DRAFT FINAL

Phase III RFI/RI Report

Rocky Flats Plant
881 Hillside Area
(Operable Unit No. 1)

Volume I
Remedial Investigation

U.S. Department of Energy
Rocky Flats Plant
Golden, Colorado

October 1992

REVIEWED FOR CLASSIFICATION/UCNI
By
Date 11/4/92

ADMIN RECORD

A-OU01-000439

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LIST OF ACRONYMS AND ABBREVIATIONS

ARARs	applicable or relevant and appropriate requirements
ASTM	American Society for Testing and Materials
BNA	base neutral acid extractable
CDH	State of Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter
cm/sec	centimeters per second
DNAPL	dense nonaqueous phase liquid
DOE	Department of Energy
EPA	Environmental Protection Agency
ft^2/min	square feet per minute
FS	feasibility study
GRRASP	General Radiochemistry and Routine Analytical Services Protocol
HQ	Hazard Quotient
HSU	hydrostratigraphic unit
I.D.	inside diameter
IHSS	Individual Hazardous Substance Site
mg/kg	milligrams per kilogram
mg/l	milligrams per liter
mm Hg	millimeters of mercury
O.D.	outside diameter
OU1	Operable Unit No. 1
OU2	Operable Unit No. 2
OU5	Operable Unit No. 5
OU10	Operable Unit No. 10
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
pCi/g	picocuries per gram
pCi/l	picocuries per liter
pCi/m^3	picocuries per cubic meter
pCi/ml	picocuries per milliliter
QA/QC	quality assurance/quality control
QAA	Quality Assurance Addendum
QAPjP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RFP	Rocky Flats Plant
RI	remedial investigation
SOP	Standard Operating Procedure
SVOC	semivolatile organic compound
SWMU	Solid Waste Management Unit

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

TCL	Target Compound List
TOC	total organic carbon
VOC	volatile organic compound
µg/kg	micrograms per kilogram
µg/l	micrograms per liter

Executive Summary

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Phase III RFI/RI Report

EXECUTIVE SUMMARY

This report presents the results for the Phase III Resource Conservation and Recovery Act (RCRA) Facility Investigation/Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Remedial Investigation (RFI/RI) of the 881 Hillside Area Operable Unit No. 1 (OU1) at the Rocky Flats Plant. The objectives of the Phase III RFI/RI were severalfold: to characterize surficial and subsurface physical features at the operable unit, to characterize contaminant sources and the nature and extent of contamination at the site, and to provide a baseline risk assessment that considers contaminant fate and transport and assesses the threat to public health and the environment from a no-action remedial alternative. Additionally the Phase III RFI/RI is to provide and develop data needed for feasibility studies of remedial alternatives as appropriate.

The 881 Hillside was originally identified as a high priority area due to high concentrations of volatile organic compounds (VOCs) detected in ground water and proximity of the 881 Hillside area to Woman Creek. In addition, concentrations of trace metals, radionuclides, and inorganic constituents above estimated RFP background values identified in the Phase I and II remedial investigation were considered to represent possible contamination resulting from past plant processes.

Geologic units present at 881 Hillside includes Rocky Flats Alluvium at the top of the hillside, colluvium and fill along central portions of the hillside, and Woman Creek valley-fill alluvium at the base of the hillside. These thin surficial units are underlain by thick Cretaceous claystone, siltstone, and sandstone of the Laramie Formation. Ground water within these shallow surficial units is sparse and varies in elevation due to seasonal variation in precipitation and depression-focused recharge. Often, large portions of this upper hydrostratigraphic unit (HSU) are dry within OU1 boundaries. When and where upper HSU ground water exists, flow is constrained laterally and vertically by the denser, low hydraulic conductivity bedrock surface. This configuration of the hydrologic system results in few continuous lateral ground water flow pathways that permit ground water flow from the rim of the valley to Woman Creek at the base

of the hillside. Likewise, the installation of a french drain along the central portion of 881 Hillside further reduces potential ground water flow paths toward Woman Creek.

In general, the contamination at OU1 is relatively minor in terms of contaminant concentrations and areal extent. Results from the Phase III RFI/RI have identified three discrete areas at OU1 impacted by past site activities and subsequent contaminant migration. These sources include individual hazardous substance site (IHSS) 119.1, IHSS 130, and surface soils in the eastern portion of OU1. The highest levels of contaminants detected at OU1 are at IHSS 119.1. Contaminants in the form of volatile organic compounds (VOCs) were identified at IHSS 119.1 in subsurface-surface soils and alluvial upper HSU ground water. Contamination at IHSS 130 is primarily limited to solid semivolatile organic compounds (SVOCs) consisting of, and derivatives of, common asphaltic materials disposed at this location.

Surface soils in the eastern portion of OU1 are contaminated with wind-blown plutonium-239,-240 and americium-241 transported from the 903 Pad. Also in surface soils in the eastern part of OU1 are windblown SVOCs derived from road dust, vehicle exhausts, and other combustion sources. Elevated concentrations of radionuclides and SVOCs are confined to the upper 6 feet of soil, and in most cases, in the upper few inches of soil.

Other occurrences of contamination at OU1 consist of trace levels of organic and inorganic compounds in subsurface soils and ground water. Trace amounts of SVOCs occur in subsurface soils at IHSSs 103, 104 and 119.2, and in surface water and sediments in the South Interceptor Ditch. Low-level VOCs occur in ground water south of IHSS 119.2, and south of the Building 881. The occurrence of trace metals exceeding RFP background values are not directly attributable to RFP activities but are probably due to natural weathering processes and variability within site geological materials.

Contaminant migration at the site was evaluated in terms of the identified pathways at OU1. Migration of VOCs in ground water at IHSS 119.1 appears to be extremely limited, constrained

by site geology and the lack of a seasonally continuous hydrogeologic flow path. The current operation of an extraction well at IHSS 119.1 is decreasing the potential for lateral and vertical migration of contaminated upper HSU ground water. VOC contamination at low part-per-billion concentrations in bedrock monitoring well 6286 in the extreme eastern portion of OU1 is likely due to migration of upper HSU ground water from OU2.

SVOCs in subsurface soils at IHSS 130 are expected to decrease in concentration with time due to natural degradation processes. These SVOCs have a low potential for migration and should remain confined to subsurface soils at IHSS 130. Metals and radionuclides in subsurface soils are also expected to remain immobilized in situ by natural geochemical processes. Radionuclides and SVOCs in surface soils are susceptible to redistribution by wind or surface water erosion events.

The baseline risk assessment for the environmental evaluation at OU1 considered the no-action alternative and found no measurable impacts above guidance levels upon ecological receptors from contamination present at the site. There also does not appear to be any predictable future ecological risk based on long-term exposure to the contaminants of concern at the site. There was found to be a slight elevated risk for a hypothetical future on-site resident.

The public health evaluation at OU1 has shown no measurable impact upon human health from contamination present at the site. The lifetime cancer risk in the Denver metropolitan area, not associated with the OU1 study area, is 33 percent (0.33) of the population (i.e., one in three persons are expected to contract cancer during their lifetime). However, the potential lifetime cancer risk to hypothetical future on-site residential receptors that is directly attributable to OU1 contaminants under "reasonable maximum exposure" conditions (potentially after a decision for residential development) is 0.00004 or 4×10^{-5}; thus, the total theoretical lifetime cancer risk for the future resident on-site population would then be potentially elevated from 0.33 to 0.33004. The risks from the most toxic COCs at OU1 are further reduced because of the very restricted distribution and low quantities of the substances.

Similarly, there is no quantifiable current risk to human health at OU1 for which the lifetime excess cancer risk exceeds the National Contingency Plan risk range. In general, the greatest risk at the site was found to be the potential impact of breathing VOCs in air derived from soil gas and ultimately ground water beneath IHSS 119.1. Even at IHSS 119.1, the contaminated areas are very restricted in size, and the concentration of COCs detected are nonhomogeneous.

Overall, the baseline ecological risk and human health assessment provides a basis for informed risk management decisions regarding future land use options and remedial measures. However, the compatibility of public health and environmental evaluations should be considered when the results of these studies are integrated for use in making risk management decisions. For example, in some cases future land uses judged as credible for the public health evaluation may have impacts upon ecological scenarios. Specifically, future commercial or residential development may alter or destroy local ecological habitats, thus having a large impact upon ecological receptors than residual contaminants at the site.

Section 1.0 · Text

Introduction

Phase III RFI/RI Report

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1.0 INTRODUCTION

This document presents the results of the Phase III Resource Conservation and Recovery Act (RCRA) Facility Investigation/Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Remedial Investigation (RFI/RI) of the 881 Hillside area (Operable Unit No. 1 [OU1]) at the Rocky Flats Plant (RFP). It addresses the characterization of contaminant sources as well as the nature and extent of contamination in soils, ground water, surface water, sediments, air, and biota. The document also discusses contaminant fate and transport and provides a baseline risk assessment, both which consider ecological and human health evaluations. The results of the remedial investigation and the baseline risk assessment are used to develop recommendations for remedial action.

The investigation summarized in this report is part of a comprehensive, phased program of site characterization, remedial investigations, feasibility studies, and remedial/corrective actions currently in progress at RFP. These investigations are pursuant to the Department of Energy (DOE) Environmental Restoration Program (formerly known as the Comprehensive Environmental Assessment and Response Program); a compliance agreement between DOE, the Environmental Protection Agency (EPA) and the Colorado Department of Health (CDH) dated July 1986; and the Federal Facility Agreement and Consent Order known as the Interagency Agreement dated January 1991. The program developed by DOE, EPA, and CDH in response to the agreements addresses RCRA and CERCLA issues and has been integrated with the Environmental Restoration Program. In accordance with the Interagency Agreement, the CERCLA terms "remedial investigation" and "feasibility study" in this document are considered equivalent to the RCRA terms "RCRA facility investigation" and "corrective measures study."

The Environmental Restoration Program is designed to investigate and clean up contaminated sites at DOE facilities and involves five major activities (formerly referred to as phases under the Comprehensive Environmental Assessment and Response Program). Activity 1, installation assessments, includes preliminary assessments and site inspections to assess potential environmental concerns. Activity 2, remedial investigations, includes the development and

implementation of sampling programs to delineate the magnitude and extent of contamination at specific sites, evaluate contaminant fate and transport, and perform baseline risk assessments. Activity 3, feasibility studies, evaluates remedial alternatives and develops remedial action plans to mitigate environmental problems identified during Activity 2. Activity 4, remedial designs/remedial actions, includes design and implementation of site-specific remedial actions selected on the basis of feasibility studies performed during Activity 3. Activity 5, compliance, implements monitoring and performance assessments of remedial actions, and verifies and documents the adequacy of remedial actions carried out under Activity 4. Activity 1 has already been completed at RFP (DOE 1986, 1992d), and Activities 2, 3, and 4 are currently in progress for OU1.

Activity 2 at OU1 includes Phase I, Phase II, and Phase III remedial investigations. A Phase I field program was completed at OU1 in 1987, and a draft remedial investigation report was submitted to EPA and CDH in July 1987 (Rockwell 1987a). Based on results of that investigation, Phase II field work was conducted at OU1 in the fall of 1987, and a draft final remedial investigation report submitted to EPA and CDH in March 1988 (Rockwell 1988c). A draft Phase III RFI/RI work plan was submitted to EPA and CDH in February 1990 (DOE 1990b), and a final Phase III RFI/RI work plan that incorporated EPA and CDH comments was submitted to EPA and CDH in October 1990 (DOE 1990e).

Revision 1 of the final Phase III RFI/RI work plan, submitted in March 1991 (DOE 1991b), incorporates EPA and CDH comments on the October 1990 submittal. Although not required by the Interagency Agreement, Revision 1 was prepared so that final agency comments are reflected in a single document prior to implementation of the work. This better ensures that the remedial investigation and corrective measures study are conducted in accordance with a plan to which all parties are in agreement. In addition, other changes were incorporated into Revision 1 that take into consideration an updated understanding of the site, concurrent study activities at other RFP operable units that may impact OU1, and regulatory issues. Based on comments from EPA and CDH and on additional data collection or evaluation requirements for the Phase III

RFI/RI, nine technical memoranda were prepared and attached as amendments to the work plan or as precursor documents to the public health evaluation. Field work for the Phase III RFI/RI began in April 1991 and was completed in January 1992.

Environmental Restoration Program Activity 3 at OU1 included the submittal of a draft feasibility study report for high-priority sites (881 Hillside area) to EPA and CDH in March 1988 (Rockwell 1988b). EPA comments for both the feasibility study and the Phase II remedial investigation reports were received in October 1988. Written responses to comments on the remedial investigation and feasibility study reports were submitted to DOE in October 1988 and forwarded to EPA in February 1989 (Rockwell 1989a). An interim measure/interim remedial action plan was developed to collect and treat contaminated alluvial ground water at OU1 (DOE 1990a), released for public comment during October and November 1989, and finalized in January 1990. Construction of the interim measure/interim remedial action began in November 1991 (EG&G 1991d), and was completed in April 1992. A final remedial action will be proposed based on Phase I, II, and III investigations, as well as the feasibility study.

1.1 PURPOSE OF REPORT

The purpose of the OU1 Phase III RFI/RI report is to present the findings of the Phase III field investigation. The seventeen specific objectives of this investigation as detailed in the work plan (DOE 1991b) are briefly described below.

Characterize Site Physical Features

- Determine the extent of saturation and ground-water flow directions for the unconfined flow system both spatially and temporally.
- Describe the interaction between the surface- and ground-water pathways.
- Quantify material properties.
- Describe all soils and rock materials.
- Verify the hydrogeologic site conceptual model for OU1 (DOE 1991b).

Characterize Contaminant Sources

- Characterize the nature and distribution of waste materials remaining on site.
- Characterize soils in proximity to the removed wastes as potential contaminant sources.
- Identify which sites or subareas of sites are sources of contaminants in ground water.

Characterize the Nature and Extent of Contamination

- Determine the horizontal and vertical extent of surficial radionuclide soil contamination due to wind dispersion.
- Determine the nature and extent of ground-water contamination in surficial materials.
- Determine the location and extent of weathered and unweathered sandstone units and associated contamination.
- Characterize the quality of the surface water.
- Characterize radionuclides in Woman Creek sediments.
- Identify and implement data management procedures.
- Collect data of sufficient quality to facilitate development of a site conceptual model and compare them to applicable or relevant and appropriate requirements (ARARs).

Provide a Baseline Risk Assessment

- Describe contaminant fate and transport.
- Assess the threat to public health and the environment from the No Action remedial alternative.

1.2 BACKGROUND

RFP is a government-owned, contractor-operated facility that is part of the nationwide nuclear weapons production complex. RFP is located in northern Jefferson County, Colorado, approximately 16 miles (26 kilometers) northwest of Denver (Figure 1-1), and comprises approximately 6,550 acres (2,652 hectares) of land in Sections 1 through 4 and 9 through 15 of

Township 2 South, Range 70 West, 6th Principal Meridian. Major buildings are located within the industrial area, which encompasses approximately 400 acres (162 hectares). The industrial area is surrounded by a buffer zone of approximately 6,150 acres (2,490 hectares).

1.2.1 Plant Operations

The Atomic Energy Commission operated RFP from 1951 to January 1975 when the commission was dissolved. At that time, responsibility for the plant was assigned to the Energy Research and Development Administration, which was succeeded by DOE in 1977. Dow Chemical U.S.A., an operating unit of the Dow Chemical Company, was the prime contractor responsible for operating RFP from 1951 until June 30, 1975. Rockwell International was the prime contractor responsible for operating RFP from July 1, 1975, until December 31, 1989. EG&G Rocky Flats, Inc., became the prime contractor at RFP on January 1, 1990, and currently operates the plant.

RFP is currently in transition from a defense production facility to a facility whose planned future missions include environmental restoration, waste management, maintaining production contingency, and eventual decontamination and decommissioning. Until January 1992, the plant was operated as a nuclear weapons research, development, and production complex. RFP fabricated nuclear weapon components from plutonium, uranium, beryllium, and stainless steel. Parts made at the plant were shipped elsewhere for assembly. Support activities included chemical recovery and purification of recyclable transuranic radionuclides and research and development in metallurgy, machining, nondestructive testing, coatings, remote engineering, chemistry, and physics (Rockwell 1987b).

Both radioactive and nonradioactive wastes were generated in the production process. Current waste handling practices involve on-site and off-site recycling of hazardous materials, on-site storage of hazardous and radioactive mixed wastes, and off-site disposal of solid radioactive materials at another DOE facility. In the past both storage and disposal of hazardous and radioactive wastes occurred on site. The preliminary assessment performed under the

Environmental Restoration Program identified some of the past on-site storage and disposal locations as potential sources of environmental contamination (DOE 1986).

1.2.2 OU1 Area Site Locations and Descriptions

Environmental Restoration Program investigations performed during Activity 1 (installation assessment) identified 12 individual hazardous substance sites (IHSSs) within OU1 (DOE 1986). The Interagency Agreement, however, lists only 11 sites within OU1. The twelfth, IHSS 177, is being investigated as part of the RFI/RI for Operable Unit No. 10 (OU10). The 11 IHSSs within OU1 (Figure 1-2) are the following:

- Oil Sludge Pit Site (IHSS 102)
- Chemical Burial Site (IHSS 103)
- Liquid Dumping Site (IHSS 104)
- Out-of-Service Fuel Tank Sites (IHSSs 105.1 and 105.2)
- Outfall Site (IHSS 106)
- Hillside Oil Leak Site (IHSS 107)
- Multiple Solvent Spill Sites (IHSSs 119.1 and 119.2)
- Radioactive Site – 800 Area Site #1 (IHSS 130)
- Sanitary Waste Line Leak (IHSS 145)

These sites were selected as high-priority sites because of the elevated concentration of volatile organic compounds (VOCs) detected in the ground water, the relatively permeable soils, and the proximity of the area to a surface water drainage. Based on previous investigations, the principal chemical contaminants of concern in alluvial or unconfined ground water at OU1 are tetrachloroethane, trichloroethene, 1,1,1-trichloroethane, and 1,1-dichloroethene (Rockwell 1986). The following historical information on each IHSS was compiled from the historical release report (DOE 1992d) and the work plan (DOE 1991b). Based on information discovered during the historical releases investigation, several of the IHSS names and disposal histories were modified or changed to clarify the location of the IHSS or to better match the history of waste disposal at the site. These modifications are discussed in the following sections; however, the

original IHSS names are used because they correspond to the names listed in the Interagency Agreement and the work plan.

1.2.2.1 Oil Sludge Pit Site (IHSS 102)

In 1958, approximately 30 to 50 drums of nonradioactive materials were dumped into a pit south of Building 881. Material in the drums consisted of sludge from oil tank cleanouts, possibly from the two No. 6 fuel oil tanks designated as IHSSs 105.1 and 105.2 (DOE 1986). The pit was backfilled when disposal operations ceased (DOE 1992d).

Previous investigations report various dimensions and locations for IHSS 102. In the RCRA Part B Operating Permit (Section 3004[u]), IHSS 102 is located 180 feet south of Building 881 and has dimensions of 50 feet by 80 feet (Rockwell 1987b). The pit location from the RCRA permit was revised based on an aerial photography study conducted as part of the Phase II remedial investigation. In the Phase II report (Rockwell 1988a) and the work plan (DOE 1991b), IHSS 102 is located 500 feet south of Building 881 and has dimensions of 40 feet by 70 feet. This site has since been disturbed during construction of the french drain interim measure/interim remedial action in 1992 and boundaries are shown with dashed lines in Figure 1-2 and in subsequent figures.

No documentation was found during the historical release investigation that verifies the existence of IHSS 102. The pit identified in the aerial photograph during the Phase II investigation was concluded to be a pond (see PAC SE-1600, DOE 1992d). Based on further historical research, IHSS 102 site has been relocated 100 feet south of Building 881 and north of the security fence, with dimensions estimated to be 25 feet by 50 feet (DOE 1992d), as shown in the Owen and Steward (1973) report. Figure 1-2 also shows the revised location for IHSS 102; however, the original location of IHSS 102 was investigated during the Phase III RFI/RI and it is shown on all subsequent maps.

1.2.2.2 Chemical Burial Site (IHSS 103)

An area south of Building 881 was reportedly used to bury unknown chemicals (DOE 1986). The exact location, dates of use, and contents of the site are unknown. The draft Comprehensive Environmental Assessment and Response Program report and the work plan state that a pit, apparently filled with liquid, is evident approximately 150 feet southeast of Building 881 on 1963 aerial photographs (DOE 1986, 1991b). The pit is circular in shape, and measures approximately 50 feet in diameter. No documentation was found during the historical release investigation that verifies the existence of this site, nor could personnel who were employed by RFP in the 1960s recall any such incidents of dumping (DOE 1992d). It is possible that this site may have been confused with IHSS 109 in Operable Unit No. 2 (OU2) (trench T-2), which is located east of OU1. IHSS 109 is believed to have been used for disposal of sewage sludge, liquid waste, and crushed drums that formerly contained oil (DOE 1992d).

1.2.2.3 Liquid Dumping Site (IHSS 104)

An area east of Building 881 was reportedly used for disposal of unknown liquids and empty drums prior to 1969 (DOE 1986). The report does not provide the exact location or dimensions of the pit. In the RCRA Part B Operating Permit, IHSS 104 has dimensions of approximately 50 feet by 50 feet, based on 1965 aerial photographs (Rockwell 1987b). Further review of these historical aerial photographs as part of the Phase II remedial investigation indicated that the identified "pit" may be a shadow on the photograph (Rockwell 1988a). It was concluded in the work plan that IHSS 104 is likely the same as IHSS 103 (DOE 1991b). No documentation was found during the historical release investigation that verifies the existence of this site nor could personnel who were employed by RFP in the 1960s recall any such incidents of dumping this close to Building 881 (DOE 1992d). These personnel concluded that IHSS 104 may have been confused with IHSS 109 in OU2 (trench T-2), which is located east of OU1. IHSS 109 is believed to have been used for disposal of sewage sludge, liquid waste, and crushed drums that formerly contained oil (DOE 1992d).

1.2.2.4 Out-of-Service Fuel Tank Sites (IHSSs 105.1 and 105.2)

Two out-of-service No. 6 fuel tanks are located immediately south of Building 881. IHSS 105.1 is the westernmost tank and IHSS 105.2 is the easternmost tank. These tanks were used to store diesel fuel from 1958 through 1976 (DOE 1991b). After 1976 they were filled with asbestos-containing material, and then later with concrete (Rockwell 1987b). IHSS 107, the hillside oil leak site, may have been caused by leakage from these tanks (DOE 1992d). IHSSs 105.1 and 105.2 are referred to as the Building 881 Westernmost Out-of-Service Fuel Tank and Building 881 Easternmost Out-of-Service Fuel Tank, respectively, in the historical release report (DOE 1992d).

1.2.2.5 Outfall Site (IHSS 106)

A 6-inch-diameter iron outfall pipe is present south of Building 881. The outfall, originally described as a 6-inch vitrified clay pipe (Rockwell 1987a, 1988b), originates at the Building 887 lift station and is the clean-out pipe for an overflow line from the Building 881 cooling tower (DOE 1992d). The outfall was used for discharge of untreated sanitary wastes in the 1950s and 1960s (DOE 1992d). In 1955, high bacterial counts were reported from water samples collected at the outfall and east along Woman Creek to the cattle fence. Due to concern about discharges from the outfall entering Woman Creek, several small retention ponds and an interceptor ditch were built in 1955 and 1979, respectively, to divert the outfall water to Pond C-2. After discharges of sanitary wastes were halted, the outfall pipe continued to be used for discharge of cooling water blowdown into the late 1970s. Cooling water was found to be discharging from the outfall onto 881 Hillside in December 1977 (DOE 1991b).

1.2.2.6 Hillside Oil Leak Site (IHSS 107)

In May 1973, oil was discovered flowing down 881 Hillside south of Building 881. The oil spill was contained with straw, and the oil-soaked straw and soil removed and disposed in the present landfill north of the plant (Rockwell 1987b). Oil was also found in a 60-inch-diameter standpipe located just south of the security fence. The oil was traced to the footing drain from Building 881 (DOE 1992d). A concrete skimming pond was built below the footing drain outfall

to contain the oil flowing from the footing drain and an interceptor ditch constructed to prevent oil-contaminated water from reaching Woman Creek (Owen and Steward 1973). The footing drain and the skimming pond were removed during construction of the french drain interim measure/interim remedial action in 1992.

The source of the oil was believed to be the two out-of-service fuel tanks (IHSSs 105.1 and 105.2) because the footing drain passes directly underneath the tanks. Both tanks and associated lines were pressure tested in 1973 and no leaks were detected (DOE 1991b). Several scenarios were presented in the historical release report to explain the oil leak. It was postulated that oil spills occurred as the tanks were filled, creating an underground oil reservoir. Oil may have seeped out of the hillside from this underground reservoir in 1973 (DOE 1992d). Alternatively, the oil may have originated from IHSS 102 or other known spill sites at OU1 (DOE 1992d). IHSS 107 is referred to as the Building 881 Hillside Oil Leak Site in the historical release report (DOE 1992d).

1.2.2.7 Multiple Solvent Spill Sites (IHSS 119.1 and 119.2)

Beginning in approximately 1968, two areas east of Building 881 and along the southern perimeter road were used for scrap metal and drum storage. The drums contained unknown quantities and types of solvents and wastes (Rockwell 1987b). The scrap metal may have been coated with residual oils and/or hydraulic coolants (DOE 1992d). Aerial photographs from 1969 and 1970 show material stored in piles and rows (DOE 1992d). Scrap metal and drums were removed in November and December 1971, and disturbed soil was revegetated the following spring (DOE 1992d). IHSS 119.1 is the larger western drum and scrap metal storage area, and IHSS 119.2 is the smaller eastern drum and scrap metal storage area. Figure 1-2 shows actual drum and scrap metal storage areas within each site.

There was no documentation found during the historical release investigation that supports the use of these sites as solvent storage areas, as stated in the RCRA Part B Operating Permit (Rockwell 1987b) and in the work plan (DOE 1991b). Historical evidence gathered during the

investigation indicates that scrap metal was stored at these sites and, therefore, IHSSs 119.1 and 119.2 are referred to as Scrap Metal Storage Areas in the historical release report to better match the history of waste disposal (DOE 1992d). It is speculated that elevated concentrations of solvents in the ground water may be from residual solvents or oils on the scrap metal or from the adjacent liquid disposal trench at IHSS 109 (trench T-2) in OU2.

1.2.2.8 Radioactive Site – 800 Area Site #1 (IHSS 130)

An area east of Building 881 and northwest of IHSS 119.1 was used between 1969 and 1972 to dispose of soil and asphalt contaminated with low levels of plutonium. IHSS 130 is referred to as the Contaminated Soil Disposal Area East of Building 881 in the historical release report to better match the history of waste disposal (DOE 1992d). The site is included in the discussion of the 900 Area at RFP in that report. The materials at this site were derived from three sources at RFP described below.

In September 1969, plutonium-contaminated soil and asphalt were removed from the west side of Building 776 and placed in the OU1 area at what is now IHSS 130 (Owen and Steward 1973). The soil and asphalt were contaminated during the May 11, 1969 fire in Building 776, and had an estimated average plutonium activity of 7.4 disintegrations per minute per gram (3.36 picoCuries per gram [pCi/g]). The total plutonium concentration of this material was estimated at 14 milligrams (864 microCuries) (Putzier 1970). Material from the 1969 fire was buried under 1 to 2 feet of fill dirt (Owen and Steward 1973).

In August 1970, a section of the Central Avenue roadway between Eighth and Tenth Streets was removed and placed in the OU1 area at what is now IHSS 130 (Owen and Steward 1973). This stretch of road was radioactively contaminated in June 1968 by a leaking drum in transit from the 903 Drum Storage Site to Building 774 (Owen and Steward 1973). The soil and asphalt from these two sources amounts to approximately 320 tons (DOE 1992d) or 250 cubic yards (Illsley 1978).

In 1972, approximately 60 cubic yards of plutonium-contaminated soil were removed from around the Building 774 process waste tanks and placed in the OU1 area (Owen and Steward 1973). The soil was placed on top of previously deposited soils at IHSS 130 and covered with approximately 3 feet of fill dirt (Illsley 1978). The estimated total long-lived alpha activity of this soil is less than 250 disintegrations per minute per gram (Illsley 1978).

1.2.2.9 Sanitary Waste Line Leak (IHSS 145)

In January 1981, the 6-inch, cast-iron sanitary sewer line that originates at the Building 887 lift station leaked on the hillside south of Building 881 (DOE 1992d). That month an earthen dike was constructed to prevent the spill from entering the South Interceptor Ditch and the line was repaired. The line had conveyed sanitary wastes and low-level radioactive laundry effluent to the sanitary treatment plant from about 1969 to 1973 (DOE 1992d). Recent review of Building 881 construction drawings for the historical releases investigation indicates that the only sanitary waste lines presently located south of the building are the 6-inch cast-iron sanitary sewer line that originates at the Building 887 lift station and a 6-inch vitrified clay pipe that runs east-west into Building 887 (DOE 1992d). This appears to contradict Section 3004(u) of the RCRA Part B Operating Permit, which states that the line is 4-inch cement/asbestos pipe (Rockwell 1987b).

1.2.3 Previous Investigations

Various studies have been conducted at RFP to characterize environmental media and to assess the extent of radiological and chemical contamination in the environment. These studies include detailed descriptions of the plant-site geology, several drilling programs that resulted in the construction of approximately 60 monitoring wells by 1982, surface and ground water investigations, an environmental impact statement, an electromagnetic survey, a soil gas survey, and numerous reports of routine environmental monitoring. In addition to these selected sitewide studies, many investigations have been completed specifically at OU1. Table 1-1 provides a chronological listing of documents pertaining to specific environmental investigations at OU1, beginning with the most recent. Selected investigations that augment the OU1 RFI/RI are discussed below.

In 1986 two major investigations were completed at RFP. The first was the Environmental Restoration Program Phase 1 installation assessment (DOE 1986), which included analyses and identification of current operational activities, active and inactive waste sites, current and past waste management practices, and potential environmental pathways through which contaminants could be transported. A number of sites were identified that could potentially have adverse impacts on the environment. These sites were designated as solid waste management units (SWMUs) by Rockwell (1987b) and were divided into three categories:

- Hazardous waste management units that will continue to operate and need a RCRA operating permit
- Hazardous waste management units that will be closed under an RCRA interim status permit
- Inactive waste management units that will be investigated and cleaned up under RCRA Section 3004(u) or under CERCLA

The Interagency Agreement redefines the SWMUs within the second and third categories as IHSSs. All IHSSs in OU1 fall within the third category.

The second major investigation involved a hydrogeologic and hydrochemical characterization of the entire site. Plans for this study were presented by Rockwell (1986). Four areas were identified as significant contributors to environmental contamination, with each area containing a number of sites. The four areas were 881 Hillside, 903 Pad, Mound, and East Trenches. The 881 Hillside was subsequently designated OU1 and the other three areas as OU2.

Four other RFP-wide studies have been conducted since the Phase II remedial investigation that further supplement RFI/RI activities at OU1: the geologic characterization program, the background geochemical characterization study, the surface water and sediment geochemical characterization study, and the historical releases investigation. The RFP geologic characterization program (EG&G 1990a, 1991g), was undertaken to develop a comprehensive geologic framework that can be used to define the direction, rate, and volume of ground water

flow; delineate contaminant migration pathways; and characterize potential seismic risks. The study was intended to be used to formulate hydrogeologic models, design and implement ground water monitoring programs, and plan remedial activities.

As part of the geologic characterization program, geologic mapping and shallow, high-resolution seismic reflection surveys were conducted at RFP (Rockwell 1989b; EG&G 1990b, 1991c, 1991e, 1992b). A geologic map of a 60-square-mile area surrounding RFP was produced; the Upper Cretaceous Fox Hills Sandstone, Laramie Formation, and Arapahoe Formation were described and criteria were developed for their identification in the surface and subsurface; previously mapped faults were verified and further characterized; new areas of structural deformation were identified; inconsistencies in previously published geologic maps (Spencer 1961; Van Horn 1972; Hurr 1976) were resolved; and the stratigraphy at RFP was directly tied to the regional stratigraphy on the basis of established lithologic criteria (EG&G 1992b).

Shallow, high-resolution seismic reflection surveys were conducted primarily to acquire stratigraphic information. Sandstone channels were mapped in bedrock beneath OU2 and east of RFP along Indiana Street (Rockwell 1989b; EG&G 1991c, 1991e). Structural features were identified in the northwest part of the buffer zone, in the central part of the plant (EG&G 1990b), beneath OU2 (EG&G 1991c), and near Indiana Street (EG&G 1991e). A deep seismic reflection survey was conducted from Coal Creek Canyon to Jefferson County Airport and across the buffer zone north of the plant, primarily to acquire structural information (EG&G 1992c). None of the seismic data were acquired at OU1; however, stratigraphic information and structural trends may be projected into the area and used to interpret site characteristics.

The second and third studies that augment site-specific RFI/RI activities at OU1 are the background geochemical characterization study and the surface water and sediment geochemical characterization study. The background geochemical characterization study summarizes background data for ground water, surface water, sediments, and geological materials, and identifies preliminary statistical boundaries of background variability (DOE 1992f). Similarly,

the surface water and sediment geochemical characterization study (EG&G 1992a) identifies surface water and sediment characteristics and documents general geochemical trends associated with environmental contamination at RFP. Seeps and depressions in OU1 were sampled as a part of this study.

The fourth study, the historical releases investigation, was required by the Interagency Agreement to provide a complete listing of all spills, releases, and/or incidents involving hazardous substances that occurred since the inception of RFP operations. Information describing individual release sites was gathered by background research, file review, site visits and photography, and employee interviews. Release sites, including existing RFP IHSSs, were designated as potential areas of concern (DOE 1992d).

Previous environmental investigations performed at OU1 include Phase I and Phase II remedial investigations (Rockwell 1987a, 1988a) and the french drain geotechnical investigation (EG&G 1990e) in support of the interim measure/interim remedial action (DOE 1990a). The Phase I remedial investigation began in March 1987 in accordance with the plans presented by DOE (1987a, 1987b). Phase II field work was performed after the draft Phase I report was submitted and after meetings with EPA and CDH to plan further work based on Phase I results. Seventeen boreholes, four alluvial monitoring wells, and three bedrock monitoring wells were drilled and installed for the Phase I program. Six boreholes, eleven alluvial monitoring wells, and one bedrock monitoring well were drilled and installed for the Phase II program. Figure 1-3 shows the locations of Phase I and Phase II boreholes and wells. While the Phase I and Phase II remedial investigations were limited in scope, they provided adequate preliminary information about waste source locations, waste source characterization, subsurface geology, and hydrology to facilitate the design of a thorough and comprehensive Phase III remedial investigation.

The interim measure/interim remedial action recently completed at OU1 includes a french drain designed to collect contaminated alluvial ground water from OU1 and prevent further downgradient migration, thereby alleviating a potential long-term threat to human health and the

environment. A geotechnical investigation was performed at OU1 as part of the interim measure/interim remedial action to evaluate the site characteristics along the proposed french drain alignment (EG&G 1990e). Thirty-eight boreholes were drilled on approximately 100-foot centers and sampled for geotechnical testing (Figure 1-4). Geotechnical testing was conducted and chemical analyses were run on soil and bedrock samples collected from selected borings. Twenty-four boreholes were packer tested, and four alluvial piezometers were installed along the eastern end of the french drain alignment (DOE 1991b). Construction of the french drain began in November 1991 and was completed in April 1992. Appendix A4 of this report includes cross sections depicting the geology of the french drain excavation walls and tables summarizing geotechnical data and hydraulic properties of samples collected in the french drain.

The french drain was constructed by excavating a trench approximately 1,435 feet in length along the downgradient boundary of OU1. The trench is keyed into bedrock material exhibiting a hydraulic conductivity on the order of 1×10^{-6} centimeters per second (cm/sec). A permeable membrane (geotextile) was placed on the north wall of the excavation to allow for capture of the alluvial ground water. An impermeable polyvinyl chloride membrane was placed on the south wall of the french drain to prevent captured ground water from migrating downgradient of the system, and perforated pipe was installed in the keyway for collection of ground water. The keyway was then backfilled with gravel and covered with geotextile, and Class I soil was placed on top of the membrane to a depth of approximately 1 foot. Finally, the entire excavation was backfilled with material excavated during the french drain construction.

1.3 SUMMARY OF TECHNICAL MEMORANDA AND STANDARD OPERATING PROCEDURE ADDENDA

Because of the unknown nature of many of the sites at RFP and the iterative nature of the RFI/RI process, additional data requirements and analyses may be identified throughout the process. When this occurs, the Interagency Agreement stipulates that DOE shall submit technical memoranda to EPA and CDH documenting the need for additional data and identifying data quality objectives. Upon agency approval, these technical memoranda are attached as

amendments to approved work plans. Nine technical memoranda have been prepared as part of the Phase III RFI/RI for OU1 (Table 1-2). They are the following:

- Technical Memorandum No. 1 – Chemical Analysis Plan
- Technical Memorandum No. 2 – Responses to Comments on the OU1 Phase III RFI/RI Work Plan (Revision 1)
- Technical Memorandum No. 3 – Multiple-Well Pumping Test Plan
- Technical Memorandum No. 4 – Tracer Test Plan
- Technical Memorandum No. 5 – Surface Soil Sampling and Analysis Plan
- Technical Memorandum No. 6 – Exposure Scenarios
- Technical Memorandum No. 7 – Description of Models for the Public Health Evaluation
- Technical Memorandum No. 8 – Contaminant Identification
- Technical Memorandum No. 9 – Toxicity Constants

In addition, three standard operating procedure (SOP) addenda were prepared to supplement the sampling procedures in the SOPs and the Phase III RFI/RI work plan (Table 1-2). They are the following:

- Soil Sampling for Geotechnical Analysis
- Soil Sampling for Total Organic Carbon Analysis
- Hand-Auger Sampling

The contents of the nine technical memoranda and three SOP addenda are summarized below.

1.3.1 Chemical Analysis Plan

Technical Memorandum No. 1 is the chemical analysis plan submitted as an addendum to the work plan in August 1991 (DOE 1991e). This plan evaluates the historical chemical data set for OU1 and presents an amended analytical strategy for the Phase III investigation.

The site-specific target analyte list was defined by tabulating and summarizing existing analytical data by analytical suite. The tabulation included the total number of analyses and the number of detections for each chemical. Three outcomes were possible from this tabulation:

1. One or more chemicals from an analytical suite were not detected at a given detection limit in a specified media.

2. One or more chemicals from an analytical suite were detected either inconsistently or at low concentrations in a specified media.

3. One or more chemicals from an analytical suite were consistently detected in a specified media.

In the first case, the analytical suite was eliminated provided that historical data were of adequate quality, usability, and were representative of the site. Evaluation of representativeness included spatial consideration. In the second case, the analytical suite was eliminated provided that data quality, spatial representativeness, temporal variations, concentrations, chemical fate and transport, and human health risks were assessed. In the third case, the analytical suite was retained in the Phase III investigation to better characterize the medium, particularly if the chemicals are mobile and toxic. In this manner, Phase III analytical suites were selected for each medium. The selection process for each suite in each medium are briefly described below.

In the ground water and surface water media, VOCs were detected in 773 out of 14,898 analyses in Phases I and II. Detected concentrations ranged from 1 to 72,000 micrograms per liter (µg/l). Because VOCs were detected at high concentrations, the plan recommends that Phase III samples be analyzed for all EPA Contract Laboratory Program Target Compound List (TCL) organics. Acid-extractable semivolatile organic compounds (SVOCs) were detected at low concentrations in 6 out of 656 analyses in Phases I and II. Because there is no documentation regarding the disposal of wastes containing acid-extractable compounds, and because the detections occurred infrequently and at low concentrations, the plan recommends that this analytical suite be eliminated from OU1 monitoring. Similarly, base/neutral extractable SVOCs were detected at low concentrations in 28 out of 2,192 analyses in Phases I and II. Because base/neutral

extractable compounds were detected infrequently and at low concentrations, and because they were detected in other media, the plan recommends that this analytical suite be eliminated from OU1 monitoring. Pesticides were detected at low concentrations in 4 out of 1,227 analyses in Phases I and II. Because there is no documentation regarding the disposal of pesticides at OU1, and because they were detected infrequently and at low concentrations, the plan recommends they be eliminated from the program. Polychlorinated biphenyls (PCBs) were not detected in ground water or surface water analyses in Phases I and II. Because there is no documentation regarding the disposal of PCBs at OU1, the plan recommends this analytical suite be eliminated from OU1 monitoring.

In the soils and sediments media, VOCs were detected in 361 out of 4,955 analyses performed during Phases I and II. Detected concentrations ranged from 3 to 860 micrograms per kilogram (µg/kg). Because these detections frequently indicated high concentrations, the plan recommends that Phase III samples be analyzed for all TCL organics. Acid-extractable SVOCs were detected at low concentrations in only 3 out of 2,572 Phase I and II analyses. Because there is no documentation regarding the disposal of wastes containing acid-extractable SVOCs at OU1, and because the detections occurred infrequently and at low concentrations, the plan recommends that this analytical suite be eliminated from OU1 monitoring. Base/neutral extractable SVOCs were detected at low concentrations in 208 out of 8,184 analyses in Phases I and II. Most of the analytes detected were phthalate esters, and a few were polynuclear aromatic hydrocarbons. Neither of these analytes/analyte groups are associated with past waste disposal practices, nor are they mobile in the environment. Because they were detected infrequently and at low concentrations, the plan recommends they be eliminated from OU1 monitoring. No pesticides were detected in Phase I and Phase II soil and sediment samples; therefore, the plan recommends that they also be eliminated from OU1 monitoring. PCBs were detected at low concentrations in only 3 out of 4,232 Phase I and II analyses. Because they occurred infrequently and at low concentrations, and because they are immobile in the environment, the plan recommends they be eliminated from OU1 monitoring.

EPA and CDH reviewed the chemical analysis plan in Technical Memorandum No. 1 after it was submitted in August 1991. Based on comments from EPA and CDH, modifications were made to the analytical suites and/or analytical methods proposed for some borehole and monitoring well locations. Table 1-3 outlines EPA/CDH modifications to the Phase III RFI/RI chemical analysis plan by IHSS and by borehole/monitoring well. Table 1-4 presents the proposed analytical suite for each borehole and monitoring well.

1.3.2 Responses to Comments on the OU1 Phase III RFI/RI Work Plan

Technical Memorandum No. 2 (DOE 1991f) is the DOE response to the August 1, 1991 EPA comments on the revised Phase III OU1 RFI/RI work plan (DOE 1991b). The memorandum is limited to responses to key EPA concerns identified in the cover letter to the comments. Six concerns are addressed in the memo and are summarized below.

The first concern is that surface soil scrape sampling should extend into IHSS 130. DOE responds that sampling to characterize the distribution of plutonium and americium in surface soils is to be conducted in IHSS 130 and that surface soil sampling for actinides in OU1 had been completed in August 1991.

The second concern is that surface contaminant particle size should be evaluated for the risk assessments. DOE responds that particle size distribution analysis is to be performed in three OU1 areas that were identified for vertical profiling of the distribution of plutonium, americium, and uranium. In addition, the concentration of actinides within the sand, silt, and clay fractions is to be analyzed for certain samples, including samples taken from the top 3 centimeters (cm) of soil.

The third concern is that sampling be conducted to characterize nonaqueous phase liquids, if present. DOE responds that sampling is to be performed on select wells within IHSSs 119.1, 119.2, 105.1, and 105.2 to determine whether light nonaqueous phase liquids or dense nonaqueous phase liquids are present and, if so, to chemically characterize the liquids.

The fourth concern is that adequate air monitoring be conducted to completely evaluate the air exposure pathway in the risk assessment and environmental evaluation. DOE states that the EPA concern over adequate air monitoring was the result of the vague way the work plan described how the nature and extent of contamination via the air pathway would be analyzed, and that the results of the in-place surface soil sampling program and the air sampling program will provide for a complete evaluation of the air pathway in the risk assessment and environmental evaluation.

The fifth concern is that ARARs be evaluated as presented in the specific comments in Section 7 of the work plan. DOE responds that the EPA comments pertaining to ARARs have been reviewed and the comments are to be addressed in the Phase III RFI/RI report.

The sixth concern is that the risk of laboratory contamination be carefully controlled and that previous data showing elevated concentrations of potential laboratory contaminants be verified. Contamination not attributable to laboratory contamination must be considered as contamination from a waste source. DOE responds that both laboratory- and field-introduced contamination of samples is to be addressed and minimized by selecting a laboratory with a track record for minimizing laboratory-introduced contamination, by strictly adhering to field SOPs, and by modifying field techniques and quality control protocols to minimize introduction of phthalate contamination in samples during handling and shipping. DOE agrees with EPA that the presence of contaminants in samples that could not be attributed to laboratory contamination must be considered as originating from waste sources.

Each of the six EPA concerns are being addressed in the Phase III RFI/RI report.

1.3.3 Multiple-Well Pumping Test Plan

Technical Memorandum No. 3 is the multiple-well pumping test plan that was submitted as an addendum to the work plan in November 1991 (DOE 1991h). The plan describes techniques that are specific to the multiple-well (15 wellpoint array) pumping tests for OU1, although these

techniques are compatible with and supplementary to Ground Water SOP GW2.08, *Aquifer Pumping Tests* (EG&G 1991a).

The multiple-well pumping test plan recommends that an exploratory borehole be drilled at each multiple-well test location to determine site-specific hydrogeologic conditions (i.e., depth to water table, depth to the base of the saturated alluvial aquifer, initial saturated thickness of the aquifer, and grain-size distribution of aquifer materials). Subsequently, 15 wellpoints are installed in a three-well by five-well array with the rows of five wells oriented perpendicularly to the estimated direction of ground water flow, and installed on nominal 2-foot centers. The wellpoints are to be developed using methods described in Ground Water SOP GW2.08, *Aquifer Pumping Tests* (EG&G 1991a), and the aquifer allowed to return to an equilibratory hydraulic condition. The central well of the wellpoint array is to be used as the pumping well during the test, and all other wells used for observation of ground water level fluctuations.

The plan recommends that a step-drawdown test be conducted to provide information on the efficiency of the pumping well and to establish a flow rate that can be sustained during the constant-rate pumping test. Water levels in the pumping well and observation wells and time-drawdown measurements are to be collected during the step-drawdown test. Results are to be analyzed and a pumping rate selected for use in the multiple-well constant-rate pumping test based on the drawdown curve calculations.

The plan calls for a constant-rate pumping test to be conducted to estimate the transmissivity and specific yield of the aquifer. The central well of the array is to be pumped for a specified period, and water levels to be measured in all wells before, during, and after the pumping to record both the drawdown and recovery of the piezometric surface.

1.3.4 Tracer Test Plan

Technical Memorandum No. 4 is the multiple-well tracer test plan that was submitted as an addendum to the work plan in November 1991 (DOE 1991i). It describes techniques that are specific to the tracer tests for OU1 and is compatible with and supplementary to Ground Water SOP GW2.07, *Tracer Tests* (EG&G 1991a).

The plan recommends that following wellpoint development and sampling, a tracer evaluation test be conducted at a single wellpoint to assess the appropriateness of three different tracers for use in the multiple-well tracer tests. Tracers to be evaluated were distilled water, rhodamine WT dye, and potassium bromide. Rhodamine WT dye and potassium bromide are recommended in the plan because of their conservative behavior, absence in the hydrogeologic environment, and ease of detection in aqueous samples.

The plan requires that potassium bromide standards be prepared and sent to the laboratory for confirmatory analysis before the multiple-well tests are conducted. These standards are used to develop a calibration curve for the analysis of bromide tracer test breakthrough data. Ground water samples collected at the site of the tracer evaluation test prior to startup of the test are also to be submitted for laboratory analysis. All other fluids are to be analyzed in the field.

The plan recommends using an injection tube to inject the tracer into the aquifer. When injection is complete, a peristaltic sampling pump is used to withdraw water from the aquifer at a rate equal to that of injection. Flow rate, time, and water levels are recorded continuously during the injection portion of the test. Samples are to be collected and analyzed in the field to determine whether tracer breakthrough occurred. The results from the in situ testing of each tracer are to be analyzed to select the most appropriate and detectable tracer for use in the multiple-well tracer tests.

A multiple-well tracer test is conducted using the same 15 wellpoint array used in the multiple-well pumping tests. Fifteen wellpoints are to be installed in a three-well by five-well array with

the rows of five wells oriented perpendicularly to the estimated direction of ground water flow. The wells are to be installed on 2-foot centers. In this arrangement, the five upgradient wells on one side of the array would serve as injection wells, the five downgradient wells on the other side of the array would serve as withdrawal or tracer recovery wells, and the central row of five wells would serve as water-level observation wells. The tracer test would be conducted as a constant hydraulic gradient test. Ground water samples are collected from the middle well of the injection row, the middle well of the observation row, and the three middle wells of the withdrawal row.

The plan recommends injecting ground water into the five injection wells so that the hydraulic head within each well is held constant at a level of 1 foot higher than the static water table, thus ensuring that the fluctuations in elevation were no more than ± 0.2 foot. The withdrawal wells are pumped at a rate that maintains ground water elevation in each well at approximately static water levels (also ± 0.2 foot). When a steady-state condition is established, tracer solution is introduced at a constant rate at the five injection wells. The tracer is injected continuously until breakthrough is observed at the withdrawal wells.

The plan calls for sampling at regular intervals. Samples are to be analyzed in the field to determine when tracer breakthrough occurred, and water level data is to be collected frequently during the test. The test is terminated when 80 to 90 percent of the relative concentration of the injected tracer is recovered.

1.3.5 Surface Soil Sampling and Analysis Plan

Technical Memorandum No. 5, *Surface Soil Sampling and Analysis Plan*, was submitted as an addendum to the work plan (DOE 1992a). Although the work plan identifies the determination of the extent of radionuclide contamination in surface soils due to wind dispersion as a specific objective of the remedial investigation, it does not provide for surface soil sampling. Therefore, the surface soil sampling plan was prepared in response to this data need.

Technical Memorandum No. 5 is divided into three sections. Section 1 presents results of prior surface soil programs at OU1 and Section 2 the formal sampling and analysis plan. Section 3 describes quality assurance/quality control (QA/QC) considerations.

Based on a review of site history and previous geochemical investigations, a site-specific chemical analysis roster was developed for surface soils at OU1. This roster includes radionuclides, metals, SVOCs, pesticides, and PCBs. VOCs are not included on the roster because they volatilize readily and because they are relatively mobile in soil and water, which makes their appearance in surface soils unlikely. The radionuclides, SVOCs, pesticides, and PCBs selected for the site-specific chemical analysis roster were detected previously in OU1 soils. All EPA priority pollutant metals, with the exception of hexavalent chromium, are included in the roster. Hexavalent chromium was considered but was not included in the analytical program because of the analytical difficulties it poses. In addition, it was assumed, based on the high reactivity of hexavalent chromium, that it was likely to be reduced to trivalent chromium in RFP surface soils. Manganese and iron were also added to the list of metals at the request of CDH.

The plan requires that OU1 surface soil data be validated before the data can be applied to toxicological interpretation in the baseline risk assessment. To meet the documentation needs of the validation process, all surface soil data were analyzed at level IV as defined by EPA (EPA 1987a).

To further ensure that data collected meet the needs of the baseline risk assessment, the plan compares the detection limits for each analyte to relevant exposure limits. Exposure limits are computed for both an on-site ecological researcher and an on-site resident. Exposure limit values are different for these two hypothetical receptors because exposure limit computations consider likely exposure times. The crucial consideration is whether detection limits for a given analyte as specified in the *General Radiochemistry and Routine Analytical Services Protocol* (EG&G 1990c) are less than the calculated exposure limit values. If the calculated exposure limit is less

than the *General Radiochemistry and Routine Analytical Services Protocol* detection limit for a particular contaminant, then concentrations of that contaminant above the exposure limit could go undetected and the analyses not provide fully meaningful results for the baseline risk assessment (EG&G 1990c).

Exposure limit values calculated for an on-site ecological researcher are greater than the detection limits for all site-specific chemical analysis roster analytes. Exposure limit values for an on-site resident, however, are less than *General Radiochemistry and Routine Analytical Services Protocol* detection limits for five roster analytes (antimony, beryllium, thallium, benzo(a)pyrene, and benzo(b)fluoranthene). While recognizing that the risk assessment objectives for these contaminants will be slightly compromised, the memorandum asserts that health effects associated with these compounds can still be quantified within an acceptable range.

The goal of the proposed sampling plan is to collect data representative of both radioactive and nonradioactive contamination in OU1 surface soils. The proposed plan includes both random and biased sample sets. The random sample set includes composite samples taken from 24 polygons chosen at random from a 454-polygon grid covering all OU1-related IHSS locations and the area topographically downgradient to Woman Creek. Data from this random sampling is suitable for determination of statistical mean contamination levels in surface soils at OU1. The biased sample set consists of four sample sites chosen specifically to investigate contamination related to IHSSs 106, 130, 119.1, and 119.2. Site history and previous analyses identified these IHSS locations as the most likely potential sources of surface soil contamination within OU1.

Surface soil sampling methods in the plan are based on the sample collection techniques described in Geotechnical SOP GT.08, *Surface Soil Sampling* (EG&G 1991a). Laboratory analyses cover the site-specific chemical analysis roster analytes, following methods referenced in the *General Radiochemistry and Routine Analytical Services Protocol* (EG&G 1990c).

Additional data to be collected in conjunction with surface soil sampling at OU1 include a background study of RFP surface soil geochemistry, the addition of three sediment sampling sites in Woman Creek downgradient of OU1, and an air sampling program aimed at determining the level of suspended particulates at OU1. Data collected from these additional activities will further supplement data collected under the Phase III RFI/RI work plan and meet the anticipated needs for the baseline risk assessment.

1.3.6 Exposure Scenarios

Technical Memorandum No. 6 presents potential exposure scenarios related to contamination at OU1 (DOE 1992c). Prepared as a preliminary report for the public health evaluation as stipulated in the Interagency Agreement, these exposure scenarios form the basis for development of the baseline risk assessment. Because these scenarios were prepared for the public health evaluation, only risks to human health were considered. Potential impacts on nonhuman receptors are considered in a parallel analysis done under the environmental evaluation portion of the baseline risk assessment.

Revision 4.0 of Technical Memorandum No. 6 was submitted for EPA and CDH review in June 1992. Comments received in August 1992 included a request for consideration of direct exposure to ground water in the future on-site residential land use scenario. The public health evaluation, Appendix F of this report, does not consider this exposure pathway because the small amount of ground water at OU1 is not exploitable and therefore represents an incomplete pathway of exposure. The following is a summary of the general approach of the exposure scenarios memorandum.

In Technical Memorandum No. 6, climate, geology, hydrology, and biota at RFP in general and at OU1 in particular are all reviewed as background information. Because the prevailing wind direction at RFP and drainage orientations at OU1 are from the north and west, the off-site receptor populations at greatest risk are those located south and east of the plant.

The memorandum includes analyses of current and future land use and related human exposure scenarios. The four land use groups considered in the memorandum include current on-site, current off-site, future on-site, and future off-site land use. Human exposure potentials associated with various land use options are evaluated separately for each of these four groups. The potential land uses considered for each group include residential, commercial/industrial, recreational, ecological reserve, and agricultural.

The current and future likelihood of each potential land use, both on and off site, is evaluated in the memorandum. Table 1-5 lists the conclusions drawn from both local and federal planning documents. Land uses classified as "credible" are the most likely, "plausible" land uses are conceivable but not expected, and "improbable" land uses are considered unlikely.

Exposure pathways are to be fully quantified in the public health evaluation for the most credible land uses described in the memorandum. Where there are several likely land use alternatives, exposure scenarios are to be quantified only for those land uses with the highest potential for human exposure. It is assumed that the potential risk associated with the quantified scenario will bound the potential risk for all other likely scenarios. Although future on-site residential use is improbable, this scenario will be considered at the request of EPA and CDH. Potential exposure pathways to the current on-site industrial worker will also be evaluated at the request of EPA and CDH.

The land use scenarios selected for quantitative exposure assessment include the following:

- Current off-site residential
- Current on-site commercial/industrial
- Future on-site residential
- Future on-site commercial/industrial
- Future on-site ecological reserve

Exposure pathways recognized as complete and the corresponding exposure parameters are identified for each of these five scenarios. The exposure parameters identified are to be used in the public health evaluation portion of the baseline risk assessment to develop reasonable maximum exposure values.

1.3.7 Description of Models for the Public Health Evaluation

Technical Memorandum No. 7 (DOE 1992e) describes the contaminant fate and transport models that are to be used to calculate the exposure to potential receptors identified in Technical Memorandum No. 6 (DOE 1992c). It was prepared as a preliminary report for the public health evaluation as required by the Interagency Agreement. Technical Memorandum No. 7 (Revision 2.0) was submitted for EPA and CDH review in July 1992. Comments received in August 1992 included a request for ground water modeling. The following is a summary of Technical Memorandum No. 7.

A conceptual model of the site is provided that illustrates the relationship between sources, release mechanisms and rates, transport media and processes, fate of contaminants, and potential receptors. The primary means of contaminant migration in the upper hydrostratigraphic unit (HSU) is by volatilization of organic compounds and subsequent upward migration as a gas in the unsaturated zone. Surface water, however, may also convey contaminants by overland flow, and fugitive dust may be episodically resuspended by wind erosion and transported to on- or off-site receptors. Pathways involving three transport media are to be modeled for the baseline risk assessment: the unsaturated (or vadose) zone, surface water, and air. Ground water modeling is not recommended because the ground water pathway is not complete and has not been associated with any potential receptors.

The following general criteria were considered in selecting the models:

- The selected model(s) should be able to adequately simulate site conditions.
- The selected model(s) should be able to satisfy the objectives of the study.

- The selected model(s) should be verified and reasonably well field-tested.
- The selected model(s) should be well documented, peer-reviewed, and available to the public.
- The selected model(s) should be practical and cost effective.

Based on these criteria, the following models were selected to simulate the migration of contaminants at OU1:

- The Jury (Jury, Spencer, and Farmer 1983) and Johnson (Johnson and Ettinger 1991) models for soil gas transport of VOCs contained in stagnant groundwater.
- The Universal Soil Loss Equation (Wischmeier and Smith 1978) and associated equations for surface water transport in overland flow to the South Interceptor Ditch.
- MILDOS-AREA (Yuan et al. 1989) for atmospheric modeling of emissions from a source, transport in air, and deposition at receptor locations. MILDOS-AREA simulated concentrations will be coupled with the plant uptake (root and foliar) models contained in the RESRAD code (Gilbert et al. 1989) and the consumption and occupancy factors (DOE 1992b) to estimate concentrations in potential receptors.

The parameters required to conduct modeling for the public health evaluation are tabulated in Technical Memorandum No. 7. The assumptions, uncertainties and limitations associated with the models selected are also included. Some data for modeling will be obtained from investigations that occurred prior to the Phase III RFI/RI field investigation. Phase III data will be used to select contaminants of concern and characterize source areas and pathways at OU1.

1.3.8 Contaminant Identification

Technical Memorandum No. 8 identifies the contaminants of concern for the risk characterization at OU1 (DOE 1992g). It was prepared as a preliminary report for the public health evaluation as stipulated in the Interagency Agreement. Technical Memorandum No. 8 was submitted to EPA and CDH for review in September 1992. The following is a summary of the contaminant identification memorandum.

Data from the OU1 Phase I, II, and III field investigations, supplemental surface soil sampling program, and routine ground water monitoring program were used to compile site-specific analyte lists for the media (ground water, surface soils, surface water, and sediment) where contaminants have been analyzed and detected. These media are sources of OU1 contaminants and represent the means by which current and future populations could potentially be exposed, either directly or indirectly.

As described in Technical Memorandum No. 6, *Exposure Scenarios* (DOE 1992c), potential receptors could be exposed to contaminants in ground water that volatilize to soil gas and potentially enter breathing air in hypothetical future on-site resident home. Ground water data was used to compile a site-specific analyte list for the soil gas exposure pathway. Analytes were limited to VOCs and SVOCs from the TCL and VOCs analyzed by EPA Method 502.2.

All of the exposure scenarios include direct contact with contaminants in surface soils and airborne contaminants released from surface soils by wind erosion. Surface soil data is used to compile a site-specific analyte list for the surface soil exposure pathway. Analytes consisted of SVOCs, PCBs, pesticides from the TCL, metals from the TCL, and select radionuclides.

The site-specific analyte list for the surface soil exposure pathway is also used for identifying contaminants of concern in surface water and sediment. Surface water and sediment monitoring stations in the South Interceptor Ditch and Woman Creek are located outside OU1 and are potentially influenced by contaminants from other operable units. Therefore, data from these stations are not exclusively representative of hazardous substances present at OU1 that may have contributed to the transport pathways.

Once site-specific analyte lists were compiled, a screening process developed using *Risk Assessment Guidance for Superfund* (EPA 1989b) was applied that consisted of the following:

- Eliminate chemicals considered essential human nutrients such as calcium, magnesium, potassium, and sodium.

- Eliminate contaminants with a detection frequency less than 5 percent.

- Delineate hot spots, a step designed to retain contaminants with elevated concentrations that might otherwise be eliminated because of infrequent detection. Contaminants exhibiting elevated concentrations with respect to the central tendency (mean) concentration include 1,1-dichloroethene, 1,1,1-trichloroethane, acetone, carbon tetrachloride, tetrachloroethane, trichloroethene, and methylene chloride.

- Eliminate contaminants with concentrations statistically similar to site background concentrations. Statistical tests performed included the F-Test, Bartlett's Test of Homogeneity of Variance, and Mann-Whitney U (Wilcoxin Rank Sum) Test. Tests were limited to metal and radionuclide data from surface soils.

- Eliminate contaminants contributing less than 1 percent of the risk based on a toxicity screen.

- Evaluate mobility, persistence, and transformation products of contaminants that were eliminated in the screening process. If high mobility, persistent or toxic transformation products were confirmed, professional judgment was used to retain these contaminants on the list of concern. Chemicals thus retained as contaminants of concern are the following: chloroform, methylene chloride, dichlorodifluoromethane, and trichlorofluoromethane.

Nineteen contaminants of concern were identified using this screening process. Dibenzofuran was one of the 19 contaminants of concern. The toxicity factor for dibenzofuran was changed during preparation of Technical Memorandum No. 9, *Toxicity Constants* (DOE 1992h), and as a result, dibenzofuran was eliminated as a contaminant of concern. Elimination of dibenzofuran allowed four polynuclear aromatic hydrocarbons (PAHs) to be retained as contaminants of concern including benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, and dibenzo(a,h)anthracene. A total of 22 contaminants of concern are to be used in the public health evaluation portion of the baseline risk assessment. They are listed below for the four media.

- Ground water: 1,1-dichloroethene, total 1,2-dichloroethene, 1,1,1-trichloroethane, carbon tetrachloride, chloroform, dichlorodifluoromethane, methylene chloride, tetrachloroethane, trichloroethene, and trichlorofluoromethane

- Surface soil: acenaphthene, AROCLOR-1254, benzo(a)pyrene, fluoranthene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, fluorene, pyrene, americium-241, plutonium-239, and plutonium-240

- Surface water: americium-241, plutonium-239, and plutonium-240
- Sediment: acenaphthene, AROCLOR-1254, benzo(a)pyrene, fluoranthene, fluorene, pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, americium-241, plutonium-239, and plutonium-240

1.3.9 Toxicity Constants

Technical Memorandum No. 9 identifies the human toxicity constants that are to be used in the public health evaluation portion of the baseline risk assessment (DOE 1992h). The baseline risk assessment is part of the Phase III RFI/RI at OU1. This memorandum was prepared as a preliminary report for the public health evaluation, as stipulated in the Interagency Agreement. Technical Memorandum No. 9 was submitted for EPA and CDH review in September 1992. The toxicity constants were developed according to procedures presented in the *Risk Assessment Guidance for Superfund* (EPA 1989b) and using the EPA *Integrated Risk Information System* and *Health Effects Assessment Summary Tables* (EPA 1991, 1992b, 1992c) as the primary information sources. The toxicity constants are to be integrated with chronic daily intakes in the risk characterization portion of the public health evaluation to yield quantitative risk estimates.

The toxicity constants for the OU1 contaminants of concern identified in Technical Memorandum No. 8, *Contaminant Identification* (DOE 1992g), include reference doses and associated uncertainty factors for noncarcinogens and cancer slope factors and weight-of-evidence classifications for carcinogens. Although health risks are calculated differently for carcinogens and noncarcinogens, some contaminants of concern (1,1-dichloroethene, carbon tetrachloride, chloroform, methylene chloride, tetrachloroethene, and trichloroethene) can have both properties. Toxicological profiles for each contaminant of concern are to be presented in the public health evaluation.

Noncarcinogenic contaminants of concern at OU1 are the following: acenaphthene, carbon tetrachloride, chloroform, dichlorodifluoromethane, 1,1-dichloroethene, 1,2-dichloroethene (cis-

and trans-), fluoranthene, fluorene, methylene chloride, pyrene, 1,1,1-trichloroethane, tetrachloroethene, trichloroethene, and trichlorofluoromethane.

Carcinogenic contaminants of concern at OU1 are divided into three groups (nonradiological carcinogens, PAHs, and radionuclides) because there are different slope factor derivations for radionuclides and nonradiological carcinogens and because slope factors for all PAHs are derived using a toxicity-weighting scheme based on the measured toxicity of benzo(a)pyrene.

Nonradiological contaminants of concern at OU1 are the following: AROCLOR-1254, carbon tetrachloride, chloroform, 1,1-dichloroethene, methylene chloride, tetrachloroethane, and trichloroethene.

PAH contaminants of concern for OU1 are the following: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, and dibenzo(a,h)anthracene. Cancer slope factors for PAHs were derived using a toxicity equivalency factor approach in the *New Interim Region IV Guidance* (EPA 1992d).

Radionuclide contaminants of concern for OU1 are the following: americium-241, plutonium-239, and plutonium-240. The radionuclide slope factors that have been determined by EPA are median estimates due to extrapolation of low dose risks from risks observed at higher doses using nonthreshold, linear dose-response relationships. The slope factors account for the distribution, retention, and decay of radionuclides and daughter products in the body, the amount of radionuclide transported into the bloodstream, the radiation dose delivered to specific organs and tissues, and the age and sex of exposed individuals.

1.3.10 Soil Sampling for Geotechnical Analysis

Geotechnical data are required to support site characterization and pathway definition, and with total organic carbon are important inputs to site-specific fate and transport models. In preparation for collecting geotechnical samples and total organic carbon samples at OU1, addenda to the

SOPs and the work plan were prepared in October 1991. This section discusses the geotechnical sampling addendum, and Section 1.3.11 discusses the total organic carbon soil sampling addendum.

The SOP addendum on soil sampling for geotechnical analysis supplements in Geotechnical SOP GT.02, *Drilling and Sampling Using Hollow Stem Auger Techniques* (EG&G 1991a). The geotechnical sampling plan for OU1 was prepared in conjunction with the SOP addendum; it identifies ten sampling locations.

The geotechnical SOP addendum calls for samples for permeameter testing to be taken by the same method used for VOC samples. The latter method uses a 3-inch stainless steel liner known as a California sleeve. The geotechnical field sampling plan requires geotechnical samples to be taken in the uppermost alluvium (within 4 feet of the surface), in the lowermost alluvium, and in the uppermost bedrock (within 4 feet of the contact). In addition, in bedrock borings, one sample is to be taken in the approximate interval selected for packer testing and well/piezometer screening. To expedite the analytical process, companion samples for sieve analysis were to be taken from material immediately above each California sleeve sample and placed into glass sample jars.

1.3.11 Soil Sampling for Total Organic Carbon Analysis

Total organic carbon analysis of soil samples was required because it is an important parameter in developing site-specific fate and transport models. An SOP addendum and field sampling plan for total organic carbon sampling were therefore prepared in October 1991 in conjunction with the geotechnical SOP and work plan addendum discussed above. The SOP addendum supplements guidelines in Geotechnical SOP GT.02, *Drilling and Sampling Using Hollow Stem Auger Techniques* (EG&G 1991a). The field sampling plan identifies ten locations for sampling.

The SOP addendum calls for composite samples to be taken at 6-foot intervals. The sample intervals required are similar to those for geotechnical sampling: uppermost alluvium (the top

6 feet), lowermost alluvium (directly above the bedrock contact), and uppermost bedrock (directly below the bedrock contact). In bedrock borings, a total organic carbon composite is also required in the approximate interval selected for packer testing and well/piezometer screening. Only one alluvial sample is required if bedrock is encountered at 6 feet or less below the ground surface.

1.3.12 Hand-Auger Sampling

This section summarizes an SOP addendum prepared in October 1991 in preparation for hand-auger sampling activities at OU1. Hand-auger sampling was to be used in sample locations where it was unsafe or impractical to use a standard drilling rig.

The hand-auger SOP addendum presents specific guidelines for hand-auger sampling using both split-spoon and sludge sampler techniques. Split-spoon methods were to be used when possible. The addendum stipulates that the split-spoon be driven with a slide hammer in 1-foot increments until auger refusal or to a depth of 10 feet. Samples were to be taken in polybutyrate tubes placed inside the split-spoons before sampling. After each 1-foot interval was driven, the split-spoon is retrieved from the hole and the polybutyrate sleeve removed, capped, taped, labelled, recorded, and placed in a cooler whose interior temperature was kept at 4 degrees Centigrade.

1.4 REPORT ORGANIZATION

This section of the Phase III RFI/RI report presents purpose, background, IHSS locations and descriptions, and a summary of technical memoranda specific to the Phase III RFI/RI. Included in Section 2.0 are descriptions of Phase III field investigation at OU1 and descriptions of other related sampling and monitoring programs. Section 3.0 presents the site characterization including surface features, demography and land use, meteorology and climatology, surface water hydrology, soils, geology, hydrogeology, and ecology. Section 4.0 discusses the nature and extent of contamination for soils within each IHSS and for other media. Section 5.0 reviews contaminant fate and transport, including contaminant modeling. Section 6.0 presents a baseline risk assessment that includes a public health evaluation and an environmental evaluation. Section 7.0 summarizes the site physical features, contaminant sources, nature and extent of

contamination, fate and transport, and risk assessment, which is followed by conclusions regarding data limitations and recommended remedial action objectives. Section 8.0 presents references. Volumes I and II contain text and supporting tables and figures for Sections 1.0 through 8.0.

Supporting data were collected and many complex computations were performed as part of data analysis methods. In order to present these data, a number of appendices have been assembled and attached to this report. The contents of these appendices are described below:

- Appendices A1–A4 (Volumes III, IV, V, and VI) contain geologic data
- Appendices B1–B4 (Volumes VII and VIII) contain ground water data, hydraulic conductivity test interpretations, and a hydrogeologic assessment of the french drain
- Appendices C1–C9 (Volumes IX, X, XI, and XII) contain chemical analytical results
- Appendix D (Volume XII) summarizes quality assurance procedures
- Appendix E (Volume XIII) is the environmental evaluation
- Appendix F (Volume XIV) is the public health evaluation

Section 2.0 · Text

OU1 Field Investigation

Phase III
RFI/RI Report

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2.0 OU1 FIELD INVESTIGATION

The OUI Phase III RFI/RI was an integrated investigation that was designed and implemented to address potential contamination in several media, and was focused to fill specific data gaps identified in previous investigations. This section of the report describes all components of the Phase III field investigation.

The four general objectives of the OU1 Phase III RFI/RI identified in the work plan (DOE 1991b) were to characterize site physical features, contaminant sources, and nature and extent of contamination, and to provide a baseline risk assessment. In order to achieve these objectives, the following types of investigations were performed at OU1:

- Individual hazardous substance site investigations
- Air quality and meteorological investigations
- Surface water and sediment investigations
- Geological investigations
- Surface soils investigations
- Ground water investigations
- Ecological investigations

In general, the source characterization objective was addressed by the IHSS investigations; the site physical features and nature and extent of contamination were characterized as a part of the IHSS, surface water and sediment, geologic, and ground water investigations; and the baseline risk assessment is supported by data from all of the investigations, including the air quality and ecological investigations. Table 2-1 displays the objectives of the Phase III RFI/RI as well as the activities that were proposed and completed in order to meet the objectives. Table 2-2 lists the various programs under which the investigations at OU1 were carried out. The following subsections describe each of the investigations listed above.

2.1 INDIVIDUAL HAZARDOUS SUBSTANCE SITE INVESTIGATIONS

The OU1 Phase III RFI/RI OU1 drilling program was conducted to provide a better definition of potential sources of contamination, site physical features, and the nature and extent of contamination present at OU1. Tables 2-3 and 2-4 present the locations, purpose, and completion details for boreholes and monitoring wells on an IHSS-by-IHSS basis. Figure 2-1 shows Phase III RFI/RI borehole and monitoring well locations.

Drilling locations were generally chosen relative to one or more of the 11 IHSS locations. For each IHSS, boreholes and/or monitoring wells were drilled within or near the IHSS for geologic characterization and definition of the nature and extent of contamination at each source. Boreholes were also drilled downgradient of various IHSSs, near the South Interceptor Ditch, and in the Woman Creek valley fill alluvium to assess the nature and extent of soil contamination in areas downgradient of IHSSs. Monitoring wells were installed both upgradient and downgradient of OU1 IHSSs to isolate the impact of these IHSSs on ground water quality. Finally, additional monitoring wells were installed along the South Interceptor Ditch and along Woman Creek in order to characterize ground water quantity and quality in these downgradient areas, and to assess the interaction of the surface water and ground water pathways.

Each drilling location specified in the work plan (DOE 1991b) was designated a piezometer (indicated by a "PZ" designation), a borehole (indicated by a "BH" designation), a monitoring well (indicated by an "MW" designation), or a combination borehole and monitoring well. These designations, shown as "proposed numbers" in Tables 2-3 and 2-4, indicate the purpose of the drilling location and the drilling and completion details. At borehole locations, the soil samples were used to characterize subsurface soils and to determine the nature and extent of soil contamination by sampling for an extensive suite of analytes. Following sample collection, the borehole was grouted to surface and the location was abandoned following procedures in Geotechnical SOP GT.05, *Plugging and Abandonment of Boreholes* (EG&G 1991a). Locations with both borehole and monitoring well designations were sampled like other boreholes, then completed as monitoring wells. At both monitoring well and piezometer locations, soil samples

were collected only at the water table and at the alluvium/bedrock contact. Both monitoring well and piezometer locations were cased and grouted. They are currently sampled during routine ground water monitoring as follows: only water elevation measurements are taken at piezometer locations, while elevation measurements and water samples are collected at monitoring well locations. Monitoring wells were installed to define the nature and extent of ground water contamination at OU1.

In addition to the borehole, piezometer, and monitoring well locations, pilot holes (indicated by a "PH" designation) were drilled at potential multiple-well test sites, and wellpoints were installed at the single site used for the multiple-well test. Limited soil sampling was also performed in the pilot holes.

A total of 114 borings were drilled, including 95 borings for sampling and/or monitoring, 3 borings for pilot holes, and 16 borings for wellpoints. All 16 wellpoints were temporary installations. Twenty-six monitoring wells and 5 piezometers were installed at 31 of the monitoring locations. Following Geotechnical SOP GT.06, *Monitoring Wells and Piezometer Installation* (EG&G 1991a). Ninety-six of the 114 drilling locations were initially drilled using rig-mounted hollow-stem augers following Geotechnical SOP GT.02, *Drilling and Sampling Using Hollow Stem Auger Techniques* (EG&G 1991a). The 16 wellpoint locations were drilled using rig-mounted solid augers, and the other 2 locations were drilled manually using a drive hammer.

All borehole piezometer, and monitoring well locations were drilled using 6-1/2-inch outside-diameter (O.D.) augers. Mechanically drilled boreholes along with bedrock piezometer and monitoring well locations were drilled approximately 3 feet into bedrock. Alluvial piezometer and monitoring well locations were drilled to the alluvium/bedrock contact. Alluvial piezometer and monitoring well locations were then reamed with 11-5/8-inch O.D. augers. After reaming, alluvial boreholes were drive-sampled at least 2 more feet into bedrock to avoid smearing bedrock clays upward on the borehole walls. Bedrock boreholes were reamed with 14-inch O.D.

augers. Wellpoint locations were drilled using 4-inch O.D. solid steel augers, with the stainless steel wellpoints driven to total depth with a drive hammer.

Continuous core samples were taken during drilling using a 2-1/2-inch inside-diameter (I.D.) split-spoon sampler. Composite samples were collected at both borehole and monitoring well locations. Composite samples consisted of material peeled from the core recovered in each of three consecutive 2-foot drilling runs. The peeled material, typically 1/4 to 1/2 of the core, was homogenized in a bowl and then placed into sample containers such that the material in each sample container was representative of the entire 6-foot interval. For each composite sample a corresponding radiological screening sample was also collected from the material in the bowl. At monitoring well locations, each 6-foot composite sample consisted only of a radiological screening sample.

For VOC and geotechnical sampling, a stainless steel sleeve was placed at the lead end of the split-spoon sampler. At borehole locations, VOC samples were taken at the base of the first 2-foot run and every 4 feet thereafter until either the water table or the alluvium/bedrock contact was encountered. In addition, one VOC sample was collected directly below the water table, and one directly below the alluvium/bedrock contact. At monitoring well locations, VOC samples were collected only at the water table and bedrock contact depths. For each VOC sample, a corresponding radiological screening sample was also collected at the same depth. Radiological screening samples were taken at all sampling locations to determine whether or not it was appropriate to ship samples off site for analysis.

Geotechnical and total organic carbon (TOC) samples were taken at 11 locations in OU1. While geotechnical samples were taken from discrete intervals, TOC samples were taken as composite samples from up to 6 feet of continuous core. The TOC samples also had their own radiological screening samples.

VOCs were the only analytes at monitoring well, piezometer, and pilot hole locations. Analyses of samples from borehole locations included VOCs, SVOCs, including acid and base/neutral extractables and pesticides/PCBs; radionuclides; metals; and inorganic compounds, including "indicator parameters." Table 2-5 presents the chemical analyses run at each of the borehole, monitoring well, piezometer, and pilot hole locations. Table 2-6 presents the list of analytes for soil sample analyses.

As prescribed by the work plan, additional samples collected during the Phase III field investigation included samples of effluent from the Building 881 footing drain as well as samples of Coherex, a dust suppressant previously used at OU1. Footing drain effluent samples were collected by lowering a bailer down through a manhole access located approximately 150 feet south of Building 881. Coherex, which has been implicated as a potential source of toluene contamination at OU1, was sampled by pouring material directly from the storage drum into sample containers.

2.2 AIR QUALITY AND METEOROLOGICAL INVESTIGATIONS

Meteorological data collected for this report are based on the primary wind site at RFP, the 61-meter tower located in the west buffer zone. The tower is instrumented at 10, 25, and 60 meters to measure horizontal wind speed, vertical wind speed, wind direction, and temperature. Dew point measurements are made at the 10-meter level. Solar radiation measurements are taken by a radiometer mounted on an unobstructed platform at 1.5 meters above ground level. Ground level precipitation and pressure are also measured. Meteorological information in this report represents 96 percent data recovery from the 61-meter instrumentation.

Air monitoring programs have been conducted at RFP since the early 1950s. The plant currently incorporates air quality programs that protect the plant employees, the general public, and the environment through appropriate engineering, administrative controls, and subsequent monitoring and assessment of the impact to the air from both radiological and nonradiological sources. As part of this effort, a sitewide sampling program following Air SOP AP.13, *Radioactive Ambient*

Air Monitoring Program (EG&G 1991a), is ongoing to monitor for potential airborne dispersion of radioactive materials from RFP into the surrounding environment. This program consists of 53 RFP-designed high-volume air samplers located throughout the plant site and the community. Data from this network are presented at monthly data exchange meetings held jointly with RFP, CDH, and representatives from the surrounding communities. In addition, an annual RFP site environmental report is published that includes all air monitoring data and associated impact analyses. The latest issue of this annual report is dated 1991 and covers the period from January through December 1990 (EG&G 1991b).

Ambient air samplers that monitor airborne dispersion of radioactive particulates from OU1 include a combination of existing samplers from the RFP Radioactive Ambient Air Monitoring Program, and four special high-volume samplers set up specifically for this project following Air SOP AP.16, *Restoration Projects Radioactive Ambient Air Particulate Sampling High-Volume Methods* (EG&G 1991a). Data used to document particulate dispersion from OU1 operations are from samplers S-9, S-10, S-11, S-17, S-23, S-38, S-39, and S-40 (Figure 2-2). Data from sampler S-32 are included to represent an upwind, background location. Ambient air samplers, designed at RFP, include a vortex-type, brushless motor that operates continuously at a volumetric flow rate of approximately 0.71 actual feet^3/minute, collecting air particulates on a 20- by 25-cm fiberglass filter. The four site-specific air samplers established for OU1 are commercially available units that use a patented critical flow device to hold the sampling flow rate at approximately 1.42 actual feet^3/minute. Figure 2-3 shows the location of these four high-volume samplers (S-81A, S-81B, S881C, and S-81D). Due to the continuous operation of the air sampler, it has been necessary to replace the carbon brush motors on a weekly basis to minimize sampler down time. Filters for all OU1-related samplers were collected biweekly, composited by location, and analyzed monthly for plutonium. Section 4.0 presents data from these samplers.

2.3 SURFACE WATER AND SEDIMENT INVESTIGATIONS

Surface water and sediment sampling are conducted on a monthly basis at RFP following Surface Water SOP SW.01, *Surface Water Data Collection Activities*, SW.02, *Field Measurement of Surface Water Field Parameters*, and SW.03, *Surface Water Sampling* (EG&G 1991a). Table 2-7 lists the chemical parameters for which sediment samples are analyzed, and Table 2-8 lists the chemical parameters for surface water samples. Analytical data retrieved from the Rocky Flats Environmental Database System were used to describe the nature and extent of contamination in surface water and sediments in this report.

The Phase III RFI/RI includes analytical data and flow measurements from ten surface water stations located along Woman Creek, the South Interceptor Ditch, and at various seeps and ponds in the vicinity of OU1 (Figure 2-4). Most of these stations have been monitored monthly since the first quarter of 1990. Three stations (SW044, SW045, and SW046) are located south of Building 881. Station SW044 monitors outfall from a pipe that drains the skimming pond and discharges to the South Interceptor Ditch. Station SW045 monitors the foundation drain discharge from Building 881. The foundation drain is a vitrified clay pipe that is buried 14 to 20 feet deep along the south and west sides of Building 881. Water in the pipe drains southward to a common pipe and then to the skimming pond. Station SW046 is located just west of the skimming pond in a small zone of seepage formed by ground water discharge. Stations SW045 and SW046 were damaged during construction of the french drain. Station SW035 monitors water quality in the South Interceptor Ditch upstream from Building 881. Station SW031 monitors water quality in the South Interceptor Ditch just downstream of station SW044. Surface water stations SW066, SW067, SW068, SW069, and SW070 monitor the South Interceptor Ditch downgradient from OU1.

Three new bedload sediment sampling stations (SED037, SED038, and SED039) were established along the South Interceptor Ditch south of OU1 near surface water stations SW035, SW067, and SW070, respectively. Figure 2-5 shows the locations of the new sediment sampling stations. Unlike the old sediment sampling stations, which are downgradient of both OU1 and OU2, the

new stations are upgradient of OU2 and downgradient of OU1. Therefore, the new stations may be used to characterize sediment bedload contamination exclusively associated with OU1 without the possibility of the samples including contaminants from OU2. Samples were collected from stations SED037, SED038, and SED039 in November 1991. Attempts were made to collect samples from stations SED037, SED038, and SED039 in December 1991 and February 1992, but the sediment was frozen. Attempts were also made to collect samples in April 1992, but the stations did not have enough sediment. Only data from November 1991 are included in this report.

2.4 GEOLOGICAL INVESTIGATIONS

Surface and subsurface geological investigations were conducted at OU1 as part of the Phase III RFI/RI site characterization. The general objectives of the geological investigation were to evaluate the influence of alluvial and bedrock geology on both the ground water flow in the upper HSU and on the release and movement of contaminants in the saturated zone. An additional goal was to obtain the geotechnical information needed for potential site remediation activities. The surface investigation included an analysis of pre-RFP historical aerial photographs to map the slumps and seeps observed during french drain construction activities. The subsurface investigation included description and logging of alluvial and bedrock material from drill cores, borehole geophysics, sample collection for geotechnical analysis, and geologic mapping of the french drain excavation.

Paired aerial photographs (1951, approximate scale 1"=750') were examined stereoscopically to locate seeps and to map slumps in the 881 Hillside area. Seeps were identified based on the nature and color of the vegetation in the photographs. Slumps were identified based on the presence of a curvilinear scarp or topographic break in slope at the top, a lobate shape, and hummocky topography at the base. Slump outlines were drawn based on these characteristics and were numbered using the numbering scheme developed in the geotechnical investigation (EG&G 1990e). A map depicting slumps and seeps was constructed from the aerial photographs (see Section 3.6.3 of this report).

Subsurface geological investigations were conducted concurrently with the IHSS investigations, as discussed above in Section 2.1. Continuous core samples for geologic description were collected from the entire depth of 97 of the Phase III boreholes. The cores were described according to Geotechnical SOP GT.01 *Logging Alluvial and Bedrock Material* (EG&G 1991a). Alluvium, colluvium, artificial fill, and soil were classified and described according to the Unified Soil Classification System. Weathered and unweathered bedrock materials were classified and described using the classification scheme developed by Compton (1962), which has been modified for use at RFP and is incorporated in the SOPs. Geologic borehole logs were input into the Rocky Flats Environmental Database System using RFP well installation/borehole logging procedures.

Subsurface investigations also included borehole geophysics. Natural gamma logs and caliper logs were run in bedrock boreholes following Geotechnical SOP GT.15, *Geophysical Borehole Logging* (EG&G 1991a), to select depth intervals for the packer tests. Natural gamma logs were used to determine relative clay content and caliper logs were used to discern borehole diameter and depth intervals subject to caving. Appendix A1 includes the geophysical logs for boreholes 37891, 37991, 38991, 39191, and 39291.

Geotechnical samples were collected during drilling operations to determine physical properties of alluvial and bedrock material at OU1. Forty-six geotechnical samples were collected from eleven boreholes (37391, 37491, 37591, 37691, 37891, 37991, 38591, 38991, 39091, 39191, and 39691). Collection of samples followed procedures in the field sampling plan, which is summarized above in Section 1.3.10. Thirty alluvial and sixteen bedrock samples were collected and sent out for analysis. Geotechnical analyses included grain-size distribution (mechanical sieve analysis and hydrometer tests), Atterberg limits including liquid and plastic limits and plasticity index, moisture content, density, back-pressure permeability, and specific gravity. Appendix A2 presents both raw test data and summary tables of geotechnical data for alluvial and bedrock materials.

The geology of the french drain excavation was mapped using methods described in Geotechnical SOP GT.07, *Logging and Sampling of Test Pits and Trenches* (EG&G 1991a). Lithologic contacts, particularly the alluvial/bedrock contact, were mapped at 25-foot transect intervals whenever construction activities of the french drain permitted. Measuring tapes were placed at transect intervals and draped vertically along the excavation to determine unit thickness, depth to sample locations, and depth to bedrock contacts. Lithologic units were described using Geotechnical SOP GT.01 *Logging Alluvial and Bedrock Material* (EG&G 1991a). Samples were collected from representative lithologic units for geotechnical analyses. In situ hydraulic conductivities were measured in bedrock according to Geotechnical SOP GT.23, *In Situ Hydraulic Conductivity Test* (EG&G 1991a). Bedding attitudes, fault plane attitudes, slump glide plane attitudes, and joint and slickenside orientations were measured where possible with a Brunton compass. Seeps, zones of saturation, zones of permeability, and staining along joint surfaces were noted.

2.5 SURFACE SOIL INVESTIGATIONS

Surface soil investigations were conducted at OU1 under two separate programs, described below in Sections 2.5.1 and 2.5.2. Surface soil sampling for radionuclides was conducted from August 1991 to October 1992 as part of the Phase II RFI/RI for OU2 (DOE 1991a) and included soil sampling locations in OU1. Surface soil sampling for radioactive and nonradioactive contaminants was conducted from February to March 1992 as part of the Phase III RFI/RI for OU1 (DOE 1992a). Data from these investigations will be used to determine the spatial and vertical extent of plutonium and americium in surficial soils, and to determine mean contaminant concentrations in surface soils for use in the baseline risk assessment.

2.5.1 Surface Soil Sampling for Radionuclides

Surface soil sampling was conducted in an area was divided into 10- and 2.5-acre plots for the purpose of sampling for radionuclides in surface soils. The 2.5-acre grid was used in areas proximal to radionuclide contamination source areas in OU2 because the large variations in soil contaminant concentrations in these areas warrant a greater density of data. The 10-acre grid was

used in distal areas where contaminant distribution is more uniform and, therefore, fewer data points were required. There were a total of eighty-five 10-acre plots and forty 2.5-acre plots; seven of the 10-acre plots and four of the 2.5-acre plots fall entirely or partially in the OU1 study area (Figure 2-6). Surface soils in all but one of the 10-acre plots and all but six of the 2.5-acre plots were sampled according to the CDH surface soil sampling protocol outlined in Geotechnical SOP GT.08, *Surface Soil Sampling* (EG&G 1991a). The seven plots that were not sampled contained obstructions such as buildings or asphalt that made sampling impossible. All 11 of the plots in OU1 were sampled. In accordance with the CDH sampling protocol, subsamples were collected on a uniform grid centered in the plot with a spacing of 132 feet for 10-acre plots and 66 feet for 2.5-acre plots. Twenty-five subsamples were collected within each 10- or 2.5-acre plot, each measuring 1/4 inch by 2 inches by 2-3/8 inches. These subsample grids were surveyed in the field using a tape and compass.

All of the plots were also sampled using an RFP surface soil sampling method. The RFP sampling method required the collection of ten subsamples, each measuring 10 cm by 10 cm by 5 cm, from each plot. Rather than distributing the subsample locations uniformly throughout the plot as with the CDH method, the RFP method involved collecting five subsamples from each of two 1-square-meter areas placed 1 meter apart. The entire 3-square-meter array was located in the geographic center of each plot. Four subsamples were collected from the four corners of each of the two 1-square-meter areas, and one subsample was collected from the center of each 1-square-meter area.

Subsamples collected both by the CDH method and by the RFP method were composited into one sample for each plot and analyzed for plutonium, uranium, and americium.

In conjunction with the surface soil sampling for radionuclides, vertical profile sampling of surface soils was performed at 25 locations. Four of the locations are in OU1 (Figure 2-6). Vertical profile samples were collected from backhoe pits, which were located in each of the 25 plots selected for vertical profile sampling. The exact location of the backhoe pit within the plot

was selected based on soil type and slope. The backhoe pits were dug 1 meter deep, and samples were taken every 10 cm. Ten samples were taken from each of the four pits in OU1. The purpose of vertical profile sampling was to assess the vertical distribution of plutonium-239, plutonium-240, and americium-241 in OU1 soils. In addition, samples were taken at all soil horizons to analyze for diagnostic soil parameters.

2.5.2 Surface Soil Sampling for Nonradioactive and Radioactive Contaminants

The OU1 surface soil sampling and analysis program for nonradioactive and radioactive contaminants was specifically designed to collect data representative of surface soil contamination at OU1 that could be used to determine mean contaminant concentrations within an acceptable error of estimation. The goal of the program was to obtain data of high statistical quality to be used in the baseline risk assessment. The study area covers the OU1 IHSSs and the area downslope to Woman Creek. This area was divided into more than four hundred fifty 50- by 100-foot contiguous rectangular plots, which were numbered sequentially. Twenty-four of the plots were selected for sampling with a random number generator. In addition, four biased sampling locations were selected in IHSSs 106, 130, 1191.1, and 119.2. These four IHSSs are considered the most likely to have surface soil contamination because they are areas where contaminated liquids were suspected to have been discharged, drummed wastes were stored, or wastes were buried at shallow depths. A total of 28 of the 50- by 100-foot plots were sampled as shown in Figure 2-7. The sampling method used was a modification of the RFP method, described above in Section 2.5.1, where an array of ten subsamples were collected in a local 3-square-meter area located at the geographic center of each plot. In this modification of the RFP method, ten subsamples were collected in the center of the selected plots, and ten subsamples were also taken at each corner of each selected plot using the same 3-square-meter configuration of subsample locations. The 50 subsamples thus collected were composited to create one sample for each of the 28 plots.

A sampling program using a scheme similar to that described above was conducted in the Rock Creek area west and north of RFP to characterize background conditions. Soil types in the Rock

Creek area parallel those at OU1, and the background soil samples were collected on a south-facing slope so that field conditions would be similar. As with OU1, the background area was divided into 50- by 100-foot rectangular plots that were sequentially numbered. Nine of the plots were selected for sampling with the random number generator. Figure 2-8 shows the locations of the nine plots sampled.

All samples taken at OU1 and in the Rock Creek area were analyzed for chemical parameters that included total metals, total radionuclides, base/neutral extractable and pesticide/PCB SVOCs (Table 2-9). In addition, approximately 20 percent of the samples (six OU1 samples and two background samples) were submitted for laboratory particle-size analysis (hydrometer test) and bulk-density testing.

2.6 GROUND WATER INVESTIGATIONS

Ground water sampling is conducted on a monthly basis at RFP following Groundwater SOP GW.01, *Water-Level Measurements in Wells and Piezometers*, GW.05, *Field Measurement of Ground Water Field Parameters*, and GW.06, *Ground Water Sampling* (EG&G 1991a). All wells installed during the Phase III RFI/RI were developed and sampled during first quarter 1992. Table 2-10 lists the chemical parameters for which ground water samples are analyzed. Four monitoring wells (0974, 1074, 0487, and 4387) were sampled for dense nonaqueous phase liquids (DNAPL) in November 1991 during routine monitoring. Groundwater was collected using a clear bailer prior to well purging and was visually inspected for DNAPL liquids. Analytical data retrieved from the Rocky Flats Environmental Database System were used to describe the nature and extent of contamination in ground water in this report. As part of the site characterization work for OU1, single well and borehole tests were conducted to develop hydraulic conductivity values for alluvial and bedrock materials. Figure 2-9 shows the locations of the single well and borehole tests.

Packer tests were performed in the uncased portion of four bedrock boreholes (37891, 37991, 39191, and 39291). Test intervals were selected using natural gamma logs to determine bedrock

lithology and using caliper logs to determine depth intervals subject to caving. Complications arising from poor weather conditions and nearby construction activities associated with the french drain prevented the conduct of a packer test in borehole 38991 prior to well installation. Table 2-11 presents information on the packer tests and Appendix B1 provides a more thorough explanation of the tests and the results.

Two types of single well tests (slug injection/slug withdrawal tests and bail down/recovery tests) were performed in Phase III monitoring wells and piezometers (Figure 2-9). Test locations were selected in monitoring wells and piezometers with sufficient water levels and available data on sustainable flow rates from surrounding older monitoring wells. Slug injection/slug withdrawal tests were performed in four alluvial monitoring wells (31891, 34791, 35691, and 37191), one alluvial piezometer (38191), one bedrock monitoring well (37891), and one bedrock piezometer (39291). Bail down/recovery tests were performed in four alluvial monitoring wells (36191, 37591, 37791, and 38591), two bedrock monitoring wells (37991 and 39191), and one bedrock piezometer (38991). Table 2-12 presents a summary of both types of aquifer tests and Appendix B1 provides a more detailed description of the field operations and results.

A multiple-well pumping and tracer test program was conducted along Woman Creek downgradient of OU1 (Figure 2-10). The purpose was to collect data to better calculate estimates of solute travel times in saturated materials in the vicinity of the creek. Three test sites were specified in the work plan (DOE 1991b), but only one site (Site #1) had a section of saturated alluvium thick enough to conduct the test.

Initially, a single temporary wellpoint (39891) was installed to a depth of 6 feet at Site #1. The wellpoint was used to conduct a step-drawdown pumping test to determine the optimum pumping rate for the multiple-well pumping test. This same wellpoint was then used to select the most appropriate tracer for the multiple-well tracer test. The test performance of distilled water was compared with potassium bromide and the latter was selected as most appropriate for the site conditions and test parameters. After completing the step-drawdown and tracer selection tests,

15 temporary wellpoints were installed, each to an approximate depth of 6 feet and 2.5 feet apart in an array of three rows of five wellpoints. This design was chosen to best produce a linear, sustainable flow field within a reasonable time period. Two multiple-well tests were conducted; a multiple-well pumping test provided data used to estimate transmissivity and specific yield, and a multiple-well tracer test provided data to determine effective porosity, linear dispersivity, and average ground water flow velocity. At the conclusion of the multiple-well tests, all 16 wellpoints were removed and the boreholes were abandoned according to Geotechnical SOP GT.05, *Plugging and Abandonment of Boreholes* (EG&G 1991a). Appendix B2 provides a more thorough explanation of the tests and the results.

2.7 ECOLOGICAL INVESTIGATIONS

Surveys of terrestrial and aquatic biota were conducted from April 1991 to February 1992 to characterize biological site conditions in terms of species presence, habitat characteristics, and community organization. Emphasis was placed on describing the structure of the biological communities within OU1 to identify potential pathways, biotic receptors, and key species likely to be impacted by chemical contaminants. Methods were developed in concert with the environmental evaluation work plan (DOE 1991c) and in compliance with Ecology SOPs (EG&G 1991a). Details of the sampling program are contained in the environmental evaluation field sampling plan (DOE 1991j).

Vegetation, wildlife, and aquatic organisms (plants and animals) can be exposed to contaminants directly through contact with contaminated media (air, soil, sediment, water). Animals can also be indirectly exposed through consumption of contaminated forage or prey (Figure 3.2-11). The conceptual model was developed to identify exposure pathways and exposure points. Each exposure pathway consists of four elements: source of contaminant, mechanism of retention or transport medium, an exposure route (e.g., ingestion), and a receptor (EPA 1989). These components can be further defined as involving primary or secondary sources and release mechanisms. A contaminant that has been released to the environment can be a contaminant

source for other media. For example, soil contaminated by a spill could be a contaminant source for ground water or surface water.

2.7.1 Synopsis of Exposure Pathways

The potentially most significant exposure pathways to biota contaminants of concern may be summarized as follows:

- Direct exposure of receptors to soil contaminants within OU1 IHSSs as well as outside the IHSS areas
- Direct exposure of aquatic organisms to contaminants transported into surface water by wind, runoff, or shallow ground water
- Imbibition of contaminated surface water (including seeps and springs) by terrestrial vertebrates
- Consumption of contaminated plant material by herbivores
- Consumption of contaminated animal tissue by predators

Data collected during the Phase III RFI/RI and ongoing RFP monitoring programs were used to evaluate exposure to contaminants in abiotic media. Evaluation of contaminant uptake by plants and animals was carried out by comparing tissue samples from OU1 with samples from areas upgradient of OU1 and from reference areas. See Section E.3.2 of Appendix E for further information on exposure pathways.

2.7.2 Sampling and Testing Procedures

Biotic diversity and community composition reflect the health of an ecosystem. Species present in either terrestrial or aquatic ecosystems can indicate the degree of stress on a community due to perturbations as pollution-intolerant species are underrepresented in a stressed environment. The sampling program was designed to reflect environmental stress from comparisons between study and reference areas. Sampling for each ecological component was conducted in accordance with the Ecology SOPs. The primary objective was to collect data for comparison between

reference and study area sites (Figures 2-12 and 2-13) that would reveal any adverse impacts in the study area.

Phytoplankton samples were collected during late summer 1991 from study and reference area ponds (Figure 2-14) in accordance with Ecology SOP EE.03 *Sampling of Plankton* (EG&G 1991a). Periphyton were collected during late summer 1991. Artificial substrates (tiles and diatomers) were used as required in accordance with Ecology SOP EE.01, *Sampling of Periphyton* (EG&G 1991a). Benthic macroinvertebrates were collected from streams and impoundments in accordance with Ecology SOP EE.02, *Sampling of Benthic Macroinvertebrates* (EG&G 1991a). Collection of these organisms was conducted in May to June and August to September 1991. Study and reference area aquatic sites were evaluated for the likelihood that fish species were present. Fish were sampled in May to June and in August to September 1991 according to the most appropriate method as outlined in Ecology SOP EE.04, *Sampling of Fishes* (EG&G 1991a).

Acute aquatic toxicity screens were conducted on samples collected from Woman Creek to ascertain gross toxicity of surface water and determine whether any toxicity detected could be a result of contaminants originating from the OU1 area. Samples were collected during low flow in August 1991 in accordance with Surface Water SOP SW.03, *Surface Water Sampling* (EG&G 1991a) and the instructions and protocols from the toxicity testing laboratory. Samples were immediately place in a cooler with "blue ice" and transported to the laboratory within 6 hours of collection. Toxicity tests commenced within 24 hours of collection and were conducted following to the techniques described in Peltier and Weber (1985) using fathead minnows and water-fleas as test organisms. These procedures are consistent with the CDH/Colorado and EPA Region III guidelines for biomonitoring. Hardness, alkalinity, conductivity, ammonia, pH, and dissolved oxygen were measured in samples prior to the toxicity tests. Other water chemistry data were obtained from results of RFP monthly surface water sampling activities.

Tissue samples were composed of plant and animal groups considered to be vulnerable components of the ecosystem (i.e., animals with small home ranges with intimate contact with the soil, plants, and aquatic organisms). Samples were taken from all sites where possible. Groups collected for tissue analysis of the terrestrial system included vascular plants, grasshoppers, small mammals, and reptiles. Specimens were collected from crayfish, salamanders, and fish for analysis of potential risk to the aquatic system. Procedures for collection and preparation followed the field sampling plan (DOE 1991j) and the appropriate Ecology SOPs (EG&G 1991a).

2.7.3 Assessment of Ecological Risk

The evaluation of ecological risks associated with contamination at OU1 was carried out using the Hazard Quotient (HQ) method (EPA 1989). This method uses the ratio of the actual or estimated exposure concentrations to toxicologically based benchmark or reference values. The HQ method, or modified versions of it have also been applied in ecological risk assessments (EPA 1989a; CDH 1990; EPA 1992e, 1992f). However, formal reference values are not readily available for most animal and plant species and must be derived from various sources.

2.7.4 Methodology for Soils, Surface Waters, and Sediments

Concentrations of contaminants of concern in soils collected during the Phase III field investigation were measured as total content per unit dry weight of soil. Data were collected for surface soils and soil borings to a maximum depth of 18 feet. Data from soil boring samples include gravel- and cobble-sized particles. This measure of soil content, which may be more properly termed geologic materials, probably overestimates the actual amount of metal that is bioavailable and, therefore, overestimates the potential toxicity.

The concentration of contaminants of concern in surface waters was evaluated from data collected during routine surface water monitoring RFP. Data from surface water stations upgradient and downgradient from OU1 IHSS areas were examined for exceedence of RFP background concentrations and surface water quality standards. Refer to Appendix E for data regarding

dissolved and total recoverable metals in surface water samples. The dissolved measure represents that fraction most available to aquatic biota and most appropriate for comparison with Colorado Water Quality Standards.

Data on contaminant distribution in sediments are also drawn from routine monitoring conducted at RFP. Sediment sampling stations have been established on Woman Creek and the South Interceptor Ditch directly south of OU1, but no data were available for these sites. Data were available, however, for sites upgradient and downgradient from OU1. Sediment sampling stations SED016 and SED017 are located on Woman Creek west (upgradient) of OU1 and correspond to surface water stations SW107 and SW041, respectively. Sediment stations SED018 and SED019 are located at groundwater seeps and correspond to surface water stations SW080 and SW104, respectively. Station SED027 is located on Woman Creek just downstream from Pond C-1, and SED026 is located further downstream just above Pond C-2. Stations SED028 and SED031 are both on the South Interceptor Ditch, downgradient from OU1 but upgradient from Pond C-2. Data for sediments were expressed as total content per unit dry weight.

