START

0027706

ENGINEERING CHANGE NOTICE

Page 1 of 1

1. ECN 169856

Proj. ECN

2. ECN Category (mark one)	3. Originator's Name, Organization, MSIN, and Telephone No.		4. Date
Supplemental []	V. J. Rohay, 81231, H6-06, 6-5507		4/20/93
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12. Description of Change

Add sampling and analysis information for in situ bioremediation well in section 3.5.5.6 and in the Field Sampling Plan, Appendix A (including new section 5.8, Continuous Split-Barrel Sampling for In Situ Bioremediation Well, and new section 8.0, Hydrologic Testing and Analysis).

Add alternative location for angle borehole in section 3.5.5.1.

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13a. Justification (mark one)							
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As-Found	[X]	Facilitate Const.	[]	Const. Error/Omission	[]	Design Error/Omission	[]

13b. Justification Details

Changes required to meet site characterization objectives.

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V. J. Rohay	H6-06	D. J. Moak	N3-05	F. Stone	H6-01		
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	ENGINEERING		CONSTRUCTION			
[] Yes	Additional	[] $	Additional	[] $	Improvement	[]
[X] No	Savings	[] $	Savings	[] $	Delay	[]

18. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 12. Enter the affected document number in Block 19.

SDD/DD	[]	Seismic/Stress Analysis	[]	Tank Calibration Manual	[]
Functional Design Criteria	[]	Stress/Design Report	[]	Health Physics Procedure	[]
Operating Specification	[]	Interface Control Drawing	[]	Spares Multiple Unit Listing	[]
Criticality Specification	[]	Calibration Procedure	[]	Test Procedures/Specification	[]
Conceptual Design Report	[]	Installation Procedure	[]	Component Index	[]
Equipment Spec.	[]	Maintenance Procedure	[]	ASME Coded Item	[]
Const. Spec.	[]	Engineering Procedure	[]	Human Factor Consideration	[]
Procurement Spec.	[]	Operating Instruction	[]	Computer Software	[]
Vendor Information	[]	Operating Procedure	[]	Electric Circuit Schedule	[]
OM Manual	[]	Operational Safety Requirement	[]	ICRS Procedure	[]
FSAR/SAR	[]	IEFD Drawing	[]	Process Control Manual/Plan	[]
Safety Equipment List	[]	Cell Arrangement Drawing	[]	Process Flow Chart	[]
Radiation Work Permit	[]	Essential Material Specification	[]	Purchase Requisition	[]
Environmental Impact Statement	[]	Fac. Proc. Samp. Schedule	[]		[]
Environmental Report	[]	Inspection Plan	[]		[]
Environmental Permit	[]	Inventory Adjustment Request	[]		[]

19. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

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20. Approvals

	Signature	Date		Signature	Date
OPERATIONS AND ENGINEERING			ARCHITECT-ENGINEER		
Cog Engineer V. J. Rohay	V J Rohay	4/20/93	PE		
Cog. Mgr. A. J. Knepp	A J Knepp	4/23/93	QA		
QA R. L. Hand	R L Hand	4/23/93	Safety		
Safety			Design		
Security			Environ.		
Environ. M. C. Hagood	M C Hagood	4/23/93	Other		
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Facilities Operations			DEPARTMENT OF ENERGY		
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Name: V. J. Rohay

V J Rohay

Signature

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7. Abstract

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1.0 INTRODUCTION

1.1 PURPOSE

This work plan presents a detailed outline for FY 93 site characterization activities to be conducted at the carbon tetrachloride contamination site in 200 West Area of the Hanford Site in southeastern Washington. The carbon tetrachloride contamination is the primary focus of both the Volatile Organic Compounds-Arid Integrated Demonstration (VOC-Arid ID) and 200 West Area Carbon Tetrachloride Expedited Response Action (ERA). The VOC-Arid ID is a technology development program to provide new technologies for cleanup of VOC, such as carbon tetrachloride, at arid sites. The ERA is an environmental restoration program to remove carbon tetrachloride from the unsaturated soils in the 200 West Area. The site characterization activities in support of the these two programs have been fully integrated throughout planning and implementation. This work plan provides the U.S. Environmental Protection Agency (EPA) and the Washington Department of Ecology (Ecology) with the objectives and scope of the unified FY 93 site characterization plan.

1.2 BACKGROUND

The VOC-Arid ID is a U.S. Department of Energy (DOE) program funded by the Office of Technology Development that is targeted at the acquisition, development, demonstration, and deployment of technologies for evaluation and cleanup of VOC and associated contaminants in soils and ground waters of arid DOE sites. The DOE contractors, national laboratories, universities, and industry are participants in the program. New technologies will be demonstrated in the areas of site characterization; performance prediction, monitoring, and evaluation; contaminant extraction and ex situ treatment; in situ remediation; and site closure and monitoring. The performance of these technologies will be compared to baseline (i.e., conventional) technologies and documented to promote the transfer of the new technologies to industry for use at the Hanford Site and other DOE sites.

An ERA is a provision included in the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) that allows accelerated cleanup activities to be undertaken at waste sites to abate imminent hazards or to prevent significantly increased degradation of the environment that might occur if action were delayed until completion of the remedial investigation/feasibility study and the record of decision. The ERA is implemented according to the requirements outlined in the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 1989), Part 3, Article XIII, Section 38), and in accordance with 40 CFR Part 300, Subpart E.

In December 1990, the EPA and Ecology requested the DOE, Richland Field Office (RL) to proceed with detailed planning, including nonintrusive field work required to implement the ERA for the carbon tetrachloride contamination in the 200 West Area. The request was made based on concerns that the carbon tetrachloride residing in the soils was continuing to spread to the ground water and, if left unchecked, would significantly increase the area of ground water contamination.

The initial demonstration site for the VOC-Arid ID is also the area of carbon tetrachloride contamination in the 200 West Area. The contamination is linked to past liquid waste disposal practices resulting from operation of the Plutonium Finishing Plant (PFP) in the 200 West Area near the center of the Hanford Site (Figure 1). Last et al. (1991) summarized the physical and chemical characteristics of this site for the principal investigators of candidate new technologies.

The first site evaluations were conducted at this site from January through April 1991 as part of the ERA to refine the preliminary conceptual model and to collect data in support of the selection and design of an initial remedial action (Hagood and Rohay 1991). The results of the Phase I ERA site evaluation were summarized in June 1991 (DOE-RL 1991, Appendix B). Based on this work and on the engineering evaluation and cost assessment, the preferred alternative for removal of the carbon tetrachloride from the unsaturated zone was identified as soil vapor extraction followed by aboveground collection on granular activated charcoal (DOE-RL 1991). In January 1992, EPA and Ecology authorized DOE to initiate soil vapor extraction for cleanup of the carbon tetrachloride in the unsaturated soils.

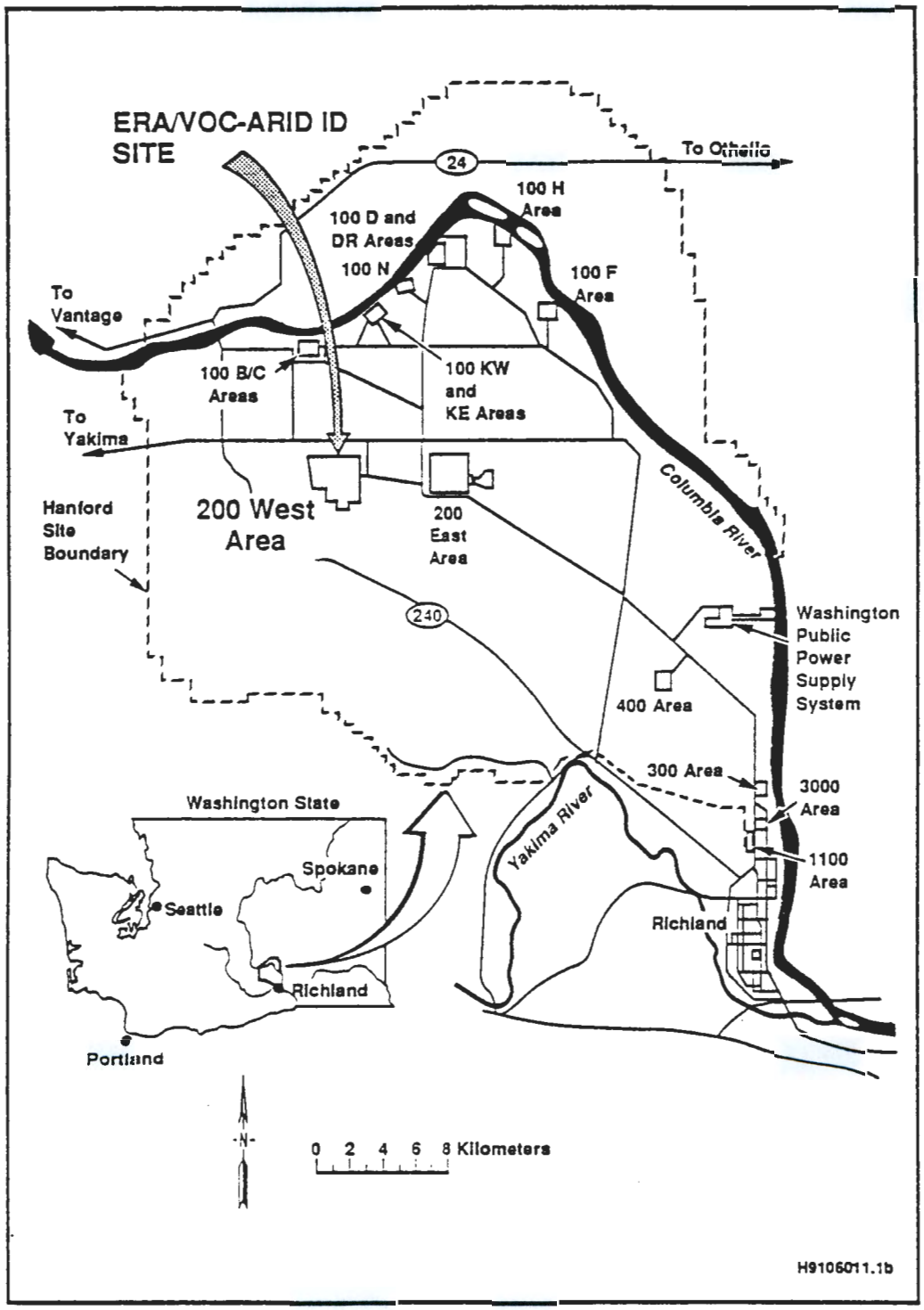
In March 1991, DOE approved the use of a categorical exclusion under Section D of DOE's National Environmental Policy Act (NEPA) Guidelines for the ERA site characterization activities. In April 1992, DOE approved the use of a categorical exclusion for the VOC-Arid ID site characterization activities. The activities discussed in this work plan, and the environmental impacts associated with these activities, are within the scope of activities and impacts discussed in the NEPA documentation supporting these two NEPA categorical exclusion approvals. It has, therefore, been determined that the activities described in this work plan are adequately addressed by this existing NEPA documentation and that no further NEPA documentation need be performed for these activities.

Detailed plans for conducting the Phase II (FY 92) of the ERA site evaluation and the initial (FY 92) VOC-Arid ID site characterization efforts were submitted in September 1991 (Rohay 1991) and November 1991 (Last and Rohay 1991), respectively. These site characterization and evaluation efforts were conducted jointly. The status and accomplishments of the combined FY 92 characterization program are described by Rohay et al. (1992). That report also includes or references all available raw data collected as part of the FY 92 characterization tasks. Interpretation and integration of the data, and the updated site conceptual model, will be reported in a separate document to be issued in January 1993.

1.3 APPROACH

The VOC-Arid ID and ERA site characterization programs have been merged to maximize efficient use of time and resources and to ensure that each activity and resulting product achieves the maximum usefulness to both programs. In addition, these activities will be coordinated with those of related programs in the 200 West Area, such as the 200 West Aggregate Area Management Study, the Resource Conservation and Recovery Act of 1976, the contemplated 200 West Area carbon tetrachloride ERA for ground water, if approved, and WAC 173-216 state waste discharge permitting.

Figure 1. Location of the VOC-Arid ID/ERA Site.



During FY 92, the carbon tetrachloride characterization effort focused on the unsaturated zone and on optimizing the effectiveness of the soil vapor extraction system in use for the ERA. Intrusive field activities were conducted near, but outside of, the carbon tetrachloride disposal sites. In FY 93, characterization will continue on the unsaturated zone, but intrusive field activities are planned to investigate directly beneath the disposal sites. In addition, characterization efforts will begin to address other remediation technologies such as in situ bioremediation and in situ heating.

2.0 SUMMARY OF SITE CHARACTERISTICS

This section provides a brief summary of site characteristics as background for this work plan. More detailed discussions of site characteristics are provided by Rohay and Johnson (1991), Last et al. (1991), and Rohay et al. (1992).

2.1 SITE OPERATIONS

This section describes the operational and disposal history of carbon tetrachloride at and near the PFP (Figure 2). No other plant in the 200 West Area is known to have used carbon tetrachloride.

The PFP was designed to process plutonium to a final product form using three process lines. Each of these process lines generated side streams that contained recoverable quantities of plutonium. The Recuplex facility and the Plutonium Reclamation Facility (PRF) (Figure 3) were established to recover plutonium from these streams and were the primary contributors of carbon tetrachloride to 200 West Area soils.

Carbon tetrachloride was used in mixtures with other organics to recover plutonium from aqueous streams. The aqueous waste stream, characterized as high-salt aqueous waste, was primarily a concentrated nitrate solution that had a pH of 1 (neutralized to a pH of 2.5 prior to discharge). The chemical processes used to recover plutonium resulted in the production of actinide-bearing aqueous and organic waste liquids. The primary radionuclide components of these liquids were plutonium-239/240 and americium-241.

Both aqueous and organic phase wastes were discharged to the same liquid waste disposal sites. The carbon tetrachloride was periodically discharged batch-wise as an organic phase mixture and was also a minor (<1%) component of the aqueous phase. The aqueous wastes were continuously discharged.

Organic liquids discharged to the disposal sites consisted of carbon tetrachloride in mixtures with tributyl phosphate, dibutyl butyl phosphonate, or lard oil. Degradation products of carbon tetrachloride include chloroform and methylene chloride. Breakdown products of tributyl phosphate include dibutyl phosphate and monobutyl phosphate. In addition to the plutonium and americium, other constituents of the waste streams discharged to the sites include aluminum, cadmium, calcium, chromium, fluoride, chloride, iron, iodine, magnesium, nickel, nitrate, rubidium, sodium, sulfate, sulfamate, cesium-137, cobalt-60, uranium, ruthenium-106, and strontium-90.

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Figure 2. Site Map of the 200 West Area.

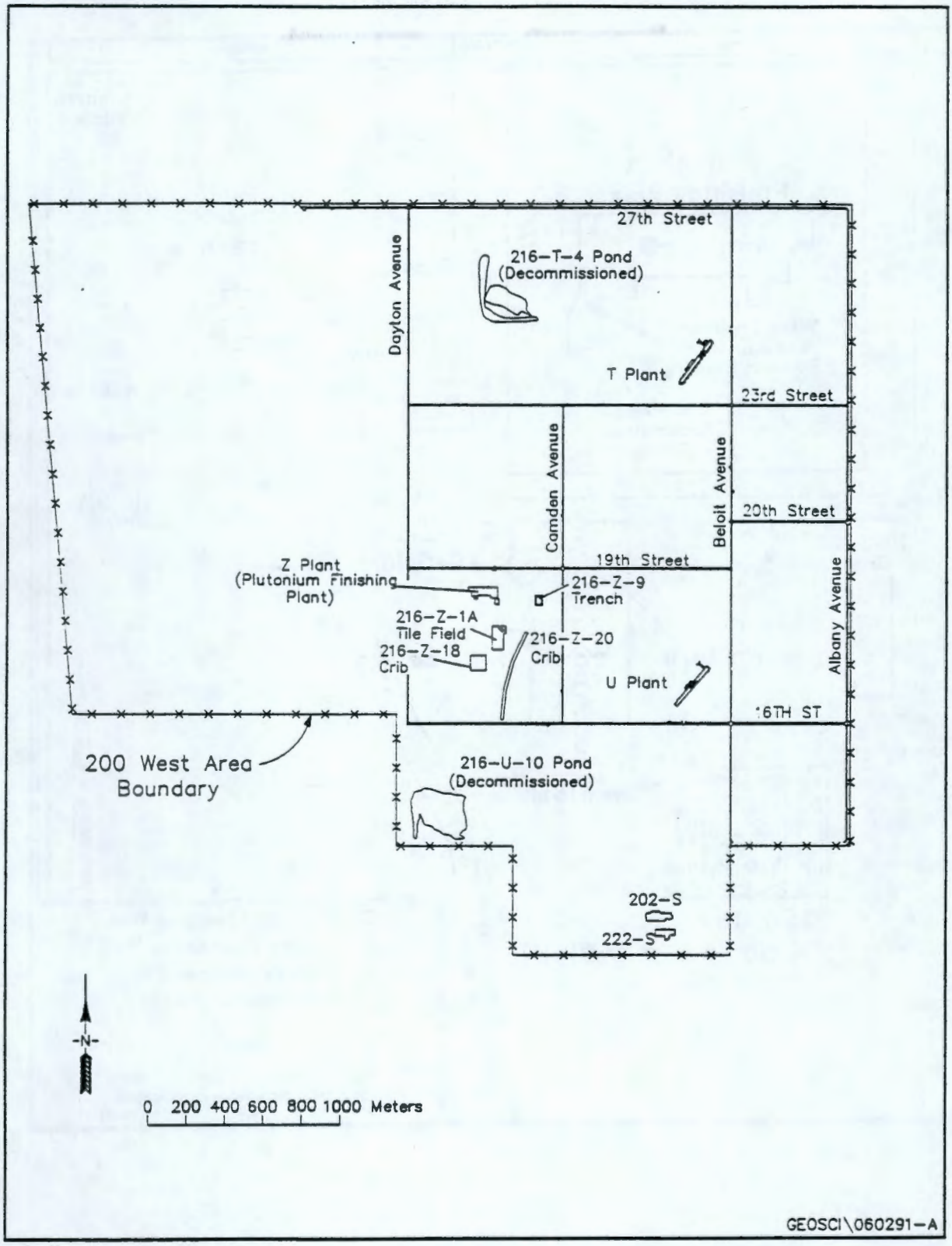
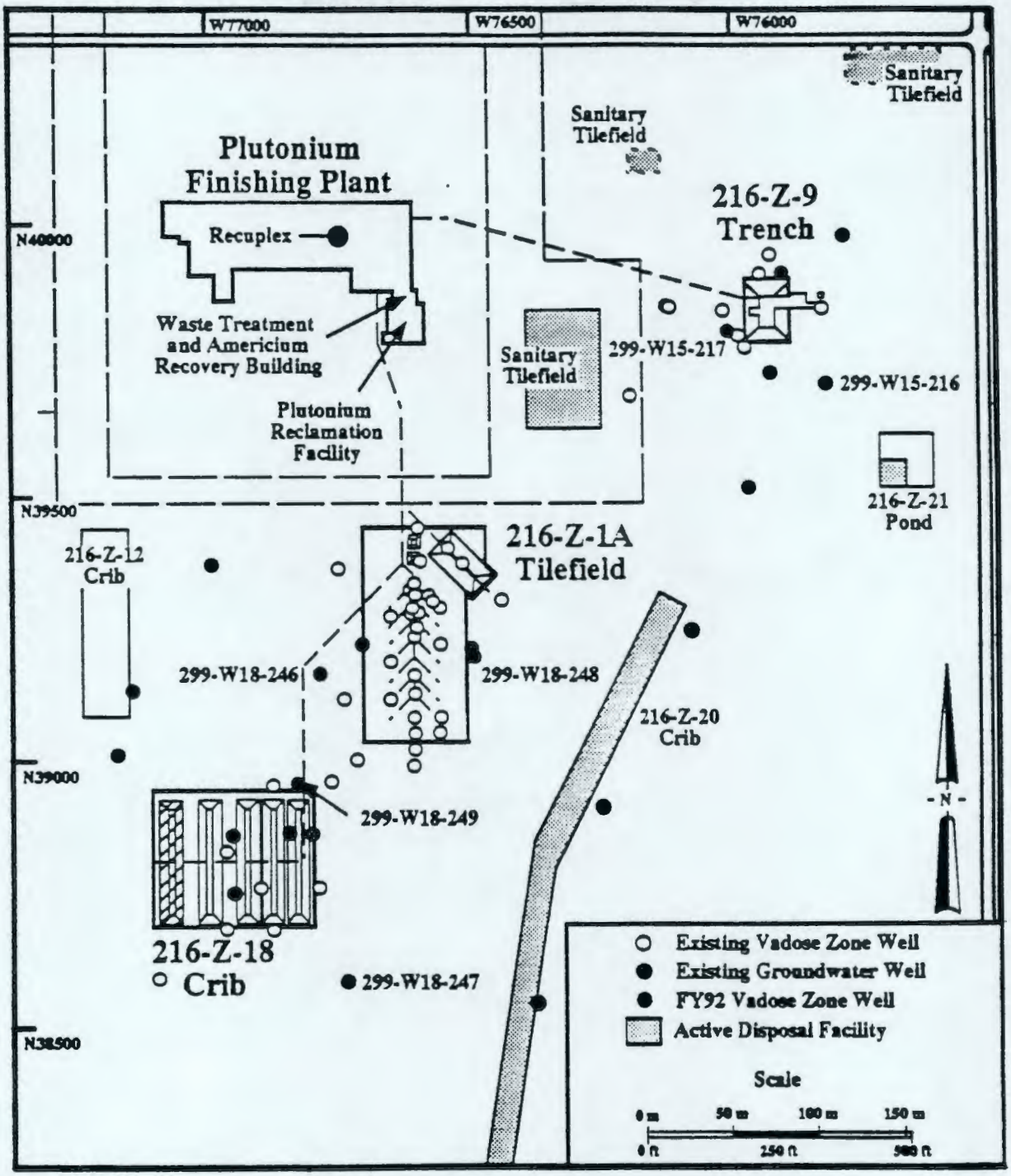


Figure 3. Existing Crib and Near-Field Wells at the Carbon Tetrachloride Site.



The carbon tetrachloride disposal sites, located near the PFP in the 200 West Area, are: the 216-Z-9 Trench; 216-Z-1A Tile Field; and 216-Z-18 Crib (Figure 3). The 216-Z-9 Trench was used from 1955 to 1962 to receive all organic and aqueous waste from the Recuplex facility. Organic and aqueous waste from the PRF was discharged to 216-Z-1A Tile Field from 1964 to 1969 and to 216-Z-18 Crib from 1969 to 1973. Discharge of carbon tetrachloride to the soil column was discontinued in 1973.

Estimates of the volumes and quantities of various liquids and contaminants discharged to the three carbon tetrachloride disposal sites are summarized in Table 1. A total of 363,000 to 580,000 L of carbon tetrachloride is estimated to have been discharged to the soil column between 1955 and 1973.

Table 1. Contaminant Inventory in Carbon Tetrachloride Liquid Waste Disposal Sites.

Contaminant	216-Z-9	216-Z-1A[a]	216-Z-18
Carbon tetrachloride (L)	83,000-300,000	170,000	110,000
Plutonium (kg)	106[b]	57	23
Americium (kg)	2.5	1	-0.4
Total Liquid (L)	4.09×10^6	5.2×10^6	3.96×10^6
Period of Use	1955-1962	1964-1969	-1973

[a]From 1949 to 1959, the 216-Z-1A Tile Field received approximately 1×10^6 L of slightly basic, aqueous waste via overflow from associated 216-Z-1, -2, and -3 Cribs prior to disposal of PRF waste. From 1964 to 1969, PRF wastes were discharged directly to 216-Z-1A.

[b]58 kg were later removed.

Boreholes were drilled from 1949 to 1978 to characterize/monitor the three carbon tetrachloride disposal sites, primarily with regard to the radionuclide concentrations. Six boreholes were installed in FY 92 as part of the VOC-Arid ID/ERA characterization program. Fifty-two boreholes are potentially available in the vicinity of the carbon tetrachloride disposal sites for additional characterization, monitoring, and remediation (Figure 3). Construction details for these boreholes are summarized in the ERA proposal (DOE-RL 1991, Appendix C) and the FY 92 characterization status report (Rohay et al. 1992).

2.2 CONCEPTUAL MODELS

2.2.1 Hydrogeology

The geology of the 200 West Area consists primarily of fluvial and glaciofluvial sediments underlain by basalts. The principal geologic units are, from youngest to oldest (Figure 4):

- Hanford formation - unconsolidated glaciofluvial gravels, sands, and silts deposited by Pleistocene cataclysmic flood waters.
- Early "Palouse" soil - eolian silt and fine-grained sand.
- Plio-Pleistocene unit - basaltic ditritus and carbonate-rich paleosol, often referred to as the caliche layer.
- Ringold Formation - a series of consolidated alluvial sands and gravels, and overbank and lacustrine deposits, of late Miocene to Pliocene age.
- Saddle Mountains Basalt Formation - a series of miocene tholeiitic basalt flows.

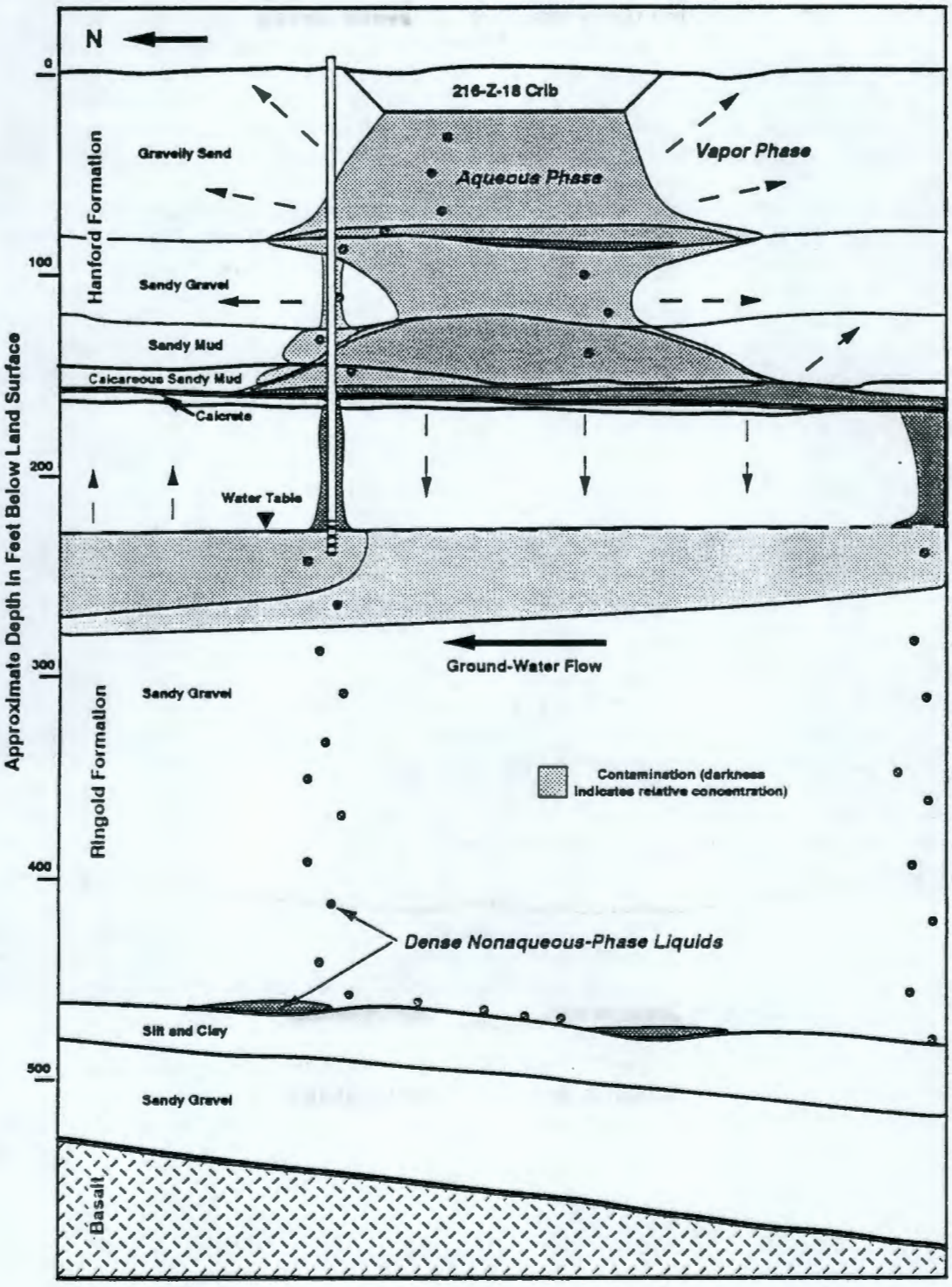
The unsaturated zone, which consists of sediments of the Ringold Formation, Plio-Pleistocene unit, early "Palouse" soil, and Hanford formation, ranges in thickness from 58 to 82 m across the 200 West Area and from 60 to 66 m beneath the carbon tetrachloride disposal sites. Because the Plio-Pleistocene unit is less permeable than the other units, it may temporarily divert or perch liquids and/or dense vapors. The top of this unit is approximately 40 m below ground surface. The topography of the Plio-Pleistocene surface suggests that it locally forms a ridge that extends south-southwest beneath the three carbon tetrachloride disposal sites and may divert fluids laterally to the west-northwest.

The uppermost aquifer in the 200 West Area is unconfined and located within the Ringold Formation. The saturated thickness of the uppermost aquifer ranges from 67 to 113 m. Ground water flow directions are generally radial outward from the southwest portion of the 200 West Area primarily because of the continuing influence of the residual ground water mound underlying the decommissioned 216-U-10 Pond (Figure 2). Recharge to the aquifer is primarily artificial recharge from waste disposal activities.

2.2.2 Carbon Tetrachloride Behavior

Carbon tetrachloride was discharged to the subsurface in the PFP area both in an aqueous solution and as a nonaqueous phase liquid. It is assumed that, initially, carbon tetrachloride was present and migrated in the unsaturated zone as an aqueous phase and as a separate, dense nonaqueous phase liquid (DNAPL). Subsequently, volatilization of the carbon tetrachloride has produced a vapor phase. Figure 4 illustrates the conceptual pathways and distribution of carbon tetrachloride released to the cribs. The conceptual behavior and distribution mechanisms are briefly described.

Figure 4. Conceptual Model of Carbon Tetrachloride Migration Pathways and Phase Distributions.



Aqueous phases containing dissolved carbon tetrachloride may have migrated directly to the ground water by exceeding the water retention capability of the soils beneath the crib. Pore volume estimates indicate that 216-Z-9 Trench is the most likely to have exceeded this capacity. Soil gas surveys also indicate the highest concentrations of carbon tetrachloride in the vicinity of the 216-Z-9 Trench. Volume estimates for the dissolved carbon tetrachloride plume in the upper 10 m of the unconfined aquifer account for <2% of the discharge inventory. This suggests that significant amounts of the carbon tetrachloride may still be present in the unsaturated zone, potentially providing a continuous source of contamination to the ground water. At a well 40 m northeast of the 216-Z-9 Trench, dissolved carbon tetrachloride is found in the aquifer 52 m below the water table; however, the borehole itself may have provided the pathway by which the carbon tetrachloride reached this depth.

Separate nonaqueous phase carbon tetrachloride may have settled deep in the aquifer via preferential pathways (such as unsealed wells) and remained undetected, providing a continuous source of contamination by dissolution. Residual DNAPL contamination may also remain trapped in the unsaturated zone pores. Separate, nonaqueous phase carbon tetrachloride has not been encountered in the either the aquifer or the unsaturated zone.

Liquid carbon tetrachloride has a moderately high vapor pressure and limited solubility, making it relatively volatile. Carbon tetrachloride vapors have been detected in gases extracted from soil pores in the unsaturated zone near the carbon tetrachloride disposal sites; measured concentrations have been highest at the 216-Z-9 Trench. In addition, carbon tetrachloride vapors have been detected at the wellhead during drilling throughout most of the 200 West Area since 1987. The density of carbon tetrachloride vapor is greater than uncontaminated vapors in the unsaturated zone. This contrast in vapor densities can result in density-driven advection, which can act to move carbon tetrachloride downward. Zones of relatively impermeable soils may laterally divert the carbon tetrachloride away from the disposal sites. In addition, carbon tetrachloride vapors in the unsaturated zone, which equilibrate with perched water and/or percolating waste water from other sources, may then be transported to the water table in dissolved form. Recent borehole drilling and sampling has indicated that the highest concentrations of carbon tetrachloride have been found in a silt and fine-grained sand (early "Palouse" soil) overlying a low permeability caliche horizon (Plio-Pleistocene unit).

Differences in crib sizes in quantities, frequencies, and concentrations of liquid wastes received and in heterogeneities of soil properties can impact mechanisms by which carbon tetrachloride is distributed in the soil.

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3.0 FY 93 SITE EVALUATION PLAN

The FY 93 site characterization work covers the unsaturated and saturated zones, and includes drilling operations, aquifer testing, effluent pipeline evaluations, various nonintrusive sampling operations, and expanded data compilation. This section outlines the site characterization objectives and describes the specific tasks planned to accomplish them. The sampling and analysis plan and health and safety plan are included in the appendices.

Although this work plan describes all the FY 93 site evaluation tasks planned to accomplish the site characterization objectives, individual tasks will be prioritized in accordance with funding requirements, recommendations by the Characterization Technical Support Group to the VOC-Arid ID, and determination that existing information is sufficient. Some tasks may be deferred to other programs. Task decisions will be recorded in the FY 93 site characterization task status report.

3.1 OBJECTIVES

The FY 93 site evaluation tasks are focused on the unsaturated zone directly beneath the carbon tetrachloride disposal sites and on the ground water in the vicinity of the carbon tetrachloride disposal sites. The primary purpose of the site characterization and evaluation activities outlined in this work plan is to refine the conceptual model of the site, both to aid development and testing of new technologies and to optimize removal of the carbon tetrachloride. Other objectives of the site characterization work include monitoring the performance of remedial actions (including remedial technology demonstrations); providing samples to support technology demonstrations; and demonstrating and using new characterization and monitoring technologies. Each of these objectives is discussed below.

