of media toxicity tests** contributes some uncertainty. The species available for aqueous testing (i.e., *Ceriodaphnia*) may be more sensitive than the indigenous species to the chemicals in BCV. Also, the water may be more toxic to naive test organisms than to equally sensitive organisms that have acclimated to the site conditions.
- **Community surveys** are not available for the tributaries or Reach 1 above BCK 12.36.
- **Modeled surface water chemical concentrations**, which are the only evidence available for estimating future risks to fish, introduce additional uncertainties to the assessment.

6.3 RISKS TO BENTHIC INVERTEBRATES

Benthic invertebrates are primarily exposed to contaminants in sediment, sediment pore water, and overlying surface water. Surface water exposures are more important in erosional areas because chemicals in sediments are primarily associated with fine grains and organic matter, which are eroded from riffles and accumulated in pools. Benthic invertebrates inhabiting depositional areas are generally immersed in the fine sediments. Thus, the primary exposures in depositional areas are to contaminated sediments and sediment pore water. The locations and types of data available for assessing these pathways in Bear Creek are sufficiently different to necessitate evaluating surface water and sediment exposures separately. That is, chemical and toxicity analyses of water were not available at most sediment depositional areas, and community surveys are available only for erosional areas.

6.3.1 Erosional Areas

6.3.1.1 Exposure assessment

Benthic invertebrates in erosional areas are exposed primarily to contaminants in water. The exposure assessments of current and future aqueous chemical concentrations, current and future aqueous radionuclide concentrations, and aqueous toxicity tests for the fish community (Sect. 6.2.1) are also representative of exposure for benthic invertebrates in erosional areas. The screening values for radiation dose rates to a small fish from water are presumed also to be protective of invertebrates exposed primarily to water, given the conservative assumptions used in their derivation.

6.3.1.2 Effects assessment

The effects assessments of aqueous chemical concentrations, aqueous radionuclide concentrations, and aqueous toxicity tests are presented in Sect. 6.2.2.

Analysis of the benthic invertebrate community survey data provides a direct measure of impacts of human activities on aquatic ecosystems. These data can provide an additional line of evidence relating to potential impacts of DOE operations on Bear Creek. Quantitative sampling of the benthic invertebrate community has been conducted at six to ten locations in Bear Creek since the spring of 1984 (refer to Sects. D.9 in Appendix D and G.3 in Appendix G and Hinzman (1995)).

6.3.1.3 Risk characterization

The weight of evidence suggests that water in Reaches 1 and 2, NT-2, SS-1, and SS-4 currently poses a significant risk to benthic invertebrates from high concentrations of calcium, cadmium, manganese, nickel, and uranium. The distribution of observed effects and toxic concentrations strongly suggests that discharges from the S-3 Ponds continue to be the primary contributor to risks. Fig. 6.6 and Table 6.4 summarizes, by location, the weighing of evidence presented in the following text. The risk characterization methods, results, and interpretation for each available line of evidence are presented in Sect G.3.1. The community is severely degraded in Reach 1, moderately degraded in Reach 2, and fully recovered in lower Reach 3 (BCK 3.25) and Reach 4. Survival and reproduction of the sensitive test organism *Ceriodaphnia dubia* in water from Reach 1 and NT-2 continue to be drastically reduced, but the water from Reach 3 has never been shown to be toxic. Concentrations of dissolved calcium, cadmium, manganese, nickel, and uranium are likely to be toxic at one or more of the upper Bear Creek locations, but none of the COPECs are likely to be toxic in Reaches 3 and 4. Habitat quality also is a contributing factor at sites in Reaches 2 and 3.

Fig. 6.6 Summary of risk characterization for benthic macroinvertebrates in Bear Creek Valley.

The weight-of-evidence for future risks to benthic invertebrates is based solely on the screening of predicted future aqueous contaminant concentrations. The results of that screening (Table 6.3) suggest that exposures are expected to increase, and future risks to the benthic invertebrate community are expected to continue to be significant, in NT-1, NT-2, and Bear Creek at BCK 9.47 (i.e., the lower end of Reach 2). Exposures are expected to increase, and future risks to the benthic invertebrate community are expected to become significant, in NT-7 and NT-8. Significant risks are not expected in NT-3. Risks in Bear Creek above NT-1 due to loading from the S-3 plume are expected to decrease in the future. However, under the no action scenario acceptable exposures are not expected to be attained for 30 to 40 years. Chemical exposures in Bear Creek between BCK 9.47 and NT-1 cannot be assumed to decrease in the future. Chemical concentrations, and therefore risks to benthic invertebrates, in NT-1 and NT-2 are expected to peak in the next 50 to 350 years. Generally, risks in NT-7 and NT-8 are expected to increase slowly over the next 1000 years. The exception is that risks from cyanide are expected to peak in the next 50 years. The peak time for BCK 9.47 could not be estimated.

6.3.2 Depositional Areas

6.3.2.1 Exposure assessment

Two different expressions of sediment contamination are used—whole sediment concentrations and estimated pore water concentrations. The use of pore water is based on the assumption that chemicals associated with the solid phase are largely not bioavailable, and, therefore, sediment toxicity can be estimated by measuring or modeling the pore water concentration. Whole sediment concentrations do not account for effects of sediment properties on bioavailability. However, they are required by EPA Region IV and may provide a better estimate of risk for chemicals that are strongly associated with particles.

Exposures to radionuclides are expressed as the dose rate received by the organism. As with radiation exposures in surface water, the total dose rate is the sum of the internal and external dose rates, which are a function of exposure to the radionuclide and the characteristics of the radiation. Radiation exposures to benthic invertebrates immersed in sediments are likely to be driven by external exposures to contaminated sediments. The exception is for alpha-emitters, such as ^{234}U and ^{230}Th . Therefore, the concentration in benthic invertebrates was estimated from the measured sediment concentrations (Sect. G.3.2).

The sediment toxicity tests include direct exposure to whole sediment (*Hyallela azteca*) and exposure to epibenthic water (*D. magna*). The chemical exposures received by the test organisms are well-known, because toxicity tests and chemical analyses were conducted for each sediment sample (Sect. B.5 in Appendix B). It is assumed that the form and bioavailability of chemicals is not altered by sediment collection and handling, so these tests represent exposures in the field.

6.3.2.2 Effects assessment

Because there are no standard screening benchmarks and sediment quality criteria are available for only a few chemicals, sets of alternative sediment benchmarks were derived for each chemical (Table G.9 in Appendix G). Whole sediment concentrations are compared with these alternative benchmarks. The use of multiple benchmarks provides greater assurance of detecting all COPECs. Sediment quality criteria are corrected for site-specific conditions.

The recommended acceptable dose rate to natural populations of aquatic biota is 1 rad/d (NCRP 1991). Although there are no standard screening benchmarks for radionuclide concentrations in

sediments, the formulas presented in Blaylock, Frank, and O'Neal (1993) were used to calculate the sediment concentration that results in a total dose rate of 1 rad/d to a small invertebrate for each radionuclide detected in the sediment samples from BCV (refer to Sect. G.3.2).

Because there is no dilution series for the sediment toxicity tests, the appropriate exposure-response relationship is the association between the significant toxic responses and either the concentrations of contaminants in the sediment or the location relative to known sources of contaminants. Test responses used in this assessment include reductions in survival of an amphipod (*H. azteca*) in 10-day exposures to whole sediment and reductions in survival and fecundity of another cladoceran (*D. magna*) in 12- to 14-day exposures to water overlying sediment.

6.3.2.3 Risk Characterization

The weight of evidence suggests that sediment from 3 of the 18 sites poses a significant risk to benthic invertebrates inhabiting those sites due to a toxic effect. However, it is unlikely that the soft-sediment benthic invertebrate community as a whole is reduced by 20% in species richness or abundance. The risk characterization methods, results, and interpretation for each available line of evidence are presented in Sect. G.3.2 and summarized in Fig. 6.6 and Table 6.5. Community survey data are not available for the depositional areas of Bear Creek. The toxicity tests of NT-2 and NT-6 sediment were too ambiguous to interpret, but the chemical analyses suggest that the reduced survival of *D. magna* is likely the result of manganese and, potentially, selenium and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). Significant risks are indicated at sediment sampling location (SD) 17 in lower Reach 4, but the toxic agent could not be identified. The sediment from this site was unambiguously toxic. However, none of the detected chemicals occur at concentrations reported to be toxic, and all chemicals detected at this site for which toxicological data were not available are present at higher concentrations at other sites where toxicity was not evident. Because the toxic agent could not be identified, causes other than the operations in Upper Bear Creek cannot be ruled out.

6.3.3 Uncertainties

The following issues constitute the major sources of uncertainty in the risk assessment for the benthic invertebrate community:

- **The cumulative effects of multiple contaminants and exposure pathways** cannot be adequately evaluated at this time. Water and sediment exposures had to be evaluated separately, and dietary exposures could not be evaluated benthic invertebrates.
- **The ecological relevance of the media toxicity tests** is somewhat. The species available for sediment testing may be less sensitive than the indigenous species to the chemicals in BCV. The species available for aqueous testing (i.e., *Ceriodaphnia*) may be more sensitive than the indigenous species. Also, the sediment and water may be more toxic to naive test organisms than to equally sensitive organisms that have acclimated to the site conditions.
- **Water sampling locations** for most tributaries, Reach 2, and Reach 3 were not in the upstream areas and, therefore, may underrepresent the risks in these areas. Also, chemical analyses are available for only three sites below BCK 11.97 (Reach 1): BCKs 0.63, 4.55, and 9.4.
- **Concurrent chemical analyses** were available for only one set of aqueous toxicity tests. Hence, some uncertainty is associated with the causes of toxicity. This uncertainty is tempered by the strong relationships between the concentrations of calcium and manganese and the toxicity to *C. dubia*.

- **Sediment effects data** are highly uncertain, because sediments are highly heterogeneous and complex. There are few standardized sediment toxicity tests and most of the available data are from marine and estuarine systems. The endpoints used to define the ER-L and ER-M range from community-level responses to suborganismal effects. These sources of variance are discussed in more detail in Sect. G.3.2.3.
- **The lack of biosurvey data** for benthic invertebrates in depositional areas and erosional areas in the tributaries and Reach 1 above BCK 12.36 also adds uncertainty.
- **Modeled surface water chemical concentrations**, which are the only evidence available for estimating future risks to fish, introduce additional uncertainties to the assessment.

6.4 RISKS TO SOIL INVERTEBRATES

6.4.1 Floodplain Areas

Six soil samples were collected from 13 transects perpendicular to Bear Creek. For each transect, two samples were collected in the creek berms on either side of Bear Creek, and two others were in the backmarsh if the floodplain was wide enough on both sides of the creek (Sect. B.5 of Appendix B). Although sample depth intervals included 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.), only the two more shallow depths are used for the assessment of toxicity to soil invertebrates.

6.4.1.1 Exposure assessment

Earthworms absorb a wide variety of inorganic and organic soil contaminants both through feeding in soil and litter and dermal exposure to soil and soil pore water through burrowing. It is assumed that these organisms represent highly exposed soil invertebrates. The bioavailability of the contaminants in soil and decomposing plant litter are controlled by soil, litter, and analyte characteristics; however, current knowledge is not sufficient to allow the prediction of bioavailability based on most soil variables.

It is assumed that the earthworms spend their entire life span in soil with contaminant levels represented by a weighted average of concentrations in the 0 to 10 cm (0 to 4 in.) and 10 to 41 cm (4 to 16 in.) fractions of the soils sampled for analyses. Because some soil invertebrates are not found throughout the top 41 cm (16 in.) of soil (see Sect. 6.4.1.2), the maximum contaminant concentrations from either depth sample were screened against toxicity benchmarks.

6.4.1.2 Effects assessment

The method used for deriving soil benchmarks is presented in Will and Suter (1995a) and the screening benchmarks for toxic effects of contaminants present in BCV floodplain soils are presented in Table G.14 in Appendix G.

The methods, results, and conclusions of the toxicity tests are presented in Sect. G.11 in Appendix G. Because there is no dilution series for the soil toxicity tests, the appropriate exposure-response relationship is the association between the significant toxic responses and either the concentrations of contaminants in the soil or the location relative to known sources of contaminants. Test responses used in this assessment include reductions in survival and fecundity of the earthworm *Eisenia foetida* in 21-day exposures to soil.

6.4.1.3 Risk characterization

A summary of the weight of evidence for risk to soil invertebrates posed by floodplain soils in BCV is given in Fig. 6.7 and Table 6.6. The only COPEC, mercury, was found above the earthworm toxicity benchmark and background at several isolated locations in the BCV floodplain. However, the weight of evidence for all transects was that soil invertebrates are not negatively impacted by contaminants in the BCV floodplain. The elevated concentrations of mercury were determined not to be entirely bioavailable to earthworms, based on the site-specific toxicity test results.

6.4.2 Source Areas

The four source areas evaluated for potential risk to ecological receptors were the S-3 Ponds area, BYBY, the combined SL 1 and OLF, and the BCBG. Separate assessments were carried out for the Creekside and Bear Creek Road Site Debris Burial areas, for which analytical results and the single-chemical toxicity screening are presented in Sect. G.4.2.3 in Appendix G.

6.4.2.1 Exposure assessment

The mechanisms by which earthworms are exposed to soil contaminants are discussed in Sects. 6.4.1 and G.4.1.1. Current risks were evaluated using the surface soil samples, aggregated by area. Future risks were evaluated by assuming that the maximum potential exposure would be to inventoried wastes. Therefore, it is assumed that existing caps are no longer present and the contaminants are freely accessible to earthworms. Combined data for S-3 Pond sludges were used to compute source term concentrations at the S-3 Ponds (Table A.3 in Appendix A), and waste inventory data for the BCBG area were used to compute source term concentrations in the BCBG wastes (Table A.27 in Appendix A).

6.4.2.2 Effects assessment

The screening benchmarks are discussed in Sect. G.4.1 in Appendix G. Although ambient soil toxicity testing was done on soil from floodplain transects only, information from those tests (refer to Sects. G.4.1.2. and G.11 in Appendix G) was used to evaluate potential toxicity of source area contaminants to earthworms.

6.4.2.3 Risk characterization

A summary of the weight of evidence findings is presented in Figs. 6.7 and Table 6.7. Most COPECs could not be excluded as COCs because the maximum concentrations were higher than those used in ambient soil toxicity testing. No COCs were identified for the BCBG aggregate. At the S-3 Ponds area, mercury was identified as the sole COC. However, much of the S-3 Ponds area is paved or graveled, providing little attractive habitat for earthworms.

Mercury was the only COC with an HQ >5 at the SL 1/OLF area, but the presence of copper and zinc at concentrations above toxicity benchmarks indicates potential toxicity to soil invertebrates at these sites. Multiple COCs with an HQ >100 were identified at the BYBY area, indicating that significant risk to soil invertebrates is likely at the BYBY area. Mercury and chromium are identified as COCs at the Creekside Burial area, and chromium, copper, mercury, and zinc are identified as COCs at the Bear Creek Road Site Debris Burial area. For future risks, chromium and mercury are retained as COCs for exposure of earthworms to the S-3 Ponds sludges, and mercury is retained as a COC for earthworm exposure in the BCBG waste inventory.

6.4.3 Uncertainties

The following factors create uncertainty in assessing the risk posed by the potential COCs in soils:

- **'Bioavailability' of elements.** The extraction methods used may remove from the soil quantities of elements and compounds greater than those that are extracted from soil as they pass through the gut of the earthworm or those that are adsorbed dermally.
- **Variable response to contaminants.** Various earthworm and other soil invertebrate species and earthworm growth stages tolerate contaminants to different degrees. The literature from which benchmarks were derived is not necessarily based on experiments using earthworm species known to be representative of those occurring in the soils of BCV.
- **Exposure to multiple contaminants.** Toxicity benchmark concentrations are derived from experiments in which earthworms are exposed to single contaminants. Typical soils of the BCV expose earthworms to multiple contaminants that may not be adequately assessed on the basis of literature-derived benchmarks.
- **Lack of benchmarks for some metals and most organic compounds.** Little research has been conducted on the toxic effects of the organic compounds, other than pesticides. Thus, it is not possible to assess the risk to earthworm populations posed by many of the analytes found in the soils.
- **Adequacy of reference soils.** Reference soils were generally more "toxic" than nonreference soils. These upland sites were apparently inappropriate matches for the contaminated sites in particle size and chemistry.
- **Chemical speciation.** Earthworm toxicity benchmarks for metals are often derived from studies with a single species of a contaminant. In this assessment, knowledge of the form of mercury would decrease the uncertainty associated with this assessment.

6.5 RISKS TO PLANTS

The major part of this assessment is an evaluation of current risks using data for soil, springs, and groundwater. Because groundwater plumes may change in concentration, area, and locations of contact with surface soil, predicted future groundwater concentrations are also evaluated for potential risks to plants.

6.5.1 Floodplain Areas

6.5.1.1 Exposure assessment

Plants are exposed to contaminants in soil and shallow groundwater primarily by uptake through the roots. As with exposures of soil invertebrates, soil exposures for plants were based on the 0 to 10 cm (0 to 4 in.) and 10 to 41 cm (4 to 16 in.) depth intervals of soil collected from 6 stations at each of 13 transects perpendicular to Bear Creek (Sects. B.5 in Appendix B and G.4.1 in Appendix G). In the absence of data on root distribution, it is assumed that the plants are rooted within the zone from which the soil was sampled for analysis [i.e., the top 41 cm (16 in.)].

It is assumed that the roots of plants near springs may be exposed to seeps of similar concentrations and to contaminants in shallow groundwater plumes, as described in Sect. G.5.1 in

Appendix G. For purposes of the floodplain assessment, estimated current (Sect. D.7 in Appendix D) and predicted future (Sect. E.4 in Appendix E) groundwater concentrations near Bear Creek are used.

6.5.1.2 Effects assessment

The methods used for deriving soil and soil solution benchmarks are presented in Will and Suter (1995b). The screening benchmarks for toxic effects of contaminants present in BCV floodplain soils and soil solution are presented in Sect. G.5 in Appendix G.

The methods, results, and conclusions of the toxicity tests are presented in Sect. G.11 and summarized in Sect G.5. Because there are no dilution series for the soil toxicity tests, the appropriate exposure-response relationship is the association between the significant toxic responses and either the concentrations of contaminants in the soil or the location relative to known sources of contaminants. Test responses used in this assessment include reductions in seed germination and above-ground plant growth of lettuce seedlings in 7- and 21-d exposures to soil, respectively.

Qualitative observations of exposed plant communities may provide evidence about the effects of contaminants. A walkthrough survey of several sites in the BCV, chosen for their location above shallow groundwater contaminant plumes, was undertaken in November 1995. Vegetation was assessed for “the presence of groupings of dead trees or shrubs, patches of groundcover vegetation, twig or bud die-back, and atypical growth form” (Sect. G.11). The evaluation of leaf stress and premature mortality was not included because most of the plants had begun senescence or were entering dormancy. A follow-up survey was conducted in June and July of 1996.

6.5.1.3 Risk characterization

The weight of evidence (Fig. 6.8 and Table 6.8) suggests that the plant community is significantly impacted by exposure to contaminants in soils at four locations (TS033, TS034, TS041, and TS042). Thus, risks from soils are observed at only two contained locations: along the floodplain near transect 3 and along NT8 on the north side of the creek.

Current risks to plants from exposure to contaminants in shallow groundwater are probably negligible (Fig. 6.8 and Table 6.9). If estimated future ground water concentrations are accurate, risks to plants from groundwater near NT1 and NT2 from the S-3 source area may be substantial in the next 60 to 160 years. Risks to plants at NT7 and NT8 will increase gradually during the next 1000 years. Risks from groundwater in the vicinity of Bear Creek are predicted to decrease, and those at NT-3 are predicted to remain the same as current risks.

6.5.2 Source Areas

The four source areas evaluated for potential risk to ecological receptors were the S-3 Ponds area, BYBY, the SL 1/OLF, and BCBG. Separate assessments were carried out for the Creekside and Bear Creek Road Site Debris Burial areas, for which analytical results and the single-chemical toxicity screening are presented in Sect. G.5.2.3 in Appendix G.

6.5.2.1 Exposure assessment

The mechanisms by which plants are exposed to soil contaminants are discussed in Sects. 6.5.1 and G.5.1.1 in Appendix G. Current risks were evaluated using the surface soil samples, aggregated by area. Future risks were evaluated by assuming that the maximum potential exposure would be to inventoried wastes. Therefore, it is assumed that existing caps are no longer present and the

Fig. 6.8 Summary of risk characterization for terrestrial plants in Bear Creek Valley.

contaminants are freely accessible to plants. Combined data for S-3 Pond sludges were used to compute source term concentrations at the S-3 Ponds (Table A.3 in Appendix A), and waste inventory data for the BCBG area were used to compute source term concentrations in the BCBG wastes (Table A.27 in Appendix A).

Soil solutions exposures were evaluated by using the concentrations of contaminants in selected shallow groundwater wells (Sect. G.5.2 in Appendix G). Wells near tributaries NT-1, -2, -6, -7, and -8 were evaluated to determine potential impacts of shallow groundwater upwelling into the tributaries. The maximum observed concentration above background in filtered and unfiltered samples from each well grouping was used in the evaluation.

6.5.2.2 Effects assessment

The screening benchmarks are discussed in Sect. 6.5.1. Although ambient soil toxicity testing was done on soil from floodplain transects only, information from those tests (refer to Sects. G.5.1.2. and G.11 in Appendix G) was used to evaluate potential toxicity of source area contaminants to plants. Results and interpretation of the vegetation surveys are discussed in Sects. 6.5.1, G.5.1, and G.5.2.

6.5.2.3 Risk characterization

A summary of the weight of evidence findings for soil exposures is presented in Fig. 6.8 and Table 6.10. The weight of evidence indicated no unacceptable risks to vegetation in soils at the source areas. Risk was indicated for exposure of plants to S-3 Ponds sludges and the BCBG waste inventory. Although soils at all source locations contained concentrations of SRCs above toxicity benchmarks, the vegetation surveys did not find evidence of dead or stressed vegetation where exposure was to soil contaminants alone. Because the maximum concentrations of SRCs in the source area soils were higher than those used in ambient soil toxicity testing, the ambient testing results could not be used to exclude COPECs as COCs.

A summary of the weight of evidence findings for soil solution exposure is presented in Fig. 6.8 and Table 6.11. The weight of evidence indicated potential risk to plants exposed to shallow groundwater near NT-3 at BYBY, near NT-4 at SL 1/OLF, and near NT-6, NT-7, and NT-8 at BCBG. Concentrations of SRCs were above toxicity benchmarks for soil solution exposure at all of these locations. The vegetation survey indicated past damage or toxicity to willows growing in a seep north of the HCDA at BYBY. Toxicity testing of soil solution was not done. Because the comparison to toxicity benchmarks was done using the maximum concentrations of SRCs at each location, it is likely that risks to plant populations in each source area were overestimated. It is unlikely that SRCs in shallow groundwater pose a risk to the plant populations in the entire BCV.

6.5.3 Uncertainties

The following factors create uncertainty in assessing the risk to plants posed by the contaminants of potential concern in the BCV soils, seeps, and underlying groundwater plume:

- **Bioavailability of elements in soil.** The extraction methods used may remove from the soil quantities of chemicals greater than are available to plants. The double-acid extraction removes the exchangeable fraction of metals, thereby giving a concentration that reflects the total potential pool of contaminants, not that to which the plant is exposed at any one time.

- **Bioavailability of elements in groundwater and springs.** Concentrations of contaminants in whole, unfiltered groundwater are probably higher than the concentrations bioavailable to plants. No background contaminant concentrations were available for comparison with filtered well data. Differences between in filtered and unfiltered BCV groundwater indicates that the bioavailability of chemicals in the two samples is probably quite different.
- **Variable response to toxicants.** Various plant species and plant growth stages tolerate contaminants to different extents. The literature from which benchmarks were derived is from largely agricultural crops in early growth stages rather than to trees and the varied ground vegetation found in BCV.
- **Multiple-contaminant exposure.** Because of our lack of understanding of the complex interactions between contaminants, benchmark levels are necessarily derived from experiments in which plants are exposed to single contaminants. Typical soils of BCV expose plants to multiple contaminants that may not be adequately assessed on the basis of literature-derived benchmarks.
- **Lack of benchmarks for some metals and most organic compounds.** Little research has been conducted on the phytotoxic effects of the organic compounds. Thus, it is not possible to assess the risk to plant growth posed by some of the analytes found in the BCV soils.
- **Adequacy of reference soils.** Reference soils were generally more “toxic” than nonreference soils. These upland sites were apparently inappropriate matches for the contaminated sites in particle size and chemistry. Nutrient differences may have interfered with observed toxic effects in contaminated soil.
- **Representativeness of groundwater wells.** Several shallow groundwater wells at sites upland from the floodplain were used to assess risks to plants in the floodplain. A comparison of risks with plants in various regions of the floodplain was impossible, given the lack of knowledge of the variability in plume depth and contaminant concentration across the floodplain.
- **Chemical speciation.** The analytical techniques did not differentiate among species of chemicals, such as mercury, present in the soil that have variable toxicity to plants.
- **Adequacy of vegetation survey.** One of the vegetation surveys was performed in November; thus, a large portion of vegetation was dormant. Also, the survey was qualitative such that plant community diversity and the presence of specific species were not ascertained.

6.6 RISKS TO WILDLIFE FROM CHEMICALS

Risks from organic and inorganic chemical contaminants were estimated for small mammals, piscivores, and wide-ranging species in the BCV watershed. Because they are highly mobile and may travel throughout the watershed, risks to piscivores and wide-ranging species were evaluated at a watershed level only. Due to their more limited spatial requirements, risks to small mammals were evaluated for the source areas and within BCV as a whole.

6.6.1 Current Exposure Assessment

Wildlife may be exposed to contaminants through ingestion of food, soil, and water. In this assessment, exposure through ingestion of food and soil was estimated using exposure models (refer to Sect. G.6.1 in Appendix G). Exposure through ingestion of water was not modeled; current water exposure was assessed by comparing measured unfiltered water concentrations with water benchmarks for wildlife (refer to Sect G.6.3). Exposure estimates were calculated using soil and

terrestrial biota data (small mammals, earthworms, and herbaceous, canopy, and browse vegetation) from 15 locations within the Bear Creek watershed (4 within the source areas and 11 within the Bear Creek floodplain) and fish data from 5 locations in Bear Creek. To estimate contaminant concentrations in biota, uptake factors were developed from the biota data collected for this assessment.

Using the equations, assumptions, and data described in Sect. G.6.1, point estimates of exposure to contaminants were estimated for each endpoint (Appendix G). Exposure estimates for all analytes detected in samples at the background location are presented. To incorporate the variation in exposure parameters and to provide a better estimate of the potential exposure experienced by wildlife in BCV, the exposure model was recalculated using Monte Carlo simulations (refer to Sect. G.6.1). Simulations were performed for each contaminant for which comparison of point estimates of exposure exceeded lowest observed adverse effect level (LOAEL), which are presented in Sect. G.6.2.

6.6.2 Effects Assessment

No observed adverse effect levels (NOAELs) and LOAELs and water benchmarks were derived for all seven endpoints from toxicity studies reported in the literature. Experimental information used to estimate these benchmarks, NOAELs, and LOAELs are presented in Appendix G. The COPECs for wildlife are presented in Supporting Information to Appendix G.

Stevens (1995) investigated bioaccumulation of mercury in mink on the ORR in 1993 through 1995. The methods used in the mink survey, while indicating that mink are present, cannot be used to estimate abundance or density of mink on the ORR.

6.6.3 Characterization of Current Risks

One line of evidence, literature toxicity data, was available to evaluate potential risk to all endpoints except mink. Monte Carlo simulation of exposure and comparison of the resulting exposure estimates with NOAELs and LOAELs and calculation of binomial probability distributions of risks to populations (Sect G.6.3) suggest that (1) antimony, mercury, PCBs, and vanadium present significant risks to the shrew population at source areas, and antimony, mercury, PCBs and vanadium present significant risks to the BCV shrew population; (2) mercury presents significant risks to the source area mouse population, but no contaminant presents significant risks to the BCV mouse population; (3) no contaminant presents a significant risk to the white-tailed deer population within the BCV; (4) copper and mercury, present significant risks to the BCV fox population; (5) no contaminant presents a significant risk to hawks in the BCV; and (6) mercury in BCV represents a significant risk to the kingfisher population in this area. Two lines of evidence, biological survey data and literature toxicity data, were available to evaluate potential risks to mink within the BCV. The weight of evidence suggests that mink are at risk from copper and mercury in the BCV. Significant risks are not indicated for any of the three T&E wildlife species that are likely to occur in the BCV (i.e., northern pine snake and the cooper's and sharp-shinned hawks).

6.6.4 Uncertainties Concerning Risks to Wildlife

The following issues constitute the major sources of uncertainty in the risk assessment for wildlife:

- **Bioavailability of Contaminants.** Bioavailability of contaminants was assumed to be comparable between soil and biota collected from the BCV and the diets used in the literature

toxicity tests. Because bioavailability may not be comparable, exposure estimates based upon the contaminant concentrations may either under- or overestimate the actual contaminant exposure experienced.

- **Extrapolation from Published Toxicity Data** While published toxicity studies are available for mink, no published data for the other endpoints exist. To estimate toxicity of contaminants at the site, it was necessary to extrapolate from studies performed on test species (i.e., mallard ducks, ring-necked pheasant, and rats). Additional extrapolation uncertainty exists for those contaminants for which data consisted of only LOAELs or tests were subchronic in duration
- **Variable Food Consumption..** Food consumption by wildlife on the ORR may be greater or less than that reported in the literature, resulting in either an increase or decrease in contaminant exposure.
- **Single-Contaminant Tests vs Exposure to Multiple Contaminants in the Field.** While piscivores on the ORR are exposed to multiple contaminants concurrently, published toxicological values only consider effects experienced by exposures to single contaminants. Because some contaminants to which wildlife are exposed can interact antagonistically, single-contaminant studies may overestimate their toxic potential. Similarly, for those contaminants that interact additively or synergistically, single-contaminant studies may underestimate their toxic potential.
- **Inorganic Forms or Species Present in the Environment.** Toxicity of metal species varies dramatically depending upon the valence state or form (organic or inorganic) of the metal, but the available data on the contaminant concentrations in media do not report which species or form of contaminant was observed
- **Contaminant Concentrations in Unanalyzed Food Types.** Contaminant data or uptake factors were not available for all food types consumed by the endpoint species.
- **Estimated Whole Fish Concentrations** Contaminant concentrations in whole fish were estimated using contaminant-specific fillet-to-whole-fish ratios.
- **Spatial averaging of exposures to estimates.** To evaluate exposure and risks to wildlife at the source area and BCV levels, Monte Carlo simulations were performed on the average exposures within these areas. This approach assumes that wildlife forage equally over the entire area and that biases associated with preferential foraging in or deliberate sampling of hotspots are balanced or insignificant.

6.6.5 Future Chemical Risks to Wildlife

As conditions within the BCV change in the future, risks that chemicals present to wildlife may change. The future chemical risks to wildlife were evaluated for inventory wastes in the sources areas that are capped and currently not available and for modeled future surface water exposures.

Future risks to wildlife in the BCV floodplain was not specifically estimated. Assuming no new sources, contamination in the BCV floodplain is expected to decrease over time due to degradation, erosion, etc. Therefore future risks to wildlife from chemical contaminants in the floodplain were assumed to be equivalent to or lower than what has been estimated under the current case.

6.6.5.1 Inventory wastes

The exposure sources evaluated in the following sections are the capped sludges at the S-3 Ponds and the capped waste inventories in the BCBG area. Contaminants in the S-3 Ponds

sludges and the BCBG waste inventory are discussed in Appendix A (Vol.2 of the BCVR Report). The sludge and waste inventory assessments evaluate future risks, assuming that caps and/or covers over the wastes degrade, allowing ready access by short-tailed shrews to the soils.

Exposure assessment

Contaminants in the S-3 Ponds sludges and the BCBG waste inventory are discussed in Appendix A. The sludge and waste inventory assessments evaluate future risks, assuming that caps and/or covers over the wastes degrade, allowing ready access by wildlife to the “soils.”

Potential future exposure of wildlife to contaminants in the S-3 Pond sludges and the BCBG area waste inventory sites was evaluated for short-tailed shrews only because they typically ingest large amounts of soil, resulting in a higher exposure of shrews to soil contaminants than occurs in mice. Therefore, these estimates are conservative for small mammals at the sites.

Exposure modeling for point estimates of exposure at the waste inventory sites was done following the procedures described in Sects. 6.1 and G.6.1.5. Unlike the exposures in the source units and the Bear Creek floodplain, which are represented by a range of contaminant concentrations, exposures at the disposal and waste inventory sites are assumed to be homogeneous, because there is a single contaminant concentration for each location. Therefore, Monte Carlo simulations, which represent exposure to the distribution of contaminant concentrations were not used to model distributions of exposure.

Effects assessment

Procedures for evaluation of toxicity data and development of toxicity benchmarks are presented in Sect. G.6.2.

Characterization of risks

A single line of evidence, literature toxicity data, was available to evaluate potential risk to short-tailed shrews and white-footed mice. The weight of evidence suggests uranium and zirconium in the S-3 Ponds sludges, and beryllium, mercury, uranium, and PCBs in the BCBG waste inventory represent significant risks to the short-tailed shrew population. Risks do not currently occur from the S-3 Ponds sludges or the BCBG waste inventory. The site that poses the highest future risk to short-tailed shrews if unlimited exposure becomes possible is the BCBG waste inventory. Exposure of wildlife to contaminants in the BCBG waste inventories, especially uranium, would be extremely hazardous

6.6.5.2 Risks from future surface water exposures

To evaluate the potential future risk that contaminants in surface water present to wildlife, the maximum estimated for concentrations in surface water were compared with LOAEL water benchmarks for all species. HQs (water concentration/benchmark value) were calculated for all species and are presented in Appendix G. No benchmarks were exceeded for any endpoint at any location. Most HQs ranged from 10^{-2} to 10^{-3} or greater, indicating minimal future risks to wildlife from contaminants in BCVR surface water.

6.6.5.3 Uncertainties

The uncertainties discussed in Sect. 6.6.4 also apply to evaluation of risks at the waste inventory sites. In addition, uncertainty about the range of contaminant concentrations exists, because only a single contaminant concentration for solid media was calculated for each of the S-3 Pond and BCBG area waste inventory locations. As noted previously, there also is some uncertainty associated with the modeling of future surface water concentrations.

6.7 RISKS TO TERRESTRIAL BIOTA FROM EXPOSURE TO RADIONUCLIDES

The potential risks to terrestrial biota (plants, invertebrates, wildlife) from current and future exposure to radionuclides are discussed in this section because the assessment of radiation exposure and effects is similar for all of these endpoints, but is very different from the assessment of chemical risks.

6.7.1 Exposure Assessment

Risks were estimated from radionuclides measured in surface soil from the floodplain and source areas and surface water from Bear Creek, its tributaries, and four seep areas. Future water-related exposures were evaluated using predicted maximum surface water activity levels at four locations (NT-1, NT-3, NT-7, and NT-8). In addition, hypothetical future exposures to waste inventories (assumed radionuclides in soil) were evaluated.

Radiation dose rates (mrad/d) were calculated for plants, earthworms, and representative terrestrial and semiaquatic wildlife species in the Bear Creek watershed using methodology adapted from Blaylock, Frank, and O'Neal (1993) and Baker and Soldat (1992). The methodology was modified to address site-specific conditions and receptors. Dose rates from internal exposures via ingestion of food, soil, and water and via inhalation of dust were evaluated, as were dose rates from external exposures via soil and water. The representative terrestrial and semiaquatic wildlife selected as endpoints and the life history parameters for the radiological assessment were the same as those for the chemical data assessment. The general methodology and the equations specific to each exposure route used to estimate dose rates for Bear Creek terrestrial biota are described in Sect. G.7 in Appendix G.

6.7.2. Effects Levels

The discharge of radioactive waste into the environment results in long-term, low-dose exposure to organisms. In most cases, acute mortality can be discounted. Any potential increase in morbidity and mortality that might result from the exposure to chronic irradiation above background is unlikely to be detected because of natural fluctuations in the size of populations. The International Atomic Energy Agency (IAEA) recommends limiting the dose for terrestrial organisms to 100 mrad/d (IAEA 1992). Species-specific effects data were not available, so 100 mrad/d was selected as the threshold dose for all representative wildlife receptors. A dose rate of 1 rad/d is generally considered protective of plant and invertebrate populations (IAEA 1992, Barnthouse 1995). Therefore, 1 rad/d was selected as the threshold dose for effects on plant and invertebrate populations.

6.7.3. Risk Characterization

No detectable radiation effects are anticipated for individual terrestrial biota frequenting the Bear Creek, floodplain, or source area sites, as the overall current dose rate was below the effects thresholds for all receptors at all of these sites (refer to Sect. G.7.3 in Appendix G).

No adverse effects from future exposures to radionuclides in surface water or surface soil are anticipated. However, the estimated inventory activities are substantially higher than those observed along Bear Creek or in the source areas and exposure to radiation of this magnitude would result in significant risks to plants, invertebrates, and wildlife. The recommended limit of 100 mrad/d is exceeded by 1-4 orders of magnitude for short-tailed shrews, white-footed mice, red fox, white-tailed deer, and red-tailed hawk at C-East and C-West. Plant and earthworm dose rates would exceed the 1 rad/d dose limit by a factor of 0.5 to 1000. Thorium accounts for greater than 90% of the dose to wildlife at both sites, but Technetium-99 in C-West contributes up to 187 mrad/d to the dose rate received by the shrew, mouse, and deer. Plant and earthworm dose rates would exceed the 1 rad/d dose limit by three orders of magnitude at C-West and by 1-2 orders of magnitude at C-East. Technetium-99 at A-North also would result in dose rates 1000 times the recommended limit for plants and earthworms, but wildlife receptor dose rates were below the wildlife dose limit of 100 mrad/d.

6.7.4 Uncertainties

A number of areas of uncertainty exist in the estimation of risks to wildlife from exposure to radionuclides at Bear Creek. It is believed that the methodology used in this assessment overestimates the dose rates that would be received. Whereas some of the information needed to implement the methodology is well-known, much is unknown or unspecified statistically. A conservative but reasonable approach to model assumptions and radiological exposure scenarios was adopted for this assessment in order to avoid underestimating risks to biota. Many of the uncertainties identified in the plant, soil invertebrate, and wildlife sections also apply to the radionuclide assessment. Specific uncertainties identified in the radionuclide assessment are presented here.

- **Uptake of radionuclides from soil, food, and water** was assumed to be similar. Radionuclides bound to soil may be less available than those in tissue or water. Therefore, assuming uptake from soil equal to uptake from food may result in a conservative estimate of actual uptake.
- **Uptake factors from soil to earthworms** were unavailable for many radionuclides. In the case of unavailability, the higher of the plant or mammal uptake factors was used for earthworms.
- **Uptake factors for birds** for all radionuclides were not available. In the absence of bird-specific uptake factors, radionuclide activities in red-tailed hawk tissues were estimated using mammal uptake factors assuming that uptake would be similar for hawks and mammals.
- **Mammal soil-to-tissue uptake factors** were calculated from measured data on small rodents. While these clearly apply directly to white-footed mice, the short-tailed shrew diets differ somewhat from that of white-footed mice, as shrews eat a higher proportion of invertebrates. However, it was assumed that site-specific data on mice was more applicable to shrews than literature-derived bioaccumulation factors.
- **Literature-derived bioaccumulation factors** were used to estimate radionuclide activities in mammal and bird tissues when site-specific data were unavailable. While these values are believed to be representative of bioaccumulation likely to be observed on site, actual values may be higher or lower than used in this assessment.

- **Radiation dose rates estimated based on the waste inventories** of the Burial Grounds were calculated using the same models and model parameters used for the floodplain soils and source areas. In the case of uptake factors, this assumes the ratio of radionuclides in tissue to soil or food remains the same even at the extremely high activity levels observed in the waste inventories. Dose rates based on the waste inventory data may be overestimated if the ratio is not linear to such high activities.
- **Species-specific time budget information** is lacking, so it was necessary to make a number of assumptions regarding the fraction of time each receptor spends above or below ground, underwater, or at the water's surface. The fractions used in this assessment were selected based on general knowledge of species behavior patterns, but actual fractions may be higher or lower.
- **The air mass loading factor** of 0.1 g/m^3 used in estimating exposures from inhalation of radionuclide-contaminated dust was selected as a conservative value. Healy (1980) suggested 0.0001 g/m^3 would be a conservative value for estimating human exposures from inhalation of dust.

6.8 SUMMARY AND CONCLUSIONS

Significant ecological risks were identified in the BCV CA from chemicals in water, sediment, soil, and shallow groundwater for one or more receptors. Metals and PCBs were the primary COECs and source area and floodplain soils, including floodplain transects away from the source areas (i.e., west of BCK 9.4), contribute to these risks. These conclusions are summarized in Figs. 6.5–6.9. and the COECs for each receptor are summarized in Table 6.12

The weight of evidence suggests that water from Bear Creek and tributaries NT-2 through NT-8 currently does not pose a significant risk of a 20% reduction in fish species richness or abundance due to a toxic effect. The Tennessee dace population in Bear Creek does not appear to be degraded due to a toxic effect, given that the highest densities occur at the most highly contaminated site (BCK 12.36) and the lower densities observed in Reach 2 and upper Reach 3 are primarily attributable to poor habitat quality. Future risks may become significant in NT-1, NT-2, NT-7, NT-8, and Bear Creek at BCK 9.47, based on predicted maximum contaminant concentrations in surface water.

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 benthic invertebrate species richness and abundance due to a toxic effect. The distribution of observed effects and toxic concentrations strongly suggests that discharges from the S-3 Ponds continue to be the primary contributor to risks. Future risks are expected to remain significant in NT-1, NT-2 and most of Bear Creek Reaches 1 and 2 and may become significant in NT-7 and NT-8, based on predicted maximum contaminant concentrations in surface water.

The weight of evidence suggests that sediment from 3 of the 18 sites poses a significant risk to benthic invertebrates inhabiting those sites due to a toxic effect. However, it is unlikely that the soft-sediment benthic invertebrate community as a whole is reduced by 20% in species richness or abundance.

Soil from the floodplain transects and the BCBG area does not appear to present a significant risk to soil invertebrates due to a toxic effect. Risks of a toxic effect to soil invertebrates are estimated to be significant in the S-3 Ponds area, SL/OLF area, BYBY area, Creekside Burial area, and the

Fig. 6.9. Distribution of risks posed to ecological receptors in BCV.

Bear Creek Road Debris Burial area. Soil at isolated locations along two floodplain transects in upper Bear Creek (i.e., transects 3 and 4) appear to pose a significant risk to plants.

The plant community in the BCV floodplain and source areas are not currently negatively impacted by contaminants in shallow groundwater or springs. However, the plant community near NT-1 and NT-2, and to a lesser extent, NT-7 and NT-8 Walk in Pits may be adversely affected by metals in ground water in the future.

Short-tailed shrews are estimated to be significantly at risk of a 20% reduction in population production from high soil concentrations of metals and PCBs. Risks are significant for both the source area and BCV populations. Chemicals in source area and floodplain soils, including transects west of BCK 9.4, contribute to these risks.

Risks to white-footed mice were observed from only in the source area from only one contaminant, mercury. Mice inhabiting the floodplain are not at significant risk from any contaminants.

Risks to white-tailed deer in BCV are estimated to be insignificant. Although concentrations of three metals and PCBs exceeded LOAELs at one or more sites, the deer inhabiting the watershed do not appear to be significantly at risk of a 20% reduction in population production.