2.7.5 Quantification of Risks

The level of risk has been categorized as low, moderate, or high. A judgment of low risk indicates an exposure approximating the concentration at or below the threshold for toxic effects. Moderate risk is assessed for contaminant levels that indicate exposures exceeding the threshold for effects to sensitive species, but not exceeding the median lethal concentration for the population. Finally, high risk was determined to exist when exposures may affect more than half of the sensitive populations and may result in toxic effects to more tolerant species. See Section E.3.7 of Appendix E for further information on risk characterization.

Whole-body burdens of target analytes in plants and animals were measured for OU1 and reference area sites to determine gross concentrations of contaminants of concern. This measure does not assess the actual incorporation of target analytes into individual tissues, a measure

needed to assess potential toxicity of accumulated contaminant loads, because nonavailable forms of contaminants of concern (e.g., minerals in soil ingested by organisms) were not quantified.

2.7.6 Taxonomic Group, Trophic Level, and Habitat Comparisons

Comparisons were made for species richness between OU1 and the Rock Creek reference area for terrestrial and aquatic taxonomic groups and trophic levels. Two computations were made for these comparisons, percentage and a chi-square statistic (Denenberg 1976). The percentage was the amount each taxonomic group or trophic level in the food web contributed to total species richness for the area. The areas were then compared, looking for a difference between areas of more than 30 percent. Thirty percent is within the range of natural variability. If a difference greater than 30 percent occurred, a more detailed evaluation, including life history requirements for species, would be used to evaluate the variation in habitats at OU1 areas. This would entail making specific comparisons on the community level.

Organisms were classified by trophic level (i.e., producers, herbivores, etc.) to examine potential risks not found through analysis of groups identified through traditional taxonomic classification. The total number of species in each trophic level was calculated and comparisons were made between numbers of species in each trophic level at the OU1 study area and the reference area. Endpoints for plants, arthropods, and small mammals included total number of taxa and species richness by taxonomic group. These endpoints were calculated from field data and tabulated using the mean, standard deviation, and standard error from the results of the four sample sites at OU1. Habitat comparisons were made by using the four sites in the OU1 study area and four sites in the Rock Creek watershed for similar habitats. Methods for the specific groups (i.e., vegetation sampling methods or small mammal sampling methods) are contained in the Ecology SOPs EE.06, *Sampling of Small Mammals*, and EE.10, *Sampling of Vegetation* (EG&G 1991a).

Section 3.0 · Text

Physical Characteristics of OU1

Phase III RFI/RI Report

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3.0 PHYSICAL CHARACTERISTICS OF OU1

Section 3.0 describes the various physical attributes of OU1. The following sections describe surface features, demography and land use, meteorology, surface water hydrology, soils, geology, hydrogeology, and ecology. Site conditions are characterized sufficiently to determine possible pathways and assess the conditions of potential contaminant fate and transport in IHSSs at OU1.

3.1 SURFACE FEATURES

The natural environment of the plant and vicinity is influenced by its proximity to the Rocky Mountain Front Range. The plant is directly east of the north-south trending Front Range and east of the Continental Divide at an elevation of approximately 6,000 feet above mean sea level. RFP is located on a broad, eastward-sloping plain of coalescing alluvial fans developed along the Front Range (Hurr 1976). The fans extend about 5 miles eastward from their origin at Coal Creek Canyon and terminate at a break in slope to low rolling hills near Indiana Street. The operational area at the plant is located near the eastern edge of the fans on a terrace between the stream-cut valleys of North Walnut Creek and Woman Creek.

RFP is located in northern Jefferson County approximately 16 miles northwest of Denver (see Figure 1-1). Other nearby cities include Boulder, Westminster, and Arvada, which are located less than 10 miles to the northwest, east, and southeast, respectively. The plant consists of approximately 6,500 acres of federally owned land in Sections 1 through 4 and 9 through 15 of Township 2 South, Range 70 West, 6th Principal Meridian. Major buildings are located within the plant security area, which encompasses approximately 400 acres and is surrounded by a security fence. A buffer zone of approximately 6,150 acres surrounds the plant security area. Two roads allow entrance to the plant site, the West Access Road from Highway 93 and the East Access Road from Indiana Street (see Figure 1-1).

OU1 is located south of the plant on a south-facing hillside that slopes down from Building 881 to Woman Creek. Topographically, the highest point near OU1 is Building 881, approximately 6,000 feet above mean sea level, and the lowest point is in Woman Creek, about 5,830 feet above

mean sea level (Figure 3-1). Two gravel roads provide access to the site; one to the areas inside the perimeter fence and the other to areas in the buffer zone. Two surface drainages occur in the vicinity of OU1. Woman Creek flows along the base of 881 Hillside south of OU1, and the South Interceptor Ditch crosses OU1 between RFP and Woman Creek. Recently a french drain was constructed across a significant portion of OU1 above the South Interceptor Ditch to collect alluvial ground water.

The terrain at OU1 varies from gently rolling to locally steep slopes on the hillside. Steeper grades are generally present near the top and bottom of the hillside with gentle, more uniform slopes in the central portion of the hillside. Natural slumping and past construction, fill placement, waste storage, and waste cleanup activities have recontoured the OU1 terrain.

3.2 DEMOGRAPHY AND LAND USE

A recent demographic study shows that approximately 2.2 million people live within 50 miles of RFP (DOE 1990d). Approximately 9,100 people live within 5 miles of RFP (DOE 1990d). The most populated sector is to the southeast, toward the center of Denver. Recent population estimates registered by the Denver Regional Council of Governments for the eight-county Denver metropolitan area display distinct growth patterns. Between 1980 and 1985, the population of the eight-county area increased by 197,890, a 2.4 percent annual growth rate. Between 1985 and 1989 a population gain of 71,575 was recorded, representing a 1.0 percent annual increase (the national average). The 1989 population showed an increase of 2,225 (or 0.1 percent) from the same date in 1988 (DRCOG 1989).

RFP is located in a rural area, bordered by three counties. Approximately 50 percent of the area within 10 miles of the plant is in Jefferson County. The remainder is located in Boulder County (40 percent) and Adams County (10 percent). According to the 1973 Colorado Land Use Map, 75 percent of this land was unused or was used for agriculture. Since that time, portions of this land have been converted to housing, and several new housing subdivisions have been started within a few miles of the buffer zone.

There are eight public schools within 6 miles of RFP. The nearest is Witt Elementary School, which is approximately 2.7 miles east of the buffer zone. The closest hospital is Centennial Peaks Hospital, located approximately 7 miles to the northeast. The closest park and recreational area is the Standley Lake area, which is approximately 5 miles southeast of RFP. Boating, picnicking, and limited overnight camping are permitted. There are several other small community parks within 10 miles. The closest major park, Golden Gate Canyon State Park, located approximately 15 miles to the southwest, provides 8,400 acres for general camping and outdoor recreational use. Other national and state parks are located in the mountains west of RFP, but all are more than 15 miles away.

Some of the land adjacent to the plant is zoned for industrial development. Industrial facilities within 5 miles include the TOSCO laboratory (a 40-acre site located 2 miles south), the Great Western Inorganics Plant (2 miles south), the Western Aggregates, Inc. Plant (2.4 miles northwest), and the Jefferson County Airport and Industrial Park (a 990-acre site located 4.8 miles northeast). Future off-site land uses are illustrated in the North Plains Community Plan Study Area Map (Figure 3-2). Land areas closest to RFP are zoned for industrial development and those furthest from RFP are zoned for residential development.

Several ranches are located within 10 miles of the plant, primarily in Jefferson and Boulder Counties. They are operated to produce crops, raise beef cattle, supply milk, and breed and train horses.

3.2.1 Land Use at OU1

In the past, Building 881 was used for enriched uranium operations and stainless steel manufacturing. Currently, the building is used for multipurpose research and development, analytical plant support, and administrative offices (CDH 1992). The general laboratories in Building 881 perform a number of analyses on a variety of materials including waste water, sludge, surface water, ground water, and production control samples from Buildings 460 and 444. When the enriched uranium processes were in operation in Building 881, the laboratories also

performed analyses of the materials generated in production. Other operations in Building 881 include generating chemical standards and "inertial fusion" activities, machining, gold plating, small parts assembly for weapons and energy generation research, and large machining operations.

Historically, portions of the land at OU1 have been used for disposal or storage of waste. Currently, OU1 is the site of waste cleanup activities. Future uses of OU1 will be limited. A U.S. Geological Survey map from 1977 (Colton and Holligan 1977) identifies the locations of past landslides and indicates the potential for landslides in the vicinity of RFP. The steepness of the slope and the potential for landslides would complicate the construction of structures on 881 Hillside.

3.3 METEOROLOGY AND CLIMATOLOGY

The RFP area has a semiarid climate that is characteristic of much of the central Rocky Mountain region. Approximately 40 percent of the 15-inch annual precipitation falls during the spring season, much of it as snow. Thunderstorms (June to August) account for an additional 30 percent of the annual precipitation. Autumn and winter are drier seasons, accounting for 19 percent and 11 percent of the annual precipitation, respectively. Snowfall averages 85 inches per year, falling from October through May (DOE 1980). Temperatures are moderate; extremely warm and cold weather is usually of short duration. On the average, daily summer temperatures range from 55 to 85 degrees Fahrenheit, and winter temperatures range from 20 to 45 degrees Fahrenheit. The low average relative humidity (46 percent) is due to the blocking effect of the Rocky Mountains.

Wind data are collected on the plant site and summarized annually. Table 3-1 presents the combined 1990 to 1991 annual summary of the percent frequency of wind directions (16 compass points) divided into five speed categories. Figure 3-3 presents these same frequency values graphically. Winds at RFP are predominantly from the northwest.

Special attention has been focused on dispersion meteorology surrounding the plant due to the remote possibility that atmospheric releases might affect the Denver metropolitan area, which is located in the predominant downwind direction (southeast). Studies of air flow and dispersion characteristics (Hodgin 1983, 1984) indicate that winds come down from the mountains to the west, turn and move toward the north and northeast along the South Platte River valley, and pass to the west and north of Brighton, Colorado (DOE 1980), which is just north of Denver.

3.4 SURFACE WATER HYDROLOGY

Three intermittent streams drain RFP and flow generally from west to east. These drainages, shown in Figure 3-4, are Rock Creek, Walnut Creek, and Woman Creek. Rock Creek drains the northwestern portion of the plant and flows northeast through the buffer zone to its off-site confluence with Coal Creek. North Walnut Creek, South Walnut Creek, and an unnamed tributary drain the northern portion of the industrial area and buffer zone. Together they flow toward Great Western Reservoir, after being intercepted by an off-site bypass ditch (Figure 3-4). An east-west trending topographic divide bisects the plant, separating the Walnut and Woman Creek drainages. Woman Creek drains the southern portion of the industrial area and buffer zone and flows eastward off site to Standley Lake (Figure 3-4). The Woman Creek drainage basin is approximately 3.1 square miles (2,000 acres) in area.

Woman Creek flows from west to east along the base of 881 Hillside south of OU1. The South Interceptor Ditch crosses 881 Hillside from west to east and lies between the industrial area and Woman Creek just above the base of the 881 Hillside slope. The South Interceptor Ditch and Pond C-2 comprise the C detention system. The South Interceptor Ditch collects runoff from the southern portion of the industrial area, including 881 Hillside, and diverts it to Pond C-2 where it is monitored in accordance with the RFP National Pollution Discharge Elimination System permit. Pond C-2 has no active outlet. Water in Pond C-2 is either evaporated or pumped to the A-series ponds in North Walnut Creek for treatment.

Surface water flows down several small gullies and drainages on the 881 Hillside and these comprise the local drainages. Water from local drainages and from overland flow is captured by the South Interceptor Ditch. In addition, the South Interceptor Ditch receives surface flows from other upstream operable units including Operable Unit No. 5 (OU5), OU10, and Operable Unit No. 12 (OU12), and one downstream operable unit, OU2. The South Interceptor Ditch may also interact with shallow alluvial ground water. Because the South Interceptor Ditch is an engineered feature with a series of riprap-lined plunge pools instead of a continuous grade, it is difficult to determine from discharge gaging data whether various reaches of the ditch are gaining or losing. Seasonal contrasts in elevation between water levels and the water table differ so that recharge/discharge relationships may vary throughout the year. In the western part of OU1, the South Interceptor Ditch may gain or lose water depending on the elevation of the localized water table. In the eastern part of OU1, the South Interceptor Ditch appears to lose flow to the underlying shallow alluvial ground water flow system because the plunge pools along this reach are almost always dry.

Although the Federal Emergency Management Agency Flood Insurance Rate maps for the area in the vicinity of RFP include a narrow strip of Woman Creek in the 100-year flood plain (Figure 3-5), IHSSs at OU1 are above the potential 100-year flood plain. Elevations of IHSSs at OU1 range from 5,944 to 5,995 feet above mean sea level. Average stream channel elevations for Woman Creek range from 5,830 to 5,880 feet.

There are ten surface water monitoring stations in the vicinity of OU1 along the South Interceptor Ditch and the hillside south of Building 881 (see Figure 2-4). Flow rates at surface water monitoring stations were measured using a portable cut-throat flume. The following sections present the flow rate results for 1990 measurements, which are summarized in Table 3-2. These are the only available flow rate measurements for OU1.

3.4.1 881 Foundation Drain, Skimming Pond, and Seep Monitoring

Surface water stations SW044, SW045, and SW046 are just south of Building 881. Station SW044 monitors the discharge from a pipe draining the skimming pond to the South Interceptor Ditch. Station SW045 monitors the foundation drain discharge from Building 881. Station SW046 is located just west of the skimming pond in a pond formed by ground water seepage from the skimming pond (DOE 1991b). Section 3.7 describes the seeps in more detail. There was no surface water flow in any of these monitoring stations during the 1990 monitoring period (Table 3-2).

3.4.2 South Interceptor Ditch

Flow in the South Interceptor Ditch is intermittent in nature, and is related to precipitation events. During periods of no measurable flow, standing pools of water occur upstream of piles of large rock riprap while the reaches of the ditch downstream from the riprap are almost always dry. Station SW035 is located upgradient from OU1. Station SW031 monitors the water quality in the South Interceptor Ditch just downstream of SW044. Stations SW066, SW067, SW068, SW069, and SW070 monitor the South Interceptor Ditch downgradient from OU1. Most of the monitoring stations are located in standing pools of water. During the 1990 monitoring period, station SW31 had measurable water flow only in April and May (Table 3-2). There was no surface water flow in stations SW066, SW067, SW068, SW069, and SW070 during the 1990 monitoring period (Table 3-2).

3.5 SOILS

The surface soils at OU1 are predominantly deep, well-drained loams, clay loams, and very cobbly sandy loams with moderate to slow permeability. The soils along the flood plain and low terraces of Woman Creek consist of stratified loamy alluvium from the Haverson series. The soils at the top of the hillside, where gravel and cobbles of the Rocky Flats Alluvium are common, consist of gravelly and sandy loam from the Flatirons series. Along the slope of the hill, soils consist of cobbly to sandy loamy alluvium from the Nederland series and clay loams from the Denver-Kutch-Midway series. Runoff is generally rapid, and erosion hazard can be

severe on the steep portions of the hillside. Most of the soil series are classified within the Argiustoll great group (Figure 3-6 and Table 3-3). Argiustolls are generally characterized as well-drained soils with mollic (dark) epipedons, argillic "B" horizons, and calcic "C" horizons. They exist in aridic and ustic (limited moisture) regimes, which are adequate for plant growth during the growing season. The two predominant subgroups are Torrertic and Aridic. Torrertic Argiustolls have a higher shrink-swell potential than Aridic Argiustolls (Department of Agriculture 1980).

3.6 GEOLOGY

Geologic units at RFP consist of unconsolidated surficial material and bedrock. Surficial units include Quaternary alluvial deposits, colluvial deposits, and artificial fill that are underlain by Cretaceous sedimentary rocks of the Arapahoe Formation, Laramie Formation, and Fox Hills Sandstone. Figure 3-7 presents a generalized stratigraphic section for RFP. RFP is located just east of the Colorado Front Range in the Denver Basin, which is an asymmetrical, north-south trending syncline with a steeply dipping western limb and a shallowly dipping eastern limb (Figure 3-8). Steeply dipping Fox Hills and Laramie Formation sandstones on the western limb of the fold form a prominent hogback that strikes north-northwest. Outcrops of Fox Hills and Laramie Formation sandstones occur sporadically along the hogback. Immediately west of RFP, where the hogback is not visible at the surface, steeply dipping (45 to 55 degrees east) Fox Hills and Laramie Formation sandstones are exposed in clay pits excavated through the Quaternary gravels (Figure 3-8). Beneath RFP, the dip of Fox Hills, Laramie, and Arapahoe Formation sandstones is much shallower, at approximately 1 to 2 degrees east (EG&G 1992b).

Geologic data used to characterize the OU1 area were compiled from previous OU1-specific studies and the present Phase III field investigation, as well as several ongoing investigations including sitewide geologic mapping, shallow seismic and drilling programs, and neighboring OU-specific studies. Data from the french drain construction project were included where possible. All these data were integrated into the current geologic conceptual model for the OU1 site. Sections 3.6.1, 3.6.2, and 3.6.3 present descriptions of the surficial geology, bedrock

geology, and geomorphology of the OU1 area. Appendix A4 provides information on the geology of the french drain excavation.

3.6.1 Surficial Geology

Surficial material consists of Quaternary and Recent valley-fill alluvial deposits, alluvial-fan deposits of the Rocky Flats Alluvium, colluvial deposits, and artificial fill. The Rocky Flats Alluvium forms the crest of the 881 Hillside area. Remnants of younger terrace deposits occur topographically below the Rocky Flats Alluvium, but have not been mapped in the vicinity of OU1 (EG&G 1992b). The slope of 881 Hillside is covered with colluvium and artificial fill. Valley fill alluvium is present along the Woman Creek drainage at the bottom of the hill.

Figure 3-9 shows the thickness and lateral distribution of these surficial materials and areas of artificial fill and disturbed soils. The Rocky Flats Alluvium is 10 to 20 feet thick and forms a uniform blanket-like deposit on the terrace that caps the 881 Hillside area. The valley-fill alluvium is less than 10 feet thick and forms a sinuous elongate deposit at the bottom of the hill. Colluvium and artificial fill cover the rest of the hillside, and range in thickness from 1 to 30 feet. Colluvium and fill are thickest on the hillside south and southeast of Building 881 and on the hillside just north of the perimeter fence and southeast of Building 881 (Figure 3-9). A comparison of past (1937) and present topographic contours indicates that artificial fill has been placed in these areas (EG&G 1990e). The zones of thicker alluvium south and southeast of Building 881 correspond to possible slumps shown on the geomorphological features map (see Figure 3-26 in Section 3.6.3). Several of the smaller northwest-southeast trending zones of thicker alluvium correspond to paleochannels shown on the bedrock topography map (see Figure 3-24 in Section 3.6.2). The thickened alluvial zones are perhaps due, therefore, to a combination of alluvial channel fill deposits and artificial fill material, or to slumping.

Seven cross sections were constructed to illustrate the lateral and vertical relationships of surficial material at the 881 Hillside area. Figure 3-10 is an index map that shows where the seven cross sections are located. Figures 3-11 through 3-17 present alluvial cross sections A-A' through

G-G'. The alluvial/bedrock contact shown in the cross sections is based on well control, and has been interpreted between control points using the bedrock topography map presented (see Figure 3-24 in Section 3.6.2).

Rocky Flats Alluvium

The Quaternary Rocky Flats Alluvium is the oldest and highest alluvial deposit at RFP (Scott 1965). It is an alluvial fan deposit that occupies an extensive erosional surface beneath RFP. The alluvium ranges from 0 to 100 feet in thickness and is thickest west of RFP near the apex of the fan and thinnest just east of RFP near the depositional limit of the fan. The Rocky Flats Alluvium is composed of yellowish brown to reddish brown, angular to subrounded, poorly sorted, coarse, bouldery gravel in a sand matrix with lenses of clay, silt, and varying amounts of caliche. Pebbles, cobbles, and boulders are composed of quartzite, but include lesser amounts of schist, gneiss, granite pegmatite, sandstone, and siltstone. Gravels range from pebbles 2 to 4 inches in diameter to boulders as large as 2 feet in diameter (EG&G 1992b).

After the Rocky Flats Alluvium was deposited, streams began dissecting the deposit. The alluvium was completely eroded in the Woman Creek and Walnut Creek drainages and tributaries. The Rocky Flats Alluvium that remains forms the crest of the hillside and the terrace on which RFP was built (Figure 3-9). The Rocky Flats Alluvium occurs east of Building 881 in french drain boreholes P302390, P302490, and P302590. It also occurs along the crest of the hill in Phase III RFI/RI wells 37591 and 37691. The Rocky Flats Alluvium in well 37591 is shown in cross section F-F' (Figure 3-16). Thickness of the alluvium in this well is 12 feet. The uppermost 3 feet are composed of dark brown to reddish brown, angular to well-rounded, poorly sorted, silty sandy gravel with varying amounts of iron staining and caliche. The gravel is underlain by 9 feet of silty sand and gravelly sandy clay. The gravel and sand lenses may extend to the northwest on the pediment surface, but terminate to the southeast at the edge of the terrace and are adjacent to areas of artificial fill.

Colluvium

Colluvium mantles the valley slopes between the pediment on which the Rocky Flats Alluvium is deposited and the valley bottoms. Colluvial materials have been deposited by slope wash and downward creep of Rocky Flats Alluvium and bedrock. The colluvium is heterogeneous and consists predominantly of clay with lenses of silt, sand, and gravel. Cross sections A-A' through G-G' (Figures 3-11 through 3-17) show the distribution of sand and gravel layers in colluvial deposits across the hillside.

Colluvial clays are most abundant between the security fence and the South Interceptor Ditch, as shown in cross sections A-A' (Figure 3-11), B-B' (Figure 3-12), D-D' (Figure 3-14), and G-G' (Figure 3-17). The clays are described as variably iron-stained, yellowish brown to very dark grayish brown, silty clay to sandy gravelly clay, with silt- to sand-sized fragments of carbonaceous material. Caliche is sometimes present. No bedding structures are apparent, and the clays generally have low plasticity. Thicknesses vary from 5 to 20 feet.

Colluvial silts are common in the area north of the security fence near IHSS 130 and 119.1, as shown in cross sections C-C' (Figure 3-13) and E-E' (Figure 3-15). They also occur between the South Interceptor Ditch and the former retention pond, as shown in cross section B-B' (Figure 3-12). The silts are described as brown to dark yellowish brown, mottled, structureless, sandy silt with gravel. Mottling is generally due to iron staining. Caliche is sometimes present. Thickness of the silts ranges from 5 to 15 feet.

Sands in the colluvium are most common between the security fence and the South Interceptor Ditch, as shown in cross sections C-C' (Figure 3-13), D-D' (Figure 3-14), E-E' (Figure 3-15), and F-F' (Figure 3-16), and south of Building 881, as illustrated in cross section B-B' (Figure 3-12). The sands are described as highly weathered and variably iron stained, brown to dark yellowish brown, very fine- to coarse-grained, subangular to subrounded, well-graded (poorly sorted) silty sands with gravel and caliche cement. Individual grains are composed of quartz, feldspar, rock fragments, mafic minerals, and micas. Thicknesses vary from 1 to 5 feet.

Colluvial gravels most commonly fill depressions in the bedrock surface southeast of Building 881, as shown in cross sections A-A' (Figure 3-11), B-B' (Figure 3-12), C-C' (Figure 3-13), and D-D' (Figure 3-14), and in the vicinity of IHSS 119.2, as illustrated in cross section G-G' (Figure 3-17). The gravels are described as light brown to dark yellowish brown, subangular to subrounded, well-graded (poorly sorted) silty sandy gravels, and sandy clayey gravels with variable amounts of caliche cement. Cobbles are composed of quartzite, granite, gneiss, and schist, and range up to 2 inches in diameter. Gravel lenses are from 2 to 6 feet thick. Although previous investigations at OU1 revealed that colluvial gravels are elongated in the north-south direction and have a rather limited extent in the east-west direction (DOE 1991b), additional wells and boreholes added in the Phase III RFI/RI drilling program showed that colluvial gravels and sands have a limited extent in both the north-south and the east-west directions.

Colluvial deposits have been disturbed by the construction of Building 881, the South Interceptor Ditch, and the french drain, and excavation activities associated with various IHSSs (Figure 3-9). Shallow excavation took place during the construction of roads and the leveling of the drum storage area within IHSSs 119.1 and 119.2 (Figures 3-15, 3-16, and 3-17). Colluvium was also disturbed south of Building 881 in the vicinity of IHSS 106 and 107 during the construction of the skimming pond (IHSS 107). Colluvium was excavated during the construction of the South Interceptor Ditch from 1979 to 1981 and during the recent construction of the french drain. Colluvial deposits may have also been disturbed by slumping of the hillside and this may account for some of the thickness variations.

Artificial Fill

A comparison of a 1937 topographic map (created with aerial photographs) with a recent topographic map indicates where artificial fill has been placed on 881 Hillside (EG&G 1990e). The three primary areas delineated by this comparison are the area around Building 881, the vicinity of IHSS 130 southeast of Building 881, and a linear east-west trending zone near the top of the hill (Figure 3-9).

Material excavated from the foundation for Building 881 was spread over a large area south and west of the building. This fill material is derived from the Rocky Flats Alluvium, colluvium, and claystone bedrock, and is composed primarily of silty clay with some gravel. The fill appears very similar in composition to natural colluvium. Boreholes B302090, B304290, B302190, and B302290 encountered buried topsoil beneath artificial fill in this area (EG&G 1990e). Thickness of the artificial fill ranges from 12 to 20 feet.

IHSS 130 was used to dispose of soil and asphalt (DOE 1991b). Artificial fill overlies natural colluvium in this area and was encountered in boreholes 36091, 36291, and 36391. Cross section C-C' (Figure 3-13) intersects the area with artificial fill in well 36391. The fill material is described as variably colored clays, sands, and gravels with sand-sized chunks of asphalt or tar, and is approximately 10 feet thick. Artificial fill is also described in core logs from boreholes 36091 and 36291 (cross-section D-D' Figure 3-14). In borehole 36091, the fill is 5 feet thick and characterized as silty, sandy gravel with asphalt-cemented chunks up to 2 inches in diameter. In borehole 36391, the fill is 4 feet thick and described as very dark gray, well-graded sand and gravel in a clay matrix with sand- and gravel-sized pieces of asphalt throughout.

Artificial fill was also placed in a linear east-west trending zone near the top of the hill, east of Building 881 and south of the 904 Pad, to extend the contractor trailer yard (EG&G 1990e). This material is very similar to natural colluvium and alluvium and has not been distinguished in drill cores. Cross section F-F' (Figure 3-16) shows an area near the top of the hill where fill may have been placed.

Valley-Fill Alluvium

Valley-fill alluvium makes up the channel and terrace deposits in and along Woman Creek. The alluvium is 4 to 8 feet thick and is derived from reworked and redeposited alluvium and bedrock. Lithologically, the valley-fill alluvium is composed of organic-rich, dark brown to very dark grayish brown, subangular to subrounded, poorly sorted coarse gravel in a clayey sand matrix. Pebbles and cobbles are composed of quartzite, schist, gneiss, granite, and some ironstone.

Gravels range from pebbles 1 to 4 inches in diameter (noted in the drill core) to boulders (observed in the field). The matrix consists of medium-grained quartz, feldspar, and biotite sand grains with varying amounts of clay. Valley-fill alluvium is present in wells 5886, 6886, 38591, 5587, 30991, 39891, and 6486, and in boreholes 32291, 38391, 38491, 38691, 38791, and 30091.

3.6.2 Bedrock Geology

At OU1, alluvial material is unconformably underlain by Cretaceous sedimentary rocks of the Laramie Formation, as illustrated in the bedrock geology map (Figure 3-18). This map differs from the one presented in the recently completed surface geologic mapping report (EG&G 1992b) in that no Arapahoe Formation is shown. This interpretation is also in contrast to the Phase II remedial investigation report (Rockwell 1988a). The reinterpretation of bedrock geology at OU1 is explained below.

In general, the base of the Arapahoe Formation is marked by the presence of medium-grained to conglomeratic sandstones composed of well-rounded, frosted quartz sand grains with pebbles of chert, rock fragments, and ironstone (EG&G 1992b). Sandstones exhibiting these distinctive characteristics are not exposed at the surface nor in any of the drill cores from OU1. Because most of the bedrock at OU1 is stratigraphically lower than bedrock interpreted as the basal Arapahoe Formation in the recent geologic mapping report, and because no sandstones exhibiting the discriminating characteristics (well-rounded, frosted sand grains, and chert and ironstone pebbles) of the marker bed at the base of the Arapahoe Formation are found at OU1, all bedrock underlying OU1 is considered to be part of the upper Laramie Formation.

Laramie Formation

The Laramie Formation is informally subdivided into two members: an upper claystone member and a lower sandstone member. The upper claystone member is 300 to 500 feet thick. It is composed primarily of light to medium gray, structureless claystones with some dark gray to black carbonaceous claystones and thin coal beds and a few thin discontinuous silty sandstone beds. The discontinuous sandstones of the upper claystone member are light gray to olive gray,

very fine- to medium-grained, subangular to subrounded, moderately to well sorted, and quartzose in composition with a few coal fragments. Small ironstone nodules and calcite blebs occur infrequently. Sedimentary structures are evident in some of the clayey siltstones and silty sandstones and include planar and climbing ripple laminations and convoluted bedding indicative of soft sediment deformation. Fractures are common and vary in orientation from near horizontal to near vertical. Most fractures are healed and exhibit iron staining along fracture surfaces.

In direct contrast to the overlying basal Arapahoe Formation sandstones, few rounded, frosted quartz grains and few rock fragments are present in upper Laramie Formation sandstones. The petrographic distinctions between Laramie and Arapahoe Formation sandstones are readily recognized with a hard lens (EG&G 1992b). The upper Laramie Formation sandstones are also typically more fine grained than the Arapahoe Formation sandstones. The lower sandstone member of the Laramie Formation is approximately 300 feet thick and is composed of light gray, fine- to coarse-grained, subangular to subrounded, moderately to well-sorted quartzose sandstone with numerous claystone and sub-bituminous coal beds (EG&G 1992b).

Three cross sections were constructed to illustrate the lateral and vertical relationships of the claystones, siltstones, and silty sandstones in the upper Laramie Formation bedrock. Figure 3-19 is an index map that shows the locations of the three cross sections and Figures 3-20 through 3-22 are the respective bedrock cross sections (H-H', I-I', and J-J'). Figure 3-23 shows the areal distribution of subcropping sandstone beds. The alluvial/bedrock contact shown in the cross sections is based on well control, and has been interpreted in between control points using the bedrock topography map (Figure 3-24).

Cross section H-H' (Figure 3-20) shows the nature of the bedrock beneath IHSS 119.1 in a west-east direction. A fairly continuous sandstone/siltstone bed is present 35 to 40 feet below the ground surface. The sandstone/siltstone bed is approximately 10 feet thick and is sandwiched in between massive, impermeable claystones. Lithologically, this unit is described as a yellowish

gray to yellowish brown, friable iron-stained, clayey siltstone to very fine-grained, clayey sandstone. Wells 37991, 0587, and 37891 are screened in this sandstone/siltstone unit.

Cross section I-I' (Figure 3-21) illustrates the extent of the same sandstone/siltstone bed from IHSS 119.1 southeast to the french drain. Wells 37891 and 39191 are screened in this unit, which thins to the southeast to only 2 or 3 feet in the french drain excavation. Well 39291 and piezometer 38991 are screened in a siltstone bed 5 to 10 feet beneath the above-mentioned sandstone/siltstone bed. These siltstones are separated by 5 to 10 feet of claystones.

Cross section J-J' (Figure 3-22) shows the nature of the bedrock from IHSS 119.2 down the hillside to the southeast. Well 4587 in IHSS 119.2 is screened in a sandstone 96 feet below the ground surface. Lithologically, the sandstone is described as a light gray to light brown, iron-stained, very fine- to medium-grained quartz sandstone. This sandstone may correlate with a similar fine- to medium-grained sandstone at a depth of 55 feet in well 6286.

Although claystones are predominant, siltstones and fine-grained silty sandstones subcrop beneath the alluvium in boreholes 32491, 36591, BH1787, 32691, 31291, B302909, B301190, 31491, B300891, B399790, well 4787, and in the french drain excavation. Figure 3-23 shows the areal distribution of subcropping sandstones and siltstones in the upper Laramie Formation based on drill-core descriptions. Most of the subcropping fine-grained sandstones and siltstones are isolated occurrences, so the geometry of the sand bodies and their lateral extent is unknown. A few of the subcropping sandstones and siltstones exhibit a shoestring-like geometry. As seen in Figure 3-23, the subcropping sandstones and siltstones are located in IHSS 119.2, downgradient of IHSS 119.2, downgradient of IHSS 119.1 along the french drain, and in the vicinity of Building 881. The remainder of the 881 Hillside area is underlain by more impermeable bedrock claystones.

The bedrock topography map (Figure 3-24) is a portrayal of the relict claystone surface scoured and shaped by various alluvial, fluvial, and geomorphological processes. Features most apparent

on the map are several northwest-southeast trending paleochannels that originate in the vicinity of Building 881 and continue towards Woman Creek. Bedrock highs are evident between the paleochannels and in an area between IHSS 119.1 and IHSS 130. Excavation during construction of Building 881 and installation of the foundation drain pipe has obviously altered the bedrock topography in the northwestern portion of the map area, but well control in this area is too sparse to make definitive interpretations. Borehole and well control points in the remainder of OU1 are denser and adequate to confidently characterize the bedrock surface. Borehole and well control points in the remainder of OU1 are denser and adequate to confidently characterize the bedrock surface. The bedrock topography map (Figure 3-24) was drawn using bedrock depths reported in the geologic borehole logs and the french drain excavation investigation.

3.6.3 Geomorphology

The geomorphology of a site can influence potential contaminant transport pathways, including surface water and ground water flow. The geomorphology at OU1 reflects the interaction of several erosional and depositional processes on the bedrock and surficial materials underlying the site, and accounts for the gently rolling to moderately steep slopes developed on 881 Hillside. Subsequent to the initial siting of the plant, the terrain has been recontoured in several areas at various times. These include the construction of Building 881, the placement of fill and waste materials in several areas including the contractor yard and several IHSSs, the grading of roads at the site, the construction of the South Interceptor Ditch and, most recently, the construction of the french drain. Although these man-made features and activities have obscured or modified the surface expression of many of the natural geomorphological features, the pre-existing site geomorphology was interpreted during the Phase III RFI/RI using historical aerial photographs to better delineate potential ground water flow pathways.

Photo interpretation during the Phase III RFI/RI identified several possible slumps or small landslides. Figure 3-25 depicts the inferred slump outlines as interpreted from a July 1951 stereo photo pair. Delineation of the outlines of the slumps was based on recognition of curvilinear

drainage features, depressions, and rolling topography in the stereo images, indicating elongate elliptical or lobate features on the hillslope.

A previous site-specific slump investigation has also been conducted at RFP. Plate 2 of the french drain geotechnical investigation (EG&G 1990e) depicts four slumps on the north slope of Woman Creek numbered WMCN1 through WMCN4. Those four slumps were observed in the field during that study. This investigation recognized the same four slumps in the photographic images, although slightly different perimeter outlines were delineated on the basis of the historical photo interpretation. The numbering scheme shown in Figure 3-25 is a continuation of the sequence used on Plate 2 (EG&G 1990e).

Recent observations of the excavated trench during the construction of the french drain confirmed the existence of slumps on 881 Hillside. Slumps occur in alluvial and bedrock material. Those shallow slump-related features that were encountered included low angle fractures, shear planes, and alluvial materials overridden by bedrock slumps (Appendix A4). Caliche was observed to cement various portions of the fractures and glide planes, indicating that at one time ground water containing carbonate had been transmitted along the fracture surfaces. Figure 3-26 is a generalized cross section from the french drain excavation south of IHSS 119.1 that shows a slump block bounded by a large, west-dipping glide plane. Excavation for the french drain caused reactivation of some of those features on the uphill side of the open trench.

Previous studies have also delineated slumps in the 881 Hillside area. In a regional study the U.S. Geological Survey published a photo-interpretive map of the Louisville quadrangle showing areas of landslides and areas susceptible to landslides (Colton and Holligan 1977). The three landslides depicted in that map encompass the slumps shown in Figure 3-25. Colton and Holligan's map also shows the remainder of the hillside as being susceptible to landslides.

In addition to identifying slumps using photo interpretation, several seeps were inferred to be present on the hillside. Most of these were observed along the rim of the hillside. These seep

locations are associated with the contact of the Rocky Flats Alluvium and the bedrock at the top of the hill. Additional seeps were observed near the uppermost extent of the areas of slumping, and a few were observed to be present along the margins of slumps. The identified seeps were inferred on the basis of patches of darker-toned soils and vegetation present in summer-season photographs. Such visual characteristics are considered to be indicative of surface discharge of ground water or very shallow ground water, which supports a more lush vegetation. In general, the inferred seeps are confined to small depressions. The presence of seeps near the upper limits of the slumps and along the margins of some of the slumps suggests a relationship between the slumps and distribution of shallow ground water on the hillside. Section 3.7 discusses this relationship in more detail.

3.7 HYDROGEOLOGY

As defined in the *Final Ground Water Assessment Plan for Rocky Flats* (DOE 1992a), the uppermost aquifer at RFP is unconfined and is comprised of Rocky Flats Alluvium, valley-fill alluvium, colluvium, bedrock sandstones, and weathered claystones of the Arapahoe and Laramie Formations. Ground water at RFP flows from the higher elevations in the west toward the lower drainages in the east, generally mimicking local topography (Hurr 1976). Sources of ground water recharge to the uppermost aquifer include infiltration of precipitation, snowmelt, and surface water in ditches, streams, and ponds. Discharge occurs through evapotranspiration and as intermittent seeps where the water table intersects the ground surface or surface water features such as streams, ditches, and ponds. Ground water levels at RFP rise annually in response to spring recharge and decline during the remainder of the year when precipitation decreases.

Data from three investigative programs conducted at OU1 were evaluated to characterize hydrogeological conditions at the site. Although this section focuses primarily on the Phase III RFI/RI data, additional evaluation of the Phase I and II remedial investigation and french drain geotechnical investigation data are included. Data from these programs include geologic borehole logs, water level data from wells and piezometers, and results of geotechnical analyses, borehole and well hydraulic conductivity tests, and multiple-well pumping and tracer tests for surficial and

bedrock materials. Geomorphological data and vegetation distribution data were also evaluated to better define hydrogeological conditions at OU1. Figure 3-27 shows borehole, well, and piezometer locations for all three investigative programs.

In general, evaluation of the Phase III RFI/RI and previous investigation results for OU1 indicate that two distinct HSUs are present, an upper HSU and a lower HSU. The term HSU is used to denote a potential ground water bearing unit and is somewhat analogous to the term aquifer. Use of the word aquifer connotes an ability of a water-bearing unit to produce water at exploitable rates. However, the shallow water-bearing units at OU1 do not contain the quantity of water necessary to sustain even low-volume use, nor do they possess physical characteristics required for substantial ground water movement or efficient ground water extraction. Therefore, water-bearing units at OU1 cannot be economically exploited and are not aquifers.

The two HSUs at OU1 exhibit different hydrogeological characteristics (hydraulic conductivities, average linear flow velocities, and recharge/discharge mechanisms). The upper HSU comprises Quaternary and Recent unconsolidated surficial material and a few discontinuous subcropping bedrock sandstones. The lower HSU comprises more consolidated Cretaceous bedrock claystones. The upper and lower HSUs correspond to the upper and lower "aquifer" presented in the ground water assessment plan (DOE 1992a).

Section 3.7.1 evaluates the hydrogeological data collected for the upper HSU and Section 3.7.2 the data for the lower HSU. Section 3.7.3 presents an evaluation of hydrogeological conditions at OU1 during the Phase III RFI/RI and subsequent to the installation of the french drain. Section 3.7.4 is a summary of hydrogeological conclusions.

3.7.1 Upper Hydrostratigraphic Unit Data

The upper HSU unit at OU1 is generally comprised of Rocky Flats Alluvium, valley-fill alluvium, colluvium and disturbed colluvium, and artificial fill material. As shown on the surficial geology and alluvial thickness map (Figure 3-9), the thickness of these deposits ranges

from approximately 1 foot to 30 feet. The thickest zones occur in the western portion of OU1 where artificial fill has been dispersed during the construction of Building 881, numerous IHSSs, and roads. The thinnest zones occur in the central and eastern portion of the OU1 site where native materials cover the relatively shallow bedrock. Along the rim of the hillside, the upper HSU is composed of Rocky Flats Alluvium. Along Woman Creek, south of OU1, the upper HSU is composed of valley-fill alluvium. The upper HSU is underlain by Laramie Formation claystones of the lower HSU at OU1.

Geotechnical analyses were performed on 30 samples of upper HSU materials collected from 11 boreholes drilled during the Phase III RFI/RI. Table 3-4 presents results for these samples. Back-pressure permeabilities, which can be used as an estimates of vertical hydraulic conductivities, ranged from 1.2×10^{-3} to 2.5×10^{-9} cm/sec for upper HSU materials. This wide range of values is expected because geological characteristics that control permeabilities vary widely in the materials that comprise the upper HSU. In samples collected at depths down to 14 feet grain sizes and lithologies range from sand to clay with varying amounts of gravel; moisture content ranges from 8 to 26 percent; and densities vary by 15 percent.

Table 3-5 summarizes hydraulic conductivity estimates from nine single-well tests conducted during the Phase I and II RI. The wells are screened in colluvium and Woman Creek valley-fill alluvium. The overall range of hydraulic conductivity values estimated for upper HSU materials was 3×10^{-3} to 3×10^{-5} cm/sec. The lower values of this range are associated with colluvial materials, and the higher values with Woman Creek valley-fill alluvial materials.

Table 3-6 summarizes hydraulic conductivity estimates from 11 single well tests conducted during the Phase III RFI/RI. The wells are screened in Rocky Flats Alluvium, colluvium, disturbed colluvium, and valley-fill alluvium. The overall range of hydraulic conductivity values estimated for upper HSU materials was 4×10^{-4} to 9×10^{-7} cm/sec using the Bouwer and Rice (1976) method of analysis. This range is wider and includes lower values than those measured during previous investigations. The difference in ranges can be attributed to the relatively low

values determined for two wells (35691 and 36191) screened in disturbed colluvium. Results from the Phase I and II RI well tests do not include values for disturbed colluvium. Appendix B1 summarizes the methods of data collection and data analyses and presents a compilation of the results for the Phase III RFI/RI.

During the Phase III RFI/RI multiple-well pumping and tracer tests were conducted in Woman Creek valley-fill alluvium of the upper HSU. The test site was located in OU5 where the saturated alluvium was thick enough to conduct the test. The multiple-well pumping test was conducted to characterize transmissivity and specific yield of the Woman Creek valley-fill alluvium. The tracer test was conducted to estimate contaminant transport characteristics such as effective porosity, linear dispersivity, and average linear velocity. Appendix B2 presents the rationale, data collection, data analysis, and results of these tests. For the multiple well pumping test, transmissivity was estimated at 0.2 foot^2/min (3.1 cm^2/sec), and hydraulic conductivity was estimated at 2.9 x 10^{-2} cm/sec based on the Theis recovery method of analysis. For the tracer test, average linear ground water velocity was estimated at 0.07 $\pm$ 0.02 feet/min (3.6 x 10^{-2} $\pm$ 0.01 cm/sec), longitudinal dispersion was estimated at 0.2 $\pm$ 0.1 feet^2/min (3.1 $\pm$ 0.62 cm^2/sec) and effective porosity was estimated to be 5 to 10 percent.

Twenty-three monitoring wells screened in the upper HSU existed prior to the Phase III RFI/RI. Water levels in these wells rise annually in response to spring recharge (second quarter) and decline during the remainder of the year. Appendix B3 presents tables and hydrographs that show the fluctuations of water levels in OU1 wells for the period from September 1986 to June 1992. Seasonal water level fluctuations range from approximately 6 to 10 feet in monitoring wells 4887, 0687, 0487, 6487, and 6987, but are as low as 1 foot in monitoring well 5287. Monitoring wells 5886, 4487, 5087, and 5187 are consistently dry or have only residual water in the sump below the well screen. Wells 5587, 4987, and 4787 are usually dry but occasionally exhibit water levels above the base of the screened interval. Three monitoring wells (5986, 0287, and 0687) screened in the surficial materials were damaged during the construction of the french drain in late 1991.

During January 1992, water levels were measured in existing wells and in 23 new monitoring wells and 3 new piezometers installed in upper HSU materials during the Phase III RFI/RI (Table 3-7). Fourteen of the newly installed monitoring wells and piezometers and seven of the previously existing monitoring wells were dry in January 1992. It is expected that fewer of these wells will be dry in late spring because historical data indicate that higher water level conditions are expected during the second quarter.

Figure 3-28 is a water table elevation map for January 1992, which represents low water level conditions. The water table elevation map was constructed using water level measurements, recharge/discharge characteristics of the upper HSU, flow control parameters (e.g., the depth to and configuration of the less permeable bedrock surface), geomorphological features such as seeps and slumps, and the historical topography map (e.g., excavation and artificial fill). The water table elevation map clearly illustrates that the upper HSU is not uniformly saturated across OU1 and that little water exists in the upper HSU during the first quarter of the year.

Average ground water gradients, based on the slope of the water table along potential ground water flow paths in the western portion of the site, range from 0.11 to 0.13 feet/foot in the colluvial materials of the upper HSU. A gradient of approximately 0.15 feet/foot exists in the vicinity of IHSS 119.1, although little flow is expected in this area. The average gradient for Woman Creek valley-fill alluvium is 0.025 feet/foot.

Figure 3-29 illustrates the relationship between the thickness of saturated alluvium in the upper HSU and the distribution of ground water during first quarter 1992. Most of the ground water within the upper HSU is in the western portion of OU1, where the upper HSU is thickest and where saturated thickness ranges from 0 to 10 feet. The source of ground water in this area is most likely seepage from the Rocky Flats Alluvium along the rim of the hillside, discharge from the Building 881 footing drain system, and discharge from drainage ditches that run through the area. In the eastern portion of the site, where the upper HSU is thinnest because the bedrock surface is high, little ground water exists in the upper HSU. The occurrence of ground water in

this area is limited to areas close to isolated recharge sources such as the north rim of the valley where seepage from the Rocky Flats Alluvium recharges colluvial materials, the losing reaches of the South Interceptor Ditch, and along Woman Creek.

Water levels from first quarter 1992 were plotted on cross sections that correspond to lithologic cross sections in Section 3.6.2. These hydrogeologic cross sections show the elevation of the water table in upper HSU materials relative to topographic and bedrock surfaces (Figure 3-30). Figures 3-31 (cross section A-A') and 3-32 (cross section B-B') are east-west and north-south cross sections in the western portion of OU1. Cross section A-A' shows the channel-like configuration of the bedrock surface roughly perpendicular to ground water flow. Cross section B-B' presents the configuration of the water table along the ground water flow direction in this area. These figures illustrate that ground water will be intercepted by the french drain under current conditions and that ground water in the upper HSU may be discharged to the South Interceptor Ditch below the french drain if water levels rise above the levels presented for first quarter 1992. At lower elevations, below the South Interceptor Ditch, the bedrock surface is relatively high and the colluvium is thin. As water levels rise in this area, the colluvial water table may intersect the ground surface above bedrock and ground water may discharge at the ground surface and flow downgradient toward Woman Creek.

Figure 3-33 (cross section C-C') is an east-west cross section of the area west of IHSS 119.1. The relatively high water level in well 37191 is most likely due to the presence of a seep in this area (confirmed by cattails and moist soils southeast of well 37191). Well 36691, which is dry, is screened in a caliche-rich zone that may extend between wells 36691 and 37191 and function as a barrier to ground water flow. Cross section D-D' (Figure 3-34) illustrates a bedrock high that apparently acts as a barrier to southeasterly ground water flow in the upper HSU in this area. If water levels rise above the bedrock surface and ground water flow becomes more continuous to the south, upper HSU ground water will flow downgradient to the french drain.

Figure 3-35 (cross section E-E') is southwest-northeast trending cross section that encompasses IHSSs 119.1 and 119.2. This cross section illustrates the channel-like configuration in the bedrock surface that constrains the ground water within the upper HSU. Cross sections F-F' (Figure 3-36) and G-G' (Figure 3-37) illustrate the approximately north-south configuration of isolated occurrences of ground water in the upper HSU at IHSSs 119.1 and 119.2, respectively. Figure 3-36 shows that the french drain would intercept upper HSU ground water when water level conditions are high enough to permit water to flow south of IHSS 119.1.

3.7.2 Lower Hydrostratigraphic Unit Data

The lower HSU at OU1 comprises of bedrock claystones, siltstones, and silty sandstones of the upper Laramie Formation. Bedding planes in the lower HSU generally dip 1 to 2 degrees east (EG&G 1992b), however, in the central part of OU1 where slumping has occurred, the dip of the bedding is highly variable (see Appendix A4). The bedrock topography map (Figure 3-24) depicts locations where the bedrock surface is anomalously high due to slumping.

Geotechnical analyses were performed on 12 samples collected from lower HSU materials during the french drain geotechnical investigation (EG&G 1990e). Table 3-8 presents results of these analyses. Geotechnical analyses were performed on 14 samples collected from lower HSU materials during the Phase III RFI/RI. Table 3-9 presents the results for these samples. Back-pressure permeabilities, which provide estimates of vertical hydraulic conductivities, range from 1.6×10^{-6} to 4.2×10^{-9} cm/sec for lower HSU materials. Back-pressure permeabilities from french drain geotechnical investigation samples ranged from 1.5×10^{-6} to 6×10^{-9} cm/sec for lower HSU materials (EG&G 1990e). The range of values from the Phase III RFI/RI field investigation corresponds well with the range of values from the french drain geotechnical investigation. The range of back-pressure permeabilities for the lower HSU is smaller than the range for the upper HSU and reflects more homogeneity in the types of material encountered. In samples collected at depths from 8 to 48 feet grain sizes and lithologies range from siltstones to claystones with varying amounts of sand, silt, and clay, moisture content ranges from 12 to 23 percent; and densities vary by 15 percent.

Although the lower limit of back-pressure permeabilities for the upper and lower HSUs are similar (Tables 3-4, 3-8, and 3-9), permeability is generally lowest in the interval just below the upper HSU/lower HSU contact (Table 3-10). This low-permeability interval limits downward infiltration of ground water from the upper HSU to the lower HSU, and is responsible for the apparently perched colluvial ground water identified at IHSS 119.1.

During the Phase I and II RI, packer tests and single well tests were conducted to determine hydraulic conductivities of bedrock materials. Table 3-11 presents results of these tests. Packer injection tests were conducted in 19 units; four tests in weathered claystone and siltstone units, 13 tests in unweathered claystone units, and two tests in sandstone units. Hydraulic conductivities ranged from 2×10^{-6} to 2×10^{-7} cm/sec for weathered claystone units, 9×10^{-7} to 1×10^{-8} cm/sec for unweathered claystone units, and 1×10^{-6} to 2×10^{-7} cm/sec for sandstone units (EG&G 1990e). Single well tests included drawdown recovery and slug injection tests. Drawdown recovery tests were conducted in five bedrock sandstone units, and slug injection tests were conducted in two bedrock sandstone units. Data were evaluated using the same method for both types of tests. Hydraulic conductivities ranged from 3×10^{-4} to 3×10^{-6} cm/sec. The results of the single well tests are roughly one order of magnitude higher than the results of the packer tests for bedrock sandstone units. This difference is attributed to better development of the aquifer during single well tests and, conversely, injection of fine-grained material into the undeveloped borehole during packer injection tests (Rockwell 1988b).

During the french drain geotechnical investigation, 67 packer injection tests were performed in lower HSU materials at 21 boreholes. Table 3-12 presents results of these tests. All tests were conducted in weathered bedrock units. Resulting hydraulic conductivities ranged from 2.3×10^{-3} to 3.6×10^{-7} cm/sec (EG&G 1990e). Table 3-8 compares back-pressure permeability and horizontal hydraulic conductivity values determined during the french drain geotechnical investigation. Horizontal hydraulic conductivities are 10 to 1,000 times greater than vertical permeabilities for all bedrock materials tested. This relationship is expected because the bedrock is composed predominantly of claystone. Clay particles are flat or platy in shape and are

preferentially deposited with their long axes oriented horizontally. This configuration reduces vertical permeability.

During the Phase III RFI/RI, packer tests and single well tests were performed to determine hydraulic conductivities of lower HSU materials. Appendix B1 describes the specific details of data collection, data analyses, and determination of hydraulic conductivities. Results of packer tests were limited due to conditions encountered during drilling and testing (e.g., borehole collapse and unsaturated conditions). Hydraulic conductivity determined for an unsaturated bedrock unit was 1.7×10^{-6} cm/sec. This value is within the range of hydraulic conductivity values for bedrock claystones and siltstones, determined from french drain geotechnical investigation packer tests. Single well tests were conducted in selected wells and piezometers after development, sampling, and water level stabilization. Table 3-13 presents the results of these tests. Hydraulic conductivities ranged from 3×10^{-5} to 5×10^{-7} cm/sec for weathered claystones and siltstones using the Bouwer and Rice (1976) method of analysis (see Appendix B1). This range of values is similar to the range of values for Phase I and II single well tests. Slug injection and slug withdrawal tests were performed at one Phase III well (31891) screened in bedrock sandstone. The hydraulic conductivity was 2×10^{-4} cm/sec for both tests. This value is near the upper limit of hydraulic conductivities for bedrock sandstones derived during previous single well tests. However, the hydraulic conductivity appears to be two to three orders of magnitude higher than hydraulic conductivities for bedrock sandstones from packer tests. Perhaps the bedrock sandstone unit tested during the Phase III RFI/RI was shallower or was mixed with upper HSU materials.

Figure 3-38 summarizes all horizontal hydraulic conductivity values for upper and lower HSU materials. The geometric mean values for lower HSU materials are typically lower than mean values for upper HSU materials. With the exception of results of packer tests conducted during the french drain geotechnical investigation, hydraulic conductivity values reported for bedrock materials are one to four orders of magnitude lower than values for upper HSU materials. This general trend indicates that the bedrock surface can function as a lateral barrier to ground water

flow in the upper HSU if the bedrock surface is locally elevated with respect to the upper HSU water table.

Prior to the Phase III RFI/RI investigation only four wells existed in bedrock materials of the lower HSU. During the Phase III RFI/RI, four additional bedrock monitoring wells (31891, 37891, 37991, and 39191) and two piezometers (38991 and 39291) were installed in the lower HSU. Appendix B3 presents water levels and hydrographs for OU1 monitoring wells. Seasonal variation in water levels is less for lower HSU wells and piezometers than for upper HSU wells and piezometers due to slow downward percolation rates and relatively small volumes of recharge and discharge in the lower HSU. Table 3-14 presents water levels for January 1992, which represent dry season conditions for first quarter 1992. Wells 0387, 0587, and 0887 were damaged during the construction of the french drain; therefore, data for these wells are not available.

The water level data for first quarter 1992 were used to create a bedrock piezometric surface map (Figure 3-39). Because the distribution of bedrock wells is localized, the piezometric surface map shows water table elevations only in the two areas with well and piezometer data. Ground water gradients range from 0.06 to 0.14 feet/foot in these areas. In addition, water level data for bedrock wells and piezometers clearly indicate that the localized water table in the colluvium is perched above the lower unconfined bedrock water table in the vicinity of IHSS 119.1.

Evaluation of water levels for bedrock monitoring wells 6286 and 31891 indicate that ground water in these bedrock wells is most likely associated with the upper HSU rather than the lower HSU. Historical water levels in bedrock wells 0387 and 0887 are approximately 40 feet below the ground surface in the vicinity of well 31891. The water level at well 31891 is only 16 feet below the ground surface, which suggests that the ground water is associated with the upper HSU (Figure 3-28). Monitoring well 31891 is located on a berm adjacent to the South Interceptor Ditch and is screened less than 10 feet below the estimated bottom of the ditch. Due to its location, it is reasonable to expect that the ground water zone monitored by well 31891 is part

of the upper HSU and originates within and upgradient of the South Interceptor Ditch. Similarly, the water level at well 6286 is much shallower than the water level at nearby bedrock well 4587 (see Figure 3-43). The sand pack in well 6286 may extend into the colluvium, and therefore the water levels and water quality samples collected at this well may reflect conditions in the upper HSU rather than the lower HSU.

Cross sections have been constructed to illustrate water levels in the bedrock of the lower HSU at IHSSs 119.1 and 119.2. Figure 3-40 is a cross-section location map for the lower HSU. Figure 3-41 is an east-west cross section in the vicinity of IHSS 119.1. The water table surface is relatively flat and is approximately perpendicular to the apparent hydraulic gradient in the lower HSU. Cross section I-I' (Figure 3-42) shows a southward sloping water table surface south of IHSS 119.1. Figure 3-43 illustrates the anomalously high water level in well 6286. With the exception of well 6286, the cross sections show that the bedrock piezometric surface is roughly 20 to 40 feet below the upper HSU/lower HSU contact.

3.7.3 Assessment of Hydrogeological Conditions

Evaluation of the hydrogeologic data presented in previous sections indicates that the upper HSU is variably saturated and that ground water in this hydrogeological setting does not exist or move as would be expected within a typical continuous, homogeneous, shallow aquifer system. The following discussion evaluates and describes the hydrogeological conditions at OU1 including ground water recharge, discharge, and flow for the upper and lower HSUs. Estimates of average horizontal ground water flow velocities are provided to illustrate the different flow characteristics of the two HSUs. Volumetric estimates for the upper HSU are included to show how little ground water is available for possible exploitation. Estimates of vertical average ground water flow velocity between the upper and lower HSUs are provided to illustrate how the two groundwater systems interact. All calculated values are intended as "order-of-magnitude" estimates to provide reasonable quantitation of hydrogeological conditions.

3.7.3.1 Upper HSU Recharge and Discharge Characteristics

Recharge and discharge characteristics of the upper HSU as well as the configuration of the bedrock surface control the limited distribution of ground water within this variably saturated unit. Sources of uniform recharge to the upper HSU at OU1 include infiltration of incident precipitation and snowmelt (15 inches annually). Most incidental precipitation is lost to runoff and evapotranspiration due to dry climatological conditions, slow percolation rates, and abundance of vegetation. Some incidental precipitation may collect in ditches and surface depressions, and if residence times are long enough, water in these ditches and depressions will infiltrate into the upper HSU. Surface water in the South Interceptor Ditch and portions of Woman Creek also provide localized surface recharge to the upper HSU. Outfall from the Building 881 footing drain was formerly a recharge source. The footing drain is now connected to the french drain. Other localized recharge sources occur as seepage from the Rocky Flats Alluvium to colluvial materials in the upper HSU along the northern rim of the hill slope. This recharge area coincides with probable seeps recognized on 1951 aerial photographs (Figure 3-26). Ground water flows from the northern rim of the hill slope to areas that are at lower elevations, although localized bedrock highs may act as physical barriers to ground water flow.

Discharge from the upper HSU occurs via evapotranspiration, which is enhanced by the south-facing orientation of the 881 Hillside area. Discharge also occurs at surface seeps, or at discharge boundaries such as Woman Creek, the bedrock surface, or the newly installed french drain. At these boundaries, ground water in the upper HSU is discharged as surface water and may travel as overland flow, reinfiltrate the upper HSU at lower elevations, infiltrate into the bedrock or lower HSU, or be extracted by the french drain pumping system.

Surface seeps have been identified at 881 Hillside during recent field investigations. Surface water monitoring station SW046 is a surface seep located near the former skimming pond south of Building 881 (see Figure 2-4). The water table is locally elevated in this area possibly due to recharge from the skimming pond. Since seasonal variation in the elevation of the water table is expected, this surface seep may appear only during the wet season. Another possible surface

seep is located near IHSS 103. This area appeared wet throughout the Phase III RFI/RI field investigation and contained cattails and other water-tolerant vegetation. The water table is locally elevated in this area, possibly due to recharge from drainage ditches or leaking discharge pipes. The locations of these two surface seeps are generally coincident with the distribution of saturated upper HSU materials (Figure 3-28).

Other seeps occur at the head region and along the margins of slumps. These seeps may be due to discharge or leakage of ponded water from bedrock depressions near the head region of associated slumps. A small area just southeast of well 37191 was observed to contain cattails and other water-tolerant vegetation during the Phase III RFI/RI field investigation and is indicative of a surface seep. This area is just downgradient of the ground water high identified near well 37191. Similar wet, patchy areas containing cattails and other water-tolerant vegetation were noted north of Woman Creek north of well 38591 and just east of well 5587. In these areas, the colluvial water table intersects the ground surface because the bedrock surface is relatively shallow, resulting in surface seeps. The patchy nature of these surface seeps suggests that colluvial ground water may preferentially flow along slump margins (Figure 3-26). The wet area around well 37191 is an example of a surface seep located at the head region of a slump and wet areas near Woman Creek are suggestive of seeps associated with slump margins.

3.7.3.2 Upper HSU Ground Water Flow/Perched Ground Water

The saturated thickness map (Figure 3-29) shows that the upper HSU ground water flow paths presented in Figure 3-28 are oriented along bedrock lows. These bedrock lows are typically associated with crown or head regions or lateral margins of slumps or with construction activities. The configuration of the water table and the bedrock surface suggests that only a limited amount of ground water in the upper HSU actually reaches Woman Creek. This conclusion is based on the limited amount of ground water recharge and high evapotranspiration rates in the shallow upper HSU as well as the presence of discharge boundaries and physical barriers to flow.

In the central and eastern portions of the 881 Hillside, large dry areas surround the small saturated areas and ground water in the upper HSU appears perched above the lower hydraulic conductivity bedrock surface. This indicates that recharge and discharge are balanced and results in the lack of a continuous ground water flow path downgradient. If ground water is retained in bedrock depressions in the upper HSU, relatively small amounts of ground water may percolate into the lower HSU. The clay-dominant lithologies and low vertical permeabilities of the lower HSU restrict the volume of water that can percolate from the upper HSU to the lower HSU. However, the degree of weathering and fracturing in bedrock material may locally influence vertical flow. The apparent perching of water in the upper HSU is a manifestation of the lower vertical permeabilities in the lower HSU. These perched conditions were observed directly during excavation of the trench for the french drain (see Appendix A4) and additional confirmatory evidence is provided in the following evaluations of hydraulic conductivity values for the upper and lower HSUs.

During excavation activities, upper HSU ground water was observed in instead sandy and silty clay lenses bounded by denser upper HSU clays or lower HSU claystones (see Appendix A4). Dry zones were documented within bedrock materials directly below lenses of saturated alluvium. These observations indicate that upper HSU ground water is perched above the lower HSU materials in the central portions of the hillside and that upper HSU ground water may flow southward and downgradient within these relatively coarser-grained horizons. Also noted during excavation activities were caliche-rich zones that bounded apparent slump blocks in the upper HSU. The caliche indicate that ground water flow has previously occurred in these glide planes or disrupted zones, but that flow has since been curtailed.

3.7.3.3 Upper HSU Ground Water Flow Velocity

Estimates of average linear ground water flow velocity were calculated for probable ground water flow paths at IHSS 119.1 (Figure 3-28). Table 3-15 presents the values and calculation methods used. Hydraulic gradients were measured along the flow paths and hydraulic conductivities were determined as the geometric mean of values resulting from well tests conducted in wells near the

flow paths. Effective porosity values of 10 to 20 percent were used. In colluvial and fill materials south of Building 881 the average linear ground water flow velocity ranges from 10 to 20 feet/year. For colluvial materials at IHSS 119.1, the average linear ground water flow velocity ranges from 37 to 73 feet/year, although this area appears hydrogeologically isolated and no net flow is expected. Along the western reaches of Woman Creek, average linear ground water flow velocities range from 150 to 300 feet/year within the valley fill alluvium. An average linear ground water flow velocity was measured during the multiple-well and tracer tests (see Appendix B2), but the measured value is based on flow induced by pumping and is not considered applicable to this discussion. Average linear ground water flow velocities for valley-fill alluvium are at least 5 to 10 times higher than average linear ground water flow velocities determined for colluvium.

3.7.3.4 Volume of Upper HSU Ground Water

To better understand hydrogeological conditions within the upper HSU, simple volume calculations were performed to estimate the volume of saturated upper HSU materials, the volume of ground water within saturated upper HSU materials, and the potential yield from the upper HSU. These estimates were derived for the OU1 area and for the area including OU1 downgradient to Woman Creek. The estimates for the volume of saturated upper HSU materials were obtained by multiplying the area of saturation (from Figure 3-28) by a typical saturated thickness (from Figure 3-29). The volume of ground water within the saturated upper HSU was obtained by multiplying the volume of saturated materials by the average porosity of these materials (from geotechnical results in Table 3-4 and Appendix A2). Table 3-16 presents the volume estimates.

The volume of upper HSU groundwater available for potential yield was estimated by multiplying the volume of saturated upper HSU materials by an effective porosity range of 0.1 to 0.2 as used in average linear ground water velocity calculations. The volume of potential yield is lower than the volume of ground water present because a relatively large fraction of ground water in the upper HSU is expected to be "bound" into pore spaces within the predominantly clay-rich upper

HSU materials. This hygroscopic water is not typically available for movement or extraction and exploitation by water users.

For the OU1 area, the volume of saturated upper HSU materials is estimated at 25.0 acre-feet. The volume of ground water in this saturated volume is approximately 10.0 acre-feet (or 3.26 x 10^6 gallons). The volume of ground water available for potential movement or yield within OU1 is estimated to range from 2.5 to 5.0 acre-feet (or 8.15 x 10^5 to 1.63 x 10^6 gallons). The estimated volumes of ground water available are very low considering that a typical household would consume from 200 to 300 gallons per day or 73,000 to 110,000 gallons per year (Driscoll 1986). If this estimated volume of ground water were to be extracted and replenished in a year, it could support the needs of approximately 9 to 18 households for 1 year.

Evaluation of other aquifer parameters such as hydraulic conductivity and aquifer transmissivity indicate that it is highly unlikely that the small estimated volume of water available for movement or yield could actually be extracted and replenished in a year. Driscoll (1986) identifies low-yield aquifers appropriate for domestic and other uses as having aquifer transmissivities of up to 0.015 square meter per second (m^2/sec) or 150 square centimeters per second (cm^2/sec). Aquifer transmissivity for the upper HSU was obtained by multiplying the highest value of hydraulic conductivity for the upper HSU colluvium from Phase III RFI/RI single well tests (1 x 10^{-4} cm/sec) by the average aquifer thickness (5.0 feet). The resulting value of aquifer transmissivity for the upper HSU is 0.015 cm^2/sec. This value is approximately 10,000 times less than that identified as appropriate by Driscoll, and indicates that the upper HSU at the 881 Hillside area should not be considered as an aquifer capable of being exploited for any reasonable use. Rather, these results confirm the conclusion that the upper HSU is a variably saturated water-bearing zone containing relatively small volumes of ground water that move slowly or not at all.

More detailed evaluation of the limited water-producing capabilities of the upper HSU are presented in appendices to Technical Memorandum No. 6 *Exposure Scenarios* (Attachment F2

of this report). The conclusions presented in Technical Memorandum No. 6 are similar to those based on the above volumetric calculations and were confirmed by the Colorado State Engineer during preliminary review of Technical Memorandum No. 6 (Van Slyke 1992).

3.7.3.5 Lower HSU Recharge and Discharge Characteristics

The lower HSU may receive recharge by infiltration of surface water in areas where the bedrock subcrops along the eastern portions of the South Interceptor Ditch. Ground water in saturated upper HSU units may also percolate downward into the lower HSU, but these recharge rates are expected to be very low. Higher conductivity bedrock sandstone channels are expected to transmit water within the lower HSU. Shallow sandstone horizons in the western portion of the site may receive recharge from the upper HSU. These units are discontinuous and subsequent slump block movement may have displaced them, further reducing hydrogeologic continuity.

Discharge from the lower HSU is difficult to quantify, but is expected to be very low. Probable discharge boundaries exist at low elevations along the 881 Hillside area, but no data were collected to evaluate lower HSU discharge because the prime focus of the Phase III RFI/RI investigation was the upper HSU.

3.7.3.6 Lower HSU Ground Water Flow

Observations made during excavation of the trench for the french drain provide some insight into hydrogeological conditions within the lower HSU materials just south of OU1 (see Appendix B4). Little ground water was observed in lower HSU materials, although some small amounts of seepage were observed in slump glide planes. The low seepage indicates that ground water may preferentially reside in the potentially higher permeability glide planes, fractures, or disturbed materials associated with these slumps, but little ground water movement is expected. The seepage from these zones is attributed to gravity drainage due to the localized release of geostatic pressure during excavation. Similarly, caliche zones were observed to bound some of these slump blocks, indicating that historical ground water flow has occurred in these features, but has subsequently been reduced due to precipitation of caliche. The high plasticity of the claystone

is expected to permit healing of fractures or voids resulting from a disruptive event such as a slump. This healing capability is expected to inhibit ground water flow in these potentially higher permeability zones within the lower HSU.

Along the north rim of the 881 Hillside, low rates of ground water flow are expected toward the east in the lower HSU due to the regional hydrological system, although no water level data exist to confirm this trend. As presented in Figure 3-39, ground water flow in the lower HSU below the central portions of the 881 Hillside area, is southerly toward Woman Creek.

3.7.3.7 Lower HSU Ground Water Flow Velocity

Using average hydraulic conductivity values from single well test data in bedrock wells, a hydraulic gradient determined from the lower HSU potentiometric surface map (Figure 3-39), and an effective porosity of 10 to 20 percent, average linear ground water flow velocities were calculated for bedrock materials near IHSS 119.1. Table 3-17 presents these calculations and results. The average linear ground water flow velocity for ground water in bedrock materials near IHSS 119.1 ranges from 5 to 10 feet/year. This range is approximately one-half to one-sixth of the range of flow velocities presented for ground water in the colluvial material of the upper HSU overlying the bedrock.

No ideally configured well clusters exist to quantify downward movement of ground water from the upper HSU to the lower HSU. However, vertical gradients were calculated at numerous well locations by comparing the water levels in upper HSU wells to water levels at nearby lower HSU monitoring wells and piezometers. Table 3-18 presents vertical hydraulic gradients calculated in the vicinity of IHSS 119.1, where water levels in the upper and lower HSU are well constrained. Estimated vertical hydraulic gradients range from 0.87 to 1.05 feet/foot. These relatively high vertical gradients indicate a strong potential for percolation from the upper HSU to the lower HSU. However, any downward movement of upper HSU ground water to the lower HSU is controlled by lower permeability horizons within the lower HSU (Table 3-10).

To confirm this conclusion, average linear ground water flow velocity in the vertical direction was calculated to estimate downward percolation from the upper HSU to the piezometric surface in the lower HSU in the vicinity of IHSS 119.1 (Table 3-19). The geometric mean of back-pressure permeability values for the first geotechnical sample collected below the alluvial/bedrock contact was used to estimate vertical hydraulic conductivity (Table 3-9). Effective porosity was estimated at 0.10 to 0.20 percent (1/10 of the estimated effective porosity for lateral flow calculations). The resulting range of average vertical linear ground water velocity is 0.2 to 0.4 feet/year. This range is approximately 25 times less than the average horizontal linear ground water velocity calculated for bedrock materials at IHSS 119.1, and 50 to 100 times less than the average horizontal ground water velocity for saturated colluvial materials. This relationship between vertical and horizontal average linear groundwater velocities implies that there is a very low rate of percolation from the upper HSU to the lower HSU and that ground water in both HSUs would preferentially move horizontally near IHSS 119.1. However, since the saturated upper HSU at IHSS 119.1 is bounded by dry wells little net horizontal flow is expected in this area except during high water level periods in the late spring or early summer months.

The high vertical gradients between the saturated upper HSU and lower HSU indicate a strong potential for infiltration, although the very low velocities indicate that little recharge of the lower HSU from vertical percolation occurs. The low recharge and discharge rates for the lower HSU further substantiate that ground water present in the lower HSU resides mostly in aquifer storage or flows very slowly within the claystone, siltstone, and discontinuous silty sandstone units. This conclusion is consistent with observations made during the field program (e.g., the absence of free water during drilling of bedrock boreholes) and with subsequent observation (e.g., stable water levels measured in bedrock wells throughout the year).

3.7.3.8 French Drain IM/IRA

The evaluation of hydrogeological conditions at the 881 Hillside area was based in part on historical hydrogeological data, but predominantly on Phase III RFI/RI hydrogeological data collected during first quarter 1992 prior to the completion of the french drain. These data were

shown to represent low water table conditions at the 881 Hillside area. Since first quarter 1992, additional data have been collected under the continuing ground water monitoring program at RFP and the french drain IM/IRA program. These data were evaluated to support and confirm hydrogeological interpretations.

Table 3-20 presents additional water level data collected from first and second quarter 1992. Since water levels are typically at their maximum in April, an April water table map was constructed to represent high water table conditions at 881 Hillside (Figure 3-44). The higher water table is evident in the eastern portion of the 881 Hillside area where increased precipitation and snowmelt are primarily responsible for an increase in thickness and extent of the saturated alluvium in this area. In the western portion of the 881 Hillside area, south of Building 881, water levels appear to have decreased north of the newly installed french drain. As discussed in detail in Appendix B4, this lowering of the water table is caused by the diversion of the Building 881 footing drain discharge to the french drain. Operation of the french drain also results in the presence of a new discharge boundary across the site that functions to reduce localized water levels.

Based on these findings, it is expected that as water levels decline during subsequent dry seasons (expected to occur in third, fourth, and first quarters due to lower precipitation and higher evapotranspiration), the upper HSU south of Building 881 will exhibit lower water levels than observed to date.

Evaluation of the eastern portion of the 881 Hillside area during April 1992 indicates that additional upper HSU ground water flow paths may exist during wetter seasons. These flow paths originate northeast of OU1 and enter the site at the northeastern boundary with OU2 in the vicinity of IHSS 119.2 (Figure 3-44). These saturated areas are expected to allow flow for the wet season only. This temporal or pulsating effect limits possible ground water migration pathways to short distances from continually saturated areas, since low hydraulic conductivities and very low average velocities limit ground water flow. As part of the french drain interception

system, a large-diameter extraction well was installed in IHSS 119.1. The extraction of the limited volume of ground water within the upper HSU at this location is expected to dry out or significantly reduce the volume of ground water in this area. This extraction of upper HSU ground water will severely limit the potential for flow of upper HSU ground water from the IHSS 119.1 area during the wet season. Likewise, the french drain appears to effectively intercept all upper HSU ground water that could potentially flow southward from other OU1 IHSSs (Figure 3-44).

3.7.4 Summary of the Shallow Hydrogeological System at OU1

Figure 3-45 presents the three-dimensional configuration of the upper HSU during the dry season before the french drain became operational. Figure 3-46 illustrates the configuration of the upper HSU water table during the wet season after the french drain became operational. These figures illustrate several conclusions that support exposure assessment, risk assessment, and subsequent feasibility study tasks, including the following:

- The upper HSU at OU1 is not a typical aquifer. It is a variably saturated water-bearing unit in which ground water moves slowly or not at all.
- The upper HSU in the eastern portion of OU1 is variably and sparsely saturated. Ground water exists only near recharge sources or stranded within depressions in the low permeability bedrock surface.
- No continuous underground flow paths exist between IHSSs in the eastern portion of OU1 and Woman Creek.
- The upper HSU contains more ground water in the western portion of OU1 than in the eastern portion. The source of ground water is former discharge from the Building 881 footing drain.
- Before the french drain became operational, complete ground water flow paths existed in the upper HSU from western OU1 IHSSs to Woman Creek along channel-like features in the bedrock surface.
- Since the french drain became operational, the volume of water in the upper HSU at OU1 has diminished, reducing possible ground water flow paths.

- The french drain and accompanying extraction well in IHSS 119.1 function as effective discharge boundaries and intercept all identified ground water flow paths north of the South Interceptor Ditch.

3.8 ECOLOGY

Survey sites in both OU1 and a reference area were used to determine whether contamination resulting from activities in OU1 have, or could in the future, adversely affect ecological health. The reference area was used to provide specimens unlikely to be contaminated for comparison with OU1 specimens.

The physical area of OU1 was expanded to include downwind and down-drainage areas. This expanded area, designated as the OU1 ecological study area (referred to as "the study area"), allowed for examination of the continuum of potential contamination levels. The design allowed sampling of a variety of habitats in a potentially affected zone down-drainage and downwind from Building 881. The study area included OU1, the 881 Hillside area, and areas outside the industrial area boundary fence that extend west to the gravel access road, south to Woman Creek, and east to Pond C-2. Woman Creek formerly received surface water runoff from the industrial area, but construction of the South Interceptor Ditch between the industrial area and Woman Creek has diverted surface water flow to Pond C-2. Woman Creek may potentially be affected by groundwater seepage, windblown materials, and overflow from the South Interceptor Ditch.

Criteria for selection of the reference area included location upwind and up drainage from 881 Hillside area activities and away from all other known RFP activities with the potential to produce contamination, habitats as close to natural conditions as possible, and an area unimpacted by other local industrial activities. The northwest portion of RFP, the Rock Creek watershed, met these criteria.

After study and reference areas were delineated, the terrestrial habitats, as identified in the SOPs, present within these areas were identified. Specific sample sites for terrestrial animal species

were established within these habitats. Because of their concurrency, the OU1 environmental evaluation was designed to use the database compiled during the baseline biological characterization of terrestrial and aquatic habitats investigation (DOE 1992i). The locations of terrestrial sample sites in the study area and reference area are shown in Figures 2-12 and 2-13, respectively.

Study sites for the aquatic ecosystem were selected from stream and pond habitats in the Rock Creek and Woman Creek watersheds (Figure 2-14). Locations upstream from the study area on Woman Creek and locations on Rock Creek were used as reference sites. Study area sites were selected along Woman Creek downstream of OU1 and along the South Interceptor Ditch, including Pond C-2.

3.8.1 Terrestrial Ecosystem

The majority of the plant species at OU1 contributing to the terrestrial communities belong to two groups—vascular cryptogams (2 species) and vascular plants (217 species) (Figure 3-47). A complete list of all plant species documented at RFP is supplied in Appendix B of the *Baseline Biological Characterization of Terrestrial and Aquatic Habitats at the Rocky Flats Plant* (DOE 1992i). Among the dominant vascular plants, various growth forms are represented. Trees and shrubs constituted 6 percent of the total number of species, forbs (broad-leaf herbs) 66 percent, graminoids (grasses and grass-like plants) 25 percent, and cactus 2 percent.

The flora of the entire RFP site are widely diverse due to varied geography, but reclamation activities (re-seeding) in the OU1 study area have limited the vegetation diversity of OU1. The OU1 study area comprises 4 percent of the total area of RFP. Although 13 vegetative habitats are represented in OU1, 2 grassland habitats (mesic mixed grassland and reclaimed) are dominant, representing about 82 percent of the total area. Another 9 percent of the area is either developed or disturbed. Marsh habitats (tall marsh, short marsh, and open water) occupy about 4 percent, woodland habitat (primarily riparian) constitutes another 4 percent, and shrub habitats (short and bottomland shrub) account for the remaining area.

Wildlife species at RFP are typical of those in similar habitats throughout the foothills area because of the absence of barriers between the western plains and the surrounding foothill terrain. Wildlife habitat at RFP is characterized according to plant communities upon which wildlife depend for food and shelter, as outlined in the baseline report (DOE 1992i).

3.8.2 Aquatic Ecosystem

The aquatic ecosystem at OU1 includes two major habitat types: streams and ponds. Neither is well developed due to the semiarid climate and seasonal distribution of rainfall that occurs along the Colorado Front Range. The Woman Creek channel west of Pond C-1 and east of Pond C-2 is essentially in native condition. The ponds and the South Interceptor Ditch represent significant alteration of the natural drainage. As a result of limited and inconsistent surface water supplies, aquatic species with short life cycles and smaller habitat requirements, such as benthic macroinvertebrates, have developed more diverse communities than fish. Fish are limited by intermittent streamflow, water temperature fluctuations, food and habitat. During the annual low rainfall periods habitat availability in the intermittent reaches of the Woman Creek watershed within the OU1 study area limits the number of life forms in the aquatic ecosystem.

Section 4.0 · Text

Nature and Extent of Contamination

Phase III RFI/RI Report

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4.0 NATURE AND EXTENT OF CONTAMINATION

In order to develop a comprehensive site conceptual model for OU1, it is necessary to characterize the nature and extent of contamination for all media. As outlined in the Final Phase III RFI/RI Work Plan (DOE 1990d), the objectives for the characterization of the nature and extent of contamination at OU1 include determining the vertical and horizontal distribution of chemical and radiochemical contamination in surface and subsurface soils, evaluating ground water and surface water quality, characterizing analytes and radionuclides present in sediments along Woman Creek and the South Interceptor Ditch, collecting sufficient data to develop a site conceptual model, and comparing site conditions to potential ARARs.

This section evaluates the nature and extent of contamination for soils, air, surface water, sediments, ground water, and biota within OU1. Site conditions were evaluated based on those data from the Phase III RFI/RI field investigation available as of August 3, 1992. Section 4.1 provides guidelines used to evaluate analytical data for purposes of contaminant distribution and assessment. The contaminant distribution in all media sampled during the Phase III RFI/RI is presented in Sections 4.2 through 4.7. Biological tissue data gathered for use in the environmental evaluation are summarized in Section 4.7, but covered in more detail in Appendix E. Section 4.8 summarizes the results of the contamination assessment and media source characterization.

This section describes the areal and vertical distribution of potential contaminants found in subsurface and surface soils, air, surface water, sediments, ground water, and biota during the Phase III RFI/RI for OU1. Data used to characterize site conditions include analytical results from soil samples collected during the Phase III RFI/RI field investigation that took place from August through December 1991. Analytical data for ground water, surface water, and sediments, are presented for fourth quarter 1991 and first quarter 1992, and were collected as part of routine RFP monitoring. Air quality data are included for 1990 and 1991 and were collected as part of the Radioactive Ambient Air Monitoring Program at RFP. Biological tissues were sampled and analyzed for use in the Environmental Evaluation. Biota results are presented in Section 4.7.

Results from unique samples taken from a manhole to characterize effluent at the 881 Building and from drums containing the dust suppressant Coherex are presented in order to characterize potential sources within OU1. A complete presentation of all analytical results used in the Phase III RI report is located in Appendix C.

Subsurface and surface soil samples collected during the Phase III RFI/RI field investigation, as well as media sampled under the routine monitoring program at RFP, were analyzed for organic compounds, metals, radionuclides, and inorganic parameters found in the EPA Contract Laboratory Program target compound list (Tables 2-6 through 2-9). Analyte groups comprising the target analyte list for the OU1 RI report include VOCs, SVOCs, radionuclides, metals, and inorganic parameters.

VOC analyses included volatile aliphatic and aromatic compounds and halogenated organic solvents. SVOC analyses included results for base-neutral-acid (BNA) extractables, pesticides, and PCBs. All media evaluated for the Phase III RI report were analyzed for VOCs and SVOCs except for surface soils, which were analyzed for SVOCs, radionuclides, and metals, only. All media were analyzed for the radionuclides listed in Tables 2-6 through 2-10. Surface water and ground water were analyzed for dissolved and total metals. Soils and sediment were analyzed for total metals only. Analyses for inorganic constituents consist of major cations and anions, and nonchemical water quality parameters useful in determining surface water and ground water quality. Soil samples taken during the Phase III RFI/RI field investigation were also locally analyzed for pH, total petroleum hydrocarbons, and total organic carbon. Surface soils were sampled and analyzed for SVOCs, radionuclides, metals, and inorganic parameters (Table 2-9).

The nature and extent of contamination at OU1 are presented separately for each medium. For subsurface soils, analyte results for VOCs, SVOCs, radionuclides, and metals are presented separately by depth interval within each IHSS. VOCs and SVOCs are presented together for surface water and ground water. Radionuclides and metals were treated separately for surface soils, surface water, sediments, and ground water.

Data presented in contaminant distribution maps include results for detections and nondetections, and locations not sampled at the time of this report. The contaminant distribution for each media in this report is limited to detected analytes. Analytical results for detections presented may be defined by laboratory qualifiers "J", "D", and "E". Results for organics and radionuclides qualified as "J" indicate that the detected concentration was less than the Contract Laboratory Program certified reporting limit, as defined in the *General Radiochemistry and Routine Analytical Services Protocol* (EG&G 1990c), but greater than the instrument detection limit. Concentrations that exceeded the upper limit of the instrument detection range are qualified as "E". Results derived from sample dilutions are qualified as "D". In addition, nondetection results are qualified with a "U". Organic analytes detected in laboratory blanks, and metals detected below the certified reporting limit, are qualified as "B", and are not used. The most common analytes detected in laboratory blanks for samples taken in soils, surface water, sediment, and ground water for use in the Phase III RFI/RI include acetone, methylene chloride, and 2-butanone.

To portray the nature and extent of contamination in OU1 subsurface soils, contaminant distribution is presented in subsections 4.2.1 through 4.2.9 for each IHSS and for nonsource areas by analyte group according to depth interval. Additionally, because of the waste disposal history associated with the former retention pond south of IHSS 102, this area—while not a designated IHSS—is discussed separately. Section 4.2.9 presents maps summarizing soil contaminant distribution by depth interval for each analytical group by depth interval. Contaminant distributions for surface soils, surface water, sediments, and ground water are presented by analyte group for all locations across OU1 as a whole since these media are not associated with historical waste disposal, or are designated as IHSSs.

In order to characterize the nature and of extent of potential contamination of naturally occurring analytes, concentrations of radionuclides and metals are compared to current RFP background values from the *Final Background Geochemical Characterization Report* (DOE 1992f) for all media except surface soils. The degree to which results exceed background concentrations may

indicate potential contamination; only detections exceeding RFP site background are presented in this report. When results exceed background by an order of magnitude or more, it is a likely indication of contamination. For purposes of this report, human-nutrient and common rock-forming elements such as calcium, potassium, sodium, magnesium, iron, manganese, and aluminum that exceed background concentrations are not represented in soil contaminant distribution maps. These major elements are primary components of the minerals comprising soil, alluvium, and bedrock units in the RFP area, and are not considered authentic contaminants. Analyses of these elements were performed to characterize the soil media for constituents necessary to evaluate potential treatment methodologies in the feasibility study and to predict geochemical interactions that influence contaminant fate and transport. Additionally, these metals are not considered indicative of contamination based on waste disposal activities and activities associated with the Building 881 laboratories.

Background concentrations of metals and inorganic analytes in soils and ground water at OU1 occur at levels that are within literature reported-ranges for typical background values for these species. However, when compared to RFP background values (DOE 1992f), some analytes exceed established background values for the RFP site. Indeed, many of the common rock-forming elements at the site exceed the calculated background values and could be potentially viewed as contaminants when in fact they are the primary components of minerals comprising soils, alluvium, and bedrock at the site. This situation indicates that classifying elements aluminum, calcium, iron, magnesium, manganese, potassium, and sodium as contaminants is inappropriate. For example, high levels of calcium can be attributed to the high amounts of atmospherically derived calcium carbonate that form caliche accumulations in surface and subsurface soils. Because these deposits are not evenly distributed across the site, isolated accumulations of calcium carbonate give the impression that background levels are being exceeded and that calcium is a contaminant. Therefore, aluninum, calcium, iron, magnesium, manganese, potassium, and sodium are excluded from maps presented for subsurface soils, surface water, sediments, and ground water at OU1.

Naturally occurring concentrations for radionuclides and metals in surface soils samples at OU1 have not previously been addressed in previous studies. The background geochemistry of surface soils sampled during the Phase III RFI/RI field investigation at OU1 is discussed Section 4.1.

4.1 COMPARATIVE GUIDELINES FOR CONTAMINANT CHARACTERIZATION

In order to evaluate and assess detected analytes that occur naturally within soils, surface water, sediment, and ground water, comparisons were made against RFP sitewide background levels. The background levels were computed and reported in the *Final Background Geochemical Characterization Report* (DOE 1992f). Table 4-1 presents values from the *Final Background Geochemical Characterization Report* used for subsurface soils, surface water, sediment, and ground water in this report. Background concentrations for organic compounds are considered the analyte detection limit. Therefore, it is assumed that any detected organic compounds exceed background. Previous investigations at OU1 established background concentration ranges for ground water based on the evaluation of ground water quality in monitoring wells west of the plant (Rockwell 1988a). Surface water background geochemistry was not established through evaluation of surface water quality outside of OU1 prior to 1990. Instead, the evaluation of surface water quality was made by comparing OU1 surface water sampling results to ground water background concentration ranges. Sediment background geochemistry was established by using results from one sediment sampling station (SED15) upgradient of OU1 on Woman Creek near the west boundary of RFP (Rockwell 1988a). This procedure has been discontinued in response to the establishment of RFP sitewide surface water and sediment background geochemistry.

Current background levels for subsurface soils, surface water, ground water, and sediments has been established for metals, radionuclides, and inorganic water quality parameters in the *Final Background Geochemical Characterization Report* (DOE 1992f). Background concentrations for metals represent analyses for total constituents in all media except surface water, where both dissolved and total metals are reported. Background concentrations for radionuclides were determined for total constituents (soils, surface water, and sediments) and dissolved constituents

(ground water only). Inorganic water quality parameters include background concentrations for pH, specific conductivity, and major anions.

Background concentrations for radionuclides were determined for single radiochemical isotopes such as uranium-233, plutonium-239, and americium-241. Radiochemical concentrations for most Phase III RFI/RI samples consist of results for a sum of two or more isotopes of a single element (i.e., uranium-233,-234; plutonium-239,-240; and uranium-233,-238,-239). Background concentrations for radionuclides are presented for isotopes that have high natural abundances. Results of analyses for multiple isotopes are compared against the background concentration of the isotope for which a background concentration exists. For example, uranium-233,-234 results are compared against the background concentration determined for uranium-233. Table 4-1 presents the comparisons for multiple isotopes.

Analyses were completed for uranium-233,-238,-239 in the vicinity of IHSS 119.2. Uranium-238 has a higher natural abundance in the environment compared to uranium-233 (99 percent compared to 0.7 percent). Uranium-239 has an extremely short half-life (23.5 minutes) (CRC 1984). Therefore, the presence of uranium isotopes 233 and 239 have no relative contribution to the analytical result for uranium-233,-238,-239. For comparative purposes in this report, background for this group of uranium isotopes is assumed to be the background calculated for uranium-238.

The background geochemistry for surface soils sampled during the Phase III RFI/RI field investigation has been established from samples taken as part of this sampling program in the Rock Creek area. The Rock Creek samples were sampled by the same method, and analyzed for the same constituents as samples taken at OU1. The surface soil samples collected in both areas were analyzed for those radionuclides, metals, and SVOCs listed in Table 4-2. Analytical results for Rock Creek samples were used to establish a natural background for these analytes in surface soils and were compared to detections of these analytes at OU1.

Following the protocol outlined in the *Final Background Geochemical Characterization Report* (DOE 1992f), the background concentration for each radiochemical and metal constituent was determined as the upper limit of the 95 percent tolerance interval within a 95 percent confidence. A summary of the statistics generated for use in determining background for surface soils using Rock Creek data is presented in Table 4-2.

In general, the data set for each surface soil constituent in the background data set was limited to 15 samples, or less. Results for "J" qualified radionuclides and "B" qualified metals were taken from those results reported from the laboratory. Results for "U" qualified metals were taken as those results reported from the laboratory. These "U" qualified metal results are reported as "actual" concentrations below the detection limit, and are not reported as the analytical detection limit in the RFEDS database. Substitutive methods were not employed for nondetects in the statistics generated for surface soil background calculations due to the actual results reported for "U" qualified data (Appendix C2).

In order to assess ground water and surface water quality for the RI, ARARs are developed as guidelines, or benchmarks, to compare levels of contamination present at a site to a regulatory health-based standard. Tables 4-3 through 4-6 represent potential ARARs for state water quality standards as they apply to RFP. Regulatory guidelines do not currently exist for soils and sediments at RFP. In accordance with the National Contingency Plan (40 CFR 300), ARARs for OU1 will be evaluated in the feasibility study process.

To provides a means of evaluating the potential for these media to be in excess of ARARs, tables 4-3 through 4-6 present chemical concentrations in surface water and ground water representing regulatory bench marks. Section 121(d) of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986, requires that Superfund-financed enforcement and federal facility remedial actions comply with federal ARARs or more stringent promulgated state requirements. CDH Water Quality Control Commission ground water standards became effective on April 30, 1991, and are therefore considered during the process of developing potential

sitewide ARARs for RFP. The values considered for use in background geochemical comparison consist of CDH Water Quality Control Commission water quality standards for ground water and surface water.

4.2 SUBSURFACE SOILS WITHIN INDIVIDUAL HAZARDOUS SUBSTANCE SITES

In order to define the nature and extent of contamination in subsurface soils, and to supplement the analytical results available from the Phase II program in 1987, 99 borehole locations were sampled across OU1 during the Phase III RFI/RI field investigation (Figure 4-1). Boreholes were sampled to determine the extent of contamination in subsurface soils within the 11 IHSSs and intervening areas in OU1.

Two distinct types of soil samples were taken during the Phase III field program. Composite samples were taken over 6-foot intervals throughout the depth of each borehole. Analyses performed on composite samples included SVOC analyses, base-neutral-acid extractables, pesticides, and PCBs (SVOCs); radionuclides; total metals; and inorganic parameters as previously discussed. SVOCs were not analyzed at all borehole locations based on the strategy presented in the Technical Memorandum 1 attachment to the OU1 Phase III RFI/RI work plan. SVOC target analytes are presented in Tables 2-6 through 2-10. Samples analyzed for VOCs were taken at all borehole and monitoring well locations by use of a California sampler. These 3-inch samples were taken at an initial 2-foot depth and at every 4-foot interval thereafter throughout the depth of each borehole down to the water table. Because VOCs were sampled at distinct depth intervals differently from composite samples, a slightly different data presentation strategy was derived for each. To present data spatially for the IHSSs, map depth intervals were chosen to provide as much consistency as possible in presenting two sample types, and to provide a detailed data presentation for the feasibility study. Concentrations of detected analytes are reported on the maps in Section 4.2. Figure 4-2 illustrates mapped depth intervals.

The nature and extent of contamination is presented for all sampled borehole locations by IHSS for each analyte group, according to depth intervals. Analytical results for boreholes that lie outside the 12 IHSSs and the former retention pond are mapped separately. The analyte groups for subsurface soils consist of all detections of VOCs, SVOCs, and radionuclides and metals exceeding background levels. Analyte abbreviations are used on the maps because of the scale of the drawings to more clearly present results for analytes with complex nomenclature.

Field QA/QC samples taken during the Phase III RFI/RI field investigation consisted of duplicate sample composites, trip blanks, and rinse blanks. Field duplicates were analyzed using the same methods as their companion samples. Trip blanks were only analyzed for VOCs; rinse blanks were only analyzed for SVOCs.

The results of QA/QC sample data available from rinse and trip blanks collected during the Phase III field soil sampling program are presented with subsurface soil data in Appendix C1. Water trip blanks were prepared on site, transported into the field, and shipped with the collected soil samples to the analytical laboratories. Rinse blanks were taken at every location requiring SVOC analyses of soils as outlined in Technical Memorandum 1 (DOE 1991d) of the OU1 Phase III RFI/RI work plan. Rinse blanks were analyzed for SVOCs. VOC and SVOC detections were reported for laboratory analyses of QA/QC samples. Analytes reported for VOCs in trip blanks included acetone, methylene chloride, toluene, and total xylenes. SVOC analyses of rinse blanks resulted in reporting the presence of, and potential cross-contamination by bis(2-ethylhexyl) phthalate and diethyl phthalate during the field sampling program. Di-n-butyl phthalate is also considered a potential field sampling contaminant due to its widespread occurrence in soil samples across OU1. The use of de-ionized water shipped in plastic carboys for decontamination rinses is the most plausible explanation for the phthalate contamination reported in rinse blanks.

4.2.1 Oil Sludge Pit Site (IHSS 102)

Nonradioactive oil sludge was cleaned from the two No. 6 fuel tanks south of Building 881 (IHSSs 105.1 and 105.2) in the late 1950s and disposed in a 25-foot by 80-foot pit south of

Building 881 (Rockwell 1987b; DOE 1991b). This pit has been designated IHSS 102. Thirty to 50 drums of the material were reportedly disposed. The pit also appears to have been in existence in 1955 aerial photographs of the area. In the photos, a pit containing oily liquids and measuring approximately 40 feet by 70 feet appears approximately 500 feet south of Building 881. Seepage from the pit is visible and appears to be directed toward a small pond near Woman Creek. The pit was subsequently backfilled (DOE 1991b), and is not visible in 1959 aerial photographs.

Phase I and Phase II RI results from IHSS 102 include one detection of tetrachloroethene in a soil gas survey near IHSS 102, and detections of methylene chloride, acetone, and bis(2-ethylhexyl)phthalate in two boreholes drilled between Building 881 and the area identified as IHSS 102 in the Phase III RI. Methylene chloride and acetone were also detected in laboratory blanks at concentrations higher than those detected in the samples. Based on a review of aerial photographs, IHSS 102 was moved from its original proposed location to its present location (Rockwell 1988a).

In the Phase III RI, two boreholes were drilled within IHSS 102 and four boreholes were drilled downgradient of IHSS 102. Table 4-7 summarizes analytes detected in subsurface soil for IHSS 102.

Five VOCs were detected in subsurface soil samples related to IHSS 102 (Figures 4-3 through 4-6). Four of these VOCs (toluene, 2-butanone, acetone, and methylene chloride) are common laboratory contaminants. The fifth and final VOC detected in IHSS 102 soils was trichloroethene.

Sitewide distributions of acetone, methylene chloride, 2-butanone, and toluene are discussed in Section 4.8.1. The only detections of these analytes considered as potential contaminants (concentrations exceeding detection limits by more than an order of magnitude) are 11 of 31 toluene detections. Six detections of toluene exceed 100 µg/kg. Detections greater than

100 µg/kg occur in only three of the eight sampling locations associated with IHSS 102 (31891, 36491, and 37391), and the maximum concentrations found in each of these locations occurs in the 0- to 2-foot interval (110, 200, and 120 µg/kg). In general, however, toluene concentrations show no consistent vertical distribution trends in IHSS 102 soils.

With the exception of toluene, trichloroethene was the only potential VOC contaminant detected in IHSS 102 soils. The single detection of trichloroethene (3 µg/kg) occurred in the 6- to 10-foot interval in borehole 31091. Based entirely on this single low-level detection, the presence of trichloroethene in IHSS 102 soils is considered uncertain.

Eleven SVOCs were detected in subsurface soil samples related to IHSS 102 (Figures 4-7 through 4-10). Five of the SVOCs detected are polynuclear aromatic hydrocarbons (benzo(a)pyrene, chrysene, naphthalene, phenanthrene, and pyrene), four are substituted aromatics (1,3-dichlorobenzene, 4-nitrophenol, benzoic acid, and pentachlorophenol), and the remaining two are phthalates (bis(2-ethylhexyl phthalate, and di-n-butyl phthalate). Commonly detected in rinse blank samples, phthalate detections are not considered reliable indicators of contamination; their sitewide occurrences are discussed in Section 4.8.1. Polynuclear aromatic hydrocarbons, and substituted aromatic compounds are, however, considered potential contaminants and their occurrences in IHSS 102 are discussed below.

Polynuclear aromatic hydrocarbon detections were limited to the 0- to 6-foot interval of borehole 37391, and the 30- to 36-foot interval of 31291. Detections in 37391 included naphthalene, phenanthrene, and pyrene. Constrained to the 0- to 6-foot interval, detections in 37391 indicate a near-surface source. Detections in 31291 included chrysene and benzo(a)pyrene; occurring at low levels (6 and 3 µg/kg, respectively) in the deepest sample interval of a single location, the significance of these detections is unclear.

Substituted aromatics were detected in the 6- to 12- and 12- to 18-foot intervals of borehole 31091, and in the 24- to 30- and 30- to 36-foot intervals of 31691.

Detections in 31091 included 4-nitrophenol, pentachlorophenol, and benzoic acid; occurring in only one sample each, there are no apparent trends in concentration. Benzoic acid, however, was detected in the lowest sample interval of 31091 (12 to 18 feet), and its vertical distribution is therefore not fully constrained. Detections in 31691 were limited to 1,3-dichlorobenzene, which occurred in both intervals sampled (24 to 30 and 30 to 36 feet). Because SVOC samples were not collected from above 24 feet or below 36 feet, vertical trends of 1,3-dichlorobenzene in 31691 are unclear.

Americium-241, plutonium-239,-240, radium-228, and tritium exceeded background levels in IHSS 102 subsurface soils (Figure 4-11). Except for a single plutonium detection in the 30- to 36-foot interval of 31291, detections greater than background were limited to the 0- to 6- and 6- to 12-foot intervals, indicating potential near-surface sources. All detections were, however, less than three times background levels and may reflect natural variations above background.

Antimony was the only metal exceeding background levels in IHSS 102 subsurface soil samples (Figure 4-12). Detections above background were limited to samples from the 24- to 30-foot intervals in each of two adjacent locations (31291 and 31691). Because samples were not collected from above 24 feet in either location, antimony concentrations above 24 feet remain unknown, and true vertical trends cannot be determined. All detections were, however, less than twice the background level (Table 4-1) and may reflect natural variations above background.

4.2.2 Chemical Burial Site (IHSS 103)

IHSS 103, southeast of Building 881, was reportedly used to bury unknown chemicals (DOE 1986, 1991b). The exact location, dates of use, and contents of the site are unknown. Aerial photographs taken in 1963 indicate a pit filled with liquid was evident approximately 150 feet southeast of Building 881. The pit is circular in the photos, and measures approximately 50 feet in diameter.

The disposal history is not known for IHSS 103. Results from Phase II indicate VOCs (methylene chloride, trichloroethene, acetone, 2-butanone, 4-methyl-2-pentanone) and SVOCs (fluorene, phenanthrene, pyrene) were detected in soil samples taken in the vicinity of IHSS 103 (Rockwell 1988a). The Phase II RI concluded acetone, 2-butanone, and bis(2-ethylhexyl)phthalate were potential laboratory contaminants.

During the Phase III field investigation, four soil boreholes were sampled in the vicinity of IHSS 103. Analytical results for Phase III samples indicate VOCs, SVOCs, and metals exceeding background are present in soils at IHSS 103 (Table 4-8). Radionuclide results for samples taken in soils are unavailable at this time.

Six VOCs were detected in subsurface soil samples related to IHSS 103 (Figures 4-13 through 4-15). Four of these (toluene, 2-butanone, acetone, and methylene chloride) are common laboratory contaminants. The two remaining VOCs detected in IHSS 103 soils are chlorinated solvents trichloroethene, and tetrachloroethene.

Sitewide distributions of acetone, methylene chloride, 2-butanone, and toluene are discussed in Section 4.8.1. The only detections of these analytes considered as potential contaminants (reported concentrations exceeding detection limits by more than an order of magnitude) are 9 of the 17 toluene detections. The only detections of toluene greater than 100 µg/kg (310 and 390 µg/kg) both occurred in the 2- to 6-foot interval of locations within IHSS 103 (36891 and 36791). There are, however, no consistent areal or vertical distribution trends apparent for toluene.

