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**FINAL
TECHNICAL MEMORANDUM NO. 1
OU-2 SUBSURFACE IM/IRA
SOIL VAPOR EXTRACTION PILOT TEST
SITE NO. 1**

Rocky Flats Plant

(Operable Unit No. 2)

U.S. DEPARTMENT OF ENERGY

**Rocky Flats Plant
Golden, Colorado**

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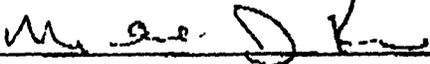
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Final OU-2 Subsurface IM/IRA	Revision No	00
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	Organization	Environmental Science and Engineering
	Effective Date	3/11/94

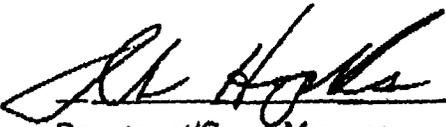
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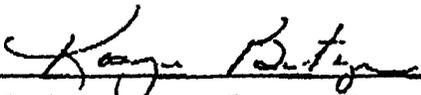
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Environmental Restoration

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Environmental Restoration

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LIST OF ACRONYMS

µg/kg microgram per kilogram
µg/l micrograms per liter
bgs below ground surface
CHCs chlorinated hydrocarbons
CLP Contract Laboratory Procedure
cm/s centimeters per second
CMS/FS Corrective Measure Study/Feasibility Study
COIs chemicals of interest
DNAPL Dense Non Aqueous Phase Liquids
DOE/RFO Department of Energy/Rocky Flats Office
DQO Data Quality Objectives
EM electromagnetics
FS Feasibility Study
GAC Granular Activated Carbon
gpm gallons per minute
GPR ground penetrating radar
GSSI Geophysical Survey Systems, Inc
HAP hazardous air pollutant
HCl hydrogen chloride
IHSS Individual Hazardous Substance Site
IM/IRAP Interim Measure/Interim Remedial Action Plan
LNAPL Light Non Aqueous Phase Liquids
lbs/hr pounds per hour
LHSU lower hydrostratigraphic unit
MDL Method Detection Limit
MPE major purchased equipment
NAPL Non Aqueous Phase Liquid
O&M operations and maintenance
OU-2 Operable Unit 2
PAHs polyaromatic hydrocarbons
PCB polychlorinated biphenyl

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PCE	tetrachloroethene
PFD	process flow diagram
PID	photoionization detector
ppb	parts per billion
ppm v/v	parts per million volume
psig	pounds per square inch gauge
RFA	Rocky Flats Alluvium
RFEDS	Rocky Flats Environmental Data System
RFI	Remedial Facility Investigation
RI	Remedial Investigation
scfm	standard cubic feet per minute
SIR	Subsurface Interface Radar
SO	System Operations
SOPs	standard operating procedures
SVE	Soil Vapor Extraction
SVOCs	semi-volatile organic compounds
TCE	trichloroethene
TM	Technical Memorandum
USHU	upper hydrostratigraphic unit
UTLs	upper tolerance limits
VOC	volatile organic compound

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1.0 INTRODUCTION

1.1 PROJECT OVERVIEW

In September 1992, the Department of Energy/Rocky Flats Office (DOE/RFO) released a final Subsurface Interim Measure/Interim Remedial Action Plan (IM/IRAP) to investigate the removal of VOC contamination from three areas within Operable Unit 2 (OU-2). Specifically, the Soil Vapor Extraction (SVE) technology would be pilot tested within, or adjacent to, suspected volatile organic compound (VOC) source areas in the 903 Pad, Mound and East Trenches. The Final Pilot Test Plan for the SVE technology was submitted to CDH and EPA in January 1993, for Pilot Test No. 1 at the East Trenches (DOE 1993 C).

In 1993, a pilot SVE unit was fabricated off site and installed at Trench T-3 located within Individual Hazardous Substance Site (IHSS) 110 within OU-2. Pilot testing of SVE is scheduled for February 1994.

1.2 MEMORANDUM OBJECTIVES

The purpose of this Technical Memorandum (TM) is to evaluate the impact of the Non Aqueous Phase Liquid (NAPL) on the SVE pilot equipment modifications and test objectives. This includes evaluating the treatment of extracted soil gas at high organic concentrations and the potential transport of the NAPL in the subsurface during the pilot test. This document is not intended to provide alternatives to address the remediation of the NAPL soil gas extracted by the SVE at IHSS 110. This TM will utilize the information from soil gas surveys, the OU-2 remedial investigation, design changes and engineering evaluations to identify whether the objectives of the pilot test plan can be achieved or if they need to be modified.

1.3 ORGANIZATION

The following is a brief discussion of the Technical Memorandum Organization

- 1 0 Introduction

This section will present a project overview and include the TM objectives and organization

- 2 0 Site Conditions

This section will contain background information on IHSS 110 using existing data, including the new soil gas survey data collected by others

- 3 0 Evaluation of Proposed Pilot Test

This section will review Data Quality Objectives (DQOs) as noted in the Final OU-2 Subsurface IM/IRA Pilot Plan including an estimate of soil gas and groundwater extraction rates based on available physical and chemical data.

- 4 0 Evaluation of the Interactive Influences between the Pilot Tests and NAPL Transport

A simple conceptual model will be presented describing the transport of NAPL at the site and the impact of this transport on the SVE test

- 5 0 Changes to Pilot Test Program

This section will identify and summarize issues and changes to SVE pilot test program

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2 0 SITE CONDITIONS

Trench T-3 (IHSS 110) is located north of Central Avenue, east of the inner fence, and south of South Walnut Creek. Sanitary sewage sludge contaminated with depleted uranium and plutonium and flattened drums contaminated with depleted uranium were buried at this trench. This trench was used from 1954 to 1963 (DOE 1991a, DOE 1992a).

The following sections will discuss the geology, hydrogeology, all field investigations performed to characterize the trench, an evaluation of the nature and extent of contamination, the presence of NAPLs, and results from the geophysical survey in and beneath Trench T-3. This information will be used in Sections 3 0 and 4 0 to evaluate contaminant impacts on the Pilot Test.

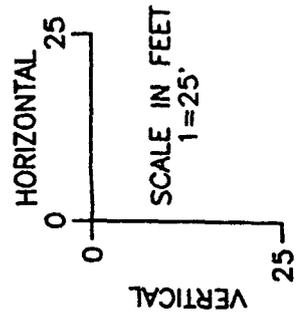
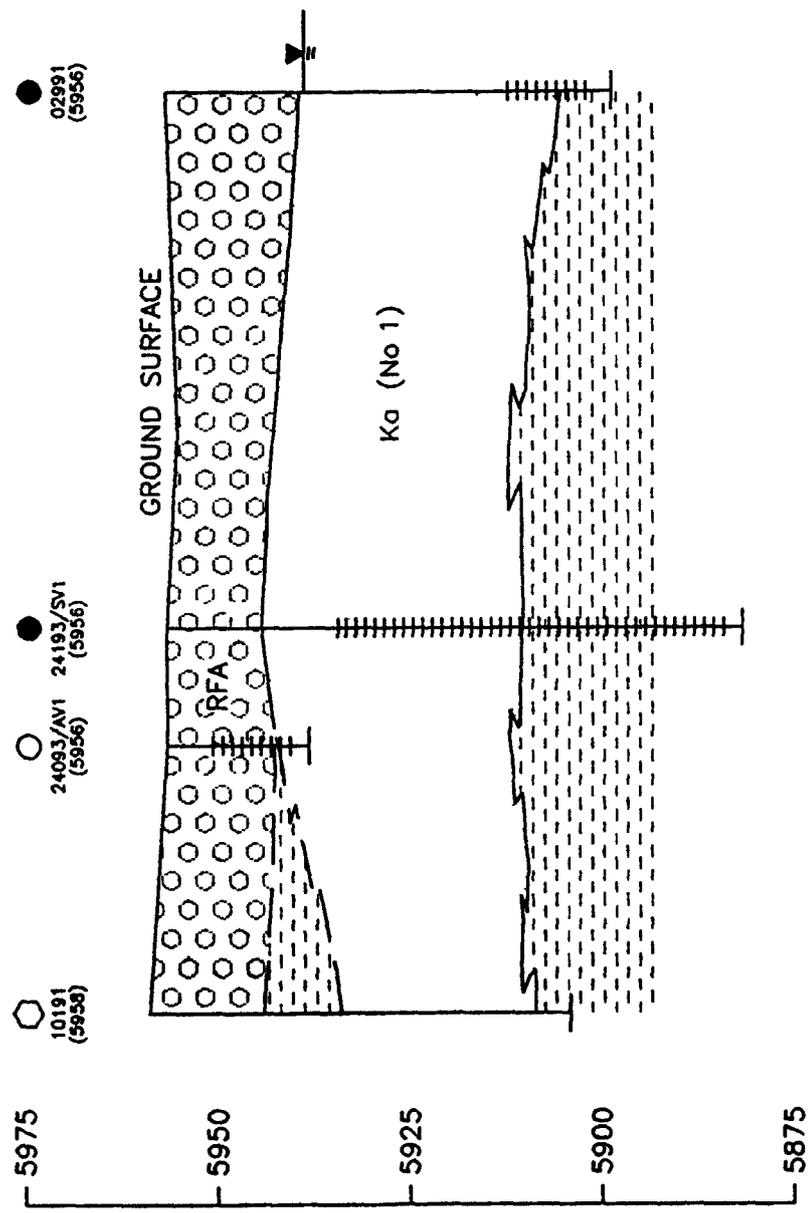
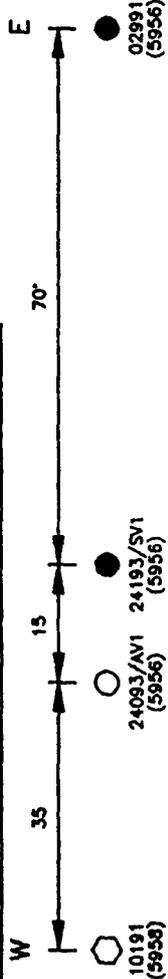
2.1 GEOLOGY AND HYDROGEOLOGY

The east trenches including Trench T-3 are underlain by Rocky Flats Alluvium (RFA) which is the topographically highest and oldest alluvial deposit beneath RFP (DOE 1993a). The RFA, in the vicinity of Trench T-3, is comprised of sandy gravel (GC and GW) with interbedded clay lenses. Grain size of the RFA ranged from fine-grained sands to cobbles. The thickness of the RFA is approximately 15 to 20 feet beneath the trench.

The Arapahoe Formation unconformably underlies the RFA, and is comprised of sandstones, siltstones, and claystone, as shown on Figure 2 1-1. The sandstone channel sequence of the Arapahoe Formation beneath and around Trench T-3 is referred to as the No 1 Sandstone. This sandstone unit is heterogeneous, moderately to highly friable, and has a range of grain size from very-fine to medium-grained sand. The No 1 Sandstone is estimated to be in contact with RFA (subcropping condition) in the areas south and east of Trench T-3 (DOE 1993a). Based on a review of the subsurface soil samples collected from the SVE boreholes and wells, the No 1 Sandstone is estimated to subcrop beneath RFA near the central and eastern parts of Trench T-3. However, in the western part of the trench (near borehole 10191), the RFA and No 1 Sandstone are separated by approximately 10 feet of claystone.