Risks to red-tailed hawks inhabiting BCV are estimated to be insignificant, but fox were estimated to be significantly at risk of a 20% reduction in population production. Copper and mercury in source area and floodplain soils, including transects west of BCK 9.4, contribute to these risks.

Both mink and kingfishers inhabiting the watershed were estimated to be significantly at risk of a 20% reduction in population production. Risks to mink are based on mercury in fish from lower Bear Creek. Copper and mercury in source area and floodplain soils, including transects west of BCK 9.4, contribute to these risks. Risks to kingfisher are based on mercury concentrations in fish, which exceeded the kingfisher LOAEL in upper and lower Bear Creek. However, the source of mercury contamination of BCV fish is unclear.

Red-tailed hawks were used as surrogates to estimate risks to T&E species that may be present in the BCV (cooper's hawks, sharp-shinned hawks and northern pine snakes). Because risks to red-tailed hawks were determined to be insignificant, risks to these three T&E species were also determined to be insignificant.

Radionuclide concentrations in BCV surface water and soil do not appear to present a significant to any of the assessment endpoints. Dose rates were below the recommended limits for fish, benthic invertebrates, plants, earthworms, and wildlife.

6.9 REMEDIAL GOAL OPTIONS

Because ecological risk assessments may be based on a weighing of multiple lines of evidence, the procedure for developing risk-based remedial goal options (RBRGOs) must also be based on weight of evidence. The procedure is described and depicted diagrammatically in Sect. G.9 in Appendix G. RBRGOs must be developed for each endpoint for which risks have been characterized as significant. The first step is to determine what means are available for determining what areas or concentrations in media may require remediation. The alternative means are the lines of evidence used to characterize ecological risks. The output of this weighing of evidence will be a set of areas

that are candidates for remediation based on risks to a particular ecological assessment endpoint. If it is possible that the remediation would consist of treatment of a source or of contaminated media within the defined areas, rather than simply removing or isolating the contaminated media (e.g., dredging or capping), then the RBRGOs should be defined as concentrations that should be achieved within those areas.

The weight of evidence suggests that the fish communities in BCV are not currently degraded due to a contaminant effect. Therefore, RBRGOs are not indicated for this assessment endpoint.

The screening of predicted future aqueous contaminant concentrations suggests that exposures are expected to increase, and future risks to the fish community are expected to be significant, in NT-1, NT-2, NT-7, NT-8, in Bear Creek at BCK 9.47, and, potentially, between BCK 9.47 and NT-1. RBRGOs are presented in Table 6.13 for chemicals for which adverse effects of predicted future concentrations are possible or expected and loading is not at steady-state. It is important to note that, generally, risks in NT-7 and NT-8 are expected to increase slowly over the next 1000 years. The exception is that risks from cyanide are expected to peak in the next 50 years. However, Chemical concentrations, and therefore risks to fish, in NT-1 and NT-2 are expected to peak in the next 50 to 350 years. The peak time for BCK 9.47 could not be estimated.

The weight of evidence suggests that water in Reaches 1 and 2, NT-2, SS-1, and SS-4 poses currently a significant risk to benthic invertebrates from high concentrations of calcium, cadmium, manganese, nickel, and uranium. RBRGOs are presented for those chemicals which are likely to be significantly toxic (Table 6.14). The characterization of risks based on the single-chemical toxicity data did not identify any chemicals in water collected from this seep that are likely to be toxic. Hence, the RBRGO for SS-4 is the reduction of toxicity due to a contaminant effect during storm events. However, two of the metals that are potentially toxic at this seep (nickel and uranium) are likely to be toxic elsewhere and have associated RBRGOs.

The weight-of-evidence for future risks to benthic invertebrates is based solely on the screening of predicted future aqueous contaminant concentrations, which suggest that exposures are expected to increase, and future risks to the benthic invertebrate community are expected to continue to be significant, in NT-1, NT-2, Bear Creek at BCK 9.47 (i.e., the lower end of Reach 2), and, potentially, between BCK 9.47 and NT-1. Exposures are expected to increase, and future risks to the benthic invertebrate community are expected to become significant, in NT-7 and NT-8. The RBRGOs for future risks to benthic invertebrates are the same as those for future risks to fish and are presented in Table 6.13 for chemicals for which adverse effects of predicted future concentrations are possible or expected.

The weight of evidence indicates that sediments pose a significant risk to the benthic invertebrates inhabiting three locations in the BCV CA: NT-2, NT-6, and SD-17. However, it is unlikely that the benthic invertebrate community as a whole is degraded. If the risk managers determine that protection of the benthic invertebrates inhabiting individual depositional areas or tributaries is warranted, actions should be taken to meet the RBRGOs for the chemicals (manganese, selenium, and 2,4,5-T) that were characterized as presenting a significant risk in NT-2 or NT-6 (Table 6.15). The toxicity tests indicate that sediment at SD-17 poses a significant risk to the benthic invertebrates inhabiting that site. Because a likely causative agent could not be determined from the available chemical data, the RBRGO for SD-17 must be defined by the sediment toxicity test results. Hence, if a removal action is taken to reduce the risks at this site, the area to be remediated is dependent on toxicity, rather than chemical analyses.

The weight of evidence indicates that the plant community is adversely impacted by contaminants in soil at near-creek locations in floodplain transects 3 and 4. Measures may be taken to ensure that chemicals at the sites do not exceed concentrations that are associated with effects. RBRGOs for reducing risk to plants in soil are presented in Table 6.16. However, risk managers must decide if a plant community in a small contaminated area should be remediated to reduce risk if the community is defined by similar vegetation across a wide geographic region.

The weight of evidence indicates that the plant community may be adversely impacted by contaminants in soil solution at a location near HCDA in BYBY. If it is deemed necessary to protect plants from exposures to contaminants in soil solution. It is likely that remediation of HCDA rather than of groundwater will be necessary. Therefore, RBRGOs are not proposed for current shallow groundwater exposures.

The plant community near NT-1 and NT-2, and to a lesser extent, NT-7 and NT-8 Walk in Pits may be adversely affected by metals in ground water in the future. If it is deemed necessary to protect plants from future exposures to contaminants in soil solution, the soil-solution toxicity benchmarks are recommended as RBRGOs (Table 6.17).

The weight of evidence indicates that soil invertebrates are negatively impacted by contaminants at the S-3 Ponds area, the SL 1/OLF area, the BYBY area, the Creekside Burial area, and the Bear Creek Road Site Debris Burial area. Measures may be taken to ensure that chemicals at the sites do not exceed concentrations that are associated with effects. RBRGOs for reducing risk to soil invertebrates are presented in Table 6.18.

RBRGOs were developed for those wildlife endpoints and chemicals where population-level risks were identified. RBRGOs, calculated based on soil concentration and the 95% UCL for Bear Creek-specific soil-to-biota contaminant uptake factors are presented in Table 6.19. To determine which sites should be remediated to reduce the estimated population-level risk to an acceptable level, Monte Carlo simulations were recalculated, and exposures at the most contaminated sites (e.g., the sites with the highest HQs) set to either zero (for PCBs) or to the estimated exposure at background (for inorganics). Effects of the remediation of selected sites on population-level risks to wildlife are presented in Table 6.20.

To reduce population-level risks to wildlife in the BCV and within the source areas, surface soils at 8 of the 17 evaluated locations are recommended for remediation. Five locations contribute significantly to risks from multiple contaminants to multiple species: the Roadside and Creekside areas, the S-3 Ponds area, the BYBY, and the OLF. The remaining locations (the BG, TS07, and TS10) only present risks to shrews from PCBs. Risks to kingfisher from mercury may be alleviated by reducing mercury concentrations in fish to the RBRGO level (Table 6.19) at BCK 12.4, BCK 4.5, and BCK 0.6. However, the source of mercury contamination of BCV fish is unclear.

The recommendation that the Bear Creek OU 1 locations (the S-3 Ponds area, the BYBY, the OLF, and the BCBG) should be remediated to reduce current on-site risk should be viewed with some caution. These sites are generally small in size and generally provide minimal habitat. The S-3 Ponds area, in particular, is a paved parking lot and has virtually no habitat currently available. Although the risk analysis may overestimate the current risks that these Bear Creek OU 1 sites present, they should still be considered for remediation because they are located at the headwaters of the Bear Creek watershed and may serve as significant sources of contamination to downstream locations.

6.10 REFERENCES

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7. REMEDIAL GOAL OPTIONS

As part of the alternative selection process, Remedial Goal Options (RGOs) are identified. RGOs are developed for each chemical identified as a chemical of concern for BCV. RGOs are media- and chemical-specific concentrations corresponding to “acceptable” levels of exposure and are used to identify alternatives and technologies that are effective for addressing potential unacceptable exposures and risks in the valley.

Chemicals of concern for BCV were identified using the following criteria:

- results of the BHHRA (Chapter 5 and Appendix F),
- results of the BERA (Chapter 6 and Appendix G),
- results of the predictive modeling (Appendix E), and
- comparison to ARARs (Chapter 4).

Tables 7.1, 7.2, 7.3, and 7.4 present a summary of the chemical- and media-specific RGOs associated with the chemicals of concern identified at BCV for soil, sediment, surface water, and groundwater, respectively. The methodologies for estimating RGOs associated with human health, ecological, predictive modeling, and ARARs are presented in the following sections.

Human Health

The BHHRA identified chemicals of concern as chemicals whose risk exceeded acceptable criteria for one of the four potential receptors: residential, recreational, industrial, or maintenance. The chemicals of concern were determined for a given medium as chemicals whose individual risks were $\geq 1 \times 10^{-6}$ and/or whose individual HQs were ≥ 0.1 within a land use scenario and whose total cumulative risk was $\geq 1 \times 10^{-4}$ and/or whose total cumulative HI was ≥ 1.0 . An exposure pathway was identified as being of concern if the total pathway risk was $\geq 1 \times 10^{-4}$ or the total pathway HI was ≥ 1.0 . The chemicals of concern were determined for each source area/FA, medium, and land use scenario.

RGOs were calculated using the methodologies presented in the *Preliminary Remediation Goals for Use at the U.S. Department of Energy Oak Ridge Operations Office* (Energy Systems 1996) for the chemicals of concern identified in the human health risk assessment. Table values for the risk-based RGOs represent the midpoint values of the acceptable risks/hazard range. RGOs for risk = 10^{-6} , 10^{-5} , 10^{-4} and HQ = 0.1, 1, 10 were calculated. The RGO summary tables present values corresponding to a risk = 10^{-5} or HQ = 1. When a chemical has both a risk and a HQ RGO, the lower of the values is used as the RGO.

Ecological

The ecological assessment identified chemicals of concern as chemicals whose concentration exceeded benchmarks and probable effects levels. The RGOs represent benchmarks, probable effects levels, ambient water quality criteria, and naturally occurring background levels (Energy Systems 1994, 1995a, 1995b, 1995c, and 1995d).

ARARs

The chemicals of concern identified during the ARAR screening represented chemicals whose concentration exceeded the appropriate ARAR (soil ARAR, MCL, and ambient water quality criteria). For chemicals of concern, the RGO presented in the summary tables included the appropriate ARAR used for comparison.

Predictive Modeling

Chemicals of concern were identified from the results of the predictive modeling, but no RGOs were calculated. The predictive modeling compared predicted groundwater concentrations to MCLs and risk-based PRGs. If modeled groundwater concentrations exceeded MCLs or PRGs, the chemical was a chemical of concern. The chemicals of concern from the modeling results presented in Table 7.1 identify if the chemical of concern resulted from the ARAR screen or the risk-based PRG screen.

7.1 REFERENCES

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8. CONCLUSIONS

The Bear Creek Valley RI Report contains a detailed analysis of environmental data for BCV. The conclusions from the analysis are conveyed via conceptual models for the nature and extent of contamination and fate and transport of contaminants (Chaps. 2 and 3 of this volume). Based on these conceptual models and contaminant exposure models, risk posed to human health and the environment in BCV is quantified in Chaps. 5 and 6.

This section of the report contains conclusions about key physical and chemical aspects of the conceptual model for BCV that will affect the success of remedial strategies and technologies. These conclusions are meant to focus the decision-making process on those critical physical and chemical factors and thus be a foundation for the FS and subsequent decision-making documents. Conclusions are presented for the current physical and chemical situation in the valley and anticipated future changes to the current situation if no action is taken. Three future land use conditions are discussed and, following the watershed approach to BCV, are used to highlight the specific physical and chemical conditions that must be addressed by remedial strategies and technologies. The major conclusions of the RI are:

- There are a number of physical and chemical aspects of the source sites that will complicate cleanup of the source areas and will limit the ability to allow unrestricted 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 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.
- A north-south line drawn at BCK-9.47/SS-5 (Fig 8.1) is a convenient location to conduct an integrator point/plane (IP) assessment of contaminant fluxes. Contaminants migrating from the waste sites east of BCK-9.47 converge at the IP: more than 99% of available water from the upper portion of the valley passes through this location as either surface water or groundwater. At the IP, potential risks from exposure to groundwater or surface water exceed 10^{-6} or an $HI > 1$ (Fig 8.2). The COCs at the IP are uranium, nitrate, boron, and fluoride and ARARs are probably exceeded in groundwater (nitrate, uranium, and VOCs). (Note: In some of the FS alternatives, unrestricted land use starts to the west of this line.) 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., 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 8.2 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 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 NT-1, NT-2, and NT-3 or shallow groundwater at the S-3 Site and BYBY could reduce the total HI at the IP below 0.8.

- Discharge of the S-3 Plume into NT-1 and NT-2 is the primary cause of current aquatic ecological impacts in BCV.
- Current collection of leachate in the BCBG results in a lesser human health risk/hazard at BCK 9.47.

8.1 CURRENT CONDITIONS IN BCV

Inherent in the accelerated watershed approach taken by this RI is a heavy reliance on historical data. 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. The data available to the RI Report were sufficient to provide a comprehensive evaluation of the conditions and risks associated with the waste sites, floodplain, and groundwater in BCV. These data also provide adequate support for future decisions that are to be made in BCV.

Waste Disposal Units. The waste areas in BCV are located in the upper 3.5 km (2.2 miles) of the valley (east of the IP) (Fig 8.3). 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 disposal has 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.

The following volumes of waste, contaminated soil, and contaminated groundwater are estimated to be present in BCV (note that volume estimates for soils and wastes do not include materials in RCRA 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 × 10⁶ 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.

Waste Constituents. Based on inventory records, uranium constitutes the major contaminant in the solid waste. The largest mass of uranium is at BCBG; however, BYBY also contains a large but undefined mass. Nitrate, VOCs, and uranium were contaminants in liquid wastes and constitute the main contaminants in groundwater and surface water.

Migration Pathways. Contaminants migrate away from the waste disposal units using the following pathways (Fig. 8.1):

- 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.

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. 8.3). 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. 8.4). 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. 8.5). 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. 8.5). In addition, ARARs are exceeded in groundwater at many locations east of the IP.

At the IP, potential human health (residential) 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 (Fig. 8.2). In addition, ARARs are exceeded in groundwater (nitrate, uranium, and VOCs).

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. 8.3 to 8.5). West of the IP, the most prevalent contaminants in groundwater and surface water this section of the valley 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.

Contaminant Fluxes. Contaminants migrating from the waste sites in BCV converge at BCK-9.47/SS-5 (termed the integrator point or IP) — more than 99% of available water from the upper portion of the valley passes through this location as either surface water or groundwater. 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. 8.2). 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 the Burial Grounds. 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 collected in BCBG.

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 VOC 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.

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 8.3). 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.

8.2 FUTURE CONDITIONS

Exhibit 8.1 lists three hypothetical future conditions for BCV and the risk-bearing pathways that would require remedial actions or controls to reach acceptable levels of exposure. In the following section, the physical, chemical, and hydrological parameters that must be addressed to achieve the remedial action objectives for each of the pathways listed in Exhibit 8.1 are listed and discussed.

8.2.1 Considerations for Mitigating Exposures to Groundwater at the Sources and Surface Water in Tributaries

- 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. 8.1). 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 (Pankow and Cherry 1995). 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 of preferential pathways are not known at this time and may be difficult to ascertain.
- Flow in 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.
- Like flow in surface water, flow in groundwater is also “flashy”. Rapid recharge and stormflow during precipitation events result in short periods of high groundwater flow that are

maintained usually for less than 3 days. During this time, contaminant concentrations in shallow groundwater are diluted.

8.2.2 Considerations for Mitigating Exposures to Groundwater and Surface Water at and West of the IP

Contamination in groundwater and surface water at, and west of, the IP is derived from migration away from the source sites. The remedial strategy for this scenario has the option of taking actions at the IP to mitigate exposures downstream, or to take actions upstream east of the IP that will result in achieving the remedial goals at the exposure point.

Considerations for groundwater/surface water actions at the IP

Groundwater

- 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 feet/a).
- 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.

Surface Water

- 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.

Considerations for groundwater/surface water actions east of the IP

Interception of contaminant pathways to tributaries (i.e. actions taken closer to the sources) would result in remediation of nitrate and uranium in contaminated surface water in Bear Creek and groundwater in the Maynardville Limestone. To mitigate exposure to contaminants in groundwater at the IP, VOC contamination in the Maynardville Limestone will also need to be addressed.

Actions taken east of the IP need to consider the physical and chemical properties of the various contaminant migration pathways from the sources in BCV to the IP. As is discussed in Sect. 8.1 the main pathway for contaminants close to the sources is in shallow groundwater and tributaries feeding Bear Creek (Fig. 8.1). The physical and chemical considerations for addressing these pathways are discussed in Sect. 8.2.1. In addition, the same potentially problematic

hydrologic parameters discussed above for remediating the Maynardville Limestone at the IP will need to be considered for VOCs in the Maynardville Limestone east of the IP.

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:

Relative importance of pathways

- Figure 8.2 shows the potential human health risks/hazards from surface water and groundwater at the IP posed by exposure to the individual COCs. Figure 8.2 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 engaged 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 human health 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 engaged flux derived from this site (assumed to be 70% of the total engaged 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 engaged flux derived from this site (assumed to be 30% of the total engaged flux) would result in a 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. (The exception is mercury, which poses a risk to piscivores and for which a source in BCV has not been identified.) 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.

8.2.3 Considerations for Mitigating Exposures to 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 exists at BYBY, SL1, 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 which limit the possibility of direct exposure to waste materials under the current land use.

8.2.4 Considerations for Mitigating Exposures to Soils/sediments in the Bear Creek Floodplain

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

Exhibit 8.1. Hypothetical future conditions in BCV and risk-bearing pathways

Possible Future Condition of BCV	Risk-bearing pathways that require remedial actions or controls to reach acceptable levels of exposure
<ul style="list-style-type: none"> • Unrestricted (e.g., residential or recreational) use of BCV West of the IP • Industrial use of BCV East of the IP • Protection of the terrestrial ecology throughout BCV and the aquatic ecology in Bear Creek main channel. 	<ul style="list-style-type: none"> • contact with waste materials and contaminated soil in the upper 16 inches of soil by industrial workers and terrestrial biota east of the IP; • contact with contaminated soils/sediments in the Bear Creek floodplain in the upper 32 inches of soil by residents and in the top 16 inches of soil by terrestrial biota west of the IP; • exposure to contaminants in surface water and sediment in Bear Creek and its tributaries for aquatic biota and piscivores; and • use of groundwater and surface water at, and west of, the IP.
<ul style="list-style-type: none"> • Unrestricted (e.g., residential) use of BCV outside the immediate vicinity of source areas (shaded areas on Fig. 8.3) • Industrial use at the source areas • Protection of the terrestrial ecology of BCV and the aquatic ecology of Bear Creek and its tributaries. 	<ul style="list-style-type: none"> • contact with waste materials and contaminated soil at sources in the upper 16 inches of soil by industrial workers and terrestrial biota; • contact with contaminated soils/sediments in the Bear Creek floodplain in the upper 32 inches by residents and in the top 16 inches of soil by terrestrial biota; • exposure to contaminants in surface water and sediment in Bear Creek and its tributaries for aquatic biota and piscivores; and • use of contaminated surface water in Bear Creek and some tributaries; and • use of contaminated groundwater in the Maynardville Limestone.
<ul style="list-style-type: none"> • Unrestricted (e.g., residential) use of BCV • Protection of the terrestrial and aquatic ecology throughout BCV 	<ul style="list-style-type: none"> • contact with waste materials and contaminated soil in the upper 8 feet of soil by residents, top 16 inches for industrial use, and in the top 16 inches of soil by terrestrial biota; • contact with contaminated soils/sediments in the Bear Creek floodplain in the upper 32 inches of soil by residents and in the top 16 inches of soil by terrestrial biota; • exposure to contaminants in surface water and sediment in Bear Creek and its tributaries for aquatic biota and piscivores; and • use of groundwater in the Maynardville Limestone and surface water in Bear Creek; and • use of contaminated groundwater at the sources and surface water in the tributaries.

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Fig. 8.1. Conceptual model for contaminant migration in BCV.

low uranium-contaminated groundwater

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Bear Creek

Bear Creek

ant transport pathway

ant transport pathway

ort

S-3 SITE

Historical Plumes act
as secondary source

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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

Potential Risks and Toxic Effects
at the Integrator Plane

Uranium Flux

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

Nitrate Flux

Fig. 8.2. Potential risks and hazards at the integrator point/plane and the relative magnitude of the sources for nitrate and uranium.

Fig. 8.3. Distribution of risks posed to potential future residential and recreational users of BCV.

Fig. 8.4. Distribution of risks posed to potential future industrial and unprotected maintenance workers in BCV.

Fig. 8.5. Distribution of risks posed to ecological receptors in BCV.

TABLES

Table 1.1. Federal regulations affecting the ORR

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

In 1989, the ORR was included on the NPL, the national ranking system to establish priority of response to various hazardous sites. The Federal Facility Agreement (FFA) between DOE, EPA, and TDEC became effective January 1, 1992. The FFA establishes the requirements for remediation of the ORR.

Resource Conservation and Recovery Act (RCRA)

The FFA for the ORR stipulates that RCRA shall be an ARAR for any actions taken at the site and that CERCLA response obligations be coordinated with the corrective measures required under the current RCRA permit for the site. The state of Tennessee has been authorized by EPA to administer all aspects of the RCRA program including the HSWA cluster I requirements (effective May 23, 1996).

National Environmental Policy Act (NEPA)

DOE, per the Secretary of Energy's June 1994 NEPA policy, will rely on the CERCLA process to incorporate NEPA procedures.

Toxic Substances Control Act (TSCA)

TSCA, administered by EPA, regulates chemicals such as polychlorinated biphenyls (PCBs) and asbestos that pose an unacceptable risk to human health or the environment. PCBs and asbestos are present in BCV.

Clean Air Act (CAA)

The TDEC Division of Air Pollution Control has the primary responsibility for enforcing compliance with the CAA within the state of Tennessee and for protecting and maintaining Tennessee ambient air quality standards pursuant to the Tennessee Air Quality Control Act. DOE-Oak Ridge Operations has received approval of its compliance plan for meeting monitoring requirements of the National Emission Standards for Hazardous Air Pollutants for radionuclides, which are regulated under CAA.

Table 1.1 (continued)

Clean Water Act (CWA)

Water pollution resulting from activities in the ORR is controlled through the Tennessee Water Quality Control Act and implementing regulations, and the National Pollution Discharge Elimination System (NPDES) permit program for the ORR is administered by TDEC's Division of Water Quality Control.

Safe Drinking Water Act (SDWA)

SDWA sets regulatory standards for levels of organic chemicals and other pollutants in drinking water and establishes programs to prevent contamination of groundwater sources. SDWA is a potential ARAR for CERCLA remediation of the ORR.

Tennessee State Laws and Regulations

State laws and regulations may also be ARARs if they have more stringent standards than the federal requirements, or address an area not covered in the federal mandates. Tennessee water quality standards (General Water Quality Criteria, Public Water Systems, and Aquatic Resource Alterations), Tennessee Hazardous Substance Site Remedial Action Program, and Tennessee Hazardous Air Contaminants Program may all apply to BCV.

DOE Orders

Most DOE Orders fall under "to-be-considered" criteria. Even if specific DOE Orders do not qualify as ARARs, they are still mandatory requirements that DOE and its contractors must meet at DOE sites.

Table 2.1. State-listed or uncommon plant and terrestrial animal species in BCV

Species	Location	Designation	Comment
Canada lily (<i>Lilium canadense</i>)	Natural Environmental Research Park Natural Area 13, base of Pine Ridge	Threatened	Occurs along forested edges of powerline right-of-way
Southern rein orchid (<i>Platanthera flava</i>)	Natural Environmental Research Park Natural Area 4	Species of special concern	Forested area with numerous wetlands, seeps, streams, and flood channels
<i>Orontium aquaticum</i>	Natural Environmental Research Park Natural Area 4	None	Uncommon aquatic plant
Big bluestem grass	Along Bear Creek Road	None	Uncommon in East Tennessee
Southeastern shrew (<i>Sorex longirostris</i>)	ORR	In need of management	Not confirmed in BCV
Pine snake (<i>Pituophis melanoleucas</i>)	Bear Creek watershed	Threatened	Has been confirmed in Bear Creek watershed
Cooper's hawk (<i>Accipiter striatus</i>)	Forests of ORR	Threatened	May occur in BCV

Table 3.1. Sites considered in this RI report that are listed in the FFA or have been identified as solid waste management units

Site ^a	Status/service history and Reference ^b
Abandoned Nitric Acid Pipeline (ANAP) (Fig. 1.2 #1)	Operable Unit (ANAP). Received CERCLA NFA ROD 9/12/94. Also located in UEFPC CA. YS-601.
S-3 (or Decant) Treatment Facility (Fig. 1.2 #2)	FFA Area of Concern in BCV CA. Formerly operated under RCRA Permit by Rule — Treatment of denitrified supernatant from S3 Ponds; denitrified supernatant from West End Treatment Facility tanks from 1985 to 1989. No longer in operation. YT-044.
S-3 Ponds (Fig. 1.2 #3)	FFA Area of Concern in BCV CA, YD-004.
West End Treatment Facility (Fig. 1.2 #4)	Active Waste Management Area [Also includes 9616-7, GWTF - Accumulation Area AA-133 (YS-822) and Groundwater Treatment Facility (YT-053) (RCRA Permit by Rule Unit)] — Treatment of nitrate-bearing wastes including bionitrification sludge, plating solutions, mopwaters, evaporator condensates, acids, caustics, and heavy metals including depleted and enriched uranium from 1985 to present. YT-150.
Interim Reactive Waste Treatment Area (Fig. 1.2 #5)	Active Waste Management Area (Interim Status IT-42) — This site treats water that may be contaminated with volatile and nonvolatile organics from the water stored at DARA Liquid Storage Facility (YS-052). YT-150.
Spoil Area 1 (Fig. 1.2 #6)	Operable Unit (BCV OU 2) SA-1 and SY-200 yard (below) were included in BCV OU 2, and received a “status quo” ROD of maintaining existing caps on these sites. The ROD is due to EPA and TDEC April 1996. There is no groundwater contamination associated with SA-1 or SY-200 Yard. YD-107.
Rust Engineering Storage Yard (Fig. 1.2 #7)	Active Process Storage Area — Storage of various types of concrete finishing and coating compounds from 1975 to present. YS-401.
SY-200 Yard (Fig. 1.2 #8)	Operable Unit (BCV OU 2) (see above). YD-125.
9720-58 Transformer Fluid Storage Facility (Fig. 1.2 #9)	Active Waste Management Area (Alias OD-9). RCRA Permitted Storage Facility. This facility stores PCB-contaminated waste and equipment. YS-039.
Rust Spoil Area (Fig. 1.2 #10)	FFA Area of Concern in BCV CA - originally part of Bear Creek OU 2 but incorporated into BCV CA due to minor groundwater contamination. YD-106.
Liquid Organic Waste Storage Facility (Fig. 1.2 #11)	Active Waste Management Area (Alias OD-10) — Used for storage of various chlorinated and non-chlorinated organics and PCBs. The site has a current RCRA permit. YS-040.
HCDA/Boneyard Burnyard (Fig. 1.2 #12)	FFA Area of Concern in BCV CA, YD-024-HC.
Oil Landfarm (Fig. 1.2 #13)	FFA Area of Concern in BCV CA, YD-014.
Oil Landfarm Soil Containment Pad (Fig. 1.2 #14)	FFA Area of Concern in BCV CA. The site is used as a storage facility for contaminated soils from the closure of the Oil Landfarm. Site contains soils that are contaminated with PCBs, organics, and uranium. A RCRA Part B permit application has been submitted. YS-050.
Sanitary Landfill 1 (Fig. 1.2 #15)	FFA Area of Concern in BCV CA, YD-101.
Oil Retention Pond 2 (Fig. 1.2 #16)	FFA Area of Concern in BCV CA, YD-009.

Table 3.1 (continued)

Site ^a	Status/service history and Reference ^b
Bear Creek Burial Grounds (Fig. 1.2 #17)	FFA Area of Concern in BCV CA, YD-024.
Oil Retention Pond 1 (Fig. 1.2 #18)	FFA Area of Concern in BCV CA, YD-008.
DARA Liquids Storage and Treatment Unit (Fig. 1.2 #19)	Active Waste Management Area operated under RCRA Permit by Rule [Accumulation Area AA-137, Alias LSF Diked Area (YS-826)] — Liquids collected from dewatering soils within the DARA soils storage facility are pumped to this DARA liquid storage facility. The liquids go through an oil/water separator and then are tankered to the GWTF adjacent to WETF. YS-052.
DARA Solids Storage Facility (Fig. 1.2 #20)	FFA Area of Concern in BCV CA. Bldg. 9720-60 is designed to dewater soils by gravity flow to sumps. Collected liquids are pumped to the DARA Liquid Storage Facility. The soil and liquids were products of the excavation and closure of the oil retention ponds and associated tributaries. Radioactive mixed waste, PCBs, uranium, and organic are among the contaminants present at this site. Site has had a RCRA permit application submitted. YS-051.
NaK Burn Facility (Fig. 1.2 #21)	Former Waste Management Area. Area where NaK alloys were ignited. Located between NT-5 and NT-6.
M.K. Ferguson Laydown Area (Fig. 1.2 #22)	Active Process Storage Area. Radiologically contaminated demarcated area
Bear Creek Road Debris Burial Area (Fig. 1.2 #23)	New found site on Bear Creek Floodplain. History unknown. Decision on inclusion in FFA is pending.
Creekside Debris Burial Area (Fig. 1.2 #24)	New found site on Bear Creek Floodplain. History unknown. Decision on inclusion in FFA is pending.
Contaminated Construction Spoil Pile (Fig. 1.2 #25)	FFA Area of Concern in BCV CA — This soil was excavated during construction of the first tank farm for WETF. It has low levels of mercury contamination, similar to other soil in the area. YS-027.
Bear Creek Groundwater, Creek Sediments, and Floodplain Soils	FFA Area of Concern in BCV CA, YS-600.
Above Grade Storage Pads	Active Waste Management Area. Currently active under a state agreement
Johnson Controls 90-Day Accumulation Area	Active Waste Management Area. RCRA 90-day Accumulation Area

^aLocations of sites identified on Fig. 1.2.

^bSites referenced in the Federal Facilities Agreement (Source: DOE 1994b)

Table 3.2. Chronological list of events at BCV^a

Year	Event
1943	BYBY. BYBY was used as a disposal site for waste from the Y-12 Plant. Burning and disposal of debris and sanitary, metallic, chemical, and radioactive wastes are known to have occurred (Energy Systems 1991).
1951	S-3. S-3 Ponds Site starts operation. Primary waste disposed of in the Ponds consisted of nitric acid, pickling and plating wastes, and liquid wastes associated with clean-up operations (Energy Systems 1992).
1955	BCBG. Disposal at BCBG began with the disposal of solid waste in Unit A (Turner et al. 1991).
1959	BCBG. Large volumes of solvent-contaminated water and oils began being disposed of in BG-A (Turner et al. 1991).
1961	BCBG. A surface tank was installed in BG-A to hold waste oils and coolants; accumulations were burned.
1962	BCBG. BG-B was opened and used for disposal of depleted uranium metal and oxides. BG-C was opened for the disposal of beryllium, beryllium oxide, thorium, and solid waste contaminated with these materials (Turner et al. 1991).
1966	BCBG. The WIP were established in the BCBG. The area was used to dispose of chemicals and uranium metal saw fines (Turner et al. 1991).
1968	BYBY. Disposal of waste at the Burnyard was discontinued.
	SL 1. SL 1 opened for disposal of combustible and decomposable solid wastes.
	BCBG. Burning of waste oils and coolants was terminated in BG-A. BG-B reached waste disposal capacity and BG-D was opened to replace BG-B.
1969	BCBG. Oil and coolants were poured into standpipes that were installed in the trenches.
1970	BYBY. Disposal of waste at the Boneyard site was discontinued.
	BCBG. Waste solvents were poured into rock piles and waste-filled trenches in BG-A. An estimated 2.3 million L (600,000 gal) of mop water were disposed of annually in BG-A (Turner et al. 1991).
1971	BCBG. ORP-1 was constructed (Bailey 1979).
1972	BCBG. ORP-2 was constructed (Bailey 1979).
1973	OLF. Landfarming activities began at the OLF. Waste oils and coolants containing beryllium, uranium, PCBs, and chlorinated organic compounds were disposed of at the site (Energy Systems 1991).
1974	OLF. 57,000 L (15,000 gal) of oil skimmed from the surface of the two ORPs in BCBG were disposed of at OLF.
1975	BYBY. An HCDA was established on ~.81 ha (2 acres) in the southeastern portion of BYBY (Energy Systems 1991 and Energy Systems 1987).
1976	S-3. The nitric acid recovery system at the S-3 Ponds becomes operational.

Table 3.2 (continued)

Year	Event
1979	<p>OLF. A permissible maximum concentration of 5 mg/L PCBs was established for oils disposed at OLF.</p> <p>BCBG. 68,400 L (18,000 gal) of oil removed from ORP-1. The disposal of mop water and oils in BG-A was terminated.</p>
1981	<p>OLF. A permissible maximum concentration of 3% chlorinated hydrocarbons was established for waste disposed at OLF.</p> <p>BYBY. Waste disposal at HCDA ceased.</p> <p>BCBG. WIP were used for disposal of uranium metal saw-fines, organics, and laboratory wastes (Energy Systems 1991 and Energy Systems 1987).</p>
1982	<p>OLF. Landfarming at OLF ceased.</p> <p>SL 1. Waste disposal at SL 1 was terminated (Turner et al. 1991).</p>
1983	<p>S-3. Nitric acid pipeline used to transport waste to the S-3 Ponds was plugged and abandoned and all waste discharges into the ponds were terminated.</p> <p>S-3. In situ treatment of wastewater in the S-3 Ponds begins. Liquid in all four ponds was neutralized and biodentrification of liquids used to reduced nitrate concentrations.</p> <p>BCBG. Sediment from ORP 1 and NT-7 was found to contain PCBs ranging from 3 to 31 mg/L (Energy Systems 1988, Jeter 1983, and Turner et al. 1991).</p>
1984	<p>S-3. In situ treatment of wastewater at the S-3 Ponds was completed. Nitrate levels were maintained below 50 ppm.</p>
1985	<p>S-3. Supernatant liquids at the S-3 Ponds were treated to remove trace metals and organics.</p> <p>OLF. OLF plots containing PCB levels >25 µg/g were delineated. Samples were also analyzed for uranium (Herbes 1989).</p> <p>SL 1. SL 1 closed by grading, capping with 0.6 m (2 ft) of clay, and establishing a vegetative cover.</p>
1988	<p>S-3. Sediment from the blue lagoon was placed in the southwest cell of the S-3 Ponds.</p> <p>S-3. The S-3 Ponds were filled and covered with a multilayered RCRA cap. Currently, the site is used as a parking lot (Energy Systems 1988 and Turner and Kamp 1984).</p>
1989	<p>OLF. Soils with PCB concentrations >25 µg/g excavated from soils at OLF and placed in the OLF Containment Pad (Bohrman 1989).</p> <p>BYBY. HCDA was covered with a RCRA-type cap (Energy Systems 1991).</p> <p>BCBG. BG-A and BG-C west were closed in place as landfills and covered with engineered caps under RCRA. 3058 m³ (4000 yd³) of sludge and soils was excavated from ORP-1, ORP-2, and NT-7. An engineered cap was constructed over each pond and NT-7 (Collins 1990a, Collins 1990b).</p>

Table 3.2 (continued)

Year	Event
1990	OLF. OLF was closed as a landfill with a multilayered engineered cap (Energy Systems 1992).
1991	S-3. DOE submitted a post-closure permit application for the Bear Creek Hydrogeologic Regime S-3 Site with a reference to CERCLA for any groundwater action.
1993	S-3. DOE, TDEC, and Energy Systems go before the State Board with a consent order signed by all parties agreeing to the CERCLA reference and agreeing to use this language as a model for all BCV. BCBG. Tributary 8 leachate collection system installed.
1994	BCBG. An engineered cap was constructed over BG-B and WIP under an approved RCRA closure plan. OLF. DOE submitted an application to add OLF BG-A and BG-C West to the BCV post-closure permit.
1995	BCBG. DOE submitted an application to add WIP cap to the BCV post closure permit. OLF and WIP added to the BCV post-closure permit.

^aSchedule is graphically portrayed in Fig. 3.2.

Table 3.3. Descriptions of operations at source sites, disposal methods, and waste streams

Site name	Description	Dates of operation	Disposal methods and waste streams	Post-operational activities
S-3 Site	Four unlined disposal ponds located at the headwaters of Bear Creek at the west end of the Y-12 Plant. Each pond was ~60 × 60 × 5 m deep (200 × 200 × 17 ft) and had a storage capacity of 9.5 million L (2.5 million gal) (Energy Systems 1992b).	Constructed in 1951, last disposal was in 1988.	<ul style="list-style-type: none"> Liquid wastes generated by Y-12 Plant operations and other facilities were discharged into the ponds. The main waste stream came from a pipeline and was: 1951 - 1975. ~7.6 million L/a 0.1 - 4% nitric acid solutions containing ~20% aluminum nitrate, contaminated with uranium and other metals. 1975 - 1983. ~10.3 million L/a mixed output from the nitrate recovery system (uranium-contaminated) and routine cleanup solutions. Sludges generated from the in situ neutralization and biode-nitrification of the pond waters from the treatment of acid raffinate. Contaminated sediments from two lagoons in Upper Bear Creek (also known as the Blue Lagoons) (Energy Systems 1988a). Other wastes included aerosol cans, machine coolants, caustic solutions, and uranyl nitrate solutions with small amounts of plutonium. 	At closure there was ~1.2 m (4 ft) or 16,000 m ³ (564,960 ft ³) of sludge in the ponds. Ponds were closed with multilayered RCRA cap in 1988.
Oil Landfarm	A 4.2 ha (10.4 acres) plot located ~2.4 km (1.5 m) west of the Y-12 Plant (Energy Systems 1994).	Operational from 1973 - 1982	<ul style="list-style-type: none"> Biological degradation of waste oils and machine coolants through landfarming. ~2.2 million L (583,500 gal.) of waste coolant and 1.6 million L (430,800 gal) of waste oils contaminated with beryllium, depleted uranium, iron, barium, phosphorus, zinc, lead, PCBs, PCE, and 1,1,1 TCE. (Tables A.5 and A.6 in Appendix A) were applied to nutrient adjusted soils during dry months (April to October) (Turner et al. 1991). Liquids wastes from routine clean up, tanker oils from K-25, wastes from cooling towers, and oils from ORP-1 in BCBG. 	Soils contaminated with >25 µg/g PCBs were excavated and removed to the OLF Pad (Bohrman 1989, see next record). Closed as a landfill with a multilayered engineered cap in 1990.
OLF Soils Containment Pad	A concrete pad containing ~305.84 m ³ (400 yd ³) of soils.	Pad has been maintained as a RCRA storage area since 1989.	<ul style="list-style-type: none"> Contains soils excavated from areas on the OLF where PCBs >25 µg/g in 1989 (Bohrman 1989). 	Maintenance.

Table 3.3 (continued)

Site name	Description	Dates of operation	Disposal methods and waste streams	Post-operational activities
Boneyard	A series of unlined trenches, exact dimensions are not known. Also a construction material laydown yard (Energy Systems 1987b).	Operational from 1943 - 1970.	<ul style="list-style-type: none"> Uranium chips were placed in open, unlined pits and burned on a weekly basis. Magnesium chips were placed in burn pans, and ignitable waste solvents were used to ignite burns. The remainder of the Boneyard was used to dispose of construction spoil material (concrete and rebar). 	
Burnyard	2 trenches ~90 m (300 ft) long and 12 m (40 ft) wide (Energy Systems 1987b).	Operational from 1943 - 1968.	<ul style="list-style-type: none"> Waste materials were placed in unlined earthen trenches and burned, then covered with soil. Oils and other flammable liquids, possibly transformer oils containing PCBs were used to start and sustain combustion. Burnyard was estimated to have received ~1000 m³ (4000 yd³) of waste per year between 1943 to 1968. 	The HCDA was constructed over the Burnyard in 1975 (Energy Systems 1991).
Hazardous Chemical Disposal Area	Built on top of former Burnyard, covering ~2 acres (Energy Systems 1987b).	HCDA was operational from 1975 to 1981.	<ul style="list-style-type: none"> HCDA received material that was ignitable, reactive, corrosive, toxic, highly flammable, or inert, including damaged or leaking gas cylinders, and laboratory chemicals such as acids, bases, organics, water-reactive compounds, and explosive compounds. Corrosive gases were bled through neutralizing slurries. Bottles of chemicals were broken under a water spray and the effluent discharged into a small unlined surface impoundment. 	The HCDA was covered with a RCRA-type cap in 1989.
Sanitary Landfill 1	A single trench excavated to depth of ~6 m (20 ft) (Energy Systems 1987b).	1968 - 1983.	<ul style="list-style-type: none"> Approximately 27,000 m³ (105,000 yd³) of refuse were disposed of at the landfill in a large trench. 	It was closed in 1985 and capped with 0.6 m (2 ft) clay and topsoil.
Bear Creek Burial Grounds	Several waste-disposal units designated as BG-A, -B, -C, -D, -E, and -J; the Walk-In Pits (WIP); the Uranium Vaults, and Oil Retention Ponds (ORPs) (ORP-1 and -2). Each waste-disposal unit consists of a series of unlined trenches (Energy Systems 1988b and 1992c)	1956 - 1991	<ul style="list-style-type: none"> Disposals at BCBG were dominated by uranium in a number of forms: uranium-contaminated waste material, large pieces of uranium metal (machined parts), uranium tailings that were the product of milling the machined parts, and uranium saw fines. After disposal, uranium tailings exposed to air often oxidized rapidly, causing uranium fires. The second major waste stream at BCBG was of waste oils, solvents, and machine coolants containing PCBs that were deposited directly in trenches through standpipes or infiltration rock pits. 	