Chlorinated solvents are potential contaminants in IHSS 103 soils. The two detections of chlorinated solvents in IHSS 103 soils, single detections of trichloroethene and tetrachloroethene, both occurred in the 6- to 10-foot interval of borehole 32191. Occurring in the same sample, these detections may indicate an isolated area of chlorinated solvent contamination.

Eight SVOCs were detected in subsurface soil samples related to IHSS 103 (Figures 4-16 through 4-18). Six of the SVOCs detected are polynuclear aromatic hydrocarbons (benzo(a)anthracene, benzo(k)fluoranthene, chrysene, fluoranthene, phenanthrene, and pyrene). The remaining two SVOCs detected in IHSS 103 subsurface soils were di-n-butyl phthalate, and AROCLOR-1254 (a PCB). Commonly detected in rinse blank samples, phthalate detections are not considered reliable indicators of contamination; their sitewide occurrences are discussed in Section 4.8.1. Polynuclear aromatic hydrocarbons and PCBs are, however, considered potential contaminants and will be discussed below.

Polynuclear aromatic hydrocarbon detections occurred in samples from three locations (36891, 36791, and 32191). In each location, however, detections were limited to the 0- to 6-foot interval. Fluoranthene and phenanthrene were detected in all three locations, pyrene was detected only in 36791. The sole detections of benzo(a) anthracene, benzo(k)fluoranthene, and chrysene, occurred in borehole 32191. Limited to the 0- to 6-foot interval, these detections indicate a near-surface source of polynuclear aromatic hydrocarbon contamination at IHSS 103.

AROCLOR-1254 was the only polychlorinated biphenyl detected in IHSS 103 subsurface soils. The fact that detections were limited to the 0- to 6-foot interval of borehole 36791 indicates an isolated near-surface source.

Americium-241, cesium-137, plutonium-239,-240, and radium-228 exceeded background levels in IHSS 103 subsurface soils (Figure 4-19). Detections above background were limited to the 0- to 6- and 6- to 12-foot intervals of the three boreholes located within the map-view boundary of IHSS 103 (36791, 36891, and 36991). Although apparently indicating an isolated near-surface source, the distribution of these data may reflect a bias in the sample set rather than a true distribution (radionuclide samples were not collected below 12 feet in 36891 or 36991).

Plutonium was the only radionuclide detected at a concentration more than an order of magnitude greater than background (0.3406 pCi/g). This single exceptional detection occurred in the 0- to

6-foot interval of 36991, indicating a near-surface source. Americium-241 reached its maximum concentration (seven times background) in the same sample. With the exception of plutonium and americium in the 0- to 6-foot interval of 36991, all other radionuclide detections were less than three times background levels and may reflect natural variations above background.

Three metals were detected above background in IHSS 103 subsurface soils (Figure 4-20). Barium, and copper were detected greater than background in only one sample each, and strontium was detected above background in two samples. All detections exceeding background occurred in either the 0- to 6-, or 6- to 12-foot intervals, indicating a near-surface source. However, all detections occurred at concentrations less than twice background levels, and may reflect natural variations above background.

4.2.3 Liquid Dumping Site (IHSS 104)

An area east of Building 881 was reportedly used for disposal of unknown liquids and empty drums prior to 1969 (DOE 1986). One reference describes the disposal of nine bottles of nickel carbonyl and one can of iron carbonyl in a pit east of Building 881 (DOE 1991b). The IHSS location was identified on a 1965 aerial photograph as a discolored area of approximately 50 feet by 50 feet (Rockwell 1988a). However, further review indicates a possible shadow on the photo. In addition, the reports of disposal of empty drums in IHSS 104 have been dismissed because geophysical surveys failed to detect magnetic anomalies in the area. It is possible that the reported waste disposal associated with this IHSS occurred instead at IHSS 103.

IHSS 104 was not investigated in the Phase II RI. During the Phase III RI, two boreholes were drilled in IHSS 104. Table 4-9 presents the analytes detected in IHSS 104 soils.

Toluene and methylene chloride were the only VOCs detected in subsurface soil samples associated with IHSS 104 (Figures 4-21 through 4-23). Recognized as common laboratory contaminants, sitewide occurrences of toluene and methylene chloride are discussed in Section 4.8.1. The only detection of these analytes considered a potential contaminant (exceeding

the detection limit by an order of magnitude) is a detection of toluene (150 µg/kg) in the 0- to 2-foot interval of borehole 37091.

Twenty-one SVOCs were detected in subsurface soil samples related to IHSS 104 (Figures 4-24). All 21 detections occurred in a single sample collected from the 0- to 6-foot interval of 36591. Seventeen of the SVOCs detected were polynuclear aromatic hydrocarbons. The remaining four detections included three substituted aromatics (benzoic acid, 2,4-dimethylphenol, and 4-methylphenol), and a single detection of di-n-butyl phthalate. The lack of detections below 6 feet indicates a near-surface source. The distribution of drilling locations in the area does not, however, place rigorous constraints on the areal extent of SVOCs in the vicinity of IHSS 104.

Polynuclear aromatic hydrocarbon concentrations in IHSS 104 were very high in comparison to polynuclear aromatic hydrocarbon detections elsewhere in OU1, ranging from 1,200 to 16,000 µg/kg. All of the polynuclear aromatic hydrocarbon detections exceeded the contract reporting limit. The three detections exceeding 10,000 µg/kg were fluoranthene (15,000 µg/kg), phenanthrene (16,000 µg/kg), and pyrene (14,000 µg/kg).

Cesium-137 and plutonium-239,-240 were the only radionuclides exceeding background levels in IHSS 104 subsurface soils (Figure 4-25). Detections above background were limited to the 0- to 6-foot interval, indicating a near-surface source. All detections were, however, less than three times background and may reflect natural variations above background.

The only metal exceeding background in IHSS 104 subsurface soils was strontium (Figure 4-26). The single exceedance occurred in the 0- to 6-foot interval of borehole 36591, indicating a potential near-surface source. However, this detection (204 µg/kg) is less than twice the background value and may reflect natural variations above background levels.

4.2.4 Multiple Solvent Spill Site (IHSSs 119.1 and 119.2)

Beginning in 1967, IHSSs 119.1 and 119.2 were used for scrap metal storage and as drum storage areas. Both areas expanded between 1967 and 1971 and all drums were removed by 1972. The drums contained unknown quantities and types of solvents and wastes (Rockwell 1988a). IHSS 119.1 is the larger westernmost area.

Tetrachloroethene and trichloroethene were most frequently detected in soil gas during the Phase II RI at IHSS 119.1. In addition, there was an isolated occurrence of trichloroethane. During the Phase II RI, six boreholes were drilled in and around IHSS 119.1, three within the IHSS and three around the periphery. Results from the boreholes in IHSS 119.1 revealed tetrachloroethene, 1,1,1-trichloroethane, and trichloroethene in surficial materials. Acetone, 2-butanone, 1,1,2-trichloroethane, and bis(2-ethylhexyl)phthalate were detected in weathered claystone bedrock at depths up to 20 feet. In the three Phase II borings around the periphery of IHSS 119.1, acetone and 2-butanone were detected in weathered claystone, and bis(2-ethylhexyl)phthalate was detected at all depths along with isolated occurrences of di-n-butyl-phthalate.

During the Phase III field investigation, ten soil borings were drilled throughout IHSS 119.1. Table 4-10 presents soil sampling analytical results for detections in soils at IHSS 119.1.

Ten VOCs were detected in subsurface soil samples related to IHSS 119.1 (Figures 4-27 through 4-29). Four of these (toluene, 2-butanone, acetone, and methylene chloride) are common laboratory contaminants. Five of the remaining six VOC detections were chlorinated solvents: 1,1,1-trichloroethane, 1,1-dichloroethene, carbon tetrachloride, tetrachloroethene, and trichloroethene. The only other VOC detected in IHSS 119.1 subsurface soils was bromomethane.

Sitewide distributions of acetone, 2-butanone, methylene chloride, and toluene are discussed in Section 4.8.1. The only detections of these analytes in IHSS 119.1 soils considered as potential contaminants (concentrations exceeding detection limits by more than an order of magnitude) are

17 of 45 toluene detections. These 17 detections are distributed throughout IHSS 119.1 and concentrations show no consistent vertical trends. However, the highest concentrations of toluene (300, 510, and 540 µg/kg) were all detected in the 0- to 2-foot interval.

Chlorinated solvents and bromomethane are potential contaminants in IHSS 119.1 soils. Detections of these analytes in 119.1 were limited to four locations located within a single 75-foot radius centered in the southwest quadrant of IHSS 119.1 (34891, 35291, 38191, and 38291). All but two of the detections (tetrachloroethene at 1 µg/kg and the sole detection of bromomethane at 2 µg/kg, both in the 0- to 2-foot interval) occurred below 6 feet.

Chlorinated solvents were detected in the lowest sampled intervals of all four locations showing detections of these analytes in IHSS 119.1. Maximum concentrations of 1,1,1-trichloroethane (5 µg/kg), 1,1-dichloroethene (12 µg/kg), trichloroethene (140 µg/kg), and tetrachloroethene (47 µg/kg) were all detected in the deepest sample interval (14 to 18 feet) of both 38191 and 38291. The sole detection of carbon tetrachloride, 18 µg/kg, occurred in the deepest sample interval of location 35291 (6 to 10 feet). These data imply that even higher concentrations of chlorinated solvents may exist in soils below the sampled intervals, and/or that chlorinated solvents are being concentrated near the alluvial-bedrock contact in IHSS 119.1.

Five SVOCs were detected in IHSS 119.1 subsurface soils (Figure 4-30). Four of the SVOCs are polynuclear aromatic hydrocarbons (anthracene, fluoranthene, phenanthrene, and pyrene); the fifth SVOC detected was bis(2-ethylhexyl)phthalate. All detections occurred below the contract reporting limit. Detections were limited to the 0- to 6-foot interval, indicating a near surface source.

Six radionuclides, including two separate isotope groupings for uranium, were detected above background in IHSS 119.1 subsurface soil samples (Figure 4-31). Four of these radionuclides exceeded background in more than one sample: americium-241 and plutonium-239,-240 in six

samples each, radium-228 in four, and cesium-137 in two. Isotope groups of uranium (uranium-238, and uranium-233,-234) were detected above background in only one sample each.

All but one of the radionuclide detections exceeding background occurred above 12 feet (americium-241 in the 12- to 14-foot interval of 34891), indicating potential near-surface sources. Plutonium-239,-240 and americium-241 concentrations reached levels more than ten times background levels in the 0- to 6-foot interval of 34691. All six radionuclides were detected at their maximum concentrations in 34691, and all but uranium-238 reached their maximum concentrations in the 0- to 6-foot interval. These data indicate that there is an isolated, near-surface source of radionuclide contamination in the vicinity of 34691.

Four metals were detected above background in IHSS 119.1 subsurface soils (Figure 4-32). Three of these metals (barium, cobalt, and tin) were detected greater than background in only one sample each. The only metal exceeding background in more than one sample was copper, which exceeded background twice.

Metals detections exceeding background were limited to the 0- to 6- and 6- to 12-foot intervals, indicating potential near-surface sources. This apparent trend may, however, simply reflect a bias in the sample set (35591, 35491, and 35291 were not sampled below 12 feet). Furthermore, all detections were less than twice background levels (Table 4-1) and may reflect natural variations above background.

4.2.5 Multiple Solvent Spill Site - East (IHSS 119.2)

IHSS 119.2 is located east of IHSS 119.1 and was used for storing scrap metal as well as drums containing unknown quantities and types of solvents. Like IHSS 119.1, IHSS 119.2 was also used for drum storage from 1967 until 1972 (Rockwell 1988a).

Tetrachloroethane was the most frequently detected compound in soil gas during Phase II at IHSS 119.2. During the Phase II RI, two boreholes were drilled within IHSS 119.2, two were

drilled to the west of IHSS 119.2, and one borehole was drilled downgradient. Methylene chloride, 2-butanone, and bis(2-ethylhexyl)phthalate were detected in the samples taken from boreholes west of the IHSS. Organic compounds 1,1,1-trichloroethane, bis(2-ethylhexyl)phthalate, and di-n-butylphthalate were detected in samples taken within the IHSS. No compounds were detected in downgradient borehole samples.

Seven Phase III boreholes were drilled in IHSS 119.2. Table 4-11 summatizes analytes detected in soils at IHSS 119.2.

Toluene, acetone, and methylene chloride were the only VOCs detected in subsurface soil samples from IHSS 119.2 (Figures 4-33 through 4-35). Recognized as common laboratory contaminants, sitewide occurrences of these VOCs are discussed in Section 4.8.1. None of the acetone or methylene chloride detections, and only 16 of the 23 toluene detections in IHSS 119.2 soils are considered as potential contaminants (concentrations exceeding detection limits by more than an order of magnitude).

The three highest detections of toluene occur in the 0- to 2-foot interval (480, 260, and 230 µg/kg). However, significant toluene detections occur throughout IHSS 119.2 and do not show any consistent vertical trends in concentration.

Thirteen SVOCs were detected in subsurface soil samples related to IHSS 119.2 (Figures 4-36 through 4-37). Nine of the SVOCs detected are polynuclear aromatic hydrocarbons (acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, fluoranthene, phenanthrene, and pyrene), and two are polychlorinated biphenyls (AROCLOR-1248, and AROCLOR-1254). The remaining two are phthalates—bis(2-ethylhexyl) phthalate and di-n-butyl phthalate.

Polynuclear aromatic hydrocarbon detections were limited to the 0- to 6-foot interval of borehole 33291, and the 6- to 12-foot interval of borehole 33591. All nine polynuclear aromatic

hydrocarbons detected in IHSS 119.2 subsurface soils were detected in the 0- to 6-foot interval of 33291, indicating a near-surface source. The one isolated detection of fluoranthene in 33591, located downgradient of 33291, is potentially related to the same source.

Detections of polychlorinated biphenyls (AROCLOR-1248, and AROCLOR-1254) were limited to the 0- to 6-foot interval of borehole 33291, indicating an isolated near-surface source.

Americium-241 and plutonium-239,-240 were the only radionuclides detected above background in IHSS 119.2 subsurface soils (Figure 4-38). Each of the two americium-241 detections, and 7 of the 10 plutonium-239,-240 detections, including maximum concentrations at each location, occurred in the 0- to 6-foot interval, indicating a near-surface source.

Plutonium-239,-240 was detected in the 0- to 6-foot interval of every sample location in IHSS 119.2. In six of the seven 0- to 6-foot samples collected (all except 32891), plutonium levels exceeded background levels by more than an order of magnitude. The maximum detection (3.167 pCi/g in 33291) exceeds background by more than two orders of magnitude. Plutonium-239,-240 detections below 6 feet occurred in 33291 and 33791 at concentrations less than twice background.

Six metals were detected above background in IHSS 119.2 subsurface soils (Figure 4-39). Five of these metals (barium, cobalt, copper, lead, and zinc) exceeded background in only one sample each. The only metal detected above background in more than one sample was cadmium, which exceeded background in three samples.

All three cadmium detections occurred above 8 feet in the eastern half of IHSS 119.2, indicating a potential area of near-surface contamination. However, occurring at concentrations less than four times background, these cadmium detections may reflect natural variations above background. All other metals were detected at concentrations less than twice background levels and therefore may also reflect natural variations above background.

4.2.6 Radioactive Site - 800 Area Site #1 (IHSS 130)

Between 1969 and 1972, the IHSS 130 area, which is located between IHSS 119.1 and Building 881, was used to dispose of up to 400 tons of soil and asphalt contaminated with low levels of plutonium. This waste material was derived from three sources: cleanup of the area on the west side of Building 776 after the May 11, 1969 fire; excavation of a contaminated section of Central Avenue roadway in 1970; and the 1972 cleanup of plutonium-contaminated soil around the Building 774 process waste tanks. The total plutonium content of the material from Building 776 was estimated at 14 grams (Putzier 1970).

Two Phase II boreholes were drilled in IHSS 130. Methylene chloride and bis(2-ethylhexyl)phthalate were detected and are most likely attributable to laboratory contamination. Although site history indicates that plutonium-contaminated soil was disposed in IHSS 130, Phase II results show plutonium was not detected in either borehole.

Eight boreholes were drilled in the vicinity of IHSS 130 as a part of the Phase III field investigation. Table 4-12 presents analytical detections for soils at IHSS 130.

Toluene, acetone, and methylene chloride were the only VOCs detected in subsurface soil samples from IHSS 130 (Figures 4-40 through 4-43). Recognized as common laboratory contaminants, sitewide occurrences of these VOCs are discussed in Section 4.8.1. None of the acetone or methylene chloride detections, and only 24 of the 33 toluene detections in IHSS 130 soils, are considered potential contaminants (exceeding detection limits by an order of magnitude).

Fifteen of the 24 significant toluene detections are between 50 and 200 µg/kg, eight range from 200 to 620 µg/kg, and the remaining toluene detection was the project-wide maximum of 1,200 µg/kg. The five highest detections (1,200, 620, 540, 510, and 380) occur in intervals above 6 feet. However, significant toluene detections occur throughout IHSS 130 and do not show any consistent vertical trends in concentration.

Eighteen SVOCs were detected in subsurface soil samples related to IHSS 130 (Figures 4-44 through 4-46). All of the SVOC detections occurred in only two locations (36091 and 36391). Fifteen of the SVOCs detected are polynuclear aromatic hydrocarbons, two are substituted aromatics (benzoic acid and pentachlorophenol). The only other SVOC detected was di-n-butyl phthalate. Commonly detected in rinse blank samples, phthalates are not considered true contaminants, and their sitewide occurrences are discussed in Section 4.8.1. Polynuclear aromatic hydrocarbons and substituted aromatic compounds are, however, considered potential contaminants and are discussed below.

Polynuclear aromatic hydrocarbon detections were limited to the 0- to 6- and 6- to 12-foot intervals. All 15 detections occurred in borehole 36391, and all except naphthalene were detected in the 0- to 6-foot interval. Seven polynuclear aromatic hydrocarbons occurring in both the 0- to 6- and 6- to 12-foot intervals reached maximum concentrations in the 0- to 6-foot interval, indicating a near-surface source. Polynuclear aromatic hydrocarbons detected in 36091 (fluoranthene and pyrene only) occurred only in the 0- to 6-foot interval, also indicating a near-surface source. The distribution of drilling locations in the vicinity of IHSS 130 does not, however, allow the precise areal extent of SVOC contamination to be determined.

Detections of substituted aromatics occurred only in borehole 36391. Pentachlorophenol was detected in the 0- to 6-, and 12- to 18-foot intervals. Separated by an interval showing no detections, the two detections of pentachlorophenol appear as isolated detections. Benzoic acid was detected only in the 0- to 6-foot interval, indicating a near-surface source.

Americium-241, cesium-137, plutonium-239,-240, and radium-228 exceeded background levels in IHSS 130 subsurface soils (Figure 4-47). Detections of radium-228 and cesium-137 were limited to intervals above 12 feet, indicating potential near-surface sources. In general, americium-241 and plutonium-239,-240 concentrations decrease with depth, indicating near-surface sources. The single exception to that general trend is an anomalously high detection of americium-241 in the lowest sample interval of 35791 (12 to 16 feet).

Americium-241 and plutonium-239,-240 were the only radionuclides detected at concentrations exceeding background by more than an order of magnitude. Both americium and plutonium reach their maximum concentrations in the 0- to 6-foot interval of 36091. The americium-241 concentration in that sample exceeded background by more than two orders of magnitude, and the plutonium-239,-241 concentration exceeded background by more than three orders of magnitude. The only other radionuclide detection exceeding background by an order of magnitude was the 1.975 pCi/g detection of americium-241 in the 12- to 16-foot interval of 35791.

Three metals were detected above background in IHSS 130 subsurface soils (Figure 4-48). Barium and strontium exceeded background in one sample each, and cobalt exceeded background in two samples. All detections were less than three times background and may therefore reflect natural variations above background values.

4.2.7 Vicinity of Building 881 (IHSSs 105, 106, 107, and 145)

IHSSs 105.1, 105.2, 106, 107, and 145 are located in the vicinity of Building 881. The site histories and Phase II results for these IHSSs are discussed in the following paragraphs. Phase III results for these IHSSs are discussed collectively rather than on an individual basis.

IHSSs 105.1 and 105.2 are the two out-of-service No. 6 fuel tanks located south of Building 881 that were used to store diesel fuel from 1958 through 1976. The tanks were then filled with asbestos-containing material and subsequently with concrete (Rockwell 1988a). The tanks tested tight when pressure tested in 1973 (Rockwell 1988a; DOE 1991b). Acetone and methylene chloride were detected during the Phase II RI in a boring located 50 feet to the southwest of the tanks. Both compounds were also detected in laboratory blanks and were interpreted as laboratory contaminants (Rockwell 1988a).

IHSS 106 is a 6-inch-diameter vitrified clay pipe outfall south of Building 881 that is an overflow line from the sanitary sewer sump in Building 887. The outfall was used for discharge

of untreated sanitary wastes in the 1950s and 1960s, and for discharge of cooling tower blowdown into the late 1970s. In 1955 a small retention pond was built to prevent sanitary wastes from flowing directly into Woman Creek. During the Phase II RI, tetrachloroethene was detected in soil gas downslope from IHSS 106. Soil samples taken from a borehole downslope from the outfall were found to contain VOCs (methylene chloride, acetone, and 2-butanone), and SVOCs (di-n-butylphthalate and bis(2-ethylhexyl)phthalate). VOC detections were highest in surficial materials just above the bedrock contact, and SVOCs were elevated both above and below the bedrock contact (Rockwell 1988a).

IHSS 107 is an area where oil was discovered flowing down the hillside south of Building 881 in May 1973. The spill was contained with straw, which was then disposed in the landfill north of the plant (Rockwell 1988a). The two No. 6 fuel tanks south of Building 881 (IHSSs 105.1 and 105.2) were considered to be the source of the oil, because the Building 881 footing drain passes directly beneath them. Consequently, a concrete skimming pond was built below the footing drain outfall and the South Interceptor Ditch was built to prevent oil-contaminated water from reaching Woman Creek (Owen and Steward 1973). No oil was observed in the outfall after 1973 (Rockwell 1988a). The skimming pond was removed during the recent french drain construction.

During the Phase II RI, tetrachloroethene, trichloroethane, trichloroethene, and dichloroethene were detected in soil gas in the vicinity of IHSS 107. No volatile organics were detected above laboratory contaminant levels in the area upgradient from the outfall or in the area downgradient from the skimming pond. However, acetone, 2-butanone, trans-1,2-dichloroethane, trichloroethene, tetrachloroethene and bis(2-ethylhexyl)phthalate were all detected in soils and groundwater south of the drain and upgradient of the skimming pond. Bis(2-ethylhexyl)phthalate was the only compound elevated in soils south of the skimming pond (Rockwell 1988a).

In January 1981, a 6-inch cast-iron sanitary sewer line that originates at the Building 887 lift station leaked on the hillside south of Building 881 (DOE 1991b). The area was designated

IHSS 145. The line had been used to convey sanitary wastes and low-level radioactive laundry effluent to the sanitary waste treatment plant. IHSS 145 was not investigated in the Phase II RI.

Eleven Phase III boreholes were completed in and around the IHSSs discussed above as a part of the Phase III RI. Table 4-13 presents aalytical results for detections in these boreholes.

Five different VOCs were detected in subsurface soil samples collected in the vicinity of Building 881 (Figures 4-49 through 4-52). Four of these (toluene, 2-butanone, acetone, and methylene chloride) are common laboratory contaminants. The fifth VOC detected in subsurface soils near Building 881 was tetrachloroethene.

Sitewide distributions of acetone, methylene chloride, 2-butanone, and toluene are discussed in Section 4.8.1. The only detections of these analytes considered as potential contaminants (concentrations exceeding detection limits by more than an order of magnitude) are 21 of 36 toluene detections. Twelve of the toluene detections exceeded 100 µg/kg. The maximum detection, 490 µg/kg, occurred in the 14- to 18-foot interval of borehole 37291. Six of the 12 toluene detections exceeding 100 µg/kg were found in borehole 37291. In general, toluene data from samples taken in the vicinity of Building 881 shows a potential areal distribution trend, with the highest detections found in boreholes near IHSSs 107 and 106. Vertical distribution trends are not, however, apparent.

The two detections of tetrachloroethene near Building 881 are indications of potential contamination. Detected concentrations are, however, both below the contract reporting limit (4 µg/kg and 1 µg/kg). The occurrence of tetrachloroethene in consecutive depth intervals (6 to 10, and 10 to 14 feet) of the same borehole (32091) indicates a discrete area of potential tetrachloroethene contamination. Potentially, these tetrachloroethene detections at 32091 may also be related to tetrachloroethene detections in the 6- to 10-foot interval of borehole 32191 (Figure 4-14) located approximately 50 feet to the east of borehole 32091.

Eight SVOCs were detected in subsurface soil samples collected in the vicinity of Building 881 (Figures 4-53 through 4-56). Four of the SVOCs detected are substituted aromatics (1,4-dichlorobenzene, 2,4-dinitrotoluene, 4-chloro-3-methylphenol, and 4-nitrophenol), and three are phthalates (bis(2-ethylhexyl) phthalate, di-n-butyl phthalate, and diethyl phthalate). There was a single detection of pyrene, a polynuclear aromatic hydrocarbon. Commonly detected in rinse blank samples, phthalates are not considered true contaminants, and their sitewide occurrences are discussed in Section 4.8.1. Polynuclear aromatic hydrocarbons and substituted aromatic compounds are, however, considered potential contaminants and their distribution in the vicinity of Building 881 is discussed below.

Substituted aromatics were detected in the 0- to 6-foot intervals of 39491 and 32491, and the 6 to 12-foot interval of 31991. The 0- to 6-foot sample from 39491 was the only subsurface soil SVOC sample collected from the skimming pond. Therefore, the extent of substituted aromatics in soils beneath the skimming pond is not well constrained. Detections in 31991 and 32491 were all below the contract reporting limit; occurring only above 12 feet, these detections indicate near surface sources. The distribution of sampling locations in the vicinity of Building 881 does not, however, allow the precise areal extent of substituted aromatic compounds to be determined.

The single detection of pyrene occurred in the 0- to 6-foot interval of 32491, indicating an isolated near-surface source.

Americium-241, plutonium-239,-240, and uranium-233,-234 exceeded background levels in subsurface soil samples collected in the vicinity of Building 881 (Figure 4-57). Plutonium-239, -240 occurred above background in five samples, americium-241 in four, and uranium-233,-234 in two. Americium-241 exceeded background in the lowest sample intervals of locations 31991 and 37291, and its vertical distribution is therefore not fully constrained. Uranium-233,-234 detections above background were limited to the 0- to 6- and 6- to 12-foot intervals of borehole 32091, indicating an isolated near-surface source. Four of the five plutonium-329,-240 exceedances occurred in 0- to 6-foot intervals, indicating near-surface sources. The sole

plutonium detection below 6 feet, in the 6- to 12-foot interval of 32391, illustrates a trend of decreasing concentration with depth.

The only radionuclide detection exceeding background by more than an order of magnitude was americium-241 in the 12- to 18-foot interval of 31991. All other detections occurred at less than three times background and may reflect natural variations above background levels.

Five metals were detected above background in subsurface soil samples collected in the vicinity of Building 881 (Figure 4-58). Three of these metals (arsenic, barium, and copper) exceeded background in only one sample each. The two metals detected above background in more than one sample were cadmium and selenium; cadmium in two samples, and selenium in three. All but one detection occurred in either the 0- to 6- or 6- to 12-foot intervals, indicating potential near-surface sources. However, with the exception of selenium, all concentrations are less than twice background levels and may reflect natural variations above background.

Selenium concentrations in borehole 32491 exceed background levels by more than two orders of magnitude. The distribution of sample locations near 32491 is not sufficient to fully delineate the extent of elevated selenium concentrations. Furthermore, because the maximum concentration (619 mg/kg) occurred in the lowest sample interval of 32491, vertical trends are not well constrained. The only detection of selenium exceeding background outside 32491 was a much lower detection (1.3 mg/kg) in the 18- to 24-foot interval of 37291. Located downgradient of 32491, it is possible that this detection in 37291 is related to the detections in 32491.

4.2.8 Former Retention Pond

Although the former retention pond is not identified by the Interagency Agreement as an IHSS, it is apparently distinct from other disposal and spill sites on the 881 Hillside. The disposal history of the former retention pond is unknown except that oil was observed leaking towards it from IHSS 102 in a 1955 aerial photograph (DOE 1991b).

The former retention pond was not investigated in the Phase II RI. During the Phase III RI, two borings were drilled within the former retention pond and one was drilled directly to the north. Table 4-14 summaries analytical detections in soils at the former retention pond.

Toluene and methylene chloride were the only VOCs detected in subsurface soil samples associated with the former retention pond (Figures 4-59 through 4-61). Recognized as common laboratory contaminants, sitewide occurrences of toluene and methylene chloride are discussed in Section 4.8.1. None of the methylene chloride detections, and only five of the toluene detections are considered as potential contaminants (concentrations exceeding detection limits by more than an order of magnitude).

Data do not show consistent vertical trends in toluene concentration. However, data currently available for RFP soils are not complete enough to rule out the possibility of vertical trends. The two samples with toluene concentrations greater than 100 µg/kg (310 and 410 µg/kg) were the only samples collected from each of two boreholes downgradient of the RFP (38491 and 38391; 2- to 6-, and 6- to 10-foot intervals, respectively).

Five SVOCs were detected in subsurface soils associated with the former retention pond (Figures 4-62 through 4-64). Three of the SVOCs are polynuclear aromatic hydrocarbons (fluoranthene, phenanthrene, and pyrene); the remaining two SVOC detections were both phthalates (bis(2-ethylhexyl)phthalate and di-n-butyl phthalate). Di-n-butyl phthalate was detected in all samples collected from 30791 (0 to 6, 6 to 12, and 12 to 18 feet). However, commonly detected in rinse blank samples, phthalate detections are not considered reliable indicators of contamination; their sitewide occurrences are discussed in Section 4.8.1.

Polynuclear aromatic hydrocarbon detections were limited to the 0- to 6-foot interval of 30691, indicating an isolated near-surface source.

Plutonium-239,-240 was the only radionuclide exceeding background levels in subsurface soils related to the former retention pond (Figure 4-65). The single detection, occurring in the 6- to 12-foot interval of borehole 30891, was less than twice background and may be a natural variation above background levels.

Antimony was the only metal exceeding background levels in subsurface soil samples associated with the former retention pond (Figure 4-66). Detections exceeding background occurred in samples collected from the 0- to 6- and 6- to 12-foot intervals of 30891 and the 0- to 6-foot interval of 30791. Located within approximately 50 feet of one another, detections in these two locations may indicate a single near-surface source. All detections were, however, less than twice background levels and may reflect natural variations above background.

4.2.9 OU1 Nonsource Areas

As a part of the Phase III RI, soil samples were taken in areas with no known or suspected history of waste disposal. Four Phase III soil boreholes were drilled in nonsource areas. In addition, VOC analyses are available from bedrock and water table VOC samples taken at nonsource area well and piezometer locations. Table 4-15 summaries analytical detections in soils in OU1 nonsource areas.

Five different VOCs were detected in subsurface soil samples collected from nonsource areas within OU1 (Figures 4-67 through 4-70). Four of these VOCs (toluene, 2-butanone, acetone, and methylene chloride) are common laboratory contaminants. The fifth and final VOC detected in nonsource area soils was 4-methyl-2-pentanone.

Sitewide distributions of acetone, methylene chloride, 2-butanone, and toluene are discussed in Section 4.8.1. The only detections of these analytes considered as potential contaminants (concentrations exceeding detection limits by more than an order of magnitude) are 16 of 29 toluene detections. The two highest concentrations (210 and 150 µg/kg) were detected in the 0-

to 2-foot interval. However, significant toluene detections occur throughout the nonsource area samples, and do not show any consistent vertical trends in concentration.

With the exception of toluene, 4-methyl-2-pentanone was the only potential VOC contaminant detected in nonsource area soils. The single detection of 4-methyl-2-pentanone (2 µg/kg) occurred in the 0- to 2-foot interval of borehole 30591. Based entirely on this single low-level detection, the presence of 4-methyl-2-pentanone in borehole 30591 soils is considered uncertain.

Bis(2-ethylhexyl) phthalate and di-n-butyl phthalate were the only SVOCs detected in subsurface soil samples collected in OU1 nonsource areas (Figures 4-71 through 4-74). Commonly detected in rinse blank samples, phthalate detections are not considered reliable indicators of contamination; their sitewide occurrences are discussed in Section 4.8.1.

Six radionuclides (including three distinct isotope groups of uranium) were detected in subsurface soil samples collected in OU1 nonsource areas (Figure 4-75). Cesium-137, plutonium-239,-240, uranium-233,-234, and uranium-238 were detected above background in one sample each. Radium-228 and uranium-235 were each detected above background twice. The only detection exceeding background by more than an order of magnitude was uranium-235 in the 6- to 12-foot interval of 30191. All other detections were less than twice background levels and may reflect natural variations above background.

Four metals were detected above background in subsurface soil samples collected in OU1 nonsource areas (Figure 4-76). Two of these metals (barium, and lithium) exceeded background in only one sample each. The two metals detected above background in more than one sample were cadmium and strontium; each was detected in two samples. Detections greater than background were limited to three locations along the road that runs east-west between IHSS 102 and the former retention pond (30191, 30291, and 30391). All but one detection (lithium in the 12- to 18-foot interval of 30391) occurred above 12 feet, indicating potential near-surface

sources. However, all concentrations were less than twice background levels and may reflect natural variations above background.

4.3 SURFACE SOILS

Surface soils were sampled at OU1 and Rock Creek during the Phase III RFI/RI field program as outlined in Technical Memorandum 5 (DOE 1992a), an addendum to the Phase III work plan. Surface soils samples were collected at 37 locations, consist of nine in the Rock Creek area and 28 locations at OU1. Surface soil samples taken from Rock Creek and OU1 were analyzed for SVOCs, radionuclides, and metals (Table 2-9). The surface soil sampling methodology is presented in Section 2.5. Surface soil sampling locations for Rock Creek are presented in Figure 4-77.

To assess potential contamination in surface soils at OU1, results for radionuclides and metals were compared to background concentrations established by Rock Creek surface soil samples. Concentrations of radionuclides and metals greater than background are presented on maps for Rock Creek and OU1 and listed in Table 4-2. Concentrations for SVOCs on maps are qualified detections in the surface soil database.

4.3.1 Rock Creek Surface Soils

Two SVOCs were detected at two locations in the Rock Creek area (Figure 4-78). Di-n-butyl phthalate and bis(2-ethylhexyl)phthalate were detected at two locations at concentrations ranging from 39 to 44 µg/kg and 35 to 140, respectively (Table 4-16). Results for these two compounds are qualified with a "J", indicating the detected concentrations are less than the certified reporting limits. Phthalates have been detected in soils at OU1, and associated equipment rinse blanks have contained phthalates at low levels. It is most likely that detection of phthalates in Rock Creek surface soils, like OU1 subsurface soils, is due to field sampling cross-contamination.

Although the results from Rock Creek samples were used to establish surface soil background, a comparison of background values greater than Rock Creek surficial soil results for

radionuclides and metals are presented in Figures 4-79 and 4-80. Because Rock Creek is a valid background sampling area for surface soils, radionuclides and metals can be excluded as contaminants at Rock Creek (Table 4-2).

4.3.2 OU1 Surface Soils

Eighteen SVOCs were detected in sixteen surface soil sampling locations in OU1 (Figures 4-81 and 4-82). Total concentrations for SVOCs in OU1 ranged from 620 µg/kg at location RA025 to greater than 10,000 µg/kg at RA023. Polynuclear aromatic hydrocarbons comprise seven of the sixteen SVOCs detected in OU1 surface soils. Polynuclear aromatic hydrocarbons were detected four to twelve times in 24 locations across OU1 (Table 4-17). The most frequently detected SVOCs in surface soils were fluoranthene, pyrene, and phenanthrene. Similarly, fluorene, pyrene, and phenanthrene were the most frequently detected SVOCs in shallow subsurface soils during the Phase III RFI/RI field investigation. Unlike samples taken at Rock Creek, phthalates were not detected in OU1 samples. This suggests that phthalates detected in Rock Creek samples could be attributed to field sampling cross-contamination.

Radionuclides, including plutonium, americium, uranium, and radium isotopes, exceed Rock Creek background values in OU1 surface soils (Table 4-2, Figure 4-83). When compared to the appropriate background, maximum concentrations of americium and plutonium in surface soils exceed by two to three orders of magnitude. Uranium isotopes do not exceed Rock Creek surface soil background by more than a factor of five (Table 4-2); and an analysis of uranium isotopes indicates that uranium concentrations in surface soils are naturally occurring (see Section 5.2).

Plutonium and americium concentrations in OU1 surface soils (upper 2 inches) range from 0.03932 to 1.944 and 0.09067 to 12.99 pCi/g, respectively. The low values for americium and plutonium were detected in the southwestern-most location at OU1 (RA012) furthest from the 903 Pad. These values are slightly greater than the maximum value detected at Rock Creek, suggesting that background levels of plutonium are approached at OU1 at distance from the 903

Pad. Americium and plutonium activities in surface soils increase dramatically to the northeast toward the 903 Pad, reaching a maximum value at surface soil location RA025 of 1.9 and 13 pCi/g, respectively. Contour maps depicting americium-241 and plutonium -239, -240 in surface soils indicate the source for radionuclides exists east of OU1, in the area of the 903 Pad (OU2) (Figures 4-85 and 4-86). A preliminary assessment of results from the surficial soil sampling program in OU2 confirms the contaminant distribution and transport processes apparent in OU1. Further evaluation of OU1 and OU2 surface soil sampling data will be required upon the completion of the Draft RFI/RI report for OU2 due January 1993.

Eighteen metals exceed background in surface soil samples at OU1 (Table 4-17, Figure 4-84). Calcium, nickel, tin, and vanadium exceed background more frequently than other metals. A comparison of background concentration to actual results indicate that metal concentrations generally do not exceed background by an order of magnitude. Copper is the only metal with a maximum concentration (181 mg/kg) approaching ten times background (18.5 mg/kg). Since copper has not been historically processed at RFP, and the disposal of copper metal at OU1 is unknown (DOE 1992d), it can not be considered a potential contaminant in OU1 surface soils. Beryllium concentrations are slightly elevated at OU1. The maximum concentration of beryllium only exceeds background by a factor of six. Because of the localized elevated occurrence of beryllium exceeding background, it is not indicative of metal contamination in OU1 surface soils.

4.4 AIR

Radiological ambient air samplers monitor airborne dispersion of radioactive materials from RFP operations. The Radiological Ambient Air Monitoring Program is the existing area-wide monitoring program consisting of 51 on-site locations at RFP, along the RFP perimeter fences, and within the Denver metropolitan area. Seven ambient air samplers are routinely monitored within OU1 (Figure 2-2). An additional sampler (S-32) upwind of OU1 provides data for background characteristics. To provide more OU1-specific air data, four high volume air

samplers (S-81A, S-81B, S-81C, and S-81D) were established in January 1990 (Figure 2-3). Tables 4-18 through 4-21 present data collected as part of the routine monitoring of air for OU1.

The ambient air samplers operate continuously at a volumetric flow rate of approximately 25 cubic feet per minute (feet^3/minute) using a RFP-designed sampler which incorporates a brushless induction-type blower assembly. The four high-volume samplers at OU1 operate at a continuous flow rate of approximately 50 feet^3/minute. Both types of samplers collect particulate matter on a fiberglass filter medium. Sampler flow rates are checked weekly, and filters are collected biweekly. Filters taken from the OU1 sampling network are analyzed for plutonium. Tables 4-18 through 4-21 present monthly averages for plutonium sampled at OU1 air sample stations.

Data for the seven ambient air samplers show that the two highest values for plutonium in 1990 and 1991 occurred at station S-9 in January 1991 (0.000461 picocuries per cubic meter [pCi/m^3]) and February 1990 (0.000328 pCi/m^3). The sampling station is downwind of the 903 Pad (OU2), and the detected values are believed to have resulted from localized resuspension from this area. OU1 site-specific monitoring results indicate plutonium was detected at a maximum concentration of 0.000119 pCi/m^3 in September 1991 at station S81D. The second highest detected value for plutonium occurred in July 1990 at sampling station S81A at a concentration of 0.000103 pCi/m^3. Elevated levels for plutonium at site-specific samplers are suspected to have occurred due to localized resuspension from vehicle traffic in the immediate area. The highest value recorded during the 1990 and 1991 sampling periods for the upwind sampler S32 was 0.000006 pCi/m^3, the monthly average for June 1991.

4.5 SURFACE WATER AND SEDIMENT

It is necessary to determine the nature and extent of contamination in surface water and sediment in order to comprehensively assess site conditions. Locations of surface water and sediment sampling stations are consistent with the locations presented in the work plan for the Phase III RFI/RI for OU1 (Figure 4-87). Analytical results presented on maps in the following discussion

are confined to sampling that took place during the time period of the Phase III RFI/RI field investigation. For purposes of this report, surface water and sediment contaminant distribution are presented for all of OU1, rather than by each IHSS.

The Phase III RFI/RI work plan for OU1 lists surface water and sediment sampling locations to be presented and evaluated in the RI (Table 4-22). In this report, surface water and sediment sampling stations located outside of OU1 are not included on the contaminant distribution maps. Of those locations listed in the work plan, only two surface water stations (stations SW020 and SW056) lie outside of the OU1 boundary. Station SW020 is located near the Solar Evaporation Ponds (OU4), and station SW056 is located upgradient of OU1 on the South Interceptor Ditch near the old landfill in OU5, the Woman Creek Drainage. Analytical results for all surface water locations listed in Table 4-22 are presented in Appendix C3.

Sediment data for locations within OU1 are not presented for fourth quarter 1991 in this report. Only three of the 13 sediment sampling stations are located within OU1 (stations SED037, SED038, and SED039). They were established during the Phase III RFI/RI field investigation to adequately characterize sediments within OU1 (DOE 1991b). The three new stations established for site characterization during the Phase III RFI/RI have not been sampled to date; therefore, data are unavailable for evaluation and presentation. Attempts were made to sample stations SED037, SED038, and SED039 in December 1991 and February 1992, but sampling could not be completed because sediment was frozen. Stations SED037, SED038, and SED039 were sampled in November 1992. The remaining ten sampling stations lie downgradient from OU1 along the South Interceptor Ditch and Woman Creek. Seven locations are hydraulically downgradient of the 903 Pad area and, therefore, may be influenced by that IHSS and other parts of OU1. Three more distant stations lie upstream (up to 10,000 feet), and downstream (approximately 9,000 feet) of OU1 (DOE 1991b). Analytical results for sediments sampled at the locations listed in Table 4-22 are presented in Appendix C4.

Surface water is sampled monthly for chemical analysis at RFP under the routine monitoring program. Analyses required for the Phase III RFI/RI include VOCs, SVOCs, dissolved radionuclides, dissolved and total metals, and inorganic water quality parameters. For this report the analytical results for surface water are presented for fourth quarter 1991. Data presented consists of VOCs, SVOCs, radionuclides detected, and metals exceeding background.

Sediments are sampled quarterly at RFP as part of the routine monitoring program. Analyses required for sediment samples include VOCs, SVOCs, total radionuclides, total metals, and inorganic parameters. Analytical data are currently unavailable for OU1 stations SED037, SED038, and SED039, because they have not yet been sampled.

4.5.1 Surface Water Quality Prior to the Phase III Remedial Investigation

The South Interceptor Ditch surface water is sampled from stations SW045, SW046, and SW044, which are just south of Building 881. Station SW045 monitors the foundation drain discharge from Building 881. This water flows into a skimming pond. Station SW044 is the discharge from a pipe draining the skimming pond to the South Interceptor Ditch. The foundation drain is a vitrified clay pipe buried 14 to 20 feet deep along the western and southern sides of the 881 Building. The pipe drains water southward to a common pipe and then into the skimming pond. Station SW046 is located at a pond formed by ground water seepage from the 881 Hillside. Station SW046 is west of the skimming pond.

Surface water runoff from the 881 Hillside area flows into the South Interceptor Ditch and then into Pond C-2. Surface water in Woman Creek is routed around Pond C-2; however, water in Pond C-2 is discharged to Woman Creek in accordance with the plant National Pollutant Discharge Elimination System permit. Station SW031 monitors water quality in the South Interceptor Ditch just downstream of station SW044. Stations SW066, SW067, SW068, SW069, and SW070 monitor the South Interceptor Ditch surface water downgradient from the 881 Hillside.

VOCs have been detected in samples from station SW045 (Building 881 foundation drain discharge), and at lower concentrations in station SW046 (pond formed by ground water seepage at 881 Hillside) and station SW044 (discharge to the South Interceptor Ditch). Samples from station SW046 in May and June 1989 indicated that tetrachloroethene was present at estimated concentrations below detection limits. No other VOCs were detected in samples from station SW046. Station SW044 showed no detectable VOCs until fourth quarter 1989 and first quarter 1990. Methylene chloride and acetone concentrations were low enough to be considered inconclusive evidence of contamination at stations SW044, SW045, and SW046 (DOE 1991b).

Volatile organics do not appear to be present in the surface water at stations SW066, SW067, SW068, SW069, and SW070 (downgradient of the South Interceptor Ditch). Methylene chloride, acetone, and 2-butanone were present at all the stations; however, these compounds were also present in laboratory blanks. Toluene was present in a sample from station SW069 only in August 1989 (also present below detection limits). No other VOCs were detected in South Interceptor Ditch surface water stations downstream from the 881 Hillside area.

Results of inorganic analyses of surface water samples from these stations indicate that total dissolved solids, nitrate, and sulfate concentrations fluctuated above and below background. Maximum concentrations were generally within a factor of two above background; however, there was one anomalous nitrate result at station SW044 (DOE 1991b). Dissolved magnesium exceeded background by approximately a factor of two at all the stations, whereas dissolved calcium and potassium exceeded background by less than 5 mg/l at stations SW044, SW045, and SW046. Both calcium and magnesium consistently exceeded background when analyzed in unfiltered samples, but the margins above background varied. Total potassium exceeded background at most of the stations by less than a factor of two.

The following dissolved metals sporadically exceed background: aluminum, beryllium, cadmium, copper, mercury, lead, strontium, zinc, chromium, selenium, and vanadium. Total metals that exceeded background are the same as dissolved constituents, except that barium and nickel are

also included, and copper is excluded. Strontium and zinc were the only dissolved trace elements above background at nearly every station; however, total aluminum, barium, iron, strontium, and zinc exceeded the background for metals in suspension at most of the stations. Total aluminum tended to widely exceed background, reflecting the variable suspended clay content of surface water under different flow conditions. Most of the trace metals exceeded background by less than a factor of two.

Dissolved radionuclide results are only available for the South Interceptor Ditch stations for the spring 1989 sampling. Dissolved gross alpha, gross beta, uranium, and plutonium exceeded background at stations SW031, SW045, SW066, SW068, SW069, and SW070 during these sampling events. Surface water at SW046 and SW067 also exceeded background for these constituents except that gross beta was not elevated. Only gross alpha and uranium were elevated at station SW044. Gross beta and plutonium were elevated at stations SW033 and SW034, and only plutonium was elevated at station SW032.

Total radionuclide results exhibit the same constituents above background, as well as strontium-89,-90; americium-241; cesium-137; and tritium. Although the total radiochemistry results are typically higher than dissolved results, as expected, the maximum dissolved plutonium did exceed total plutonium at stations SW045, SW066, SW068, SW069, and SW070. Because samples for dissolved and total plutonium are separate grab samples, it is possible that the data reflect the variable colloidal content of different grab samples (DOE 1991b).

Woman Creek

Stations SW032, SW033, and SW034 monitor the surface water on Woman Creek and are located on the creek directly south of the 881 Hillside and South Interceptor Ditch and upstream from the 903 Pad Area. VOCs were not detected in Woman Creek surface water with the exception of presumed laboratory contaminants methylene chloride, acetone, and one instance of toluene at station SW032. Results of inorganics analyses from these surface water stations were all within tolerance interval values calculated from 1989 background surface water sampling results.

Of the dissolved metals, only zinc at stations SW032 to SW034, and strontium at station SW032 were elevated above background (DOE 1991b). Radiochemistry data for these stations are analogous to those from the South Interceptor Ditch, although total uranium values are typically lower in Woman Creek. Plutonium and americium were both just detectable at several of these stations. Radium-226 was not analyzed for the Woman Creek samples.

4.5.2 Surface Water Quality During Phase III

Organic Compounds

Surface water sampling locations SW30 and SW70 were the only locations with detections of organics during the fourth quarter of 1991 (Figure 4-88). Location SW030 had a single detection of beta-BHC at a concentration of 0.021J µg/l. Location SW070 had a single detection of 2-butanone at a concentration of 17 µg/l. There no detections in the first quarter of 1992.

Radionuclides

Radionuclides were detected at four sampling locations (stations SW030, SW032, SW035, and SW046) at OU1 during the fourth quarter of 1991 (Figure 4-89). Radionuclides detected include cesium-137; uranium-233,-234; uranium-235; and uranium-238. These radionuclides do not exceed background levels by more than an order of magnitude, and are not indicative of contamination in surface water.

Metals

Metals were detected above background levels at surface water sampling stations SW032, SW033, and SW034 along Woman Creek, stations SW030, SW068, SW069, and SW070 along the South Interceptor Ditch, and SW035 and SW046 south of Building 881 (Figure 4-90). Analytes detected include barium, lithium, and strontium. Lithium was detected at all sampling locations with the exception of SW030. Concentrations ranged from 0.0155 mg/l at SW046 to 0.0065 mg/l at SW033.

There was only one detection of metals in the first quarter of 1992. The analyte detected was dissolved magnesium at a concentration of 9.62 mg/l at station SW033.

Metals in surface water during Phase III sampling did not exceed background my more than a factor of ten and are not indicative of metal contamination in OU1.

Inorganics

Sulfate, nitrate and nitrite, phosphorous, chloride, oil and grease, and total dissolved solids were detected in concentrations above background levels in OU1 surface water during the fourth quarter of 1991 (Figure 4-91). Total dissolved solids were the most widespread, with detections occurring at four sampling stations (SW035, SW046, SW068, and SW069). Concentrations ranged from 316 mg/l at station SW069 to 490 mg/l at station SW046. Sulfate was detected at stations SW046, SW068, and SW069 at concentrations ranging from 35.2 mg/l at station SW069 to 42.1 mg/l at station SW046. Nitrites were found at sampling stations SW035, SW069, and SW070, with nitrate+nitrite occurring at station SW46. The concentrations ranged from 0.022 mg/l at station SW069 to 0.14 mg/l at station SW035. Station SW046 had the only detection of nitrate+nitrite at a concentration of 7.0 mg/l. Phosphorus was detected at stations SW035 and SW069 with concentrations of 0.90 mg/l and 0.28 mg/l, respectively. The only detection of chloride was at station SW046 at a concentration of 96.2 mg/l; station SW034 had a sole detection of oil and grease at 18.5 mg/l.

Tab;e 4-23 presents summaries of analytes detected in surface water during fourth quarter 1991 and first quarter 1992.

4.5.3 Sediment

Organic compounds found at SED037, SED038, and SED039 include acetone, AROCLOR-1254, bis(2-ethylhexyl phthalate), chrysene, di-n-butyl phthalate, di-n-octyl phthalate, fluoranthene, methylene chloride, pyrene, and 2-butanone (Figure 4-92). The majority of the detections

occurred at SED038, with SED039 having only detections of bis(2-ethylhexyl phthalate), chrysene, and fluoranthene.

Acetone was detected at SED037 and SED038 at concentrations of 54 and 71 µg/kg, respectively. AROCLOR-1254 was detected at SED037 and SED038 at concentrations of 86J µg/kg and 84J µg/kg. Bis(2-ethylhexyl)phthalate was detected at all three sediment locations with concentrations ranging from 280J µg/kg at SED039 to 1,400 µg/kg at SED038. Chrysene was detected only at SED039 at a concentration of 63J µg/kg. Di-n-butyl phthalate and octyl phthalate occurred only at SED038 at concentrations of 65J and 210J µg/kg, respectively. Fluoranthene was detected at SED038 (70J µg/kg) and SED039 (130J µg/kg). Methylene chloride was detected at both SED37 at 8 µg/kg and SED038 at 14 µg/kg. Pyrene was detected only at SED038 at a concentration of 87J µg/kg. SED037 and SED038 each had detections of 2-butanone at 14J and 19 µg/mg.

VOCs and SVOCs at low levels, including acetone, methylene chloride, 2-butanone, and phthalates are not indicative of sediment contamination at OU1. SVOCs detected in sediment including chrysene, pyrene, phenanthrene, and AROCLOR-1254 indicate sediment in the South Interceptor Ditch contains low-level contamination that may be attributed to surface runofffrom surface soils (see Section 4.8.2.2). A list of analytes detected in sediment in the fourth quarter of 1992 can be found in Table 4-24.

4.6 GROUND WATER

It is necessary to determine the nature and extent of contamination in ground water in order to comprehensively assess site conditions. Locations of ground water monitoring wells remain consistent with those locations presented in the work plan for the Phase III RFI/RI for OU1 (Figure 4-93). In addition, monitoring wells that were installed during Phase I and II supplement data from Phase III monitoring wells for use in characterizing site conditions. Analytical results presented on maps in the following discussions are confined to sampling that took place during

the time period of the Phase III RFI/RI field investigation. For this report, ground water contaminant distribution is presented for all of OU1, rather than by each IHSS.

The Phase III RFI/RI work plan for OU1 presents ground water sampling locations to be presented and evaluated in the RI (Table 4-25). For this report, ground water monitoring wells located outside of OU1 are not included on the contaminant distribution maps. Of those locations listed in the work plan, only three lie outside the OU1 boundary. Monitoring wells B301889, B304789, and B302089 are located south of OU1 and Woman Creek and are sampled as part of the RFP sitewide background geochemical characterization study. Analytical results for all ground water monitoring well locations listed in Table 4-25 are presented in Appendix C4.

Ground water is sampled quarterly for chemical analysis at RFP under the routine monitoring program. Analyses that are required for the Phase III RI include VOCs, SVOCs, dissolved radionuclides, dissolved and total metals, and inorganic water quality parameters. For this report the analytical results for ground water are presented for fourth quarter 1991 (Table 4-25) and first quarter 1992 (Table 4-26). These two are the only time periods for which data are available for monitoring wells installed as part of the Phase III RFI/RI field investigation. Data presented consists of all VOCs and SVOCs detected, and metals and inorganic parameters exceeding background.

4.6.1 OU1 Ground Water Quality Prior to the Phase III Remedial Investigation

Organic, and possibly major ion, trace metal and uranium contamination were detected in ground water within surficial materials and in some bedrock at the 881 Hillside area during the period from 1989 to 1991. VOCs exist in elevated concentrations in the eastern portion of OU1, and may be derived primarily from IHSS 119.1. The available data suggest that organic contamination is restricted to a small area around that apparent source. The ground water data for the western group of IHSS show frequent unsaturated conditions that may have inhibited contaminant migration. The presence of 1,1,1-trichloroethane at monitoring well 0187 may

indicate contamination from an upgradient source or from a sidegradient portion of the 881 Hillside area (IHSS 145).

Conclusions regarding inorganic contamination are limited by the preliminary nature of background data. The preceding sections listed all constituents above background as if each represents contamination. On the basis of background data, results from 1989 to 1991 indicate distinctly elevated major ions throughout most of the site, and potential contamination emanating from both the western and eastern portions of the 881 Hillside (DOE 1991b). The extent of such plumes of inorganics at the site has not been delineated by existing data. The metals data exceed background more erratically than do the major ions and offer more ambiguous evidence of contamination emanating from the IHSSs. The list of elevated constituents includes elements that could be attributed to natural sources in this sedimentary geologic environment (e.g., selenium, zinc, strontium) as well as elements that may suggest human influence (nickel, beryllium). Radionuclide data are similarly ambiguous. Results from ground water monitoring from 1989 to 1991 indicate that uranium isotopes occur more frequently above background than other radionuclides. Plutonium and americium exceed background in ground water at OU1 during 1989 through 1991 indicating potential contamination of these radionuclides exists.

4.6.2 Ground Water Quality During Fourth Quarter 1991

During fourth quarter 1991 monitoring wells installed as part of the Phase III field program were sampled for the first time. Analytical results for all monitoring wells listed in Table 4-26 are presented in Appendix C4. Table 4-26 summarizes the analytes detected in ground water as a result of ground water monitoring at OU1 during fourth quarter 1991.

Organic Compounds

Volatile organics were detected in eight alluvial wells and four bedrock well during the Phase III field sampling program (Figure 4-94). Analytes detected include toluene, methylene chloride, trichloroethene, tetrachloroethene, carbon tetrachloride, chloroform, 1,1,1-trichloroethane,

1,1-dichloroethene, 1,1-dichloroethane, 1,3-dimethylbenzene, 2-hydroxy-2-methyl-4-pentanone, cis-1,2-dichloroethene, dichlorofluoromethane, and p-cymene.

Alluvial well 5187, directly downgradient of Building 881, yielded only tetrachloroethene at a concentration of 10 µg/l. There were also detections of tetrachloroethene in alluvial wells 5187 at 10 µg/l, 0974 at 1,800 µg/l, and 4387 at 5,700E µg/l. There were also two detections of tetrachloroethene occurring in bedrock wells 6286 (0.20 µg/l) and 37991 (16 µg/l). Toluene occurred in three alluvial wells (wells 6886 and 4387) and two bedrock wells (wells 37991 and 6286) at concentrations ranging from 0.14 to 57J µg/l. Methylene chloride occurred only in well 4387 at a concentration of 37J µg/l.

Trichloroethene was detected in alluvial wells 1074, 0974, 4387, and 37791 and bedrock wells 37891 and 37991 with concentrations ranging from 1.3 µg/l in well 37891 to 11,000E µg/l in well 4387. Carbon tetrachloride was detected in two wells: well 6286 (5.02 µg/l) and well 1074 (2500D). Chloroform was detected in bedrock wells 6286, 37891, and 37991 and alluvial well 1074 at concentrations of 0.43, 6.8, 9.3, and 78 µg/l, respectively. Alluvial wells 37491 and 37791 and bedrock well 39191 had detections of 2-hydroxy-2-methyl-4-pentanone at concentrations of 9.6J, 10J, and 8.9, respectively. Of the remaining analytes, 1,1,1-trichloroethane, 1,1-dichloroethene, and 1,1,-dichloroethane were detected in wells 4387 and 0974. Concentrations of 1,1,1-trichloroethane ranged from 7,600 µg/l in well 0974 to 20,000E µg/l in well 4387; 1,1-dichloroethene concentrations were 7,900E in well 4387, 7,900 µg/l in well 0974; and 1,1-dichloroethane at 23J µg/l in well 4387.

Semivolatile Organic Compounds

Semivolatile organics were not detected as frequently as VOCs with detections of 2,6-dinitrotoluene, di-n-butyl phthalate, bis(2-ethylhexyl)phthalate, diethyl phthalate, and alpha-benzene hexachloride occurring in wells 31891, 35691, 36191, 37191, and 1074 (Figure 4-94). Alluvial well 36191 yielded the only detection of 2,6-dinitrotoluene found at a concentration of 2J µg/l. Detections of diethyl phthalate occurred at concentrations of 2 µg/l in

well 31891 and 6 µg/l in well 1074. Di-n-butyl phthalate was detected in wells 31891 and 35691 at 2 µg/l. Bis(2-ethylhexyl)phthalate was detected in alluvial wells 36191 and 37191 at concentrations of 8J and 2J µg/l. Alpha-benzene hexachloride was detected only in wells 35691 and 36191 at 0.12 µg/l and 0.082 µg/l, respectively.

Radionuclides

Radionuclides were detected at levels exceeding background in ground water within OU1 during the fourth quarter of 1991 and include americium-241, cesium-137, plutonium-239,-240, strontium-89,-90, tritium, and uranium-233,-235,-235, and -238. Concentrations of radionuclides in ground water do not exceed background levels by more than an order of magnitude, and, therefore, are not indicative of ground water contamination at OU1.

Metals

Metals were detected above background levels in five alluvial wells. Analytes exceeding background include antimony, barium, chromium, copper, lead, nickel, selenium, strontium, and zinc (Figure 4-95). Antimony was detected in wells 35691 and 5487 at levels of 0.0664 and 0.076.1 mg/l, respectively. Barium was detected in well 35691 at a level of 0.245 mg/l. Chromium was detected in one well at a concentration of 0.0198 mg/l in well 35691. Copper was detected in wells 0187 and 5487 at concentrations of 0.0371 and 0.0585 in well 0187 and 1.210 mg/l, in well 5487. Lead was detected in wells 5187 and 35691 at dissolved concentrations of 0.062 and 0.0118 mg/l, respectively. Total strontium was also detected in well 35691 at a concentration of 1.330 mg/l. Selenium was only detected in well 5187 at a dissolved concentration of 0.017 mg/l and total concentration of 0.015 µg/l. Metal concentrations during fourth quarter 1991 are slightly elevated compared to current background levels. These elevated concentrations may be indicative of aquifer trauma due to the installation of monitoring wells during fourth quarter 1991.

4.6.3 Ground Water Quality During First Quarter 1992

Volatile Organic Compounds

Volatile organics were detected in 14 alluvial wells and four bedrock wells during the Phase III field sampling program in 1992 (Figure 4-96). Analytes detected include 1,1,1-trichloroethane, 1,1,2-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene, 1,2,3-trichlorobenzene, 1,2,4-trimethylbenzene, 1,2-dichloroethane, 1,2-dichloroethene, benzene, carbon tetrachloride, chloroform, cis-1,2-dichloroethene, methylene chloride, p-Chlorotoluene, styrene, tert-butyl benzene, tetrachloroethene, toluene, total xylenes, trichloroethene, and trichlorofluoromethane (Table 4-27).

Carbon tetrachloride was detected in three bedrock wells (37991, 39191, and 6286) and four alluvial wells (6886, 1074, 0487, and 6486) at concentrations ranging from 0.1J µg/l in well 6886 to 3400 µg/l in well 1074. Chloroform was detected in three bedrock wells and five alluvial wells at concentrations ranging from 0.11 µg/l in alluvial well 6486 to 92J µg/l in alluvial well 1074.

Tetrachloroethene and trichloroethene were also fairly widespread with tetrachloroethene detections occurring in nine alluvial wells and three bedrock wells at concentrations ranging from 0.1 µg/l in alluvial well 37791 to 4200E µg/l in alluvial well 4387. Trichloroethene detections also occurred in nine alluvial wells and four bedrock wells at concentrations ranging from 0.15 µg/l in well 0187 to 4,700E µg/l in well 4387.

Semivolatile Organic Compounds

Semivolatile organics were detected in three alluvial wells and one bedrock well during the first quarter of 1992. Analytes detected include 1,2,4-trichlorobenzene, bis(2-ethylhexyl) phthalate, diethyl phthalate, di-n-butyl phthalate, and hexachlorobutadiene. The analytes 1,2,4-trichlorobenzene and hexachlorobutadiene each occurred in alluvial well 6886. The remaining analytes each occurred only once in the remaining wells; alluvial wells 31791, 0974, and bedrock well 37891.

Radionuclides

Radionuclides were available for ground water sampled within OU1 during the first quarter of 1992.

Metals

Metals were detected at levels exceeding background in ground water within OU1 during the first quarter of 1992 (Figure 4-97). Metals detected at alluvial wells 35691, 36191, and 5287 include chromium, copper, lead, strontium, and zinc. Strontium was detected at all well locations with concentrations ranging from 0.487 mg/l (dissolved) at well 36191 to 1.220 mg/l (total) at well 35691. Strontium was also the only metal detected at well 35691. Lead and zinc each occurred in wells 5287 and 36191 at concentrations of 0.095 and 0.0042 mg/l for lead and 0.0989 and 0.0283 mg/l for zinc. Chromium and copper were detected only in alluvial well 5287 at concentrations of 0.0143 and 0.0419 mg/l, respectively.

Orthophosphate and total dissolved solids were the only water quality parameters exceeding background in ground water during the fourth quarter of 1992. Alluvial well 5287 had one detection of orthophosphate at a concentration of 0.08 mg/l and alluvial well 35691 had a detection of total dissolved solids at a concentration of 1,200 mg/l.

Metal concetrations decreased from fourth quarter 1991 to first quarter 1992. Fewer metal concentrations exceed background levels. Typically, background exceedances are a factor of two, and are not indicative of ground water metal contamination in OU1.

4.7 BIOTA

The initial list of contaminants of concern for the OU1 Environmental Evaluation included heavy metals, cyanide, and radionuclides that were detected at concentrations above background levels in OU1 study area soils, surface water, or sediments. Several chemicals were selected from this list for evaluation of potential impact on ecological species of concern. The final list of contaminants of concern for use in tissue sample analyses was developed in accordance with the

guidance of the Interagency Agreement (IAG 1991). Specifically, this list includes eight heavy metals and four radionuclides. The heavy metals are cadmium, chromium, copper, lead, mercury, selenium, silver, and zinc. The radionuclides are americium-241, plutonium-239,-240, radium-226, and total uranium.

A reference area located upwind and upgradient of the industrial area in the Rock Creek watershed was used for collection of control samples with which to compare tissue samples from the OU1 study area. There were 19 terrestrial tissue sampling sites in the OU1 study area (Figure 4-98) and 14 corresponding sites in the Rock Creek reference area (Figure 4-99). The difference in number of sites between areas was due to the fact that several habitat types (e.g., reclaimed grasslands and disturbed areas) were not present in the Rock Creek watershed. Aquatic samples were collected from five tissue sampling sites in the OU1 study area and from two sites in the reference area (Figure 4-100). The difference in numbers of aquatic sample sites is due to the intermittent flow of Rock Creek.

The species selected for tissue samples (Table 4-28) fall into four taxonomic groups: vegetation, insects, small mammals, and fish. These groups were selected because they live in direct contact with potentially contaminated media, have a small home range (i.e., individuals are expected to spend their lives within the OU1 study area), and provide a food base for other animals and so could serve as vectors for biomagnification. Individuals from each of these groups were analyzed for whole body burdens of the selected contaminants of concern. The purpose of this analysis was to identify increased uptake of contaminants due to elevated levels in environmental media at OU1.

Samples collected from reference areas in the Rock Creek watershed were used to characterize background concentrations in biological tissues. Tables 4-29 through 4-32 present samples from the OU1 study area that exceeded the background concentration for a given metal. Forty-two vegetation samples were collected, 34 from the OU1 study area and 8 from the reference area. Eight samples of insects (grasshoppers), including five from OU1 and three from the reference

area were used for tissue analysis. Thirty small mammal samples were collected, 16 from the OU1 study area and 14 from the reference area. Forty-four fish samples, including 38 from OU1 and six from the reference area were analyzed. The plant and animal tissues analyzed from the above samples may have included significant quantities of soil and sediment from exterior surfaces of samples and/or animal intestinal residues. In other words, dust and grit contributed to the contaminant concentrations in the tissue samples. The issue now becomes a question of bioavailability. Research studies on bioavailibility of metals using labeled radionuclides have shown that as little as 0.01 percent of the total amount of certain metals are bioavailable once inside the body (ICRP 1960).

Vegetation

Five heavy metals detected in vegetation tissue samples from OU1 were above background concentrations. The metals are cadmium, chromium, copper, lead, and zinc. Cadmium ranged from 0.02 to 1.73 times the background level. Chromium levels ranged from 1.08 to 63.0 times the background tissue levels. Copper tissue levels ranged from 1.02 to 2.98 times the background levels. Tissue levels of lead were 1.17 to 2.0 times the background levels. Levels of zinc in vegetation tissue were 1.03 to 1.33 above background. Two radionuclides were also detected in vegetation tissue samples at OU1. There were two detections of radium-226, both of 11.0 pCi/g. The single detection of total uranium was 1.3 pCi/g. No radionuclides were detected in reference area tissue samples.

Insects

Tissue samples from grasshoppers sampled in OU1 and the reference area indicated the uptake of four heavy metals and two radionuclides. The heavy metals were cadmium, chromium, lead, and zinc; the radionuclides were americium-241 and plutonium-239,-240. Cadmium was detected at levels 1.06 to 1.78 times the background tissue levels. OU1 grasshopper tissue samples for copper were 1.21 to 3.08 times the background levels. Lead was detected in tissues at levels 1.9 to 3.5 times the background levels, but only two samples indicated lead presence. Zinc tissue levels from OU1 were 1.04 to 1.75 greater than background levels in grasshoppers. Americium-

241 was detected in only one sample, at a concentration of 0.021 pCi/g. There were two detections of plutonium-239,-240, at concentrations of 0.027 and 0.033 pCi/g.

Small Mammals

Small mammal tissue samples indicated the presence of five heavy metals and three radionuclides in OU1. The heavy metals in OU1 small mammal tissues were cadmium, chromium, copper, lead, and zinc; the radionuclides were americium-241, plutonium-239,-240, and total uranium. Cadmium was found to exceed background levels by 1.19 to 2.72 times. There was no chromium in the tissue samples from the reference area; the OU1 study area revealed one hit of 3.4 mg/kg. Copper was found in OU1 tissue samples at levels 1.01 to 3.69 times the background levels. Lead tissue levels exceeded background by 1.06 to 3.15 times. Tissue levels of zinc were 1.03 to 1.98 times the background values. No radionuclides were detected in small mammal tissue from the reference area. Americium-241 was detected in only one OU1 tissue sample at 0.086 pCi/g. There were only two plutonium-239/240 hits, at concentrations of 0.026 and 0.47 pCi/g. Total uranium was found in only one OU1 tissue sample, at a concentration of 0.26 pCi/g.

Fish

Fish tissue samples from OU1 indicated the potential uptake of four heavy metals and three radionuclides. Metals included cadmium, chromium, copper, and lead; the radionuclides were plutonium-239,-240, radium-226, and total uranium. No cadmium was detected in reference area tissue samples, and there were only two hits, of 3.3 and 3.9 mg/kg, in the OU1 tissue samples. Chromium was detected in OU1 tissue samples at levels 1.18 to 1.41 times background. Copper tissue levels exceeded background 1.43 to 16.06 times. Lead concentrations in fish were 1.02 to 1.49 times greater than in reference area samples. There was only one hit each of plutonium-239,-240 and radium-226 in OU1 fish tissue samples; the concentrations were 0.034 and 24.0 pCi/g, respectively. Total uranium was detected in seven OU1 samples, but the highest concentration was only 0.31 pCi/g.

Tissue samples from the four taxonomic groups analyzed for contaminants indicated the presence of five heavy metals and four radionuclides potentially from OU1 sources. Of 139 tissue samples, only 17 had heavy metal levels greater than twofold above background, and only four of those samples were fivefold greater than background. Only chromium levels in vegetation samples and copper concentrations from fish samples indicated potential concern. The higher tissue concentrations were few enough to suggest that only a few isolated areas of elevated concentration are of potential concern. As chromium readings were total rather than only hexavalent chromium, and only the latter is toxic to plants and animals, the high concentrations found in the two tissue samples are probably an overestimate of risk to ecological receptors. The uncertainty associated with whole body burden sampling methods (see Appendix E, Section E3.3.4, Uncertainty Analyses for Data Collections) may account for the few high tissue burdens.

There were a total of 19 radionuclide detections in tissue samples from OU1, but only three of those were greater than 1.5 pCi/g. All of those were radium-226, two in vegetation tissue samples and one in fish tissue. Because total body burden samples include nonbioavailable elements, high tissue concentrations are likely to overestimate risk to ecological receptors. The three high radium concentrations indicate elevated concentrations of potential concern. The sample site from which the fish tissue sample with elevated radium-226 was taken lies in OU2 rather than OU1; it is recommended that tissue samples from the OU2 area be taken to ascertain whether this single high reading was valid. The two hits of elevated tissue levels of radium-226 in vegetation were collected just south of the 903 Pad, but the nearest soil samples showed no radium-226 above background.

Results from the field tissue data comparisons were linked to abiotic data in the OU1 study area through the ecological risk assessment (see Appendix E). This risk assessment compiles information on toxicity and exposure for each contaminant and characterizes a risk associated with the combined exposure to all contaminants of concer. The risk assessment suggests low risk

for all terrestrial and aquatic taxonomic groups except terrestrial vegetation located in IHSS areas, for which the risk was rated moderate.

4.8 CONTAMINATION ASSESSMENT

The Phase III RFI/RI and previous investigations of the 881 Hillside area have provided historical, physical, and chemical data necessary to characterize potential contamination at OU1. Section 4.8 integrates these data to characterize potential contaminant sources. Sections 4.2 through 4.7 previously discussed in detail the contamination detected in the various sampled media at OU1.

Section 4.8.1 summarizes contamination for the three primary media most capable of acting as sources of contamination and most likely to be the focus of remediation feasibility or corrective measures studies. Section 4.8.2 summarizes contamination in terms of the four main contaminant groups analyzed for at OU1. Individual contaminants within these four groups typically have somewhat similar behavior characteristics. This section summarizes the occurrence of contaminants in one or more media for locations at OU1. Showing a linkage between contaminants in more than one medium is the first step in assessing site-specific fate and transport circumstances and is a preparatory step in performing a baseline risk assessment. Using the relationships summarized in Section 4.8, the fate and transport assessment presented in Section 5.0 interprets the viability of migration pathways and quantifies contaminant behavior from source discharges into soils, air, ground water, surface water, sediments, and biota.

4.8.1 Assessment by Media

Based on the nature and extent of organic compounds, radionuclides, and metals detected in each medium and the relationship between those media, three primary media of concern exist at OU1: surface soils, subsurface soils, and ground water. Surface water, sediment, air, and biota have shown only sporadic detections of contaminants, and are considered secondary media at OU1. Sporadic occurrences of organics and elevated radionuclides and metals in secondary media were found during Phase III sampling, but the sources for those analytes may occur outside OU1. Due

to transport mechanisms associated with secondary media, it is possible that the sources for any potential contamination exist upgradient or downgradient of OU1 in areas associated with OU2 and OU5. An assessment of each primary medium is presented below.

4.8.1.1 Surface Soils Summary

Two groups of analytes exist as contaminants in OU1 surface soils: SVOCs and radionuclides. Each group is assessed for surface soils below.

SVOCs

SVOCs occur in 24 of 28 sample locations at OU1, with total concentrations ranging from approximately 600 µg/kg to greater than 10,000 µg/kg. SVOCs are a product of incomplete combustion of hydrocarbons. Vehicular operation produces emissions of exhaust particles containing adsorbed SVOCs. The occurrence of SVOCs in OU1 surface soils is most likely attributed to cumulative deposition on surface soils of hydrocarbon combustion byproducts from multiple sources. There was heavy vehicular traffic in the area during the Phase III RFI/RI. During the time of surface soil sampling (February through March 1992) vehicular and heavy equipment traffic was unusually heavy at OU1 due to the ongoing construction of the french drain. Routine vehicular traffic at OU1 is comprised of security patrols and vehicles used for monitoring surface water, sediment, and ground water locations in OU1. Additionally, OU1 is downwind of RFP asphalt parking lots and the decontamination pad in the contractors' yard, and SVOCs may also be attributed to the eolian transport of SVOC-containing dust from these asphalt-paved areas.

Radionuclides

Historical releases of plutonium to the environment from RFP have contaminated surface and subsurface soils at OU1 at levels above those attributed to atmospheric fallout. Releases occurred from two major fires (1957 and 1969), from leaking drums containing plutonium contaminated waste oils stored at the 903 Pad, and from atmospheric emissions in 1974 (Johnson et al. 1976).

Releases from the 903 Pad are thought to be the primary contributor of plutonium and americium in surface soils at OU1 (Krey and Hardy 1970; Seed et al. 1971).

Atmospheric nuclear tests have injected plutonium isotopes into the stratosphere that have subsequently reached the ground as particulate fallout and in rainwater. Total rainout/fallout of plutonium-239,-240 is estimated at 8 pCi/m^2/year (Thein et al. 1980). Lesser concentrations of plutonium-238 and americium-241 are also present in fallout matter. Background concentrations in soil as a result of atmospheric fallout in Colorado range from 0.012 to 0.06 pCi/cm^2, and average 0.04 pCi/cm^2 (Poet and Martell 1972; Johnson et al. 1976). Background plutonium concentrations in Rock Creek surface soil samples range from 0.0245 to 0.0609 pCi/g, with a mean of 0.0428 pCi/g (the calculated 95 percent upper tolerance interval is 0.0481 pCi/g). Comparison of these values suggests that Rock Creek surface soils are in agreement with values derived by Poet and Martell (1972) and Johnson et al. (1976) for background plutonium values.

The distribution pattern of plutonium-239,-240 and americium-241 concentrations in surface soils at OU1 indicates a source for these radionuclides to the northeast of OU1 and that dispersion in a southwesterly direction has occurred (Figures 4-85 and 4-86). This pattern is more readily attributed to primary dispersion into OU1 from an external source rather than being caused directly by activities within OU1. The concentration isopleths for both radionuclides exhibit an elongate east-northeast orientation that appears to straddle the OU1 perimeter road and southern boundary fence. Dispersion of plutonium-239,-240 and americium-241 contaminated particles may have been caused by wind blown dust from 903 Pad, overland flow or ditch flow of eroded soil in storm runoff from the same area, or anthropogenically induced dispersion from vehicular traffic along OU1 roads. This concentration gradient pattern may be reflective of one or more of these multiple transport processes. Secondary distribution of radionuclides in surface soils at OU1 includes anthropogenic processes such as vehicular traffic, which generates and redeposits dust, and removal and placement of soil due to construction and road grading. Transport of radionuclides in surface soil at OU1 will be discussed more in Section 5.

Other radionuclides do not show coherent dispersion patterns like plutonium-239,-240 and americium-241 nor do they exhibit patterns readily attributable to waste disposal activities (Table 4-83). At OU1, the other radionuclides while elevated locally above background do not indicate substantial surface soil contamination trends.

4.8.1.2 Subsurface Soils Summary

Four analytical groups are considered contaminants in subsurface or vadose zone soils at OU1. VOCs, SVOCs, radionuclides, and metals are discussed separately below.

VOCs

VOCs were detected across OU1 at all depth intervals down to the greater than 18-foot depth interval. Of the VOCs detected, toluene had the highest frequency of detections and was detected in samples collected from 95 of 99 borehole locations including pilot hole 39091 east of OU1 along Woman Creek (Figure 4-101). In addition to soil samples, toluene was detected at low concentrations in trip blanks which are field QA/QC samples collected during the Phase III soil sampling program.

Toluene is recognized as a common laboratory contaminant by EPA (EPA 1990a), and at OU1. By screening for toluene detections less than ten times the analytical detection limit, or certified reporting limit, 143 of 249 toluene detections can be excluded from consideration as potential contamination (EPA 1989, 1990). The remaining 106 toluene detections occur in OU1 soils where the widespread use and disposal of toluene cannot be substantiated (CDH 1991, 1992; DOE 1992d). Of particular note is the solitary nature of the toluene detections; there were no companion contaminants reported for these many widespread detections. Typically, toluene would be expected to be associated with one or more similar VOCs.

Concentrations for the metals copper and beryllium are elevated in OU1 surface soils. Copper occurrences cannot be attributed to RFP plant processed and occur sporadically in exceedance of background. Beryllium occurs in a localized area exceeding background by a factor of six,

but shows no apparent trends for contaminant dispersion. Metals detected in surface soils are not indicative of contamination at OU1.

Based on the french drain geotechnical investigation (EG&G 1990e), toluene detected in soil samples during 1990 was attributed to the dispersion of the dust suppressant Coherex used at RFP during 1986 and 1987. The Phase III RFI/RI field investigation at OU1 required that samples be obtained from a drum of Coherex to determine the potential for toluene contamination from the dispersion of this chemical product. Samples were collected and analyzed for VOCs and SVOCs. Toluene was not detected in the two Coherex samples (Appendix C7). Based on these data, toluene cannot be attributed to previous applications of Coherex to OU1 soils.

Another noteworthy aspect of toluene in subsurface soils at RFP is a similar frequency of detection in the sitewide Phase II Geologic Characterization drilling in buffer zone areas, particularly Rock Creek, a recognized background area. This observation was based on a preliminary review of analytical data from that 1991/1992 drilling program.

Therefore, given the large weight of evidence, toluene is not considered to represent substantial contamination at OU1. However, so as not to risk dismissing a potential contaminant too readily, the following conservative screening approach is followed. Figure 4-101 presents the occurrence of toluene by location compared to the certified reporting limit. Those locations where at least one detection of toluene exceeds the certified reporting limit by a factor of ten, or more, are indicated. Toluene can only be considered a potential contaminant at OU1 only for those concentrations exceeding the certified reporting limit by an order of magnitude.

In addition to toluene, three other VOCs were detected across OU1 in soil samples at low levels indicating the possibility of laboratory contamination by these analytes. The three VOCs include methylene chloride, acetone, and 2-butanone. These three compounds aare also recognized by EPA as common laboratory contaminants (EPA 1990). By screening for detections of these common laboratory contaminants at levels greater than ten times their appropriate certified

reporting limits, all detections for acetone and 2-butanone fall into the laboratory artifact category. Figure 4-102 presents the distribution of common laboratory contaminants at levels less than ten times the analyte-specific certified reporting limit. Subsurface soil samples from IHSS 119.1 contained VOCs, other than suspected laboratory contaminants, and are associated with similar ground water contamination.

VOCs not related to laboratory contamination were detected in OU1 subsurface soils, and are attributable to waste disposal in the area of Building 881 and IHSS 119.1. The occurrence of 4-methyl-2-pentanone (methyl isobutyl ketone), a common laboratory solvent used in the preparation of samples analyzed for metals, frequently is attributed to laboratory contamination (EPA 1990), but at this time is considered a potential contaminant in OU1 subsurface soils samples. Isolated detections of trichloroethene and tetrachloroethene occurred in adjacent boreholes within two separate IHSSs. These VOCs are considered contaminants in subsurface soils based on their occurrence in subsurface soils and related waste disposal areas.

- Trichloroethene
- Tetrachloroethene
- Methylene chloride (borehole 37891 in IHSS 119.1 only)
- 4-methyl 1-2-pentanone

Figure 4-103 depicts the distribution of VOC contamination of subsurface soils.

SVOCs

SVOCs were detected in near-surface soils and to depths greater than 18 feet within OU1 subsurface soils (Figure 4-104). SVOCs occur less frequently than VOCs, but concentrations of SVOCs often exceeded 1,000 µg/kg when detected. SVOCs occur less frequently in areas where they are detected in near-surface soils. The most commonly detected SVOCs in subsurface soils were fluoranthene, phenanthrene, and pyrene. At locations where these three analytes are detected, they usually occur together and at higher concentrations than other detected SVOCs. PCB compounds were detected in IHSS 119.2 and 103 (AROCLOR-1248 and AROCLOR-1254).

Di-n-butyl phthalate and bis-2(ethylhexyl)phthalate also occurred at frequent low levels in soils at OU1. Elevated detections of SVOCs within IHSS 130 and 104 are typical of the waste disposal histories associated with each IHSS. Asphalt from Central Avenue was disposed in IHSS 130, in close proximity to IHSS 104. Asphalt is visible at the ground surface in IHSS 130. Also, geologic core descriptions indicate that asphalt material was present in surface and near-surface soil samples encountered during the Phase III RFI/RI field sampling program.

Phthalates were also detected in subsurface soils previously during the Phase II RI field investigation. In order to further evaluate the presence of phthalates in subsurface soils during the Phase III field investigation, samples were analyzed for SVOCs, and equipment rinse blanks were taken to check for field cross-contamination. Bis(2-ethylhexyl)phthalate, diethyl phthalate, and di-n-butyl phthalate were detected in subsurface soils. Phthalates were detected in surface and subsurface soils at maximum concentrations below the certified reporting limit ("J" qualified). Analytes detected in rinse blanks included bis(2-ethylhexyl)phthalate and diethyl phthalate and were "J" qualified concentrations. Phthalates have been established to be common laboratory contaminants at low concentrations (EPA 1990). Phthalates are associated with the production of plastics which are a common laboratory equipment material. Current data suggests that phthalates detected in subsurface soils are not related to waste disposal at OU1, but are due to field sampling and laboratory cross-contamination. One mode by which cross-contamination is likely to have occurred was due to the use of de-ionized water containerized in plastic carboys for field rinse blanks and equipment washes.

Radionuclides

Radionuclides exceed background in soils locally to depths greater than 18 feet across OU1. Uranium isotopes and radium-226 exceed background more frequently than other radionuclides. Activities of these radionuclides decrease with depth, which indicates a near-surface source. Plutonium, americium, cesium, and strontium isotopes occur predominantly in the 0- to 6-foot depth interval. Below 6 feet these radionuclides only occur sporadically in IHSS 102, 145, and in the area of the former retention pond. Wind dispersion of radionuclides from a source area

to the north and east of OU1 such as 903 Pad may account for elevated occurrences of plutonium and americium in IHSS 119.2.

Plutonium distribution in subsurface soils at OU1 occurs primarily in the 0- to 6-foot depth interval. Figures 4-105 and 4-106 depict depth profiles for plutonium and americium activities for locations where surface soil sampling locations were in close proximity to borehole locations for which radionuclide data were available. It is apparent from these profiles that plutonium and americium activities approach RFP background rapidly with depth, usually within the upper 6 feet of the surface. The only exception is in borehole 34891 where americium activity increases with depth between 12 and 18 feet below ground surface, but decreases rapidly to background levels below 18 feet. This borehole sampled materials in IHSS 130 where radionuclide-contaminated asphalt materials were buried. There is no corresponding activity of americium above background in ground water at this location.

Metals

Metals exceed background in subsurface soils at OU1 locally at all depths intervals; however, metal concentrations exceed background by more than an order of magnitude in samples from location 32491. Selenium in detected the 0- to 6-foot and 6- to 12-foot intervals at a maximum concentration of 619 mg/kg. Since selenium does not occur at similar levels elsewhere at OU1, and concentration increases with depth, it is assumed to be a naturally occuring constituent in bedrock fill material around Building 881. Selenium is not detected in ground water, thus its presence is not indicative of contamination in OU1 soils. The levels at which metals are detected with respect to background are not indicative of metals contamination in OU1 soils, and are not directly attributable to any known plant processes or waste disposal history.

4.8.1.3 Ground Water Summary

Ground water results presented in this report are data from fourth quarter 1991 and first quarter 1992 sampling events. VOCs and SVOCs were detected in alluvial and bedrock ground water during both quarters, primarily in the area associated with IHSS 119.1 Trace amounts of

radionuclides were detected in exceedance of background during fourth quarter 1991 only. Total and dissolved metals were detected in exceedance of background during fourth quarter 1991, but dissipated during first quarter 1992.

VOCs and SVOCs

Ground water monitoring wells were sampled for VOCs and SVOCs during Phase III. VOCs were analyzed by two different methods as described in Technical Memorandum 1, Chemical Analysis Plan, an addendum to the Phase III work plan. Wells in known areas of ground water contamination were analyzed using the EPA Contract Laboratory Program method for target compound list VOCs. This method uses a gas chromatography-mass spectrometry to identify and measure the amounts of volatile organics in a water sample. The second method of analysis, used on samples from wells in downgradient wells, or wells completed in bedrock, was EPA method 502.2 for selected VOCs. Method 502.2 employs the use of a gas chromatograph, and can achieve detection limits as low as 0.01 µg/l compared to 10 µg/l using the standard VOACLP method. This method is preferable for samples taken from ground water in areas where historically VOCs have not been detected using the standard VOACLP method. Target compound list SVOCs were analyzed using the standard EPA SVOC method. Detection limits for the SVOC method in ground water were typically 5 or 10 µg/l. Target compound list pesticides were analyzed for in groundwater samples using the standard EPA pesticide method with detection limits ranging from 0.05 to 1 µg/l.

Organic compounds, VOCs, and SVOCs (including pesticides) were detected in upper HSU ground water during Phase III sampling (October 1991 through March 1992). The highest detections of VOCs occurred in monitoring wells in the area of IHSS 119.1. Samples from alluvial monitoring wells 0974, 1074, and 4387 contained multiple VOCs including trichloroethene, tetrachloroethene, dichloroethanes, and trichloroethanes at concentrations often exceeding 1,000 µg/kg.

Upper HSU ground water in the area of IHSS 119.1 is contaminated by chlorinated VOCs associated with waste disposal at this IHSS. Subsurface soil samples from IHSS 119.1 which contained trichloroethene and tetrachloroethene, confirm VOCs detected in ground water.

Bedrock or lower HSU monitoring wells in IHSS 119.1 (including 37891, 37991, and 39191) were sampled and analyzed using the 502.2 method for VOCs. Organic compounds detected in lower HSU ground water associated with IHSS 119.1 included carbon tetrachloride, chloroform, trichloroethene, and tetrachloroethene.

Organic compounds were detected sporadically, and at trace levels, in upper HSU monitoring wells in the vicinity of Building 881. Trichloroethene and tetrachloroethene occur most often and are attributed to waste disposal associated with IHSSs in the vicinity. Subsurface soil sampling confirms the presence of low-level VOCs in the Building 881 area, and correlates to the low levels of organics detected in ground water.

Detections of methylene chloride, toluene, bis(2-ethylhexyl)phthalate, diethyl phthalate, and di-n-butyl phthalate may be due to potential laboratory artifacts and field sampling cross-contamination. These analytes typically occur at levels less than ten times the analyte-specific certified reporting limit, and thus are not considered indicative of ground water contamination.

Radionuclides

Based on the revised RFP background concentrations, only one radionuclide was in exceedance in ground water during Phase III sampling. Radium-226, a naturally occurring radionuclide, exceeded background by a factor of two in one well during fourth quarter 1991. Other radionuclides do not exceed site background in ground water during first quarter 1992. Based on current data, radionuclides are not considered contaminants in ground water at OU1.

Metals

Total and dissolved metals exceed background in ground water at OU1. Results of fourth quarter sampling indicate that six dissolved metals exceed background by factors up to greater than ten, and include antimony, chromium, copper, nickel, and selenium, and zinc. Dissolved nickel and zinc concentrations exceed background by factors greater than twenty. Total metals exceeding background during fourth quarter include antimony, copper, lead, nickel, and strontium. These wells are screened in artificial fill in the vicinity of Building 881, and are probably due to the release of naturally occurring metals in the disturbed materials.

During the first quarter of 1992, fewer metals exceed background in ground water. Dissolved metals detected in ground water do not exceed background during first quarter 1992. Total metals which consistently exceed background during Phase III include copper and strontium; and these metals only exceed background by a factor of less than two.

The number of total metal and dissolved concentrations exceeding background decreased from fourth quarter 1991 to first quarter 1992. Aquifer trauma due to monitoring well installations may account for the elevated metals concentrations during the initial sampling period. The observed decrease in metal concentrations may be due to the re-establishment of natural conditions. Further monitoring should continue to confirm or refute this trend. Based on current RFP background and data from Phase III sampling, metals have been excluded from consideration as contaminants in OU1 ground water.

4.8.2 Contaminant Source Characterization

Contaminant sources at OU1 resulted from waste disposal activities associated with IHSSs, and subsequent migration of contaminants from sources to surface and vadose zone soils and ground water. OU1 sources were previously investigated during the Phase I and Phase II remedial investigation reports, and are currently assessed below based on Phase III data.

The nature and extent of contamination in surface and subsurface soils and ground water were determined for the OU1 media considering all VOCs and SVOCs detections and only radionuclide and metal detections exceeding background concentrations. As a preliminary step in assessing contaminant sources, the occurrence of contaminant groups in one or more media at a location is assessed. This sets the stage for evaluating fate and transport of individual contaminants in Section 5 and evaluating potential exposure to human and ecological receptors in Section 6 (and Appendices E and F). Locations considered below include IHSSs where contaminants were detected in vadose zone soils, ground water below and downgradient of IHSSs, and locations at and between IHSSs where dispersion from non-OU1 sources has contributed contaminants to surface soils.

4.8.2.1 Volatile Organic Compounds

VOCs were detected in subsurface soils and ground water during Phase III sampling. Surface soils were not sampled for VOCs due to the volatility of these organics under surface conditions. VOCs detected in media at OU1 were classified into two distinct groups—laboratory contaminants and actual contaminants.

Laboratory contaminants detected in subsurface soils and ground water include methylene chloride, acetone, 2-butanone, and toluene. All acetone, 2-butanone, and methylene chloride detections in subsurface soils and ground water are excluded as contaminants due to their low concentrations. Methylene chloride, is also excluded as a contaminant with the exception of IHSS 119.1 where one occurrence in subsurface soils and several occurrences in ground water suggest contamination. Elsewhere due to its relatively low concentrations in subsurface soils and sporadic occurrence in ground water, it is excluded.

Toluene was detected in subsurface soil samples ranging from 1 to 1,200 µg/kg. By screening out those detections less than ten times the toluene certified reporting limit, 106 detections of toluene remain. Toluene detected in subsurface soils cannot be attributed to plant processes and waste disposal at RFP. Additionally, toluene cannot be attributed to dust suppressant used at OU1

during 1986 and 1987 based on analytical data for the Coherex samples taken during the Phase III field investigation. Based on a preliminary review of analytical data from samples taken in subsurface soils during Phase II sitewide geological characterization drilling valid at Rock Creek, a background site for Phase III surface soils, toluene was detected at depths of 80 feet at concentrations up to 100 µg/kg. Toluene occurrences in OU1 subsurface soils may possibly be attributed to laboratory contamination. Ground water samples from fourth quarter 1991 and first quarter 1992 indicate toluene was detected at low concentrations primarily in wells at and downgradient of IHSS 119.1 and at well 6286. Toluene in ground water is attributed to laboratory contamination at locations other than IHSS 119.1. At this time toluene remains a questionable contaminant at OU1 although at IHSS 119.1 there does appear to be some correlation between toluene reported in vadose zone soils and ground water (Figures 4-94, 4-96, and 4-101).

VOC contamination was detected in subsurface soils and ground water at OU1. Analytical results for subsurface soil samples indicate VOCs not associated with laboratory contamination occurred sporadically in ten borehole locations in OU1 (Figure 4-103). These locations are predominantly in areas around Building 881 and in IHSS 119.1. VOCs detected in subsurface soils include trichloroethene and tetrachloroethene at concentrations seldom exceeding 100 µg/kg.

Ground water sampled in OU1 during Phase III indicates that ground water contamination exists at IHSS 119.1 (Figures 4-94 and 4-96). VOCs have been consistently detected in ground water at and downgradient of IHSS 119.1 at concentrations exceeding 10,000 µg/l since 1986. The VOCs most commonly detected in alluvial or upper HSU ground water include trichloroethene, tetrachloroethene, carbon tetrachloride, and chloroform among other VOCs. Bedrock or lower HSU ground water in IHSS 119.1 contains low levels of VOCs, predominantly trichloroethene, tetrachloroethene, and chloroform.

Alluvial ground water contamination is sporadic outside of IHSS 119.1 and in areas near Building 881. Among the sporadic VOC ground water detections in monitoring wells near Building 881

are the occurrences of several VOCs including trichloroethene and tetrachloroethene in well 37791, located northwest and upgradient of the building. It is likely a source for these VOCs is located outside and upgradient of OU1 elsewhere in the RFP complex, as no VOCs were detected in the subsurface soils at this well.

Bedrock ground water contamination in well 6286 southeast of IHSS 119.2, may be associated with ground water flow from OU2. Chlorinated solvents have been detected in ground water at OU2; and based on preliminary interpretations of ground water flow patterns, well 6286 is downgradient of OU2. It is likely that ground water contamination in 6286 is due to ground water migration from OU2 to OU1. This circumstance will be addressed more rigorously in the upcoming OU2 RFI/RI.

In summary, based on data from Phase III, vadose subsurface soils are a source for VOC contamination in upper HSU and lower HSU ground water in at IHSS 119.1. The probable source for VOC contamination at monitoring well 6286 is outside OU1 in OU2. For other sporadic VOC detections in ground water at OU1, there is no clearly defined linkage to isolated discrete VOC detections in vadose zone soils as sources.

4.8.2.2 Semivolatile Organic Compounds

SVOCs were detected in surface and subsurface soils, and ground water during Phase III sampling. SVOCs detected in media at OU1 occur two distinct groups: field sampling cross-contaminants and actual contaminants.

SVOCs were detected in surface soils at OU1 during Phase III, and included polynuclear aromatic hydrocarbons and PCBs (Figure 4-82). SVOCs were detected in 26 of 28 sampling locations in OU1. This may be attributed to heavy vehicular traffic during sampling due to the ongoing construction of the french drain and potential eolian deposition from upwind sources at RFP outside of OU1. Polynuclear aromatic hydrocarbons are produced by incomplete combustion of vehicle fuel and are subsequently deposited in surface soils. Other SVOCs such

as fluorene, pyrene, and phenanthrene can be related to asphaltic hydrocarbons which are found at the surface and subsurface in IHSS 130 and are components of parking lots at RFP upwind of OU1. Additionally, PCBs (AROCLOR-1248 and AROCLOR-1254) were detected sporadically. Subsurface or vadose zone soils exhibited detections of similar SVOCs. At IHSSs 130 and 104, the subsurface SVOCs can be attributed to waste burial, but at other locations infiltration of surface soil SVOCs is a viable explanation for the occurrences.

As secondary media, surface water and sediments downgradient OU1 have received contamination as a result of eolian transport of surface soil dust, and surface water runoff from OU1 sources. Sediments sampled in the South Interceptor Ditch during Phase III contained low levels of SVOCs most likely sourced from surface soils (Figure 4-92). However, because of the presence at upgradient stations, upstream sources may be contributing SVOCs to the South Interceptor Ditch as well as potential sources in OU1.

Subsurface soil samples from the Phase III field investigation contained SVOCs including polynuclear aromatic compounds, PCBs, and phthalates. SVOCs were detected sporadically in OU1 at predominantly the 0- to 6-foot depth interval, in areas with histories associated with asphalt and liquid disposal areas. Phthalates including bis(2-ethylhexyl)phthalate, di-n-butyl phthalate, and diethyl phthalate occurred in samples taken across OU1, and are associated with cross-contamination in field sampling. Equipment rinse blanks were analyzed for SVOCs and contained detectable levels of these phthalates. Phthalates are used in the production of plastics. One potential source for phthalates in OU1 samples and rinse blanks can be attributed to the use of de-ionized water stored in plastic carboys for decontamination and equipment washes.

SVOCs in OU1 ground water occurred as sporadic low-level pesticide and phthalate detections during Phase III sampling. Alpha benzene hexachloride was detected once in two wells in fourth quarter 1991 in the area of Building 881 (Figure 4-94). Subsequent sampling in first quarter 1992 failed to detect this compound. Alpha benzene hexachloride was not detected in surface and vadose zone soils in the vicinity of these wells, so no sources for these one-time detections

were identified. Since the pesticide only occurred sporadically in ground water at low concentrations and no soil source was found, further monitoring is necessary to substantiate its long-term existence in ground water. The phthalates detected in ground water occur infrequently at concentrations below the certified reporting limit and are not considered contaminants in ground water at OU1.

Based on the Phase III field investigation and routine monitoring of ground water, SVOCs occurring in subsurface soils are not considered a source of SVOC contamination to ground water because no correlation was found between soil and ground water SVOCs contamination. SVOCs present in surface soils may be a potential source to surface water and sediments downgradient of OU1, but other sources outside OU1 may also contribute. Surface SVOCs also may act as a source to vadose zone soils from infiltrating water carrying dissolved and very fine particulates downward through the soil column.

4.8.2.3 Radionuclides

Various radionuclides were detected in surface and subsurface soils as well as ground water exceeding background concentrations during Phase III sampling; current RFP background levels are used as a basis of comparison. For use in determining contamination and sources, only radionuclide concentrations that exceed background by more than a factor of ten are considered indicative of contamination.

Surface soil samples from OU1 contained several radionuclides exceeding background levels. Of those radionuclides, only americium and plutonium exceeded background by more than a factor of ten. Based on contour map depicting americium and plutonium concentrations, it is evident that these radionuclides occur at concentrations which are greatest in the northeast, and decrease to the west and southwest areas of OU1. The source for the americium and plutonium in OU1 surface soils is most likely the 903 Pad in OU2. Eolian transport and possibly surface water and anthropogenic transport and subsequent deposition of particles containing these radionuclides accounts for the distribution of americium and plutonium in surface soils. The

distribution patterns for uranium and other radionuclides were also evaluated, but no clear cut spatial trends could be found which implied dispersal from a source or a relationship with waste disposal.

Radionuclides including plutonium, americium, uranium, and radium exceed background levels in OU1 subsurface soils. Uranium and radium are elevated in OU1 soils, but are considered to occur as a result of natural geologic conditions. No clear concentration pattern could be discerned which can be attributed to waste disposal activities or to contaminant dispersion. Based on analysis of isotopic ratios of uranium, all concentrations indicate uranium exists in subsurface soils as a result of natural processes and not RFP processes. Americium-241 and plutonium-239,-240 do exceed background by more than an order of magnitude. Based on surface soil data from OU1, it is evident that concentration for americium an plutonium are greatest on the surface, and decrease in concentration to depths sampled greater than 30 feet. Americium and plutonium are considered contaminants in subsurface soils at OU1.

Only one radionuclide exceeds background levels in ground water during Phase III sampling. Radium-226 exceeds background during fourth quarter 1991 at a concentration slightly exceeding the background level. Phase II data indicates radionuclides are not contaminants in OU1 ground water.

As secondary media, surface water and sediments the South Interceptor Ditch have a potential for contamination to occur as a result of eolian transport of surface soil dust, and surface water runoff. However, surface water sampled during Phase III contained low levels of uranium only, most likely sourced from surface soils upstream of OU1 and from OU2. No linkage to OU1 is apparent. No radionuclides were detected in sediments above background levels.

Based on current data from the Phase III field investigation and routine monitoring of ground water, surface and subsurface soils are not a source of radionuclide contamination to ground water. Plutonium and americium show well defined dispersion trends in surface soils and are

a source of contaminant migration to subsurface soils based on decreasing downward concentrations at several locations. Surface soils may be a potential source to surface water and sediment downgradient of OU1 but no direct correlation has been established yet.

4.8.2.4 Metals

Metals were detected in surface and subsurface soils, and ground water exceeding background during Phase III sampling; current RFP background levels are used as a basis of comparison. For use in determining contamination and sources, metals concentrations greater than background levels are not considered indicative of contamination unless detections exceed background by more than a factor of ten. Also, spatial concentration trends were evaluated to determine if metals could be attributed to waste disposal activities or reflected dispersion from a source or sources.

Metals in surface soils did not exceed background levels by more than an order of magnitude in OU1 surface soils. Copper is the only metal which has a concentration approaching ten times background. Since copper has no history of being processed at RFP, it cannot be considered a potential contaminant. Beryllium is slightly elevated in a localized area and is not indicative of metal contamination in OU1 surface soils.

Metals detected in subsurface soils slightly exceed background levels at OU1. Typically metals exceed background by a factor of two, and sometimes approaching a factor of five. Only selenium in samples from 32491 exceed background by an order of magnitude. Elevated concentrations of selenium detected in the 0- to 6- foot and 6- to 12-foot depth intervals can be attributed to a localized metal occurrence in bedrock fill materials in OU1. At these levels, metals in subsurface soils are not considered contaminants at OU1. Also, no coherent lateral or vertical trends were found that would reflect dispersion from a source of contamination.

Ground water sampled at OU1 contained total and dissolved metals which exceeded background levels during Phase III sampling. Fourth quarter 1992 sampling results indicated up to six metals

exceeded background by a factor of ten. The next round of sampling, first quarter 1992, indicated the concentrations of metals had decreased from levels detected previously. During first quarter 1992, only strontium and copper still exceed background levels; and these metals only exceed background by a factor of two. These trends and the current data indicate that metals should not be considered contaminants in OU1 ground water.