3.1.1 Refine Conceptual Model of Site

Critical aspects of the model include descriptions of: (1) the nature and extent of the contamination; (2) the preferential transport pathways and rates (i.e., the hydrogeologic model); and (3) the behavioral characteristics of the wastes.

3.1.1.1 Nature and Extent of Contamination. Describing the nature and extent of contamination includes determining the identity, phase, concentration, and current distribution of the individual contaminants. This information is fundamental for identifying technology needs and for designing effective remedial actions.

3.1.1.2 Preferential Transport Pathways and Rates. Determination of the preferential transport pathways and rates is needed for both the unsaturated zone and unconfined aquifer, and requires defining the hydrogeologic model. Particular emphasis is on identifying the physical, chemical, and microbiological parameters of the subsurface environs that affect transport and on describing the spatial variability of these parameters. This information is needed to support predictive modeling (simulation) of the unsaturated zone in the vicinity of the carbon tetrachloride disposal facilities.

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3.1.1.3 Behavioral Characteristics of the Wastes. Determining the behavior of the wastes includes defining the physical (i.e., phase partitioning, fluid properties, etc.) and chemical properties of the carbon tetrachloride, the co-contaminants and the mixtures discharged to the carbon tetrachloride disposal sites. Of principal interest are the physical, chemical, and microbiological characteristics of the wastes that affect their transport, sorption, and natural degradation. Descriptions of the behavioral characteristics of the wastes are needed to support predictive modeling and to identify technology needs.

3.1.2 Monitor Performance of Remedial Actions

Changes in the nature and extent of contamination can be used to assess the impact and performance of various remedial actions. Emphasis is on monitoring the ongoing vapor extraction operations for carbon tetrachloride in the unsaturated zone. Baseline data will also be collected for assessing future remedial technology demonstrations or actions in the unsaturated zone and ground water. Of particular importance is distinguishing the effects of natural stresses on the system from man-induced stresses.

3.1.3 Provide Data to Support Technology Demonstrations

Per request, data and samples are provided to principal investigators to support the design and demonstration of their individual technologies. In addition, baseline data are collected for performance evaluation of comparative technologies. Data are also collected to guide selection of appropriate new technologies for demonstration.

3.1.4 Demonstrate and Use New Characterization and Monitoring Technologies

Promising new site characterization and monitoring technologies are demonstrated as part of the site evaluation efforts. These technologies may be in addition to those sponsored by individual VOC-Arid ID principal investigators. The demonstrations are designed to collect site characterization data for the VOC-Arid ID/ERA in addition to testing the feasibility and value of the technology itself. Those technologies that constitute improvements to conventional methods will be used in site characterization activities.

3.2 DATA TECHNICAL NEEDS

The FY 93 site evaluation tasks designed to accomplish the four objectives described in Section 3.1 include field investigations, laboratory studies, data management and evaluation, and technology demonstration support. A discussion of each objective, the data needed to accomplish it, and the tasks designed to acquire these data is provided in this section. Table 2 outlines the data needs and data acquisition tasks designed to accomplish each objective.

Table 2. Data Technical Needs.

TASKS	Source Term	Soil Gas	Geophysical Surveys	Existing Wells	New Wells	GW Sampling	Lab. Studies	Data Mgmt.	Numerical Modeling	Data Evaluation	Support Tech. Demos
OBJECTIVE/DATA NEEDS											
REFINE CONCEPTUAL MODEL											
NATURE OF CONTAMINATION										X	
Source Term	X										
Chemical Constituents/Mixtures Present		X		X	X	X		X			X
Phase(s) of Constituents/Mixtures		X			X	X					
Temporal Changes		X		X		X					
EXTENT OF CONTAMINATION										X	
Distribution of Contaminants in all media		X	X	X	X	X		X			X
Concentrations of Contaminants in all media		X		X	X	X		X			X
Inventory/Mass Balance Assessment		X			X	X			X		
Temporal Changes		X		X		X		X	X		
TRANSPORT PATHWAYS										X	
Vadose Zone/Groundwater											
Hydrogeologic Framework			X	X	X			X			X
Integrety of Old Wells				X							
Natural/Artifical Recharge	X			X							
Groundwater Potentials				X	X	X					
Pathways to Atmosphere											
Soil Gas Mechanisms		X									X
Well Head Mechanisms				X							
Biological Pathway											
Vegetation Concentrations	X										
TRANSPORT RATES										X	
Soil Vapor Movement					X		X		X		
Aqueous Waste Movement			X	X	X				X		
NAPL Movement							X		X		
Sorption/Desorption Parameters							X				
WASTE BEHAVIOR											
Physical Properties										X	
Phase Partitioning							X				
Movement in Porous Media							X				
Chemical Properties											
Degredation Chain							X				
Sorption							X				
Microbiological Degredation Chain											
SUPPORT TECH. DEMOS					X		X	X		X	X
DEMO. CHAR./ MON. TECHNOLOGIES	X	X	X	X	X					X	X

3.2.1 Refine Conceptual Model of the Site

The conceptual models presented in Section 2.2 were developed by integrating a general understanding of the behavior of carbon tetrachloride in the subsurface with the distribution of carbon tetrachloride observed during FY 91 and FY 92 site characterization. However, the nature of the carbon tetrachloride and co-contaminants and their lateral and vertical extent remain largely unknown. The location of principal pathways, transport rates, and waste behavior in the subsurface environs is also poorly defined. A better understanding of the contaminants, their distribution, and behavior is needed to assess the effectiveness of remedial actions, to improve the design of the remediation systems, to improve the selection and appropriate deployment of new promising technologies, and to support predictive modeling.

The data needed to meet this objective include: (1) better definition of the source terms (i.e., accurate contaminant inventories, the number and location of contaminant release points, and accurate release histories); (2) better definition of the wastes present in the environment (i.e., chemical constituents and mixtures, their physical phases), their distribution, and their concentrations in various media; (3) better definition of the hydrogeologic facies and their transport properties (e.g., porosity, pore size distribution, hydraulic conductivities, air permeabilities); (4) identification of probable manmade pathways (e.g., poorly sealed wells, intercomunication in wells, open/perforated wells); (5) definition of the driving forces (i.e., natural and artificial recharge, hydraulic potentials, barometric potentials, earth tides); (6) evaluation of the potential for vegetation uptake and release; and (7) determination of the waste mixture behavior (e.g., three-phase flow, chemical degradation cycles, microbiological degradation cycles, sorption/desorption).

Tasks identified to accomplish these objectives will test assumptions and predictions based on the hydrogeologic and contaminant behavior conceptual models and will take advantage of the opportunities to collect additional data. These tasks include: source term characterization; soil gas surveys; evaluation and sampling of existing wells; deepening/installing of crib wells; installation of a deep ground water well; ground water sampling; physical, chemical, and microbiological analyses; geochemical studies; waste transport studies; data management and evaluation; and numerical modeling.

3.2.2 Monitor Performance of Remedial Actions

Probes and sensors that can be resampled over a selected period of time probably provide the most useful data for monitoring and assessing performance of remedial action. Soil gas surveys, geophysical surveys, ground water sampling, and soil gas sampling at new and existing wells all provide opportunities to establish datasets on changes in contaminant and co-contaminant distributions and concentrations over time. Baseline monitoring for the ERA, which consists of periodic monitoring of soil gas at wellheads and probes, is designed in part to monitor the performance of the vapor extraction operations. Meteorological data collected at the Hanford Meteorological Station and at site-specific locations near the carbon tetrachloride disposal sites are needed to evaluate the effects of natural stresses on the systems.

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3.2.3 Provide Data to Support Technology Demonstrations

The selection and success of new technologies are dependent on understanding the physical, chemical, and/or microbial constraints of the subsurface environment, and the nature, distribution, and concentration of the contaminants. For example, the high permeability of the unsaturated zone may be favorable to vapor extraction technologies; but the same coarse, unconsolidated, clast-supported gravels inhibit some advanced drilling technologies. Likewise, the nature and concentration of the contaminants may favor some sensor technologies over others, and/or may be more suitable to some in situ remediation technologies (e.g., bioremediation) than others. Virtually all data collected during site characterization will be useful in selecting and evaluating various new technologies. Site-specific data and samples requested by principal investigators of new the technologies are collected during soil gas surveys, drilling and sampling of crib boreholes, and drilling of a deep ground water well. Data from these tasks will also be used to support the ERA activities (e.g., vapor extraction system design and wellfield design).

The technology support needs identified to date include: collection of soil samples to support the in situ bioremediation and supercritical fluid extraction/field transportable detection technology demonstrations; access to a number of isolated screened intervals to support sensor technology demonstrations; and analytical data on the concentration of co-contaminants (principally the phosphonates and phosphates) that may affect sensor performance. Other technology support needs are expected to arise as the technology demonstrations mature.

3.2.4 Demonstrate and Use New Characterization and Monitoring Technologies

Before new technologies can be adopted for environmental restoration work, including site characterization, they must compare favorably to the conventional technologies in terms of safety, speed, reliability, accuracy, economy, and/or feasibility. Data collected during site characterization activities using conventional technologies is thus needed as the baseline for evaluation of the new technologies. The specific data needed will depend on the technology being demonstrated. In addition, new technologies are tested as part of site characterization to evaluate their utility.

3.3 DATA QUALITY NEEDS

The EPA has devised a classification of analytical levels for contaminant data (EPA 1987):

- Level I consists of field screening methods
- Level II entails more advanced on site analytical techniques
- Level III pertains to standard laboratory program procedures
- Level IV consists of EPA Contract Laboratory Program (CLP) procedures
- Level V pertains to specially developed procedures where standard methods are not available or where a high degree of analytical sensitivity is required.

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As the analytical level increases, costs and turnaround times also increase substantially.

The data quality needs are defined by the analytical levels required to meet the VOC-Arid ID and ERA objectives. In general, the VOC-Arid ID/ERA site characterization analytical data should be reproducible and reliable, and realtime, but do not need to be validated in accordance with CLP procedures. The data quality needs are identified in Table 3, which lists the analytical levels to be applied to each type of analysis. Data quality needs in this context apply only to laboratory or field analyses.

Table 3. Data Quality Needs.

Subsurface Material	Type of Analysis	EPA Analytical Level
Soil	Soil gas volatile organic analysis	I, II
	Geotechnical testing of cores	I, II, III
	Chemical analyses of soil samples	I, II, III
	Volatile organic analysis of soil samples	I, II, III
	Microbial analyses	I, II, III
Ground water	Chemical analyses	I, II, III, IV

3.4 SITE EVALUATION APPROACH AND TASKS

The FY 93 site evaluation tasks are designed to be consistent with the following investigation approach:

- Maximize use of field screening methods as appropriate
- Maximize use of existing data and wells
- Focus data collection on specific contaminants of concern
- Use "off-the-shelf" technology as appropriate, in conjunction with the demonstration of new technologies.

The FY 93 site evaluation tasks include intrusive field activities such as drilling new wells. However, these tasks are designed to minimize the generation of hazardous, radioactive, and/or mixed waste and to prevent downward migration of contaminants.

The FY 93 site evaluation tasks are summarized in this section. Descriptions of each task are presented in the following sections.

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3.4.1 Field Investigation Tasks

Field investigation tasks are composed of the following:

- Source Term Characterization
  - Evaluate effluent pipeline integrity
  - Investigate source of secondary ground water maximum
  - Assess artificial recharge
- Conduct Soil Gas Surveys
  - Map lateral distribution of VOC
  - Estimate VOC vapor flux from soils
  - Map vertical distribution of VOC
- Conduct Geophysical Surveys
- Existing Well Investigations
  - Borehole geophysical logging
  - Evaluate integrity of old wells
  - Sample selected wells
- New Well Investigations
  - Crib wells
  - Deep ground water monitoring well
  - Chemical analyses
  - Physical analyses
  - Microbiological analyses
  - Technology demonstration boreholes
- Sample Ground Water.

3.4.2 Laboratory Studies

Laboratory studies include the following:

- Geochemical
- Soil Physics/Waste Characteristic.

3.4.3 Data Management and Evaluation Tasks

Data management and evaluation tasks include the following:

- Data Management, Integration, Presentation
- Numerical Modeling
- Data Evaluation
  - Refine conceptual model
  - Evaluate efficiency of remedial actions
  - Assess risk.

3.4.4 Technology Demonstrations Support

Technology demonstrations support includes the following:

- Miscellaneous Support to Technology Demonstrations
- Support Characterization Technology Demonstrations.

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3.5 FIELD INVESTIGATION TASKS

A description of each field investigation task is provided below. This description includes the task objectives and scope (including sample locations, and analyses, where appropriate). Additional detailed information, including procedures, is provided in the sampling and analysis plan (Appendix A).

3.5.1 Source Term Characterization

The objective of this task is to identify all sources of carbon tetrachloride contamination observed in the subsurface. This information will be used to guide remediation and monitoring efforts.

The scope of this task includes identifying locations and timing of carbon tetrachloride discharges to the soil column and assessing the impact of other aqueous discharges on the distribution of the carbon tetrachloride.

3.5.1.1 Evaluate Effluent Pipeline Integrity. The objective of this subtask is to estimate the location and quantity of any leaks from the carbon tetrachloride effluent pipelines to estimate how much organic and aqueous effluent discharged from PFP actually went to the three carbon tetrachloride disposal cribs as intended. The effluent pipelines to be examined include those used to convey organic and aqueous effluent from 1955 to 1973 from the Recuplex facility to the 216-Z-9 Trench and from the PRF to the 216-Z-1A Tile Field and the 216-Z-18 Crib. The 216-Z-9 pipelines will be examined first using a forward-looking color camera. Other methods, such as surface and vegetation sampling, soil gas sampling, cone penetrometer vapor sampling, and/or soil sampling via borings, may be used for confirmation and plume definition/leak volume estimates. If feasible, pipelines used after 1973 for liquid transfer will also be evaluated. (NOTE: This task was approved as part of the FY 92 ERA Phase II plan (Rohay 1991) and thus can be initiated immediately. It was postponed to FY 93 for budgetary reasons.)

3.5.1.2 Investigate Source of Secondary Ground Water Maximum. The objective of this subtask is to determine the source of the secondary concentration maximum in the dissolved ground water plume. Methods of investigation include examining historical waste management practices for possible sources in this area; comparing the ground water chemistry at points along the principal flow path of the carbon tetrachloride ground water plume for indications of multiple sources; and evaluating carbon tetrachloride degradation rates and ground water travel times. Additional/confirmatory data might be collected, if needed, via vegetation sampling, soil gas surveys, sampling of existing wells (soil gas and ground water), cone penetrometer vapor sampling, and/or installation of new wells.

3.5.1.3 Assess Artificial Recharge. Data on the discharge volumes/rates, and locations of all effluents (including sanitary tile fields) within 1 km of the primary carbon tetrachloride disposal sites will be compiled and evaluated for possible impacts on the unsaturated zone and ground water hydrogeology and/or redistribution of carbon tetrachloride wastes. These data will be acquired from existing documents and/or personnel interviews.

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3.5.2 Conduct Soil Gas Surveys

The objective of this activity is to map the lateral and vertical distribution of carbon tetrachloride and other selected VOC in the vicinity of and away from the three disposal sites. This information will support determination of the nature and distribution of the contaminants and will provide baseline data for comparison of soil gas and sensor technologies. The general distribution of the soil gas concentrations will be compared to the locations of the disposal facilities and the ground water concentrations.

The scope of this task includes the lateral and vertical distribution of VOC in the unsaturated zone and VOC flux at the soil-air interface.

3.5.2.1 Map Lateral Distribution of VOC. New soil gas surveys will be conducted to complement previous soil gas surveys. A total of 150 to 530 soil gas sampling points have been planned (Last and Rohay 1992). Twenty-two points were installed in FY 91 and 60 points were installed in FY 92. In FY 93, approximately 40 points will be installed (some through asphalt) to define the maximum extent of detectable VOC (>0.02 ppm carbon tetrachloride). Figure 5 illustrates the location of the soil gas points.

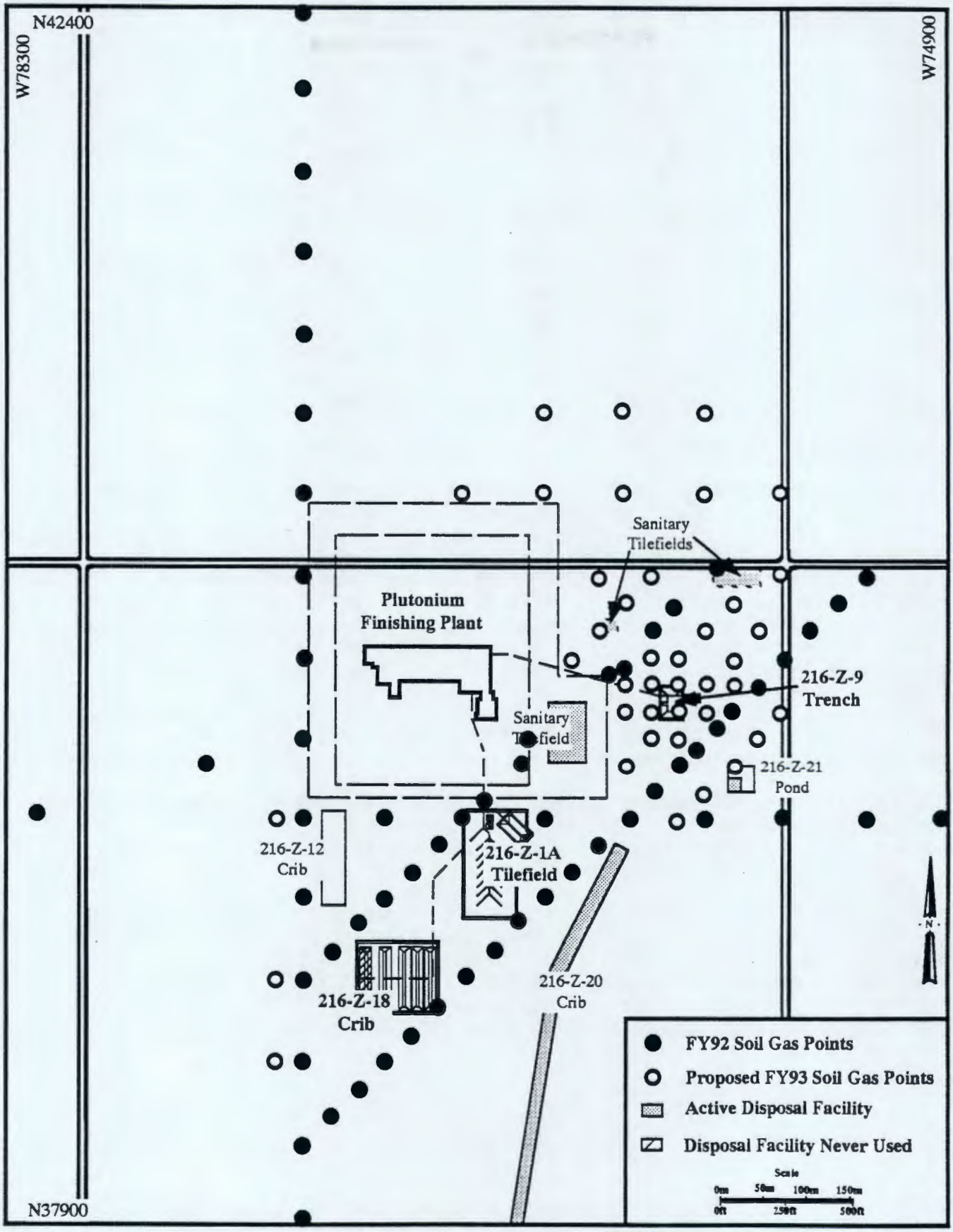
The sampling points consist of expendable (left-in-place) tips installed to a depth of approximately 1.2 m. New points will be completed in such a fashion as to prevent intercommunication with the atmosphere (i.e., a surface seal of bentonite or other suitable material will be installed). The concentrations of VOC will be measured at least once at all new and existing soil gas points using a gas chromatograph (GC) and field screening instruments (e.g., photoionization detector [PID], organic vapor monitor, Odyssey). Empirical correlations will be established between the GC and field screening results. Alternative analytical methods (e.g., ion-trap) may be demonstrated. Oxygen and carbon dioxide levels will be measured using field instrumentation as possible indicators of biological activity.

If possible, continuous monitoring of selected ports will be conducted to establish the time variant behavior of VOC concentrations to assist selection of the periodicity of routine monitoring.

3.5.2.2 Estimate VOC Vapor Flux From Ambient Soil Surface. Passive soil gas technologies will be used to estimate the vapor flux from the soil-air surface. These technologies will also continue to be evaluated for use as prospecting and/or monitoring tools.

3.5.2.3 Map Vertical Distribution of VOC. Existing wells of various depths will be sampled for VOC vapor concentrations. Existing perforated intervals and some new perforated intervals will be packed off and sampled. If available, a cone penetrometer will be used to conduct vertical profile sampling, and/or install deep soil gas ports for monitoring purposes. The VOC vapor concentrations will be measured using both GC and field screening instrumentation.

Figure 5. Proposed Soil Gas Sampling Locations.



3.5.3 Conduct Geophysical Surveys

The objective of this task is to define the three-dimensional configuration of mappable hydrofacies and/or contaminant plumes in the vicinity of the three principal carbon tetrachloride disposal sites.

The scope of this task includes surface geophysical techniques. Most of the geophysical surveys for FY 93 will be conducted as part of site characterization technology demonstrations. For example, Colman Research Corporation (Coleman Research) plans to conduct direct current resistivity, time-domain electromagnetics (TDEM), frequency-domain electromagnetics (FDEM), ground-penetrating radar (GPR), spectral-induced polarization (SIP), and seismic reflection and refraction surveys in the 200 West Area. This work will also support Coleman Research's data fusion task. A separate test plan provides details of these activities (WHC 1993).

3.5.4 Existing Well Investigations

The objective of this task is to continue assessments of the old wells as contaminant transport pathways; remove any known pathways; and evaluate the lithology and/or contamination penetrated by the boreholes.

The scope of this task includes borehole geophysical logging, past well maintenance practices, water level measurements, and archived borehole samples.

3.5.4.1 Borehole Geophysical Logging. Borehole geophysical logging will be conducted at selected wells within a 100-m radius around the three carbon tetrachloride disposal sites. The geophysical tools to be used include gross gamma and/or spectral gamma (for delineation of radiological contamination, and marker lithologic units). Other tools such as neutron-epithermal neutron (for detection of perched water) and/or neutron thermal lifetime (for detection of chlorine) may also be tested. Downhole camera surveys, caliper logs, magnetic logs and/or other tools may be run in those wells where potential contaminant pathways exist, and/or extensive remediation is planned.

3.5.4.2 Wellhead Vapor Emissions. Personnel interviews will be conducted to investigate the historical use of various well cap designs. Wellhead concentrations and fluxes of VOC vapor will also be measured at selected wells.

3.5.4.3 Well Remediation. Ten ground water wells and two unsaturated zone wells were evaluated as part of FY 92 well evaluation activities (Rohay et al. 1992). Remediation or modification of the ground water wells in proximity to the 216-Z-9 Trench (299-W15-5, 299-W15-6, 299-W15-8, and 299-W15-9) should receive priority because the contaminant concentrations appear to be highest at that site and because these wells still intersect the water table. Consideration will be given to use of the wells for vapor extraction and/or monitoring and ground water investigations.

Other old wells within a 100-m radius of each site will be reviewed for remediation needs (surface seals, paint, well numbers, new well caps, annular seals, packers, abandonment) and a plan developed for the completion of these modifications. If possible, all wells not surveyed, or surveyed prior to 1992 will be resurveyed using both Lambert metric and Hanford plant coordinates.

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3.5.4.4 Water Level Measurements. Water level measurements will be taken once per quarter in all available ground water wells within a 1-km radius around the three primary disposal sites. Ground water potential maps and flow nets will be constructed from these data and corrected for open interval length and position within the aquifer.

3.5.4.5 Evaluation of Archived Borehole Samples. Archived sediment samples from critically located wells (i.e., deep wells, and those along selected cross section lines) will be relogged by a geologist. Geological samples collected during FY 92 will be sieved and analyzed for clay content.

3.5.5 New Well Investigations

The objective of this task is to obtain data on the nature, distribution, transport pathways, and behavior of contaminants (e.g., phase partitioning, sorption parameters) immediately below each disposal facility and fully penetrating the uppermost aquifer.

The scope of this task includes:

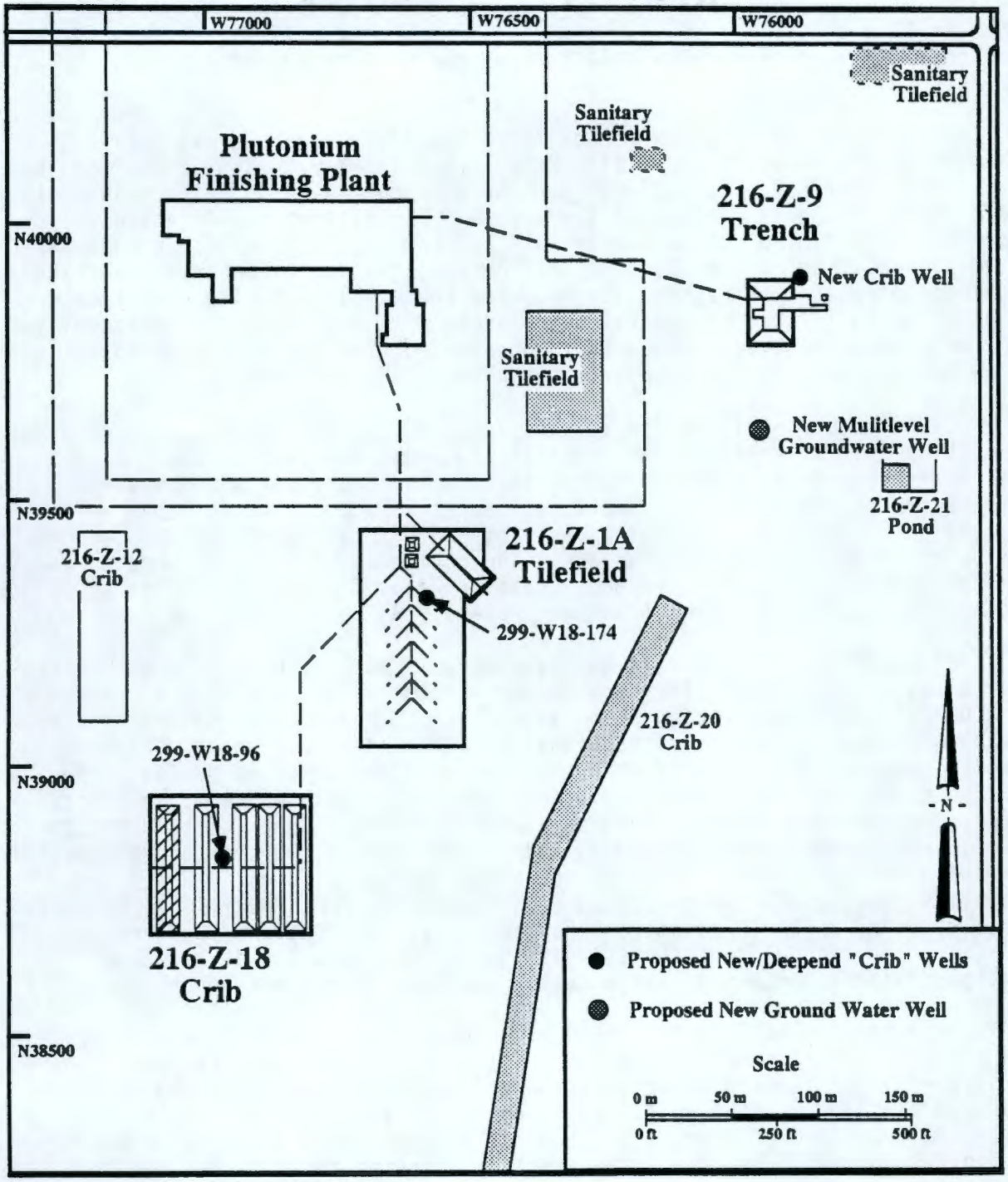
- Deepening existing boreholes that have already penetrated the radiological contamination within the cribs.
- Installing an angle borehole underneath a crib.
- Drilling and sampling one deep ground water well.
- Drilling and sampling one bioremediation well.
- Drilling one in situ heating well if requested.
- Collecting geochemical, lithologic, hydrologic, and microbiologic samples.

In addition, at least five vapor extraction and/or monitoring wells will be drilled in the carbon tetrachloride disposal area. These wells are part of wellfield enhancement for the active vapor extraction operations and are described in a separate work plan (Rohay and Cameron 1993). (NOTE: The deepening of existing wells was approved as part of the FY 92 VOC-Arid ID work plan (Last and Rohay 1991). The work was postponed until FY 93 to allow time for preparation, which was actively pursued during FY 92. Drilling of the deep ground water well was approved as part of the FY 92 ERA work plan (Rohay 1991). It was postponed to FY 93 for budgetary reasons.)

3.5.5.1 Crib Boreholes. This subtask involves deepening two existing boreholes within the 216-Z-1A Tile Field and the 216-Z-18 Crib confines and drilling one new well that angles beneath the 216-Z-9 Trench.

Existing wells selected for deepening are 299-W18-174 (216-Z-1A Tile Field) and 299-W18-96 (216-Z-18 Crib). The locations of these wells are shown in Figure 6. Wells 299-W18-174 and 299-W18-96 were originally completed just below field detectable radionuclide contamination. Each borehole will be deepened a minimum of 3 to 6 m (10 to 20 ft) below the bottom of the innermost well casing or, at a maximum, to the top of the Plio-Pleistocene unit at 43 m depth.

Figure 6. Location of Proposed Crib and Near-Field Boreholes/Monitoring Wells.



The angle borehole will be drilled at the northeast corner of the 216-Z-9 Trench and will proceed toward the southwest corner. Because this facility consists of an excavation with a concrete cover, access to beneath the crib will be approached from outside the crib boundaries. The target depth is 35 m at the top of the Plio-Pleistocene unit. It is anticipated that the sonic drilling technology will be used and will be provided through the VOC-Arid ID.

An alternative location for drilling the angle borehole has been selected in the event that drilling beneath the 216-Z-9 trench is not feasible during this phase of site evaluation. The alternative is to drill underneath the parking lot north of the 216-Z-9 trench. The alternative location will provide access to the subsurface beneath the parking lot, which has been targeted for vapor extraction because shallow soil gas probes indicate relatively high concentrations of carbon tetrachloride there. If the alternate location is used for this first demonstration of angle drilling using the sonic drill rig, consideration should be given to proceeding with angled access to soils below the 216-Z-9 trench during additional drilling activities.

Each borehole will be periodically sampled for VOC vapors, sampled using a split-barrel for physical and chemical analyses, and geophysically logged. These boreholes will be drilled using techniques to prevent the downward propagation of contaminants. The final depths will be selected based on results of well cutting screening analyses and discrete soil gas samples collected during drilling operations. The boreholes will be constructed as unsaturated zone monitoring/vapor extraction wells for the ERA and to accommodate technology demonstrations (Appendix A).

If possible, in situ soil gas samples will be collected from each borehole at selected horizons (every 6 m, approximately) using a SEAMIST (tradename of Science & Engineering Associates, Inc., Santa Fe, New Mexico) system (Rohay and McLellan 1992), conventional packer assemblies, and/or the Bore Sampler (WHC 1992). Tests of other in situ soil gas sampling devices, if available, may be conducted at selected horizons. Radiological conditions/safety concerns may prohibit this sampling in places. Geophysical logging (e.g., gross gamma, spectral gamma, and/or other tools) may be conducted after the installation of each length of temporary casing. If possible, air permeability testing will be conducted at selected horizons (every 6 m, approximately) using a SEAMIST system (Rohay and McLellan 1992) and/or other technologies. Additional geotechnical testing may be conducted at selected horizons, with a maximum of three tests conducted in any one borehole.

Soil samples will be collected continuously or at a minimum of every 1.5 m and at significant lithologic, moisture, or contaminant changes. These samples will be obtained using split-barrel sampling techniques and/or other approved sampling methods (e.g., drive-barrel). Split-barrel samples will be collected a minimum of every 6 m. LEXAN (tradename of the General Electric Company) liners will be used in conjunction with the split-barrel sampler.

An onsite geologist will examine and qualitatively describe all core and borehole cuttings for grain size, $CaCO_3$, lithology, and moisture. All borehole cuttings and samples will be screened for VOC using organic vapor monitoring instruments.

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If the data obtained by deepening these two wells are not sufficient (e.g., if no co-contaminants are encountered), new wells may be installed to investigate the contaminant characteristics at the crib bottoms and in other radiologically contaminated areas. The new wells may be drilled within the existing crib boundaries. If needed, these wells will be described in the work plan for FY 94 site characterization activities.

3.5.5.2 Install Deep Ground Water Well. The objective of this subtask is to obtain data on the nature and distribution of contaminants in the aquifer in the vicinity of the disposal facilities, and to obtain data on the lithology, geochemistry, hydrology, and microbiology of the aquifer materials.

This subtask involves the drilling of a deep well to the top of basalt (160 m). This well will be located within the vicinity of the 216-Z-9 Trench, but outside of its radiological unsaturated zone plume, to characterize the distribution of carbon tetrachloride within the unconfined aquifer as related to wells 299-W15-6 and 299-W15-8 as possible conduits for carbon tetrachloride migration. Figure 6 illustrates the proposed location of this deep well. Other existing wells may be deepened or at least cleaned out to their original depth to provide data on contamination at depth within the unconfined aquifer. Lithologic samples, soil gas samples, and depth-discrete water samples will be collected. Geophysical logging using gross gamma, spectral gamma, and/or other tools will be performed. Aquifer tests will be conducted so as to not produce large volumes of purge water (e.g., slug interference testing).

The well will be drilled by telescoping the temporary casing to seal off any perched water and to prevent the downward propagation of contaminants to deeper levels. Completion details for the deep well are dependent on the results of the depth-discrete ground water samples.

An onsite geologist will examine and qualitatively describe all core and borehole cuttings according to a regimented protocol for grain size, $CaCO_3$, lithology, and moisture. All borehole cuttings and samples will be screened for VOC using organic vapor monitoring instruments.