Table 3.3 (continued)

Site name	Description	Dates of operation	Disposal methods and waste streams	Post-operational activities
Burial Grounds - Area A (BG-A North and South, areas A-16 through A-18)	<ul style="list-style-type: none"> A series of trenches 4.3 to 7.6 m (14 to 25 ft) deep. Approximated waste volumes are: A North, 65,828 m³ (86095 yd³); A South, 46,734 m³ (61,122 yd³); A-16, 33,643 m³ (44,000 yd³); A-17, 51,993 m³ (68,000 yd³); A-18, 25,996 m³ (34,000 yd³) 	Area A South: 1956 - 1981 Area A North: 1969 - 1981 A-16: 1983 - 1987 A-17: 1983 - 1987 A-18: 1988 - 1991	<ul style="list-style-type: none"> Uranium-contaminated waste material, uranium tailings or chips, thorium-contaminated sludge. Large quantities of waste oils, solvents, and machine coolants containing PCBs were deposited directly in the trenches of A-South and A-North through standpipes or rock pits. The <i>Isolation Area</i> of A-South received thousands of gallons of organic solvent wastes and fuel-contaminated waters (gasoline/water mixtures) between 1970 and 1979. Contains a segregated location for asbestos-containing materials. Areas A-16 through A-18 were designated for uranium-contaminated garbage. 	BG-A closed in place as landfills and covered with a RCRA cap in 1989. A leachate collection system was installed on NT-7
Burial Grounds - Areas B,D,E, and J	<ul style="list-style-type: none"> A series of trenches 4.3 to 7.6 m (14 - 25 ft) deep. Approximated waste volumes are: Area B, 11,062 m³ (14468 yd³); Area D East, 8,158 m³ (10,670 yd³); Area D West, 841 m³ (1,100 yd³); Area D South, 65 m³ (85 yd³); Area E, 2,688 m³ (3,516 yd³); Area J: 4,036 m³ (5,278 yd³) 	Area B: 1962 - 1968 Area D East: 1968 - 1989 Area D West: 1983 - 1990 Area D South: 1988 - 1990 Area E: 1983 - 1990 Area J: 1983 - 1990	<ul style="list-style-type: none"> Tailings (chips), metal (machined parts), oxide wastes, and thorium (Area B). Estimated that ~70% of total uranium deposited in BCBG was placed in these areas. 	BG-B was covered with a RCRA cap in 1994 and closed (Energy Systems 1995).
Burial Grounds - Area C	<ul style="list-style-type: none"> A series of trenches 4.3 to 7.6 m (14 - 25 ft) deep. Approximated waste volumes are: C East: 8,828 m³ (11,546 yd³); C West, 23,014 m³ (30,100 yd³) 	Area C East: 1962 - 1989 Area C West: 1962 - 1989	<ul style="list-style-type: none"> Designated for the disposal of industrial wastes contaminated with beryllium, uranium, thorium, and technetium. Lithium compounds also disposed of in this area A minor amount of material potentially contaminated with enriched uranium was deposited in this area. 	BG-C West was closed in place as a landfill and covered with a RCRA cap in 1989. At this time a leachate collection system installed on NT-8 and Seep 2 The part of BG-C East adjacent to BG-B was covered with a RCRA cap in 1994 (Energy Systems 1995).

Table 3.3 (continued)

Site name	Description	Dates of operation	Disposal methods and waste streams	Post-operational activities
Walk-In Pits	<ul style="list-style-type: none"> WIP-1 (North) and WIP 2 and 3 (South) Approximated waste volumes are: WIP North, 16,365 m³ (21,404 yd³); WIP South, 10,469 m³ (13,692 yd³) (Energy Systems 1995). 	<p>WIP North: 1966 - 1991</p> <p>WIP South: 1966 - 1989</p>	<ul style="list-style-type: none"> These areas were used for the disposal of laboratory and industrial chemicals of all types, however, uranium metal saw fines were the primary waste disposed in the WIP (estimated 15% of the total BCBG uranium). Other wastes deposited include benzene, beryllium, chromium, PCBs, thorium, and many common solvents such as acetone, alcohols, carbon tetrachloride, cyclohexane, methyl ethyl ketone, methyl isobutyl ketone, toluene, and xylenes. 	WIP North and South were covered with a RCRA cap in 1994 and closed (Energy Systems 1995).
DARA Soils Storage Facility	A concrete pad containing ~3,058.4 m ³ (4,000 yd ³) of soils.	Pad has been maintained as a RCRA storage area since 1989.	<ul style="list-style-type: none"> Contains soils excavated from ORPs-1 and -2 and NT-7 where PCBs >25 µg/g in 1989 (Collins 1990a). 	Maintenance.
Oil Retention Ponds	Two small ponds: ORP-1 in NT-7 and ORP-2 in NT-6	<p>ORP-1 - 1971</p> <p>ORP-2 - 1972</p>	<ul style="list-style-type: none"> The ORPs were constructed to prevent downstream transport of oil seeping from BG-A in Tributaries NT-6 and NT-7 (Bailey 1979). 	<p>~144,000 L (38,000 gal) of oil were removed from the surface of ORP-1 between 1974 and 1979 (Battelle 1986).</p> <p>980 m³ (3842 yd³) of sludge, sediment, and soil was excavated and placed in the DARA solid storage facility (Collins 1990a). Sediments remaining have <25 µg/g PCBs (except Seep 1).</p> <p>Both ORPs were closed and capped in 1989.</p>

Table 3.4. Hydrogeologic and contaminant status of source areas

Site name	Current status	Hydrology	Waste/contaminant chemistry	Future industrial CQCs
S-3 Site	Ponds are filled and capped. Site is currently a parking lot.	Intermittent inundation	Nitrate, VOCs, other organics, mercury, uranium, ¹³⁷ Cs, ⁵⁷ and ⁶⁰ Co, ²³⁷ Np, ⁹⁵ Nb, ²³⁸ and ²³⁹ Pu, ¹⁰⁶ Ru, ⁹⁰ Sr, ²²⁸ , ²³⁰ , ²³² , ²³⁴ Th, ⁹⁹ Tc, ⁹⁵ Zr, uranium daughter isotopes, and isotopes of Am, Cf, I, and Ni (Table A.3 in Appendix A) (Turner and Kamp 1984).	Be, PCB-1248, ¹³⁷ Cs, ²³⁷ Np, ²³⁸ Pu, ¹⁰⁶ Ru, ²²⁸ Th, ²³⁰ Th, ⁹⁹ Tc, ²³⁴ U, ²³⁵ U, ²³⁸ U.
Oil Landfarm	Closed with a multilayered engineered cap.	"Dry"	PCBs (<25 µg/g) , uranium (Table A.8 in Appendix A; Bohrman 1989).	
OLF Soils Containment Pad	Maintained as a RCRA storage area.	"Dry"	PCBs, metals, uranium (Table A.7 in Appendix A; Herbes 1989)	Be, PCB, ²³⁵ U, ²³⁸ U.
Boneyard	No usage	Inundated during wet season; intermittent during dry season	Uranium, mercury, other metals, PCBs, PAHs (Section 3.2.4)	
Burnyard	HCDA constructed over the Burnyard. See below for current status.	Inundated during wet season; intermittent during dry season	Uranium, mercury, other metals, PCBs, PAHs (Section 3.2.4)	
Hazardous Chemical Disposal Area	Covered with a RCRA-type cap.	"Dry"		
Sanitary Landfill 1	Closed, capped, and vegetated.	Inundated during wet season; intermittent during dry season	PCBs, mercury, uranium (Section 3.2.4)	

Table 3.4 (continued)

Site name	Current status	Hydrology	Waste/contaminant chemistry	Future industrial COCs
Burial Grounds - Area A		<ul style="list-style-type: none"> • South - perennially inundated • North - northern trenches dry; southern trenches may be inundated • A-17 - bathtubbing of stormflow • A-16 & A-18 - "dry", may bathtub 	<ul style="list-style-type: none"> • South - >100,000 kg uranium, >10,000 kg 1,1,1-TCA, PCE, freon, >1000 kg benzene, TCE, MEK, PCBs, <100 kg:Be, Li, and asbestos fuel-water, waste oils, mop water, alcohol • North - >100,000 kg uranium, PCBs, >100 kg Th, <100 kg Be, Li, and Tc, and asbestos, waste oils, mop water • A-16, A-17, A-18: >10,000 kg uranium 	<ul style="list-style-type: none"> • South - Be, U, Benzene, PCB, PCE, TCE, ²³⁴U, ²³⁵U, ²³⁸U. • North - Be, U, PCB, ²³⁴U, ²³⁵U, ²³⁸U.
Burial Grounds - Areas B, D, E, and J		<ul style="list-style-type: none"> • B - "dry" • D, E, and J - intermittent during storms, may bathtub 	<ul style="list-style-type: none"> • BG-B - >1,000,000 kg uranium, >1,000 kg Th • BG-D South - >100,000 kg uranium • BG-D East - >1,000,000 kg uranium • BG-D West, BG-E, BG-J - >1,000,000 kg uranium 	<ul style="list-style-type: none"> • BG-B - U, ²³⁴U, ²³⁵U, ²³⁸U. • BG-D South - U, ²³⁴U, ²³⁵U, ²³⁸U. • BG-D East - U, ²³⁴U, ²³⁵U, ²³⁸U. • BG-D West, BG-E, BG-J - U, ²³⁴U, ²³⁵U, ²³⁸U.
Burial Grounds - Area C	East - Covered with 2 ft of clay West - Covered with a RCRA-type cap.	<ul style="list-style-type: none"> • East - perennially inundated • West - probably inundated only during wet season 	<ul style="list-style-type: none"> • East - >100,000 kg uranium, >10,000 kg Li, Be, Th • West - >100,000 kg uranium, >10,000 kg Th, Be, >1,000 kg Li, and <1,000 kgTc 	<ul style="list-style-type: none"> • East - Be, U, ²³²Th, ²³⁴U, ²³⁵U, ²³⁸U. • West - Be, U, ²³²Th, ²³⁴U, ²³⁵U, ²³⁸U.
Walk-In Pits	Covered with a RCRA-type cap.	"Dry"	<ul style="list-style-type: none"> • North ->1,000,000 kg uranium, >10,000 kg Th, >1,000 kg total organics, waste oil • South - >1,000,000 kg uranium, >1,000 kg mixed acids, <1,000 kg Ch, Hg 	<ul style="list-style-type: none"> • North - Be, U, benzene, benzidine, PCB, TCE, ²³²Th, ²³⁴U, ²³⁵U, ²³⁸U. • South - U, ²³⁴U, ²³⁵U, ²³⁸U.

Table 3.4 (continued)

Site name	Current status	Hydrology	Waste/contaminant chemistry	Future industrial COCs
DARA Soils Storage facility	Maintained as a RCRA storage area.	"Dry"	PCBs, metals, uranium (Table A.11 in Appendix A; Collins 1990a)	
ORPs-1 and -2	Covered with RCRA-type caps.	Probably inundated	PCBs (25 µg/g), metals, uranium (Collins 1990a)	

Table 3.5. Summary of estimated uranium quantities in the BCBG^a

Area	Assumed % of total estimate	Estimated uranium mass (Kg)	Estimated uranium concentration (mg/Kg)
A-South	5.0	0.93×10^6	15,000
A-North	5.0	0.93×10^6	11,000
A-16 thru -18	0.5	0.09×10^6	610
B	33.0	6.14×10^6	300,000
C	5.0	East 0.25×10^6	21,000
		West 0.68×10^6	22,000
		East 3.35×10^6	240,000
		South 0.03×10^6	240,000
D	20.0	West 0.35×10^6	260,000
		1.21×10^6	260,000
		1.86×10^6	260,000
E	6.5	1.67×10^6	72,000
J	10.0	1.12×10^6	75,000
WIP North	9.0		
WIP South	6.0		
		18.6×10^6 Kg as uranium	
Total Estimate ^b		17.3×10^6 Kg of uranium	

^aThe "Historical Radionuclide Releases, May 1988" reports a total of 19.3×10^6 Kg buried.

^bNineteen separate waste streams over a 17-year period totaled 26.2×10^6 lbs of uranium type materials. This is equivalent to 11.9×10^6 Kg as UO_2 or 10.5×10^6 Kg as U. A per year estimate then becomes 620,000 Kg/year of uranium, multiplied by a 30-year site history provides a total estimate of 18.6×10^6 Kg as uranium.

Table 3.6. Sources of existing surface water contamination in BCV

Watershed	Primary source units	Secondary sources	Most likely source(s) of detected contamination in tributary
Upper Bear Creek (BCK 12.38)	Former S-3 Ponds	Nitrate and uranium plumes in groundwater in the Nolichucky Shale	Plumes in the Nolichucky Shale
NT-1			
NT-2		S-3 plumes	S-3 plumes
NT-3	BYBY, OLF, SL-1, HCDA	BYBY uranium and organic plumes	BYBY source and plumes
NT-4	OLF SL-1	OLF plume	only low levels detected
NT-5			only low levels detected
NT-6	BG-A South, BG-A North	VOC plume in the Nolichucky below BG-A	only low levels detected
NT-7	BG-A South, BG-A North, A-16, A-17, A-18, BG-B, WIP-South, WIP North, BG-C East	BG-A South and North organic plumes, WIP plumes	(1) BG-A South, (2) BG-A North
NT-8	BG-B, WIP North, BG-C East, BG-C West, BG-D East, BG-D West, BG-E, BG-J	BG-C West organic plume, BG-C West, D-East, and WIP-N shallow plume	BG-C East, BG-D East, BG-C West
SS-4		S-3 nitrate and uranium plume, BYBY uranium plume, BYBY overland flow; Bear Creek Road Site Debris Burial Area	S-3 and BYBY plumes
SS-5		Same as SS-4	S-3 and BYBY plumes

Table 3.7. Results of drained analysis of wastes, soils, groundwater, and surface water at the S-3 Site

Analyte ^e	Wastes ^a		Soils ^b		SRC ?	Groundwater ^c			SRC ?	Surface Water ^d			
	S-3 sludges	Results > detection limit	Maximum detect	Average result		Freq. of wells w. detects	Max detect	Mean of the medians ^g		Freq. of detect	Avg. ^f result BCK 12.46	Avg. ^f result NT-1	SRC ?
Inorganics (water - mg/L, soils - mg/kg)													
Aluminum	22134	40/ 40	29000	15600		23/ 23	800	81.05	Y	70/ 82	0.506	0.56	
Antimony		2/ 2	0.34	0.3		0/ 20	.	0.025					
Arsenic	1.12	40/ 40	20.5	3.5		1/ 9	0.009	0.003					
Barium	133.5	40/ 40	712	145	Y	24/ 24	380	19.137	Y	77/ 78	0.092	0.554	Y
Beryllium	2.74	36/ 40	1.8	1.0		11/ 22	0.11	0.0119	Y	3/ 78	0.0000	0.0002	
Boron	27.64	NA				24/ 24	4.40	0.29	Y	78/ 78	0.086	0.073	Y
Cadmium	4.9	2/ 40	2	0.2		10/ 25	4	0.174	Y	3/ 4		0.015	Y
Calcium	42215.6	39/ 39	318000	26700		26/ 26	10,000	1,665.6		78/ 78	164.5	228.3	
Chromium	133.2	40/ 40	69.6	30.8		13/ 25	0.31	0.017	Y				
Cobalt	3.47	40/ 40	31.1	16.6		11/ 23	2.3	0.268	Y	5/ 78	0.001	0.007	
Copper	92.45	38/ 40	50.8	22.3	Y	20/ 21	3.1	0.278	Y	4/ 78	0.005	0.002	
Cyanide	5.95	4/ 40	7.8	0.6	Y	0/	.	.		6/ 72	0.001		Y
Iron	3647	40/ 40	48300	25600		23/ 23	28	3.59		46/ 78	0.743	0.233	
Lead	35.79	40/ 40	82.3	15.5	Y	21/ 26	0.66	0.0106	Y	1/ 4		0.003	
Lithium	75.68					7/ 7	3.5	0.88	Y	33/ 72	0.015		
Magnesium	1941.32	40/ 40	60400	6930		26/ 26	2,500	263.3		78/ 78	23.4	29.8	
Manganese	99.67	40/ 40	2000	707		24/ 24	220	24.162	Y	78/ 78	0.046	3.0	
Mercury	2.28	26/ 39	82.9	7.8	Y	15/ 26	0.1100	0.0042	Y	18/ 72	0.0000		
Molybdenum	15.2	1/ 40	3.7	0.5		3/ 19	0.023	0.006					
Nickel	550.32	40/ 40	128	29.6	Y	22/ 24	20	2.07	Y	5/ 78	0.005	0.068	Y
Niobium	20.87					4/ 5	0.10	0.027	Y				
Phosphorous	952.9									41/ 72	0.058		Y
Potassium	1625.6	40/ 40	3990	2120		26/ 26	200	30.95		78/ 78	5.126	4.5	
Selenium	0.77	2/ 40	0.66	0.31		3/ 10	0.014	0.003		1/ 72	0.001		

Table 3.7 (continued)

Analyte ^e	Wastes ^a		Soils ^b			Groundwater ^c			Surface Water ^d				
	S-3 sludges	Results > detection limit	Maximum detect	Average result	SRC ?	Freq. of wells w. detects	Max detect	Mean of the medians ^g	SRC ?	Freq. of detect	Avg. ^f result BCK 12.46	Avg. ^f result NT-1	SRC ?
Silicon						24/ 24	39	9.99					
Silver	1.87	26/ 40	4.3	1.8		0/ 6	.	.					
Sodium	2722.2	32/ 40	313	117		26/ 26	3,200	357.6		78/ 78	57.04	29.5	
Strontium	35.49					22/ 22	340	17.93	Y	78/ 78	0.42	0.692	Y
Thallium	0.33	2/ 40	0.75	0.22		1/ 8	0.01	0.005		2/ 72	0.001		
Thorium	195.1					1/ 20	0.28	0.109		2/ 72	0.006		
Tin	1.57	3/ 40	7.7	1.7		3/ 6	0.018	0.01					
Titanium	398.6					7/ 7	0.85	0.237	Y	3/ 72	0.009		
Total uranium (fluorometric)	991.71					22/ 26	44	2.90	Y	78/ 78	0.621	0.075	Y
Vanadium	7.1	40/ 40	91.9	24.4	Y	5/ 20	0.036	0.004	Y	1/ 72	0.003		
Zinc	58.27	40/ 40	163	50.1	Y	24/ 24	20	0.497	Y	30/ 78	0.013	0.014	
Zirconium	478.4					3/ 4	0.051	0.018		1/ 71	0.002		
<i>Common Anions (water - mg/L, soils - mg/kg)</i>													
Ammonia nitrogen						2/ 4	4.8	1.19					
Chloride						26/ 26	1,341	106.2	Y	6/ 6		27.4	Y
Fluoride						23/ 25	110	1.32	Y	6/ 6		1.0	Y
Kjeldahl nitrogen	460					4/ 4	1.8	0.73					
Nitrate - N	1130					19/ 26	13,400	1,659.	Y	77/ 77	38.83	166.6	Y
Nitrite						1/ 4	6.7	20.2					
Sulfate	220					23/ 23	2,204	204.7	Y	6/ 6		46.8	Y
<i>Organics (water - µg/L, soils - µg/kg)</i>													
Endrin aldehyde		1/ 13	5.4	2.3	Y								
Methoxychlor		1/ 13	5.9	9.8	Y								
PCB-1248	5666.8	4/ 39	3300	108	Y								

Table 3.7 (continued)

Analyte ^e	Wastes ^a	Results > detection limit	Soils ^b		SRC ?	Groundwater ^c			SRC ?	Surface Water ^d			
	S-3 sludges		Maximum detect	Average result		Freq. of wells w. detects	Max detect	Mean of the medians ^g		Freq. of detect	Avg. ^f result BCK 12.46	Avg. ^f result NT-1	SRC ?
PCB-1254		15/ 39	370	59	Y								
PCB-1260		6/ 39	280	38.2	Y								
1,1,1-Trichloroethane						9/ 27	28	3.8	Y				
1,1,2-Trichloroethane	75.37					1/ 26	1	2.5					
1,1,2,2-Tetrachloroethane	383.5												
1,1,2-Trichloro-1,2,2- trifluoroethane	4.35												
1,1-Dichloroethene						3/ 26	5	2.5					
1,2-Dichloroethane						1/ 26	4	2.5					
1,2-Dichloroethene						3/ 25	100	5.0	Y				
2-Butoxyethanol	2289.6												
2-(2-Butoxyethoxy)- Ethanol	1908.0												
2,4-Dinitrophenol						1/ 3	77	20.8	Y				
2-Butanone						9/ 26	32	5.0	Y				
2-Chloroethylvinyl ether						1/ 10	4	5					
2-Hexanone		2/ 39	17	6.5	Y	3/ 26	4	5					
2-Hexanol	295.7												
2-Nitrophenol						1/ 3	71	20.3	Y				
3-(1,1-Dimethylethyl)- Phenol	6038.8												
4-Methyl-2-pentanone		5/ 40	28	6.4	Y	1/ 27	97	8.4					
4-Nitrophenol						1/ 3	120	30.3	Y				
Acetone	22.95	17/ 32	4200	275	Y	19/ 27	6,000	51.8	Y	1/ 5		5	Y
Benzene						4/ 26	3	2.5	Y				

Table 3.7 (continued)

Analyte ^e	Wastes ^a		Soils ^b		SRC ?	Groundwater ^c			SRC ?	Surface Water ^d			
	S-3 sludges	Results > detection limit	Maximum detect	Average result		Freq. of wells w. detects	Max detect	Mean of the medians ^e		Freq. of detect	Avg. ^f result BCK 12.46	Avg. ^f result NT-1	SRC ?
Benzenemethanol						1/3	2	4.2					
Benzoic acid						2/3	58	25.0	Y				
Bis(2-ethylhexyl)phthalate						2/3	32	6.3	Y				
Bromodichloromethane						2/26	3	2.5					
Bromoform						1/26	2	2.5					
Butylbenzylphthalate						2/3	1	3.3					
Carbon disulfide						5/26	2	2.5					
Carbon tetrachloride						1/26	0.7	2.5					
Chlorobenzene						2/26	3	2.5					
Chloroform						14/27	69	7.0	Y				
Chloromethane						1/26	10	5					
Dibromochloromethane						1/26	1	2.5					
Diethylphthalate	522.8												
Di-n-butylphthalate						1/3	2	4.2					
Di-n-octylphthalate						2/3	3	3.5					
Dimethylbenzene						5/26	16	2.5	Y				
Ethylbenzene						3/26	4	2.5					
Methylene chloride	0.49	17/32	4200	275	Y	19/27	560	17.3	Y				
Naphthalene						1/3	1	3.7					
Phenols (mg/L or mg/kg)	7345.8					2/7	0.002	0.003	Y	54/72	0.0018		Y
Tetrachloroethene	793.0	10/40	24	3.9	Y	12/27	9,000	269.9	Y	6/6		3	Y
Toluene	0.27	19/39	120	9.9	Y	11/27	35	3.2	Y				
trans-1,2-Dichloroethene						2/13	2	2.8					
Trichloroethene	0.28					6/27	16	2.9	Y				
Trichlorofluoromethane	0.38												

Table 3.7 (continued)

Analyte ^e	Wastes ^a	Results > detection limit	Soils ^b		SRC ?	Groundwater ^c			SRC ?	Surface Water ^d			
	S-3 sludges		Maximum detect	Average result		Freq. of wells w. detects	Max detect	Mean of the medians ^g		Freq. of detect	Avg. ^f result BCK 12.46	Avg. ^f result NT-1	SRC ?
Vinyl acetate						1/ 26	1	5					
<i>Radioactivity (water - pCi/L, soils pCi/g)</i>													
Alpha activity	925.1	22/ 40	92	10.9		14/ 18	24,400	615.7	Y	75/ 78	270.5	26.3	Y
Americium-241	0.01	3/ 40	0.12	0.01	Y	1/ 4	38	7.5	Y				
Beta activity	1903.2	27/ 40	180	21.6		17/ 18	75,000	2,620.8	Y	78/ 78	164.1	226.7	Y
Cesium-137	4.8					2/ 4	9.7	5.3	Y				
Iodine-125/129						/ 1	.	2.7					
Iodine-129						/ 1	.	2.7					
Iodine-131						/ 1	.	0					
Neptunium-237	9.9	9/ 40	0.27	0.03		1/ 4	1,090	106.3	Y				
Plutonium-238	25.3	2/ 40	0.36	0.02	Y	/ 3	.	.					
Plutonium-239/240	2.5	1/ 38	0.015	0.005		/ 4	.	.					
Total Radium						1/ 1	35.14	35.14	Y				
Radium-228						/ 1	.	.					
Ruthenium-106	33.3												
Strontium-90	12.9					3/ 4	254	194	Y				
Technetium-99	7520.3	4/ 40	36	2.82	Y	3/ 4	80,400	17,538	Y	2/ 2 ^h		206 ^h	Y ^h
Thorium-228	267.3	34/ 40	3.5	0.8		1/ 4	3.2	1.0	Y	1/ 1 ⁱ	0.1030 ⁱ		Y ⁱ
Thorium-230	544.1	35/ 40	3.4	0.7	Y	2/ 4	0.59	0.36	Y				
Thorium-232	87.5	32/ 40	3.6	0.6		/ 3	.	.					
Tritium						9/ 12	5406	1245	Y				

Table 3.7 (continued)

Analyte ^e	Wastes ^a	Soils ^b				Groundwater ^c				Surface Water ^d			
	S-3 sludges	Results >	Maximum detect	Average result	SRC ?	Freq. of wells w. detects	Max detect	Mean of the medians ^g	SRC ?	Freq. of detect	Avg. ^f	Avg. ^f	SRC ?
		detection limit									result BCK 12.46	result NT-1	
Uranium-233/234	124.1	40/ 40	17	2.1	Y	3/ 4	4,650	660	Y	1/ 1 ⁱ	52.8 ⁱ		Y ⁱ
Uranium-235	8.1	22/ 40	0.99	0.12	Y	2/ 4	547	68.8	Y	1/ 1 ⁱ	4.7 ⁱ		Y ⁱ
Uranium-238	332.3	40/ 40	43	4.6	Y	3/ 4	13,600	1,601	Y	1/ 1 ⁱ	127.0 ⁱ		Y ⁱ

^a Refer to Table A.3 in Appendix A

^b Soil data are combined results for shallow and deep intervals for both soil aggregates at the S-3 site. These data are presented in Tables D.15, D.16, D.17, and D.18 in Appendix D.

^c Groundwater data are the results for the S-3 site groundwater aggregate. These data are presented in Table D.30 in Appendix D.

^d Surface water data are the results for the BCK 12.46 NT-1 aggregate. These data are presented in Tables D.20 and Table D.22 in Appendix D.

^e Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^f 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.

^g 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.

^h ⁹⁹Tc is not an SRC in the Bear Creek BCK 12.46 and NT-1 surface water aggregates; however this analyte is an SRC in the NT-2 surface water aggregate and is only excluded from the NT-1 and BCK 12.46 aggregates because of poor data quality (no MDAs).

ⁱ These radionuclides are not SRCs in the Bear Creek BCK 12.46 and NT-1 surface water aggregates; however they are SRCs in the BCK 12.71 surface water sample and are only excluded from the NT-1 and BCK 12.46 aggregates because of poor data quality (no MDAs).

SRC—site-related contaminant

**Table 3.8 Summary of predicted future groundwater and surface water concentrations
at NT-1 and NT-2 due to contaminant loading from S-3 Site**

Constituents	Predicted Maximum Groundwater Concentration Range ^a	Predicted Time Range for Peak Concentrations (Years from Start)	Predicted Maximum Surface Water Concentration Range ^a	Observed Surface Water Concentration Range	Groundwater RGOs ^e
NT-1					
<i>Inorganics^b</i>					
Beryllium	0.01 to 0.03	40-200	0.00 to 0.001	0.0003 to 0.0007	0.005 M
Cadmium	0.27 to 0.90	40-200	0.01 to 0.05	0.017 to 0.038	0.005 M
Manganese	29 to 96	Steady State	1.74 to 5.76	0.10 to 6.93	0.05 M ²
Mercury	0.01 to 0.03	40-100	0.00 to 0.004	0.0002 to 0.0002	0.002 M
Nickel	2.10 to 7.26	40-100	0.10 to 0.33	0.048 to 0.15	0.1 M
Strontium	1.27 to 4.49	Steady State	0.25 to 0.87	0.33 to 0.81	22 R
Total uranium	6.78 to 16.58	40-150	0.81 to 1.99	0.031 to 0.075	0.02 M
<i>Common Anions^b</i>					
Nitrate	2,093 to 4,518	33-100	251 to 541	230 to 230	10 M
<i>Organics^c</i>					
Tetrachloroethene	39.9 to 581.4	33-75	3.99 to 58.1	1.0 to 19.0	5 M
<i>Radioactivity^d</i>					
⁹⁹ Tc	7,023 to 23,176	33-100	465 to 1,538	890 to 1,110	34 R
NT-2					
<i>Inorganics^b</i>					
Barium	25 to 95	40-100	2 to 9	0 to 1	2 M
Manganese	2 to 7	50-200	0 to 1	0 to 0	0.05 M ²
Strontium	23 to 87	100-200	2 to 8		22 R
Total uranium	0 to 0	100-1000	0 to 0	0 to 0	0.02 M
<i>Common Anions^b</i>					
Nitrate	5,026 to 8,221	75-400	483 to 791	3 to 211	10 M

^a These concentrations represent predicted peak concentrations over a simulation period of 1000 years.

^b Concentrations of inorganics and common anions are reported as mg/l.

^c Concentrations of organics are reported as ug/l.

^d Concentrations of radioactivity are reported as pCi/l.

^e M = MCL, M² = Secondary MCL, M³ = MCLG, R = Risk-based

**Table 3.9. Summary of predicted future groundwater concentrations
at Bear Creek above BCK 12.46 due to contaminant loading from S-3 Site**

Constituents	<i>Predicted Maximum Groundwater</i>		<i>Predicted Time Range</i>	<i>Groundwater</i>	
	<i>Concentration</i>	<i>Range^a</i>	for Peak Concentration (years from start)	RGOs ^e	
<i>Inorganics^b</i>					
Beryllium	0.002	to 0.01	<45	0.005	M
Cadmium	0.08	to 0.25	<45	0.005	M
Manganese	7.00	to 21.00	<45	0.05	M ²
Mercury	0.003	to 0.01	<45	0.002	M
Nickel	0.75	to 2.24	<45	0.1	M
Strontium	0.51	to 1.53	<45	22	R
Total uranium	1.22	to 3.49	<45	0.02	M
<i>Common Anions^b</i>					
Nitrate	151.4	to 583	<45	10	M
<i>Organics^c</i>					
1,1,2-Trichloroethane	1.42	to 5.09	<45	5	M
Tetrachloroethene	82.36	to 210	<45	5	M
<i>Radioactivity^d</i>					
⁹⁹ Tc	2109.00	to 6,752	<45	34	R

^a These concentrations represent predicted peak concentrations over a simulation period of 1000 years.

^b Concentrations of inorganics and common anions are reported as mg/l.

^c Concentrations of organics are reported as ug/l.

^d Concentrations of radioactivity are reported as pCi/l.

^e M = MCL, M² = Secondary MCL, M³ = MCLG, R = Risk-based

Table 3.10. Results of chemical analysis of soils, groundwater, and surface water at BYBY

Analyte ^d	Soils ^a				Groundwater ^b				Surface Water ^c (NT-3)			
	Results > detection limit	Max detect	Avg. ^e result	SRC ?	Freq. of wells w. detects	Max detect	Avg. ^e result	SRC ?	Freq. of detect	Max detect	Avg. ^e result	SRC ?
<i>Inorganics (mg/L or mg/kg)</i>												
Aluminum	35/ 35	23100	14800		8/ 8	19.2	7.32	Y	18/ 21	3.8	1.166	
Antimony	15/ 15	1650	112	Y	1/ 8	0.03	0.004		4/ 21	0.0049	0.0011	
Arsenic	35/ 35	32.5	8.54	Y	4/ 8	0.013	0.003		4/ 21	0.0036	0.0012	
Barium	35/ 35	1100	234	Y	8/ 8	0.57	0.214		21/ 21	0.105	0.0675	
Beryllium	32/ 35	3.3	1.37	Y	3/ 8	0.0017	0.0005	Y	1/ 21	0.00035	0.0002	
Cadmium	13/ 35	32.3	4.86	Y								
Calcium	35/ 35	75300	18000		8/ 8	413.	157.3		21/ 21	110	68.84	
Chromium	35/ 35	140	47.2	Y								
Cobalt	35/ 35	131	22.9	Y	5/ 8	0.035	0.014	Y	1/ 21	0.0039	0.0013	
Copper	33/ 35	6220	913	Y	3/ 8	0.12	0.03	Y	1/ 21	0.003	0.0047	
Cyanide	4/ 33	7.4	0.659									
Iron	35/ 35	102000	38000		8/ 8	44.2	16.8		18/ 21	4.97	1.69	
Lead	35/ 35	1870	297	Y	7/ 8	0.118	0.027	Y				
Lithium									7/ 7	0.175	0.1352	Y
Magnesium	35/ 35	15000	4770		8/ 8	33.5	15.19		21/ 21	16.4	10.16	
Manganese	35/ 35	3120	948	Y	8/ 8	7.58	1.88	Y	21/ 21	1.19	0.2727	
Mercury	30/ 35	77.7	14.4	Y	8/ 8	0.078	0.009	Y	10/ 21	0.00053	0.0002	Y
Molybdenum	3/ 31	50.3	4.83	Y	2/ 8	0.129	0.02	Y				
Nickel	35/ 35	10600	389	Y	8/ 8	0.08	0.04	Y	4/ 21	0.0086	0.0036	

Table 3.10 (continued)

Analyte ^d	Soils ^a				Groundwater ^b				Surface Water ^c (NT-3)			
	Results > detection limit	Max detect	Avg. ^e result	SRC ?	Freq. of wells w. detects	Max detect	Avg. ^e result	SRC ?	Freq. of detect	Max detect	Avg. ^e result	SRC ?
Potassium	35/ 35	5070	2450		8/ 8	13.7	6.39	Y	20/ 21	6.85	3.987	
Selenium	10/ 33	132	4.65	Y	2/ 8	0.004	0.002					
Silver	31/ 35	61.5	11.7	Y								
Sodium	34/ 35	960	152		8/ 8	15.8	9.7		20/ 21	6.03	3.538	
Thallium	1/ 35	0.87	0.231		0/ 8	0	0.001					
Tin	14/ 34	102	17.2	Y	0/ 8	0	0.005					
Vanadium	35/ 35	57.9	27.7		5/ 8	0.032	0.01	Y	5/ 21	0.0083	0.0022	
Zinc	35/ 35	4380	590	Y	4/ 8	0.32	0.069	Y	9/ 21	0.0449	0.0137	
<i>Common Anions (mg/L or mg/kg)</i>												
Chloride					8/ 8	35	10.3	Y	21/ 21	5.8	2.367	Y
Cyanide					1/ 8	0.04	0.008	Y				
Fluoride					4/ 8	4	1.04	Y	21/ 21	2.6	1.602	Y
Nitrate					5/ 8	6.7	0.82		7/ 21	1.2	0.1476	
Sulfate					8/ 8	300	101.4444	Y	20/ 21	114	65.81	Y
<i>Organics (µg/L or µg/kg)</i>												
2378-TCDD	6/ 11	7.72	1.77	Y								
PCB-1254	15/ 30	5800	808	Y	1/ 7	0.45	0.54					
PCB-1260	4/ 29	2500	191	Y								
2,4-Dimethylphenol	1/ 32	110	202	Y								

Table 3.10 (continued)

Analyte ^d	Soils ^a				Groundwater ^b				Surface Water ^c (NT-3)			
	Results > detection limit	Max detect	Avg. ^e result	SRC ?	Freq. of wells w. detects	Max detect	Avg. ^e result	SRC ?	Freq. of detect	Max detect	Avg. ^e result	SRC ?
2-Methylnaphthalene	10/ 33	2600	275	Y								
4-Methylphenol	1/ 32	140	203	Y								
Acenaphthene	14/ 33	6700	551	Y								
Acenaphthylene	8/ 31	490	195	Y								
Anthracene	15/ 33	53000	2480	Y								
Benzo(a)anthracene	18/ 33	120000	6240	Y								
Benzo(a)pyrene	18/ 33	76000	4300	Y								
Benzo(b)fluoranthene	18/ 33	86000	5130	Y								
Benzo(ghi)perylene	16/ 33	30000	2020	Y								
Benzo(k)fluoranthene	18/ 33	80000	4410	Y								
Bis(2-ethylhexyl)phthalate	22/ 31	880	227	Y	2/ 7	2	4.69					
Butylbenzylphthalate	4/ 29	87	186	Y								
Carbazole	14/ 33	25000	1320	Y								
Chrysene	19/ 33	120000	6250	Y								
Di-n-butylphthalate	2/ 31	2500	302	Y								
Dibenzo(a,h)anthracene	14/ 33	12000	991	Y								
Dibenzofuran	14/ 33	10000	600	Y								
Diethylphthalate	1/ 31	65	209	Y								
Fluoranthene	20/ 33	270000	13600	Y								

Table 3.10 (continued)

Analyte ^d	Soils ^a				Groundwater ^b				Surface Water ^c (NT-3)			
	Results > detection limit	Max detect	Avg. ^e result	SRC ?	Freq. of wells w. detects	Max detect	Avg. ^e result	SRC ?	Freq. of detect	Max detect	Avg. ^e result	SRC ?
Fluorene	14/33	17000	982	Y								
Indeno(1,2,3-cd)pyrene	16/33	31000	2080	Y								
Naphthalene	14/33	5000	350	Y								
Phenanthrene	20/33	180000	8740	Y								
Phenol	10/31	280	172	Y								
Pyrene	20/33	210000	10900	Y								
1,1,2,2-Tetrachloroethane	1/39	4	3.12	Y								
1,1,2-Trichloroethane	1/39	2	3.06	Y	2/8	5	2.8	Y				
1,1-Dichloroethane					4/8	9	3.3	Y				
1,1-Dichloroethene					2/8	110	14.7	Y				
1,2-Dichloroethane	1/39	2	3.06	Y	2/8	23	5.2	Y	7/20	22	7.575	Y
1,2-Dichloroethene	2/39	6	3.14	Y	3/8	1,100	132.9	Y				
2-Butanone	2/39	18	6.91	Y					1/20	8	2.775	
2-Hexanone	1/39	14	6.44	Y					1/20	6	2.675	
4-Methyl-2-pentanone	1/39	13	6.21	Y					1/20	6	2.675	
Acetone	21/36	180	44.7	Y	2/8	64	16.4	Y	6/20	26	8.525	Y
Benzene					3/8	10	3.8	Y				
Bromoform	1/39	4	3.12	Y								
Carbon disulfide	1/39	2	3.08	Y								

Table 3.10 (continued)

Analyte ^d	Soils ^a				Groundwater ^b				Surface Water ^c (NT-3)			
	Results > detection limit	Max detect	Avg. ^e result	SRC ?	Freq. of wells w. detects	Max detect	Avg. ^e result	SRC ?	Freq. of detect	Max detect	Avg. ^e result	SRC ?
Chloromethane					1/8	17	6	Y	7/20	12	4.3	Y
Chloroform					1/8	140	17.8	Y				
Dibromochloromethane	1/39	2	3.06	Y								
Di-N-Butylphthalate					2/7	1	4.5					
Fluoranthene					4/7	4	4.2					
Phenanthrene					3/7	3	4.3					
Pyrene					4/7	3	3.9					
Tetrachloroethene	4/39	13	3.45	Y	2/8	620	72.5	Y				
Toluene	23/39	590	57.8	Y	3/8	1	2		1/20	2	2.475	
Trichloroethene	2/39	6	3.13	Y	3/8	2,000	247.6	Y				
Vinyl chloride					2/8	73	13	Y				
Radionuclides (pCi/L or pCi/g)												
Alpha activity	32/37	710	100		6/8	2,200	295	Y	20/20	1350	455.4	Y
Antimony-125					0/8	0	4.3					
Beta activity	26/37	1600	137		7/8	2,800	378	Y	20/20	603	221.8	Y
Bismuth-212					0/8	0	32					
Cerium-144					0/8	0	10.6					
Cesium-134					0/8	0	2.4					
Cesium-137					0/8	0	5					

Table 3.10 (continued)

Analyte ^d	Soils ^a				Groundwater ^b				Surface Water ^c (NT-3)			
	Results > detection limit	Max detect	Avg. ^e result	SRC ?	Freq. of wells w. detects	Max detect	Avg. ^e result	SRC ?	Freq. of detect	Max detect	Avg. ^e result	SRC ?
Chromium-51					0/8	0	14.9					
Cobalt-57					0/8	0	1.3					
Cobalt-58					0/8	0	0.2					
Cobalt-60					0/8	0	6.3					
Iron-59					0/8	0	5.2					
Lead-212	1/37	1.9	2.41		1/8	16	10.7	Y				
Manganese-54					0/8	0	0.3					
Niobium-95					0/8	0	2.3					
Potassium-40					1/8	170	106	Y				
Ruthenium-106					0/8	0	24.9					
Sodium-22					0/8	0	0.7					
Strontium-90	3/26	1.9	0.185	Y	0/8	0	0.3		3/11	1.94	0.7204	Y
Technetium-99	8/26	77	13	Y	0/8	0	4.1					
Thallium-208					0/8	0	12					
Thorium-228	31/36	2.4	0.641		6/8	2.3	1.2	Y	4/11	0.31	0.1314	Y
Thorium-230	34/36	7.1	0.698	Y	6/8	2.6	1.4	Y	6/11	19.5	1.939	Y
Thorium-232	30/36	44	1.67		2/8	1.2	0.57	Y	7/11	1.79	0.2782	Y
Uranium-233/234	34/37	260	49	Y	8/8	1,300	207.9	Y	18/18	217	130.8	Y
Uranium-235	26/37	17	2.55	Y	4/8	53	8.1	Y	17/18	17.7	6.6	Y

Table 3.10 (continued)

Analyte ^d	Soils ^a				Groundwater ^b				Surface Water ^c (NT-3)			
	Results > detection limit	Max detect	Avg. ^e result	SRC ?	Freq. of wells w. detects	Max detect	Avg. ^e result	SRC ?	Freq. of detect	Max detect	Avg. ^e result	SRC ?
Uranium-238	36/ 37	880	71.9	Y	8/ 8	1,800	246	Y	18/ 18	543	304.7	Y
Zinc-65					0/ 8	0	2.2					
Zirconium-95					0/ 8	0	4.8					

^a Soil data are combined results for shallow and deep intervals for the soil aggregate at BYBY. These data are presented in Tables D.36 and D.37 in Appendix D.

^b Groundwater data are the results for the BYBY OU 1 groundwater aggregate. These data are presented in Table D.60 in Appendix D.

^c Surface water data are the results for the NT-3 aggregate. These data are presented in Table D.48 in Appendix D.

^d Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^e 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.

**Table 3.11. Summary of predicted future groundwater and surface water concentrations
at NT-3 due to contaminant loading from BYBY**

Constituents	Predicted Maximum Groundwater Conc. Range ^a	Predicted Time Range for Peak Conc. (years from start)	Predicted Maximum Surface Water Conc. Range ^a	Observed Surface Water Conc. Range	Groundwater RGOs ^e	
<i>Inorganics^b</i>						
Antimony	0.26 to 0.63	Steady State	0.03 to 0.08	0.0017 to 0.0049	0.006	M
Cadmium	0.02 to 0.04	Steady State	0.002 to 0.005		0.005	M
Manganese	1.89 to 4.45	Steady State	0.230 to 0.530	0.021 to 1.2	0.05	M
Mercury	0.03 to 0.06	Steady State	0.00 to 0.01	0.0002 to 0.00053	0.002	M
Nickel	0.46 to 1.27	Steady State	0.06 to 0.15	0.0042 to 0.0086	0.1	M
Total uranium	3.07 to 4.65	Steady State	0.37 to 0.56	0.191 to 1.632	0.02	M
<i>Organics^b</i>						
1,1,2,2-Tetrachloroethane	0.00 to 1.27	<45	0.00 to 0.15		0.43	R
1,1-Dichloroethene	0.00 to 25.7	<45	0.00 to 3.08		7	M
1,2-Dichloroethene	160.95 to 413.16	<45	19.28 to 49.48		330	R
Methylene chloride	0.00 to 122.6	<45	0.00 to 14.7		5	M
Tetrachloroethene	162.4 to 480	<45	19.4 to 57.4		5	M
Trichloroethene	110.6 to 423	<45	13.25 to 50.6		5	M
Vinyl Chloride	9.6 to 26	<45	1.15 to 3.1		2	M
<i>Radioactivity^c</i>						
⁹⁹ Tc	5,911 to 7,694	Steady State	708 to 921		34	R

^a These concentrations represent predicted peak concentrations over a simulation period of 1000 years.