Based on data from the Phase III field investigation and the current routine monitoring data for ground water, metals are not considered contaminant sources in any of the primary media at OU1. The trend of decreasing concentrations with time in newly installed wells is considered to reflect aquifer disruption associated with well installation in clay-rich saturated materials at OU1.

4.9 PRELIMINARY BENCHMARKS FOR CONTAMINATED MEDIA AT OU1

Benchmarks are regulatory standards, or guidelines, which are considered preliminary Applicable or Relevant and Appropriate Requirements (ARARs), or action levels to be considered (TBCs) for the eventual remediation of contaminated materials. A regulatory-based screening of ARARs will be performed during the CMS/FS, and are subsequently finalized in the Record of Decision (ROD). Tables 4-33 and 4-34 present Federal and State ground water and surface water quality standards, or ARARs, compared to results from the Phase III routine monitoring program at OU1. Regulatory guidelines presented in Tables 4-33 and 4-34 include Safe Drinking Water Act maximum contaminant levels (MCL) and maximum contaminant level goals (MCLG), CDH standards for ground water, and ambient water quality criteria (AWQC) values. Results for ground water and surface water represent maximum values detected for the two media during the time period October 1991 through March 1992 considered for the Phase III RFI/RI.

Contaminants in ground water at OU1 include VOCs detected in the upper HSU at IHSS 119.1. Table 4-34 lists the maximum concentrations of VOCs in ground water and comparable guidelines for a preliminary assessment of regulatory limits applicable to OU1. Fifteen VOCs detected in ground water are listed in Table 4-33, and indicate six analytes exceed one, or more

regulatory standards. Concentrations for these six VOCs exceed the benchmarks by a factor ranging from 10 to 10,000 times the MCL or CDH standard for an analyte. Radionuclides and metals concentrations do not indicate contamination in ground water at OU1, and are presented anyway in Table 4-33 for visual comparison to the preliminary benchmarks. SVOCs detected in ground water, with available benchmarks are presented in Table 4-33, indicate that these analytes do not exceed regulatory standards.

Surface water quality criteria and OU1 detected analytes are presented in Table 4-34. Radionuclides and metals detected in surface water are not indicative of contamination OU1, and are presented anyway for purposes of comparison to the preliminary benchmarks. VOCs and SVOCs detected in surface water generally include analytes attribtable to laboratory contamination or field sampling cross-contamination and are not considered contaminants in surface water at OU1 based on the contamination assessment presented in Section 4.8.2 of this report.

Section 5.0 · Text

Contaminant Fate and Transport

Phase III RFI/RI Report

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5.0 CONTAMINANT FATE AND TRANSPORT

It is necessary to understand the environmental fate and transport of contaminants present at OU1 in order to determine the potential for on-site and off-site migration of contaminants of concern, and then to assess the potential for present and future exposure to these contaminants. The mobility and persistence of contaminants within the various environmental media at OU1 are affected by the physical and chemical characteristics of the contaminant and of each media, the release of a contaminant to a migration pathway, the rate of migration along a pathway, and the type and rate of degradation and transformation in the media or pathway. These complex interactions between the contaminants and the media are controlled by the individual characteristics of each contaminant and media.

Section 5.0 discusses the processes that affect contaminant fate and transport at OU1. The physical characteristics of the media in OU1 have previously been described in Section 3.0, and the types, concentrations, and areal extent of contamination have been described in Section 4.0. With those descriptions as a basis, this section evaluates the potential for contaminant migration at OU1. Section 5.0 first reviews the general framework of the potential routes of migration. This background is followed by a detailed discussion of the physical and chemical characteristics of the media and contaminants that influence contaminant behavior and mobility. Section 5.0 closes with a discussion of major contaminant migration pathways and modeling methods and results.

More specifically, Section 5.1 describes the general processes active at OU1 that potentially control the identified migration routes. Section 5.2 enumerates the physical and chemical properties of the media and contaminants that influence migration and persistence, describes the behavior characteristics of individual contaminants, and contrasts the predicted and observed behavior of contaminants with respect to OU1 conditions. Section 5.3 describes the major migration pathways that account for contaminant transport at OU1 and reviews the results of contaminant transport modeling completed to support of the risk assessment.

5.1 POTENTIAL ROUTES OF MIGRATION

Contaminant fate and transport at OU1 are potentially controlled by release, transport, and degradation processes operating in each of the environmental media present: surface and subsurface soils, ground water, surface water, sediments, air, and biota. Processes likely to control contaminant fate and transport at OU1 are discussed below; the discussion is based on known site conditions using data from the Phase III RI. Because human activities can also influence the distribution of contaminants at the site, especially contaminants resident in surface soils, probable anthropogenic processes are also considered. Figure 5-1 summarizes the probable fate and transport processes operating at OU1 are displayed in schematic form.

Contaminants were first introduced into the OU1 environment by atmospheric releases from RFP plant processes (including fires at RFP), and by waste storage and disposal, resulting in the localized contamination of surface and subsurface soils and ground water. Contaminant radionuclides in surface and subsurface soils (alluvium/colluvium) soils were introduced to the OU1 site from leaking drums of waste oil containing americium and plutonium at the 903 Pad, and from radionuclides released from RFP fires. Radionuclides in surface soils were subsequently redistributed by eolian, anthropogenic, and surface water transport processes from the 903 Pad to OU1 resulting in the present distribution of radionuclides in surface soils at OU1 depicted in Figures 4-85 and 4-86. Leakage of drums containing unknown quantities of waste and solvents at IHSS 119.1 resulted in contamination of subsurface soils and ground water with chlorinated solvents at that location. Disposal of waste asphalt at IHSS 130 has resulted in elevated concentrations of semivolatile PAHs in the upper 6 feet of soil. Trace amounts of chlorinated solvents have also been detected in wells screened in artificial fill proximal to the Building 881 footing drain.

Figure 5-1 demonstrates that contaminants present in surface and subsurface soils (radionuclides, chlorinated solvents, and SVOCs) may potentially be released to the unconfined upper HSU ground water by a variety of desorption or leaching processes. Organic contaminants in subsurface soils may be released to soil gas or the atmosphere through volatilization.

Radionuclides and semivolatile PAHs present in surface soils may be transported to surface water or spatially redistributed by erosion and overland flow or dust resuspension by eolian processes. Contaminants in surface water may enter the South Interceptor Ditch or Woman Creek, or infiltrate to the upper HSU. Fugitive dust containing particulate contaminants can be redeposited onto surface soils, and volatile contaminants in air disperse and eventually attenuate.

Contaminants present in upper HSU ground water (considered a secondary source) may migrate by advection and dispersion, discharge to surface water via seeps, or volatilize to soil gas and ultimately disperse into the atmosphere. Contaminated ground water in the upper HSU at OU1 is almost entirely captured by the french drain, although a small quantity may infiltrate into the low-permeability claystone strata of the lower HSU.

General contaminant transport processes considered to be relevant to conditions in each of the media at OU1 are discussed in Section 5.1.1 and Section 5.1.2 compares and contrasts the fate and transport processes operating at the individual IHSSs at OU1.

5.1.1 Transport Processes in OU1 Media

5.1.1.1 Soil Processes

Surface and subsurface (vadose zone) soils are both a primary host of contaminants and a pathway for contaminants. Contaminants present in surface and vadose zone soils have the potential to migrate from these source areas to underlying ground water in the upper HSU. Contaminants in source area soils are subject to a variety of potential desorption and leaching processes involving infiltrating water from the surface. Contaminants with high aqueous solubilities are most susceptible to leaching and desorption, while contaminants with an affinity for the solid phase (low solubility) are generally retarded in the vadose zone and exhibit low mobility. In areas where vadose zone soil are thick or where alluvial ground water does not occur, as in most of the eastern portion of OU1, the vadose zone soils may act as an attenuating and retarding medium to the downward transport of contaminants because of its physical and chemical properties (i.e., high clay content and low permeability).

Where organic contaminants are present in surface soils, releases to the atmosphere by volatilization may occur. Volatile or semivolatile contaminants in subsurface soils may migrate to the atmosphere via volatilization to soil gas, which then migrates through the vadose zone to the atmosphere. In general, volatilization leads to dispersion, migration, and dilution of contaminants in the vapor phase. Solid phase contaminants or contaminants adsorbed to the solid phase may be released to the air for transport by the suspension of contaminated particles by wind erosion. Transport of contaminants as fugitive dust results in redeposition on surface soils both on and off site.

In addition to transport processes affecting contaminants in OU1 soils, there are various decay and transformational processes that alter the concentration or persistence of contaminant species. Decay and transformation can be caused by abiotic chemical reactions, such as oxidation, hydrolysis, or photolysis. Degradation and transformation also can be biologically mediated by microbes and other organisms residing in surface soils and vadose zone alluvium/colluvium materials. The type, rate, and completeness of any transformation process is ultimately controlled by the physical and chemical conditions present in OU1 soils. Section 5.2 discusses the physical and chemical conditions that affect both transport and decay processes.

5.1.1.2 Ground Water Processes

Ground water at OU1 is both a source of contamination and a contaminant transport medium. Several contaminants at OU1 specifically the chlorinated solvents are thought to have originated as pure liquid phases and migrated to ground water after percolating directly through the vadose zone soils. For contamination residing in surface and subsurface soils, transfer to ground water can occur by various desorption, dissolution, and leaching processes. Another potential mechanism of release to ground water is the dissolution of immobile residual free-phase organic contaminants residing in vadose zone soils or in direct contact with ground water in saturated soils. Free-phase organic liquids have not been observed in ground water samples, nor have the concentrations detected in vadose zone soils been high enough to suggest the presence of free-

phase product. However, this process could have been active at IHSS 119.1 and is inferred based on the high concentrations of chlorinated solvents reported in ground water samples.

Once having entered ground water, contaminants can migrate further by advective flow, which is the transport of solutes via bulk flow of ground water in response to hydraulic gradients. Contaminants in ground water may also migrate by dispersion, which is caused primarily by mechanical mixing during fluid flow, and generally results in the dilution of contaminants with increasing distance from the source. The migration of contaminants is typically retarded to some degree with respect to ground water flow rates by the interaction of contaminants with the solid phases present. Retardation of contaminants is a function of the affinity of a contaminant for the solid phase and is dependent upon the properties of the contaminant and on the organic carbon or clay content of aquifer materials. However, lateral advection and dispersion of contaminants by ground water is not considered a significant pathway at IHSS 119.1 due to a lack of a complete hydrologic pathway in the upper HSU (see Section 3.7).

The collection well affiliated with the french drain along the southern perimeter of OU1 captures contaminated ground water from the upper HSU at IHSS 119.1 above the alluvium-bedrock contact. The captured water is then pumped to a treatment facility and subsequently discharged to the South Interceptor Ditch. The french drain was not designed to capture contaminated ground water that has infiltrated from the perched upper HSU to the lower HSU in response to downward hydraulic gradients. However, the quantity of contaminated water percolating into the lower HSU (specifically at IHSS 119.1) is considered to be minor due to the low permeability of the upper Laramie Formation claystones that compose the lower HSU. Contaminants that do enter the lower HSU would be subject to retardation processes in this low permeability clay-rich unit.

Contaminants in ground water may migrate further by volatilization to soil gas and become susceptible to evapotranspiration. Volatilization of contaminants from ground water is controlled by several factors including the thickness of the overlying vadose zone soils, soil permeability,

moisture content, vapor concentration gradients, vapor pressure, and the Henry's law constants of individual contaminants. Evapotranspiration involves the direct evaporation of water or the uptake of ground water by plants, which in turn release it to the atmosphere. Evapotranspiration occurs at OU1, and seasonal variations may account for considerable water loss in certain locations. However, the volumetric importance of this mechanism as a contaminant pathway is considered minimal when contrasted with other processes.

As in vadose zone soils, decay and transformation processes can alter or degrade contaminants in the saturated zone. The type, rate, and completeness are also controlled by the physical and chemical conditions present. Details of known and inferred conditions at OU1 are described in Section 5.2.

5.1.1.3 Surface Water and Sediment Processes

Transportation of contaminants by surface water may occur with the contaminant in the aqueous dissolved phase or in the solid phase adsorbed to suspended material or bed load sediments. Contaminants may be released into the surface water medium by leaching from surface soils or by suspension of soil particles in flowing surface water. At OU1, the most readily identifiable means for surface water to become contaminated is from episodic erosion of surface soils by overland flow caused by precipitation events and snowmelt. Channelized flow is confined to intermittent, ephemeral flow in the South Interceptor Ditch, which is designed to capture and divert any overland flow on 881 Hillside area prior to reaching Woman Creek. At OU1, surface water containing dissolved or suspended contaminants is likely either to infiltrate through the vadose zone soils to the water table, or flow into the South Interceptor Ditch, downgradient from OU1.

5.1.1.4 Air Processes

Contaminants may enter the atmosphere at OU1 either through direct volatilization from surface soil, surface water, or ground water seeps, by atmospheric exchange with soil gas, or by eolian resuspension of contaminants adsorbed to particulates. These surficial soil data compiled from

various investigations at OU2 for the OU2 RFI/RI Work Plan (DOE 1991a) show eolian transport of particulates to be an important migration pathway for radionuclides and possibly for other contaminants (EG&G 1991b). These soil data and surface soil data from OU1 suggest that eolian transport is likely to be significant at OU1 as well. Surficial soil data from samples collected in OU1 for the Phase III RFI/RI and data from air monitoring programs at RFP and OU1 show slightly elevated plutonium concentrations downwind of OU2 and at the site-specific air samplers at OU1. The occurrence of plutonium is likely to have resulted from localized resuspension of surface soil by wind and localized resuspension from vehicular traffic.

Air is generally not considered a significant pathway for volatile gas-phase contaminants, which attenuate and degrade rapidly in the atmosphere; however, these contaminants could migrate into a confined space, such as a hypothetical structure built in the future on 881 Hillside area, where volatile compounds would not disperse as readily as in the open atmosphere. This scenario is addressed specifically in Section 5.3 of this report and in the Public Health Evaluation in Section 6.1 and Appendix F.

5.1.1.5 Anthropogenic Processes

Human activities resulting in contaminant transport that would not otherwise occur are referred to as anthropogenic processes. Examples of anthropogenic transport of contaminants include the adherence of contaminated soil particles to vehicles or equipment, or when the ground surface is modified by excavations, grading, or construction activities. Widespread occurrences of plutonium, americium, and PAHs in OU1 surface soils are attributable to this process as discussed in Sections 4.3 and 5.3 of this report.

The future contribution to contaminant transport by anthropogenic processes is less likely to occur because of mitigative measures implemented to minimize human influence. At OU1, access to and egress from IHSSs are restricted and controlled by fences, signs, and security procedures, decreasing the probability of incidental transport. If access is needed for sampling or monitoring, individuals adhere to strict personal and equipment decontamination procedures

as well as health and safety protocols specifically designed to prevent the spread of contamination.

The installation of the french drain involved excavation and displacement of a substantial volume of material at OU1. However, the placement of the french drain at OU1 took into consideration the suspected location of contaminated soils by avoiding IHSSs wherever possible along its alignment. Also, the french drain geotechnical investigation characterized soils by analyzing for contaminants in exploratory boreholes along the proposed alignment prior to commencing construction in order to avoid disturbing contaminated soils, or to accommodate the proper handling of contaminated soil that would unavoidably be encountered. All these precautions collectively reduced the viability of contaminant transport by human activities at OU1.

5.1.1.6 Biota Processes

Biota may be exposed to contaminants by root uptake of contaminants, ingestion of contaminated materials, inhalation, or contact with contaminated soils or water. Although low trophic-level species may serve as contaminant pathways to higher trophic-level species, biota as a whole are normally considered to be receptors. Biological media are not a significant contaminant transport pathway at OU1 from a volumetric standpoint. However, even minor concentrations of highly bioaccumulative contaminants in lower trophic (feeding) levels are important due to biomagnification of contaminants through successive predation in a food web. Potential contamination in biota and its behavior in the food web is discussed in greater detail in Section 6.3 of this report, and in the Environmental Evaluation in Appendix E.

5.1.2 Migration Routes from OU1 IHSSs

Data from the Phase III OU1 RFI/RI indicate that migration of contamination at OU1 is constrained by the limited number of potential contaminant migration routes at the site. Contamination at OU1, as outlined in Section 4.0, is limited to the occurrence of asphalt-derived SVOCs and trace levels of radionuclides in surface and subsurface soils at IHSS 130, VOCs (chlorinated solvents) in subsurface soil and ground water at IHSS 119.1, traces of (chlorinated

solvents) in bedrock well 6286 (south of IHSS 119.2) and in alluvial ground water next to Building 881, and areally limited occurrence of PAHs and radionuclides in surface soils in the east and northeast area of OU1. Based on this distribution, and known site geology and hydrogeology, the following potential pathways are likely to occur at OU1.

The waste material at IHSS 130 (asphaltic materials tainted with radionuclides) is partially exposed at the surface or buried beneath a thin cover of surface soil. Given this scenario, the most important contaminant pathways are likely to be eolian resuspension of fine particulates and dust and/or surface water erosion by channelized runoff and overland flow. Leaching and dissolution of this material by infiltrating surface runoff or meteoric recharge is also a potential migration pathway; however, due to the extremely low solubility of the compounds at IHSS 130 this pathway is likely to be minimal. Volatilization of SVOC materials exposed at the surface is also possible, but only in minuscule amounts.

Potential pathways at IHSS 119.1 are linked to the occurrence of chlorinated solvents in subsurface (vadose zone) soils and alluvial and bedrock ground water. For residual chlorinated solvents in vadose zone soils, volatilization to soil gas and desorption and dissolution to infiltrating water are the probable major pathways. Volatilization to soil gas can result in migration to the atmosphere where dispersion, photolysis, and dilution mechanisms will substantially reduce the concentrations of these compounds. Solvents in soil gas can also remain trapped in the vadose zone and become sorbed to the solid matrix or become dissolved in infiltrating water. Dissolution of residual solvents in infiltrating vadose zone water will eventually reach the upper HSU ground water.

Ground water in the upper HSU at IHSS 119.1 occurs as a discrete and hydrologically perched interval isolated within a bedrock topographic depression, as described in Section 3.7. A potential pathway exists during the "wet season" when rising water levels create an apparent hydrologic connection between alluvial ground water and the french drain. However, operation of the extraction well installed in this area will significantly reduce the potential for ground water

migration from IHSS 119.1. Other potential pathways of contaminants in alluvial ground water include volatilization to soil gas, sorption to saturated aquifer materials, or vertical downward migration into the lower HSU. The most important pathway for contaminated ground water in the lower HSU beneath IHSS 119.1 and in well 6286 is advective flow in the Laramie Formation where degradation and retardation processes are likely to decrease concentrations over time significantly.

Potential pathways for contaminants in alluvial ground water surrounding Building 881 include volatilization to soil gas and advective flow to the french drain. The concentrations of chlorinated solvents in this area are extremely low and in most cases are below MCL standards for drinking water. Therefore, potential degradation and transformation process are likely to reduce or eliminate these compounds before they are realistically transported any significant distance.

The most important pathways identified for radionuclides and PAHs resident in OU1 surface soils include remobilization by surface water runoff or by eolian processes. Remobilization by surface water will result in short-travel distances due to the presence of the South Interceptor Ditch. The South Interceptor Ditch is located due south of the french drain, effectively intercepting all surface runoff from OU1. Remobilization of contaminated soil particulates and dust is potentially the greatest pathway for on-site and off-site redistribution of contaminants in surface soils. In addition to Phase III RFI/RI data, other data describing the distribution of radionuclides in surface soils at OU1 and in areas east of RFP (M. Litaor, EG&G, Personal Communication, 1992) appear to confirm eolian transport as a contaminant pathway that has dispersed contaminants at OU1.

5.2 CONTAMINANT MOBILITY AND BEHAVIOR

Observed contaminant distributions at OU1 are the result of chemical and physical interactions between contaminants and the environmental media in which the contaminant resides. These interactions involve processes that determine the transport and fate of contaminants in site soils, sediments, and surface and ground waters. These processes include, but are not limited to:

adsorption/desorption reactions (including ion exchange), oxidation/reduction, complexation, precipitation/dissolution, volatilization, hydrolysis, dehalogenation, radioactive and chemical decay, and biodegradation.

Contaminant behaviors and mobilities, outlined in the following sections, are derived from the physical and chemical properties of individual contaminants (as indicated in literature sources) in the context of the physical and chemical properties of the site, as determined from field and laboratory data collected for the specific media at OU1. These data are subsequently used to derive quantitative distribution coefficients (K_d) and retardation values (R_f), where applicable, and qualitative assessments of behavior and migration where quantitative analyses are not appropriate. These are discussed in Section 5.3.

5.2.1 Physical and Chemical Properties that Influence Mobility

All contaminants have unique physical and chemical properties. These properties cause the contaminant to respond in predictable ways under a given set of environmental conditions. When chemicals are released to environmental media, the behavior of the chemical in that media (reactivity, mobility, persistence) is controlled by the physical and chemical properties of the media. It is necessary to characterize the media properties that affect the behavior of the contaminant the most. At OU1, the occurrence of contaminants in surface and subsurface soils and alluvial and bedrock ground water require that these media be characterized before transport and fate processes and ultimately, remedial action can be effectively described and implemented.

5.2.1.1 OU1 Media Physical and Chemical Properties

The physical characteristics of OU1 media are described in Section 3.0. Surface soils are discussed in Section 3.5; site geology in Section 3.6; and site hydrogeology in Section 3.7. The discussion in this section focuses on the physical and chemical properties of surface soils, subsurface soils, bedrock, and ground water that most influence the reactivity, mobility, and persistence of contaminants at OU1. These properties include, but are not limited to: organic carbon content, clay content and mineralogy, presence of sesquioxides, oxidation potential (Eh),

pH, and chemical composition of ground water in contact with the soils. The sections below discuss the importance of these properties in relation to the fate and transport of contaminants at OU1.

The partitioning of contaminants from the liquid or dissolved phase to the solid phase is proportional to the organic carbon content of the media. When organic carbon content is high, contaminant partitioning to the solid phase is proportionally high. When organic carbon content is low, contaminant partitioning becomes increasingly dominated by inorganic solids with high surface areas, such as clays. Tables 5-1, 5-2, and 5-3 list the organic carbon content and grain size distribution for geologic material at OU1. It is apparent that the majority of geologic materials investigated at OU1 are high in clay (or claystone for bedrock materials) and low in organic carbon.

The fraction of clay minerals and clay-size particles present in geologic media is significant due to the adsorption and cation exchange capacities of these materials (Birkeland 1984; Dragun 1988). The presence of clays in a soil or aquifer also tends to lower the effective permeability of the media thereby reducing ground water flow velocities and increasing residence times. Increased residence times increase the probability that geochemical processes such as adsorption and ion exchange will approach equilibrium. Clays are also significant when considering remediation of contaminants by pump and treat methods. Clays tend to sorb contaminants and therefore represent long-term contaminant sources to ground water through desorption of contaminants in response to decreased ground water concentrations induced by remedial pumping or flushing.

Organic Carbon Content

Organic carbon content ranges from 2.3 percent in the upper 3 feet of surficial soils to nondetect values (<0.05 percent) for most deeper geologic materials. Organic carbon in surface and near-surface soils (0 to 6 feet) range from 0.1 percent to 2.3 percent, with a site-wide average of 0.64 percent. Organic carbon content in the uppermost 20 cm of surface soils at OU1 has been

observed to be as high as 6 percent (M. Litaor, EG&G, Personnal Communication, 1992). Organic carbon values in alluvium/colluvium materials (>6 feet deep) range from 0.01 percent to 1.8 percent, with an average value of 0.2 percent. However, this average value is probably not representative of most alluvium/colluvium samples due to the occurrence of isolated pockets of organic carbon identified in lithologic logs that may skew the mean toward a higher value (e.g., see logs for boreholes 37291 or 37991). The majority of values for alluvium/colluvium are below detection limit (<0.05 percent). Seven of eleven alluvium/colluvium samples had non-detectable organic carbon. Two of the four samples that did detect organic carbon had levels of 0.1 percent or less. Bedrock values range from 0.01 percent to 1.1 percent, with a sitewide mean of 0.29 percent. Again, most bedrock samples are much lower than 0.29 percent, averaging closer to 0.03 percent. Of four bedrock samples, two were non-detect and one was below 0.06 percent organic carbon.

A conservative value of 0.01 percent was used in place of nondetect values (<0.05 percent) in calculations which required a value for percent organic carbon. This equates to an f_{oc} of 0.0001 (f_{oc} represents the fraction of organic carbon, or percentage divided by 100). Actual values probably vary, however, if organic carbon is higher than 0.01 percent, then partitioning to the organic solid phase would be higher than calculated and contaminant retardation will be proportionally higher. If organic carbon values are lower than 0.01 percent, then partitioning to organic carbon in soils at OU1 is not likely to have any significant effect upon contaminant fate or transport (McCarty et al. 1981; Karickhoff 1984). Calculations evaluating the importance of organic carbon in OU1 subsurface soils are performed in Section 5.2.2.1.

There is a critical level of organic carbon (f_{oc}^*) in geologic materials below which partitioning of organic contaminants to inorganic surfaces dominates the adsorption process (Olsen and Davis 1990). The first step toward characterizing the dominant adsorption mechanism in OU1 geologic media is to determine the critical level of organic carbon. Once this is established, distribution coefficients describing contaminant partitioning can be calculated, and used to calculate a retardation factor for each contaminant.

Karickhoff (1984) identified threshold values at which adsorption to inorganic surfaces becomes significant relative to organic carbon. The threshold values are based on the ratio of the percent of clay in the sample to the percentage of organic carbon. For the nonpolar chlorinated solvents detected at OU1, the threshold ratio is >60. Using the average clay value of 38 percent for OU1 surficial materials (colluvium/alluvium) from Table 5-2 and the average organic carbon content of 0.21 percent from Table 5-1, the sitewide average ratio at OU1 is 181, or three times greater than the minimum threshold value for inorganic surfaces adsorption. For bedrock at OU1, the threshold ratio is 186, again greater than the minimum threshold value by a factor of three. This indicates that adsorption processes at OU1 are dominated by inorganic surfaces. For those localized areas in the subsurface where organic carbon occurs in concentrated pockets, inorganic surfaces may be subordinate to organic sorption. A similar but more quantitative method used to assess inorganic surface partitioning at OU1 is based on McCarty (1981) and is presented in Section 5.2.2.1.

Clay Content

Clay content in OU1 geologic materials ranges from 25 percent to 82 percent, with a sitewide mean of 46 percent for surficial soils and alluvial/colluvial materials (Table 5-2) and 54 percent in bedrock materials (Table 5-3). Alluvium, colluvium, and artificial fill at OU1 have been characterized as being generally clay-rich. Borehole logs from OU1 (Appendix A) describe these materials as ranging from relatively "pure" clays to gravelly sandy silt-clay mixtures, including sandy clays, gravelly clays, and sandy clayey silts. Grain size distribution plots for OU1 samples (Appendix A2) submitted for geotechnical analysis confirm field observations regarding particle size distribution. Clay content in alluvial/colluvial materials ranged from 25 percent (borehole 37591) to 52 percent (borehole 38991), with a sitewide average of 38 percent (Table 5-2). Clay (claystone) content in bedrock materials ranges from 28 percent (borehole 37891) to 82 percent (borehole 37891), with an average value of 54 percent (Table 5-3).

Clay mineralogy at OU1 was not determined but probably consists of a variety of clay types, each exhibiting a range of chemical and physical properties. However, in arid environments

characterized by mollisol soils, such as OU1, smectite clays are typically common in addition to other typical soil-forming clays such as vermiculite, illites, and kaolinite. Smectites are 2:1 layer clay minerals that have very high surface areas and high cation exchange capacities. Smectites include the minerals montmorillonite, beidellite, and nontronite (Birkeland 1984). Smectite content at OU1 may range from 20 percent to 80 percent of clay content, depending on the type of geologic media.

Smectites have been tentatively assigned a surface area of 100 m^2 per gram of clay. This is a conservative estimate, considering literature values that report smectite surface areas up to 800 m^2/g (Dragun 1988) (Table 5-4). Soils that have high surface areas are more chemically active than low surface area soils due to the higher charge per unit volume of material. High charge per volume ratios result in increased adsorption capacities and higher CEC values (Sposito 1989).

Surface area values are also used to calculate the surface-specific distribution coefficient, K_s, which is used to predict the partitioning of an organic compound between the solid (adsorbed) phase and the dissolved phase for inorganic surfaces. The K_s can then be used to calculate a retardation factor, R_f, for organic contaminants at the site (McCarty et al. 1981).

In addition to surface adsorption, all clay minerals exhibit some degree of ion exchange (Drever 1988). For inorganic species, especially cations, the partitioning between the aqueous phase and the solid phase in clay-rich sediments may be dominated by ion exchange reactions. The ion exchange capacities of geologic materials are difficult to quantify without actual laboratory measurements due to the number of variables that affect the process (i.e., pH, solution chemistry, nature of the exchanging solid, type and quantity of ions occupying exchange sites). However, the cation-exchange capacity of natural materials can be estimated from literature values. Table 5-4 is a compilation of literature-derived CEC values for a range of natural geologic materials, many of which certainly occur at OU1. High cation-exchange values are associated with montmorillonites, vermiculites, and other clays.

Sesquioxides

Sesquioxides are a loosely defined group of crystalline and amorphous iron-, manganese-, and aluminum-oxyhydroxides that are generally stable under oxidizing conditions. These solids have proved to be excellent scavengers of trace metals and radionuclides and exert substantial influence on adsorption and coprecipitation processes. Table 5-4 lists some of the physical and chemical properties of sesquioxides.

In general, oxyhydroxides of iron have the highest potential for removing metal cations and radionuclides (plutonium and americium) from aqueous solution, thereby reducing the concentration and mobility of those species (Stumm and Morgan 1981; McKinley and Jenne 1992). Borehole logs from OU1 document the presence of abundant oxidized iron in the form of secondary coatings, fracture fill material, iron enriched zones, and pigmentation agents imparting typically yellow or reddish-brown colors to OU1 subsurface sediments. Manganese solids, which have also been observed at OU1, exhibit adsorption behavior similar to iron solids and occur in similar form, but are far less abundant than iron at OU1. (LeGendre and Runnells 1975; Runnells 1976; Hem 1985).

Table 5-4 also lists isoelectric point values for natural materials, many of which exist in soils at OU1. The isoelectric point is the pH at which the net charge on the material surface is zero. For pH values less than the isoelectric point, the surface charge will be positive; pH values greater than the isoelectric point result in negative surface charges. From Table 5-4 it is apparent that at aqueous pH values typically encountered in OU1 ground water (range 6.95 to 8.38), the majority of iron and manganese oxyhydroxide solids should have negative surface charges. Negative surface charges will favor the adsorption of metal and radionuclide cations at OU1. For those solids with isoelectric points greater than pH 7.5, such as some aluminum oxyhydroxides, the net positive charge on these solids favors anion adsorption processes.

Computer modeling of major cations and anions in ground water using the geochemical code WATEQ (Truedell and Jones 1974), and using data from alluvial monitoring wells at OU1,

indicate that ground water is supersaturated with respect to various iron, manganese, and aluminum solid phases as well as calcium solid phases. Aqueous solutions that are supersaturated with respect to one or more of these phases have increased capacities to remove other dissolved elements, especially trace metal cations, through the process of coprecipitation (Runnells 1976; Sposito 1989). Table 5-5 lists trace elements that are susceptible to coprecipitation by various solid phases, many of which exist at OU1.

Oxidation Potential

The oxidation potential of the subsurface environment is important in determining whether a chemical species is susceptible to oxidation or reduction processes (hereafter referred to as "redox" processes). The oxidation potential of the subsurface environment at OU1 can be characterized from lithologic descriptions of soils from geologic borehole logs at the site and extrapolated from field parameter dissolved oxygen values taken during the sampling of monitoring wells.

The color of a rock or soil is strongly dependent upon the oxidation potential of the environment. Redox-sensitive elements such as iron are typically abundant in clay-rich sediments and exhibit colors such as red, yellow, and reddish brown when in the oxidized state (Birkeland 1984; Dragun 1988). Lithologic descriptions consistently report sediment colors ranging from light yellowish brown (2.5Y 6/3), to reddish brown (5YR 4/4), to reddish yellow (7.5YR 6/6), to light brownish gray (2.5Y 6/2). In addition, the presence of iron oxides were noted as frequently occurring both mixed in with clay and as coatings in fractures. These colors imply relatively oxidizing conditions in OU1 soils.

The visual characterization of OU1 soils as oxidized is further supported by water quality measurements of dissolved species in ground water. Water quality data indicate the presence of oxidized forms of sulfur (sulfate), nitrogen (nitrate/nitrite), phosphorus (orthophosphate), and measurable dissolved oxygen in OU1 ground water.

Dissolved oxygen values from monitoring wells sampled during fourth quarter 1991 range from 0.0 milligram per liter (µg/l) for monitoring well 37791 to 5.9 µg/l for monitoring wells 35691 and 36191, with an average value of 4.8 µg/l for seven wells. Eh values calculated from the average dissolved oxygen value using the computer program WATEQ (Truesdell and Jones 1974) averaged 0.8 volt (corresponding to 4.8 µg/l dissolved oxygen). At an average pH of 7.59 (Tabel 5-6) and an average Eh of 0.8 volt, ground water conditions at OU1 are considered very oxidizing.

While these dissolved oxygen values probably represent high-end values for ground water based on the high calculated Eh values, they are useful for predicting a range of potential Eh values in ground water at the site. Figure 5-2 is an Eh-pH diagram showing the approximate range of ground water values for OU1 wells in relation to the distribution of Eh and pH regions considered oxidizing, transitional, and reducing for natural environments.

The oxidation potential of a system is important in assessing contaminant fate and transport and in applying remedial technologies for several reasons. First, the oxidation state of metals and radionuclides that have multiple oxidation states in large part determines the mobility of the metal and in some cases the toxicity. For example, the solubility and mobility of ferrous iron, $Fe^{+2}_{(aq)}$, the reduced form of iron, is orders of magnitude greater than that of ferric iron, $Fe^{+3}_{(aq)}$, the oxidized form of iron under most environmental conditions. Similarly, trivalent plutonium ($Pu^{+3}_{(aq)}$) is soluble and mobile relative to Pu(IV), which forms the highly insoluble oxide, $PuO_{2(c)}$. In contrast to iron and plutonium, the oxidized form of chromium, hexavalent chromium ($Cr^{+6}_{(aq)}$) is highly soluble and mobile as the anion $CrO_4^{-2}{}_{(aq)}$, in comparison to the reduced chromium species, $Cr^{+3}_{(aq)}$, which forms the relatively insoluble compound, $Cr(OH)_{3(c)}$. Other transition metals, and radionuclides such as uranium and americium, exhibit similar behavior.

Second, the oxidation state of a species may determine its relative toxicity. Using chromium as an example, hexavalent chromium is considered more toxic than trivalent chromium. Considering the higher solubility and mobility of hexavalent chromium relative to trivalent chromium, it is

essential to determine the oxidation state of the metal before its fate and transport behavior can be evaluated. Determining the oxidation potential of soils and ground water at a site is therefore important from a public health standpoint when modeling the transport of dissolved inorganics.

Third, the type of microbial communities present in the subsurface will depend upon the oxidation state of the environment. Heterotrophic bacteria can only degrade compounds residing on primary or secondary substrates in the presence of an electron acceptor. The electron acceptor will be oxygen in an aerobic (oxidizing) environment or sulfate, nitrate, or carbon dioxide in an anaerobic (reducing) setting (Suflita 1989). Environments with measurable dissolved oxygen such as OU1 will likely support aerobic bacteria over anaerobic forms. This is significant for OU1 because chlorinated solvents, such as those detected at IHSS 119.1, will degrade faster in an anaerobic environment than in an aerobic environment. Degradation rate constants are expected to be very low for chlorinated solvents under the oxidizing conditions at OU1.

Remedial approaches aimed at lowering concentrations of dissolved chlorinated solvents at OU1 using insitu biodegradation must use anaerobic or methanogenic bacteria to chemically reduce the already oxidized forms of carbon to carbon dioxide and water. This is typically done by introducing alternating pulses of oxygen and methane into the subsurface to stimulate any indigenous methanogenic bacteria (Lanzarone and McCarty 1990).

However, this approach will subsequently lower the system Eh, which will in turn decrease the stability of sesquioxides present in the geologic matrix. Decreased stability results in increased solubility of sesquioxide solids and may in turn release adsorbed or precipitated trace metals or radionuclides to solution. This will increase the concentration and mobility of these elements, and increase the chance of introducing contaminants to the environment that were previously bound in the solid phase. In addition, increased sesquioxide solubility will increase the dissolved solids concentration which may foul pumps or other mechanical remedial systems.

In similar fashion, the susceptibility of inorganic species to microbially mediated oxidation or reduction reactions is dependent upon the redox status of the environment (Suflita 1989). High dissolved sulfate in ground water at OU1 is likely to result from a combination of biotic and abiotic oxidation processes that convert sulfide phases such as pyrite to sulfate. Sulfide oxidation increases the solubility and mobility of sulfur in the subsurface environment at OU1. Pyrite has been observed in sandstone lenses of the basal Arapahoe Formation in a road cut east of the Solar Evaporation Ponds vicinity at RFP (EG&G 1992b).

Soil and Ground Water pH

Tables 5-6 lists surface soil pH values. The OU2 surface soil trenching program included the soil pH measurements for three trenches located within OU1 (DOE 1991a). Soil pH was recorded for various depth intervals from surface to 120 cm depth. Values ranged from pH 6.4 to 8.2, with a mean of 7.4, indicating that slightly alkaline conditions exist in OU1 surface soils. One hundred twenty four (124) subsurface soil samples from OU1 were analyzed for soil pH. Values ranged from a minimum of 7.05 to a maximum of 8.60, with a sitewide mean value of 7.80. These results indicate that subsurface soils at OU1 are alkaline as well.

Alkalinity of soils depends on the strength of the base that is formed in the soil solution. For the calcium carbonate rich soils at OU1, the formation of $Ca(OH)_{2(aq)}$ in solution likely results in pH values approaching 8 and in some cases, 8.60. High sodium values in ground water suggest that the occurrence of the complex $NaHCO_{3(aq)}$ in soils may also regulate pH values.

The significance of alkaline soil pH values at OU1 is twofold. First, the buffering capacity of calcium carbonate-rich soils at OU1 acts to neutralize organic acids that are produced in the A-horizon of site surface soils. Neutralization of acids keeps the pH from fluctuating and reduces the potential for mobilizing metals and especially radionuclides (eg., plutonium) that are present in surface soils. Second, alkaline pH values act to precipitate metals or radionuclides that have been introduced to surface or subsurface soil by anthropogenic processes. At pH values greater than 5 or 6, most inorganic cations will precipitate as hydroxides or carbonates, thereby reducing

their mobility and ability to migrate to ground water. In addition, the precipitation of metal hydroxides such as ferric iron hydroxide, will reduce the concentration of other metals by the process of coprecipitation.

The pH of water in contact with the geologic media will affect the transport of contaminants by influencing the magnitude and type of surface charge on clays and other media solids. For smectites, the surface charge is relatively independent of pH because the surface charge is due to cation substitutions in the silicate framework. However for other clay minerals, silica, and metal oxides, the surface charge is dependent upon pH. Values of pH obtained during fourth quarter 1991 sampling of ground water from wells at OU1 range from 7.17 to 8.18, and average 7.59.

At acidic pH values the matrix surfaces will be positively charged due to the adsorption of hydrogen ion, H^+, and cation exchange and cation adsorption will be low. Similarly, alkaline pH values result in negatively charged surfaces and relatively high CEC and cation adsorption values (Drever 1988).

The parameter that determines the surface charge of a substance is the isoelectric point or the pH at which the surface charge is zero. Table 5-4 also lists some of the isoelectric points for various naturally occurring substances. It is apparent from this table that at the pH values observed at OU1, many of the materials will have negative surface charges. As a result, cation exchange and cation adsorption should be significant processes retarding the mobility of metals and radionuclides at the site. Figure 5-3 shows the effects of pH on the adsorption of trace metals by iron and aluminum.

Inorganic Ground Water Chemistry

The inorganic chemistry of surface and ground waters at OU1 were characterized using the computer program HC-GRAM (Version 2.22). This program was used to create Stiff and Piper (trilinear) diagrams to graphically characterize the major cation and anion chemistry of selected

surface and ground waters at OU1. Chemical input to HC-GRAM consisted of dissolved concentrations of major cations (calcium, magnesium, sodium, potassium, and iron) and major anions (bicarbonate, sulfate, chloride, and carbonate) for each water analysis. Output on Stiff diagrams were in chemical units of milliequivalents per liter. Output on trilinear diagrams were in terms of percent of total milliequivalents per liter.

Figures 5-4 and 5-5 depict Stiff diagrams for surface water and ground water in the upper HSU, and lower HSU, respectively. The width of a Stiff diagram is a function of the total dissolved solids and is typically an indication of residence time in the aquifer with increasing total dissolved solids directly proportional to increased residence time. Wells with narrow Stiff patterns (low total dissolved solids) are likely receiving recharge from near-surface sources. Wells with wide Stiff patterns are likely intercepting water that has been in contact with the aquifer long enough to dissolve a significant amount of solutes. However, some deep bedrock wells exhibit Stiff patterns similar to shallow wells (low total dissolved solids); conversely some shallow alluvial wells have wide Stiff patterns indicative of long residence times. This suggests that some deep wells may be receiving direct recharge from near-surface sources and similarly some shallow wells.

Surface water from the South Interceptor Ditch and Woman Creek were used to characterize surface water chemistry at OU1. Samples from the South Interceptor Ditch were taken from surface water stations SW031, SW044, and SW066. Woman Creek stations included SW032, SW033, and SW034. Surface waters from the South Interceptor Ditch and Woman Creek are characterized by calcium-bicarbonate water and low total dissolved solids. Total dissolved solids range from 335 to 400 µg/l in South Interceptor Ditch water, and from 230 to 235 µg/l in Woman Creek. Chloride is the secondary anion in both South Interceptor Ditch and Woman Creek waters. Concentrations of magnesium and sodium/potassium are typically similar at all stations. Ion concentrations in surface waters are typically less than 5 milliequivalents per liter, producing a relatively narrow Stiff pattern indicative of low total dissolved solids. The close grouping of the six surface water analysis on the trilinear diagram (Figure 5-6) illustrates the similarity of the

major ion chemistry of Woman Creek and water from the South Interceptor Ditch. Cation abundances are almost identical whereas anion concentrations show some differences. Figure 5-6 is a trilinear diagram representing surface water chemistry. Figures 5-7 and 5-8 are trilinear diagrams of alluvial and bedrock ground water, respectively. The trilinear diagram shows the effects of the mixing of upstream Woman Creek water (point e) and water from the small tributary (point f) to produce water of intermediate composition represented by point d.

Ground water at OU1 ranges from calcium bicarbonate water in alluvial wells screened close to the surface to calcium sulfate, sodium bicarbonate, and sodium sulfate water in deep bedrock wells. One well, 34791, an alluvial well located in IHSS 199.2, has calcium chloride water. This well is screened at a depth of 6.0 to 8.0 feet below ground surface. The proximity of this well to the site decontamination pad suggests that chloride from the pad is influencing the anion chemistry. Other wells that have high chloride also exhibit high sulfate, suggesting an extended residence time wherein sulfate and chloride have an opportunity to buildup over time.

The distinction between alluvial wells and bedrock wells based on major cation and anion chemistry is often unclear. This suggests that mixing between alluvial water and bedrock water may occur in some places. In addition, changes in the geologic and mineralogic composition of subsurface materials, such as the existence of caliche zones along slump block planes (source of calcium carbonate), the occurrence of abundant clay (sites of cation exchange), or the differential weathering of primary and secondary solids in the geologic matrix likely influences the chemistry of OU1 ground water.

Attempts to identify sitewide trends in the water chemistry data were unsuccessful as anion concentrations varied widely from well to well, and showed little correlation to depth of well or flowpath. However, trends and chemical signatures were established for some localized areas. Ground water in wells screened close to the surface or in wells that are in hydrologic connection with surface waters often exhibit chemical characteristics that are similar to surface waters, but with higher amounts of total dissolved solids.

Geochemical Modeling of OU1 Ground Water

Equilibrium modeling using the geochemical code WATEQ was used in order to understand the processes controlling the geochemistry of ground water at OU1. Water chemistry data from two monitoring wells, 35691 and 31891, were examined because these wells lie along the flow path of ground water in the western part of OU1. Modeling was performed using dissolved (filtered) analyte results from the wells to determine the degree of saturation of the analytes relative to their respective solid phases. This process enables the model to determine potential solubility controls on dissolved species at each well, in addition to establishing possible solubility controls on trace metals and radionuclides. While the modeling of ground water chemistry using WATEQ assumes equilibrium between the dissolved and solid species and does not account for the presence of "dissolved" colloidal particulates, it is very useful in establishing reasonable estimates of the chemical state of a system. Parameters listed in Table 5-7 lists the chemical and physical characteristics of dissolved species in ground water used as the input parameters to WATEQ. Table 5-8 lists the results for potential mineral phases and the calculated saturation indices as determined by WATEQ for each solid species for the two wells.

Although the equilibrium model results can only be considered as rough estimates of the actual conditions at the two wells, they do indicate the general supersaturation of the water with respect to calcium, iron and manganese solid phases. Supersaturation with respect to the iron and manganese solid phases is especially significant because of the "scavenging" effect that precipitating iron and manganese solids have on the removal of trace metals (and potentially radionuclides) from solution (Runnells 1976; Drever 1988; Sposito 1989).

The most noticeable difference between the two wells is the magnitude of the total dissolved solids (TDS) concentrations as ground water moves downgradient. Decreases are noted for all dissolved analytes with the exception of orthophosphate, fluoride, and nitrate/nitrite. Other parameters such as pH, temperature, and oxidation potential (calculated from dissolved oxygen) remain relatively constant between the two wells. Decreases in TDS suggest that some

mechanism(s) is controlling the solubility of dissolved ions, indicating that a potential scavenging effect may be operating.

5.2.1.2 Contaminant Physical and Chemical Properties

Important physical and chemical properties for organic contaminants at OU1 include the aqueous solubility, vapor pressure and Henry's law constant (K_h), octanol-water partition coefficient (K_{ow}), organic carbon partition coefficient (K_{oc}), potential transformation products, and the susceptibility of the contaminant to various forms of abiotic and biotic degradation. Chemical and physical properties of chlorinated organic contaminants detected at OU1 are listed in Table 5-9, and semivolatile compounds are listed in Table 5-10. Because radionuclides are inorganic species they are discussed separately in Section 5.2.2.3.

Physical State

The physical state of a chemical contaminant is defined as its most stable form at ambient temperature and pressure (ATP). At OU1, ambient conditions are defined as an average annual temperature of 50°F and an average atmospheric pressure of approximately 613 millimeters of mercury (mm Hg) (RFP is approximately 6,000 feet above mean sea level). Pure phase VOCs at OU1 exist in the liquid state at ambient temperatures and pressures. However, because of the typically high vapor pressures of these compounds (ranging from 17.8 to 600 mm Hg) a significant fraction of these compounds can also exist in the vapor phase, especially when released to surface environments such as surface soils or surface waters. The majority of SVOCs organic compounds detected at OU1 exist in the solid state under ambient conditions. Exceptions include the AROCLOR compounds and naphthalene, which are liquids at ambient conditions.

Contaminants that exist in liquid form typically dissolve more readily in water and infiltrate subsurface soils and aquifers more rapidly than do those in solid form. Liquid phases with high vapor pressures are subject to volatilization to the gaseous phase. Gaseous phase contaminants have the potential to dissolve in water, migrate as a gas through the vadose zone soils, and potentially diffuse to the atmosphere.

Aqueous Solubility

The aqueous solubility of a compound is defined as the maximum concentration that will dissolve in a unit volume of water under specific conditions. The solubility of an organic compound is a function of the chemical and physical properties of the compound, and has been correlated with organic carbon partition coefficients (K_{oc}), Henry's law constants, and bioconcentration factors (BCFs).

Solubility is perhaps the most important parameter used to estimate the fate and transport of a compound in soil-water systems. The aqueous solubility of a chemical in part determines its mobility in ground water as well as its potential for biodegradation. Highly soluble chemicals are less likely to partition to soil or sediment (due to their low organic carbon partition coefficient), to volatilize from water (because of low Henry's law constants), to bioconcentrate in organisms (due to low octanol-water partition coefficients), and are generally more likely to biodegrade. Low solubility chemicals exhibit the opposite behavior (Howard et al. 1990).

For purposes of this discussion, organic compounds with solubilities of less than 50 µg/l are considered slightly soluble. At OU1 these compounds include most of the SVOCs. Compounds with solubilities greater than 50 µg/l but less than 10,000 µg/l are considered moderately soluble and include most of the volatile organic compounds at OU1. In general, the chlorinated solvents detected at OU1 have moderate to high aqueous solubilities, ranging from 150 µg/l (tetrachloroethene) to 20,000 µg/l (methylene chloride). Compounds with solubilities greater than 10,000 µg/l are considered highly soluble. At OU1 these compounds include methylene chloride (20,000 µg/l) and semivolatiles such as 4-methylphenol (24,000 µg/l) and benzoic acid (27,000 µg/l).

Vapor Pressure and Henry's Law Constant

The vapor pressure of a substance is the pressure at which a pure solution of a compound and its vapor are in equilibrium at a given temperature and pressure. The vapor pressure of a chemical determines its volatility and, hence, the tendency of a pure chemical to partition to the

gas phase. The chlorinated solvents at OU1 have typically high vapor pressures and correspondingly high volatilities. Vapor pressures for these compounds range from 17.8 mm Hg for tetrachloroethene to 600 mm Hg for 1,1-dichloroethene. SVOCs at OU1 have typically low vapor pressures and low volatilities, hence the designation "semivolatile" compounds.

The volatilization of a chemical dissolved in water is dependant upon the vapor pressure in addition to its aqueous solubility and its Henry's law constant. Henry's law constant (K_h) is defined as the ratio of the partial pressure of a compound in air to the concentration of the compound in water at a given temperature under equilibrium conditions (Montgomery 1992). Chemicals with a Henry's law constant of less than 10^{-7} atm-m^3/mol are less volatile than water and the concentration of the compound will increase as water evaporates. Chemicals with a Henry's law constant on the order of 10^{-7} to 10^{-5} atm-m^3/mol are considered moderately volatile and will volatilize slowly from water, and those with Henry's law constants on the order of 10^{-5} to 10^{-3} atm-m^3/mol are considered very volatile and volatilize rapidly from water (Howard et al. 1990). Henry's law constants for chlorinated solvents at OU1 range from 0.000978 to 0.034 atm-m^3/mole. Semivolatile values are typically lower by an order of magnitude or more than volatile organic compounds. Chemicals with high Henry's law constants, such as the chlorinated solvents at OU1, are expected to volatilize rapidly from surface waters and also to partition to soil gas in the vadose zone soils. SVOCs such as the polynuclear aromatic compounds in OU1 surface soils are not expected to volatilize from water or partition to soil gas.

Abiotic and Biotic Degradation

Degradation processes determine whether a chemical will persist in the environment or be transformed. Degradation processes may involve chemical or biological mechanisms. These mechanisms include, but are not limited to, photolysis, hydrolysis, oxidation, reduction, dehalogenation, and biodegradation. Surface processes involve chemical-, biological-, or photo-oxidation processes occurring in aerobic settings. Photochemical processes include both direct photolysis and sensitized photolysis. In direct photolysis, a compound adsorbs solar radiation and

is transformed, while in sensitized photolysis, the energy that transforms the compound is derived from another species in solution. Photolysis reactions may occur in either air, near-surface soils, or surface water.

Subsurface processes may involve oxidation or reduction processes often involving catalysis by microbes. Abiotic degradation processes in the subsurface are typically limited to hydrolysis or dehydrohalogenation reactions, although degradation by transient radicals such as peroxy radicals and singlet oxygen do occur for some chemicals (Howard et al. 1990). Dehydrohalogenation involves halogenated compounds and consists of the removal of a halogen atom and a hydrogen atom to form an ethene from a saturated halogenated compound. Reaction rates are dependent upon the degree of halogenation. Increased halogenation increases the rate of dehydrohalogenation (Olsen and Davis 1990).

In contrast, dehalogenation is the replacement of a halogen, such as chloride, by a hydrogen atom. This process is responsible for the transformation of one chlorinated ethene, such as trichloroethene, to another ethene such as dichloroethene. These reactions are essentially reduction reactions wherein an electron acceptor (chlorine) is replaced by an electron donor (hydrogen). As a result, these reactions are most likely to occur in anaerobic environments (Figure 5-9). For example, degradation of 1,1,1-trichloroethane produces 1,1-dichloroethane, 1,2-dichloroethene, and 1,1-dichloroethene as daughter products (Figure 5-10). The presence of various daughter products at OU1 suggests that some form of dehydrohalogenation may be occurring. However, because it is unknown how much of these compounds were present initially in drums stored at 119.1 it is impossible to tell how much is due to degradation processes.

Hydrolysis is a process in which a compound reacts with water, or with the hydronium or hydroxide ions associated with water. The reaction often involves the introduction of a hydroxyl group into the molecule and subsequent loss of another functional group, such as a halogen. The rate of hydrolysis is strongly dependent on pH. Sorption effects may also influence the rate of hydrolysis by controlling the availability of a compound to react with free radicals in solution.

It is well established that oxidized hydrocarbons such as chlorinated hydrocarbons require anaerobic conditions before biodegradation is effective. Biodegradation of chlorinated hydrocarbons under aerobic conditions occurs very slowly if at all (Vogel et al. 1987; Howard et al. 1990). Biodegradation in soils and ground water is expected to be low under the relatively oxidizing conditions found at OU1. Abiotic chemical degradation by hydrolysis or dehydrohalogenation should also be low under the oxidizing conditions. Under the relatively oxidizing conditions found in the subsurface at OU1, only reduced hydrocarbons (e.g., naphthalene or toluene) are likely to be degraded and only if the compound is in the dissolved phase (Howard et al. 1990). In contrast, the oxidizing conditions prevalent in surface soils will act to catalyze degradation reactions (biotic and abiotic) involving SVOCs. These compounds are susceptible to oxidation processes and are likely to degrade over time.

5.2.2 Contaminant Behavior

The environmental mobility of contaminants at OU1 is evaluated by considering the interaction between contaminant and media properties, and the probable fate and transport processes operating at the site. The mobility of each contaminant is then predicted for the appropriate environmental media in which the contaminant resides at OU1. Organic contaminants are discussed in Sections 5.2.2.1. and 5.2.2.2. Radionuclides are discussed in Section 5.2.2.3.

5.2.2.1 Volatile Organic Compounds

The majority of ground water contamination from chlorinated hydrocarbons occurs in wells screened in the upper HSU at IHSS 119.1. The origin of these compounds in ground water and subsurface soils is leakage from drums containing unknown quantities of chlorinated solvents and wastes that were stored at IHSS 119.1 from 1968 to 1971.

When chlorinated solvents are released to soils, they migrate vertically through the vadose zone by gravity and capillary forces. The volume of solvents that is retained in vadose zone soils is dependent upon whether dense non-aqueous phase liquids (DNAPL) are initially present in the drums, the octanol-water partition coefficient of the individual compounds, and the aqueous

solubility. The retention of chlorinated solvents in vadose soils increases with clay and organic matter content of the geologic media, octanol-water partition coefficients, and low aqueous solubility.

The presence of low part-per-billion amounts of tetrachloroethene, trichloroethene, 1,1,1-trichloroethane, and other chlorinated solvents in vadose zone soils indicates that some retention of these compounds has occurred. Calculations were performed on the highest concentration observed in vadose soils at IHSS 119.1 (tetrachloroethene at 93 µg/kg in boring 38191) to determine if residual free phase DNAPL was present, based on methodology established by Feenstra et al. (1991). This method uses the soil concentration to calculate a theoretical soil water concentration in contact with the soil to determine if DNAPL is present. The theoretical soil water concentration in contact with 93 µg/kg of PCE is 192 µg/l, or 0.13 percent of the solubility of PCE. This indicates that no DNAPL is present in OU1 vadose zone soils based on Phase III soil samples.

Table 5-11 lists ground water concentrations of the individual chlorinated hydrocarbons detected in wells for four quarters of 1991 and first quarter of 1992. This table shows the ground water concentrations detected at IHSS 119.1 and the percent of theoretical solubilities calculated from the ground water concentrations. The percent of theoretical solubility calculation is used to determine if any free phases chlorinated hydrocarbons, or DNAPLs, are present (Cherry 1991). Those concentrations exceeding 1 percent of theoretical solubility suggest that DNAPL may be present. Tetrachloroethene consistently occurs at concentrations above 1 percent solubility in wells 0974 and 4387, indicating that residual DNAPL is probably present in subsurface soils at IHSS 119.1. Trichloroethene also occurs at concentrations above 1 percent solubility in well 0974, as does 1,1,1-trichloroethane in well 4387. Given the hydrogeologically isolated nature of the saturated interval at IHSS 119.1, it may be that concentrations at 1 percent solubility only represent immobile residual DNAPL in saturated soils and not free phase mobile DNAPL. It must be made clear, however, that DNAPL at IHSS 119.1 has not been found in either soil or ground water samples.

Because DNAPLs have densities greater than water, they sink to the bottom of an aquifer and have the potential for further downward migration into underlying bedrock. The detection of chlorinated solvents in bedrock wells beneath IHSS 119.1 may indicate the migration of contaminants into the lower HSU or it may be due to cross-contamination from the upper HSU during the installation of these bedrock wells. Further monitoring of these wells is needed to determine if chlorinated solvents are actually present in the lower HSU.

Distribution Coefficients and Retardation Factors

The soil-water partition coefficient (K_d) for the saturated zone, is defined as the ratio of the concentration of the chemical on the solid phase to the concentration in the aqueous phase:

$$K_d = \frac{S}{C^{1/n}} \qquad (5\text{-}1)$$

where:

S is the concentration on the solid phase in µg/kg, C is the concentration in solution in µg/l and where 1/n is the Freundlich adsorption constant. The units of K_d are typically ml/g or l/kg. This relation is valid only if the partitioning of the chemical between solid and liquid is fast and reversible relative to the flow of ground water (Freeze and Cherry 1979; Olsen and Davis 1990). When n=1, a plot of S versus C is linear and is referred to as a linear adsorption isotherm. Nonlinear partitioning behavior can be described by the same equation but where 1/n is not equal to unity. The solid phase may be inorganic, such as a clay surface, or organic, such as soil organic matter or organic carbon (Olsen and Davis 1990).

Distribution coefficients used to describe the partitioning behavior of a contaminant in the presence of organic carbon are dependent upon the fraction of solid organic carbon in the soil-water system (f_{oc}) and the organic carbon partition coefficient (K_{oc}) according to the following equation (Lyman et al. 1982):

$$K_d = f_{oc} \times K_{oc} \quad (5\text{-}2)$$

K_{oc} is often calculated from a related parameter, the octanol-water partition coefficient, K_{ow}. K_{oc} is typically derived from K_{ow} using a regression equation prepared for related classes of compounds, and take the general form:

$$\log K_{oc} = a \log K_{ow} + b \quad (5\text{-}3)$$

where a and b are constants. Units of K_{oc} are typically given in l/kg or ml/g.

Both K_{oc} and K_{ow} are used in calculations to determine the distribution coefficients of chemicals in the subsurface. The K_{oc} is used to calculate K_d when matrix organic carbon is the solid medium and K_{ow} is used when inorganic surfaces are the primary solid (Olsen and Davis 1990). Partitioning in sediments with low organic carbon content (f_{oc} of 0.001 or less) becomes increasingly dominated by mineral surface interactions as the fraction of organic carbon decreases (Olsen and Davis 1990). When organic carbon levels in sediments are below a certain level, adsorption onto inorganic surfaces will predominate (McCarty et al. 1981; Karickhoff 1984). This level is termed the "critical level of organic carbon" and is designated as f_{oc}* (McCarty et al. 1981). In calculating distribution coefficients is therefore necessary to calculate the critical level of organic carbon for each contaminant of interest to determine which mechanism controls adsorption.

McCarty et al. (1981) have developed the following equation to determine the critical level of organic carbon that must be present before adsorption onto inorganic surfaces become important:

$$f_{oc}* = \frac{SA}{200\ (K_{ow})^{0.84}} \qquad (5\text{-}4)$$

where:

SA = the surface area of the matrix solids in square meters per gram, and

K_{ow} the octanol-water partition coefficient for the chemical of interest.

Calculations of the critical level of organic carbon using the McCarty equation for chlorinated solvents and sediments at OU1 are presented in Table 5-12. When the organic carbon content is below the critical level, the inorganic partition coefficient is used, which is based on the surface area of the sediment. McCarty et al. (1981) have developed an equation to calculate the inorganic partition coefficient or surface specific distribution coefficient, K_s:

$$K_s = \frac{SA}{200}\ (K_{ow})^{0.16} \qquad (5\text{-}5)$$

where:

SA = the surface area in square meters per gram of sediment

K_{ow} has been previously defined.

Examination of this equation reveals that as the surface area increases, so does the value of K_s, and the greater the adsorption of the chemical to the solid surface.

If a compound is under the influence of partitioning by both organic carbon and inorganic surface area, the total K_d can be calculated. Total K_d is the sum of the partitioning due to each medium (McCarty et al. 1981; Karickoff 1984) and is expressed as:

$$K_d \text{ (Total)} = (f_{oc} \times K_{oc}) + (f_{io} \times K_s) \quad (5\text{-}6)$$

where:

f_{io} = the fraction of inorganic material ($f_{oc} + f_{io} = 1$), and

K_s = the surface-specific distribution coefficient.

Table 5-13 presents distribution coefficients based on differing assumed percentages of inorganic surface areas. Total distribution coefficients are also calculated in this table as are retardation factors corresponding to each calculated total distribution coefficient.

Retardation factors (R_f) depend upon distribution coefficients to predict the velocity, or migration rate, of a solute relative to the rate of flow of the advecting media in which it resides. In the case of a contaminant in ground water, the velocity of the solute is typically less than the velocity of the water due to physical and chemical interactions between the solute (liquid phase) and the aquifer matrix (solid phase).

The retardation factor, R_f, that quantifies the velocity of the contaminant with respect to the velocity of the water, is dependant upon the properties of the geologic media and the properties of the contaminant as described by the following equation:

$$R_f = 1 + \frac{\rho K_d}{n} = \frac{V_w}{V_c} \quad (5\text{-}7)$$

where:

p = bulk density of the geologic media

n = effective porosity

Kd = distribution coefficient of the contaminant

Because the determination of the existence of equilibrium conditions at a site are difficult at best the potential exists for considerable error in assigning distribution coefficient values, and should be used with caution.

The greater the value of K_d (or K_s) the greater the compound is attracted to aquifer matrix and the slower it will migrate with respect to the ground water velocity. A chemical with a retardation factor of 1 is not retarded relative to the flow of ground water, whereas a retardation factor of 2 means that the chemical travels at one half the velocity of ground water. The following discussion reviews the procedure used to calculate a theoretical retardation factor for a compound in colluvial materials at OU1. The compound used in this example is trichloroethene.

Given a sample of colluvium containing 38.2 percent clay (sitewide average) and assuming a range of smectite values of between 20 and 80 percent (with a theoretical surface area of 100 m^2 per gram) the calculated f_{oc}* values are 0.0004 and 0.0015, respectively. These values are greater than the organic carbon content by a factor of 4 and 15, respectively, indicating that partitioning of trichloroethene will be dominated by adsorption to clay. The distribution coefficient is then calculated using the surface specific distribution coefficient equation (equation 5-5).

The calculated K_s values for trichloroethene are listed in Table 5-13, and are 0.092 and 0.367, respectively. The total distribution coefficient is also calculated, using an f_{oc} of 0.0001, resulting in values of 0.105 and 0.380. Retardation factors based on the total distribution coefficients, a bulk density of 1.77 g/cc, and an effective porosity of 10 percent, are 2.8 and 7.7. These calculations show that the migration of trichloroethene is significantly retarded relative to ground water flow in the clay-rich geologic materials at OU1.

Theoretical retardation factors have been calculated for VOCs detected at OU1 (Table 5-13). From Table 5-13 it is apparent that when smectite clay values are low (i.e., 20 percent of total clay content) the organic carbon-based distribution coefficient, K_d, is still smaller by as much a

factor of two for 1,1,1-trichloroethane and carbon tetrachloride, and smaller by a factor of 67 for methylene chloride, than the surface-specific distribution coefficient, K_s, given typical organic carbon values of 0.0001. Those compounds with higher organic carbon partition coefficients, K_{oc}, have higher K_d values than compounds with low K_{oc} values. Similarly, those compounds with higher octanol-water partition coefficients also have higher K_s values. Compounds with high K_{oc}, have higher K_d may values also have the highest retardation factors (e.g., tetrachloroethene). Considering the potential for high variability in K_{oc} and f_{oc} values, the use of these retardation factors should be used with caution. There may be large differences in mobility for a given compound in different environments. For example, mobility may be enhanced by facilitated transport, which includes cosolvent effects and particle transport (EPA 1989).

5.2.2.2 Semivolatile Organic Compounds

Semivolatile organic compounds (SVOCs) were detected in surface and subsurface soils and ground water at OU1. Physical and chemical properties of selected semivolatile organic compounds are listed in Table 5-10. The following discussion describes the environmental chemistry of these compounds and properties affecting the fate and transport and mobility of these compounds.

Polynuclear Aromatic Hydrocarbons

PAHs are hydrocarbons with more than one aromatic ring. This group of compounds comprises the largest number of SVOCs detected in soils at OU1. The vast majority of PAHs are solids at standard temperatures and pressures. These compounds are characterized by low solubilities, moderate to low volatilities, and moderate to high partition coefficients. PAHs are considered relatively immobile in soil-water systems (Howard et al. 1990). The absence of PAHs in deeper soil intervals or ground water at OU1 reflects the immobility of these compounds.

Volatilization is typically minor for PAHs with more than three-fused aromatic rings, which comprise the majority of OU1 PAHs. However, for naphthalene, a two-fused aromatic ring PAH and the simplest of the PAHs, volatilization may be significant for surface soils. The solubility

of naphthalene is about 32 µg/l, making it the most soluble and mobile of the PAHs (Howard et al. 1990). In contrast, chrysene, a four-fused aromatic ring PAH detected at OU1, has a solubility of 3.8 µg/l, approximately 8,500 times less than naphthalene. As a general rule, solubility, volatility, and biodegradation potential decreases with an increasing number of fused aromatic rings.

Many two-, three-, four-, and five-fused ring PAHs have been reported to undergo bacterially mediated mineralization in aerobic environments in the presence of oxygen (Bauer and Capone 1985; Keck et al. 1989). However, it has also been demonstrated that PAH mineralization will occur when alternative electron acceptors such as nitrate, manganese (Mn^{+4} or MnO_2), iron (Fe^{+3}), sulfate, and carbonate are present (McFarland and Simms 1991). Free energy calculations indicate that PAH oxidation will utilize the following electron acceptors in sequential order: Mn^{+4}, O_2, NO^{3-}, Fe^{+3}, MnO_2, FeOOH, SO_4^{-2}, and CO_2 (McFarland and Simms 1991).

The presence of these additional electron acceptors in soils and ground waters at OU1 has been established. In soils at OU1, oxygen and the ferric and manganese oxyhydroxides will be the primary oxidants, whereas in ground water, oxygen, NO^{3-}, SO_4^{-2}, and CO_3^{-2} should be the main oxidants. The occurrence of PAHs in the presence of the aforementioned oxidants in near-surface soils at OU1 suggests that PAH degradation is expected to occur, especially in the near-surface soils (0 to 6 feet) in which most of the PAHs are found. In addition, the high soil-water partition coefficients of most PAHs suggest that partitioning to the aqueous phase will be low and that mobility in the soil-water system at OU1 will also be low. However, the potential for eolian transport as adsorbed phases onto dust particles will be relatively high if the PAHs are exposed at the surface due to the high affinity of PAHs for the solid phase.

Other semivolatiles detected in soils at OU1 include 2,4-dimethylphenol, 4-methylphenol, dibenzofuran, pentachlorophenol, benzoic acid, AROCLOR-1248, AROCLOR-1254, and di-n-butylphthalate. All of these compounds were detected in minor amounts in near-surface soils

(0 to 6 feet), with the exception of pentachlorophenol (0 to 6 feet and 6 to 12 feet) and di-n-butylphthalate (0 to 6 feet, 6 to 12 feet, greater than 12 feet).

2,4-Dimethylphenol and 4-methylphenol were detected in near surface (0 to 6 feet) soils at one location only (IHSS 130, borehole 36591) at concentrations of 89 µg/kg and 140 µg/kg, respectively. These chemicals are associated with coal tar and asphalt products, such as the asphaltic materials encountered in subsurface soils at IHSS 130.

2,4-Dimethylphenol has an aqueous solubility of 6,200 µg/l and an octanol-water partition coefficient of 200. It is highly susceptible to biodegradation, with a half-life of hours to days (Howard et al. 1990). It is also expected to moderately adsorb to soils. 4-Methylphenol is very soluble in water (24,000 µg/l), has a low octanol-water partition coefficient (87), and is very susceptible to biodegradation.

The very low concentrations of these compounds in soil and the absence of them in ground water suggests that these compounds are probably adsorbed to soil and may be subject to biodegradation processes in the oxidizing near-surface environment of IHSS 130. The absence of these chemicals at depth in soils suggests that they are relatively immobile in their present locations.

Dibenzofuran was detected at two locations at OU1 (boreholes 36591 and 36391) at concentrations of 1,700 µg/kg and 110 µg/kg, respectively. Dibenzofuran is also associated with coal-tar and asphaltic materials. Dibenzofuran has an aqueous solubility of 10 µg/l, an octanol-water partition coefficient of 13,182 (Table 5-10), and is expected to partition strongly to soils. Dibenzofuran is susceptible to biodegradation in aerobic environments such as the near surface soils at OU1, and is not expected to mobilize from its present location. Concentrations of dibenzofuran in soils at OU1 should decrease readily with time.

Pentachlorophenol was detected at depths up to 12 feet in soils at borehole 36391 at low concentrations of 250 µg/kg and 390 µg/kg. It has a solubility of 14 µg/l, and an octanol-water partition coefficient of 151,356. Pentachlorophenol has a very strong affinity for the solid phase and is not expected to desorb from soils to ground water, as evidenced by its absence in ground water.

Benzoic acid was detected in near surface soils (0 to 6 feet) at two locations (IHSS 130) at concentrations of 230 µg/kg and 840 µg/kg. Benzoic acid has an aqueous solubility of 27,000 µg/l, an octanol-water partition coefficient of 74, and a dissociation constant (pKa) of 4.2 (Howard et al. 1990). Given an average soil pH of 7.8 at OU1, over 99.9 percent of the acid is expected to occur in the dissociated form. Benzoic acid is highly susceptible to biodegradation. Biodegradation half-lives of less than one week for soils and 0.2 to 3.6 days for water have been reported (Howard et al. 1990).

Benzoic acid is expected to be highly mobile in soils given the low octanol-water partition coefficient and high solubility. However, the absence of benzoic acid in soils at depths greater than 6 feet, and its absence in ground water suggests it is being retained in the near surface soils, and probably undergoing rapid biodegradation. Therefore, benzoic acid at OU1 is not expected to migrate from its present location and should disappear from soils relatively soon.

PCBs were detected in two locations at OU1. AROCLOR-1248 and AROCLOR-1254 were both detected at IHSS 119.2 in borehole 33291 at concentrations of 7,200 µg/kg and 5,200 µg/kg, respectively. AROCLOR-1254 was also detected in borehole 36791 at a concentration of 480 µg/kg. All detects of PCBs were within the upper 6 feet of soil.

AROCLOR-1248 and AROCLOR-1254 are characterized by very low solubilities (54 µg/l and 57 µg/l, respectively), very high octanol-water partition coefficients (log K_{ow} = 6.11 and 6.47, respectively), and low susceptibility to biodegradation in aerobic soils (Montgomery and Welkom

1990). The absence of PCBs in ground water at OU1 reflects its immobility in soil-water systems.

PCBs are expected to be very immobile given the high K_{ow} values and the high clay content in alluvium at OU1. As a result of the high affinity for the solid phase, adsorption of PCBs at OU1 are expected to be very substantial. As a result, potential migration pathways for PCBs at OU1 are probably limited to eolian transport on soil or dust particulates. Biodegradation is not expected to be an important degradation process at OU1 due to the oxidizing conditions observed there. However, abiotic processes such as dehalogenation may act to reduce the concentration of PCBs over time.

5.2.2.3 Radionuclides

Nuclear properties of radionuclides are listed in Table 5-14. Based on Phase III data, the majority of radionuclide species occurring above background at OU1 are found in surface soils (0 to 2 inches) and to a lesser extent to 6 foot depths in alluvial/colluvial materials (see Section 4.0). The primary source of radionuclides at OU1, specifically plutonium and americium, is from the 903 Pad. The occurrence of uranium isotopes at levels above or below background is attributed to natural sources and is discussed in detail later in this section.

The geochemistry and mobility of radionuclides in soil-water systems is controlled by a variety of processes, including adsorption, ion exchange, complexation, precipitation, and oxidation/reduction reactions (Brookins 1988). However, the absolute effect that each of these processes has on the mobility of individual radionuclides in a soil cannot be directly determined without site-specific data that quantitatively describe the soil-radionuclide interactions. These data usually involve specially designed laboratory experiments, such as batch or column tests, for individual radionuclides. However, in the absence of such tests, use of published soil/water distribution coefficients in conjuction with known OU1 soil properties (e.g., organic carbon content, clay content, and soil pH) can be used to derive qualitative estimates of radionuclide

mobilities in site soils. Table 5-15 presents published distribution coefficients for radionuclides detected at OU1 for four major soil types.

Distribution coefficients typically describe adsorption processes. Adsorption processes are surficial reactions involving organic carbon and/or inorganic solids such as clays and iron oxyhydroxides that involve the transfer of a radionuclide from the liquid phase to the solid phase. In general, radionuclide adsorption increases with increases in organic carbon and clay and iron oxyhydroxide content.

For surface soils at OU1, the relatively high organic carbon content of the A-horizon indicates that adsorption of radionuclides will be high. In contrast, the low organic carbon content of subsurface soils (alluvium and colluvium) indicates that adsorption is controlled by fine-grained inorganic solids and metal oxyhydroxides. The high surface charges of these solids act to preferentially adsorb multivalent elements with high ionic potentials (charge to radius ratios) such as plutonium and americium. Alluvial/colluvial deposits at OU1 average slightly more than 38 percent clay, so adsorption of radionuclides to the solid phase is expected to be very high at OU1. In the vadose zone soils at OU1, where the moisture content ranges from 8.2 percent to 25.8 percent and conditions are oxidizing, the mobility of all radionuclides should be very low, approaching relative immobility. Even during episodic recharge events when the water to rock ratio is at its highest the mobility of most radionuclides should be at a minimum. Individual radionuclides are discussed below regarding their predicted behavior and mobility under the conditions known at OU1.

Plutonium

Plutonium (Pu) is a transuranic radioactive element produced by fission reactions in nuclear reactors, by the explosion of nuclear fission devices, and by natural radioactive processes. There are 15 isotopes of plutonium, with half-lives ranging from minutes to thousands of years. The principal isotope of plutonium, plutonium-239, has a half-life of 24,400 years and a specific activity of 6.13×10^{10} pCi/g. A similar isotope, plutonium-240, has a half-life of 6,580 years.

Small amounts of plutonium-239 are produced naturally in uranium minerals, such as pitchblende and carnotite, by neutron capture of uranium-238 followed by beta-decay of the resulting uranium-239 and neptunium-239 (Faure 1991).

Plutonium is stable in two oxidation states in most natural environments as Pu^{+3} or Pu^{+4}. Pu(III) is the dominant species in acidic environments, whereas plutonium(IV) is the dominant species under alkaline or oxidizing conditions, such as at OU1. Figures 5-11a and 5-11b are Eh-pH diagrams for plutonium (Brookins 1988). Figure 5-11a shows plutonium species for the system Pu-O-H. This figure illustrates that solid plutonium dioxide ($PuO_{2(c)}$) is stable over the range of Eh-pH conditions present in the subsurface at OU1. This species has an extremely low solubility at near-neutral pH values. For example, at a pH of 7.5, the solubility of $Pu^{+4}_{(aq)}$ ion in equilibrium with solid $PuO_{2(c)}$, in the absence of complexing, is approximately $10^{-37.5}$ molar or 10^{-32} µg/l.

Figure 5-11b depicts the system Pu-C-O-H, showing the stability ranges for the hydroxide species of plutonium. The important difference between diagrams is that Figure 5-11b predicts that under alkaline and oxidizing conditions, a soluble form of plutonium, $Pu(OH)_5^-{}_{(aq)}$ is potentially stable, by the hydroysis of solid $Pu(OH)_{4(c)}$. The formation of this species would be likely to occur only under high water to rock ratios, such as would occur during recharge events in the vadose zone soils (Brookins 1988). However, thermodynamic calculations indicate that the conversion of plutonium hydroxide to plutonium dioxide is mildly exothermic, indicating that with sufficient time, freshly precipitated $Pu(OH)_{4(c)}$ will convert to $PuO_{2(c)}$. Conversion of the hydroxide to the oxide would reduce the potential to release the Pu-hydroxide anion to solution and thereby lower its potential mobility. The relatively low seasonal recharge rates at RFP favor the formation of $PuO_{2(c)}$.

In general, plutonium species have a strong affinity for the solid phase as indicated by the high K_d values listed in Table 5-15. Mean distribution coefficients range from 550 ml/g in sandy soils (>70 percent sand-sized particles) to 5,100 ml/g in clay soils (>35 percent clay-sized particles).

A value of 5100 ml/g indicates that plutonium is strongly adsorbed to clay particles, and is also expected to undergo strong cation exchange reactions due to its strong positive charge. The restricted occurrence of plutonium at OU1 in near-surface soils and the lack of plutonium in surface or ground water is consistent with plutonium behavior documented in the literature.

Americium

Americium (Am) is produced by the beta-emission disintegration of plutonium-241 (Poet and Martell 1972; Faure 1991). Americium has the potential to exist in two oxidation states in natural systems, americium (III) and americium (IV), however trivalent americium is the most stable form.

Figure 5-12 is the Eh-pH diagram for americium for the system Am-C-O-H (Brookins 1988). There are two main fields of stability for americium species at pH values typically found in natural systems. For acidic pH values of 6 or less, the trivalent americium cation is stable. For pH values above 6, the carbonate solid, $Am_2(CO_3)_{3(c)}$, and the solid americium dioxide, $AmO_{2(c)}$, are stable (Brookins 1988). For conditions at OU1, where carbonate-rich sediments and ground water exist, the americium carbonate solid should be the stable form.

Americium is known to be strongly adsorbed to clays and carbonate solids such as calcite. Data for the equilibrium partitioning of americium to calcite is on the order of 10^5 or greater (Faure 1991). The positive three charge on the trivalent americium ion indicates that it is strongly partitioned by adsorption or ion exchange such as to solids (silts, clays, and iron oxyhydroxides) that exhibit high negative surface charges. Because the subsurface sediments and soils at OU1 have a high percentage of these solids, americium solubility and mobility in the vadose zone soils, in ground water, and dissolved in surface water at OU1 should be very low. Americium does have the potential, however, to be transported as an adsorbed particle via eolian transport or overland flow to surface water if it is present at the soil-atmosphere interface.

Uranium

Uranium (U) exists in nature in two oxidation states, uranium(IV) and uranium(VI) (Hem 1985). The Eh-pH diagram presented in Figure 5-13 depicts the system U-C-O-H, which can be used to describe the geochemistry of uranium in carbonate-rich soils and ground waters such as at OU1. In general, the environment at OU1 is oxidizing with ground water pH values between 7 and 8. Soil pH values range from 7.05 to 8.60, confirming that an alkaline soil-water environment exists.

Examination of Figure 5-13 shows that tetravalent uranium is relatively insoluble in soil-water systems, existing primarily as the solid species $UO_{2(c)}$ across the entire spectrum of pH values, and at reducing Eh values. When oxidized to the hexavalent form uranium is highly mobile under all pH conditions, except for a limited area around pH 5 to pH 6.5 where the uranium carbonate is stable, precipitating as $UO_2CO_{3(c)}$. At pH values greater than 6, the uranyl carbonate complex $UO_2(CO_3)_2^{-2}{}_{(aq)}$ becomes stable thereby increasing the solubility of uranium. At highly alkaline values, the highly soluble complex $UO_2(CO_3)_3^{-4}{}_{(aq)}$ is stable.

The occurrence of uranium at all depths in soils at OU1 (ranging from 3.24 pCi/g at borehole 31091 to 0.01 pCi/g at borehole 33791) and the detection of uranium in site ground water suggests that uranium is mobile under OU1 site conditions. The apparently homogenous distribution of uranium in subsurface soils could also be explained as the random distribution of naturally occurring uranium in the Rocky Flats alluvium/colluvium at OU1. Given the alkaline nature of OU1 soils, high carbonate content, and relatively oxidizing conditions in the subsurface, it is highly likely that the soluble uranium anion complex, $UO_2\ (CO_3)_2^{-2}$, is stable at OU1.

Uranium isotopes found in surface and subsurface soils at RFP also occur naturally in sedimentary and precambrian rocks just a few miles west of RFP. Therefore, it must be determined if the occurrence of uranium at OU1 is man-made (enriched or depleted) or natural. The method used to distinguish these sources compares the isotopic mass abundances of uranium isotopes at OU1 to known isotope ratios for natural, depleted, and enriched uranium. Natural

uranium is composed of 99.2739 percent uranium-238, 0.72 percent uranium-235, and 0.0057 percent uranium-234. Depleted uranium is composed of 99.75 percent uranium-238, 0.25 percent uranium-235, and 0.0005 percent uranium-234. Enriched uranium is composed of 97 percent uranium-238, 3 percent uranium-235 and 0.03 percent uranium-234 (EG&G 1988). Table 5-16 lists the ratios of uranium isotopes in surface soils at OU1. The average percentage of uranium-238 is 99.268 percent, uranium-235 is 0.727 percent, and uranium-234 is 0.005 percent. These ratios indicate that uranium at OU1 is well within the mass percentage values for natural uranium. A verification of the mass ratio calculations can be made by comparing the activity ratios of uranium-234 to uranium-238. Natural activity ratios are close to 1.0. Uranium ratios at OU1 average 0.98, confirmation that uranium in surface soils at OU1 is naturally derived.

Similar calculations were also performed on subsurface soil and surface water samples at OU1. The average percentage in surface soils of uranium-238 is 98.854 percent, uranium-235 is 1.14 percent, and uranium-234 is 0.006 percent. Activity ratios of uranium-234 to uranium-238 average 1.17. Surface water samples average 99.78 percent uranium-238, 0.207 percent of uranium-235, and 0.0079 percent uranium-234. The uranium-234/uranium-238 activity ratio in surface water is approximately 1.48. These values also fall within the ranges for naturally occurring uranium.

5.2.2.4 Metals

The paucity or absence of trace elements and trace metals above background in OU1 ground water indicates that various mechanisms in site soils are acting to restrict the solubility of these elements and therefore the movement of these elements to the dissolved phase. These mechanisms have been discussed earlier in this section, and include such processes as adsorption to clays, iron oxyhydroxides and other reactive solid phases, ion exchange reactions, precipitation and coprecipitation reactions, and oxidation-reduction reactions. In the clay and iron oxyhydroxide-rich matrix of OU1 colluvium, these processes are likely restricting the availability and mobility of these elements.

Table 5-5 lists trace elements that are subject to coprecipitation by various solid phases. In addition, Figure 5-3 shows the effect of solution pH values on the adsorption of various metal cations. For the slightly alkaline pH values of soils and ground water at OU1, it is apparent that adsorption to solid phases is likely controlling the solubility of trace metals that are found in the vadose zone soils.

In summary, the occurrence of metals in soils at OU1 appears to reflect natural variability of soils derived from alluvium or claystone bedrock sources. The lack of dissolved metals in ground water at OU1 suggest that natural reactions diminish metal availability for transport in ground water. Furthermore, modeling indicates that the chemistry would favor precipitation of most metals because of the major element characteristics and reaction dynamics. This would act to retard most metal transport.

5.2.3 Summary of Processes and Behavior

Of the media transport processes controlling potential routes of contaminant migration at OU1 soil, ground water, surface water and sediment, air, anthropogenic, and biotic processes only a few of these processes are considered significant. The importance of each media transport process is dependent upon the extent to which each process operates, which in turn affects the transport of contaminants from the source area to a potential receptor. In addition, each transport process is potentially affected by processes that attenuate contaminants during the transport process. Attenuation processes include processes such as adsorption, biodegradation, or oxidation-reduction reactions. The processes responsible for redistributing contaminants at the individual IHSSs at OU1 differ in significance at each IHSS. Those transport pathways identified as significant for the OU1 IHSSs are discussed below.

Contaminants were originally introduced to the environment at OU1 by waste storage, disposal, or discharges to surface soils. Surface and vadose zone soils (colluvium) are therefore considered as both a primary host of contaminants and a pathway for contaminant migration to surface water, ground water, sediments, soil gas, and the atmosphere.

Transfer of contaminants from soils to surface water and sediments at OU1 occurs primarily by wind erosion. Transfer by surface water erosion and overland flow events are minimized by the South Interceptor Ditch. Transfer of contaminants from soils to upper HSU ground water has occurred at OU1 as a result of leaching or desorption mechanisms in response to percolating meteoric water. Transfer of contaminants from soils to soil gas is generally restricted to the insitu volatilization of VOCs, and to a lesser extent SVOCs. Similarly, minor releases to the atmosphere occur by volatilization of VOCs and by suspension of contaminated soil and dust particles by wind.

IHSSs 102, 103, 105, 106, 107, and 145 are areally small and represent discrete spill or liquid disposal sites. Contamination at these areas ranges from spotty low-level occurrences of SVOCs in near-surface soils (predominantly PAHs in low ppm to low ppb levels), to low levels of radionuclides in near-surface soils, and low levels (ppb) of VOCs and trace metals in ground water.

The most important migration processes identified in the aforementioned IHSSs are leaching and desorption of contaminants by infiltrating meteoric water to ground water and the subsequent capture of those contaminants by the french drain. Lesser migration processes identified in this area include volatilization of VOCs to soil gas and the atmosphere, and suspension of near-surface contaminants by eolian processes and surface water runoff. Volatilization of contaminants to soil gas and to the atmosphere is considered very minor due to the extremely low concentrations of volatile and semivolatile contaminants in this area. In addition, the low permeability of the clay-rich subsurface soils restricts the mobility of gases in the subsurface. Similarly, suspension of VOC and SVOC contaminants from surface soils by eolian processes is also considered insignificant because of low concentrations.

Transport and distribution of radionuclides by wind and surface water are potentially important pathways at OU1. The high distribution coefficients of most radionuclides partitions them to the solid phase, effectively immobilizing them in soils, unless the soil particles are physically moved.

As a result, redistribution of adsorbed radionuclides by soil or dust particles mobilized by wind is considered a major potential pathway at OU1. Surface water transport of radionuclides is considered a minor pathway. The virtual absence of radionuclides in ground water precludes this as a pathway.

The very low levels (low ppb) of SVOCs and VOCs in soils in these IHSSs are most likely attenuated by chemical and biological degradation processes that restrict their mobility and lower their concentrations with time. The trace amounts of VOCs and SVOCs in ground water near Building 881 are subject to capture by the french drain.

Metals in soils and ground water in this area occur at levels approaching background and are not considered contaminants. In addition, the metals that have been detected in media at the site are being effectively attenuated and immobilized by a combination of adsorption and coprecipitation reactions due to site geochemical and geologic parameters.

IHSSs 104, 119.1, 119.2, and 130 are sites where disposal and releases of both solid and liquid wastes have occurred over extended periods of time. Subsurface soils at these sites contain low levels (low ppm to low ppb levels) of SVOCs, radionuclides, and VOCs. SVOCs and radionuclides are the most frequently detected contaminant group in near-surface soils. SVOCs occur predominantly at IHSS 130 in low ppm and ppb levels. Radionuclides occur across the eastern and northern parts of OU1 at low picocurie per gram levels. VOCs are present in subsurface soils and ground water at IHSS 119.1.

Ground water beneath these eastern IHSSs occurs as small and hydraulically isolated "pools" that are isolated by local bedrock highs. Flow in these areas appears to be temporal or nonexistent with the exception of possible vertical flow to the lower HSU induced by vertical gradients. As a result, lateral flows of upper HSU ground water in the eastern areas of OU1 is considered a potentially insignificant pathway. Transport of contaminants from the upper HSU to the lower

HSU with subsequent lateral migration is a possibility and ground water in this area should continued to be monitored.

The bulk of contaminated ground water at OU1 occurs at IHSS 119.1 where spills and leaks of chlorinated hydrocarbons from drums stored at the surface have contaminated underlying soils and ground water. Ground water contamination by chlorinated hydrocarbons also occurs at IHSS 119.2 and south of Building 881, occurring at very low ppb levels. Recent installation of an extraction well at IHSS 119.1 will decrease the migration potential of ground water contaminants in both the upper and lower HSU by decreasing both lateral and vertical hydraulic gradients. However, migration of upper HSU ground water to lower HSU ground water is a possible contaminant pathway especially in well 6286, located south of IHSS 119.2. The detection of trace amounts (low ppb levels) of carbon tetrachloride and other VOCs in bedrock well 6286 may be from sources in OU2. This suggests that cross-contamination between the two operable units may be occurring. Further monitoring of the lower HSU ground water at this location is recommended.

The concentrations of metals in soils and ground water occur at levels approaching background and are not considered contaminants at OU1. Of those metals that do exist in concentrations exceeding background, natural attenuation processes such as oxidation reactions, precipitation, and coprecipitation should act to keep these metals relatively immobilized.

In summary, based on Phase III data for OU1, contaminants at the site occur in discrete and limited areas, predominantly as SVOCs and radionuclides in surface soils, and VOCs in ground water. The main body of SVOCs occur as asphaltic materials in IHSS 130, where adsorption processes are likely acting to immobilize the dissolved fraction of these compounds insitu and chemical and biological degradation and oxidation processes should decrease the concentrations with time. Contaminated ground water is mainly limited to VOC-contaminated ground water at IHSS 119.1, with lesser amounts south of IHSS 119.2, and south of Building 881. The isolated ground water flow regimes at 119.1 and 119.2 restrict migration of those contaminants to other

areas via the ground water pathway. Radionuclides in surface soils should be highly immobile due to the extremely high soil/water distribution coefficients of these elements.

5.3 CONTAMINANT MIGRATION

Contaminant migration is of concern from the dual standpoints of understanding how time will alter the nature and extent of contamination and where, and at what levels, receptor populations might be exposed to contamination over time. Section 5.3 discusses processes active along potential migration routes at OU1 that create complete migration pathways where contaminants are or may be transported. Section 5.3 also presents a discussion of selected contaminant behavior along the delineated migration pathways, and where appropriate, summarizes the results of modeling undertaken for the baseline risk assessment to quantify contaminant flux and predict plausible exposure concentrations.

Section 5.3.1 describes the characteristics of the migration pathways of unsaturated and saturated zones, surface water, and air in terms of the Phase III revised conceptual model. Using these pathway conceptual models, Section 5.3.2 discusses the applicability of contaminant transport modeling in light of the available Phase III data. Section 5.3.2 also briefly summarizes quantitative modeling of contaminant transport in soil gas, surface water, and the atmosphere, which was performed to simulate exposure point concentrations. Ground water flow modeling was not conducted because of the lack of a complete transport pathway for contaminated ground water and the recent installation of the french drain, which was designed and constructed to intercept the flow of all ground water present in the upper HSU at OU1. For a detailed discussion of the modeled migration pathways and a presentation of the complete methodology and results of the public health evaluation modeling effort, refer to Appendix F (Volume XIV) of this report.

5.3.1 Migration Pathways

In order to evaluate the relative vulnerability of an aquifer to contamination from surface sources, EPA's DRASTIC system can be employed (EPA 1987a). This system systematically evaluates

and assigns weights to seven physical parameters that cumulatively result in a vulnerability index value representing the relative vulnerability of an aquifer to surface contaminant sources. The physical parameters evaluated in the model are depth to water, recharge characteristics, aquifer media characteristics, soil media characteristics, topography, impact of vadose zone, and hydraulic conductivity. Qualitative evaluation of these parameters, which are presented in Section 3.0 of this report, indicates that the lower HSU at OU1 would have a low vulnerability index value. This conclusion is based on the documented low recharge rates, low hydraulic conductivity, steep topography, and very poor aquifer characteristics (e.g., heterogeneity, anisotropy, and discontinuous water-bearing strata) associated with the lower HSU. Evaluation of the upper HSU would result in a higher vulnerability index value due to its shallower depth and locally coarser-grained and weathered nature. However, this unit is extremely heterogeneous, variably saturated, and the water-bearing zones are very limited in areal extent; therefore, the resulting vulnerability index value would be reduced greatly in significance. The DRASTIC system analysis adds perspective regarding the scale and significance of potential groundwater contamination migration pathways at OU1.

Substantial differences have been identified in the nature and extent of ground water contamination in the western portion of OU1 surrounding Building 881 and in the eastern portion of OU1 by IHSS 119.1. Each of these areas has unique sources, different contaminant suites and concentration ranges, as well as differences in migration pathways. The presence of contaminants or other indicator constituents detected in a pathway indicates the completeness of the pathway. This also is a reflection of the degree to which contaminant migration is now active or has been active in the past. The sections below discuss possible pathways recognized in the western and eastern areas of OU1 and assess the degree of completeness of each pathway.

5.3.1.1 Building 881 Area

As discussed in Section 4.0, contaminants were only infrequently detected in spatially separated locations in and around Building 881 vadose zone soils. The reported concentrations were generally at low to trace levels, and with the exception of the VOCs that were detected, the

contaminants found exhibit relatively immobile behavior (Section 5.2). Also, contaminants were detected only infrequently in ground water in this area. Where contaminants were detected, concentrations characteristically were at low levels, commonly approaching lower detection limits. Therefore, as discussed in Section 4.0, there is generally little contamination available for transport in the Building 881 area. Migration pathways in the vicinity of Building 881 are discussed below in the context of the few contaminant detections that have been reported.

The presence of a continuous saturated zone from Building 881 to the Woman Creek valley fill alluvium distinguishes it from the eastern area by IHSS 119.1 where ground water occurs in isolated and discontinuous zones. The ground water flow path in the Building 881 area has been characterized as having an average linear flow velocity ranging from 10 to 20 feet per year (Table 3-15). This ground water flow pathway is presently intercepted by the french drain, which captures ground water flowing in the upper HSU downgradient of Building 881 (Appendix B4).

Organic contaminants detected in upper HSU ground water in the vicinity of Building 881 include sporadic detections of VOCs at low µg/l concentrations during several sampling events in several monitoring wells proximal to, but downgradient of Building 881, and a one-time detection of a single SVOC in a newly installed well during fourth quarter 1991.

VOCs similar to the ones found in ground water south and southwest of Building 881 have also been detected in soils just southeast of Building 881, and near IHSS 103. However, there does not appear to be a direct hydrologic connection between those borehole locations with VOC detections and monitoring wells with VOC detections (Figures 3-28, 3-44, 4-13, 4-14, 4-15, 4-49, 4-50, 4-51, 4-52, 4-94, and 4-96). In addition, the lack of consistent repeat detections in ground water from these monitoring wells and the absence of VOC detections in monitoring wells downgradient from the area indicates that the vadose zone soils are not presently acting as significant sources of VOCs to ground water.

A detection of alpha-benzene hexachloride in Phase III monitoring well 35691 occurs during fourth quarter 1991. This SVOC, also known as alpha-lindane, is relatively immobile in water and a photodegradation product of gamma-lindane, a pesticide. This compound was not detected in soil samples collected from the borehole in which this well was constructed, nor was it detected in soil or ground water samples elsewhere at OU1. No source in vadose zone soils or ground water has therefore been shown for this contaminant. Judgment as to whether this one-time detection is reflective of contamination should be withheld until after confirmatory sampling has been conducted. The well casing at 35691 was damaged during construction of the french drain in January 1992, and further monitoring is questionable. Additional data needed to verify alpha-benzene hexachloride in ground water are unavailable at this time.

Besides the major elements calcium, magnesium, sodium, and potassium, which were occasionally detected above RFP background in ground water, the trace elements antimony, chromium, copper, nickel, strontium, and zinc were also detected above the calculated RFP background values in a limited number of fourth quarter 1991 samples. These metals were only elevated in new Phase III wells installed in or near artificial fill materials near Building 881. The effects of aquifer trauma associated with the physical disturbance of these materials during drilling may be the cause for the elevated metals in these wells. First quarter 1992 sampling results indicate that only copper and strontium occur above background, and in fewer wells, compared to fourth quarter 1991. This suggests that the effects of aquifer trauma in these wells are being stabilized and concentrations of these metals should continue to decrease with time.

So, while a potential ground water pathway exists in the area surrounding Building 881, it is clear from the ground water monitoring that substantial contaminant migration is not presently taking place nor has it taken place historically due to an apparent lack of contaminant sources. Additionally, according to the Phase III analyses there are no demonstrated sources of mobile organic contaminants that are readily available in vadose zone soils for release to ground water for transport. The migration of inorganic soil constituents, with the possible exception of naturally occurring uranium, is also suppressed due to soil and ground water geochemical

conditions. The french drain presently intercepts the water flow path in this area of OU1 and is capable of capturing upper HSU ground water should any contamination appear in the future.

Volatilization from ground water into soil gas is not a substantial migration process in the area surrounding Building 881 as is indicated by low concentrations and sporadic detections of VOCs in ground water. Very low soil and ground water VOC concentrations also indicate that a separate nonaqueous phase is not present in soils or ground water in this part of OU1.

Shallow subsurface soil data from the 0- to 6-foot interval indicate that locally SVOCs, including PAH compounds, and some metals and radionuclides above RFP background would be susceptible to eolian transport by resuspension of fugitive dust. Aerially limited detections and low concentrations indicate that this pathway has not been a significant factor in past contaminant distribution in the vicinity of Building 881. Similarly, because only limited areas in this area have elevated contaminants at the surface susceptible to wind or surface water transport, these pathways are not considered to be important mechanisms for substantial current or future contaminant migration.

In summary, pathways active in the past in the western area and around Building 881 have included only limited transfer of VOCs from vadose zone soils to upper HSU ground water. Ground water in this area of OU1 is estimated to flow southeasterly at a rate of 10 to 20 feet per year. Volatilization from ground water to soil gas, with subsequent discharge to the atmosphere, does not cause substantial migration because the low concentrations detected in ground water do not constitute a viable source for soil gas transport. Radionuclide-contaminated particulates have been distributed in limited areas over surficial soils in the western areas of OU1 with very little vertical subsequent migration in the vadose zone soils. Some minor surface water/overland flow may have taken place, but the effects of this cannot be separated from wind blown dispersion and are considered negligible.

5.3.1.2 IHSS 119.1 and Well 6286

A very limited volume of saturated materials above bedrock in the vicinity of IHSS 119.1 significantly reduces the potential for ground water transport in the upper HSU pathway. The absence of continuous, hydraulically connected saturated zones in the upper HSU in this part of OU1 indicates that ground water flow here is not a viable lateral migration pathway. For example, there is not a physically complete route in the upper HSU for the dissolved VOCs in and near IHSS 119.1 to migrate from the site. For this discrete body of ground water, lateral flow does not occur for most of the year because of the physical barriers to flow caused by low permeability bedrock materials. During low water table conditions, ground water here is essentially in a static condition where inflow from infiltration and lateral recharge matches outflow from evapotranspiration and vertical infiltration to the lower HSU, resulting no net loss or gain of water.

During a short period at the end of spring and early summer, water levels rise in response to increased in precipitation and snowmelt. At this time, water levels may rise enough to allow ground water to flow over the bedrock surface and permit an apparent ground water flow path to exist. If high water table conditions in the upper HSU exist for 3 months, then flow may proceed for approximately 10 to 20 feet downgradient (based on one quarter of average linear ground water velocity values presented in Table 3-15). The potential downgradient advancement of ground water is expected to be lost to evapotranspiration during the remaining 9 months of the year. Figures 5-14 and 5-15 present a conceptual model of this system during the typical and extended lower water table period and the short high-water-table conditions, respectively.

Concentrations of total VOCs in ground water at IHSS 119.1 monitoring wells and in downgradient wells confirm this conceptual model. Concentrations of VOCs in wells at IHSS 119.1 tend to remain steady from year to year, although there is some variability of individual contaminant concentrations. Concentrations of VOCs tend to increase during low water table conditions and decrease because of dilution during high water table conditions. This systematic seasonal variability indicates little or no net loss of VOCs.

The possibility for lateral flow and transport of VOCs has been reduced even further for this pathway by the installation and operation of the collection well affiliated with the french drain. Extraction of ground water from this well will reduce or possibly reverse the hydraulic gradient in the area for the purpose of capturing VOC-contaminated ground water beneath IHSS 119.1. Vertical migration of VOCs has taken place through the vadose zone soils and the upper HSU to the lower HSU, in and downgradient of IHSS 119.1.

The lack of companion SVOCs in ground water below IHSS 119.1 suggests that co-solvent effects that could potentially mobilize normally immobile SVOCs into ground water from soils are not active in this location. The lack of VOC and SVOCs together in the same sample or in adjacent samples from the same boreholes in IHSS 119.1 soils further supports the premise that the mobility of SVOCs has not been augmented by VOC solvents present in the soils and ground water.

Many of the same VOCs have been detected in Phase III soil samples in IHSS 119.1, which indicates that the contaminants in ground water have passed through vadose zone soils, leaving residual traces adsorbed to soil particles. Alternatively, elevated concentrations of some VOCs in ground water suggests the possible presence of an immobile residual nonaqueous phase in saturated zone materials.

Volatilization of VOCs from ground water to soil gas is a viable pathway at IHSS 119.1. An estimate of the concentration of VOCs in soil gas with subsequent flow into a hypothetical building on 881 Hillside was computed in the public health evaluation included in Appendix F of this report. This modeling showed that in theory sufficient mass of contaminants were transported to hypothetical future occupants to slightly elevate risk from exposure to certain inhaled VOCs.

The presence of several repeat low-level detections of VOCs have also been observed in bedrock monitoring well 6286, however, no contaminant source is conclusively documented in this area.

Monitoring well 6286 is potentially downgradient from IHSS 119.2 and was completed in fine-grained sandstone of the upper Laramie Formation, which could act as a very restricted migration pathway. Very little upper HSU ground water is present at IHSS 119.2, so vertical migration would be directly through vadose zone soils to the lower HSU with little intervening residence of contaminants in saturated materials of the upper HSU. No VOCs were detected in Phase III soil samples from IHSS 119.2, so the Phase III results do not directly link IHSS 119.2 as the source for VOCs detected in lower HSU ground water at monitoring well 6286.

Evaluation of Figure 3-44 indicates the presence of a potential ground water pathway to monitoring well 6286 originating from the northeast, apparently near OU2. Preliminary analyses of ground water at OU2 indicates the presence of a similar suite of VOCs as detected in well 6286. As discussed for the IHSS 119.1 area, this pathway in the upper HSU may only exist for only a few months during the year. As discussed in Section 3.7.3, well 6286 may reflect upper HSU ground water conditions since the sand pack extends upward into the contact of the colluvium and Laramie claystone. This is supported by the Stiff diagram for this well, which has characteristics of upper and lower HSU water. Therefore, a potential pathway exists for contaminants to migrate to this location from the OU2 area through upper HSU materials and appear in this well.