Soil samples (via drive barrel where possible) will be collected every 1.5 m and at lithologic, moisture, and/or contaminant changes. Split-barrel samples will be collected approximately every 6 m for determination of carbon tetrachloride concentrations. Other split-barrel samples may be collected where screening analyses of the well cuttings and/or soil samples indicate the presence of VOC. In addition, split-barrel samples (representing the range of unsaturated zone hydrogeologic units) will be collected to support the testing of a centrifuge for unsaturated zone transport measurements and to support the testing of supercritical fluid extraction technology. Special split-barrel samples will be collected to support the characterization of subsurface microbial populations pursuant to testing of biological treatment technologies.

The unsaturated zone will be sampled in situ for soil gas vapors and tested for air permeability using a SEAMIST system (Rohay and McLellan 1992) or other technologies (e.g., Bore Sampler). The in situ soil gas samples will be analyzed for VOC, including carbon tetrachloride and chloroform, using a GC. Soil gas samples may be collected with time during air withdrawal tests.

Depth-discrete ground water samples will be collected at 6-m intervals and at significant lithologic and/or contaminant changes (noted via screening techniques) throughout the unconfined aquifer.

3.5.5.3 Conduct Physical Sample Analyses. All uncontaminated (i.e., below field detection) soil samples will be analyzed in the laboratory for particle size (including hydrometer analyses), $CaCO_3$, moisture content, and lithology (binocular microscope). Selected core samples will be analyzed for their water-retention characteristic curves, saturated hydraulic conductivity, bulk density, porosity, air permeability, and mineralogy (including clays). In addition, some thin sections may be made for detailed lithological, mineralogical, and pore size distribution analyses. Other cores may be analyzed for thermal conductivity and electrical resistivity as functions of water content.

3.5.5.4 Conduct Chemical Analyses. Discrete soil gas samples may be analyzed for VOC (using a mobile laboratory and GC or other fast-turnaround technology).

Soil samples may be analyzed for pH, total organic compounds (TOC), total organic halogens (TOX), specific conductance, VOC, semivolatile and other organic compounds, metals, cations, and anions. The list of target constituents is presented in Table 4. The intervals to be analyzed will be selected based on the depth-discrete soil gas sampling and other screening results. VOC samples will be collected at a minimum of every 1.5 m.

Selected cores may also be analyzed for geochemical constituents. Geochemical analyses may include cation exchange capacity, total carbon, surface area, pore water chemistry, sorption studies, and isotope (e.g., ^{36}Cl) analyses.

Table 4. Target Compounds.

Volatile Organic Compounds	
Carbon tetrachloride	Chloroform
Methylene chloride	Tetrachloroethylene
Trichloroethylene	Methyl ethyl ketone
Semivolatile and Other Organic Compounds	
Tributyl phosphate	Dibutyl phosphate
Dibutyl butyl phosphonate	Monobutyl phosphate
Triglycerides (lard oil)	
Metals	
Aluminum	Magnesium
Iron	Chromium
Cadmium	Nickel
Anions/Cations	
Chloride	Nitrate
Fluoride	Sulfate
Calcium	Phosphate

(NOTE: Compounds may be added to or deleted from this list as investigation progresses, based on feasibility of analytical techniques and identification of additional co-contaminants, by the project scientist or task manager.)

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Ground water samples may be analyzed for pH, TOC, TOX, specific conductance, VOC, semivolatiles and other organic compounds, metals, anions, and cations. Target constituents are presented in Table 4.

3.5.5.5 Conduct Microbiological Analyses. Aseptic split-barrel samples will be collected for microbiological analyses based on recommendations from the in situ bioremediation technology team.

3.5.5.6 Drill Technology Demonstration Boreholes. Two boreholes will be drilled as part of technology demonstrations for in situ treatment tasks of the VOC-Arid ID. One will be in support of the In Situ Biological Treatment of Hanford Groundwater task, and one will be in support of the In Situ Heating/Corona Destruction task.

The in situ bioremediation task is directed toward demonstrating biodegradation of carbon tetrachloride in ground water. Aseptic split-barrel samples will be collected for microbiological analyses to characterize the in situ microbial populations and the conditions under which they degrade carbon tetrachloride. Sampling will be conducted to better define the relationship between sediment properties and microbiologic population distribution and to assess the hydrologic properties of the sediments governing hydrologic transport in the saturated zone.

During FY 93, bioremediation well 299-W11-32 will be drilled at the in situ bioremediation demonstration field site in the 200 West Area between 241-T Tank Farm and 221-T Plant, where two bioremediation boreholes, 299-W11-29 and 299-W11-30, have already been installed (Figure 7). The in situ bioremediation field site, west of T Plant, is approximately 1.6 km northeast of the carbon tetrachloride disposal sites (Figure 2) and lies within the dissolved carbon tetrachloride ground water plume. The new well will be located between the two existing wells shown in Figure 7. The new well will have three separate screened intervals placed between 73 and 93 m below land surface. Additional multi-screened wells are planned, but will not be constructed this fiscal year.

Well 299-W11-32 will have a twofold purpose. First, samples will be collected to characterize the hydrogeology of the demonstration site; aquifer tests will be conducted to characterize the hydraulics of the hydrologic system; and samples will be collected to characterize the chemistry of the sediments and ground water. Secondly, the completed well will be used as part of the network of wells with which the in situ bioremediation of carbon tetrachloride will be implemented and monitored.

During drilling, geologic samples will be collected by core barrel or split-barrel samplers every 1.5 m and after a major lithologic change is encountered. In addition, samples collected every 1.5 m will be submitted for geotechnical analyses including sediment grain-size distribution, lithologic description, calcium-carbonate content, moisture content, saturated hydraulic conductivity, bulk density, particle density, water suction potential, and porosity. Not all analyses will be conducted on every sample collected. A suite of samples will also be collected with the microbiologic samples to characterize the chemistry of the sediments and ground water. Borehole geophysical logs will be run to provide data on the subsurface distribution of lithologic units. Geophysical surveys may include: natural gamma log, neutron-epithermal neutron, density, and fluid temperature.

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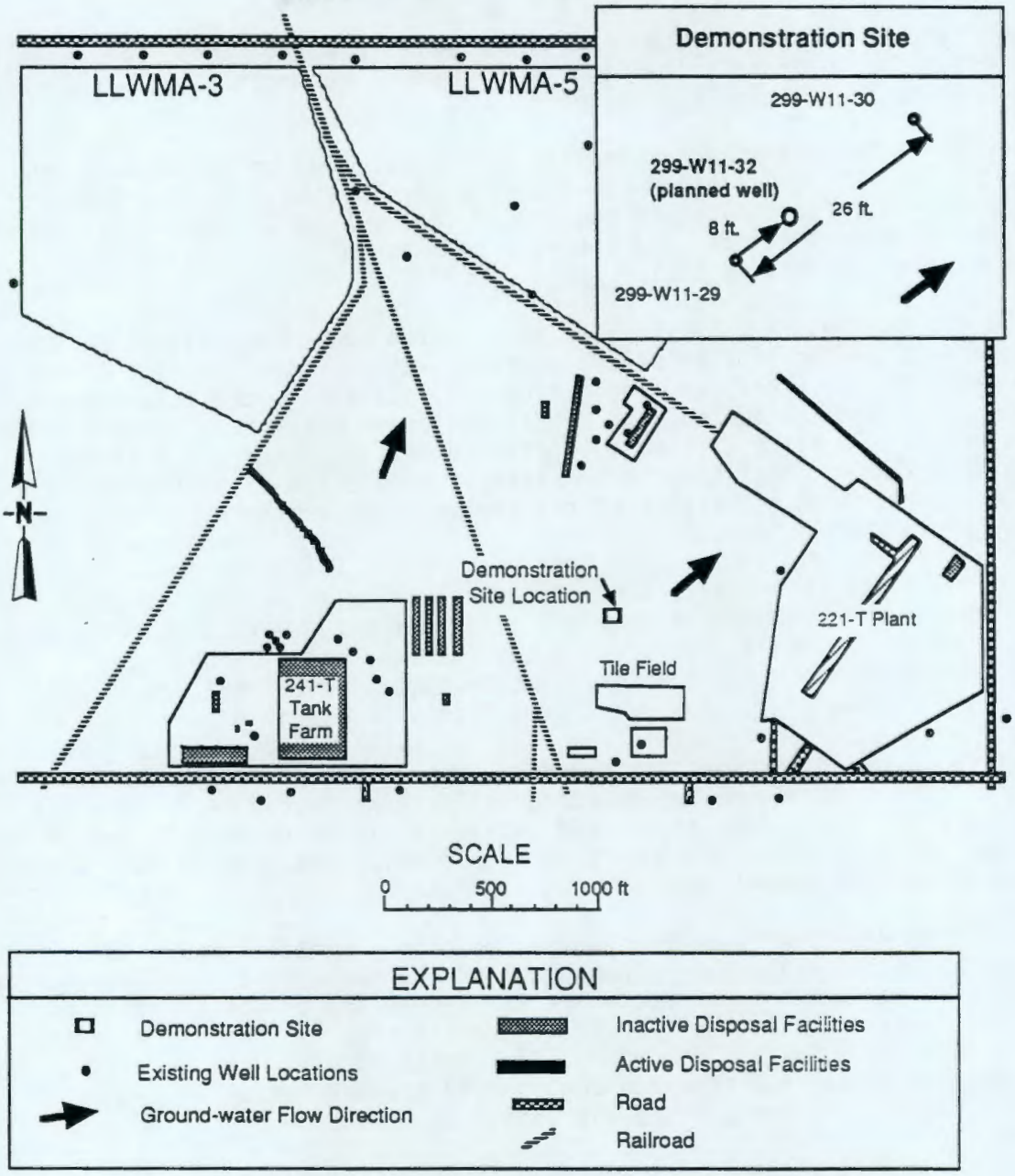
Figure 7. Location of Proposed Bioremediation Wells.



After the well has been completed, aquifer testing will be conducted to determine aquifer hydraulic properties. Test methods will include standard hydrologic techniques such as slug (single-well) and constant rate pumping tests, as well as state-of-the-art slug or pulse interference methods. The single-well tests are planned for each of the two existing wells, 299-W11-29 and 299-W11-30. The multiple-well interference tests will include all three wells.

Ground water samples will be collected from each screened interval in the new well using submersible pumps or bailers. Unstable hydrochemical parameters, such as pH, Eh, oxygen content, and alkalinity will be determined in the field at the time of sample collection.

Tracer testing will be conducted in selected wells and monitoring intervals to further refine the understanding of the hydrologic and transport properties of the unconfined aquifer. Initial testing will consist of the standard borehole-dilution tracer techniques; dynamic cross-hole tracer tests will also be considered.

Installation of a new well is planned to support field testing of an in situ heating technology. Tentative plans are to conduct the field test at a site of volatile organic contamination near the fire station in the 300 Area. The proposed well would be approximately 15 m deep. Details on the construction and sampling will be provided in the test plan for this activity.

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3.5.6 Ground Water Sampling

The objective of this task is to monitor concentrations of VOC in ground water from wells in and around the three disposal sites and at the perimeter of the ground water plume. In addition, the vertical distribution of such compounds within the aquifer will be further investigated wherever feasible.

The scope of this task includes obtaining ground water samples from existing wells and from any new wells drilled during FY 93. If necessary, sampling pumps and/or packers will be installed and wells will be rehabilitated. The data will be integrated with the results from the ongoing Hanford Site ground water monitoring programs.

Ground water samples will be collected from approximately 26 wells. The initial list of wells to be sampled (Table 5) was chosen based on sampling conducted during FY 91 and FY 92 and in coordination with other ground water monitoring programs. At the discretion of the project scientist or field team leader, wells may be added or subtracted from this list based on results of current sampling. Sampling during FY 93 will occur twice, once in November and once in May.

Ongoing Hanford Site ground water monitoring programs that include 200 West Area wells are: (1) the Operational Ground Water Monitoring Network, (2) the RCRA program, (3) the 200 West Aggregate Area Management Study under CERCLA, (4) any ground water monitoring required by liquid waste discharge permits, and (5) Pacific Northwest Laboratory site-wide monitoring. The various sampling efforts are coordinated by the Operational Ground Water Program. Table 5 indicates which wells are already being sampled under an existing program. Duplication of sampling efforts will be avoided whenever possible.

Ground water sampling from discrete zones at varying depths will be conducted in existing wells that have a suitable screened interval within the aquifer. Based on the FY 92 well evaluation (Rohay et al. 1992), it is recommended the sampling be conducted from the bottom of the screened interval in well 299-W15-6 to assess the extent of the carbon tetrachloride contamination encountered there. Well 299-W15-5 is scheduled for sampling in October 1992. Other wells that may be suitable for further investigation of the vertical distribution of organic compounds in the aquifer include 299-W18-1 and 299-W18-3. This work will be coordinated with the vertical profiling of ground water contaminants being conducted by the 200 West Aggregate Area Management Study during FY 93.

Table 5. Ground Water Wells to be Sampled.

Well	Responsible Program
299-W7-4	RCRA
299-W7-5	RCRA
299-W10-4	N/A
299-W10-15[a]	RCRA
299-W10-17[a]	RCRA
299-W10-18[a]	RCRA
299-W11-28[a]	RCRA
299-W14-12[a]	RCRA
299-W15-6	200 West Aggregate Area Management Study
299-W15-8	Operational Ground Water Monitoring Network
299-W15-12	N/A
299-W15-16[a]	RCRA
299-W15-22[a]	RCRA
299-W18-2	N/A
299-W18-9[b]	N/A
299-W18-17	Operational Ground Water Monitoring Network
299-W18-20	Operational Ground Water Monitoring Network
299-W18-25[a]	RCRA
299-W18-29	RCRA/Operational Ground Water Monitoring Network
299-W18-30[a]	RCRA
299-W19-32[a]	RCRA
299-W23-13[a]	RCRA
699-38-70	N/A
699-39-79	N/A
699-43-88	N/A
699-49-79	N/A

[a]VOA samples added for November and May sampling.
[b]Bailed sample.

Ground water samples will be analyzed for VOC using a gas chromatograph/mass spectrometer (GC/MS) in the laboratory and/or with portable field screening equipment, if feasible. Samples from wells that have carbon tetrachloride concentrations at or below 5 ppb (e.g., 699-43-88 and 699-49-79) will be analyzed using a more sensitive GC method. In-well sampling will be conducted, if feasible, using a permeation sampler.

3.6 LABORATORY STUDIES

Soil physics and geochemical laboratory studies will be conducted to define some of the basic behavioral properties of the carbon tetrachloride waste in the site soils. This information will contribute to the refinement of the conceptual model; to predictive modeling of contaminant transport; and to the design of effective remediation strategies. Conduct of these studies is dependent on the FY 93 funding levels.

3.6.1 Soil Physics/Waste Characteristic Studies

The objective of these studies is to characterize the distribution, transport, and behavior of fluids and vapors in the unsaturated zone.

The scope of this work includes both laboratory experiments and computer simulations, using liquid organic waste mixtures, particularly those containing carbon tetrachloride, carbon tetrachloride vapor, and subsurface conditions similar to those encountered in the 200 West Area.

3.6.1.1 Retention of Organics. The objective of this subtask is to measure the retention of liquid organic waste mixtures in porous media as a function of water content. A unique air-organic-water retention cell will be constructed that will be able to measure the retention of fluids by capillary forces. The cell, which will be connected to vacuum-pressure regulators and burets, will be packed with sediments similar to those of the 200 West Area and saturated with varying amounts of water and liquid organic mixtures. The liquid organics will then be extracted from the cell at a constant rate through chemically treated ceramics until the organic liquid phase appears to be immobile. The organic liquid content remaining in the porous media will be determined via mass balance. The data can be used to determine how much organic liquid will drain from the Hanford sediments toward the water table.

3.6.1.2 Transport of Vapors. The objective of this subtask is to evaluate the potential of carbon tetrachloride vapors to move throughout the subsurface. The advective movement of fluid is a result of a pressure difference in the fluid phase and the influence of gravity. When the fluid is a gas, the gravity component is typically neglected. However, when liquid organic wastes contain dense VOC, such as carbon tetrachloride, the gaseous phase adjacent to where volatilization is occurring may be denser than ambient gaseous-phase densities. This density difference may enhance the downward movement of contaminant molecules, which can significantly affect the rate and extent by which ground water becomes contaminated. The other major mechanism by which contaminant molecules can move through the subsurface, other than advective flow, is chemical diffusion, where chemical diffusion is the spreading of contaminant molecules because of a spatial concentration difference. Under this subtask, the movement of carbon tetrachloride vapor molecules because of diffusive and advective processes will be evaluated. This will involve both laboratory and computer investigations. In the laboratory, the diffusion of carbon tetrachloride will be measured in Hanford sediments. The effects of organic liquids co-disposed with carbon tetrachloride on carbon tetrachloride volatilization will also be measured. Computer investigations will focus on forecasting the subsurface behavior of carbon tetrachloride vapors. A predictive computer tool will be adapted to model advective and diffusive gaseous movement.

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3.6.2 Geochemical Studies

The objectives of the geochemical studies will be to evaluate the waste-sediment interactions influencing the sorption/desorption of carbon tetrachloride and its decomposition products, chloroform and methylene chloride, on mineral surfaces.

This task will evaluate the interactions of the primary contaminants with Hanford sediments, clay minerals isolated from those sediments, and model clay minerals under saturated aqueous conditions and also under unsaturated conditions that mimic the conditions found in the unsaturated zone. The effects of the various co-contaminants (i.e., alkyl phosphates and lard oil) on retention of the primary contaminants by these sediments will also be evaluated. The emphasis will be on determining retardation factors and other parameters important for estimating transport of the primary contaminants in the saturated and unsaturated zones of the Hanford sediments.

As a consequence of having no dipole moment, no hydrogen bonding capacity, and no charge, carbon tetrachloride interacts only weakly with solid surfaces. Highly polar molecules like water, on the other hand, interact very strongly with charged solid surfaces and may exclude nonpolar molecules like carbon tetrachloride from any interaction with the surface. With uncharged, nonpolarizable surfaces, however, the interactions of polar molecules are similar to those of carbon tetrachloride. Not surprisingly, then, retention of carbon tetrachloride by soil mineral surfaces in contact with aqueous solutions is essentially nil, whereas retention by soil humic surfaces is more favorable (water is not as strongly attracted to uncharged portions of the humic solids). Although humic retention of carbon tetrachloride would be expected to be of limited importance in water-saturated Hanford sediments because of their low native organic matter contents, the co-disposal of large amounts of alkyl phosphates and lard oil with carbon tetrachloride at Hanford may have created hydrophobic surfaces or reservoirs in the sediments that could serve to retain carbon tetrachloride and other organic solvents. In the unsaturated zone, drier conditions reduce the competition from water and thus may allow more interaction of carbon tetrachloride vapors with soil mineral surfaces than that observed for dissolved carbon tetrachloride in the saturated sediments. Because their dipole moments fall between those for water and carbon tetrachloride, the behavior of chloroform and methylene chloride with respect to sediment surfaces would also be expected to fall between that for water and carbon tetrachloride.

3.6.2.1 Unsaturated Conditions. Vapor-phase adsorption isotherms for all primary contaminants will be performed at several temperatures, using thin films of sediment or sediment plus co-contaminant mounted on windows in an infrared gas cell. The amounts adsorbed at equilibrium, as well as the rates of adsorption and removal by air stripping, will be quantified by infrared spectroscopy. Use of infrared spectroscopy will also provide direct evidence for reaction mechanisms and modes of interaction. Vapor-flow column studies will be performed at several temperatures and relative humidities using infrared and/or GC detection systems. The impact of nutrient additions on primary contaminant mobility will be investigated in future years.

3.6.2.2 Saturated Conditions. Adsorption isotherms using radiolabeled compounds will be performed at several temperatures to allow estimation of the heat of sorption. The emphasis in the first year will be on chloroform and

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methylene chloride retention because of previous work showing essentially no interaction between carbon tetrachloride and sediments under saturated conditions. The impact of co-contaminants and bi-phasic systems on retention will also be investigated in batch equilibrium and flow-through column studies. In future years, the introduction of nutrients into sediments and its impact on fate and transport of radionuclides (e.g., americium, plutonium) and VOC will be studied. In addition, chemical and radiological degradation rates of key VOC will be studied in laboratory experiments if significant concentrations of degradation products are identified in near-crib unsaturated zone sediments during the FY 93 characterization activities.

3.7 DATA MANAGEMENT, INTEGRATION, AND PRESENTATION

Characterization data collected from these site evaluation efforts will be managed and integrated with those data collected in support of other Hanford Site programs (e.g., RCRA, CERCLA).

The objective of this task is to establish an interactive database/ graphics retrieval and display capability.

The Hanford Environmental Information System (HEIS) and Geographical Information System (GIS) will be used as the backbone for all data entry, storage, and graphics retrieval/display capability.

3.7.1 Data Entry

The objective of data entry is to enter all VOC-Arid ID and ERA site data into the HEIS database, as appropriate. This subtask includes the entry of existing data (e.g., drillers logs, geophysical logs, chemical analysis data, etc.), the acquisition/modification of field computers and macros for direct data entry, and HEIS support for preparation of new data fields and loader programs.

3.7.2 Data Manipulation and Display

The HEIS/GIS will form the heart of the data manipulation and display tools. This system will be used to generate concentration contour maps, geologic cross sections, isopach maps, and structural contour maps. Some software modifications are anticipated to develop new HEIS/GIS capabilities (e.g., full well displays, addition of data qualifiers, definition of formation tops, etc.). Other programs/protocols will be developed to assist the use of off-the-shelf graphics and modeling software. The subtask will also produce report tables, maps, graphs, etc. as needed.

3.7.3 Support Data Fusion Efforts

Data fusion support is aimed at providing Coleman Research with the environmental and site-specific expertise necessary to make the development of an environmental data fusion work station successful. Coleman Research has been funded by the Characterization, Monitoring, and Sensor Technology Integrated Program to apply U.S. Department of Defense data fusion capabilities to the DOE's Environmental Restoration Program. The VOC-Arid ID site

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was selected as the initial demonstration site for this technology. Support to Coleman Research will consist of technical guidance regarding environmental assessments, providing historical and recently collected data on the VOC-Arid ID site, providing interpreted data sets for use in their data fusion work station, providing field and laboratory support for their geophysical data collection efforts, and testing of the prototype work station.

3.7.4 Issue U Pond Characterization Report

The U Pond characterization report covers revision and documentation of a U Pond characterization report drafted in 1981. This report contains valuable information on disposal facilities in the vicinity of the carbon tetrachloride disposal facilities.

3.8 NUMERICAL MODELING

The work planned for numerical modeling of the distribution of carbon tetrachloride in the subsurface environment at Hanford will build on the work accomplished in FY 92. This work includes two modeling efforts: numerical modeling of multiphase flow in the unsaturated zone using the Single-Phase And Multiphase Flow and Transport in 2 Dimensions (SAMFT2D) model; and development of the Engineering Simulator.

3.8.1 Multiphase Flow in the Unsaturated Zone

The objective of this task is to simulate the behavior of the multiphase system -- carbon tetrachloride/water/vapor -- in the unsaturated zone to aid the design and monitoring of remedial activities.

The scope of the work for FY 93 is to use SAMFT2D to investigate two important aspects of the two-phase flow analysis completed in FY 92 and to perform a three-phase flow analysis of the disposal of carbon tetrachloride at the 216-Z-9 Trench.

The initial objective for FY 93 is to evaluate the effect of sequential batching of the water and carbon tetrachloride in the source term and the slope of the Plio-Pleistocene (caliche) layer in the unsaturated zone. In FY 92, runs made with SAMFT2D assumed that the water and carbon tetrachloride were both released from the processing facility simultaneously, although the fluids were assumed to be immiscible. This was done as an expediency since the timing for the release of the two liquids was not known. The first task in FY 93 will be to assume that the liquid disposal operation involved disposal of carbon tetrachloride first with the water being discharged at a later time in a given interval. While the exact manner of disposal of the liquids is not known, several combinations will be tried to evaluate what the effect, if any, that this sequential mixing would have on the distribution of carbon tetrachloride in the subsurface.

The conceptual model applied in the FY 92 modeling process also assumed that the Plio-Pleistocene layer was horizontal. This assumption reduced the size of the simulation grid in that the model could be made symmetrical about the centerline of the crib and, therefore, was more economical for getting the model operational. However, the slope of the Plio-Pleistocene unit could have

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a significant effect on the distribution of the carbon tetrachloride by permitting it to move down dip on this unit of lower hydraulic conductivity. The quantity of carbon tetrachloride percolating into the Plio-Pleistocene may also be reduced.

Work accomplished in FY 92 treated three-phase flow in the subsurface, i.e., the flow of liquid water, liquid carbon tetrachloride, and gas (air). SAMFT2D has the capability of dealing with carbon tetrachloride vapor as well, i.e., three-phase flow plus carbon tetrachloride vapor. In FY 93, SAMFT2D will be employed in a three-phase mode to simulate the movement and distribution of water, air, and carbon tetrachloride vapor and liquid. This will result in a more realistic simulation since carbon tetrachloride has a high vapor pressure and can be expected to readily move in the gaseous state. Three-phase simulation will provide information as to the extent that carbon tetrachloride may have moved in its liquid and gaseous forms. This simulation will provide input for air flow models being used for wellfield design and can be expected to complement the analyses that those models can perform.

As with any modeling effort, the simulations are dependent on information obtained during the field investigations. In this regard, close contact will be maintained with those performing field activities to maximize the information obtained.

3.8.2 Engineering Simulator

This work is being conducted in support of treatment technology demonstrations and is covered under a separate scope of work within the VOC-Arid ID, but is included here for completeness. The Engineering Simulator is a predictive modeling tool to aid both in remediation selection and design and in process control, optimization, and performance evaluation during remedial operations. The activities to be conducted include: (1) application of the predictive modeling tools to support the field design, operations, and data evaluations of VOC-Arid ID technology demonstrations; (2) assess the impact of subsurface spatial heterogeneity on proposed remediation technologies; (3) evaluate the technical and regulatory effectiveness of remedial technologies being demonstrated; and (4) develop and test the Engineering Simulator within the end-user community.

3.9 DATA EVALUATION

The purpose of site data evaluation is threefold: to further refine the conceptual model of the site and carbon tetrachloride behavior; to evaluate the risks associated with contamination present at this site; and, to evaluate the effectiveness of remedial actions.

Site data will be integrated and evaluated to refine the current hydrogeologic conceptual model and the conceptual understanding of carbon tetrachloride behavior. The nature and distribution of contaminants will be refined and compared from pre- and postremedial actions. Hydrostratigraphic units will be delineated, along with unsaturated zone and ground water flow paths and rates. The conceptual understanding of multiphase flow will be evaluated, along with sorption and other contaminant transport parameters and microbial species and populations.

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This task is designed to produce the reports described in Chapter 4 of this work plan.

3.10 SUPPORT TECHNOLOGY DEMONSTRATIONS

The objective of this task is to provide the principal investigators of new technologies with specific site data, samples, and/or other needs to support the development and/or demonstration of their technology.

3.10.1 Miscellaneous Support to Technology Demonstrations

Miscellaneous support to technology demonstrations includes the dissemination of existing site data on an as-needed basis, the collection of specific site data and/or samples, and acquisition or access to specialized equipment needed to support the technology demonstrations. The support needs identified to date include: collecting soil samples to support the bioremediation and supercritical fluid extraction/optical detection (SFE/OD) technology demonstrations; providing access to a number of isolated screened intervals to support sensor technology demonstrations; and collecting analytical data on the concentration of co-contaminants (principally the phosphonates and phosphates) which may affect sensor performance. Other support needs are expected to arise as the technology demonstrations mature.

The sample needs identified to date include: three aseptic soil cores of the aquifer material and three of the early "Palouse" soil horizon to support bioremediation technology demonstrations; small (50-g) samples of all nonradiologically contaminated horizons and up to three bulk (15- to 20-L) samples to support the SFE/OD technology demonstrations. The tasks that will directly address these needs include the drilling and sampling of new wells (and installation of multiple-screens in the unsaturated zone wells) and the chemical analysis of soil gas samples from these wells.

3.10.2 Support to Characterization and Monitoring Technology Demonstrations

Data collected from the field investigation tasks will be used for comparison to data collected during the demonstration of new site characterization and monitoring technologies. Efforts will be made to provide opportunities for demonstration of new technologies during the characterization activities to allow evaluation of the new technologies relative to speed, reliability, accuracy, and economy. In addition, the data will provide a useful means of evaluating changes in the contaminant distributions induced by the ERA, remedial technology demonstrations, and other natural and/or human-induced stresses to the subsurface environment.

This task also includes support of the site characterization technical support group, identification of site characterization and monitoring technology needs, and review of the principal investigator technology test plans and evaluation reports. Included in this subtask is travel and preparation of presentations essential for attracting innovative technologies and external peer review of the technology demonstrations.

4.0 REPORTING/DELIVERABLES

The results from the FY 92 site evaluations will be compiled and integrated with existing data and with data collected in support other Hanford Site programs. These data and the resulting interpretations will be displayed in cross sections, maps, and tables that illustrate the nature and distribution of contaminants, the site characteristics (geology, hydrology, geochemistry), and the behavior of carbon tetrachloride and other contaminants in the system. A final report on the results of the FY 92 site evaluation will be submitted at the end of January 1993. A technical journal article will be prepared on the FY 92 results and submitted for external peer review by April 1993.

A similar report will be prepared for the work completed during FY 93. A report presenting the status of the FY 93 activities and the resulting data will be submitted at the end of September 1993. The final report, including data evaluations, will be submitted at the end of March 1994.

5.0 SCHEDULE

The tentative schedule for completing the FY 93 site evaluation activities is presented in Figure 8.

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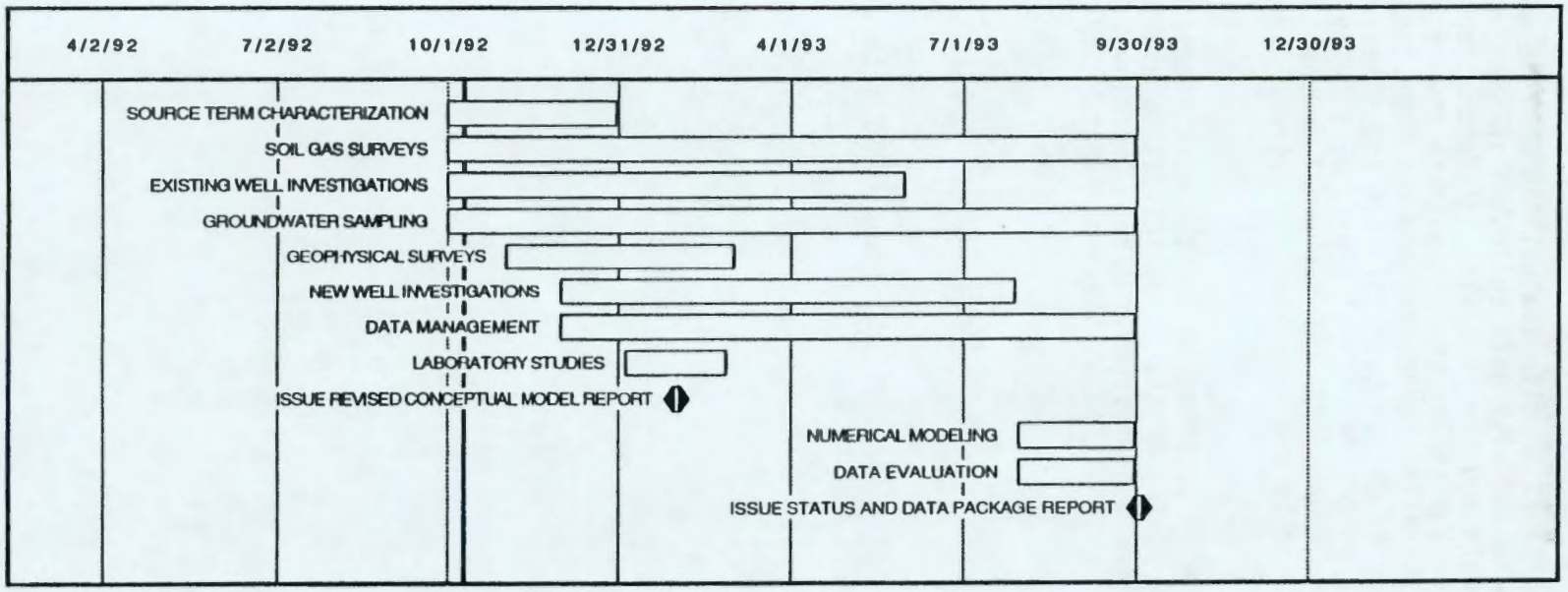
Figure 8. Tentative Schedule for FY 92 Site Characterization.



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APPENDIX A

VOLATILE ORGANIC COMPOUNDS-ARID INTEGRATED DEMONSTRATION (VOC-ARID ID) AND 200 WEST AREA CARBON TETRACHLORIDE EXPEDITED RESPONSE ACTION (ERA) SAMPLING AND ANALYSIS PLAN

PART 1 - FIELD SAMPLING PLAN

PART 2 - QUALITY ASSURANCE PROJECT PLAN

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PART 1

FIELD SAMPLING PLAN

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9 3 1 2 9 3 2 1 5 7 2

1.0 SITE BACKGROUND

This field sampling plan addresses the new well drilling and sampling activities to be conducted as part of the FY 93 Volatile Organic Compounds-Arid Integrated Demonstration (VOC-Arid ID)/200 West Area Carbon Tetrachloride Expedited Response Action (ERA) site characterization. Background information on the site can be found in Section 2 of the work plan.

2.0 SAMPLING OBJECTIVES

Field investigation tasks were described in Section 3.5 of the work plan. Details regarding the sample locations, frequencies, and analyses for each task are included in Section 3.5 or will be included in individual test plans, statements of work, letters of instruction, work orders, or internal memoranda. Field conditions may preclude sampling at pre-defined locations, intervals, or frequencies. Changes in sample locations, intervals, or frequencies may be made at the discretion of the well site geologist.