^b Concentrations of inorganics are reported as mg/l.

^c Concentrations of organics are reported as µg/l.

^d Concentrations of radioactivity are reported as pCi/l.

^e M = MCL, M² = Secondary MCL, M³ = MCLG, R = Risk-based

Table 3.12. Results of analyses for waste leachate, soil, groundwater, and surface water at BCBG

Analyte ^d	Soils ^a					Groundwater ^b				Surface water ^c			
	Seep 2 leachate 3/9/93	Results > detection limit	Max detect	Avg. result	SRC ?	Freq. of wells w. detects	Max detect	Mean of the medians ^f	SRC ?	Freq. of detect	Max detect	Avg. ^e result	SRC ?
<i>Inorganics (mg/L or mg/kg)</i>													
Aluminum	159	79/ 79	29100	16000		59/ 59	27	0.417		37/ 56	30.1	2.274	Y
Antimony		21/ 21	0.56	0.29		4/ 61	0.16	0.026		4/ 56	0.003	0.001	
Arsenic	0.8	78/ 79	52.6	5.35	Y	1/ 16	0.01	0.003		14/ 56	0.032	0.003	
Barium	2.89	79/ 79	728	168	Y	61/ 61	1.6	0.188	Y	56/ 56	0.157	0.0661	
Beryllium	1.11	77/ 79	4.8	1.14	Y	30/ 61	0.0038	0.0002		6/ 56	0.0086	0.0004	Y
Boron	17.5					57/ 57	31	0.796	Y				
Cadmium	0.02U					18/ 64	0.0520	0.0014	Y				
Calcium	531	74/ 79	16500	2540		65/ 65	190	33.7		56/ 56	75	40.72	
Cerium	1.22												
Chromium	0.28	79/ 79	51.1	29.9		36/ 65	0.51	0.008					
Cobalt	0.21					17/ 61	0.099	0.004		7/ 56	0.015	0.002	
Cyanide		7/ 79	142	2.73	Y					1/ 56	0.031	0.003	Y
Copper	0.64	72/ 78	101	22.3	Y	56/ 60	6.6	0.008	Y	2/ 56	0.022	0.006	
Gallium	0.09U												
Iron	1290	79/ 79	66800	28300		57/ 57	43	1.38		50/ 56	42.7	3.775	
Lead	0.8	79/ 79	124	14.4	Y	58/ 64	0.7000	0.0057	Y				
Lithium	11.9					16/ 16	0.99	0.107	Y	21/ 21	0.188	0.073	Y
Magnesium	50.9	79/ 79	9830	4200		65/ 65	34	6.54		56/ 56	11	5.913	
Manganese	18.7	79/ 79	7120	953	Y	60/ 60	19	0.59		54/ 56	1.65	0.302	
Mercury	0.0002U	16/ 79	0.47	0.065	Y	12/ 60	0.0007	0.0001		9/ 56	0.00045	0.0001	Y
Molybdenum	0.07	4/ 79	5	0.745		7/ 59	0.071	0.005					
Nickel	0.36	79/ 79	206	36.5	Y	41/ 61	1.7	0.016		8/ 56	0.022	0.004	Y
Niobium	0.05U					8/ 16	0.017	0.005	Y				
PCB	0.0005U												
Potassium	18	79/ 79	3960	2280						56/ 56	115	8.461	
Phosphorus	9.1												
Selenium	0.5U	14/ 79	2.8	0.426	Y	0/ 20	0	0.003		1/ 56	0.003	0.001	

Table 3.12 (continued)

Analyte ^d	Seep 2 leachate 3/9/93	Results > detection limit	Soils ^a			Groundwater ^b			Surface water ^c				
			Max detect	Avg. result	SRC ?	Freq. of wells w. detects	Max detect	Mean of the medians ^f	SRC ?	Freq. of detect	Max detect	Avg. ^e result	SRC ?
Silicon						56/ 56	3	7.758					
Silver	0.03U	59/ 79	6.4	2.06	Y	0/ 20	0	0.005					
Sodium	5.1	32/ 79	116	47.8		65/ 65	2,100	105		54/ 56	18.1	4.579	
Strontium	0.954					57/ 57	1.5	0.1958					
Thallium	0.2U					0/ 9	0	0.005					
Thorium	0.11					0/ 61	0	0.1					
Tin		10/ 79	15.5	1.99	Y								
Titanium	1.02					12/ 16	0.13	0.0198					
Total uranium (fluorometric)	1.49					54/ 65	0.174	0.001					
Vanadium	0.89	79/ 79	68.8	24.5	Y	14/ 61	0.04	0.0027		16/ 56	0.07	0.006	Y
Zinc	3.20	78/ 79	399	64.6	Y	60/ 60	1.6	0.017	Y	15/ 56	0.132	0.015	Y
Zirconium	0.16					3/ 16	0.02	0.002					
<i>Common Anions (mg/L or mg/kg)</i>													
Chloride						65/ 65	3,910	104	Y	56/ 56	36.3	11.37	Y
Fluoride						57/ 61	14	0.814		39/ 56	0.87	0.134	Y
Nitrate						26/ 65	5.1	0.153		42/ 56	24.8	1.539	Y
Sulfate						65/ 65	344	19.75		38/ 56	78.8	11.82	
<i>Organics (µg/L or µg/kg)</i>													
4,4'-DDE		1/ 76	0.92	2.02	Y								
4,4'-DDT		1/ 76	1	2.02	Y								
Methoxychlor		3/ 76	6	9.96	Y								
PCB-1254		12/ 76	10000	163	Y								
PCB-1260		4/ 76	36000	524	Y								
1,4-Dichlorobenzene	10U	1/ 29	92	204	Y								
Benzo(a)anthracene		1/ 29	87	201	Y								
Benzo(b)fluoranthene		1/ 29	90	202	Y								
Benzo(k)fluoranthene		1/ 29	94	202	Y								
Bis(2-ethylhexyl)phthalate	10U	8/ 29	8700	623	Y								

Table 3.12 (continued)

Analyte ^d	Seep 2 leachate 3/9/93	Results > detection limit	Soils ^a			Freq. of wells w. detects	Groundwater ^b			SRC ?	Surface water ^c			
			Max detect	Avg. result	SRC ?		Max detect	Mean of the medians ^f	Freq. of detect		Max detect	Avg. ^e result	SRC ?	
Chrysene		1/ 29	93	202	Y									
Di-n-octylphthalate		1/ 29	63	203	Y									
Fluoranthene		1/ 29	230	206	Y									
Phenanthrene		2/ 29	150	199	Y									
Pyrene		3/ 29	240	201	Y									
1,1,1-Trichloroethane	5J	3/ 84	19	3.3	Y	18/ 65	13,000	93	Y	35/ 55	35	9	Y	
1,1,2-Trichloroethane	.010U					4/ 65	300	6.2	Y	5/ 55	2	2	Y	
1,1,2,2-Tetrachloroethane						2/ 65	24	2.8						
1,1-Dichloroethane	8I	4/ 84	72	4.09	Y	23/ 65	7,800	133.4	Y	38/ 55	27	10	Y	
1,1-Dichloroethene	.010U	3/ 84	6	3.16	Y	12/ 65	13,000	82.4	Y	31/ 55	16	5.7	Y	
1,2-Dichloroethane	2J	2/ 84	3	3.09	Y	10/ 65	102	5	Y	27/ 55	24	5.7	Y	
1,2-Dichloroethene		9/ 84	470	9.72	Y	15/ 63	5,400	157.6	Y	43/ 55	410	113.7	Y	
2,4-Dimethylphenol	6J													
2-Butanone		2/ 84	72	7.32	Y	15/ 65	3,600	5.8	Y	2/ 55	6	2.7	Y	
2-Hexanone						9/ 65	220	5.6	Y					
1,2,4-Trichlorobenzene	10U													
4-Methyl-2-pentanone		7/ 83	15	6.26	Y	16/ 65	320	5.5	Y					
Acetone		22/ 76	180	30.1	Y	42/ 65	850	5.8	Y	10/ 55	34	7	Y	
Benzene	4J	4/ 84	180	6.17	Y	21/ 65	420	7.9	Y	7/ 55	3	2	Y	
Bromodichloromethane						1/ 65	2	2.8						
Bromoform						1/ 65	20	2.8						
Carbon disulfide						5/ 65	36	2.8	Y	2/ 55	6	2.6		
Carbon tetrachloride						6/ 65	190	2.8	Y					
Chlorobenzene		2/ 83	4	3.09	Y	2/ 65	1	2.8		1/ 55	1	3		
Chloroethane	640	2/ 84	170	8.26	Y	10/ 65	740	17.2	Y	1/ 55	93	4	Y	
Chloroform		1/ 84	15	3.25	Y	17/ 65	1,700	3.2	Y	31/ 55	8	3	Y	
Chloromethane						2/ 65	8	5.5		12/ 55	14	3.7	Y	
cis-1,3-Dichloropropene						2/ 65	4	2.8						

Table 3.12 (continued)

Analyte ^d	Seep 2 leachate 3/9/93	Results > detection limit	Soils ^a			Groundwater ^b				Surface water ^c			
			Max detect	Avg. result	SRC ?	Freq. of wells w. detects	Max detect	Mean of the medians ^e	SRC ?	Freq. of detect	Max detect	Avg. ^e result	SRC ?
Dimethylbenzene						15/ 65	130	3.4	Y				
Ethylbenzene	.010U					14/ 65	33	2.9	Y				
Methylene chloride	56	6/ 79	86	8.73	Y	30/ 65	490	4.8	Y	9/ 55	4	2.8	Y
Naphthalene	10U												
Phenols						12/ 23	0.2	0.009	Y				
Styrene						1/ 65	12	2.8					
Tetrachloroethene	.010U	12/ 83	220	7.78	Y	28/ 65	63,000	453.2	Y	36/ 55	120	33	Y
Toluene	7J	31/ 84	360	17.9	Y	16/ 65	670	3.9	Y	2/ 55	1	2.5	
Trans-1,2-Dichloroethene	2J					9/ 14	50,000	1049	Y				
trans-1,3-Dichloropropene						1/ 65	15	2.8					
Trichloroethene	.010U	6/ 84	85	4.56	Y	27/ 65	24,000	286.4	Y	37/ 55	82	21	Y
Trichlorofluoromethane										4/ 53	4	3	Y
Vinyl acetate						3/ 65	6	5.5					
Gross Gamma	80±16												
Oil and Grease	2.5												
Total Organic Carbon	76												
Total Suspended Solids	36												
Vinyl chloride	10J	2/ 84	19	6.27	Y	14/ 65	3,400	65.8	Y	32/ 55	33	8.7	Y
<i>Radioactivity (pCi/L or pCi/g)</i>													
Alpha activity	730±96	33/ 83	140	6.54	Y	18/ 52	330	7.7	Y	34/ 51	135	22.5	Y
Americium-241						/ 10	.	0.01					
Beta activity	260±33	48/ 83	71	10.2	Y	18/ 52	300	7.55	Y	36/ 51	117	20.9	Y
Cesium-137		1/ 83	1.6	1.2		4/ 10	11	4.59					
Neptunium-237						3/ 10	0.85	0.23					
Plutonium-238						/ 9	.	0.07		1/ 9	0.223	0.03	Y
Plutonium-239/240						/ 10	.	0.01					
Radium-228						/ 9	.	0.12					
Technetium-99		6/ 74	130	3.82	Y	4/ 10	110	16.55					

Table 3.12 (continued)

Analyte ^d	Seep 2 leachate 3/9/93	Results > detection limit	Soils ^a			Freq. of wells w. detects	Groundwater ^b		SRC ?	Surface water ^c			
			Max detect	Avg. result	SRC ?		Max detect	Mean of the medians ^f		Freq. of detect	Max detect	Avg. ^e result	SRC ?
Thorium-228		72/ 79	1.7	0.657	Y	2/ 9	0.96	0.25		4/ 11	0.48	0.15	Y
Thorium-230		69/ 79	1.2	0.455		6/ 9	0.51	0.34		6/ 11	0.57	0.2	Y
Thorium-232		65/ 79	1.1	0.426		2/ 9	0.38	0.09		3/ 11	0.38	0.1	Y
Total radioactive strontium						/ 4		1.01					
Tritium						3/ 10	4200	781					
Uranium-234		80/ 83	5.8	0.54	Y	9/ 10	58	7.19		56/ 56	56	8.2	Y
Uranium-235	0.23	16/ 83	0.16	0.0392		3/ 9	3.9	0.49		8/ 56	6.2	0.5	Y
Uranium-238		81/ 83	36	1.41	Y	6/ 10	350	36.30		56/ 56	440	23	Y

^a Soil data are combined results for shallow and deep intervals for all soil aggregates at the BCBG. These data are presented in Tables D.65, D.66, D.67, D.68, D.70, D.71, D.73, D.74, D.76, D.77, D.79 and D.80 in Appendix D.

^b Groundwater data are the results for the BCBG groundwater aggregate. These data are presented in Table D.91 in Appendix D.

^c Surface water data are the combined results for the NT-6, NT-7, and NT-8 surface water aggregates. These data are presented in Tables D.81, D.83, and D.85 in Appendix D.

^d Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^e 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.

^f 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 3.13. Summary of predicted future groundwater and surface water concentrations at NT-7 due to contaminant loading from BG A-North and A-South

Constituents	Predicted Max. Groundwater Conc. Range ^a	Predicted Time Range for Peak Conc. (years from start)	Predicted Max. Surface Water Conc. Range ^a	Observed Surface Water Concentration Range	Groundwater RGOs ^c
<i>Inorganics^b</i>					
Antimony	0.04 to 0.11	>1000	0.004 to 0.012	0.0023 to 0.003	0.006 M
Beryllium	0.27 to 1.62	>1000	0.03 to 0.18	0.0004 to 0.0013	0.005 M
Boron	15.3 25.0	>1000	1.73 2.82		3.3 R
Cadmium	0.02 0.04	>1000	0.003 0.005		0.005 M
Copper	1.8 to 4.1	>1000	0.20 to 0.46	0.0306 to 0.0306	1 M
Cyanide	22.0 to 214.0	10-100	2.5 to 24.1	0.0139 to 0.0139	0.2 M
Lead	0.07 0.30	>1000	0.008 0.034		0.015 M ³
Lithium	0.29 to 1.87	>1000	0.03 to 0.21	0.0283 to 0.057	0.073 R
Manganese	3.73 to 10.3	>1000	0.4 to 1.2	0.0085 to 1.01	0.05 M ²
Nickel	0.25 to 0.83	>1000	0.03 to 0.09	0.0031 to 0.022	0.1 M
Total uranium	1.79 to 2.88	>1000	0.20 to 0.32	0.0114 to 0.1524	0.02 M
<i>Organics^c</i>					
1,1,1-Trichloroethane	576.2 to 3,861.7	20-150	65.0 to 435.9	3 to 35	200 M
1,1,2-Trichloroethane	14.2 59.3	20-250	1.6 6.7		5 M
1,1-Dichloroethene	0.00 to 144.7	20-55	0.00 to 16.3	2 to 16	7 M
1,2-Dichloroethane	5.97 to 40.5	20-130	0.67 to 4.6	1 to 19	5 M
1,2-Dichloroethene	506.6 to 1,587.8	20-300	57 to 179	33 to 290	330 R
Benzene	18.4 to 158.4	20-150	2.1 to 17.9	1 to 2	5 M
Carbon tetrachloride	0.00 796.6	20-100	0.00 89.9		5 M
Chloroform	366.0 to 1,789.3	20-325	41.3 to 202.0	1 to 8	100 M
Methylene chloride	0.00 to 20.1	10-45	0.00 to 2.26	1 to 4	5 M
Tetrachloroethene	1,920.1 to 10,417.8	20-200	216.7 to 1175.8	16 to 120	5 M
Trans-1,2-Dichloroethene	4,801.4 14,341.8	20-225	542 1619		100 M
Trichloroethene	651.9 to 3,758.2	20-200	73.6 to 424.2	8 to 82	5 M
Vinyl chloride	305.9 to 990.8	20-170	34.5 to 111.8	6 to 33	2 M
<i>Radioactivity^d</i>					
⁴⁰ K	70.9 to 122.2	>1000	8.0 to 13.8		3.8 R

^a These concentrations represent predicted peak concentrations over a simulation period of 1000 years.

^b Concentrations of inorganics and common anions are reported as mg/l.

^c Concentrations of organics are reported as ug/l.

^d Concentrations of radioactivity are reported as pCi/l.

^e M = MCL, M² = Secondary MCL, M³ = MCLG, R = Risk-based

**Table 3.14. Summary of predicted surface water concentration at NT-8 due to
contaminant loading from BG-WIP and BG-C West**

Constituents	Surface Water Concentrations at NT-8 Range	Predicted Time Range for Peak Conc. (years from start)	Observed Surface Water Concentration Range at NT-8	Groundwater RGOs ^o	
Inorganics ^b					
Arsenic	0.05 to 0.07	>1000	0.0024 to 0.0143	0.05	M
Barium	0.20 to 0.44	>1000	0.031 to 0.102	2	M
Beryllium	0.02 to 0.06	>1000	0.0004 to 0.0086	0.005	M
Boron	11.45 to 25.20	>1000		0.33	R
Cadmium	0.00 to 0.00	>1000		0.005	M
Chromium	0.04 to 0.08	>1000		0.1	M
Copper	0.03 to 0.05	>1000		1	M ²
Cyanide	0.67 to 2.38	10-100	0.0215 to 0.0215	0.2	M
Lead	0.02 to 0.05	>1000		0.015	M ³
Lithium	2.95 to 6.48	>1000	0.0134 to 0.188	0.073	R
Manganese	1.23 to 2.70	>1000	0.0259 to 0.425	0.05	M ²
Nickel	0.01 to 0.03	>1000	0.0046 to 0.0046	0.1	M
Selenium	0.05 to 0.10	>1000		0.05	M
Thallium	0.02 to 0.04	>1000		0.002	M
Total uranium	0.30 to 0.41	>1000	0.06 to 1.32	0.02	M ³
Organics ^c					
1,1,1-Trichloroethane	381.82 to 840.00	20-180	2 to 11	200	M
1,1,2-Trichloroethane	4.46 to 11.24	20-180	1 to 2	5	M
1,1-Dichloroethene	11.61 to 137.64	10-40	5 to 11	7	M
1,2-Dichloroethane	254.55 to 560.00	10-100	2 to 4	5	M
Benzene	681.58 to 2273.12	20-130	1 to 3	5	M
Bis (ethylhexyl)phthalate	11.18 to 24.60			4.8	R
Carbon tetrachloride	0.44 to 2.85	20-100		5	M
Chloroethane	245.45 to 540.00		93 to 93	860	R

T-40

Table 3.14. (continued)

Constituents	Surface Water Concentrations at NT-8 Range	Predicted Time Range for Peak Conc. (years from start)	Observed Surface Water Concentration Range at NT-8	Groundwater RGOs ^c	
Chloroform	20.26 to 57.03	20-200	1 to 3	100	M
Methylene Chloride	5.58 to 81.96	10-45	1 to 3	5	M
PCB(Total)	11.82 to 26.00			5	M
Tetrachloroethene	101.25 to 277.73	30-225	26 to 58	5	M
Trans-1,2-Dichloroethene	1101.16 to 2394.05	20-160		100	M
Trichloroethene	13.64 to 30.00	30-225	13 to 29	5	M
Vinyl chloride	209.09 to 460.00	20-140	3 to 21	2	M
<i>Radioactivity^d</i>					
⁴⁰ K	9.86 to 14.47	>1000	130 to 130	3.8	R
⁹⁹ Tc	621.01 to 719.55	>1000		34	R
^{233/234} U	0.00 to 0.00	>1000	6.6 to 56	1.1	R
²³⁵ U	20.45 to 45.00	>1000	1.07 to 6.2	1.1	R
²³⁸ U	0.89 to 1.96	>1000	21.5 to 440	1.1	R

^a These concentrations represent predicted peak concentrations over a simulation period of 1000 years.

^b Concentrations of inorganics and common anions are reported as mg/l.

^c Concentrations of organics are reported as ug/l.

^d Concentrations of radioactivity are reported as pCi/l.

^e M = MCL, M² = Secondary MCL, M³ = MCLG, R = Risk-based

Table 3.15. Results of chemical analysis of groundwater in the Maynardville Limestone and Bear Creek FA and of surface water at SS-4, SS-5, and BCK 9.47

Analyte ^b	Groundwater				SS-4 ^a				SS-5 ^a				Bear Creek at BCK 9.47 ^a			
	Freq. of wells w. detects	Max detect	Mean of the medians ^c	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?
<i>Inorganics (mg/L)</i>																
Aluminum	78/ 78	68	0.3		19/ 27	2.98	0.34		17/ 27	0.813	0.098		26/ 35	29.8	1.68	Y
Antimony	1/ 78	0.13	0.027		1/ 13	0.0028	0.001		1/ 13	0.003	0.001		4/ 22	0.003	0.001	
Arsenic	1/ 17	0.005	0.0025										5/ 22	0.023	0.003	
Barium	78/ 78	10	0.23		27/ 27	0.24	0.15		27/ 27	0.12	0.083		33/ 35	0.204	0.099	
Beryllium	40/ 78	0.0039	0.0002						1/ 27	0.0003	0.0002		1/ 35	0.0015	0.0002	
Boron	78/ 78	3	0.16	Y	14/ 14	0.26	0.11	Y	13/ 14	0.18	0.075	Y	13/ 13	4.1	0.80	Y
Cadmium	21/ 82	1.0200	0.008													
Calcium	82/ 82	880	119.52		27/ 27	140	100.2		27/ 27	87	62.73		35/ 35	101	64.67	
Chromium	39/ 82	0.71	0.007										1/ 11	0.01	0.006	
Cobalt	17/ 78	0.140	0.003										3/ 35	0.014	0.002	
Copper	70/ 78	0.19	0.005	Y	4/ 27	0.007	0.002		2/ 27	0.007	0.002		1/ 35	0.005	0.003	
Iron	78/ 78	170	1.82		23/ 27	3.72	0.46		20/ 26	1.13	0.111		34/ 35	38	2.39	
Lead	61/ 82	0.23	0.0046	Y	1/ 12	0.005	0.002		1/ 12	0.012	0.003					
Lithium	5/ 6	0.085	0.029	Y	7/ 7	0.036	0.029		7/ 7	0.014	0.010		7/ 7	0.091	0.060	Y
Magnesium	82/ 82	250	28.58		27/ 27	26	20.27		27/ 27	20	15.34		35/ 35	18.1	11.44	
Manganese	78/ 78	16	0.37	Y	26/ 27	0.809	0.14	Y	21/ 27	0.048	0.007		34/ 35	0.708	0.126	
Mercury	11/ 79	0.0019	0.0001		3/ 24	0.0002	0.0001						3/ 32	0.0002	0.0001	

Table 3.15 (continued)

Analyte ^b	Groundwater				SS-4 ^a				SS-5 ^a				Bear Creek at BCK 9.47 ^a			
	Freq. of wells w. detects	Max detect	Mean of the medians ^c	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?
Molybdenum	6/ 78	3.5	0.0052													
Nickel	57/ 78	0.23	0.0087		3/ 27	0.022	0.005		1/ 27	0.01	0.004		6/ 35	0.021	0.005	Y
Niobium	3/ 6	0.029	0.0073													
Potassium	82/ 82	44	4.0		26/ 27	5.4	3.0		26/ 27	3.2	1.767		35/ 35	12.2	4.16	
Selenium	2/ 20	0.005	0.0025										1/ 22	0.003	0.001	
Silicon	63/ 63	18	5.12		3/ 3	4.1	3.9		3/ 3	3.6	3.5		3/ 3	3.7	3.5	
Silver	0/ 19	0	0.005		1/ 27	0.007	0.003									
Sodium	82/ 82	1,300	33.4		27/ 27	25	15.79		27/ 27	14	7.8		34/ 35	17.1	9.5	
Strontium	77/ 77	23	0.91	Y	14/ 14	0.42	0.23	Y	14/ 14	0.2	0.11	Y	13/ 13	0.22	0.16	Y
Thallium	0/ 15	0	0.005													
Thorium	0/ 78	0	0.105													
Tin	0/ 1	0	0.005													
Titanium	5/ 6	0.052	0.0183													
Total uranium (fluorometric)	71/ 82	0.30	0.0092	Y	14/ 14	0.285	0.136	Y	14/ 14	0.117	0.058	Y	13/ 13	0.152	0.103	Y
Vanadium	20/ 78	0.13	0.0026		1/ 27	0.004	0.002		1/ 27	0.0037	0.0019		6/ 35	0.058	0.005	Y
Zinc	78/ 78	5.1	0.0452	Y	12/ 27	0.02	0.006		13/ 27	0.02	0.005		19/ 35	0.223	0.018	Y
Zirconium	2/ 6	0.0081	0.003													

Table 3.15 (continued)

Analyte ^b	Groundwater				SS-4 ^a				SS-5 ^a				Bear Creek at BCK 9.47 ^a			
	Freq. of wells w. detects	Max detect	Mean of the medians ^c	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?
Common Anions (mg/L)																
Ammonia nitrogen	1/4	2.9	0.1													
Chloride	81/82	2,180	49.4	Y	26/26	41.5	25.91	Y	26/26	23.9	13.5	Y	34/34	34.4	17.1	Y
Fluoride	70/80	1.9	0.234		26/27	0.6	0.362	Y	24/27	0.44	0.205		35/35	0.4	0.26	Y
Kjeldahl nitrogen	3/4	4.9	1.4													
Nitrate	64/82	918	29.5	Y	26/27	67.6	31.58	Y	26/27	27	11.04	Y	35/35	46.2	14.47	Y
Nitrite	0/4	0	1.625													
Sulfate	82/82	2,833	95.9		26/27	45	27.7	Y	27/27	29	16.75	Y	33/35	29.6	21.24	
Organics (µg/L)																
1,1,1-Trichloroethane	25/83	43	2.7	Y	2/27	1	2.5	Y					1/35	0.4	2.5	
1,1-Dichloroethane	16/83	21	2.8	Y									3/35	2	2.5	Y
1,1-Dichloroethene	18/83	36	2.7	Y	3/27	3	2.6	Y								
1,2-Dichloroethane	4/83	2	2.5										7/35	20	5.1	Y
1,2-Dichloroethene	44/83	140	5.7	Y	21/27	21	7.7	Y	8/27	2	2.3	Y	34/35	28	7.1	Y
2-Butanone	15/83	16	5.1										2/35	24	4.2	Y
2-Hexanone	5/83	5	5.1													
4-Methyl-2-pentanone	9/83	8	5.1						1/27	4	3.3		1/35	86	5.4	
Acetone	44/83	180	5.1	Y					2/27	6	3.6	Y	6/35	23	6.7	Y

Table 3.15 (continued)

Analyte ^b	Groundwater				SS-4 ^a				SS-5 ^a				Bear Creek at BCK 9.47 ^a			
	Freq. of wells w. detects	Max detect	Mean of the medians ^c	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?
Benzene	17/ 83	10	2.5													
Bromodichloromethane	1/ 83	4	2.5													
Bromoform	2/ 83	1	2.5													
Carbon tetrachloride	25/ 83	9	2.6	Y												
Carbon disulfide	6/ 83	2	2.5		1/ 27	2	2.6		1/ 27	1	2.5					
Chlorobenzene	4/ 83	8	2.5													
Chloroethane	5/ 83	8	5.1													
Chloromethane													6/ 35	7	3.9	Y
Chloroform	34/ 83	11	2.5	Y												
Dimethylbenzene	4/ 83	8	2.5													
Ethylbenzene	7/ 83	2	2.5													
Methylene chloride	32/ 83	23	2.5	Y					2/ 27	4	2.7	Y	3/ 35	4	2.4	Y
Phenols	4/ 21	0.006	0.008													
Styrene	3/ 83	1	2.5													
Tetrachloroethene	35/ 83	55	3.1	Y									14/ 35	4	2.1	Y
Toluene	19/ 83	1	2.5										1/ 35	1	2.5	
Trichloroethene	57/ 83	460	21.9	Y	26/ 27	23	8.8	Y	6/ 27	2	2.4	Y	7/ 35	2	2.2	Y
Trans-1,2-Dichloroethene	5/ 16	86	7.8	Y												

Table 3.15 (continued)

Analyte ^b	Groundwater			SS-4 ^a				SS-5 ^a				Bear Creek at BCK 9.47 ^a				
	Freq. of wells w. detects	Max detect	Mean of the medians ^c	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?
Vinyl acetate	15/ 83	10	5.1													
Vinyl Chloride	4/ 83	35	5.3													
<i>Radioactivity (pCi/L)</i>																
Alpha activity	43/ 73	108	4.69	Y	27/ 27	130	52.94	Y	22/ 27	75.8	29.35	Y	32/ 32	138	54.64	Y
Americium-241	. / 8		0.03													
Beta activity	53/ 73	197	16.7	Y	26/ 26	143	82.29	Y	24/ 26	81.75	37.83	Y	34/ 34	119.8	59.62	Y
Cesium-137	3/ 7	8.8	4.3													
Neptunium-237	. / 8		0.05													
Plutonium-238	. / 8		0.03													
Plutonium-239/240	. / 8		0.01													
Radium-228	2/ 7	7.8	1.46													
Technetium-99	3/ 8	39	9.38		2/ 3	220	136.6	Y					1/ 7	110	43.86	Y
Thorium-228	2/ 8	0.92	0.24										1/ 3	0.13	0.05	Y
Thorium-230	6/ 8	0.65	0.35		1/ 3	0.11	0.6	Y	1/ 3	0.21	0.14	Y	1/ 3	0.2	0.1	Y
Thorium-232	. / 5		0.02													
Total radioactive strontium	. / 8		0.69													
Tritium	. / 8		14.8													
Uranium-233/234																

Table 3.15 (continued)

Analyte ^b	Groundwater			SS-4 ^a				SS-5 ^a				Bear Creek at BCK 9.47 ^a			
	Freq. of wells w. detects	Max detect	Mean of the medians ^c	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?
Uranium-234	5/ 8	22	4.06	13/ 13	37.3	27.26	Y	13/ 13	26.6	13.97	Y	21/ 21	29.2	18.74	Y
Uranium-235	1/ 7	0.89	0.16	10/ 13	3.62	1.57	Y	3/ 13	2.98	0.84	Y	6/ 21	1.69	0.9	Y
Uranium-238	4/ 8	42	7.24	13/ 13	82.6	57.59	Y	13/ 13	58.4	26.71	Y	21/ 21	64.5	40.29	Y

^a Groundwater data are the results for the SS-4, SS-5, and BC at BCK 9.47. These data are presented in Table D.112, D.114, and D.106 in Appendix D.

^b Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^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.

Table 3.16. Results of chemical analysis of surface water at SS-6, SS-8, and Lower Bear Creek

Analyte ^b	Bear Creek below BCK 4.55				SS-6 ^a				SS-8 ^a			
	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?
<i>Inorganics (mg/L)</i>												
Aluminum	79/ 84	4.21	0.57		17/ 23	3.77	0.257		23/ 25	1.87	0.31	
Antimony	1/ 1	0.057	0.057		1/ 12	0.002	0.001		1/ 13	0.0015	0.0009	
Arsenic	2/ 2	0.06	0.055						1/ 13	0.0019	0.0011	
Barium	84/ 84	0.091	0.061		23/ 23	0.083	0.049		25/ 25	0.0604	0.0428	
Beryllium	3/ 84	0.0072	0.0003									
Boron	84/ 84	0.31	0.07	Y	10/ 11	0.02	0.012		11/ 12	0.036	0.018	
Calcium	84/ 84	71	41.39		23/ 23	53.5	32.78		25/ 25	43.8	33.42	
Chromium	2/ 24	0.014	0.006									
Cobalt	8/ 84	0.008	0.002		1/ 23	0.004	0.002					
Copper	5/ 84	0.014	0.003		2/ 23	0.049	0.004		1/ 25	0.0094	0.0020	
Gallium	1/ 56	0.02	0.01									
Iron	78/ 84	5.85	0.76		21/ 23	4.27	0.359		24/ 25	2.76	0.43	
Lead	4/ 24	0.011	0.003									
Lithium	8/ 56	0.03	0.01		6/ 6	0.006	0.004		3/ 7	0.0019	0.0011	
Magnesium	84/ 84	18.9	11.49		23/ 23	19.3	14.8		25/ 25	16	11.88	
Manganese	84/ 84	0.447	0.062		23/ 23	0.352	0.043		25/ 25	0.12	0.02	
Mercury	1/ 78	0.0003	0.0001									
Nickel	4/ 84	0.011	0.005		1/ 23	0.004	0.004		1/ 25	0.017	0.004	
Potassium	84/ 84	3.5	1.8		19/ 23	1.3	0.78		25/ 25	1.4	0.98	
Selenium												

Table 3.16 (continued)

Analyte ^b	Bear Creek below BCK 4.55				SS-6 ^a				SS-8 ^a			
	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?
Silicon	6/ 6	3.7	2.8		3/ 3	3.4	3.3		3/ 3	3.7	3.57	
Silver	1/ 84	0.006	0.003		1/ 23	0.007	0.003		1/ 25	0.0079	0.0026	
Sodium	84/ 84	11.9	4.7		23/ 23	3.27	1.35		25/ 25	3.8	1.90	
Strontium	84/ 84	0.149	0.078	Y	11/ 11	0.028	0.021		12/ 12	0.052	0.032	
Thallium	1/ 56	0.03	0.2									
Titanium	16/ 56	0.05	0.02	Y								
Vanadium	9/ 84	0.008	0.003		2/ 23	0.009	0.002		2/ 25	0.0046	0.0020	
Zinc	36/ 84	0.04	0.008		12/ 23	0.078	0.019		9/ 25	0.033	0.007	
Total Uranium (Fluorometric)	27/ 28	0.067	0.0302	Y					1/ 12	0.001	0.001	
<i>Common Anions (mg/L)</i>												
Chloride	82/ 83	15	7.3	Y	15/ 22	5.8	2.6	Y	24/ 24	6	2.8	
Fluoride	73/ 84	0.66	0.13	Y	2/ 23	0.11	0.05	Y	1/ 25	0.1	0.05	
Nitrate	206/ 206	500	9.7	Y	11/ 22	2.6	0.45	Y	20/ 24	1.2	0.29	
Sulfate	48/ 84	26	10.23		22/ 23	14.5	8.4		12/ 25	11	3.68	
<i>Organics (µg/L)</i>												
2-Hexanone					1/ 23	3	4					
Acetone	1/ 28	1	4.4						1/ 24	7	3.6	
Methylene chloride					2/ 23	4	2					
<i>Radioactivity (pCi/L)</i>												
Alpha Activity	21/ 28	27.3	13.71	Y								
Beta Activity	25/ 28	37.56	19.66	Y								

Table 3.16 (continued)

Analyte ^b	Bear Creek below BCK 4.55				SS-6 ^a				SS-8 ^a			
	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?	Freq. of detect	Max detect	Avg. ^c result	SRC?
Uranium-233/234					6/ 12	1.34	0.96	Y				
Uranium-238					8/ 12	2.07	1.21	Y				

^a Groundwater data are the results for the Bear Creek below BCK 4.55, SS-6, and SS-8. These data are presented in Table D.108, D.116, and D.119 in Appendix D.

^b Analytes detected at least once are summarized. Results reflect data validation and data usability screens.

^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.

Table 3.17. Results of chemical analysis of floodplain soils and sediments in BCV

Analyte ^a	Bkgd criteria ^b	Freq of detect	Soils				Freq of detect	Sediments			SRC Y/N
			Detects > bkgd	Max detect	Avg. ^c result	SRC Y/N		Detects > bkgd	Max detect	Avg. ^c result	
Inorganics (mg/kg)											
Aluminum	46700	37/ 37	0/ 37	27800	7890	No	18/ 18	6/ 18	20900	10400	Yes
Antimony							2/ 17	1/ 17	4.6	0.587	Yes
Arsenic	20.2	37/ 37	0/ 37	15.8	4.19	No	16/ 18	10/ 18	17.5	8.7	Yes
Barium	212	37/ 37	0/ 37	148	87.5	No	18/ 18	6/ 18	571	194	Yes
Beryllium	2.12	35/ 37	3/ 37	3	0.813	Yes	15/ 18	9/ 18	3.4	1.16	Yes
Cadmium	0.31	20/ 37	15/ 37	11.1	1.72	Yes	8/ 18	8/ 18	21.7	4.13	Yes
Calcium	1860	37/ 37	14/ 37	9590	1900	No	18/ 18	14/ 18	25600	6410	No
Chromium	80.1	37/ 37	0/ 37	27.1	14.6	No	18/ 18	9/ 18	1040	85.9	Yes
Cobalt	40.1	37/ 37	0/ 37	20.2	11.6	No	18/ 18	7/ 18	60.1	23.1	Yes
Copper	35.5	37/ 37	1/ 37	42.7	10.5	No	18/ 18	10/ 18	241	27	Yes
Cyanide	0.63	1/ 37	1/ 37	1.1	0.357	No					
Iron	52000	37/ 37	0/ 37	24500	13200	No	18/ 18	4/ 18	61400	29500	No
Lead	49.6	37/ 37	1/ 37	52.3	18.5	No	18/ 18	12/ 18	107	31.4	Yes
Lithium	33	27/ 37	4/ 37	55.2	12.7	Yes	17/ 18	7/ 18	69	19.5	Yes
Magnesium	6630	37/ 37	0/ 37	2150	896	No	18/ 18	5/ 18	8260	2090	No
Manganese	2220	37/ 37	0/ 37	2040	953	No	17/ 18	8/ 18	9280	2260	Yes
Mercury	0.34	24/ 25	17/ 25	7.3	1.02	Yes	14/ 14	2/ 14	6.9	0.923	Yes

Table 3.17 (continued)

Analyte ^a	Bkgd criteria ^b	Freq of detect	Soils			SRC Y/N	Freq of detect	Sediments			SRC Y/N
			Detects > bkgd	Max detect	Avg. ^c result			Detects > bkgd	Max detect	Avg. ^c result	
Nickel	56.7	37/ 37	2/ 37	62.8	16	Yes	18/ 18	12/ 18	160	39.9	Yes
Potassium	5560	37/ 37	0/ 37	2000	840	No	18/ 18	1/ 18	2070	1170	No
Selenium	1.2	32/ 37	29/ 37	3.2	1.63	Yes	14/ 18	3/ 18	6.7	3.08	Yes
Silver	2.8	7/ 37	0/ 37	0.4	0.104	No	7/ 18	4/ 18	2.8	0.287	Yes
Sodium	.	29/ 37		286	161	No	1/ 18		479	204	No
Thallium	0.79	1/ 37	1/ 37	1.9	0.632	No					
Vanadium	60.1	37/ 37	0/ 37	32.8	17.1	No	18/ 18	11/ 18	249	43.5	Yes
Zinc	108	37/ 37	0/ 37	103	37.2	No	18/ 18	13/ 18	408	87.4	Yes
2,4,5-T	.	17/ 37		14	11.8	Yes	6/ 18		50	20.7	Yes
2,4-D	.	15/ 37		120	65.5	Yes	1/ 18		82	87.9	Yes
Silvex	.	12/ 37		15	14.9	Yes					
4,4'-DDD	.	4/ 36		0.83	2.05	Yes	5/ 17		1.4	2.18	Yes
4,4'-DDE	.	14/ 36		7	1.96	Yes	12/ 17		6.2	1.62	Yes
4,4'-DDT	.	7/ 36		1.6	1.89	Yes	6/ 17		2.8	2.08	Yes
Aldrin	.	1/ 36		0.22	1.11	No	3/ 16		0.21	1.14	Yes
Dieldrin	.	20/ 36		13	2.11	Yes	2/ 17		12	3.29	Yes
Endosulfan I	.	3/ 36		0.76	1.09	Yes	3/ 16		0.75	1.2	Yes

Table 3.17 (continued)

Analyte ^a	Bkgd criteria ^b	Freq of detect	Soils				Freq of detect	Sediments			
			Detects > bkgd	Max detect	Avg. ^c result	SRC Y/N		Detects > bkgd	Max detect	Avg. ^c result	SRC Y/N
Endosulfan II	.	3/ 36		3	2.16	Yes	2/ 16		20	3.66	Yes
Endosulfan sulfate	.	5/ 36		1.7	2.02	Yes	7/ 16		4.2	2.38	Yes
Endrin	.	2/ 36		0.41	2.12	Yes	4/ 16		0.9	2.12	Yes
Endrin aldehyde	.	21/ 36		38	4.95	Yes	13/ 17		15	3.73	Yes
Endrin ketone	.	1/ 36		0.1	2.16	No	1/ 16		0.51	2.61	Yes
Heptachlor							1/ 16		0.38	1.32	Yes
Heptachlor epoxide	.	2/ 36		1.6	1.13	Yes	5/ 16		1.1	1.15	Yes
Methoxychlor	.	11/ 36		7.4	8.53	Yes	7/ 16		2.4	8.25	Yes
PCB-1254	.	6/ 36		780	68.2	Yes	4/ 16		1200	159	Yes
PCB-1260	.	27/ 36		1700	248	Yes	12/ 18		2500	240	Yes
alpha-BHC	.	4/ 36		0.1	1.02	Yes	3/ 16		0.29	1.15	Yes
alpha-Chlordane	.	20/ 36		6.9	1.41	Yes	6/ 16		0.58	0.937	Yes
beta-BHC	.	2/ 36		0.98	1.12	Yes	1/ 16		0.29	1.3	Yes
delta-BHC	.	5/ 36		0.41	1.01	Yes	1/ 16		3.5	1.51	Yes
gamma-BHC	.	2/ 36		0.071	1.08	Yes	1/ 16		0.3	1.33	Yes
gamma-Chlordane	.	10/ 36		2.1	0.993	Yes	9/ 16		2.4	0.903	Yes
Benzo(a)anthracene	.	5/ 37		150	202	Yes	8/ 18		5800	506	Yes
Benzo(a)pyrene	.	4/ 37		100	202	Yes	7/ 18		4800	462	Yes

Table 3.17 (continued)

Analyte ^a	Bkgd criteria ^b	Freq of detect	Soils				Freq of detect	Sediments			
			Detects > bkgd	Max detect	Avg. ^c result	SRC Y/N		Detects > bkgd	Max detect	Avg. ^c result	SRC Y/N
Benzo(b)fluoranthene	.	7/ 37		190	200	Yes	9/ 18		9100	695	Yes
Benzo(k)fluoranthene	.	7/ 37		160	196	Yes	9/ 18		8300	653	Yes
Bis(2-ethylhexyl)phthalate	.	20/ 37		420	154	Yes	7/ 18		920	241	Yes
Chrysene	.	6/ 37		150	199	Yes	7/ 18		5800	516	Yes
Di-n-butylphthalate	.	14/ 37		260	179	Yes	12/ 18		150	163	Yes
Diethylphthalate	.	2/ 37		260	217	Yes					
Fluoranthene	.	11/ 37		180	182	Yes	9/ 18		12000	861	Yes
Indeno(1,2,3-cd)pyrene	.	1/ 37		55	216	No	4/ 18		1600	312	Yes
Phenanthrene	.	5/ 37		86	198	Yes	6/ 18		6900	584	Yes
Pyrene	.	9/ 37		190	188	Yes	9/ 18		8600	669	Yes
Chloroform	.	1/ 37		60	4.89	No					
4-Methylphenol							1/ 18		260	270	Yes
Acenaphthene							1/ 18		190	268	Yes
Anthracene							1/ 18		1100	318	Yes
Benzo(ghi)perylene							4/ 18		960	278	Yes
Carbazole							1/ 18		520	286	Yes
Dibenzo(a,h)anthracene							1/ 18		350	276	Yes
Dibenzofuran							1/ 18		200	268	Yes

Table 3.17 (continued)

Analyte ^a	Bkgd criteria ^b	Freq of detect	Soils				SRC Y/N	Sediments				SRC Y/N
			Detects > bkgd	Max detect	Avg. ^c result			Detects > bkgd	Max detect	Avg. ^c result		
Fluorene								1/ 18	290	273		Yes
Naphthalene								1/ 18	88	262		Yes
1,2-Dichloroethene								1/ 18	3	4.03		Yes
Acetone								1/ 17	20	6.12		Yes
Americium-241	0.058	13/ 36	9/ 36	0.16	0.0386	Yes	4/ 18	2/ 18	0.07	0.0367		Yes
Cesium-137	1.4	27/ 37	0/ 37	1.33	0.347	No	13/ 18	0/ 18	0.18	0.112		No
Curium-243	0.075	5/ 36	2/ 36	0.19	0.0556	Yes						
Curium-244	3.5	7/ 36	0/ 36	0.21	0.0439	No	1/ 18	1/ 18	0.3	0.03		Yes
Plutonium-238	0.12	1/ 37	0/ 37	0.03	0.00784	No						
Plutonium-239/240	0.065	7/ 37	0/ 37	0.04	0.0105	No						
Technetium-99	4.07	12/ 37	7/ 37	11.98	2.21	Yes	3/ 18	3/ 18	8.74	1.98		Yes
Thorium-228	2.88	37/ 37	0/ 37	1.92	1.05	No	18/ 18	1/ 18	2.17	1.14		Yes
Thorium-230	2.3	37/ 37	0/ 37	1.72	0.937	No	18/ 18	4/ 18	1.3	0.787		Yes
Thorium-232	2.75	37/ 37	0/ 37	1.91	0.911	No	18/ 18	2/ 18	1.65	0.867		Yes

Table 3.17 (continued)

Analyte ^a	Bkgd criteria ^b	Freq of detect	Soils				Freq of detect	Sediments			
			Detects > bkgd	Max detect	Avg. ^c result	SRC Y/N		Detects > bkgd	Max detect	Avg. ^c result	SRC Y/N
Uranium-234	3.2	37/ 37	21/ 37	44.13	9.69	Yes	18/ 18	10/ 18	25.36	7.04	Yes
Uranium-235	0.24	35/ 37	19/ 37	2.66	0.614	Yes	16/ 18	13/ 18	1.24	0.339	Yes
Uranium-238	2.6	37/ 37	22/ 37	94.35	18.8	Yes	18/ 18	18/ 18	36.53	10.8	Yes

^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.