Tetrachloroethene was detected both in soil gas at IHSS 119.2 during previous soil gas investigations and in a fourth quarter 1991 ground water sample from monitoring well 6286. Therefore, only one VOC contaminant found previously in soil gas at IHSS 119.2 corresponds with the same compound found in ground water at well 6286. Based on this similarity and the fact that monitoring well 6286 may be downgradient from IHSS 119.2, IHSS 119.2 may be a potential source for contamination in monitoring well 6286. However, as previously discussed, a more plausible source exists at OU2.

A one-time low-level detection of chloroform was reported in Phase II ground water sampled from monitoring well 4587, a bedrock well beneath IHSS 119.2. Chloroform and has been

detected repeatedly in monitoring well 6286 through first quarter 1992. Monitoring well 6286 is south of, and topographically lower than, monitoring well 4587, although monitoring well 4587 has a lower water level. This suggests that the two wells are not completed in hydrologically connected units (Figures 3-24 and 3-50). Therefore, no clear groundwater pathway is expected to exist between these two locations.

Surficial soils in the eastern part of OU1 containing plutonium, americium, and SVOCs are susceptible to surface transport by eolian resuspension and surface water runoff. Shallow subsurface soil data from the 0- to 6-foot interval indicate that locally SVOCs, including PAH compounds, would also be susceptible to eolian transport by resuspension of fugitive dust. When compared with deeper borehole depth intervals, the greater number of detections and higher detection levels for plutonium and americium in the uppermost samples from Phase III boreholes indicate that eolian transport has been a factor in past contaminant distribution and dispersion in the eastern OU1 area. This conclusion is drawn from the subsurface soil analytical data.

In summary, the primary pathways that are active in discrete areas in the eastern OU1 area include the transfer of VOCs from vadose zone soils to upper HSU ground water in small local zones but with little subsequent lateral flow, eolian transport of contaminated fugitive dust and surface soil particulates, and limited transport by surface water/overland flow.

At IHSS 119.1, some limited vertical migration from the vadose zone soils and/or upper HSU to the lower HSU appears to be taking place. At IHSS 119.1, VOCs have been introduced into the lower HSU ground water below the site where little lateral flow is taking place in the upper HSU. It is unclear whether the low concentrations of VOCs detected in bedrock monitoring wells results from vertical contaminant migration or cross contamination of the lower HSU during well installation. Also potentially active at IHSS 119.1 is volatilization from upper HSU ground water to soil gas with subsequent discharge to the atmosphere. Radionuclide-contaminated particulates originating near 903 Pad in OU2 have been distributed onto surficial soils in the eastern OU1 area with only very limited vertical migration in the vadose zone soils. After

deposition by eolian transport, some subsequent limited surface water/overland flow and anthropogenic remobilization may have taken place.

5.3.2 Modeling Methods and Results

The three most important pathways for transport of contaminants of concern to potential human receptor populations have been modeled for the public health evaluation. The contaminants of concern are a subset of the total list of detected analytes that have been selected based on a number of criteria including frequency of detection, carcinogenic nature, detection at concentrations statistically greater that background, and other factors. Technical Memorandum 8, *Contaminant Identification* (Appendix F attachments) describes the process used to screen for human health contaminants of concern and presents the list derived for the OU1 public health evaluation.

The three modeled pathways include volatilization of organic compounds from ground water to soil gas with subsequent transfer to the interior of a hypothetical building, eolian transport of resuspended contaminated soil and fugitive dust, and episodic surface water transport of contaminated surficial soil particles by overland flow with ultimate deposition in the South Interceptor Ditch. These three pathways are considered to be more important in the eastern part of OU1 than in the western part of OU1 because there is more contamination in media available for transport. A fourth migration pathway, that of ground water transport in the upper HSU, is not considered a viable pathway. If the water table is high enough for groundwater to flow, it will be intercepted by the french drain. Additionally, the isolated contaminated ground water below IHSS 119.1 is captured by the newly installed collection well for the french drain. Therefore, ground water transport was not modeled for the Phase III RFI/RI at OU1.

Section 5.3.2 summarizes the results of modeling conducted for the public health evaluation and presents a synopsis of the findings. Appendix F presents the complete modeling discussion. The modeled estimates can be compared to measured values at locations equivalent to the designated exposure point.

5.3.2.1 Soil Gas Transport

The objective of soil gas modeling is to predict the transport and resulting concentrations of contaminants through the soil gas pathway at a given exposure point. These predictions are used in conducting the OU1 Public Health Evaluation. For a more detailed coverage of the soil gas modeling, refer to Appendix F (Attachment F-3).

Technical Memorandum 7, *Description of Models* (attached to Appendix F) describes the models considered for this effort. Considering site conditions, the Johnson and Ettinger (1991) soil gas model (hereafter called the Johnson model) was selected as most appropriate to simulate potential future conditions in a hypothetical structure at OU1 affected by the migration of VOCs in soil gas volatilized from contaminated ground water in the saturated zone. The models were used to simulate conditions for a hypothetical future on-site commercial/industrial worker and a hypothetical future on-site resident. Typical building dimensions were assumed as those that could be constructed in the future on the hillside east of Building 881. Technical Memorandum 6, *Exposure Scenarios* (attached to Appendix F) describes these and other exposure scenarios. This model calculates diffusion of contaminants from the source in ground water to a location near the base of the hypothetical structure, estimates the migration of the gas through the wall or floor of the structure, and then predicts the concentration of contaminants in gas based on mixing calculations, taking into account ventilation within the building.

In applying the model, various input parameters are used for the calculations and estimates. These include chemical parameters such as contaminant concentration in ground water, Henry's law constant, coefficients for organic carbon partitioning, distribution, molecular diffusion in air and water, and effective diffusion. Contaminant concentrations from IHSS 119.1 ground water samples were used for the model. Other input parameters include environmental conditions such as evaporation, relative humidity, temperature, and material properties such as bulk density, moisture content, hydraulic conductivity, fraction of organic carbon, intrinsic permeability, and porosity. Characteristics of the residential and commercial buildings included area, volume, and

air exchange rates. These parameters were assembled from a variety of site-specific data, RFP data, and literature values where appropriate.

Input parameters for the following contaminants of concern were compiled for the modeling:

- Carbon tetrachloride
- Chloroform
- 1,1-Dichloroethene
- total 1,2-Dichloroethene
- Dichlorodifluoromethane
- Methylene chloride
- Tetrachloroethene
- 1,1,1-Trichloroethane
- Trichloroethene
- Trichlorofluoromethane

The Johnson model does not contain a temporal component and therefore considers a nondepleting source, projecting concentration results as constant through time, or effectively approximating steady-state conditions. This approach produces a highly conservative building concentration for hypothetical future on-site receptors and yields one concentration value per contaminants of concern.

As part of the modeling, a sensitivity analysis was completed to qualitatively examine model response to variability in the following input parameters: fraction of organic carbon, intrinsic permeability, porosity, building under-pressurization, volumetric moisture content, and soil bulk density. Carbon tetrachloride is most sensitive to fraction of organic carbon, moisture content, porosity, and dry density. The other contaminants of concern exhibited similar responses to the variation in input. The sensitivity of the model to these parameters can be attributed to the effective diffusion coefficient, which is the property principally responsible for volatilization of an organic compound. For VOCs residing predominantly in the gas phase, the effective diffusion

coefficient is proportional to the 1000 times the volumetric air content. Therefore, an increase in soil water content decreases volatilization flux over any time period (Jury et al. 1990).

After completion of the sensitivity analysis, an uncertainty analysis was conducted for the parameters of porosity, moisture content, bulk density and fraction of organic content for the contaminants of concern listed above. Additionally, predicted building concentrations were assessed considering the uncertainty of the concentration of each contaminant of concern. The results of the uncertainty analysis, using Latin hypercube sampling and simple random sampling methodologies, were used as input into the Johnson model.

Residential/commercial building concentrations derived using the Johnson model are given in Table 5-17. These results are steady-state (i.e., a constant concentration source) and represent a conservative approximation of building concentrations. Building concentration distributions for each contaminant of concern from the Johnson model are assumed to be log normal and results (mean and standard deviation) are presented as natural log values.

5.3.2.2 Ground Water Transport

For the 881 Hillside area, the construction and operation of the french drain simplifies the ground water flow system beneath the site by reducing ground water travel times and distances. The french drain was assumed to be 100 percent effective in capturing shallow, contaminated ground water (Section 3.5.1.1). Therefore, to provide a conservative simulation of soil gas transport, ground water transport is assumed to be so slow that no measurable ground water transport over 30 years would occur. Based on this assumption, no ground water transport was simulated.

5.3.2.3 Surface Water Transport

The purpose of the surface water transport modeling is to estimate the potential concentration of contaminants in the South Interceptor Ditch caused by future erosion of surface soils by overland flow in OU1. Sediment within the South Interceptor Ditch was sampled and chemical analyses were performed as part of the Phase III RFI/RI, with the exception of data from the new

OU1-specific sediment sampling stations (SED037, SED038, and SED039). These data are probably affected by contaminants from the 903 Pad area (DOE 1991b).

An empirical mathematical model was used to evaluate potential future contaminant transport from OU1 surface water erosion. For this estimate, the ratio of the area of contaminated soil to the total OU1 area on 881 Hillside was used to calculate contributions of contaminants of concern to the South Interceptor Ditch. It was assumed that each IHSS is uniformly contaminated over its entire area. Input parameters required for the modeling include the area of OU1, the area of contaminated soil, contaminant concentrations in soils, soil erodibility, soil losses due to vegetation grading, contouring, roads, slope length, and the erosive energy of rainstorms. A detailed description of the surface water modeling is provided in Appendix F and includes computations, assumptions, and limitations. Much of the data presented in Technical Memorandum 7 (DOE 1992e) was collected prior to the Phase III field investigation, however, Phase III data were used in the actual modeling.

The contaminants of concern considered for the modeling of surface water or overland flow included the following:

- Acenaphthene
- Fluoranthene
- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Dibenzo(a,h)anthracene
- Fluorene
- Plutonium-239,-240

Results of the surface water modeling are summarized in Table 5-18.

The modeling results can be compared to measured values. From these comparisons it can be concluded that the modeled estimate of contaminant concentration in sediment delivered to the South Interceptor Ditch is less than measured detections at stations in the South Interceptor Ditch. However, it should be noted that the source for contaminated sediment in the South Interceptor Ditch includes not only OU1 but the 903 Pad as well, which has been identified as a source of contaminated sediment (DOE 1991b).

5.3.2.4 Atmospheric Emissions and Transport

Air modeling was performed to provide estimates of emissions, dispersion, and deposition of contaminants, including SVOCs and radionuclides, present in OU1 surface soils. The scope of the atmospheric transport modeling included modeling both near-field (on-site) and far-field (off-site) scenarios. Far-field models are more complex and include most of the requirements of near-field models, with the addition of transport, dispersion, and deposition of contaminants. Technical Memorandum 7, *Description of Models* (Appendix F) describes the air modeling methodology for the OU1 public health evaluation.

In summary the air modeling used the MILDOS-AREA code (Yuan et al. 1989) to model particulate emissions from the source, transport in air, and deposition at receptor locations for contaminants originating at OU1. This model can be used to determine the amount of contaminants released and the contaminant concentrations at the receptor location, rather than actual receptor doses. The MILDOS-AREA code was not used to compute the actual point concentrations of individual contaminants. Rather, the code was used to derive unit concentration factors at receptor locations based on unit concentrations in soil at the source. Once concentrations at the receptor locations were calculated, near-field models were then applied. Appendix F includes assumptions for and limitations of the modeling methodologies, a discussion of the application, a summary of the model parameter input, and the computational framework.

The results of the MILDOS-AREA simulation run were used to convert soil contaminant concentrations at OU1 into contaminant concentrations at receptor locations. The

far-field model was used to estimate the total annual emission of contaminants per unit contaminant concentration in soil at OU1.

The concentration of each of the contaminants of concern measured in OU1 surface soils was multiplied by 30-year-average scaling factors presented in Table 5-19. This was used to determine the concentration of each contaminant in air (as respirable particulates - PM10) and in soil at the location of the current off-site resident. These contaminant-specific concentrations are presented in Table 5-20. The on-site concentrations of respirable contaminants in air, calculated using the box model of the near-field model, are also presented in Table 5-20. The exposure point concentrations resulting from the air emission and transport pathways are used in the public health evaluation to estimate the risks to exposed individuals. Appendix F presents additional details regarding the application and results of the air emission and transport modeling.

Section 6.0 · Text

Baseline Risk Assessment

Phase III RFI/RI Report

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6.0 BASELINE RISK ASSESSMENT

Section 6.0 summarizes the environmental evaluation and the public health evaluation and determines the overall risk to both the environment and human health from potentially toxic contaminants present at OU1. Both evaluations use data collected through the Phase III RFI/RI conducted at OU1 during 1991 through spring 1992. Figure 6-1 illustrates the relationship of risk evaluation activities in the RI/FS process. Section 6.1 provides a brief overview of the specific requirements of each evaluation process at OU1. Section 6.2 summarizes the environmental evaluation and Section 6.3 focuses on the public health evaluation conducted at OU1. A summary of these risk evaluations is presented in Section 6.4

6.1 SIMILARITIES AND DIFFERENCES OF THE ENVIRONMENTAL EVALUATION AND THE PUBLIC HEALTH EVALUATION

The public health evaluation and environmental evaluation are integral components of the OU1 baseline risk assessment. Both consider the OU1 conceptual model of site conditions, contaminants, and exposure pathways with respect to determining risk to potentially exposed populations. However, there are procedural differences in evaluating the data against the site conceptual model. These are discussed in general below.

Human health risk assessment and environmental risk assessment are procedurally different, but they share common information needs for chemical sampling and environmental data. Data requirements on stressors (any physical, chemical, or biological entity that can induce an adverse effect) will vary from site to site for public health evaluation and environmental evaluation reports. These data are used to provide an analysis of baseline risks and help determine the need for possible remedial action at sites within the OU1 study area. The ecological risk assessment for the OU1 environmental evaluation differs distinctively from the public health evaluation in its emphasis in five areas:

- Ecological risk assessment considers effects beyond those on individuals of a single species (i.e., *Homo sapiens*) and examines impacts at population, community, or ecosystem levels.

- No single set of ecological values can be generally applied for the environmental evaluation. The values (e.g., level of acceptable diversity) are selected from a number of possibilities based on both scientific and policy considerations.

- Only chemical stressors that are bioavailable need to be considered for the environmental evaluation, thus contaminants of concern will be different.

- Only noncarcinogenic stressors are assessed in the environmental evaluation, thus the contaminants of concern will be different.

- The public health evaluation study area includes the 881 Hillside area and neighboring community residents outside the RFP boundary, while the environmental evaluation study area includes portions of Woman Creek and its tributaries.

Flexibility is important in designing both public health and ecological risk assessments. Unique models or methods play an ever-increasing role in attempts to determine the effects of contaminants in the ecosystem. Knowledge of toxicology and ecology are combined to assess variation in both natural and anthropogenic sources of stress in the ecosystem of which humans and wildlife coexist. Ecological impacts can cause loss of habitat and thereby loss of species. Loss of wildlife species is a yardstick of overall environmental quality—a common threat to humans.

6.2 ENVIRONMENTAL EVALUATION

Section 6.2 summarizes the environmental evaluation as provided in Appendix E. Subsections of Section 6.2 parallel those in Appendix E, without the extensive detail.

The principal objective of the remedial investigation at RFP is to collect data necessary to determine the nature, extent, distribution, and migration pathways of contaminants within the OU1 study area that have the potential to cause adverse ecological impacts. The responsibility of Appendix E—the environmental evaluation for OU1—is to determine if contaminants of concern that are potentially the result of plant releases are producing adverse ecological impacts.

The ecological evaluation in this report is conducted using a three step process. The first step (screening) consists of identifying potential contaminants of concern that are known to be present at OU1. The second step, ecological risk assessment (characterizing potential impacts), consists of reviewing research and regulatory findings to determine potential toxicity and behavior of contaminants of concern in the soils, surface waters, and sediments. The third step, ecological comparison (actual ecological impacts), consists of evaluating ecological data from RFP to determine if measurable ecological impacts result from contaminants of concern at the OU1 study area.

The environmental evaluation consists of an ecological risk assessment and ecological comparisons. A five-step process for the ecological risk assessment was used, while ecological comparisons consisted of two components. The ecological risk assessment steps were data collection, data evaluation, toxicity assessment, exposure assessment, and risk characterization. The ecological evaluation consisted of species diversity and trophic level comparisons between the OU1 study area and Rock Creek watershed, the reference area.

The period of chemical and biological data collections at RFP for the OU1 environmental evaluation was January 1991 through March 1992. A total of 139 biological tissue samples were collected to determine if contaminants of concern were bioavailable to the ecosystem. Ecological samples of plant and animal taxa, populations, and communities reported 399 taxa. There were 219 species of plants and 180 taxa of animals within the OU1 study area. The most important factor affecting species diversity in communities at RFP is the amount of moisture available to support plant growth, the primary producers in the food web, and food for animals.

Results of the ecological risk assessment section are presented under three headings—toxicity assessment, exposure assessment, and risk characterization.

6.2.1 Toxicity Assessment

The toxicity assessment considers chemicals at OU1 that present a significant threat to ecological receptors and evaluates their potential toxicity. General toxicity information on each contaminant of concern is used to develop TRVs and FRVs for comparison with actual and estimated exposures at OU1. The first stage screening of contaminants of concern included heavy metals, cyanide, and radionuclides (because of their high profile at the site) that have been detected above background in soils, surface water, or sediments at OU1. Soils, surface water, and sediments are considered the main pathways for direct exposure of ecological receptors to contaminated media. The second stage screening process was based primarily on exceedance of RFP background concentrations, and secondarily on relative toxicity and bioavailability. The screening process identified chromium, lead, and zinc for soils; chromium, lead, and mercury for surface water; and no contaminants of concern were identified for sediments. Radionuclide levels in environmental media was of no concern to ecological receptors because of the very low concentrations.

6.2.2 Exposure Assessment

The exposure assessment is conducted to estimate the magnitude of actual or predicted exposure concentrations and pathways by which ecological receptors are potentially exposed to contamination from the contaminants of concern occurring at IHSSs within the OU1 study area. Several very restricted areas have elevated concentrations of heavy metals in the soil. Most metals did not exceed background concentrations by more than twofold and probably do not represent contamination from releases at RFP. The background concentration of contaminants of concern at RFP was assumed to be below the toxicity threshold for metals of ecological receptors. Moreover, the exposure assessment failed to provide clear evidence of transport of contaminants away from the localized source areas at IHSSs. However, there was some evidence that sources in upgradient areas impacted water and sediment chemistry in areas adjacent to and downgradient from OU1. The upgradient areas having the highest metal concentration were natural ground-water seeps affected by the highly mineralized bedrock.

6.2.3 Risk Characterization

The risk characterization summarizes and combines outputs of the toxicity and exposure assessment sections to estimate the relative risk from exposure to contaminants of concern at OU1, both in quantitative expressions and qualitative statements. The risk characterization focuses on toxicological risks to ecological receptors from exposure to chromium, lead, zinc, and mercury, and the aggregate risk of simultaneous exposure to these contaminants of concern.

Chromium risks were assessed for soils and surface water. The Hazard Quotient method indicated a moderate risk level associated with the highest chromium concentrations in IHSSs 119.1 and 119.2 for soils and low risk level for all other sites in the OU1 study area. The overall risk to ecological receptors from exposure to chromium in soils in the OU1 area is low. Chromium was above background levels in surface water in only a single sample from sample station SW070. No samples exceeded the (chronic) Colorado Surface Water Quality Standard for total chromium of 170 µg/l. The restricted distribution of chromium at OU1 and lack of downgradient contamination indicate low risk to ecological receptors from exposure, and little or no risk of off-site transport.

Lead risks were assessed for soils and surface water. Lead was detected at concentrations above background in soils at four sites within and around IHSSs 119.1 and 119.2. Concentrations at three of the sites were approximately 10 percent above background. The fourth sample from IHSS 119.1 contained lead at 228 mg/kg, greater than fourfold the RFP background; a second sample from the same site contained only 78 mg/kg. These data suggest that lead contamination in soils within IHSS 119.1 at OU1 is highly localized. The Hazard Quotient value for exposure to lead by vegetation and soil invertebrates indicated moderate risk. Without the isolated high lead concentration in soil the mean lead value in the OU1 study area is in the range of RFP background concentrations. The Hazard Quotient method indicated low risk to ecological receptors from lead in soils at OU1 because of the restricted distribution. In surface water lead was above background for Woman Creek upgradient and downgradient of the OU1 study area. The highest lead concentration in the Woman Creek drainage was 13.2 µg/l from a tributary south

of the plant site and upgradient of OU1 study area. The South Interceptor Ditch had the overall highest lead concentration, 38.4 µg/l (dissolved); however, lead levels of this magnitude were detected only once. All other samples from the same station in the South Interceptor Ditch contained lead concentrations only slightly above the RFP background level. The Hazard Quotient value for the highest lead concentration in surface water from the single sample in the South Interceptor Ditch corresponds to high environmental risk. However, the overall risk to ecological receptors due to lead exposure in OU1 is considered low. This evaluation is based on the generally low level of lead in soils, surface water, and sediments, and the restricted distribution of areas with elevated concentrations. Lead concentration in biological tissue from OU1 indicate minimal uptake of lead.

Zinc risks were assessed for soils at OU1 where the distribution was similar to that of chromium. The average zinc concentration was near background with only 3 of 28 sample sites exceeding twofold the background concentration at RFP. The highest zinc concentrations were detected in IHSS 119.2 and around Building 881. The mean zinc concentration of the three highest values was 70.73±15.2 mg/kg which is near the background level (61.98±12.74 mg/kg). None of the zinc Hazard Quotient values for soil indicated risks above the low level. The overall Hazard Quotient values for vegetation and soil invertebrates also are at the low risk level.

Mercury risks were assessed for surface water at OU1. Mercury concentrations did not exceed background in OU1 soils, surface water, or sediments in Woman Creek downgradient from OU1 IHSSs. Mercury concentration in surface water samples did exceed background in two sites on branches of Woman Creek that drain areas south of the RFP industrial area. However, these areas are outside potential impact from OU1 areas and the concentrations exceeded background by less than 30 percent. Mercury concentrations did exceed background in surface water samples at two stations in the South Interceptor Ditch, however, the source is likely upgradient of OU1 sources and the water from the South Interceptor Ditch, a ground water collection system, is not discharged into surface streams without treatment. The highest concentration of mercury in surface water from the single station in the South Interceptor Ditch was 1.0 µg/l; the Hazard

Quotient value indicates a moderate ecological risk. The risk from mercury in surface water at other stations is low. The acute and chronic Colorado Water Quality Standards for mercury are 2.4 and 0.1 µg/l, respectively. Therefore, the overall risk to ecological receptors from mercury exposure at OU1 is judged to be low. This assessment is due to the infrequent exceedances of background levels in surface water and the lack of evidence for contamination in other media, including biological tissues collected from the site.

The sum of the mean Hazard Quotient values Hazard Indices for exposure of vegetation and soil invertebrates was used to assess the overall risk attributed to soils in OU1 IHSS and non-IHSS areas. The Hazard Index values for vegetation in IHSS areas, non-IHSS areas, and background areas were 3.4, 2.4, and 2.5, respectively; the values for the same components for soil invertebrates were 2.5, 1.8, and 1.9, respectively. This suggests that vegetation growing in the IHSS areas may be at moderate risk from exposure and that vegetation in non-IHSS areas, and soil invertebrates in all areas are at low risk. For both taxonomic groups, the Hazard Index for non-IHSS areas in OU1 was not different from that calculated for the background areas in the Rock Creek drainage.

The risks to ecological receptors from exposure to multiple contaminants in aquatic habitat is also low. Mercury and lead were the only analytes to exceed background by more than twofold at any surface water or sediment station downgradient of OU1 source areas. Their distribution was restricted to the South Interceptor Ditch which was constructed and is maintained as a wastewater collection system. The South Interceptor Ditch provides limited and low quality aquatic habitat because of frequent absence of surface water. The South Interceptor Ditch drains to Pond C-2, the terminal pond in its path. Data from the surface water monitoring program did not indicate concentration of the contaminants of concern exceeded RFP background. It should be noted that data on sediments were not available for Pond C-1 or C-2 and, therefore, information on contamination of sediments in the ponds is lacking.

Both the ecological risk characterization and ecological comparisons sections of this report focus on the toxicity threshold for sensitive organisms (i.e., the concentration of chemicals that produce measurable toxic effects on ecological receptors). Since each species has a different sensitivity threshold, increasing the concentration of toxic chemicals selectively impacts intolerant species. This is reflected by reductions in species diversity (richness), as well as occasional increases in abundance of the remaining tolerant species because of reduced competition for food and habitat. Food webs respond in a similar manner by loss of species performing functions at impacted trophic levels. An ecosystem may become dysfunctional if chemical concentrations are such that species are eliminated.

Ecological comparisons at RFP were conducted at two organizational levels for the OU1 ecosystem—taxonomic structure and trophic function. The taxonomic structure, species diversity, is widely used to compare study areas with similar "nonimpacted" reference areas to determine if pollutional stress is affecting the species composition of communities. As environmental stress from pollutants is gradually increased, the number of species decreases in response to surpassing toxic thresholds for individual species. Since each species occupies a niche, the ecological role or trophic function, then impacts are measurable also by trophic level comparisons. Together the taxonomic and trophic level comparisons provide a yardstick to assess the health of an ecosystem.

The taxonomic group comparisons provided an estimate of the ecosystem's general health based on species diversity within the OU1 study area. The terrestrial ecosystem revealed no difference between the percentage of small mammalian species at OU1 and the Rock Creek reference area. The highest difference was only 3 percent, indicating similar species richness in the two areas. Small mammals are very sensitive indicators of stress caused by contaminants of concern entering the food pathway because they are primarily omnivores and herbivores and live in close contact with the soil, the major exposure point in the OU1 study area. The aquatic ecosystem showed slight differences in species richness for plankton and benthic macroinvertebrates. Rock Creek had 11 percent more plankton species and 9 percent less benthic macroinvertebrate taxa than the OU1 study area. These differences were expected since the semiarid climate caused both streams

to have recurring loss of habitat during intermittent flow. In particular, Rock Creek has a smaller watershed area upgradient of RFP contributing to the base flow. The comparison of species richness for the OU1 study area and Rock Creek indicates similar levels of ecosystem health. Statistical evaluations, using chi-square calculations, showed no significant difference between OU1 and Rock Creek for terrestrial or aquatic taxonomic richness.

The species used in the taxonomic level comparison were organized by trophic levels for a food web comparison. Terrestrial arthropods were compared separately since a less detailed identification endpoint was selected for study objectives. As in the taxonomic comparisons, trophic comparisons revealed much similarity between the OU1 and the Rock Creek ecosystems. The maximum percentage difference for any trophic level between these two areas was approximately 4 percent. Comparisons of terrestrial arthropods showed differences of only 6 percent or less between the two areas.

Trophic level comparisons for aquatic primary producers and omnivores showed differences up to 10 percent between OU1 streams and Rock Creek. The comparison of aquatic primary producers does not differ from the plankton comparison. Comparison of species richness for omnivores at the two areas revealed greater species richness at OU1, reflecting good ecosystem health in the OU1 study area.

Chi-square calculations for terrestrial trophic levels revealed no significant difference between areas, again indicating much similarity between areas. Aquatic trophic levels, however, did show a significant difference between areas. This is due to the total number of aquatic taxa being higher in OU1 streams than in Rock Creek, although primary producers (algae) were higher in Rock Creek. Rock Creek tends to be more intermittent than Woman Creek, and therefore is a more harsh environment for aquatic organisms, explaining the diminished number of taxa at the Rock Creek reference area when compared to the OU1 area in Woman Creek watershed.

Results for food web comparisons did not indicate a stressed ecosystem, nor did they reveal ecological problem areas. These results, along with those of tissue sample analysis, should be viewed as further weight-of-evidence indicating an ecologically healthy state at the OU1 study area.

Plant and animal endpoints were compared by habitat type using the mean, standard deviation of a population, and a standard error to compare ecological habitat quality. While reviewing this endpoint data, three general sources of variability became apparent. The first, dealing with the xeric habitat sites, is that only one sample site for OU1 could be established within the ecological study area boundary. Four sites were established in the Rock Creek reference area, this being the normal protocol. The low number of replicates available in OU1 causes variability in the data in that the reference results were derived from four times the number of observations. In addition, the soil in the single OU1 xeric site was extremely compacted, which physically inhibits plant growth and small mammal burrowing. Second, the marsh habitats in OU1 and Rock Creek comprise different wetland plant types. The OU1 marsh habitats are the result of construction activities that created the South Interceptor Ditch and Ponds C-1 and C-2. These areas contain mainly cattails and open water. The vegetative structure differs from marsh habitat found in Rock Creek, which are mostly the result of ground-water seeps and are more suitable habitat for rushes and wet grass species. Although both areas are hydric in nature, these site differences explain the considerable variation of species richness and productivity of both plants and animals. Finally, results for ecological comparisons do not indicate a difference that may be the result of contaminants.

6.2.4 Conclusions

The results and analysis of environmental evaluation data contribute the following six conclusions:

- Contaminated areas are very restricted in size, and the concentrations of contaminants of concern detected were nonhomogeneous. Some sample stations had high concentrations of contaminants of concern in one sample, while other samples indicated only background levels. Therefore, any remedial actions, if needed, would be minor.

- Chromium, lead, mercury, and zinc were identified as contaminants of concern that were found in the OU1 study area in concentrations greater than twofold above background RFP values. These contaminants of concern potentially were released by site activities, but were ascertained to pose low risk to ecological receptors.

- IHSSs 119.1 and 119.2 areas have the highest levels of contaminants of concern for chromium, lead, and zinc.

- There is low bioaccumulation of contaminants of concern in ecological receptors at OU1.

- Ecological comparisons at OU1 show no significant difference between species diversity at OU1 and Rock Creek, the reference area. Therefore, there is no indication of adverse ecological impacts as a result of RFP activities.

- The minor ecological differences found between the OU1 study area and Rock Creek were the types of stresses caused by the semiarid climate and not by metal contamination.

- There is low overall risk to ecological receptors at OU1 from contaminants of concern.

6.3 PUBLIC HEALTH EVALUATION

This study developed a quantitative description and assessment of the risk to the public health posed by the contaminants of concern at OU1. Potential contaminants of concern are identified along with applicable scenarios that link the contaminants of concern to potentially exposed populations. Estimated incremental risks presented by the contaminants of concern to which the populations are exposed are then compared to EPA guidance. Finally, the uncertainty analysis formalizes and quantifies the conclusions drawn regarding the risk of the identified contaminants of concern.

As precursor documents to this report, four technical memoranda were prepared to address the public health evaluation process components. The technical memoranda for exposure scenarios model selection, contaminants of concern, and toxicity constants are summarized in Section 2 and are attached to Appendix F.

The list contaminants of concern were derived according the screening process involving consideration of detection frequency, hot spots, statistical comparison to background, toxicity concentration screening, and transformation products. Application of the screening process produced a list of 22 chemicals that qualify as contaminants of concern at OU1: 1,1-dichloroethene, carbon tetrachloride, dichlorodifluoromethane, tetrachloroethene, total 1,2-dichloroethene, trichlorofluoromethane, 1,1,1-trichloroethane, acenaphthene, fluoranthene, chloroform, methylene chloride, trichloroethene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, AROCLOR-1254 (a PCB), fluorene, pyrene, americium-241, plutonium-239,-240, and dibenzo(a,h)anthracene.

The OU1 physical environment, exposure pathways, potentially exposed population, and land use scenarios are discussed in Technical Memorandum No. 6, Revision 4.0, *Exposure Scenarios*. Ground water was not a potential exposure pathway to humans because of the low quantity, and low water table, and because a municipal water source is currently on site. The following describe the specific land use scenarios and pathways selected for a quantitative assessment:

- Current Off-Site Residential Land Use
  - Inhalation (particulates)
  - Ingestion (vegetables, soil)
  - Direct dermal contact (soil)

- Current On-Site Commercial/Industrial Land Use
  - Inhalation (particulates)
  - Ingestion (vegetables, soil)
  - Direct dermal contact (soil)

- Hypothetical Future On-Site Residential Land Use
  - Inhalation (indoor volatiles, particulates)
  - Ingestion (vegetables, soil, sediment, surface water)
  - Direct dermal contact (soil, sediment, surface water)

- Hypothetical Future On-Site Commercial/Industrial Land Use
  - Inhalation (indoor volatiles, particulates)
  - Ingestion (vegetables, soil, sediment, surface water)
  - Direct dermal contact (soil, sediment, surface water)

- Hypothetical Future On-Site Ecological Reserve Land Use
  Inhalation (particulates)
  Ingestion (soil, sediment, surface water)
  Direct dermal contact (soil, sediment, surface water)

Exposure point concentrations for each receptor were estimated through the use of fate and transport models or from statistical evaluation of the data. Modeling was used to study migration of VOCs from ground water through soil into a hypothetical future structure; concentration of contaminants in sediments in the South Interceptor Ditch; and air dispersion, deposition, and uptake of contaminants by vegetation. Summary statistics of the data were generated after substitution for nondetects of chemicals in samples using a log-probability method capable of processing multiple detection limits.

Receptor intakes were estimated using methods consistent with data quality objectives for the *Risk Assessment Guidance for Superfund* (EPA 1989a). The exposure parameter values used were identified in various EPA documents or published literature. Intake estimates are presented for each receptor by contaminant for each applicable pathway.

Toxicity constants for all contaminants, except for PAHs, were taken directly from the *Integrated Risk Information System* and *Health Effects Assessment Summary Tables* (EPA 1992b, 1992c). Toxicity constants for PAH are based on toxicity equivalency factors using the slope factor of benzo(a)pyrene in accordance with EPA protocals.

The results of the exposure and toxicity assessments were combined to provide reasonable maximum exposure risk estimates and to facilitate uncertainty analysis. Monte Carlo simulations, used with exposure parameter distributions derived from EPA documents, illustrate the magnitude of uncertainty for the risk-predominant pathways involving indoor inhalation of VOCs and ingestion of homegrown vegetables contaminated with PAHs and PCBs. Specifically, Monte Carlo simulations were run for 1,1-dichloroethene, carbon tetrachloride, benzo(a)anthracene,

benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, and AROCLOR-1254.

6.3.1 Risk Characterization Results and Conclusions

Risks were characterized to provide explanation of key points and uncertainties associated with the numerical estimates of health risk. Two commonly used descriptors of risk, individual reasonable maximum exposure risks, and collective risks, were used for risk characterization. The following individual latent excess cancer risks were estimated for each scenario receptor.

- Current Off-Site Residential Receptor, risk = 3E-09
- Current On-Site Commercial/Industrial Receptor, risk = 3E-07
- Hypothetical Future On-Site Residential Receptor, risk = 4E-05
- Hypothetical Future On-Site Commercial/Industrial Receptor, risk = 1E-05
- Hypothetical Future On-Site Ecological Reserve Receptor, risk = 5E-06

The total latent excess cancer risk to a hypothetical future on-site resident, under conditions of "reasonable maximum exposure" was calculated to be 4E-05. The only identified risk that exceeds the National Contingency Plan risk range of 10^{-6} to 10^{-4} is associated with inhalation of 1,1-dichloroethene by a future on-site resident living in a house over the most elevated concentration of contaminants at IHSS 119.1. This risk was calculated to be 2.7E-03. Risk from two additional chemicals also associated with the IHSS 119.1 area were calculated to be in the 1E-04 range (Table 6-1).

There were four combinations (two adult and two child) of noncarcinogenic Hazard Quotient values and associated Hazard Indices that were calculated to exceed unity. Unity is when the exposure divided by reference dose ratio is equal to 1.0; this ratio is not a statistical probability. Further, it is important to emphasize that the level of concern does not increase linearly as the referense dose is approached or exceeded because reference doses do not have equal accuracy nor precision and are not based on the same severity of toxic effects. Thus, the slopes (ratios) of the dose-response curve in excess of the referense dose can range widely depending on the

substance. All occur with the future on-site resident living on the "hot spot." The highest Hazard Quotient valued calculated is for exposure to carbon tetrachloride by the child (36.5). The next highest Hazard Quotient value was calculated for exposure to 1,1-dichloroethene by a child (12.0). Significant adult exposure associated with the "hot spot" were calculated to be 14.7 and 4.8 for each of these volatile organics, respectively. None of the other scenarios and pathways exceed the National Contingency Plan target Hazard Index of unity.

6.3.2 Comparison to Background

For comparison of incremental latent excess cancer risks due to contaminants at the site to the National Contingency Plan (risk range of 10^{-4} to 10^{-6}) (EPA 1990d), relevant natural background risks should also be considered. Several naturally occurring substances present both on- and off-site present typical risks in the 10^{-4} to 10^{-5} range. Arsenic, radon progeny, and PAHs (from volcanoes, natural fires, and anthropogenic combustion processes) are some notable examples, presenting approximate risks of 1E-5, 1E-4, and 4E-4, respectively.

6.3.3 Expected Impact on the Community

Collective risks, the multiplication of the individual risk times the affected population, were estimated for off-site and hypothetical future on-site populations. The off-site collective risk based on the maximally exposed off-site individual was estimated to be 1.3E-4 for a radial distance range of 0 to 80 km. The estimated collective risk for future on-site individuals was calculated to be 6.73E-03. Simply stated, there are 7 chances in 1,000 that a cancer death would be observed from complete residential development of OU1.

Although a risk assessment can estimate numerical risks with regard to carcinogenic contaminants, there is no epidemiological basis for expecting to observe any increases in incidence or fatality from the low risks typical of environmental levels. Epidemiologic studies have little chance of establishing causal relations between exposure and elevations in cancer rates. This failure is due to the lack of strength in positive findings, usually borderline statistical

significance, and a consistent disregard for the effect of low statistical power and substantial Type II (false negative) error probability.

6.3.4 Quantification of Human Carcinogenicity

Since risk at low exposure levels cannot be measured directly either in laboratory animals or human epidemiology studies, mathematical models have been developed to extrapolate from high to low exposure levels. Various models have been proposed to extrapolate from high to low doses (i.e., to estimate the dose-response relationship at low doses). The three most frequently used models are the one-hit model, the log-probit model, and the multistage model (Armitage and Doll 1961). Currently, regulatory decisions are based on the output of the linearized multistage model (EPA 1986). Most models produce quantitatively similar results in the range of observable data, but yield estimates that can vary by three or four orders of magnitude at lower doses.

6.3.5 Range of Cancer Risk Estimates

A summary of the key contaminants and their contribution to the total risk for the hypothetical future on-site residential scenario is provided in Table 6-1. The range of the total risk spans almost four orders of magnitude, from the 5th percentile of 1E-8 to the 95th percentile of 8E-5, while the central tendency is indicated by the 50th percentile of 5E-7. The reasonable maximum exposure estimates are generally greater than the 95th percentile, with the exception of carbon tetrachloride, with an reasonable maximum exposure at approximately the 80th percentile. As the table indicates, the highest contributor to risk is 1,1-dichloroethene, a Class C carcinogen (i.e., a possible human carcinogen with limited evidence of carcinogenicity in animals and a lack of evidence or inadequate data for human carcinogenicity). As stated in *Risk Assessment Guidance for Superfund* (EPA 1989a), decisions to provide quantitative risk assessment for Class C carcinogens are made on a case by case basis; it has been provided here to allow numerical comparison with other carcinogens. The low confidence in the toxicity value provided in the *Integrated Risk Information System* (EPA 1992b) is reflected in the uncertainty distribution of the calculated risk (see Table 6-1).

The special cases of residential use at the "hot spot" (IHSS 119.1) and the "clean" area (the site excluding IHSS 119.1) are provided to indicate the impact of the localized contaminants in IHSS 119.1. The risk directly over IHSS 119.1 is estimated to be 2E-3, which is greater than the 95th percentile of the sitewide residential risk. The risk associated the "clean" area is estimated to be 3E-5, equal to the 90th percentile of the sitewide residential risk. It should be noted that the "clean" area refers only to the absence of IHSS 119.1 ground water volatiles; the risks from sitewide surface soil contaminants are still included. With the exception of the risk calculated for a resident living at the point of greatest exposure ("hot spot"), all calculated risks meet the National Contingency Plan acceptable risk range criterion.

Cancer incidence in the Denver metropolitan area, not associated with the OU1 study area, is one in three persons (i.e., 33 percent [0.33] of the population are expected to contract cancer during their lifetime) (CDH 1991). The potential lifetime cancer risk to hypothetical on-site residential receptors directly attributable to the site under "reasonable maximum exposure" conditions at some time in the future is 0.00004, yielding a theoretical total lifetime cancer incidence of 0.33004.

As mentioned, there are many unquantified uncertainties, including the degree of confidence that residential use of the site would ever be permitted. Therefore, the impacts calculated under the on-site residential land use scenario are extremely conservative; actual exposure, even under plausible future use scenario, will undoubtably be much lower.

Given the uncertainty in quantifying intakes, toxicological and carcinogenic responses, credibility of future exposure scenarios, and the magnitude of "background" risks, which together produce a very conservative estimate of actual risks, great care should be exercised in the use of reasonable maximum exposure risk estimates for regulatory decision making.

6.4 OVERALL RISK ASSESSMENT

The ecological and public health risk assessments are the two components of the baseline risk assessment at OU1 in the Phase III RFI/RI process at RFP. The results will be used to plan the feasibility study and select potential remedial action alternatives. One concern for evaluating remedial actions is quantification of environmental impacts expected from the selected remedial actions (e.g., french drains constructed in 1992 at OU1 to collect ground water may reduce the ground water level that is necessary to sustain wetlands).

Criteria for selection of contaminants of concern used in both components of the baseline risk assessment are selected because of their potential to cause measurable impacts to the ecosystem, including humans. The environmental evaluation and public health evaluation primarily screened candidate contaminants of concern based on actual toxicity, persistence in the environment, bioavailability, and to a lesser extent the concentration present. Pathways by which contaminants may cause an adverse effect at OU1 evaluated in the environmental evaluation are soils, surface water, and sediments for plants and wildlife; the public health evaluation evaluated inhalation, ingestion, and direct dermal contact for humans.

The overall level of risk to ecological receptors (plants and animals) and humans from potential exposure to contaminants of concern at OU1 are low based on both theoretical calculations (for humans and ecological receptors) and weight of evidence for ecological receptors. The highest potential risk to ecological receptors and humans at OU1 based on surface soils analyses is the IHSS 119.1 area. Even at IHSS 119.1 the contaminated areas are very restricted in size and the concentration of contaminants of concern detected are nonhomogeneous. For example, some sample stations had high concentrations of a target contaminant of concern in one sample while other samples indicated only background levels.

The lifetime cancer risk in the Denver metropolitan area, not associated with the OU1 study area, is one in three persons (i.e., 33 percent [0.33] of the population are expected to contract cancer during their lifetime). However, the potential lifetime cancer risk to hypothetical on-site

residential receptors that is directly attributable to RFP under "reasonable maximum exposure" conditions (potentially after a decision for residential development) is 0.00004; the total theoretical lifetime cancer risk for the population would then be potentially elevated from 0.33 to 0.33004. The risks from the most toxic contaminants of concern at OU1 are further reduced because of the very restricted distribution and low quantities of the substances.

Section 7.0 · Text

Summary and Conclusions

Phase III RFI/RI Report

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7.0 SUMMARY AND CONCLUSIONS

Section 7.0 summarizes the physical features, contaminant sources, nature and extent of contamination, contaminant fate and transport characteristics, and the baseline risk assessment for OU1. Conclusions regarding data limitations and recommended remedial action objectives are also discussed.

7.1 SUMMARY OF FINDINGS

Seventeen site-specific objectives, outlined in the work plan and numbered in Table 2-1, were developed after completion of the Phase I and II RI. These objectives have been addressed in the report and are outlined by number in the first paragraph of each subsection. Subsequent text summarizes each numbered objective individually.

7.1.1 Site Physical Features

Various physical attributes of OU1 were characterized by: (1) determining the extent of saturation and ground water flow directions both spatially and temporally for the unconfined flow system, or upper HSU ground water, (2) describing the interaction between surface water and ground water, (3) quantifying aquifer properties for the upper and lower HSUs, (4) describing all soil and rock materials, and (5) refining the hydrogeologic site conceptual model for OU1. Site conditions are characterized sufficiently to determine pathways and assess contaminant transport at OU1. These are summarized below.

(1) Ground Water in the Upper HSU – Twenty-three alluvial wells, three bedrock wells, three alluvial piezometers, and two bedrock piezometers were installed during the Phase III RFI/RI at OU1 to supplement the existing monitoring well network at the site. Water level data from Phase I, II, and III wells and piezometers were used in this study. Distribution and flow of ground water in the upper HSU is controlled by recharge and discharge characteristics of the area and the topography of the bedrock surface. The upper HSU is not a typical aquifer; rather, it is a variably saturated water-bearing hydrostratigraphic unit.

(2) Ground Water/Surface Water Interaction – Upper HSU ground water is recharged by infiltration of incident precipitation, snowmelt, and surface water from ditches and ponds, and seepage from the Rocky Flats Alluvium along the north rim of the hillside. Ground water discharges from the upper HSU by evapotranspiration, at surface seeps, and into the french drain. Ground water at the base of the hillside seasonally discharges to the surface as seeps and to Woman Creek.

In general, ground water gradients in the upper HSU at OU1 indicate flow to the south from higher elevations to lower elevations toward Woman Creek. In eastern portions of OU1, ground water in the upper HSU resides in isolated horizons, perched above the bedrock claystones. Ground water flow from these isolated horizons may only occur during the short wet season when water levels rise. During this season, additional ground water flow paths may exist and ground water may flow downgradient to the french drain. Larger quantities of ground water exist in the western portions of OU1 due to the presence or former presence of surface recharge sources such as the Building 881 footing drain. The abundance of upper HSU ground water in this area permitted continuous ground water flow paths from just south of Building 881 to Woman Creek before completion of the french drain. The Building 881 footing drain, now connected to the french drain, and the skimming pond, destroyed during construction of the french drain, are no longer sources of recharge.

(3) Hydrogeological Properties – Hydrogeological tests were conducted to estimate hydraulic conductivity and average linear ground water flow velocity for the upper and lower HSUs. Hydraulic conductivity values ranged from 3×10^{-3} to 9×10^{-7} cm/sec for the upper HSU and 2×10^{-3} to 1×10^{-8} cm/sec for the lower HSU. However, geometric means of the lower HSU test results are up to four orders of magnitude lower than those presented for the upper HSU. Back-pressure permeabilities representing vertical hydraulic conductivities ranged from 1.2×10^{-3} to 2.5×10^{-9} cm/sec for the upper HSU and 1.5×10^{-6} to 4.2×10^{-9} cm/sec for the lower HSU. Linear ground water flow velocities range from 150 to 300 feet/year for valley fill alluvium, 10 to 20 feet/year for colluvium, and 5 to 10 feet/year for claystones of the lower HSU. Based on

these values, and observations documented during the construction of the french drain, ground water flows more rapidly to the east in valley fill alluvial material than southward in colluvium. Vertical ground water flow between the upper and lower HSUs may occur at less than one-half foot per year in the vicinity of IHSS 119.1. Ground water flow in the lower HSU may be slower than reported due to low hydraulic conductivities and the discontinuities caused by slumping.

(4) Geology – Descriptions of unconsolidated surficial material and bedrock are based on drill core descriptions from 98 Phase III RFI/RI boreholes, the french drain geologic characterization and previous work. The Rocky Flats Alluvium is 10 to 20 feet thick and forms a uniform blanket-like deposit at the crest of the 881 Hillside. Colluvial deposits formed by slope wash, downslope creep, and slumping of the Rocky Flats Alluvium, bedrock, and artificial fill comprise the bulk of surficial materials underlying OU1, and may be up to 30 feet thick. Gravel and sand lenses in the colluvium are limited in vertical and areal extent. Artificial fill from excavation and disposal activities occurs in three areas on the hillside and is 5 to 20 feet thick. The Woman Creek valley fill alluvium is less than 10 feet thick and forms a sinuous elongate deposit at the bottom of the 881 Hillside area.

Surficial material is unconformably underlain by bedrock claystones, clayey siltstones and fine-grained silty sandstones of the upper Laramie Formation. The Arapahoe Formation does not exist at OU1. The bedrock surface has been scoured and shaped by various alluvial, fluvial, and geomorphological processes. The most apparent features on the bedrock surface are several northwest-southeast trending paleochannels separated by bedrock highs that originate near Building 881 and extend to Woman Creek. Slump blocks bounded by basal glide planes or shear surfaces and cemented by caliche zones commonly occur on the hillside and may restrict ground water distribution and flow in both the upper and lower HSUs.

(5) Hydrogeologic Site Conceptual Model – All historical and Phase III RFI/RI hydrogeological data, as well as subsequent water level data have been integrated into a refined hydrogeologic conceptual model that was verified against field observations and contaminant distributions. This

refined conceptual model better describes hydrological conditions at 881 Hillside. Much of the model is explained in discussion of the interaction of surface water and ground water in objective (2). In summary, this refined conceptual model confirms that the french drain and accompanying extraction well function as effective discharge boundaries and intercept all identified upper HSU ground water flow paths originating from or passing through OU1. The operation of the french drain and the extraction well will reduce upper HSU water levels through time, ultimately dewatering IHSS 119.1. Vertical migration between the upper and lower HSUs will also be reduced.

7.1.2 Contaminant Sources

Contaminant sources at OU1 were characterized by determining (6) the nature and distribution of waste materials on site, (7) the soil quality beneath wastes or in soils at sites where wastes have been removed (considered as potential contaminant sources), and (8) whether sites or subareas of sites were potential sources of contaminants in ground water. The objectives, meant to characterize contaminant sources at OU1, are summarized below.

(6) Waste Materials – Soil samples were collected from boreholes drilled directly through IHSSs to characterize the nature and distribution of any waste materials still existing on site. Materials encountered during the drilling included metal shards in boreholes drilled in IHSSs 119.1 and 119.2 and asphalt in boreholes drilled in IHSS 130. Asphalt chunks were collected in some of the soil samples and were analyzed with the soils. SVOCs were detected in shallow soils at IHSSs 104 and 130 and are associated with asphalt disposal in that area.

Additional potential waste sampling that was performed as part of the Phase III RFI/RI field investigation included VOC sampling of effluent from the Building 881 footing drain manhole, and VOC and SVOC sampling of a drum of Coherex, a soil tackifier and dust suppressant formerly used at OU1. VOCs were detected in both samples.

(7) Soil Contamination Sources – In order to characterize subsurface soils beneath wastes and soils at sites where wastes have been removed, 419 soil samples from boreholes were collected and analyzed. To characterize surface soils, samples were collected from 28 locations at OU1. VOCs, SVOCs, and radionuclides and metals exceeding background were detected in subsurface soils. SVOC and radionuclides were detected above background in surface soils. Radionuclide data for surface soil samples indicate that levels of plutonium and americium exceed sitewide background concentrations at OU1. The plutonium and americium are due to wind transport and deposition from source areas outside OU1 such as the 903 Pad in OU2. Levels of plutonium and americium decrease vertically to background levels within 6 feet or less of the surface. Radionuclides do not occur above background in OU1 ground water. Except for two discrete locations with elevated selenium in subsurface soils, and beryllium in surface soils, metal concentrations in surface and subsurface soils do not indicate contamination at OU1. Typically, metals do not exceed background levels. For the few detections exceeding background, the concentration is elevated only by a factor of two, and sometimes approaching five, for a few sporadic detections. Also, no coherent lateral or vertical trends were found in OU1 soils that would reflect dispersion from a contaminant source.

(8) Ground Water Contamination Sources – Eleven alluvial monitoring wells were installed within IHSSs. Additionally, four upgradient and eight downgradient monitoring wells were installed near individual IHSSs or groups of IHSSs. Samples were collected from new and existing wells and analyzed where ground water was present. The current contamination assessment for soils and groundwater is based on available results for surface and subsurface soils from the Phase III RFI/RI and groundwater sampled during fourth quarter 1991 and first quarter 1992. Surface water and sediments data were utilized from fourth quarter 1991 and first quarter 1992. Data were used to identify sources of contaminants in ground water. Soils in IHSSs 119.1 are residual sources of VOC ground water contamination at OU1.

7.1.3 Nature and Extent of Contamination

The nature and extent of contamination was characterized by: (9) determining the horizontal and vertical extent of radionuclide contamination in surface soils due to wind dispersion, (10) determining the nature and extent of ground water contamination in surficial materials, (11) determining the location and extent of weathered and unweathered sandstone units and associated contamination, (12) characterizing surface water quality, (13) characterizing radionuclides in Woman Creek sediments, (14) identifying and implementing data management procedures, and (15) collecting data of sufficient quality to facilitate development of a site conceptual model and initiate comparison to ARARs.

(9) Radionuclides in Surface Soils – Surface soil samples were collected at 28 locations at OU1 to a depth of 5 cm (2.5 inches). A separate program implemented at OU2 involved collection of radionuclide samples from 11 locations and three vertical soil profiles at OU1. Preliminary comparison of data from the two programs are consistent, and indicate radionuclides detected in surface soils at OU1 can be attributed to a contamination source to the east in OU2. Data from the vertical soil profiles in OU1 will be further evaluated pending finalization of the OU2 draft Phase II RFI/RI report in January 1993.

(10) Contamination in Upper HSU Ground Water – Four upgradient and eight downgradient monitoring wells were installed relative to a single IHSS or groups of IHSSs. Samples were collected and analyzed where ground water was present. Ground water samples were also collected from pre-existing wells. Data indicates ground water contamination in the upper HSU occurs in a small, hydraulically isolated zone at IHSS 119.1. Contamination reported during fourth quarter 1991 and first quarter 1992 consists of total chlorinated hydrocarbons ranging from 1 to 45,000 µg/l. IHSSs in the vicinity of Building 881 can be considered sources for the sporadic low levels of contaminants detected in ground water.

(11) Contamination in Subcropping Sandstones – Five bedrock boreholes were drilled to determine the areal extent of subcropping bedrock sandstones. Three monitoring wells and two

piezometers were installed in the upper Laramie Formation to quantify the hydrogeologic characteristics of the site. Bedrock siltstones were encountered rather than sandstone horizons. Low levels of VOCs were detected in ground water associated with these units.

(12) Contamination in Surface Water – Surface water stations continued to be monitored on a monthly basis as part of the routine monitoring program. VOCs and SVOCs were detected in surface water sampled during the fourth quarter 1991 and first quarter 1992. Radionuclides were detected at sampling stations in Woman Creek, however, none of the detections exceed RFP background values. Metals and inorganic constituents exceed RFP sitewide background concentrations at sampling stations in the South Interceptor Ditch and in Woman Creek. These metals and inorganics occur at elevated concentrations due to natural geologic conditions.

(13) Radionuclides in Sediment – Three new sediment stations (SED037, SED038, SED039) were established in the South Interceptor Ditch to monitor contaminant levels directly associated with OU1. Samples were collected from these stations in November 1992. Sediments sampled in the South Interceptor Ditch during the Phase III RFI/RI contained low levels of SVOCs most likely sourced from surface soils. However, because of the presence at upgradient stations, upstream sources may also be contributing SVOCs to the South Interceptor Ditch.

(14) Data Management Procedures – All data collected during the Phase III RFI/RI field investigation were input to the Rocky Flats Environmental Database System. Field and analytical data are routinely input as they are received.

(15) Data Quality – The Phase III RFI/RI data collection effort at OU1 was implemented in accordance with the Environmental Restoration program, Quality Assurance Project Plan, General Radiochemistry and Routine Analytical Services Protocol, and the OU1 Quality Assurance Addendum, for the purpose of meeting data quality objectives. The data were subsequently used to refine the site conceptual model. Data are of sufficient quality to meet the specified data

quality objectives, to facilitate comparison to benchmarks or ARARs, and to conduct a baseline risk assessment.

To avoid redundant discussion, additional information regarding nature and extent of contamination is incorporated into the contaminant fate and transport discussion summarized below in Section 7.14.

7.1.4 Fate and Transport

The nature and extent of contamination was tied to the risk assessment by: (16) describing contaminant fate and transport. An overview of contaminant fate and transport applicable to OU1 is presented below.

(16) Contaminant Fate and Transport – Contaminants were originally introduced to the environment at OU1 by waste storage, disposal, or discharges to surface soils. Surface and vadose zone (colluvium) soils are therefore considered as both a primary host of contaminants and a pathway for contaminant migration to surface water, ground water, sediments, soil gas, and air. Transfer of contaminants from soils to surface water and sediments at OU1 occurs primarily by wind and surface water erosion and rare overland flow events. Transfer of contaminants from soils to upper HSU ground water has occurred at OU1 as a result of leaching or desorption mechanisms in response to percolating meteoric water. Transfer of contaminants from soils to soil gas is generally restricted to the in situ volatilization of VOCs, and to a lesser extent SVOCs. Similarly, releases to air occur primarily by suspension of contaminated soil and dust particles by wind, and to a lesser extent by volatilization of VOCs. Anthropogenic transport of contaminants has been reduced by restricting access to OU1 and implementing decontamination procedures.

IHSSs located in the western area of OU1 are typically small and represent discrete spill or liquid disposal sites. Contamination at IHSSs 102, 103, 105, 106, 107, and 145 consist of sporadic low-

level occurrences of SVOCs in near-surface soils and radionuclides to low-level sporadic occurrences of VOCs and trace metals slightly exceeding background in ground water.

Migration processes identified in the western IHSSs are relatively insignificant but include leaching and desorption of contaminants by infiltration of meteoric water to slowly flowing ground water and the subsequent capture of those contaminants by the french drain. Other migration processes identified in this area include volatilization of VOCs to soil gas and the atmosphere, and suspension of near-surface contaminants by eolian processes and surface water runoff. Volatilization of contaminants to soil gas and to the atmosphere is considered negligible due to the extremely low concentrations of VOC and SVOC contaminants in this area. Similarly, suspension of VOC, SVOC, and radionuclide contaminants from surface soils by eolian processes and overland surface water flow are also considered insignificant because of low concentrations.

SVOCs and VOCs in subsurface soils in the western part of OU1 IHSSs are likely being attenuated by chemical and microbial degradation processes that act to restrict their mobility and lower their concentrations with time. The trace amounts of VOCs and SVOCs in ground water near Building 881 are currently captured by the french drain.

Metals in soils and ground water in the western part of OU1 occur at levels approaching background and are not considered contaminants. In addition, the metals that have been detected in media at the site occur in artificial fill around Building 881 and are being effectively attenuated and immobilized by a combination of adsorption and coprecipitation reactions due to site geochemical processes.

IHSSs located east of Building 881 (IHSSs 104, 119.1, 119.2, and 130) are sites where disposal and releases of both solid and liquid wastes have occurred. Subsurface soils at these sites contain VOCs, SVOCs, radionuclides, and metals. SVOCs are the most frequently detected contaminant group in near-surface soils, occurring predominantly at IHSSs 104 and 130 in low µg/kg and mg/kg levels.

Transport and distribution of radionuclides and SVOCs from surface soils by wind and surface water are important pathways at OU1. The high distribution coefficients of most radionuclides partitions them to the solid phase, thereby effectively immobilizing them in soils unless the soil particles are physically moved. As a result, redistribution of adsorbed radionuclides by soil or dust particles mobilized by wind or surface water is considered a major pathway at OU1 where nonvolatile contaminants are exposed to the atmosphere at the ground surface.

Ground water beneath IHSSs in the eastern part of OU1 occurs as small and static, hydraulically isolated horizons laterally and vertically constrained by the bedrock surface. During most of the year, recharge to these isolated zones appears to be balanced by evapotranspiration and possible minor amounts of vertical flow to the lower HSU resulting in little net movement of ground water in these areas. As a result, upper HSU ground water in the eastern OU1 area is considered a less important and potentially insignificant pathway for contaminants than ground water in the western OU1 area.

Most contaminated ground water at OU1 occurs at IHSS 119.1, where spills and leaks of liquids containing chlorinated solvents occurred from drums stored at the surface. Recent installation of an extraction well at IHSS 119.1 will decrease the migration potential of ground water contaminants within the upper and into the lower HSU by decreasing both lateral and vertical hydraulic gradients. Therefore, vertical migration of upper HSU ground water is a potential contaminant pathway, especially at IHSS 119.1.

Detections of VOCs at well 6286 located in the easternmost portion of the 881 Hillside area most likely result from the existence of a seasonal upper HSU ground water migration pathway originating from OU2. Since no identified OU1 sources or pathways exist to explain these VOC detections, and a similar suite of VOCs at high concentrations exist at OU2, evaluation and monitoring of this pathway should be performed under OU2 investigative programs.

In summary, based on the Phase III data contaminants occur predominantly as VOCs in ground water, and as SVOCs and radionuclides in subsurface soils. Contaminated ground water is primarily limited to VOC-contaminated ground water at IHSS 119.1, with sporadic occurrences east and south of Building 881. The isolated ground water at IHSS 119.1 and eastern areas restrict migration of those contaminants to other areas via ground water flow. SVOC contamination occurs primarily in IHSSs 103, 104, and 130 where adsorption processes are currently acting to immobilize these compounds in situ unless physically disturbed and transported, and chemical and microbial degradation processes are acting to decrease the SVOC concentrations with time. For radionuclides detected in surface soils, it can be concluded that the geochemical environment immobilizes these potential contaminants unless the materials are physically transported. Metals concentrations are considered to occur at concentrations reflective of ranges in background levels and are, therefore, not considered significant at OU1.

7.1.5 Baseline Risk Assessment

A baseline risk assessment was prepared by: (17) assessing the threat to public health and the environment from the no-action remedial alternative.

(17) Baseline Risk Assessment – The ecological evaluation in this report was conducted using a three-step process. The first step (screening) consists of identifying potential contaminants of concern that are known to be present at OU1. The second step, ecological risk assessment (characterizing potential impacts), consists of reviewing research and regulatory findings to determine potential toxicity and behavior of contaminants of concern in the soils, surface waters, and sediments. The third step, ecological comparison (actual ecological impacts), consists of evaluating ecological data from RFP to determine if measurable ecological impacts result from contaminants of concern at the OU1 study area.

Using Phase III data the public health evaluation developed a quantitative assessment of the public health risk posed by the contaminants of concern at OU1. Contaminants of concern were identified along with plausible scenarios and exposure pathways that link the contaminants of

concern to potentially exposed populations. Estimated incremental risks presented by the contaminant of concern to which the populations would be exposed were computed and then compared to EPA guidance values. An uncertainty analysis was completed that formalizes and quantifies the conclusions drawn regarding the risk of the identified contaminants of concern and as a measure of the degree of confidence in the estimated risk.

The ecological and public health risk evaluations are the two components of the baseline risk assessment at OU1 in the Phase III RFI/RI process at RFP. The results of these studies will be used to plan the feasibility study and select potential remedial action alternatives. One concern for evaluating remedial actions in the future is quantification of environmental impacts expected from the selected remedial actions (e.g., the french drain constructed in 1991/1992 at OU1 to collect ground water may reduce the ground water level necessary to sustain wetlands).

Criteria for selection of contaminants of concern used in both components of the baseline risk assessment were selected because of the potential to cause measurable impacts to the ecosystem including human health. The environmental evaluation and public health evaluation primarily screened candidate contaminants of concern based on actual toxicity, persistence in the environment, bioavailability, and the concentration present. Pathways by which contaminants may cause an adverse effect at OU1 evaluated in the environmental evaluation are soils, surface water, and sediments for plants and wildlife; the public health evaluation evaluated inhalation, ingestion, and direct dermal contact for humans. After determination of exposures, risks were characterized by considering toxicity factors. Overall risks were then compared to guidance values.

The overall level of risk to ecological receptors (plants and animals) and humans from potential exposure to contaminants of concern at OU1 are low based on both theoretical calculations (for humans and ecological receptors) and weight of evidence for ecological receptors. The highest potential risk to ecological receptors at OU1 based on surface soils analyses are the IHSS 119.1 area. However, at IHSS 119.1 the contaminated areas are very restricted in size and the

concentration of contaminants of concern detected are nonhomogeneous. For example, some sample stations had high concentrations of a target contaminant of concern in one sample while other samples indicated only background levels. The individual latest excess cancer risk for the reasonable maximum exposure for hypothetical future on-site resident was found to be the highest of the five scenarios examined. It was calculated to be 4×10^{-5}, which falls within the EPA guidance range of 10^{-6} to 10^{-4}. A special case was evaluated for inhalation of soil gas over the ground water hot spot at IHSS 119.1. For this limited case the risk was calculated to be 2.7×10^{-3}, which exceeds the EPA guidance range.

7.2 CONCLUSIONS

Conclusions regarding data limitations and recommended remedial action objectives are drawn from the findings summarized above in Section 7.1.

7.2.1 Data Limitations

Currently, two limitations exist to supplement the site conceptual model at OU1, and these include:

- Radionuclide data for sediment sample locations SED037, SED038, and SED039 for fourth quarter 1991. Samples from sediment locations SED037, SED038, and SED039 were not sufficient in volume to account for a complete analytical suite during fourth quarter 1991. Sediments were not sampled during first quarter 1992 because sediments were frozen. Data for a complete sampling round for a subsequent quarter should be evaluated once available.

- Surface soil radionuclide results for the sampling done at RFP as implemented from the Phase II work plan for OU2. This includes samples collected from surface soil plots and vertical profiles in OU1. Surface soil sample results for OU1 plots and vertical profiles will be available upon completion of the OU2 Phase II draft RFI/RI report in January 1993.

7.2.2 Remedial Action Objectives to be Considered in the Feasibility Study

The first step in the feasibility study process—development of alternatives—involves establishing remedial action objectives that specify the contaminants and media of interest, exposure pathways, and preliminary remediation goals, and developing a range of treatment and containment alternatives. Identifying and refining remedial action objectives is an ongoing process of narrowing focus that begins during the remedial investigation and continues during the feasibility study. Several preliminary and remedial action objectives have been identified for OU1 based on the results of site characterization in the Phase III RFI/RI. These objectives consider the contaminants and media of concern and the transport and exposure pathways as well as risk-based concerns developed in the baseline risk assessment.

Six remedial action objectives recommended for consideration for OU1 are:

- Consider continued operation and monitoring of the extraction well at IHSS 119.1. Effective ground water extraction at this location will lower the localized upper HSU water table and is expected to ultimately dewater the upper HSU in IHSS 119.1.

- IHSS 119.1 is the only IHSS at OU1 that exhibits VOC contamination levels above potential ground water quality standards, currently acts as a source of VOCs and contributes a substantial part of the risk. Consider evaluation of source removal and treatment or in situ treatment of saturated, partially saturated, and unsaturated upper HSU materials.

- Consider continued ground water monitoring and operation of the french drain. Also consider elimination of depression focused surface water recharge points in the Building 881 area to enhance ground water extraction efficiency, and diminish the volume of water to be treated by the french drain system.

- SVOC- and radionuclide-contaminated subsurface soils in IHSS 130 are currently immobile and are not available to the surface exposure pathway. Stabilization of the soils should be considered to minimize the possibility of future erosion.

- Ground water contamination at monitoring well 6286 could be addressed as part of the OU2 RFI/RI.

- Radionuclide-contaminated surface soils in the eastern part of OU1 are contiguous with OU2 and could be addressed as part of the OU2 RFI/RI.

Section 8.0

References

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8.0 REFERENCES

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Section 1.0 · Tables

Introduction

Phase III RFI/RI Report

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Title of Document	Author	Date
Public Health Risk Assessment, 881 Hillside Area (OU1), Technical Memorandum No. 9, Toxicity Constants, Department of Energy, Rocky Flats Plant, Golden Colorado	DOE	September 1992
Public Health Evaluation, 881 Hillside Area (OU1), Technical Memorandum No. 8, Contaminant Identification, Department of Energy, Rocky Flats Plant, Golden, Colorado, Draft	DOE	September 1992
Description of Models for the Public Health Evaluation, Operable Unit One, Technical Memorandum No. 7, Department of Energy, Rocky Flats Plant, Golden, Colorado, Revision 2.0	DOE	July 1992
Public Health Risk Assessment, 881 Hillside Area (OU1), Technical Memorandum No. 6, Exposure Scenarios, Department of Energy, Rocky Flats Plant, Golden, Colorado, Revision 4.0	DOE	June 1992
Final Interim Measure/Interim Remedial Action French Drain Performance Monitoring Plan, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	May 1992
Draft Final Technical Memorandum No. 5, Addendum to Final Phase III RFI/RI Work Plan, Surface Soil Sampling and Analysis Plan, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	February 1992
Technical Memorandum No. 4, Addendum to the Final Phase III RFI/RI Work Plan, Tracer Test Plan, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	November 1991
Technical Memorandum No. 3, Addendum to Final Phase III RFI/RI Work Plan, Multi-Well Pumping Test Plan, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	November 1991
Draft Final Phase III RI/FS Environmental Evaluation Field Sampling Plan, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	November 1991
Technical Memorandum No. 2, Responses to August 1, 1991 EPA Comments on the Operable Unit No. 1 RFI/RI Work Plan, Environmental Restoration, Program Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	August 1991
Technical Memorandum No. 1, Addendum to Final Phase III RFI/RI Work Plan, Chemical Analysis Plan, Rocky Flats Plant, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	August 1991

Title of Document	Author	Date
Quality Assurance Addendum (QAA 1.1) to the Rocky Flats Site-Wide Quality Assurance Project Plan for CERCLA RI/FS and RCRA RFI/CMS Activities for Operable Unit No. 1, 881 Hillside Area Phase III RFI/RI, Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	July 1991
Final Phase III RFI/RI Environmental Evaluation Work Plan, Rocky Flats Plant, 881 Hillside (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	June 1991
Final 881 Hillside Area Phase III Field Program (Operable Unit No. 1) Site Health and Safety Plan, EG&G Rocky Flats, Inc.	EG&G	April 1991
Final Phase III RFI/RI Work Plan, Rocky Flats Plant, 881 Hillside Area (Operable Unit No. 1), Department of Energy, (Revision 1), Rocky Flats Plant, Golden, Colorado	DOE	March 1991
Operable Unit No. 1 Interim Measure/Interim Remedial Action Implementation Document for Department of Energy, Rocky Flats Plant, Golden, Colorado	EG&G	February 1991
Response to EPA and CDH Comments on the Draft Phase III, RI/FS Work Plan 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	October 1990
Final Phase III RFI/RI Work Plan, Rocky Flats Plant, 881 Hillside Area (Operable Unit No. 1), Deparment of Energy, Rocky Flats Plant, Golden, Colorado	DOE	October 1990
French Drain Geotechnical Investigation, Department of Energy, Rocky Flats Plant, Golden, Colorado	EG&G	October 1990
Final Interim Measures/Interim Remedial Action Plan and Decision Document, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	January 1990
Final Environmental Assessment for 881 Hillside (High Priority Sites) Interim Remedial Action, Department of Energy, Rocky Flats Plant, Golden, Colorado	DOE	January 1990
Drawing No. 38548-127, General Site Plan and French Drain Re-Survey, Remedial Action, 881 Hillside Area, Rocky Flats Plant	Engineering-Science	1990

Title of Document	Author	Date
881 Hillside Remedial Investigation and Feasibility Study Response to EPA Comments	Rockwell	February 1989
Draft Feasibility Study Report for High Priority Sites (881 Hillside Area), Department of Energy, Rocky Flats Plant, Golden, Colorado	Rockwell	March 1988
Draft Final Remedial Investigation Report for High Priority Sites (881 Hillside Area), Department of Energy, Rocky Flats Plant, Golden, Colorado	Rockwell	March 1988

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CDH = Colorado Department of Health
CMS = Corrective Measure Study
EPA = Environmental Protection Agency
OU1 = Operable Unit No. 1
RCRA = Resource Conservation and Recovery Act
RFI/RI = RCRA Facility Investigation/Remedial Investigation
RI/FS = Remedial Investigation/Feasibility Study

Table 1-2 Summary of Phase III RFI/RI Work Plan Technical Memoranda and Standard Operating Procedure Addenda

Technical Memorandum/ SOP Addendum	Title of Document	Date
1	Addendum to the Final Phase III RFI/RI Work Plan, Chemical Analysis Plan, Rocky Flats Plant, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	August 1991
2	Responses to August 1, 1991 EPA Comments on the Operable Unit No. 1 RFI/RI Work Plan, Environmental Restoration Program, Department of Energy, Rocky Flats Plant, Golden, Colorado	August 1991
3	Addendum to the Final Phase III RFI/RI Work Plan, Multi-Well Pumping Test Plan, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	November 1991
4	Addendum to the Final Phase III RFI/RI Work Plan, Tracer Test Plan, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado	November 1991
5	Addendum to the Final Phase III RFI/RI Work Plan, Surface Soil Sampling and Analysis Plan, Rocky Flats Plant, 881 Hillside Area (Operable Unit No. 1), Department of Energy, Rocky Flats Plant, Golden, Colorado, Draft Final	February 1992
6	Public Health Risk Assessment, 881 Hillside Area (OU1), Exposure Scenarios, Department of Energy, Rocky Flats Plant, Golden, Colorado, Revision 4.0	June 1992
7	Description of Models for the Public Health Evaluation, Operable Unit One, Department of Energy Rocky Flats Plant, Golden, Colorado, Revision 2.0	July 1992
8	Public Health Evaluation, 881 Hillside Area (OU1), Contaminant Identification, Department of Energy, Rocky Flats Plant, Golden, Colorado, Draft	September 1992

EMD = Environmental Management Department
EPA = Environmental Protection Agency
OU1 = Operable Unit No. 1
RFI/RI = RCRA Facility Investigation/Remedial Investigation
SOPA = Standard Operating Procedure Addendum
TOC = Total Organic Carbon

Technical Memorandum/ SOP Addendum	Title of Document	Date
9	Public Health Risk Assessment, 881 Hillside Area (OU1), Toxicity Constants, Department of Energy, Rocky Flats Plant, Golden, Colorado	September 1992
Geotechnical	EMD Geotechnical SOPA, OU1 Soil Sampling for Geotechnical Testing Addendum, Rocky Flats Plant	October 1991
TOC	EMD Geotechnical SOPA, OU1 Soil Sampling for Total Organic Carbon Anaysis, Rocky Flats Plant	October 1991
Hand Auger	EMD Geotechnical SOPA, OU1 Hand Auger Sampling, Rocky Flats Plant	October 1991

EMD = Environmental Management Department
EPA = Environmental Protection Agency
OU1 = Operable Unit No. 1
RFI/RI = RCRA Facility Investigation/Remedial Investigation
SOPA = Standard Operating Procedure Addendum
TOC = Total Organic Carbon

Table 1-3 EPA/CDH Modifications to Chemical Analysis Plan for Phase III RFI/RI

IHSS Number	Borehole/ Well/SED Number	Workplan BH/MW/SED Designation	Proposed Chemical Analysis	EPA/CDH Modifications	Justification Provided for Modification
102	0887	0887	CLP VOA	EPA Method 502.2 VOA	Bedrock well downgradient from IHSS
107	39491	BH21	CLP VOA	All TCL organics	Not previously investigated
	0387	0387	CLP VOA	EPA Method 502.2 VOA	Previous sampling indicates contamination; only bedrock well downgradient from IHSS
119.1	0487	0487	CLP VOA	All TCL organics	Previous sampling indicates contamination
	4387	4387	CLP VOA	All TCL organics	Previous sampling indicates contamination
	0587	0587	CLP VOA	EPA Method 502.2 VOA	Only bedrock well in area of known contamination
	32791	MW25	CLP VOA	All TCL organics	Downgradient from known contamination
	33091	MW28	CLP VOA	All TCL organics	Downgradient from known contamination
	34891	BH27	CLP VOA	All TCL organics	Adjacent to well with known contamination
	33691	MW10	CLP VOA	All TCL organics	Not previously investigated
119.2	4587	4587	CLP VOA	EPA Method 502.2 VOA	Only bedrock well in IHSS
	33191	BH35	CLP VOA	All TCL organics	Not previously investigated
	32991	BH39	CLP VOA	All TCL organics	Not previously investigated
	34591	MW12	CLP VOA	All TCL organics	Not previously investigated
	34791	MW13	CLP VOA	All TCL organics	Not previously investigated
Woman Creek	30091	BH54	CLP VOA	All TCL organics	Not previously investigated
	SED 37	SED 37	CLP VOA	CLP VOA, pesticides/PCBs	Not previously investigated
	SED 38	SED 38	CLP VOA	CLP VOA, pesticides/PCBs	Not previously investigated
	SED 39	SED 39	CLP VOA	CLP VOA, pesticides/PCBs	Not previously investigated

BH = Borehole
CDH = Colorado Department of Health
CLP = Contract Laboratory Program
EPA = Environmental Protection Agency
IHSS = Individual Hazardous Substance Site
MW = Monitoring well
PCB = Polychlorinated biphenyls
SED = Sediment sampling station number
TCL = Target Compound List
VOA = Volatile organics analysis

Table 1-4 Proposed Analytical Suite for Each Phase III Borehole and Monitoring Well

Borehole/Well Number	Work Plan Designation	VOCs	SVOCs	Radionuclides	Metals	Indicators
30091	BH54	X	X	X	X	X
30191	BH53	X	NA	X	X	X
30291	BH06	X	X	X	X	X
30391	BH52	X	NA	X	X	X
30491	BH52 offset	X	NA	X	X	X
30591	BH51	X	X	X	X	X
30691	BH09	X	X	X	X	X
30791	BH08/MW36	X	X	X	X	X
30891	BH07	X	X	X	X	X
30991	MW35	X	NA	NA	NA	NA
31091	BH05	X	X	X	X	X
31191	MW32	X	NA	NA	NA	NA
31291	BH05 offset	X	NA	X	X	X
31391	MW31	X	NA	NA	NA	NA
31491	MW30	X	NA	NA	NA	NA
31591	BH03	X	X	X	X	X
31691	BH05 offset	X	X	X	X	X
31791	MW36 offset	X	NA	NA	NA	NA
31891	BH04/MW02	X	X	X	X	X
31991	BH48	X	X	X	X	X
32091	BH18	X	X	X	X	X
32191	BH16	X	NA	X	X	X
32291	MW33	X	NA	NA	NA	NA
32391	BH49	X	X	X	X	X
32491	BH17	X	X	X	X	X
32591	MW24	X	NA	NA	NA	NA
32691	BH36	X	NA	X	X	X
32791	MW25	X	NA	NA	NA	NA
32891	BH38	X	NA	X	X	X
32991	BH39	X	X	X	X	X
33091	MW28	X	NA	NA	NA	NA
33191	BH35	X	X	X	X	X
33291	BH34	X	X	X	X	X

NA = Not Analyzed
SVOC = Semivolatile Organic Compound
VOC = Volatile Organic Compound

Borehole/Well Number	Work Plan Designation	VOCs	SVOCs	Radionuclides	Metals	Indicators
33391	MW27	X	NA	NA	NA	NA
33491	MW09	X	NA	NA	NA	NA
33591	BH37	X	X	X	X	X
33691	MW10	X	NA	NA	NA	NA
33791	BH33	X	NA	X	X	X
33891	MW08	X	NA	NA	NA	NA
33991	BH25	X	NA	X	X	X
34091	BH29	X	NA	X	X	X
34191	MW07	X	NA	NA	NA	NA
34291	BH28	X	X	X	X	X
34391	MW11	X	NA	NA	NA	NA
34491	BH24	X	NA	X	X	X
34591	MW12	X	NA	NA	NA	NA
34691	BH32	X	X	X	X	X
34791	MW13	X	NA	NA	NA	NA
34891	BH27	X	X	X	X	X
34991	BH31	X	NA	X	X	X
35091	MW26	X	NA	NA	NA	NA
35191	BH19/MW06	X	NA	X	X	X
35291	BH30	X	NA	X	X	X
35391	BH50/MW19	X	NA	X	X	X
35491	BH26	X	NA	X	X	X
35591	BH23	X	NA	X	X	X
35691	MW17	X	NA	NA	NA	NA
35791	BH43	X	NA	X	X	X
35891	BH40	X	NA	X	X	X
35991	MW18	X	NA	NA	NA	NA
36091	BH44	X	X	X	X	X
36191	MW05	X	NA	NA	NA	NA
36291	BH41	X	NA	X	X	X
36391	BH45/MW14	X	X	X	X	X
36491	BH01/MW01	X	X	X	X	X
36591	BH13	X	X	X	X	X

NA = Not Analyzed
SVOC = Semivolatile Organic Compound
VOC = Volatile Organic Compound

Table 1-4 Proposed Analytical Suite for Each Phase III Borehole and Monitoring Well

Borehole/Well Number	Work Plan Designation	VOCs	SVOCs	Radionuclides	Metals	Indicators
36691	BH46/MW15	X	NA	X	X	X
36791	BH12	X	X	X	X	X
36891	BH11	X	X	X	X	X
36991	BH10/MW04	X	X	X	X	X
37091	BH14	X	X	X	X	X
37191	BH47/MW16	X	X	X	X	X
37291	BH20	X	X	X	X	X
37391	BH02	X	X	X	X	X
37491	BH42	X	NA	X	X	X
37591	MW22	X	NA	NA	NA	NA
37691	MW23	X	NA	NA	NA	NA
37791	MW21	X	NA	NA	NA	NA
37891	MW27offset	X	NA	NA	NA	NA
37991	MW29	X	NA	NA	NA	NA
38091	MW20	X	NA	NA	NA	NA
38191	PZ05	X	NA	NA	NA	NA
38291	PZ06	X	NA	NA	NA	NA
38391	MW03	X	NA	NA	NA	NA
38491	MW03 offset	X	NA	NA	NA	NA
38591	MW34	X	NA	NA	NA	NA
38691	MW37	X	NA	NA	NA	NA
38791	MW37 offset	X	NA	NA	NA	NA
38891	PZ02	X	NA	NA	NA	NA
38991	PZ03	X	NA	NA	NA	NA
39091	PH01	X	NA	NA	NA	NA
39191	MW28 offset	X	NA	NA	NA	NA
39291	PZ01	X	NA	NA	NA	NA
39391	PZ02	X	NA	NA	NA	NA
39491	BH21	X	X	X	X	X
39591	BH22	X	NA	X	X	X
39691	MW20 offset	X	NA	NA	NA	NA
39791	PH03	X	NA	NA	NA	NA
39891	Drive Point Hole	X	NA	NA	NA	NA

NA = Not Analyzed
SVOC = Semivolatile Organic Compound
VOC = Volatile Organic Compound

Table 1-5 Analysis of Current and Future Land Use for Rocky Flats Plant Operable Unit No. 1*

Land Use Classification or Category	Current		Future	
	Off-Site	On-Site	Off-Site	On-Site
Residential	Yes	No	Credible	Improbable
Commercial/Industrial	Yes	Yes	Credible	Credible
Recreational	Yes	No	Credible	Plausible
Ecological Reserve	No	No	Improbable	Credible
Agricultural	Yes	No	Plausible	Improbable

* Land use possibilities are addressed in Technical Memorandum No. 6 (Revision 4.0). Supplementary scenarios have been included in the public health evaluation.

Section 2.0 · Tables

OU1 Field Investigation

Phase III
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Table 2-1 Phase III RFI/RI Objectives, Proposed Work, and Completed Work

Objective	Proposed Work	Completed Work
Characterize Site Physical Features		
(1) Determine the extent of saturation and ground water flow directions for the unconfined flow system both spatially and temporally.	• Install additional monitoring wells and piezometers.	• Installed 23 new alluvial wells, 3 new bedrock wells, 3 new alluvial piezometers, and 2 new bedrock piezometers.
	• Maintain and utilize the Rocky Flats Environmental Database System (RFEDS) for water level data from which potentiometric surface maps, saturated thickness maps, cross sections, and hydrographs can be prepared.	• All new geologic and hydrologic data were input to the RFEDS database, which was then utilized to select an integrated data subset for preparation of maps and cross sections used to refine the Operable Unit No. 1 (OU1) hydrogeologic model.
(2) Describe the interaction between the surface water and ground water pathways.	• Compare water levels and water quality data from surface water sampling locations and ground water.	• The interaction of surface water and ground water was described utilizing an integrated data set taken from surface water and ground water monitoring locations.
(3) Quantify material properties.	• Perform aquifer tests to develop hydraulic conductivity and storage coefficient values for surficial materials.	• Aquifer tests were performed at the following locations: packer tests at 37891, 37991, 39191, and 39291; slug injection/slug withdrawal tests at 31891, 34791, 35691, 37191, 37891, 38191, and 39291; bail down/recovery tests at 36191, 37591, 37791, 37991, 38591 and 39191; pumping tests and tracer tests at 39891 and at 15-wellpoint array at Test Site # 1.
(4) Describe all soils and rock materials.	• Implement field logging program utilizing Standard Operating Procedures (SOPs).	• Soils and rock materials recovered at 98 drilling locations were logged according to the SOPs.
(5) Verify the hydrogeologic site conceptual model for OU1.	• Integrate sitewide geologic and geophysical studies with hydrogeologic data from OU1.	• Geologic and hydrogeologic findings from sitewide geologic mapping, drilling, geophysics, french drain geologic mapping, and adjoining Operable Unit No. 2 (OU2) studies were integrated with OU1 data to refine the conceptual model.

Objective	Proposed Work	Completed Work
Characterize Contaminant Sources		
(6) Characterize the nature and distribution of waste materials remaining on site.	• Collect samples from boreholes drilled directly through individual hazardous substance sites (IHSSs) where possible. Collect waste samples as well as soil samples from beneath the wastes. Analyze samples for Target Compound List (TCL) volatiles, semivolatiles, pesticides/polychlorinated biphenyls (PCBs), metals and inorganics, and radionuclides	• Four-hundred-nineteen soil samples were collected from soil boreholes as well as from monitoring well boreholes. Additional samples were taken from the effluent of the Building 881 footing drain and a drum of Coherex. Any recognizable waste materials were sampled according to the SOPs, along with the underlying soils. Analyses were completed according to the chemical analysis plan (Technical Memorandum No. 1). Boreholes were within all designated IHSSs as well as in intervening areas. Figure 2-1 depicts the locations of all Phase III boreholes and monitoring wells relative to IHSSs. Results were used to characterize wastes and underlying soils.
(7) Characterize soils beneath wastes as well as soils at sites where wastes have been removed as potential contaminant sources.	• See above.	• See above.
(8) Identify which sites or subareas of sites are sources of contaminants in ground water.	• Install alluvial ground water monitoring wells directly beneath sites to assess ground water levels and quality. • Install alluvial ground water monitoring wells directly upgradient and downgradient of each site to pinpoint the source of contaminants.	• Eleven alluvial monitoring wells were installed in sites and IHSSs. Samples were collected under the routine monitoirng program and analyzed where ground water was present. Data were used to identify sources of ground water contamination. • Four upgradient and eight downgradient monitoring wells were installed relative to individual or groups of IHSSs. Wells were developed and samples were collected under the routine monitoring program and analyzed where ground water was present. Data were used to locate sources of ground water contamination and determine the extent of contamination.

Objective	Proposed Work	Completed Work
Characterize the Nature and Extent Of Contamination		
(9) Determine the horizontal and vertical extent of surface radionuclide soil contamination due to wind dispersion.	• Collect surface soil scrapes in the study area following Colorado Department of Health (CDH) sampling procedures and analyze for radionuclides. • Sample and analyze vertical soil profiles for radionuclides.	• Surface soil samples were collected as part of the OU2 Phase II RFI/RI investigation according to CDH procedures at 11 locations in OU1 and analyzed for radionuclides. Surface soil samples were collected according to Rocky Flats Plant (RFP) procedures at 28 locations (Technical Memorandum No. 5), and were analyzed for radionuclides and other contaminants. • Samples were collected from vertical soil profiles at four locations and were analyzed for radionuclides as part of the OU2 Phase II RFI/RI field investigation.
(10) Determine the nature and extent of ground water contamination in surficial (i.e., alluvial) materials.	• Install alluvial ground water monitoring wells in surficial materials located between areas of known ground water contamination and areas with no ground water contamination to delineate the extent. Collect ground water samples and analyze for TCL volatiles, semivolatiles, pesticides/PCBs, metals and inorganics, and radionuclides.	• See Objective 8, second bullet under the Completed Work column.
(11) Determine the location of the weathered and unweathered sandstone units and the extent of the associated contamination.	• Install bedrock monitoring wells in new boreholes in which sandstones are encountered, including boreholes that were initially planned for installation of alluvial wells, as well as selected boreholes planned specifically to seek sandstone. Produce east-west and north-south geologic and water level cross sections as data permit. Collect ground water samples and analyze for TCL volatiles, semivolatiles, pesticides/PCBs, metals and inorganics, and radionuclides.	• Three new bedrock monitoring wells were installed in boreholes planned specifically to seek bedrock sandstone. No sandstones were encountered below the bedrock contact in boreholes initially planned for alluvial wells, so no additional bedrock monitoring wells were installed. Two new bedrock piezometers were installed in bedrock boreholes planned specifically to seek sandstone; in one of these, sandstone was not encountered, but a piezometer was installed nevertheless. Wells were developed and samples were collected under the routine monitoring program and analyzed where ground water was present. Data were used to determine the location of the weathered and unweathered sandstone units and the extent of the associated contamination.

Objective	Proposed Work	Completed Work
(12) Characterize surface water quality.	• Continue collection of surface water from existing monitoring stations on a quarterly basis. Establish sediment stations directly associated with OU1 as sediment availability permits. Analyze samples for TCL volatiles, metals and inorganics, and radionuclides. Analyze surface water samples for both dissolved and total metals and radionuclides to determine if constituents are suspended or dissolved. Continue routine flow rate measurements at surface water stations.	• Samples were collected from surface water stations under the routine monitoring program on a monthly basis. Three new sediment stations (SED037, SED038, and SED039) were established downgradient of OU1 in the South Interceptor Ditch. The surface water and sediment samples were analyzed according to the chemical analysis plan (Technical Memorandum No. 1). Routine flow measurements at surface water stations were continued. Data were used to characterize surface water quality.
(13) Characterize radionuclides in Woman Creek sediments.	• Continue collection of surface water and sediment from existing monitoring stations on a quarterly basis. Establish sediment stations directly associated with OU1 as sediment availability permits. Analyze samples for TCL volatiles, metals and inorganics, and radionuclides. Analyze surface water samples for both dissolved and total metals and radionuclides to determine whether constituents are suspended or dissolved. Continue routine flow rate measurements at surface water stations.	• See above.
(14) Identify and implement data management procedures.	• Maintain the RFEDS for all data collected during the Phase III RFI/RI. Utilize this database system to evaluate resulting data.	• All data collected during the Phase III RFI/RI were input to the RFEDS database and then extracted for evaluation and assessment.
(15) Collect data of sufficient quality to facilitate development of a site conceptual model and comparison to applicable or relevant and appropriate requirements (ARARs).	• Adhere to the Rocky Flats Plant Environmental Restoration (ER) Program Quality Assurance Project Plan (QAPjP), General Radiochemistry and Routine Analytical Services Protocol (GRRASP), and the site-specific Quality Assurance Addendum (QAA).	• The Phase III RFI/RI data collection effort at OU1 was implemented in accordance with the RFP ER Program QAPjP, GRRASP, and the QAA for OU1 resulting in data meeting data quality objectives. The data were used to refine the site conceptual model and to facilitate comparison to potential ARARs.

Objective	Proposed Work	Completed Work
Provide a Baseline Risk Assessment		
(16) Describe contaminant fate and transport.	• Use existing literature and field data to describe the physiochemical processes associated with site contaminants. Incorporate Phase III results into risk analysis.	• Contaminant fate and transport have been described using up-to-date literature and all field data. Phase III data have been used in the risk analysis.
(17) Assess the threat to public health and the environment from the No Action remedial alternative.	• Prepare a baseline risk assessment as part of the RI data analysis based on Phase I, II, and III RI.	• A baseline risk assessment has been performed using Phase III data.