The contact between the RFA and the underlying bedrock units is highly irregular, due to the erosion of the top of bedrock surface. Therefore, the thickness and geometry of the RFA is controlled by

IHSS 110



EXPLANATION

- BORE HOLE LOCATION
- ALLUVIAL MONITORING WELL LOCATION
- BEDROCK MONITORING WELL LOCATION
- WELL SCREEN INTERVAL
- TOTAL DEPTH OF BORHOLE
- HIGH WATER LEVEL (SECOND QUARTER 1992)
- ROCKY FLATS ALLUVIAL
- CLAYSTONE
- ARAPAHOE FORMATION NO 1 SANDSTONE
- LOCATION SYMBOL
- LOCATION NUMBER
- LOCATION ELEVATION

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OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO 1

WEST/EAST CROSS-SECTION
BENEATH TRENCH T-3
(IHSS 110)

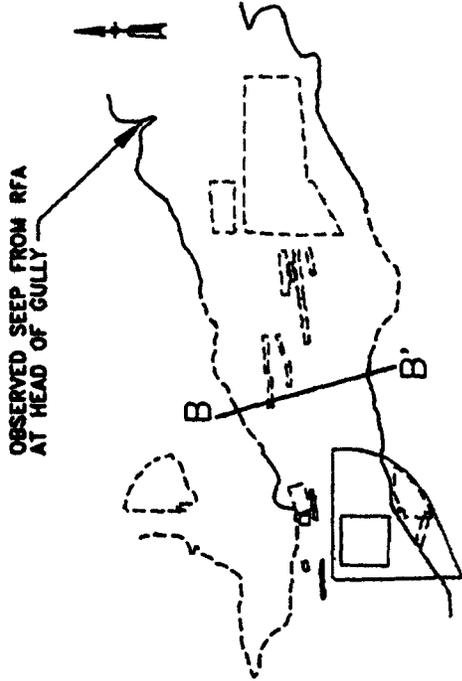
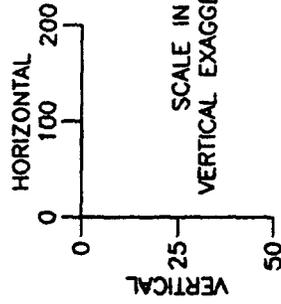
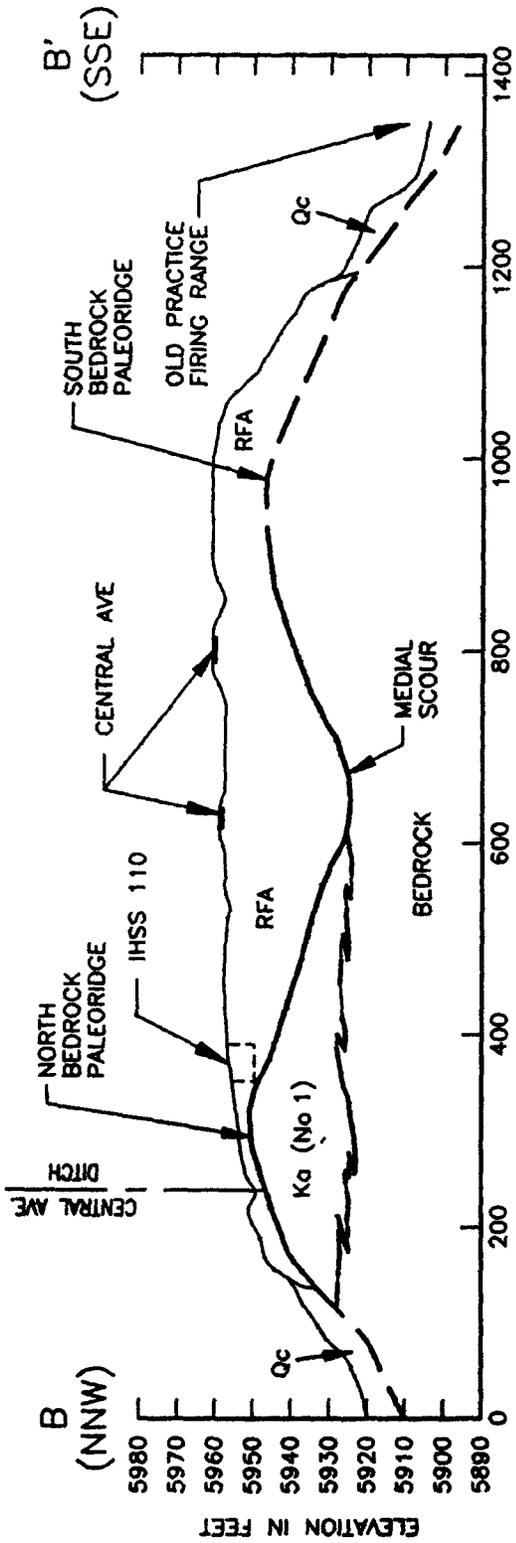
certain top of bedrock features In OU-2, prominent top of bedrock features include the north and south paleoridges and the medial paleoscour (DOE 1993a)

The north and south paleoridges are generally southwest-northeast trending bedrock high features that are indicated by borehole control (DOE 1993a, Figures 3 5-5 and 3 5-6) Trench T-3 is located above the southern flank of the north paleoridge The medial paleoscour is a bedrock trough feature that is believed to originate in the 903 Pad Area and trends to the northeast between the paleoridges This paleoscour takes a northward bend and is truncated along the north-facing hillside of the South Walnut Creek drainage Where the paleoscour intersects the hillside, a well-developed surface drainage gully had developed (DOE 1993a, Figure 3 5-6) Groundwater has been observed to seep from the RFA along the head of this gully during parts of the year These geological features are shown on Figure 2 1-2

The upper hydrostratigraphic unit (UHSU) groundwater flow system in the vicinity of Trench T-3 is comprised of saturated RFA and the No 1 Sandstone The medial paleoscour contains and transmits most alluvial groundwater The geometry of the paleoscour strongly influences alluvial groundwater flow direction, which is generally to the northeast The paleoridges apparently bound the lateral extent of saturated alluvium within the paleoscour, restricting alluvial flow from occurring to the north or south

Alluvial/colluvial potentiometric surface maps for the first three quarters of 1992 (DOE 1993a, Figures 3 6-8 through 3 6-10) indicate that the RFA is saturated only during parts of the year beneath Trench T-3 During high water periods (typically in spring and early summer), the lateral extent of saturated alluvium extends to the southern flank of the north paleoridge, resulting in a saturated alluvial thickness of up to 4 feet beneath Trench T-3 (DOE 1993a, Figure 3 6-3) During low water periods (e g, March 1992), the alluvium is unsaturated beneath the trench

The estimated average hydraulic gradient for the alluvium from 1992 water level measurements is 0 020 feet/foot Estimated values of hydraulic conductivity for the RFA from pump tests conducted at a well cluster comprised of wells 05691, 11491, 20291, and 20491 range from 8×10^{-4} cm/s to 4×10^{-3} cm/s (DOE 1992a) Another pump test conducted at a well cluster including wells 1787,



EXPLANATION

TOP OF BEDROCK SURFACE
 Dashed Where Approximate
 Extrapolated

RFA
 Qc
 Ka (No 1)

ROCKY FLATS ALLUVIUM
 COLLUVIUM
 ARAPAHOE FORMATION No 1 SANDSTONE

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CROSS SECTION SHOWING
 ALLUVIAL AND BEDROCK
 FEATURES

20591, and 20691 resulted in a range of hydraulic conductivities from 6×10^{-5} cm/s to 9×10^{-4} cm/s (DOE 1992). The geometric mean of values from these 1992 tests is 8×10^{-4} cm/s. Trench T-3 is located approximately midway between the two pumping test well clusters.

Groundwater flow in the No. 1 Sandstone is strongly influenced by the geometry of the sandstone unit and its interaction with the overlying alluvium and the South Walnut Creeks drainage. The primary direction of flow in the sandstone is to the north-northeast in the vicinity of Trench T-3. Under high water conditions, the sandstone may receive recharge from overlying alluvium in the Trench T-3 area. This is probably not a significant process in that the saturated thickness of overlying alluvium is usually less than 4 feet and frequently dry. The depth to groundwater in the No. 1 Sandstone ranged typically between 20 to 25 feet.

The No. 1 Sandstone is truncated along the South Walnut Creek hillside. Groundwater discharges from the sandstone along the hillside to seeps. The location of sandstone seeps is shown in the Phase II RFI/RI Report for OU-2 (DOE 1993a, Plate 3 6-1).

Calculated values of hydraulic conductivity for the No. 1 Sandstone from 1992 pumping test measurements from a cluster of wells (3687, 20991, 21091, and 20891) range from 3.7×10^{-4} to 6.2×10^{-4} cm/s (DOE 1993b). These values may or may not be representative of conditions in the No. 1 Sandstone beneath the trench. The estimated hydraulic gradient in the No. 1 Sandstone ranges from 0.03 to 0.1 feet/foot (DOE 1993a).

2.2 RELOCATION OF PILOT TEST FROM IHSS 111.1 TO 110

A review was performed of the original proposed site location for the OU-2 Soil Vapor Extraction pilot test to recommend an alternative site. The original proposed pilot test site was located in Trench T-4 (IHSS 111.1). A change in the pilot test location was recommended to Trench T-3 (IHSS 110) based on higher reported contamination in Trench T-3 than reported in Trench T-4. The recommendation to relocate the pilot test site was based upon the following observations:

- A preliminary data search was completed to gather all available analytical data for subsurface soil samples collected within OU-2. These analytical data were evaluated to identify samples with VOC concentrations detected in the unsaturated zone.

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Analytical sample results from borehole 10191 had the highest VOC concentrations than the other unsaturated borehole results. Borehole 10191 is located within Trench T-3.

- The presence of VOCs in the unsaturated soils in and around Trench T-3 was supported by a recent soil gas survey. The majority of the VOCs detected in the soil gas survey were 1,1-dichloroethane (1,1-DCA), carbon tetrachloride (CCl₄), trichloroethene (TCE), and tetrachlorethene (PCE).

The supporting documentation on the site change is found in EG&G correspondence (WCFS 1993a).

2.3 FIELD INVESTIGATIONS

Numerous investigations have been performed at OU-2 to define the nature and extent of contamination from past waste disposal practices. The investigations have identified Trench T-3 (IHSS 110) as a source of VOCs to the surrounding subsurface soils and the UHSU groundwater. These investigations included the following:

- Phase I Remedial Investigation (RFI/RI) conducted in 1987
- Phase II Alluvial and Bedrock RFI/RI conducted in 1991 and 1993, respectively
- Two soil gas surveys conducted in 1993
- The SVE Pilot Test Implementation conducted in 1993

The Phase I RFI/RI involved drilling and sampling of two source boreholes in and around Trench T-3 (BH3987 and BH4087). The Phase II (alluvial) RFI/RI included drilling and sampling of one source borehole (10191) and two plume characterization wells (02991 and 12191) south of Trench T-3. The Phase II (bedrock) investigation included drilling and sampling of one pilot borehole (21693) and one lower hydrostratigraphic unit (LHSU) monitoring well (22493) north of Trench T-3. The SVE Pilot Test Investigation consisted of drilling and sampling of two boreholes and nine wells near Trench T-3. Analyses performed included VOCs, metals, and radionuclides. The specific radionuclide analyses

were for alpha, beta, americium-241 (Am-241), plutonium-239/240 (Pu-239/240), strontium-89/90 (Sr-89/90), tritium, and uranium isotopes. To date, 16 analytical sample results out of the 20 analytical samples collected have been received by Rocky Flats Environmental Data System (RFEDS). Fourteen of the 16 analytical sample results received from RFEDS were analyzed for VOCs, two metals sample results and no radionuclide results have been received. The two soil gas surveys included sampling of near-surface and deeper (5- to 10-foot sampling interval) subsurface soils in and around Trench T-3.

2.4 NATURE AND EXTENT OF CONTAMINATION

The following discussion provides a description of the nature and extent of contamination within subsurface soils, soil gas, and UHSU groundwater in the vicinity of Trench T-3. In general, VOC and semi-volatile organic compound (SVOC) analytical results for these media are discussed in greater detail than the remaining chemical groups (metals, water quality parameters, radionuclides) because non-organic compounds are of lesser importance to this IM/IRA. In addition to the discussion of contamination by media, NAPLs are discussed separately in Section 2.4.4.

