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Revision 0

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Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

United States Department of Energy
P.O. Box 550
Richland, Washington 99352

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EXECUTIVE SUMMARY

The purpose of this remedial investigation (RI) report is to present the data collected during the RI and other characterization activities for the Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit (OU) (Plutonium/Organic-Rich Group OU). The Plutonium/Organic-Rich Group OU includes three OUs where liquid wastes were disposed of into cribs, french drains, trenches, an injection/reverse well, settling tanks, drain/tile fields, and at an unplanned release site.

- 200-PW-1 OU waste sites primarily received plutonium- and organic-rich wastes (mostly carbon tetrachloride, tributyl phosphate, and lard oil) from processes within the Z Plant Complex (now referred to as the Plutonium Finishing Plant Complex).

- 200-PW-3 OU waste sites received organic-rich wastes (primarily refined kerosene [normal paraffin hydrocarbon, tributyl phosphate, and butanol) from the A Plant (plutonium-uranium extraction process).

- 200-PW-6 OU waste sites received plutonium-rich wastes from the Plutonium Finishing Plant Complex, but did not receive organic-rich wastes from that complex.

The data quality objectives process for the Plutonium/Organic-Rich Group OU was performed to determine the environmental measurements necessary to refine the preliminary site conceptual models, support an evaluation of risk, and support an evaluation of remedial alternatives. The data presented as part of this RI report were evaluated against the data quality requirements to determine if sufficient data have been collected to (1) satisfy the optimized sampling designs in the data quality objectives summary reports as implemented by the remedial investigation/ feasibility study Work Plan (DOE/RL-2001-01, *Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan, Includes: 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*),[1] (2) support risk assessment, and (3) support remedial decision making. This evaluation, documented in D&D-30565, *Data Quality*

[1] DOE/RL-2001-01, 2004, *Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan, Includes: 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*, Rev. 0, Reissue, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Assessment Reports for the 200-PW-1 and 200-PW-3 Operable Units: 216-A-8 Crib Borehole, 216-Z-9 Trench Vertical Borehole, 216-Z-9 Trench Slant Borehole, and Dispersed Carbon Tetrachloride Vadose-Zone Plume,[2] and summarized in this RI report, determined that sufficient data were collected to satisfy the optimized sampling designs in the data quality objectives summary reports as implemented by the Work Plan, and that the data are the right type, quality, and quantity to support risk-assessment activities and evaluation of remedial alternatives in the feasibility study.

The data collected during the RI were evaluated, and those contaminants detected above background levels were used to refine the contaminant distribution models, which are presented in Chapter 3.0. The baseline risk assessment that usually is included in an RI report will be included in the Plutonium/Organic-Rich Group OU feasibility study.

The Plutonium/Organic-Rich Group OU consists of 17 *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*[3] past-practice and unplanned release waste sites. This RI report focuses primarily on the characterization of four representative waste sites:

- 216-Z-1A Tile Field
- 216-Z-9 Trench
- 241-Z-361 Settling Tank
- 216-A-8 Crib.

In addition, this RI report also focuses on the significant characterization activities conducted to define the nature and extent of the "dispersed" carbon tetrachloride vadose-zone plume that has migrated away from the 200-PW-1 OU waste sites.

Data-collection requirements were followed as defined in DOE/RL-2001-01. The characterization activities and results for carbon tetrachloride as a dense, nonaqueous-phase liquid (DNAPL) in the 200 West Area, defined in DOE/RL-2004-78, *Work Plan for Integrated*

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[2] D&D-30565, 2007 anticipated, *Data Quality Assessment Reports for the 200-PW-1 and 200-PW-3 Operable Units: 216-A-8 Crib Borehole, 216-Z-9 Trench Vertical Borehole, 216-Z-9 Trench Slant Borehole, and Dispersed Carbon Tetrachloride Vadose-Zone Plume*, Fluor Hanford, Inc., Richland, Washington.

[3] *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC 9601, et seq.

Approach for Carbon Tetrachloride Source Term Location in the 200 West Area of the Hanford Site,[4] also are included in this RI report.