Table 3.18. Comparison of model predicted future concentrations with analytical measurements for surface water concentrations at BCK 9.47

Constituents	Overall Predicted Range	Predicted Range excluding contribution from NT-8	Observed Range	Groundwater RGOs ^d
<i>Inorganics^a</i>				
Antimony	0.004 to 0.009	0.004 to 0.009	0.002 to 0.003	0.006 M
Beryllium	0.004 to 0.020	0.002 to 0.014	0.002 to 0.002	0.005 M
Cadmium	0.002 to 0.006	0.002 to 0.005		0.005 M
Cyanide	0.247 to 2.01	0.180 to 1.80		0.2 M
Lithium	0.29 to 0.64	0.002 to 0.02	0.028 to 0.091	0.073 R
Manganese	0.42 to 1.12	0.23 to 0.73	0.025 to 0.708	0.05 M ²
Thallium	0.002 to 0.004	0.000 to 0.000		0.002 M
Total Uranium	0.16 to 0.31	0.12 to 0.25	0.005 to 0.152	0.02 M
<i>Common Anions^a</i>				
Nitrate	62.17 to 113.2	62.17 to 113.2	0 to 46.2	10 M
<i>Organics^b</i>				
1,1-Dichloroethene	1.1 to 14.9	0.01 to 1.6		7 M
1,2-Dichloroethane	25.0 to 55.4	0.06 to 0.4	12 to 20	5 M
Benzene	66.59 to 222.8	0.16 to 1.4		5 M
Carbon tetrachloride	0.04 to 6.89	0.00 to 6.60		5 M
Methylene chloride	0.98 to 10.91	0.03 to 2.10	3 to 4	5 M
Tetrachloroethene	28.6 to 125	18.7 to 98	0.5 to 4	5 M
Trans-1,2-Dichloroethene	162 to 386	39.8 to 119		100 M
Trichloroethene	9.3 to 42.3	7.0 to 36.7	0.6 to 2	5 M
Vinyl chloride	28.08 to 65.98	2.70 to 8.50		2 M
<i>Radioactivity^c</i>				
⁴⁰ K	1.54 to 2.41	0.59 to 1.01		3.8 R
⁹⁹ Tc	171.7 to 293.0	111.6 to 223.1	110 to 110	34 R

^a Concentrations of inorganics and common anions are reported as mg/l.

^b Concentrations of organics are reported as µg/l.

^c Concentrations of radioactivity are reported as pCi/l.

^d M = MCL, M² = Secondary MCL, R = Risk-based

Table 3.19. Integration point assessment results

Subwatershed	Major sources	Cancer effects		Toxic effects	
		Relative risk (percent)	Contaminants contributing the majority to risk at BCK 9.47	Relative toxicity (percent)	Contaminants contributing the most to toxic effects BCK 9.47
BCK 12.38/ NT-1/SS-1	S-3, S-3 plumes	17.4	uranium	26.5	uranium, nitrate
NT-2	S-3 plumes	<0.1	-	1.7	nitrate
NT-3	BYBY	38.5	uranium	27.7	uranium
NT-4	-	<0.1	-	0.2	-
NT-5	-	0.45	-	1.7	-
NT-6	-	0.92	-	0.6	-
NT-7	BG	9.1	uranium, PCE, TCE	5.1	uranium, vanadium
NT-8	BG	13.0	uranium, PCE, TCE	7.1	uranium
Ungaged	S-3 and BYBY subsurface plumes, ungaged runoff from BYBY	20.7	uranium	29.4	uranium, vanadium
BCK 9.47		100		100	uranium, vanadium, nitrate

**Table 4.1. ARARs/To-Be-Considered (TBC) Guidance for Contaminants
Occuring Above Background in Groundwater in Bear Creek Valley**

Contaminant	ARAR		TBC Guidance	
	Tennessee Standards ($\mu\text{g/L}$)		Federal Standards ($\mu\text{g/L}$)	
	MCL ^a	SMCL ^b	Proposed MCL ^c	Proposed SMCL ^d
Aluminum		200		
Antimony	6			
Arsenic	50			
Barium	2,000			
Beryllium	4			
Boron				
Cadmium	5			
Chloride		250,000		
Chromium	100			
Cobalt				
Copper	TT ^e	1,000		
Cyanide	200			
Fluoride	4,000	2,000		
Iron		300		
Lead	TT ^e			
Lithium				
Manganese		50		
Mercury	2			
Molybdenum				
Nickel	100 ^a			
Nitrate (as N)	10,000			
Nitrite (as N)	1,000			
Nitrate + Nitrite (as N)	10,000			
Selenium	50			
Silver		100		
Strontium (as a metal)				

Table 4.1. (continued)

Contaminant	ARAR		TBC Guidance	
	Tennessee Standards ($\mu\text{g/L}$)		Federal Standards ($\mu\text{g/L}$)	
	MCL ^a	SMCL ^b	Proposed MCL ^c	Proposed SMCL ^d
Sulfate		250,000	500,000	
Thallium	2			
Total Uranium			20 ^f	
Vanadium				
Zinc		5,000		
1,1,2,2-Tetrachloroethane				
1,1,1-Trichloroethane	200			
1,1,2-Trichloroethane	5			
1,1-Dichloroethane				
1,1-Dichloroethene	7			
1,2-Dichloroethane	5			
<i>cis</i> -1,2-Dichloroethene	70			
<i>trans</i> -1,2-Dichloroethene	100			
1,2-Dichloropropane	5			
1,4-Dichlorobenzene				
1,4-Dioxane				
2,4-Dimethylphenol				
2,4-Dinitrophenol				
2,4-Dinitrotoluene				

Table 4.1. (continued)

Contaminant	ARAR		TBC Guidance	
	Tennessee Standards ($\mu\text{g/L}$)		Federal Standards ($\mu\text{g/L}$)	
	MCL ^a	SMCL ^b	Proposed MCL ^c	Proposed SMCL ^d
2,6-Dinitrotoluene				
2-Butanone				
4-Methyl-2-pentanone				
Acetone				
Benzene	5			
Benzidine				
bis(2-Ethylhexyl)phthalate	6			
Bromodichloromethane	100 ^g		80 ^g	
Bromoform	100 ^g		80 ^g	
Carbon tetrachloride	5			
[mono]Chlorobenzene	100			
Chloroform	100 ^g		80 ^g	
Chloromethane				
Dibromochloromethane	100 ^g		80 ^g	
Ethylbenzene	700			30
Methylene chloride	5			
di-N-Octyl phthalate				
Pentachlorophenol	1			30
Phenol				
PCB-1254	(see PCBs)			
Polychlorinated biphenyls (PCBs) (total)	0.5			

Table 4.1. (continued)

Contaminant	ARAR		TBC Guidance	
	Tennessee Standards ($\mu\text{g/L}$)		Federal Standards ($\mu\text{g/L}$)	
	MCL ^a	SMCL ^b	Proposed MCL ^c	Proposed SMCL ^d
Tetrachloroethene	5			
Toluene	1,000			40
Trichloroethene	5			
Trichlorofluoromethane				
Trihalomethanes (total)	100 ^g		80 ^g	
Vinyl chloride	2			
Xylenes, total	10,000			20
Alpha activity (gross)	15 pCi/L ^h		15 pCi/L ^h	
Americium-241			6.34 pCi/L ^j	
Beta activity (gross)	4 mrem/yr ^k		4 mrem/yr ^k	
Cesium-137			119 pCi/L ⁱ	
Lead-212			123 pCi/L ⁱ	
Neptunium-237			7.06 pCi/L ^j	
Potassium-40				
Radium	5 pCi/L ^l		20 pCi/L ^l	
Strontium-90	8 pCi/L ⁱ		42.0 pCi/L ⁱ	
Technetium-99			3,790 pCi/L ⁱ	
Thorium-228			125 pCi/L ^j	
Thorium-230			79.2 pCi/L ^j	
Thorium-232			88.0 pCi/L ^j	

Table 4.1. (continued)

Contaminant	ARAR		TBC Guidance	
	Tennessee Standards ($\mu\text{g/L}$)		Federal Standards ($\mu\text{g/L}$)	
	MCL ^a	SMCL ^b	Proposed MCL ^c	Proposed SMCL ^d
Tritium	20,000 pCi/L ⁱ		60,900 pCi/L ⁱ	
Uranium-234			13.9 pCi/L ^j	
Uranium-235			14.5 pCi/L ^j	
Uranium-238			14.6 pCi/L ^j	

^aRules of the Tennessee Department of Environment and Conservation (TDEC), Chapter 1200-5-1 (January, 1994). Tennessee's maximum contaminant levels (MCLs) are identical to the federal MCLs, with the exception of the MCL for nickel. Tennessee retains a nickel MCL of 100 $\mu\text{g/L}$ in its currently effective drinking water regulations. The Environmental Protection Agency (EPA) has deleted from the Code of Federal Regulations the MCL for nickel, which was vacated by a court ruling, effective February 23, 1995 (60 FR 33926, June 29, 1995).

^bRules of the TDEC, Chap. 1200-5-1-.12 (January, 1994). Tennessee state secondary maximum contaminant levels (SMCLs) are legally enforceable and are, therefore, applicable or relevant and appropriate requirements (ARARs) rather than "to-be-considered" (TBC) guidance for CERCLA response actions in the absence of an MCL for a particular contaminant.

^cProposed National Primary Drinking Water Standard (59 FR 65578, December 20, 1994; 50 FR 33050, July 18, 1991); these TBC guidance levels do not become ARAR until promulgated.

^dProposed National Secondary Drinking Water Standards (54 FR 22062, May 22, 1989). The EPA has deferred setting final standards for these chemicals pending further study (56 FR 3526, January 30, 1991).

^eTT = Treatment technique; when an "action level" of 15 $\mu\text{g/L}$ for lead or 1300 $\mu\text{g/L}$ for copper, measured in the 90th percentile at the consumer's tap, is exceeded, corrosion control studies and treatment requirements are mandated. However, an OSWER memorandum (June 21, 1990) recommends that a final cleanup level of 15 $\mu\text{g/L}$ for lead in groundwater usable for drinking water is protective of sensitive subpopulations; this is TBC guidance, not an ARAR.

^fThis MCL is expressed in terms of natural uranium. 20 $\mu\text{g/L}$ is approximately equal to 30 pCi/L [Proposed rule, July 18, 1991 (56 FR 33050); final rule on hold until September, 1996].

^gThe MCL for total trihalomethanes is 100 $\mu\text{g/L}$; the proposed MCL for total trihalomethanes is 80 $\mu\text{g/L}$ (59 FR 38668, July 29, 1994). Total trihalomethanes are the sum of the concentrations of bromodichloromethane, dibromochloromethane, bromoform, and chloroform.

^hThe present MCL includes ²²⁶Ra and excludes radon and uranium (Rules of the TDEC, Chap. 1200-5-1-.06(5), January, 1994); the proposed MCL excludes all three radionuclides (56 FR 33050, July 18, 1991; final action on hold).

ⁱThese values are not MCLs in and of themselves but, rather, concentrations that result in the effective dose equivalent (ede) of the MCL for gross beta emissions, 4 mrem/year.

^jThese values are not MCLs in and of themselves but, rather, concentrations that represent a 10⁻⁴ lifetime incidence risk in drinking water (assuming ingestion of 2 liters daily), which is the level EPA's MCLs are based on.

^kThe average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than four (4) millirem/year (Rules of the TDEC, Chap. 1200-5-1-.06(5), January, 1994); proposed federal rule, July 18, 1991 (56 FR 33050).

^lThe present MCL applies to combined radium-226 and radium-228; the proposed federal MCL applies to each separately (56 FR 33050, July 18, 1994).

(Note: All contaminants occurring above background in groundwater are listed on this table; as can be seen on the table, however, not all contaminants have ARARs/TBC criteria available for them.)

**Table 4.2. ARARs for contaminants occurring above background
In surface water in Bear Creek Valley**

Contaminant	<u>Recreation</u> <u>Water Quality Criteria</u> ^{a,b} ($\mu\text{g/L}$)	<u>Fish & Aquatic Life</u> <u>Water Quality Criteria</u> ^c ($\mu\text{g/L}$)	
	For Organisms Only	Maximum ^d	Continuous ^e
Aluminum			
Antimony	4,300		
Arsenic (c) ^f	1.4	360 ^g	190 ^g
Barium			
Beryllium			
Boron			
Cadmium, dissolved		3.9 ^h	1.1 ^h
Calcium			
Chromium, total			100
Chromium, VI		16	11
Copper, dissolved		17.7 ^h	11.8 ^h
Chloride			
Cyanide	220,000.0	22	5.2
Fluoride			
Lead, dissolved		81.7 ^h	3.2 ^h
Lithium			
Manganese			
Mercury	0.15	2.4	0.012
Nickel, dissolved	4,600	1,418 ^h	158 ^h
Nitrate (as N)			
Selenium		20	5
Silver, dissolved		4.1 ^h	
Strontium, as a metal			
Sulfate			
Thallium	6.3		
Titanium			

Table 4.2 (continued)

Contaminant	<u>Recreation</u> <u>Water Quality Criteria</u> ^{a,b} ($\mu\text{g/L}$)	<u>Fish & Aquatic Life</u> <u>Water Quality Criteria</u> ^c ($\mu\text{g/L}$)	
	For Organisms Only	Maximum ^d	Continuous ^e
Total Uranium			
Vanadium			
Zinc, dissolved		117 ^h	106 ^h
1,1,1-Trichloroethane			
1,1,2-Trichloroethane (c)	420		
1,1-Dichloroethane			
1,1-Dichloroethene (c)	32		
1,2-Dichloroethane (c)	990		
1,2-Dichloroethene			
2-Butanone			
2-Hexanone			
4-Methyl-2-Pentanone			
Acetone			
Benzene (c)	710		
Carbon disulfide			
Chloroethane			
Chloroform (c)	4,700.0		
Chloromethane			
Methylene Chloride (c)	16,000		
Tetrachloroethene (c)	88.5		
Toluene	200,000		
Trichloroethene (c)	810		
Trichlorofluoromethane			
Vinyl Chloride (c)	5,250		
Alpha activity			
Beta activity			

Table 4.2 (continued)

Contaminant	<u>Recreation</u> <u>Water Quality Criteria</u> ^{a,b} ($\mu\text{g/L}$)	<u>Fish & Aquatic Life</u> <u>Water Quality Criteria</u> ^c ($\mu\text{g/L}$)	
	For Organisms Only	Maximum ^d	Continuous ^e
Neptium-237			
Plutonium-238			
Potassium-40			
Radium (total alpha)			
Strontium-90			
Technetium-99			
Thorium-228			
Thorium-230			
Thorium-232			
Uranium-233/234			
Uranium-235			
Uranium-238			

^aTennessee Department of Environment and Conservation (TDEC) Rules, Chap. 1200-4-3-.03(4), effective July 30, 1995. These are TDEC's water quality criteria for streams designated for "recreational" use. They are equivalent to EPA's Human Health water quality criteria (WQC) for consumption of aquatic organisms only. CERCLA §121(d)(2)(a) specifically states that remedial actions shall, at a minimum, attain federal ambient WQC established under the Clean Water Act (CWA) if they are relevant and appropriate. However, any existing state WQC are site-specific promulgated standards that are relevant and appropriate to remedial actions and, therefore, take precedence over corresponding federal ambient WQC.

^bTDEC uses a 10^{-5} risk level for all carcinogenic pollutants.

^cTDEC, Chap. 1200-4-3-.03(3), effective July 30, 1995.

^dThe highest concentration of a pollutant to which aquatic life can be exposed to for a one-hour average time period.

^eThe highest concentration of a pollutant to which aquatic life can be exposed to in a four-day time period.

^fThe letter "c" stands for carcinogen.

^gTrivalent form of arsenic.

^hFish and aquatic life criteria for these metals are expressed as a function of total hardness. Values listed correspond to a total hardness of 100 mg/L.

ARAR = Applicable or relevant and appropriate requirement.

(Note: All contaminants occurring above background in surface water are listed on this table; as can be seen on the table, however, not all contaminants have ARARs criteria available for them.)

Table 5.1 (continued)

Area	Medium	COCs ^a	Frequency of Detect	UCL95 Conc. ^b	Ingestion Risk	Inhalation Risk	Dermal Risk	External Exposure Risk	Ingestion HQ	Inhalation HQ	Dermal HQ
<i>Floodplain (western BCV)</i>											
FP (wBCV)	Soil (creek floodplain)	None									
<i>Disposal Area Remedial Action Solids Unit</i>											
DARA	Soil Inventory	None									
<i>Oil Landfarm Storage Pad</i>											
OLF SP	Soil Inventory	None									
<i>Bear Creek Road Debris Burial</i>											
BCR DB	Soil (hot spot)	None									
<i>Creekside Debris Burial</i>											
CS DB	Soil (hot spot)	None									

^a The COCs presented in this table are associated with data aggregates which best represent each source area/FA, i.e., location-specific COCs are not shown in this table.

^b The units of measure for the 95% UCL concentrations for radionuclides are pCi/g and pCi/L for soil and water, respectively; for chemicals, the units are mg/L and mg/kg for water and soil, respectively.

Table 5.2. BCV industrial worker chemicals of concern

Area	Medium ^a	COCs ^b	Frequency of detect	UCL95 conc. ^c	Ingestion risk	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ	Inhalation HQ	Dermal HQ
<i>S-3 Ponds</i>											
S-3 Ponds	Soil (1-9)	None									
S-3 Ponds	Soil (10)	None									
S-3 Ponds	Waste Inv. (soil)	Beryllium		2.74E+00	2.1E-06		1.3E-05				
S-3 Ponds	Waste Inv. (soil)	PCB-1248		5.67E+00	7.6E-06		5.4E-06				
S-3 Ponds	Waste Inv. (soil)	Cesium-137		4.77E+00				4.6E-05			
S-3 Ponds	Waste Inv. (soil)	Neptunium-237		9.85E+00				2.1E-05			
S-3 Ponds	Waste Inv. (soil)	Plutonium-238		2.53E+01	2.3E-06						
S-3 Ponds	Waste Inv. (soil)	Ruthenium-106		3.33E+01				1.2E-04			
S-3 Ponds	Waste Inv. (soil)	Technetium-99		7.52E+03	3.3E-06						
S-3 Ponds	Waste Inv. (soil)	Thorium-228		2.67E+02	1.9E-05			1.2E-03			
S-3 Ponds	Waste Inv. (soil)	Thorium-230		5.44E+02	6.4E-06						
S-3 Ponds	Waste Inv. (soil)	Uranium-234		1.24E+02	1.7E-06						
S-3 Ponds	Waste Inv. (soil)	Uranium-235		8.06E+00				9.8E-06			
S-3 Ponds	Waste Inv. (soil)	Uranium-238		3.32E+02	6.4E-06			8.0E-05			
<i>Oil Landfarm</i>											
OLF	Soil	Arsenic	8/8	1.13E+01	3.0E-06						
OLF	Soil	Cobalt-60	4/8	1.54E+00				6.9E-05			
OLF	Soil	Lead-212	1/8	2.60E+00				3.6E-06			
OLF	Soil	Thallium-208	1/8	4.60E+00				3.0E-04			
OLF	Soil Inventory	None									
<i>Sanitary Landfill 1</i>											
SLF	Soil	None									
<i>Boneyard/Burnyard</i>											
BYBY	Soil	Antimony	12/12	2.95E+02					3.6E-01		1.1E+00
BYBY	Soil	Arsenic	15/15	2.16E+01	5.7E-06						
BYBY	Soil	Beryllium	14/15	1.70E+00	1.3E-06		8.1E-06				
BYBY	Soil	Benzo(a)anthracene	14/14	6.85E+01	8.7E-06		1.8E-05				

Table 5.2 (continued)

Area	Medium ^a	COCs ^b	Frequency of detect	UCL95 conc. ^c	Ingestion risk	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ	Inhalation HQ	Dermal HQ
BYBY	Soil	Benzo(a)pyrene	14/14	4.60E+01	5.9E-05		1.2E-04				
BYBY	Soil	Benzo(b)fluoranthene	14/14	5.97E+01	7.6E-06		1.6E-05				
BYBY	Soil	Benzo(k)fluoranthene	14/14	3.97E+01			1.0E-06				
BYBY	Soil	Dibenzo(a,h)anthracene	13/14	3.37E+00	4.3E-06		8.8E-06				
BYBY	Soil	Indeno(1,2,3-cd)pyrene	14/14	2.17E+01	2.8E-06		5.6E-06				
BYBY	Soil	Uranium-234	17/17	2.60E+02	3.6E-06						
BYBY	Soil	Uranium-235	15/17	8.62E+00				1.0E-05			
BYBY	Soil	Uranium-238	17/17	5.27E+02	1.0E-05			1.3E-04			
BYBY	Soil (hot spot)	Uranium-235	1/1	7.36E+02	1.1E-05			8.9E-04			
BYBY	Soil (hot spot)	Uranium-238	1/1	4.76E+04	9.2E-04	1.7E-05		1.1E-02			
<i>Burial Grounds</i>											
BG A-16	Soil	Thallium-208	1/2	3.70E+00				2.4E-04			
BG A-16	Waste Inv. (soil)	None									
BG A-17	Soil	Thallium-208	1/2	3.70E+00				2.4E-04			
BG A-17	Waste Inv. (soil)	None									
BG A-18	Soil	Thallium-208	1/2	3.70E+00				2.4E-04			
BG A-18	Waste Inv. (soil)	None									
BG A-North	Soil	None									
BG A-North	Waste Inv. (soil)	Beryllium		3.00E-01			1.4E-06				
BG A-North	Waste Inv. (soil)	Total Uranium		1.10E+04					1.8E+00		1.3E-01
BG A-North	Waste Inv. (soil)	PCBs		1.30E+03	1.7E-03		1.2E-03				
BG A-North	Waste Inv. (soil)	Uranium-234 (calc.)		3.73E+03	5.2E-05	1.5E-06					
BG A-North	Waste Inv. (soil)	Uranium-235 (calc.)		1.70E+02	2.5E-06			2.1E-04			
BG A-North	Waste Inv. (soil)	Uranium-238 (calc.)		3.64E+03	7.0E-05	1.3E-06		8.7E-04			
BG A-South	Soil	None									
BG A-South	Waste Inv. (soil)	Beryllium		1.20E+00			5.7E-06				
BG A-South	Waste Inv. (soil)	Total Uranium		1.50E+04					2.4E+00		1.8E-01
BG A-South	Waste Inv. (soil)	Benzene		1.40E+02		1.5E-05					

Table 5.2 (continued)

Area	Medium ^a	COCs ^b	Frequency of detect	UCL95 conc. ^c	Ingestion risk	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ	Inhalation HQ	Dermal HQ
BG A-South	Waste Inv. (soil)	PCBs		2.10E+01	2.8E-05		2.0E-05				
BG A-South	Waste Inv. (soil)	Tetrachloroethene		8.90E+02	8.1E-06	5.6E-06	5.1E-06				
BG A-South	Waste Inv. (soil)	Trichloroethene		8.50E+01		1.9E-06					
BG A-South	Waste Inv. (soil)	Uranium-234 (calc.)		5.09E+03	7.1E-05	2.1E-06					
BG A-South	Waste Inv. (soil)	Uranium-235 (calc.)		2.31E+02	3.4E-06			2.8E-04			
BG A-South	Waste Inv. (soil)	Uranium-238 (calc.)		4.96E+03	9.6E-05	1.8E-06		1.2E-03			
BG B	Soil	None									
BG B	Waste Inv. (soil)	Total Uranium		3.00E+05					4.9E+01		3.6E+00
BG B	Waste Inv. (soil)	Uranium-234 (calc.)		1.02E+05	1.4E-03	4.2E-05		9.9E-06			
BG B	Waste Inv. (soil)	Uranium-235 (calc.)		4.63E+03	6.8E-05	1.8E-06		5.6E-03			
BG B	Waste Inv. (soil)	Uranium-238 (calc.)		9.92E+04	1.9E-03	3.6E-05		2.3E-02			
BG C-East	Soil	None									
BG C-East	Waste Inv. (soil)	Beryllium		1.10E+03	8.3E-04		5.2E-03		1.1E-01		6.8E-01
BG C-East	Waste Inv. (soil)	Total Uranium		2.10E+04					3.4E+00		2.5E-01
BG C-East	Waste Inv. (soil)	Thorium-232 (calc.)		5.78E+02	5.9E-06						
BG C-East	Waste Inv. (soil)	Uranium-234 (calc.)		7.13E+03	9.9E-05	2.9E-06					
BG C-East	Waste Inv. (soil)	Uranium-235 (calc.)		3.24E+02	4.8E-06			3.9E-04			
BG C-East	Waste Inv. (soil)	Uranium-238 (calc.)		6.94E+03	1.3E-04	2.5E-06		1.7E-03			
BG C-West	Soil	None									
BG C-West	Waste Inv. (soil)	Beryllium		1.10E+03	8.3E-04		5.2E-03		1.1E-01		6.8E-01
BG C-West	Waste Inv. (soil)	Total Uranium		2.20E+04					3.6E+00		2.7E-01
BG C-West	Waste Inv. (soil)	Thorium-232 (calc.)		3.38E+02	3.5E-06						
BG C-West	Waste Inv. (soil)	Uranium-234 (calc.)		7.47E+03	1.0E-04	3.0E-06					
BG C-West	Waste Inv. (soil)	Uranium-235 (calc.)		3.39E+02	5.0E-06			4.1E-04			
BG C-West	Waste Inv. (soil)	Uranium-238 (calc.)		7.27E+03	1.4E-04	2.6E-06		1.7E-03			
BG D-East	Soil	None									
BG D-East	Soil (hot spot)	Beryllium	1/1	5.90E-01			2.8E-06				
BG D-East	Soil (hot spot)	Uranium-234	1/1	1.54E+05	2.1E-03	6.3E-05		1.5E-05			

Table 5.2 (continued)

Area	Medium ^a	COCs ^b	Frequency of detect	UCL95 conc. ^c	Ingestion risk	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ	Inhalation HQ	Dermal HQ
BG D-East	Soil (hot spot)	Uranium-235	1/1	2.56E+03	3.8E-05			3.1E-03			
BG D-East	Soil (hot spot)	Uranium-238	1/1	2.09E+05	4.1E-03	7.6E-05		4.9E-02			
BG D-East	Waste Inv. (soil)	Total Uranium		2.40E+05					3.9E+01		2.9E+00
BG D-East	Waste Inv. (soil)	Uranium-234 (calc.)		8.14E+04	1.1E-03	3.3E-05		8.0E-06			
BG D-East	Waste Inv. (soil)	Uranium-235 (calc.)		3.70E+03	5.4E-05	1.4E-06		4.5E-03			
BG D-East	Waste Inv. (soil)	Uranium-238 (calc.)		7.93E+04	1.5E-03	2.9E-05		1.9E-02			
BG D-South	Soil	None									
BG D-South	Waste Inv. (soil)	Total Uranium		2.40E+05					3.9E+01		2.9E+00
BG D-South	Waste Inv. (soil)	Uranium-234 (calc.)		8.14E+04	1.1E-03	3.3E-05		8.0E-06			
BG D-South	Waste Inv. (soil)	Uranium-235 (calc.)		3.70E+03	5.4E-05	1.4E-06		4.5E-03			
BG D-South	Waste Inv. (soil)	Uranium-238 (calc.)		7.93E+04	1.5E-03	2.9E-05		1.9E-02			
BG D-West,E,J	Waste Inv. (soil)	Total Uranium		2.60E+05					4.2E+01		3.2E+00
BG D-West,E,J	Waste Inv. (soil)	Uranium-234 (calc.)		8.82E+04	1.2E-03	3.6E-05		8.6E-06			
BG D-West,E,J	Waste Inv. (soil)	Uranium-235 (calc.)		4.01E+03	5.9E-05	1.5E-06		4.8E-03			
BG D-West,E,J	Waste Inv. (soil)	Uranium-238 (calc.)		8.60E+04	1.7E-03	3.1E-05		2.0E-02			
BG WIP-North	Soil	None									
BG WIP-North	Waste Inv. (soil)	Beryllium		2.60E+01	2.0E-05		1.2E-04				
BG WIP-North	Waste Inv. (soil)	Total Uranium		7.20E+04					1.2E+01		8.7E-01
BG WIP-North	Waste Inv. (soil)	Benzene		1.30E+02		1.4E-05					
BG WIP-North	Waste Inv. (soil)	Benzidine		3.10E+01	1.2E-03		9.9E-04				
BG WIP-North	Waste Inv. (soil)	PCBs		1.70E+00	2.3E-06		1.6E-06				
BG WIP-North	Waste Inv. (soil)	Uranium-234 (calc.)		2.44E+04	3.4E-04	1.0E-05		2.4E-06			
BG WIP-North	Waste Inv. (soil)	Uranium-235 (calc.)		1.11E+03	1.6E-05			1.3E-03			
BG WIP-North	Waste Inv. (soil)	Uranium-238 (calc.)		2.38E+04	4.6E-04	8.6E-06		5.7E-03			
BG WIP-South	Soil	None									
BG WIP-South	Waste Inv. (soil)	Total Uranium		7.50E+04					1.2E+01		9.1E-01
BG WIP-South	Waste Inv. (soil)	Uranium-234 (calc.)		2.55E+04	3.5E-04	1.0E-05		2.5E-06			
BG WIP-South	Waste Inv. (soil)	Uranium-235 (calc.)		1.16E+03	1.7E-05			1.4E-03			

Table 5.2 (continued)

Area	Medium ^a	COCs ^b	Frequency of detect	UCL95 conc. ^c	Ingestion risk	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ	Inhalation HQ	Dermal HQ
BG WIP-South	Waste Inv. (soil)	Uranium-238 (calc.)		2.48E+04	4.8E-04	9.0E-06		5.9E-03			
<i>Floodplain (western BCV)</i>											
FP (wBCV)	Soil (creek floodplain)	None									
<i>Disposal Area Remedial Action Solids Storage Unit</i>											
DARA	Soil Inventory	HxCDD ^d	22/32	2.65E-03	2.9E-06		3.6E-06				
DARA	Soil Inventory	PCB-1254	32/32	1.03E+02					2.5E+00		1.8E+00
DARA	Soil Inventory	2,3,7,8-TCDD ^d	2/32	2.40E-03	6.3E-05		8.0E-05				
DARA	Soil Inventory	Uranium-234	32/32	1.14E+02	1.6E-06						
DARA	Soil Inventory	Uranium-235	32/32	4.91E+00				5.9E-06			
DARA	Soil Inventory	Uranium-238	32/32	7.69E+01	1.5E-06			1.8E-05			
<i>Oil Landfarm Storage Pad</i>											
OLF SP	Soil Inventory	Beryllium	40/40	5.82E+00	4.4E-06		2.8E-05				
OLF SP	Soil Inventory	PCBs	40/40	2.65E+01	3.6E-05		2.5E-05				
OLF SP	Soil Inventory	Uranium-235	40/40	1.53E+00				1.9E-06			
OLF SP	Soil Inventory	Uranium-238	40/40	2.40E+01				5.7E-06			
<i>Bear Creek Road Debris Burial</i>											
BCR DB	Soil (hot spot)	None									
<i>Creekside Debris Burial</i>											
CS DB	Soil (hot spot)	None									

^a Waste Inv. (soil) = Waste Inventory (soil)

^b The COCs presented in this table are associated with data aggregates which best represent each source area/FA, i.e., location-specific COCs are not shown in this table.

^c The units of measure for the UCL95 concentrations for radionuclides are pCi/g and pCi/L for soil and water, respectively; for chemicals, the units are mg/L and mg/kg for water and soil, respectively.

^d For the DARA soils inventory, hexachlorodibenzo-p-dioxins were evaluated as HxCDD, and tetrachlorodibenzo-p-dioxins were evaluated as 2,3,7,8-TCDD.

Table 5.3. BCV recreational chemicals of concern

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
<i>Floodplain (western BCV)</i>												
FP (wBCV)	Fish	Mercury	35/35	1.30E+00						1.3E+00		
FP (wBCV)	Fish	PCB-1254	35/35	7.70E-01						3.9E+00		
FP (wBCV)	Fish	PCB-1260	35/35	8.90E-01	3.0E-04							
FP (wBCV)	Sediment	None										
FP (wBCV)	Soil (creek floodplain)	None										
FP (wBCV)	Surface Water	None										

^a The COCs presented in this table are associated with data aggregates which best represent each source area/FA, i.e., location-specific COCs are not shown in this table.

^b The units of measure for the UCL95 concentrations for radionuclides are pCi/g and pCi/L for soil and water, respectively; for chemicals, the units are mg/L and mg/kg for water and soil, respectively.

^c Recreational receptors include: adult/child combination (i.e., age-adjusted intake factor) for incidental ingestion of soil and sediment (for carcinogens/risk), adult and child considered separately (for noncarcinogens/HQ), and adult only for all other exposure media and pathways (Energy Systems 1996b; EPA 1991a).

Table 5.4. BCV residential chemicals of concern

Area	Medium	COCs ^a	Frequency of detect	UCL ₉₅ conc. ^b	External exposure							
					Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
S-3 Ponds												
S-3 Ponds	Groundwater	Barium	104/104	1.56E+02						6.1E+01		2.1E+00
S-3 Ponds	Groundwater	Beryllium	18/66	1.92E-02	9.7E-04		2.4E-04			1.1E-01		
S-3 Ponds	Groundwater	Boron	87/91	3.63E-01						1.1E-01		
S-3 Ponds	Groundwater	Cadmium	93/154	2.69E-01						1.5E+01		3.6E+00
S-3 Ponds	Groundwater	Chromium	23/157	2.40E-02						1.3E-01		
S-3 Ponds	Groundwater	Fluoride	84/152	2.99E+00						1.4E+00		
S-3 Ponds	Groundwater	Manganese	93/95	1.01E+01						2.0E+00		1.2E-01
S-3 Ponds	Groundwater	Mercury	47/167	5.20E-03						4.7E-01		
S-3 Ponds	Groundwater	Nickel	28/74	3.29E+00						4.5E+00		
S-3 Ponds	Groundwater	Nitrate (as N)	155/155	2.11E+03						3.6E+01		1.8E-01
S-3 Ponds	Groundwater	Nitrite (as N)	1/9	6.70E+00						1.8E+00		
S-3 Ponds	Groundwater	Strontium	80/80	8.80E+01						4.0E+00		
S-3 Ponds	Groundwater	Total Uranium	129/163	2.56E+00						2.3E+01		
S-3 Ponds	Groundwater	1,1-Dichloroethene	12/195	2.63E-03	1.9E-05	1.9E-04						
S-3 Ponds	Groundwater	2,4-Dinitrophenol	2/11	3.20E-02						4.4E-01		
S-3 Ponds	Groundwater	Benzene	10/195	2.61E-03		4.4E-06						
S-3 Ponds	Groundwater	Bis(2-ethylhexyl)phthalate	6/11	1.83E-02	3.0E-06							
S-3 Ponds	Groundwater	Chloroform	87/199	6.20E-03		2.9E-05						2.8E-01
S-3 Ponds	Groundwater	Di-N-Octylphthalate	2/11	2.79E-03								
S-3 Ponds	Groundwater	Methylene Chloride	82/203	2.42E-02	2.1E-06	2.3E-06						
S-3 Ponds	Groundwater	Tetrachloroethene	108/203	4.21E-01	2.6E-04	4.9E-05	2.3E-04			1.2E+00		1.0E+00
S-3 Ponds	Groundwater	Trichloroethene	51/196	5.28E-03		1.9E-06						
S-3 Ponds	Groundwater	Vinyl Chloride	10/195	5.04E-03	1.1E-04	8.9E-05	2.0E-06					
S-3 Ponds	Groundwater	Americium-241	5/8	3.14E+01	2.2E-04							
S-3 Ponds	Groundwater	Cesium-137	1/3	6.00E+00	4.0E-06							
S-3 Ponds	Groundwater	Neptunium-237	7/10	5.87E+02	3.7E-03							
S-3 Ponds	Groundwater	Radium (total alpha)	2/2	3.51E+01	2.2E-04							

Table 5.4 (continued)

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
S-3 Ponds	Groundwater	Strontium-90	8/9	1.92E+02	2.2E-04							
S-3 Ponds	Groundwater	Technetium-99	10/10	6.94E+04	2.0E-03							
S-3 Ponds	Groundwater	Thorium-228	1/3	3.20E+00	1.6E-05							
S-3 Ponds	Groundwater	Tritium	9/11	4.10E+03	6.1E-06							
S-3 Ponds	Groundwater	Uranium-234	10/10	3.14E+03	2.9E-03							
S-3 Ponds	Groundwater	Uranium-235	8/10	3.53E+02	3.5E-04							
S-3 Ponds	Groundwater	Uranium-238	10/10	7.48E+03	9.7E-03							
S-3 Ponds	Soil (1-9)	Arsenic	18/18	7.22E+00	1.7E-05				3.1E-01			
S-3 Ponds	Soil (1-9)	Mercury	15/18	2.65E+01					1.1E+00	1.2E-01		
S-3 Ponds	Soil (10)	None										
S-3 Ponds	Surface Water	Barium	55/55	3.08E-01						1.2E-01		
S-3 Ponds	Surface Water	Beryllium	5/55	2.25E-04	1.1E-05		2.8E-06					
S-3 Ponds	Surface Water	Cadmium	4/16	9.78E-03						5.4E-01		1.3E-01
S-3 Ponds	Surface Water	Fluoride	55/55	6.15E-01						2.8E-01		
S-3 Ponds	Surface Water	Manganese	54/55	1.15E+00						2.3E-01		
S-3 Ponds	Surface Water	Nitrate (as N)	55/55	9.74E+01						1.7E+00		
S-3 Ponds	Surface Water	Total Uranium	20/20	6.10E-02						5.6E-01		
S-3 Ponds	Surface Water	Tetrachloroethene	37/55	2.85E-03	1.7E-06		1.6E-06					
S-3 Ponds	Surface Water	Strontium-90	7/11	1.39E+00	1.6E-06							
S-3 Ponds	Surface Water	Technetium-99	8/9	3.27E+02	9.6E-06							
S-3 Ponds	Surface Water	Uranium-233/234	34/35	2.83E+01	2.6E-05							
S-3 Ponds	Surface Water	Uranium-235	16/35	1.60E+00	1.6E-06							
S-3 Ponds	Surface Water	Uranium-238	34/35	5.87E+01	7.6E-05							
S-3 Ponds	Waste Inv. (soil)	Arsenic		1.12E+00	2.6E-06							
S-3 Ponds	Waste Inv. (soil)	Beryllium		2.74E+00	1.8E-05		3.7E-05					
S-3 Ponds	Waste Inv. (soil)	Nickel		5.50E+02					3.5E-01			
S-3 Ponds	Waste Inv. (soil)	Total Uranium		9.92E+02					4.2E+00	4.5E-01		
S-3 Ponds	Waste Inv. (soil)	PCB-1248		5.67E+00	6.8E-05		1.5E-05					

Table 5.4 (continued)