Table 2-2 Investigative Programs at Operable Unit No. 1

Type of Investigation	Program
Individual Hazardous Substance Site Investigations	Phase III RFI/RI Field Investigation
Air Quality and Meteorological Investigations	Routine Ambient Air Monitoring Program
Surface Water and Sediment Investigations	Routine Monitoring Program for Ground Water, Surface Water, and Sediments
Geological Investigations	Phase III RFI/RI Field Investigation
	French Drain Geologic Characterization Program
Surface Soils Investigation	Surface (Radionuclides) Soil Sampling and Analysis Program for OU1 and OU2 (conducted under the Phase II RFI/RI Field Investigation for OU2)
	Surface Soil Sampling and Analysis Program for OU1
Ground Water Investigations	Routine Monitoring Program for Ground Water, Surface Water, and Sediments
Ecological Investigations	Phase III Environmental Evaluation

RFI/RI = RCRA Facility Investigation/Remedial Investigation
OU1 = Operable Unit No. 1
OU2 = Operable Unit No. 2

IHSS Number	Borehole Number (Proposed Number)	Location	Purpose	Details: Borehole	Details: Total Depth (feet below ground surface)	Details: Alluvium/ Bedrock Contact (feet below ground surface)
102	36491 (BH01/MW01)	IHSS 102, Oil Sludge Pit Site	Characterize the nature and extent of contamination.	36491	18.6	14.0
	37391 (BH02)			37391	18.2	15.1
	31591 (BH03)	Within area of seepage from IHSS 102 identified on 1955 air photos	Characterize the nature and extent of contamination downgradient of IHSS 102; 31591 (BH03), 31091 (BH05), and 30291 (BH06) will also be used to evaluate the proposed french drain alignment.	31591	16.3	10.7
	31891 (BH04/MW02)			31891	21.6	17.2
	31091 (BH05)			31091	32.5	--
	31291 (BH05 offset)			31291	36.0	12.5
	31691 (BH05 offset)			31691	32.6	29.0
	30291 (BH06)	Downgradient of seepage area from IHSS 102	Characterize the nature and extent of contamination downgradient of IHSS 102	30291	22.9	15.5
	30891 (BH07)			30891	18.0	2.7
	30791 (BH08/MW36)	Vicinity of the former retention pond	Characterize the nature and extent of contamination within the site.	30791	18.7	9.5
	30691 (BH09)			30691	14.7	7.5
103	36991 (BH10/MW04)	IHSS 103, Chemical Burial Site; not previously drilled	Characterize the nature and extent of contamination within the site.	36991	11.3	8.0
	36891 (BH11)			36891	13.6	9.1
	36791 (BH12)			36791	16.3	12.5
104	36591 (BH13)	IHSS 104, Liquid Dumping Site; suspected to be mislocated from IHSS 103	Characterize the nature and extent of contamination to determine whether IHSS 104 has been mislocated.	36591	17.6	10.0
	37091 (BH14)			37091	8.6	4.1

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Alluvium/bedrock contact not encountered
est = Estimated

IHSS Number	Borehole Number (Proposed Number)	Location	Purpose	Details: Borehole	Details: Total Depth (feet below ground surface)	Details: Alluvium/ Bedrock Contact (feet below ground surface)
105.1 and 105.2	(BH15)	IHSS 105.1 and 105.2, Out-of-Service Fuel Tank Sites	Characterize the nature and extent of contamination within the site.	Not Drilled		
	32191 (BH16)			32191	18.6	15.0
	32491 (BH17)			32491	10.9	6.0
	32091 (BH18)			32091	20.7	16.1
106	35191 (BH19/MW06)	IHSS 106, Outfall Site	Characterize the nature and extent of contamination in conjunction with a drainage test of Building 887 sump.	35191	6.3	2.0
	37291 (BH20)			37291	28.3	23.3
107	39491 (BH21)	IHSS 107, Hillside Oil Leak Site; boreholes to be within the skimming pond	Characterize nature and extent of contamination (using hand auger until refusal) in conjunction with effluent sampling from Building 885 footing drains.	39491	4.0	1.4
	39591 (BH22)			39591	3.0	--
119.1	35591 (BH23)	IHSS 119.1, Multiple Solvent Spill Site, within the Western Barrel Storage Area	Characterize the nature and extent of contamination within the site.	35591	6.3	2.3
	34491 (BH24)			34491	6.5	0.6
	33991 (BH25)			33991	12.6	2.4
	35491 (BH26)			35491	10.4	6.8
	34891 (BH27)			34891	14.6	11.0
	34291 (BH28)			34291	8.6	3.4
	34091 (BH29)			34091	10.3	6.2
	35291 (BH30)			35291	12.6	8.0
	34991 (BH31)			34991	16.3	12.3
	34691 (BH32)			34691	14.0	10.0

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Alluvium/bedrock contact not encountered
est = Estimated

IHSS Number	Borehole Number (Proposed Number)	Location	Purpose	Details: Borehole	Details: Total Depth (feet below ground surface)	Details: Alluvium/ Bedrock Contact (feet below ground surface)
119.2	33791 (BH33)	IHSS 119.2, Multiple Solvent Spill Site, within the Eastern Barrel Storage Area	Characterize the nature and extent of contamination within the site.	33791	22.6	16.2
	33291 (BH34)			33291	14.8	10.0
	33191 (BH35)			33191	6.6	1.4
	32691 (BH36)			32691	8.6	3.3
	33591 (BH37)			33591	16.6	12.0
	32891 (BH38)			32891	8.8	4.0
	32991 (BH39)			32991	8.6	3.7
130	35891 (BH40)	IHSS 130, Radioactive Site - 800 Area Site #1, located within the site	Characterize the nature and extent of contamination within the site.	35891	12.6	8.0
	36291 (BH41)			36291	13.9	8.5
	37491 (BH42)			37491	16.0	12.0
	35791 (BH43)			35791	16.3	11.2
	36091 (BH44)			36091	18.6	14.3
	36391 (BH45/MW14)			36391	29.8	26.4
	36691 (BH46/MW15)			36691	28.3	25.0
	37191 (BH47/MW16)			37191	23.8	20.5
145	31991 (BH48)	IHSS 145, Sanitary Waste Line Leak, located within the site	Determine whether indications of possible contamination in nearby monitoring well 0187 are associated with the site.	31991	18.6	14.8
	32391 (BH49)			32391	12.9	4.2
177	35391 (BH50/MW19)	IHSS 177, Building 885 Drum Storage Site, downgradient of the site	Characterize the nature and extent of soil contamination downgradient from this site.	35391	12.0	6.0

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Alluvium/bedrock contact not encountered
est = Estimated

Table 2-3 Phase III RFI/RI Borehole Summary

IHSS Number	Borehole Number (Proposed Number)	Location	Purpose	Details: Borehole	Details: Total Depth (feet below ground surface)	Details: Alluvium/ Bedrock Contact (feet below ground surface)
South Interceptor Ditch	30591 (BH51) 30391 (BH52) 30491 (BH52 offset)	Downgradient of the South Interceptor Ditch	Characterize the nature and extent of soil contamination downgradient of the South Interceptor Ditch.	30591 30391 30491	12.0 32.5 32.0	7.0 28.0 (est.) 28.0
Woman Creek	30191 (BH53) 30091 (BH54)	Along Woman Creek downgradient of OU1	Characterize the nature and extent of contamination in the valley-fill alluvium along Woman Creek.	30191 30091	19.8 13.9	14.0 8.1
	39091 (PH01) 39391 (PH02) 39791 (PH03) 39891 (Drive Point Hole)		Characterize soil and groundwater conditions of the multiple-well test sites.	39091 39391 39791 39891	8.0 10.0 8.0 6.0	6.0 7.0 4.6 6.0

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Alluvium/bedrock contact not encountered
est = Estimated

Table 2-4 Phase III RFI/RI Monitoring Well and Piezometer Summary

IHSS Number	Well/Piezometer (Proposed Number)	Location	Purpose	Completion Details: Well/ Piezometer	Completion Details: Screened Interval (feet below ground surface)	Completion Details: Alluvium/ Bedrock Contact (feet below ground surface)
102	(MW01)	IHSS 102, Oil Sludge Pit Site	Characterize colluvial ground water beneath the site.	Not Installed	--	--
	31891 (BH04/MW02)	Area of seepage from IHSS 102	Characterize colluvial ground water beneath the site.	31891	16.59-18.59	17.2
	31791 (MW36 offset)	Vicinity of former retention pond	Characterize Woman Creek valley-fill alluvial ground water downgradient of IHSS 102.	31791	6.80-11.80	8.8
	38391 (MW03)			Abandoned	--	4.9-8.3 (est.)
	38491 (MW03 offset)			Abandoned	--	4.0
103	36991 (BH10/MW04)	IHSS 103, Chemical Burial Site	Characterize colluvial ground water beneath the site.	36991	6.62-8.62	8.0
	36191 (MW05)	IHSS 103	Characterize colluvial ground water immediately downgradient of IHSS 103.	36191	9.52-14.60	14.0

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Not applicable
est = Estimated

Table 2-4 Phase III RFI/RI Monitoring Well and Piezometer Summary

IHSS Number	Well/Piezometer (Proposed Number)	Location	Purpose	Completion Details: Well/ Piezometer	Completion Details: Screened Interval (feet below ground surface)	Completion Details: Alluvium/ Bedrock Contact (feet below ground surface)
106	35191 (BH19/MW06)	IHSS 106, Outfall Site	Characterize colluvial ground water beneath the outfall.	Abandoned	--	2.0
107	35691 (MW17)	IHSS 107, Hillside Oil Leak Site, within the skimming pond area	Characterize colluvial ground water beneath the site.	35691	15.58-26.56	25.2
119.1	34191 (MW07)	IHSS 119.1, Multiple Solvent Spill Site, within and downgradient from the Western Barrel Storage Area	Characterize colluvial ground water beneath and at the downgradient edge of the site.	Abandoned	--	4.0
	33891 (MW08)			33891	6.70-8.70	8.1
	33491 (MW09)			33491	6.68-8.69	8.0
	33691 (MW10)			33691	6.19-8.11	7.8
	34391 (MW11)			Abandoned	--	2.7

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Not applicable
est = Estimated

IHSS Number	Well/Piezometer (Proposed Number)	Location	Purpose	Completion Details: Well/ Piezometer	Completion Details: Screened Interval (feet below ground surface)	Completion Details: Alluvium/ Bedrock Contact (feet below ground surface)
119.2	34591 (MW12)	IHSS 119.2, Multiple Solvent Spill Site, at the downgradient edge of the site	Characterize alluvial ground water at the sites east-southeast downgradient edge.	34591	6.90-8.90	8.2
	34791 (MW13)			34791	6.00-8.00	8.0
130	36391 (BH45/MW14)	IHSS 130, Radioactive Site - 800 Area Site #1 at the downgradient edge of the site	Characterize colluvial ground water at the downgradient edge of the site.	36391	17.43-27.41	26.4
	36691 (BH46/MW15)			36691	15.83-25.83	25.0
	37191 (BH47/MW16)			37191	11.12-21.07	20.5
145	35991 (MW18)	Downgradient of IHSS 145, Sanitary Waste Line Leak	Characterize colluvial ground water downgradient of the site.	35991	8.68-13.70	12.1
Down-gradient of 177	35391 (BH50/MW19)	Downgradient of IHSS 177, Building 885 Drum Storage Site, adjacent to 35391 (BH50)	Characterize colluvial ground water downgradient of the site	35391	6.10-8.11	6.0

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Not applicable
est = Estimated

IHSS Number	Well/Piezometer (Proposed Number)	Location	Purpose	Completion Details: Well/ Piezometer	Completion Details: Screened Interval (feet below ground surface)	Completion Details: Alluvium/ Bedrock Contact (feet below ground surface)
Up-gradient of 119.1 and 119.2	38091 (MW20)	On the Rocky Flats Alluvium terrace north of IHSS 119.1 and IHSS 119.2	Characterize the upgradient alluvial ground water at OU1.	Abandoned	--	--
	39691 (MW20 offset)			39691	7.00-9.00	6.8
	37791 (MW21)			37791	10.60-20.60	20.0
	37591 (MW22)			37591	7.60-12.60	12.0
	37691 (MW23)			37691	6.51-16.50	16.2
Down-gradient of 119.1	32591 (MW24)	Downgradient of IHSS 119.1, between wells 0974 and 0487	To further characterize the extent of volatile organics detected in wells 4887, 1074, 0974, and 0487. Wells 37591 (MW22) and 37691 (MW23) will also further delineate the extent of colluvial saturation and water quality in their locations.	32591	11.50-16.50	15.9

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Not applicable
est = Estimated

Table 2-4 Phase III RFI/RI Monitoring Well and Piezometer Summary

IHSS Number	Well/Piezometer (Proposed Number)	Location	Purpose	Completion Details: Well/ Piezometer	Completion Details: Screened Interval (feet below ground surface)	Completion Details: Alluvium/ Bedrock Contact (feet below ground surface)
119.1 and 130	32791 (MW25)	In the vicinity of IHSS 119.1 and 130 in the sandstone screened by well 0587BR. MW27 presumably upgradient (west), MW28 presumably sidegradient (south), and MW29 presumably downgradient (east)	To further investigate elevated levels of total dissolved solids (TDS), strontium, and selenium detected in well 0587BR during 1989. Water levels will also be used to determine ground water flow directions in the bedrock sandstone.	Abandoned	--	2.7
	35091 (MW26)			Abandoned	--	4.7
	33391 (MW27)			Abandoned	--	5.0
	37891 (MW27 offset)			37891	43.20-53.20	4.7
	33091 (MW28)			Abandoned	--	2.6
	39191 (MW28 offset)			39191	32.80-42.80	7.1
	37991 (MW29)			37991	45.20-55.20	6.9

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Not applicable
est = Estimated

IHSS Number	Well/Piezometer (Proposed Number)	Location	Purpose	Completion Details: Well/ Piezometer	Completion Details: Screened Interval (feet below ground surface)	Completion Details: Alluvium/ Bedrock Contact (feet below ground surface)
South Interceptor Ditch	31491 (MW30)	Installed along the South Interceptor Ditch	Characterize colluvial ground water adjacent to the South Interceptor Ditch. Data to be used to evaluate interactions between the ditch surface water and unconfined ground water.	31491	13.90-18.90	16.5
	31391 (MW31)			Abandoned	--	2.5
	31191 (MW32)			Abandoned	--	4.7
Woman Creek	32291 (MW33)	Along Woman Creek downgradient of the OU1 area	Used to further characterize valley-fill alluvial ground water and surface water/ground water interaction along Woman Creek downgradient of OU1.	Abandoned	--	4.1
	38591 (MW34)			38591	5.66-7.66	7.2
	30991 (MW35)			30991	5.10-9.90	9.0
	38691 (MW37)			Abandoned	--	7.4
	38791 (MW37 offset)			Abandoned	--	6.2

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Not applicable
est = Estimated

IHSS Number	Well/Piezometer (Proposed Number)	Location	Purpose	Completion Details: Well/ Piezometer	Completion Details: Screened Interval (feet below ground surface)	Completion Details: Alluvium/ Bedrock Contact (feet below ground surface)
French Drain	39291 (PZ01)	Adjacent to wells 32591 (MW24) and 32791 (MW25)	Characterize the extent of weathered bedrock claystone saturation in weathered claystone upgradient of the french drain in conjunction with wells 32591 (MW24) and 32791 (MW25).	39291	33.95-43.95	10.7
	38891 (PZ02)	Downgradient of french drain	Characterize the extent of colluvial saturation downgradient of the french drain.	38891	7.30-9.30	9.0
	38991 (PZ03)	Downgradient of french drain	Characterize the extent of weathered bedrock claystone saturation downgradient of the french drain.	38991	26.80-36.80	19.5
	(PZ04)	Downgradient of french drain	Characterize the extent of weathered bedrock claystone saturation downgradient of the french drain.	Not Installed	--	--
119.1	38191 (PZ05)	IHSS 119.1, in between boreholes 34991 (BH31) and 34691 (BH32)	Provide additional colluvial ground water level data within IHSS 119.1.	38191	10.00-15.00	14.6
	38291 (PZ06)			38291	6.70-8.70	8.4

IHSS = Individual Hazardous Substance Site
BH = Borehole
MW = Monitoring Well
PH = Pilot Hole
-- = Not applicable
est = Estimated

Table 2-5 Soil Samples Collected During the Phase III RFI/RI Field Program for Chemical Analyses

Borehole/ Well Number	Work Plan Designation	VOCs	SVOCs	Radionuclides*	Metals+	Indicators*•
30091	BH54	X	X	X	X	X
30191	BH53	X	X	X	X	X
30291	BH06	X	X	X	X	X
30391	BH52	X	X	X	X	X
30491	BH52 offset	X	X	X	X	X
30591	BH51	X	X	X	X	X
30691	BH09	X	X	X	X	X
30791	BH08/MW36	X	X	X	X	X
30891	BH07	X	X	X	X	X
30991	MW35	X	NA	NA	NA	NA
31091	BH05	X	X	X	X	X
31191	MW32	NA	NA	NA	NA	NA
31291	BH05 offset	X	X	X	X	X
31391	MW31	X	NA	NA	NA	NA
31491	MW30	X	NA	NA	NA	NA
31591	BH03	X	X	X	X	X
31691	BH05 offset	X	X	X	X	X
31791	MW36 offset	X	NA	NA	NA	NA
31891	BH04/MW02	X	X	X	X	X
31991	BH48	X	X	X	X	X
32091	BH18	X	X	X	X	X
32191	BH16	X	X	X	X	X
32291	MW33	X	NA	NA	NA	NA
32391	BH49	X	X	X	X	X
32491	BH17	X	X	X	X	X
32591	MW24	X	NA	NA	NA	NA
32691	BH36	X	NA	X	X	X
32791	MW25	X	NA	NA	NA	NA

X = Method analyzed
NA = Method not analyzed
VOCs = Volatile organic compounds analyzed by EPA CLP or EPA Method 502.2
SVOCs = Semivolatile organic compounds analyzed by EPA CLP BNA and EPA CLP pesticides/PCBs
CLP = Contract laboratory program
EPA = Environmental Protection Agency
BNA = Base/neutral/acid extractables
* = Gross alpha/beta, tritium, and radiochemical isotopes
+ = Metals analyzed by EPA CLP
** = Water quality parameters

Table 2-5 Soil Samples Collected During the Phase III RFI/RI Field Program for Chemical Analyses

Borehole/ Well Number	Work Plan Designation	VOCs	SVOCs	Radionuclides*	Metals+	Indicators**
32891	BH38	X	NA	X	X	X
32991	BH39	X	X	X	X	X
33091	MW28	X	N/A	NA	NA	NA
33191	BH35	X	X	X	X	X
33291	BH34	X	X	X	X	X
33391	MW27	X	NA	NA	NA	NA
33491	MW09	X	NA	NA	NA	NA
33591	BH37	X	X	X	X	X
33691	MW10	X	NA	NA	NA	NA
33791	BH33	X	NA	X	X	X
33891	MW08	X	NA	NA	NA	NA
33991	BH25	X	NA	X	X	X
34091	BH29	X	NA	X	X	X
34191	MW07	X	NA	NA	NA	NA
34291	BH28	X	X	X	X	X
34391	MW11	X	NA	NA	NA	NA
34491	BH24	X	NA	X	X	X
34591	MW12	X	NA	NA	NA	NA
34691	BH32	X	X	X	X	X
34791	MW13	NA	NA	NA	NA	NA
34891	BH27	X	X	X	X	X
34991	BH31	X	X	X	X	X
35091	MW26	X	NA	NA	NA	NA
35191	BH19/MW06	X	X	X	X	X
35291	BH30	X	NA	X	X	X
35391	BH50/MW19	X	NA	X	X	X
35491	BH26	X	NA	X	X	X
35591	BH23	X	NA	X	X	X

X = Method analyzed
NA = Method not analyzed
VOCs = Volatile organic compounds analyzed by EPA CLP or EPA Method 502.2
SVOCs = Semivolatile organic compounds analyzed by EPA CLP BNA and EPA CLP pesticides/PCBs
CLP = Contract laboratory program
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BNA = Base/neutral/acid extractables
* = Gross alpha/beta, tritium, and radiochemical isotopes
+ = Metals analyzed by EPA CLP
** = Water quality parameters

Table 2-5 Soil Samples Collected During the Phase III RFI/RI Field Program for Chemical Analyses

Borehole/ Well Number	Work Plan Designation	VOCs	SVOCs	Radionuclides*	Metals+	Indicators**
35691	MW17	X	NA	NA	NA	NA
35791	BH43	X	NA	X	X	X
35891	BH40	X	NA	X	X	X
35991	MW18	X	NA	NA	NA	NA
36091	BH44	X	X	X	X	X
36191	MW05	X	NA	NA	NA	NA
36291	BH41	X	NA	X	X	X
36391	BH45/MW14	X	X	X	X	X
36491	BH01/MW01	X	NA	X	X	X
36591	BH13	X	X	X	X	X
36691	BH46/MW15	X	NA	X	X	X
36791	BH12	X	X	X	X	X
36891	BH11	X	X	X	X	X
36991	BH10/MW04	X	NA	X	X	X
37091	BH14	X	X	X	X	X
37191	BH47/MW16	X	NA	X	X	X
37291	BH20	X	X	X	X	X
37391	BH02	X	X	X	X	X
37491	BH42	X	NA	X	X	X
37591	MW22	X	NA	NA	NA	NA
37691	MW23	X	NA	NA	NA	NA
37791	MW21	X	NA	NA	NA	NA
37891	MW27offset	X	NA	NA	NA	NA
37991	MW29	X	NA	NA	NA	NA
38091	MW20	NA	NA	NA	NA	NA
38191	PZ05	X	NA	NA	NA	NA
38291	PZ06	X	NA	NA	NA	NA
38391	MW03	X	NA	NA	NA	NA

X = Method analyzed
NA = Method not analyzed
VOCs = Volatile organic compounds analyzed by EPA CLP or EPA Method 502.2
SVOCs = Semivolatile organic compounds analyzed by EPA CLP BNA and EPA CLP pesticides/PCBs
CLP = Contract laboratory program
EPA = Environmental Protection Agency
BNA = Base/neutral/acid extractables
* = Gross alpha/beta, tritium, and radiochemical isotopes
+ = Metals analyzed by EPA CLP
** = Water quality parameters

Table 2-5 Soil Samples Collected During the Phase III RFI/RI Field Program for Chemical Analyses

Borehole/ Well Number	Work Plan Designation	VOCs	SVOCs	Radionuclides*	Metals+	Indicators**
38491	MW03 offset	X	NA	NA	NA	NA
38591	MW34	X	NA	NA	NA	NA
38691	MW37	X	NA	NA	NA	NA
38791	MW37 offset	X	NA	NA	NA	NA
38891	PZ02	X	NA	NA	NA	NA
38991	PZ03	X	NA	NA	NA	NA
39091	PH01	X	NA	NA	NA	NA
39191	MW28 offset	X	NA	NA	NA	NA
39291	PZ01	X	NA	NA	NA	NA
39391	PH02	X	NA	NA	NA	NA
39491	BH21	X	X	X	X	X
39591	BH22	X	NA	X	X	NA
39691	MW20 offset	X	NA	NA	NA	NA
39791	PH03	X	NA	NA	NA	NA
39891	Drive Point Hole	NA	NA	NA	NA	NA

X = Method analyzed
NA = Method not analyzed
VOCs = Volatile organic compounds analyzed by EPA CLP or EPA Method 502.2
SVOCs = Semivolatile organic compounds analyzed by EPA CLP BNA and EPA CLP pesticides/PCBs
CLP = Contract laboratory program
EPA = Environmental Protection Agency
BNA = Base/neutral/acid extractables
* = Gross alpha/beta, tritium, and radiochemical isotopes
+ = Metals analyzed by EPA CLP
** = Water quality parameters

Table 2-6 Chemical Parameters for Phase III Soil Samples

Volatile Organic Compounds (VOCs)

1,1,1-Trichloroethane
1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane
1,1-Dichloroethane
1,1-Dichloroethene
1,2-Dichloroethane
1,2-Dichloroethene
1,2-Dichloropropane
2-Butanone
2-Hexanone
4-Methyl-2-pentanone
Acetone
Benzene
Bromodichloromethane
Bromoform
Bromomethane
Carbon disulfide
Carbon tetrachloride
Chlorobenzene
Chloroethane
Chloroform
Chloromethane
Dibromochloromethane
Ethylbenzene
Methylene chloride
Styrene
Tetrachloroethene
Toluene
Total xylenes
Trichloroethene
Vinyl acetate
Vinyl chloride
cis-1,2-Dichloroethene
trans-1,2-Dichloroethene
trans-1,3-Dichloropropene

Semivolatile Organic Compounds (SVOCs)

1,2,4-Trichlorobenzene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,4-Dichlorophenol
2,4-Dimethyphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
2-Chloronaphthalene
2-Chlorophenol
2-Methylnaphthalene
2-Methyphenol
2-Nitroaniline
2-Nitrophenol
3,3'-Dichlorobenzidine
3-Nitroaniline
4,4'-DDD
4,4'-DDE
4,4'-DDT
4,6-Dinitro-2-methylphenol
4-Bromophenyl phenyl ether
4-Chloro-3-methylphenol
4-Chloroaniline
4-Chlorophenyl phenyl ether
4-Methylphenol
4-Nitroaniline
4-Nitrophenol
Acenaphthene
Acenaphthylene
Aldrin
Anthracene
AROCLOR-1016
AROCLOR-1221
AROCLOR-1232
AROCLOR-1242
AROCLOR-1248
AROCLOR-1254
AROCLOR-1260
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(ghi)perylene
Benzo(k)fluoranthene
Benzoic acid
Benzyl alcohol
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether
Bis(2-chloroisopropyl)ether
Bis(2-ethylhexyl)phthalate
Butyl benzyl phthalate
Chrysene
Di-n-butyl phthalate
Di-n-octyl phthalate
Dibenzo(a,h)anthracene
Dibenzofuran
Dieldrin
Diethyl phthalate
Dimethyl phthalate
Endosulfan I
Endosulfan II
Endosulfan sulfate
Endrin
Endrin ketone
Fluoranthene
Fluorene
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)pyrene

Isophorone
Methoxychlor
n-Nitroso-di-n-propylamine
n-Nitroso-diphenylamine
Naphthalene
Nitrobenzene
Pentachlorophenol
Phenanthrene
Phenol
Pyrene
Toxaphene
alpha-BHC
alpha-Chlordane
beta-BHC
delta-BHC
gamma-BHC (Lindane)
gamma-Chlordane

Radionuclides

Americium-241
Cesium-137
Gross alpha - dissolved
Gross beta - dissolved
Plutonium-239,-240
Radium-226
Radium-228
Strontium-89,-90
Tritium
Uranium-233,-238,-239
Uranium-233,-234
Uranium-235
Uranium-235,-236

Metals

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Cesium
Chromium
Cobalt
Copper
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Potassium
Selenium
Silicon
Silver
Sodium
Strontium
Thallium
Tin
Vanadium
Zinc

Indicators

Total petroleum hydrocarbons
Total organic carbon
pH

Table 2-7 Chemical Parameters for Phase III Sediment Samples

Volatile Organic Compounds (VOCs)

1,1,1-Trichloroethane
1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane
1,1-Dichloroethane
1,1-Dichloroethene
1,2-Dichloroethene
1,2-Dichloroethane
1,2-Dichloropropane
1,2-Dimethylbenezene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2-Butanone
2-Hexanone
4-Methyl-2-pentanone
Acetone
Benzene
Bromodichloromethane
Bromoform
Bromomethane
Carbon disulfide
Carbon tetrachloride
Chlorobenzene
Chloroethane
Chloroform
Chloromethane
Dibromochloromethane
Ethylbenzene
Methylene chloride
Styrene
Tetrachloroethene
Toluene
Total xylenes
Trichloroethene
Vinyl acetate
Vinyl chloride
cis-1,3-Dichloropropene
trans-1,2-Dichloroethene
trans-1,3-Dichloropropene

Semivolatile Organic Compounds (SVOCs)

1,2,4-Trichlorobenzene
1,2-Dichlorobenzene
1,2-Dichloroethane
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,4-Dichlorophenol
2,4-Dimethyphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
2-Chloroethyl vinyl ether
2-Chloronaphthalene
2-Chlorophenol
2-Methylnaphthalene
2-Methyphenol
2-Nitroaniline
2-Nitrophenol
3,3'-Dichlorobenzidine
3-Nitroaniline
4,4'-DDD
4,4'-DDE
4,4'-DDT
4,6-Dinitro-2-methylphenol
4-Bromophenyl phenyl ether
4-Chloro-3-methylphenol
4-Chloroaniline
4-Chlorophenyl phenyl ether
4-Methylphenol
4-Nitroaniline
4-Nitrophenol
Acenaphthene
Acenaphthylene
Aldrin
Anthracene
AROCLOR-1016
AROCLOR-1221
AROCLOR-1232
AROCLOR-1242
AROCLOR-1248
AROCLOR-1254
AROCLOR-1260
Benzenamine
Benzidine
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(ghi)perylene
Benzo(k)fluoranthene
Benzoic acid
Benzyl alcohol
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether
Bis(2-chloroisopropyl)ether
Bis(2-ethylhexyl)phthalate
Butyl benzyl phthalate
Chlordane
Chrysene
Di-n-butyl phthalate
Di-n-octyl phthalate
Dibenzo(a,h)anthracene
Dibenzofuran
Dieldrin
Diethyl phthalate
Dimethyl phthalate
Endosulfan I
Endosulfan II
Endosulfan sulfate
Endrin
Endrin ketone
Fluoranthene
Fluorene
Heptachlor

Semivolatile Organic Compounds (SVOCs), continued

Heptachlor epoxide
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)pyrene
Isophorone
Methoxychlor
n-Nitroso-di-n-propylamine
n-Nitrosodimethylamine
n-Nitrosodiphenylamine
Naphthalene
Nitrobenzene
Pentachlorophenol
Phenanthrene
Phenol
Pyrene
Toxaphene
alpha-BHC
alpha-Chlordane
beta-BHC
delta-BHC
gamma-BHC (Lindane)
gamma-Chlordane

Radionuclides

Americium-241
Cesium-137
Gross alpha - dissolved
Gross alpha - particle radioactivity
Gross beta - dissolved
Gross beta -particle radioactivity
Gross gamma
Plutonium-238
Plutonium-239
Plutonium-239,-240
Radium-226
Radium-228
Strontium-89,-90
Strontium-90
Tritium
Uranium-233,-238,-239
Total uranium
Uranium-233,-234
Uranium-234
Uranium-235
Uranium-235,-236
Uranium-238

Metals

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Cesium
Chromium
Copper
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Potassium
Selenium
Silicon
Silver
Sodium
Strontium
Thallium
Tin
Vanadium
Zinc

Indicators

% Moisture
% Solids
Alkalinity
Ammonia
Bicarbonate
Bromide
Carbonate
Chloride
Cyanide
Dissolved oxygen
Fluoride
Hardness
Ignitability
Nitrate
Nitrate + Nitrite
Nitrite
Oil and grease
pH
Phosphate
Phosphorus
Specific conductivity
Sulfate
Sulfide
Total dissolved solids
Total organic carbon
Total suspended solids
Turbidity

Volatile Organic Compounds (VOCs)

1,1,1-Trichloroethane
1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane
1,1-Dichloroethane
1,1-Dichloroethene
1,2-Dichloroethane
1,2-Dichloroethene
1,2-Dichloropropane
2-Butanone
2-Hexanone
4-Methyl-2-pentanone
Acetone
Benzene
Bromodichloromethane
Bromoform
Bromomethane
Carbon disulfide
Carbon tetrachloride
Chlorobenzene
Chloroethane
Chloroform
Chloromethane
Dibromochloromethane
Ethylbenzene
Methylene chloride
Styrene
Tetrachloroethene
Toluene
Total xylenes
Trichloroethene
Vinyl acetate
Vinyl chloride
cis-1,2-Dichloroethene
trans-1,3-Dichloropropene

Semivolatile Organic Compounds (SVOCs)

1,2,4-Trichlorobenzene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,4-Dichlorophenol
2,4-Dimethyphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
2-Chloronaphthalene
2-Chlorophenol
2-Methylnaphthalene
2-Methyphenol
2-Nitroaniline
2-Nitrophenol
3,3-Dichlorobenzidine
3-Nitroaniline
4,4'-DDD
4,4'-DDE
4,4'-DDT
4,6-Dinitro-2-methylphenol
4-Bromophenyl phenyl ether
4-Chloro-3-methylphenol
4-Chloroaniline
4-Chlorophenyl phenyl ether
4-Methylphenol
4-Nitroaniline
4-Nitrophenol
Acenaphthene
Acenaphthylene
Aldrin
Anthracene
AROCLOR-1016
AROCLOR-1221
AROCLOR-1232
AROCLOR-1242
AROCLOR-1248
AROCLOR-1254
AROCLOR-1260
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(ghi)perylene
Benzo(k)fluoranthene
Benzoic acid
Benzyl alcohol
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether
Bis(2-chloroisopropyl)ether
Bis(2-ethylhexyl)phthalate
Butyl benzyl phthalate
Chrysene
Di-n-butyl phthalate
Di-n-octyl phthalate
Dibenzo(a,h)anthracene
Dibenzofuran
Dieldrin
Diethyl phthalate
Dimethyl phthalate
Endosulfan I
Endosulfan II
Endosulfan sulfate
Endrin
Endrin ketone
Fluoranthene
Fluorene
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)pyrene

Semivolatile Organic Compounds (SVOC) continued

Isophorone
Methoxychlor
n-Nitroso-di-n-propylamine
n-Nitroso-diphenylamine
Naphthalene
Nitrobenzene
Pentachlorophenol
Phenanthrene
Phenol
Pyrene
Toxaphene
alpha-BHC
alpha-Chlordane
beta-BHC
delta-BHC
gamma-BHC (Lindane)
gamma-Chlordane

Radionuclides

Cesium-137
Gross alpha - dissolved
Gross alpha - particle radioactivity
Gross beta - dissolved
Gross beta -particle radioactivity
Gross gamma
Plutonium-239
Plutonium-239,-240
Radium-226
Strontium-89
Strontium-89,-90
Strontium-90
Tritium
Uranium-233,-238,-239
Uranium-233,-234
Uranium-234
Uranium-235
Uranium-235,-236
Uranium-238

Metals

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Cesium
Chromium
Cobalt
Copper
Cyanide
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Potassium
Selenium
Silicon
Silver
Sodium
Strontium
Thallium
Tin
Vanadium
Zinc

Indicators

Bicarbonate
Carbonate
Chloride
Dissolved organic carbon
Fluoride
Nitrite
Nitrate + Nitrite
Oil and grease
pH
Phosphate
Phosphorus
Silica
Nonvolatile suspended solids
Sulfate
Sulfide
Total dissolved solids
Total organic carbon
Total suspended solids

Table 2-9 Chemical Parameters for OU1 and Rock Creek Surface Soil Samples

Semivolatile Organic Compounts (SVOCs)

1,2,4-Trichlorobenzene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,4-Dichlorophenol
2,4-Dimethyphenol
2,4-Dimitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
2-Chloronaphthalene
2-Chlorophenol
2-Methylnaphthalene
2-Methyphenol
2-Nitroaniline
2-Nitrophenol
3,3'-Dichlorobenzidine
3-Nitroaniline
4,6-Dinitro-2-methylphenol
4-Bromophenyl phenyl ether
4-Chloro-3-methylphenol
4-Chloroaniline
4-Chlorophenyl phenyl ether
4-Methylphenol
4-Nitroaniline
4-Nitrophenol
Acenaphthene
Acenaphthylene
Anthracene
Benzo(a)anthracene
Benzo (a)pyrene
Benzo(b)fluoranthene
Benzo(ghi)perylene
Benzo(k)fluoranthene
Benzoic acid
Benzyl alcohol
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether
Bis(2-chloroisopropyl)ether
Bis(2-ethylhexyl)phthalate
Butyl benzyl phthalate
Chrysene
Di-n-butyl phthalate
Di-n-octyl phthalate
Dibenzo(a,h)anthracene
Dibenzofuran
Diethyl phthalate
Dimethyl phthalate
Fluoranthene
Fluorene
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)pyrene
Isophorone
n-Nitroso-di-n-propylamine
n-Nitroso-diphenylamine
Naphthalene
Nitrobenzene
Pentachlorophenol
Phenanthrene
Phenol
Pyrene
0-Fluorophenol
4,4'-DDD
4,4'-DDE
4,4'-DDT
Aldrin
AROCLOR-1016
AROCLOR-1221
AROCLOR-1232
AROCLOR-1242
AROCLOR-1248
AROCLOR-1254
AROCLOR-1260
Dieldrin
Endosulfan I
Endosulfan II
Endosulfan sulfate
Endrin
Endrin ketone
Heptachlor
Heptachlor epoxide
Methoxychlor
Toxaphene
alpha-BHC
alpha-Chlordane
beta-BHC
delta-BHC
gamma-BHC (Lindane)
gamma-Chlordane

Radionuclides

Americium-241
Gross alpha - dissolved
Gross beta - dissolved
Plutonium-239,-240
Radium-226
Radium-228
Uranium-233,-234
Uranium-235
Uranium-238

Metals

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Cesium
Chromium
Cobalt

Metals (continued)

Copper
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Potassium
Selenium
Silicon
Silver
Sodium
Strontium
Thallium
Tin
Vanadium
Zinc

Indicators

Percent solids
Ammonia
Bicarbonate as $CaCO_3$
Carbonate
Nitrate+Nitrite
Oil and grease
Specific conductivity
Total organic carbon
pH

Volatile Organic Compounds (VOCs)

1,1,1,2-Tetrachloroethane
1,1,1-Trichloroethane
1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane
1,1-Dichloroethane
1,1-Dichloroethene
1,1-Dichloropropene
1,2,3-Trichlorobenzene
1,2,3-Trichloropropane
1,2-Dibromoethane
1,2-Dichloroethane
1,2-Dichloroethene
1,2-Dichloropropane
1,2-Dimethylbenzene
1,3-Dichloropropane
1,3-Dimethylbenzene
2-Butanone
2-Hexanone
4-Methyl-2-pentanone
Acetone
Benzene
1,2,4-Trimethyl benzene
1,2,5-Trimethyl benzene
Bromobenzene
Bromochloromethane
Bromodichloromethane
Bromoform
Bromomethane
Carbon disulfide
Carbon tetrachloride
Chlorobenzene
Chloroethane
Chloroform
Chloromethane
Dibromochloromethane
Dibromoethane
Dichlorodifluoromethane
Ethylbenzene
Methylene chloride
Styrene
1,2-Dibromo-3-chloropropane
Tetrachloroethene
Toluene
Total xylenes
Trichloroethene
Trichlorofluoromethane
Vinyl acetate
Vinyl chloride
cis-1,2-Dichloroethene
cis-1,2-Dichloropropene
n-Butylbenzene
n-Propylbenzene
o-Chlorotoluene
p-Chlorotoluene
p-Cymene
sec-Butylbenzene
tert-Butylbenzene
trans-1,2-Dichloroethene
trans-1,3-Dichloropropene

Semivolatile Organic Compounds (SVOCs)

1,2,4-Trichlorobenzene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,4-Dichlorophenol
2,4-Dimethyphenol
2,4-Dimitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
2-Chloronaphthalene
2-Chlorophenol
2-Methylnaphthalene
2-Methyphenol
2-Nitroaniline
2-Nitrophenol
3,3'-Dichlorobenzidine
3-Nitroaniline
4,4'-DDD
4,4'-DDE
4,4'-DDT
4,6-Dinitro-2-methylphenol
4-Bromophenyl phenyl ether
4-Chloro-3-methylphenol
4-Chloroaniline
4-Chlorophenyl phenyl ether
4-Methylphenol
4-Nitroaniline
4-Nitrophenol
Acenaphthene
Aldrin
Anthracene
AROCLOR-1016
AROCLOR-1221
AROCLOR-1232
AROCLOR-1242
AROCLOR-1248
AROCLOR-1254
AROCLOR-1260
Benzo(a)anthracene
Benzo (a)pyrene
Benzo(b)fluoranthene
Benzo(ghi)perylene
Benzo(k)fluoranthene
Benzoic acid
Benzyl alcohol
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether
Bis(2-chloroisopropyl)ether
Bis(2-ethylhexyl)phthalate
Butyl benzyl phthalate

Semivolatile Organic Compounds (SVOC) continued

Chrysene
Cumene
Di-n-butyl phthalate
Di-n-octyl phthalate
Dibenzo(a,h)anthracene
Dibenzofuran
Dieldrin
Diethyl phthalate
Dimethyl phthalate
Endosulfan I
Endosulfan II
Endosulfan sulfate
Endrin
Endrin ketone
Fluoranthene
Fluorene
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno(1,2,3-cd)pyrene
Isophorone
Methoxychlor
n-Nitroso-di-n-propylamine
n-Nitroso-diphenylamine
Naphthalene
Nitrobenzene
Pentachlorophenol
Phenanthrene
Phenol
Pyrene
Toxaphene
alpha-BHC
alpha-Chlordane
beta-BHC
delta-BHC
gamma-BHC (Lindane)
gamma-Chlordane

Radionuclides

Americium-241
Cesium-137
Gross alpha - dissolved
Gross beta - dissolved
Plutonium-238
Plutonium-239,-240
Radium-226
Strontium-89,-90
Tritium
Uranium-233,-234
Uranium-235
Uranium-238

Metals

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Chromium
Cobalt
Copper
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Potassium
Selenium
Silicon
Silver
Sodium
Strontium
Thallium
Tin
Vanadium
Zinc

Indicators

Alkalinity
Bicarbonate
Carbonate
Chloride
Cyanide
Fluoride
Nitrate
Nitrite
Nitrate + Nitrite
pH
Phosphate
Silica
Sulfate
Total dissolved solids
Total suspended solids

Table 2-11 Phase III RFI/RI Packer Test Information

Borehole Number	Water Level (feet)	Test Interval (feet)	Lithology
37891	40.50	37.20 - 56.30	Claystone, clayey siltstone, silty claystone, siltstone with trace clay and sand
		29.20 - 57.00	Claystone, clayey siltstone, silty claystone, siltstone with trace clay and sand
37991	Dry	42.10 - 51.90	Clayey siltstone, claystone, sandy clayey siltstone, silty claystone
		42.10 - 57.50	Clayey siltstone, claystone, sandy clayey siltstone, silty claystone
38991	No test due to hazardous access and poor weather conditions.		
39191	Dry	17.60 - 26.80	Claystone with varying amounts of silt
39291	43.17	43.20 - 47.60	Silty claystone

Table 2-12 Phase III RFI/RI Single Well Test Information

Well/Piezometer Number	Sand (BGS) (feet)	Screen (BGS) (feet)	Water Level for Test (feet)	Lithologic Zone*	Saturated Lithologies Tested	Selected Type of Test
31891	14.6-19.0	16.8-18.4	15.51	A, B	Alluvial sandy clay Bedrock clayey sandstone	Slug injection/slug withdrawal
34791	5.9-9.5	6.2-7.7	2.44	A	Silty sand, gravel	Slug injection/slug withdrawal
35691	13.4-13.3	15.8-26.4	9.34	A	Silty clay with some sand and gravel; sandy clay and clayey gravel	Slug injection/slug withdrawal
36191	7.4-14.9	9.7-14.4	11.94	A	Well graded gravelly sand with a 0.06 foot layer of clay	Bail down/recovery
37191	9.2-22.0	11.3-20.9	7.13	A	Gravelly, sandy clay	Slug injection/slug withdrawal
37591	5.6-14.6	7.8-12.4	11.19	A	Gravel, sand, and clay	Bail down/recovery
37791	8.8-22.6	10.8-20.4	20.01	A	Clay with silt, sand, and gravel	Bail down/recovery
37891	40.0-55.2	43.4-53.0	41.90	B	Silty claystone, clayey siltstone; siltstone with clay, trace sand	Slug injection/slug withdrawal
37991	43.0-57.2	45.4-55.0	48.78	B	Claystone, sandy clayey siltstone	Bail down/recovery
38191	8.1-14.9	10.1-14.9	9.38	A	Sand, silt, and clay with gravels and silty gravelly sand	Slug injection/slug withdrawal
38591	5.0-8.0	5.9-7.5	6.50	A	Silty sand with clay and gravel	Bail down/recovery
38991	24.8-37.8	27.0-36.6	27.80	B	Claystone, siltstone with clay and sand, silty claystone and clayey siltstone	Bail down/recovery

BGS = Below Ground Surface

*A = Alluvial
B = Bedrock

Table 2-12 Phase III RFI/RI Single Well Test Information

Well/Piezometer Number	Sand (BGS) (feet)	Screen (BGS) (feet)	Water Level for Test (feet)	Lithologic Zone*	Saturated Lithologies Tested	Selected Type of Test
39191	30.0-45.0	33.0-42.6	35.36	B	Clayey siltstone with organics; claystone with silt, siltstone with clay	Bail down/recovery
39291	31.7-45.9	34.2-43.8	30.25	B	Claystone, silty claystone, clayey siltstone	Slug injection/slug withdrawal

BGS = Below Ground Surface

*A = Alluvial
B = Bedrock

Table 2-13 Chemical Parameters for Biological Tissue Samples

Radionuclides

Americium-241 (Am-241)
Plutonium-239,-240 (Pu-239,-240)
Plutonium-238 (Pu-238)
Radium-226 (R-226)
Total Uranium

Metals

Cadmium (Cd)
Chromium (Cr)
Copper (Cu)
Lead (Pb)
Mercury (Hg)
Selenium (Se)
Silver (Ag)
Zinc (Zn)

Section 3.0 · Tables

Physical Characteristics of OU1

Phase III RFI/RI Report

U1 OU1 OU
881 Hillside
OU1 OU1 O
Hillside 881
1 OU1 OU1
side 881 Hill
U1 OU1 OU
881 Hillside
OU1 OU1 O
Hillside 881

Table 3-1 Wind Direction Frequency (Percent) by Four Wind-Speed Classes*

Fifteen-Minute Averages - 1990 through 1991

	Calm	1-3 m/s (2-7 mi/hr)	3-7 m/s (7-16 mi/hr)	7-15 m/s (16-34 mi/hr)	>15 m/s (>34 mi/hr)	TOTAL
—	3.40					3.40
N	0.00	2.86	3.85	0.47	0.00	7.18
NNE	0.00	2.89	2.69	0.20	0.00	5.79
NE	0.00	2.82	1.50	0.03	0.00	4.35
ENE	0.00	2.21	0.77	0.01	0.00	2.99
E	0.00	2.55	0.72	0.01	0.00	3.27
ESE	0.00	2.49	1.12	0.00	0.00	3.62
SE	0.00	2.72	2.38	0.06	0.00	5.17
SSE	0.00	2.50	2.40	0.21	0.00	5.11
S	0.00	2.57	2.57	0.17	0.00	5.32
SSW	0.00	2.37	2.21	0.15	0.00	4.73
SW	0.00	2.30	3.12	0.19	0.00	5.61
WSW	0.00	2.56	4.07	0.81	0.01	7.46
W	0.00	3.17	3.18	2.29	0.39	9.03
WNW	0.00	3.04	4.27	4.23	0.33	11.87
NW	0.00	3.00	4.34	1.34	0.01	8.69
NNW	0.00	2.53	3.65	0.23	0.00	6.41
TOTALS	3.40	42.58	42.85	10.41	0.75	100.00

* See wind rose in Figure 3-3.
m/s = Meters per second
mi/hr = Miles per hour

N = North
E = East
S = South
W = West

Table 3-2 Surface Water Flow Rates (1990)

Surface Water Station*	Location	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
SW044	Skimming Pond Discharge	No flow	No flow	No flow	--	No flow	No flow	--	No flow	No flow
SW045	881 Foundation Drain	No flow	No flow	--	--	No flow	--	--	--	--
SW046	Seep	--	--	--	--	--	--	--	No flow	No flow
SW031	South Interceptor Ditch	0.07	<0.1	No flow	--	--	No flow	No flow	No flow	No flow
SW035	South Interceptor Ditch	--	--	No flow	--	No flow	No flow	No flow	No flow	No flow
SW066	South Interceptor Ditch	No flow	--	--	--	No flow	--	No flow	--	--
SW067	South Interceptor Ditch	No flow	No flow	--	--	No flow	--	No flow	--	--
SW068	South Interceptor Ditch	No flow	No flow	--	--	No flow	No flow	--	No flow	--
SW069	South Interceptor Ditch	No flow	No flow	--	--	--	--	No flow	No flow	No flow
SW070	South Interceptor Ditch	No flow	No flow	--	--	No flow	--	No flow	--	No flow

(Source : OU1 Workplan DOE 1991b)

* See surface water monitoring station locations in Figure 2-4; flow rates are in cubic feet per second (cfs)

-- = No data available

Table 3-3 Soil Types at Operable Unit No. 1

Series	Family	Phase	Minimum-Maximum Slope (%)	Infiltration Rate	Soil Type*
Denver-Kutch-Midway	Torrertic Argiustolls	clay loam	9-25	slow	31
Flatirons	Aridic Paleustolls	very cobbly sandy loam	0-3	slow	45
Haverson	Ustic Torrifluvents	loam	0-3	slow	60
Nederland	Aridic Argiustolls	very cobbly sandy loam	15-50	moderate	100

* Soil type number corresponds to soil type in Figure 3-6.

Table 3-4 Upper Hydrostratigraphic Unit Geotechnical Results - Phase III RFI/RI

Borehole Number/ Sample Number	Test Interval (feet below ground surface)	Grain Size (%)			Lithologic Name	Atterberg Limits			USCS	Moisture Content (% dry wt)	Dry Density (lb/ft^3)	Wet Density (lb/ft^3)	Back-Pressure Permeability (cm/sec)[1]	Specific Gravity
		Sand	Silt	Clay		Liquid Limit	Plastic Limit	Plastic Index						
37391/BH00648EBU1	2.55-2.80	--	--	--	--	--			--	22.1	98.8	120.6	8.1×10^{-9}	--
37391/BH00661EBU1	2.20-2.55	44	19	37	Silty sandy clay	52.8/22.6/30.2			CH	--	--	--	--	--
37391/BH00660EBU1	11.00-11.75	27	27	46	Silty sandy clay	48.8/17.1/31.7			CL	--	--	--	--	--
37391/BH00658EBU1	11.75-12.00	--	--	--	--	--			--	25.8	103.0	129.6	2.5×10^{-9}	--
37491/BH00570EBU1	2.70-3.00	--	--	--	--	--			--	17.4	113.2	132.9	1.7×10^{-8}	--
37491/BH00571EBU1	3.00-3.25	44	26	30	Silty sandy clay	37.3/15.1/22.2			CL	--	--	--	--	--
37591/BH00665EBU1	3.00-3.25	38	13	49	Silty sandy clay	57.3/25.0/32.8			CH	--	--	--	--	--
37591/BH00664EBU1	3.25-3.50	--	--	--	--	--			--	24.9	96.3	120.3	5.9×10^{-6}	--
37591/BH00671EBU1	6.95-7.45	64	11	25	Silty clayey sand	43.8/15.4/28.4			SC	--	--	--	--	--
37591/BH00670EBU1	7.45-7.70	--	--	--	--	--			--	12.6	114.0	128.3	1.3×10^{-5}	--
37691/BH00592EBU1	7.40-7.55	78	11	11	Silty clayey sand	36.2/16.7/19.5			SM	--	--	--	--	--
37691/BH00591EBU1	7.55-7.80	--	--	--	--	--			--	N/A	N/A	N/A	N/A	--
37691/BH00596EBU1	13.50-13.80	56	14	30	Silty clayey sand	43.8/19.4/24.4			SC	--	--	--	--	--
37691/BH00595EBU1	13.80-14.00	--	--	--	--	--			--	18.4	111.0	131.4	3.7×10^{-8}	--
37891/BH00712EBU1	0.80-1.10	33	22	45	Silty sandy clay	54.4/20.5/33.9			CH	--	--	--	--	--
37891/BH00711EBU1	1.10-1.35	--	--	--	--	--			--	13.3	107.4	121.6	1.8×10^{-7}	--

N/A = Information not available
cm/sec = Centimeters per second
lb/ft^3 = Pounds per cubic foot
USCS = Unified Soil Classification System
CH = Fat clay
CL = Lean clay
ML = Silt
SC = Clayey sand
SM = Silty sand
SW = Clean sand

1 Values of back-pressure permeability also presented in Table 3-10

Table 3-4 Upper Hydrostratigraphic Unit Geotechnical Results - Phase III RFI/RI

Borehole Number/ Sample Number	Test Interval (feet below ground surface)	Grain Size (%)			Lithologic Name	Atterberg Limits			USCS	Moisture Content (% dry wt)	Dry Density (lb/ft^3)	Wet Density (lb/ft^3)	Back-Pressure Permeability (cm/sec)[1]	Specific Gravity
		Sand	Silt	Clay		Liquid Limit	Plastic Limit	Plastic Index						
37991/BH00720EBU1	3.00-3.50	06	13	81	Clay	58.1/20.5/37.6			CH	--			--	--
37991/BH00719EBU1	3.50-3.75	--	--	--	--	--			--	15.2	113.5	130.8	1.3×10^{-8}	--
38591/BH00812EBU1	4.80-5.05	82	11	7	Sand	20.9/15.9/5.0			SM	--	--	--	--	2.72
38591/BH00811EBU1	5.05-5.30	--	--	--	--	--			--	N/A	N/A	N/A	N/A	--
38991/BH00833EBU1	1.50-1.75	43	19	38	Silty sandy clay	50.8/19.7/31.1			CH	--	--	--	--	2.75
38991/BH00832EBU1	1.75-2.00	--	--	--	--	--			--	14.5	97.7	111.9	1.7×10^{-5}	--
38991/BH00840EBU1	11.50-11.75	24	24	52	Sandy silty clay	43.5/15.0/28.5			CL	--	--	--	--	2.70
38991/BH00839EBU1	11.75-12.00	--	--	--	--	--			--	10.1	114.2	125.8	5.1×10^{-8}	--
39091/BH00753EBU1	0.50-0.90	93	03	04	Sand	N/A			SW	--	--	--	--	2.68
39091/BH00752EBU1	0.90-1.15	--	--	--	--	--			--	8.2	97.9	105.9	1.2×10^{-3}	--
39191/BH00761EBU1	3.00-3.25	11	16	73	Sandy silty clay	62.6/22.2/40.4			CH	--	--	--	--	2.78
39191/BH00760EBU1	3.25-3.50	--	--	--	--	--			--	21.0	102.1	123.6	2.1×10^{-8}	--
39691/BH00866EBU1	5.00-5.25	28	29	43	Sandy silty clay	34.3/12.5/21.8			CL	--	--	--	--	2.71
39691/BH00865EBU1	5.25-5.50	--	--	--	--	--			--	17.4	109.5	128.6	7.6×10^{-7}	--

1 Values of back-pressure permeability also presented in Table 3-10

N/A = Information not available
cm/sec = Centimeters per second
lb/ft^3 = Pounds per cubic foot
USCS = Unified Soil Classification System
CH = Fat clay
CL = Lean clay
ML = Silt
SC = Clayey sand
SM = Silty sand
SW = Clean sand

Table 3-5 Upper Hydrostratigraphic Unit Hydraulic Conductivity Estimates - Single Well Tests Phase I and II RI

Well/Borehole Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Upper HSU Classification
5686	$2x10^{-3}$	Drawdown/recovery	--	Woman Creek valley-fill alluvium
6586	$3x10^{-3}$	Drawdown/recovery	2.5-8.0	Woman Creek valley-fill alluvium
6886	$1x10^{-3}$	Drawdown/recovery	1.5-3.5	Woman Creek valley-fill alluvium
6986	$5x10^{-4}$	Drawdown/recovery	3.0-14.0	Colluvium
6986	$2x10^{-4}$	Slug test	3.0-14.0	Colluvium
7086	$9x10^{-4}$	Drawdown/recovery	--	Woman Creek valley-fill alluvium
0287	$4x10^{-5}$ $3x10^{-5}$	Drawdown/recovery Slug test	3.22-9.08 3.22-9.08	Colluvium Colluvium
0487	$5x10^{-4}$	Drawdown/recovery	3.51-19.47	Colluvium

Source (Rockwell 1988)

cm/sec = Centimeters per second
-- = unavailable
HSU = hydrostratigraphic unit
[1]Hydraulic conductivity values also presented in Figure 3-38.

Table 3-6 Upper Hydrostratigraphic Unit Hydraulic Conductivity Estimates - Single Well Tests Phase III RFI/RI

Well/ Piezometer Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Lithologic Description	Upper HSU Classification
34791	$1x10^{-5}$ $6x10^{-6}$	Slug injection/ slug withdrawal	6.2-7.7	Sand and gravel	Colluvium
35691	$1x10^{-6}$ $9x10^{-7}$	Slug injection/ slug withdrawal	15.8-26.4	Silt, clay, and gravel	Disturbed colluvium
36191	$1x10^{-6}$	Bail down/recovery	9.7-14.4	Sand and gravel	Disturbed colluvium
37191	$1x10^{-4}$ $4x10^{-5}$	Slug injection/ slug withdrawal	11.3-20.9	Gravelly, sandy clay	Colluvium
37591	$7x10^{-6}$	Bail down/recovery	7.8-12.4	Gravel, sand, and clay	Rocky Flats Alluvium
38191	$1x10^{-5}$ $2x10^{-6}$	Slug injection/ slug withdrawal	10.1-14.9	Sand, silt, clay, and gravel	Colluvium
38591	$4x10^{-4}$	Bail down/recovery	5.9-7.5	Silty sand with clay and gravel	Woman Creek valley-fill alluvium

cm/sec = centimeters per second
HSU = hydrostratigraphic unit
[1]Hydraulic conductivity values also presented in Figure 3-38

Table 3-7 Upper Hydrostratigraphic Unit Water Levels (January 1992)

Location	Bottom of Screen (feet above MSL)	Contact Elevation (feet above MSL)	Top of Casing (feet above MSL)	Water Level below Top of Casing	Ground Water Elevation (feet above MSL)	*Alluvial/Colluvial Saturated Thickness (feet)
0974	NR	NR	5926.25	9.81	5916.44	NR
1074	NR	NR	5925.91	9.31	5916.60	NR
5886	5891.71	5892.21	5897.65	6.05	5891.60	BBS
6386	5885.84	5886.29	5902.01	0.00	DRY	DRY
6486	5830.06	5830.56	5841.05	8.44	5832.61	2.05
6886	5884.47	5885.17	5890.49	3.71	5886.78	1.61
6986	5907.46	5906.96	5922.52	3.85	5918.67	11.71
0187	5980.66	5980.62	5994.08	7.99	5986.09	5.47
0487	5890.32	5890.29	5911.58	14.39	5897.19	6.90
4387	5912.81	5913.06	5926.41	10.08	5916.33	3.27
4487	5946.13	5946.43	5951.10	0.00	DRY	DRY
4787	5875.51	5873.76	5884.64	9.45	5875.19	BBS
4887	5899.62	5899.67	5911.41	0.00	DRY	DRY
4987	5907.91	5903.66	5914.27	0.00	DRY	DRY
5087	5919.64	5920.64	5934.78	0.00	DRY	DRY
5187	5949.43	5950.77	5965.22	15.51	5949.71	BBRC
5287	5947.60	5947.85	5969.57	9.67	5959.90	12.05
5387	5950.94	5949.99	5961.81	4.99	5956.82	6.83
5487	5951.32	5951.85	5957.62	3.29	5954.33	2.48
5587	5852.74	5852.89	5858.39	0.00	DRY	DRY
B301889	5844.20	5844.50	5868.83	0.00	DRY	DRY
30991	5839.42	5840.32	5851.82	0.00	DRY	DRY
31491	5883.68	5886.08	5905.03	0.00	DRY	DRY
31791	5865.26	5868.26	5879.80	15.91	5863.89	BBS
32591	5898.36	5898.96	5917.41	18.90	5898.51	BBRC
33491	5917.37	5918.01	5928.59	0.00	DRY	DRY
33691	5918.88	5919.19	5929.24	0.00	DRY	DRY

* = Saturated thickness presented is saturated interval above bedrock contact.
NR = No record available.
MSL = Mean Sea Level.
0.00 or DRY = Denotes well was determined to be dry at the time of measurement.
BBS = Denotes measured water level was below the bottom of the screen.
BBRC = Denotes measured water level was below bedrock contact for alluvial/colluvial wells ground water elevations also presented in Figure 3-28 and Table 3-20.

Table 3-7 Upper Hydrostratigraphic Unit Water Levels (January 1992)

Location	Bottom of Screen (feet above MSL)	Contact Elevation (feet above MSL)	Top of Casing (feet above MSL)	Water Level below Top of Casing	Ground Water Elevation (feet above MSL)	*Alluvial/Colluvial Saturated Thickness (feet)
33891	5918.84	5919.44	5929.94	0.00	DRY	DRY
34591	5943.29	5943.99	5954.63	0.00	DRY	DRY
34791	5943.39	5943.39	5953.91	5.27	5948.64	5.25
35391	5952.42	5957.83	5963.03	12.35	5950.68	BBS
35691	5912.20	5913.56	5941.36	12.05	5929.31	15.75
35991	5959.55	5961.10	5976.45	19.08	5957.37	BBS
36191	5948.29	5948.89	5965.17	11.83	5953.34	4.45
36391	5937.16	5938.17	5967.01	31.68	5935.33	BBS
36691	5923.93	5924.76	5951.52	27.95	5923.57	BBS
36991	5960.86	5961.48	5972.31	0.00	DRY	DRY
37191	5924.84	5925.36	5948.29	10.02	5938.27	12.91
37591	5978.82	5979.42	5993.45	10.41	5983.04	3.62
37691	5967.96	5968.26	5985.24	0.00	DRY	DRY
37791	5981.56	5982.16	6004.18	21.63	5982.55	0.39
38191	5909.47	5909.82	5926.40	10.29	5916.11	6.29
38291	5915.79	5916.09	5926.71	0.00	DRY	DRY
38591	5857.06	5857.47	5866.62	8.55	5858.07	0.60
38891	5881.96	5882.26	5893.24	0.00	DRY	DRY
39691	5997.26	5999.46	6008.37	10.10	5998.27	BBRC

*	=	Saturated thickness presented is saturated interval above bedrock contact.
NR	=	No record available.
MSL	=	Mean Sea Level.
0.00 or DRY	=	Denotes well was determined to be dry at the time of measurement.
BBS	=	Denotes measured water level was below the bottom of the screen.
BBRC	=	Denotes measured water level was below bedrock contact for alluvial/colluvial wells ground water elevations also presented in Figure 3-28 and Table 3-20.

Table 3-8 Lower Hydrostratigraphic Unit Geotechnical Results - French Drain Geotechnical Investigation

Borehole Number	Inerval of Packer Test (feet below ground surface)	Permeability of Packer Test (cm/sec)	Field Lithology Description	Interval of Back-Pressure Permeability Test (feet below ground surface)	Back-Pressure Permeability Test (cm/sec)	Grain Size Analysis Results
B300690	14.98-20.25	$<3.7x10^{-6}$	Claystone and silty sandstone	18.5-19.0	$1.6x10^{-7}$	N/A
B300709	17.0-23.0	$<4.8x10^{-6}$	Claystone	18.6-18.8	$6.0x10^{-9}$	N/A
B301090	25.03-30.3	N/A	claystone	25.5-26.0	$3.1x10^{-8}$	N/A
B301190	23.0-28.0	$<6.6x10^{-6}$	Claystone and clayey siltstone	23.6-24.0	$2.4x10^{-8}$	Sandy siltstone
B301190	34.0-39.0	$<3.5x10^{-6}$	Claystone and siltstone	35.0-35.5	$1.1x10^{-8}$	Sandy clayey siltstone
B301390	N/A	N/A	Sandy claystone and silty sandstone	23.8-24.4	$1.9x10^{-7}$	Clayey siltstone
B301490	27.5-32.77	$<2.3x10^{-6}$	Claystone	28.3-28.6	$3.1x10^{-8}$	N/A
B301590	26.3-30.3	$8.0-10^{-6}$	Claystone and sandstone	26.75-27.1	$1.5x10^{-6}$	Silty Sandstone
B301690	24.75-32.9	$<4.3x10^{-7}$	Claystone, siltstone, and sandstone	29.6-30.0	$2.4x10^{-8}$	Clayey siltstone
B301690	32.9-37.8	$<4.x10^{-7}$	Claystone, sandstone, and siltstone	32.4-32.7	$7.1x10^{-8}$	Sandy siltstone
B301990	26.6-31.6	$<5.4x10^{-7}$	Sandy claystone	29.6-30.3	$7.0x10^{-8}$	Sandy clayey siltstone
B303790	27.0-32.0	$<5.4x10^{-7}$	Silty claystone	30.8-31.5`	$4.0x10^{-8}$	Clayey siltstone

Source (EG&G 1990i)

N/A = Not applicable

Table 3-9 Lower Hydrostratigraphic Unit Geotechnical Results - Phase III RFI/RI

Borehole Number/ Sample Number	Test Interval (feet below ground surface)	Grain Size (%)			Lithologic Name	Atterberg Limits			Moisture Content (% dry wt)	Dry Density (lb/ft^3)	Wet Density (lb/ft^3)	Back-Pressure Permeability (cm/sec)[1]	Specific Gravity
		Sand	Silt	Clay		Liquid Limit	Plastic Limit	Plastic Index					
37891/BH00716EBU1	7.20-7.50	27	26	47	Silty sandy claystone	57.5/23.6/33.9			--	--	--	--	--
37891/BH00715EBU1	7.50-7.75	--	--	--	--	--			21.5	99.5	121.0	$3.8x10^{-8}$	--
37891/BH00738EBU1	10.00-10.20	02	16	82	Claystone	61.5/24.5/37.0			--	--	--	--	2.69
37891/BH00737EBU1	10.20-10.45	--	--	--	--	--			21.7	100.6	122.5	$4.7x10^{-8}$	--
37891/BH00747EBU1	45.70-46.15	08	64	28	Sandy clayey siltstone	38.3/19.9/18.4			--	--	--	--	3.72
37891/BH00746EBU1	46.15-46.40	--	--	--	--	--			14.8	100.3	115.2	$5.0x10^{-8}$	--
37991/BH00724EBU1	11.10-11.40	3	17	80	Claystone	65.2/22.7/42.5			--	--	--	--	--
37991/BH00723EBU1	11.40-11.65	--	--	--	--	--			22.7	103.4	126.8	$5.5x10^{-9}$	--
37991/BH00734EBU1	46.70-48.00	14	50	36	Sandy clayey siltstone	40.3/16.9/23.4			--	--	--	--	2.69
37991/BH00732EB41	46.45-46.70	--	--	--	--	--			15.1	92.0	105.9	$7.8x10^{-5}$	--
38991/BH00845EBU1	20.90-21.15	02	21	77	Silty claystone	64.9/23.4/41.5			--	--	--	--	2.76
38991/BH00844EBU1	21.15-21.40	--	--	--	--	--			21.4	106.4	129.2	$4.2x10^{-9}$	--
39191/BH00766EBU1	11.50-11.75	10	43	47	Sandy silty claystone	39.7/15.8/23.9			--	--	--	--	2.64
39191/BH00765EBU1	11.75-12.00	--	--	--	--	--			12.0	124.0	138.9	$9.5x10^{-8}$	--
39191/BH00775EBU1	42.00-42.25	04	57	39	Clayey siltstone	43.2/17.4/25.8			--	--	--	--	2.76
39191/BH00774EBU1	42.25-42.50	--	--	--	--	--			15.6	109.8	126.9	$1.6x10^{-6}$	--

cm/sec = Centimeters per second
N/A = Information not available
lb/ft^3 = Pounds per cubic foot
CH = Fat Clay
CL = Lean Clay
M L = Silt
-- = Not analyzed
[1] Values of back-pressure permeability are also presented in Table 3-10.

Table 3-10 Vertical Distribution of Back-Pressure Permeability in Samples from Upper and Lower Hydrostratigraphic Units

Borehole Number	HSU	Lithological Classification	Sample Depth (feet below ground surface)	Back-Pressure Permeability (cm/sec)[1]
37891	Upper	Colluvium	1.10-1.35	1.8×10^{-7}
	Lower	Weathered claystone	7.50-7.75	3.8×10^{-8}
	Lower	Weathered claystone	10.20-10.45	4.7×10^{-8}
	Lower	Weathered claystone	46.15-46.40	5.0×10^{-8}
37991	Upper	Colluvium	3.50-3.75	1.3×10^{-8}
	Lower	Weathered claystone	11.40-11.65	5.5×10^{-9}
	Lower	Weathered siltstone	46.70-48.00	7.8×10^{-5}
38991	Upper	Colluvium	1.75-2.00	1.7×10^{-5}
	Upper	Colluvium	11.75-12.00	5.1×10^{-8}
	Lower	Weathered claystone	21.15-21.40	4.2×10^{-9}
39191	Upper	Colluvium	3.25-3.50	2.1×10^{-8}
	Lower	Weathered claystone	11.75-12.00	9.5×10^{-8}
	Lower	Weathered claystone	21.15-21.40	4.2×10^{-9}
	Lower	Weathered siltstone	42.25-42.50	1.6×10^{-6}

HSU = Hydrostratigraphic Unit
cm/sec = centimeters per second
1 Back-pressure permeability values are also presented on Tables 3-4 and 3-9.

Table 3-11 Lower Hydrostratigraphic Unit Hydraulic Conductivity Estimates - Phase I and II RI

Well/Borehole Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Lower HSU Classification
0387 BR	$1x10^{-8}$	Packer	62.9-72.6	Unweathered claystone
	$3x10^{-7}$	Packer	62.9-72.6	Unweathered claystone
	$2x10^{-8}$	Packer	62.9-72.6	Unweathered claystone
	$5x10^{-8}$	Packer	74.6-84.2	Unweathered claystone
	$4x10^{-8}$	Packer	74.6-84.2	Unweathered claystone
	$5x10^{-8}$	Packer	88.2-97.9	Unweathered claystone
	$2x10^{-7}$	Packer	N/A	Sandstone
	$3x10^{-6}$	Drawdown/recovery	102.8-107.8	Sandstone and claystone
0587 BR	$2x10^{-6}$	Packer	26.4-36-1	Weathered claystone
	$1x10^{-6}$	Packer	36.1-45.7	Weathered claystone
	$2x10^{-7}$	Packer	36.1-45.7	Weathered claystone
	$1x10^{-6}$	Packer	N/A	Sandstone
	$7x10^{-5}$	Drawdown/recovery	42.0-51.2	Sandstone and claystone
	$7x10^{-5}$	Slug	42.0-51.2	Sandstone and claystone
0887 BR	$7x10^{-7}$	Packer	62.6-72.3	Weathered claystone
	$9x10^{-8}$	Packer	83.5-93.1	Unweathered claystone with lignite
	$1x10^{-8}$	Packer	83.5-93.1	Unweathered claystone with lignite
	$1x10^{-7}$	Packer	N/A	Unweathered claystone with lignite

HSU = Hydrostratigraphic Unit
N/A = Data not available
[1]Hydraulic conductivity values are also presented in Figure 3-38.

Table 3-11 Lower Hydrostratigraphic Unit Hydraulic Conductivity Estimates - Phase I and II RI

Well/Borehole Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Lower HSU Classification
0887 BR	$3x10^{-6}$	Drawdown/recovery	84.0-89.0	Unweathered claystone with lignite
4587 BR	$2x10^{-7}$	Packer	60.6-70.2	Unweathered claystone
	$3x10^{-7}$	Packer	60.6-70.2	Unweathered claystone
	$2x10^{-8}$	Packer	70.2-79.2	Unweathered claystone
	$9x10^{-7}$	Packer	70.2-79.2	Unweathered claystone
5986 BR	$3x10^{-4}$	Drawdown/recovery	19.0-28.0	Sandstone
6286 BR	$3x10^{-5}$	Drawdown/recovery	N/A	Sandstone
	$6x10^{-6}$	Slug	N/A	Sandstone

(Source: Rockwell 1988)

HSU = Hydrostratigraphic Unit
N/A = Data not available
[1]Hydraulic conductivity values are also presented in Figure 3-38.

Table 3-12 Lower Hydrostratigraphic Unit Hydraulic Conductivity Estimate- French Drain Geotechnical Investigation

Well/Borehole Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Lithology Classification	Comments
B300190	$<1.5x10^{-6}$	Packer	18.8-25.1	Claystone and siltstone	
B300290	$2.2x10^{-3}$	Packer	14.9-21.2	Claystone and siltstone	
	$2.3x10^{-3}$	Packer	18.1-24.3	Silty claystone	
B300590	$<2.8x10^{-6}$	Packer	9.7-15.0	Clay and claystone	No water loss
	$<3.7x10^{-6}$	Packer	14.8-20.0	Silty claystone	No water loss
	$<4.5x10^{-6}$	Packer	17.1-22.4	Silty claystone	No water loss
B300690	$3.3x10^{-6}$	Packer	10.1-15.4	Clay, claystone and siltstone	No water loss
	$3.7x10^{-6}$	Packer	15.0-20.2	Claystone and siltstone	No water loss
	$8.4x10^{-7}$	Packer	20.1-25.4	Claystone, siltstone and sandstone	
B300790	$<5.0x10^{-6}$	Packer	10.1-13.0	Claystone and sandstone	No water loss
	$<8.4x10^{-6}$	Packer	13.0-17.0	Silty claystone	No water loss
	$<4.8x10^{-6}$	Packer	17.0-23.0	Claystone	No water loss
B300890	$<5.9x10^{-6}$	Packer	16.3-19.5	Claystone	No water loss
	$<3.4x10^{-6}$	Packer	19.5-25.0	Silty claystone	No water loss
	$2.0x10^{-6}$	Packer	24.5-29.5	Silty claystone and claystone	
B300990	$<2.6x10^{-6}$	Packer	14.3-19.3	Claystone	No water loss
	$<1.3x10^{-6}$	Packer	19.3-24.3	Claystone	No water loss
	$<2.0x10^{-6}$	Packer	24.3-29.3	Claystone	No water loss
B301090	$<6.4x10^{-6}$	Packer	22.1-27.3	Claystone	No water loss

(Source: EG&G 1990e)

[1] Hydraulic conductivity values also presented in Figure 3-38.
< = denotes no water loss during test and value is estimated upper bound

Table 3-12 Lower Hydrostratigraphic Unit Hydraulic Conductivity Estimate- French Drain Geotechnical Investigation

Well/Borehole Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Lithology Classification	Comments
B301190	$<6.6x10^{-6}$	Packer	23.0-28.0	Claystone and clayey siltstone	No water loss
	$<5.3x10^{-6}$	Packer	28.0-33.0	Claystone and siltstone	No water loss
	$<3.5x10^{-6}$	Packer	34.0-39.0	Claystone and siltstone	No water loss
B301290	$<1.5x10^{-6}$	Packer	9.5-14.5	Claystone	No water loss
	$<1.0x10^{-6}$	Packer	14.5-19.5	Claystone	No water loss
	$1.1x10^{-4}$	Packer	19.5-24.5	Sandy claystone	
B301390	$3.5x10^{-6}$	Packer	14.8-18.8	Claystone	
	$1.7x10^{-7}$	Packer	18.8-23.8	Claystone and silty sandstone	
	$3.5x10^{-6}$	Packer	24.8-28.8	Claystone and silty sandstone	
	$<5.0x10^{-7}$	Packer	28.8-33.8	Claystone	No water loss
B301490	$<4.9x10^{-6}$	Packer	18.0-23.3	Claystone	No water loss
	$<6.0x10^{-6}$	Packer	22.7-28.0	Claystone, siltstone, and sandstone	No water loss
	$<2.3x10^{-6}$	Packer	27.5-32.8	Claystone	No water loss
B301590	$8.5x10^{-4}$	Packer	16.5-20.3	Claystone	
	$4.2x10^{-5}$	Packer	20.3-25.3	Claystone and siltstone	
	$2.3x10^{-6}$	Packer	25.3-30.3	Claystone and sandstone	
	$8.0x10^{-6}$	Packer	26.3-30.3	Claystone and sandstone	
B301690	$<6.6x10^{-7}$	Packer	22.8-27.6	Claystone and siltstone	No water loss
	$<4.3x10^{-7}$	Packer	24.7-32.9	Claystone, siltstone and sandstone	No water loss
	$4.4x10^{-7}$	Packer	32.9-37.8	Claystone, siltstone, and sandstone	

(Source: EG&G 1990e)

[1] Hydraulic conductivity values also presented in Figure 3-38.
< = denotes no water loss during test and value is estimated upper bound

Table 3-12 Lower Hydrostratigraphic Unit Hydraulic Conductivity Estimate- French Drain Geotechnical Investigation

Well/Borehole Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Lithology Classification	Comments
B301790	$<1.3x10^{-6}$	Packer	22.8-24.6	Claystone	No water loss
	$<5.8x10^{-7}$	Packer	24.6-29.6	Sandy claystone	No water loss
	$<4.8x10^{-7}$	Packer	29.6-34.6	Claystone	No water loss
	$<4.1x10^{-7}$	Packer	34.6-39.6	Claystone	No water loss
B301890	$<8.3x10^{-7}$	Packer	23.5-26.9	Claystone	No water loss
	$3.9x10^{-6}$	Packer	26.9-31.9	Claystone and siltstone	
	$<4.5x10^{-7}$	Packer	31.9-36.9	Claystone and siltstone	No water loss
	$<4.5x10^{-7}$	Packer	37.9-41.9	Claystone	No water loss
B301990	$<7.4x10^{-7}$	Packer	22.6-26.6	Silty claystone	No water loss
	$<5.4x10^{-7}$	Packer	26.6-31.6	Sandy claystone	No water loss
	$<5.6x10^{-7}$	Packer	31.6-36.6	Silty claystone	No water loss
	$<5.3x10^{-7}$	Packer	38.6-41.6	Silty claystone	No water loss
B302090	$<7.2x10^{-7}$	Packer	29.0-32.0	Silty claystone	No water loss
	$<5.5x10^{-7}$	Packer	32.0-37.0	Silty claystone	No water loss
	$<5.2x10^{-7}$	Packer	33.0-37.0	Silty claystone	No water loss
	$<4.5x10^{-7}$	Packer	38.0-42.0	Silty claystone	No water loss
B302190	$<6.2x10^{-7}$	Packer	32.0-35.2	Claystone	No water loss
	$<4.2x10^{-7}$	Packer	35.2-40.0	Claystone	No water loss
	$<3.6x10^{-7}$	Packer	40.0-45.0	Claystone and siltstone	No water loss
B302290	$<7.4x10^{-7}$	Packer	23.0-27.0	Claystone	No water loss
	$<5.4x10^{-7}$	Packer	27.0-32.0	Claystone	No water loss
	$<4.5x10^{-7}$	Packer	32.0-37.0	Claystone	No water loss

(Source: EG&G 1990e)

[1] Hydraulic conductivity values also presented in Figure 3-38.
< = denotes no water loss during test and value is estimated upper bound

Well/Borehole Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Lithology Classification	Comments
B303790	$<8.2 \times 10^{-7}$	Packer	17.0-22.0	Silty claystone	No water loss
	$<6.6 \times 10^{-7}$	Packer	22.0-27.0	Claystone	No water loss
	$<5.4 \times 10^{-7}$	Packer	27.0-32.0	Silty claystone	No water loss
B303890	$<1.2 \times 10^{-6}$	Packer	14.0-18.0	Claystone	No water loss
	$<1.0 \times 10^{-6}$	Packer	20.0-23.0	Claystone	No water loss
	$<6.2 \times 10^{-7}$	Packer	23.0-28.0	Claystone	No water loss

(Source: EG&G 1990e)

[1] Hydraulic conductivity values also presented in Figure 3-38.
< = denotes no water loss during test and value is estimated upper bound

Table 3-13 Lower Hydrostratigraphic Unit Hydraulic Conductivity Estimates - Phase III RFI/RI

Well/ Piezometer Number	Hydraulic Conductivity (cm/sec)[1]	Type of Test	Test Interval (feet below ground surface)	Lithologic Description	Lower HSU Classification
31891	$2x10^{-4}$ $2x10^{-4}$	Slug injection/ slug withdrawal	16.8-18.4	Sandy claystone and clayey sandstone	Bedrock sandstone
37891	$5x10^{-7}$ $1x10^{-6}$	Slug injection/ slug withdrawal	43.4-53.0	Silty claystone, clayey siltstone	Weathered claystone, siltstone
37991	$7x10^{-6}$	Bail down/recovery	45.4-55.0	Claystone, sandy, clayey siltstone	Weathered claystone, siltstone
38991	$1x10^{-6}$	Bail down/recovery	27.0-36.6	Claystone, siltstone	Weathered claystone, siltstone
39191	$2x10^{-5}$	Bail down/recovery	33.0-42.6	Clayey siltstone, silty claystone	Weathered claystone, siltstone
39291	$3x10^{-5}$ $3x10^{-5}$	Slug injection/ slug withdrawal	34.2-43.8	Claystone, silty claystone, clayey siltstone	Weathered claystone, siltstone

cm/sec = centimeters per second
[1] Hydraulic conductivity values are also presented in Figure 3-38.

Table 3-14 Lower Hydrostratigraphic Unit Water Levels (January 1992)

Well/Piezometer	Top of Casing (feet above MSL)	Bottom of Screen (feet above MSL)	Water Level (feet below top of casing)	Ground Water Elevation January 1992 (feet above MSL)[1]
6286*	5903.18	5866.81	27.38	5875.80
0587	5930.16	5876.51	46.62	5883.54
0887	5921.55	5830.68	NR	NR
1187	5915.12	5893.40	19.06	5896.06
1287	5936.30	NR	8.69	5927.61
4587	5950.91	5848.27	89.60	5861.31
B304789	5869.56	5829.93	40.37	5829.19
31891*	5919.52	5898.32	18.39	5901.13
37891	5926.29	5872.02	42.71	5883.58
37991	5933.55	5876.25	49.42	5884.13
38991	5895.49	5856.28	28.91	5866.58
39191	5918.32	5875.36	37.92	5880.40
39291	5910.21	5864.43	32.24	5877.97

MSL - Mean Sea Level
NR - No record
* - Due to well construction well may indicate upper hydrostratigraphic unit water levels
[1] Ground water elevations are presented in Figure 3-39.

Table 3-15 Upper Hydrostratigraphic Unit Average Linear Groundwater Flow Velocities.

Location	Lithological Unit	Average Hydraulic Gradient i (feet/foot)	Average Hydraulic Conductivity K (feet/min)	Estimated Effective n (percent)	Average Linear Velocity V_{ave} (feet/yr)†
Western portion of site south of 881 Building	Colluvium and disturbed colluvium	0.12	* 3.2×10^{-5}	10	20
		0.12	3.2×10^{-5}	20	10
IHSS 119.1	Colluvium	0.15	** 9.3×10^{-5}	10	73
		0.15	9.3×10^{-5}	20	37
Along western Woman Creek	Woman Creek valley fill alluvium	.025	*** 2.3×10^{-3}	10	300
		.025	2.3×10^{-3}	20	150

* K = geometric mean of hydraulic conductivity values at wells 35691, 31891, 36191, and 6986.
** K = geometric mean of hydraulic conductivity values at wells 38191 and 0487
*** K = geometric mean of hydraulic conductivity values at wells 5686, 6586, 6886, 7086, and 38591
† V_{ave} (feet/min) x 5.26 x 10^5 (min/year) = V_{ave} (feet/yr)

Average hydraulic gradient (i) = measured from water table map (Figure 3-28) along flow paths
Average hydraulic conductivity (K) = geometric mean of values in nearby tested wells
Effective porosity (n) = 10-20% estimated range
Average velocity (V_{ave}) = after (Fetter 1988): $V_{ave} = Ki/n$
where: K = hydraulic conductivity
i = hydraulic gradient
n = effective porosity

Note: Results of tracer tests are not included in this table.

Table 3-16 Upper Hydrostratigraphic Unit Volumetric Calculations for January 1992

	Saturated Map Area (acres)	Saturated Thickness (feet)	Volume of Saturated Materials (acre-feet)	Total Porosity	Volume of Ground Water (acre-feet)	Effective Porosity	Volume of Ground Water Available for Movement or Yield (acre-feet)
Area within OU1 boundaries	5.0	5.0	25.0	0.4	10.0	0.1-0.2	2.5-5.0
Area with OU1 and downgradient North of Woman Creek	15.3	5.0	76.6	0.4	30.6	0.1-0.2	7.5-15.0

HSU = Hydrostratigraphic unit
OU1 = Operable Unit No. 1

Note: Total map area with OU1 boundaries equals 18.7 acres (from Figure 3-28).
Saturated map area was calculated using AUTOCAD (by AUTODESK, Inc.).
Saturated thickness is typical value (from Figure 3-29).
Total porosity is based on average values of all upper HSU geotechnical samples (data is presented in Appendix A2 and Table 3-4).
Effective porosity range is based on horizontal effective porosity values presented as discussed for average ground water flow velocity calculations. (Table 3-15)

Table 3-17 Lower Hydrostratigraphic Unit Average Linear Groundwater Flow Velocity

Location	Average Hydraulic Gradient i (feet/foot)	Average Hydraulic Conductivity K (feet/minute)	Effective Porosity n (%)	Average Velocity V_{ave} (feet/year)
IHSS 119.1	0.14	1.4×10^{-5}	10	10
			20	5

Average hydraulic gradient (i) = measured from water table map (Figure 3-39) along flow paths
Average hydraulic conductivity (K) = geometric mean of values for nearby tested wells (37891, 37791, 38991, 39291)
Effective porosity (n) = 10-20% estimated range
Average velocity (V_{ave}) = after (Fetter 1988): $V_{ave} = Ki/n$

where: K = hydraulic conductivity
i = hydraulic gradient
n = effective porosity

and:

V_{ave} (feet/minute) x 5.26×10^{-5} (minute/year) = V_{ave} (feet/year)

Table 3-18 Vertical Hydraulic Gradients Between the Upper and Lower Hydrostratigraphic Unit

Well/ Piezometer	Lithologic Unit	Water Level Elevation January 1992 (feet above sea level)[1]	*Screen Midpoint Elevation (feet above sea level)	**Estimated Vertical Hydraulic Gradient i_v (feet/foot)
0487	Colluvium	5890.32	5893.76	0.79
39291	Bedrock	5864.43	5869.43	
4387	Colluvium	5916.33	5914.57	0.87
37891	Weathered bedrock	5883.58	5877.02	
38191	Colluvium	5916.11	5911.97	1.05
39191	Weathered bedrock	5880.40	5877.86	
4387	Colluvium	5916.33	5914.57	0.98
39191	Weathered becrock	5880.40	5877.86	
				Geometric mean = 0.92

* = Calculated as mid-point of saturated screen interval (see Appendix)

$$** = i_v = \frac{\text{Water level in bedrock well — water level in colluvial well}}{\text{midpoint of bedrock well screen — midpoint of colluvial well screen}}$$

[1]Gound water elevations are also presented in Tables 3-7 and 3-14.

Table 3-19 Vertical Average Linear Ground Water Velocity Between the Upper and Lower Hydrostratigraphic Unit Near IHSS 119.1

Location	Average Hydraulic Gradient i (feet/foot)	Average Hydraulic Conductivity K (feet/minute)	Effective Porosity n (%)	Linear Average Velocity V_{ave} (feet/year)
IHSS 119.1	0.92	8.6×10^{-9}	0.1	0.4
			0.2	0.2

Average hydraulic gradient (i) = geometricmean of values presented in Table 3-18
Average hydraulic conductivity (K) = geometric mean of values for nearby tested wells (37891, 37791, 38991, 39291)
Effective porosity (n) = 10-20% estimated range
Average velocity (V_{ave}) = after (Fetter 1988): $V_{ave} = Ki/n$

where: K = hydraulic conductivity
i = hydraulic gradient
n = effective porosity

and:

V_{ave} (feet/minute) x 5.26×10^{-5} (minute/year) = V_{ave} (feet/year)

Table 3-20 Upper Hydrostratigraphic Unit Water Levels January through July 1992

Location	Groundwater Elevation and Saturated Thickness by Month[1]													
	January		February		March		April		May		June		July	
	*Elev.	**Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.
0974	5916.44	NR	5916.58	NR	--	--	5918.51	NR	5917.68	NR	--	--	--	--
1074	5916.60	NR	5917.11	NR	--	--	5921.39	NR	5919.83	NR	--	--	--	--
5886	5891.60	BBS	5891.70	BBS	--	--	5981.77	BBRC	DRY	DRY	--	--	5891.28	BBS
6386	DRY	DRY	DRY	DRY	DRY	DRY	5888.44	2.15	5888.09	1.80	5887.75	1.46	5885.69	BBS
6486	5832.61	2.05	5833.77	3.21	--	--	5833.93	3.37	--	--	--	--	5830.82	0.26
6886	5886.78	1.61	5887.07	1.90	--	--	5887.44	2.27	5886.88	1.71	--	--	5886.49	1.32
6986	5918.67	11.71	--	--	--	--	--	--	--	--	--	--	--	--
0187	5986.09	5.47	5984.16	3.54	--	--	5986.16	5.54	5984.48	3.86	--	--	5982.80	2.18
0487	5897.19	6.90	5897.26	6.97	5897.64	7.35	5901.81	11.52	5901.79	11.50	5901.65	11.36	5899.71	9.42
4387	5916.33	3.27	5916.52	3.46	5916.23	3.17	5918.51	5.45	5917.49	4.43	5917.44	4.38	5917.21	4.15
4487	DRY	DRY	DRY	DRY	DRY	DRY	5947.18	0.75	5945.79	BBRC	DRY	DRY	--	--
4787	5875.19	BBS	DRY	DRY	5875.03	BBS	DRY	DRY	5879.21	5.45	5878.00	4.24	5877.28	3.52
4887	DRY	DRY	--	--	--	--	5906.33	6.66	5906.17	6.50	--	--	5905.61	5.94
4987	DRY	DRY	--	--	--	--	5909.41	5.75	5908.49	4.83	--	--	5908.02	4.36
5087	DRY	DRY	--	--	--	--	DRY	DRY	--	--	--	--	NA	NA
5187	5949.70	BBRC	--	--	--	--	5949.75	BBRC	--	--	--	--	5949.72	BBRC

*Elev. = Groundwater elevation above mean sea level (feet)
**Sat. = Alluvial/colluvial saturated thickness (feet)
BBS = Denotes measured water level was below the bottom of the screen
BBRC = Denotes measured water level was below bedrock contact for alluvial/colluvial wells
NA = Denotes well was obstructed at the time of measurement (no measurement was reported)
DRY = Denotes well was determined to be dry at the time of measurement
-- = No record of water level measurement
NR = No record of well construction or lithological information
1 Ground water elevations also presented in Figure 3-28 and Table 3-20.

Table 3-20 Upper Hydrostratigraphic Unit Water Levels January through July 1992

Location	Groundwater Elevation and Saturated Thickness by Month[1]													
	January		February		March		April		May		June		July	
	*Elev.	**Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.
5287	5959.98	12.13	--	--	--	--	5960.04	12.19	--	--	--	--	5959.52	11.67
5387	5956.82	6.83	--	--	--	--	5956.45	6.46	--	--	--	--	5954.46	4.47
5487	5954.33	2.48	DRY	DRY	5954.90	3.05	5954.66	2.03	5951.70	BBRC	5955.04	3.19	5953.53	1.67
5587	DRY	DRY	DRY	DRY	5848.93	BBS	5851.99	BBS	5951.28	BBS	5850.05	BBS	5850.21	BBS
B301889	DRY	DRY	--	--	--	--	DRY	DRY	--	--	--	--	5842.73	BBS
B302089	--	--	--	--	5893.19	BBS	5893.55	BBS	--	--	5895.01	1.01	5893.44	BBS
30991	--	--	DRY	DRY	5838.48	BBS	5842.97	2.65	5841.53	1.21	--	--	5841.53	1.21
31491	--	--	DRY	DRY	DRY	DRY	5888.98	2.90	5886.05	1.06	--	--	5884.73	BBRC
31791	5863.89	BBS	5870.57	2.32	5870.72	2.46	5873.60	5.34	5870.82	2.56	--	--	5869.75	1.49
32591	5898.51	BBRC	5898.38	BBRC	5898.59	BBRC	5899.30	0.34	5898.94	0.08	--	--	5897.39	BBS
33491	DRY	DRY	DRY	DRY	5917.27	BBS	5917.83	BBS	5918.17	0.16	5918.44	0.43	5917.67	BBRC
33691	DRY	DRY	5916.49	BBS	5917.00	BBS	5918.31	BBS	5918.68	BBS	5918.89	BBRC	NA	NA
33891	DRY	DRY	DRY	DRY	DRY	DRY	5918.56	BBS	5919.31	BBRC	5919.76	0.32	5919.18	BBRC
34591	DRY	DRY	5941.31	BBS	5941.68	BBS	5941.83	BBS	5941.94	BBS	5940.94	BBS	NA	NA
34791	5948.64	5.25	5948.66	5.27	5948.15	4.76	5951.99	8.60	5949.81	6.42	--	--	5948.98	5.59
35391	5950.68	BBS	5952.26	BBS	5950.29	BBS	5951.94	BBS	5952.39	BBS	5952.60	BBRC	5950.61	BBS

*Elev. = Groundwater elevation above mean sea level (feet)
**Sat. = Alluvial/colluvial saturated thickness (feet)
BBS = Denotes measured water level was below the bottom of the screen
BBRC = Denotes measured water level was below bedrock contact for alluvial/colluvial wells
NA = Denotes well was obstructed at the time of measurement (no measurement was reported)
DRY = Denotes well was determined to be dry at the time of measurement
-- = No record of water level measurement
NR = No record of well construction or lithological information
1 Ground water elevations also presented in Figure 3-28 and Table 3-20.

Table 3-20 Upper Hydrostratigraphic Unit Water Levels January through July 1992

Location	Groundwater Elevation and Saturated Thickness by Month[1]													
	January		February		March		April		May		June		July	
	*Elev.	**Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.	Elev.	Sat.
35691	5929.31	15.75	5926.50	12.94	5925.05	11.49	5925.33	11.77	5925.24	11.68	--	--	5924.91	11.35
35991	5957.37	BBS	5957.53	BBS	5957.88	BBS	5958.42	BBS	5958.68	BBS	5958.91	BBS	NA	NA
36191	5953.34	4.45	5957.77	8.88	5950.75	1.86	5959.45	10.56	5960.56	11.67	5959.97	11.08	5951.30	2.41
36391	5935.33	BBS	5937.31	BBRC	5937.95	BBRC	5944.47	6.30	5941.82	3.65	5944.92	6.75	5943.97	5.80
36691	5923.57	BBS	5924.87	0.86	5923.94	BBRC	5924.84	0.08	5926.27	1.51	--	--	5926.56	1.80
36991	DRY	DRY	DRY	DRY	DRY	DRY	--	--	--	--	--	--	DRY	DRY
37191	5938.27	12.91	5938.12	12.76	5938.47	13.11	5942.68	17.32	5941.65	16.29	5940.21	14.85	5939.99	14.63
37591	5983.04	3.62	5984.18	4.76	5981.38	1.96	5987.72	8.30	5986.49	7.07	5986.37	6.95	5985.81	6.39
37691	DRY	DRY	DRY	DRY	DRY	DRY	5971.96	3.70	5968.24	BBRC	5968.34	0.08	5967.61	BBS
37791	5982.98	0.82	--	--	5983.82	1.66	5984.72	2.56	--	--	--	--	5985.11	2.95
38191	5916.11	6.29	--	--	5916.57	6.75	5918.72	8.90	5918.20	8.38	--	--	5917.18	7.36
38291	DRY	DRY	--	--	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	NA	NA
38591	5858.07	0.60	5858.24	0.77	5858.27	0.80	5858.88	1.41	5958.23	0.76	--	--	5857.73	0.26
38891	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	NA	NA
39691	5998.27	BBRC	5998.19	BBRC	5998.07	BBRC	6000.12	0.66	5998.88	BBRC	--	--	5997.78	BBRC

*Elev. = Groundwater elevation above mean sea level (feet)
**Sat. = Alluvial/colluvial saturated thickness (feet)
BBS = Denotes measured water level was below the bottom of the screen
BBRC = Denotes measured water level was below bedrock contact for alluvial/colluvial wells
NA = Denotes well was obstructed at the time of measurement (no measurement was reported)
DRY = Denotes well was determined to be dry at the time of measurement
-- = No record of water level measurement
NR = No record of well construction or lithological information
1 Ground water elevations also presented in Figure 3-28 and Table 3-20.

Section 4.0 · Tables

Nature and Extent of Contamination

Phase III RFI/RI Report

U1 OU1 OU
881 Hillside
OU1 OU1 O
Hillside 881
1 OU1 OU1
side 881 Hill
U1 OU1 OU
881 Hillside
OU1 OU1 O
Hillside 881

Table 4-1 Geochemical Background Concentrations for Subsurface Soils, Ground Water, Surface Water, and Sediments at Rocky Flats Plant

Analyte	Background Concentration	Concentration Unit
Subsurface Soil		
Nitrate+Nitrite	3.220	mg/kg
pH	9.660	pH unit
Sulfide	8383.120	mg/kg
Aluminum (Al)	46580.730[T]	mg/kg
Antimony (Sb)	9.320[T]	mg/kg
Arsenic (As)	12.140[T]	mg/kg
Barium (Ba)	438.140[T]	mg/kg
Beryllium (Be)	18.120[T]	mg/kg
Cadmium (Cd)	1.080[T]	mg/kg
Calcium (Ca)	23235.880[T]	mg/kg
Cesium (Cs)	146.750[T]	mg/kg
Chromium (Cr)	NA	
Cobalt (Co)	14.360[T]	mg/kg
Copper (Cu)	32.270[T]	mg/kg
Iron (Fe)	33287.210[T]	mg/kg
Lead (Pb)	30.030[T]	mg/kg
Lithium (Li)	18.530[T]	mg/kg

Table 4-1 Geochemical Background Concentrations for Subsurface Soils, Ground Water, Surface Water, and Sediments at Rocky Flats Plant

Analyte	Background Concentration	Concentration Unit
Subsurface soil (cont.)		
Magnesium (Mg)	7600.650[T]	mg/kg
Manganese (Mn)	643.490[T]	mg/kg
Mercury (Hg)	0.470[T]	mg/kg
Molybdenum (Mo)	63.890[T]	mg/kg
Nickel (Ni)	NA	
Potassium (K)	3726.430[T]	mg/kg
Selenium (Se)	1.240[T]	mg/kg
Silver (Ag)	22.920[T]	mg/kg
Sodium (Na)	1321.26[T]	mg/kg
Strontium (Sr)	131.130[T]	mg/kg
Thallium (Tl)	1.390[T]	mg/kg
Tin (Sn)	259.150[T]	mg/kg
Vanadium (V)	77.100[T]	mg/kg
Zinc (Zn)	141.740[T]	mg/kg
Americium-241 (Am-241)	0.010[T]	pCi/g
Cesium-137 (Cs-137)	0.080[T]	pCi/g
Gross Alpha	51.310[T]	pCi/g

Analyte	Background Concentration	Concentration Unit
Subsurface Soil (cont.)		
Gross Beta	36.930[T]	pCi/g
Plutonium-239 (Pu-239)	0.020[T]	pCi/g
Radium-226 (Ra-226)	1.500[T]	pCi/g
Radium-228 (Ra-228)	2.260[T]	pCi/g
Strontium-90 (Sr-90)	0.640[T]	pCi/g
Tritium	411.450[T]	pCi/l
Uranium-233,234 (U-233,234)	1.750[T]	pCi/g
Uranium-235 (U-235)	0.170[T]	pCi/g
Uranium-238 (U-238)	1.680[T]	pCi/g
Total Uranium	3.430[T]	pCi/g
Surface Water		
Bicarbonate	288.149	mg/l
Carbonate	4.712	mg/l
Carbonate as $CaCO_3$	10.913	mg/l
Chloride (Cl)	72.912	mg/l
Cyanide	0.018	mg/l

Table 4-1 Geochemical Background Concentrations for Subsurface Soils, Ground Water, Surface Water, and Sediments at Rocky Flats Plant

Analyte	Background Concentration	Concentration Unit
Surface Water (cont.)		
Fluoride	0.528	mg/l
Nitrate	3.864	mg/l
Nitrate+Nitrite	2.790	mg/l
Nitrite	0.022	mg/l
Oil and Grease	8.033	mg/l
Orthophosphate	0.058	mg/l
pH	8.395	pH unit
Phosphate	0.617	mg/l
Phosphorus	0.138	mg/l
Silica, dissolved	26.128	mg/l
Sulfate	35.091	mg/l
Sulfide	2.569	mg/l
Total dissolved soilds	312.491	mg/l
Total organic carbon	19.662	mg/l
Total suspended solids	85.085	mg/l
Aluminum (Al)	5.706^{T} 0.295^{D}	mg/l mg/l

Table 4-1 Geochemical Background Concentrations for Subsurface Soils, Ground Water, Surface Water, and Sediments at Rocky Flats Plant

Analyte	Background Concentration	Concentration Unit
Surface Water (cont.)		
Antimony (Sb)	0.020[T] 0.036[D]	mg/l mg/l
Arsenic (As)	0.002[T] 0.003[D]	mg/l mg/l
Barium (Ba)	0.116[T] 0.222[D]	mg/l mg/l
Beryllium (Be)	0.002[T] 0.007[D]	mg/l mg/l
Cadmium (Cd)	0.002[T] 0.003[D]	mg/l mg/l
Calcium (Ca)	66.809[T] NA	mg/l
Cesium (Cs)	0.531[T] 0.763[D]	mg/l mg/l
Chromium (Cr)	0.012[T] 0.010[D]	mg/l mg/l
Cobalt (Co)	0.005[T] 0.025[D]	mg/l mg/l
Copper (Cu)	0.023[T] 0.018[D]	mg/l mg/l
Iron (Fe)	7.559[T] NA	mg/l

Table 4-1 Geochemical Background Concentrations for Subsurface Soils, Ground Water, Surface Water, and Sediments at Rocky Flats Plant

Analyte	Background Concentration	Concentration Unit
Surface Water (cont.)		
Lead (Pb)	0.008[T] 0.004[D]	mg/l mg/l
Lithium (Li)	0.012[T] 0.002[D]	mg/l mg/l
Magnesium (Mg)	9.852[T] 9.611[D]	mg/l mg/l
Manganese (Mn)	0.687[T] 0.292[D]	mg/l mg/l
Mercury (Hg)	0.618[T] 0.303[D]	mg/l mg/l
Molybdenum (Mo)	0.012[T] 0.076[D]	mg/l mg/l
Nickel (Ni)	0.012[T] 0.024[D]	mg/l mg/l
Potassium (K)	NA	
Selenium (Se)	0.001[T] 0.004[D]	 mg/l
Silicon (Si)	12.646[T]	mg/l
Silver (Ag)	0.005[T] 0.007[D]	mg/l mg/l
Sodium (Na)	33.767[T] NA	mg/l

Table 4-1 Geochemical Background Concentrations for Subsurface Soils, Ground Water, Surface Water, and Sediments at Rocky Flats Plant

Analyte	Background Concentration	Concentration Unit
Surface Water (cont.)		
Strontium (Sr)	0.364[T] 0.521[D]	mg/l mg/l
Thallium (Tl)	0.002[T] 0.005[D]	mg/l mg/l
Tin (Sn)	0.070[T] 0.074[D]	mg/l mg/l
Vanadium (V)	0.012[T] 0.019[D]	mg/l mg/l
Zinc (Zn)	0.221[T] 0.141[D]	mg/l mg/l
Americium-241 (Am-241)	0.018[T] 0.032[D]	pCi/l pCi/l
Cesium-137 (Cs-137)	0.734[T] 0.200[D]	pCi/l pCi/l
Gross Alpha	30.032[T] 2.713[D]	pCi/l pCi/l
Gross Beta	20.556[T] 7.946[D]	pCi/l pCi/l
Gross Gamma	0.764[D]	pCi/l
Plutonium-238	-0.00035	pCi/l
Plutonium-239 /-240 (Pu-239/240)	0.019[T] 0.366[D]	pCi/l pCi/l

Table 4-1 Geochemical Background Concentrations for Subsurface Soils, Ground Water, Surface Water, and Sediments at Rocky Flats Plant

Analyte	Background Concentration	Concentration Unit
Surface Water (cont.)		
Radium-226 (Ra-226)	2.300[T] 1.561[D]	pCi/l pCi/l
Radium-228 (Ra-228)	NA 20.372[D]	 pCi/l
Strontium-89	0.600[D]	pCi/l
Strontium-89, 90	1.630[T] 2.264[D]	pCi/l pCi/l
Strontium-90 (Sr-90)	1.409[T] 0.901[D]	pCi/l pCi/l
Tritium	475.216[T] 977.976[D]	pCi/l pCi/l
Uranium-233,234 (U-233,234)	1.074[D] 1.456[T]	pCi/l pCi/l
Uranium-235 (U-235)	0.369[D] 0.152[T]	pCi/l pCi/l
Uranium-238 (U-238)	1.332[T] 0.958[D]	pCi/l pCi/l
Uranium, total	1.998[T] 1.400[D]	pCi/l pCi/l
Sediments		
Nitrate+Nitrite	41.757	mg/kg

Table 4-1 Geochemical Background Concentrations for Subsurface Soils, Ground Water, Surface Water, and Sediments at Rocky Flats Plant

Analyte	Background Concentration	Concentration Unit
Sediments (cont.)		
Nitrite	1.117	mg/kg
pH	9.090	pH unit
Aluminum (Al)	20839.704[T]	mg/kg
Antimony (Sb)	20.341[T]	mg/kg
Arsenic (As)	11.469[T]	mg/kg
Barium (Ba)	237.879[T]	mg/kg
Beryllium (Be)	1.212[T]	mg/kg
Cadmium (Cd)	2.689[T]	mg/kg
Calcium (Ca)	43078.241[T]	mg/kg
Cesium (Cs)	231.433[T]	mg/kg
Chromium (Cr)	25.263[T]	mg/kg
Cobalt (Co)	11.945[T]	mg/kg
Copper (Cu)	55.438[T]	mg/kg
Iron (Fe)	33548.400[T]	mg/kg
Lead (Pb)	169.734[T]	mg/kg
Lithium (Li)	21.279[T]	mg/kg
Magnesium (Mg)	9110.102[T]	mg/kg

Table 4-1 Geochemical Background Concentrations for Subsurface Soils, Ground Water, Surface Water, and Sediments at Rocky Flats Plant

Analyte	Background Concentration	Concentration Unit
Sediments (cont.)		
Manganese (Mn)	1675.660[T]	mg/kg
Mercury (Hg)	0.108[T]	mg/kg
Molybdenum (Mo)	7.794[T]	mg/kg
Nickel (Ni)	40.884[T]	mg/kg
Potassium (K)	4395.039[T]	mg/kg
Selenium (Se)	1.710[T]	mg/kg
Silicon (Si)	2304.398[T]	mg/kg
Silver (Ag)	1.027[T]	mg/kg
Sodium (Na)	425.618[T]	mg/kg
Strontium (Sr)	285.297[T]	mg/kg
Thallium (Tl)	0.549[T]	mg/kg
Tin (Sn)	22.030[T]	mg/kg
Vanadium (V)	102.877[T]	mg/kg
Zinc (Zn)	168.581[T]	mg/kg
Americium-241 (Am-241)	1.597[T]	pCi/g
Cesium-137 (Cs-137)	1.155[T]	pCi/g
Gross Alpha	69.203[T]	pCi/g

Analyte	Background Concentration	Concentration Unit
Sediments (cont.)		
Gross Beta	55.464[T]	pCi/g
Plutonium-239 (Pu-239)	4.963[T]	pCi/g
Radium-226 (Ra-226)	1.780[T]	pCi/g
Radium-228 (Ra-228)	3.744[T]	pCi/g
Strontium-90 (Sr-90)	0.931[T]	pCi/g
Tritium	374.202[T]	pCi/l
Uranium-233,234 (U-233,234)	4.018[T]	pCi/g
Uranium-235 (U-235)	0.174[T]	pCi/g
Uranium-238 (U-238)	3.717[T]	pCi/g
Alluvial Groundwater		
Bicarbonate	1023.013	mg/l
Bicarbonate as $CaCO_3$	516.772	mg/l
Carbonate	3.867	mg/l
Carbonate as $CaCO_3$	3.982	mg/l
Chloride	68.469	mg/l
Cyanide	0.016	mg/l

Analyte	Background Concentration	Concentration Unit
Alluvial Groundwater (cont.)		
Fluoride	2.350	mg/l
Nitrate+Nitrite	9.069	mg/l
Nitrite	0.074	mg/l
Orthophosphate	0.053	mg/l
pH	6.900	pH unit
Phosphorus (P)	4.647	mg/l
Sodium Nitrite	0.020	mg/l
Sulfate	353.556	mg/l
Total dissolved solids	1186.750	mg/l
Total suspended soilds	782.782	mg/l
Gross Alpha - dissolved	249.879	pCi/l
Gross Beta - dissolved	175.433	pCi/l
Aluminum (Al)	37.773[T] 0.259[D]	mg/l mg/l
Antimony (Sb)	0.045[T] 0.047[D]	mg/l mg/l
Arsenic (As)	0.002[T] 0.003[D]	mg/l mg/l

Analyte	Background Concentration	Concentration Unit
Alluvial Groundwater (cont.)		
Barium (Ba)	0.319[T]	mg/l
	0.167[D]	mg/l
Beryllium (Be)	0.002[T]	mg/l
	0.002[D]	mg/l
Cadmium (Cd)	0.004[T]	mg/l
	0.004[D]	mg/l
Calcium (Ca)	146.299[T]	mg/l
	155.637[D]	mg/l
Cesium (Cs)	0.240[T]	mg/l
	0.692[D]	mg/l
Chromium (Cr)	0.040[T]	mg/l
	0.016[D]	mg/l
Cobalt (Co)	0.015[T]	mg/l
	0.013[D]	mg/l
Copper (Cu)	0.039[T]	mg/l
	0.018[D]	mg/l
Iron (Fe)	50.271[T]	mg/l
	0.311[D]	mg/l
Lead (Pb)	0.022[T]	mg/l
	0.004[D]	mg/l
Lithium (Li)	0.120[T]	mg/l
	0.152[D]	mg/l

Analyte	Background Concentration	Concentration Unit
Alluvial Groundwater (cont.)		
Magnesium (Mg)	25.316[T] 42.066[D]	mg/l mg/l
Manganese (Mn)	1.132[T] 0.163[D]	mg/l mg/l
Mercury (Hg)	NA	
Molybdenum (Mo)	0.028[T] 0.034[D]	mg/l mg/l
Nickel (Ni)	0.032[T] 0.020[D]	mg/l mg/l
Potassium (K)	5.099[T] 3.858[D]	mg/l mg/l
Selenium (Se)	0.032[T] 0.033[D]	mg/l mg/l
Silicon (Si)	35.663[T] 13.871[D]	mg/l mg/l
Silver (Ag)	0.003[T] 0.007[D]	mg/l mg/l
Sodium (Na)	107.586[T] 186.709[D]	mg/l mg/l
Strontium (Sr)	1.015[T] 1.321[D]	mg/l mg/l

Analyte	Background Concentration	Concentration Unit
Alluvial Groundwater (cont.)		
Thallium (Tl)	0.002[T] 0.088[D]	mg/l mg/l
Tin (Sn)	0.035[T] 0.106[D]	mg/l mg/l
Vanadium (V)	0.060[T] 0.017[D]	mg/l mg/l
Zinc (Zn)	0.250[T] 0.056[D]	mg/l mg/l
Americium-241 (Am-241)	0.031[T] 0.308[D]	pCi/l pCi/l
Cesium-137 (Cs-137)	0.692[T] NA	pCi/l
Gross Alpha	NA 88.406[D]	pCi/l
Gross Beta	NA 35.5941[D]	pCi/l
Plutonium-239 (Pu-239)	0.056[T] 0.011[D]	pCi/l pCi/l
Radium-226 (Ra-226)	0.851[T] 0.497[D]	pCi/l pCi/l
Radium-228 (Ra-228)	NA NA	

Analyte	Background Concentration	Concentration Unit
Alluvial Groundwater (cont.)		
Strontium-89 (Sr-89)	0.0905[T] 0.841[D]	pCi/l pCi/l
Strontium-90 (Sr-90)	0.929[T] 0.841[D]	pCi/l pCi/l
Tritium	589.218[T] 324.761[D]	pCi/l pCi/l
Uranium-233,234 (U-233,234)	104.331[T] 58.497[D]	pCi/l pCi/l
Uranium-235 (U-235)	3.610[T] 1.483[D]	pCi/l pCi/l
Uranium-238 (U-238)	75.426[T] 39.814[D]	pCi/l pCi/l
Bedrock Groundwater		
Bicarbonate	468.999	mg/l
Bicarbonate as $CaCO_3$	336.614	mg/l
Carbonate	9.006	mg/l
Carbonate as $CaCO_3$	21.374	mg/l
Chloride	355.538	mg/l
Cyanide	0.020	mg/l
Fluoride	1.928	mg/l

Analyte	Background Concentration	Concentration Unit
Bedrock Groundwater (cont.)		
Nitrate+Nitrite	3.147	mg/l
Nitrite	1.027	mg/l
Orthophosphate	0.043	mg/l
pH	NA	
Phosphorus	3.926	mg/l
Sulfate	683.195	mg/l
Total dissolved solids	1422.391	mg/l
Total suspended solids	1490.664	mg/l
Aluminum (Al)	166.827[T] 0.216[D]	mg/l mg/l
Antimony (Sb)	1.318[T] 0.035[D]	mg/l mg/l
Arsenic (As)	0.011[T] 0.006[D]	mg/l mg/l
Barium (Ba)	1.501[T] 0.146[D]	mg/l mg/l
Beryllium (Be)	0.131[T] 0.005[D]	mg/l mg/l
Cadmium (Cd)	1.406[T] 0.006[D]	mg/l mg/l

Table 4-1 Geochemical Background Concentrations for Subsurface Soils, Ground Water, Surface Water, and Sediments at Rocky Flats Plant

Analyte	Background Concentration	Concentration Unit
Bedrock Groundwater (cont.)		
Calcium (Ca)	154.031[T]	mg/l
	83.254[D]	mg/l
Cesium (Cs)	0.216[T]	mg/l
	0.534[D]	mg/l
Chromium (Cr)	1.301[T]	mg/l
	0.011[D]	mg/l
Cobalt (Co)	1.325[T]	mg/l
	0.019[D]	mg/l
Copper (Cu)	1.432[T]	mg/l
	0.015[D]	mg/l
Iron (Fe)	249.672[T]	mg/l
	0.232[D]	mg/l
Lead (Pb)	0.051[T]	mg/l
	0.016[D]	mg/l
Lithium (Li)	0.272[T]	mg/l
	0.100[D]	mg/l
Magnesium (Mg)	26.784[T]	mg/l
	13.955[D]	mg/l
Manganese (Mn)	2.350[T]	mg/l
	0.026[D]	mg/l
Mercury (Hg)	NA	
	0.001[D]	mg/l
Molybdenum (Mo)	1.309[T]	mg/l
	0.047[D]	mg/l

Analyte	Background Concentration	Concentration Unit
Bedrock Groundwater (cont.)		
Nickel (Ni)	1.359[T] 0.015[D]	mg/l mg/l
Potassium (K)	7.133[T] 6.447[D]	mg/l mg/l
Selenium (Se)	0.002[T] 0.004[D]	mg/l mg/l
Silicon (Si)	190.690[T] 11.059[D]	mg/l mg/l
Silver (Ag)	0.246[T] 0.007[D]	mg/l mg/l
Sodium (Na)	1751.483[T] 418.724[D]	mg/l mg/l
Strontium (Sr)	1.842[T] 0.994[D]	mg/l mg/l
Thallium (Tl)	0.001[T] 0.010[D]	mg/l mg/l
Tin (Sn)	0.067[T] 0.050[D]	mg/l mg/l
Vanadium (V)	1.367[T] 0.020[D]	mg/l mg/l
Zinc (Zn)	4.027[T] 0.049[D]	mg/l mg/l
Americium-241 (Am-241)	0.042[T] 0.028[D]	pCi/l pCi/l

Analyte	Background Concentration	Concentration Unit
Bedrock Groundwater (cont.)		
Cesium-137 (Cs-137)	0.479[T] NA	pCi/l
Gross Alpha	NA 19.590[D]	 pCi/l
Gross Beta	NA 10.687[D]	 pCi/l
Plutonium-239 (Pu-239)	0.007[T] NA	pCi/l
Radium-226 (Ra-226)	4.019[T] 48.414[D]	pCi/l pCi/l
Radium-228 (Ra-228)	NA NA	
Strontium-89 (Sr-89)	1.977[T] 0.975[D]	pCi/l pCi/l
Strontium-90 (Sr-90)	11.794[T] 0.975[D]	pCi/l pCi/l
Tritium	6555.654[T] 347.420[D]	pCi/l pCi/l
Uranium-233,234 (U-233,234)	3.685[T] 9.057[D]	pCi/l pCi/l
Uranium-235 (U-235)	0.131[T] 0.184[D]	pCi/l pCi/l

Table 4-1 Geochemical Background Concentrations for Subsurface Soils, Ground Water, Surface Water, and Sediments at Rocky Flats Plant

Analyte	Background Concentration	Concentration Unit
Uranium-238 (U-238)	7.1107[T] 4.765[D]	pCi/l pCi/l

NOTES:

Background concentrations are equal to the upper limit of the tolerance interval reported in the 1992 Final Background Geochemical Characterization Report for Rocky Flats Plant unless signified by the following:

* Background concentration equal the maximum detected concentration for that particular analyte as reported in the 1992 Final Background Geochemical Characterization Report

NA Analyte was not detected or analyzed for in the background geochemical characterization study.