2.4.1 Subsurface Soils

Three source boreholes, four plume characterization monitoring wells, and six SVE locations were drilled and sampled during Phase I, Phase II, and SVE investigations to characterize the vertical extent of contamination in Trench T-3 (10191, 02991, 12191, 21693, 22493, BH3987, BH4087, 24093, 24193, 24493, 24593, 24693, 24793, and 25093). The subsurface soil sample results from these boreholes and wells were used in the statistical detection frequency calculations (Table 2.4-1). The VOC, SVOC and pesticide/PCB results are shown on Figure 2.4-1.

VOCs

Seventeen VOCs were detected in subsurface soil samples collected within Trench T-3 (IHSS 110), as shown on Table 2.4-1. Some of these are suspected laboratory and field contaminants (see the OU-2 Phase II RFI/RI report [DOE 1993a] for further discussion), (acetone, toluene, methylene chloride, and 2-butanone). Chlorinated hydrocarbons (CHCs), including 1,1,1-trichloroethane (1,1,1-TCA), CCl₄, chloroform (CHCl₃), PCE, TCE, 1,1-dichloroethene (1,1-DCE), 1,2-dichloroethene (1,2-

TABLE 2 4-1
ANALYTES DETECTED IN SUBSURFACE SOILS AT IHSS 110 (NORTHEAST TRENCHES AREA)

Analyte	Background 95% UTL		Number of Samples	Number of Detections(2)	Percent Detections	Concentration or Activity Range(3)	Mean Concentration(4)
	Concentration(1)	Concentration(1)					
Volatile Organic Compounds (µg/kg)							
Acetone	NA	NA	57	30	52.6%	1085 - 96,000	7,511
Toluene	NA	NA	58	33	56.9%	5J - 7,600	465
Methylene chloride	NA	NA	58	15	25.9%	45 - 20	8.8
2-Butanone	NA	NA	58	9	15.5%	40J - 140	67.1
1,1,1-Trichloroethane	NA	NA	58	9	15.5%	6 - 27,000	8047
Carbon tetrachloride	NA	NA	58	19	32.8%	3J - 700,000	62,964
Chloroform	NA	NA	58	17	29.3%	1J - 8800	536
Tetrachloroethene	NA	NA	58	28	48.3%	1J - 13,000,000	1,037,989
Trichloroethene	NA	NA	58	7	12.1%	1J - 120,000	18,303
1,1-Dichloroethene	NA	NA	58	1	1.7%	9	9
1,2-Dichloroethane	NA	NA	58	4	6.9%	6J - 15J	11.7
1,2-Dichloroethene	NA	NA	58	1	1.7%	1J	1
2-Propenoic acid, 2-methyl	NA	NA	1	1	100.0%	6J	6
Ethylbenzene	NA	NA	58	1	1.7%	2J	2
Methyl methacrylate	NA	NA	1	1	100.0%	6J	6
Styrene	NA	NA	58	1	1.7%	2BJ	2
Total xylenes	NA	NA	58	1	1.7%	7BJ	7
Semivolatile Organic Compounds (µg/kg)							
Bis(2-ethylhexyl)phthalate	NA	NA	21	20	95.2%	51J - 5500	503.8
Di-n-butyl phthalate	NA	NA	21	1	4.8%	1300J	1300
Phenanthrene	NA	NA	21	1	4.8%	2700J	2700
N-nitrosodiphenylamine	NA	NA	21	1	4.8%	33J	33
2-Methylphenol	NA	NA	21	1	4.8%	450	450
4-Methylphenol	NA	NA	21	1	4.8%	2900	2900
Hexachlorobutadiene	NA	NA	21	1	4.8%	170J	170
Hexachloroethane	NA	NA	21	2	9.5%	370-1100	735
2-Methylnaphthalene	NA	NA	21	1	4.8%	8100D	8100
Naphthalene	NA	NA	21	1	4.8%	2000	2000

**TABLE 2 4-1
ANALYTES DETECTED IN SUBSURFACE SOILS AT IHSS 110 (NORTHEAST TRENCHES AREA)**

Analyte	Background 95% UTL		Number of Samples	Number of Detections(2)	Percent Detections	Concentration or Activity Range(3)	Mean Concentration(4)
	Concentration(1)	Number of Samples					
Pesticides/PCBs (ug/kg)							
Aroclor-1254	NA	21	1	4 8%	6900D	6900	
Metals above background UTLs (mg/kg)(5)							
Arsenic	12	21	5	23 8%	15 - 37	24 1	
Barium	270	21	1	4 8%	413	413	
Cadmium	1	21	9	42 9%	1 2 - 6 2	8 1	
Cobalt	15	21	1	4 8%	17 3	17 3	
Copper	35	21	1	4 8%	37 8	37 8	
Lead	27	21	1	4 8%	86 4	86 4	
Manganese	822	22	2	9 1%	1440 - 3090	2265	
Silver	22 5	21	1	4 8%	96 5	96 5	
Zinc	131	22	1	4 5%	133	133	

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TABLE 2 4-1
ANALYTES DETECTED IN SUBSURFACE SOILS AT IHSS 110 (NORTHEAST TRENCHES AREA)

Analyte	Background 95% UTL Concentration(1)	Number of Samples	Number of Detections(2)	Percent Detections	Concentration or Activity Range(3)	Mean Concentration(4)
Radionuclides above background UTLs (pCi/g)(5)						
Americium-241	0 01	21	12	57 1%	0 01 - 0 5983	0 090
Plutonium-239	0 02	12	7	58 3%	0 02 - 1 1	0 209
Plutonium-239/240	0 02	9	8	88 9%	0 02855 - 3 12	0 47
Uranium-238	1 5	9	2	22 2%	1 611 - 26 37	14 0
Uranium-233,234	2 5	9	1	11 1%	14 35	14 35
Uranium-235	0 2	9	1	11 1%	0 7509	0 7509
Strontium-90	0 9	21	3	14 3%	0 9 - 1 1	1 0
Tritium (pCi/l)	366	21	1	4 8%	400	400 00

Locations BH3987, BH4087, 02991, 10191, 12191, 21693, 22493, 24093, 24193, 24493, 24593, 24693, 24793, 25093

NA = not applicable

UTLs = upper tolerance limit

(1) Background concentrations do not exist and are not applicable for organic compounds

(2) For metals and radionuclides, the number of detections represent only detected concentrations exceeding the background 95% UTL

(3) B and J qualifiers represent estimated result, D qualifier represents dilution result.

(4) The calculation for the mean concentration includes all J, D, and B qualified data

(5) Only metals and radionuclides detected above the background UTLs are listed. Number of detection, percent detections, concentration range, and mean concentration refer only to results exceeding background UTLs

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DCE), and 1,2-dichloroethane (1,2-DCA) were detected at concentrations ranging from parts per billion to parts per thousand, as shown in Figure 2 4-1 The vertical extent of selected CHC contaminants are presented on Figure 2 4-2 Free product was observed in borehole 10191 at a depth of 4 2 feet during drilling Borehole 10191 was being drilled in December of 1991 during the OU-2 Phase II RFI/RI alluvial program Source borehole 10191 exhibited elevated levels of 1,1,1-TCA, CCl₄, CHCl₃, PCE, and TCE in the samples collected above the initial water at the time of drilling In general, the concentrations of the CHCs decreased with depth in the vadose zone in source borehole 10191 Below the water table, concentrations increased again, but to levels significantly lower than those seen in the vadose zone, as discussed in Section 2 4 3

In addition to these CHCs, five other VOCs were detected in subsurface soil samples collected from the SVE locations (2-propanoic acid, 2-methyl, ethylbenzene, methyl methacrylate, styrene, and total xylenes)

SVOCs

Ten SVOCs were detected in subsurface soil samples collected within Trench T-3, as shown on Table 2 4-1 Two were phthalates, bis(2-ethylhexyl)phthalate, di-n-butyl phthalate, two were naphthalenes, 2-methylnaphthalene and naphthalene, and two were polyaromatic hydrocarbons (PAHs), phenanthrene and n-nitrosodiphenylamine SVOCs detected, except for phthalates, are illustrated on Figure 2 4-1 (see the OU-2 Phase II RFI/RI Report [DOE 1993a] for further discussion on the phthalates presence) Phenanthrene was detected in 1 out of 21 samples analyzed from source borehole 10191 at a depth of 4 2 to 8 feet N-nitrosodiphenylamine was detected in 1 out of 21 samples analyzed at an estimated concentration of 33 µg/kg from location BH3987 at a depth of 0 to 2 feet 2-methylnaphthalene, 2-methylphenol, and 4-methylphenol were each detected in 1 out of 21 samples analyzed from source borehole 10191 at a depth of 4 2 to 8 feet Hexachlorobutadiene was detected in 1 out of 21 samples analyzed from borehole BH4087 Hexachloroethane was detected in 2 out of 21 samples analyzed from borehole 10191 at two depths 8 to 14 1 feet and 14 1 to 20 1 feet

Pesticides/PCBs

Aroclor-1254, a polychlorinated biphenyl (PCB), was detected at an estimated concentration of 6,900D µg/kg in borehole 10191 from 1 out of 21 samples analyzed, taken at the depth of 4 2 to

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8 feet, as shown on Table 2 4-1 and Figure 2 4-1

Metals

Table 2 4-1 indicates that nine metals were detected at concentrations above the background upper tolerance limits (UTLs) in subsurface soil samples from Trench T-3 (DOE 1993b). Among these, arsenic and cadmium are considered to be OU-2 chemicals of interest (COIs). Arsenic was detected above the background UTL in 5 out of 21 samples analyzed from borehole BH3987. Cadmium exceeded the background UTL in 9 out of 21 samples analyzed from borehole BH3987 at concentrations within the same order of magnitude as the background UTL. However, elevated cadmium results were ubiquitous in the 1987 borehole data and are constant with depth. As discussed in the introduction of Section 4 3 of the OU-2 Phase II RFI/RI report (DOE 1993a), cadmium is not considered a waste-related contaminant in OU-2 soil, in general, or in Trench T-3. Due to infrequent detections and low concentrations, barium, cobalt, copper, manganese, and zinc are not considered to be contaminants. Lead and silver may or may not be waste-related contaminants.

No metals were detected above the background UTLs in the sample collected from well 24793.

Radionuclides

Eight radionuclides detected at activities above the background UTLs are presented in Table 2 4-1. Am-241, plutonium-239 (Pu-239) and Pu-239/240 are OU-2 COCs. Uranium-233,234 (U-233,234), uranium-235 (U-235), and uranium-238 (U-238) are considered to be special case OU-2 contaminants in Trench T-3. Am-241 was detected at activities above the background UTL in 12 out of 21 samples analyzed. The maximum activities of Am-241, Pu-239/240, U-233,234, U-235, and U-238 were found in a sample collected at a depth of 4 2 to 8 feet from borehole 10191. The maximum activity of Pu-239/240 (3 12 pCi/g) is about 100 times higher than the background UTL. Elevated levels of radionuclides are concentrated in the 4 2- to 8-foot interval of borehole 10191 and generally decrease with depth, indicating the source of radionuclides to be within Trench T-3. Trench T-3 is estimated to be between 5 and 10 feet deep.

Both tritium and Sr-90 were infrequently detected at activities only slightly above the background UTLs. Therefore, their presence is not considered to be waste-related.

Other Analytes and Parameters

The pH of subsurface soils in Trench T-3 ranged from 6.23 to 9.17. Ammonia concentrations ranged from 0.48 to 8.38 µg/g and nitrate/nitrite ranged in concentration of 0.27 to 7.18 µg/g. Total organic carbon content ranged from 167 to 19,200 µg/g, the maximum concentration was found in a sample from borehole 10191 collected at a depth of 4.2 to 8 feet. The maximum total organic carbon result may be associated with NAPL contamination in borehole 10191.