Three unsaturated zone boreholes are planned for FY 93. Two existing boreholes will be deepened, and one new angled crib well drilled to investigate contamination in the unsaturated zone directly beneath the carbon tetrachloride disposal sites. If sufficient funds are available, one deep ground water well will be drilled to investigate the vertical distribution of carbon tetrachloride in the unconfined aquifer in the vicinity of these carbon tetrachloride disposal facilities. One new bioremediation ground water well will be installed to characterize site conditions at the in situ bioremediation demonstration field site and to conduct and monitor the bioremediation demonstration. These investigations are summarized in Table FSP 2-1.

3.0 SAMPLE LOCATION AND FREQUENCY

Tables FSP 3-1, 3-2, 3-3, 3-4, and 3-5 show approximate borehole sampling depths and frequencies for the five boreholes. These locations and number of samples may change based on actual field site conditions, ability to collect representative samples, and updated data needs as identified by project personnel.

4.0 SAMPLE DESIGNATION

Each sample interval will be assigned a unique Hanford Environmental Information System (HEIS) sample number. HEIS numbers for samples going to Data Chem and PNL laboratories will be assigned by Pacific Northwest Laboratory (PNL). These include soil and ground water VOA, SVOA, and chemical samples. The soil subsamples to be analyzed for chemicals will keep the HEIS number of the original sample liner. If more than one subsample is collected for the same analysis in the sample interval, each subsample will have a different HEIS number. All ground water samples from the same sampling location will have the same HEIS number. HEIS numbers for all other samples will be assigned by the field geologist. The HEIS numbers will be used on all documentation of the samples.

9 3 1 1 9 3 2 1 5 7 3

Table FSP 2-1. New Well Investigations Summary. (Sheet 1 of 6)

299-W18-96	**(Deepen)**
LOCATION	216-Z-18 Crib; deepen well 299-W18-96.
DEPTH	41 m to top of Plio-Pleistocene unit.
COMPLETION	Unsaturated zone monitoring/vapor extraction well.
POTENTIAL CONTAMINATION	Carbon tetrachloride, chloroform, tributyl phosphate, dibutyl phosphate, dibutylbutyl phosphonate, plutonium, americium.
RATIONALE	Collect data on nature and distribution of carbon tetrachloride waste discharged to 216-Z-18 Crib. Collect site-specific hydrogeologic data (e.g., pore size distribution). Collect data to monitor and evaluate vapor extraction of carbon tetrachloride from subsurface sediments.
TERMS	VOC: Volatile Organic Compound $CaCO_3$: Calcium Carbonate SVOC: Semi-Volatile Organic Compound
- - - - - - - - - - - - - - - - SAMPLING / ANALYSES - - - - - - - - - - - - - - - -	
NOTE ON SAMPLING AND ANALYSES	• Listed samples, locations, and analyses are approximate. Actual samples, locations, and analyses will be determined in the field.
WELLHEAD MONITORING/ DRIVE BARREL SCREENING	• Every 1.5 m interval. • Other depths at the discretion of the project scientist. • Look for changes of 1 order of magnitude in concentrations of VOCs and radionuclides (as screened for by the HPT).
DRIVE BARREL/ HARD TOOL SAMPLING	• Every 1.5 m interval to the bottom of the Hanford Formation. • VOC and SVOC analyses in all drive barrel/hard tool intervals. • Lithologic (moisture, $CaCO_3$, particle size distribution) analyses in all drive barrel/hard tool intervals. • Supercritical Fluid Extraction (SFE) matrix characterization analyses from drive barrel samples in fine grained sediments of the lower Hanford Formation and/or early "Palouse" soil (sampling intervals to be determined in the field).
SPLIT-BARREL SAMPLING	• Every 6 m interval to the bottom of the Hanford Formation. • Every 1.5 m interval from the bottom of the Hanford Formation through the early "Palouse" soil to the top of the Plio-Pleistocene unit. • At significant lithologic and/or VOC concentration changes (i.e. lithologic contacts or changes of 1 order of magnitude in concentration, as determined by field instruments). • VOC, SVOC, physical properties, bulk density/porosity, air permeability, and chemical analyses from all split-barrel sample intervals (subject to sufficient core recovery).
ASEPTIC SAMPLING	• Aseptic split-barrel sampling from early "Palouse" soil. • Microbial analyses.
OTHER TESTING	• Associated geophysical logging, soil gas sampling, geochemical, and geotechnical testing as determined to be necessary during drilling.

9 3 1 2 9 3 2 1 5 7 4

Table FSP 2-1. New Well Investigations Summary. (Sheet 2 of 6)

299-W18-174	**(Deepen)**
LOCATION	216-Z-1A Tile Field, deepen well 299-W18-174.
DEPTH	41 m to top of Plio-Pleistocene unit.
COMPLETION	Unsaturated zone monitoring/vapor extraction well.
POTENTIAL CONTAMINATION	carbon tetrachloride, chloroform, tributyl phosphate, dibutyl phosphate, dibutylbutyl phosphonate, plutonium, americium.
RATIONALE	Collect data on nature and distribution of carbon tetrachloride directly beneath the 216-Z-1A Tile Field. Collect site-specific hydrogeologic data (e.g., pore size distribution). Provide data on the geometry of the Plio-Pleistocene unit.
TERMS	VOC: Volatile Organic Compound SVOC: Semi-Volatile Organic Compound $CaCO_3$: Calcium Carbonate
- - - - - - - - - - - - - - - - SAMPLING / ANALYSES - - - - - - - - - - - - - - - -	
NOTE ON SAMPLING AND ANALYSES	• Listed samples, locations, and analyses are approximate. Actual samples, locations, and analyses will be determined in the field.
WELLHEAD MONITORING/ DRIVE BARREL SCREENING	• Every 1.5 m interval. • Other depths at the discretion of the project scientist. • Look for changes of 1 order of magnitude in concentrations of VOCs and radionuclides (as screened for by the HPT).
DRIVE BARREL/ HARD TOOL SAMPLING	• Every 1.5 m interval to the bottom of the Hanford Formation. • VOC and SVOC analyses in all drive barrel/hard tool intervals. • Lithologic (moisture, $CaCO_3$, particle size distribution) analyses in all drive barrel/hard tool intervals. • Supercritical Fluid Extraction (SFE) matrix characterization analyses from drive barrel samples in fine grained sediments of the lower Hanford Formation and/or early "Palouse" soil (sampling intervals to be determined in the field).
SPLIT-BARREL SAMPLING	• Every 6 m interval to the bottom of the Hanford Formation. • Every 1.5 m interval from the bottom of the Hanford Formation through the early "Palouse" soil to the top of the Plio-Pleistocene unit. • At significant lithologic and/or VOC concentration changes (i.e. lithologic contacts or changes of 1 order of magnitude in concentration, as determined by field instruments). • VOC, SVOC, physical properties, bulk density/porosity, air permeability, and chemical analyses from all split-barrel sample intervals (subject to sufficient core recovery).
ASEPTIC SAMPLING	• Aseptic split-barrel sampling from early "Palouse" soil. • Microbial analyses.
OTHER TESTING	• Associated geophysical logging, soil gas sampling, geochemical, and geotechnical testing as determined to be necessary during drilling.

9 3 1 2 9 3 2 1 5 7 5

Table FSP 2-1. New Well Investigations Summary. (Sheet 3 of 6)

New Crib Well at 216-Z-9 Trench

LOCATION	216-Z-9 Trench; located near NE corner proceeding at 45-deg angle towards the SW corner; new well.
DEPTH	35 m to top of Plio-Pleistocene unit, total length equals 50 m.
COMPLETION	Unsaturated zone monitoring/vapor extraction well.
POTENTIAL CONTAMINATION	carbon tetrachloride, chloroform, tributyl phosphate, dibutyl phosphate, dibutylbutyl phosphonate, plutonium, americium, cadmium.
RATIONALE	Collect data on nature and distribution of carbon tetrachloride and co-contaminants discharged to 216-Z-9 Trench. Collect site-specific hydrogeologic data.
TERMS	VOC: Volatile Organic Compound SVOC: Semi-Volatile Organic Compound $CaCO_3$: Calcium Carbonate

- - - - - - - - - - - - - - - - SAMPLING / ANALYSES - - - - - - - - - - - - - - - -

NOTE ON SAMPLING AND ANALYSES	• Listed samples, locations, and analyses are approximate. Actual samples, locations, and analyses will be determined in the field.
WELLHEAD MONITORING/ DRIVE BARREL SCREENING	• Every 1.5 m interval. • Other depths at the discretion of the project scientist. • Look for changes of 1 order of magnitude in concentrations of VOCs and radionuclides (as screened for by the HPT).
CORE BARREL	• Every 1.5 m interval to the bottom of the Hanford Formation. • VOC and SVOC analyses in all core barrel intervals. • Lithologic (moisture, $CaCO_3$, particle size distribution) analyses in all core barrel intervals. • Supercritical Fluid Extraction (SFE) matrix characterization analyses from core barrel samples in fine grained sediments of the lower Hanford Formation and/or early "Palouse" soil (sampling intervals to be determined in the field).
SPLIT-BARREL SAMPLING	• Every 6 m interval to the bottom of the Hanford Formation. • Every 1.5 m interval from the bottom of the Hanford Formation through the early "Palouse" soil to the top of the Plio-Pleistocene unit. • At significant lithologic and/or VOC concentration changes (i.e. lithologic contacts or changes of 1 order of magnitude in concentration, as determined by field instruments). • VOC, SVOC, physical properties, bulk density/porosity, air permeability, and chemical analyses from all split-barrel sample intervals (subject to sufficient core recovery).
ASEPTIC SAMPLING	• Aseptic split-barrel sampling from early "Palouse" soil. • Microbial analyses.
OTHER TESTING	• Associated geophysical logging, soil gas sampling, geochemical, and geotechnical testing as determined to be necessary during drilling.

9 3 1 2 9 3 2 1 5 7 6

Table FSP 2-1. New Well Investigations Summary. (Sheet 4 of 6)

New Deep Ground Water Monitoring Well

Location	South of 216-Z-9 Trench, midway between wells 299-W15-8 and 299-W15-5; new well.
Depth	160 m to top of basalt.
Completion	Deep ground water monitoring well.
Potential Contamination	Unsaturated Zone: carbon tetrachloride, chloroform, tributyl phosphate, dibutyl phosphate, plutonium, americium, cadmium. Perched Water (encountered in 299-W15-216): Same as unsaturated zone. Saturated Zone: Carbon tetrachloride, chloroform, cyanide, iodine-129, uranium, tetrachloroethylene, trichloroethylene.
Rationale	Characterize distribution of carbon tetrachloride within unsaturated zone and unconfined and semiconfined aquifers; investigate preferential pathway (formerly unsealed boreholes 299-W15-5, 299-W15-6, and 299-W15-8).
Terms	VOC: Volatile Organic Compound SVOC: Semi-Volatile Organic Compound $CaCO_3$: Calcium Carbonate

- - - - - - - - - - - - - - - - SAMPLING / ANALYSES - - - - - - - - - - - - - - -

NOTE ON SAMPLING AND ANALYSES	• Listed samples, locations, and analyses are approximate. Actual samples, locations, and analyses will be determined in the field.
	Unsaturated Zone:
WELLHEAD MONITORING/ DRIVE BARREL SCREENING	• Every 1.5 m interval. • Other depths at the discretion of the project scientist. • Look for changes of 1 order of magnitude in concentrations of VOCs and radionuclides (as screened for by the HPT).
DRIVE BARREL/ HARD TOOL SAMPLING	• Every 1.5 m interval to the bottom of the Hanford Formation. • VOC and SVOC analyses in all drive barrel/hard tool intervals. • Lithologic (moisture, $CaCO_3$, particle size distribution) analyses in all drive barrel/hard tool intervals. • Supercritical Fluid Extraction (SFE) matrix characterization analyses from drive barrel samples in fine grained sediments of the lower Hanford Formation and/or early "Palouse" soil (sampling intervals to be determined in the field).

9 3 1 2 9 3 2 1 5 7 7

Table FSP 2-1. New Well Investigations Summary. (Sheet 5 of 6)

New Deep Ground Water Well (cont.)	
SPLIT-BARREL SAMPLING	• Every 6 m interval to the bottom of the Hanford Formation. • Each 1.5 m interval from the bottom of the Hanford Formation through the early "Palouse" soil and Plio-Pleistocene unit into the top of the Ringold Formation. • At significant lithologic and/or VOC concentration changes (i.e. lithologic contacts or changes of 1 order of magnitude in concentration, as determined by field instruments). • VOC, SVOC, physical properties, bulk density/porosity, air permeability, and chemical analyses from all split-barrel sample intervals (subject to sufficient core recovery).
ASEPTIC SAMPLING	• Aseptic split-barrel sampling from early "Palouse" soil. • Microbial analyses.
OTHER TESTING	• Associated geophysical logging, soil gas sampling, geochemical, and geotechnical testing as determined to be necessary during drilling.
	<u>Saturated Zone</u>:
WELLHEAD MONITORING/ DRIVE BARREL SCREENING	• Every 1.5 m interval. • Other depths at the discretion of the project scientist. • Look for changes of 1 order of magnitude in concentrations of VOCs and radionuclides (as screened for by the HPT).
DRIVE BARREL/ HARD TOOL SAMPLING	• Every 1.5 m interval to the bottom of the Hanford Formation. • VOC and SVOC analyses every 15 m. • Lithologic (moisture, $CaCO_3$, particle size distribution) analyses in all drive barrel/hard tool intervals.
SPLIT-BARREL SAMPLING	• Every 15 m interval to the top of basalt. • At significant lithologic and/or VOC concentration changes (i.e. lithologic contacts or changes of 1 order of magnitude in concentration, as determined by field instruments). • VOC, SVOC, physical properties, bulk density/porosity, air permeability, and chemical analyses from all split-barrel sample intervals (subject to sufficient core recovery).
GROUND WATER SAMPLING	• Every 6 m interval to the top of basalt. • At significant lithologic and/or VOC concentration changes (i.e. lithologic contacts, changes of 1 order of magnitude in concentration). • VOC, SVOC, and chemical analyses from all ground water samples (subject to sufficient recovery).
OTHER TESTING	• Associated geophysical logging, soil gas sampling, geochemical, and geotechnical testing as determined to be necessary during drilling.

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Table FSP 2-1. New Well Investigations Summary. (Sheet 6 of 6)

299-W11-32

LOCATION	West of T-Plant, near previously drilled wells 299-W11-29 and 299-W11-30
DEPTH	93 m (305 ft), to a depth of approximately 18 m (60 ft) into the saturated zone
COMPLETION	Three screened intervals: across the water table (73.2-76.2 meter depth), above the cemented zone (83.2-84.7 meter depth), and at the bottom of the borehole(91.4-93.0 meter depth)
POTENTIAL CONTAMINATION	Carbon tetrachloride, chloroform, nitrate, trichloroethylene
RATIONALE	Collect site-specific hydrogeologic data (e.g., grain size distribution). Collect data on nature and distribution of carbon tetrachloride in the saturated zone. Collect data on microbial populations and their distribution in the saturated zone.
- - - - - - - - - - - - - - - - SAMPLING / ANALYSES - - - - - - - - - - - - - - - -	
DRIVE BARREL/ HARD TOOL SAMPLING	• Every 1.5 m (5 ft) to the top of the capillary fringe. • Particle size distribution analyses through unsaturated and saturated zone. • 2 archive samples from each 1.5 m interval
SPLIT-BARREL UNSATURATED ZONE SAMPLING	• 2 aseptic split-barrel samples: one from the lower Hanford fmtn. and one from the early "Palouse" soil for microbiologic analyses • 2 (each) Physical properties sample and geochemical characterization sediment sample from associated microbiologic sampling interval
SPLIT-BARREL SATURATED ZONE SAMPLING	• Each 1.5 m (5 ft) from the capillary fringe to the bottom of the borehole to collect aseptic split-barrel samples for microbiologic analyses and associated physical and geochemical parameters. • VOC, physical properties, bulk density/porosity, air permeability, chemical, total organic carbon and mineralogic analyses from all split-barrel sample intervals.
GROUNDWATER SAMPLING	• In-situ groundwater monitoring for geochemical parameters • Groundwater samples collected for anion, metals and TOC analyses at 3.0 m (10 ft) intervals • Groundwater samples collected for dissolved organic constituent analyses at 3.0 m (10 ft) intervals • Samples collected from completed well
HYDROLOGIC TESTING	• Slug tests during well installation, up to 3 • Hydrologic testing to determine hydraulic and transport properties
OTHER TESTING	• Associated geophysical logging • Borehole sampler tool collects soil gas samples for analyses • Additional testing as determined to be necessary during drilling.

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Table FSP 3-1. 299-W18-96 Sample Matrix.

		Analysis	Screening		Physical						Supercritical Fluid Extr.		Microbial	VOA				CHEMICAL				Soil Gas	
		Laboratory	WHC		WHC					WSU / PNL	PNL		PNL	PNL				DATA CHEM				WHC	PNL
		Contact	V. Rohay		V. Rohay					Conca/Serne	J. Amonette		M. Truex	K. Olsen				J. Julya				V. Rohay	S. Luttrell
		Sample Type	Field		Field	Field	Field	Field	Field	Field	Field	Field	Field	Field		Field		Field		Lab		Field	Field
		Analyses	Wellhead/ Cuttings	Rad Release Survey	Archive Lithologic	Moisture CaCO3	Part. Size Dist.	Porosity Bulk Density	Air Perm.	Unsat. K Sat. K Pore Water Chem	Mineralogy Cation Ex. Cap.		Micro-biology	VOA Drive Barrel		VOA Split Barrel		SVOA (ABN) DB	SB	Ions,ICP Pb, Hg Cyn	TOC	SEAMIST	Bore Sampler
		Sample Method	A	B	C	C	C	D	D	D	C	C	E	F	G	F	G	F	D	D	D	H	I
Depth		Container Key	1, 2	1, 3	4	5	4	6	6	6	4	7	8	9	9	9	9	10	10	11	12	1	1
Ft	M	Horizon																					
5	1.5	Existing Well																					
10	3.0	Existing Well																					
15	4.6	Existing Well																					
20	6.1	Existing Well																					
25	7.6	Existing Well																					
30	9.1	Existing Well																					
35	10.7	Existing Well																					
40	12.2	Existing Well																					
45	13.7	Existing Well																					
50	15.2	Existing Well																					
55	16.8	Existing Well																					
60	18.3	Existing Well																					
65	19.8	Existing Well																					
70	21.3	Existing Well																					
75	22.9	Existing Well																					
80	24.4	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	
85	25.9	Hanford	1	1	2	1	1							1	1			1					
90	27.4	Hanford	1	1	2	1	1							1	1			1					
95	29.0	Hanford	1	1	2	1	1							1	1			1					
100	30.5	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	
105	32.0	Hanford	1	1	2	1	1							1	1			1					
110	33.5	Hanford	1	1	2	1	1				1	1		1	1			1					
115	35.1	Hanford	1	1	2	1	1							1	1			1					
120	36.6	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	
125	38.1	Early Palouse	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)		
130	39.6	Early Palouse	1	1	2	1	1	1	1	1	1	1		1	1	1	1	1	1	(1)	(1)		
135	41.1	Early Palouse	1	1	2	1	1	1	1	1			1	1	1	1	1	1	1	(1)	(1)		
140	42.7	Early Palouse	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)		
145	44.2	Plio-Pleist.	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	
Approx. Total Samples			14	14	28	14	14	8	8	8	2	2	1	14	14	8	8	14	8	(8)	(8)	4	0

Container Key

[1] Value entry in borehole log
[2] Headspace container
[3] Plastic Bag
[4] Glass mason jar - clear
[5] Metal moisture tin
[6] Lexan liner - 15 cm length
[7] 15-20 liter plastic bucket
[8] Aseptically sampled split-barrel core - 61 cm length, Lexan liner
[9] 40 ml glass vial, amber w/septum, methanol preservative
[10] 125 ml glass jar - amber
[11] 250 ml (8 oz.) glass jar - clear
[12] 40 ml glass vial - amber

Laboratory Key

Data Chem Data Chem Laboratories - Richland, WA
PNL Pacific Northwest Laboratory - Richland, WA
WHC Westinghouse Hanford Co. - Richland, WA
WSU Washington State University - Richland, WA

1 set of Trip Blanks
1 set of Equipment Blanks
2 VOA Duplicates
1 set of Chem Duplicates

Sample Method Key

A Organic Vapor Monitor, Colorimetric Tube
B Rad Scanners as used by HPT
C Drive Barrel
D Split Barrel
E Aseptic Split Barrel
F Grab sample
G Core-Borer
H SEAMIST - Soil Gas Sampler
I Bore Sampler - Soil Gas Sampler

NOTE: Sample numbers in "( )" represent LAB samples split up from field samples

NOTE: Depths are approximate. Actual depths will be determined in the field.

(a) Field sample is split into containers for lab analyses.

Table FSP 3-2. 299-W18-174 Sample Matrix.

Analysis			Screening		Physical						Supercritical Fluid Extr.		Microbial	VOA				CHEMICAL				Soil Gas	
Laboratory			WHC		WHC					WSU / PNL	PNL		PNL	PNL				DATA CHEM				WHC	PNL
Contact			V. Rohay		V. Rohay					Conca/Serne	J. Amonette		M. Truex	K. Olsen				J. Julye				V. Rohay	S. Luttrell
Sample Type			Field		Field	Field	Field	Field	Field	Field	Field	Field	Field	Field		Field		Field		Lab		Field	Field
Analyses			Wellhead/ Cuttings	Rad Release Survey	Archive Lithologic	Moisture CaCO3	Part. Size Dist.	Porosity Bulk Density	Air Perm.	Unsat. K Sat. K Pore Water Chem	Mineralogy Cation Ex. Cap.		Micro-biology	VOA Drive Barrel		VOA Split Barrel		SVOA (ABN)		Ions, ICP Pb, Hg Cyn	TOC	SEAMIST	Bore Sampler
		Sample Method	A	B	C	C	C	D	D	D	C	C	E	F	G	F	G	F	D	D	D	H	I
Depth		Container Key	1, 2	1, 3	4	5	4	6	6	6	4	7	8	9	9	9	9	10	10	11	12	1	1
Ft	M	Horizon																DB	SB				
5	1.5	Existing Well																					
10	3.0	Existing Well																					
15	4.6	Existing Well																					
20	6.1	Existing Well																					
25	7.6	Existing Well																					
30	9.1	Existing Well																					
35	10.7	Existing Well																					
40	12.2	Existing Well																					
45	13.7	Existing Well																					
50	15.2	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)		
55	16.8	Hanford	1	1	2	1	1							1	1			1					
60	18.3	Hanford	1	1	2	1	1							1	1			1					
65	19.8	Hanford	1	1	2	1	1							1	1			1					
70	21.3	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)		
75	22.9	Hanford	1	1	2	1	1							1	1			1					
80	24.4	Hanford	1	1	2	1	1							1	1			1					
85	25.9	Hanford	1	1	2	1	1							1	1			1					
90	27.4	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)		
95	29.0	Hanford	1	1	2	1	1							1	1			1					
100	30.5	Hanford	1	1	2	1	1							1	1			1					
105	32.0	Hanford	1	1	2	1	1							1	1			1					
110	33.5	Hanford	1	1	2	1	1	1	1	1	1	1		1	1	1	1	1	1	(1)	(1)		
115	35.1	Hanford	1	1	2	1	1							1	1			1					
120	36.6	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)		
125	38.1	Early Palouse	1	1	2	1	1	1	1	1			1	1	1	1	1	1	1	(1)	(1)		
130	39.6	Early Palouse	1	1	2	1	1				1	1		1	1	1	1	1	1	(1)	(1)		
135	41.1	Early Palouse	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)		
140	42.7	Early Palouse	1	1	2	1	1							1	1	1	1	1	1	(1)	(1)		
145	44.2	Plio-Pleist.	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)		
Approx. Total Samples			20	20	40	20	20	8	8	8	2	2	1	20	20	10	10	20	10	(10)	(10)	0	0

Container Key

[1] Value entry in borehole log
[2] Headspace container
[3] Plastic Bag
[4] Glass mason jar - clear
[5] Metal moisture tin
[6] Lexan liner - 15 cm length
[7] 15-20 liter plastic bucket
[8] Aseptically sampled split-barrel core - 61 cm length, Lexan liner
[9] 40 ml glass vial, amber w/septum, methanol preservative
[10] 125 ml glass jar - amber
[11] 250 ml (8 oz.) glass jar - clear
[12] 40 ml glass vial - amber

NOTE: Sample numbers in "( )" represent LAB samples split up from field samples

Laboratory Key

Data Chem Data Chem Laboratories - Richland, WA
PNL Pacific Northwest Laboratory - Richland, WA
WHC Westinghouse Hanford Co. - Richland, WA
WSU Washington State University - Richland, WA

1 set of Trip Blanks
1 set of Equipment Blanks
2 VOA Duplicates
1 set of Chem Duplicates

NOTE: Depths are approximate. Actual depths will be determined in the field.

Sample Method Key

A Organic Vapor Monitor, Colorimetric Tube
B Rad Scanners as used by HPT
C Drive Barrel
D Split Barrel
E Aseptic Split Barrel
F Grab sample
G Core-Borer
H SEAMIST - Soil Gas Sampler
I Bore Sampler - Soil Gas Sampler

(a) Field sample is split into containers for lab analyses.

Table FSP 3-3. New Inclined Well Sample Matrix.

Analysis			Screening		Physical						Supercritical Fluid Extr.		Microbial	VOA				CHEMICAL				Soil Gas	
Laboratory			WHC		WHC					WSU / PNL	PNL		PNL	PNL				DATA CHEM				WHC	PNL
Contact			V. Rohay		V. Rohay					Conca/Serne	J. Amonette		M. Truex	K. Olsen				J. Julya				V. Rohay	S. Luttrell
Sample Type			Field		Field	Field	Field	Field	Field	Field	Field	Field	Field	Field		Field		Field		Lab		Field	Field
Analyses			Wellhead/ Cuttings	Rad Release Survey	Archive Lithologic	Moisture CaCO3	Part. Size Dist.	Porosity Bulk Density	Air Perm.	Unsat. K Sat. K Pore Water Chem	Mineralogy Cation Ex. Cap.		Micro-biology	VOA Drive Barrel		VOA Split Barrel		SVOA (ABN)		Ions,ICP Pb, Hg Cyn	TOC	SEAMIST	Bore Sampler
		Sample Method	A	B	C	C	C	D	D	D	C	C	E	F	G	F	G	F	D	D	D	H	I
Depth		Container Key	1, 2	1, 3	4	5	4	6	6	6	4	7	8	9	9	9	9	10	10	11	12	1	1
Ft	M	Horizon																DB	SB				
5	1.5	Hanford	1	1	2	1	1							1	1			1					
10	3.0	Hanford	1	1	2	1	1							1	1			1					
15	4.6	Hanford	1	1	2	1	1							1	1			1					
20	6.1	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	
25	7.6	Hanford	1	1	2	1	1							1	1			1					
30	9.1	Hanford	1	1	2	1	1							1	1			1					
35	10.7	Hanford	1	1	2	1	1							1	1			1					
40	12.2	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	
45	13.7	Hanford	1	1	2	1	1							1	1			1					
50	15.2	Hanford	1	1	2	1	1							1	1			1					
55	16.8	Hanford	1	1	2	1	1							1	1			1					
60	18.3	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	
65	19.8	Hanford	1	1	2	1	1							1	1			1					
70	21.3	Hanford	1	1	2	1	1							1	1			1					
75	22.9	Hanford	1	1	2	1	1							1	1			1					
80	24.4	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	
85	25.9	Hanford	1	1	2	1	1							1	1			1					
90	27.4	Hanford	1	1	2	1	1							1	1			1					
95	29.0	Hanford	1	1	2	1	1							1	1			1					
100	30.5	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	
105	32.0	Hanford	1	1	2	1	1							1	1			1					
110	33.5	Early Palouse	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	
115	35.1	Early Palouse	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	(1)	(1)		
120	36.6	Plio-Pleist.	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)		
125	38.1																						
130	39.6																						
135	41.1																						
140	42.7																						
145	44.2																						
Approx. Total Samples			24	24	48	24	24	8	8	8	1	1	1	24	24	8	8	24	8	(8)	(8)	6	0

Container Key

[1] Value entry in borehole log
[2] Headspace container
[3] Plastic Bag
[4] Glass mason jar - clear
[5] Metal moisture tin
[6] Lexan liner - 15 cm length
[7] 15-20 liter plastic bucket
[8] Aseptically sampled split-barrel core - 61 cm length, Lexan liner
[9] 40 ml glass vial, amber w/septum, methanol preservative
[10] 125 ml glass jar - amber
[11] 250 ml (8 oz.) glass jar - clear
[12] 40 ml glass vial - amber

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2 VOA Duplicates
1 set of Chem Duplicates

Sample Method Key

A Organic Vapor Monitor, Colorimetric Tube
B Rad Scanners as used by HPT
C Drive Barrel
D Split Barrel
E Aseptic Split Barrel
F Grab sample
G Core-Borer
H SEAMIST - Soil Gas Sampler
I Bore Sampler - Soil Gas Sampler

NOTE: Sample numbers in "( )" represent LAB samples split up from field samples

NOTE: Depths are approximate. Actual depths will be determined in the field.

(a) Field sample is split into containers for lab analyses.

Table FSP 3-4. New Deep Ground Water Monitoring Well Sample Matrix (sheet 1 of 3).

		Analysis	Screening		Physical						Supercritical Fluid Extr.		Microbial	VOA				CHEMICAL				Soil Gas	
		Laboratory	WHC		WHC					WSU / PNL	PNL		PNL	PNL				DATA CHEM				WHC	PNL
		Contact	V. Rohay		V. Rohay					Conca/Serne	J. Amonette		M. Truex	K. Olsen				J. Julya				V. Rohay	S. Luttrell
		Sample Type	Field		Field	Field	Field	Field	Field	Field	Field	Field	Field	Field		Field		Field		Lab		Field	Field
		Analyses	Wellhead/ Cuttings	Rad Release Survey	Archive Lithologic	Moisture CaCO3	Part. Size Dist.	Porosity Bulk Density	Air Perm.	Unsat. K Sat. K Pore Water Chem	Mineralogy Cation Ex. Cap		Micro-biology	VOA Drive Barrel		VOA Split Barrel		SVOA (ABN)		Ions,ICP Pb, Hg Cyn	TOC	SEAMIST	Bore Sampler
		Sample Method	A	B	C	C	C	D	D	D	C	C	E	F	G	F	G	F	D	D	D	H	I
Depth		Container Key	1, 2	1, 3	4	5	4	6	6	6	4	7	8	9	9	9	9	10	10	11	12	1	1
Ft	M	Horizon																					
5	1.5	Hanford	1	1	2	1	1							1	1			1					
10	3.0	Hanford	1	1	2	1	1							1	1			1					
15	4.6	Hanford	1	1	2	1	1							1	1			1					
20	6.1	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	1
25	7.6	Hanford	1	1	2	1	1							1	1			1					
30	9.1	Hanford	1	1	2	1	1							1	1			1					
35	10.7	Hanford	1	1	2	1	1							1	1			1					
40	12.2	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	1
45	13.7	Hanford	1	1	2	1	1							1	1			1					
50	15.2	Hanford	1	1	2	1	1							1	1			1					
55	16.8	Hanford	1	1	2	1	1							1	1			1					
60	18.3	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	1
65	19.8	Hanford	1	1	2	1	1							1	1			1					
70	21.3	Hanford	1	1	2	1	1							1	1			1					
75	22.9	Hanford	1	1	2	1	1							1	1			1					
80	24.4	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	1
85	25.9	Hanford	1	1	2	1	1							1	1			1					
90	27.4	Hanford	1	1	2	1	1							1	1			1					
95	29.0	Hanford	1	1	2	1	1							1	1			1					
100	30.5	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	1
105	32.0	Hanford	1	1	2	1	1							1	1			1					
110	33.5	Hanford	1	1	2	1	1							1	1			1					
115	35.1	Hanford	1	1	2	1	1				1	1		1	1			1					
120	36.6	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	1
125	38.1	Hanford	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)		1
130	39.6	Early Palouse	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	(1)	(1)		1
135	41.1	Early Palouse	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)		1
140	42.7	Early Palouse	1	1	2	1	1	1	1	1			1	1	1	1	1	1	1	(1)	(1)	1	
145	44.2	Plio-Pleist.	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)		
150	45.7	Plio-Pleist.	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)		
155	47.2	Plio-Pleist.	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)		
160	48.8	Ringold	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	
165	50.3	Ringold	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)		
170	51.8	Ringold	1	1	2	1	1							1	1			1					
175	53.3	Ringold	1	1	2	1	1							1	1			1					
180	54.9	Ringold	1	1	2	1	1	1	1	1				1	1	1	1	1	1	(1)	(1)	1	
185	56.4	Ringold	1	1	2	1	1							1	1			1					
190	57.9	Ringold	1	1	2	1	1							1	1			1					
195	59.4	Ringold	1	1	2	1	1			Ground Water Table				1	1			1					
Approx. Total Samples (Unsaturated Zone)			39	39	78	39	39	16	16	16	2	2	2	39	39	16	16	39	16	(16)	(16)	9	9

Table FSP 3-4. New Deep Ground Water Monitoring Well Sample Matrix (sheet 2 of 3).