Background concentrations represent total constituent unless noted otherwise.

D Background concentration refers to dissolved constituents only

T Background concentration refers to total constituents only

Table 4-2 Geochemical Background Concentrations for OU1 Surface Soils

Analyte	Background Concentration*	Concentration Unit
Radionuclides		
Americium-241	0.229	pCi/g
Plutonium-239,-240	0.0481	pCi/g
Radium-226	1.133	pCi/g
Radium-228	2.314	pCi/g
Uranium-233,-234	1.289	pCi/g
Uranium-235	0.0706	pCi/g
Uranium-238	1.288	pCi/g
Metals		
Aluminum	16,080	mg/kg
Antimony	9.578	mg/kg
Arsenic	6.778	mg/kg
Barium	241.6	mg/kg
Beryllium	0.8921	mg/kg
Cadmium	0.7667	mg/kg
Calcium	82.45	mg/kg
Cesium	2.537	mg/kg
Chronium	18.31	mg/kg
Cobalt	9.052	mg/kg
Copper	18.46	mg/kg
Iron	18,960	mg/kg
Lead	40.07	mg/kg

Table 4-2 Geochemical Background Concentrations for OU1 Surface Soils

Analyte	Background Concentration*	Concentration Unit
Metals (continued)		
Lithium	14.07	mg/kg
Magnesium	4128	mg/kg
Maganese	435.4	mg/kg
Mercury	0.0692	mg/kg
Molybdenum	2.098	mg/kg
Nickel	16.09	mg/kg
Potassium	4036	mg/kg
Selenium	0.5423	mg/kg
Silicon	206.1	mg/kg
Silver	1.140	mg/kg
Sodium	148.6	mg/kg
Strontium	55.43	mg/kg
Thallium	0.3170	mg/kg
Tin	47.43	mg/kg
Vanadium	37.71	mg/kg
Zinc	71.20	mg/kg

• Background concentrations represent the upper limit of the 95% tolerance interval for analytes detected at Rock Creek in surface soils.

Table 4-3 Potential Chemical-Specific Benchmarks, Federal Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

Parameter	Type (7)	PQL MDL RFP	PQL MDL CDH	Method (8)	SDWA Maximum Contaminant Levels (a)	SDWA Maximum Contaminant Levels (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	CWA AWQC for Protection of Aquatic Life (c) Acute Value	CWA AWQC for Protection of Aquatic Life (c) Chronic Value	CWA AWQC for Protection of Human Health (c) Water and Fish Ingestion	CWA AWQC for Protection of Human Health (c) Fish Consumption Only	NRC Effluent Standards Water pCi/L
Bicarbonate	A	10,000		E310.1									
Carbonate	A	10,000		E310.1									
Chloride	A	5,000		E325	250,000*				860,000(e)	230,000(e)			
Chlorine	A	1,000		E4500					19	11			
Flouride	A	5,000		E340	4,000; 2,000*		4,000					4,000	
N as Nitrate	A	5,000		E353.1	10,000			10,000			10,000		
N as Nitrate+Nitrite	A	5,000		E353.1		10,000		10,000					
N as Nitrite	A	5,000		E354.1		1,000		1,000					
Sulfate	A	5,000		E375.4	250,000*								
Sulfide	A												
Coliform (Fecal)	B	1		SM9221C	1/100 ml								
Ammonia as N	C	5,000		E350					Criteria are pH	and temperature	dependent – see	criteria document	
Dioxin	D			d					0.01	0.00001	0.000000013	0.000000014	
Sulfur	E	100,000		E600									
Dissolved Oxygen	FP	500		SM4500					5,000				
pH	FP	0.1		E150.1	6.5–8.5 *					6.5–9			
Specific Conductance	FP	1		E120.1									
Temperature	FP								SS	SS			
Boron	I	5,000		E6010									
Total Dissolved Solids	I	10,000		E160.1	500,000*				SS	SS	250,000		
Aluminum	M	200		CT		50 to 200*			750	87			
Antimony	M	60		CT					9,000	1,600	146	45,000	
Arsenic	M	10		CT	50						0.0022	0.0175	
Arsenic III	M								360	190			
Arsenic V	M								850	48			
Barium	M	200		CT	1,000	2,000 (f)		2,000 (f)			1,000		
Beryllium	M	5		CT					130	5.3	.0068**	.117**	

Table 4-3 Potential Chemical-Specific Benchmarks, Federal Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

Parameter	Type (7)	PQL MDL RFP	PQL MDL CDH	Method (8)	SDWA Maximum Contaminant Levels (a)	SDWA Maximum Contaminant Levels (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	CWA AWQC for Protection of Aquatic Life (c) Acute Value	CWA AWQC for Protection of Aquatic Life (c) Chronic Value	CWA AWQC for Protection of Human Health (c) Water and Fish Ingestion	CWA AWQC for Protection of Human Health (c) Fish Consumption Only	NRC Effluent Standards Water pCi/L
Cadmium	M	5		CT	10	5		5	3.9 (3)	1.1 (3)	10		
Calcium	M	5,000		CT									
Cesium	M	1,000		NC									
Chromium	M	10		CT	50	100		100					
Chromium III	M	5		SW8467196					1,700	210	170,000	3,433,000	
Chromium VI	M	10		E218.5					16	11	50		
Cobalt	M	50		CT									
Copper	M	25		CT	1,000*			1,300 (g)	18 (3)	12 (3)			
Cyanide	M	10		CT					22	5.2	200		
Iron	M	100		CT	300 *					1,000	300		
Lead	M	5		CT	50			0 (g)	82 (3)	3.2 (3)	50		
Lithium	M	100		NC									
Magnesium	M	5000		CT									
Manganese	M	15		CT	50 *						50	100	
Mercury	M	0.2		CT	2	2		2	2.4	0.012	0.144	0.146	
Molybdenum	M	200		NC									
Nickel	M	40		CT					1,400 (3)	160 (3)	13.4	100	
Potassium	M	5000		CT									
Selenium	M	5		CT	10	50		50	20 (d)	5 (d)	10		
Silver	M	10		CT	50	100 *			4.1 (3)	0.12	50		
Sodium	M	5000		CT									
Strontium	M	200		NC									
Thallium	M	10		CT					1,400 (1)	40 (1)	13	48	
Tin	M	200		NC									
Titanium	M	10		E6010									
Tungsten	M	10		E6010									
Vanadium	M	50		CT									
Zinc	M	20		CT	5,000 *				120 (3)	110 (3)			

Table 4-3 Potential Chemical-Specific Benchmarks, Federal Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

Parameter	Type (7)	PQL MDL RFP	PQL MDL CDH	Method (8)	SDWA Maximum Contaminant Levels (a)	SDWA Maximum Contaminant Levels (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	CWA AWQC for Protection of Aquatic Life (c) Acute Value	CWA AWQC for Protection of Aquatic Life (c) Chronic Value	CWA AWQC for Protection of Human Health (c) Water and Fish Ingestion	CWA AWQC for Protection of Human Health (c) Fish Consumption Only	NRC Effluent Standards Water pCi/L
2,4,5-TP Silvex	P		0.5	d	10	50		50					
2,4-Dichlorophenoxyacetic Acid (2,4-D)	P		1	d	100	70		70					
Acrolein	P		10						68(1)	21(1)	320	780	
Aldicarb	P		10			3 (f)		1 (f)					
Aldrin	P	0.05	0.1	CP					3.0		0.000074	0.000079	
Bromacil	P												
Carbofuran	P			d		40		40					
Chloranil													
Chlordane (Alpha)	P	0.5	1	CP		2		0	2.4	0.0043	0.00046	0.00048	
Chlordane (Gamma)	P	0.5	1	CP		2		0	2.4	0.0043	0.00046	0.00048	
Chlorpyrifos	P		0.1	E619					0.063	0.041			
DDT	P	0.1	0.1	CP					1.1	0.0011	0.000024	0.000024	
DDT metabolite (DDD)	P	0.1	0.1	CP					0.06				
DDT metabolite (DDE)	P	0.1	0.1	CP					1,050				
Demeton	P		1							0.1			
Diazinon	P												
Dieldrin	P	0.1	0.1	CP					2.5	0.0019	0.00007	0.000076	
Endosulfan I	P	0.05	0.1	CP					0.22	0.056	74	159	
Endosulfan II	P	0.1	0.1	CP									
Endosulfan Sulfate	P	0.1	0.1	CP									
Endrin	P	0.1	0.1	CP	0.2				0.18	0.0023	1		
Endrin Aldehyde	P		0.1										
Endrin Ketone	P	0.1		CP						0.01			
Guthion	P		1.5										
Heptachlor	P	0.05	0.05	CP		0.4		0	0.52	0.0038	0.00028	0.00029	
Heptachlor Epoxide	P	0.05	0.05	CP		0.2		0					
Hexachlorocyclohexane, Alpha	P	0.05	0.05	CP							0.0092	0.031	
Hexachlorocyclohexane, Beta	P	0.05	0.05	CP							0.0163	0.0547	
Hexachlorocyclohexane, BHC	P	0.05	0.05										

Table 4-3 Potential Chemical-Specific Benchmarks, Federal Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

Parameter	Type (7)	PQL MDL RFP	PQL MDL CDH	Method (8)	SDWA Maximum Contaminant Levels (a)	SDWA Maximum Contaminant Levels (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	CWA AWQC for Protection of Aquatic Life (c) Acute Value	CWA AWQC for Protection of Aquatic Life (c) Chronic Value	CWA AWQC for Protection of Human Health (c) Water and Fish Ingestion	CWA AWQC for Protection of Human Health (c) Fish Consumption Only	NRC Effluent Standards Water pCi/L
Hexachlorocyclohexane, Delta	P	0.05		CP									
Hexachlorocyclohexane, Technical	P		0.2	f							0.0123	0.0414	
Hexachlorocyclohexane, (Lindane) Gama	P	0.05	0.05	CP	4	0.2		0.2	2.0	0.08			
Malathion	P		0.2							0.01			
Methoxychlor	P	0.5	0.5	CP	100	40		40		0.03	100		
Mirex	P		0.1							0.001			
Parathion	P								0.065	0.013			
PCBs	P	0.5	1	CP		0.5		0	2.0	0.014	0.000079**	0.000079**	
Simazine	P			e									
Toxaphene	P	1	5	CP		3		0	0.73	0.0002	0.00071**	0.00073**	
Vaponite 2	P												
Aroclor 1016	PP	0.5		CP									
Aroclor 1221	PP	0.5		CP									
Aroclor 1232	PP	0.5		CP									
Aroclor 1242	PP	0.5		CP									
Aroclor 1248	PP	0.5		CP									
Aroclor 1254	PP	1		CP									
Aroclor 1260	PP	1		CP									
Atrazine	PP			e		3		3					
Americium (pCi/l)	R												20
Americium 241 (pCi/l)	R	0.01											900
Cesium 134 (pCi/l)	R	1											1000
Cesium 137 (pCi/l)	R	1											
Gross Alpha (pCI/l)	R	2			15 (10)							15	
Gross Beta (pCi/l)	R	4			50 (4 mrem/yr)								
Plutonium (pCi/l)	R												20
Plutonium 238+239+240 (pCi/l)	R	0.01											60
Radium 226+228 (pCi/l)	R	0.5/0.1 (9)			5							5	

Table 4-3 Potential Chemical-Specific Benchmarks, Federal Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

Parameter	Type (7)	PQL MDL RFP	PQL MDL CDH	Method (8)	SDWA Maximum Contaminant Levels (a)	SDWA Maximum Contaminant Levels (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	CWA AWQC for Protection of Aquatic Life (c) Acute Value	CWA AWQC for Protection of Aquatic Life (c) Chronic Value	CWA AWQC for Protection of Human Health (c) Water and Fish Ingestion	CWA AWQC for Protection of Human Health (c) Fish Consumption Only	NRC Effluent Standards Water pCi/L
Strontium 89+90 (pCi/l)	R	1											500
Strontium 90 (pCi/l)	R				8 (6)							8	500
Thorium 230+232 (pCi/l)	R												30
Tritium (pCi/l)	R				20,000 (6)								1000000
Uranium 233+234 (pCi/l)	R												300
Uranium 235 (pCi/l)	R	0.6											300
Uranium 238 (pCi/l)	R	0.6											300
Uranium (total) (pCi/l)	R												
1,2,4,5-Tetrachlorobenzene	SV		10	b							38	48	
1,2,4-Trichlorobenzene	SV	10		CS									
1,2-Dichlorobenzene (Ortho)	SV	10	10	CS		600		600					
1,2-Diphenylhydrazine	SV			b					270 (1)				
1,3-Dichlorobenzene (Meta)	SV	10	1	CS									
1,4-Dichlorobenzene (Para)	SV	10	1	CS	75		75						
2,4,5-Trichlorophenol	SV	50		CS							2,800		
2,4,6-Trichlorophenol	SV	10	50	CS						970 (1)	1.2 **	3.6 **	
2,4-Dichlorophenol	SV	10	50	CS					2,020 (1)	365 (1)	3,090		
2,4-Dimethylphenol	SV	10	50	CS					2,120 (1)				
2,4-Dinitrophenol	SV	50	50	CS									
2,4-Dinitrotoluene	SV	10	10	CS							0.11 **	9.1 **	
2,6-Dinitrotoluene	SV	10	10	CS					330 (1)	230 (1)	70	14,300	
2-Chloronaphthalene	SV	10		CS									
2-Chlorophenol	SV	10	so	CS					4,360 (1)	2,000 (1)			
2-Methylnaphthalene	SV	10		CS									
2-Methylphenol	SV	10		CS									
2-Nitroaniline	SV	50		CS									
2-Nitrophenol	SV	10		CS									
3,3-Dichlorobenzidine	SV	20	10	CS							0.01	0.02	

Table 4-3 Potential Chemical-Specific Benchmarks, Federal Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

Parameter	Type (7)	PQL MDL RFP	PQL MDL CDH	Method (8)	SDWA Maximum Contaminant Levels (a)	SDWA Maximum Contaminant Levels (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	CWA AWQC for Protection of Aquatic Life (c) Acute Value	CWA AWQC for Protection of Aquatic Life (c) Chronic Value	CWA AWQC for Protection of Human Health (c) Water and Fish Ingestion	CWA AWQC for Protection of Human Health (c) Fish Consumption Only	NRC Effluent Standards Water pCi/L
3-Nitroaniline	SV	50		CS									
4,6-Dinitro-2-methylphenol	SV	50	50	CS									
4-Bromophenyl Phenylether	SV	10		CS									
4-Chloroaniline	SV	10		CS									
4-Chlorophenyl Phenyl Ether	SV	10		CS									
4-Chloro-3-methylphenol	SV	10	50	CS					30 (1)				
4-Methylphenol	SV	10		CS									
4-Nitroaniline	SV	50		CS									
4-Nitrophenol	SV	50		CS					230 (1)	150 (1)			
Acenaphthene	SV	10	10	CS					1,700 (1)	520 (1)			
Anthracene	SV	10	1	CS									
Benzidine	SV		1	d					2,500		0.00012	0.00053	
Benzoic Acid	SV	50		CS									
Benzo(a)anthracene	SV	10	10	CS									
Benzo(a)pyrene	SV	10	10	CS									
Benzo(b)fluoranthene	SV	10	10	CS									
Benzo(g,h,i)perylene	SV	10	10	CS									
Benzo(k)fluoranthene	SV	10	10	CS									
Benzyl Alcohol	SV	10		CS									
bis(2-Chloroethoxy)methane	SV	10		CS									
bis(2-Chloroethyl)ether	SV	10	10	CS							0.03**	1.36 **	
bis(2-Chloroisopropyl)ether	SV	10	10	CS							34.7	4,360	
bis(2-Ethylhexyl)phthalate	SV	10	10	CS							15,000	50,000	
Butadiene	SV												
Butylbenzylphthalate	SV	10	10	CS									
Chlorinated Ethers	SV												
Chlorinated Napthalenes	SV								1,600 (1)				
Chloroalkylethers	SV	10		CS					238,000 (1)				
Chlorophenol	SV		50										

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Chrysene	SV	10	10	CS									
Dibenzofuran	SV	10		CS									
Dibenz(a,h)anthracene	SV	10	10	CS									
Dichlorobenzenes	SV		1						1,120 (1)	763 (1)	400	2,600	
Dichlorobenzidine	SV	20	10	CS							0.01	0.02	
Diethylphthalate	SV	10	10	CS							350,000	1,800,000	
Dimethylphthalate	SV	10	10	CS							313,000	2,900,000	
Di-n-butylphthalate	SV	10	10	CS									
Di-n-octylphthalate	SV	10		CS									
Ethylene Glycol	SV			d									
Fluoranthene	SV	10	10	CS					3,980 (1)		42	54	
Fluorene	SV	10	10	CS									
Formaldehyde	SV												
Haloethers	SV								380 (1)	122 (1)			
Hexachlorobenzene	SV	10	10	CS							0.00072**	0.00074**	
Hexachlorobutadiene	SV	10	10	CS					90 (1)	9.3 (1)	0.45**	50 **	
Hexachlorocyclopentadiene	SV	10	10	CS					7 (1)	5.2 (1)	206		
Hexachloroethane	SV	10	10	CS					980 (1)	540 (1)	1.9	8.74	
Hydrazine	SV												
Indeno(1,2,3-cd)pyrene	SV	10	10	CS									
Isophorone	SV	10	10	CS					117,000 (1)		5,200	520,000	
Naphthalene	SV	10	10	CS					2,300 (1)	620 (1)			
Nitrobenzene	SV	10	10	CS					27,000 (1)		19,800		
Nitrophenols	SV								230 (1)	150 (1)			
Nitrosamines	SV								5,850 (1)				
Nitrosodibutylamine	SV		10	b							0.0064	0.587	
Nitrosodiethylamine	SV		10	b							0.0008	1.24	
Nitrosodimethylamine	SV		10	b							0.0014	16	
Nitrosopyrrolidine	SV		10	b							0.016	91.9	

Table 4-3 Potential Chemical-Specific Benchmarks, Federal Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

Parameter	Type (7)	PQL MDL RFP	PQL MDL CDH	Method (8)	SDWA Maximum Contaminant Levels (a)	SDWA Maximum Contaminant Levels (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	CWA AWQC for Protection of Aquatic Life (c) Acute Value	CWA AWQC for Protection of Aquatic Life (c) Chronic Value	CWA AWQC for Protection of Human Health (c) Water and Fish Ingestion	CWA AWQC for Protection of Human Health (c) Fish Consumption Only	NRC Effluent Standards Water pCi/L
N-Nitrosodiphenylamine	SV	10	10	b							4.9 **	16.1 **	
N-Nitroso-di-n-dipropylamine	SV	10	10	b									
Pentachlorinated Ethanes	SV			b					7,240 (1)	1,100 (1)			
Pentachlorobenzene	SV		10	b							74	85	
Pentachlorophenol	SV	50	50	CS		1 (f)		0 (f)	20 (4)	13 (4)	1,010		
Phenanthrene	SV	10	10	CS									
Phenol	SV	10	50	CS					10,200 (1)	2,560 (1)	3,500		
Phthalate Esters	SV			e					940 (1)	3 (1)			
Polynuclear Aromatic Hydrocarbons	SV		10	b							0.0028**	0.0311**	
Vinyl Chloride	SV	10	2	CV	2		0				2 **	525 **	
1,1,1-Trichloroethane	V	5	1	CV	200		200				18,400	1,030,000	
1,1,2,2-Tetrachloroethane	V	5	1	CV						2,400	0.17**	10.7 **	
1,1,2-Trichloroethane	V	5	1	CV						9,400	0.6**	41.8 **	
1,1-Dichloroethane	V	5		CV									
1,1-Dichloroethene	V	5	1	CV	7		7						
1,2-Dichloroethane	V	5	1	CV	5		0		118,000	20,000	0.94**	243 **	
1,2-Dichloroethene (cis)	V		1	a		70		70					
1,2-Dichloroethene (total)	V	5		CV									
1,2-Dichloroethene (trans)	V	5	1	a		100		100					
1,2-Dichloropropane	V	5	1	CV		5		0	23,000	5,700			
1,3-Dichloropropene (cis)	V	5	1	CV					6,060	244 (1)	87	14,100	
1,3-Dichloropropene (trans)	V	5	1	CV					6,060	244 (1)	87	14,100	
2-Butanone	V	10		CV									
2-Hexanone	V	10		CV									
4-Methyl-2-pentanone	V	10		CV									
Acetone	V	10		CV									
Acrylonitrile	V		5	c					7,500	2,600	0.058	0.65	
Benzene	V	5	1	CV	5		0		5,300		0.66**	40 **	

Table 4-3 Potential Chemical-Specific Benchmarks, Federal Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

Parameter	Type (7)	PQL MDL RFP	PQL MDL CDH	Method (8)	SDWA Maximum Contaminant Levels (a)	SDWA Maximum Contaminant Levels (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	CWA AWQC for Protection of Aquatic Life (c) Acute Value	CWA AWQC for Protection of Aquatic Life (c) Chronic Value	CWA AWQC for Protection of Human Health (c) Water and Fish Ingestion	CWA AWQC for Protection of Human Health (c) Fish Consumption Only	NRC Effluent Standards Water pCi/L
Bromodichloromethane	V	5	1	CV									
Bromoform	V	5	1	CV									
Bromomethane	V	10	1	CV									
Carbon Disulfide	V	5		CV									
Carbon Tetrachloride	V	5	1	CV	5		0		35,200 (1)		0.4**	6.94 **	
Chlorinated Benzenes	V	10		CV/CS					250 (1)	50 (1)			
Chlorobenzene	V	5	1	CV/CS		100		100					
Chloroethane	V	10		CV									
Chloroform	V	5	1	CV	Tot THM<100 (2)				28,900 (1)	1,240 (1)	0.19 **	15.7 **	
Chloromethane	V	10	1	CV									
Dibromochloromethane	V	5	1	CV									
Dichloroethenes	V		1						11,600 (1)		0.033**	1.85 **	
Ethyl Benzene	V	5	1	CV		700		700	32,000 (1)		1,400	3,280	
Ethylene Dibromide	V			d		0.05		0					
Ethylene Oxide	V												
Halomethanes	V				100				11,000 (1)		0.19**	15.7 **	
Methylene Chloride	V	5	1	CV									
Pyrene	V	10	10	CS									
Styrene	V	5		CV		100		100					
Tetrachloroethanes	V	5	1	CV					9,320 (1)				
Tetrachloroethene	V	5	1	CV		5		0	5,280 (1)	840 (1)	0.80**	8.85 **	
Toluene	V	5	1	CV		1,000		1,000	17,500 (1)		14,300	424,000	
Trichloroethanes	V	5	1	CV					18,000 (1)				
Trichloroethene	V	5	1	CV	5		0		45,000 (1)	21,900 (1)	2.7 **	80.7 **	
Vinyl Acetate	V	10		CV									
Xylenes (total)	V	5		CV		10,000		10,000					

Table 4-3 Potential Chemical-Specific Benchmarks, Federal Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

Parameter	Type (7)	PQL MDL RFP	PQL MDL CDH	Method (8)	SDWA Maximum Contaminant Levels (a)	SDWA Maximum Contaminant Levels (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	CWA AWQC for Protection of Aquatic Life (c) Acute Value	CWA AWQC for Protection of Aquatic Life (c) Chronic Value	CWA AWQC for Protection of Human Health (c) Water and Fish Ingestion	CWA AWQC for Protection of Human Health (c) Fish Consumption Only	NRC Effluent Standards Water pCi/L

EXPLANATION OF TABLE

* = secondary maximum contaminant level

** = Human health criteria for carcinogens reported for three risk levels. Value presented is the 10-5 risk level.

AWQC = Ambient Water Quality Criteria
CLP = Contract Laboratory Program
CWA = Clean Water Act
EPA = Environmental Protection Agency
pCi/l = picocuries per liter
PCB = polychlorinated biphenyl
PQL = Practical Quantitation Level
SDWA = Safe Drinking Water Act
SS = Species Specific
TAL = Target Analyte List
THM = Total Trihalomethanes
TIC = Tentatively Identified Compound
MDL = Minimum Detection Limit for radionuclides (pCi/l)
ug/l = micrograms per liter
VOA = Volatile Organic Analysis

Table 4-3 Potential Chemical-Specific Benchmarks, Federal Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

Parameter	Type (7)	PQL MDL RFP	PQL MDL CDH	Method (8)	SDWA Maximum Contaminant Levels (a)	SDWA Maximum Contaminant Levels (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	CWA AWQC for Protection of Aquatic Life (c) Acute Value	CWA AWQC for Protection of Aquatic Life (c) Chronic Value	CWA AWQC for Protection of Human Health (c) Water and Fish Ingestion	CWA AWQC for Protection of Human Health (c) Fish Consumption Only	NRC Effluent Standards Water pCi/L

(1) criteria not developed; value presented is lowest observed effects level (LOEL)
(2) total trihalomethanes: chloroform, bromoform, bromodichloromethane, dibromochloromethane
(3) hardness dependent criteria
(4) pH dependent criteria (7.8 pH used)
(5) standard is not adequately protective when chloride is associated with potassium, calcium, or magnesium, rather than sodium.
(6) if both strontium-90 and tritium are present, the sum of their annual dose equivalents to bone marrow shall not exceed 4 mrem/yr.
(7) type abbreviations are: A=anion; B=bacteria; C=cation; D=dioxin; E=element; I=indicator; FP=field parameter; M=metal; P=pesticide; PP=pesticide/PCB; R=radionuclide; SV=semi-volatile; V=volatile
(8) method abbreviations are: CT=CLP-TAL; NC=non-CLP; CV=CLP-VOA; CS=CLP-SEMI; EP=EPA-PEST; CP=CLP-PEST; E=EPA; a = detected as total in CV; b = detected as TIC in CS; c = detected as TIC in CV; d = not routinely monitored; e = monitored in discharge ponds; f = mixture-individual isomers detected.
(9) MDL for radium 226 is 0.5; MDL for radium 228 is 1.0
(10) Value for gross alpha excludes uranium

(a) EPA National Primary and Secondary Drinking Water Regulations, 40 CFR 141 and 40 CFR 143 (as of May 1990).
(b) EPA National Primary and Secondary Drinking Water Regulations, 40 CFR Parts 141, 142 and 143, Final Rule, effective July 30, 1992 (56 Federal Register 3526; 1/30/1991).
(c) EPA, Quality Criteria for Protection of Aquatic Life, 1986
(d) EPA, National Ambient Water Quality Criteria for Selenium - 1987
(e) EPA, National Ambient Water Quality Criteria for Chloride - 1988
(f) EPA National Primary and Secondary Drinking Water Regulations, 40 CFR Parts 141, 142, and 143, Final Rule (56 FR 30266; 7/1/1991) effective 1/1/1993.
(g) EPA Maximum Contaminant Level Goals and National Primary Drinking Water Regulations for Lead and Copper, 40 CFR 141 and 142 (56 FR 26460; 6/7/1991) effective 12/7/91.
(h) NRC Effluent Water Concentrations - 10 CFR 20 Appendix A, Table 2, Column 2 "Effluent Concentrations for Water" (56 FR 23412 - 23464, May 21, 1991) effective 6/20/91.

Table 4-4 Potential Chemical-Specific Benchmarks, Statewide and Basin Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

					Statewide Standards (a)								Basin Standards (b)	
					Human Health Carcinogens/ Noncarcinogens (2) (8)		Aquatic Life (8)		Tables I,II,III (1) Aquatic Life				Organics (7)	
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	Water Supply	Water and Fish	Acute Value	Chronic Value	Acute Value (2)	Chronic Value (2)	Agricul-tural Standard (3)	Domestic Water Supply (4)	Aquatic Life	Water Supply
Bicarbonate	A	10,000		E310.1										
Carbonate	A	10,000		E310.1										
Chloride	A	5,000		E325								250,000		
Chlorine	A	1,000		E4500					19	11				
Fluoride	A	5,000		E340								2,000		
N as Nitrate	A	5,000		E353.1							100,000	10,000		
N as Nitrate+Nitrite	A	5,000		E353.1							100,000	10,000		
N as Nitrite	A	5,000		E354.1					SS	SS	10,000	1,000		
Sulfate	A	5,000		E375.4								250,000		
Sulfide	A									2		50		
Coliform (Fecal)	B	1		SM9221C								2000/100 ml		
Ammonia as N	C	5,000		E350					620	60		500		
Dioxin	D			d	0.00000022	0.000000013	0.01	0.00001						
Sulfur	E	100,000		E600										
Dissolved Oxygen	FP	500		SM4500					5,000	5,000	3,000	3,000		
pH	FP	0.1		E150.1					6.5-9.0	6.5-9.0		5.0-9.0		
Specific Conductance	FP	1		E120.1										
Temperature	FP								30 degrees	30 degrees				
Boron	I	5,000		E6010							750			
Total Dissolved Solids	I	10,000		E160.1										
Aluminum	M	200		CT					750	87				
Antimony	M	60		CT								14		
Arsenic	M	10		CT					360	150	100	50		
Arsenic III	M													
Arsenic V	M													
Barium	M	200		CT								1,000		

Table 4-4 Potential Chemical-Specific Benchmarks, Statewide and Basin Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

					Statewide Standards (a)								Basin Standards (b)	
					Human Health Carcinogens/ Noncarcinogens (2) (8)		Aquatic Life (8)		Tables I,II,III (1)				Organics (7)	
									Aquatic Life					
Parameter	Type (5)	PQL MDL RFP	CDH	Method (6)	Water Supply	Water and Fish	Acute Value	Chronic Value	Acute Value (2)	Chronic Value (2)	Agricul-tural Standard (3)	Domestic Water Supply (4)	Aquatic Life	Water Supply
Beryllium	M	5		CT							100	0.0076		
Cadmium	M	5		CT					TVS	TVS	10	10		
Calcium	M	5,000		CT										
Cesium	M	1,000		NC										
Chromium	M	10		CT										
Chromium III	M	5		SW8467196					TVS	TVS	100	50		
Chromium VI	M	10		E218.5					16	11	100	50		
Cobalt	M	50		CT										
Copper	M	25		CT					TVS	TVS	200	1,000		
Cyanide	M	10		CT					5	5	200	200		
Iron	M	100		CT						1,000		300 (dis)		
Lead	M	5		CT					TVS	TVS	100	50		
Lithium	M	100		NC										
Magnesium	M	5000		CT										
Manganese	M	15		CT						1,000	200	50 (dis)		
Mercury	M	0.2		CT					2.4	0.1		2.0		
Molybdenum	M	200		NC										
Nickel	M	40		CT					TVS	TVS	200			
Potassium	M	5000		CT										
Selenium	M	5		CT					135	17	20	10		
Silver	M	10		CT					TVS	TVS		50		
Sodium	M	5000		CT										
Strontium	M	200		NC										
Thallium	M	10		CT						15		0.012		
Tin	M	200		NC										
Titanium	M	10		E6010										
Tungsten	M	10		E6010										
Vanadium	M	50		CT										
Zinc	M	20		CT					TVS	TVS	2,000	5,000		

Table 4-4 Potential Chemical-Specific Benchmarks, Statewide and Basin Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

					Statewide Standards (a)								Basin Standards (b)	
					Human Health Carcinogens/ Noncarcinogens (2) (8)		Aquatic Life (8)		Tables I,II,III (1)				Organics (7)	
									Aquatic Life					
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	Water Supply	Water and Fish	Acute Value	Chronic Value	Acute Value (2)	Chronic Value (2)	Agricul-tural Standard (3)	Domestic Water Supply (4)	Aquatic Life	Water Supply
2,4,5-TP Silvex	P		0.5	d	50									
2,4-D	P		1	d	70									100
Acrolein			10			320	68	21						
Aldicarb	P		10		10									
Aldrin	P	0.05	0.1	CP	0.002 (8)	0.00013	1.5						0.003	
Bromacil	P													
Carbofuran	P			d	36									
Chloranil	P			E619										
Chlordane (Alpha)	P	0.5	1	CP	0.03 (8)		1.2	0.0043						
Chlordane (Gamma)	P	0.5	1	CP	0.03 (8)	0.00058	1.2	0.0043						
Chlorpyrifos	P		0.1				0.083	0.041						
DDT	P	0.1	0.1	CP	0.1	0.00059	0.55	0.001					0.001	
DDT Metabolite (DDD)	P	0.1	0.1	CP		0.0008	0.6						0.001	
DDT Metabolite (DDE)	P	0.1	0.1	CP	0.1	0.00059	1,050						0.001	
Demeton	P		1					0.1					0.1	
Diazinon	P													
Dieldrin	P	0.1	0.1	CP	0.002	0.00014	1.3	0.0019					0.003	
Endosulfan I	P	0.05	0.1	CP		0.93	0.11	0.056					0.003	
Endosulfan II	P	0.1	0.1	CP										
Endosulfan Sulfate	P	0.1	0.1	CP		0.93								
Endrin	P	0.1	0.1	CP	0.2		0.09	0.0023					0.004	
Endrin Aldehyde	P		0.1		0.2	0.2								
Endrin Ketone	P	0.1		CP										
Guthion	P		1.5					0.01					0.01	
Heptachlor	P	0.05	0.05	CP	0.008	0.00021	0.26	0.0038					0.001	0.2
Heptachlor Epoxide	P	0.05	0.05	CP	0.09	0.0001	0.26	0.0038						
Hexachlorocyclohexane, Alpha	P	0.05	0.05	CP	0.006		0.0039							
Hexachlorocyclohexane, Beta	P	0.05	0.05	CP		0.014								

Table 4-4 Potential Chemical-Specific Benchmarks, Statewide and Basin Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

						Statewide Standards (a)							Basin Standards (b)	
					Human Health Carcinogens/ Noncarcinogens (2) (8)		Aquatic Life (8)		Tables I,II,III (1)				Organics (7)	
									Aquatic Life					
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	Water Supply	Water and Fish	Acute Value	Chronic Value	Acute Value (2)	Chronic Value (2)	Agricul-tural Standard (3)	Domestic Water Supply (4)	Aquatic Life	Water Supply
Hexachlorocyclohexane, BHC	P	0.05	0.05				100							
Hexachlorocyclohexane, Delta	P	0.05		CP										
Hexachlorocyclohexane, Tech.	P		0.2	f		0.012								
Hexachlorocyclohexane, Lindane	P	0.05	0.05	CP	0.2	0.019	1.0	0.08					0.01	4.0
Malathion	P		0.2					0.1					0.1	
Methoxychlor	P	0.5	0.5	CP	40			0.03					0.03	100
Mirex	P		0.1					0.001					0.001	
Parathion	P												0.04	
PCBs	P	0.5	1	CP	0.005	0.000044	2.0	0.014					0.001	
Simazine	P			e										
Toxaphene	P	1	5	CP	0.03	0.00073	0.73	0.0002					0.005	5.0
Vaponite 2	P													
Aroclor 1016	PP	0.5		CP										
Aroclor 1221	PP	0.5		CP										
Aroclor 1232	PP	0.5		CP										
Aroclor 1242	PP	0.5		CP										
Aroclor 1248	PP	0.5		CP										
Aroclor 1254	PP	1		CP										
Aroclor 1260	PP	1		CP										
Atrazine	PP			e										
Americium (pCi/l)	R													
Americium 241 (pCi/l)	R	0.01												
Cesium 134 (pCi/l)	R	1			80 (10)									
Cesium 137 (pCi/l)	R	1												
Gross Alpha (pCi/l)	R	2												
Gross Beta (pCi/l)	R	4												
Plutonium (pCi/l)	R													
Plutonium 238+239+240 (pCi/l)	R	0.01			15 (10)									

Table 4-4 Potential Chemical-Specific Benchmarks, Statewide and Basin Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

							Statewide Standards (a)						Basin Standards (b)	
					Human Health Carcinogens/ Noncarcinogens (2) (8)		Aquatic Life (8)		Tables I,II,III (1) Aquatic Life				Organics (7)	
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	Water Supply	Water and Fish	Acute Value	Chronic Value	Acute Value (2)	Chronic Value (2)	Agricul-tural Standard (3)	Domestic Water Supply (4)	Aquatic Life	Water Supply
Radium 226+228 (pCi/l)	R	0.5/1 (9)			5 (10)									
Strontium 89+90 (pCi/l)	R	1												
Strontium 90 (pCi/l)	R				8 (10)									
Thorium 230+232 (pCi/l)	R				60 (10)									
Tritium (pCi/l)	R				20,000 (10)									
Uranium 233+234 (pCi/l)	R													
Uranium 235 (pCi/l)	R	0.6												
Uranium 238 (pCi/l)	R	0.6												
Uranium (Total) (pCi/l)	R								TVS	TVS				
1,2,4,5-Tetrachlorobenzene	SV		10	b	2 (8)									
1,2,4-Trichlorobenzene	SV	10		CS										
1,2-Dichlorobenzene (Ortho)	SV	10	1	CS	620	620								
1,2-Diphenylhydrazine	SV			b	0.05	0.04	270							
1,3-Dichlorobenzene (Meta)	SV	10	1	CS	620	400								
1,4-Dichlorobenzene (Para)	SV	10	1	CS	75	75								
2,4,5-Trichlorophenol	SV	50		CS										
2,4,6-Trichlorophenol	SV	10	50	CS	2	2		970						
2,4-Dichlorophenol	SV	10	50	CS	21	21	2,020	365						
2,4-Dimethylphenol	SV	10	50	CS			2,120							
2,4-Dinitrophenol	SV	50	50	CS	14	14								
2,4-Dinitrotoluene	SV	10	10	CS		0.11								
2,6-Dinitrotoluene	SV	10	10	CS			330	230						
2-Chloronaphthalene	SV	10		CS										
2-Chlorophenol	SV	10	50	CS			4,380	2,000						
2-Methylnaphthalene	SV	10		CS										
2-Methylphenol	SV	10		CS										
2-Nitroaniline	SV	50		CS										
2-Nitrophenol	SV	10		CS										

Table 4-4 Potential Chemical-Specific Benchmarks, Statewide and Basin Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

						Statewide Standards (a)								Basin Standards (b)	
					Human Health Carcinogens/ Noncarcinogens (2) (8)		Aquatic Life (8)		Tables I,II,III (1) Aquatic Life				Organics (7)	
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	Water Supply	Water and Fish	Acute Value	Chronic Value	Acute Value (2)	Chronic Value (2)	Agricul-tural Standard (3)	Domestic Water Supply (4)	Aquatic Life	Water Supply
3,3-Dichlorobenzidine	SV	20	10	CS		0.039								
3-Nitroaniline	SV	50		CS										
4,6-Dinitro-2-methylphenol	SV	50	50	CS		13								
4-Bromophenyl Phenylether	SV	10		CS										
4-Chloroaniline	SV	10		CS										
4-Chlorophenyl Phenyl Ether	SV	10		CS										
4-Chloro-3-methylphenol	SV	10	50	CS			30							
4-Methylphenol	SV	10		CS										
4-Nitroaniline	SV	50		CS										
4-Nitrophenol	SV	50		CS										
Acenaphthene	SV	10	10	CS			1,700	520						
Anthracene	SV	10	1	CS		0.0028								
Benzidine	SV		10	d	0.0002	0.00012(8)	2,500						0.1	0.01
Benzoic Acid	SV	50		CS										
Benzo(a)anthracene	SV	10	10	CS		0.0028								
Benzo(a)pyrene	SV	10	10	CS		0.0028								
Benzo(b)fluoranthene	SV	10	10	CS		0.0028								
Benzo(g,h,i)perylene	SV	10	10	CS		0.0028								
Benzo(k)fluoranthene	SV	10	10	CS		0.0028								
Benzyl Alcohol	SV	10		CS										
bis(2-Chloroethoxy)methane	SV	10		CS										
bis(2-Chloroethyl)ether	SV	10	10	CS	0.03 (8)	0.03 (8)								
bis(2-Chloroisopropyl)ether	SV	10	10	CS		1,400								
bis(2-Ethylhexyl)phthalate	SV	10	10	CS		1.8 (8)								
Butadiene	SV													
Butyl Benzylphthalate	SV	10	10	CS		3,000								
Chlorinated Ethers	SV													
Chlorinated Napthalenes	SV													
Chloroalkylethers	SV	10		CS										

Table 4-4 Potential Chemical-Specific Benchmarks, Statewide and Basin Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

					Statewide Standards (a)								Basin Standards (b)	
					Human Health Carcinogens/ Noncarcinogens (2) (8)		Aquatic Life (8)		Tables I,II,III (1)				Organics (7)	
									Aquatic Life					
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	Water Supply	Water and Fish	Acute Value	Chronic Value	Acute Value (2)	Chronic Value (2)	Agricul-tural Standard (3)	Domestic Water Supply (4)	Aquatic Life	Water Supply
Chlorophenol	SV		50										1.0	1.0
Chrysene	SV	10	10	CS		0.0028								
Dibenzofuran	SV	10		CS										
Dibenz(a,h)anthracene	SV	10	10	CS		0.0028								
Dichlorobenzenes	SV		1											
Dichlorobenzidine	SV	20	10	CS		0.039								
Diethylphthalate	SV	10	10	CS		23,000								
Dimethylphthalate	SV	10	10	CS		313,000								
Di-n-butylphthalate	SV	10	10	CS		2,700								
Di-n-octylphthalate	SV	10		CS										
Ethylene Glycol	SV			d										
Fluoranthene	SV	10	10	CS		42	3,980							
Fluorene	SV	10	10	CS		0.0028								
Formaldehyde	SV													
Haloethers	SV													
Hexachlorobenzene	SV	10	10	CS	6	0.00072								
Hexachlorobutadiene	SV	10	10	CS	1	0.45	90	9.3						
Hexachlorocyclopentadiene	SV	10	10	CS		240	7	5						
Hexachloroethane	SV	10	10	CS		1.9	980	540						
Hydrazine	SV													
Indeno(1,2,3-cd)pyrene	SV	10	10	CS		0.0028								
Isophorone	SV	10	10	CS	1,050	8.4	117,000							
Naphthalene	SV	10	10	CS		0.0028	2,300	620						
Nitrobenzene	SV	10	10	CS	3.5	3.5	27,000							
Nitrophenols	SV													
Nitrosamines	SV													
Nitrosodibutylamine	SV		10	b		0.0064								
Nitrosodiethylamine	SV		10	b		0.0008								
Nitrosodimethylamine	SV		10	b		0.00069								

Table 4-4 Potential Chemical-Specific Benchmarks, Statewide and Basin Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

							Statewide Standards (a)						Basin Standards (b)	
					Human Health Carcinogens/ Noncarcinogens (2) (8)		Aquatic Life (8)		Tables I,II,III (1)				Organics (7)	
									Aquatic Life					
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	Water Supply	Water and Fish	Acute Value	Chronic Value	Acute Value (2)	Chronic Value (2)	Agricul-tural Standard (3)	Domestic Water Supply (4)	Aquatic Life	Water Supply
Nitrosopyrrolidine	SV		10	b		0.016								
N-Nitrosodiphenylamine	SV	10	10	CSb		4.9								
N-Nitroso-di-n-dipropylamine	SV	10	10	CSb		0.005								
Pentachlorinated Ethanes	SV			b										
Pentachlorobenzene	SV		10	b	6 (8)									
Pentachlorophenol	SV	50	50	CS	200		9	5.7						
Phenanthrene	SV	10	10	CS		0.0028								
Phenol	SV	10	50	CS		21,000	10,200	2,560					500	1.0
Phthalate Esters	SV			e										
Polynuclear Aromatic Hydrocarbon	SV		10	b		0.0028								
Vinyl Chloride	SV	10	2	CV	2	2								
1,1,1-Trichloroethane	V	5	1	CV	200	200								
1,1,2,2-Tetrachloroethane	V	5	1	CV		0.17		2,400						
1,1,2-Trichloroethane	V	5	1	CV	3	0.6	9,400							
1,1-Dichloroethane	V	5		CV										
1,1-Dichloroethene	V	5	1	CV	7	0.057								
1,2-Dichloroethane	V	5	1	CV	0.4	0.4	118,000	20,000						
1,2-Dichloroethene (cis)	V		1	a	70									
1,2-Dichloroethene (total)	V	5		CV										
1,2-Dichloroethene (trans)	V	5	1	a	100									
1,2-Dichloropropane	V	5	1	CV	0.56 (8)	0.56	23,000	5,700						
1,3-Dichloropropene (cis)	V	5	1	CV		10	6,060	244						
1,3-Dichloropropene (trans)	V	5	1	CV		10	6,060	244						
2-Butanone	V	10		CV										
2-Hexanone	V	10		CV										
4-Methyl-2-pentanone	V	10		CV										
Acetone	V	10		CV										
Acrylonitrile	V		5	c		0.58	7,550	2,600						

Table 4-4 Potential Chemical-Specific Benchmarks, Statewide and Basin Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

					Statewide Standards (a)								Basin Standards (b)	
					Human Health Carcinogens/ Noncarcinogens (2) (8)		Aquatic Life (8)		Tables I,II,III (1) Aquatic Life				Organics (7)	
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	Water Supply	Water and Fish	Acute Value	Chronic Value	Acute Value (2)	Chronic Value (2)	Agricul-tural Standard (3)	Domestic Water Supply (4)	Aquatic Life	Water Supply
Benzene	V	5	1	CV	1	1	5,300							
Bromodichloromethane	V	5	1	CV	0.3	0.3								
Bromoform	V	5	1	CV	4	4								
Bromomethane	V	10	1	CV		48								
Carbon Disulfide	V	5		CV										
Carbon Tetrachloride	V	5	1	CV	0.3	0.25	35,200							
Chlorinated Benzenes	V	10		CV/CS										
Chlorobenzene	V	5	1	CV/CVS	100	100								
Chloroethane	V	10		CV										
Chloroform	V	5	1	CV	6	6	28,900	1,240						
Chloromethane	V	10	1	CV		5.7								
Dibromochloromethane	V	5	1	CV	14	6								
Dichloroethenes	V		1											
Ethyl Benzene	V	5	1	CV	680	3,100	32,000							
Ethylene Dibromide	V			d										
Ethylene Oxide	V													
Halomethanes	V				100									
Methylene Chloride	V	5	1	CV		4.7								
Pyrene	V	10	10	CS		0.0028								
Styrene	V	5		CV										
Tetrachloroethanes	V	5	1	CV										
Tetrachloroethene	V	5	1	CV	5	0.8	5,280	840						
Toluene	V	5	1	CV	1,000	1,000	17,500							
Trichloroethanes	V	5	1	CV										
Trichloroethene	V	5	1	CV	5	2.7	45,000	21,900						
Vinyl Acetate	V	10		CV										
Xylenes (Total)	V	5		CV										

Table 4-4 Potential Chemical-Specific Benchmarks, Statewide and Basin Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

							Statewide Standards (a)						Basin Standards (b)	
					Human Health Carcinogens/ Noncarcinogens (2) (8)		Aquatic Life (8)		Tables I,II,III (1) Aquatic Life				Organics (7)	
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	Water Supply	Water and Fish	Acute Value	Chronic Value	Acute Value (2)	Chronic Value (2)	Agricul-tural Standard (3)	Domestic Water Supply (4)	Aquatic Life	Water Supply

EXPLANATION OF TABLE

CLP = Contract Laboratory Program
CDH = Colorado Department of Health
dis = dissolved
EPA = Environmental Protection Agency
pCi/l = picocuries per liter
PCB = polychlorinated biphenyl
PQL = Practical Quantitation Level
SS = species specific
TAL = Target Analyte List
THM = Total Trihalomethanes
TIC = Tentatively Identified Compound
TVS = Table Value Standard (hardness dependent), see Table III in (a)
MDL = Minimum Detection Limit for radionuclides (pCi/l)
ug/l = micrograms per liter
VOA = Volatile Organic Analysis
CWQC = Colorado Water Quality Control Commission

(1) Table I = physical and biological parameters
Table II = inorganic parameters
Table III = metal parameters
Values in Tables I, II, and III for recreational uses, cold water biota and domestic water supply are not included.
(2) In the absence of specific, numeric standards for non-naturally occurring organics, the narrative standard is interpreted as zero with enforcement based on practical quantification levels (PQLs) as defined by CDH/WQCC or EPA
(3) All are 30-day standards except for nitrate+nitrite
(4) Ammonia, sulfide, chloride, sulfate, copper, iron, manganese, and zinc are 30-day standards, all others are 1-day standards
(5) type abbreviations are: A=anion; B=bacteria; C=cation; I=indicator; FP=field parameter; M=metal; P= pesticide; PP=pesticide/PCB; R=radionuclide; SV=semi-volatile; V=volatile

Table 4-4 Potential Chemical-Specific Benchmarks, Statewide and Basin Surface Water Quality Standards in Micrograms per Liter (February 1, 1992)

							Statewide Standards (a)						Basin Standards (b)	
					Human Health Carcinogens/ Noncarcinogens (2) (8)		Aquatic Life (8)		Tables I,II,III (1)				Organics (7)	
									Aquatic Life					
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	Water Supply	Water and Fish	Acute Value	Chronic Value	Acute Value (2)	Chronic Value (2)	Agricul-tural Standard (3)	Domestic Water Supply (4)	Aquatic Life	Water Supply

(6) method abbreviations are: CT=CLP-TAL; NC=non-CLP; CV=CLP-VOA; CS=CLP-SEMI; EP=EPA-PEST; CP=CLP-PEST; E=EPA; a = detected as total in CV; b = detected as TICs in CS; c = detected as TIC in CV; d = not routinely monitored; e = monitored in discharge ponds; f = mixture-individual isomers detected.

(7) See Section 3.8.5 (2)(a) in (b)

(8) Where standard is below (more stringent than) PQL (CDH), PQL is standard.

(9) MDL for Radium 226 is 0.5; MDL for Radium 228 is 1.0

(10) See section 3.1.11 (f) (2) in (a)

(a) CDH/CWQCC, Colorado Water Quality Standards 3.1.0 (5 CCR 1002-8) 1/15/1974; amended 10/17/1991 (ARAR). (Envrionmental Reporter 726:1001-1020:6/1990)

(b) CDH/CWQCC, Classifications and Numeric Standards for S. Platte River Basin, Laramie River Basin, Republican River Basin, Smoky Hill River Basin 3.8.0 (5 CCR 1002-8) 4/6/1981; amended 2/15/1990 - Basin-wide standards are ARAR.

Table 4-5 Potential Chemical-Specific Benchmarks, Stream Segment Surface Water Quality in Micrograms per Liter (February 1, 1992)

					Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)						
		PQL MDL			Tables A,B (1)	Table C Fish & Water Ingestion	Table D Radio-nuclide	Stream Segment Table (5)		Table 2 Radionuclides	
Parameter	Type (5)	RFP	CDH	Method (6)				Acute Value	Chronic Value	Woman Creek	Walnut Creek
Bicarbonate	A	10,000		E310.1							
Carbonate	A	10,000		E310.1							
Chloride	A	5,000		E325				250,000	250,000		
Chlorine	A	1,000		E4500				3	3		
Fluoride	A	5,000		E340							
N as Nitrate	A	5,000		E353.1				10,000	10,000		
N as Nitrate+Nitrite	A	5,000		E353.1							
N as Nitrite	A	5,000		E354.1				1,000	1,000		
Sulfate	A	5,000		E375.4				250,000	250,000		
Sulfide	A										
Coliform (Fecal)	B	1		SM9221C							
Ammonia as N	C	5,000		E350				620	60		
Dioxin	D			d	0.00000022	0.000000013			0.000000013		
Sulfur	E	100,000		E600				2.0	2.0		
Dissolved Oxygen	FP	500		SM4500				5,000	5,000		
pH	FP	0.1		E150.1				6.5-9	6.5-9		
Specific Conductance	FP	1		E120.1							
Temperature	FP										
Boron	I	5,000		E6010				750	750		
Total Dissolved Solids	I	10,000		E160.1							
Aluminum	M	200		CT							
Antimony	M	60		CT							
Arsenic	M	10		CT				50			
Arsenic III	M										
Arsenic V	M										
Barium	M	200		CT							

Table 4-5 Potential Chemical-Specific Benchmarks, Stream Segment Surface Water Quality in Micrograms per Liter (February 1, 1992)

					Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)						
								Stream Segment Table (5)		Table 2 Radionuclides	
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	Tables A,B (1)	Table C Fish & Water Ingestion	Table D Radio-nuclide	Acute Value	Chronic Value	Woman Creek	Walnut Creek
Beryllium	M	5		CT							
Cadmium	M	5		CT				TVS	TVS		
Calcium	M	5,000		CT							
Cesium	M	1,000		NC							
Chromium	M	10		CT							
Chromium III	M	5		SW8467196				50			
Chromium VI	M	10		E218.5				TVS	TVS		
Cobalt	M	50		CT							
Copper	M	25		CT				TVS	TVS		
Cyanide	M	10		CT				5	5		
Iron	M	100		CT					300 (3)		
Lead	M	5		CT				TVS	TVS		
Lithium	M	100		NC							
Magnesium	M	5000		CT							
Manganese	M	15		CT					50 (3)		
Mercury	M	0.2		CT					0.01		
Molybdenum	M	200		NC							
Nickel	M	40		CT				TVS	TVS		
Potassium	M	5000		CT							
Selenium	M	5		CT				10			
Silver	M	10		CT				TVS	TVS		
Sodium	M	5000		CT							
Strontium	M	200		NC							
Thallium	M	10		CT							
Tin	M	200		NC							
Titanium	M	10		E6010							
Tungsten	M	10		E6010							
Vanadium	M	50		CT							
Zinc	M	20		CT				TVS	TVS		

Table 4-5 Potential Chemical-Specific Benchmarks, Stream Segment Surface Water Quality in Micrograms per Liter (February 1, 1992)

					Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)						
		PQL MDL			Tables A,B (1)	Table C Fish & Water Ingestion	Table D Radio-nuclide	Stream Segment Table (5)		Table 2 Radionuclides	
Parameter	Type (5)	RFP	CDH	Method (6)				Acute Value	Chronic Value	Woman Creek	Walnut Creek
2,4,5-TP Silvex	P		0.5	d	10						
2,4-D	P		1	d	100						
Acrolein	P		10								
Aldicarb	P		10		10						
Aldrin	P	0.05	0.1	CP	0.002 (6)	0.000074			0.000074		
Bromacil	P										
Carbofuran	P			d	36						
Chloranil	P			E619							
Chlordane (Alpha)	P	0.5	1	CP	0.03 (6)	0.00046			0.00046		
Chlordane (Gamma)	P	0.5	1	CP	0.03 (6)	0.00046			0.00046		
Chlorpyrifos	P		0.1								
DDT	P	0.1	0.1	CP	0.1 (6)	0.000024			0.000024		
DDT Metabolite (DDD)	P	0.1	0.1	CP							
DDT Metabolite (DDE)	P	0.1	0.1	CP							
Demeton	P		1								
Diazinon	P										
Dieldrin	P	0.1	0.1	CP	0.002 (6)	0.000071			0.000071		
Endosulfan I	P	0.05	0.1	CP							
Endosulfan II	P	0.1	0.1	CP							
Endosulfan Sulfate	P	0.1	0.1	CP							
Endrin	P	0.1	0.1	CP	0.2						
Endrin Aldehyde	P		0.1								
Endrin Ketone	P	0.1		CP							
Guthion	P		1.5								
Heptachlor	P	0.05	0.05	CP	0.008 (6)	0.00028			0.00028		
Heptachlor Epoxide	P	0.05	0.05	CP	0.004 (6)						
Hexachlorocyclohexane, Alpha	P	0.05	0.05	CP		0.0092			0.0092		
Hexachlorocyclohexane, Beta	P	0.05	0.05	CP		0.0163			0.0163		

Table 4-5 Potential Chemical-Specific Benchmarks, Stream Segment Surface Water Quality in Micrograms per Liter (February 1, 1992)

					Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)						
		PQL MDL			Tables A,B	Table C Fish & Water	Table D Radio-	Stream Segment Table (5)		Table 2 Radionuclides	
Parameter	Type (5)	RFP	CDH	Method (6)	(1)	Ingestion	nuclide	Acute Value	Chronic Value	Woman Creek	Walnut Creek
Hexachlorocyclohexane, BHC	P	0.05	0.05								
Hexachlorocyclohexane, Delta	P	0.05		CP							
Hexachlorocyclohexane, Tech.	P		0.2	f		0.0123			0.0123		
Hexachlorocyclohexane, Lindane	P	0.05	0.05	CP	4	0.0186			0.0186		
Malathion	P		0.2								
Methoxychlor	P	0.5	0.5	CP	100						
Mirex	P		0.1								
Parathion	P										
PCBs	P	0.5	1	CP	0.005 (6)	0.000079			0.000079		
Simazine	P			e		4			4		
Toxaphene	P	1	5	CP	5						
Vaponite 2	P										
Aroclor 1016	PP	0.5		CP							
Aroclor 1221	PP	0.5		CP							
Aroclor 1232	PP	0.5		CP							
Aroclor 1242	PP	0.5		CP							
Aroclor 1248	PP	0.5		CP							
Aroclor 1254	PP	1		CP							
Aroclor 1260	PP	1		CP							
Atrazine	PP			e		3			3		
Americium (pCi/l)	R									0.05	0.05
Americium 241 (pCi/l)	R	0.01					30				
Cesium 134 (pCi/l)	R	1			80		80			80	80
Cesium 137 (pCi/l)	R	1									
Gross Alpha (pCi/l)	R	2								7	11
Gross Beta (pCi/l)	R	4								5	19
Plutonium (pCi/l)	R									0.05	0.05
Plutonium 238+239+240 (pCi/l)	R	0.01					15				

Table 4-5 Potential Chemical-Specific Benchmarks, Stream Segment Surface Water Quality in Micrograms per Liter (February 1, 1992)

					Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)						
		PQL MDL			Tables A,B (1)	Table C Fish & Water Ingestion	Table D Radio-nuclide	Stream Segment Table (5)		Table 2 Radionuclides	
Parameter	Type (5)	RFP	CDH	Method (6)				Acute Value	Chronic Value	Woman Creek	Walnut Creek
Radium 226+228 (pCi/l)	R	0.5/1.0 (7)					5				
Strontium 89+90 (pCi/l)	R	1									
Strontium 90 (pCi/l)	R						8			8	8
Thorium 230+232 (pCi/l)	R						60				
Tritium (pCi/l)	R						20,000			500	500
Uranium 233+234 (pCi/l)	R										
Uranium 235 (pCi/l)	R	0.6									
Uranium 238 (pCi/l)	R	0.6									
Uranium (Total) (pCi/l)	R						40			5	10
1,2,4,5-Tetrachlorobenzene	SV		10	b	2 (6)						
1,2,4-Trichlorobenzene	SV	10		CS							
1,2-Dichlorobenzene (Ortho)	SV	10	1	CS	620						
1,2-Diphenylhydrazine	SV			b	0.05 (6)						
1,3-Dichlorobenzene (Meta)	SV	10	1	CS	620						
1,4-Dichlorobenzene (Para)	SV	10	1	CS	75						
2,4,5-Trichlorophenol	SV	50		CS	700						
2,4,6-Trichlorophenol	SV	10	50	CS	2.0 (6)	1.2			1.2		
2,4-Dichlorophenol	SV	10	50	CS	21 (6)						
2,4-Dimethylphenol	SV	10	50	CS							
2,4-Dinitrophenol	SV	50	50	CS							
2,4-Dinitrotoluene	SV	10	10	CS							
2,6-Dinitrotoluene	SV	10	10	CS							
2-Chloronaphthalene	SV	10		CS							
2-Chlorophenol	SV	10	50	CS							
2-Methylnaphthalene	SV	10		CS							
2-Methylphenol	SV	10		CS							
2-Nitroaniline	SV	50		CS							
2-Nitrophenol	SV	10		CS							

Table 4-5 Potential Chemical-Specific Benchmarks, Stream Segment Surface Water Quality in Micrograms per Liter (February 1, 1992)

					Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)						
		PQL MDL			Tables A,B (1)	Table C Fish & Water Ingestion	Table D Radio-nuclide	Stream Segment Table (5)		Table 2 Radionuclides	
Parameter	Type (5)	RFP	CDH	Method (6)				Acute Value	Chronic Value	Woman Creek	Walnut Creek
3,3-Dichlorobenzidine	SV	20	10	CS		0.01			0.01		
3-Nitroaniline	SV	50		CS							
4,6-Dinitro-2-methylphenol	SV	50	50	CS							
4-Bromophenyl Phenylether	SV	10		CS							
4-Chloroaniline	SV	10		CS							
4-Chlorophenyl Phenyl Ether	SV	10		CS							
4-Chloro-3-methylphenol	SV	10	50	CS							
4-Methylphenol	SV	10		CS							
4-Nitroaniline	SV	50		CS							
4-Nitrophenol	SV	50		CS							
Acenaphthene	SV	10	10	CS							
Anthracene	SV	10	1	CS							
Benzidine	SV		10	d	0.0002 (6)	0.00012			0.00012		
Benzoic Acid	SV	50		CS							
Benzo(a)anthracene	SV	10	10	CS							
Benzo(a)pyrene	SV	10	10	CS							
Benzo(b)fluoranthene	SV	10	10	CS							
Benzo(g,h,i)perylene	SV	10	10	CS							
Benzo(k)fluoranthene	SV	10	10	CS							
Benzyl Alcohol	SV	10		CS							
bis(2-Chloroethoxy)methane	SV	10		CS							
bis(2-Chloroethyl)ether	SV	10	10	CS	0.03 (6)	0.0000037			0.0000037		
bis(2-Chloroisopropyl)ether	SV	10	10	CS							
bis(2-Ethylhexyl)phthalate	SV	10	10	CS							
Butadiene	SV										
Butyl Benzylphthalate	SV	10		CS							
Chlorinated Ethers	SV										
Chlorinated Napthalenes	SV										
Chloroalkylethers	SV	10		CS							

Table 4-5 Potential Chemical-Specific Benchmarks, Stream Segment Surface Water Quality in Micrograms per Liter (February 1, 1992)

					Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)						
		PQL MDL			Tables A,B (1)	Table C Fish & Water Ingestion	Table D Radio-nuclide	Stream Segment Table (5)		Table 2 Radionuclides	
Parameter	Type (5)	RFP	CDH	Method (6)				Acute Value	Chronic Value	Woman Creek	Walnut Creek
Chlorophenol	SV		50								
Chrysene	SV	10	10	CS							
Dibenzofuran	SV	10		CS							
Dibenz(a,h)anthracene	SV	10	10	CS							
Dichlorobenzenes	SV		1								
Dichlorobenzidine	SV	20	10	CS		0.01			0.01		
Diethylphthalate	SV	10	10	CS							
Dimethylphthalate	SV	10	10	CS							
Di-n-butylphthalate	SV	10	10	CS							
Di-n-octylphthalate	SV	10		CS							
Ethylene Glycol	SV			d							
Fluoranthene	SV	10	10	CS							
Fluorene	SV	10	10	CS							
Formaldehyde	SV										
Haloethers	SV										
Hexachlorobenzene	SV	10	10	CS	0.02 (6)	0.00072			0.00072		
Hexachlorobutadiene	SV	10	10	CS	14	0.45			0.45		
Hexachlorocyclopentadiene	SV	10	10	CS	49						
Hexachloroethane	SV	10	10	CS		1.9			1.9		
Hydrazine	SV										
Indeno(1,2,3-cd)pyrene	SV	10	10	CS							
Isophorone	SV	10	10	CS	1,050						
Naphthalene	SV	10	10	CS							
Nitrobenzene	SV	10	10	CS	3.5 (6)						
Nitrophenols	SV										
Nitrosamines	SV										
Nitrosodibutylamine	SV		10	b		0.0064			0.0064		
Nitrosodiethylamine	SV		10	b		0.0008			0.0008		
Nitrosodimethylamine	SV		10	b		0.0014			0.0014		

Table 4-5 Potential Chemical-Specific Benchmarks, Stream Segment Surface Water Quality in Micrograms per Liter (February 1, 1992)

					Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)						
		PQL MDL			Tables A,B (1)	Table C Fish & Water Ingestion	Table D Radio-nuclide	Stream Segment Table (5)		Table 2 Radionuclides	
Parameter	Type (5)	RFP	CDH	Method (6)				Acute Value	Chronic Value	Woman Creek	Walnut Creek
Nitrosopyrrolidine	SV		10	b		0.016			0.016		
N-Nitrosodiphenylamine	SV	10	10	CSb		4.9			4.9		
N-Nitroso-di-n-dipropylamine	SV	10	10	CSb							
Pentachlorinated Ethanes	SV			b							
Pentachlorobenzene	SV		10	b	6 (6)						
Pentachlorophenol	SV	50	50	CS	200						
Phenanthrene	SV	10	10	CS							
Phenol	SV	10	50	CS							
Phthalate Esters	SV			e							
Polynuclear Aromatic Hydrocarbons	SV		10	b		0.0028			0.0028		
Vinyl Chloride	SV	10	2	CV	2						
1,1,1-Trichloroethane	V	5	1	CV	200						
1,1,2,2-Tetrachloroethane	V	5	1	CV		0.17			0.17		
1,1,2-Trichloroethane	V	5	1	CV	28	0.60			0.60		
1,1-Dichloroethane	V	5		CV							
1,1-Dichloroethene	V	5	1	CV	7						
1,2-Dichloroethane	V	5	1	CV	5						
1,2-Dichloroethene (cis)	V		1	a	70						
1,2-Dichloroethene (total)	V	5		CV							
1,2-Dichloroethene (trans)	V	5	1	a	70						
1,2-Dichloropropane	V	5	1	CV	0.56 (6)						
1,3-Dichloropropene (cis)	V	5	1	CV							
1,3-Dichloropropene (trans)	V	5	1	CV							
2-Butanone	V	10		CV							
2-Hexanone	V	10		CV							
4-Methyl-2-pentanone	V	10		CV							
Acetone	V	10		CV							
Acrylonitrile	V		5	c		0.058			0.058		

Table 4-5 Potential Chemical-Specific Benchmarks, Stream Segment Surface Water Quality in Micrograms per Liter (February 1, 1992)

					Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)						
						Table C		Stream Segment Table (5)		Table 2 Radionuclides	
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	Tables A,B (1)	Fish & Water Ingestion	Table D Radio-nuclide	Acute Value	Chronic Value	Woman Creek	Walnut Creek
Benzene	V	5	1	CV	5						
Bromodichloromethane	V	5	1	CV							
Bromoform	V	5	1	CV							
Bromomethane	V	10	1	CV							
Carbon Disulfide	V	5		CV							
Carbon Tetrachloride	V	1		CV	5						
Chlorinated Benzenes	V	10		CV/CS							
Chlorobenzene	V	5	1	CV/CVS	300						
Chloroethane	V	10		CV							
Chloroform	V	5	1	CV	Tot THM <100*	0.19			0.19		
Chloromethane	V	10	1	CV							
Dibromochloromethane	V	5	1	CV							
Dichloroethenes	V		1								
Ethyl Benzene	V	5	1	CV	680						
Ethylene Dibromide	V			d							
Ethylene Oxide	V										
Halomethanes	V				100	0.19			0.19		
Methylene Chloride	V	5	1	CV							
Pyrene	V	10	10	CS							
Styrene	V	5		CV							
Tetrachloroethanes	V	5	1	CV		0.8			0.8		
Tetrachloroethene	V	5	1	CV	10						
Toluene	V	5	1	CV	2,420						
Trichloroethanes	V	5	1	CV							
Trichloroethene	V	5	1	CV	5						
Vinyl Acetate	V	10		CV							
Xylenes (Total)	V	5		CV							

Table 4-5 Potential Chemical-Specific Benchmarks, Stream Segment Surface Water Quality in Micrograms per Liter (February 1, 1992)

					Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)						
		PQL MDL				Table C Fish & Water Ingestion		Stream Segment Table (5)		Table 2 Radionuclides	
Parameter	Type (5)	RFP	CDH	Method (6)	Tables A,B (1)		Table D Radio-nuclide	Acute Value	Chronic Value	Woman Creek	Walnut Creek

EXPLANATION OF TABLE

*	= Total trihalomethanes:chloroform, bromoform, bromodichloromethane, dibromochloromethane
CLP	= Contract Laboratory Program
CDH	= Colorado Department of Health
dis	= dissolved
EPA	= Environmental Protection Agency
pCi/l	= picocuries per liter
PCB	= polychlorinated biphenyl
PQL	= Practical Quantitation Level
RFP	= Rocky Flats Plant
SS	= species specific
TAL	= Target Analyte List
THM	= Total Trihalomethanes
TIC	= Tentatively Identified Compound
TVS	= Table Value Standard (hardness dependent), see Table III in (a)
MDL	= Minimum Detection Limit for radionuclides (pCi/l)
ug/l	= micrograms per liter
VOA	= Volatile Organic Analysis
CWQCC	= Colorado Water Quality Control Commission

Table 4-5 Potential Chemical-Specific Benchmarks, Stream Segment Surface Water Quality in Micrograms per Liter (February 1, 1992)

					Segment 4 & 5 Stream Classification and Water Quality Standards (b)(4)						
						Table C		Stream Segment Table (5)		Table 2 Radionuclides	
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	Tables A,B (1)	Fish & Water Ingestion	Table D Radio-nuclide	Acute Value	Chronic Value	Woman Creek	Walnut Creek

(1) In the absence of specific, numeric standards for non-naturally occurring organics, the narrative standard is interpreted as zero with enforcement based on practical quantification levels (PQLs) as defined by CDH/CWQCC or EPA

(2) Ammonia, sulfide, chloride, sulfate, copper, iron, manganese, and zinc are 30-day standards, all others are 1-day standards

(3) Lowest value given: dissolved or total recoverable

(4) Segment 5 standards are goals

(5) Includes Table 1: Additional Organic Chemical Standards (chronic only)

(6) Standard is below (more stringent than) PQL, therefore PQL is standard.

(7) MDL for Radium 226 is 0.5; MDL for Radium 228 is 1.0

(a) CDH/CWQCC, Colorado Water Quality Standards 3.1.0 (5 CCR 1002-8) 1/15/1974; amended 9/30/1989. (Envrionmental Reporter 726:1001-1020:6/1990)

(b) CDH/CWQCC, Classifications and Numeric Standards for S. Platte River Basin, Laramie River Basin, Republican River Basin, Smoky Hill River Basin 3.8.0 (5 CCR 1002-8) 4/6/1981; amended 2/15/1990.

Table 4-6 Potential Chemical-Specific Benchmarks, Ground Water Quality Standards in Micrograms per Liter (February 1, 1992)

					FEDERAL STANDARDS					STATE STANDARDS							
										CDH CWQCC Groundwater Quality Standards (d)							
										Statewide	Site-Specific (g)						
		PQL MDL			SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	RCRA Subpart F Limit (c)	Table A (d) (7)	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6 Radionuclides	
Parameter	Type (5)	RFP	CDH	Method (6)												Woman Creek	Walnut Creek
Bicarbonate	A	10,000		E310.1													
Carbonate	A	10,000		E310.1													
Chloride	A	5,000		E325	250,000 *							250,000					
Chlorine	A	1,000		E4500													
Fluoride	A	5,000		E340	4,000; 2,000*		4,000				4,000		2,000				
N as Nitrate	A	5,000		E353.1	10,000			10,000			10,000						
N as Nitrate+Nitrite	A	5,000		E353.1		10,000		10,000					100,000				
N as Nitrite	A	5,000		E354.1		1,000		1,000			1,000		10,000				
Sulfate	A	5,000		E375.4	250,000*							250,000					
Sulfide	A																
Coliform (total)	B	1		SM9221C	1/100 ml						1/100 ml						
Ammonia as N	C	5,000		E350													
Dioxin	D		0.01(9)	d						0.00000022					0.000000013		
Sulfur	E	100,000		E600													
Dissolved Oxygen	FP	500		SM4500													
pH	FP	0.1		E150.1	6.5-8.5 *							6.5-8.5	6.5-8.5				
Specific Conductance	FP	1		E120.1													
Temperature	FP																
Boron	I	5,000		E6010									750				
Total Dissolved Solids	I	10,000		E160.1	500,000*									400,000 (1)			
Aluminum	M	200		CT		50 to 200*							5,000				
Antimony	M	60		CT													
Arsenic	M	10		CT	50				50		50		100				
Arsenic III	M																
Arsenic V	M																
Barium	M	200		CT	1,000	2,000 (e)		2,000 (e)	1,000		1,000						

Table 4-6 Potential Chemical-Specific Benchmarks, Ground Water Quality Standards in Micrograms per Liter (February 1, 1992)

					FEDERAL STANDARDS					STATE STANDARDS							
										CDH CWQCC Groundwater Quality Standards (d)							
										Statewide	Site-Specific (g)						
		PQL MDL			SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	RCRA Subpart F Limit (c)	Table A (d) (7)	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6 Radionuclides	
Parameter	Type (5)	RFP	CDH	Method (6)												Woman Creek	Walnut Creek
Beryllium	M	5		CT									100				
Cadmium	M	5		CT	10	5		5	10		10		10				
Calcium	M	5,000		CT													
Cesium	M	1,000		NC													
Chromium	M	10		CT	50	100		100	50		50		100				
Chromium III	M	5		SW8467196													
Chromium VI	M	10		E218.5													
Cobalt	M	50		CT									50				
Copper	M	25		CT	1,000 *			1,300 (f)				1,000	200				
Cyanide	M	10		CT							200						
Iron	M	100		CT	300 *							300	5,000				
Lead	M	5		CT	50			0 (f)	50		50		100				
Lithium	M	100		NC									2,500				
Magnesium	M	5000		CT													
Manganese	M	15		CT	50 *							50	200				
Mercury	M	0.2		CT	2	2		2	2		2		10				
Molybdenum	M	200		NC													
Nickel	M	40		CT									200				
Potassium	M	5000		CT													
Selenium	M	5		CT	10	50		50	10		10		20				
Silver	M	10		CT	50	100 *			50		50						
Sodium	M	5000		CT													
Strontium	M	200		NC													
Thallium	M	10		CT													
Tin	M	200		NC													
Titanium	M	10		E6010													
Tungsten	M	10		E6010													
Vanadium	M	50		CT									100				
Zinc	M	20		CT	5,000 *							5,000	2,000				

Table 4-6 Potential Chemical-Specific Benchmarks, Ground Water Quality Standards in Micrograms per Liter (February 1, 1992)

					FEDERAL STANDARDS					STATE STANDARDS							
										CDH CWQCC Groundwater Quality Standards (d)							
										Statewide	Site-Specific (g)						
		PQL MDL			SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	RCRA Subpart F Limit (c)	Table A (d) (7)	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6 Radionuclides	
Parameter	Type (5)	RFP	CDH	Method (6)												Woman Creek	Walnut Creek
2,4,5-TP Silvex	P		0.5	d	10	50		50	10	50							
2,4-Dichlorophenoxyacetic Acid	P		1	d	100	70		70	100	70							
(2,4-D)	P																
Acrolein	P		10														
Aldicarb	P		10			3 (e)		1 (e)		10							
Aldrin	P	0.05	0.1	CP						0.002					0.000074		
Bromacil	P																
Carbofuran	P			d		40		40		36							
Chloranil	P																
Chlordane (Alpha)	P	0.5	1	CP		2		0		0.03					0.00046		
Chlordane (Gamma)	P	0.5	1	CP		2		0		0.03					0.00046		
Chlorpyrifos	P			E619													
DDT	P	0.1	0.1	CP						0.1					0.000024		
DDT Metabolite (DDD)	P	0.1		CP													
DDT Metabolite (DDE)	P	0.1	0.1	CP						0.1							
Demeton	P																
Diazinon	P																
Dieldrin	P	0.1	0.1	CP						0.002					0.000071		
Endosulfan I	P	0.05		CP													
Endosulfan II	P	0.1		CP													
Endosulfan sulfate	P	0.1		CP													
Endrin	P	0.1	0.1	CP	0.2				0.2	0.2							
Endrin Aldehyde	P		0.1							0.2							
Endrin Ketone	P	0.1		CP													
Guthion	P																
Heptachlor	P	0.05	0.05	CP		0.4		0		0.008					0.00028		
Heptachlor Epoxide	P	0.05	0.05	CP		0.2		0		0.09							
Hexachlorocyclohexane, Alpha	P	0.05	0.05	CP						0.006					0.0092		

Table 4-6 Potential Chemical-Specific Benchmarks, Ground Water Quality Standards in Micrograms per Liter (February 1, 1992)

					FEDERAL STANDARDS					STATE STANDARDS							
										CDH CWQCC Groundwater Quality Standards (d)							
										Statewide	Site-Specific (g)						
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	RCRA Subpart F Limit (c)	Table A (d) (7)	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6 Radionuclides Woman Creek	Table 6 Radionuclides Walnut Creek
Hexachlorocyclohexane, Beta	P	0.05	0.1(9)	CP											0.0163		
Hexachlorocyclohexane, BHC	P		0.05														
Hexachlorocyclohexane, Delta	P	0.05		CP											0.0123		
Hexachlorocyclohexane, Tech	P		0.5(9)	f											0.0186		
Hexachlorocyclohexane, Lindane	P	0.05	0.05	CP	4	0.2		0.2	4.0	0.2							
Malathion	P																
Methoxychlor	P	0.5	0.5	CP	100	40		40	100	40	100						
Mirex	P																
Parathion	P																
PCBs	P	0.5	1	CP		0.5		0		0.005					0.000079		
Simazine	P			e											4		
Toxaphene	P	1	5	CP		3		0	5.0	0.03	5						
Vaponite 2	P																
Aroclor 1016	PP	0.5		CP													
Aroclor 1221	PP	0.5		CP													
Aroclor 1232	PP	0.5		CP													
Aroclor 1242	PP	0.5		CP													
Aroclor 1248	PP	0.5		CP													
Aroclor 1254	PP	1		CP													
Aroclor 1260	PP	1		CP													
Atrazine	PP		1 (9)	e		3		3							3		
Americium (pCi/l)	R															0.05	0.05
Americium 241 (pCi/l)	R	0.01								80 (2)						80	80
Cesium 134 (pCi/l)	R	1															
Cesium 137 (pCi/l)	R	1															
Gross Alpha (pCi/l)	R	2			15 (8)						15(8)					7	11
Gross Beta (pCi/l)	R	4			50 (4 mrem/yr)						4 mrem/yr					5	19
Plutonium (pCi/l)	R															0.05	0.05

Table 4-6 Potential Chemical-Specific Benchmarks, Ground Water Quality Standards in Micrograms per Liter (February 1, 1992)

					FEDERAL STANDARDS					STATE STANDARDS							
										CDH CWQCC Groundwater Quality Standards (d)							
										Statewide	Site-Specific (g)						
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	RCRA Subpart F Limit (c)	Table A (d) (7)	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6 Radionuclides Woman Creek	Table 6 Radionuclides Walnut Creek
Plutonium 238+239+240 (pCi/l)	R	0.01								15 (2)							
Radium 226+228 (pCi/l)	R	0.5/1.0 (4)			5					5 (2)							
Strontium 89+90 (pCi/l)	R	1															
Strontium 90 (pCi/l)	R				8 (3)					8 (2)						8	8
Thorium 230+232 (pCi/l)	R									60 (2)							
Tritium (pCi/l)	R				20,000 (3)					20,000 (2)						500	500
Uranium 233+234 (pCi/l)	R																
Uranium 235 (pCi/l)	R	0.6															
Uranium 238 (pCi/l)	R	0.6															
Uranium (Total) (pCi/l)	R															5	10
1,2,4,5-Tetrachlorobenzene	SV		10	b						2							
1,2,4-Trichlorobenzene	SV	10		CS													
1,2-Dichlorobenzene (Ortho)	SV	10	1	CS		600		600		620							
1,2-Diphenylhydrazine	SV			b						0.05							
1,3-Dichlorobenzene (Meta)	SV	10	1	CS						620							
1,4-Dichlorobenzene (Para)	SV	10	1	CS	75		75			75							
2,4,5-Trichlorophenol	SV	50		CS						700							
2,4,6-Trichlorophenol	SV	10	50	CS						2					1.2		
2,4-Dichlorophenol	SV	10	50	CS						21							
2,4-Dimethylphenol	SV	10		CS													
2,4-Dinitrophenol	SV	50	50	CS						14							
2,4-Dinitrotoluene	SV	10		CS													
2,6-Dinitrotoluene	SV	10		CS													
2-Chloronaphthalene	SV	10		CS													
2-Chlorophenol	SV	10		CS													
2-Methylnaphthalene	SV	10		CS													
2-Methylphenol	SV	10		CS													
2-Nitroaniline	SV	50		CS													

Table 4-6 Potential Chemical-Specific Benchmarks, Ground Water Quality Standards in Micrograms per Liter (February 1, 1992)

					FEDERAL STANDARDS					STATE STANDARDS							
										CDH CWQCC Groundwater Quality Standards (d)							
										Statewide	Site-Specific (g)						
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	RCRA Subpart F Limit (c)	Table A (d) (7)	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6 Radionuclides Woman Creek	Table 6 Radionuclides Walnut Creek
2-Nitrophenol	SV	10		CS													
3,3-Dichlorobenzidine	SV	20		CS													
3-Nitroaniline	SV	50		CS													
4,6-Dinitro-2-methylphenol	SV	50		CS													
4-Bromophenyl Phenylether	SV	10		CS													
4-Chloroaniline	SV	10		CS													
4-Chlorophenyl Phenyl Ether	SV	10		CS													
4-Chloro-3-methylphenol	SV	10		CS													
4-Methylphenol	SV	10		CS													
4-Nitroaniline	SV	50		CS													
4-Nitrophenol	SV	50		CS													
Acenaphthene	SV	10		CS													
Anthracene	SV	10		CS													
Benzidine	SV		10	d						0.0002	0.1				0.00012		
Benzoic Acid	SV	50		CS													
Benzo(a)anthracene	SV	10		CS													
Benzo(a)pyrene	SV	10		CS													
Benzo(b)fluoranthene	SV	10		CS													
Benzo(g,h,i)perylene	SV	10		CS													
Benzo(k)fluoranthene	SV	10		CS													
Benzyl Alcohol	SV	10		CS													
bis(2-Chloroethoxy)methane	SV	10		CS													
bis(2-Chloroethyl)ether	SV	10		CS						0.03					0.0000037		
bis(2-Chloroisopropyl)ether	SV	10		CS													
bis(2-Ethylhexyl)phthalate	SV	10		CS													
Butadiene	SV																
Butylbenzylphthalate	SV	10		CS													
Chlorinated Ethers	SV																
Chlorinated Napthalenes	SV																

Table 4-6 Potential Chemical-Specific Benchmarks, Ground Water Quality Standards in Micrograms per Liter (February 1, 1992)

					FEDERAL STANDARDS					STATE STANDARDS							
										CDH CWQCC Groundwater Quality Standards (d)							
										Statewide	Site-Specific (g)						
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	RCRA Subpart F Limit (c)	Table A (d) (7)	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6 Radionuclides Woman Creek	Table 6 Radionuclides Walnut Creek
Chloroalkylethers	SV	10		CS													
Chlorophenol	SV										1						
Chrysene	SV	10		CS													
Dibenzofuran	SV	10		CS													
Dibenz(a,h)anthracene	SV	10		CS													
Dichlorobenzenes	SV																
Dichlorobenzidine	SV	20	10(9)	CS											0.01		
Diethylphthalate	SV	10		CS													
Dimethylphthalate	SV	10		CS													
Di-n-butylphthalate	SV	10		CS													
Di-n-octylphthalate	SV	10		CS													
Ethylene Glycol	SV			d						7,000							
Fluoranthene	SV	10		CS													
Fluorene	SV	10		CS													
Formaldehyde	SV																
Haloethers	SV																
Hexachlorobenzene	SV	10	10	CS						6					0.00072		
Hexachlorobutadiene	SV	10	10	CS						1					0.45		
Hexachlorocyclopentadiene	SV	10		CS						49							
Hexachloroethane	SV	10		CS											1.9		
Hydrazine	SV																
Indeno(1,2,3-cd)pyrene	SV	10		CS													
Isophorone	SV	10	10	CS						1,050							
Naphthalene	SV	10		CS													
Nitrobenzene	SV	10	10	CS						3.5							
Nitrophenols	SV																
Nitrosamines	SV		10														
Nitrosodibutylamine	SV			b											0.0064		
Nitrosodiethylamine	SV		10	b											0.0008		

Table 4-6 Potential Chemical-Specific Benchmarks, Ground Water Quality Standards in Micrograms per Liter (February 1, 1992)

					FEDERAL STANDARDS					STATE STANDARDS							
										CDH CWQCC Groundwater Quality Standards (d)							
										Statewide	Site-Specific (g)						
		PQL MDL			SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	RCRA Subpart F Limit (c)	Table A (d) (7)	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6 Radionuclides	
Parameter	Type (5)	RFP	CDH	Method (6)												Woman Creek	Walnut Creek
Nitrosodimethylamine	SV		10	b											0.0014		
Nitrosopyrrolidine	SV		10	b											0.016		
N-Nitrosodiphenylamine	SV	10	10(9)	CSb											4.9		
N-Nitroso-di-n-dipropylamine	SV	10		CSb													
Pentachlorinated Ethanes	SV			b													
Pentachlorobenzene	SV		10	b						6 (7)							
Pentachlorophenol	SV	50	50	CS		1 (e)		0 (e)		200							
Phenanthrene	SV	10		CS													
Phenol	SV	10		CS							1						
Phthalate Esters	SV																
Polynuclear Aromatic Hydrocarb	SV		1 (9)	b											0.0028		
Vinyl Chloride	SV	10	2	CV	2		0			2							
1,1,1-Trichloroethane	V	5	1	CV	200		200			200							
1,1,2,2-Tetrachloroethane	V	5	1 (9)	CV											0.17		
1,1,2-Trichloroethane	V	5	1	CV						3					0.6		
1,1-Dichloroethane	V	5		CV													
1,1-Dichloroethene	V	5	1	CV	7		7			7							
1,2-Dichloroethane	V	5	1	CV	5		0			0.4							
1,2-Dichloroethene (cis)	V		1	a		70		70		70							
1,2-Dichloroethene (total)	V	5		CV													
1,2-Dichloroethene (trans)	V		1	a		100		100		100							
1,2-Dichloropropane	V	5	1	CV		5		0		0.56							
1,3-Dichloropropene (cis)	V	5		CV													
1,3-Dichloropropene (trans)	V	5		CV													
2-Butanone	V	10		CV													
2-Hexanone	V	10		CV													
4-Methyl-2-pentanone	V	10		CV													
Acetone	V	10		CV													

Table 4-6 Potential Chemical-Specific Benchmarks, Ground Water Quality Standards in Micrograms per Liter (February 1, 1992)

					FEDERAL STANDARDS					STATE STANDARDS							
										CDH CWQCC Groundwater Quality Standards (d)							
		PQL MDL								Statewide	Site-Specific (g)						
Parameter	Type (5)	RFP	CDH	Method (6)	SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	RCRA Subpart F Limit (c)	Table A (d) (7)	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6 Radionuclides Woman Creek	Table 6 Radionuclides Walnut Creek
Acrylonitrile	V		15(9)	c											0.058		
Benzene	V	5	1	CV	5		0			1							
Bromodichloromethane	V	5	1	CV						0.3							
Bromoform	V	5	1	CV						4							
Bromomethane	V	10		CV													
Carbon Disulfide	V	5		CV													
Carbon Tetrachloride	V	5	1	CV	5		0			0.3							
Chlorinated Benzenes	V	10		CV/CS													
Chlorobenzene	V	5	1	CV/CS		100		100		100							
Chloroethane	V	10		CV													
Chloroform	V	5	1	CV	Tot THM <100**					6					0.19		
Chloromethane	V	10		CV													
Dibromochloromethane	V	5	1	CV						14							
Dichloroethenes	V																
Ethyl Benzene	V	5	1	CV		700		700		680							
Ethylene Dibromide	V			d		0.05		0		0.0004							
Ethylene Oxide	V																
Halomethanes	V		1 (9)		100					100					0.19		
Methylene Chloride	V	5		CV													
Pyrene	V	10		CS													
Styrene	V	5		CV		100		100									
Tetrachloroethanes	V	5		CV													
Tetrachloroethene	V	5	1	CV		5		0		5					0.8		
Toluene	V	5	1	CV		1,000		1,000		1,000							
Trichloroethanes	V	5		CV													
Trichloroethene	V	5	1	CV	5		0			5							
Vinyl Acetate	V	10		CV													
Xylenes (total)	V	5		CV		10,000		10,000									

Table 4-6 Potential Chemical-Specific Benchmarks, Ground Water Quality Standards in Micrograms per Liter (February 1, 1992)

					FEDERAL STANDARDS					STATE STANDARDS							
										CDH CWQCC Groundwater Quality Standards (d)							
										Statewide	Site-Specific (g)						
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	RCRA Subpart F Limit (c)	Table A (d) (7)	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6 Radionuclides Woman Creek	Table 6 Radionuclides Walnut Creek

EXPLANATION OF TABLE

* = secondary maximum contaminant level

** = total trihalomethanes: chloroform, bromoform, bromodichloromethane, dibromochloromethane

CDH = Colorado Department of Health
CLP = Contract Laboratory Program
EPA = Environmental Protection Agency
pCi/l = picocuries per liter
PCB = polychlorinated biphenyl
PQL = Practical Quantitation Limit
RCRA = Resource Conservation and Recovery Act
RFP = Rocky Flats Plant
SDWA = Safe Drinking Water Act
TAL = Target Analyte List
THM = Total Trihalomethanes
TIC = Tentatively Identified Compound
MDL = Minimum Detection Limit for radionuclides (pCi/l)
ug/l = micrograms per liter
VOA = Volatile Organic Analysis
CWQC = Colorado Water Quality Control Commission

(1) TDS standard - see Table 4 in (d); standard is 400 mg/l or 1.25 times the background level, whichever is least restrictive
(2) radionuclide standards - see sec. 3.11.5(c)2 in (d)
(3) If both strontium-90 and tritium are present, the sum of their annual dose equivalents to bone marrow shall not exceed 4 mrem/yr.
(4) MDL for Radium 226 is 0.5; MDL for radium 228 is 1
(5) type abbreviations are: A=anion; B=bacteria; C=cation; D=dioxin; E=element; FP=field parameter; I=indicator; M=metal; P=pesticide; PP=pesticide/PCB; R=radionuclide; SV=semi-volatile; V=volatile
(6) method abbreviations are: CT=CLP-TAL; NC=non-CLP; CV=CLP-VOA; CS=CLP-SEMI; EP=EPA-PEST; CP=CLP-PEST; E=EPA; a = detected as total in CV; b = detected as TICs in CS; c = detected as TIC in CV;

Table 4-6 Potential Chemical-Specific Benchmarks, Ground Water Quality Standards in Micrograms per Liter (February 1, 1992)

					FEDERAL STANDARDS					STATE STANDARDS							
										CDH CWQCC Groundwater Quality Standards (d)							
										Statewide	Site-Specific (g)						
Parameter	Type (5)	PQL MDL RFP	PQL MDL CDH	Method (6)	SDWA Maximum Contaminant Level (a)	SDWA Maximum Contaminant Level (b)	SDWA Maximum Contaminant Level Goals (a)	SDWA Maximum Contaminant Level Goals (b)	RCRA Subpart F Limit (c)	Table A (d) (7)	Table 1 Human Health	Table 2 Secondary Drinking	Table 3 Agriculture	Table 4 TDS	Table 5 Chronic	Table 6 Radionuclides Woman Creek	Table 6 Radionuclides Walnut Creek

d = not routinely monitored; e = monitored in discharge ponds; f = mixture-individual isomers detected.

(7) Where standard is below (more stringent than) PQL (CDH), PQL is standard.

(8) Value for gross alpha excludes uranium.

(9) Value is CDH detection level (PQL not available)

(a) EPA National Primary and Secondary Drinking Water Regulations, 40 CFR 141 and 40 CFR 143 (as of 5/1990)

(b) EPA National Primary and Secondary Drinking Water Regulations, 40 CFR Parts 141, 142, 143, Final Rule, Effective July 30, 1992 (56 Federal Register 3526; 1/30/1991)

(c) NCP, 40 CFR 300; NCP Preamble 55 FR 8764; CERCLA Compliance with Other Laws Manual, EPA/540/G-89/006, August 1988, 40 CFR 264.94.

(d) CDH/Colorado Water Quality Control Commission, The Basic Standards for Ground Water, 3.11.0 (5 CCR 1002-8) 1/5/1987 amended 11/30/1991; statewide radioactive standards listed in 3.11.5(c)(2).

(e) EPA National Primary and Secondary Drinking Water Regulations, 40 CFR Parts 141, 142, 143, Final Rule, Effective January 1, 1993 (56 FR 30266; 7/1/1991)

(f) EPA Maximum Contaminant Level Goals and National Primary Drinking Water Regulations for Lead and Copper, 40 CFR 141 and 142 (56 FR 26460; 6/7/91) effective 12/7/92.

(g) CDH/Colorado Water Quality Control Commission, Classifications and Water Quality Standards for Ground Water, 3.12.0 (9/19/1991).