Summary

The subsurface soil analytical data collected from Trench T-3 indicate that it is a source of VOC contamination (1,1,1-TCA, CCl₄, CHCl₃, PCE, TCE, and 1,2-DCA) to the subsurface soil and potentially to UHSU groundwater. The concentrations of CHCs decrease with depth down to the water table. There is minor contamination by PAHs and other SVOCs. The presence of arsenic, lead, and silver in this trench may be associated with waste disposal. Elevated activities of Am-241, Pu-239, Pu-239/240, U-233,234, U-235, and U-238 are also present in Trench T-3.

2.4.2 Soil Gas

Two soil gas surveys have been performed around Trench T-3 (IHSS 110). Both a shallow and a deeper survey have been performed. The findings of the soil gas surveys are summarized below. The shallow (near surface less than a depth of five feet) soil gas survey analyses included the following VOCs:

- 1,1-DCE
- trans-1,2-dichloroethene (trans-1,2-DCE)
- cis-1,2-dichloroethene (cis-1,2-DCE)
- 1,1-DCA
- 1,2-DCA
- CCl₄
- PCE
- TCE
- vinyl chloride

- Total VOCs

1,1-DCE, trans-1,2-DCE, cis-1,2-DCE, and 1,2-DCA were not detected in the soil vapor. 1,1-DCA was detected in 16 of 35 sampling locations and concentrations ranged from 40 to 1,900 µg/l. CCl₄ was detected in 18 of the 35 sampling locations with concentrations ranging from 0.36 to 111 µg/l. TCE was detected in 14 of the 35 sampling locations with concentrations ranging from 1.2 to 21 µg/l. PCE was detected in 22 of the 35 sampling locations with concentrations ranging from 0.11 to 410 µg/l. While vinyl chloride was detected in two sampling locations at concentrations less than 23 µg/l.

Review of the spatial distribution of the soil gas data in Trench T-3 indicates that CCl₄ may be found only in the west end of the trench (west of borehole 10191). The PCE soil gas plume is located in the west central part of Trench T-3 (located east of borehole 10191 and around the SVE wells and boreholes). The TCE soil gas plume is similar in location to the PCE plume. Two elevated total VOC concentration areas are observed in and around Trench T-3. One is located in the west central part of Trench T-3 (around the SVE wells and boreholes) and the second is located on the western end of Trench T-3 (west of borehole 10191).

The deeper soil gas survey (two surveys from depths of 5 and 10 feet) analytes included

- 1,1-DCA
- CCl₄
- PCE
- TCE
- Total VOCs

Based on the evaluation of the soil gas obtained from the 5-foot sampling intervals, total VOCs appear to be concentrated on the western part of Trench T-3 (around borehole 10191). The CCl₄ soil vapor plume is located west of Trench T-3 boundary, while 1,1-DCA, PCE, and TCE are located at the western end of Trench T-3.

Review of the soil gas data obtained from a depth of 10 feet indicates that total VOCs, CCl₄, and PCE were observed at higher concentrations than at the 5-foot depth. 1,1-DCA was not detected in the 10-foot sample and TCE was detected at relatively low concentrations.

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2.4.3 Groundwater

The nature and extent of contamination in the UHSU groundwater in the vicinity of Trench T-3 was evaluated based on plume maps of contaminants presented in the OU-2 Phase II RFI/RI Report (DOE 1993a). In general, contamination in the saturated zone beneath the site is not believed to have a significant impact on the SVE study. The depth to groundwater is generally greater than 20 feet beneath Trench T-3. The evaluation focused on the VOCs, which are of primary concern for the SVE pilot study.

Alluvial/Colluvial Groundwater

Plume maps for OU-2 chemicals of concern in alluvial/colluvial groundwater indicate that VOCs with low concentrations are detected in the Trench T-3 area. As stated in Section 2.1, the alluvial/colluvial component of the UHSU is saturated beneath Trench T-3 only under high water conditions. Well 2487 was sampled during second quarter 1992 (high water period). Analytical results for CCl₄, CHCl₃, 1,1-DCE, PCE and TCE were all reported below detection limits for that sampling event (DOE 1993a, Section 4.4).

No. 1 Sandstone Groundwater

Since the groundwater in the vicinity of Trench T-3 is primarily located within the No. 1 Sandstone, the distribution of VOC contaminants will be evaluated only in monitoring wells completed in the No. 1 Sandstone, as shown on Figure 2.4-4. Isoconcentration maps were constructed to illustrate the areal extent of CCl₄, CHCl₃, and PCE. The isoconcentration maps were constructed using analytical data obtained during the second quarter of 1992. Review of the CCl₄ isoconcentration map (Figure 2.4-5) indicated that the concentrations of CCl₄ increased around Trench T-3 as observed in well 12191 (400 µg/l), as well as in down-gradient wells 03391 (450 µg/l) and 11691 (580 µg/l). Figure 2.4-6 showed that CHCl₃ concentrations were an order of magnitude lower than the CCl₄ concentrations and ranged from 11 to 14 µg/l in these wells. Review of the PCE isoconcentration map (Figure 2.4-7) illustrated that the concentrations of PCE were slightly lower than the CCl₄ concentrations in the wells surrounding Trench T-3. The analytical data indicate that Trench T-3 is a source of VOC contamination to the UHSU groundwater in the No. 1 Sandstone.

Two of the nine wells installed during the SVE investigation (wells 24193 and 24393) were sampled and analyzed using both the VOA CLP and VOA 524 2 methods. Since well 24193 and 24393 were not installed until third quarter of 1993, they are not shown on the isoconcentration maps. The analytical results obtained from the VOA CLP method were reviewed and will be discussed in this section. Nine VOCs were detected in the No. 1 Sandstone groundwater collected from these two wells (1,1,1-TCA, 1,1-DCE, 1,2-DCE, CCl₄, CHCl₃, PCE, toluene, total xylenes, and TCE).

<u>VOC Detected</u>	<u>Concentration Range (µg/l)</u>
1,1,1-TCA	6-110
1,1-DCE	4-56
1,2-DCA	10
CCl ₄	230-3000
CHCl ₃	8-170
PCE	220-740
Toluene	26
Total Xylenes	73
TCE	38-65

2.4.4 Nonaqueous Phase Liquid (NAPL)

A free phase NAPL was observed in borehole 10191 (Phase II RFI/RI program) at a depth of approximately 4 feet and a residual NAPL was identified at approximately 6.5 to 7 feet during drilling operations. The NAPL that was dripping from the core was described to be dark-brown in color. Borehole 10191 was drilled to a depth of 54 feet in three days. Analytical results obtained at this depth indicated the NAPL to contain the following chemicals: 1,1,1-TCA (13,000 µg/kg or ppb), CCl₄ (28,000 µg/kg), CHCl₃ (8,800 µg/kg), PCE (1,300,000 µg/kg), and TCE (120,000 µg/kg).

At borehole 24793 in the SVE Pilot Test program, two VOC samples were collected due to elevated organic readings in the field by the photoionization detector (PID) and the observation of discolored soil in the borehole from the 7 7- to 8-foot sampling interval. The 7 7- to 8-foot core samples were described in the field to be a residual of a NAPL that discolored the soil. No free phase liquids were observed for these samples. Elevated PCE (1,090,000 µg/kg) and TCE (8,100 µg/kg) were detected in these samples.

During the numerous investigations of Trench T-3, a free phase NAPL was observed in one sample from borehole 10191, and a residue NAPL was observed in the borehole from well 24793. Upon encountering the NAPL in borehole 24793, drilling was stopped and the borehole was abandoned in accordance with standard operating procedure (SOP) GT 5, Plugging and Abandonment of Boreholes to prevent further contaminant migration. Based on the physical properties that control the migration of NAPLs, the existence of free phase still in or beneath Trench T-3 is unclear. It is possible that the free phase NAPL observed in borehole 10191 migrated vertically during the Phase II drilling operations or could be still trapped in Trench T-3.

2.5 GEOPHYSICAL SURVEY OF TRENCH

Geophysical methods were used to investigate the location of the trench. The geophysical methods used were chosen to allow delineation of the trench edges and thereby optimize the positioning of the SVE borings. The geophysical methods used were electromagnetics (EM) and ground penetrating radar (GPR).

EM methods provide a rapid means of measuring the electrical conductivity of subsurface soil, rock, and groundwater. By measuring variations in electrical conductivity, subsurface conditions can be assessed, including variations in soil conditions and the presence of ferrous and nonferrous materials. The trench was reported to likely contain metallic debris, so EM was used to identify buried metal and thus aid in defining the edges of the trench. A limitation of the method is that the EM response is based on sampling a volume of subsurface material, and thus lateral variations in conductivity (indicative of a trench wall) can only be resolved to within a couple of feet.

EM data were collected with a Geonics EM-31 terrain conductivity entered in a continuous recording fashion over the survey area in accordance with Rocky Flats ERM SOP GT 18, Surface Geophysical

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Surveys The continuous recording allowed the geophysicist to directly assess natural versus metal-bearing areas in the field. Although the trench edges were generally identified, more resolution was desired, so GPR was used to augment the EM data.

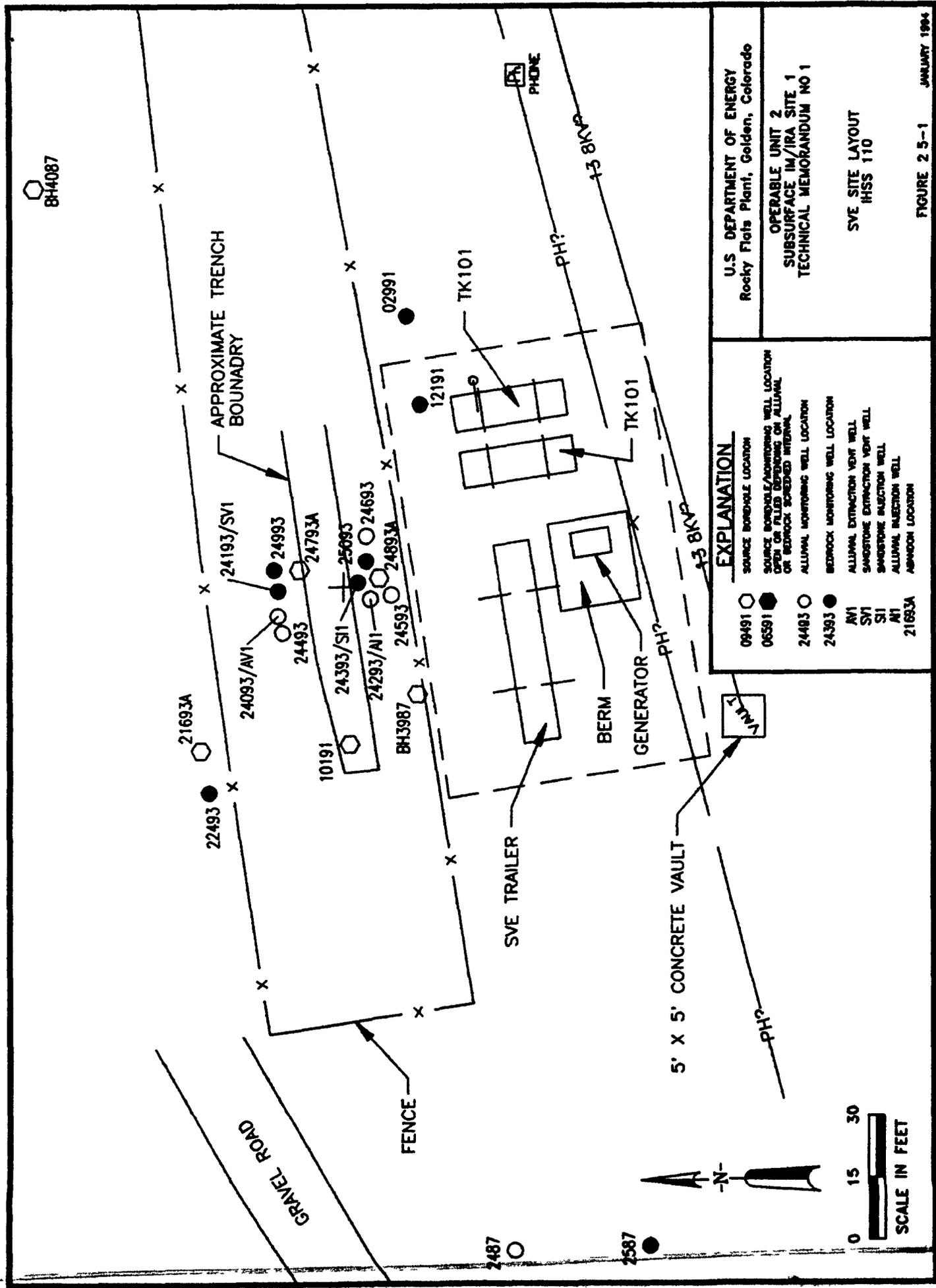
GPR data were collected with a Geophysical Survey Systems, Inc (GSSI) Subsurface Interface Radar (SIR) System-3 in accordance with Rocky Flats ERM SOP GT 18, Surface Geophysical Surveys. The system included a profiling recorder and appropriate transmitting and receiving antennas, and provided instantaneous and continuous radar profiles.