		Analysis	Screening		Physical						Supercritical Fluid Extr.		Microbial	VOA			Chemical						Soil Gas	
		Laboratory	WHC		WHC					WSU / PNL	PNL		PNL	PNL			Data Chem						WHC	PNL
		Contact	V. Rohay		V. Rohay					Conca/Serne	J. Amonette		M. Truex	K. Olsen			J. Julya						Rohay	Luttrell
		Sample Type	Field		Field	Field	Field	Field	Field	Field	Field	Field	Field	Field			Field		Lab		Field		Field	Field
		Analyses	Wellhead/ Cuttings	Rad Survey	Archive Lithologic	CaCO3	Part. Size Dist.	Porosity Bulk Density	Air Perm.	Sat. K Pore Water Chem	Mineralogy Cation Ex. Cap.		Micro-biology	VOA			SVOA (ABN)		Ions, ICP Pb, Hg Cyn	TOC	ICP	Ions	SEA-MIST	Bore Sampler
		Sample Method	A	B	C	C	C	D	D	D	C	C	E	GW J	DB G	SB G	GW J	SB D	D	D	GW J	GW J	H	I
Depth		Container Key	1, 2	1, 3	4	5	4	6	6	6	4	7	8	12	9	9	15	10	11	12	13	14	1	1
Ft	M	Horizon																						
200	61.0	Ringold	1	1	2	1	1	1	1	1				1	1	1	1	1	(1)	(1)	1	1		
205	62.5	Ringold	1	1	2	1	1																	
210	64.0	Ringold	1	1	2	1	1																	
215	65.5	Ringold	1	1	2	1	1																	
220	67.1	Ringold	1	1	2	1	1							1			1				1	1		
225	68.6	Ringold	1	1	2	1	1																	
230	70.1	Ringold	1	1	2	1	1																	
235	71.6	Ringold	1	1	2	1	1																	
240	73.2	Ringold	1	1	2	1	1							1			1				1	1		
245	74.7	Ringold	1	1	2	1	1																	
250	76.2	Ringold	1	1	2	1	1	1	1	1					1	1		1	(1)	(1)				
255	77.7	Ringold	1	1	2	1	1																	
260	79.2	Ringold	1	1	2	1	1							1			1				1	1		
265	80.8	Ringold	1	1	2	1	1																	
270	82.3	Ringold	1	1	2	1	1																	
275	83.8	Ringold	1	1	2	1	1																	
280	85.3	Ringold	1	1	2	1	1							1			1				1	1		
285	86.9	Ringold	1	1	2	1	1																	
290	88.4	Ringold	1	1	2	1	1																	
295	89.9	Ringold	1	1	2	1	1																	
300	91.4	Ringold	1	1	2	1	1	1	1	1				1	1	1	1	1	(1)	(1)	1	1		
305	93.0	Ringold	1	1	2	1	1																	
310	94.5	Ringold	1	1	2	1	1																	
315	96.0	Ringold	1	1	2	1	1																	
320	97.5	Ringold	1	1	2	1	1							1			1				1	1		
325	99.1	Ringold	1	1	2	1	1																	
330	100.6	Ringold	1	1	2	1	1																	
335	102.1	Ringold	1	1	2	1	1																	
340	103.6	Ringold	1	1	2	1	1							1			1				1	1		
345	105.2	Ringold	1	1	2	1	1																	
350	106.7	Ringold	1	1	2	1	1	1	1	1					1	1		1	(1)	(1)				
355	108.2	Ringold	1	1	2	1	1																	
360	109.7	Ringold	1	1	2	1	1							1			1				1	1		
365	111.3	Ringold	1	1	2	1	1																	
370	112.8	Ringold	1	1	2	1	1																	
375	114.3	Ringold	1	1	2	1	1																	
380	115.8	Ringold	1	1	2	1	1							1			1				1	1		
385	117.3	Ringold	1	1	2	1	1																	
390	118.9	Ringold	1	1	2	1	1																	
395	120.4	Ringold	1	1	2	1	1																	
400	121.9	Ringold	1	1	2	1	1	1	1	1				1	1	1	1	1	(1)	(1)	1	1		
405	123.4	Ringold	1	1	2	1	1																	
410	125.0	Ringold	1	1	2	1	1																	
415	126.5	Ringold	1	1	2	1	1																	
420	128.0	Ringold	1	1	2	1	1							1			1				1	1		

Table FSP 3-4. New Deep Ground Water Monitoring Well Sample Matrix (sheet 3 of 3).

Analysis			Screening		Physical								Microbial	VOA			Chemical						Soil Gas	
Laboratory			WHC		WHC					WSU / PNL	PNL		PNL	PNL			Data Chem						WHC	PNL
Contact			V. Rohay		V. Rohay					Conca/Serne	J. Amonette		M. Truex	K. Olsen			J. Julya						V. Rohay	S. Luttrell
Sample Type			Field		Field	Field	Field	Field	Field	Field	Field	Field	Field	Field			Field		Lab		Field		Field	Field
Analyses			Wellhead/ Cuttings	Rad Survey	Archive Lithologic	CaCO3	Part. Size Dist.	Porosity Bulk Density	Air Perm.	Sat. K Pore Water Chem	Mineralogy Cation Ex. Cap.		Micro-biology	VOA			SVOA (ABN)		Ions,ICP Pb, Hg Cyn	TOC	ICP	Ions	SEA-MIST	Bore Sampler
		Sample Method	A	B	C	C	C	D	D	D	C	C	E	GW J	DB G	SB G	GW J	SB D	D		GW J	GW J	H	I
Depth		Container Key	1, 2	1, 3	4	5	4	6	6	6	4	7	8	12	9	9	15	10	11	12	13	14	1	1
Ft	M	Horizon																						
425	129.5	Ringold	1	1	2	1	1																	
430	131.1	Ringold	1	1	2	1	1																	
435	132.6	Ringold	1	1	2	1	1																	
440	134.1	Ringold	1	1	2	1	1							1			1				1	1		
445	135.6	Ringold	1	1	2	1	1																	
450	137.2	Ringold	1	1	2	1	1	1	1	1					1	1		1	(1)	(1)				
455	138.7	Ringold	1	1	2	1	1																	
460	140.2	Ringold	1	1	2	1	1							1			1				1	1		
465	141.7	Ringold	1	1	2	1	1																	
470	143.3	Ringold	1	1	2	1	1																	
475	144.8	Ringold	1	1	2	1	1																	
480	146.3	Ringold	1	1	2	1	1							1			1				1	1		
485	147.8	Ringold	1	1	2	1	1																	
490	149.4	Ringold	1	1	2	1	1																	
495	150.9	Ringold	1	1	2	1	1																	
500	152.4	Ringold	1	1	2	1	1	1	1	1				1	1	1	1	1	(1)	(1)	1	1		
505	153.9	Ringold	1	1	2	1	1																	
510	155.4	Ringold	1	1	2	1	1																	
515	157.0	Ringold	1	1	2	1	1																	
520	158.5	Ringold	1	1	2	1	1							1			1				1	1		
525	160.0	Ringold	1	1	2	1	1																	
Total Sediment Samples (Saturated Zone)			66	66	132	66	66	7	7	7	•	•	•	•	7	7	•	7	7		•	•	•	•
Total GW Samples			•	•	•	•	•	•	•	•	•	•	•	17	•	•	17	•	•		17	17	•	•

Container Key

[1] Value entry in borehole log
[2] Headspace container
[3] Plastic Bag
[4] Glass mason jar - clear
[5] Metal moisture tin
[6] Lexan liner - 15 cm length
[7] 15-20 liter plastic bucket
[8] Aseptically sampled split-barrel core - 61 cm length, lexan liner
[9] 40 ml glass jar, amber w/septum, methanol preservative
[10] 125 ml glass jar - amber
[11] 250 ml (8 oz.) glass jar - clear
[12] 40 ml glass vial - amber
[13] 500 ml polypropolene bottle
[14] 125 ml polypropolene bottle
[15] 2000 ml polypropolene bottle
[16] 1000 ml polypropolene bottle

Laboratory Key

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PNL Pacific Northwest Laboratory - Richland, WA
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Sample Method Key

A Organic Vapor Monitor, Colorimetric Tube
B Rad Scanners as used by HPT
C Drive Barrel
D Split Barrel
E Aseptic Split Barrel
F Grab sample
G Core-Borer
H SEAMIST - Soil Gas Sampler
I Bore Sampler - Soil Gas Sampler
J Teflon Bailer

NOTE: Sample numbers in "( )" represent LAB samples split up from field samples

NOTE: Depths are approximate. Actual depths will be determined in the field.

(a) Field sample is split into containers for lab analyses.

Table FSP 3-5a. 299-W11-32 Unsaturated Zone Sample Matrix.

Depth (meters)	Depth (feet)	Archive (Lithologic)	Moisture Content	CaCO3	Particle Size Distribution	Water Suction
1.5	5	1				
3	10	1			1	
4.6	15	1				
6.1	20	1			1	
7.6	25	1				
9.1	30	1			1	
10.7	35	1				
12.2	40	1			1	
13.7	45	1				
15.2	50	1			1	
16.8	55	1				
18.3	60	1			1	
19.8	65	1				
21.3	70	1			1	
22.9	75	1				
24.4	80	1			1	
25.9	85	1				
27.4	90	1			1	
29	95	2*	1*		1*	
30.5	100	1	1	1	1	
32	105	1				
33.5	110	1			1	
35.1	115	1				
36.6	120	2*	1*	1*	1*	1*
38.1	125	1			1	
39.6	130	1			1	
41.1	135	1				
42.7	140	1				
44.2	145	2*	1*	1*	1*	1*
45.7	150	2*	1*		1*	
47.2	155	1				
48.8	160	1			1	
50.3	165	1				
51.8	170	1			1	
53.3	175	1				
54.9	180	1			1	
56.4	185	1				
57.9	190	1			1	
59.4	195	1				
61	200	1			1	
62.5	205	1				
64	210	1			1	
65.5	215	1			1	
67.1	220	1			1	
68.6	225	2			1	
70.1	230	2			1	
71.7	235	2*	1*		1*	
73.2	240	2*	1*		1*	1*
Estimated total #		56	7	3	29	3

* Indicates samples are shown on Table 3-5b also

9 3 1 2 9 3 2 1 5 8 6

Table FSP 3-5b. 299-W11-32 Split-Barrel Sample Matrix.

			ASEPTIC	SEDIMENT PHYSICAL PROPERTIES							SEDIMENT CHEMISTRY			WATER CHEMISTRY					BORE
			PNL Truex	PNL Doremus							PNL Amonette	Huff man	PNL Veverka	PNL Doremus	PNL Veverka	DataChem			SAMPLER Luttrell
planned screened	Depth (meters)	Depth (feet)	micro biologic	particle size	density porosity	hydraulic conductivity	CaCO3	moisture content	archive (lithologic)	water suction	minerals	TOC	VOA	in situ	VOA	metals	anions	DOC	soil gas
interval		containe	a	b	b	a	c	c	m	c	c	d	e	n/a	d	h	j	k	g
	29	95		1				1	2				2●						1●
	36.5-38.1	120-125	1 or 2$	1	1	1	1	1	2	1	1	1	2●						1●
	42.7-44.2	140-145	1 or 2$	1	1	1	1	1	2	1	1	1	2●						1●
	45.7	150		1				1	2				2●						1●
	71.6	235		1				1	2				2●						1●
top=240'	73.2-74.7	240-245	1 or 2$	2	1	1		1	2	1	1	1							
	(water table)																		
	74.7-76.2	245-250	1 or 2$	2					2			1	1	1	1	1	1	1	
	76.2-77.7	250-255	1	2	1	1			2		1	1	1	1	1	1	1	1	
bottom= 255'	77.7-79.2	255-260	1	2					2		1*	1*		1	1	1	1	1	
	79.2-80.8	260-265	1 or 2$	2	1*	1*			2	1	1	1		1	1	1	1	1	
	80.8-82.3	265-270	1 or 2$	2	1	1			2		1	1	1	1	1	1	1	1	
top=273'	82.3-83.8	270-275	1	2	1*	1*			2		1*	1*							
	83.8-85.3	275-280	1 or 2$	2	1	1	1		2		1	1	1	1	1	1	1	1	
bottom= 278'	85.3-86.8	280-285	1	2	1*	1*	1		2		1*	1*	1						
	86.8-88.4	285-290	1	2					2		1*	1*	1	1	1	1	1	1	
	88.4-89.9	290-295	1 or 2$	2	1*	1*			2		1	1	1						
top=300'	89.9-91.4	295-300	1	2					2	1	1*	1*		1	1	1	1	1	
	91.4-93.0	300-305	1 or 2$	2	1	1			2		1	1	1						
bottom= 305'	93.0-94.5	305-310	1 or 2$	2					2		1	1	1	1	1	1	1	1	
	Estimated total #		12	33	11	11	4	6	38	5	15	16	19	7	7	7	7	7	5

* Indicates samples will be collected if microbiologic sample is collected successfully in that depth interval

\# Indicates the potential maximum number of samples collected

$ Highest priority depth interval for microbiologic sample collection

● See BoreSampler test plan for specific sample locations

Container Key:

a) 1 ft length sediment core
b) 0.5 ft length sediment cor
c) metal moisture tin
d) 40 ml amber vial
e) 40 ml amber vial w/ metl
f) 250 ml glass jar
g) 500 ml glass bulb
h) 500 ml polypropylene bottle
j) 250 ml polypropylene bottle
k) 500 ml glass amber
l) 100 ml glass (aspetic)
m) pint canning jars

5.0 SAMPLING PROCEDURES

Sediment samples will be collected for analyses to characterize the host material and contaminants. Analyses may include:

- analysis of chemical constituent concentrations in the sediment matrix and sorbed to the sediment particles
- physical property analysis for properties governing hydrologic movement in sediment
- mineralogic analysis and lithologic description
- microbiologic analysis
- pore water analysis.

Ground water samples will be collected from the single deep ground water monitoring borehole and the in situ bioremediation well. Ground water samples will be analyzed for chemical, volatile, and semivolatile constituents.

In situ soil-gas samples may be collected from the boreholes during drilling using the SEAMIST (tradename of Science & Engineering Associates, Inc., Santa Fe, New Mexico) system and/or the BoreSampler soil gas sampling system.

5.1 SAMPLE PROCESSING

Samples will be taken and handled according to the requirements defined for each specific sample. The general procedure governing sample handling, from collection through analysis, is similar in scope for all samples. Once samples are collected (according to the defined procedure), they will be screened for any radioactivity before further handling. While the radioactivity screening is being done, samples will be stored onsite according to the appropriate preservation technique. Samples containing no detectible radioactive contamination are then given a radiation release, which allows additional handling and analysis to proceed. Once released, chemical samples will be divided into specific containers for laboratory distribution and all samples will be transported (under the appropriate preservation method) to either the PNL field sampling and analysis group for offsite distribution, or to the specific onsite laboratory personnel responsible for analysis. Remaining sampled material will be disposed of at the collection site, or by the laboratory personnel according to laboratory procedures. Sample processing steps are shown in Table FSP 5-1. All sample handling will be documented on chain-of-custody forms.

5.2 RADIATION RELEASE RECORDS

All samples that are to be removed from the drill site must be released by the responsible Health Physics Technician (HPT). Effective communication with the HPT is required so that samples are released and transported in a timely manner, without exceeding sample holding times.

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Table FSP 5-1. Sample Processing.

SAMPLING AND SAMPLE HANDLING	REQUIRED DOCUMENTATION	RESPONSIBLE PERSONNEL	LOCATION	ASSOCIATED ACTIVITIES AND DATA HANDLING	RESPONSIBLE PERSONNEL
Sample Equipment Decontamination	Equipment Decon Documentation	Sampler or Laborer	Laboratory or Drill Site		
Sample Collection	Chain-of-Custody Forms Generated	Sampler(s) and Field Geologist	Drill Site	HEIS Numbers Assigned for: VOA, SVOA, and Chem Samples	Lead Sampler
				HEIS Numbers Assigned for Other Samples	Field Geologist
Collect Rad Analysis Sample		Sampler(s)	Drill Site	Rad Analysis at 222S Lab	Sampler / HPT
Rad Release	Rad Release Documentation	HPT	Drill Site		
Subsampling (Non-rad Contaminated)	New Chain-of-Custody Forms Generated	Sampler(s)	Sample Handling Trailer	Samples Under Proper Preservation Method	Sampler(s)
Sample Transport		Sample Handler / Geologist	Onsite Labs or Sigma V	Samples Under Proper Preservation Method	Sampler(s)
Sample Analysis		Analytical Lab Personnel or Principal Investigator	Analytical Laboratories	Analysis Results Prepared in Report Form or Published	Analytical Lab Personnel or Principal Investigator
Sample Disposal	Chain-of-Custody Form	Lab Personnel or Sampler	Drill Site or Laboratory		
Analysis Results Transmitted to PNL	Lab Report	Analytical Lab Personnel or Principal Investigator	Sigma V	Results Entered Into HEIS	PNL HEIS Data Management Staff

Sediment samples must be unconditionally released, which requires laboratory analysis of sediment from the sampled interval. For samples that must be transported within holding times, this entails arranging laboratory analysis time with the HPT before the sample is collected. When the sample is cleared for transport, documentation is generated to notify sample handlers that the sample is free of radioactive contamination.

Ground water samples will also be released for transport. When the sample is cleared for transport, documentation is generated to notify sample handlers that the sample is free of radioactive contamination.

No sediment or ground water sample can be removed from the site without the radiation release documentation.

5.3 CHAIN-OF-CUSTODY FORMS

Chain-of-custody forms will be generated per EII 5.1, Rev. 5 (WHC 1988a) for every solid and liquid sample collected. There may be more than one sample on a chain-of-custody form. Chain-of-custody forms will not be filled out for gas samples. Soil-gas field sampling/laboratory analysis records will be filled out instead.

Included on each original chain-of-custody form will be:

- chain-of-custody number
- custody form initiator
- company contact and telephone number
- project designation/sampling location
- collection date and time (the date and time the drive barrel, split-barrel, or bailer is first brought out of the borehole at each sampling interval)
- field log book number
- method of shipment
- shipped to (lab name and/or person)
- possible sample hazards/remarks
- sample identification
- HEIS number of each sample
- specific sample type, container, and depth interval
- preservation method
- signature and date when sample custody is transferred.

When samples are divided into new containers or transferred to a new chain-of-custody form for any other reason, the following information must be transferred from the original chain-of-custody form to the new one, and is in addition to any pre-printed information on the new form:

- original chain-of-custody number
- date and time of collection for each sample
- HEIS number of each sample
- preservation method
- possible sample hazards/remarks.

9 3 1 2 9 3 2 1 5 9 0

Chain-of-custody forms going to analytical laboratories will have only the original chain-of-custody number, date/time of collection, sampler, HEIS number, preservative method, and possible sample hazards/remarks transferred onto them. No information about the well will be provided to the analytical laboratories. All new chain-of-custody numbers will be noted on the original chain-of-custody forms.

5.4 WELLHEAD MONITORING AND FIELD SCREENING

Wellhead monitoring and field screening of drill cuttings will be performed at a minimum of once each 1.5-m interval. Because of variable VOC readings on drill cuttings due to atmospheric conditions, screening of drill cuttings will be done from the sediment pile and in a headspace screening container. Radiological controls may preclude sediment pile and headspace container screening. In that event, screening data will be collected through a hole (sampling port) in the side of the drive barrel.

5.4.1 Data Needs Defining the Screening Locations

Wellhead monitoring and field screening of drill cuttings for volatile organic compounds (VOC) will be required to aid sampling decisions by onsite personnel. Changes in VOC concentrations of one order of magnitude or more at depths other than the predefined sampling depths will indicate that additional samples may be collected at those depths. The initial VOC concentration (as detected with field monitoring equipment) used to signal the need for collection of an additional sample will be 1 ppm, if the background level is zero. Otherwise, a change of one order of magnitude from the previous sample will indicate an additional sample may be required. Comparison of these results with VOA results will indicate if different action levels are required. Elevated radionuclide levels, those greater than the background level, may preclude additional sampling at that depth. Radionuclide screening will be performed as indicated in the applicable Radiation Work Permit.

5.4.2 Screening Equipment

VOC screening equipment may include the following:

- organic vapor monitor (OVM)
- photoionization detector (PID)
- colorimetric tubes for carbon tetrachloride.

5.4.3 Screening Procedures

Sampling of wellhead gases and drill cuttings for VOC will be performed as outlined in Environmental Investigation Instruction (EII) 3.4, Rev 0, Field Screening (WHC 1988a) and the following procedure:

- Take wellhead readings as soon as drill string is out of the casing.

9 3 1 2 9 3 2 1 5 9 1

- If screening through the drive barrel sampling port:
  - Insert the sampling tube of the OVM into the sampling port and let the OVM instrument adjust for manufacturer's recommended stabilization period.
  - Record sampling interval, instrument type, and instrument reading in the field activity report and borehole log.

Otherwise:

- After the sediment has been dropped into a plastic bucket, collect drill cuttings from at least 2.5 cm below the surface of the sediment pile in the bucket.

- Place a 2.5-cm-thick layer of drill cuttings in the mason jar headspace screening container, being careful to keep all sediment off the screw-on threads.

- Place aluminum foil over the container opening and screw on the lid ring, being careful not to tear the aluminum foil.

- Locate the container (in a heated enclosure, during winter weather conditions) away from machinery and kerosene heaters and let warm for at least 5 min.

- Agitate sample (shake container back and forth three times).

- Take drill cuttings reading from sediment pile.

- Insert sampling tube through the aluminum foil over the opening of the headspace container.

- Let OVM instrument adjust for manufacturer's recommended stabilization period.

- Record sampling interval, instrument type, and instrument reading for each screening method in the field activity report and borehole log.

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5.5 DRIVE-BARREL/HARD-TOOL SAMPLING

Drive barrel samples will be collected routinely within 1.5-m intervals in the unsaturated and saturated zones, or more frequently if there are changes in the lithology, detected contaminant concentrations, or other unusual factors.

Samples from the drive barrel or hard tool bailer may be taken for the following analyses:

- volatile organics analysis (VOA)
- semivolatile organics analysis (SVOA)
- moisture content
- calcium carbonate ($CaCO_3$) content
- archive lithologic
- particle size distribution

- mineralogic analyses
- supercritical fluid extraction (SFE) sediment matrix characterization.

If possible, two VOA sampling methods will be used to determine the most effective sampling technique. The samples will be collected using a core borer subsampling tool to remove sediment from a portion of the drive barrel and/or using a metal scoop. The type of tool will depend on the lithology of the sampled material.

SVOA samples will be collected with the metal scoop (grab sample).

Moisture content, $CaCO_3$ content, archive lithologic, and particle size distribution samples will be collected by metal scoop (grab sample) from sediment dropped in a bucket. $CaCO_3$ content and particle size distribution samples will be collected from both the saturated and unsaturated zones. Moisture content samples will not be collected from the saturated zone or from the slurry recovered during hard tool drilling. Particle size distribution samples will not be collected from the slurry recovered during hard tool drilling.

SFE sediment matrix characterization samples will be collected from unsaturated, fine-grained sediments.

5.5.1 Data Needs Defining the Sample Locations

Analyses will be performed to identify the presence of carbon tetrachloride and other VOC. Because the results are important both to understand and evaluate carbon tetrachloride storage and transport and to help define the vertical extent of VOC in the borehole vicinity, VOA samples will be collected within 1.5-m intervals during drilling operations in the crib boreholes and the unsaturated zone of the deep ground water monitoring borehole. VOA samples will be collected at 15-m intervals in the saturated zone of the deep ground water monitoring borehole and the angled borehole.

Analyses for SVOC will be performed to identify the presence of some of the organic co-contaminants, such as lard oil and alkyl phosphates, disposed with the carbon tetrachloride. Because the results are important for helping define the vertical extent of SVOC in the borehole vicinity, SVOA samples will be collected within 1.5-m intervals during drilling operations in the crib boreholes and the unsaturated zone of the deep ground water monitoring borehole. SVOA samples will be collected at 15-m intervals in the saturated zone of the deep ground water monitoring borehole and the angled borehole.

Samples to characterize the vertical distribution of sediment lithologies will be collected within every 1.5 m in all the boreholes. These samples may be analyzed for moisture content, $CaCO_3$ content, and/or particle size distribution. The resulting analyses will characterize the sediments through which the boreholes are drilled.

Samples will be collected for use in determining sediment properties that influence the laboratory extraction of lard oil and alkyl phosphates. Sediment matrix characterization is a component of the analyses to determine how best to extract lard oil and alkyl phosphates from sediment using SFE.

9 3 1 2 9 3 2 1 5 9 3

Samples will be collected in large volumes (15- to 20-L bucket) to allow the extraction methods to be tested repeatedly on the same sample type. To test the methods on a wide variety of sediments, samples will be collected with a wide range of mineralogic and textural properties. Fine-grained sediments will afford the greatest volume percentage to be used for analyses. Unsaturated samples will be collected from the drive barrel. It is preferable to take SFE samples adjacent to the intervals sampled for chemical analysis, so that results can be compared.

5.5.2 Decontamination Procedures

Sampling equipment requiring decontamination between sampling intervals will be decontaminated per EII 5.4, Section 6.3.2.2 (WHC 1988a).

Sample containers requiring decontamination will be decontaminated by the container supplier.

5.5.3 Sample Collection Equipment and Sample Containers

Drive barrel/hard tool sampling equipment is as follows:

- rubber gloves
- metal scoop
- waterproof markers
- cooler with frozen blue ice or natural ice
- box with dividers or vial rack (to keep VOA vials in vertical position)
- tamper-evident tape
- plastic baggies with "zip" closure openings
- chain-of-custody forms
- drilling and sampling procedures specified in this FSP.

VOA sampling equipment and sample containers, for each sampling interval, required to be decontaminated:

- core borer subsampling tool
- metal scoopula
- two 40-mL amber vials with teflon septum caps, containing methanol.

SVOA sampling equipment and sample containers, for each sampling interval, required to be decontaminated:

- small metal sediment scoop
- a 125-mL glass bottle.

Lithologic sampling equipment and sample containers for each sampling interval:

- teflon tape
- plastic bags for wrapping moisture sample containers
- a metal container (moisture content tin) with press-on lid
- three pint glass jars with screw-on lid (mason jar).

SFE sediment matrix sampling equipment and sample containers:

- hammer (to seal bucket)
- 15- to 20-L plastic bucket and lid.

5.5.4 Sample Preservation Procedures

Because the analytes are volatile, care must be taken to collect and preserve VOA samples as soon as the sediment has been removed from the borehole. Sediment will be placed in a 40-mL amber glass vial containing a methanol preservative to fix the volatiles in solution. VOA sample vials must be kept vertical and under refrigeration. Only when the sample is actually extracted from the sediments should the VOA vial be out of a refrigerated container. Between 5 and 10 g of sediment is the optimum sample size. Tamper evident seals are not placed directly on VOA vials. The vials will be placed in a plastic bag and the seal placed on the bag opening. The samples will be released at the same time as the other samples.

Methanol will be added to the VOA sample containers and weighed prior to samples being placed in them. If the methanol is released from the vial either by evaporation or by spilling, the measurement is inaccurate.

SVOA samples require refrigeration during storage and transport.

The moisture/$CaCO_3$ content sample container is required to be taped and placed in a sealed bag for storage and transport. No special preservation techniques are required for the particle size distribution sample and archive lithologic samples.

No special preservation techniques are required for the SFE sediment matrix characterization samples.

5.5.5 Sample Collection Procedures

The order of drive barrel/hard tool sampling for VOA, SVOA, lithologic, and SFE sediment matrix samples is:

1. VOA core borer sampling, if sampling fine-grained sediment or soil
2. VOA scoop sampling
3. SVOA scoop sampling
4. Radioactivity release sampling
5. Moisture/$CaCO_3$ content sampling
6. Particle size distribution sampling
7. Archive lithologic sampling
8. SFE sediment matrix characterization sampling.

NOTE: The date and time of collection for all samples from each drive barrel is the date and time the drive barrel is first brought out of the borehole.

VOA Core Borer Sampling From Drive Barrel - The core borer will be used to sample in fine-grained sediments where a "plug" of material can be extracted and put into a sample vial with minimal disturbance. When the drive

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barrel is raised above ground surface (and out of the casing) a sample will be collected with the core borer directly from sediments in the drive barrel. The sample will be collected either from the bottom of the drive barrel or through a hole (sample port) in the side of the drive barrel, depending on the radiological controls for the drill site or the lithology of the sediments.

- Insert the core borer at least 2.5 cm into the sediment.
- Withdraw the core borer with a smooth motion.
- Wipe off any sediment from the outside of the core borer.
- Use the sample prod to push 1.2 cm of sediment out of the forward end of the core borer into the vial.

NOTE: Do not get sediment on the vial's threads. Even if the threads are wiped off, volatiles can be lost!

- Drop 1.2 cm of sediment into the vial and the methanol preservative.
- Cap the vial firmly, but not so tight as to deform the teflon liner.

Once the sample is collected:

- Mark the sample collection date and time on the sample container label.
- Mark on the label: (1) HEIS number and (2) "DB" for drive barrel.
- Put the sample vial into a plastic bag.
- Use tamper-evident tape to seal the bag opening. Write the sampler's initials and date of sealing on the tape.
- Place the sample in a refrigerated enclosure maintaining the vial's upright position.
- Document sample on appropriate chain-of-custody form.
- Store sample onsite until sample is released by the HPT.
- Place radiation release documentation with sample container prior to transport offsite.

VOA Sediment Scoop Sampling From Drive Barrel - Once the first VOA sample is collected with the core borer, the remaining sediments will be dropped from the drive barrel into a bucket. If no core borer sample is to be collected, two scoop samples will be collected.

- Immediately after transfer to the bucket, use the small metal sediment scoop to dig 5 to 10 g of sediment out from at least 2.5-cm below the top of the sediment pile.
- Drop the sediment into the vial and the methanol preservative.

NOTE: Do not get sediment on the vial's threads. Even if the threads are wiped off, volatiles can be lost!

- Cap the vial firmly, but not so tight as to deform the teflon liner.

Once the sample is collected:

- Follow the same steps as listed for the core borer VOA sample.

VOA Sediment Scoop Sampling From Hard Tool Drilling - During hard tool drilling, VOA samples will be collected from the slurry of sediment and added water. Samples will be collected using the metal scoop only. The core borer is not used to collect slurry samples.

Once the sediments are retrieved from the borehole, they will be dropped from the bailer into a bucket.

- Immediately after transfer to the bucket, use the small metal sediment scoop to dig 5 to 10 g of sediment from the slurry.
- Drop the sediment into the vial (no methanol preservative).

NOTE: Do not get slurry on the vial's threads. Even if the threads are wiped off, volatiles can be lost!

- Cap the vial firmly, but not so tight as to deform the teflon liner.

Once the sample is collected:

- Follow the same steps as listed for the core borer VOA sample.
- Mark on the bag: (1) HEIS number and (2) "HT" for hard tool.

SVOA Sampling - Once the VOA samples are collected, the SVOA sample will be collected from the remaining sediments or slurry in the bucket.

- Use the sediment scoop to dig sediments out from at least 2.5 cm below the top of the sediment pile or from the slurry.
- Drop the sediment or slurry into the bottle. Be careful not to get sediment or slurry on the vial's threads.
- Cap the vial firmly.

Once the sample is collected:

- Mark on the pre-printed label: (1) HEIS number and (2) "DB" for drive barrel or "HT" for hard tool.
- Use tamper-evident tape to seal the bottle cap. Write the sampler's initials and date of sealing on the tape.
- Place the sample in a refrigerated enclosure maintaining the bottle's upright position.
- Document sample on appropriate chain-of-custody form.
- Store sample onsite until sample is released by the HPT.
- Place radiation release documentation with sample container prior to transport offsite.

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Radiation Release Sampling - Any samples collected for analyses require unconditional radioactivity release, as described in Section 5.2 of the FSP, before being removed from the drill site. This sample is for analysis at the 222-S laboratory in the 200 West Area.

- Collect sediment or slurry in a plastic baggy.
- Mark on the bag: (1) well number; (2) depth interval; and (3) date/time of collection.
- Submit sample for analysis.

Moisture/$CaCO_3$ Content Samples - Collect samples from sediments recovered from the drive barrel or bailer. The sediments will be first dropped into a sediment collection bucket.

- Use a metal scoop to transfer sediments or slurry to the moisture content tin as soon as the sediments have been dropped into the sediment collection bucket and the VOA and SVOA samples have been collected. Use sediment from a few centimeters below the surface of the pile.
- Close the tin immediately and seal with teflon tape.
- On the tape, mark: (1) HEIS number; (2) "DB" for drive barrel or "HT" for hard tool; and (3) "Moisture/$CaCO_3$" for sediment or "$CaCO_3$" for slurry.
- Use tamper-evident tape to seal the lid. Write the sampler's initials and date of sealing on the tape.
- Wrap the sample container in two plastic bags, each one sealed to be as air-tight as possible.
- Document sample on appropriate chain-of-custody form.
- Store sample onsite until sample is released by the HPT.
- Place radiation release documentation with sample container prior to transport offsite.

NOTE: Moisture content analyses will not be performed for hard tool or saturated zone samples.

Particle Size Distribution Samples - Take samples only from sediments collected with the drive barrel. The sediments will be first dropped into a sediment collection bucket.

- Use a metal scoop to transfer sediments to the pint glass jar after taking the moisture content/$CaCO_3$ content sample.
- Close the screw-on lid.
- On the top of the lid, mark: (1) HEIS number; (2) "DB" for drive barrel or "HT" for hard tool; and (3) "Particle Size".
- Use tamper-evident tape to seal the lid. Write the sampler's initials and date of sealing on the tape.
- Document sample on appropriate chain-of-custody form.
- Store sample onsite until sample is released by the HPT.
- Place radiation release documentation with sample container prior to transport offsite.

NOTE: Particle size distribution analyses will not be done for hard tool samples.

Archive Lithologic Samples - Take samples at 1.5-m intervals only from sediments collected with the drive barrel. The sediments are first dropped into a sediment collection bucket.

- Use a metal scoop to transfer sediments to the two pint glass jars after taking the particle size distribution sample.
- Close the screw-on lid.
- On the top of the lid, mark: (1) HEIS number; (2) "DB" for drive barrel or "HT" for hard tool; and (3) "Archive Lithologic".
- Document sample on appropriate chain-of-custody form.
- Store sample onsite until sample is released by the HPT.
- Place radiation release documentation with sample container prior to transport offsite.

SFE Sediment Matrix Characterization Samples - Sample intervals will be defined by the sampling staff when a fine grained lithologic unit is encountered during drive barrel drilling.

- Collect a large volume sample directly from the drive barrel into a 15- to 20-L plastic bucket. If there is not enough sediment to fill the bucket 3/4 full, sediment from the next drive barrel may be used also.
- Use the hammer to seal the lid of the sample container and store the sample onsite until it has been released for transport.
- Use tamper-evident tape to seal the lid. Write the sampler's initials and date of sealing on the tape.
- Document sample on appropriate chain-of-custody form.
- Store sample onsite until sample is released by the HPT.
- Place radiation release documentation with sample container prior to transport offsite.

5.5.6 Sample Documentation

Any samples taken for analyses require unconditional radioactivity release before being removed from the drill site, as described in Section 5.2 of the FSP.

- Submit sediment or slurry from the sample interval for analysis.
- Place radiation release documentation with each sample container.

Chain-of-custody forms will be filled out for each sample, as described in Section 5.3 of the FSP. There may be more than one sample on a chain-of-custody form.