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
S-3 Ponds	Waste Inv. (soil)	Cesium-137		4.77E+00				2.3E-04				
S-3 Ponds	Waste Inv. (soil)	Neptunium-237		9.85E+00	3.7E-06			1.0E-04				
S-3 Ponds	Waste Inv. (soil)	Plutonium-238		2.53E+01	9.4E-06							
S-3 Ponds	Waste Inv. (soil)	Plutonium-239/240		2.54E+00	1.0E-06							
S-3 Ponds	Waste Inv. (soil)	Ruthenium-106		3.33E+01	1.4E-06			5.8E-04				
S-3 Ponds	Waste Inv. (soil)	Technetium-99		7.52E+03	1.3E-05							
S-3 Ponds	Waste Inv. (soil)	Thorium-228		2.67E+02	7.8E-05	1.3E-06		6.1E-03				
S-3 Ponds	Waste Inv. (soil)	Thorium-230		5.44E+02	2.6E-05							
S-3 Ponds	Waste Inv. (soil)	Thorium-232		8.75E+01	3.6E-06							
S-3 Ponds	Waste Inv. (soil)	Uranium-234		1.24E+02	6.9E-06							
S-3 Ponds	Waste Inv. (soil)	Uranium-235		8.06E+00				4.9E-05				
S-3 Ponds	Waste Inv. (soil)	Uranium-238		3.32E+02	2.6E-05			4.0E-04				
<i>Oil Landfarm, Sanitary Landfill 1, and Boneyard/Burnyard</i>												
OLF,BYBY,SLF 1	Groundwater	Barium	71/71	3.45E-01						1.4E-01		
OLF,BYBY,SLF 1	Groundwater	Beryllium	17/71	4.40E-04	2.2E-05		5.4E-06					
OLF,BYBY,SLF 1	Groundwater	Boron	65/65	3.55E-01						1.1E-01		
OLF,BYBY,SLF 1	Groundwater	Cadmium	9/73	3.29E-03						1.8E-01		
OLF,BYBY,SLF 1	Groundwater	Chromium	33/95	3.00E-02						1.6E-01		
OLF,BYBY,SLF 1	Groundwater	Fluoride	26/82	4.00E-01						1.8E-01		
OLF,BYBY,SLF 1	Groundwater	Manganese	72/74	1.09E+00						2.1E-01		
OLF,BYBY,SLF 1	Groundwater	Mercury	9/71	3.12E-03						2.8E-01		
OLF,BYBY,SLF 1	Groundwater	1,1-Dichloroethene	77/117	2.97E-02	2.1E-04	2.1E-03	4.5E-06					
OLF,BYBY,SLF 1	Groundwater	1,2-Dichloroethane	13/116	4.90E-03	5.2E-06	2.6E-05						
OLF,BYBY,SLF 1	Groundwater	Benzene	35/116	6.91E-03	2.4E-06	1.2E-05						
OLF,BYBY,SLF 1	Groundwater	Carbon Tetrachloride	11/117	3.26E-03	5.0E-06	1.0E-05				1.3E-01		
OLF,BYBY,SLF 1	Groundwater	Chloroform	25/116	1.01E-02		4.8E-05						
OLF,BYBY,SLF 1	Groundwater	Methylene Chloride	24/115	8.21E-02	7.2E-06	7.9E-06						
OLF,BYBY,SLF 1	Groundwater	PCB-1254	1/5	4.50E-04						6.2E-01		5.7E-01

Table 5.4 (continued)

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
OLF,BYBY,SLF 1	Groundwater	Tetrachloroethene	55/117	1.01E-01	6.2E-05	1.2E-05	5.6E-05			2.8E-01		2.5E-01
OLF,BYBY,SLF 1	Groundwater	Trans-1,2-Dichloroethene	28/31	1.37E-01						1.9E-01		
OLF,BYBY,SLF 1	Groundwater	Trichloroethene	84/117	1.29E-01	1.7E-05	4.5E-05	4.3E-06					
OLF,BYBY,SLF 1	Groundwater	Vinyl Chloride	30/117	9.69E-03	2.2E-04	1.7E-04	3.8E-06					
OLF,BYBY,SLF 1	Groundwater	Cesium-137	1/9	4.60E+00	3.1E-06							
OLF,BYBY,SLF 1	Groundwater	Lead-212	1/6	1.56E+01	5.9E-06							
OLF,BYBY,SLF 1	Groundwater	Neptunium-237	1/3	2.40E-01	1.5E-06							
OLF,BYBY,SLF 1	Groundwater	Potassium-40	1/6	1.51E+02	4.0E-05							
OLF,BYBY,SLF 1	Groundwater	Thorium-228	4/9	1.29E+00	6.3E-06							
OLF,BYBY,SLF 1	Groundwater	Thorium-230	6/9	2.14E+00	1.7E-06							
OLF,BYBY,SLF 1	Groundwater	Uranium-234	9/9	1.30E+03	1.2E-03							
OLF,BYBY,SLF 1	Groundwater	Uranium-235	5/9	2.89E+01	2.9E-05							
OLF,BYBY,SLF 1	Groundwater	Uranium-238	8/9	7.21E+02	9.4E-04							
OLF,BYBY,SLF 1	Surface Water	Arsenic	5/43	8.16E-04	1.4E-05							
OLF,BYBY,SLF 1	Surface Water	Barium	52/52	2.75E-01						1.1E-01		
OLF,BYBY,SLF 1	Surface Water	Cadmium	5/8	7.52E-03						4.1E-01		
OLF,BYBY,SLF 1	Surface Water	Fluoride	39/52	1.16E+00						5.3E-01		
OLF,BYBY,SLF 1	Surface Water	Nitrate (as N)	38/52	4.93E+01						8.4E-01		
OLF,BYBY,SLF 1	Surface Water	Total Uranium	10/10	2.24E-01						2.0E+00		
OLF,BYBY,SLF 1	Surface Water	Strontium-90	3/13	9.30E-01	1.1E-06							
OLF,BYBY,SLF 1	Surface Water	Technetium-99	2/12	8.41E+01	2.5E-06							
OLF,BYBY,SLF 1	Surface Water	Uranium-233/234	21/42	5.62E+01	5.2E-05							
OLF,BYBY,SLF 1	Surface Water	Uranium-235	19/42	5.26E+00	5.2E-06							
OLF,BYBY,SLF 1	Surface Water	Uranium-238	21/42	1.11E+02	1.5E-04							
<i>Oil Landfarm</i>												
OLF	Soil	Arsenic	8/8	1.13E+01	2.6E-05		1.3E-06		4.8E-01			
OLF	Soil	PCB-1260	3/8	1.16E-01	1.4E-06							
OLF	Soil	Cobalt-60	4/8	1.54E+00				3.5E-04				

Table 5.4 (continued)

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
OLF	Soil	Lead-212	1/8	2.60E+00				1.8E-05				
OLF	Soil	Thallium-208	1/8	4.60E+00				1.5E-03				
OLF	Soil	Uranium-238	8/8	1.94E+00				2.3E-06				
OLF	Soil Inventory	Total Uranium	140/149	8.72E+01					3.7E-01			
OLF	Soil Inventory	PCB-1254	70/93	5.79E+00					3.7E+00	4.0E-01		2.3E-01
OLF	Soil Inventory	PCB-1260	57/57	7.37E+00	8.9E-05		2.0E-05					
OLF	Soil Inventory	PCBs	183/186	8.90E+00	1.1E-04		2.4E-05					
OLF	Soil Inventory	Uranium-234 (calc.)	140/149	2.98E+01	1.7E-06							
OLF	Soil Inventory	Uranium-235 (calc.)	140/149	1.35E+00				8.2E-06				
OLF	Soil Inventory	Uranium-238 (calc.)	140/149	2.90E+01	2.3E-06			3.5E-05				
<i>Sanitary Landfill 1</i>												
SLF 1	Soil	Mercury	5/5	2.68E+01					1.1E+00	1.2E-01		
SLF 1	Soil	Benzo(a)anthracene	3/5	3.65E+00	4.2E-06		2.7E-06					
SLF 1	Soil	Benzo(a)pyrene	3/5	2.70E+00	3.1E-05		2.0E-05					
SLF 1	Soil	Benzo(b)fluoranthene	3/5	3.70E+00	4.2E-06		2.7E-06					
SLF 1	Soil	Dibenzo(a,h)anthracene	1/5	7.08E-01	8.1E-06		5.2E-06					
SLF 1	Soil	Indeno(1,2,3-cd)pyrene	3/5	9.95E-01	1.1E-06							
SLF 1	Soil	PCB-1232	1/5	8.22E-01	9.9E-06		2.2E-06					
SLF 1	Soil	PCB-1254	2/5	1.21E+00					7.7E-01			
SLF 1	Soil	PCB-1260	1/4	8.57E-02	1.0E-06							
SLF 1	Soil	Cobalt-60	1/5	1.30E+00				2.9E-04				
SLF 1	Soil	Uranium-235	4/5	4.84E-01				2.9E-06				
SLF 1	Soil	Uranium-238	5/5	1.55E+01	1.2E-06			1.9E-05				
<i>Boneyard/Burnyard</i>												
BYBY	Soil	Antimony	12/12	2.95E+02					9.4E+00	1.0E+00		2.7E+00
BYBY	Soil	Arsenic	15/15	2.16E+01	5.1E-05		2.5E-06		9.2E-01			
BYBY	Soil	Beryllium	14/15	1.70E+00	1.1E-05		2.3E-05					

Table 5.4 (continued)

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
BYBY	Soil	Cadmium	11/15	2.75E+01					3.5E-01			2.0E-01
BYBY	Soil	Chromium	15/15	8.10E+01					2.1E-01			
BYBY	Soil	Manganese	15/15	1.56E+03					1.4E-01			
BYBY	Soil	Mercury	15/15	4.32E+01					1.8E+00	2.0E-01		1.5E-01
BYBY	Soil	Nickel	15/15	1.57E+03					1.0E+00	1.1E-01		
BYBY	Soil	Silver	14/15	4.54E+01					1.2E-01			
BYBY	Soil	Zinc	15/15	4.38E+03					1.9E-01			
BYBY	Soil	2,3,7,8-TCDD	2/3	7.72E-06	1.8E-06							
BYBY	Soil	Benzo(a)anthracene	14/14	6.85E+01	7.8E-05		5.0E-05					
BYBY	Soil	Benzo(a)pyrene	14/14	4.60E+01	5.3E-04		3.4E-04					
BYBY	Soil	Benzo(b)fluoranthene	14/14	5.97E+01	6.8E-05		4.4E-05					
BYBY	Soil	Benzo(k)fluoranthene	14/14	3.97E+01	4.5E-06		2.9E-06					
BYBY	Soil	Dibenzo(a,h)anthracene	13/14	3.37E+00	3.8E-05		2.5E-05					
BYBY	Soil	Indeno(1,2,3-cd)pyrene	14/14	2.17E+01	2.5E-05		1.6E-05					
BYBY	Soil	PCB-1254	11/11	3.48E+00					2.2E+00	2.4E-01		1.4E-01
BYBY	Soil	PCB-1260	3/10	5.29E-01	6.4E-06		1.4E-06					
BYBY	Soil	Uranium-234	17/17	2.60E+02	1.5E-05							
BYBY	Soil	Uranium-235	15/17	8.62E+00				5.3E-05				
BYBY	Soil	Uranium-238	17/17	5.27E+02	4.1E-05			6.4E-04				
BYBY	Soil (hot spot)	Uranium-235	1/1	7.36E+02	4.4E-05			4.5E-03				
BYBY	Soil (hot spot)	Uranium-238	1/1	4.76E+04	3.7E-03	2.9E-05		5.6E-02				
<i>Burial Grounds</i>												
BG	Groundwater	Barium	97/97	2.83E-01						1.1E-01		
BG	Groundwater	Beryllium	14/96	3.45E-04	1.7E-05		4.2E-06					
BG	Groundwater	Cadmium	24/126	3.74E-03						2.0E-01		
BG	Groundwater	Chromium	48/127	3.48E-02						1.9E-01		
BG	Groundwater	Fluoride	67/103	1.14E+00						5.2E-01		
BG	Groundwater	1,1,1-Trichloroethane	82/146	5.68E-01						1.7E-01	2.7E-01	

Table 5.4 (continued)

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
BG	Groundwater	1,1,2-Trichloroethane	15/135	2.27E-02	1.5E-05	7.6E-05				1.6E-01		
BG	Groundwater	1,1-Dichloroethane	97/146	6.46E-01						1.8E-01	6.2E-01	
BG	Groundwater	1,1-Dichloroethene	71/145	5.41E-01	3.8E-03	3.7E-02	8.2E-05			1.6E+00		
BG	Groundwater	1,2-Dichloroethane	51/136	1.85E-02	2.0E-05	9.9E-05						
BG	Groundwater	1,2-Dichloroethene	74/105	1.47E-01						4.5E-01		
BG	Groundwater	Benzene	57/137	4.38E-02	1.5E-05	7.4E-05						
BG	Groundwater	Chloroform	41/138	3.92E-02	2.8E-06	1.9E-04				1.1E-01		
BG	Groundwater	Methylene Chloride	52/136	2.63E-02	2.3E-06	2.5E-06						
BG	Groundwater	Tetrachloroethene	102/147	3.15E+00	1.9E-03	3.7E-04	1.7E-03			8.6E+00		7.7E+00
BG	Groundwater	Trans-1,2-Dichloroethene	36/38	4.24E+00						5.8E+00		
BG	Groundwater	Trichloroethene	109/147	1.66E+00	2.1E-04	5.9E-04	5.6E-05					
BG	Groundwater	Trichlorofluoromethane	2/6	8.19E-01							5.6E-01	
BG	Groundwater	Vinyl Chloride	83/143	2.71E-01	6.0E-03	4.8E-03	1.1E-04					
BG	Groundwater	Cesium-137	2/12	5.77E+00	3.8E-06							
BG	Groundwater	Potassium-40	1/6	1.29E+02	3.4E-05							
BG	Groundwater	Thorium-228	7/12	1.20E+00	5.8E-06							
BG	Groundwater	Uranium-238	6/12	9.31E-01	1.2E-06							
BG	Surface Water	Beryllium	6/35	2.28E-04	1.2E-05		2.8E-06					
BG	Surface Water	1,1,2-Trichloroethane	5/34	2.00E-03	1.3E-06	6.7E-06						
BG	Surface Water	1,1-Dichloroethene	31/34	8.72E-03	6.1E-05	6.1E-04	1.3E-06					
BG	Surface Water	1,2-Dichloroethane	13/27	2.95E-03	3.1E-06	1.6E-05						
BG	Surface Water	1,2-Dichloroethene	33/34	2.11E-01						6.4E-01		
BG	Surface Water	Benzene	7/34	2.58E-03		4.4E-06						
BG	Surface Water	Chloroform	31/34	4.39E-03		2.1E-05						
BG	Surface Water	Tetrachloroethene	32/34	6.17E-02	3.8E-05	7.2E-06	3.4E-05			1.7E-01		1.5E-01
BG	Surface Water	Trichloroethene	32/34	4.84E-02	6.2E-06	1.7E-05	1.6E-06					
BG	Surface Water	Vinyl Chloride	32/34	1.70E-02	3.8E-04	3.0E-04	6.7E-06					
BG	Surface Water	Potassium-40	1/2	1.30E+02	3.4E-05							

Table 5.4 (continued)

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
BG	Surface Water	Thorium-228	3/8	3.09E-01	1.5E-06							
BG	Surface Water	Uranium-233/234	35/35	1.34E+01	1.2E-05							
BG	Surface Water	Uranium-238	35/35	3.77E+01	4.9E-05							
Seep 1	Leachate	1,1,2-Trichloroethane	1/1	3.00E-03	2.0E-06	1.0E-05						
Seep 1	Leachate	1,1-Dichloroethane	1/1	4.00E-01						1.1E-01	3.8E-01	
Seep 1	Leachate	1,1-Dichloroethene	1/1	1.30E-02	9.2E-05	9.2E-04	2.0E-06					
Seep 1	Leachate	1,2-Dichloroethane	1/1	7.00E-03	7.5E-06	3.7E-05						
Seep 1	Leachate	2,4-Dimethylphenol	1/1	2.10E-01						2.9E-01		1.5E-01
Seep 1	Leachate	2,4-Dinitrotoluene	1/1	1.00E-03	8.0E-06							
Seep 1	Leachate	2,6-Dinitrotoluene	1/1	2.00E-03	1.6E-05							
Seep 1	Leachate	Benzene	1/1	1.90E-02	6.5E-06	3.2E-05						
Seep 1	Leachate	Benzidine	1/1	5.00E-03	1.3E-02		5.3E-05					
Seep 1	Leachate	Bis(2-ethylhexyl)phthalate	1/1	3.30E-02	5.4E-06		1.6E-06					
Seep 1	Leachate	Chloroform	1/1	4.00E-03		1.9E-05						
Seep 1	Leachate	Cis-1,2-Dichloroethene	1/1	4.90E+00						1.3E+01		3.3E-01
Seep 1	Leachate	Di-N-Octylphthalate	1/1	4.00E-03								4.0E-01
Seep 1	Leachate	Dibromochloromethane	1/1	4.00E-03	3.9E-06							
Seep 1	Leachate	Pentachlorophenol	1/1	6.00E-03	8.5E-06		1.3E-05					
Seep 1	Leachate	PCBs	1/1	3.20E-01	2.9E-02		2.7E-02					
Seep 1	Leachate	Vinyl Chloride	1/1	9.90E-01	2.2E-02	1.7E-02	3.9E-04					
Seep 1	Leachate	Cesium-137	1/1	6.10E+00	4.0E-06							
Seep 1	Leachate	Neptunium-237	1/1	7.50E-01	4.7E-06							
Seep 1	Leachate	Uranium-234	1/1	6.30E+00	5.9E-06							
Seep 1	Leachate	Uranium-238	1/1	4.70E+00	6.1E-06							
Seep 2	Leachate	Arsenic	1/2	8.00E-01	1.4E-02		8.3E-05			7.3E+01		4.3E-01
Seep 2	Leachate	Barium	2/2	2.89E+00						1.1E+00		
Seep 2	Leachate	Beryllium	1/2	1.11E+00	5.5E-02		1.3E-02			6.1E+00		1.5E+00
Seep 2	Leachate	Boron	2/2	1.75E+01						5.3E+00		

Table 5.4 (continued)

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
Seep 2	Leachate	Chromium	1/2	2.80E-01						1.5E+00		1.9E-01
Seep 2	Leachate	Manganese	2/2	1.87E+01						3.7E+00		2.2E-01
Seep 2	Leachate	Molybdenum	1/2	7.00E-02						3.8E-01		
Seep 2	Leachate	Nickel	1/2	3.60E-01						4.9E-01		
Seep 2	Leachate	Total Uranium	2/2	1.49E+00						1.4E+01		
Seep 2	Leachate	Vanadium	1/2	8.90E-01						3.5E+00		8.4E-01
Seep 2	Leachate	Zinc	1/2	3.20E+00						2.9E-01		
Seep 2	Leachate	1,2-Dichloroethane	2/2	2.00E-03	2.1E-06	1.1E-05						
Seep 2	Leachate	1,4-Dioxane	1/1	1.80E-01	2.3E-05							
Seep 2	Leachate	Benzene	1/2	4.00E-03	1.4E-06	6.8E-06						
Seep 2	Leachate	Methylene Chloride	2/2	5.60E-02	4.9E-06	5.4E-06						
Seep 2	Leachate	Vinyl Chloride	2/2	1.00E-02	2.2E-04	1.8E-04	3.9E-06					
Seep 2	Leachate	Neptunium-237	1/1	8.50E-01	5.4E-06							
Seep 2	Leachate	Technetium-99	1/1	1.10E+02	3.2E-06							
Seep 2	Leachate	Tritium	1/1	4.20E+03	6.3E-06							
Seep 2	Leachate	Uranium-234	1/1	5.80E+01	5.4E-05							
Seep 2	Leachate	Uranium-235	1/1	3.90E+00	3.8E-06							
Seep 2	Leachate	Uranium-238	1/1	3.50E+02	4.6E-04							
Seeps 3&4	Leachate	Barium	2/2	2.22E+00						8.7E-01		
Seeps 3&4	Leachate	Beryllium	2/2	3.30E-02	1.7E-03		4.0E-04			1.8E-01		
Seeps 3&4	Leachate	Boron	2/2	1.26E+02						3.8E+01		1.0E-01
Seeps 3&4	Leachate	Manganese	2/2	1.35E+01						2.6E+00		1.6E-01
Seeps 3&4	Leachate	Molybdenum	1/2	1.40E-01						7.7E-01		
Seeps 3&4	Leachate	Vanadium	1/2	6.00E-02						2.3E-01		
Seeps 3&4	Leachate	1,1,2-Trichloroethane	1/2	1.00E-03		3.3E-06						
Seeps 3&4	Leachate	1,1-Dichloroethane	2/2	4.10E-01						1.1E-01	3.9E-01	
Seeps 3&4	Leachate	1,1-Dichloroethene	2/2	3.00E-02	2.1E-04	2.1E-03	4.6E-06					
Seeps 3&4	Leachate	1,2-Dichloroethane	2/2	8.00E-03	8.5E-06	4.3E-05						

Table 5.4 (continued)

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
Seeps 3&4	Leachate	1,4-Dichlorobenzene	2/2	2.60E-02	7.3E-06		1.2E-06					
Seeps 3&4	Leachate	1,4-Dioxane	1/1	2.00E-01	2.6E-05							
Seeps 3&4	Leachate	Benzene	2/2	5.30E-02	1.8E-05	9.0E-05						
Seeps 3&4	Leachate	Cis-1,2-Dichloroethene	2/2	9.20E-01						2.5E+00		
Seeps 3&4	Leachate	Methylene Chloride	2/2	3.30E-02	2.9E-06	3.2E-06						
Seeps 3&4	Leachate	PCBs	2/2	9.50E-03	8.6E-04		8.0E-04					
Seeps 3&4	Leachate	Tetrachloroethene	2/2	1.80E-02	1.1E-05	2.1E-06	9.9E-06					
Seeps 3&4	Leachate	Trichloroethene	2/2	2.10E-02	2.7E-06	7.4E-06						
Seeps 3&4	Leachate	Vinyl Chloride	2/2	1.80E-01	4.0E-03	3.2E-03	7.1E-05					
Seeps 3&4	Leachate	Uranium-234 (calc.)	2/2	3.43E+00	3.2E-06							
Seeps 3&4	Leachate	Uranium-238 (calc.)	2/2	3.34E+00	4.3E-06							
C-West Toe	Leachate	Barium	2/2	5.24E-01						2.1E-01		
C-West Toe	Leachate	Beryllium	1/2	3.00E-03	1.5E-04		3.7E-05					
C-West Toe	Leachate	Boron	2/2	6.33E+01						1.9E+01		
C-West Toe	Leachate	Manganese	2/2	1.01E+01						2.0E+00		1.2E-01
C-West Toe	Leachate	Molybdenum	1/2	3.00E-02						1.6E-01		
C-West Toe	Leachate	Total Uranium	2/2	4.40E-02						4.0E-01		
C-West Toe	Leachate	1,1-Dichloroethane	2/2	1.30E-01							1.2E-01	
C-West Toe	Leachate	1,1-Dichloroethene	1/2	8.00E-03	5.6E-05	5.6E-04	1.2E-06					
C-West Toe	Leachate	1,2-Dichloroethane	2/2	7.00E-03	7.5E-06	3.7E-05						
C-West Toe	Leachate	1,4-Dichlorobenzene	2/2	1.40E-02	3.9E-06							
C-West Toe	Leachate	1,4-Dioxane	1/1	1.90E-01	2.5E-05							
C-West Toe	Leachate	Benzene	2/2	3.90E-02	1.3E-05	6.6E-05						
C-West Toe	Leachate	Bis(2-ethylhexyl)phthalate	1/1	7.00E-03	1.2E-06							
C-West Toe	Leachate	Cis-1,2-Dichloroethene	2/2	1.90E-01						5.2E-01		
C-West Toe	Leachate	Methylene Chloride	2/2	4.70E-02	4.1E-06	4.5E-06						
C-West Toe	Leachate	PCBs	2/2	1.80E-02	1.6E-03		1.5E-03					
C-West Toe	Leachate	Tetrachloroethene	1/2	8.00E-03	4.9E-06		4.4E-06					

Table 5.4 (continued)

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
C-West Toe	Leachate	Trichloroethene	1/2	2.30E-02	3.0E-06	8.1E-06						
C-West Toe	Leachate	Vinyl Chloride	2/2	5.60E-02	1.2E-03	9.9E-04	2.2E-05					
C-West Toe	Leachate	Neptunium-237	1/1	5.20E-01	3.3E-06							
C-West Toe	Leachate	Radium (total alpha)	1/1	6.50E-01	4.0E-06							
C-West Toe	Leachate	Tritium	1/1	2.40E+03	3.6E-06							
C-West Toe	Leachate	Uranium-234	1/1	3.90E+00	3.6E-06							
C-West Toe	Leachate	Uranium-238	1/1	6.10E+00	7.9E-06							
BG A-16	Soil	PCB-1248	1/2	4.00E-01	4.8E-06		1.1E-06					
BG A-16	Soil	Thallium-208	1/2	3.70E+00				1.2E-03				
BG A-16	Waste Inv. (soil)	Total Uranium		6.10E+02					2.6E+00	2.8E-01		
BG A-16	Waste Inv. (soil)	Uranium-234 (calc.)		2.07E+02	1.2E-05							
BG A-16	Waste Inv. (soil)	Uranium-235 (calc.)		9.40E+00				5.7E-05				
BG A-16	Waste Inv. (soil)	Uranium-238 (calc.)		2.02E+02	1.6E-05			2.4E-04				
BG A-17	Soil	PCB-1248	1/2	4.00E-01	4.8E-06		1.1E-06					
BG A-17	Soil	Thallium-208	1/2	3.70E+00				1.2E-03				
BG A-17	Waste Inv. (soil)	Total Uranium		6.10E+02					2.6E+00	2.8E-01		
BG A-17	Waste Inv. (soil)	Uranium-234 (calc.)		2.07E+02	1.2E-05							
BG A-17	Waste Inv. (soil)	Uranium-235 (calc.)		9.40E+00				5.7E-05				
BG A-17	Waste Inv. (soil)	Uranium-238 (calc.)		2.02E+02	1.6E-05			2.4E-04				
BG A-18	Soil	PCB-1248	1/2	4.00E-01	4.8E-06		1.1E-06					
BG A-18	Soil	Thallium-208	1/2	3.70E+00				1.2E-03				
BG A-18	Waste Inv. (soil)	Total Uranium		6.10E+02					2.6E+00	2.8E-01		
BG A-18	Waste Inv. (soil)	Uranium-234 (calc.)		2.07E+02	1.2E-05							
BG A-18	Waste Inv. (soil)	Uranium-235 (calc.)		9.40E+00				5.7E-05				
BG A-18	Waste Inv. (soil)	Uranium-238 (calc.)		2.02E+02	1.6E-05			2.4E-04				
BG A-North	Soil	None										
BG A-North	Waste Inv. (soil)	Beryllium		3.00E-01	2.0E-06		4.0E-06					
BG A-North	Waste Inv. (soil)	Total Uranium		1.10E+04					4.7E+01	5.0E+00		3.1E-01

Table 5.4 (continued)

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
BG A-North	Waste Inv. (soil)	PCBs		1.30E+03	1.6E-02		3.5E-03					
BG A-North	Waste Inv. (soil)	Uranium-234 (calc.)		3.73E+03	2.1E-04	2.6E-06		1.8E-06				
BG A-North	Waste Inv. (soil)	Uranium-235 (calc.)		1.70E+02	1.0E-05			1.0E-03				
BG A-North	Waste Inv. (soil)	Uranium-238 (calc.)		3.64E+03	2.8E-04	2.2E-06		4.4E-03				
BG A-South	Soil	None										
BG A-South	Waste Inv. (soil)	Beryllium		1.20E+00	8.1E-06		1.6E-05					
BG A-South	Waste Inv. (soil)	Total Uranium		1.50E+04					6.4E+01	6.8E+00		4.3E-01
BG A-South	Waste Inv. (soil)	1,1,1-Trichloroethane		9.60E+02					1.4E-01			
BG A-South	Waste Inv. (soil)	Benzene		1.40E+02	6.4E-06	2.5E-05	1.3E-06					
BG A-South	Waste Inv. (soil)	PCBs		2.10E+01	2.5E-04		5.6E-05					
BG A-South	Waste Inv. (soil)	Tetrachloroethene		8.90E+02	7.2E-05	9.5E-06	1.4E-05		1.1E+00	1.2E-01		
BG A-South	Waste Inv. (soil)	Trichloroethene		8.50E+01	1.5E-06	3.2E-06	1.9E-06					
BG A-South	Waste Inv. (soil)	Uranium-234 (calc.)		5.09E+03	2.8E-04	3.5E-06		2.5E-06				
BG A-South	Waste Inv. (soil)	Uranium-235 (calc.)		2.31E+02	1.4E-05			1.4E-03				
BG A-South	Waste Inv. (soil)	Uranium-238 (calc.)		4.96E+03	3.9E-04	3.0E-06		6.0E-03				
BG B	Soil	Arsenic	4/4	2.75E+01	6.5E-05		3.1E-06		1.2E+00	1.3E-01		
BG B	Soil	PCB-1254	2/4	8.39E+00					5.4E+00	5.7E-01		3.4E-01
BG B	Soil	PCB-1260	1/4	3.02E+01	3.6E-04		8.0E-05					
BG B	Soil	Uranium-238	4/4	9.26E+00				1.1E-05				
BG B	Waste Inv. (soil)	Total Uranium		3.00E+05					1.3E+03	1.4E+02		8.5E+00
BG B	Waste Inv. (soil)	Thorium-232 (calc.)		4.47E+01	1.8E-06							
BG B	Waste Inv. (soil)	Uranium-234 (calc.)		1.02E+05	5.7E-03	7.0E-05		5.0E-05				
BG B	Waste Inv. (soil)	Uranium-235 (calc.)		4.63E+03	2.7E-04	2.9E-06		2.8E-02				
BG B	Waste Inv. (soil)	Uranium-238 (calc.)		9.92E+04	7.7E-03	6.0E-05		1.1E-01				
BG C-East	Soil	Arsenic	2/2	3.94E+01	9.3E-05		4.5E-06		1.7E+00	1.8E-01		
BG C-East	Soil	Beryllium	2/2	4.80E+00	3.2E-05		6.4E-05					
BG C-East	Soil	Vanadium	2/2	6.88E+01					1.3E-01			
BG C-East	Soil	Uranium-238	2/2	3.60E+01	2.8E-06			4.3E-05				

Table 5.4 (continued)

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
BG C-East	Waste Inv. (soil)	Beryllium		1.10E+03	7.4E-03		1.5E-02		2.8E+00	3.0E-01		1.6E+00
BG C-East	Waste Inv. (soil)	Total Uranium		2.10E+04					8.9E+01	9.6E+00		6.0E-01
BG C-East	Waste Inv. (soil)	Thorium-232 (calc.)		5.78E+02	2.4E-05							
BG C-East	Waste Inv. (soil)	Uranium-234 (calc.)		7.13E+03	4.0E-04	4.9E-06		3.5E-06				
BG C-East	Waste Inv. (soil)	Uranium-235 (calc.)		3.24E+02	1.9E-05			2.0E-03				
BG C-East	Waste Inv. (soil)	Uranium-238 (calc.)		6.94E+03	5.4E-04	4.2E-06		8.4E-03				
BG C-West	Soil	Arsenic	10/10	2.48E+01	5.8E-05		2.8E-06		1.1E+00	1.1E-01		
BG C-West	Soil	PCB-1260	1/9	4.20E-01	5.1E-06		1.1E-06					
BG C-West	Soil	Cobalt-60	1/10	1.20E+00				2.7E-04				
BG C-West	Soil	Uranium-238	10/10	1.46E+01	1.1E-06			1.8E-05				
BG C-West	Waste Inv. (soil)	Beryllium		1.10E+03	7.4E-03		1.5E-02		2.8E+00	3.0E-01		1.6E+00
BG C-West	Waste Inv. (soil)	Total Uranium		2.20E+04					9.4E+01	1.0E+01		6.3E-01
BG C-West	Waste Inv. (soil)	Thorium-232 (calc.)		3.38E+02	1.4E-05							
BG C-West	Waste Inv. (soil)	Uranium-234 (calc.)		7.47E+03	4.2E-04	5.1E-06		3.7E-06				
BG C-West	Waste Inv. (soil)	Uranium-235 (calc.)		3.39E+02	2.0E-05			2.1E-03				
BG C-West	Waste Inv. (soil)	Uranium-238 (calc.)		7.27E+03	5.7E-04	4.4E-06		8.8E-03				
BG D-East	Soil (hot spot)	Beryllium	1/1	5.90E-01	4.0E-06		7.9E-06					
BG D-East	Soil (hot spot)	Uranium-234	1/1	1.54E+05	8.6E-03	1.1E-04		7.6E-05				
BG D-East	Soil (hot spot)	Uranium-235	1/1	2.56E+03	1.5E-04	1.6E-06		1.5E-02				
BG D-East	Soil (hot spot)	Uranium-238	1/1	2.09E+05	1.6E-02	1.3E-04		2.2E-01				
BG D-East	Soil	Arsenic	2/2	3.94E+01	9.3E-05		4.5E-06		1.7E+00	1.8E-01		
BG D-East	Soil	Beryllium	2/2	4.80E+00	3.2E-05		6.4E-05					
BG D-East	Soil	Vanadium	2/2	6.88E+01					1.3E-01			
BG D-East	Soil	Uranium-238	2/2	3.60E+01	2.8E-06			4.3E-05				
BG D-East	Waste Inv. (soil)	Total Uranium		2.40E+05					1.0E+03	1.1E+02		6.8E+00
BG D-East	Waste Inv. (soil)	Uranium-234 (calc.)		8.14E+04	4.6E-03	5.6E-05		4.0E-05				
BG D-East	Waste Inv. (soil)	Uranium-235 (calc.)		3.70E+03	2.2E-04	2.4E-06		2.2E-02				
BG D-East	Waste Inv. (soil)	Uranium-238 (calc.)		7.93E+04	6.2E-03	4.8E-05		9.1E-02				

Table 5.4 (continued)

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
BG D-South	Soil	Arsenic	4/4	2.75E+01	6.5E-05		3.1E-06		1.2E+00	1.3E-01		
BG D-South	Soil	PCB-1254	2/4	8.39E+00					5.4E+00	5.7E-01		3.4E-01
BG D-South	Soil	PCB-1260	1/4	3.02E+01	3.6E-04		8.0E-05					
BG D-South	Soil	Uranium-238	4/4	9.26E+00				1.1E-05				
BG D-South	Waste Inv. (soil)	Total Uranium		2.40E+05					1.0E+03	1.1E+02		6.8E+00
BG D-South	Waste Inv. (soil)	Uranium-234 (calc.)		8.14E+04	4.6E-03	5.6E-05		4.0E-05				
BG D-South	Waste Inv. (soil)	Uranium-235 (calc.)		3.70E+03	2.2E-04	2.4E-06		2.2E-02				
BG D-South	Waste Inv. (soil)	Uranium-238 (calc.)		7.93E+04	6.2E-03	4.8E-05		9.1E-02				
BG D-West,E,J	Waste Inv. (soil)	Total Uranium		2.60E+05					1.1E+03	1.2E+02		7.4E+00
BG D-West,E,J	Waste Inv. (soil)	Uranium-234 (calc.)		8.82E+04	4.9E-03	6.1E-05		4.3E-05				
BG D-West,E,J	Waste Inv. (soil)	Uranium-235 (calc.)		4.01E+03	2.4E-04	2.6E-06		2.4E-02				
BG D-West,E,J	Waste Inv. (soil)	Uranium-238 (calc.)		8.60E+04	6.7E-03	5.2E-05		9.9E-02				
BG WIP-North	Soil	Arsenic	4/4	2.75E+01	6.5E-05		3.1E-06		1.2E+00	1.3E-01		
BG WIP-North	Soil	PCB-1254	2/4	8.39E+00					5.4E+00	5.7E-01		3.4E-01
BG WIP-North	Soil	PCB-1260	1/4	3.02E+01	3.6E-04		8.0E-05					
BG WIP-North	Soil	Uranium-238	4/4	9.26E+00				1.1E-05				
BG WIP-North	Waste Inv. (soil)	Beryllium		2.60E+01	1.8E-04		3.5E-04					
BG WIP-North	Waste Inv. (soil)	Mercuric Chloride		1.70E+01					7.2E-01			
BG WIP-North	Waste Inv. (soil)	Total Uranium		7.20E+04					3.1E+02	3.3E+01		2.0E+00
BG WIP-North	Waste Inv. (soil)	4,4'-DDT		4.90E+00	2.6E-06				1.3E-01			
BG WIP-North	Waste Inv. (soil)	Benzene		1.30E+02	5.9E-06	2.3E-05	1.2E-06					
BG WIP-North	Waste Inv. (soil)	Benzidine		3.10E+01	1.1E-02		2.8E-03		1.3E-01			
BG WIP-North	Waste Inv. (soil)	PCBs		1.70E+00	2.0E-05		4.5E-06					
BG WIP-North	Waste Inv. (soil)	Trichloroethane		7.70E+00		1.5E-06						
BG WIP-North	Waste Inv. (soil)	Thorium-232 (calc.)		6.32E+01	2.6E-06							
BG WIP-North	Waste Inv. (soil)	Uranium-234 (calc.)		2.44E+04	1.4E-03	1.7E-05		1.2E-05				
BG WIP-North	Waste Inv. (soil)	Uranium-235 (calc.)		1.11E+03	6.6E-05			6.8E-03				
BG WIP-North	Waste Inv. (soil)	Uranium-238 (calc.)		2.38E+04	1.9E-03	1.4E-05		2.8E-02				

Table 5.4 (continued)

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
BG WIP-South	Soil	Arsenic	4/4	2.75E+01	6.5E-05		3.1E-06		1.2E+00	1.3E-01		
BG WIP-South	Soil	PCB-1254	2/4	8.39E+00					5.4E+00	5.7E-01		3.4E-01
BG WIP-South	Soil	PCB-1260	1/4	3.02E+01	3.6E-04		8.0E-05					
BG WIP-South	Soil	Uranium-238	4/4	9.26E+00				1.1E-05				
BG WIP-South	Waste Inv. (soil)	Chromium		4.70E+01					1.2E-01			
BG WIP-South	Waste Inv. (soil)	Total Uranium		7.50E+04					3.2E+02	3.4E+01		2.1E+00
BG WIP-South	Waste Inv. (soil)	Uranium-234 (calc.)		2.55E+04	1.4E-03	1.7E-05		1.3E-05				
BG WIP-South	Waste Inv. (soil)	Uranium-235 (calc.)		1.16E+03	6.8E-05			7.1E-03				
BG WIP-South	Waste Inv. (soil)	Uranium-238 (calc.)		2.48E+04	1.9E-03	1.5E-05		3.0E-02				
<i>Floodplain (western BCY)</i>												
FP (wBCV)	Groundwater	None										
FP (wBCV)	Sediment	Arsenic	6/8	1.20E+01	2.8E-05		1.4E-06		5.1E-01			
FP (wBCV)	Sediment	Chromium	8/8	6.58E+01					1.7E-01			
FP (wBCV)	Sediment	Manganese	8/8	2.42E+03					2.2E-01			
FP (wBCV)	Sediment	PCB-1254	3/8	3.33E-01					2.1E-01			
FP (wBCV)	Soil (creek floodplain)	None										
FP (wBCV)	Surface Water	None										
<i>Disposal Area Remedial Action Soils Storage Unit</i>												
DARA	Soil Inventory	HxCDD ^d	22/32	2.65E-03	2.6E-05		1.0E-05					
DARA	Soil Inventory	PCB-1254	32/32	1.03E+02					6.6E+01	7.1E+00		4.2E+00
DARA	Soil Inventory	Pentachlorobenzene	3/32	2.50E+01					4.0E-01			
DARA	Soil Inventory	2,3,7,8-TCDD ^d	2/32	2.40E-03	5.6E-04		2.2E-04					
DARA	Soil Inventory	Uranium-234	32/32	1.14E+02	6.4E-06							
DARA	Soil Inventory	Uranium-235	32/32	4.91E+00				3.0E-05				
DARA	Soil Inventory	Uranium-238	32/32	7.69E+01	6.0E-06			9.3E-05				
<i>Oil Landfarm Storage Pad</i>												
OLF SP	Soil Inventory	Arsenic	40/40	2.55E+00	6.0E-06				1.1E-01			

Table 5.4 (continued)

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
OLF SP	Soil Inventory	Beryllium	40/40	5.82E+00	3.9E-05		7.8E-05					
OLF SP	Soil Inventory	PCBs	40/40	2.65E+01	3.2E-04		7.1E-05					
OLF SP	Soil Inventory	Uranium-234	40/40	2.25E+01	1.3E-06							
OLF SP	Soil Inventory	Uranium-235	40/40	1.53E+00				9.4E-06				
OLF SP	Soil Inventory	Uranium-238	40/40	2.40E+01	1.9E-06			2.9E-05				
<i>Bear Creek Road Debris Burial</i>												
BCR DB	Soil (hot spot)	Arsenic	1/1	1.07E+01	2.5E-05		1.2E-06		4.6E-01			
BCR DB	Soil (hot spot)	Barium	1/1	6.33E+02					1.2E-01			
BCR DB	Soil (hot spot)	Beryllium	1/1	8.80E-01	5.9E-06		1.2E-05					
BCR DB	Soil (hot spot)	Cadmium	1/1	1.56E+01					2.0E-01			1.1E-01
BCR DB	Soil (hot spot)	Chromium	1/1	7.81E+01					2.0E-01			
BCR DB	Soil (hot spot)	Mercury	1/1	5.40E+00					2.3E-01			
BCR DB	Soil (hot spot)	PCB-1254	1/1	3.60E+00					2.3E+00	2.5E-01		1.5E-01
BCR DB	Soil (hot spot)	Cesium-137	1/1	1.19E+00				5.7E-05				
BCR DB	Soil (hot spot)	Curium-243	1/1	3.30E-01				1.3E-06				
BCR DB	Soil (hot spot)	Thorium-228	1/1	8.80E-01				2.0E-05				
BCR DB	Soil (hot spot)	Uranium-234	1/1	4.11E+02	2.3E-05							
BCR DB	Soil (hot spot)	Uranium-235	1/1	1.81E+00				1.1E-05				
BCR DB	Soil (hot spot)	Uranium-238	1/1	6.38E+01	5.0E-06			7.7E-05				
<i>Creekside Debris Burial</i>												
CS DB	Soil (hot spot)	Arsenic	1/1	7.90E+00	1.9E-05				3.4E-01			
CS DB	Soil (hot spot)	Beryllium	1/1	1.40E+00	9.4E-06		1.9E-05					
CS DB	Soil (hot spot)	Chromium	1/1	1.07E+02					2.7E-01			
CS DB	Soil (hot spot)	Mercury	1/1	3.30E+01					1.4E+00	1.5E-01		1.1E-01
CS DB	Soil (hot spot)	Benzo(a)anthracene	1/1	1.00E+01	1.1E-05		7.3E-06					
CS DB	Soil (hot spot)	Benzo(a)pyrene	1/1	8.00E+00	9.1E-05		5.8E-05					
CS DB	Soil (hot spot)	Benzo(b)fluoranthene	1/1	1.40E+01	1.6E-05		1.0E-05					
CS DB	Soil (hot spot)	Benzo(k)fluoranthene	1/1	1.30E+01	1.5E-06							

Table 5.4 (continued)

Area	Medium	COCs ^a	Frequency of detect	UCL95 conc. ^b	Ingestion risk ^c	Inhalation risk	Dermal risk	External exposure risk	Ingestion HQ (child) ^c	Ingestion HQ (adult)	Inhalation HQ	Dermal HQ
CS DB	Soil (hot spot)	Dibenzo(a,h)anthracene	1/1	3.50E-01	4.0E-06		2.6E-06					
CS DB	Soil (hot spot)	Indeno(1,2,3-cd)pyrene	1/1	2.20E+00	2.5E-06		1.6E-06					
CS DB	Soil (hot spot)	PCB-1254	1/1	1.20E+00					7.7E-01			
CS DB	Soil (hot spot)	Cesium-137	1/1	2.10E-01				1.0E-05				
CS DB	Soil (hot spot)	Thorium-228	1/1	2.20E+00				5.0E-05				
CS DB	Soil (hot spot)	Uranium-234	1/1	2.79E+01	1.6E-06							
CS DB	Soil (hot spot)	Uranium-235	1/1	1.45E+00				8.8E-06				
CS DB	Soil (hot spot)	Uranium-238	1/1	2.48E+01	1.9E-06			3.0E-05				

^a The COCs presented in this table are associated with data aggregates which best represent each source area/FA, i.e., location-specific COCs are not shown in this table.