Testing of various GPR data acquisition parameters was conducted as part of the feasibility study. Two antenna frequencies were available for testing, the 300 Mhz and 500 Mhz. During testing, it was concluded that the 300 Mhz would not provide the resolution required for discerning the targets of interest, so the 500 Mhz antenna was used for the survey. Other data acquisition parameters were tested for optimum data resolution given survey objectives. The following recording parameters were tested:

- Time range for recording
- Signal range gain
- High and low pass filter settings (given time range for recording)
- Printer speed
- Antenna towing speed

The final data acquisition parameters allowed identification of the trench walls, and the disturbed fill area within the trench. Interpreted trench edges were then staked in the field to facilitate appropriate positioning of the SVE borings. An approximate location of the trench edge is shown in Figure 2 5-1.

BH4087



EXPLANATION

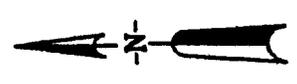
○	09491	SOURCE BOND-HOLE LOCATION
●	06591	SOURCE BOND-HOLE/MONITORING WELL LOCATION OPEN OR FILLED DEPENDING ON ALLUVAL OR BEDROCK SCREENED INTERVAL
○	24483	ALLUVAL MONITORING WELL LOCATION
●	24393	BEDROCK MONITORING WELL LOCATION
○	AVI	ALLUVAL EXTRACTION VENT WELL
○	SVI	SANDSTONE EXTRACTION VENT WELL
○	SI	SANDSTONE INJECTION WELL
○	AI	ALLUVAL INJECTION WELL
○	21693A	AMMOCH LOCATION

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OPERABLE UNIT 2
SUBSURFACE IM/IRA SITE 1
TECHNICAL MEMORANDUM NO 1

SVE SITE LAYOUT
IHSS 110

FIGURE 2 5-1
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3.0 EVALUATION OF PROPOSED PILOT TEST

3.1 REVIEW PILOT TEST OBJECTIVES

The purpose of the IM/IRAP was to investigate the removal of VOC contamination in suspected subsurface areas at RFP OU-2 using SVE technology to identify if SVE was applicable for final remedial action. The IM/IRAP identified three locations to test SVE technology:

- East Trenches
- Mound
- 903 Pad

The SVE pilot study to implement the IM/IRAP for the East Trenches Area was designed to select a contaminated site based on soil gas survey data. The following are overall objectives of the pilot study:

- Assess the SVE technology for removal of VOCs in the Rocky Flats Alluvium (RFA) formation
- Assess the SVE technology for removal of VOCs in sandstone with groundwater extraction
- Assess active versus passive air injection
- Incorporate information into the Corrective Measure Study/Feasibility Study (CMS/FS)
- Minimize adverse effects to environment during the pilot test

In summary, the pilot study is to provide information concerning the removal of residual contamination to support the CMS/FS evaluation of SVE as a remedial action alternative in the East Trenches Area.

The pilot study modified the IM/IRAP in the following ways

- Operate vapor treatment system with two blowers operating in series for negative operating pressure
- Expect 5 gpm pumping rates instead of 1 gpm
- Sample exhaust gas to verify absence of radioactive species instead of downstream from HEPA filter
- Evaluate heat input from the blower injection system versus passive air injection

The analytical data quality objectives were divided into the following primary and secondary objectives

- Primary - Contaminant mass recovery rate - measuring how mass recovery rates change with particular system configuration
- Secondary - Measuring effectiveness of off-gas treatment equipment, characterization of soil samples and pumped groundwater

Analytical data collection will be made with the following requirements

- Off-gas samples analyzed for TCE, PCE, CCl₄, using Level II data requirements obtained with field or laboratory GC, a 20 ppbv Method Detection Limit (MDL), greater than 70% data complete. A list of off-gas samples and turnaround times is provided in Table 3-1
- HEPA filter media - Field measurement, bench-top alpha detector
- Soil and groundwater using Level III or IV data requirements

TABLE 3-1
Summary of Soil Gas Sampling

Pilot Test Number	Sampling Requirements				Analytical Requirements		
	Soil Gas Samples	Make-up Air Samples	QA Samples	Total Number of Samples Collected	Number of CLP Samples ¹	Number of Certificate of Analysis Samples ²	Analysis Turnaround Period
1	4	1	1	6	1	5	48 hrs
2-1	16	1	2	19	5	14	48 hrs
2-2	16	1	2	19	5	14	48 hrs
2-3	16	1	2	19	5	14	48 hrs
3-1	16	1	2	19	5	14	48 hrs
3-2	16	1	2	19	5	14	48 hrs
3-3	16	1	2	19	5	14	48 hrs
4-1	16	1	2	19	5	14	48 hrs
4-2	16	1	2	19	5	14	48 hrs
4-3	16	1	2	19	5	14	48 hrs
5	20	1	2	23	5	18	14 days
6	16	1	2	19	5	14	14 days
7	16	1	2	19	5	14	14 days
8	16	1	2	19	5	14	14 days
9	16	1	2	19	5	14	14 days
Total	232	15	29	276	71	205	

¹ Samples collected from the stack including one duplicate per run

² Samples collect from the wellhead(s), Blower B-300 outlet, and the GAC D-400 outlet including one duplicate per run

The design objectives of the pilot system test, equipment, and field installations include the following

- Draw air under the trench and laterally through the trench
- Design the sandstone well to recover free phase or perched DNAPL from the groundwater
- Use pressure monitoring probes to collect subsurface pressure measurements to estimate radius of influence
- Overlap cones of depression for groundwater extraction
- Ensure negative subsurface pressure when injecting air

The pilot test is divided into the following separate operations to collect information on SVE system treatment performance, operating configurations, and contaminant removal

- System Operations (SO) Testing
- Pilot Testing
- Sustained Operations

The main objective of the SO Testing is to evaluate whether the SVE system is operating as designed
The pilot test operations is divided into the following nine separate tests

- Pilot Test No 1 - Initial Vapor Treatment System Performance
- Pilot Test No. 2 - Alluvium System Performance
- Pilot Test No 3 - Sandstone System Performance

- Pilot Test No 4 - Concurrent Groundwater Extraction and Sandstone System Performance
- Pilot Test No 5 - Concurrent Alluvium and Sandstone System Performance
- Pilot Test No 6 - Alluvium Passive Air Inlet Performance
- Pilot Test No 7 - Sandstone Passive Air Inlet Performance
- Pilot Test No 8 - Alluvium Forced Air Inlet Performance
- Pilot Test No 9 - Sandstone Forced Air Inlet Performance

The pilot tests are described in detail in the OU-2 Subsurface IM/IRA Pilot Test Plan (DOE 1993c)

These individual tests are designed to collect data for evaluation or estimating the following

- Air Permeability of individual strata.
- Contaminant removal rates
- Time to reach steady state
- Air injection effects
- Air removal rates and radius of influence
- Vapor treatment system effectiveness
- Groundwater extraction rates and radius of influence

Table 3-2 describes the individual tests and the individual test objectives and operating criteria.

TABLE 3-2
PILOT TEST OBJECTIVES/OPERATING CRITERIA

Pilot Test	Objective/Operating Criteria
1 Test Objectives	<p><u>Objectives</u></p> <ul style="list-style-type: none">• Evaluate initial performance of vapor treatment, AV1 for 4 hours at 100 inches of water column operating pressure• Verify organics are not being discharged to atmosphere• Pressure test the system• Evaluate proper operation of equipment and instruments <p><u>Operating Criteria</u></p> <ul style="list-style-type: none">• Gas samples to be analyzed prior to the start of the next test• Measurements and samples to be collected are outlined in Table 7-2 of the OU-2 Subsurface IM/IRA Pilot Test Plan - Pressure, temperature, relative humidity, radiological, OVA, and gas samples• If OVA reading at the stack is 10 relative units above background, collect stack sample for immediate laboratory analysis• Use a field GC for analytical testing of field samples, 2 to 4 hour turn around• If vapor treatment is determined to be adequate, subsequent pilot tests will be performed
2 Alluvium System Performance	<p><u>Objectives</u></p> <ul style="list-style-type: none">• Evaluate performance of alluvium extraction vent and collect pressure readings to estimate alluvium air permeability• Identify subsequent air flow removal rates by varying operating pressures• Identify the time to reach steady state in the alluvium• Identify contaminant removal rates for varying operating pressures and air flow removal rates• Identify radius of influence at varying operating pressures• Identify the maximum radius of influence of AV1 <p><u>Operating Criteria</u></p> <ul style="list-style-type: none">• Collect soil gas pressure monitoring data to estimate air permeability of the alluvium• Test will consist of three runs at 60, 100, and 140 inches of water column operating pressures for a minimum of 16 hours each or until last three pressure readings at APM3 are within 5 percent of each other

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TABLE 3-2
(continued)

Pilot Test	Objective/Operating Criteria
3 Sandstone System Performance	<p>Objectives</p> <ul style="list-style-type: none">• Evaluate the performance of the sandstone vapor extraction vent (SVI) without groundwater extraction and collect pressure readings to estimate sandstone air permeability• Identify the time to reach steady state in the sandstone• Identify contaminant removal rates at SV1 for varying operating pressures and air flow removal rates• Identify radius of influence of SV1 at varying operating pressures• Identify the maximum radius of influence of SV1 <p>Operating Criteria</p> <ul style="list-style-type: none">• If groundwater rises more than 30 inches, groundwater will be extracted to maintain the original level prior to vacuum extraction• Test will consist of three runs at 60, 100, and 140 inches of water column operating pressures for a minimum of 16 hours each or until last three pressure readings at SPM2 are within 5 percent of each other• Vary operating pressures to identify subsequent air flow removal rates• Collect soil gas pressure monitoring data to estimate air permeability of the sandstone

TABLE 3-2
 (continued)

Pilot Test	Objective/Operating Criteria
<p>4 Concurrent Groundwater Extraction and Sandstone System Performance</p>	<p><u>Objectives</u></p> <ul style="list-style-type: none"> • Evaluate the performance of the sandstone vapor extraction vent (SVI) with groundwater extraction and collect pressure readings to estimate sandstone air permeability • Identify contaminant removal rates for varying operating pressures and air flow removal rates • Identify radius of influence at varying operating pressures • Identify the maximum radius of influence of SVI • Identify the time to reach steady state in the sandstone <p><u>Operating Criteria</u></p> <ul style="list-style-type: none"> • Test will consist of three runs at 60, 100, and 140 inches of water column operating pressures for a minimum of 16 hours each or until last three pressure readings at SPM2 are within 5 percent of each other • Groundwater will be extracted from SV1 and S11 at a rate of 2 gpm, if draw down is less than 10 feet after 24 hours of pumping rate will be increased. • Groundwater table must stabilize prior to initiation of the vacuum extraction test • Stabilization of the ground water level is defined as less than 0.1 foot change in SPM1 over a 1 hour period • After ground water extraction rate is determined, groundwater will be extracted for 24 hours • Groundwater level will be maintained at the original level prior to vacuum extraction • Vary operating pressures to identify subsequent air flow removal rates • Collect soil gas pressure monitoring data to estimate air permeability of the sandstone • Collect groundwater samples for laboratory testing for VOCs, metals, and radionuclides