5.5.7 Sample Handling and Analysis

VOA samples will be analyzed within 14 days after the sample is collected. They must be kept refrigerated and be transported to the analytical laboratory within 2 to 3 days of sampling. Analyses may be conducted at Sigma V or in a mobile laboratory onsite. Custody transfer will take place at the location where analysis will occur.

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SVOA samples will be extracted within 7 days after the sample is collected, and analyzed within 40 days of extraction. They must be kept refrigerated, and be transported to the Sigma V Sample Storage Facility and then to the analytical laboratory within 2 to 3 days of sampling.

Moisture/$CaCO_3$ content samples collected from the three unsaturated zone boreholes and the deep ground water well will be transported to the 300 Area Geotechnical Engineering Laboratory for storage, per EII 5.7A, Rev 3 (WHC 1988a). Analyses will be conducted at the Geotechnical Engineering Laboratory.

Moisture/$CaCO_3$ content samples collected from the in situ bioremediation well will be transported to the PNL Sigma V Building, Soil Physics Laboratory, where analyses will be conducted. Moisture content analyses will be conducted according to SA-7, Water Content (PNL 1992).

Archive lithologic samples will be transported to the Hanford Geotechnical Sample Library at 2101M Building, 200 East Area for archiving, per EII 5.7A, Rev 3 (WHC 1988a).

Particle-size distribution samples collected from the three unsaturated zone boreholes and the deep ground water well will be transported to the 300 Area Geotechnical Engineering Laboratory for storage, per EII 5.7A, Rev 3 (WHC 1988a). Analyses will be conducted at the Geotechnical Engineering Laboratory.

Particle-size distribution samples collected from the in situ bioremediation well will be transported to the PNL Sigma V Building, Soil Physics Laboratory, where analyses will be conducted according to SA-2, Sieve Procedure, and SA-3, Particle-Size Analysis (Hydrometer Method) (PNL 1992).

SFE sediment matrix characterization samples will be transported to PNL's Sigma V laboratory. Transport to the laboratory requires no specific preservation procedures. Samples will be delivered to the 1423 laboratory.

5.6 SPLIT-BARREL SAMPLING

Continuous split-barrel sampling in the in situ bioremediation well is described in Section 5.8.

Split-barrel samples will be collected routinely within 6-m intervals in the unsaturated zones and 15-m intervals in the saturated zone, or more frequently if there are changes in the lithology or detected contaminant concentrations, or other unusual factors.

Samples will be collected using methods deemed most capable of preserving the in situ environment. Split-barrel sampling will be done to collect relatively undisturbed samples for analyses. LEXAN liners will be placed in the split-barrel prior to sampling in the borehole. Four liners will be used to collect samples for the following analyses:

Liner 1: VOA, SVOA, and chemical constituents analysis
Liner 2: Porosity and bulk density analyses
Liner 3: Air permeability analysis
Liner 4: Physical properties analysis.

Sediment from one liner will be subsampled and put into containers for VOA, SVOA, and chemical analyses. The other three liners will be delivered to the appropriate analytical laboratories intact.

VOA Sampling - As with drive barrel sampling, two VOA subsampling methods will be attempted, when feasible, to determine the most effective sampling technique. One sample will be collected using the core borer to remove sediment from the end of liner 1. The other sample will be collected using a metal scoop to remove sediment from the same end of liner 1. Core borer sampling will be dependent on sediment lithology, as indicated in Section 5.5 of the FSP.

SVOA Sampling - SVOA samples will be collected with the metal scoop (grab sample) from the sediment in liner 1 near where the VOA samples were collected.

Chemical Sampling - Samples will be collected for chemical analyses to help characterize the sediments of both the saturated and unsaturated zones. A liner will be used to collect sediment to be subsampled for these analyses. Sediment from the liner will be transferred to prelabeled sample vials and bottles for laboratory analyses.

Porosity/Bulk Density, Air Permeability, and Physical Property Sampling - Samples will be collected in liners to recover sediment that is representative of the actual depositional structures. Porosity/bulk density and air permeability analyses will help to identify the rate of moisture movement through the sediment package. Physical property characterization of sediments will help formulate a better understanding of the transport and storage of carbon tetrachloride in the unsaturated zone. One liner will be used to collect the sample for porosity and bulk density analyses. One liner will be used to collect the sample for air permeability analysis. One liner will be used to collect the physical property sample. All these samples will remain in the liners during handling and transport to the analytical laboratories.

5.6.1 Data Needs Defining the Sample Locations

Volatile Organic Compounds - Data needs are as described in Section 5.5.1 of the FSP. VOA samples will be collected from all split-barrel intervals.

Semi-Volatile Organic Compounds - Data needs are as described in Section 5.5.1 of the FSP. SVOA samples will be collected from all split-barrel intervals.

Chemical Constituents - Samples will be collected to characterize the sediments of both the saturated and unsaturated zones. The samples will be collected routinely at all split-barrel intervals.

Porosity and Bulk Density, Air Permeability, and Other Physical Properties - The results of the FY 92 site characterization activities have shown the highest concentrations of carbon tetrachloride to be present in the early "Palouse" soil or just above it. The physical properties of this lithologic unit and the surrounding sediments have specific influence over the distribution of the carbon tetrachloride. Consequently, the physical

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properties of the sediments of the Hanford formation directly overlying the early "Palouse" soil, the early "Palouse" soil itself, the Plio-Pleistocene unit directly beneath the early "Palouse" soil, and the Ringold sediments directly beneath the Plio-Pleistocene unit are the focus of the FY 93 portion of the physical property characterization. The samples will be collected routinely at all split-barrel intervals.

5.6.2 Decontamination Procedures

Sampling equipment requiring decontamination between sampling intervals will be decontaminated according to EII 5.4 or EII 5.5 (WHC 1988a) depending on the type of analyses planned for that sample.

Sampling equipment will be decontaminated prior to use. The split-barrels and head will be washed with a nonphosphate detergent and raw water, rinsed with raw water, allowed to dry, and wrapped in plastic.

Equipment that requires decontamination according to EII 5.5 (WHC 1988a) will be decontaminated at the 100K laboratory. Laboratory cleaned equipment must be transported to the drill site before sampling proceeds. The split-barrel shoe, core catcher, spacer, LEXAN liners, liner caps, and core borer subsampling tools will be decontaminated according to EII 5.5 and wrapped in aluminum foil.

Split-barrels, head, shoe, spacer, core-catcher and liners will be assembled by personnel wearing new disposable rubber or plastic gloves. The entire assembly will be wrapped in aluminum foil until it is needed.

Sample containers requiring decontamination will be decontaminated by the container supplier.

5.6.3 Sample Collection Equipment and Sample Containers

Split-barrel sampling equipment:

- rubber gloves
- waterproof markers
- cooler with frozen blue ice or natural ice
- box with dividers or vial rack (to keep VOA vials in vertical position)
- tamper-evident tape
- plastic baggies with "zip" closure openings
- aluminum foil (to isolate the ends of core samples)
- chain-of-custody forms
- drilling and sampling procedures as called out in this FSP.

Sampling equipment required to be decontaminated, per EII 5.4:

- split-barrel halves
- split-barrel head.

These items will be washed with a nonphosphate detergent and raw water, rinsed with raw water, allowed to dry, and then wrapped in plastic.

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Sampling equipment required to be decontaminated, per EII 5.5:

- split-barrel shoe
- core catcher
- spacer
- LEXAN liners
- LEXAN liner end caps
- core borer subsampling tool
- metal scoop
- metal spatula.

These items will be decontaminated at the 100K laboratory and transported to the sampling site before sampling proceeds at the scheduled interval.

Sample containers (for each sampled interval):

- split-barrel containers - four LEXAN liners with two caps each

- subsample containers for chemical analyses:

  - two 40-mL amber glass vials containing 5 mL methanol, with screw-on cap and teflon septum (VOA)
  - a 125-mL glass bottle with screw-on cap (SVOA)
  - a 250-mL glass bottle with screw-on cap (ICP metals, anions, lead, mercury, cyanide)
  - a 40-mL amber glass vial with screw-on cap (TOC).

5.6.4 Sample Preservation Procedures

Preserve VOA samples as required in Section 5.5.4 of the FSP.

Preserve SVOA samples as required in Section 5.5.4 of the FSP.

The liner designated for chemical subsampling will be sealed with end caps and refrigerated until subsampling takes place. After subsampling into new sample containers, chemical samples require refrigeration during storage and transport.

Porosity/bulk density, air permeability, and physical property samples must retain as much of the sediment structure intact during sample collection and transport. To ensure that the sediment structure of the samples taken for these analyses remain intact, the LEXAN liners in which these samples are collected must be completely full of sediment. The sampled sediment will be sealed inside the liners with liner caps. Samples will be protected from physical shock during both the sampling and transport process. Samples do not require refrigeration during transport.

5.6.5 Sample Collection Procedures

Split-barrel sampling consists of the following six steps:

1. Clean the borehole out using either the drive barrel or bailer.
2. Measure and record a depth-to-bottom of the borehole.

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3. Attach the sampler to the drill string and lower it to the bottom of the borehole.
4. Drive the split-barrel into the sediment for 0.60 m, recording the number of blow counts for the sampler to advance each 0.15 m.
5. Retrieve the split-barrel from the bottom of the borehole. Place the split-barrel on a plastic-covered sampling table and open.
6. Immediately start VOA subsampling. Then, proceed with the rest of the subsampling and liner capping in the order listed below.

The order of split-barrel subsampling and liner capping for VOA, SVOA, chemical, porosity and bulk density, air permeability, and physical property samples is:

1. VOA core borer subsampling, if sampling fine-grained sediment or soil.
2. VOA scoop (grab) subsampling.
3. SVOA scoop (grab) subsampling.
4. Radioactivity release subsampling.
5. Chemical liner capping.
6. Porosity and bulk density liner capping.
7. Air permeability liner capping.
8. Physical property liner capping.

VOA Core Borer Sampling From Split-Barrel - Immediately after separating the split-barrels, the core borer will be used to extract sediment from the end of the liner designated for chemical analyses.

Collect and handle the sample as required for drive barrel VOA core borer sampling in Section 5.5.5 of the FSP. Mark on the bag: (1) HEIS number and (2) "SB" for split-barrel.

VOA Sediment Scoop Sampling From Split-Barrel - Once the first VOA sample is collected with the core borer, the remain-ing sediments in the liner will be sampled with the metal scoop. If no core borer sample is to be collected, two scoop samples will be collected.

Collect and handle the sample as required for drive barrel VOA scoop (grab) sampling in Section 5.5.5 of the FSP. Mark on the bag: (1) HEIS number and (2) "SB" for split-barrel.

SVOA Sampling - Once the VOA samples are collected, the SVOA sample will be collected from the remaining sediments in the liner.

Collect and handle the sample as required for drive barrel SVOA scoop (grab) sampling in Section 5.5.5 of the FSP. Mark on the bag: (1) HEIS number and (2) "SB" for split-barrel.

Radiation Release Sampling - Any samples collected for analyses require unconditional radioactivity release, as described in Section 5.2 of the FSP, before being removed from the drill site.

Collect and handle the sample as required for radiation release sampling in Section 5.5.5 of the FSP.

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Chemical Liner Capping - Capping is accomplished as follows:

- Cap both ends of the chemical liner with plastic end caps.
- Use teflon tape and tamper-evident tape to seal the end caps. Write the sampler's initials and date of sealing on the tamper-evident tape.
- Mark on the liner: (1) HEIS number; (2) "chem"; and (3) an arrow pointing in the "up" direction.
- Place the sample in a refrigerated enclosure maintaining the liner's upright position.
- Document sample on appropriate chain-of custody form.
- Store sample onsite until sample is released by the HPT.
- Place radiation release documentation with sample container prior to transport offsite.

Porosity and Bulk Density Liner Capping - The liner designated for porosity/bulk density analyses must be completely full of sediment. This will ensure that the sediment structure is not destroyed during transport, and that sediment samples are representative of the particle size fraction present in the sampled interval.

- Cap and handle this liner as required for the chemical liner, above.
- Mark on the liner: (1) HEIS number; (2) "porosity/bulk density"; and (3) an arrow pointing in the "up" direction.
- Place the sample in a transport box maintaining the liner's upright position.

Air Permeability Liner Capping - The liner designated for air permeability analyses must be completely full of sediment. This will ensure that the sediment structure is not destroyed during transport, and that sediment samples are representative of the particle size fraction present in the sampled interval.

- Cap and handle this liner as required for the porosity/bulk density liner, above.
- Mark on the liner: (1) HEIS number; (2) "air permeability"; and (3) an arrow pointing in the "up" direction.

Physical Property Liner Capping - The liner designated for physical property analyses must be completely full of sediment. This will ensure that the sediment structure is not destroyed during transport, and that sediment samples are representative of the particle size fraction present in the sampled interval.

- Cap and handle this liner as required for the porosity/bulk density liner.
- Mark on the liner: (1) HEIS number; (2) "phys. prop. - WSU"; and (3) an arrow pointing in the "up" direction.

5.6.6 Sample Documentation

Radiation release documentation and a chain-of-custody form will be filled out for each sample, as described in Section 5.5.6 of the FSP.

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5.6.7 Sample Handling and Analysis

Handle and analyze the samples as required for VOA samples in Section 5.5.7 of the FSP.

Handle and analyze the samples as required for SVOA samples in Section 5.5.7 of the FSP.

Chemical subsamples from the chemical liner will be collected and handled as in Section 5.6.8 of the FSP.

Porosity and bulk density samples will be transported to the 300 Area Geotechnical Engineering Laboratory for storage, per EII 5.7A, Rev 3. During transport, the sample must be protected from physical shock to retain sediment structure integrity. Samples should not be refrigerated. There is no holding time limit for the physical property samples. Analyses will be conducted at the Geotechnical Engineering Laboratory.

Air permeability samples will be transported to the 300 Area Geotechnical Engineering Laboratory for storage, per EII 5.7A, Rev 3. During transport, the sample must be protected from physical shock to retain sediment structure integrity. Samples should not be refrigerated. There is no holding time limit for the physical property samples. Analyses will be conducted at the Geotechnical Engineering Laboratory.

Physical property samples will be transported from the drill site to the Washington State University (WSU) Tri-Cities laboratory for analyses. Custody will be transferred to WSU laboratory personnel. During transport, the sample will be protected from physical shock to retain sediment structure integrity. Samples will not be refrigerated. There is no holding time limit for the physical property samples.

5.6.8 Subsampling

Subsamples for chemical analyses will be collected from the chemical liner and put in pre-labeled containers for transport to analytical laboratories. After the chemical liner is released by the HPT, subsampling will take place in the on site mobile lab/sample handling trailer. Transport of samples to Sigma V will be by government vehicle.

Chain of custody for subsamples will be transferred to a new form as specified in Section 5.3 of the FSP. Copies of both chain-of-custody forms will be retained and filed together.

Chemical subsamples will be transported to their respective laboratories, and then analyzed within specified holding times, as listed in Table FSP 5-2. The chemical subsamples will be transported to Sigma V and custody transferred to the PNL sampling staff. These personnel will be responsible for distributing the samples to the laboratories, and receiving and distributing the analytical results.

VOA samples will be transported to Sigma V for analysis.

Table FSP 5-2. Containers, Quantities, Preservation, and Holding Times for Soil Samples.

Analysis	Container	Quantity	Preservation	Holding Time	Lab
Volatile Organic Analysis (VOA)	40 ml amber glass w/teflon septum	5-10 gm	methanol, 4-deg C	14 days (1)	PNL
Semi-Volatile Organics (SVOA)	125 ml amber glass	120 gm	4-deg C	7 days before extraction 40 days after extraction	DCL
Chemical Analyses					
Total Organic Carbon	40 ml amber glass	20 gm	4-deg C	28 days	PNL
1 container:					
Cyanide (CN)	250 ml glass	50 gm	4-deg C	14 days	DCL
Anions				ASAP after collection	
Mercury (HG)				28 days	
Lead (PB)				6 months	
ICP metals				6 months	

PNL = Pacific Northwest Laboratory
DCL = Data Chem Laboratory

NOTE: The holding times begin at the time of collection.

(1) Although the EPA recommended holding time for volatile organic compounds is 14 days, a much shorter holding time is desired, and may be achieved by efficient and timely communication and transport between the sampler and HPT, and the sampler and analyst.

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5.6.9 Split-Barrel Sampler Temperature

To obtain a baseline of split-barrel sampler temperatures, selected samplers will have the presampling and postsampling temperatures recorded. The frequency performed will be as directed by the field team leader. Temperature-sensitive tape may be applied to the inside of the split tube approximately 2.5 cm above the bottom of the threads. If the ambient air temperature is 27°C (80°F) or greater, sampler components should be stored in a shaded or cooler area and assembled immediately prior to use.

5.7 ASEPTIC (MICROBIAL) SPLIT-BARREL SAMPLING

Samples for microbiologic analysis will be collected to assess what microorganisms are present in the subsurface, under what condition these organisms survive, and whether these organisms are capable of degrading carbon tetrachloride to less toxic substances.

5.7.1 Data Needs Defining the Sampling Locations

FY 92 investigations have shown abundant microbial populations exist in the early "Palouse" soil. FY 93 investigations will further examine the conditions that contribute to the growth of existing populations. The laboratory studies will focus on determining which nutrients present in sediments limit microbial growth. In addition, analyses will be conducted to determine what available sediment constituents are potential electron donors or acceptors for microbes during the degradation process.

Samples will be taken to characterize these parameters in both the saturated and unsaturated zones. A maximum of six samples total will be collected from the unsaturated zone (early "Palouse" soil) from well 299-W18-96, well 299-W18-174, the angle borehole, and the deep ground water well. Approximately 12 samples are anticipated from the unsaturated and saturated zones at well 299-W11-32, the in situ bioremediation well. Saturated zone samples will be collected as convenient with other sampling activities and the drilling operations.

5.7.2 Decontamination Procedures

Aseptic core samples will be collected using a split-barrel sampler having a LEXAN liner that has been sterilized prior to sampling.

- Have the liner autoclaved in a laboratory and wrapped in sterile packaging before being brought out to the drill site.
- Pick up the liner at the PNL Microbiology Laboratory in the 324 Building.
- When at the drill site, wash the split-barrel and head (used to attach the barrel to the drilling tools) in a bleach solution.
- Spray the shoe of the split-barrel assembly and the springs used to retain the sediment inside the split-barrel with ethanol and then flame and air cool.
- Just prior to taking the sample, assemble the sampler using sterile gloves, then wrap and seal the sampler in sterile paper.

5.7.3 Sample Equipment and Sample Containers

Sample collection equipment:

- laboratory sterilized, 0.6 m length LEXAN liner (wrapped in sterile brown paper)
- laboratory sterilized liner caps (sealed in whirl pack bags)
- sterile plastic gloves
- laboratory sterilized brown paper
- ethanol and sprayer (to apply ethanol to sample equipment)
- striker (or matches or lighter)
- metal tray (for onsite sampling equipment sterilization)
- chlorine bleach (for onsite sampling equipment sterilization)
- buckets and brushes (for onsite sampling equipment sterilization)
- plastic tape and markers
- plastic transport bag (to place samples in once retrieved)
- argon tank (requires approved transport to site)

- argon regulator and tube
- large cooler (1.2-m length) and frozen blue ice
- plastic baggies (for radioactivity sample determination).

5.7.4 Sample Preservation Procedures

Pristine sediment samples must be taken during the drilling operations to accurately assess the microorganisms present in the sediments. These samples will be recovered using sterilized sampling tools to retrieve subsurface sediment and then isolated from microbiologic or chemical contamination, in an argon atmosphere, during transport to the laboratory.

Once collected, samples will be sealed inside the liners in which they were recovered. Additional sample containers will not be not used. Chain-of-custody forms will be filled in for the samples. Samples will be transported to the laboratory in the sealed LEXAN liner and argon atmosphere within 72 h of sampling.

5.7.5 Sample Collection Procedures

Because analyses will be done in a "clean" laboratory, samples with high VOC content will not be accepted for analysis, as these would contaminate the laboratory. Concentrations of above 100 ppm in the vapor phase, as determined by field screening of sampled core with OVM, constitutes high VOC content.

Aseptic split-barrel sampling consists of the following steps:

1. Clean the borehole out using either the core barrel or bailer.
2. Measure and record a depth-to-bottom of the borehole.
3. Attach the sampler to the drill string with the paper seal in place.
4. Remove the paper seal and lower the sampler to the bottom of the borehole.
5. Drive the split-barrel into the sediment for 0.60 m, recording the number of blow counts for the sampler to advance each 0.15 m.
6. Retrieve the split-barrel from the bottom of the borehole. Place the split-barrel on a clean, plastic-covered sampling table.
7. Open the split-barrel and collect a small sample from the "shoe" for submission for radiation release analysis.
8. Seal the ends of the liner with previously sterilized end caps and plastic tape.
9. Place the sealed liner in a plastic transport bag. Fill and purge the bag three times using argon gas. Fill the bag with argon gas and seal the bag while it's under positive pressure.
10. Refrigerate and transport the sample to the analytical laboratory.

5.7.6 Sample Documentation

Radiation release documentation and a chain-of-custody form will be completed for each sample, as described in Section 5.5.6 of the FSP.

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5.7.7 Sample Handling and Analysis

Samples will be delivered to the 324 Building.

5.8 CONTINUOUS SPLIT-BARREL SAMPLING FOR IN SITU BIOREMEDIATION WELL

Samples for microbiologic characterization, sediment physical and chemical characterization, and ground water characterization will be taken from 1.5-m intervals in the in situ bioremediation well. It is anticipated that it will not be possible to collect aseptic samples from each of the 1.5-m intervals from which sampling is planned. Therefore, more samples are planned for collection than will actually be analyzed. Slough that is removed to prepare for sample recovery with the split-barrel may be used for lithologic characterization and particle-size analyses. If slough samples are not determined to accurately represent the subsurface sedimentary environment by the site geologist, the sampling personnel or the site coordinator, samples for lithologic characterization will only be taken from the sediment recovered in the split barrel.

Two sets of characterization samples will be collected with the split-barrel sampler from the unsaturated zone and a maximum of 14 samples will be collected from the saturated zone. Unsaturated zone samples will be collected from the lower Hanford formation and the early "Palouse" soil. Saturated zone sampling will be attempted in the Ringold Formation from the capillary fringe at a depth of approximately 73 m below ground surface to the bottom of the borehole at a depth of approximately 93 m.

Calcium carbonate content and mineralogic analyses will be performed on sediment samples collected from the 85.3-m depth to characterize the cementation. The complete set of samples planned for continuous sampling, as well as the depths at which samples will be collected and analyzed, is shown in Table FSP 3-5b.

Sample collection will be conducted differently for the saturated and unsaturated zones. For the unsaturated zone sample intervals (approximately two), sampling will consist of: (1) collecting an aseptic sample and physical property sample together (0.3 m length for each) from one split-barrel core; and (2) collecting a chemical characterization split-barrel sample.

Saturated zone samples will be collected continuously in sets at intervals of 1.5 m. Saturated zone sampling in each interval will proceed depending on the successful recovery of an aseptic sample for microbial characterization. If a microbiologic sample is collected successfully, the following sampling events will take place:

1. Collect an aseptic sample and hydraulic conductivity sample together (0.3 m length LEXAN sleeve for each) from one split-barrel core. Collect particle-size distribution sample from slough generated during this sample collection.

2. Collect a chemical characterization and physical property characterization split-barrel sample together (each 0.3 m in length).

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3. Collect ground water chemistry samples (as defined in Section 5.9).

4. Insert datasonde into the ground water to measure in situ geochemical parameters (as defined in Section 5.9).

If an undisturbed aseptic sample is not collected during the first sampling attempt, whatever sediment is recovered will be designated for physical and chemical property analyses. A second attempt will be made to recover an aspetic sample from the same interval this time using the entire 0.6 m length of the split-barrel sample for microbiological sample collection. The site geologist, or site coordinator will be responsible for determining whether the sample is aseptic. The decision will be based on a visual inspection of the recovered core. If the split-barrel liner is not full or if the sediment clasts have spaces between them, the liner will be designated as contaminated, and a second attempt at aseptic sample collection will be made. Sampling will proceed as follows if the second attempt to recover an aseptic sample is successful:

1. Collect a physical property sample (bulk density, particle density, and particle size distribution) sample and, if there is enough sediment recovered, a sediment chemistry sample.

2. Collect a 0.6 m length aseptic microbiologic sample.

3. If necessary, collect a sediment chemistry sample and hydraulic conductivity sample and particle size distribution sample.

4. Collect ground water chemistry samples (as described in Section 5.9).

5. Insert datasonde into the ground water to measure in situ geochemical parameters (as described in Section 5.9).

If the second attempt at collecting an aseptic sample is not successful, all remaining sampling will be abandoned until the next 1.5-m interval is encountered, where sample collection will begin again. This sampling approach is diagramed in Table FSP 5-3. The specific order of sampling may be changed by the site geologist or field sampling personnel if a different order will accomplish the desired sampling and analysis objectives.

To help determine whether contamination from borehole fluids has entered the sample during sample collection, a tracer consisting of microspheres with a particular fluorescence may be used. A bag containing a predetermined amount of the microsphere tracer will be lowered to the bottom of the borehole and broken open immediately before aseptic sample collection. The tracer concentration and distribution in the sample will be measured to evaluate whether sample contamination occurred.

If the first attempt at aseptic sample collection (for microbiologic characterization) is unsuccessful and the second attempt is successful, additional split-barrel samples may be taken at the discretion of site geologist. These split-barrel samples may be used for any of the planned analyses: hydraulic conductivity measurements, chemical property analyses, or physical property analyses.

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Table FSP 5-3. Continuous Split-Barrel Sampling Options.

1 **First** attempt at aseptic sample collection successful.

Core samples will be designated as shown:

1st Core Recovered		2nd Core Recovered		3rd Core
sediment chemistry (and particle size)	aseptic (microbiology)	hydraulic conductivity	sediment physical properties	particle size distribution or other

(to be taken at the discretion of the site geologist, depending upon previous sample recovery)

Groundwater Samples will be taken as follows , if the core samples are collected from the 3 meter (10 ft) interval defined for groundwater sampling:

- Groundwater Samples Collected
- Groundwater Probe Inserted for Geochemical measurements

2 **Second** attempt at aseptic sample collection successful (first attempt unsuccessful)

Core samples will be designated as shown:

1st Core Recovered		2nd Core Recovered	3rd Core	
sediment chemistry	sediment physical properties	aseptic (microbiology)	hydraulic conductivity	particle size distribution or other

(to be taken at the discretion of the site geologist, depending upon previous sample recovery)

Groundwater Samples will be taken as follows, if the core samples are collected from the 3 meter (10 ft) interval defined for groundwater sampling:

- Groundwater Samples Collected
- Groundwater Probe Inserted for Geochemical measurements

3 If **both** attempts at aseptic sample collection in the specified interval are unsuccessful, and samples are not being collected from the previous 4.5 m (15 ft)

Core samples will be designated as shown:

1st Core Recovered		2nd Core Recovered	
sediment chemistry	sediment physical properties	hydraulic conductivity	particle size distribution or other

Groundwater Samples will be taken as follows, if aseptic sample recovery has been unsuccessful for previous 4.5 meters (15 ft):

- Groundwater Samples Collected
- Groundwater Probe Inserted for Geochemical measurements

The sediment chemical characterization analyses that will be performed are shown in Table FSP 3-5b.

5.8.1 Data Needs Defining the Sample Locations

Split-barrel samples will be collected for analyses to characterize the microbiologic consortia present, the geochemistry of the unsaturated and saturated zone sediments, the physical properties of the sediments, and the contaminants present in the saturated and unsaturated zones.

Site characterization data collected from the in situ bioremediation wells installed during 1991 and 1992 indicate the presence of a zone of increased cementation between approximately 85.0 and 85.6 m deep, 10 m below the water table. The degree of semiconfinement of this thin zone is important because of its potential influence on ground water flow during the field demonstration test.

Further site characterization is necessary to establish a more complete understanding of the hydrogeologic and hydrochemical conditions at the demonstration site. The degree of heterogeneity and anisotropy within the saturated interval are key data needs for effectively simulating the ground water flow regime near the in situ bioremediation wells and designing the demonstration system.

5.8.2 Decontamination Procedures

Decontamination of sampling equipment between sampling intervals will be conducted according to EII 5.4 or 5.5 (WHC 1988a) depending on the type of analyses planned for that sample. Sampling equipment will be decontaminated prior to use as described in Section 5.6.2 of this FSP.

For physical property samples, the initial decontamination procedure is sufficient for the split-barrel samplers. LEXAN sleeves that line the split-barrel sampler normally do not require decontamination after arriving from the manufacturer when used for physical property sampling. However, in this well, physical property samples will frequently be collected with aseptic microbiologic samples. In this situation, the physical property sample collection equipment will require the additional decontamination procedures that aseptic microbial sampling entails.

Decontamination procedures for aseptic core samples collected using a split-barrel sampler are described in Section 5.7.2 of this FSP. Equipment for chemical sampling will be decontaminated according to EII 5.5 (WHC 1988a), as described in Section 5.6.2 of this FSP.

5.8.3 Sample Collection Equipment and Sample Containers

Split-barrel sampling equipment for chemical and physical property analyses is listed in Section 5.6.3 of this FSP. Split-barrel sampling equipment for aseptic microbiological analysis is listed in Section 5.6.3 of this FSP.

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The subsample containers (for each sampled interval) for chemical analyses are:

- two 40-mL amber glass vials containing 5 mL methanol, with screw-on cap and teflon septum (VOA)
- one 40-mL amber glass vial with screw-on cap (TOC)
- two 500-mL glass canning jars (particle size distribution analyses)
- one moisture content tin (mineralogic analyses).

Sediment samples for VOA will be collected from the same split-barrel sediment from which other chemical characterization samples are collected.

5.8.4 Sample Preservation Procedures

Microbiologic Samples - Once the sediment sample is retrieved, the core is sealed inside the liners in which it is recovered by taping the caps in place and marking the LEXAN liner with pertinent sampling information (see Section 5.5.4). The sealed core is placed inside a plastic bag and the bag filled with argon. Gas is purged from the plastic bag three times and the plastic bag, filled with argon, sealed around the core. Purging is done by:

1. stand the core (inside the plastic bag) upright vertically, inside the bag, with the bag open at the top
2. inserting the tube from the argon tank into the plastic bag and holding the bag opening (at the top) closed by hand
3. fill the plastic bag with argon from the tank until fully inflated, then turn down the pressure from the argon tank
4. while continuing to hold the bag closed by hand, compressing the bottom of the bag to push the argon out the top opening
5. continue compressing the bag and move vertically up the core, until all the argon is pushed out of the bag, while holding the top closed (loosely, to allow the argon to escape, but no air to enter the bag)
6. repeat steps 3 through 5 twice more
7. the bag should retain positive pressure, so air does not enter the bag, pull the tube from the argon tank out of the bag
8. twist the top of the bag, fold it over onto itself, and tape the "twist" down onto the bag firmly with green tape
9. mark the bag with: (1) borehole number; (2) depth interval; (3) date and time of recovery; (4) sampler's initials; and (5) "ASEPTIC SAMPLE"
10. place sealed sample in cooler with blue ice, ensure a temperature in the cooler of 10°C or less until transfer to the laboratory.

Samples will be transported to the laboratory in the sealed LEXAN liner and argon atmosphere under refrigeration within 48 hours of sampling.

VOA Samples - Because the analytes are volatile, care must be taken to collect and preserve VOA samples as soon as the sediment has been removed from the borehole. Holding times, sample containers, preservation, and laboratory for the VOA samples are listed in Table FSP 5-1. Sediment will be placed in a 40-mL amber jar containing a methanol preservation to fix the volatiles in the methanol solution. Wet sediment samples are placed in a container with the drilling liquid; methanol is not used as a preservative. VOA sample vials must be vertical and under refrigeration (at a temperature of <10°C) at all times. Only when the sample is actually extracted from the sediments should the VOA vial be out of a refrigerated container. Between 5 and 10 g of sediment is the optimum sample size. Tamper-evident seals are not placed directly on VOA vials. The vials will be placed in a plastic bag and the seal placed on the bag opening. The samples will be released at the same time as the other samples.

Sediment Chemistry Samples - The liner designated for sediment chemistry characterization will be sealed with end caps and refrigerated until subsampling takes place. Holding times, sample containers, preservation, and laboratory for the sediment chemistry samples are listed in Table FSP 5-2. Subsampling will be done in the Soil Physics Laboratory of Sigma V within 48 hours of sample collection. The site coordinator is responsible for subsampling, and sample distribution to the appropriate analytical laboratory. For subsampling, the sample is divided into the appropriate volumes and placed into new sample containers for distribution to the laboratory. Chemical samples require refrigeration during storage and transport.

Porosity, Bulk Density, and Other Physical Properties - Porosity/bulk density samples must retain the sediment structure intact to the highest degree possible during sample collection and transport. To ensure that the sediment structure of the samples taken for these analyses remain intact, the LEXAN liners in which these samples are collected must be completely full of sediment. The sampled sediment will be sealed inside the liners with liner caps. Samples will be protected from physical shock during both the sampling and transport process. Samples do not require refrigeration transport.

Hydraulic Conductivity - Hydraulic conductivity samples must retain as much of the sediment structure intact as possible during sample collection and transport. To ensure that the sediment structure of the samples taken for these analyses remains intact, the LEXAN liners in which these samples are collected must be completely full of sediment. The sampled sediment will be sealed inside the liners with liner caps, and the caps taped in place. Samples will be protected from physical shock during both the sampling and transport process. Samples do not require refrigeration during transport.

5.8.5 Sample Collection Procedures

Split-barrel sample collection will require two samplers onsite to ensure that sample collection and handling procedures are carried out.

The first five steps listed in Section 5.6.5 of this FSP will be completed for all split-barrel sampling. After step 5, the microbiologic samples must be immediately covered with sterilized end caps and the caps taped in place. Then proceed with any other subsampling and liner capping.

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The priority for split-barrel subsampling and liner capping of VOA, chemical, porosity and bulk density, and physical property samples, is:

1. microbiologic sample processing
2. VOA core borer subsampling
3. sediment chemistry sample LEXAN liner capping
4. porosity and bulk density liner capping
5. hydraulic conductivity liner capping
6. radioactivity release subsampling.