Field investigations and data collection from the four representative waste sites (216-Z-1A Tile Field, 216-Z-9 Trench, 241-Z-361 Settling Tank, and 216-A-8 Crib) and the dispersed carbon tetrachloride vadose-zone plume included in this RI report were conducted primarily from 1999 to January 2007. Data collected before the RI also are discussed in this report. During the data quality objectives process, the existing data at the 216-Z-1A Tile Field and the 241-Z-361 Settling Tank were determined to be sufficient to support an evaluation of remedial alternatives, but RIs were required at the 216-Z-9 Trench and the 216-A-8 Crib to resolve data gaps. RIs also were required to characterize the nature and extent of the dispersed carbon tetrachloride vadose-zone plume and to define the potential presence and extent of carbon tetrachloride DNAPL at the 216-Z-9 Trench and the 216-Z-1A Tile Field.

The RIs at the 216-Z-9 Trench and the 216-A-8 Crib included drilling vadose-zone boreholes (one vertical and one slant borehole at the 216-Z-9 Trench and one vertical borehole at the 216-A-8 Crib), subsurface soil and soil-vapor sampling, and borehole geophysical logging in the RI boreholes and nearby wells to define the vertical and lateral extent of contamination at these waste sites. The RIs for the dispersed carbon tetrachloride vadose-zone plume and the carbon tetrachloride DNAPL investigation involved a variety of field and non-field activities, including the following:

- Passive soil-vapor surveys
- Subsurface soil and soil-vapor sampling in direct-push holes, boreholes, and wells
- Cross-well seismic reflection surveys at the 216-Z-9 Trench and the 216-Z-1A Tile Field to develop subsurface topographic maps of fine-grained layers that may be carbon tetrachloride DNAPL accumulation areas

[4] DOE/RL-2004-78, 2004, *Work Plan for Integrated Approach for Carbon Tetrachloride Source Term Location in the 200 West Area of the Hanford Site*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

- Soil-vapor and shallow-groundwater sampling in existing monitoring wells at eight areas of persistent carbon tetrachloride concentrations ("hot spots") in the carbon tetrachloride groundwater plume to evaluate whether vadose-zone soil vapor is impacting the groundwater in these areas

- Modeling studies of carbon tetrachloride DNAPL transport in the vadose zone beneath the 216-Z-9 Trench

- Particle-tracking analysis of the movement of the carbon tetrachloride groundwater plume to help identify potential vadose-zone source areas other than the known 200-PW-1 OU waste sites

- Geostatistical analysis of the persistence of carbon tetrachloride groundwater concentrations in the eight "hot spot" areas of the carbon tetrachloride groundwater plume.

The summaries of these RI activities are provided in Chapter 2.0, and the results are provided in Chapter 3.0.

Since 1992, an interim action in the 200-PW-1 OU has used soil-vapor extraction to minimize the migration of the dispersed carbon tetrachloride vadose-zone plume away from the 200-PW-1 OU waste sites. A summary of the performance evaluation of this interim action is included in Chapter 2.0.

The preliminary conceptual contaminant distribution models developed in the Work Plan (DOE/RL-2001-01) were refined based on the data collected during the RI. The refined contaminant distribution models depict current contaminant distribution beneath the representative waste sites and the dispersed carbon tetrachloride vadose-zone plume and were used to qualitatively evaluate current and future impacts to groundwater. All available historical data and borehole geophysical logs were used to prepare conceptual contaminant distribution models for all of the waste sites in the 200-PW-1/3/6 OUs. These models will be used in the feasibility study to apply the analogous-site approach to the remaining waste sites (analogous sites).