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TABLE 3-2
(continued)

Pilot Test	Objective/Operating Criteria
5 Concurrent Alluvium and Sandstone System Performance	<p><u>Objectives</u></p> <ul style="list-style-type: none">• Test will consist of a single run to evaluate the interaction between AV1 and SV1 when operating simultaneously and the overall system performance <p><u>Operating Criteria</u></p> <ul style="list-style-type: none">• Single run for a minimum of 16 hours or until steady state conditions are developed as defined in Pilot Test Nos 2 and 3• AV1 will be operated at the pressure showing the highest contaminant removal during Pilot Test No 2• SV1 will be operated at the pressure that showed the highest contaminant removal during Pilot Tests Nos 3 and 4• Steady state groundwater level conditions must be attained as defined by Pilot Test No 4
6 Alluvium Passive Air Inlet Performance	<p><u>Objectives</u></p> <ul style="list-style-type: none">• Evaluate AII as a passive air injection vent and its influence on Alluvium performance <p><u>Operating Criteria</u></p> <ul style="list-style-type: none">• AII will be opened to the atmosphere• Single run for a minimum of 16 hours or until steady state conditions are developed as defined in Pilot Test Nos 2 and 3• AV1 will be operated at the pressure showing the highest contaminant removal during Pilot Test No 2
7 Sandstone Passive Air Inlet Performance	<p><u>Objectives</u></p> <ul style="list-style-type: none">• Evaluate SII as a passive air injection vent and its influence on sandstone performance <p><u>Operating Criteria</u></p> <ul style="list-style-type: none">• SII will be opened to the atmosphere• Single run for a minimum of 16 hours or until steady state conditions are developed as defined in Pilot Tests Nos 3 and 4• SV1 will be operated at the pressure showing the highest contaminant removal during Pilot Test Nos 3 and 4• Steady state groundwater level conditions must be attained as defined by Pilot Test No 4

TABLE 3-2
(continued)

Pilot Test	Objective/Operating Criteria
8 Alluvium Forced Air Inlet Performance	<p><u>Objective</u></p> <ul style="list-style-type: none">• Evaluate AII as an active air injection vent and its influence on Alluvium performance <p><u>Operating Criteria</u></p> <ul style="list-style-type: none">• AII will be connected to air injection blower for a constant supply of air• AII injection rate will be between 10 to 50 percent of AV1 extraction rate• AII injection rate will be limited to insure a vacuum operating pressure at APM2• Single run for a minimum of 16 hours or until steady state conditions are developed as defined in Pilot Test Nos 2 and 3• AV1 will be operated at the pressure showing the highest contaminant removal during Pilot Test No 2
9 Sandstone Forced Air Inlet Performance	<p><u>Objective</u></p> <ul style="list-style-type: none">• Evaluate SII as an active air injection vent and its influence on sandstone performance <p><u>Operating Criteria</u></p> <ul style="list-style-type: none">• SII will be connected to air injection blower for a constant supply of air• SII injection rate will be between 10 to 50 percent of SV1 extraction rate• SII injection rate will be limited to insure a vacuum operating pressure at SPM2• Single run for a minimum of 16 hours or until steady state conditions are developed as defined in Pilot Tests Nos 3 and 4• SV1 will be operated at the pressure showing the highest contaminant removal during Pilot Tests Nos 3 and 4• Steady state groundwater level conditions must be attained as defined by Pilot Test No 4

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The Sustained Operations test is designed to conduct an extended test (6 weeks) of one pilot test configuration that shows an overall contaminant removal rate of greater than 1 pound of VOCs per 24 hour operating period. The information gathered during the sustained operation period will be used to support the evaluation of the technology in the CMS/FS and to assess the benefit of IM/IRA operation. Contaminant removal rate versus time and radius of influence will provide information to evaluate long-term performance information and estimate capital and operations and maintenance (O&M) costs for a full-scale system.

3.2 SOIL GAS EXTRACTION PRODUCTION

As noted in Section 2.0, two vapor extraction wells were installed for the pilot test. The extraction well installed in the Alluvium (AV1) has 10 feet of screened length and the well installed in the sandstone (SV1) has a screened length of 50 feet. A range of 20 to 40 feet of screen in the sandstone would be exposed during dewatering. An evaluation can be made on soil gas production per unit well screen lengths possible based on soil types and vacuum applied (EPA 1991) for purposes of refining off-gas flow rate estimates.

Based upon the description of soil and bedrock in Section 2.0, it is assumed that the alluvial material physical properties resemble a sandy gravel and that the sandstone physical properties resemble a fine sand. It is assumed based on the blower manufacturers data that a maximum vacuum at each well (P_w) of approximately 10 inches of mercury vacuum is available. P_w at the more permeable AV1 should be less than the maximum vacuum. However, changes in the estimate of P_w would most likely decrease predicated flow rates by no more than fifty percent. Regardless, soil permeabilities are a more significant variable than P_w in estimating soil gas extraction rates. Given P_w , a range of soil permeabilities for the alluvial is assumed to be 10 to 12 darcies (1 darcy = 9.87×10^{-9} cm²) and for the sandstone 0.5 to 5 darcies (EPA 1991). Thus, a range of flow rates can be assumed from 4.5 to 25 standard cubic feet per minute (scfm) per linear foot of well screen in the alluvial well and 0.15 to 5.1 scfm per linear foot of well screen in the sandstone well. As such, estimated flow rates for AV1 would be 45 scfm to 250 scfm. Estimated flow rates from SV1 would be 3 scfm to 204 scfm. Maximum flow rates from SV1 would be halved if the water table is drawdown only 10 feet from the original water table.

3.3 GROUNDWATER EXTRACTION

In order to evaluate the extent of groundwater drawdown during the pilot test, an evaluation of groundwater extraction was performed. As part of the pilot test, groundwater will be extracted from the two sandstone wells SV1 and S11 in order to depress the water table. The pumping rates and the potential radius of influence for the pilot test are estimated based on the site specific information obtained from the pumping test results in the sandstone northeast of IHSS 110 (DOE 1992b). This pumping test with a constant pumping rate of 1 62 gallons per minute (gpm) caused a steady drawdown of 7 feet in the pumping well, and drawdowns of 5 7 feet, 4 3 feet and 3 5 feet in the three observation wells which are 6 feet, 11 feet and 21 feet away from the pumping well respectively. The hydraulic conductivity values estimated from the drawdown curves at these four locations did not show significant differences. Therefore an average hydraulic conductivity value of the sandstone in the surrounding area of Trench T-3 was estimated at 1 5 ft/day ($5 \text{ E-}04 \text{ cm/s}$)

As the sandstone is under unconfined condition, Thiem-Dupuit equation was used to estimate the pumping rates and the cone of depression based on the ideal assumptions required by analytical solution, such as homogeneous, isotropic, and steady-state horizontal flow

Extraction rates were estimated for achieving a maximum drawdown of 30 feet and a minimum drawdown of 10 feet in pumping wells, respectively. Estimation was based on the following assumptions,

- The average saturated thickness of sandstone before pumping was 30 feet
- The radius of pumping well was 2 inches
- The distance between the two extraction wells was approximately 15 feet (Figure 2 5-1)

A radius of influence under the pumping test conditions was estimated at 110 feet using the Thiem-Dupuit equation. Therefore, the radius of influence under the test conditions (10-foot drawdown and 30-foot drawdown) was assumed to be 150 feet and 200 feet, respectively

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Calculations based on these assumptions show that to obtain a drawdown of 30 feet in both pumping wells, an equal pumping rate of 3 0 gpm for each of the two extraction wells would be required For a drawdown of 10 feet in both pumping wells, an equal pumping rate of 1 4 gpm would be required

4.0 EVALUATION OF THE INTERACTIVE INFLUENCES BETWEEN THE PILOT PUMP TESTS AND DNAPL DISTRIBUTION AND MOVEMENT IN THE NO. 1 SANDSTONE

As noted in Section 2.0, DNAPL was observed in Trench T-3 in the free-phase during the drilling of borehole 10191, and in the residual-phase in subsurface soil samples from the borehole for nearby well 24793. Based on the subsurface hydrogeologic conditions present in this area (discussed in Section 2.1), and an understanding of typical DNAPL behavior in the subsurface environment, a conceptual model has been developed to evaluate the potential presence and distribution of DNAPL in the subsurface in this area, and the potential for the proposed pilot pump test to affect DNAPL distribution in the Arapahoe Formation No. 1 Sandstone, and for the SVE pilot treatment system to be effected by the presence of DNAPLs.

4.1 TYPICAL BEHAVIOR AND DISTRIBUTION OF DNAPL IN THE SUBSURFACE

DNAPLs released to the subsurface typically migrate vertically downward into the underlying vadose zone and saturated zone under the influence of gravity. As the DNAPLs migrate downward, they leave behind a trail of residual contamination as the DNAPLs are adsorbed onto soils or are left behind as droplets trapped in dead-end pore spaces in the geologic materials. If the quantity of DNAPL is small, or the depth to the saturated zone is large, the liquid-phase or free-phase DNAPL may be held in the vadose zone by adsorption to soil or trapping in pores until only residual-phase DNAPL remains. Under this condition, the residual-phase DNAPL in the vadose zone is essentially immobile under normal subsurface conditions, and further migration of the DNAPL ceases. However, this residual-phase DNAPL in the vadose zone may be dissolved by water percolating downward, potentially affecting underlying groundwater quality on a continuing basis.

If the quantity of DNAPL released to the subsurface is large, or the depth to groundwater is small, the free-phase DNAPL will continue to migrate downward until encountering a hydraulic (i.e., capillary fringe) or lithologic (i.e., fine-grained geologic unit) barrier. DNAPLs that reach the capillary fringe can penetrate into the saturated zone only if they can build sufficient pressure or head to overcome the capillary pressure. Likewise, DNAPLs that encounter a lithologic barrier can only penetrate that barrier if they can overcome the increased capillary pressure in the fine-grained materials. When capillary pressure cannot be overcome, lateral spreading or pooling of the DNAPL

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on top of the capillary fringe or lithologic barrier may occur. In the case of a discontinuous fine-grained lithologic barrier surrounded by coarser-grained material (e.g., a discontinuous claystone lens in the No. 1 Sandstone), lateral spreading may occur on top of the barrier until the DNAPL spills over the edge of the barrier, at which point the DNAPL may continue downward until reaching another barrier.

4.2 POTENTIAL PRESENCE OF DNAPL IN THE VADOSE ZONE AND SATURATED ZONE AT TRENCH T-3

As a result of the processes described above, DNAPLs in the vicinity of Trench T-3 may exist in the vadose zone or saturated zone in the residual phase (i.e., adhered to soils or trapped in pore spaces). They may also exist in the vadose zone or saturated zone as discrete pools of free-phase DNAPL pooled on top of the capillary fringe, on top of clay layers within the alluvium or No. 1 Sandstone, or on top of the claystone at the base of the No. 1 Sandstone.

As noted above, free-phase DNAPL was observed to flow into borehole 10191 at a depth of about 4 feet while drilling in Trench T-3 during the OU-2 Phase II RFI/RI alluvial field program in December 1991. At that time, drilling was immediately halted for the day. When drilling resumed the next day, the free-phase DNAPL was no longer present in the borehole, and drilling of the borehole was continued to its final depth of 54 feet. Residual-phase DNAPL was observed in collected soil samples to a depth of about 8 feet. The origin of the free-phase DNAPL and its distribution within Trench T-3 is unknown. It has been speculated that the drill may have penetrated a container, releasing the DNAPL into the borehole, or that the DNAPL was pooled on a liner or other low permeability boundary within or at the base of the trench. However, based on detailed logging of the core from borehole 10191, no indications of a container or liner were identified (e.g., metal shavings or plastic fragments), and it was not possible to identify the base of the trench. Therefore, the source of the free-phase DNAPL, or its fate following its observation in 1991 are unknown.