^b The units of measure for the UCL95 concentrations for radionuclides are pCi/g and pCi/L for soil and water, respectively; for chemicals, the units are mg/L and mg/kg for water and soil, respectively.

^c Residential receptors include: adult/child combination (i.e., age-adjusted intake factor) for incidental ingestion of soil and sediment (for carcinogens/risk), adult and child considered separately (for noncarcinogens/HQ), and adult only for all other exposure media and pathways (Energy Systems 1996b; EPA 1991a).

^d For the DARA soil inventory, hexachlorodibenzo-p-dioxins were evaluated as HxCDD, and tetrachlorodibenzo-p-dioxins were evaluated as 2,3,7,8-TCDD.

Table 5.5. Human health media of concern for the BCV source areas/FAs

Medium	S-3 Ponds			Oil Landfarm			Boneyard/ Burnyard			Sanitary Landfill-1			Burial Grounds			DARA			OLF Storage Pad			BC Road Debris			Creekside Debris			Floodplain Area (western BCV)			
	R	I	M	R	I	M	R	I	M	R	I	M	R	I	M	R	I	M	R	I	M	R	I	M	R	I	M	R	I	M	Rc
Groundwater	Y			Y			Y			Y			Y															N ^a			
Surface water	Y			Y			Y			Y			Y															N ^b			N
Soil (source area)	Y	N	N	Y	Y	N	Y	Y	N	Y	N	N	Y	Y	N																
Soil (hot spot)							Y	Y	Y				Y	Y	Y							Y	N	N	Y	N	N				
Waste Inventory	Y	Y											Y	Y																	
Soil Inventory				Y	N											Y	Y	N	Y	Y	N										
Leachate													Y																		
Fish																															Y
Creek Sediment																												Y ^c			N
Floodplain Soils																												N ^d	N	N	N

R = Residential; I = Industrial; M = Maintenance; Rc = Recreational; Y = Yes; N = No

A blank box implies "not applicable" and/or "not evaluated".

^a With the exception of location-specific COCs in GW-711 (Picket W well).

^b With the exception of location-specific COCs at location BCK-0.63 (near East Fork Poplar Creek).

^c Sediment COCs were identified at locations SD10 (between NT-8 and NT-9) and SD11 (near NT-11).

^d With the exception of location-specific COCs at location SP04 (near Hwy-95).

Table 6.1. Rationale for selection of assessment endpoints

Endpoint Entity	Level of Organization (Representative species)	Rationale
Fish	Community (N/A)	The fish community is considered to be an appropriate endpoint because it is ecologically important, susceptible, and has a scale appropriate to the site. The ecological significance comes from the fact that much of the energy flow in temperate streams passes through fishes, and fishes are a major nutrient reservoir in those systems. In addition, most of the fish species in the BCV CA move within an area smaller than the CA, so the scale is appropriate
Benthic invertebrates	Community (N/A)	The benthic invertebrate community is considered to be an appropriate endpoint community because benthic invertebrates are highly susceptible and have a scale appropriate to the site. The high susceptibility of these organisms is due to their association with the sediment and water. In addition, the insects and crustaceans that dominate this community are sensitive to a variety of contaminants. Because these organisms are sedentary, their scale is highly appropriate to the scale of the site.
Piscivorous wildlife	Population (mink and belted kingfisher)	Piscivorous wildlife are considered to be an appropriate endpoint trophic group because they are highly susceptible. Two of the contaminants of potential concern, PCBs and mercury, biomagnify in aquatic food webs, leading to high levels of exposure in piscivorous wildlife. Mink have been shown to be highly sensitive to the toxic effects of PCBs and mercury in toxicity tests. Reproduction of piscivorous birds has been shown to be highly sensitive to PCBs. Although populations of piscivorous wildlife are not as clearly associated with the CA as the aquatic communities, individuals forage within an area smaller than BCV (at least during the breeding season). Although the individuals inhabiting the CA do not constitute a biological population, they have been defined as a population for regulatory purposes. By this definition, the CA is an appropriate scale for this endpoint.
Terrestrial plants	Community (N/A)	The terrestrial plant community is considered to be an appropriate endpoint because it is ecologically important, susceptible, and has a scale appropriate to the site. The ecological significance comes from the fact that the plant community is responsible for primary production. This community is susceptible because it is directly exposed to the contaminants in the floodplain and source area soils. Finally, the scale is appropriate because plants are immobile and because a distinct plant community exists in BCV.

Table 6.1 (continued)

Endpoint Entity	Level of Organization (Representative species)	Rationale
Soil invertebrates	Community (N/A)	The soil invertebrate community is considered to be an appropriate endpoint because it is ecologically important, susceptible, and has a scale appropriate to the site. The primary value of this community is its functional role in decomposition and energy and nutrient cycling. The soil community is highly exposed to contaminated soil. The inherent sensitivity of soil processes to contaminants is low, but the sensitivity of particular taxa including earthworms is largely unknown. Earthworms are probably the most important soil invertebrate in promoting soil fertility (Edwards 1992). Their feeding and burrowing activities act to break down organic matter resulting in release of nutrients and to improve aeration, drainage, and aggregation of soil. Earthworms are also important components of the diets of many animals. Because of their small size and relative immobility, earthworms can be assessed on the scale of small subunits of OUs. The chosen characteristics of this endpoint are abundance or production.
Small vermivorous wildlife	Population (short-tailed shrew)	Small vermivorous wildlife are considered to be an appropriate endpoint because they are susceptible and have a scale appropriate to the site. Because vermivorous wildlife consume large volumes of invertebrates, they are highly exposed and susceptible to contaminants bioaccumulated by soil invertebrates. In addition, shrews, amphibians, and reptiles burrow and are in close physical contact with soil and may take up contaminants directly through ingestion or dermal contact. These species, however, are not known to play any particularly significant role in the ecosystems that they inhabit. Because many vermivores have limited home ranges and relatively low mobility, the CA is an appropriate scale to assess risks to their populations.
Small omnivorous wildlife	Population (white-footed mouse)	are considered to be an appropriate endpoint because they are susceptible and have a scale appropriate to the site. Omnivorous wildlife are more exposed to chemicals than herbivores, possibly because of their consumption of ground invertebrates (Talmadge and Walton 1993). In addition, small omnivores burrow and are in close physical contact with soil and may take up contaminants directly through ingestion or dermal contact. Small omnivores are likely to be the most abundant mammalian group on most of the CA, though they are not known to play any particularly significant role in the ecosystems that they inhabit. Because small omnivores have limited home ranges, the CA is an appropriate scale to assess risks to their populations.

Table 6.1 (continued)

Endpoint Entity	Level of Organization (Representative species)	Rationale
Large herbivorous wildlife	Population (white-tailed deer)	Large herbivorous wildlife are considered to be an appropriate endpoint because they are societally important. Most large herbivores are valued game species, conspicuous, and aesthetically pleasing and therefore have high societal value. In general, these species are not known to play any particularly significant role in the ecosystems that they inhabit. Although populations of large herbivores are not as clearly associated with the CA as the small omnivores and vermivores, individuals are likely to forage within an area the size of the Bear Creek watershed. Although the individuals inhabiting the CA do not constitute a biological population, they have been defined as a population for regulatory purposes. By this definition, the CA is an appropriate scale for this endpoint.
Predators and scavengers	Population (red-tailed hawk and red fox)	Predators and scavengers are considered to be an appropriate endpoint because they are susceptible and societally important. They are susceptible to contamination because they are at the top of the food web and spatially integrate chemicals bioaccumulated by lower trophic levels. Avian predators and scavengers are conspicuous and generally aesthetically appealing so they have high societal value. While most mammalian predators are not conspicuous, the status of their populations is a concern to the public. Although populations of predators and scavengers are not as clearly associated with the CA as the small omnivores and vermivores, individuals are likely to forage within an area the size of the Bear Creek watershed. Although the individuals inhabiting the CA do not constitute a biological population, they have been defined as a population for regulatory purposes. By this definition, the CA is an appropriate scale for this endpoint.
Threatened and endangered species	Individuals (cooper's hawk, sharp-shinned hawk, and northern pine snake)	Threatened and endangered species are, in general, too rare to be ecologically significant and may not be particularly susceptible or clearly associated with the site. However, they have high societal and policy importance. Because of the particular societal value placed on these organisms, as reflected in the Endangered Species Act, the endpoint properties for these species are any toxic effect that would reduce survivorship or fecundity of individuals of listed threatened or endangered species that currently occur in the CA or may occur in the future. Threatened and endangered species that occur in the region are listed in Appendix D. The evaluation of federally and state-listed threatened and endangered species with habitat requirements or food habits that could lead to significant exposure in the CA is addressed in Sect. G.1.

Table 6.2. Summary of the current risk characterization for the fish communities in Bear Creek and tributaries NT-2 through NT-8

Exposure area	Evidence	Result	Explanation
Reach 1	Biological surveys	-	Species richness and total density of fish community has increased since 1989 and is comparable to reference communities.
		-	Tennessee dace has successfully colonized this reach. Densities at the uppermost site are comparable to the reference streams, though the high year-to-year variability may obscure subtle differences. Observed differences are likely to be due to low stream flow, especially at BCK 11.83.
	Toxicity tests	+	Survival and reproduction of <i>Ceriodaphnia dubia</i> continue to be drastically reduced. Calcium and manganese concentrations were significantly correlated with these responses.
	Body burdens	-	Mercury and PCB concentrations for whole fish are less than all body burden benchmarks.
	Media analyses	+	Calcium, cadmium, and uranium concentrations are likely to be toxic. Nickel is likely to be toxic to sensitive species. Toxicity is possible, but not likely, from barium and copper.
	Weight of evidence	-	The fish community does not appear to be significantly degraded due to contaminant concentrations. The surveyed fish community is apparently less sensitive than <i>Ceriodaphnia</i> to the elevated chemical concentrations.
		-	The Tennessee dace population does not appear to be reduced by a contaminant effect: highest densities occur at the most highly contaminated site (BCK 12.36). Lower densities at BCK 11.83 are likely due to intermittent stream flow.
Reach 2	Biological surveys	-	Species richness and total density of fish community is comparable to reference communities. Habitat quality (i.e., intermittent flow and siltation) and the weir at BCK 4.55 are probably limiting factors.
		-	Densities of Tennessee dace at several sites are low relative to reference streams, but this appears to be due to low stream flow and/or siltation, especially at BCKs 11.09 and 9.91.
	Toxicity tests	-	100% mortality of <i>Ceriodaphnia dubia</i> in water from furthest upstream site (BCK 11.09) was observed once in 1991. Significant effects have not been observed since then, or at other sites in this reach. Hence this is considered to be not representative of current conditions in this reach.

Table 6.2 (continued)

Exposure area	Evidence	Result	Explanation
Reach 3	Body burdens	N/A	Body burdens were not measured.
	Media analyses	+	Cadmium concentrations are likely to be toxic at BCK 9.4. Toxicity also is possible, but not likely, from barium, boron, copper, iron, nickel, and uranium.
	Weight of evidence	-	The fish community does not appear to be significantly degraded due to a contaminant effect.
		-	The Tennessee dace population does not appear to be reduced by a contaminant effect. Low stream flow and siltation are probably limiting factors.
	Biological surveys	-	Species richness and total density of fish community are comparable to reference communities.
		-	Tennessee dace densities are within the range of densities observed at reference sites, though high year-to-year variability may obscure subtle differences. Siltation has been identified as a possible problem at BCK 7.87.
	Toxicity tests	-	Significant toxic effects have not been observed in this reach.
	Body burdens	-	Significant toxicity is not expected. Mercury concentrations are below all benchmarks and PCB concentrations exceeded only one very low screening value.
	Media analyses	-	None of the COPECs occur at concentrations likely to be toxic. Toxicity is possible, but not likely, from copper, iron, nickel, and uranium.
	Weight of evidence	-	The fish community does not appear to be significantly degraded due to a contaminant effect.
		-	The Tennessee dace population does not appear to be reduced by a contaminant effect. Habitat quality is probably a limiting factors.
Reach 4	Biological surveys	-	Species richness and total density of fish community are comparable to reference communities.
		N/A	Tennessee dace are not expected to inhabit this reach.
	Toxicity tests	N/A	Toxicity tests were not conducted.

Table 6.2 (continued)

Exposure area	Evidence	Result	Explanation
NT-2	Body burdens	±	Mercury and PCB concentrations in rock bass fillets suggest that toxicity to sensitive species is possible, but unlikely. Increasing mercury concentrations suggest that risks may increase in the future.
	Media analyses	-	None of the COPECs occur at concentrations likely to be toxic. Toxicity is possible, but not likely, from copper, iron, nickel, and uranium.
	Weight of evidence	-	The fish community does not appear to be significantly impacted in this reach.
		-	The Tennessee dace is not expected to use this reach.
	Biological surveys	N/A	The fish community was not surveyed.
	Toxicity tests	+	<i>Ceriodaphnia dubia</i> reproduction was reduced by 37% in one of two tests, though survival was 100% in both tests. Calcium concentrations were significantly correlated with this response. Fathead minnows were not significantly affected. However, the intensity and frequency of effects was higher for Reach 1.
	Body burdens	N/A	Body Burdens were not measured.
	Media analyses	+	Calcium concentrations are likely to be toxic. Toxicity also is possible, but not likely, from barium. However, there were more COPECs at higher concentrations in Reach 1.
	Weight of evidence	-	Given that the fish community in Reach 1 is not at risk, it is highly unlikely that the fish using NT-2 are at risk. Also, the fish in NT-2 are functionally part of the community in Reach 1, because NT-2 is too small to support a distinct fish community.
	Weight of evidence	-	The toxicity tests are considered to best represent the actual risks to fish and none of the COPECs are likely to be toxic.
NT-3	Biological surveys	N/A	The fish community was not surveyed.
	Toxicity tests	-	<i>Ceriodaphnia dubia</i> and fathead minnows were not significantly affected during the two tests conducted using water from this site.
	Body burdens	N/A	Body Burdens were not measured.
	Media analyses	+	Toxicity is possible, but not likely, from the observed concentrations of lithium.
	Weight of evidence	-	The toxicity tests are considered to best represent the actual risks to fish and none of the COPECs are likely to be toxic.
NT-4	Biological surveys	N/A	The fish community was not surveyed.

Table 6.2 (continued)

Exposure area	Evidence	Result	Explanation
NT-5	Toxicity tests	-	<i>Ceriodaphnia dubia</i> and fathead minnows were not significantly affected during the two tests conducted using water from this site.
	Body burdens	N/A	Body Burdens were not measured.
	Media analyses	-	None of the COPECs occurred at concentrations likely to be toxic.
	Weight of evidence	-	The toxicity tests are considered to represent the actual risks to fish and none of the COPECs are likely to be toxic.
	Biological surveys	N/A	The fish community was not surveyed.
NT-6	Toxicity tests	-	<i>Ceriodaphnia dubia</i> and fathead minnows were not significantly affected during the two tests conducted using water from this site.
	Body burdens	N/A	Body Burdens were not measured.
	Media analyses	-	None of the COPECs occurred at concentrations likely to be toxic.
	Weight of evidence	-	The toxicity tests are considered to represent the actual risks to fish and none of the COPECs are likely to be toxic.
	Biological surveys	N/A	The fish community was not surveyed.
NT-7	Toxicity tests	-	<i>Ceriodaphnia dubia</i> and fathead minnows were not significantly affected during the two tests conducted using water from this site.
	Body burdens	N/A	Body Burdens were not measured
	Media analyses	-	Toxicity is possible, but not likely, from the observed concentrations of lithium.
	Weight of evidence	-	The toxicity tests are considered to represent the actual risks to fish and none of the COPECs are likely to be toxic.
	Biological surveys	N/A	The fish community was not surveyed.

Table 6.2 (continued)

Exposure area	Evidence	Result	Explanation
NT-8	Biological surveys	N/A	The fish community was not surveyed.
	Toxicity tests	-	<i>Ceriodaphnia dubia</i> and fathead minnows were not significantly affected during the two tests conducted using water from this site.
	Body burdens	N/A	Body Burdens were not measured.
	Media analyses	-	Toxicity is possible, but not likely, from the observed concentrations of lithium and mercury.
	Weight of evidence	-	The toxicity tests are considered to represent the actual risks to fish and none of the COPECs are likely to be toxic.

+ indicates that the evidence is consistent with the occurrence of a 20% reduction in species richness or abundance of the fish community.

- indicates that the evidence is inconsistent with the occurrence of a 20% reduction in species richness or abundance of the fish community.

± indicates that the evidence is too ambiguous to interpret.

Table 6.3 Summary of the characterization of future risks to aquatic biota based on predicted maximum surface water concentrations^a

Location	Likelihood of Effects (predicted time range) ^b		Future Risks
	Possible	Expected	
NT-1	Mercury (40-100)	Cadmium (40-200) Calcium (35-100) Nickel (40-100) Uranium (40-150)	Increase - peak exposures expected in ~50-150 years.
NT-2	Barium (40-100)	Calcium (75-400)	Increase - peak exposures expected in ~50-350 years.
NT-3	Mercury (steady-state)	Cadmium (steady-state) Nickel (steady-state) Uranium (steady-state)	Unchanged.
NT-7	Tetrachloroethene (20-200)	Beryllium (>1000) Cadmium (>1000) Copper (>1000) Cyanide (10-100) Lead (>1000) Lithium (>1000) Nickel (>1000) Uranium (>1000)	Increase - slowly over next 1000 years for most chemicals.
NT-8	Cadmium (>1000)	Boron (steady-state) Beryllium (>1000) Copper (>1000) Cyanide (10-100) Lead (>1000) Lithium (>1000) Nickel (>1000) Uranium (>1000) Total PCBs (steady-state) Bis(2-ethylhexyl)-phthalate (steady-state)	Increase - slowly over next 1000 years for most chemicals.
Bear Creek above NT-1	Not Applicable	Not Applicable	Decrease - exposures not expected to meet RBRGOs for 30 - 40 years.
Bear Creek Between BCK 9.47 and NT-1	Not Predicted	Not Predicted	Not Predicted - but cannot be assumed to decrease given increased inputs from NT-1 and NT-2.

Table 6.3 (continued)

Location	Likelihood of Effects (predicted time range) ^b		
	Possible	Expected	Future Risks
Bear Creek at BCK 9.47	Beryllium (Not Predicted) Copper (Not Predicted)	Cadmium (Not Predicted) Cyanide (Not Predicted) Lithium (Not Predicted) Uranium (Not Predicted)	Increase - peak times could not be estimated as modeled.

^abased on model results and evaluations presented in Appendix E.

^btime range is estimated number of years, from start of waste operations, to reach peak concentrations.

Table 6.4. Summary of the current risk characterization for the benthic invertebrate communities in Bear Creek, tributaries NT-2 through NT-8, and seeps SS-1, SS-4, SS-5, SS-6, and SS-8

Exposure area	Evidence	Result	Explanation
Reach 1	Biological surveys	+	The community has improved, but is still severely degraded. Total and EPT richness continue to be lower than reference streams. The snail <i>Elimia</i> is still absent from the uppermost site (BCK 12.36). The absence of mayflies (<i>Ephemeroptera</i>) is suggestive of metals toxicity.
	Toxicity tests	+	Survival and reproduction of <i>Ceriodaphnia dubia</i> continue to be drastically reduced. Calcium and manganese concentrations were significantly correlated with these responses.
	Media analyses	+	Calcium, cadmium, and uranium concentrations are likely to be toxic. Nickel is likely to be toxic to sensitive species. Toxicity is possible, but not likely, from barium and copper.
	Weight of evidence	+	Reach 1 water appears to pose a significant risk to the benthic invertebrate community from high concentrations of calcium, cadmium, manganese, nickel, and uranium.
Reach 2	Biological surveys	+	Community has improved, but is still moderately degraded. Total and EPT richness and abundance are generally lower than reference streams. The very low mayfly (<i>Ephemeroptera</i>) density and richness is suggestive of metals toxicity.
	Toxicity tests	-	100% mortality of <i>Ceriodaphnia dubia</i> in water from the farthest upstream site (BCK 11.09) was observed once in 1991. Significant effects have not been observed since then, or at other sites in this reach. Hence this is not considered to be representative of current conditions in this reach.
	Media analyses	+	Cadmium concentrations are likely to be toxic at BCK 9.4. Toxicity also is possible, but not likely, from barium, boron, copper, iron, nickel, and uranium.
	Weight of evidence	+	Reach 2 water appears to pose a significant risk to the benthic invertebrate community from high concentrations of cadmium.

Table 6.4 (continued)

Exposure area	Evidence	Result	Explanation
Reach 3	Biological surveys	+	Community has improved, but is still moderately degraded above BCK 3.25. Total and EPT richness and abundance are generally lower than reference streams. The very low mayfly (<i>Ephemeroptera</i>) density and richness is suggestive of metals toxicity. Habitat quality is likely a contributing factor at BCK 7.87.
	Toxicity tests	-	Significant toxic effects have not been observed in this reach.
	Media analyses	-	None of the COPECs occur at concentrations likely to be toxic. Toxicity is possible, but not likely, from copper, iron, nickel, and uranium.
	Weight of evidence	-	Although the benthic invertebrate communities just below BCK 9.4 and at BCK 7.87 are generally less rich and abundant than references, none of the COPECs are likely to be toxic, the water has never been shown to be toxic, and siltation at BCK 7.87 has degraded the habitat.
Reach 4	Biological surveys	-	The benthic invertebrate community is comparable to reference communities.
	Toxicity tests	N/A	Toxicity tests were not conducted.
	Media analyses	-	None of the COPECs occur at concentrations likely to be toxic. Toxicity is possible, but not likely, from copper, iron, nickel, and uranium.
	Weight of evidence	-	The benthic invertebrate community does not appear to be significantly degraded in this reach.
NT-2	Biological surveys	N/A	The benthic invertebrate community was not surveyed.
	Toxicity tests	+	<i>Ceriodaphnia dubia</i> reproduction was reduced by 37% in one of two tests, though survival was 100% in both tests. Calcium concentrations were significantly correlated with this response. Fathead minnows were not significantly affected.
	Media analyses	+	Calcium concentrations are likely to be toxic. Toxicity also is possible, but not likely, from barium.
	Weight of evidence	+	Toxicity tests results indicate that chronic toxicity to sensitive species during base flow conditions is likely. The most probable contributor to toxicity is calcium.

Table 6.4 (continued)

Exposure area	Evidence	Result	Explanation
NT-3	Biological surveys	N/A	The benthic invertebrate community was not surveyed.
	Toxicity tests	-	<i>Ceriodaphnia dubia</i> and fathead minnows were not significantly affected during the two tests conducted using water from this site.
	Media analyses	-	Toxicity is possible, but not likely, from the observed concentrations of lithium.
	Weight of evidence	-	The toxicity tests are considered to best represent the actual risks to benthic invertebrates and none of the COPECs are likely to be toxic.
NT-4	Biological surveys	N/A	The benthic invertebrate community was not surveyed.
	Toxicity tests	-	<i>Ceriodaphnia dubia</i> and fathead minnows were not significantly affected during the two tests conducted using water from this site.
	Media analyses	-	None of the COPECs occurred at concentrations likely to be toxic.
	Weight of evidence	-	The toxicity tests are considered to represent the actual risks to benthic invertebrates and none of the COPECs are likely to be toxic.
NT-5	Biological surveys	N/A	The benthic invertebrate community was not surveyed.
	Toxicity tests	-	<i>Ceriodaphnia dubia</i> and fathead minnows were not significantly affected during the two tests conducted using water from this site.
	Media analyses	-	None of the COPECs occurred at concentrations likely to be toxic.
	Weight of evidence	-	The toxicity tests are considered to represent the actual risks to benthic invertebrates and none of the COPECs are likely to be toxic.
NT-6	Biological surveys	N/A	The benthic invertebrate community was not surveyed.
	Toxicity tests	-	<i>Ceriodaphnia dubia</i> and fathead minnows were not significantly affected during the two tests conducted using water from this site.
	Media analyses	-	None of the COPECs occurred at concentrations likely to be toxic.
	Weight of evidence	-	The toxicity tests are considered to represent the actual risks to benthic invertebrates and none of the COPECs are likely to be toxic.

Table 6.4 (continued)

Exposure area	Evidence	Result	Explanation
NT-7	Biological surveys	N/A	The benthic invertebrate community was not surveyed.
	Toxicity tests	-	<i>Ceriodaphnia dubia</i> and fathead minnows were not significantly affected during the two tests conducted using water from this site.
	Media analyses	-	Toxicity is possible, but not likely, from the observed concentrations of lithium.
	Weight of evidence	-	The toxicity tests are considered to represent the actual risks to benthic invertebrates and none of the COPECs are likely to be toxic.
NT-8	Biological surveys	N/A	The benthic invertebrate community was not surveyed.
	Toxicity tests	-	<i>Ceriodaphnia dubia</i> and fathead minnows were not significantly affected during the two tests conducted using water from this site.
	Media analyses	-	Toxicity is possible, but not likely, from the observed concentrations of lithium and mercury.
	Weight of evidence	-	The toxicity tests are considered to represent the actual risks to benthic invertebrates and none of the COPECs are likely to be toxic.
SS-1	Biological surveys	N/A	The benthic invertebrate community was not surveyed.
	Toxicity tests	+	<i>Ceriodaphnia dubia</i> survival was reduced by 40% in May 1994 and reproduction was reduced by 52% and 45% in May and August of 1994, respectively. Fathead minnow survival was reduced by 30% in May 1994.
	Media analyses	+	Calcium, cadmium, and nickel concentrations are likely to be toxic. Toxicity also is possible, but not likely, from barium, copper, iron, nickel, and manganese.
	Weight of evidence	+	SS-1 water appears to pose a significant risk to benthic invertebrates from high concentrations of calcium, cadmium, and nickel.
SS-4	Biological surveys	N/A	The benthic invertebrate community was not surveyed.
	Toxicity tests	+	<i>Ceriodaphnia dubia</i> reproduction was reduced by 29% in August 1994. Fathead minnow survival was reduced by 21% in August 1994.
	Media analyses	-	Toxicity is possible, but not likely, from the observed concentrations of lithium, barium, nickel, and uranium.

Table 6.4 (continued)

Exposure area	Evidence	Result	Explanation
SS-5	Weight of evidence	+	The toxicity tests are considered to represent the actual risks to benthic invertebrates. Although the evidence is weak, lithium, barium, nickel, or uranium may be the cause of toxicity.
	Biological surveys	N/A	The benthic invertebrate community was not surveyed.
	Toxicity tests	-	<i>Ceriodaphnia dubia</i> and fathead minnows were not significantly affected during the two tests conducted using water from this site.
	Media analyses	-	Toxicity is possible, but not likely, from the observed concentrations of copper and nickel.
SS-6	Weight of evidence	-	The toxicity tests are considered to represent the actual risks to benthic invertebrates and none of the COPECs are likely to be toxic.
	Biological surveys	N/A	The benthic invertebrate community was not surveyed.
	Toxicity tests	-	<i>Ceriodaphnia dubia</i> and fathead minnows were not significantly affected during the two tests conducted using water from this site.
	Media analyses	-	Toxicity is possible, but not likely, from the observed concentrations of copper, nickel, and uranium.
SS-8	Weight of evidence	-	The toxicity tests are considered to represent the actual risks to benthic invertebrates and none of the COPECs are likely to be toxic.
	Biological surveys	N/A	The benthic invertebrate community was not surveyed.
	Toxicity tests	-	<i>Ceriodaphnia dubia</i> and fathead minnows were not significantly affected during the two tests conducted using water from this site.
	Media analyses	-	Toxicity is possible, but not likely, from the observed concentrations of copper and nickel.
	Weight of evidence	-	The toxicity tests are considered to represent the actual risks to benthic invertebrates and none of the COPECs are likely to be toxic.

+ indicates that the evidence is consistent with the occurrence of a 20% reduction in species richness of abundance of the fish community.

- indicates that the evidence is inconsistent with the occurrence of a 20% reduction in species richness of abundance of the fish community.

± indicates that the evidence is too ambiguous to interpret.

Table 6.5. Summary of the risk characterization for benthic invertebrates in depositional areas in Bear Creek and tributaries NT-2, NT-3, NT-4, NT-6, NT-8, and ET-4

Exposure area (site)	Evidence	Result	Explanation
Reach 1 (SD 2)	Toxicity tests	-	<i>H. azteca</i> and <i>D. magna</i> survival were not significantly reduced.
	Media analyses	+	Cadmium, mercury, manganese, and nickel concentrations are likely to be toxic.
	Weight of evidence	-	SD 2 sediment does not appear to be toxic to benthic invertebrates.
Reach 1 (SD 1)	Toxicity tests	-	<i>H. azteca</i> and <i>D. magna</i> survival were not significantly reduced.
	Media analyses	+	Endrin concentrations are likely to be toxic.
	Weight of evidence	-	SD 1 sediment does not appear to be toxic to benthic invertebrates.
Reach 1 (SD 14)	Toxicity tests	-	<i>H. azteca</i> and <i>D. magna</i> survival were not significantly reduced.
	Media analyses	+	Cadmium, iron, manganese, and nickel concentrations are likely to be toxic.
	Weight of evidence	-	SD 14 sediment does not appear to be toxic to benthic invertebrates.
NT-2 (SD 3)	Toxicity tests	±	<i>D. magna</i> survival was reduced by 33%, which was not statistically different from references, and <i>H. azteca</i> survival was not reduced by 20% or more relative to references.
	Media analyses	+	Manganese concentrations are likely to be toxic, but concentrations are higher at several other sites where toxicity was not evident. The highest concentration of 2,4,5-T, for which a benchmark is not available, occurs at this site.
	Weight of evidence	+	SD 3 sediment appears to pose a significant risk to benthic invertebrates, potentially from high concentrations of 2,4,5-T.
NT-3 (SD 4)	Toxicity tests	-	<i>H. azteca</i> and <i>D. magna</i> survival were not significantly reduced.
	Media analyses	+	Cadmium, chromium, copper, iron, lead, mercury, manganese, silver, zinc, and Total PAH concentrations are likely to be toxic.
	Weight of evidence	-	Although this is the most contaminated site, SD 4 sediment does not appear to be toxic to benthic invertebrates.
NT-4 (SD 5)	Toxicity tests	-	<i>H. azteca</i> and <i>D. magna</i> survival were not significantly reduced.

Table 6.5 (continued)

Exposure area (site)	Evidence	Result	Explanation
Reach 2 (SD 7)	Media analyses	-	None of the COPECs occur at concentrations that are likely to be toxic.
	Weight of evidence	-	SD 5 sediment does not appear to be toxic to benthic invertebrates.
	Toxicity tests	-	<i>H. azteca</i> and <i>D. magna</i> survival were not significantly reduced.
	Media analyses	+	Cadmium and manganese concentrations are likely to be toxic.
	Weight of evidence	-	SD 7 sediment does not appear to be toxic to benthic invertebrates.
Reach 2 (SD 6)	Toxicity tests	-	<i>H. azteca</i> and <i>D. magna</i> survival were not significantly reduced.
	Media analyses	+	None of the COPECs occur at concentrations that are likely to be toxic.
	Weight of evidence	-	SD 6 sediment does not appear to be toxic to benthic invertebrates.
	Toxicity tests	±	<i>D. magna</i> survival was reduced by 30%, which was not statistically different from references, and <i>H. azteca</i> survival was not reduced by 20% or more relative to references.
NT-6 (SD 8)	Media analyses	+	Iron and manganese concentrations are likely to be toxic. This is the highest manganese concentration, but iron concentrations are higher at other sites where toxicity was not observed. Also, some of the highest concentrations of two chemicals for which benchmarks are not available occur at this site: selenium and 2,4,5-T.
	Weight of evidence	+	SD 8 sediment appears to pose a significant risk to the benthic invertebrate community from high concentrations of manganese, and, potentially, selenium and 2,4,5-T.
	Toxicity tests	-	<i>H. azteca</i> and <i>D. magna</i> survival were not significantly reduced.
	Media analyses	-	None of the COPECs occur at concentrations that are likely to be toxic.
NT-8 (SD 9)	Weight of evidence	-	SD 9 sediment does not appear to be toxic to benthic invertebrates.
	Toxicity tests	-	<i>H. azteca</i> and <i>D. magna</i> survival were not significantly reduced.
	Media analyses	-	None of the COPECs occur at concentrations that are likely to be toxic.
Reach 2 (SD 10)	Toxicity tests	-	<i>H. azteca</i> and <i>D. magna</i> survival were not significantly reduced.

Table 6.5 (continued)

Exposure area (site)	Evidence	Result	Explanation
Reach 3 (SD 11)	Media analyses	+	Endrin and manganese concentrations are likely to be toxic.
	Weight of evidence	-	SD 10 sediment does not appear to be toxic to benthic invertebrates.
	Toxicity tests	-	<i>H. azteca</i> and <i>D. magna</i> survival were not significantly reduced.
	Media analyses	+	Chromium, iron, and manganese concentrations are likely to be toxic.
Reach 3 (SD 12)	Weight of evidence	-	SD 11 sediment does not appear to be toxic to benthic invertebrates.
	Toxicity tests	-	<i>H. azteca</i> and <i>D. magna</i> survival were not significantly reduced.
	Media analyses	-	None of the COPECs occur at concentrations that are likely to be toxic.
	Weight of evidence	-	SD 12 sediment does not appear to be toxic to benthic invertebrates.
Reach 3 (SD 13)	Toxicity tests	±	<i>D. magna</i> survival was reduced by 22%, but this was not statistically different from references, this test may not be reliable, and <i>H. azteca</i> survival was not reduced by 20% or more relative to references.
	Media analyses	-	None of the COPECs occur at concentrations that are likely to be toxic. All chemicals detected at this site for which benchmarks were not available are present at higher concentrations at other sites where toxicity was not evident.
	Weight of evidence	-	SD 13 sediment was toxic to <i>D. magna</i> , but confidence in this test is low and none of the COPECs occur at concentrations that are likely to be toxic.
	Toxicity tests	-	<i>H. azteca</i> and <i>D. magna</i> survival were not significantly reduced.
Reach 3 (SD 15)	Media analyses	-	None of the COPECs occur at concentrations that are likely to be toxic.
	Weight of evidence	-	SD 15 sediment does not appear to be toxic to benthic invertebrates.
	Toxicity tests	-	<i>H. azteca</i> and <i>D. magna</i> survival were not significantly reduced.
	Media analyses	-	None of the COPECs occur at concentrations that are likely to be toxic.

Table 6.5 (continued)

Exposure area (site)	Evidence	Result	Explanation
Reach 4 (SD 17)	Weight of evidence	-	SD 16 sediment does not appear to be toxic to benthic invertebrates.
	Toxicity tests	+	<i>H. azteca</i> and <i>D. magna</i> survival were reduced by 38% and 44%, respectively, and the mortality of <i>H. azteca</i> was statistically significantly different from controls.
	Media analyses	-	None of the COPECs occur at concentrations that are likely to be toxic. All chemicals detected at this site for which toxicological data were not available are present at higher concentrations at other sites where toxicity was not evident.
ET-4 (SD 18)	Weight of evidence	+	SD 17 sediment appears to pose a significant risk to benthic invertebrates at this site, but none of the COPECs occur at concentrations that are likely to be toxic.
	Toxicity tests	N/A	Toxicity tests were not conducted for this site.
	Media analyses	-	None of the COPECs occur at concentrations that are likely to be toxic.
	Weight of evidence	-	SD 18 sediment is not expected to be toxic to benthic invertebrates.

+ indicates that the evidence is consistent with the occurrence of a 20% reduction in species richness of abundance of the fish community.

- indicates that the evidence is inconsistent with the occurrence of a 20% reduction in species richness of abundance of the fish community.

± indicates that the evidence is too ambiguous to interpret.

Table 6.6. Summary of risk characterization for soil invertebrates by transect

Transect	Evidence	Result	Explanation
TS01	Literature toxicity data	+	Mercury at concentration 70 times benchmark.
	Medium toxicity tests	-	No evidence of toxicity to earthworms.
	Weight of evidence	-	There is no evidence that the soils of TS01 are toxic to soil invertebrates.
TS02	Literature toxicity data	+	Mercury at concentration 20 times benchmark.
	Medium toxicity tests	-	No evidence of toxicity to earthworms.
	Weight of evidence	-	There is no evidence that the soils of TS02 are toxic to soil invertebrates.
TS03	Literature toxicity data	+	Mercury at concentration 30 times benchmark.
	Medium toxicity tests	-	No evidence of toxicity to earthworms.
	Weight of evidence	-	There is no evidence that the soils of TS03 are toxic to soil invertebrates.
TS04	Literature toxicity data	+	Mercury at concentration above benchmark.
	Medium toxicity tests	-	No evidence of toxicity to earthworms.
	Weight of evidence	-	There is no evidence that the soils of TS04 are toxic to soil invertebrates.
TS05	Literature toxicity data	-	No contaminants above benchmark concentration.
	Medium toxicity tests	-	No evidence of toxicity to earthworms.
	Weight of evidence	-	There is no evidence that the soils of TS05 are toxic to soil invertebrates.
TS06	Literature toxicity data	+	Mercury at concentration above benchmark.
	Medium toxicity tests	-	No evidence of toxicity to earthworms.
	Weight of evidence	-	There is no evidence that the soils of TS06 are toxic to soil invertebrates.
TS07	Literature toxicity data	+	Mercury at concentration benchmark.
	Medium toxicity tests	-	No evidence of toxicity to earthworms.
	Weight of evidence	-	There is no evidence that the soils of TS07 are toxic to soil invertebrates.
TS08	Literature toxicity data	+	Mercury at concentration above benchmark.
	Medium toxicity tests	-	No evidence of toxicity to earthworms.

Table 6.6 (continued)

Transect	Evidence	Result	Explanation
TS09	Weight of evidence	-	There is no evidence that the soils of TS08 are toxic to soil invertebrates.
	Literature toxicity data	-	Contaminant concentrations not measured above background.
	Medium toxicity tests	±	Low growth of earthworms at one site.
TS10	Weight of evidence	-	There is no evidence that the soils of TS09 are toxic to soil invertebrates.
	Literature toxicity data	-	No contaminants above benchmark concentration.
	Medium toxicity tests	-	No evidence of toxicity to earthworms.
TS11	Weight of evidence	-	There is no evidence that the soils of TS10 are toxic to soil invertebrates.
	Literature toxicity data	-	Contaminant concentrations not measured above background.
	Medium toxicity tests	NA	Growth of earthworms not tested.
TS12	Weight of evidence	-	There is no evidence that the soils of TS11 are toxic to soil invertebrates.
	Literature toxicity data	-	Contaminant concentrations not measured above background.
	Medium toxicity tests	NA	Growth of earthworms was not tested.
TS13	Weight of evidence	-	There is no evidence that the soils of TS12 are toxic to soil invertebrates.
	Literature toxicity data	-	No contaminants above benchmark concentration.
	Medium toxicity tests	-	No evidence of toxicity to earthworms.
	Weight of evidence	-	There is no evidence that the soils of TS13 are toxic to soil invertebrates.

Table 6.7. Summary of risk characterization for soil invertebrates in source areas

Source area	Evidence	Result	Explanation
S-3 Ponds area	Literature toxicity data	+	Mercury concentrations at mean of 148 and maximum of 829 times toxicity benchmarks.
	Medium toxicity tests	Insufficient data	No evidence that concentrations of mercury that are toxic to earthworms under laboratory conditions are not toxic in BCV soils.
	Weight of evidence	+	Mercury is an apparent COC for exposure of soil invertebrates in some parts of the S-3 Ponds area.
Boneyard Burnyard area	Literature toxicity data	+	Maximum concentrations of cadmium, chromium, copper, lead, mercury, nickel, and zinc are above toxicity benchmarks by a range of 1.6 to >750 fold.
	Medium toxicity tests	Insufficient data	No evidence that concentrations of contaminants that are toxic to earthworms under laboratory conditions are not toxic in BCV soils.
	Weight of evidence	+	Cadmium, chromium, copper, lead, mercury, nickel, and zinc are apparent COCs for exposure of soil invertebrates in some parts of the BYBY area.
Sanitary Landfill/Oil Landfarm area	Literature toxicity data	+	Maximum concentrations of copper, mercury, and zinc are above toxicity benchmarks. Mean copper and zinc concentrations are below toxicity benchmarks.
	Medium toxicity tests	Insufficient data	No evidence that concentrations of contaminants that are toxic to earthworms under laboratory conditions are not toxic in BCV soils.
	Weight of evidence	+	Copper, mercury, and zinc are apparent COCs for exposure of soil invertebrates in some parts of the SL/OLF area.
Burial Grounds area	Literature toxicity data	±	Maximum concentrations of chromium, mercury, and nickel exceed toxicity benchmarks. However, chromium exceeds background by only 5%, mercury is within the range of unpolluted soils, and nickel exceeds the benchmark by only 3%. The mean concentrations of all three COPECs are below background.
	Medium toxicity tests	Insufficient data	No evidence that concentrations of contaminants that are toxic to earthworms under laboratory conditions are not toxic in BCV soils.

Table 6.7 (continued)

Source area	Evidence	Result	Explanation
Creekside Debris Burial area	Weight of evidence	-	No evidence that BG soils are toxic to soil invertebrates.
	Literature toxicity data	+	The observed concentration of mercury exceeds the toxicity benchmark by >100-fold. The observed concentration of chromium exceeds the toxicity benchmark by >20-fold.
	Medium toxicity tests	Insufficient data	No evidence that concentrations of contaminants that are toxic to earthworms under laboratory conditions are not toxic in BCV soils.
Bear Creek Road Debris Burial area	Weight of evidence	+	Chromium and mercury are apparent COCs for exposure of soil invertebrates in the Creekside Debris Burial area.
	Literature toxicity data	+	The observed concentration of chromium exceeds the toxicity benchmark by >100-fold. The observed concentrations of copper and mercury exceed the toxicity benchmark by >30-fold. The observed concentration of zinc exceeds the toxicity benchmark by >5-fold.
	Medium toxicity tests	Insufficient data	No evidence that concentrations of contaminants that are toxic to earthworms under laboratory conditions are not toxic in BCV soils.
	Weight of evidence	+	Chromium, copper, mercury, and zinc are apparent COCs for exposure of soil invertebrates in the Bear Creek Road Debris Burial area.

Table 6.8. Summary of risk characterization for terrestrial plants by transect

Transect	Evidence	Result	Explanation
TS01	Literature toxicity data	+	Cadmium (TS012), lead (TS012), lithium (TS012), mercury (TS012, TS016), and selenium (TS012, TS016) at concentrations above benchmarks.
	Biological surveys	-	Several dead trees southeast of NT2 (near TS011, TS012, TS013), attributable to causes other than contaminants.
	Medium toxicity tests	-	No evidence of toxicity to lettuce seedlings.
	Weight of evidence	-	There is no evidence that the soils of TS02 are toxic to plants.
TS02	Literature toxicity data	+	Mercury, selenium, and thallium at concentrations above benchmarks at TS023.
	Biological surveys	NA	No surveys were performed.
	Medium toxicity tests	-	No evidence of toxicity to lettuce seedlings.
	Weight of evidence	-	There is no evidence that the soils of TS02 are toxic to plants.
TS03	Literature toxicity data	+	Cadmium (TS033), lithium (TS033), mercury (TS033, TS034), nickel (TS033, TS034), selenium (TS033, TS034) at concentrations above benchmarks.
	Biological surveys	-	No dead or visibly stressed vegetation near NT7 confluence with Bear Creek (near TS034, TS035, and TS036).
	Medium toxicity tests	±	Marginally low mean growth of lettuce seedlings at TS034.
	Weight of evidence	+	There is some evidence of adverse impacts to the plant community at TS033 and TS034.
TS04	Literature toxicity data	+	Lithium (TS042), selenium (TS041, TS042), mercury (TS042) at concentrations above benchmarks.
	Biological surveys	±	Several dead trees and stumps in wetland.
	Medium toxicity tests	+	Low mean growth of lettuce seedlings at TS041 and TS042.
	Weight of evidence	+	There is some evidence of adverse impacts to the plant community at TS041 and TS042.
TS05	Literature toxicity data	±	Selenium at concentration above benchmark at TS051.