The results of the RI characterization of the 216-Z-1A Tile Field, 216-Z-9 Trench, and 216-A-8 Crib indicate that the vadose zone is contaminated by both radiological and nonradiological contaminants of potential concern. Groundwater has been impacted by these sites in the past, but these sites are not likely to be significant current sources of groundwater contamination. The RI characterization results of the 241-Z-361 Settling Tank indicate that although the tank contains approximately 75 m^3 (82 yd^3) of sludge contaminated with radionuclides, metals, organics, and polychlorinated biphenyls, the tank has not leaked, so this site is not considered to be a past or current source of groundwater contamination. The results of the RI characterization of the dispersed carbon tetrachloride vadose-zone plume indicate that the highest carbon tetrachloride concentrations are near the 216-Z-9 Trench and the 216-Z-1A Tile Field. These concentrations are being reduced by interim-action soil-vapor extraction, and away from these waste sites the concentrations that were found are not considered to have the potential for significant current or future groundwater impacts.

Chapter 4.0 presents the conclusions and discusses the path forward for the Plutonium/ Organic-Rich Group OU. In the feasibility study, the baseline risk assessment will identify the contaminants of potential concern that will be retained for further analysis, and remedial alternatives will be developed and evaluated with regard to meeting potential applicable-or-relevant-and-appropriate requirements, performance standards, and evaluation criteria. The decision-making process for the Plutonium/Organic-Rich Group OU will be based on the proposed plan and record of decision. The record of decision for this OU Group will cover all of the waste sites in the three OUs, not just the representative waste sites characterized under the RI. After the record of decision has been issued, a remedial-design report and remedial-action work plan will be prepared to detail the scope of the remedial action.

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TERMS

amsl	above mean sea level
ARAR	applicable or relevant and appropriate requirement
ASG	active soil gas
bgs	below ground surface
c/s	counts per second
CAS	Chemical Abstracts Service
CCl_4	carbon tetrachloride
CCU	Cold Creek unit
CCUc	Cold Creek unit caliche
CCUz	Cold Creek unit silt
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COI	contaminant of interest
COPC	contaminant of potential concern
CPP	CERCLA past-practice
CPT	cone penetrometer
CT	carbon tetrachloride
DBBP	dibutyl butyl phosphonate
DBP	dibutyl phosphate
DNAPL	dense, nonaqueous-phase liquid
DOE	U.S. Department of Energy
DQA	data quality assessment
DQO	data quality objective
EAPS	Enhanced Access Penetration System
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
FS	feasibility study
FY	fiscal year
GPS	Global Positioning System
Guzzler	Guzzler Vacuum Extraction System
HEIS	*Hanford Environmental Information System* database
HEPA	high-efficiency particulate air (filter)
HFGD	Hanford formation gravel dominated
HFSD	Hanford formation sand dominated
HFUF	Hanford formation upper fines
HHR	hydraulic hammer rig
HRLS	High-Rate Logging System
HVAC	heating, ventilation, and air conditioning
HWIS	*Hanford Well Information System* database
ID	identification (number)
IDF	Integrated Disposal Facility

Implementation Plan	*200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program* (DOE/RL-98-28)
LERF	Liquid Effluent Retention Facility
LLWMA	low-level waste management area
MBP	monobutyl phosphate
N/A	not applicable
NM	not measured
NPH	normal paraffin hydrocarbon
OU	operable unit
OVA	organic vapor analyzer
PCE	tetrachloroethylene
PFP	Plutonium Finishing Plant
PNNL	Pacific Northwest National Laboratory
ppb	parts per billion
ppm	parts per million
ppmv	parts per million by volume
PRF	Plutonium Reclamation Facility
PSG	passive soil gas
PUREX	Plutonium-Uranium Extraction (Plant or process)
QA	quality assurance
QC	quality control
RCRA	*Resource Conservation and Recovery Act of 1976*
RECUPLEX	Recovery of Uranium and Plutonium by Extraction (Plant or process)
REDOX	Reduction-Oxidation (Plant or process)
RI	remedial investigation
RL	U.S. Department of Energy, Richland Operations Office
ROD	record of decision
SAF	Sampling Authorization Form (number)
SALDS	state-approved land-disposal site
SAP	sampling and analysis plan
SGLS	Spectra Gamma Logging System
SIM	Soil Inventory Model
STOMP	Subsurface Transport over Multiple Phases (PNNL-12028)
SVE	soil-vapor extraction
SVOC	semivolatile organic compound
TBP	tributyl phosphate
TPH	total petroleum hydrocarbon
Tri-Parties	Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989, as amended)
UPR	unplanned release
VOA	volatile organic analyte
VOC	volatile organic compound