During drilling of the borehole for nearby well 24793 in 1993, residual-phase DNAPL was observed in soil samples collected from the Rocky Flats Alluvium at depths of 7.7 to 8 feet. This borehole is believed to be 2 feet from the north wall of Trench T-3. Based on the observations at boreholes

10191 and 24793, it appears that free-phase and residual-phase DNAPL have been or are present in and near Trench T-3

Depending on the original quantity of free-phase DNAPL present in the trench, it may have been adsorbed onto soils in the unsaturated portions of the Rocky Flats Alluvium and underlying No 1 Sandstone and exists now only in the residual-phase, or it may have migrated in the free-phase to the underlying saturated zone in the No 1 Sandstone. In either case, it could act as a continuing source of dissolved-phase contamination in groundwater in the saturated zone of the No 1 Sandstone. If DNAPL is present in the free-phase in the saturated zone, its distribution in the No 1 Sandstone could be effected by the proposed pilot pump tests. Additionally, its presence could affect the SVE pilot treatment system.

According to EPA guidance (1992), if the concentration of a compound in groundwater exceeds one percent of that compound's solubility in water, then its potential presence as a DNAPL in the saturated zone should be considered. Table 4-2-1 shows the comparison of concentrations of several compounds in groundwater from wells SV1 and S11 to their respective solubilities in water. Observed PCE concentrations in groundwater are as high as 749 µg/l (0.5 percent of its solubility in water) in the vicinity of Trench T-3. CCl₄ concentrations in groundwater are as high as 3,000 µg/l (0.4 percent of its solubility in water) in the vicinity of Trench T-3. The concentrations of these compounds in groundwater do not exceed one percent of their respective solubilities in water, but are close enough to suggest that NAPLs are potentially present in the saturated zone. Thus, an evaluation of the potential effects of the proposed pilot pump test is appropriate.

4.3 SVE PILOT PUMP TEST

4.3.1 Potential Effects of the Pilot Pump Test on the Distribution of DNAPL in the No. 1 Sandstone

To evaluate potential effects from the pilot pump test to the distribution of DNAPL in the No 1 Sandstone, if it exists, four hypothetical scenarios were developed and evaluated. Each scenario assumed a certain initial distribution of DNAPL in the No 1 Sandstone.

TABLE 4.2-1

GROUNDWATER CONCENTRATIONS VS. ORGANIC SOLUBILITIES

Organic Compound	Groundwater concentrations around IHSS 110 $\mu\text{g/l}$	Solubility limit in water $\mu\text{g/l}$	1% of solubility limit $\mu\text{g/l}$	Groundwater concentration (as a percent of the 1% solubility limit) %
PCE	220 - 749	150,000	1,500	15 - 50
TCE	38 - 65	1,100,000	11,000	0.6
CCl_4	230 - 3000	800,000	8,000	3 - 38
1,1-DCE	4 - 56	400,000	4,000	1.4
CHCl_3	8 - 170	8,200,000	82,000	0.2

Scenario 1 Free-phase DNAPL exists in discrete pools perched on top of discontinuous claystone lenses in the saturated No 1 Sandstone

Scenario 2 Free-phase DNAPL exists in discrete pools of small thickness on top of the claystone at the base of the saturated No 1 Sandstone This is considered a relatively unlikely scenario

Scenario 3 Residual-phase DNAPL exists in the saturated No 1 Sandstone

Scenario 4 Free-phase DNAPL exists in discrete pools on top of the capillary fringe above the water table in the No 1 Sandstone

These four scenarios were then evaluated assuming a pump test was performed in Well 24193/SV1 The potential resulting movement of DNAPL was then assessed as described below

Scenario 1

If free-phase DNAPL is perched on claystone lenses in the saturated zone in the No 1 Sandstone, groundwater pumping could cause the free-phase DNAPL to migrate laterally toward the pumping well As it migrates, the free-phase DNAPL will leave a trail of residual-phase DNAPL along the migration pathway If the free-phase DNAPL is of sufficient quantity and is close to the well, there is the potential for the free-phase DNAPL to reach the well and enter the filter pack or well casing Once in the well casing or filter pack, the free-phase DNAPL could sink, particularly once pumping has stopped Because Well 24193/SV1 is screened across both the No 1 Sandstone and a portion of the underlying claystones of the Lower Hydrostratigraphic Unit (LHSU), this could result in movement of contamination into the LHSU Because the LHSU is composed primarily of claystone at this location, the potential for subsequent movement of contamination away from the well into the LHSU appears to be small However, this is a potential pathway for UHSU contamination to migrate to the LHSU

If the free-phase DNAPL is further away from the pumping well or is present in small quantities, the free-phase DNAPL may not reach the well casing or filter pack before the pump test is discontinued, or it may be held as residual-phase DNAPL along the migration pathway If free-phase DNAPL is

present at the conclusion of the test, and it has moved beyond the perching claystone layer, it may then migrate downward even after pumping is discontinued

Scenario 2

If DNAPL is present in pools on top of the claystone at the base of the No 1 Sandstone, pumping in the sandstone could induce migration of the free-phase DNAPL toward the well. As for Scenario 1, DNAPL could enter the extraction well or filter pack and sink into the LHSU, or it could move toward the well without reaching it prior to completion of the pump test.

Scenario 3

If only residual-phase DNAPL exists in the saturated No 1 Sandstone, pumping will not induce movement of the DNAPL within the sandstone. However, enhanced dissolution of the residual-phase DNAPL to the dissolved phase could occur as water is drawn past the residual-phase DNAPL, potentially increasing dissolved concentrations in groundwater at the well.

Scenario 4

If DNAPL exists in the free phase as small pools of limited thickness on top of the capillary fringe above the water table, the lowering of the water table in the No 1 Sandstone during the pilot pump test could cause the DNAPL pools to move downward with the water table, potentially leaving a trail of residual-phase DNAPL along the migration pathway. As the water table recovers following the test, the free-phase pools may rise with it, but the residual-phase DNAPLs will remain behind in the saturated zone and be susceptible to dissolution. As such, they will likely act as sources of contamination to groundwater.

Other scenarios of DNAPL distribution in the No 1 Sandstone that could be influenced by the pilot pump test are possible. Potential adverse effects from pumping-induced movement of DNAPL, if it occurs, will depend on the location and quantity, as well as the thickness and the contact angle of free-phase DNAPL in the No 1 Sandstone, if any, the duration and the pumping rate of the pilot pump test, and other factors such as the degree of permeability in the UHSU and LHSU at this location.

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In general, it is believed that movement of potential DNAPLs in the No 1 Sandstone from the limited duration pilot pump test should be relatively minor, resulting in little or no adverse impacts with respect to the nature and extent of contamination. An exception to this involves the potential movement of DNAPLs or dissolved contamination into the LHSU by way of the pumping well, which is screened across both the No 1 Sandstone and a portion of the LHSU. Pump test procedures should be designed to minimize this potential.

4.3.2 Potential Impacts to Granular Activated Carbon (GAC) Usage from the Presence of DNAPLs

Using the soil gas extraction rates developed in Subsection 4.3.1, an estimate can be made of granular activated carbon (GAC) usage. GAC loading estimates will be developed using total VOCs in soil gas, and calculated PCE values for saturated conditions.

As noted in Section 2.0, the maximum total VOC concentration in soil gas adjacent to Trench T-3 is 1,000 µg/l (approximately 150 ppm v/v) at 10 feet below ground surface (bgs). Maximum PCE concentrations at the same depth are 600 µg/l. For purposes of calculating carbon usage, it is assumed that the total VOCs in the soil gas have an average GAC loading similar to PCE.

In addition, it is assumed that concentrations of VOCs in the extracted soil gas for the pilot tests could vary two orders of magnitude greater, 10,000 ppm v/v, than the soil gas concentrations reported above. Then using an estimated soil gas extraction rate of 100 scfm and estimated GAC loadings of as low as 5 percent, the first GAC unit (1,800 lbs) could be exhausted in as soon as four hours. GAC usage calculations are provided in Appendix A.

High concentrations of organics in the gas stream being treated with GAC have the potential to overheat the treatment media as a result of the heat of adsorption being released when organics are adsorbed on the GAC. This energy is typically either dissipated into the gas stream or results in volatilization of water from the GAC media into the gas stream. Excessive concentrations can potentially elevate the bed temperature to a point where it could damage the adsorption unit and potentially ignite the GAC media.

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A recent SVE pilot test in April 1993 at Hanford, Washington had an overheat situation in a GAC unit used for off-gas treatment. Extracted soil gas at an inlet concentration of 28,000 ppm v/v of CCl_4 elevated the GAC bed to an estimated 650°F. The temperature of the GAC unit was lowered by introducing water to the vessel (WCFS 1993b).

Due to the potential presence of DNAPL in the vadose zone, elevated concentrations greater than 10,000 ppm v/v potentially exist in the extracted soil gas. To reduce the potential for an overheat situation, VOC inlet concentrations should be monitored and limited. The SVE unit provides for the introduction of the necessary dilution air prior to GAC treatment. The maximum inlet concentration to the GAC units (after dilution) will be limited to 10,000 ppm v/v at an air flow rate of 300 scfm to prevent an overheat situation.

Based on results from the initial pilot tests, GAC usage will be estimated to complete the pilot test and sustained operation. This information will be presented in a memorandum for distribution.

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5.0 CHANGES TO PILOT TEST PROGRAM

As noted in Section 1 0, a major objective of the TM was to evaluate the impact of DNAPLs on the SVE pilot equipment and test objectives. As part of that evaluation, the following changes to the original pilot test plan and objectives have been identified:

- Soil gas extraction rates are modified because an exothermic reaction may be initiated in the GAC units and carbon usage may be excessive.

The following additional changes to the pilot test plan and objectives have been identified:

- Given a system operating pressure of 10 inches of Hg vacuum (approximately 136 inches of water vacuum), the maximum operating pressures for Pilot Tests 2, 3, and 4 of 140 inches of water vacuum may not be attainable.
- Field GC program has been replaced with an off-site analytical laboratory. Therefore, 3 to 4 hour analytical turnaround is not possible.

In order to incorporate the general changes to the original pilot test plan and objectives identified above, the following specific changes will be needed:

- Field GC will be replaced with off-site analytical laboratory with 48 hour turnaround time on pilot test samples to demonstrate and evaluate performance.

Initiation of pilot test No 2 may not occur until rush analytical data are available from Pilot Test No 1 to confirm the system is operating properly. The Final OU-2 Subsurface IM/IRA Implementation Plan (EG&G, 1993d) will need to be revised to reflect this change.

- Soil gas flow rates are modified to reduce potential exothermic reactions and off-gas carbon usage rates.