Table 4-7 Analytes Detected in Subsurface Soils at IHSS 102

Analyte	Background Concentration(1)	Sample Size	Number of Detections(2)	Concentration Range	Concentration Mean
Volatile Organic Compounds (µg/kg)					
Acetone	NA	33	2	1-4	2.5
2-Butanone	NA	33	2	2-7	4.5
Methylene chloride	NA	33	4	1-54	17.75
Toluene	NA	33	31	3-200	58.61
Trichloroethene	NA	33	1	3	3
Semivolatile Organic Compounds (µg/kg)					
1,3-Dichlorobenzene	NA	25	2	110-180	145
4-Nitrophenol	NA	25	1	95	95
Bis(2-ethyhexyl)phthalate	NA	25	1	480	480
Benzo(a)pyrene	NA	25	1	3	3
Benzoic acid	NA	25	1	110	110
Chrysene	NA	25	1	6	6
Di-n-butyl phthalate	NA	25	4	21-230	105
Naphthalene	NA	25	1	390	390
Pentachlorophenol	NA	25	1	120	120
Phenanthrene	NA	25	1	110	110
Pyrene	NA	25	1	100	100
Metals (mg/kg)					
Antimony	9.320	25	2	9.8-14.6	12.2
Radionuclides (pCi/g)					
Americium-241	0.010	25	2	0.019-0.0242	0.0216
Plutonium-239,240	0.020	25	4	0.023-0.0294	0.0255
Radium-228	2.260	25	2	2.384-2.722	2.553
Tritium	411.450	25	1	420	420

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Table 4-8 Analytes Detected in Subsurface Soils at IHSS 103

Analyte	Background Concentration[1]	Sample Size	Number of Detections[2]	Concentration Range	Concentration Mean
Volatile Organic Compounds (µg/kg)					
Acetone	NA	17	1	44	44
2-Butanone	NA	17	1	5	5
Methylene chloride	NA	17	2	1	1
Tetrachloroethene	NA	17	1	12	12
Toluene	NA	17	17	7-390	86.24
Trichloroethene	NA	17	1	12	12
Semivolatile Organic Compounds (µg/kg)					
AROCLOR-1254	NA	10	1	480	480
Benzo(a)anthracene	NA	10	1	130	130
Benzo(k)fluoranthene	NA	10	1	110	110
Chrysene	NA	10	1	180	180
Di-n-butyl phthalate	NA	10	5	160-410	262
Fluoranthene	NA	10	3	87-440	215.67
Phenanthrene	NA	10	3	91-380	207
Pyrene	NA	10	2	120-380	250
Metals (mg/kg)					
Barium	438.140	10	1	595	595
Copper	32.270	10	1	32.6	32.6
Strontium	131.130	10	2	134-136	135
Radionuclides (pCi/g)					
Americium-241	0.010	10	3	0.01888-0.0681	0.03661
Cesium-137	0.080	10	1	0.08413	0.0848
Plutonium-239,240	0.020	10	2	0.0262-0.3406	0.1834
Radium-228	2.260	10	2	2.35-2.576	2.463

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Table 4-9 Analytes Detected in Subsurface Soils at IHSS 104

Analyte	Background Concentration[1]	Sample Size	Number of Detections[2]	Concentration Range	Concentration Mean
Volatile Organic Compounds (µg/kg)					
Methylene chloride	NA	6	1	1	1
Toluene	NA	10	5	7-150	48.2
Semivolatile Organic Compounds (µg/kg)					
2,4-Dimethylphenol	NA	2	1	89	89
2-Methylnaphthalene	NA	2	1	1,200	1,200
4-Methylphenol	NA	2	1	140	140
Acenaphthene	NA	2	1	3,600	3,600
Anthracene	NA	2	1	4,800	4,800
Benzo(a)anthracene	NA	2	1	7,300	7,300
Benzo(a)pyrene	NA	2	1	6,000	6,000
Benzo(b)fluoranthene	NA	2	1	5,200	5,200
Benzo(g,h,i)perylene	NA	2	1	3,700	3,700
Benzo(k)fluoranthene	NA	2	1	6,100	6,100
Benzoic acid	NA	2	1	230	230
Chrysene	NA	2	1	7,100	7,100
Di-n-butyl phthalate	NA	2	1	410	410
Dibenzo(a,h)anthracene	NA	2	1	1,700	1,700
Dibenzofuran	NA	2	1	1,700	1,700
Fluoranthene	NA	2	1	15,000	15,000
Fluorene	NA	2	1	3,100	3,100
Naphthalene	NA	2	1	4,500	4,500
Indeno(1,2,3-c,d)pyrene	NA	2	1	3,800	3,800
Phenanthrene	NA	2	1	16,000	16,000
Pyrene	NA	2	1	14,000	14,000
Metals (mg/kg)					
Strontium	131.130	2	1	204	204
Radionuclides (pCi/g)					
Cesium-137	0.080	2	1	0.1507	0.1507
Plutonium-239,240	0.020	2	2	0.03298-0.0526	0.04279

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Table 4-10 Analytes Detected in Subsurface Soils at IHSS 119.1

Analyte	Background Concentration(1)	Sample Size	Number of Detections(2)	Concentration Range	Concentration Mean
Volatile Organic Compounds (µg/kg)					
1,1,1-Trichloroethane	NA	121	2	5	5
1,1-Dichloroethene	NA	121	3	2-12	8.67
2-Butanone	NA	121	2	2-12	7
Acetone	NA	121	6	3-10	5.83
Bromomethane	NA	121	1	2	2
Carbon tetrachloride	NA	121	1	18	18
Methylene chloride	NA	121	9	1-14	6.44
Tetrachloroethene	NA	121	4	1-47	24.25
Toluene	NA	121	45	11-540	82.67
Trichloroethene	NA	121	6	1-140	49.17
Semivolatile Organic Compounds (µg/kg)					
Anthracene	NA	17	1	150	150
Bis(2-ethylhexyl)phthalate	NA	17	1	180	180
Fluoranthene	NA	17	1	160	160
Phenanthrene	NA	17	1	160	160
Pyrene	NA	17	2	110-160	135
Metals (mg/kg)					
Barium	438.140	17	1	736	736
Cobalt	14.360	17	1	22.4	22.4
Copper	32.270	17	2	32.6-34.4	33.5
Tin	259.150	17	1	392	392
Radionuclides (pCi/g)					
Americium-241	0.010	17	7	0.020-0.172	0.0493
Cesium-137	0.080	17	2	0.198-0.219	0.2085
Plutonium-239,-240	0.020	17	8	0.020-1.117	0.236
Radium-228	2.260	17	4	2.319-2.784	2.522
Uranium-233,-234	1.750	17	1	2.109	2.109
Uranium-238	1.680	17	1	1.846	1.846

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Table 4-11 Analytes Detected in Subsurface Soils at IHSS 119.2

Analyte	Background Concentration(1)	Sample Size	Number of Detections(2)	Concentration Range	Concentration Mean
Volatile Organic Compounds (µg/kg)					
Acetone	NA	22	5	8-15	10.4
Methylene chloride	NA	22	4	2-3	2-3
Toluene	NA	22	22	10-480	10-480
Semivolatile Organic Compounds (µg/kg)					
Acenaphthene	NA	12	1	63	63
Anthracene	NA	12	1	91	91
AROCLOR-1248	NA	12	1	7,200	7,200
AROCLOR-1254	NA	12	1	5,200	5,200
Benzo(a)anthracene	NA	12	1	250	250
Benzo(a)pyrene	NA	12	1	220	220
Benzo(b)fluoranthene	NA	12	1	230	230
Bis(2-ethylhexyl)phthalate	NA	12	3	53-4,500	2,017.67
Chrysene	NA	12	1	300	300
Di-n-butyl phthalate	NA	12	1	80	80
Fluoranthene	NA	12	2	270-540	405
Phenanthrene	NA	12	1	510	510
Pyrene	NA	12	1	760	760
Metals (mg/kg)					
Barium	438.140	12	1	550	550
Cadmium	1.080	12	3	3.3-3.6	3.47
Cobalt	14.360	12	1	21.8	21.8
Copper	32.270	12	1	32.7	32.7
Lead	30.030	12	1	42.2	42.2
Zinc	141.740	12	1	148	148
Radionuclides (pCi/g)					
Americium-241	0.010	12	2	0.058-0.062	0.06
Plutonium-239,-240	0.020	12	9	0.024-3.167	0.6252

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Table 4-12 Analytes Detected in Subsurface Soils at IHSS 130

Analyte	Background Concentration(1)	Sample Size	Number of Detections(2)	Concentration Range	Concentration Mean
Volatile Organic Compounds (µg/kg)					
Acetone	NA	43	12	2-21	7.83
Methylene chloride	NA	43	16	1-57	22.06
Toluene	NA	43	33	16-1200	184.27
Semivolatile Organic Compounds (µg/kg)					
Acenaphthene	NA	9	2	93-250	171.5
Anthracene	NA	9	2	130-260	195
Benzo(a)anthracene	NA	9	2	170-530	360
Benzo(a)pyrene	NA	9	1	480	480
Benzo(b)fluoranthene	NA	9	1	390	390
Benzo(g,h,i)perylene	NA	9	1	180	180
Benzo(k)fluoranthene	NA	9	1	460	460
Benzoic acid	NA	9	1	840	840
Chrysene	NA	9	2	180-560	370
Dibenzofuran	NA	9	1	110	110
Di-n-butyl phthalate	NA	9	1	110	110
Fluoranthene	NA	9	3	160-1600	746.67
Fluorene	NA	9	1	190	190
Indeno(1,2,3-c,d)pyrene	NA	9	1	170	170
Naphthalene	NA	9	1	91	91
Pentachlorophenol	NA	9	2	250-390	320
Phenanthrene	NA	9	2	570-1,500	1,035
Pyrene	NA	9	3	160-1,400	653
Radionuclides (pCi/g)					
Americium-241	0.010	17	13	0.013-3.195	0.425
Cesium-137	0.080	17	1	0.09892	0.09892
Plutonium-239,-240	0.020	17	4	0.04796-31.61	7.996
Radium-228	2.260	17	3	2.387-2.559	2.478
Metals (mg/kg)					
Barium	438.140	17	1	719	719
Cobalt	14.360	17	2	22.6-36.5	29.55
Strontium	131.130	17	1	172	172

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Table 4-13 Analytes Detected in Subsurface Soils in the Vicinity of Building 881

Analyte	Background Concentration(1)	Sample Size	Number of Detections(2)	Concentration Range	Concentration Mean
Volatile Organic Compounds (µg/kg)					
2-Butanone	NA	39	1	14	14
Acetone	NA	39	7	6-47	16.29
Methylene chloride	NA	39	19	2-51	13
Tetrachloroethene	NA	39	2	1-4	2.5
Toluene	NA	39	36	4-490	96.75
Semivolatile Organic Compounds (µg/kg)					
1,4-Dichlorobenzene	NA	20	1	78	78
2,4-Dinitrotoluene	NA	20	1	73	73
4-Chloro-3-methylphenol	NA	20	1	72	72
4-Nitrophenol	NA	20	1	180	180
Bis(2-ethyhexyl)phthalate	NA	20	3	9-94	40
Di-n-butyl phthalate	NA	20	5	140.160-250	182.03
Diethyl phthalate	NA	20	1	520	520
Pyrene	NA	20	1	150	150
Metals (mg/kg)					
Arsenic	12.140	20	1	14.7	14.7
Barium	438.140	20	1	690	690
Cadmium	1.080	20	2	1.5	1.5
Copper	32.270	20	1	64.1	64.1
Selenium	1.240	20	2	1.30-619	310.15
Radionuclides (pCi/g)					
Americium-241	0.010	20	4	0.014-0.265	0.0813
Plutonium-239,-240	0.020	20	5	0.021-0.052	0.030
Uranium-233,234	1.750	20	2	2.26-2.51	2.39

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Table 4-14 Analytes Detected in Subsurface Soils at the Former Retention Pond

Analyte	Background Concentration(1)	Sample Size	Number of Detections(2)	Concentration Range	Concentration Mean
Volatile Organic Compounds (µg/kg)					
Methylene chloride	NA	16	7	2-14	4.71
Toluene	NA	16	16	12-410	76.69
Semivolatile Organic Compounds (µg/kg)					
Bis(2-ethyhexyl)phthalate	NA	12	1	290	290
Di-n-butyl phthalate	NA	12	3	440-630	526.67
Fluoranthene	NA	12	1	300	300
Phenanthrene	NA	12	1	280	280
Pyrene	NA	12	1	260	260
Metals (mg/kg)					
Antimony	9.320	12	3	14.1-15.1	14.67
Radionuclides (pCi/g)					
Plutonium-239,-240	0.020	12	1	0.033	0.033

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Table 4-15 Analytes Detected in Subsurface Soils in OU1 Nonsource Areas

Analyte	Background Concentration(1)	Sample Size	Number of Detections(2)	Concentration Range	Concentration Mean
Volatile Organic Compounds (µg/kg)					
2-Butanone	NA	30	2	1-3	2
4-Methyl-2-pentanone	NA	30	1	2	2
Acetone	NA	30	2	13-29	21
Methylene chloride	NA	30	6	1-13	5.33
Toluene	NA	30	29	6-210	66.26
Semivolatile Organic Compounds (µg/kg)					
Bis(2-ethyhexyl)phthalate	NA	18	1	480	480
Di-n-butyl phthalate	NA	18	3	110-140	126.67
Metals (mg/kg)					
Barium	438.140	18	1	836	836
Cadmium	1.080	18	2	1.70-2.10	1.90
Lithium	18.530	18	1	25.3	25.3
Strontium	131.130	18	2	145-158	151.5
Radionuclides (pCi/g)					
Cesium-137	0.080	18	1	0.1759	0.1759
Radium-228	2.260	18	2	2.264-2.51	2.387
Uranium-233,-234	1.750	18	1	2	2
Uranium-235	0.170	18	2	0.2465-2.113	1.1798
Uranium-238	1.680	18	1	1.683	1.683

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Table 4-16 Analytes Detected in Rock Creek Surface Soils

Analyte	Background Concentration(1)	Sample Size	Number of Detections(2)	Concentration Range	Concentration Mean
Semivolatile Organic Compounds (µg/kg)					
Bis(2-ethylhexyl)phthalate	NA	9	2	35-140	87.5
Di-n-butyl phthalate	NA	9	2	39-44	41.5
Radionuclides (pCi/g)					
Americium-241	0.0229	9	4	0.02404-0.04046	0.02984
Plutonium-239,-240	0.0481	9	4	0.05029-0.06093	0.05552
Radium-226	1.1330	9	4	1.159-1.275	1.214
Radium-228	2.3140	9	6	2.382-2.655	2.475
Uranium-233,-234	1.2890	9	3	1.326-1.472	1.409
Uranium-235	0.0706	9	3	0.07436-0.1393	0.1018
Uranium-238	1.2877	9	7	1.296-1.521	1.38
Metals (mg/kg)					
Barium	241.5885	9	4	244-324	279
Beryllium	0.8921	9	2	1.1	1.1
Chromium	18.3105	9	3	20.2-22	21.27
Cobalt	9.0518	9	1	12.2	12.2
Copper	18.4618	9	2	21.6-24	22.8
Lead	40.0661	9	2	42.3-50	46.15
Nickel	16.0933	9	3	17.4-19.1	18.1
Silicon	206.1	9	1	368	368
Strontium	55.4309	9	1	109	109
Tin	47.4271	9	2	53.8-58.5	56.15
Vanadium	37.7119	9	3	41.4-47	43.87
Zinc	71.2058	9	2	78-94.3	86.15

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Table 4-17 Analytes Detected in OU1 Surface Soils

Analyte	Background Concentration[1]	Sample Size	Number of Detections[2]	Concentration Range	Concentration Mean
Semivolatile Organic Compounds (µg/kg)					
Acenaphthene	NA	26	7	45-240	130.71
Anthracene	NA	26	6	47-330	159
AROCLOR-1248	NA	26	1	670	670
AROCLOR-1254	NA	26	3	180-1,200	640
Benzo(a)anthracene	NA	26	11	140-830	357.27
Benzo(a)pyrene	NA	26	12	120-750	320.83
Benzo(b)fluoranthene	NA	26	11	180-810	349.09
Benzo(g,h,i)perylene	NA	26	8	82-350	191.5
Benzo(k)fluoranthene	NA	26	10	120-740	331
Chrysene	NA	26	14	120-790	365.71
Dibenzo(a,h)anthracene	NA	26	4	43-92	64.25
Dibenzofuran	NA	26	2	37-86	61.5
Fluoranthene	NA	26	17	240-1,900	760.59
Fluorene	NA	26	5	54-230	122.2
Indeno(1,2,3-c,d)pyrene	NA	26	10	88-250	174.4
Naphthalene	NA	26	1	110	110
Phenanthrene	NA	26	15	130-1,600	572
Pyrene	NA	26	16	220-1,800	709.38
Radionuclides (pCi/g)					
Americium-241	0.0229	26	23	0.03932-1.944	0.4354
Plutonium-239,-240	0.0481	26	26	0.09067-12.99	2.5863
Radium-226	1.1330	26	4	1.153-1.349	1.239
Radium-228	2.3140	26	2	2.53-3.054	2.792
Uranium-233,-234	1.2890	26	6	1.296-1.662	1.508
Uranium-235	0.0706	26	11	0.07489-0.3261	0.1151
Uranium-238	1.2877	26	11	1.319-2.199	1.594
Metals (mg/kg)					
Beryllium	0.8921	26	4	1.2-6.2	2.45
Cadmium	0.7667	26	1	1.3	1.3
Chromium	18.3105	26	6	21.6-107	44.23

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Analyte	Background Concentration(1)	Sample Size	Number of Detections(2)	Concentration Range	Concentration Mean
Metals (mg/kg) (cont.)					
Cobalt	9.0518	26	3	10.7-11.7	11.13
Copper	18.4618	26	7	20-181	50.43
Lead	40.0661	26	5	41.7-228	81.78
Nickel	16.0933	26	10	16.1-101	31
Silicon	206.1	26	14	319-1,560	744.21
Strontium	55.4309	26	8	56.5-88.7	70.06
Tin	47.4271	26	10	47.6-104	63.45
Vanadium	37.7119	26	12	38.7-69.6	48.53
Zinc	71.2058	26	8	72-182	112.85

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Table 4-18 Plutonium Detected in Radioactive Ambient Air Monitoring Program Samplers in 1990

Sampler	Date 1990	Air Volume (m^3)	Plutonium Concentration pCi/m^3	± 95 percent Confidence Interval (pCi/m^3)
S-9	January	36859	0.000166	0.000021
S-9	February	38149	0.000328	0.000056
S-9	March	37000	0.000243	0.000041
S-9	April	50579	0.000033	0.000010
S-9	May	29798	0.000040	0.000012
S-9	June	27476	0.000090	0.000020
S-9	July	24766	0.000119	0.000039
S-9	August	27000	0.000064	0.000026
S-9	September	27317	0.000042	0.000019
S-9	October	31427	0.000046	0.000014
S-9	November	31159	0.000040	0.000010
S-9	December	33877	0.000074	0.000015
Max Value			**0.000328**	
Mean Value			**0.000107**	

** = Sampler was inoperable during the sampling period
m^3 = cubic meters
pCi/m^3 = picocuries per cubic meter

Table 4-18 Plutonium Detected in Radioactive Ambient Air Monitoring Program Samplers in 1990

Sampler	Date 1990	Air Volume (m^3)	Plutonium Concentration pCi/m^3	± 95 percent Confidence Interval (pCi/m^3)
S-10	January	33352	0.000002	0.000002
S-10	February	33482	0.000007	0.000004
S-10	March	17000	0.000016	0.000009
S-10	April	46488	0.000004	0.000002
S-10	May	31009	0.000005	0.000003
S-10	June	29549	0.000008	0.000004
S-10	July	29199	0.000007	0.000004
S-10	August	23960	0.000005	0.000005
S-10	September	24953	0.000005	0.000005
S-10	October	30490	0.000003	0.000003
S-10	November	30628	0.000004	0.000004
S-10	December	31478	0.000002	0.000003
Max Value			**0.000016**	
Mean Value			**0.000006**	

** = Sampler was inoperable during the sampling period
m^3 = cubic meters
pCi/m^3 = picocuries per cubic meter

Table 4-18 Plutonium Detected in Radioactive Ambient Air Monitoring Program Samplers in 1990

Sampler	Date 1990	Air Volume (m^3)	Plutonium Concentration pCi/m^3	± 95 percent Confidence Interval (pCi/m^3)
S-11	January	32000	0.000006	0.000003
S-11	February	33000	0.000005	0.000004
S-11	March	32000	0.000008	0.000004
S-11	April	48000	0.000004	0.000002
S-11	May	32000	0.000006	0.000003
S-11	June	31000	0.000004	0.000003
S-11	July	30000	0.000007	0.000004
S-11	August	30000	0.000007	0.000005
S-11	September	30000	0.000007	0.000005
S-11	October	31000	0.000001	0.000003
S-11	November	30000	0.000003	0.000004
S-11	December	32000	0.000000	0.000003
Max Value			**0.000008**	
Mean Value			**0.000005**	

** = Sampler was inoperable during the sampling period
m^3 = cubic meters
pCi/m^3 = picocuries per cubic meter

Table 4-18 Plutonium Detected in Radioactive Ambient Air Monitoring Program Samplers in 1990

Sampler	Date 1990	Air Volume (m^3)	Plutonium Concentration pCi/m^3	± 95 percent Confidence Interval (pCi/m^3)
S-17	January	30000	0.000015	0.000005
S-17	February	9000	0.000007	0.000012
S-17	March	32000	0.000022	0.000007
S-17	April	47000	0.000005	0.000002
S-17	May	32000	0.000007	0.000004
S-17	June	31000	0.000011	0.000005
S-17	July	30000	0.000002	0.000006
S-17	August	30000	0.000008	0.000006
S-17	September	33000	0.000007	0.000005
S-17	October	32000	0.000001	0.000005
S-17	November	29000	0.000008	0.000007
S-17	December	32000	0.000008	0.000004
Max Value			**0.000022**	
Mean Value			**0.000008**	

** = Sampler was inoperable during the sampling period
m^3 = cubic meters
pCi/m^3 = picocuries per cubic meter

Sampler	Date 1990	Air Volume (m^3)	Plutonium Concentration pCi/m^3	± 95 percent Confidence Interval (pCi/m^3)
S-23	January	33158	0.000001	0.000002
S-23	February	32855	0.000003	0.000004
S-23	March	32000	0.000005	0.000003
S-23	April	52577	0.000002	0.000001
S-23	May	34528	0.000003	0.000002
S-23	June	34378	0.000003	0.000002
S-23	July	34526	0.000003	0.000002
S-23	August	33858	0.000005	0.000004
S-23	September	31937	0.000006	0.000005
S-23	October	31772	0.000001	0.000003
S-23	November	32119	0.000002	0.000003
S-23	December	31760	0.000001	0.000003
Max Value			**0.000006**	
Mean Value			**0.000003**	

** = Sampler was inoperable during the sampling period
m^3 = cubic meters
pCi/m^3 = picocuries per cubic meter

Sampler	Date 1990	Air Volume (m^3)	Plutonium Concentration pCi/m^3	± 95 percent Confidence Interval (pCi/m^3)
S-32	January	33000	0.000000	0.000001
S-32	February	51000	0.000000	0.000002
S-32	March	35000	0.000001	0.000001
S-32	April	33000	0.000001	0.000002
S-32	May	32000	0.000002	0.000002
S-32	June	31000	0.000002	0.000002
S-32	July	46000	0.000000	0.000001
S-32	August	31000	0.000000	0.000001
S-32	September	13000	0.000003	0.000004
S-32	October	32000	0.000002	0.000002
S-32	November	24000	0.000002	0.000002
S-32	December	48000	0.000001	0.000001
Max Value			**0.000003**	
Mean Value			**0.000001**	

** = Sampler was inoperable during the sampling period
m^3 = cubic meters
pCi/m^3 = picocuries per cubic meter

Sampler	Date 1990	Air Volume (m^3)	Plutonium Concentration pCi/m^3	± 95 percent Confidence Interval (pCi/m^3)
S-38	January	33099	0.000002	0.000002
S-38	February	50271	0.000001	0.000002
S-38	March	34000	0.000000	0.000001
S-38	April	33000	0.000001	0.000002
S-38	May	31446	0.000000	0.000001
S-38	June	30648	0.000005	0.000003
S-38	July	44531	0.000000	0.000001
S-38	August	30302	0.000000	0.000001
S-38	September	30240	0.000001	0.000001
S-38	October	31210	0.000181	0.000032
S-38	November	32760	0.000008	0.000004
S-38	December	48000	0.000001	0.000001
Max Value			**0.000181**	
Mean Value			**0.000017**	

** = Sampler was inoperable during the sampling period
m^3 = cubic meters
pCi/m^3 = picocuries per cubic meter

Sampler	Date 1990	Air Volume (m^3)	Plutonium Concentration pCi/m^3	± 95 percent Confidence Interval (pCi/m^3)
S-39	January	33369	0.000002	0.000002
S-39	February	50563	-0.000001	0.000002
S-39	March	33000	0.000000	0.000001
S-39	April	34000	0.000000	0.000001
S-39	May	34136	0.000002	0.000002
S-39	June	32743	0.000002	0.000002
S-39	July	48911	0.000001	0.000001
S-39	August	33371	-0.000001	0.000001
S-39	September	33440	0.000000	0.000001
S-39	October	31805	0.000002	0.000002
S-39	November	31855	0.000000	0.000001
S-39	December	47000	0.000000	0.000001
Max Value			**0.000002**	
Mean Value			**0.000001**	

** = Sampler was inoperable during the sampling period
m^3 = cubic meters
pCi/m^3 = picocuries per cubic meter

Sampler	Date 1990	Air Volume (m^3)	Plutonium Concentration pCi/m^3	± 95 percent Confidence Interval (pCi/m^3)
S-40	January**			
S-40	February	25144	0.000000	0.000004
S-40	March	33000	0.000003	0.000002
S-40	April	33000	0.000000	0.000001
S-40	May	32877	0.000001	0.000002
S-40	June	31003	0.000002	0.000001
S-40	July	44056	0.000001	0.000003
S-40	August	30916	0.000000	0.000001
S-40	September	31096	0.000032	0.000008
S-40	October	32468	0.000002	0.000002
S-40	November	32184	0.000000	0.000001
S-40	December	49000	0.000000	0.000001

** = Sampler was inoperable during the sampling period
m^3 = cubic meters
pCi/m^3 = picocuries per cubic meter

Table 4-19 Plutonium Detected in Radioactive Ambient Air Monitoring Program Samplers in 1991

Sampler	Date 1991	Air Volume (m^3)	Pu Concentration (pCi/m^3)	± 95 percent Confidence Interval (pCi/m^3)
S-9	January	35000	0.000461	0.000085
S-9	February	33000	0.000043	0.000009
S-9	March	Sample lost; no data		
S-9	April	31000	0.000060	0.000014
S-9	May	32000	0.000056	0.000010
S-9	June	25000	0.000055	0.000011
S-9	July	28000	0.000160	0.000030
S-9	August	28000	0.000052	0.000010
S-9	September	45000	0.000002	0.000001
S-9	October	31000	0.000082	0.000017
S-9	November	33000	0.000016	0.000005
S-9	December	32000	0.000071	0.000014
Max Value			**0.000461**	
Mean Value			**0.000096**	

* = Sampler was inoperable for part of the sampling period.
** = Sampler was inoperable during the sampling period.
m^3 = cubic meter
pCi/m^3 = picocuries per cubic meter

Table 4-19 Plutonium Detected in Radioactive Ambient Air Monitoring Program Samplers in 1991

Sampler	Date 1991	Air Volume (m^3)	Pu Concentration (pCi/m^3)	± 95 percent Confidence Interval (pCi/m^3)
S-10	January	31000	0.000004	0.000000
S-10	February	31000	0.000001	0.000003
S-10	March	45000	0.000001	0.000003
S-10	April	32000	0.000093	0.000021
S-10	May	32000	Incomplete Lab Analysis	
S-10	June	13000	0.000013	0.000010
S-10	July	30000	0.000010	0.000007
S-10	August	30000	0.000001	0.000003
S-10	September	46000	0.000016	0.000004
S-10	October	30000	0.000004	0.000003
S-10	November	32000	0.000004	0.000003
S-10	December	31000	0.000006	0.000006
Max Value			**0.000093**	
Mean Value			**0.000014**	

* = Sampler was inoperable for part of the sampling period.
** = Sampler was inoperable during the sampling period.
m^3 = cubic meter
pCi/m^3 = picocuries per cubic meter

Table 4-19 Plutonium Detected in Radioactive Ambient Air Monitoring Program Samplers in 1991

Sampler	Date 1991	Air Volume (m^3)	Pu Concentration (pCi/m^3)	± 95 percent Confidence Interval (pCi/m^3)
S-11	January	31000	0.000005	0.000002
S-11	February	31000	0.000003	0.000003
S-11	March	47000	0.000000	0.000002
S-11	April	30000	0.000001	0.000003
S-11	May	32000	0.000005	0.000003
S-11	June	13000	0.000006	0.000004
S-11	July	30000	0.000015	0.000009
S-11	August	30000	0.000001	0.000003
S-11	September	46000	0.000005	0.000002
S-11	October	32000	0.000004	0.000003
S-11	November	32000	0.000001	0.000002
S-11	December	31000	0.000009	0.000003
Max Value			**0.000015**	
Mean Value			**0.000005**	

* = Sampler was inoperable for part of the sampling period.
** = Sampler was inoperable during the sampling period.
m^3 = cubic meter
pCi/m^3 = picocuries per cubic meter

Table 4-19 Plutonium Detected in Radioactive Ambient Air Monitoring Program Samplers in 1991

Sampler	Date 1991	Air Volume (m^3)	Pu Concentration (pCi/m^3)	± 95 percent Confidence Interval (pCi/m^3)
S-17	January	32000	0.000007	0.000004
S-17	February	30000	0.000008	0.000004
S-17	March	48000	0.000005	0.000004
S-17	April	30000	0.000013	0.000006
S-17	May	32000	Incomplete Lab Analysis	
S-17	June	18000	0.000009	0.000005
S-17	July	29000	0.000017	0.000009
S-17	August	29000	0.000005	0.000004
S-17	September	43000	0.000005	0.000002
S-17	October	29000	0.000004	0.000003
S-17	November*	13000	0.000007	0.000006
S-17	December**			
Max Value			**0.000017**	
Mean Value			**0.000007**	

* = Sampler was inoperable for part of the sampling period.
** = Sampler was inoperable during the sampling period.
m^3 = cubic meter
pCi/m^3 = picocuries per cubic meter

Sampler	Date 1991	Air Volume (m^3)	Pu Concentration (pCi/m^3)	± 95 percent Confidence Interval (pCi/m^3)
S-23	January	31000	0.000002	0.000002
S-23	February	36000	-0.000001	0.000003
S-23	March	48000	0.000004	0.000003
S-23	April	31000	0.000000	0.000003
S-23	May	33000	0.000005	0.000003
S-23	June*	3000	0.000011	0.000013
S-23	July*	16000	0.000008	0.000004
S-23	August	32000	-0.000001	0.000002
S-23	September	48000	0.000006	0.000002
S-23	October	31000	0.000001	0.000002
S-23	November	33000	0.000001	0.000002
S-23	December	32000	0.000004	0.000003
Max Value			**0.000011**	
Mean Value			**0.000003**	

* = Sampler was inoperable for part of the sampling period.
** = Sampler was inoperable during the sampling period.
m^3 = cubic meter
pCi/m^3 = picocuries per cubic meter

Sampler	Date 1991	Air Volume (m^3)	Pu Concentration (pCi/m^3)	± 95 percent Confidence Interval (pCi/m^3)
S-32	January	35000	0.000001	0.000001
S-32	February	34000	0.000004	0.000002
S-32	March	33000	0.000001	0.000002
S-32	April	34000	-0.000002	0.000003
S-32	May	33000	0.000003	0.000002
S-32	June	36000	0.000006	0.000003
S-32	July	49000	0.000002	0.000001
S-32	August	33000	-0.000002	0.000002
S-32	September	34000	0.000001	0.000001
S-32	October	33000	-0.000003	0.000003
S-32	November	35000	-0.000001	0.000001
S-32	December	35000	-0.000001	0.000001
Max Value			**0.000006**	
Mean Value			**0.00000075**	

* = Sampler was inoperable for part of the sampling period.
** = Sampler was inoperable during the sampling period.
m^3 = cubic meter
pCi/m^3 = picocuries per cubic meter

Sampler	Date 1991	Air Volume (m^3)	Pu Concentration (pCi/m^3)	± 95 percent Confidence Interval (pCi/m^3)
S-38	January	35000	0.000001	0.000001
S-38	February	34000	0.000000	0.000001
S-38	March	29000	0.000002	0.000002
S-38	April	31000	-0.000001	0.000003
S-38	May	27000	0.000006	0.000003
S-38	June	27000	0.000005	0.000003
S-38	July	41000	0.000004	0.000002
S-38	August	27000	0.000000	0.000003
S-38	September	28000	0.000000	0.000001
S-38	October	25000	-0.000002	0.000005
S-38	November	31000	0.000000	0.000001
S-38	December	31000	0.000000	0.000001
Max Value			**0.000006**	
Mean Value			**0.00000125**	

* = Sampler was inoperable for part of the sampling period.
** = Sampler was inoperable during the sampling period.
m^3 = cubic meter
pCi/m^3 = picocuries per cubic meter

Sampler	Date 1991	Air Volume (m^3)	Pu Concentration (pCi/m^3)	± 95 percent Confidence Interval (pCi/m^3)
S-39	January*	31000	0.000007	0.000003
S-39	February	36000	0.000003	0.000002
S-39	March	37000	0.000001	0.000001
S-39	April	34000	-0.000002	0.000003
S-39	May	29000	0.000003	0.000002
S-39	June	28000	0.000002	0.000002
S-39	July	29000	0.000004	0.000002
S-39	August**			
S-39	September	29000	0.000001	0.000002
S-39	October	28000	-0.000002	0.000004
S-39	November	33000	0.000002	0.000002
S-39	December	33000	0.000002	0.000002
Max Value			**0.000007**	
Mean Value			**0.000002**	

* = Sampler was inoperable for part of the sampling period.
** = Sampler was inoperable during the sampling period.
m^3 = cubic meter
pCi/m^3 = picocuries per cubic meter

Table 4-19 Plutonium Detected in Radioactive Ambient Air Monitoring Program Samplers in 1991

Sampler	Date 1991	Air Volume (m^3)	Pu Concentration (pCi/m^3)	± 95 percent Confidence Interval (pCi/m^3)
S-40	January	35000	0.000004	0.000002
S-40	February	34000	0.000005	0.000003
S-40	March	34000	0.000002	0.000002
S-40	April	34000	0.000001	0.000003
S-40	May	34000	0.000000	0.000001
S-40	June	39000	0.000001	0.000001
S-40	July	48000	0.000002	0.000001
S-40	August	32000	0.000004	0.000003
S-40	September	33000	0.000001	0.000001
S-40	October	32000	0.000000	0.000004
S-40	November	35000	0.000000	0.000001
S-40	December	35000	0.000000	0.000001
Max Value			**0.000005**	
Mean Value			**0.000002**	

* = Sampler was inoperable for part of the sampling period.
** = Sampler was inoperable during the sampling period.
m^3 = cubic meter
pCi/m^3 = picocuries per cubic meter

Table 4-20 Plutonium Detected in OU1 High Volume Air Samplers in 1990

Sampler	Date 1990	Air Volume (m^3)	Plutonium Concentration pCi/m^3	± 95 percent Confidence Interval (pCi/m^3)
S-81A	July	136277	0.000103	0.000003
S-81A	August**			
S-81A	September	27216	0.000003	0.000004
S-81A	October	68075	0.000004	0.000001
S-81A	November	56828	0.000006	0.000007
S-81A	December	56615	0.000006	0.000000
Max Value			**0.000103**	
Mean Value			**0.0000244**	
S-81B	July	30000	0.000008	0.000007
S-81B	August**			
S-81B	September*			
S-81B	October	22459	0.000012	0.000003
S-81B	November	50276	0.000017	0.000003
S-81B	December	55479	0.000009	0.000006
Max Value			**0.000017**	
Mean Value			**0.0000115**	

Note: Routine sampling at these sites began in July of 1990.
* = Sampler down for part of the sampling period; insufficient capture for quality analysis during period sampling
** = Sampler moter failure; nor sampler operation during sampling period
m^3 = cubic meters
pCi/m^3 = picocuries per cubic meter

Table 4-20 Plutonium Detected in OU1 High Volume Air Samplers in 1990

Sampler	Date 1990	Air Volume (m^3)	Plutonium Concentration pCi/m^3	± 95 percent Confidence Interval (pCi/m^3)
S-81C	July	46402	0.000003	0.000009
S-81C	August**			
S-81C	September	44863	0.000002	0.000005
S-81C	October	20992	0.000006	0.000006
S-81C	November	35875	0.000003	0.000001
S-81C	December	19620	0.000015	0.000002
Max Value			**0.000015**	
Mean Value			**0.0000058**	
S-81D	July	44160	0.000002	0.000005
S-81D	August**			
S-81D	September	47542	0.000007	0.000003
S-81D	October*			
S-81D	November	57741	0.000004	0.000006
S-81D	December	37479	0.000009	0.000009
Max Value			**0.000009**	
Mean Value			**0.0000055**	

Note: Routine sampling at these sites began in July of 1990.
* = Sampler down for part of the sampling period; insufficient capture for quality analysis during period sampling
** = Sampler moter failure; nor sampler operation during sampling period
m^3 = cubic meters
pCi/m^3 = picocuries per cubic meter

Table 4-21 Plutonium Detected in OU1 High Volume Air Samplers in 1991

Sampler	Date 1991	Air Volume (m^3)	Plutonium Concentration pCi/m^3	± 95 percent Confidence Interval (pCi/m^3)
S-81A	January	13037	0.000028	0.000001
S-81A	February*			
S-81A	March	49930	0.000012	0.000002
S-81A	April	34381	0.000005	0.000003
S-81A	May*			
S-81A	June	13886	0.000004	0.000003
S-81A	July	34713	0.000004	0.000002
S-81A	August	46964	0.000020	0.000006
S-81A	September	50866	0.000005	0.000001
S-81A	October	39984	0.000008	0.000005
S-81A	November	30075	0.000006	0.000005
S-81A	December	67420	0.000044	0.000009
Max Value			**0.000044**	
Mean Value			**0.0000145**	

* = Sampler down for part of the Sampling period; insufficient capture for quality analysis during Sampling period.
** = Sampler motor failure; no sampler operation during Sampling period.
m^3 = cubic meters
pCi/m^3 = picocuries per cubic meter

Table 4-21 Plutonium Detected in OU1 High Volume Air Samplers in 1991

Sampler	Date 1991	Air Volume (m^3)	Plutonium Concentration pCi/m^3	± 95 percent Confidence Interval (pCi/m^3)
S-81B	January	27021	0.000012	0.000006
S-81B	February*			
S-81B	March	28837	0.000035	0.000009
S-81B	April	26684	0.000026	0.000003
S-81B	May	42966	0.000012	0.000004
S-81B	June	28627	0.000006	0.000002
S-81B	July	51513	0.000004	0.000002
S-81B	August	70588	0.000003	0.000003
S-81B	September	56448	0.000015	0.000009
S-81B	October	49230	0.000026	0.000006
S-81B	November	37066	0.000006	0.000002
S-81B	December	34439	0.000014	0.000002
Max Value			**0.000026**	
Mean Value			**0.000011**	

* = Sampler down for part of the Sampling period; insufficient capture for quality analysis during Sampling period.
** = Sampler motor failure; no sampler operation during Sampling period.
m^3 = cubic meters
pCi/m^3 = picocuries per cubic meter

Table 4-21 Plutonium Detected in OU1 High Volume Air Samplers in 1991

Sampler	Date 1991	Air Volume (m^3)	Plutonium Concentration pCi/m^3	± 95 percent Confidence Interval (pCi/m^3)
S-81C	January	28823	0.000008	0.000002
S-81C	February	13786	0.000010	0.000003
S-81C	March	40975	0.000014	0.000004
S-81C	April*			
S-81C	May**			
S-81C	June	22557	0.000004	0.000001
S-81C	July	14481	0.000006	0.000002
S-81C	August	46611	0.000001	0.000001
S-81C	September	77413	0.000005	0.000001
S-81C	October	14481	0.000006	0.000004
S-81C	November*			
S-81C	December	60839	0.000004	0.000003
Max Value			**0.000006**	
Mean Value			**0.000004**	

* = Sampler down for part of the Sampling period; insufficient capture for quality analysis during Sampling period.
** = Sampler motor failure; no sampler operation during Sampling period.
m^3 = cubic meters
pCi/m^3 = picocuries per cubic meter

Table 4-21 Plutonium Detected in OU1 High Volume Air Samplers in 1991

Sampler	Date 1991	Air Volume (m^3)	Plutonium Concentration pCi/m^3	± 95 percent Confidence Interval (pCi/m^3)
S-81D	January	14576	0.00002	0.000003
S-81D	February*			
S-81D	March**			
S-81D	April	27069	0.000009	0.000003
S-81D	May**			
S-81D	June	28953	0.000004	0.000005
S-81D	July	14279	0.000004	0.000005
S-81D	August	53050	0.000003	0.000002
S-81D	September	71001	0.000119	0.000006
S-81D	October	53532	0.000002	0.000000
S-81D	November	57536	0.000002	0.000001
S-81D	December	31269	0.000005	0.000004
Max Value			**0.000119**	
Mean Value			**0.000023**	

* = Sampler down for part of the Sampling period; insufficient capture for quality analysis during Sampling period.
** = Sampler motor failure; no sampler operation during Sampling period.
m^3 = cubic meters
pCi/m^3 = picocuries per cubic meter

Surface Water		Sediment
SW030*	SW070	SED001*
SW031	SW071*	SED014*
SW032*	SW072*	SED015*
SW033*	SW126*	SED025*
SW034*	SW125*	SED026*
SW035		SED027*
SW044		SED028*
SW045		SED029*
SW046		SED030*
SW066		SED031*
SW067		SED037
SW068		SED038
SW069		SED039

*Location is outside of OU1, (based on the OU1 Quality Assurance Addendum to the Quality Assurance Project Plan for Rocky Flats Plant); analytical data is presented in Appendix C2, and/or on maps in Section 4.5.

Table 4-23 Analytes Detected in Surface Water, Fourth Quarter 1991

Analyte	Background Concentration(1)	Sample Size	Number of Detections(2)	Concentration Range	Concentration Mean
Volatile Organic Compounds (µg/l)					
Beta - BHC	NA	9	1	0.021	0.021
2 - Butanone	NA	9	1	17	17
Radionuclides, Total (pCi/l)					
Cesium-137	0.734	9	1	1.4	1.4
Uranium-233,-234	1.456	9	1	4.4	4.4
Uranium-235	0.152	9	1	0.36	0.36
Uranium-238	1.332	9	3	1.4-2.5	1.87
Metals, Dissolved (mg/l)					
Lithium	0.002	9	8	0.0065-0.0155	0.0090
Strontium	0.521	9	1	0.5840	0.5840
Metals, Total (mg/l)					
Barium	0.116	9	2	0.120-0.450	0.285
Strontium	0.364	9	2	0.420-0.450	0.435
Inorganics (mg/l)					
Chloride	72.912	9	1	96.2	96.2
Nitrite	0.022	9	3	0.022-0.14	0.063
Nitrate + Nitrite	2.79	9	1	7.0	7.0
Oil and grease	8.033	9	1	18.5	18.5
Phosphorus	0.138	9	2	0.28-0.90	0.59
Sulfate	35.091	9	3	35.2-42.1	38.13
Total dissolved solids	312.491	9	4	316-490	382.5

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Table 4-24 Analytes Detected in Sediment, Fourth Quarter 1991

Analyte	Background Concentration[1]	Sample Size	Number of Detections[2]	Concentration Range	Concentration Mean
Volatile Organic Compounds (µg/kg)					
2-Butanone	NA	3	2	14-19	16.5
Acetone	NA	3	2	54-71	62.5
Methylene chloride	NA	3	2	8-14	11
Semivolatile Organic Compounds (µg/kg)					
AROCLOR-1254	NA	3	2	84-86	85
Bis(2-ethylehexyl)phthalate	NA	3	3	280-1,400	706.67
Chrysene	NA	3	1	63	63
Di-n-butyl phthalate	NA	3	1	65	65
Di-n-octyl phthalate	NA	3	1	210	210
Fluoranthene	NA	3	2	70-130	100
Pyrene	NA	3	1	87	87

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Table 4-25 Ground Water Monitoring Well Locations for the Phase III RFI/RI

Alluvial Wells	5986	35691	**Bedrock Wells**
0187	5986R	35991	0387
0287	6286	36191	0587
0487	6386	36391	0887
0687	6486	36691	4587
0974	6886	36991	37891
1074	6986	37191	37991
4387	30991	37591	39191
4787	31491	37691	**Piezometers** †
4887	31791	37791	Alluvial
4987	31891	38591	38191
5087	32591	39691	38291
5187	33491		38891
5287	33691		Bedrock
5387	33891		38991
5487	34591		39291
5587	34791		
5886	35391		

* - Location outside of OU1; analytical data are presented in Appendix C4.
† - Analytical data are unavailable for piezometers.

Analyte	Background Concentration	Sample Size	Number of Detections	Concentration Range	Concentration Mean
Volatile Organic Compounds (µg/l)					
1,1,1-Trichloroethane	NA	25	2	7,600-20,000	13,800
1,1-Dichloroethane	NA	25	1	23	23
1,1-Dichloroethene	NA	25	2	7,900	7,900
1,3-Dimethylbenzene	NA	25	1	0.39	0.39
2-Hydroxy-2-methyl-4-pentanone	NA	25	3	8.9-10	9.5
Carbon tetrachloride	NA	25	2	5.02-2,500	1,252.51
Chloroform	NA	25	4	0.43-78	23.63
Dichlorodifluoromethane	NA	25	2	0.81-2.82	1.82
Methylene chloride	NA	25	1	37	37
Tetrachloroethene	NA	25	5	0.2-5,700	1,505.24
Toluene	NA	25	5	0.14-57	18.10
Trichloroethene	NA	25	6	0.12-11,000	3,610.79
cis-1,2-Dichloroethene	NA	25	1	0.23	0.23
p-Cymene	NA	25	1	0.38	0.38
Semivolatile Organic Compounds (µg/l)					
2,6-Dinitrotoluene	NA	25	1	2	2
Bis(2-ethylhexyl)phthalate	NA	25	2	2-8	5
Di-n-butyl phthalate	NA	25	2	2	2
Diethyl phthalate	NA	25	2	2-6	4
alpha-BHC	NA	25	2	0.082-0.12	0.101
Radionuclides, Dissolved (pCi/l)					
Radium-226	0.497	25	1	0.7042	0.7042
Metals, Dissolved (mg/l)					
Antimony	0.047	25	1	0.0761	
Chromium	0.016	25	1	0.0198	0.0198
Copper	0.018	25	2	0.03710-1.210	0.6236
Nickel	0.020	25	2	0.104-4.950	2.5270
Zinc	0.056	25	1	9.850	9.850

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Analyte	Background Concentration	Sample Size	Number of Detections	Concentration Range	Concentration Mean
Metals, Total (mg/l)					
Antimony	0.045	25	1	0.0664	0.0664
Copper	0.039	25	1	0.0585	0.0585
Lead	0.022	25	1	0.0620	0.0620
Nickel	0.032	25	1	0.0853	0.0853
Strontium	1.015	25	2	1.330-1.970	1.650

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Table 4-27 Analytes Detected in Ground Water, First Quarter 1992

Analyte	Background Concentration(1)	Sample Size	Number of Detections(2)	Concentration Range	Concentration Mean
Volatile Organic Compounds (µg/l)					
1,1,1-Trichloroethane	NA	26	3	5-4,600	3,001.67
1,1,2-Trichloroethane	NA	26	2	28-72	50
1,1-Dichloroethane	NA	26	2	19-20	19.50
1,1-Dichloroethene	NA	26	3	9.2-5,800	3,536.40
1,2,3-Trichlorobenzene	NA	26	1	0.11	0.11
1,2,4-Trimethyl benzene	NA	26	1	0.12	0.12
1,2-Dichloroethane	NA	26	2	7-22	14.50
1,2-Dichloroethene	NA	26	3	10-30	17.33
Benzene	NA	26	1	1	1
Carbon tetrachloride	NA	26	7	0.1-3,400	493.97
Chloroform	NA	26	8	0.11-92	15.34
Methylene chloride	NA	26	3	3.3-27	11.43
Styrene	NA	26	2	0.2-0.4	0.30
Tetrachloroethene	NA	26	12	0.1-4,200	353.76
Toluene	NA	26	3	0.3-47	20.77
Total Xylenes	NA	26	1	2	2
Trichloroethene	NA	26	13	0.15-4,700	795.11
Trichlorofluoromethane	NA	26	1	1.1	1.1
cis-1,2-Dichloroethene	NA	26	2	0.18-0.86	0.52
p-Chloro toluene	NA	26	1	0.6	0.6
tert-Butyl benzene	NA	26	1	4	4
Semivolatile Organic Compounds (µg/l)					
1,2,4-Trichlorobenzene	NA	26	1	11	11
1,2,4-Trichlorobenzene	NA	26	1	0.08	0.08
Bis(2-ethylhexyl)phthalate	NA	26	1	2	2
Di-n-butyl phthalate	NA	26	1	2	2
Diethyl phthalate	NA	26	1	3	3
Hexachlorobutadiene	NA	26	1	0.1	0.1
		26			
Metals, Total (mg/l)					
Copper	0.039	19	1	0.0419	0.0419
Strontium	1.015	19	1	1.220	1.220

NA = Not Applicable
(1) = Background concentrations do not exist and are not applicable for organic compounds
(2) = For radionuclides and metals the number of detections represent only detected concentrations exceeding background.

Table 4-28 Species Sampled for Biological Tissues

Code	Latin Name	Common Name
PLANTS		
ARLU	*Artemisia ludoviciana*	white sage
BOGR	*Bouteloua gracilis*	blue grama
BRIN	*Bromus ionermis*	smooth brome
MEOF	*Melilotus officinalis*	yellow sweet clover
POCO	*Poa compressa*	Canada bluegrass
ANIMALS		
ACRI	*Acrididae*	grasshoppers
CACO	*Catostomus commersoni*	white sucker
LECY	*Lepomis cyanellus*	green sunfish
MIPE	*Microtus pennsylvanicus*	meadow vole
MISA	*Micropterus salmoides*	largemouth bass
NOCR	*Notemigonus crysoleucas*	golden shiner
PEMA	*Permomyscus maniculatus*	deer mouse
PIPR	*Pimephales promelas*	fathead minnow
SEAT	*Semotilus atromaculatus*	creek chuib

Note: Latin names for genus and species are in italics; family names are represented in plain text.

Table 4-29 Vegetation Tissue Samples Exceeding Background at OU1 Sites

Site	Species	Analyte	OU1 Sample	RFP Background	Units
MA01A	POCO1	Copper	3.3	1.7	mg/kg
MA01A	POCO1	Lead	0.7	0.6	mg/kg
MA01A	POCO1	Zinc	13.6	12.6	mg/kg
MA02A	MEOF1	Chromium	37.8	0.6	mg/kg
MA02A	MEOF1	Lead	0.7	0.5	mg/kg
MA02A	MEOF1	Total Uranium	1.3	0	pCi/g
MA04A	BRIN1	Chromium	1.9	1.1	mg/kg
MA04A	BRIN1	Lead	0.5	0.4	mg/kg
MD01A	BRIN1	Chromium	1.5	1.3	mg/kg
MD01A	BRIN1	Copper	4.8	4.7	mg/kg
MG02A	ARLU1	Copper	11.4	10.7	mg/kg
MG02A	ARLU1	Zinc	50.9	44.8	mg/kg
MG02A	ARLU1	Zinc	45.6	44.8	mg/kg
MG02A	BOGR1	Chromium	1.7	1.3	mg/kg
MG02A	BOGR1	Chromium	1.4	1.3	mg/kg
MG02A	BOGR1	Copper	14	4.7	mg/kg
MG03A	ARLU1	Cadmium	1.9	1.2	mg/kg
MG03A	ARLU1	Cadmium	1.8	1.2	mg/kg
MG03A	ARLU1	Chromium	2.1	1.3	mg/kg
MG03A	ARLU1	Copper	14.6	10.7	mg/kg
MG03A	ARLU1	Copper	15.2	10.7	mg/kg
MG03A	ARLU1	Zinc	56.4	44.8	mg/kg
MG03A	ARLU1	Zinc	48.1	44.8	mg/kg

BRIN *Bromus inermis*
ARLU *Artemisia ludoviciana*
POCO *Poa compressa*
MEOF *Melilotus officinalis*
BOGR *Bouteloua gracilis*

Site	Species	Analyte	OU1 Sample	RFP Background	Units
MG03A	BOGR1	Chromium	2.1	1.3	mg/kg
MG03A	BOGR1	Chromium	2.2	1.3	mg/kg
MG04A	ARLU1	Chromium	3.4	1.3	mg/kg
MG04A	ARLU1	Copper	16.3	10.7	mg/kg
MG04A	ARLU1	Lead	1.9	1.4	mg/kg
MG04A	ARLU1	Zinc	46.9	44.8	mg/kg
MG04A	ARLU1	Zinc	59.8	44.8	mg/kg
MG04A	BOGR1	Chromium	1.6	1.3	mg/kg
MG04A	BOGR1	Copper	5.4	4.7	mg/kg
MG04A	BOGR1	Zinc	20.7	19.8	mg/kg
MG04A	BOGR1	Radium-226	11	0	pCi/g
MR01A	BRIN1	Chromium	1.5	1.3	mg/kg
MR02A	ARLU1	Chromium	2.7	1.3	mg/kg
MR02A	ARLU1	Copper	12.6	10.7	mg/kg
MR04A	ARLU1	Chromium	1.6	1.3	mg/kg
MR04A	ARLU1	Chromium	1.9	1.3	mg/kg
MR04A	ARLU1	Radium-226	11	0	pCi/g
MR04A	BRIN1	Chromium	1.5	1.3	mg/kg
MR04A	BRIN1	Chromium	2	1.3	mg/kg
MR04A	BRIN1	Zinc	22.5	19.8	mg/kg
MW01A	BRIN1	Cadmium	0.3	0	mg/kg

BRIN *Bromus inermis*
ARLU *Artemisia ludoviciana*
POCO *Poa compressa*
MEOF *Melilotus officinalis*
BOGR *Bouteloua gracilis*

Site	Species	Analyte	OU1 Sample	RFP Background	Units
MW01A	BRIN1	Chromium	34.1	1.1	mg/kg
MW01A	BRIN1	Lead	0.8	0.4	mg/kg
MW01A	BRIN1	Zinc	28.1	19.4	mg/kg
MW03A	ARLU1	Cadmium	1.9	1.1	mg/kg
MW03A	ARLU1	Cadmium	1.6	1.1	mg/kg
MW03A	ARLU1	Copper	11.5	10.2	mg/kg
MW03A	ARLU1	Copper	11.2	10.2	mg/kg
MW03A	POCO1	Cadmium	0.2	0	mg/kg
MW03A	POCO1	Zinc	13	12.6	mg/kg
MW04A	ARLU1	Chromium	23.3	5.4	mg/kg
MW04A	POCO1	Zinc	14.2	12.6	mg/kg

BRIN *Bromus inermis*
ARLU *Artemisia ludoviciana*
POCO *Poa compressa*
MEOF *Melilotus officinalis*
BOGR *Bouteloua gracilis*

Table 4-30 Terrestrial Arthropod Tissue Samples Exceeding Background at OU1 Sites

Site	Species	Analyte	OU1 Sample	RFP Background	Units
MA04A	ACRI	Cadmium	6.4	3.6	mg/kg
MA04A	ACRI	Copper	204	66.3	mg/kg
MA04A	ACRI	Zinc	210	144	mg/kg
MD01A	ACRI	Cadmium	3.8	3.6	mg/kg
MD01A	ACRI	Copper	133	73.9	mg/kg
MD01A	ACRI	Zinc	144	138	mg/kg
MD01A	ACRI	Plutonium -239,-240	0.027	0	pCi/g
MG03A	ACRI	Cadmium	4.6	3.6	mg/kg
MG03A	ACRI	Copper	130	73.9	mg/kg
MG03A	ACRI	Lead	3.5	0	mg/kg
MG03A	ACRI	Zinc	242	138	mg/kg
MG03A	ACRI	Americium-241	0.021	0	pCi/g
MG03A	ACRI	Plutonium -239,-240	0.033	0	pCi/g
MR03A	ACRI	Copper	89.2	73.9	mg/kg
MR03A	ACRI	Lead	1.9	0	mg/kg
MR03A	ACRI	Zinc	162	138	mg/kg

ACRI aggregate Orthoptera

Table 4-31 Small Mammal Tissue Samples Exceeding Background at OU1 Sites

Site	Species	Analyte	OU1 Sample	RFP Background	Units
MA01A	MIPE1	Lead	2.9	1.7	mg/kg
MA01A/3A	MIPE1	Lead	3.8	1.7	mg/kg
MA02A	PEMA1	Copper	18.7	17	mg/kg
MA02A	PEMA1	Copper	23.8	17	mg/kg
MA03A	MIPE1	Lead	2	1.7	mg/kg
MA04A	PEMA1	Cadmium	1.9	1.6	mg/kg
MA04A	PEMA1	Copper	22	17	mg/kg
MA04A	PEMA1	Zinc	133	106	mg/kg
MD01A	PEMA1	Copper	158	42.8	mg/kg
MD01A	PEMA1	Plutonium-239,-240	0.026	0	pCi/g
MD02A	MIPE1	Copper	36.2	26.2	mg/kg
MD02A	MIPE1	Lead	2.3	1.7	mg/kg
MG01A	MIPE1	Cadmium	6.4	3.1	mg/kg
MG01A	MIPE1	Copper	34.4	26.2	mg/kg
MG01A	MIPE1	Lead	6.9	1.7	mg/kg
MG03A	PEMA1	Cadmium	10.6	3.9	mg/kg
MG03A	PEMA1	Copper	43.1	42.8	mg/kg
MG03A	PEMA1	Lead	8.5	2.7	mg/kg
MG03A	PEMA1	Zinc	151	146	mg/kg
MG04A	MIPE1	Lead	1.9	1.7	mg/kg
MG04A	MIPE1	Americium-241	0.086	0	pCi/g
MG04A	MIPE1	Plutonium-239,-240	0.47	0	pCi/g

PEMA1 *Peromyscus maniculatus*
MIPE1 *Microtus pennsylvanicus*

Table 4-31 Small Mammal Tissue Samples Exceeding Background at OU1 Sites

Site	Species	Analyte	OU1 Sample	RFP Background	Units
MR02A	MIPE1	Cadmium	4.1	3.1	mg/kg
MR02A	MIPE1	Lead	3.1	1.7	mg/kg
MR02A	MIPE1	Total Uranium	0.26	0	pCi/g
MW01A	PEMA1	Zinc	210	106	mg/kg
MW02A	MIPE1	Lead	1.8	1.7	mg/kg
MW03A	PEMA1	Chromium	3.4	0	mg/kg
MW03A	PEMA1	Copper	17.3	17	mg/kg
MW04A	PEMA1	Copper	28.2	17	mg/kg
MW04A	PEMA1	Lead	2.9	2.6	mg/kg
MW04A	PEMA1	Zinc	153	106	mg/kg

PEMA1 *Peromyscus maniculatus*
MIPE1 *Microtus pennsylvanicus*

Table 4-32 Fish Tissue Samples Exceeding Background at OU1 Sites

Site	Species	Analyte	OU1 Sample	RFP Background	Units
SW039	NONE				
SW033	SEAT1	Lead	5.7	4.3	mg/kg
SW033	SEAT1	Total Uranium	0.25	0	mg/kg
SW032	NONE				
SWC001	NONE				
SWC001	LECY1	Copper	52.6	10.3	mg/kg
SWC001	LECY1	Lead	2.6	1.9	mg/kg
SWC001	MISA1	Chromium	4.5	3.8	mg/kg
SWC001	NOCR1	Cadmium	3.3	0	mg/kg
SWC001	NOCR1	Cadmium	3.9	0	mg/kg
SWC001	NOCR1	Chromium	10.4	7.4	mg/kg
SWC001	NOCR1	Chromium	8.9	7.4	mg/kg
SWC001	NOCR1	Copper	103	40.9	mg/kg
SWC001	NOCR1	Copper	73	40.9	mg/kg
SWC001	SEAT1	Copper	657	40.9	mg/kg
SWC001	SEAT1	Lead	6.4	4.3	mg/kg
WORI03	SEAT1	Copper	65.7	40.9	mg/kg
WORI03	SEAT1	Copper	58.4	40.9	mg/kg
SW026	SEAT1	Lead	5.8	4.3	mg/kg

SEAT1 *Semotilus atromaculatus*
LECY1 *Lepomis cyanellus*
MISA1 *Micropterus salmonoides*
NOCR1 *Notropis cornutus*
PIPR1 *Pimephales promelas*
CACO1 *Catostomus commersoni*

Table 4-32 Fish Tissue Samples Exceeding Background at OU1 Sites

Site	Species	Analyte	OU1 Sample	RFP Background	Units
SW026	SEAT1	Radium-226	24	0	pCi/g
SW026	SEAT1	Total Uranium	0.24	0	pCi/g
SW026	SEAT1	Total Uranium	0.28	0	pCi/g
WORI01	NOCR1	Copper	76.9	40.9	mg/kg
WORI01	NOCR1	Copper	83.9	40.9	mg/kg
WORI01	PIPR1	Plutonium-239,-240	0.034	0	pCi/g
WOPO02	CACO1	Copper	115	40.9	mg/kg
WOPO02	CACO1	Lead	4.4	4.3	mg/kg
WOPO02	SEAT1	Total Uranium	0.31	0	pCi/g
WOPO02	SEAT1	Total Uranium	0.38	0	pCi/g
WOPO02	SEAT1	Total Uranium	0.21	0	pCi/g
WOPO02	SEAT1	Total Uranium	0.29	0	pCi/g

SEAT1 *Semotilus atromaculatus*
LECY1 *Lepomis cyanellus*
MISA1 *Micropterus salmonoides*
NOCR1 *Notropis cornutus*
PIPR1 *Pimephales promelas*
CACO1 *Catostomus commersoni*

Table 4-33 OU1 Ground Water Quality and Chemical-Specific Benchmarks

Parameter	OU1 Maximum Concentration	FEDERAL STANDARDS: SDWA Maximum Contaminant Level (a)	FEDERAL STANDARDS: SDWA Maximum Contaminant Level (b)	CDH Statewide Table A (c) (3)
Chloride	710,000	250,000 *		
Fluoride	2,400	4,000; 2,000*		
N as Nitrate+Nitrite	43,000		10,000	
Sulfate	1,300,000	250,000*		
Total Dissolved Solids	1,900,000	500,000*		
Aluminum	41,200		50 to 200*	
Antimony	76.1			
Barium	1,880	1,000	2,000 (d)	
Cadmium	6.9	10	5	
Chromium	19.8	50	100	
Copper	1,210	1,000 *		
Iron	56,500	300 *		
Lead	62	50		
Manganese	3,660	50 *		
Mercury	0.56	2	2	
Selenium	1,400	10	50	
Strontium	1,970			
Zinc	9,850	5,000 *		
Gross Alpha (pCi/l)	60.63	15 (4)		
Gross Beta (pCi/l)	31.58	50 (4 mrem/yr)		
Plutonium 238+239+240 (pCi/l)	0.03			15 (1)
Radium 226+228 (pCi/l)	0.7042	5		5 (1)
Strontium 90 (pCi/l)	2.47	8 (2)		8 (1)
Tritium (pCi/l)	771	20,000 (2)		20,000 (1)
Hexachlorobutadiene	0.1			1
1,1,1-Trichloroethane	20,000	200		200
1,1,2-Trichloroethane	72			3
1,1-Dichloroethane	23			
1,1-Dichloroethene	7,900	7		7
1,2-Dichloroethane	0.1	5		0.4
1,2-Dichloroethene (cis)	0.86		70	70
1,2-Dichloroethene (trans)	0.1		100	100
Benzene	1	5		1
Carbon Tetrachloride	3,400	5		0.3
Chloroform	92	Tot THM <100**		6
Styrene	0.4		100	
Tetrachloroethene	5,700		5	5
Toluene	57		1,000	1,000
Trichloroethene	9,800	5		5
Xylenes (total)	2		10,000	

EXPLANATION OF TABLE

* = secondary maximum contaminant level

** = total trihalomethanes: chloroform, bromoform, bromodichloromethane, dibromochloromethane

NOTE: Units in micrograms per liter (mg/l), unless otherwise noted

CDH	= Colorado Department of Health
OU1	= Operable Unit 1
pCi/l	= picocuries per liter
SDWA	= Safe Drinking Water Act
THM	= Total Trihalomethanes

(1) radionuclide standards - see sec. 3.11.5(c)2 in (d)

(2) If both strontium-90 and tritium are present, the sum of their annual dose equivalents to bone marrow shall not exceed 4 mrem/yr.

(3) Where standard is below (more stringent than) PQL (CDH), PQL is standard.

(4) Value for gross alpha excludes uranium.

(a) EPA National Primary and Secondary Drinking Water Regulations, 40 CFR 141 and 40 CFR 143 (as of 5/1990)

(b) EPA National Primary and Secondary Drinking Water Regulations, 40 CFR Parts 141, 142, 143, Final Rule, Effective July 30, 1992 (56 Federal Register 3526; 1/30/1991)

(c) CDH/Colorado Water Quality Control Commission, The Basic Standards for Ground Water, 3.11.0 (5 CCR 1002-8) 1/5/1987 amended 11/30/1991; statewide radioactive standards listed in 3.11.5(c)(2).

(d) EPA National Primary and Secondary Drinking Water Regulations, 40 CFR Parts 141, 142, 143, Final Rule, Effective January 1, 1993 (56 FR 30266; 7/1/1991)

Table 4-34 OU1 Surface Water Quality and Chemical-Specific Benchmarks

Parameter	OU1 Maximum Concentration	SDWA Maximum Contaminant Levels (a)	SDWA Maximum Contaminant Levels (b)	CWA AWQC for Protection of Aquatic Life (c) Acute Value	Chronic Value
Chloride	107,000	250,000*		860,000(e)	230,000(e)
Fluoride	1,000	4,000; 2,000*			
N as Nitrate+Nitrite	2,900		10,000		
N as Nitrite	41		1,000		
Sulfate	93,500	250,000*			
Total Dissolved Solids	650,000	500,000*		SS	SS
Aluminum	2,770		50 to 200*	750	87
Antimony	14			9,000	1,600
Barium	450	1,000	2,000 (f)		
Beryllium	0.9			130	5.3
Chromium	16	50	100		
Copper	60.9	1,000*		18 (1)	12 (1)
Iron	2,250	300 *			1,000
Lead	4.6	50		82 (1)	3.2 (1)
Manganese	1,020	50 *			
Nickel	7.2			1,400 (1)	160 (1)
Selenium	2.6	10	50	20 (d)	5 (d)
Zinc	195	5,000 *		120 (1)	110 (1)
Dieldrin	0.13			2.5	0.0019
Endosulfan I	0.06			0.22	0.056
Endrin	0.13	0.2		0.18	0.0023
Heptachlor	0.06		0.4	0.52	0.0038
Heptachlor Epoxide	0.06		0.2		
Toxaphene	1.30		3	0.73	0.0002
Gross Alpha (pCi/l)	1.40	15 (3)			
Gross Beta (pCi/l)	7.90	50 (4 mrem/yr)			
Tritium (pCi/l)	270	20,000 (2)			

EXPLANATION OF TABLE
* = secondary maximum contaminant level
NOTE: Units in micrograms per liter (mg/l), unless otherwise noted

AWQC = Ambient Water Quality Criteria
CWA = Clean Water Act
pCi/l = picocuries per liter
SDWA = Safe Drinking Water Act

(1) hardness dependent criteria
(2) if both strontium-90 and tritium are present, the sum of their annual dose equivalents to bone marrow shall not exceed 4 mrem/yr.
(3) Value for gross alpha excludes uranium
(a) EPA National Primary and Secondary Drinking Water Regulations, 40 CFR 141 and 40 CFR 143 (as of May 1990).
(b) EPA National Primary and Secondary Drinking Water Regulations, 40 CFR Parts 141, 142 and 143, Final Rule, effective July 30, 1992 (56 Federal Register 3526; 1/30/1991).
(c) EPA, Quality Criteria for Protection of Aquatic Life, 1986
(d) EPA, National Ambient Water Quality Criteria for Selenium - 1987
(e) EPA, National Ambient Water Quality Criteria for Chloride - 1988
(f) EPA National Primary and Secondary Drinking Water Regulations, 40 CFR Parts 141, 142, and 143, Final Rule (56 FR 30266; 7/1/1991) effective 1/1/1993.

Section 5.0 · Tables

Contaminant Fate and Transport

Phase III RFI/RI Report

U1 OU1 OU
881 Hillside
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Hillside 881
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side 881 Hill
U1 OU1 OU
881 Hillside
OU1 OU1 O
Hillside 881

Table 5-1 Fraction of Organic Carbon Content in OU1 Boreholes

Well/Borehole Number	Sample Interval: Soils (0 - 6 feet)	Sample Interval: Alluvium/Colluvium (6 feet - bedrock)	Sample Interval: Bedrock
37291	0.0008	—	—
37291	—	0.0007	—
37391	0.0110	—	—
37391	—	0.003	—
37491	0.00001 (ND)	—	—
37491	—	0.0001 (ND)	—
37591	0.0130	—	—
37591	—	0.0001 (ND)	—
37691	0.0060	—	—
37691	0.0090	—	—
37691	—	0.0001 (ND)	—
37891	0.0001 (ND)	—	—
37891	—	0.0001 (ND)	—
37891	—	0.0001 (ND)	—
37891	—	—	0.0006
37991	0.0001 (ND)	—	—
37991	—	0.0001 (ND)	—
37991	—	—	0.011
38091	0.0040	—	—
38591	—	0.001	—
38991	—	—	0.0001 (ND)
38991	0.0230	—	—
38991	—	0.018	—
39191	0.0038	—	—
39191	—	0.0001 (ND)	—
39191	—	—	0.0001 (ND)
	Mean = 0.0064	Mean = 0.0021	Mean = 0.0029

(ND) = Actual value was <0.0005 and reported as Non-Detect. Assumed value was 0.0001 for calculation purposes.

Table 5-2 Summary of Geotechnical Results for Unconsolidated Surficial Geologic Materials at OU1

Borehole	Sampled Depth Interval (feet)	Sand (%)	Silt (%)	Clay (%)	Total* Porosity (%)	Moisture Content (% dry weight)	Dry Density (g/cm^3)
Surficial Soils							
37391	2.55- 2.80	44	19	37	42.8	22.1	1.58
37491	2.7-3.25	44	26	30	33.8	17.4	1.81
37591	3.0-3.5	38	13	49	45.3	24.9	1.54
37891	0.8-1.35	33	22	45	43.0	13.3	1.72
37991	3.0-3.75	6	13	81	38.8	15.2	1.82
38991	1.5-2.0	43	19	38	44.5	14.5	1.56
39191	3.0-3.5	11	16	73	45.1	21.0	1.64
39691	5.0-5.5	28	29	43	36.3	17.4	1.75
	Mean =	31	20	50	41.2	18.2	1.68
Alluvium/Colluvium							
37391	11.0-12.0	27	27	46	44.6	25.8	1.65
37591	6.95-7.70	64	11	25	31.5	12.6	1.82
37691	13.5-13.8	56	14	30	35.9	18.4	1.78
38991	11.5-12.0	24	24	52	37.5	10.1	1.83
	Mean =	43	19	38	37.4	16.7	1.77
Overall Mean for Surficial Materials =		35	19	46	39.9	17.7	1.71

% = percent
g/cm^3 = grams per cubic centimeter
* = Total porosity determined by gravimetric difference. Effective porosities range from 10%-20%, as determined by hydrologic field data.

Table 5-3 Summary of Geotechnical Results for Bedrock Geologic Materials at OU1

Borehole	Sampled Depth Interval (feet)	Sandstone (%)	Siltstone (%)	Claystone (%)	Total* Porosity (%)	Moisture Content (% dry weight)	Dry Density (g/cm^3)
Bedrock							
37891	7.2-7.75	27	26	47	42.3	21.5	1.59
37891	10.0-10.45	2	16	82	45.4	21.7	1.61
37891	45.7-46.4	8	64	28	42.3	14.8	1.61
37991	11.0-11.65	3	17	80	43.8	22.7	1.66
37991	46.5-48.0	14	50	36	44.5	15.1	1.47
38991	20.9-21.4	2	21	77	44.9	21.4	1.70
39191	11.5-11.75	10	43	47	31.8	12.0	1.98
39191	42.0-42.5	4	57	39	41.1	15.6	1.76
	Mean =	9	37	54	42.0	18.1	1.67

% = percent
g/cm^3 = grams per cubic centimeter
* = by gravimetric difference method. Bedrok effective porosities estimated at 10%-20%

Table 5-4 Surface Areas, Cation Exchange Capacities, and Isoelectric Points for Selected Natural Materials

Material	Surface Area (m^2/gram)	Cation-Exchange Capacity (meq/100 grams)	Isoelectric Point (pH)
Soil			
Sandy Loam	10-40	2-18	—
Loam	50-100	8-22	—
Silt Loam	50-150	9-27	—
Silty Clay Loan	120-200	4-32	—
Clay	150-250	5-60	—
Soil Clay Minerals			
Kaolinite	5-50	3-15	3.5 - 4.6
Halloysite	21-43	5-10	—
Chlorite	25-40	10-40	—
Illite	100-200	10-40	—
Montmorillonite	700-800	80-150	2.5
Vermiculite	750-800	100-150	—
Allophane	145-900	25-70	—
Imogolite	900-1100	—	—

Modified from: Dragun 1988; Drever 1988; Stumm and Morgan 1981; Birkeland 1984; and Faure 1991
— = Data unavailable
m^2/gram = square meters per gram
meq/100 grams = milliequivalents per 100 grams

Table 5-4 Surface Areas, Cation Exchange Capacities, and Isoelectric Points for Selected Natural Materials

Material	Surface Area (m^2/gram)	Cation-Exchange Capacity (meq/100 grams)	Isoelectric Point (pH)
Sesquioxides			
Iron Oxides			
Goethite (FeOOH)	14-90	4	6-7
Hematite (Fe_2O_3)	34-45	—	6-7
Magnetite	—	—	6.5
Aluminum Oxides			
Gibbsite ($Al(OH)_3$)	—	4	5-9
Al_2O_3	—	—	9.1
Manganese Oxides			
MnO_2	—	—	2 - 4.5
Quartz			
Spherical (SiO_2)	2	2-7	1-2
Calcite ($CaCO_3$)	12.5	—	—

Modified from: Dragun 1988; Drever 1988; Stumm and Morgan 1981; Birkeland 1984; and Faure 1991
— = Data unavailable
m^2/gram = square meters per gram
meq/100 grams = milliequivalents per 100 grams

Table 5-5 Trace Elements Potentially Coprecipitated with Secondary Soil Minerals

Solid	Coprecipitated Trace Elements
Fe and Al oxides	B, P, V, Mn, Ni, Cu, Zn, Mo, As, Se
Mn oxides	P, Fe, Co, Ni, Zn, Mo, As, Se, Pb
Ca carbonates	P, V, Mn, Fe, Co, Cd
Illites	B, V, Ni, Co, Cr, Cu, Zn, Mo, As, Se, Pb
Smectites	B, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Pb

From: Sposito 1989

Table 5-6 Surface and Subsurface Soil and Groundwater pH Values at OU1

IHSS	Number of Measurements	pH Range Minimum	pH Range Maximum	Mean Value
Surface Soil	18	6.4	8.2	7.85
Subsurface Soils				
102	8	7.65	8.20	7.89
103	14	7.40	8.25	7.81
104	4	7.25	8.05	7.73
881 Building Area (105.1, 105.2, 106, 107, 145, 177)	13	7.05	8.60	7.93
119.1	19	7.15	8.10	7.63
119.2	9	7.20	8.40	7.99
130	27	7.10	8.60	7.81
Former Retention Pond	6	7.30	8.00	7.82
Nonsource Areas	24	7.05	8.20	7.73
Totals	**124**	**Mean = 7.05**	**8.60**	**7.80**
Groundwater		6.95	8.38	7.59

IHSS = Individual Hazardous Substance Site

Table 5-7 Chemical and Physical Characteristics of Dissolved Species in Ground Water for Monitoring Wells 35691 and 31891 at OU1, Sampled Fourth Quarter 1991

Parameter	35691 (upgradient)	31891 (downgradient)
Temperature, °C	11.2	11.6
Dissolved Oxygen	5.9	4.4
pH (s.u.)	7.43	7.52
Eh (mV)	0.808	0.800
Ca	182	91.5
Mg	45.6	22.1
Na	137	59.8
Cl	120	77
SO_4	480	110
HCO_3	450	320
$H_4 SiO_4$	9.3	6.6
Fe	0.703	0.398
PO_4	0.02	0.02
Sr	1.31	0.674
F	1.1	1.0
NO_3/NO_2	0.04	0.05
Mn	0.386	0.1
Cr	0.0198	—
TDS	1200	510

(All values are in mg/L unless otherwise noted.)

Table 5-8 Calculated Saturation Indices of Selected Mineral Phases in Ground Water at Monitoring Wells 35691 and 31891 at OU1 Using WATEQ

Mineral Phase	Formula	Well No. 35691	Well No. 31891
Aragonite	$CaCO_3$	+0.3	+0.1
Calcite	$CaCO_3$	+0.4	+0.3
Gypsum	$CaSO_4 \cdot 2H_2O$	-0.7	-1.4
Ferrihydrite	$Fe(OH)_3$	+2.8	+2.6
Goethite	FeOOH	+9.3	+9.2
Hematite	α - Fe_2O_3	+18.2	+17.9
Maghemite	γ - Fe_2O_3	+8.9	+8.6
Strengite	$FePO_4 \cdot 2H_2O$	-0.6	-0.8
Magnesite	$MgCO_3$	-0.3	-0.5
Pyrolusite	MnO_2	+9.5	+9.1
Bixbyite	Mn_2O_3	+9.4	+8.7
Manganite	MnOOH	+4.9	+4.6
Quartz	SiO_2	+0.4	+0.3
Celestite	$SrSO_4$	-1.2	-1.4
Strontianite	$SrCO_3$	-1.3	-1.9

Note: Values less than zero (negative values) indicate that dissolved concentrations are undersaturated with respect to the solid phase.
Values of zero indicate dissolved concentrations are in equilibrium with the solid phase.
Values grater than zero (positive values) indicate dissolved concentrations are supersaturated with respect to the solid phase.

Table 5-9 Physical and Chemical Properties of Volatile Organic Compounds at OU1

Compound	CAS No.	Formula	Molecular Weight (g/mol)	Physical State	Density (g/ml)*	Aqueous Solubility (mg/l)**	Vapor Pressure (mm Hg)*	Henry's Law Constant (atm-m2/mol)*	Koc (mL/g)**	KOW**	Soil Half-Lives	Groundrater Half Lives	Hydrolysis Half-Life#
Tetrachloroethene	127-18-4	C_2Cl_4	165.8	Liquid	1.63	150	17.8	0.0259	364	398	6mo-12mo	12mo-2yr	–
Trichloroethene	79-01-6	C_2HCl_3	131.5	Liquid	1.46	1100	57.9	0.0091	126	240	6mo-12mo	10.7mo-4.5yr	10.7mo
1,1,1-Trichloroethane	71-55-6	C_2HCl_3	133.4	Liquid	1.35	1500	123	0.0144	152	316	20wk-39wk	20wk-78wk	8mo
1,1,2-Trichloroethane	79-00-5	$C_2H_3Cl_2$	133.4	Liquid	1.44	4500	30	0.00117	56	295	4.5mo-12mo	4.5mo-2yr	37yr
cis-1,2-Dichloroethylene	156-59-2	$C_2H_3Cl_2$	97	Liquid	1.28	3500	208	0.00758	49	5.01	4wk-6mo	8wk-95mo	–
trans-1,2-Dichloroethylene	156-60-5	$C_2H_3Cl_2$	97	Liquid	1.26	6300	324	0.00656	59	3.02	4wk-6mo	8wk-95mo	–
1,1-Dichloroethane	75-35-4	$C_2H_3Cl_2$	97	Liquid	1.22	2250	600	0.034	65	69.2	4wk-6mo	8wk-19wk	–
1,1-Dichloroethene	75-34-3	$C_2H_3Cl_2$	99	Liquid	1.17	5500	182	0.00431	30	61.7	4.5wk-22wk	9wk-22wk	–
1,2-Dichloroethane	107-06-2	$C_2H_3Cl_2$	99	Liquid	1.26	8520	64	0.000978	14	30.2	14wk-12mo	14wk-12mo	1.1yr
Chloroform	67-66-3	$CHCl_3$	119.4	Liquid	1.49	8200	151	0.00287	47	93.3	8wk-5yr	8wk-5yr	3500yr
Carbon Tetrachloride	56-23-5	CCl_4	153.8	Liquid	1.59	757	90	0.0241	439	437	6mo-1yr	1wk-1yr	7000yr
Methylene Chloride	75-09-2	$C_2H_3Cl_2$	84.9	Liquid	1.33	20000	362	0.00203	8.8	20	1wk-4wk	2wk-8wk	704yr

* Data from Schwille (1988)
** Data from USEPA (1986)
\# Data from Howard et al. (1991)

Table 5-10 Physical and Chemical Properties of Semivolatile Organic Compounds at OU1

Compound	CAS No.	Formula	Molecular Weight (g/mol)	Physical State	Density (g/ml)*	Aqueous Solubility (mg/l)*	Vapor Pressure (mm Hg)*	Henry's Law Constant (atm-m2/mol)*	Log Koc (mL/g)*	Log Kow**	Soil Half-Lives#	Ground Water Half Lives#	Photooxidation (air) Half-Life#
Acenaphthene	83-32-9	$C_{12}H_{10}$	154.2	solid	1.024	3.42	10 (132°C)	0.006	3.92	3.4	12d-100d	3h-60h	1h-8h
AROCLOR-1254	11097-69-1	$C_{12}H_6C_{14}$	327	liquid	1.5	0.057	7.7E-5	0.0156	6.47	5.61	NA	–	NA
Benzo(a)anthracene	56-55-3	$C_{18}H_{12}$	228.3	solid	NA	0.014	5.0	NA	5.61	5.7-6.3	10d-2y	1h-3h	1h-8h
Benzo(a)pyrene	50-32-8	$C_{20}H_{12}$	252.3	solid	1.35	0.0038	5E-9	2.0E-5	5.98	6.74	60d-1.5y	0.4h-1h	0.5h-4h
Benzo(b)fluoranthene	205-99-2	$C_{20}H_{12}$	252.3	solid	NA	0.0012	5.0×10^{-7}	NA	6.12	NA	1y-2y	9h-720h	1.5h-14h
Benzo(k)fluoranthene	207-08-9	$C_{20}H_{12}$	252.3	solid	NA	0.00076	9.6E-11	1.7E-6	6.84	6.0	2.5-6y	3.8h-500h	1hr-11h
Dibenzo(a,h)anthracene	53-70-3	$C_{22}H_{14}$	278.4	solid	1.28	0.0005	1.0E-10	3E-6	6.5	6.3	1y-2.5y	6h-30d	0.5h-4h
Fluoranthene	206-44-0	$C_{16}H_{10}$	202.3	solid	1.25	0.265	NA	2.71E-4	4.9	4.90	140d-440d	280d-2.4y	2h-20h
Fluorene	86-73-7	$C_{13}H_{10}$	166.2	solid	1.20	1.9	10 (146°C)	4.88E-3	4.18	4.18	30d-60d	6.4d-120d	7h-3d
Pyrene	129-00-0	$C_{16}H_{10}$	202.3	solid	1.27	0.16	6.85E-7	2.13E-4	4.88	2.84	200d-5.2y	0.7h-2h	1h-8h
Other Semivolatiles													
Anthracene	120-12-7	$C_{14}H_{10}$	178.2	solid	1.28	1.29	4.8E-4	3.58E-3	4.45	4.41	50d-1.3y	100d-2.5y	0.5-5.0h
AROCLOR-1248	12672-29-6	$C_{12}H_5Cl_5$	288	liquid	1.41	0.054	4.94E-4	0.202	6.11	5.64	—	—	—
Benzo(ghi)perylene	191-24-2	$C_{12}H_{12}$	276.3	solid	NA	0.00026	1.9E-10	6.6E-5	6.58	5.0	1.6y-1.8y	3.2y-3.6y	0.3h-3h
Chrysene	218-01-9	$C_{18}H_{12}$	228.3	solid	1.27	0.003	6.3E-7	9.4E-8	5.61	5.57	1.0y-2.7y	2.0y-5.5y	1h-8h
Dibenzofuran	132-64-9	$C_{12}H_8O$	168.2	solid	1.09	10.0	4.4E-3	3.98E-3	4.12	3.77	1d-7d	2d-14d	2h-19h
Indeno (1,2,3-cd)pyrene	193-39-5	$C_{22}H_{12}$	276.3	solid	NA	0.062	1.0E-10	2.4E-8	6.6	4.3	1.6y-2.0y	3.3y-4.0y	0.6h-6h
Naphthalene	91-20-3	$C_{10}H_8$	128.2	solid	1.03	30	0.082	2.01E-2	3.29	2.97	16.6f-48f	258d	3h-30h
Phenanthrene	85-01-8	$C_{14}H_{10}$	178.2	solid	0.98	0.816	1.0	1.64E-3	4.46	4.36	16f-200f	32d-1.1y	–

– = No data found
* = Data from Tomes Data Base (1992)
\# = Data from Howard et al. (1991)
h = hour
d = days
y = years

Table 5-11 Concentrations of Chlorinated Hydrocarbons at IHSS 119.1

Well	Analyte	First Quarter 1991		Second Quarter 1991		Third Quarter 1991		Fourth Quarter 1992		First Quarter 1992	
		Conc. µg/l	% Sol.	Conc. µg/l	% Sol.	Conc. µg/l	% Sol.	Conc. µg/l	% Sol.	Conc. µg/l	% Sol.
0974	1,1,1-Trichloroethane			13000	0.87	14000	0.93	7600	0.51	4400E	0.29
	Tetrachloroethene			2300	1.5	3000	2	1800	1.2	1500E	1
	Trichloroethene	NO DATA		13000	1.2	14000	1.3	9800	0.9	4400E	0.4
	1,1-Dichloroethylene			—	—	18000	0.8	7900	0.35	5800E	0.26
	1,2-Dichloroethylene			14000	0.4	—	—	—	—	30	<.001
	1,1,2-Trichloroethane			—	—	—	—	—	—	72	0.002
	1,1-Dichloroethane			—	—	—	—	—	—	20	<0.001
	1,2-Dichloroethane			—	—	—	—	—	—	22	<0.001
	Chloroform			—	—	—	—	—	—	3J	<0.001
	Methylene Chloride			—	—	—	—	—	—	27	<0.001
1074	Trichloroethene			1300 D	0.12	1200	0.11	860	0.08	1200	0.11
	Chloroform	NO DATA		81 DJ	0.001	87 J	0.001	78	0.001	92J	0.001
	Carbon Tetrachloride			3100 E	0.41	3800	0.5	2200 E	0.29	3400	0.45
4387	1,1,1-Trichloroethane	5900	0.39	4500	0.3	10000	0.67	20000	1.33	4600E	0.31
	Tetrachloroethene	2900	1.93	2000	1.3	5700	3.8	5700	3.8	4200E	2.8
	Trichloroethene	5300	0.48	2700	0.24	8700	0.8	11000	1	4700E	0.43
	1,1-Dichloroethylene	2900	.13	3600	.16	7200	.32	7900	.35	4800E	0.21
	1,2-Dichloroethylene	ND	—	17	<.0001	ND	—	ND	—	12	<0.001
	1,1,2-Trichloroethane	—	—	—	—	—	—	—	—	—	<0.001

Table 5-11 Concentrations of Chlorinated Hydrocarbons at IHSS 119.1

Well	Analyte	First Quarter 1991		Second Quarter 1991		Third Quarter 1991		Fourth Quarter 1992		First Quarter 1992	
		Conc. µg/l	% Sol.	Conc. µg/l	% Sol.	Conc. µg/l	% Sol.	Conc. µg/l	% Sol.	Conc. µg/l	% Sol.
4387 (cont.)	1,1-Dichloroethane	—	—	—	—	—	—	—	—	—	<0.001
	1,2-Dichloroethane	—	—	—	—	—	—	—	—	—	<0.001
	Chloroform	—	—	—	—	—	—	—	—	—	<0.001
	Methylene Chloride	—	—	—	—	—	—	—	—	—	<0.001

µg/l = micrograms per liter
ND = Not Detected
E = estimated (exceeded calibration range of instrument)
D = secondary dilution factor
J = estimated
— = No Data

Analyte	Solubility
1,1,1-Trichloroethane	= 1500 milligrams/liter (mg/l)
Tetrachloroethene	= 150 mg/l
Trichloroethene	= 1100 mg/l
1,1-Dichloroethylene	= 2250 mg/l
cis-1,2-Dichloroethylene	= 3500 mg/l
Chloroform	= 8200 mg/l
Carbon tetrachloride	= 757 mg/l
1,1,2-Trichloroethane	= 4500 mg/l
1,1-Dichloroethane	= 5500 mg/l
1,2-Dichloroethane	= 8520 mg/l
Methylene Chloride	= 20,000 mg/l

(Data from EPA, 1986b)

Table 5-12 Calculated Critical Levels Of Organic Carbon (f_{oc}*) for Chlorinated Hydrocarbons at OU1 (after McCarty et al. 1981)

Compound	K_{ow}	A. f_{oc}* (20%)	B. f_{oc}* (80%)
1,1,1-trichloroethane	316	0.0003	0.001
1,1,2-trichloroethane	295	0.0003	0.001
1,1-dichloroethene	69	0.001	0.004
cis-1,2-dichloroethene	5	0.01	0.004
trichloroethene	240	0.0004	0.0015
tetrachloroethene	398	0.0003	0.001
carbon tetrachloride	437	0.0002	0.0009
chloroform	93	0.0008	0.003
1,1-dichloroethane	62	0.001	0.005
1,2-dichloroethane	30	0.002	0.009
methylene chloride	20	0.003	0.01

Surface areas were calculated using a site-wide average of 38.2% clay for alluvium/colluvium materials and assuming a smectite (montmorillonite) content ranging from 20% to 80% with smectites having a theoretical surface area of 100 m^2/gram of material.

A. Surface area calculated as follows: 38.2% x 0.20 = 7.64% x 100 m^2/g = 7.64 m^2/g

B. Surface area calculated as follows: 38.2% x 0.80 = 30.6% x 100 m^2/g = 30.6 m^2/g

$$f_{oc}^* = \frac{SA\ (m^2/gram)}{200\ (kow)}$$

Table 5-13 Calculation of Distribution Coefficients and Retardation Values for Chlorinated Hydrocarbons at OU1

Compound	K_{oc}[1] (ml g^{-1})	K_d[2]	K_{ow}[3]	K_s (20%)[4]	K_s (80%)[5]	Total K_d (20%)[6]	Total K_d (80%)[7]	R_f (20%)[8]	R_f (80%)[9]
1,1,1-trichloroethane	152	0.015	316	0.096	0.384	0.111	0.399	2.96	8.1
1,1-dichloroethene	65	0.0065	69	0.075	0.301	0.082	0.308	2.4	6.4
Cis-1,2-dichloroethene	49	0.005	5	0.049	0.198	0.054	0.203	1.9	4.6
trichloroethene	126	0.013	240	0.092	0.367	0.105	0.38	2.8	7.7
tetrachloroethene	364	0.036	398	0.099	0.398	0.135	0.434	3.4	8.6
carbon tetrachloride	439	0.044	437	0.101	0.405	0.15	0.45	3.6	9.0
chloroform	47	0.0047	93	0.079	0.317	0.083	0.321	2.5	6.7
1,1,2-trichloroethane	56	0.0056	295	0.095	0.38	0.1	0.38	2.8	7.7
1,1-dichloroethane	30	0.003	62	0.074	0.297	0.077	0.3	2.4	6.3
1,2-dichloroethane	14	0.0014	30	0.066	0.263	0.067	0.26	2.2	5.6
methylene chloride	8.8	0.0009	20	0.06	0.25	0.061	0.251	2.1	5.4

1. Organic Carbon Partition Coefficient (data from EPA 1986b).
2. Organic Carbon Distribution Coefficient (based on foc = 0.0001 where: Kd = foc x Koc) and f_{oc} = 0.0001
3. Octanol-Water Partition Coefficient (data from EPA, 1986b)
4. Surface Specific Distribution Coefficient (assuming 20% smectite fraction of total clays, SA=7.64 m^2/g)
5. Surface specific Distribution Coefficient (assuming 80% smectite fraction of total clays. SA = 30.6 m^2/g)
6. Total Kd by addition of Ks (20%) and organic carbon distribution coefficient, Kd.
7. Total Kd by addition of Ks (80%) and organic carbon distribution coefficient, Kd.
8. Retardation factor calculated using Total Kd (20%)[6]
9. Retardation factor calculated using Total Kd (20%)[7]

$$\text{Retardation Factor} = 1 + \left(\frac{P\,K_{d\,(T)}}{n}\right)$$ where: p = dry density = 1.77 g/cm^3, n = porosity = 37.4%, $K_{d\,(T)}$ = total K_d

Table 5-14 Nuclear Properties of Radionuclide Species Detected at OU1

Radionuclide Species	Symbol	Half-life	Mode of Decay	Principal Decay Products (1/2-life > 1 year)	Specific Activity (pCi/mg)	Occurrence (% of natural)
Americium 241	$_{95}Am^{241}$	458 yr	α, γ	$_{93}Np^{237}, _{92}U^{233}$	3.24×10^{9}	0
Cesium 137	$_{55}Cs^{137}$	30.2 yr	β^-, γ, e^-	$_{56}Ba^{137}$	8.7×10^{10}	0
Plutonium 239	$_{94}Pu^{239}$	24,400 yr	α, γ	$_{92}U^{235}$	6.13×10^{7}	trace
Plutonium 240	$_{94}Pu^{240}$	6,580 yr	α, γ	$_{92}U^{236}$	2.27×10^{8}	0
Radium 226	$_{88}Ra^{226}$	1,602 yr	α, γ	$_{82}Pb^{210}, _{82}Pb^{206}$	9.88×10^{8}	100
Radium 228	$_{88}RA^{228}$	5.77 yr	β^-, γ	$_{90}Th^{228}, _{82}Pb^{208}$	2.72×10^{7}	0
Strontium 89	$_{38}Sr^{89}$	52 days	β^-, γ	$_{39}Y^{89}$	2.82×10^{13}	0
Strontium 90	$_{38}Sr^{90}$	28 yr	β^-	$_{40}Zr^{90}$	1.41×10^{7}	0
Tritium	$_{1}H^{3}$	12.26 yr	β^-	$_{2}He^{3}$	9.64×10^{12}	0
Uranium 233	$_{92}U^{233}$	1.62×10^{5} yr	α, γ	$_{90}Th^{229}, _{83}Bi^{209}$	9.48×10^{6}	0
Uranium 234	$_{92}U^{234}$	2.47×10^{5} yr	α, γ	$_{90}Th^{230}, _{88}Ra^{226}$	6.19×10^{6}	0.005
Uranium 235	$_{92}U^{235}$	7.1×10^{8} yr	α, γ	$_{91}Pa,^{231}, _{89}Ac^{227}, _{82}Pb^{207}$	2.14×10^{3}	0.72
Uranium 238	$_{92}U^{238}$	4.51×10^{9} yr	α, γ	$_{92}U^{234}$	3.33×10^{2}	99.275

α = alpha decay
β^- = beta decay
γ = gamma decay
e^- = electron capture

Table 5-15 Range of Distribution Coefficients for Radionuclides at OU1 for Four Major Soil Types*

	Sand		Loam		Clay		Organic – Rich	
Radionuclide	Geometric Mean	Range	Geometric Mean	Range	Geometric Mean	Range	Geometric Mean	Range
Americium	1,900	8-300,000	9,600	400-48,300	8,400	25-400,000	112,000	6,400-450,000
Cesium	280	0.2-10,000	4,600	560-61,200	1,900	37-31,500	270	0.4-145,000
Plutonium	550	27-36,000	1,200	100-6,000	5,100	316-190,000	1,900	60-62,000
Strontium	15	0.05-190	20	0.01-300	110	3.6-32,000	150	8-4,800
Uranium	35	0.03-2,200	15	0.2-4500	1,600	46-395,000	410	33-7,350

* Data from Sheppard and Thibault (1990); all values are in milliliters per gram (ml/g)

Table 5-16 Determination of Uranium-Isotope Ratios in OU1 Surface Soils

OU1	Isotope Activity (pCi/g)			Isotope Mass (g)			Weight %			Activity
Location	U-234	U-235	U-238	U-234	U-235	U-238	U-234	U-235	U-238	234/238
RA001	1.255	0.03671	1.521	2.02E-10	1.72E-08	4.57E-06	0.004408	0.374144	99.62145	0.825115
RA002	1.2394	0.07405	1.1947	2E-10	3.46E-08	3.59E-06	0.00551	0.955221	99.03927	1.037415
RA003	1.18	0.09176	1.306	1.9E-10	4.29E-08	3.92E-06	0.004792	1.081428	98.91378	0.903522
RA004	0.9605	0.03218	0.9524	1.55E-10	1.5E-08	2.86E-06	0.005379	0.522994	99.47163	1.008505
RA005	1.266	0.07436	1.365	2.04E-10	3.47E-08	4.1E-06	0.004931	0.840523	99.15455	0.927473
RA006	1.215	0.01087	1.447	1.96E-10	5.08E-09	4.35E-06	0.004497	0.116752	99.87875	0.839668
RA007	1.285	0.05562	0.8439	2.07E-10	2.6E-08	2.53E-06	0.008082	1.015089	98.97683	1.522692
RA008	1.428	0.02637	1.337	2.3E-10	1.23E-08	4.02E-06	0.005709	0.305952	99.68834	1.068063
RA009	1.472	0.05298	1.389	2.37E-10	2.48E-08	4.17E-06	0.005649	0.589991	99.40436	1.059755
RA010	1.089	0.07489	1.196	1.75E-10	3.5E-08	3.59E-06	0.004835	0.964919	99.03025	0.910535
RA012	1.148	0.05843	1.028	1.85E-10	2.73E-08	3.09E-06	0.005935	0.876644	99.11742	1.116732
RA013	0.7366	0.06091	0.9003	1.19E-10	2.85E-08	2.7E-06	0.004341	1.041753	98.95391	0.818172
RA014	0.9722	0.1036	0.8502	1.57E-10	4.84E-08	2.55E-06	0.006017	1.860738	98.13324	1.143496
RA015	1.393	0.07352	1.516	2.24E-10	3.44E-08	4.55E-06	0.00489	0.748946	99.24616	0.918865
RA016	0.6781	0.03261	0.7637	1.09E-10	1.52E-08	2.29E-06	0.00473	0.660027	99.33524	0.887914
RA017	0.7611	0.05699	0.8466	1.23E-10	2.66E-08	2.54E-06	0.004771	1.036584	98.95865	0.899008
RA018	1.25	0.05301	1.183	2.01E-10	2.48E-08	3.55E-06	0.005626	0.692407	99.30197	1.056636
RA019	1.16	0.02426	1.169	1.87E-10	1.13E-08	3.51E-06	0.005304	0.321872	99.67282	0.992301
RA020	0.9581	0.07895	0.9509	1.54E-10	3.69E-08	2.86E-06	0.005334	1.275409	98,71926	1,007572
RA021	1.662	0.03401	1.769	2.68E-10	1.59E-08	5.31E-06	0.005023	0.298257	99.69672	0.9395114
RA022	1.287	0.09047	1.479	2.07E-10	4.23E-08	4.44E-06	0.0062	0.942828	99.05255	0.870183

Table 5-16 Determination of Uranium-Isotope Ratios in OU1 Surface Soils

OU1	Isotope Activity (pCi/g)			Isotope Mass (g)			Weight %			Activity
Location	U-234	U-235	U-238	U-234	U-235	U-238	U-234	U-235	U-238	234/238
RA023	1.462	0.08075	1.571	2.35E-10	3.77E-08	4.72E-06	0.00495	0.793443	99.20161	0.930617
RA024	1.602	0.03897	1.732	2.58E-10	1.82E-8	5.2E-06	0.004942	0.348878	99.64618	0.924942
RA025	1.494	-0.00581	1.448	2.41E-10	-2.7E-09	4.35E-06	0.005536	-0.06247	100.0569	1.031768
RA026	1.045	0.03379	1.319	1.68E-10	1.58E-08	3.96E-06	0.004231	0.397034	99.59873	0.792267
RA027	1.192	0.02854	1.18	1.92E-10	1.33E-08	3.54E-06	0.005396	0.374928	99.61968	1.010169
RA028	1.296	0.008597	1.502	2.09E-10	4.02E-09	4.51E-06	0.004623	0.088982	99.9064	0.86285
RA029	1.266	0.05302	1.129	2.04E-10	2.48E-08	3.39E-06	0.005969	0.725418	99.26861	1.121346
RA030	1.234	0.0304	0.9403	1.99E-10	1.42E-08	2.82E-06	0.007002	0.500527	99.49247	1.312347
RA031	1.0105	0.05605	1.359	1.63E-10	2.62E-08	4.08E-06	0.003962	0.637663	99.35838	0.743461
RA032	1.155	0.0609	1.304	1.86E-10	2.85E-08	3.92E-06	0.004715	0.721448	99.27384	0.885736
RA033	1.136	0.1037	1.854	1.83E-10	4.85E-08	5.57E-06	0.003257	0.862823	99.13392	0.612729
RA035	1.223	0.05256	1.285	1.97E-10	2.46E-08	3.86E-06	0.005071	0.632419	99.36251	0.951751
RA036	0.8822	0.06435	0.6257	1.42E-10	3.01E-08	1.88E-06	0.007441	1.575017	98.41754	1.409941
RA037	1.088	0.0925	1.0767	1.75E-10	4.32E-08	3.23E-06	0.005347	1.319128	98.67553	1.010495
AVERAGE							0.005224	0.726792	99.26798	0.981533

pCi/g = picoCuries per gram
g = gram
% = percent

Table 5-17 Residential/Commercial Building Concentrations Estimated from Johnson Model

Contaminants of Concern	Residential/Commercial Mean (µg/l)[a]	Residential/Commercial Standard Deviation (µg/l)[a]
Carbon tetrachloride	1.450	2.444
1,1-Dichloroethene	1.631	2.955
Total 1,2-Dichloroethene	1.603	1.543
Tetrachloroethene	-1.064	4.957
1,1,1-Trichloroethane	-1.795	5.908
Trichloroethene	0.156	5.398
Chloroform	0.940	1.986
Methylene Chloride	1.313	1.448
Dichlorodifluoromethane	-1.048	1.069
Trichlorofluoromethane	0.732	1.339

[a] Mean and standard deviations are all natural log values in micrograms per liter (µg/l)
Statistical sampling performed using Latin hypercube method. Results based on 100 simulations

Table 5-18 Estimated Soil Concentrations in Sediments of the South Interceptor Ditch

Contaminants of Concern	95 percent Upper Confidence Limit Surface Soil Concentration	Estimated South Interceptor Ditch Concentration [a] from IHSS 119.1 [b]	Estimated South Interceptor Ditch Concentration [a] from IHSSs 119.1, 119.2 and 130 [c]
Acenaphthene (µg/kg)	1.33E-01	8.42E-03	2.29E-02
Fluoranthene (µg/kg)	3.41E-01	2.16E-02	5.87E-02
Benzo(a)anthracene (µg/kg)	2.92E-01	1.85E-02	5.03E-02
Benzo(a)pyrene (µg/kg)	2.81E-01	1.78E-02	4.84E-02
Benzo(b)fluoranthene (µg/kg)	3.11E-01	1.97E-02	5.35E-02
Benzo(k)fluoranthene (µg/kg)	2.82E-01	1.79E-02	4.86E-02
AROCLOR-1254 (µg/kg)	9.00E-02	5.70E-03	1.55E-02
Fluorene (µg/kg)	1.85E-01	1.17E-02	3.19E-02
Pyrene (µg/kg)	4.40E-01	2.79E-02	7.58E-02
Americium-241 (pCi/g)	2.20E+02	1.39E+01	3.79E+01
Plutonium-239,-240 (pCi/g)	1.35E+03	8.55E+01	2.32E+02
Dibenzo(a,h)anthracene (µg/kg)	1.85E-01	1.17E-02	3.19E-02

[a] Total area above South Inceptor Ditch affected by runoff 1.6×10^6 square ft (see Figure 2-4 of Technical Memorandum No. 7, Appendix F)
[b] Area of IHSS 119.1 = 101,327 square ft
[c] Total area of IHSSs 119.1, 119.2 and 130 = 275,493 square ft

Table 5-19 Results of Far-Field Air Transport Model

Time Step	Concentration in Air */m^3 per */g		Soil Surface Concentration	Concentration in 15 centimeters of Soil
	Particles <10μm	Particles >10μm	*/m^3 per */g	*/g per */g
Year 0-5	3.39×10^{-7}	1.56×10^{-7}	1.60	6.66×10^{-6}
Year 5-10	3.39×10^{-7}	1.57×10^{-7}	3.09	1.29×10^{-5}
Year 10-15	3.40×10^{-7}	1.58×10^{-7}	4.48	1.87×10^{-5}
Year 15-20	3.40×10^{-7}	1.59×10^{-7}	5.78	2.41×10^{-5}
Year 20-25	3.40×10^{-7}	1.60×10^{-7}	6.99	2.91×10^{-5}
Year 25-30	3.41×10^{-7}	1.61×10^{-7}	8.12	3.38×10^{-5}
Average Year 0-30	3.40×10^{-7}	1.58×10^{-7}	5.01	2.09×10^{-5}

* = contaminant unit: pCi for radioactive contaminants, mg for chemical contaminants
*/m^3 per */g = concentration (pCi/m^3) in air at the receptor per concentration (pCi/g) in soil at the source

Table 5-20 Contaminant Concentrations Used in Exposure Models

Chemicals	On-site Indoor Air (mg/m3)	Hot Spot Indoor Air (mg/m3)	Clean Area Indoor Air (mg/m3)	On-site Outside Air (*/m3)	On-site Surf Soil (*/kg)	On-site Sed (*/kg)	On-site Surf Water (*/l)	Off-site Dust (*/m3)	Off-site Soil (*/kg)	Off-site Crops (*/kg)	On-site Crops (*/kg)	On-site Crops (*/kg)
1,1-Dichloroethene	1.00E-03	1.76E-01	2.66E-04	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon Tetrachloride	4.31E-04	4.16E-02	1.78E-04	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dichlorodifluoromethane	1.59E-02	NA	1.40E-02	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene	1.19E-05	3.12E-02	4.79E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total 1,2-Dichloroethene	2.84E-05	3.18E-04	6.11E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trichlorofluoromethane	1.55E-01	NA	1.89E-01	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	3.43E-05	6.15E-01	3.09E-04	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	NA	NA	NA	4.77E-0	1.33E-01	NA	NA	4.52E-11	2.78E-06	5.28E-07	2.29E-02	2.36E-08
Fluoranthene	NA	NA	NA	1.22E-0	3.41E-01	2.71E-01	NA	1.16E+10	7.13E--06	2.99E-07	4.39E-03	2.36E-08
Chloroform	2.04E-05	1.16E-04	1.53E-05	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene Chloride	1.66E-05	1.31E-04	1.93E-05	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trichloroethene	6.06E-05	1.08E-01	3.43E-06	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzeo(a)anthracene	NA	NA	NA	1.05E-0	2.92E-01	NA	NA	9.94E-11	6.11E-06	2.46E-07	6.59E-03	2.36E-08
Benzo(a)pyrene	NA	NA	NA	1.01E-0	2.81E-01	NA	NA	9.54E-11	5.87E-06	1.20E-07	7.86E-04	2.36E-08
Benzo(b)fluoranthene	NA	NA	NA	1.12E-0	3.11E-01	NA	NA	1.06E-10	6.51E-06	1.46E-07	9.16E-04	2.36E-08
Benzo(k)fluoranthene	NA	NA	NA	1.01E-0	2.82E-01	NA	NA	9.60E-11	5.90E-06	1.18E-07	6.44E-04	2.36E-08
AROCLOR-1254	NA	NA	NA	3.23E-0	9.00E-02	5.37E-02	NA	3.06E-11	1.88E-06	9.87E-08	6.71E-04	1.13E-08
Fluorene	NA	NA	NA	6.64E-0	1.85E-01	NA	NA	6.29E-11	3.87E-06	6.47E-07	2.76E-02	2.36E-08
Pyrene	NA	NA	NA	1.58E-0	4.40E-01	6.00E-01	NA	1.50E-10	9.19E-06	3.19E-07	7.42E-03	2.36E-08
Americium-241	NA	NA	NA	7.90E-0	2.20E+02	9.45E+01	1.00E-02	7.48E-08	4.60E-03	5.82E-05	1.80E-01	6.46E-10
Plutonium-239,-240	NA	NA	NA	4.85E-0	1.35E+03	4.77E+02	2.00E-03	4.59E-07	2.82E-02	5.63E-04	3.02E+00	3.32E-10
Dibenzo(a,h)anthracene	NA	NA	NA	6.64E-01	1.85E-01	NA	NA	6.29E-11	3.87E-06	1.57E-07	4.17E-03	2.36E-08

* Units are in mg, or pCi as applicable

Section 6.0 · Tables

Baseline Risk Assessment

Phase III RFI/RI Report

U1 OU1 OU
881 Hillside
OU1 OU1 O
Hillside 881
1 OU1 OU1
side 881 Hill
U1 OU1 OU
881 Hillside
OU1 OU1 O
Hillside 881

Table 6-1 Summary of Key Contaminants and Risks for the Hypothetical Future On-Site Resident

CHEMICALS	RME[a]	"Hotspot"	"Clean"	PERCENTILES 5	10	25	50	75	90	95
1,1-Dichloroethene	1E-5*	2E-3	3E-6	1E-18	4E-18	3E-17	5E-16	8E-15	9E-14	5E-13
Carbon tetrachloride	4E-6	4E-4	2E-6	2E-10	1E-9	1E-8	2E-7	2E-6	3E-5	7E-5
Dibenzo(a,h)anthracene	1E-5	1E-5	1E-5	1E-9	3E-9	1E-8	1E-7	9E-7	2E-6	4E-6
Benzo(a)pyrene	6E-6	6E-6	6E-6	3E-10	8E-10	4E-9	2E-8	2E-7	7E-7	1E-6
Benzo(a)anthracene	2E-6	2E-6	2E-6	3E-10	8E-10	3E-9	2E-8	1E-7	5E-7	8E-7
Benzo(a)fluoranthene	6E-7	6E-7	6E-7	4E-11	1E-10	4E-10	2E-9	2E-8	8E-8	1E-7
Benzo(k)fluoranthene	5E-7	5E-7	5E-7	2E-11	6E-11	3E-10	2E-9	1E-8	5E-8	8E-8
AROCLOR-1254	3E-6	3E-6	3E-6	1E-8	3E-8	8E-8	2E-7	6E-7	1E-6	2E-6
TOTAL	**4E-5**	**2E-3**	**3E-5**	**1E-8**	**4E-8**	**1E-7**	**5E-7**	**4E-6**	**3E-5**	**8E-5**

[a] Point estimate using the Environmental Protection Agency's reasonable maximum exposure (RME) method

* 1E-5 is equivalent to 1×10^{-5}