Procedures for aseptic microbiologic sampling are described in Section 5.7.5 of this FSP. Procedures for VOA core-borer subsampling from the split-barrel, chemical liner capping, and porosity and bulk density liner capping are described in Section 5.6.5 of this FSP.

The liner designated for hydraulic conductivity analyses will be handled as described in Section 5.6.5 of this FSP for the porosity and bulk density liner.

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5.8.6 Sample Documentation

Radiation release documentation and a chain-of-custody form will be completed for each sample as described in Section 5.5.6 of this FSP.

5.8.7 Sample Handling and Analysis

Microbiologic Samples - The sealed liner in argon atmosphere is placed in a cooler with blue ice. The temperature will be kept at 10°C or less. Label the bag containing the core marked with borehole number, depth interval sample was recovered from, date and time of recovery, sampler's initials, and "ASEPTIC SAMPLE". The core will remain in a refrigerated container before being released for transport, and during transport. The sample will be transferred off the site once unconditionally released by the responsible HPT. The sample will be delivered to the PNL Microbiology Laboratory in the 324 Building and custody transferred for analyses.

VOA Samples - Handle VOA samples as described in Section 5.4 of this FSP. Holding times, sample containers, preservation, and laboratory for the sediment chemistry samples are listed in Table FSP 5-2. Analytical methods are provided in the Quality Assurance Project Plan (QAPP) (Table QAPP 7-1). Samples will be transferred to Sigma V and custody transferred to laboratory personnel. Samples will be analyzed using an internal procedure, PNL VOA-3, EPA method 502.2: Volatile Organic Compounds in Water by Purge and Trap Capillary Column Gas Chromatography with Photoionization and Electrolytic Conductivity Detectors in Series, modified for sediment samples.

Chemical Samples - Chemical subsamples from the chemical liner will be collected and handled as described in Section 5.5.8. Holding times, sample containers, preservation, and laboratory for the sediment chemistry samples are listed in Table FSP 5-2. Analytical methods are provided in the QAPP,

Table QAPP 7-1. Custody will be transferred to laboratory personnel at the Sigma V Soil Physics Laboratory upon sample delivery.

Porosity and Bulk Density Samples - Porosity and bulk density samples will be transported to the Soil Physics Laboratory, Sigma V, for analyses. During transport, the sample must be protected from physical shock to retain sediment structure integrity. Samples may be refrigerated if the holding time exceeds 5 days, to prevent any microbiologic growth on the sampled sediments. The holding time limit for the physical property samples is 90 days. Analyses will be conducted at the Soil Physics Laboratory. Physical property analyses and their respective governing procedures are listed in Table FSP 5-2. Custody will be transferred to laboratory personnel at the Soil Physics Laboratory at Sigma V upon sample delivery.

Hydraulic Conductivity Samples - Hydraulic conductivity samples will be transported from the drill site to the Soil Physics Laboratory at Sigma V for analyses. Custody will be transferred to laboratory personnel. During transport, the sample will be protected from physical shock to retain sediment structure integrity. Samples will be frozen once they arrive at the laboratory. There is no holding time limit for the hydraulic conductivity samples. Hydraulic conductivity samples will be analyzed by either one of the procedures from PNL, SA-4, Constant Head Hydraulic Conductivity Determination, or SA-5, Falling Head Hydraulic Conductivity Procedure (PNL 1992).

5.8.8 Sediment Chemistry Subsampling

After the chemical liner is released by the HPT, liners will be taken to Sigma V for subsampling. Transport of samples to Sigma V will be by government vehicle, in a refrigerated container at a temperature of 10°C or less.

The sediment chemistry characterization analysis that will be performed are (1) total organic carbon content and (2) mineralogy.

Subsamples for chemistry characterization analyses will be transferred from the chemical liner and put in pre-labeled containers for transport to analytical laboratories. The pre-labeled containers and the respective chain-of-custody forms will be prepared by the Field Sampling and Analysis Group staff. Chemical subsamples will be transported to their respective laboratories, and then analyzed within specified holding times, as listed in Table FSP 5-2. The site coordinator and Field Sampling and Analysis Group staff will be responsible for distributing the samples to the laboratories within the holding time limits; and receiving and distributing the analytical results.

5.9 GROUND WATER SAMPLING

Ground water samples will be collected and analyzed from the deep ground water well and the in situ bioremediation well. The deep ground water well may be drilled through the entire unconfined saturated zone. At that location, the water table is at 59 m below ground surface and the basalt is at a depth of 160 m. The bioremediation well will be drilled approximately 20 m below the water table, which is 75 m below ground surface at the in situ bioremediation demonstration site.

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5.9.1 Data Needs Defining the Sampling Locations

In the deep ground water well, ground water samples will be collected routinely at 6-m intervals, or more frequently if there are changes in the lithology or detected contaminant concentrations, or other unusual factors.

In the in situ bioremediation well, ground water samples will be collected for laboratory analyses, and a sensor will be inserted into the borehole to measure in situ ground water geochemical parameters. The sampling and measurements will be done sequentially to characterize the ground water chemistry in which microorganisms are found. Ground water samples and geochemical measurements will be done with alternate microbiologic characterization sampling; in at least 3-m depth intervals. If microbiologic characterization samples are collected successfully, ground water measurements will be made. A total of seven ground water measurements out of 10 possible aseptic sampling intervals is anticipated (Table FSP 3-5b). In the event that repeated attempts at aseptic sample collection are unsuccessful, ground water samples will be collected at least from every 4.5-m depth interval.

In situ ground water geochemical measurements are scheduled for the same seven intervals. Measurements will be required only where ground water samples are collected. However, depending on availability of the sensor, time required to deploy the sensor and to take measurements, and variability of the measured parameters, more measurements can be made at the discretion of the site geologist, the site coordinator, or other project personnel.

Ground water samples will be collected from the bioremediation well to characterize the metals concentrations of the ground water (including dissolved iron), the anion concentrations, the volatile organic constituent concentrations, and the dissolved organic carbon concentrations. The in situ sensor will be used to measure the ground water geochemical parameters of dissolved oxygen, redox potential, pH, temperature, and depth.

5.9.2 Decontamination Procedures

The bailer used for ground water sampling will be decontaminated by washing with a laboratory cleanser and flushing with deionized water. The bailer will be sealed in a plastic bag until the time of sampling. Sample containers requiring decontamination will be decontaminated by the container supplier.

5.9.3 Sample Equipment and Sample Containers

Sample collection equipment includes:

- rubber gloves
- waterproof markers
- cooler with frozen blue ice or natural ice
- box with dividers or vial rack (to keep VOA vials in vertical position)
- tamper-evident tape
- plastic baggies with "zip" closure openings
- teflon bailer - laboratory cleaned, wrapped in plastic

- tripod w/pulley and depth indicator
- string and motorized reel (to raise and lower bailer)
- chain-of-custody forms
- drilling and sampling procedures as called out in this FSP.

The sample containers and chain-of-custody forms will be prepared by PNL. Containers used for each sampled interval are listed in Table FSP 5-3.

5.9.4 Sample Preservation Procedures

Samples will be refrigerated with specific preservation as listed in Table FSP 5-4.

5.9.5 Sample Collection Procedures

Ground water samples will be collected from specific depth intervals in the aquifer. Prior to sampling:

- measure the depth to the bottom of the borehole
- measure the depth to water
- bail ground water from the hole before sampling. (The amount of water to be removed will be determined by field personnel at the time of sampling.)

Table FSP 5-4. Containers, Quantities, Preservation, and Holding Times for Water Samples.

Analysis	Container (full)	Preservation	Holding Time	Laboratory
Organics				
Volatile Organic Analysis (VOA)	40-mL amber glass with teflon septum	4°C	14 d (1)	PNL
Semi-Volatile Organics (SVOA)	2,000 mL amber glass	4°C	7 d	DCL
Dissolved organic carbon	500 mL amber glass			
Chemical				
ICP metals	500 mL poly	Nitric acid pH <2	6 mo	DCL
Ions	125 mL poly	4°C	None	DCL

NOTE: Holding times begin at the time of collection.

PNL = Pacific Northwest Laboratory.
DCL = Data Chem Laboratory.

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After bailing the borehole:

- Allow well recovery until the water level is at least 1.5 m above the bottom of the borehole (a depth of 0.9 m is required for the sampling bailer to collect a sample).
- Set up the tripod with calibrated pulley (to determine depth of sampling) and the line and motorized reel which lowers and lifts the bailer from the borehole.
- Remove two full bailers of water from the borehole and dump it into the purge water barrels before collecting the ground water samples (ground water samples should be as free of sediment as possible).
- Collect the water samples with the bailer. It may take several bailers full to collect enough water.
- Pour the water into opened sample jars being careful to spill and jostle the water as little as possible. The sample containers will be full and have a positive meniscus before capping.

5.9.6 Sample Documentation

Radiation release documentation and a chain-of-custody form will be completed for each sample, as described in Section 5.5.6 of the FSP.

5.9.7 Sample Handling and Analysis

Once collected, the samples will be refrigerated. Bottles will be marked with the collection date and time, HEIS number, and sampler. Tamper evident tape will be placed over the lids. Volatile organic sample vials will be placed in plastic bags and the tamper evident tape placed on the bag, not the vial. Samples will be released for transport by the HPT before being moved from the drill site.

Once released by the HPT, samples will be transported to Sigma V and custody transferred to the PNL sampling staff, who will distribute the samples to the analytical laboratories.

5.10 SOIL-GAS SAMPLING

In situ soil-gas samples will be collected from each borehole, if feasible, to determine the vertical distribution of VOC vapor. Samples will be taken using the Science and Engineering Associates Membrane Instrumentation and Sampling Technique (tradename of Science & Engineering Associates, Inc., of Santa Fe, New Mexico) and/or BoreSampler soil-gas sampling system. Both of these technologies were tested during FY 92 in support of VOC-Arid ID/ERA site characterization. Continued testing of the BoreSampler is planned for FY 93 and will be described in a separate test plan. Testing of the SEAMIST for the VOC-Arid ID/ERA site characterization was completed in FY 92.

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Both the SEAMIST and the BoreSampler are designed to be used in between drilling runs. To minimize interruption to drilling operations, in situ soil-gas samples will be collected at intervals adjacent to those sampled for chemical analysis using the split-barrel sampler, whenever possible. Procedures governing use of the SEAMIST and BoreSampler systems are included in the test plans for these technologies (Rohay and McLellan 1992 and WHC 1992, respectively).

Soil gas sampling using the BoreSampler is planned for up to five intervals in the in situ bioremediation borehole. In that borehole, sediment samples will be collected with the split-barrel sampler at intervals immediately above and below the interval from which soil gas samples are collected.

6.0 SAMPLE ANALYSIS REPORTING

Samples will be handled and transported as specified in the procedures in Section 5. Results of VOC, SVOC, and chemical analyses will be sent to the sampling staff at PNL. Analysis results will be entered into the HEIS database. Results of physical property analyses, SFE sediment matrix characterization, and microbiological analyses will be published in report form.

7.0 SAMPLE DISPOSAL

Once samples have been analyzed, the samples will be disposed of by the sampling or laboratory personnel. Sampled material that remains on Hanford Site will be disposed of at the drill site where it was collected. If samples are contaminated, they will be disposed of per WHC (1988b).

8.0 HYDROLOGIC TESTING AND ANALYSIS

The following subsections discuss specific development, testing, and analysis activities that will be undertaken in the in situ bioremediation well, 299-W11-32.

8.1 WELL DEVELOPMENT

Following completion, the new well will be developed. The well will be bailed after installation of filter pack material and before installation of bentonite seal material for each screen interval to settle the filter pack.

After the well has been constructed, it will be developed, as directed specifically by the site hydrologist, by pulsed pumping (pump on and off) in a stepwise fashion using a submersible pump <u>without</u> a check valve. The pumping will increase in steps of approximately 38 L/min and ending at approximately 190 L/min. The pump may be turned on and off several times during each step,

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the number of pulses dependent on the turbidity. Development will be conducted until the turbidity is approximately 10 NTU at the maximum flow rate step, or as directed by the site hydrologist overseeing development. A maximum of approximately 15,000 L of water will be purged during development.

8.2 HYDROLOGIC TESTS

Tests that are planned for FY 93 in well 299-W11-32 include:

- a series of two to three slug tests during the drilling phase
- screen interval isolation tests
- vertical permeability pumping tests
- recirculation tracer test.

All water pumped from the wells shall be contained in tanker trucks to be transported for proper disposal. At least two tankers must be available at all times, and up to three during off-normal hours, for containing purged water during pumping except when alternating between runs to empty the tanks. A tee in the discharge line at the wellhead shall be configured with valves to allow for outflow to either tanker. The volume of purge water will be measured and recorded.

Each of the planned hydrologic tests is described below in some detail. Additional changes or details, as necessary, will be provided in correspondence to the project file with appropriate personnel copied for information purposes.

8.2.1 Slug Displacement Tests

A series of up to three slug displacement tests will be conducted in well 299-W11-32. The purpose of these tests is to provide a qualitative indication of the variability in the hydraulic conductivity through the saturated interval in zones other than those in which screens will be placed. Based on geologic and geophysical logs, tests will be conducted within depth intervals of approximately 78 to 79 m, 85 to 85.1 m, and 87 to 88 m. These depth intervals may be changed based on field site conditions.

In particular, one of the test intervals will be in the zone of increased cementation at a depth of approximately 85 m that was encountered in the previously drilled wells. Results from this test will be compared with geologic and geochemical data for the interval and with results from tests conducted in the overlying intervals.

The slug tests will be conducted during the drilling phase after reaching the water table, but before final well completion. The slug tests will be coordinated with the collection of some selected water chemistry samples. For the tests above and below the cemented unit, a 1.5-m temporary screen (approximately 20 cm telescoping) with a bottom hook and end cap will be installed at each desired depth interval to prevent caving of the formation. The well casing will be backpulled 0.6 to 1 m and the well will be bailed to remove drilling fluid and to partially develop the test interval. For testing the cemented unit, the well will be open hole and may not require a screen. Drilling will cease after drilling through approximately the upper

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0.3 m of the cemented unit, careful not to penetrate completely through this unit, and the casing will be advanced to the top of the unit to isolate the cemented unit from the overlying unit.

After the water level has been allowed to reach equilibrium, the test will be performed by instantaneously injecting/withdrawing a cylindrical rod to displace the water column. Water level will be monitored in the borehole until it reaches at least 90% recovery. The tests may be repeated, if necessary. After completion of each test, the screen will be removed and drilling will resume.

The required data that will be collected during the test will be water-level recovery with respect to the instantaneous water-level change induced at the beginning of the test. Measurements of the dimension of the slugging rod is required to estimate the displacement volume. The water-level data will be processing and analyzed using conventional methods (i.e., Bouwer and Rich 1976) to calculate a qualitative estimate of hydraulic conductivity for each particular test interval. Values of hydraulic conductivity will be used to compare relative hydraulic conductivity between each test interval.

8.2.2 Screen Interval Isolation Tests

Tests will be conducted to verify the integrity of the seals between the screens and the packer assembly, and isolation of screen intervals, as well as to collect water chemistry samples from each screen interval. The well will be equipped with a submersible pump (without a check valve) and inflatable packer system. The pump and packer system will be reconfigured between each successive isolation test. The lower screen will be pumped first, followed by the middle screen, then the upper screen. This way, the pump and packer will not have to be reconfigured for the single-well, vertical hydraulic conductivity pumping test, which is planned to follow the screen interval isolation tests.

The pumping within each isolated zone will have a maximum flow rate of approximately 190 L/min. It is expected that approximately 34,000 L of water will be purged during screen isolation testing.

During each isolation test, each of the isolated zones will be monitored with pressure transducers to measure and record hydraulic heads. Hydraulic heads will be measured to determine the distribution of drawdown for a given flow rate. These data will be used for planning the single-well, vertical hydraulic conductivity pumping tests.

The flow rate will be measured periodically and the total volume of water purged will be calculated from the measured flow rate. All water pumped from the well will be contained in a tanker truck(s) to be transported for proper disposal. A tee in the discharge line at the wellhead shall be configured with valves to allow for outflow to more than one tanker truck.

8.2.3 Single-Well Pumping Test

A single-well, vertical hydraulic conductivity pumping test will be conducted in the proposed multi-screened well after it is completed and developed. The test design will involve pumping at a constant producing rate

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from the upper screen interval while monitoring pressures in the middle and lower screen intervals. If schedule and budget allow, a second test may be conducted that will pump from the middle screen and monitor the lower screen. A schematic illustration of each test design is presented in Figure FSP 8-1.

Each of the screened intervals will be hydraulically isolated with inflatable packers. Inflatable packers will be installed between each screen interval within the blank sections of casing at a depth of approximately 81 m and 88 m. Since the packer string is lowered into the well as a single unit, care will be taken to ensure proper spacing between each packer as well as proper instrumentation.

The packers will be inflated via inflation tube(s) with a pressurized nitrogen bottle. The nitrogen bottle will be equipped with a regulator valve to control the inflation pressure. The packers will be inflated to a pressure recommended by the manufacturer and this pressure will be maintained throughout the duration of testing. An electrical submersible pump with a check valve will be installed in-line with the packer system, separated from the packer beneath with a pump shroud. The pump will be placed below the lowest expected pressure head to eliminate problems associated with cavitation.

Pressure transducers will be used to monitor pressure within each test interval and will be assembled with the packer system. The flow rate will be measured with an in-line flowmeter at the surface and verified by timing a known volume (i.e., stopwatch and 20-L bucket).

As a minimum, it is expected that each pumping test will last for approximately 12 hr at a flow rate of approximately 375 L/min, yielding 27,000 L of purge water per test.

Details of the test design (i.e., flow rate, test duration, expected pressure responses) will be determined after the isolation tests are conducted and pre-test simulations are run. Before the first test is conducted, pre-test pumping for a short duration (e.g., 1 hr) will be conducted to ensure that the field equipment is functioning properly and to fill the vertical section of the discharge line. Recovery will be allowed to establish equilibrium before conducting the actual test. Following the pumping test, water-level recovery measurements will be recorded. A check valve installed in the pump mechanism is necessary for the recovery test.

Analysis of the water-level pressure data will require the use of line-source solution techniques by Hantush (1964) or Neuman (1975). Wellbore storage is related to the blank casing separating the test intervals and will be accounted for during the analysis.

A variation of the single-well pumping test is planned in addition to that described above, providing budget and schedule will allow. This method, called the dipole flow test, can be used in conjunction with previous pumping tests to determine the anisotropy ratio of hydraulic conductivity (Kabala 1993). This test is advantageous in that, instead of withdrawing water from the well for disposal, it is circulated into an upper or lower screen via the wellbore. For the multi-screened well, the primary test would be to pump from the upper screen interval and inject into the middle interval (or vice versa). A second test would be to pump from middle screen interval and inject into the lower interval (or vice versa).

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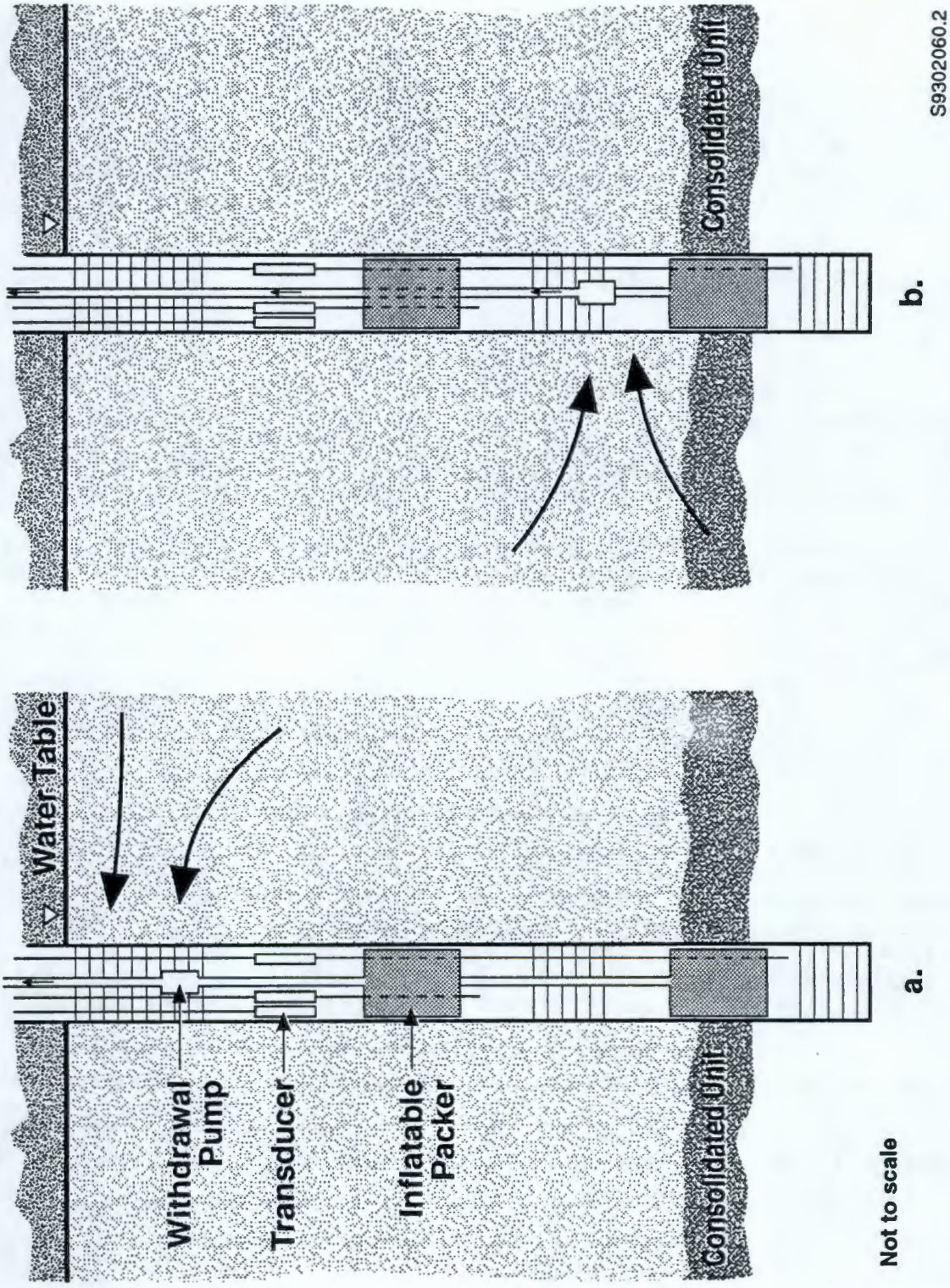
Figure FSP 8-1. Schematic Illustration of Single-Well Vertical Permeability Pump Test Design.



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The test configuration for the dipole test is similar to the single-well pumping test described above except that, when pumping from an upper to a lower interval, the pump mechanism must be inverted or, when pumping from a lower to an upper interval, a plug must be inserted in the riser pipe above the injected interval to prevent upward flow in the riser pipe.

Pressure transducers will be used to monitor pressure within each test interval and will be assembled with the packer system. If possible, an in-line flowmeter will be installed downhole to measure the flow rate of the circulated water. Analysis of the pressure data will require the solution described by Kabala (1993).

8.2.4 Recirculation/Mixing Test

A vertical recirculation test will be conducted in the multi-screen well. The purpose of this test is to determine the tracer distribution (radius of tracer envelope), determine the residence time of the tracer at the applied stress to the aquifer, and to compare the results to modeling simulations. Microspheres for simulating various sized microbes within the aquifer will be injected with the tracer. The results of this test and the modeling simulations will be used to design the field test for in situ bioremediation.

This test will be conducted by inducing a downward vertical hydraulic gradient between the upper and middle screened intervals and simultaneously injecting a tracer slug in the upper interval. Water will be pumped at a constant rate from the middle screened interval and reinjected into the upper screened interval. After reaching quasi-steady state hydraulic conditions, a tracer pulse will be injected into the upper screen. The tracer concentration will be measured with downhole probes in each of the screened intervals and in the neighboring monitoring wells until the trailing limb of the center of mass has been observed in the lower (pumped) interval.

A schematic illustration of the test design is shown in Figure FSP 8-2. Inflatable packers will be installed within the blank sections of casing to isolate each screen interval. To minimize the potential for injected tracer to become stagnated below the screen, the top of the upper packer will be installed just below the bottom of the upper screen, at a depth of approximately 78 m. The bottom of the lower packer will be placed at a depth of approximately 88 m. Since the packer string is lowered into the well as a single unit, care will be taken to ensure proper spacing between each packer.

The packers will be inflated via an inflation tube(s) with a pressurized nitrogen bottle. The nitrogen bottle will be equipped with a regulator valve to control the inflation pressure. The packers will be inflated to a pressure exceeding the expected maximum pressure head exerted on the upper packer, as recommended by the manufacturer, and this pressure will be maintained throughout the duration of pumping.

An electric submersible pump will be placed in the middle of the middle screened interval at a depth of approximately 85 m. The discharge line will be run through the center of the inflatable packers and the outflow of recirculated water will be located just above the upper packer. This will minimize affects of turbulence on the downhole probes within the upper screen. The riser pipe will extend to the surface and be equipped with an in-line gate

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valve downhole. If possible, an in-line flowmeter will be installed downhole to measure the flow rate of the circulated water.

Ion-selective bromide probes will be installed at stationary positions in the test well to monitor each test interval. The probe in the upper screen will be placed near the water table, several feet from the outflow location. Downhole ion-selective probes will also monitor the vertical distribution of tracer concentration within one or both of the adjacent existing wells, 299-W11-29 and 299-W11-30.

Downhole pressure transducers will be installed within each screened interval in the multi-screened well and in wells 299-W11-29 and -30. The transducers will measure the pressure head distribution during all phases (i.e., pre-test, stress, and recovery) of the test.

Several days of pumping may be required to run the recirculation tracer test. No water will be purged for disposal during this test because water will be recirculated within the saturated interval (except for water that will be removed for sample collection).

Depending on the results of the test and other prospective data needs, a second recirculation test may be conducted between the lower two screened intervals (see Figure FSP 8-2). An additional test may hinge on the schedule and budget.

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8.2.5 Water-Level Monitoring

Water-level measurements will be collected from the existing wells periodically (i.e., every 2 to 4 wk) to evaluate the hydraulic gradient and to monitor the decline in the water table. These measurements will be collected throughout the duration of the hydrogeologic characterization activities in 1993 and 1994. Water-level measurements from any new wells will be incorporated into the schedule once they are completed. Water levels will also be measured in a network of wells in the vicinity of the field site on a quarterly basis.

8.3 GROUND WATER SAMPLING AND ANALYSIS

After the multi-screened well is completed, ground water samples will be collected from each of the monitored zones during each screen isolation test. The samples will be collected via a sampling port in the discharge line. Samples will be placed in coolers for storage and sent to the laboratory for analysis. Additional ground water samples will be collected for field analysis. Sample collection, handling, preservation, transport, and analysis for the samples requiring laboratory analysis will be conducted according to the methods contained in this work plan.

For each interval, the samples will be analyzed in the laboratory for VOC, metals, anions, ammonia, sulfide, Fe^{3+}, Fe^{2}, specific conductivity, alkalinity, pH, and selected radionuclides. The chemical parameters pH, temperature, electrical potential (Eh), dissolved oxygen, nitrate, nitrite, sulfide, specific conductance, ammonia, and alkalinity will be measured from each interval in the field during sample collection.

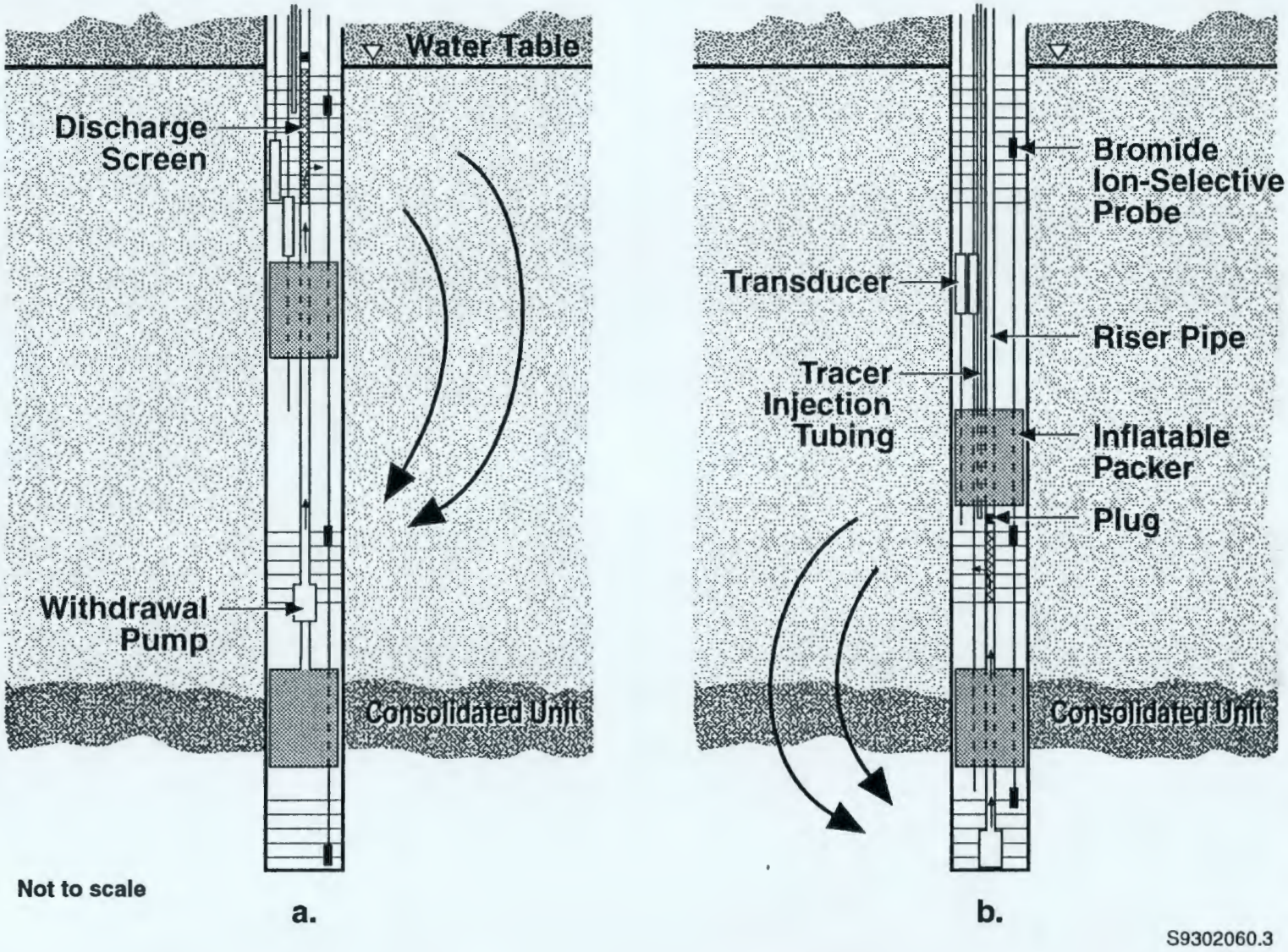

Figure FSP 8-2. Dual-Screen Recirculation/Mixing Test Schematic Design.

Field monitoring of selected hydrochemical constituents may be conducted during one or more of the hydrologic tests in which water is withdrawn from the well. The constituents will be Ph, temperature, Eh, specific conductance, dissolved oxygen, iron, sulfide, ammonia, nitrite, nitrate, and VOC. These samples will help to support background chemistry conditions of the ground water for the field demonstration test.

8.4 EQUIPMENT NEEDS

A list of field equipment that will be needed for carrying out the characterization activities for FY 93 is provided below:

- slugging rod
- 1.5-m screen with bottom hook
- inflatable packer systems with riser pipe and fittings
- pressurized nitrogen bottle and regulator
- inflation line for inflatable packer systems
- electric submersible pumps
- pump shroud for packer system configuration
- small-capacity sampling pumps
- water level recorder (five downhole probes)
- six downhole ion-selective probes and logger
- wellhead assembly with sampling port, gate valve, and tee
- in-line flowmeter
- field water chemistry analysis equipment
- flow-through cell and meter
- downhole flowmeter.

The downhole ion-selective probes will be fabricated at PNL. The slugging rod will be fabricated by WHC or Kaiser Engineers Hanford (KEH). Some of the equipment may be available through support by WHC or KEH. Most of the other equipment will have to be purchased. A lead of approximately 2 mo is required for most of the purchased equipment.

8.5 SCHEDULE FOR HYDROLOGIC TESTING

The integrated schedule for all drilling, sampling, and testing activities is provided in Figure FSP 8-3. Detailed schedule considerations for specific hydrologic test activities are provided.

The slug tests will be scheduled with the drilling after drilling reaches the water table. The slug tests are expected to take no more than 1 day each.

Well development is expected to take 2 days. The screen isolation tests will require up to 3 days for preparation (e.g., installation of the packer system) and then approximately 4 days to conduct the tests, including reconfiguration of the packer system between tests. The single-well, vertical hydraulic conductivity tests will be conducted after screen isolation tests. The initial test will require up to 3 days to prepare for and approximately 4 days to conduct. The dipole test will require approximately 3 days for preparation and approximately 4 days to conduct the tests. The recirculation/mixing test will be conducted after dipole test is complete. Approximately

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4 days is planned for packer and pump reconfigu-ration before the actual test. Up to 10 days are planned for conducting the recirculation test. An additional day is planned between each set of tests, resulting in a total duration of approximately 40 work days (8 wk) for the above activities.

8.6 SPECIAL NOTIFICATIONS AND PURGE WATER REQUIREMENTS

The Washington Department of Ecology and the EPA will be kept informed of the hydrologic testing plans and volumes of water planned to be withdrawn from the wells. A memorandum-to-file as required by NEPA was approved for hydrologic testing activities in support of in situ bioremediation characterization. Documentation of the volumes of water removed will be essential; these will be provided in a letter to project files and transmitted to Ecology and WHC personnel. A summary of the maximum estimated volumes of water that will be withdrawn is provided in Table FSP 8-1.

The purge water removed from this will be handled and tracked per EII 10.3, Purgewater Management (WHC 1988a). PNL personnel will ensure that records regarding purge water are maintained according to EII 10.3.