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In an attempt to minimize the potential of an exothermic reaction and to prevent exhausting the carbon units during the pilot tests, Pilot Test No 1 should start off with a 20 scfm flow rate from AV1 PID readings of total VOCs would be taken every fifteen minutes on the extracted soil gas The soil gas flow rate from AV1 would be increased systematically until a safety level of total VOCs is reached As noted in Section 3 0, 10,000 pm v/v would be an appropriate cutoff value for Pilot Test No 1 This level is estimated to be adequate to limit the potential of an exothermic reaction in the GAC unit However, VOC concentrations at this level may exhaust the GAC after the first pilot test. Based on the data obtained in Pilot Test No 1 a maximum flow rate would be established for the other pilot tests These modifications for Pilot Test No 1 may extend the test from 4 to 8 hours

- The following SVE monitoring changes should be made to reduce VOC loadings on the GAC units
 - Install a real time VOC analyzer to monitor extracted soil concentrations prior to dilution
 - Install a flow meter to monitor extracted soil gas flow rate prior to dilution
 - Install thermocouples in GAC units to monitor for overheat situation
 - Limit VOC loading to the GAC (less than 10,000 pm v/v) unit by controlling the extracted soil gas and dilution gas flow rates and monitoring the extracted soil gas total VOC concentrations
 - The Final OU-2 Subsurface IM/IRA Implementation Plan (EG&G, 1993d) would need to be revised to reflect this change
- Operating pressures of 140 inches of water may not be possible Pilot Tests 2, 3, and 4 will be operated at up to the maximum operating pressure of the SVE pilot unit (10 inches Hg) However, no attempt should be made to increase the operating pressure

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above this threshold The Final OU-2 Subsurface IM/IRA Implementation Plan would need to be revised to reflect this change

- To minimize the potential for introduction of contamination to the LHSU, the extraction well pump should be positioned above the base of the No 1 Sandstone This should induce an upward flow in the portion of the well within the LHSU, reducing the potential for introduction of contamination
- After completion of the pilot tests and sustained operations at Site No 1, the need for a long term monitoring program at IHSS 110 will be evaluated to monitor potential effects from the SVE pilot tests or sustained operations

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Subject SVE Carbon Loading

Project No 4045

By B. O'Mel.

Checked By DRP

Task No 110

Date 1/12/93

Date 1/17/93

File No _____

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Use equation (2) to find lbs of VOCs extracted for varying concentrations

- Assume total VOC concentrations 100 ug/l, 1000 ug/l, 10,000 ug/l

- Assume flow rate of 100 SCFM

- Results presented in attached table

Use equation (2) to estimate carbon capacity

• Assume carbon loading of 5% and 25% (see attached graph)

• Use 1800 lb carbon beds, although system includes 2 x 1,800 lb carbon units in series

• Results attached

(4)

Equation (3)

ug/l to ppm v/v

$$\frac{1000 \text{ ug PCE}}{2 \text{ Air}}$$

$$\frac{1 \text{ mole PCE}}{165.8 \text{ gr PCE}}$$

$$\frac{1 \text{ gr PCE}}{1 \times 10^6 \text{ ug PCE}}$$

$$\frac{24.4 \text{ L air}}{1 \text{ gr mole air}} = 147.7 \text{ ppm v/v}$$

CARBON XLS

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VOC CONCENTRATION (ppmv/v)	VOC CONCENTRATION (ug/l)	Q(lbs/hr) at 100 scfm	HOURS TO EXHAUST CARBON	
			CARBON LOADING	
			5%	25%
10	68	0.03	3541	17707
100	680	0.25	354	1771
147	999 1000	0.37	241	1205
1000	6795	2.54	35	177
6360	43217	16.16	6	28
10000	67951	25.41	4	18

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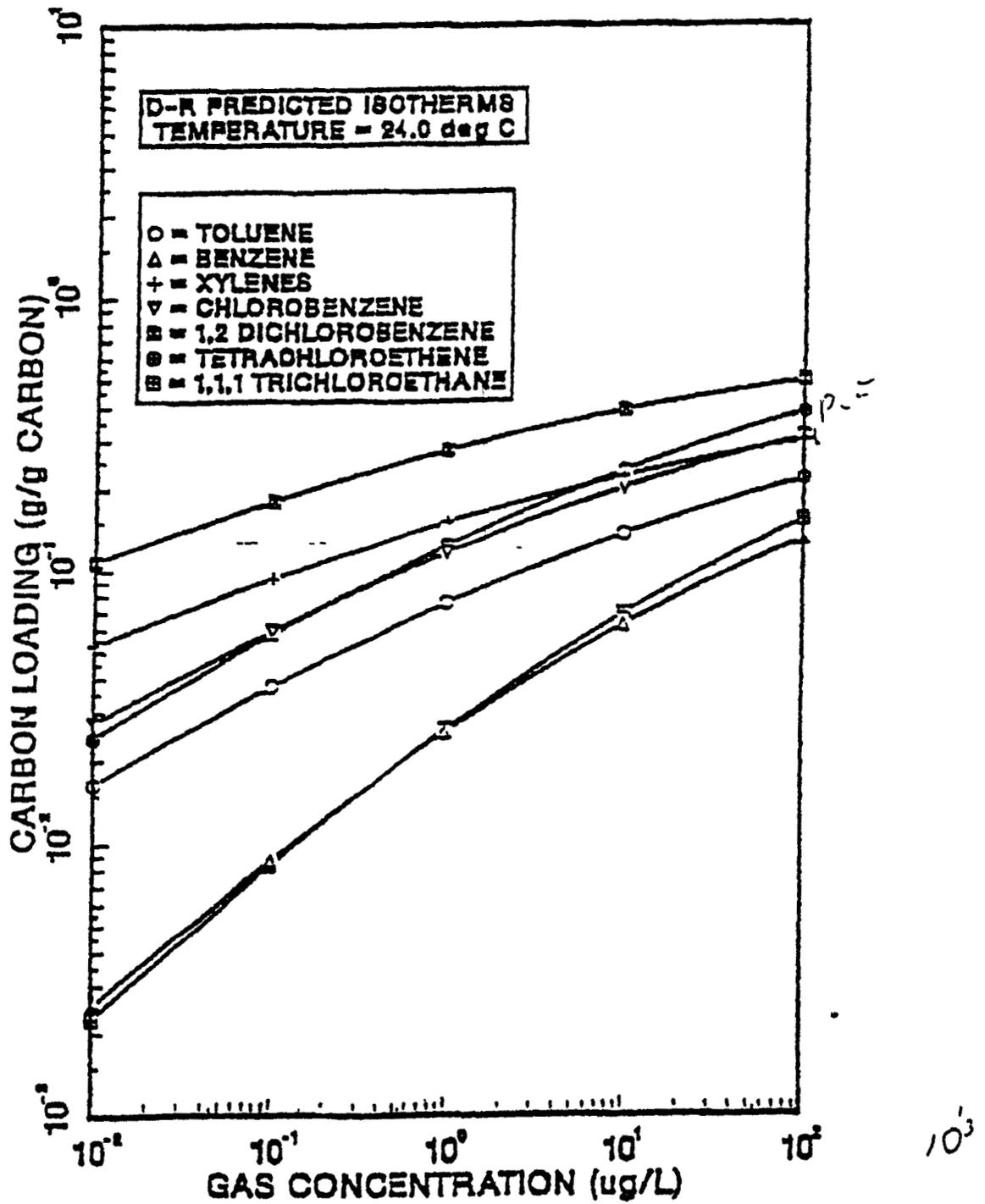


Figure 36. D-R Predicted Isotherms for Common Groundwater VOCs - (Low Surface Loading (Gas Concentrations at STP)).

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ANALYTE ABBREVIATIONS

VOLATILE ORGANIC COMPOUNDS

1 1 1 2-PCA
 1 1 2 2-PCA
 1 1 1 -TCA
 1 1 -DCA
 1 1 -DCE
 1 2 -DCA
 1 2 -DCE
 CCL₄
 CHCL₃
 Cis-1 2-DCE
 PCE
 TCE

1 1 1 2-TETRACHLOROETHANE
 1 1 2 2-TETRACHLOROETHANE
 1 1 1 -TRICHLOROETHANE
 1 1 -DICHLOROETHANE
 1 1 -DICHLOROETHENE
 1 2 -DICHLOROETHANE
 1 2 -DICHLOROETHENE
 CARBON TETRACHLORIDE
 CHLOROFORM
 Cis-1 2-DICHLOROETHENE
 TETRACHLOROETHENE
 TRICHLOROETHENE

METALS AND OTHER COMPOUNDS

Al ALUMINUM
 As ARSENIC
 Ba BARIUM
 Cd CADMIUM
 CN CYANIDE
 Cr CHROMIUM
 Li LITHIUM
 Mn MANGANESE
 Ni NICKEL
 Pb LEAD
 Sb ANTIMONY
 Se SELENIUM
 Sn TIN
 Sr STRONTIUM
 Zn ZINC

RADIONUCLIDES

Am-241 AMERICIUM-241
 Cs-137 CESIUM-137
 Pu-239 PLUTONIUM-239
 Pu-239/240 PLUTONIUM-239/240
 Ra-226 RADIUM-226
 Ra-228 RADIUM-228
 Sr-89 90 STRONTIUM-89 90
 U-233 234 URANIUM-233 234
 U-235 URANIUM-235
 U-238 URANIUM-238

OTHER ABBREVIATIONS

(D) DISSOLVED (FILTERED SAMPLE)
 (T) TOTAL (UNFILTERED SAMPLE)

LABORATORY QUALIFIERS

B = ORGANICS (VOLATILES SEMIVOLATILES PESTICIDES) INDICATES CHEMICAL WAS IN BOTH THE SAMPLE AND METHOD BLANK

B = INORGANIC (METALS & INORGANICS) DETECTED CONCENTRATION WAS LESS THAN CONTACT REQUIRED QUANTITATION LIMIT

B = RADIONUCLIDES - THE ACTIVITY IN THE METHOD BLANK EXCEEDED THE MINIMAL DETECTABLE ACTIVITY

C = PESTICIDE RESULT WHERE IDENTIFICATION WAS CONFIRMED BY GAS CHROMATOGRAPH/MASS SPECTROMETRY

C = RADIONUCLIDES INDICATED ELEVATED TDS

E = ORGANICS - CHEMICAL EXCEEDS CALIBRATION RANGE OF THE INSTRUMENT

E = INORGANIC - REPORTED VALUE IS ESTIMATED DUE TO INTERFERENCE

F = ALPHA SPECTROMETRY - FULL WITH HALF MAXIMUM EXCEEDED ACCEPTANCE LIMITS

D = ORGANICS - ANALYSIS WAS PERFORMED AT A DILUTION

J = ORGANICS - POSITIVELY IDENTIFIED - RESULT IS CONSIDERED TO BE ESTIMATED

J = INORGANICS & RADIONUCLIDES - ESTIMATED QUANTIFICATION

N = METALS - SPIKE RECOVERIES IN THE MATRIX SPIKE SAMPLE DID NOT MEET ADVISORY LIMITS

S = METALS - THE REPORTED VALUE WAS DETERMINED BY THE METHOD OF STANDARD ADDITION (MSA)

U = ALL ANALYSES - ANALYZED CHEMICAL WAS NOT DETECTED ABOVE THE SAMPLE QUANTITATION LIMIT

W = METALS - POST DIGESTION SPIKE DID NOT MEET CONTROL LIMITS

X = OPEN AND DEFINED BY LABORATORY

Y = RADIONUCLIDES - CHEMICAL YIELD EXCEEDED ACCEPTANCE LIMITS

* = METALS - MATRIX DUPLICATE ANALYSIS DO NOT MEET ADVISORY LIMITS

VALIDATION CODES AND QUALIFIERS

A = RESULT ACCEPTED WITH QUALIFICATIONS

AJ = RESULT ACCEPTED BUT WAS ESTIMATED

J = ESTIMATED RESULT DUE TO OUTSIDE HOLDING TIME IMPROPERLY PRESERVED QUALITY CONTROL PARAMETER OUTSIDE CONTROL LIMIT

R = REJECTED RESULT

U = ALL ANALYSES - ANALYZED CHEMICAL WAS NOT DETECTED ABOVE THE SAMPLE QUANTITATION LIMIT

V = VALID RESULT

VA = VALID RESULT WITH QUALIFICATIONS

U S DEPARTMENT OF ENERGY
 Rocky Flats Plant Golden Colorado

OPERABLE UNIT 2
 SUBSURFACE IM/IRA SITE 1
 TECHNICAL MEMORANDUM NO 1

ANALYTE ABBREVIATIONS,
 LABORATORY AND VALIDATION
 QUALIFIERS