Table 6.8 (continued)

Transect	Evidence	Result	Explanation
TS06	Biological surveys	NA	No surveys were performed.
	Medium toxicity tests	-	No evidence of toxicity to lettuce seedlings.
	Weight of evidence	-	There is no evidence that the soils of TS05 are toxic to plants.
	Literature toxicity data	+	Mercury (TS063, TS064) and selenium (TS064) at concentrations above benchmark.
TS07	Biological surveys	NA	No surveys were performed.
	Medium toxicity tests	-	No evidence of toxicity to lettuce seedlings.
	Weight of evidence	-	There is no evidence that the soils of TS06 are toxic to plants.
	Literature toxicity data	+	Cadmium (TS071), mercury (TS071, TS073), selenium (TS071, TS073) at concentrations above benchmark.
TS08	Biological surveys	NA	No surveys were performed.
	Medium toxicity tests	-	No evidence of toxicity to lettuce seedlings.
	Weight of evidence	-	There is no evidence that the soils of TS07 are toxic to plants.
	Literature toxicity data	+	Mercury and selenium at concentrations above benchmark.
TS09	Biological surveys	NA	No surveys were performed.
	Medium toxicity tests	-	No evidence of toxicity to lettuce seedlings.
	Weight of evidence	-	There is no evidence that the soils of TS08 are toxic to plants.
	Literature toxicity data	-	Contaminant concentrations not measured above background.
TS10	Biological surveys	NA	No surveys were performed.
	Medium toxicity tests	-	No evidence of toxicity to lettuce seedlings.
	Weight of evidence	-	There is no evidence that the soils of TS09 are toxic to plants.
	Literature toxicity data	±	Selenium concentration slightly above benchmarks.
	Biological surveys	NA	No surveys were performed.

Table 6.8 (continued)

Transect	Evidence	Result	Explanation
TS11	Medium toxicity tests	-	No evidence of toxicity to lettuce seedlings.
	Weight of evidence	-	There is little evidence that the soils of TS10 are toxic to plants.
	Literature toxicity data	-	Contaminant concentrations not measured above background.
	Biological surveys	NA	No surveys were performed.
TS12	Medium toxicity tests	NA	Growth of lettuce seedlings not tested.
	Weight of evidence	-	There is no evidence that the soils of TS11 are toxic to plants.
	Literature toxicity data	-	Contaminant concentrations not measured above background.
	Biological surveys	NA	No surveys were performed.
TS13	Medium toxicity tests	NA	Growth of lettuce seedlings not tested.
	Weight of evidence	-	There is no evidence that the soils of TS12 are toxic to plants.
	Literature toxicity data	-	Mercury, selenium at concentrations slightly above benchmarks.
	Biological surveys	NA	No surveys were performed.
	Medium toxicity tests	-	No evidence of toxicity to lettuce seedlings.
	Weight of evidence	-	There is little evidence that the soils of TS13 are toxic to plants.

Table 6.9. Summary of risk characterization for plants exposed to groundwater

Location	Evidence	Result	Explanation
SS1 region	Literature toxicity data	±	Aluminum at concentrations above benchmarks in unfiltered samples, but below background in filtered.
	Biological surveys	NA	The plant community was not surveyed.
	Weight of evidence	-	There is no evidence that groundwater feeding the spring is adversely impacting vegetation.
SS2 region	Literature toxicity data	NA	No contaminant data available.
	Biological surveys	-	Two dead trees observed, probably caused by canopy closure.
	Weight of evidence	-	There is no evidence that groundwater feeding the spring is adversely impacting vegetation.
SS3 region	Literature toxicity data	NA	No contaminant data available.
	Biological surveys	-	No dead, damaged or stressed vegetation was observed.
	Weight of evidence	-	There is no evidence that groundwater feeding the spring is adversely impacting vegetation.
SS4 region	Literature toxicity data	±	Aluminum at concentrations above benchmarks in unfiltered samples, but below background in filtered.
	Biological surveys	-	No dead, damaged or stressed vegetation was observed.
	Weight of evidence	-	There is no evidence that groundwater feeding the spring is adversely impacting vegetation.
SS5 region	Literature toxicity data	±	Arsenic at concentrations above benchmarks in two (of 14) filtered samples, but below background in unfiltered.
	Biological surveys	-	No dead, damaged or stressed vegetation was observed.
	Weight of evidence	-	There is no evidence that groundwater feeding the spring is adversely impacting vegetation.
SS6 region	Literature toxicity data	±	Aluminum at concentrations above benchmarks in unfiltered samples, but below background in filtered.
	Biological surveys	NA	The plant community was not surveyed.

Table 6.9 (continued)

Location	Evidence	Result	Explanation
SS8 region	Weight of evidence	-	There is no evidence that groundwater feeding the spring is adversely impacting vegetation.
	Literature toxicity data	+	Cadmium (TS071), mercury (TS071, TS073), selenium (TS071, TS073) at concentrations above benchmark.
	Biological surveys	NA	The plant community was not surveyed.
BCV floodplain at NT-1	Weight of evidence	-	There is no evidence that the soils of TS07 are toxic to plants.
	Literature toxicity data	±	Copper at concentrations above benchmarks in unfiltered samples from GW 345 and GW 526.
	Biological surveys	-	Several dead green ash and red maples, surrounded by healthy saplings
	Weight of evidence	-	There is no evidence that groundwater is adversely impacting vegetation.
BCV floodplain at NT-2	Literature toxicity data	-	Contaminant concentrations not measured above background in GW 537
	Biological surveys	±	Dead honeysuckle and several dead trees southeast of NT2, including tulip poplar and misshapen ash
	Medium toxicity tests	-	No evidence of toxicity to lettuce seedlings
	Weight of evidence	-	There is no evidence that groundwater is adversely impacting vegetation.

Table 6.10. Summary of risk characterization for terrestrial plants exposed to contaminants in soil in source areas

Evidence	Result	Explanation
<i>S-3 Ponds area, current exposure</i>		
Literature toxicity data	+	Mercury concentrations at maximum of 278 times toxicity benchmarks; arsenic, nickel, silver, vanadium, and zinc also exceed toxicity benchmarks.
Biological surveys	-	No dead or visibly stressed vegetation was observed in vegetated areas near the S-3 Ponds area during the June-July 1996 survey.
Medium toxicity tests	Insufficient data	Growth of lettuce seedlings was not tested. There is no evidence that observed concentrations of COPECs above soil toxicity benchmarks are not toxic to lettuce seeds.
Weight of evidence	-	Despite high apparent exposure of plants to arsenic, mercury, nickel, silver, vanadium, and zinc in soil, biological surveys do not indicate that soils in the S3 Ponds area are toxic to plants.
<i>BYBY area, current exposure</i>		
Literature toxicity data	+	Maximum concentrations of aluminum, antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, tin, vanadium, and zinc are above toxicity benchmarks by a range of 2 to >350 fold.
Biological surveys	-	No dead or visibly stressed vegetation was observed in portions of the BYBY area east, south, and northwest of the HCDA, except for willows that have died and resprouted in a seep north of the HCDA.
Medium toxicity tests	Insufficient data	Growth of lettuce seedlings was not tested. There is no evidence that observed concentrations of COPECs above soil toxicity benchmarks are not toxic to lettuce seeds.
Weight of evidence	-	Despite high apparent exposures of plants to aluminum, antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, tin, vanadium, and zinc in soil, biological surveys do not indicate that soils in the BYBY area are toxic to plants.
<i>SL 1/OLF area, current exposure</i>		
Literature toxicity data	+	Maximum concentrations of aluminum, arsenic, cobalt, copper, lithium, manganese, mercury, nickel, silver, vanadium, and zinc are above toxicity benchmarks by a range of 2.5 to 138 fold.
Biological surveys	-	No dead or visibly stressed vegetation was observed in the eastern end of the SL 1/OLF during the June-July 1996 survey.
Medium toxicity tests	Insufficient data	Growth of lettuce seedlings was not tested. There is no evidence that observed concentrations of COPECs above soil toxicity benchmarks are not toxic to lettuce seeds.
Weight of evidence	-	Despite high apparent exposure of plants to aluminum, arsenic, cobalt, copper, lithium, manganese, mercury, nickel, silver, vanadium, and zinc in soil, biological surveys do not indicate that soils in the SL 1/OLF area are toxic to plants.

Table 6.10. (continued)

Evidence	Result	Explanation
<i>BCBG area, current exposure</i>		
Literature toxicity data	+	Maximum concentrations of aluminum, arsenic, chromium, lithium, manganese, nickel, selenium, silver, vanadium, and zinc are above toxicity benchmarks by a range of 2 to >80 fold.
Biological surveys	-	No dead or visibly stressed vegetation was observed in portions of the BCBG area during the June-July 1996 survey. Ground cover was lacking or sparse at disturbed sites or those with little or no surface soil.
Medium toxicity tests	Insufficient data	Growth of lettuce seedlings was not tested. There is no evidence that observed concentrations of COPECs above soil toxicity benchmarks are not toxic to lettuce seeds.
Weight of evidence	-	Despite high apparent exposure of plants to aluminum, arsenic, chromium, lithium, manganese, nickel, selenium, silver, vanadium, and zinc in soil, biological surveys do not indicate that soils in the BCBG area are toxic to plants.
<i>Creekside Debris Burial area, current exposure</i>		
Literature toxicity data	+	Maximum concentrations of chromium, mercury, selenium, silver, and zinc exceed toxicity benchmarks by a range of 2.5 to ~150 fold.
Biological surveys	-	No dead or visibly stressed vegetation was observed in the Creekside Debris Burial area during the June-July 1996 survey.
Medium toxicity tests	Insufficient data	Growth of lettuce seedlings was not tested. There is no evidence that observed concentrations of COPECs above soil toxicity benchmarks are not toxic to lettuce seeds.
Weight of evidence	-	Despite high apparent exposure of plants to chromium, mercury, selenium, silver, and zinc in soil, biological surveys do not indicate that soils in the Creekside Debris Burial area are toxic to plants.
<i>Bear Creek Road Debris Burial area, current exposure</i>		
Literature toxicity data	+	Maximum concentrations of barium, cadmium, copper, mercury, nickel, selenium, silver, and zinc exceed toxicity benchmarks by a range of 1.2 to 18 fold.
Biological surveys	Insufficient data	Biological survey was not conducted.
Medium toxicity tests	Insufficient data	Growth of lettuce seedlings was not tested.
Weight of evidence	-	Concentrations of barium, cadmium, copper, mercury, nickel, selenium, silver, and zinc in debris are not higher than at sites where biological surveys do not indicate that soils are toxic to plants.
<i>S-3 Ponds sludges, future exposure</i>		

Table 6.10. (continued)

Evidence	Result	Explanation
Literature toxicity data	+	Estimated concentrations of chromium, lithium, and uranium exceed toxicity benchmarks by >100-fold. Concentrations of boron and nickel exceed toxicity benchmarks by >10-fold. concentrations of cadmium, mercury, and molybdenum exceed toxicity benchmarks by <10-fold.
Biological surveys	Insufficient data	Biological survey was not conducted.
Medium toxicity tests	Insufficient data	Growth of lettuce seedlings was not tested. There is no evidence that observed concentrations of COPECs above soil toxicity benchmarks are not toxic to lettuce seeds.
Weight of evidence	+	Boron, cadmium, chromium, lithium, mercury, molybdenum, nickel, and uranium are COCs for potential future exposure of plants to S-3 Pond sludges.
<i>BCBG Waste Inventory, future exposure</i>		
Literature toxicity data	+	Estimated concentrations of uranium exceed toxicity benchmarks by a range of >100 to >50,000-fold. Concentrations of beryllium and lithium exceed toxicity benchmarks by up to 110-fold and 140-fold, respectively. Lead and mercury exceed toxicity benchmarks by a range of 10- to >50-fold.
Biological surveys	Insufficient data	Biological survey was not conducted.
Medium toxicity tests	Insufficient data	Growth of lettuce seedlings was not tested. There is no evidence that observed concentrations of COPECs above soil toxicity benchmarks are not toxic to lettuce seeds.
Weight of evidence	+	Beryllium, lead, lithium, mercury, and uranium are COCs for potential future exposure of plants to inventoried wastes at the Burial Grounds area.

Table 6.11. Summary of risk characterization for terrestrial plants exposed to contaminants in shallow groundwater in source areas

Evidence	Result	Explanation
<i>S-3 Ponds area, NT1 and NT2</i>		
Literature toxicity data	+	Copper exceeded background and the toxicity benchmark, with HQ=1.6.
Medium toxicity tests	Insufficient data	No ambient toxicity testing of soil solutions was done.
Vegetation survey	-	No evidence was found for damage to plants by contaminants in groundwater or soil near NT1 and NT2.
Weight of evidence	-	Single chemical toxicity screen not supported by results of the vegetation survey.
<i>Boneyard Burnyard area, NT3</i>		
Literature toxicity data	+	Maximum concentrations of aluminum, arsenic, and lead are above toxicity benchmarks by a range of 2.5 to >15 fold.
Medium toxicity tests	Insufficient data	No ambient toxicity testing of soil solutions was done.
Vegetation survey	-	No evidence was found for damage to plants by contaminants in groundwater or soil near NT3, but dead vegetation was found in a seep on the north edge of HCDA.
Weight of evidence	+	HQs are low, and results of single chemical toxicity screen were not supported by results of the vegetation survey, except for possible intermittent toxicity in a seep near HCDA.
<i>Sanitary Landfill/Oil Landfarm area, NT4</i>		
Literature toxicity data	-	Maximum concentrations of aluminum, chromium, cobalt, iron, lead, and manganese are above toxicity benchmarks by a range of 1.5 to 215-fold.
Medium toxicity tests	Insufficient data	No ambient toxicity testing of soil solutions was done.
Vegetation survey	-	Vegetation near NT4 was not surveyed.
Weight of evidence	Insufficient data	No evidence was found for risk to plant populations

Table 6.11 (continued)

Evidence	Result	Explanation
<i>Burial Grounds area, NT6</i>		
Literature toxicity data	+	Maximum concentrations of aluminum, chromium, and lead are above toxicity benchmarks by a range of 1.2 to 16-fold.
Medium toxicity tests	Insufficient data	No ambient toxicity testing of soil solutions was done.
Vegetation survey	Insufficient data	Vegetation of NT7 was not surveyed.
Weight of evidence	-	Chromium HQ is low. Aluminum and lead concentrations are lower than at locations where the vegetation survey found no evidence of dead or stressed vegetation.
<i>Burial Grounds area, NT7</i>		
Literature toxicity data	+	Maximum concentrations of lead are above toxicity benchmarks by 26-fold.
Medium toxicity tests	Insufficient data	No ambient toxicity testing of soil solutions was done.
Vegetation survey	Insufficient data	Vegetation of NT7 was not surveyed.
Weight of evidence	-	Lead concentrations are lower than at locations where the vegetation survey found no evidence of dead or stressed vegetation.
<i>Burial Grounds area, NT8</i>		
Literature toxicity data	+	Maximum concentrations of aluminum, copper, iron, and lead are above toxicity benchmarks by a range of 3.3 to 132-fold.
Medium toxicity tests	Insufficient data	No ambient toxicity testing of soil solutions was done.
Vegetation survey	-	No evidence of dead or stressed vegetation.
Weight of evidence	-	Single chemical toxicity screen not supported by results of the vegetation survey.
<i>Burial Grounds area</i>		
Literature toxicity data	-	No contaminants were above background and a toxicity benchmark.
Medium toxicity tests	Insufficient data	No ambient toxicity testing of soil solutions was done.
Vegetation survey	-	No evidence of dead stressed vegetation.

Table 6.11 (continued)

Evidence	Result	Explanation
Weight of evidence	-	No COCs for exposure of plants to soil solution in parts of the BG area away from tributaries.

Table 6.12. Summary of COECs in non-waste inventory environmental media for ecological endpoint receptors

	Medium	Current COECs	Future COECs
Fish	Surface water	None	Barium, beryllium, cadmium, calcium, copper, cyanide, lead, lithium, mercury, nickel, uranium, and tetrachlorethene
Benthic invertebrates	Surface water	Cadmium, calcium, manganese, nickel, uranium	Barium, beryllium, cadmium, calcium, copper, cyanide, lead, lithium, mercury, nickel, uranium, and tetrachlorethene
Benthic invertebrates	Sediment	Manganese, selenium, 2,4,5-T	Assumed same as current.
Plants	Soil	Cadmium, lead, lithium, mercury, nickel, selenium	Assumed same as current.
Plants	Shallow groundwater	Aluminum, arsenic, chromium, cobalt, copper, iron, lead, manganese	Arsenic, beryllium, boron, cadmium, chromium, copper, lead, manganese, mercury, nickel, and tetrachlorethene
Soil invertebrates	Soil	Cadmium, chromium, copper, lead, mercury, nickel, zinc	Assumed same as current
Wildlife	Soil	Antimony, cadmium, chromium, copper, mercury, vanadium, PCBs	Assumed same as current
Wildlife	Surface water	None	None
Wildlife	Fish	Copper and mercury	Assumed same as current

Table 6.13 RBRGOs for reducing future risks to aquatic biota from chemicals for which adverse effects of predicted concentrations are possible or expected

Chemical	Modeled Location	Recommended RBRGO (mg/L)	Explanation
Barium	NT-2	5.8	LCV Daphnids
Beryllium	NT-7, NT-8, and BCK 9.47	0.0053	LCV Daphnids
Cadmium	NT-1, NT-7, and BCK 9.47	0.002	Chronic NAWQC ^a
Calcium	NT-1 and NT-2	116	LCV Daphnids
Copper	NT-7, NT-8, and BCK 9.47	0.0214	Chronic NAWQC ^a
Cyanide	NT-7, NT-8, and BCK 9.47	0.0052	Chronic NAWQC
Lead	NT-7 and NT-8	0.0077	Chronic NAWQC ^a
Lithium	NT-7, NT-8, and BCK 9.47	0.0144	Secondary Chronic Value
Mercury	NT-1	0.0013	Secondary Chronic Value
Nickel	NT-1, NT-7 and NT-8	0.015	background criteria (UTL)
Uranium	NT-1, NT-7, NT-8, and BCK 9.47	0.142	LCV Fish
Tetrachloroethene	NT-7	0.750	LCV Daphnids

^aBased on 200 mg/L hardness.

Table 6.14. RBRGOs for reducing risks to the benthic invertebrate community from contaminants in water

Chemical	Location	Recommended RBRGO (mg/L) ^a	Explanation
Cadmium	Reach 1, Reach 2, and SS-1	0.002	Chronic NAWQC2 ^b
Calcium	Reach 1, NT-2, and SS-1	116	LCV Daphnids
Manganese	Reach 1	6.6	background criteria (UTL)
Nickel	Reach 1, SS-1, and potentially SS-4	0.015	background criteria (UTL)
Uranium	Reach 1 and potentially SS-4	0.142	LCV Fish

^aConcentrations are dissolved for phase.

^bBased on 200 mg/L hardness.

Table 6.15. RBRGOs for reducing risks to benthic invertebrates inhabiting soft sediments from contaminants in sediments

Chemical	Location	Recommended RBRGO (mg/kg)	Explanation ^a
Manganese	NT-6 (SD 8)	7320	SSNAEL
Selenium	NT-6 (SD 8)	6.6	SSNAEL
2,4,5-T	NT-2 (SD 3) and NT-6 (SD 8)	0.013	SSNAEL

^aHighest concentration was among the following: generic probable effect levels, background UTL, and SSNAEL.

Table 6.16. RBRGOs for reducing risks to the plant community from contaminants in soils

Chemical	Location	Recommended RBRGO (mg/kg)	Explanation ^a
Antimony	BYBY	5	benchmark concentration
Arsenic	BYBY, SL/OLF, BG	20	background criteria (UTL)
Barium	BYBY, Bear Creek Rd. Debris Burial area	500	benchmark concentration
Cadmium	TS01, TS03, BYBY, Bear Creek Rd. Debris Burial area	0.3	benchmark concentration
Chromium	BYBY, BG, Creekside Debris Burial area	80	background criteria (UTL)
Cobalt	BYBY, SL/OLF	40	background criteria (UTL)
Copper	BYBY, SL/OLF, Bear Creek Rd. Debris Burial area	100	benchmark concentration
Lead	TS01, BYBY	50	benchmark concentration
Lithium	TS01, TS03, TS04, BYBY, SL/OLF, BG	1	benchmark concentration
Manganese	BYBY, SL/OLF, BG	2220	background criteria (UTL)
	TS01, TS03, TS04, S3 ponds, BYBY, SL/OLF, Creekside Debris Burial area, Bear Creek Rd. Debris Burial area		
Mercury		0.7	SSNAEL
Molybdenum	BYBY	2	benchmark concentration
	TS03, S3 ponds, BYBY, SL/OLF, BG, Bear Creek Rd. Debris Burial area		
Nickel		57	background criteria (UTL)
	TS01, TS03, TS04, BYBY, BG, Creekside Debris Burial area, Bear Creek Rd. Debris Burial area		
Selenium		2.5	SSNAEL
	S3 ponds, BYBY, SL/OLF, BG, Creekside Debris Burial area, Bear Creek Rd. Debris Burial area		
Silver		2.8	background criteria (UTL)
Tin	BYBY	50	benchmark concentration
Vanadium	S3 ponds, BYBY, SL/OLF, BG	60	background criteria (UTL)
	S3 ponds, BYBY, SL/OLF, BG, Creekside Debris Burial area, Bear Creek Rd. Debris Burial area		
Zinc		108	background criteria (UTL)

^aHighest concentration was among the following: benchmark, background UTL, and SSNAEL.

Table 6.17. RBRGOs for reducing risks to the plant community from contaminants in soil solution

Chemical	Location	Recommended RBRGO (mg/L)	Explanation ^a
Aluminum	SL/OLF near NT4, BG area near NT6, BG area near NT8	0.2	benchmark concentration
Chromium	SL/OLF near NT4	0.05	benchmark concentration
Cobalt	SL/OLF near NT4	0.06	benchmark concentration
Copper	BG area near NT8	0.05	benchmark concentration
Iron	SL/OLF near NT4, BG area near NT8	10	benchmark concentration
Lead	SL/OLF near NT4, BG area near NT6, BG area near NT7, BG area near NT8	0.02	benchmark concentration
Manganese	SL/OLF near NT4	4	benchmark concentration

^aHighest concentration was among the following: benchmark, UTL, and SSNAEL.

Table 6.18. RBRGOs for reducing risks to soil invertebrates from contaminants in soils

Chemical	Location	Recommended RBRGO (mg/kg)	Explanation ^a
Cadmium	BYBY	20	benchmark concentration
Chromium	BYBY, Creekside debris burial area, Bear Creek Rd. debris burial area	80	background criteria (UTL)
Copper	BYBY, SL/OLF, Bear Creek Rd. debris burial area	50	benchmark concentration
Lead	BYBY	500	benchmark concentration
Mercury	S3 ponds, BYBY, SL/OLF, Creekside debris burial area, Bear Creek Rd. debris burial area	0.7	SSNAEL
Nickel	BYBY	200	benchmark concentration
Zinc	BYBY, SL/OLF, Bear Creek Rd. debris burial area	200	benchmark concentration

^aHighest concentration was among the following: benchmark, UTL, and SSNAEL.

Table 6.19. Suggested RBRGOs for wildlife

Analyte	Calculated RGO (mg/kg)					Background Concentration (mg/kg)	Suggested RGO (mg/kg)
	Short-tailed Shrew ^a	White-footed Mouse ^a	Red Fox ^a	Mink ^a	Belted Kingfisher ^b		
Antimony	19 ^c					ND	19
Copper	45		18.5	36.5 ^d		15	18.5
Mercury	0.535	3.9	0.43	1.2 ^d	0.126	0.13	0.43
Vanadium	34					41	41
PCBs	0.18					NA	0.18

^aRGO represents the maximum allowable concentration in surface soil.

^bRGO represents the maximum allowable concentration in forage fish.

^cRGO represents exposure through soil consumption only

^dRGO represents exposure through consumption of soil and small mammals only

Table 6.20. Effects of remediation of selected sites on population-level risks to wildlife in Bear Creek

Endpoint	Area	Analyte	Sites where exposure set to 0 or background	Estimated Exposure (mg/kg/d)			LOAEL (mg/kg/d)	%> LOAEL
				Mean	Standard Deviation	80th Percentile		
Short-tailed Shrew	BCOU1	Antimony	BYBY	0.144	0.006	0.150	1.49	<5%
	BCV	Antimony	BYBY	0.124	0.002	0.126	1.49	<5%
	BCV	Copper	Roadside Area	10.83	1.95	12.38	44	<5%
	BCOU1	Mercury	S3, BYBY, OLF	0.220	0.004	0.223	0.352	<5%
	BCV	Mercury	Roadside Area, Creekside Area, S3, BYBY, OLF	0.212	0.018	0.228	0.352	<5%
	BCOU1	PCBs	Burial Grounds	0.127	0.029	0.15	0.668	<5%
	BCV	PCBs	Roadside Area, Creekside Area, Burial Ground, TS07, TS10	0.118	0.669	0.612	0.668	15%
White-footed Mouse	BCOU1	Mercury	S3	0.107	0.039	0.136	0.320	<5%
Red Fox	BCV	Copper	Roadside Area	3.001	1.044	3.879	10.6	<5%
	BCV	Mercury	Roadside Area, Creekside Area, S3, BYBY, OLF	0.0077	0.0007	0.008	0.017	<5%
Mink	BCV	Copper	Roadside Area	2.261	0.828	2.912	15.4	<5%
	BCV	Mercury	Roadside Area, Creekside Area, S3, BYBY, OLF	0.0027	0.0003	0.003	0.025	<5%

Table 7.1. Remedial goal options for chemicals of concern identified for BCV soils^a

Chemicals	Risk-based ^b						ARARs-based ^c
	Human health		Ecological				Future potential leaching to groundwater
	Residential	Industrial	Earth worm	Plants	Small mammal	Wide ranging	Human health receptor
Example of Entire-Risk Range (ILCR of 10 ⁻⁶ to 10 ⁻⁴ , or HQ of 0.1 to 10):							
	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴				
Benzo(a)anthracene (entire range)	0.53	5.3	53	(values for an ILCR of 10 ⁻⁵ or an HI of 1 will be presented)			
Benzo(a)anthracene (table value)		5.3					
<i>Inorganics (mg/kg)</i>							
Antimony	80 ^c	200 ^c		5	10.8	47	X (Risk)
Arsenic	4.1 ^d	33 ^d		20			X (ARAR)
Barium				500			X (ARAR)
Beryllium	0.5 ^d	1.8 ^d					X (ARAR)
Boron							X (Risk)
Cadmium	120 ^d		20	0.3	0.25		X (ARAR)
Chromium			80	80	65		X (ARAR)
Cobalt				40			
Copper			50	100			X (ARAR)
Cyanide							X (ARAR)
Lead			500	50			X (ARAR)
Lithium				1			
Manganese				2220			X (ARAR)
Mercury	120 ^c		0.7	0.7	0.53	0.43	X (ARAR)
Molybdenum				2			X (Risk)
Nickel	12000 ^c		200	57			X (Risk)
Selenium				2.5			X (ARAR)
Silver				2.8			X (ARAR)
Strontium							X (Risk)
Tin				50			X (Risk)
Total Uranium	2100 ^c	5700 ^c					X (ARAR)
Vanadium				60	41		
Zinc			200	108			X (ARAR)

Table 7.1 (continued)

Chemicals	Risk-based ^b					ARARs-based ^c	
	Human health		Ecological			Future potential leaching to groundwater	
	Residential	Industrial	Earth worm	Plants	Small mammal	Wide ranging	Human health receptor
<i>Organics (mg/kg)</i>							
1,1-Dichloroethane							X (Risk)
1,1-Dichloroethene							X (ARAR)
1,1,1-Trichloroethane							X (ARAR)
1,1,2-Trichloroethane							X (ARAR)
1,1,2,2-Tetrachloroethane							X (Risk)
1,1,2-Trichloro-1,2,2-trifluoroethane							X (Risk)
1,2-Dichloroethene							X (ARAR)
1,4-Dichlorobenzene							X (Risk)
2-Butanone							X (Risk)
2,3,7,8-TCDD	0.00003 ^d						
4,4'-DDT	15 ^c						
Acetone							X (Risk)
Acenaphthene							X (Risk)
Benzene	42 ^d	86 ^d					X (ARAR)
Benidine	0.022 ^d	0.14 ^d					
Benzo(a)anthracene	5.3 ^d	26 ^d					
Benzo(a)pyrene	0.53 ^d	2.6 ^d					
Benzo(b)fluoranthene	5.3 ^d	26 ^d					
Benzo(k)fluoranthene	53 ^d	260 ^d					
bis(2-Ethylhexyl)phthalate							X (Risk)
Carbazole							X (Risk)
Chloroform							X (ARAR)
Dibenzo(a,h)anthracene	0.53 ^d	2.6 ^d					
Diethylphthalate							X (Risk)
Freon							X (Risk)
Hexachlorodibenzo-p-dioxins	0.0007 ^d	0.004 ^d					
Indeno(1,2,3-cd)pyrene	5.3 ^d	26 ^d					
Methanol							X (Risk)

Table 7.1 (continued)

Chemicals	Risk-based ^b					ARARs-based ^c	
	Human health		Ecological			Future potential leaching to groundwater	
	Residential	Industrial	Earth worm	Plants	Small mammal	Wide ranging	Human health receptor
Methoxychlor							X (Risk)
Methylene Chloride							X (ARAR)
PCB-1232	0.68 ^d						
PCB-1248	0.68 ^d	4.4 ^d					X (ARAR)
PCB-1254	9.2 ^d	24 ^d					X (ARAR)
PCB-1260	0.68 ^d	44 ^d					X (ARAR)
Phenol							X (Risk)
Polychlorinated Biphenyls	0.68 ^d	4.4 ^d			0.27	1.5	X (ARAR)
Tetrachlorodibenzo-p-dioxins	0.00003 ^d	0.00017 ^d					
Tetrachloroethene	92 ^d	470 ^d					X (ARAR)
Toluene							X (ARAR)
Trichloroethane	33 ^d	76 ^d					
Trichloroethene	130 ^d	310 ^d					X (ARAR)
Trichlorofluoromethane							X (Risk)
Vinyl Chloride							X (ARAR)
<i>Radionuclides (pCi/g)</i>							
Cesium-137	0.21 ^d	1 ^d					X (Risk)
Cobalt-60	0.045 ^d	0.22 ^d					
Curium-243	2.3 ^d						
Lead-212	1.4 ^d	7.3 ^d					
Neptunium-237	0.91 ^d	4.5 ^d					X (Risk)
Plutonium-238	27 ^d	110 ^d			0.23	0.05	X (Risk)
Plutonium-239/240	25 ^d						X (Risk)
Ruthenium-106	0.57 ^d	2.9 ^d					X (Risk)
Strontium-90							X (Risk)
Technetium-99	5600 ^d	23000 ^d					X (Risk)
Thallium-208	0.03 ^d	0.15 ^d					X (Risk)
Thorium-228	0.43 ^d	2.2 ^d					
Thorium-230	200 ^d	810 ^d					

Table 7.1 (continued)

	Risk-based ^b						ARARs-based ^c
	Human health		Ecological				Future potential leaching to groundwater
	Residential	Industrial	Earth worm	Plants	Small mammal	Wide ranging	Human health receptor
Chemicals							
Thorium-232	230 ^d	920 ^d					X (Risk)
Uranium-234	180 ^d	700 ^d					X (Risk)
Uranium-235	1.6 ^d	8.2 ^d					X (Risk)
Uranium-236							X (Risk)
Uranium-238	7.8 ^d	39 ^d					X (Risk)

^a "Soils" include BCV soils, hot spot soils, floodplain soils, and waste inventory solids. The only ARAR for soils is for PCBs and is 10 to 50 mg/kg.

^b There are no soil chemicals of concern and therefore no Risk-based RGOs for Human Health under recreational Scenario. The only soil RGOs for the Maintenance Worker Scenario are ²³⁴U (4800 pCi/g), ²³⁵U (57 pCi/g), and ²³⁸U (270 pCi/g).

^c No RGOs are presented for the predictive modeling results. An "X" indicates a chemical was a chemical of concern from the modeling. The "(ARAR)" or "(Risk)" indicates whether concentration for chemical of concern exceeded risk-based or ARAR-based screening value.

^d value represents an ILCR of 10⁻⁵

^e value represents an MQ of 1.0

Table 7.2. Remedial goal options for chemicals of concern identified for BCV sediments^a

Chemicals	Risk-based ^b						
	Human health			Ecological			
	Residential			Benthic invertebrates			
Example of Entire Risk Range (ILCR of 10 ⁻⁶ to 10 ⁻⁴ , or HQ of 0.1 to 10):							
	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴	10	1.0	0.1	
Beryllium (entire range)	0.05	0.5	5.0	5900	880	58	(values for an ILCR of 10 ⁻⁵ or an HI of 1 will be presented)
Benzo(a)anthracene (table value)		5.3					
Inorganics (mg/kg)							
Arsenic				4.1 ^d			
Beryllium				0.5 ^d			
Chromium				1000 ^{cd}			
Manganese						7320	
Selenium						6.6	
Vanadium				810 ^e			
Organics (mg/kg)							
Benzo(a)anthracene				5.3 ^d			
Benzo(a)pyrene				0.53 ^d			
Benzo(b)fluoranthene				5.3 ^d			
Dibenzo(a,h)anthracene				0.53 ^d			
Indeno(1,2,3-cd)pyrene				5.3 ^d			
PCB-1260				0.68 ^d			
2,4,5-T						0.013	
Radionuclides (pCi/g)							
Thorium-228				0.43 ^d			
Uranium-234				180 ^d			
Uranium-235				1.6 ^d			
Uranium-238				7.8 ^d			

^a There are no ARAR-based RGOs for sediments.^b There are no sediment chemicals of concern and therefore no Risk-based RGOs for Human Health under the Recreational Scenario.^c RGO is for Chromium VI.^d values represent on ILCR of 10^{-5} ^e value represents on HQ of 1.0

Table 7.3. Remedial goal options for chemicals of concern identified for BCV surface water

Chemicals	Risk-based			ARARs-based	
	Human health ^a	Ecological ^b		ARARs AWQC	
	Residential	Benthic invertebrates	Piscivores	Human health	Ecological
Example of Entire Risk Range (ILCR of 10 ⁻⁶ to 10 ⁻⁴ , or HQ of 0.1 to 10):					
	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴		
Chloromethane (entire range)	0.0019	0.019	0.19		
Chloromethane (table value)	0.019	(values for an ILCR of 10 ⁻⁵ or an HI of 1 will be presented)			
Inorganics (mg/L)					
Antimony	0.013 ^f				
Arsenic	0.00056 ^e			0.0014	0.19
Barium	2.5 ^f				
Beryllium	0.00016 ^e				
Boron	3.3 ^f				
Cadmium	0.015 ^f	0.002			0.0011
Calcium		116			
Chromium					0.1 ^c
Copper					0.0118
Cyanide				220	0.0052
Fluoride	2.2 ^f				
Lead					0.0032
Manganese	4.8 ^f	6.6			
Mercury			0.126	0.00015	0.000012
Nickel	0.72 ^f	0.015		4.6	0.158
Nitrate (as N)	58 ^f				
Selenium	0.18 ^f				0.005
Silver					0.0041 ^d
Thallium				0.0063	
Uranium (total)	0.11 ^f	0.142			
Zinc					0.106
Organics (mg/L)					
1,1,2-Trichloroethane	0.0025 ^e			0.42	
1,1-Dichloroethene	0.00013 ^e			0.032	
1,2-Dichloroethane	0.0016 ^e			0.99	
1,2-Dichloroethene	0.33 ^f				
Benzene	0.0049 ^e			0.71	
Chloroform	0.0021 ^e			4.7	
Chloromethane	0.019 ^e				
Methylene Chloride				16	

Table 7.3 (continued)

Chemicals	Risk-based			ARARs-based	
	Human health ^a		Ecological ^b	ARARs AWQC	
	Residential	Benthic invertebrates		Human health	Ecological
Tetrachloroethene	0.0078 ^c			0.0885	
Toluene				200	
Trichloroethene	0.019 ^c			0.81	
Vinyl Chloride	0.00025 ^c			5.25	
<i>Radionuclides (pCi/L)</i>					
Neptunium-237	1.6 ^c				
Plutonium-238	1.6 ^c				
Potassium-40	38 ^c				
Radium (total Alpha)	1.6 ^c				
Strontium-90	8.5 ^c				
Technetium-99	340 ^c				
Thorium-228	2.1 ^c				
Uranium-233/234	11 ^c				
Uranium-235	10 ^c				
Uranium-238	7.7 ^c				

^a There are no surface water chemicals of concern and therefore no Risk-based Human Health RGOs for the Recreational Scenario. Three RGOs exist for the three COCs for recreational/consumption of fish. The human health/recreation/fish RGOs are: PCB-1254 (0.2 mg/kg fish), PCB-1260 (0.03 mg/kg fish), and mercury (3 mg/kg fish) at risk = 10^{-5} and/or MQ = 1.0

^b There are no Risk-based Ecological RGOs for Fish, Small Mammals, and Wide Ranging Species.

^c Value for Chromium total.

^d Maximum value.

^e Value represents an ICCR of 10^{-5} .

^f Value represents an MQ of 1.0.

Table 7.4. Remedial goal options for chemicals of concern identified for BCV groundwater

Chemicals	Risk-based		ARAR-based		
	Human health	Ecological	ARARs AWQC		
	Residential	Plants	Federal primary MCLs	Human health	Ecological
Example of Entire Risk Range (ILCR of 10^{-6} to 10^{-4} , or HQ of 0.1 to 10):					
		10^{-6} 10^{-5} 10^{-4}			
Chloromethane (entire range)		0.0019 0.019 0.19	(values for an ILCR of 10^{-5} or an HI of 1 will be presented)		
Chloromethane (table value)		0.019			

<i>Inorganics (mg/L)</i>					
Antimony	0.013 ^g	0.2 ^a	0.006		
Arsenic	0.00056 ^f			0.0014	0.19
Barium	2.5 ^g		2		
Beryllium	0.00016 ^f		0.004		
Boron	3.3 ^g				
Cadmium	0.015 ^g		0.005		0.0011
Chromium	0.16 ^{ef}	0.05 ^a	0.1		0.1 ^b
Cobalt		0.06 ^a			
Copper		0.05 ^a	TT ^h		0.0118
Cyanide			0.2	220	0.0052
Fluoride	2.2 ^g		4		
Iron		10 ^a			
Lead		0.02 ^a	TT ^h		0.0032
Manganese	4.8 ^g	4 ^a			
Mercury	0.011 ^g		0.002	0.00015	0.000012
Molybdenum	0.18 ^g				
Nickel	0.72 ^g		– 60FR33926 ⁱ	4.6	0.158
Nitrate (as N)	58 ^g		10		
Nitrite (as N)	3.6 ^g		1		
Nitrate + Nitrite (as N)			10		
Selenium					0.005
Silver					0.0041 ^c
Strontium	22 ^g				

Table 7.4 (continued)

Chemicals	Risk-based		ARAR-based		
	Human health	Ecological	ARARs AWQC		
	Residential	Plants	Federal primary MCLs	Human health	Ecological
Sulfate			500		
Thallium			0.002	0.0063	
Vanadium	0.21 ^g				
Uranium (total)	0.11 ^g				
Zinc	11 ^g				0.106
<i>Organics (mg/L)</i>					
1,1,1-Trichloroethane	1.3 ^g		0.2		
1,1,2,2-Tetrachloroethane	0.00071 ^g			0.11	
1,1,2-Trichloroethane	0.0025 ^f		0.005	0.42	
1,1-Dichloroethane	0.81 ^g				
1,1-Dichloroethene	0.00013 ^f		0.007	0.032	
1,2-Dichloroethane	0.0016 ^f		0.005	0.99	
1,2-Dichloroethene	0.33 ^g				
1,2-Dichloropropane	0.0083 ^g				
1,4-Dichlorobenzene	0.03 ^f				
1,4-Dioxane	0.077 ^f				
2,4-Dimethylphenol	0.48 ^g				
2,4-Dinitrophenol	0.072 ^g			14	
2,4-Dinitrotoluene	0.0012 ^f				
2,6-Dinitrotoluene	0.0012 ^f				
2-Butanone	1.9 ^g				
4-Methyl-2-pentanone	0.16 ^g				
Acetone	3.6 ^g				
Benzene	0.0049 ^f		0.005	0.71	
Benzidine	0.0000037 ^f				
bis(2-Ethylhexyl)phthalate	0.047 ^f			0.059	
Bromodichloromethane	0.014 ^f				
Bromoform	0.11 ^f				
Carbon Tetrachloride	0.0021 ^f		0.005	0.044	

Table 7.4 (continued)

Chemicals	Risk-based		ARAR-based		
	Human health	Ecological	ARARs AWQC		
	Residential	Plants	Federal primary MCLs	Human health	Ecological
Chlorobenzene	0.039 ^g				
Chloroform	0.0021 ^f			4.7	
Chloromethane	0.019 ^f				
cis-1,2-Dichloroethene	0.36 ^g				
di-n-Octylphthalate	0.0099 ^g				
Dibromochloromethane	0.01 ^g				
Ethylbenzene			0.7	29	
Methylene Chloride	0.054 ^f		0.005	16	
PCB-1254	0.00038 ^g				
Pentachlorophenol	0.0028 ^f				
Phenol				4600	
Polychlorinated Biphenyls	0.000057 ^f			0.00000045 ^d	0.000014 ^d
Tetrachloroethene	0.0078 ^f		0.005	0.0885	
Toluene	0.74 ^g		1	200	
trans-1,2-Dichloroethene	0.73 ^g		0.1	140	
Trichloroethene	0.019 ^f		0.005	0.81	
Trichlorofluoromethane	1.3 ^g				
Trihalomethanes (total)			0.1		
Vinyl Chloride	0.00025 ^f		0.002	5.25	
<i>Radionuclides (pCi/L)</i>					
Americium-241	1.5 ^f				
Cesium-137	15 ^f				
Lead-212	26 ^f				
Neptunium-237	1.6 ^f				
Potassium-40	38 ^f				
Radium (total Alpha)	1.6 ^f				
Strontium-90	8.5 ^f				
Technetium-99	340 ^f				
Thorium-228	2.1 ^f				

Table 7.4 (continued)

Chemicals	Risk-based		ARAR-based		
	Human health	Ecological	ARARs AWQC		
	Residential	Plants	Federal primary MCLs	Human health	Ecological
Thorium-230	13 ^f				
Tritium	5800 ^f				
Uranium-234	11 ^f				
Uranium-235	10 ^f				
Uranium-238	7.7 ^f				

^a RGOs apply to shallow groundwater.

^b Value for Chromium (total).

^c Maximum value.

^d For each Aroclor.

^e Value for chromium VI.

^f Value represents an ICCR of 10⁻⁵.

^g Value represents an MQ of 1.0.

^h TT = Treatment Technology

ⁱ 60FR33296 = EPA has deleted from the *CFR* the MCL and MCLG for nickel, which have been vacated by a court ruling, effective June 29, 1995.

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