8.7 DOCUMENTATION

All water level data that will be recorded from automatic water level recorders will be stored on disks. Other data pertaining to the hydrologic tests (e.g., flow rate, time pump turned on, etc.) will be recorded on "aquifer test data sheets" per PNL (1990, Procedure AT-5). All other data not specific to hydrologic testing, such as tracer concentration and field chemistry analysis, will be recorded on standard log sheets. Field notebooks can be used also. Calibration of all test equipment used for this work will be documented.

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Figure FSP 8-3. Tentative Schedule of Drilling and Hydrologic Testing Activities for Well 299-W11-32 in FY 93.

ACTIVITY	FEBR.	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	DURATION (DAYS)
Natural-gradient tracer test									Ongoing
Drilling/construction									60
Drill above water table									32
Drill below water table									20
Construct well									8
Collect geologic samples									52
Collect in situ groundwater									20
Conduct slug tests									3
Develop well/collect samples									5
Single-well dipole pump test									15
Sediment and water analysis									80
Two-well dynamic tracer test (?)									12
Recirculation tracer tests									25
Tracer sample analysis									35
Data processing and analysis									115
Reporting									Continues
Draft report to peer review									40
Results to system designers									
Plan FY 1994 activities									Continues

Notes: Two-well dynamic tracer test will likely not be conducted due to budget, schedule, and purgewater disposal constraints.

Table FSP 8-1. Summary of Maximum Estimated Water Withdrawn During In Situ Bioremediation Characterization Activities.

Hydrologic Test Type	Maximum No. of Tests	Maximum Estimated Volumes	
		Gallons	Liters
Development	1	4,000	15,000
Screen Isolation	3	9,000	34,000
Single-Well Pumping	2	15,000	57,000
Recirculation/Mixing (sampling)	2	2,000	8,000
Additional Sampling (if needed)	3	3,000	11,000
Estimated Total	11	33,000	125,000

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PART 2

QUALITY ASSURANCE PROJECT PLAN

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1.0 PROJECT DESCRIPTION

1.1 OBJECTIVE

The primary objective of the Volatile Organic Compounds-Arid Integrated Demonstration (VOC-Arid ID) is to demonstrate new technologies for the characterization, remediation, and monitoring of the 200 West Area carbon tetrachloride contamination. The primary objective of the 200 West Area expedited response action (ERA) is to remove carbon tetrachloride from the unsaturated soils in the 200 West Area. The VOC-Arid ID and ERA site characterization programs have been merged to maximize efficient use of time and resources and to ensure that each activity and the resulting products achieve the maximum usefulness to both programs. The focus of the FY 93 VOC-Arid ID/ERA site characterization effort will be on further refining the conceptual model and on providing baseline data to support the technology demonstrations. Specific project objectives for the field investigation tasks of the FY 93 site evaluation are outlined in Section 3.1 of this work plan.

1.2 BACKGROUND

The VOC-Arid ID/ERA site is located in the south-central part the Hanford Site's 200 West Area (Figures 1, 2, and 3 of this work plan). The descriptions of the location and physical characteristics of the demonstration site, nature and extent of contamination, and detailed background information regarding the history of this site is in Section 2.0 of this work plan.

1.3 APPLICABILITY

This QA project plan applies specifically to the FY 93 site characterization field activities and laboratory analyses performed as part of environmental investigations for the VOC-Arid-ID/ERA. It is an element of the SAP prepared specifically for this phase of investigation. All plans and procedures referenced herein are available for review on request at the direction of the project manager. QA/QC for these activities will consist of technically sound procedures with associated instrument calibration and maintenance, and field and laboratory documentation.

1.4 SPECIFIC OBJECTIVES

Specific objectives for field investigation tasks are given in Table QAPP 1-1.

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Table QAPP 1-1. Field Investigation Task Objectives.

Field Task	Objective
Source Term Characterization	Identify all sources of carbon tetrachloride observed in the subsurface.
Conduct Soil Gas Surveys	Map the lateral and vertical distribution of carbon tetrachloride vapor and other selected VOC in the vicinity of and away from the three disposal sites.
Conduct Geophysical Surveys	Define the three-dimensional configuration of major mappable hydrofacies and/or contaminant plumes in the vicinity of the three principal carbon tetrachloride disposal sites.
Existing Well Investigations	Continue assessments of the old wells as contaminant transport pathways; remove any known pathways; and evaluate the lithology and/or contamination penetrated by the boreholes.
New Well Investigations	Obtain data on the nature, distribution, transport pathways, and behavior of contaminants (e.g., phase partitioning, sorption parameters): (1) below each disposal facility, down to the Plio-Pleistocene unit; (2) adjacent to the disposal facility and fully penetrating the unconfined aquifer; and (3) obtain data to characterize the in situ microbial populations and the conditions under which they degrade carbon tetrachloride.

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2.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

Overall responsibility of site characterization activities for the VOC-Arid ID/ERA will be maintained by the Westinghouse Hanford Company (WHC) project manager. The WHC field team leader will be responsible for coordinating onsite drilling activities with Kaiser Engineers-Hanford (KEH) or other applicable drilling personnel. WHC personnel will be responsible for site geologist support (with the exception of the bioremediation well subtask). Pacific Northwest Laboratory (PNL) personnel will be responsible for coordinating environmental sampling, volatile organics analyses, and special sampling for principal investigators; coordinating the chemical analyses by DataChem Laboratories or other applicable laboratories; and the reporting of analytical results.

During the bioremediation well installation, the WHC field team leader is responsible for overall management of well drilling and construction activities and health and safety; however safety is the responsibility of all staff working on the project.

PNL personnel are responsible for sample collection, handling, transport, and analysis, and for documenting well drilling and completion.

Well installation will be under PNL supervision and documentation will be per EII 6.8, Well Completion (WHC 1988a). Sampling activities will be recorded as described by PNL (1992, Procedure DO-1). It is the responsibility of the site coordinator and the site geologist to ensure that samples are taken according to procedures outlined in this work plan and at the specified intervals herein. It is the responsibility of the site coordinator to ensure that samples are transported and distributed according to the defined protocols herein and within the holding times identified for the appropriate sample. It is the responsibility of the Field Sampling and Analysis Group staff to ensure that samples are distributed to the correct offsite laboratory, within the holding times prescribed, once the samples are in their custody. It is the responsible of the site coordinator and the sampling coordinator to ensure that samples analyzed in the Soil Physics Laboratory are completed within the required holding times, and according to the correct procedure. It is the responsibility of the Field Sampling and Analysis Group staff to ensure that the results of offsite laboratory analyses are reported to the site coordinator. It the responsibility of the site coordinator to assemble and report to the task manager all data collected during the activities described herein except results of the microbiologic characterization analyses.

3.0 QA OBJECTIVES FOR MEASUREMENT

The data quality needs, which are the analytical levels required to meet the VOC-Arid ID/ERA objectives, are explained in Section 3.3 and listed in Table 3 of this work plan. Table QAPP 3-1 is a list of analytical levels and expanded definitions (adapted from EPA 1987).

Table QAPP 3-1. EPA Analytical Levels.

Level I	Field screening or analysis using portable instruments. Results are often not compound specific and not quantitative, but results are available in real time. It is the least costly of the analytical options.
Level II	Field analysis using more sophisticated portable analytical instruments; in some cases, the instruments may be set up in a mobile laboratory onsite. There is a wide range in the quality of data that can be generated. Quality depends on the use of suitable calibration standards, reference materials, and sample preparation equipment; and the training of the operator. Results are available in real time or several hours.
Level III	All analyses performed in an offsite analytical laboratory. Level III analyses usually use EPA (1986) analytical methods, but may also elect to use Contract Laboratory Program (CLP) procedures. Level III analyses do not usually utilize the validation or documentation procedures required of CLP Level IV analysis. The laboratory may or may not be a CLP laboratory.

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Table QAPP 3-1. Continued.

Level IV	CLP Routine Analytical Services (RAS). All analyses are performed in an offsite CLP-qualified analytical laboratory following CLP protocols. Level IV analyses are characterized by rigorous QA/QC protocols and prescribed documentation.
Level V	Analysis by nonstandard methods. All analyses are performed in an offsite analytical laboratory which may or may not be a CLP laboratory. Method development or method modification may be required for specific constituents or detection limits. CLP Special Analytical Services (SAS) are Level V.

In general, the ERA analytical data should be reproducible and reliable, but do not need to be validated in accordance with CLP procedures. Data quality needs in this context apply only to laboratory or field analyses.

Field screening of most sediment and soil gas samples will be analyzed at EPA Level II (EPA 1987) using a portable gas chromatograph or other field screening equipment to determine if more precise sampling and analysis is necessary. Field screening with a calibrated instrument is adequate for determining concentrations of 1 ppm or more, and the results may be obtained in real time. Laboratory screening will be technically correct using a calibrated instrument and documented.

A field sampling matrix relating the field investigation tasks to subtasks, investigation methods, analytical levels, and estimated numbers of samples is shown in Table QAPP 3-2.

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Table QAPP 3-2. Field Investigation Tasks and Analytical Levels (Sheet 1 of 6).

Controlling Task	Subtasks	Primary Method(s) of Investigation	Sample Method(s) and/or Analyses	Est. No. of Samples	Analytical Level	Potential Additional/Confirmatory Method(s) of Investigation	Sample Method(s) and/or Analyses	Est. No. of Samples	Analytical Level
Source Term Characterization *Identify all sources of CCl4 contamination observed in the subsurface*	Evaluation of Effluent Pipelines	Forward-looking color camera	Visual analysis of recorded image	5	I	Surface/Vegetation		5	I, II
						Soil gas sampling	GC, Field Screening	20	I, II
						Cone penetrometer	GC, Field Screening	5	I, II
						Soil sampling (borings)	GC, Field Screening	1	I, II
	Investigate Source of Secondary Ground Water Maximum	Survey of existing documents	Paper search	N/A	I	Vegetation sampling		5	I, II
		Comparison of ground water chemistry along principal flow path of CCl4 plume	Ground water monitoring	N/A	I	Soil gas surveys	GC, Field Screening	20	I, II
						Sample existing wells - soil gas and ground water	GC, Field Screening	10	I, II
		Evaluate CCl4 degradation rates and ground water travel times	Ground water monitoring	N/A	I	Cone penetrometer	GC, Field Screening	5	I, II
						Install new wells		1	N/A
	Assessment of Artificial Recharge	Compile/evaluate data on discharge volumes/rates, and locations of effluents within 1 km of primary CCl4 disposal sites	Compilation/evaluation of existing documents	N/A	I				
			Personal interviews	N/A	I				
Conduct Soil Gas Surveys *Map lateral and vertical distribution of CCl4 and other VOC in the vicinity and away from the three disposal sites*	Map Lateral Distribution of VOC	Soil gas survey of new and existing soil gas points	GC, OVM, Odyssey	366	I, II	Ion-trap			I, II
		Survey of oxygen and carbon dioxide levels	Field instrumentation	122	I, II	Continuous monitoring of selected ports	Odyssey	5	I, II
	Estimate VOC Vapor Flux From Ambient Soil Surface	Passive soil gas survey technologies	EMFLUX, PETREX	50	I, II				
	Map Vertical Distribution of VOC	Soil gas survey of existing wells - existing and new perforated intervals	GC, OVM	30	I, II	Cone penetrometer vertical profile sampling	GC, OVM	20	I, II

Table QAPP 3-2. Field Investigation Tasks and Analytical Levels (Sheet 2 of 6).

Controlling Task	Subtasks	Primary Method(s) of Investigation	Sample Method(s) and/or Analyses	Est. No. of Samples	Analytical Level	Potential Additional/Confirmatory Method(s) of Investigation	Sample Method(s) and/or Analyses	Est. No. of Samples	Analytical Level
Geophysical Surveys *Define the 3-D configuration of major mappable hydrofacies and/or contaminant plumes in the vicinity of the three principal CCl4 disposal sites*		Surface geophysical techniques	Seismic Reflection/ Refraction	4	I, II				
			Electromagnetic Induction (FDEM, TDEM)	2	I, II				
			Resistivity (DC, SIP)	2	I, II				
			Ground Penetrating Radar	1	I, II				
Existing Well Investigations *Continue assessments of old wells as contaminant pathways; remove any known pathways; evaluate the lithology and/or contamination penetrated by the boreholes*	Borehole Geophysical Logging	Borehole geophysical logging of selected wells within a 100-m radius around the three CCl4 disposal sites	Gross Gamma/ Spectral Gamma	19	I, II	Neutron/Epithermal Neutron	Detection of perched water	6	I, II
						Neutron Thermal Lifetime	Detection of chlorine	5	I, II
						Downhole camera surveys	Visual	15	I, II
						Caliper, Corrosion logs	Visual	15	I, II
						Magnetic Tool	Visual	15	I, II
	Wellhead Vapor Emissions	Personal interviews - historical use of various well cap designs	Compilation/Evaluation	N/A	I				
		Measurement of well head concentrations and fluxes of VOC vapor at selected wells	Field screening PID, GC	120	I				
	Well Remediation	Remediation or modification of ground water wells in proximity to the 216-Z-9 Trench		N/A	N/A	Vapor extraction	Compilation/Evaluation	N/A	I
						Ground water monitoring		N/A	I
		Survey of wells using both Lambert metric and Hanford plant coordinates		30	I	Physical/Document Review	Compilation/Evaluation	N/A	I

Table QAPP 3-2. Field Investigation Tasks and Analytical Levels (Sheet 3 of 6).

Controlling Task	Subtasks	Primary Method(s) of Investigation	Sample Method(s) and/or Analyses	Est. No. of Samples	Analytical Level	Potential Additional/Confirmatory Method(s) of Investigation	Sample Method(s) and/or Analyses	Est. No. of Samples	Analytical Level
Existing Well Investigations (continued)	Water Level Measurements	Water level measurements taken once per quarter in all available ground water wells within a 1-km radius around the three primary disposal sites	Steel Tape, Transducer	80	I	Groundwater potential maps, flow nets constructed		N/A	I
	Evaluation of Archived Borehole Samples	Relog samples from critically located wells using a regimented protocol	Visual	800	I				
		FY92 samples to be sieved and analyzed for clay content	ASTM Procedure	200	I, II, III				
New Well Investigations *Obtain data on the nature, distribution, transport pathways, and behavior of contaminants immediately below each disposal facility and fully penetrating the uppermost aquifer*	New Crib Wells *Deepen 2 Existing Wells: 299-W18-174 (216-Z-1A Tile Field) and 299-W18-96 (216-Z-18 Crib)* *Drill 1 new inclined well under the 216--Z-9 Trench*	Wellhead vapor monitoring	GC, colorimetric tube, radionuclide detectors	54	I, II	Soil gas sampling	Tests of other soil gas sampling devices	23	I
		Soil gas sampling	GC, colorimetric tube, SEAMIST, Borehole Sampler	23	I, II	Air Permeability	SEAMIST	23	I, II
		Geophysical logging	Gross Gamma/ Spectral Gamma	9	I, II	Other logging tools			
		Core and borehole cuttings	Grain Size, $CaCO_3$, pH, moisture, lithology, radioactivity, VOCs, particle size (hydrometer)	54	I, II, III				
		Split-barrel soil sampling	water retention, unsat. hydraulic conduct., bulk density, porosity, air permeability, mineralogy	23	I, II, III				
			- and - Thin sections: lithology, mineralogy, pore size distribution	3	I, II				
			- and - Cation exchange cap., total organic carbon, surface area, Pore water chemistry, sorption studies, isotope analysis	3	I, II, III				

Table QAPP 3-2. Field Investigation Tasks and Analytical Levels (Sheet 4 of 6).

Controlling Task	Subtasks	Primary Method(s) of Investigation	Sample Method(s) and/or Analyses	Est. No. of Samples	Analytical Level	Potential Additional/Confirmatory Method(s) of Investigation	Sample Method(s) and/or Analyses	Est. No. of Samples	Analytical Level
New Well Investigations (continued)	New Crib Wells (continued)	Split-barrel sampling (cont.)	VOAs, SVOCs, metals, ions	54	I, II, III V				
		Aseptic split-barrel sampling	Microbiology analysis	2	I, II, III				
	Install Deep Ground Water Well	Wellhead vapor monitoring	GC, colorimetric tube, radionuclide detectors	105	I, II	Deepen or clean out existing wells	Ground water monitoring	17	I, II
	Obtain data on the nature and distribution of contaminants in the aquifer in the vicinity of the disposal facilities, and obtain data on the lithology, geochemistry, hydrology, and microbiology of the aquifer materials	Soil gas sampling	MS, GC, colorimetric tube, SEAMIST, Borehole Sampler	17	I, II				
			Oxygen, carbon dioxide	17	I, II				
		Geophysical logging	Gross / Spectral Gamma	3	I, II	Other logging tools			
		Core and borehole cuttings	Grain Size, $CaCO_3$, pH, moisture, lithology, radioactivity, VOCs, particle size (hydrometer)	105	I, II, III				
		Split-barrel soil samples	moisture content, water retention, unsat. hydraulic conduct., bulk density, porosity, air permeability, mineralogy - and -	40	I, II, III				
			Thin sections: lithology, mineralogy, pore size distribution - and -	3	I, II				
			Cation exchange cap., total carbon, surface area, Pore water chemistry, sorption studies, isotope analysis	6	I, II, III				
			VOCs, SVOCs, metals, ions	33	I, II, III V				
			sat. hydr. con., pore water chem, mineralogy	18	I, II, III				
		Aseptic split-barrel sampling	Microbiology analysis	4	I, II, III				

Table QAPP 3-2. Field Investigation Tasks and Analytical Levels (Sheet 5 of 6).

Contolling Task	Subtasks	Primary Method(s) of Investigation	Sample Method(s) and/or Analyses	Est. No. of Samples	Analytical Level	Potential Additional/Confirmatory Method(s) of Investigation	Sample Method(s) and/or Analyses	Est. No. of Samples	Analytical Level
New Well Investigations (continued)	Install Deep Ground Water Well (continued)	Groundwater sampling	pH, TOC, TOX, specific conductance, VOGC, SVOCs, metals, anions, ions	18	I, II, III				
Ground Water Sampling *Monitor concentrations of VOCs in ground water from wells in and around the three disposal sites and at the perimeter of the ground water plume* *Investigate the vertical distribution of VOCs within the aquifer*		Ground water sampling of 17 wells in November 1992 and in May 1993	GC, portable field screening equipment, MS	17	I, II	Groundwater Sampling	Permeation sampler		I, II

VOC - volatile organic compound
VOGC - volatile organic gas chromatograph
SVOC - semi-volatile organic compound
TOX - total organic halogens
TOC - total organic carbon
PID - photoionization detector
GC - gas chromatograph
OVM - organic vapor monitor

Table QAPP 3-2. Field Investigation Tasks and Analytical Levels (Sheet 6 of 6).

Controlling Task	Subtasks	Primary Method(s) of Investigation	Sample Method(s) and/or Analyses	Est. No. of Samples	Analytical Level	Potential Additional/Confirmatory Method(s) of Invetigation	Samplet Method(s) and/or Analyses	Est. No. of Samples	Analytical Level
New Well Investigations	Install Bioremediation Well	Aseptic split-barrel sampling	Microbiologic analysis	12	V				
		Split-Barrel Sampling	VOA, TOC, mineralogy	12	III,V				
		Sediment physical property characterization	particle size, density, porosity, hydraulic conductivity, CaCO3, moisture content, water suction	12	III				
		Core and borehole cuttings	particle size distribution, moisture content, water suction CaCO3	31	I, III, V				
		Groundwater Sampling	VOA, metals anions, DOC	7	III				
		In situ geochemical parameter measurement (groundwater)	dissolved oxygen, pH, temp, Eh	7	II				
		Aquifer Hydrologic Testing	slug tests, tracer tests, screen interval isolation test recirculation tests, pump tests	N/A	V	Sediment physical property characterization	particle size distribution, hydraulic conductivity		
		Soil Gas sampling with Bore Sampler	VOA	5	V	Sediment chemical characterization	VOA		
		Geophysical Logging	gross gamma response	3	I,II	Lithologic description	visual observation	60	I

4.0 SAMPLING PROCEDURES

Procedures that will be used to support the field sampling plan (FSP) are stated in the *Environmental Engineering, Technology, and Permitting Function Quality Assurance Program Plan* (WHC 1990); environmental investigation instructions (EII) are stated in the *Environmental Investigations and Site Characterization Manual* (WHC 1988a); quality requirements (QR) and quality instructions (QI) are stated in the *Quality Assurance Manual* (WHC 1988b); and detailed field sampling procedures and protocols are described in the FSP.

The field tasks of the FY 93 site evaluation are discussed in Section 3.5 of this work plan. EII will govern these tasks as applicable. Tasks performed by subcontractors or participant contractors will comply with applicable portions of the EII (WHC 1988a) and/or with WHC-approved subcontractor or participant contractor procedures.

Procedural approval, revision, and distribution control requirements applicable to EII are addressed in EII 1.2, Preparation and Revision of Environmental Investigations Instructions. Deviations from established EII required in response to unforeseen field situations may be authorized in compliance with EII 1.4, Deviation from Environmental Investigations Instructions.

Sampling locations, frequencies, and analyses for new well investigations are described in the FSP.

Borehole sampling for lithologic, physical, geochemical, microbial, volatile organics, chemical, radionuclide, and soil gas analyses will be performed as defined in the FSP. Sample numbers, types, locations, and other site-specific considerations will also be defined in the FSP.

5.0 SAMPLE CUSTODY

Sample custody will be maintained using chain-of-custody forms if sample analysis does not immediately follow sample collection. Results of analyses will be traceable to original samples through the unique code or identifier assigned to the sample in the field and recorded on the chain-of-custody form and/or sampling form.

6.0 CALIBRATION PROCEDURES

Calibration of measuring equipment will be done according to manufacturer's manuals governing its use. Calibration of WHC, participant contractor, or subcontractor analytical equipment shall be as defined by applicable standard analytical methods.

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7.0 ANALYTICAL PROCEDURES

Methods of investigation are identified in Table QAPP 3-2. Analytical procedures for these methods will be selected or developed prior to use, and will be in compliance with WHC procedures and/or procurement control requirements where applicable. EPA Level III and V analyses will be performed by qualified WHC and PNL employees or offsite laboratories. Analytical procedures and reporting units for different sample types are given in Table QAPP 7-1.

8.0 DATA REDUCTION, VALIDATION, AND REPORTING

The task coordinator will be responsible for preparing a detailed data package. As a minimum, data packages for Level III and V analyses will include:

- Sample documentation, including identification of the organization and individuals performing the extraction and/or analysis; documentation of any sample custody; and the date/time of sample receipt, extraction, and analysis.
- Instrument calibration documentation, including equipment type and model, for the time period in which the sample analysis was performed.
- QC data for the methods used.
- Analytical results or data deliverables, including reduced data, reduction formulae or algorithms, and identification of data outliers or deficiencies.

The project managers/principal investigators will be responsible for preparing a report summarizing and interpreting the results of analyses.

9.0 INTERNAL QC

Internal QC methods will be used, and include:

- field duplicate samples
- equipment blanks
- trip blanks.

As feasible, duplicate samples will be analyzed by field- and laboratory-screening equipment.

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Table QAPP 7-1. Sampling, Analysis, and Reporting Summary.

SOIL Sample Type	Container	Quantity	Preservation	Holding time	Analytical Level	Prep Method/ Analytical Procedure	Detection Level	Reporting Units
VOA	40 ml amber glass w/ teflon septum	5-10 gm	Methanol Refrigeration	14 days	III	PNL: VOA-3	PID: 10 ppb ELCD: 40 ppb	ppb
SVOA (ABN)	125 ml glass jar	120 gm	Refrigeration	7 days - extraction 40 days - analysis	III	3540 or 3550/ 8270 (1)	660-66000 (2)	µg/kg
ICP Metals	250 ml glass jar	5 gm	Refrigeration	6 months	III	3010/ 6010 (1)	300-30000 (2)	µg/kg
Pb	all in same jar	5 gm	Refrigeration	6 months	III	7421 (1)	500 µg/kg	µg/kg
Hg		5 gm	Refrigeration	28 days	III	7471 (1)	400 µg/kg	µg/kg
Anions		5 gm	Refrigeration	ASAP after collection	III	300.0, EPA-600/ 4-84-017	200-1000 (2)	µg/kg
TOC	40 ml amber	20 gm	Refrigeration	28 days	III	9060 (1)	N/A	µg/kg
Moisture Content	moisture tin		none	ASAP	III	N/A	N/A	per cent
$CaCO_3$ content			none	1 year	III	N/A	N/A	per cent
Particle Size Distribution	500 ml glass "mason" jar	1 kg (approximate)	none	1 year	III	N/A	N/A	per cent
SPE Sediment Matrix Char.	5 gallon bucket	1-5 gallons	none	14 days	III	N/A	N/A	. (3)
Bulk Density/Porosity	0.5' length Lexan liner	0.5-ft. core	none	N/A	III	N/A	N/A	. (3)
Air Permeability	0.5' length Lexan liner	0.5-ft. core	none	N/A	III	N/A	N/A	. (3)
Microbiologic	1' or 2' length sediment core	core	Argon atmosphere Refrigeration	ASAP	III	N/A	N/A	N/A
Soil Gas	750 ml glass bulb	750 ml	(Al foil wrap)	24 hours	III	N/A	N/A	ppb
GROUND WATER Sample Type	Container	Quantity	Preservation	Holding time	Analytical Level	Prep Method/ Analytical Procedure	Detection Level	Reporting Units
ICP Metals	1000 ml poly	(full jar)	Nitric Acid with pH < 2	6 months	III	3010/ 6010	3-300 (2)	µg/L
Ions	125 ml poly	(full jar)	none	Per procedure	III	300.0, EPA-600/4-84-017	100-500 (2)	µg/L
SVOA (ABN)	2000 ml glass amber	(full jar)	none	7 days	III	3510 or 3520/ 625 (1)	10-1000 (2)	µg/L
VOA	40 ml amber glass w/ teflon septum	40 ml	pH < 2 Methanol Refrigeration	14 days	III	PNL: VOA-3	PID: 10 ppb ELCD: 40 ppb	ppb

(1) SW 846, EPA, 1987. (2) Depends on constituent(3) Depends on analysis.

10.0 PERFORMANCE AND SYSTEMS AUDITS

Audits in environmental investigations are considered to be systematic checks that verify the quality of operation of one or more elements of the total measurement system. Performance audit requirements will be met by the use of internal QC methods. Systems audits will be scheduled if requested by the project manager or the U.S. Department of Energy, Richland Field Office.

11.0 PREVENTIVE MAINTENANCE

All measurement and testing equipment used in the field that directly affects the quality of the analytical data will be subject to preventive maintenance measurements that ensure minimization of measurement system downtime. Field equipment maintenance instructions will be as defined by the procedures governing their use.

12.0 DATA ASSESSMENT PROCEDURES

Measurement data will be assessed and documented by the task coordinator responsible for that measure-ment. Any data evaluation will be documented in field and laboratory note-books in which information related to the sampling activities is recorded.

13.0 CORRECTIVE ACTIONS

Corrective actions are procedures that might be implemented on samples that do not meet QA specifications. A corrective action request might be generated, for example, by an audit. Corrective actions may include resampling or reanalyzing samples, if feasible. The primary responsibility for corrective action resolution is assigned to the WHC cognizant engineer.

14.0 REFERENCES

EPA, 1986, *Test Methods for Evaluating Solid Waste - Physical/Chemical Methods*, 3rd Ed., SW-846, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.

EPA, 1987, *Data Quality Objectives for Remedial Response Activities: Volume 1, Development Process*, EPA/540/G-97-003, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.

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PNL, 1989, *Procedures for Ground-Water Investigations*, PNL-MA-567, Pacific Northwest Laboratory, Richland, Washington.

PNL, 1992, *Procedures for Ground Water Investigations*, PNL 6894, Rev. 1, Pacific Northwest Laboratory, Richland, Washington.

WHC, 1988a, *Environmental Investigations and Site Characterization Manual*, WHC-CM-7-7, Westinghouse Hanford Company, Richland, Washington.

WHC, 1988b, *Quality Assurance Manual*, WHC-CM-4-2, Westinghouse Hanford Company, Richland, Washington.

WHC, 1990, *Environmental Engineering, Technology, and Permitting Function Quality Assurance Program Plan*, WHC-EP-0383, Westinghouse Hanford Company, Richland, Washington.

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degradation products such as chloroform and methylene chloride, and tributyl phosphate degradation products such as dibutyl phosphate and monobutyl phosphate, are also likely. A cadmium nitrate solution was sprayed on the soil at the 216-Z-9 Trench.

The principal radiological contaminants in the unsaturated zone underlying the three disposal sites are plutonium-239/240 and americium-241. Minor amounts of cesium-137 and strontium-90 are also indicated in the Waste Information Data System database for the 216-Z-9 Trench and the 216-Z-1A Tile Field.

Ground water contaminants identified in the 200 West Area include carbon tetrachloride, chloroform, cyanide, fluoride, hexavalent chromium, trichloroethylene, nitrate, strontium-90, tritium, technetium-99, iodine-129, and uranium.

GENERAL SAFETY ISSUES

Aside from the chemical and radiological contamination present in the area, this project will involve a number of industrial safety issues. Some of the disposal sites involve the potential for cave-in. This could cause personnel injury or equipment damage and will be controlled through strict compliance with safety plans. Equipment used for some tasks will expose personnel to mechanical hazards such as pinch points and overhead hazards. Noise, possible flying objects, and lifting heavy tools and equipment will be involved. Potentially encountering underground utility lines is a concern when driving soil-gas probes or drilling holes; these activities are controlled by excavation permits/geophysical surveys. All equipment used will be in good condition and equipped with the proper safety devices. Safety plans will be developed for the specific work tasks and will adequately address both chemical and industrial safety issues. These plans are reviewed and approved by Westinghouse Hanford Company (WHC) internal safety organizations prior to work initiation.

TRAINING

Work crews at the site will have routine safety meetings and will have received the appropriate training based on the work being carried out. Other specific training will be spelled out in SSSP as they are developed.

SITE CONTROL/EMERGENCY PLANS

With the exception of installation of new wells, field investigation tasks of the FY 93 site evaluation (work plan, Section 3.5) will require relatively few individuals to complete. Site control should not be an issue when inside the 216-Z-1A Tile Field because the tile field is fenced. Site control at the 216-Z-9 Trench, the 216-Z-18 Crib, and other areas will be controlled through the use of control zones where necessary. The field team leader/site safety officer will control and coordinate access to the site. Visitors will be kept at a safe distance from field activities at all times. Only trained team members will be allowed routine access to field activities. Further site control requirements will be identified in safety plans where

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HEALTH AND SAFETY PLAN

This health and safety plan (HSP) addresses potential health and safety issues in a generic manner for characterization during the Volatile Organic Compounds-Arid Integrated Demonstration (VOC-Arid ID) and the 200 West Area Carbon Tetrachloride Expedited Response Action (ERA). The HSP consists of the site description, types/sources of contamination, general training and medial surveillance requirements, and plans for general site control and emergency actions.

Specific information such as personal protective equipment, monitoring strategies, and decontamination procedures will be specified in site- /task-specific safety plans for each new task taking the form of a site-specific safety plan (SSSP) or a hazardous waste operations permit (HWOP). These safety plans will expand on subjects such as site control, emergency plans, and training requirements in more detail depending on the complexity and degree of hazard associated with each task. The standard operating procedures used to carry out the major tasks are found in environmental investigations instructions (EII) (WHC 1988). No confined space entry will be required for this work.

Radiological safety requirements and controls are identified in site- or task-specific radiation work permits (RWP). The RWP identifies radiological conditions expected to be encountered, dosimetry and protective clothing requirements, and Health Physics Technologists (HPT) coverage.

SITE DESCRIPTION

The VOC-Arid ID/ERA is focused on three retired liquid waste disposal facilities associated with the Plutonium Finishing Plant (PFP) plutonium recovery processes: (1) the 216-Z-1A Tile Field, (2) the 216-Z-9 Trench, and (3) the 216-Z-18 Crib. The VOC-Arid ID/ERA activities include use of existing structures (e.g., boreholes, vents, and piping) and installation of wells located within and near these facilities. These three cribs received the bulk of the carbon tetrachloride disposed to the ground between 1955 and 1973, when soil column disposal of carbon tetrachloride associated with PFP processes ceased. Locations and descriptions of the cribs are summarized in this work plan, Section 2.1, Site Operations. Detailed information is available in the ERA proposal (DOE-RL 1991).

TYPES/SOURCES OF CONTAMINATION

The three principal carbon tetrachloride disposal sites received acidic and organic, actinide-bearing liquid wastes (work plan, Section 2.1). Based on existing information, the contaminants discharged to the cribs are both chemical and radiological.

Aqueous solutions discharged to three principal carbon tetrachloride disposal sites were concentrated, acidic, metal nitrate salt wastes. Organic material, including carbon tetrachloride, tributyl phosphate, dibutyl butyl phosphonate, and fabrication oil, were disposed in saturation amounts in the aqueous solution and also separately in batches. Carbon tetrachloride

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APPENDIX B

HEALTH AND SAFETY PLAN

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necessary. Site access and training requirements for visitors are described by Laurenz (1992).

Response to possible emergencies at the site will generally require notification of emergency response personnel either by phone or plant radio. Minor personnel injuries can be treated at the 200 West Area first aid station. Site personnel will discuss actions to be taken in regular safety meetings held at the site. With the exception of installation of new wells, field investigation tasks will not require detailed emergency plans as they are relatively simple, low hazard tasks. As the remedial action decisions are made and tasks become more complex, both emergency plans and safety plans will become detailed.

REFERENCES

DOE-RL, 1991, *Expedited Response Action Proposal for 200 West Area Carbon Tetrachloride Plume*, DOE/RL-91-32, U.S. Department of Energy, Richland Field Office, Richland, Washington.

Laurenz, J. E., 1992, *Field Access Guide for Visitors of the Volatile Organic Compounds - Arid Integrated Demonstration Site*, WHC-SD-EN-AR-002, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1988, *Environmental Investigations and Site Characterization Manual*, WHC-CM-7-7, Westinghouse Hanford Company, Richland, Washington.

WHC, 1991, *WIDS Database Field Descriptions and Data*, WHC-MR-0056, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

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J.S.

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