WIDS	*Waste Information Data System* database
WMA	waste management area
Work Plan	*Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan, Includes: 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units* (DOE/RL-2001-01)

METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
If you know	*Multiply by*	*To get*	*If you know*	*Multiply by*	*To get*
Length			**Length**		
inches	25.40	millimeters	millimeters	0.0394	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	meters	meters	3.281	feet
yards	0.914	meters	meters	1.094	yards
miles (statute)	1.609	kilometers	kilometers	0.621	miles (statute)
Area			**Area**		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.0929	sq. meters	sq. meters	10.764	sq. feet
sq. yards	0.836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.591	sq. kilometers	sq. kilometers	0.386	sq. miles
acres	0.405	hectares	hectares	2.471	acres
Mass (weight)			**Mass (weight)**		
ounces (avoir)	28.349	grams	grams	0.0353	ounces (avoir)
pounds	0.453	kilograms	kilograms	2.205	pounds (avoir)
tons (short)	0.907	ton (metric)	ton (metric)	1.102	tons (short)
Volume			**Volume**		
teaspoons	5	milliliters	milliliters	0.034	ounces (U.S., liquid)
tablespoons	15	milliliters	liters	2.113	pints
ounces (U.S., liquid)	29.573	milliliters	liters	1.057	quarts (U.S., liquid)
cups	0.24	liters	liters	0.264	gallons (U.S., liquid)
pints	0.473	liters	cubic meters	35.315	cubic feet
quarts (U.S., liquid)	0.946	liters	cubic meters	1.308	cubic yards
gallons (U.S., liquid)	3.785	liters			
cubic feet	0.0283	cubic meters			
cubic yards	0.764	cubic meters			
Temperature			**Temperature**		
Fahrenheit	(°F-32)*5/9	Centigrade	Centigrade	(°C*9/5)+32	Fahrenheit
Radioactivity			**Radioactivity**		
picocurie	37	millibecquerel	millibecquerel	0.027	picocurie

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1.0 INTRODUCTION

The purpose of this remedial investigation (RI) report is to present the data collected during the RI and other characterization activities for the Plutonium/Organic-Rich Group Operable Unit (OU). The Plutonium/Organic-Rich Group OU includes three OUs where liquid wastes were disposed of into cribs, french drains, trenches, an injection/reverse well, settling tanks, drain/tile fields, and at an unplanned release (UPR) site.

- 200-PW-1 OU waste sites primarily received plutonium- and organic-rich wastes (mostly carbon tetrachloride, tributyl phosphate [TBP], and lard oil) from processes within the Z Plant Complex (now referred to as the Plutonium Finishing Plant [PFP] Complex).
- 200-PW-3 OU waste sites received organic-rich wastes (primarily refined kerosene [normal paraffin hydrocarbon or NPH], TBP, and butanol) from the A Plant (plutonium-uranium extraction [PUREX] process).
- 200-PW-6 OU waste sites received plutonium-rich wastes from the PFP Complex, but did not receive organic-rich wastes from that complex.

The data quality objectives (DQO) process for the Plutonium/Organic-Rich Group OU was performed to determine the environmental measurements necessary to refine the preliminary site conceptual models, support an evaluation of risk, and support an evaluation of remedial alternatives. The data presented as part of this RI report were evaluated against the data quality requirements to determine if sufficient data have been collected to support risk assessment activities and remedial decision making. This evaluation, documented in D&D-30565, *Data Quality Assessment Reports for the 200-PW-1 and 200-PW-3 Operable Units: 216-A-8 Crib Borehole, 216-Z-9 Trench Vertical Borehole, 216-Z-9 Trench Slant Borehole, and Dispersed Carbon Tetrachloride Vadose-Zone Plumes*, and summarized in Section 1.2.1, determined that the data are the right type, quality, and quantity to support risk-assessment activities and evaluation of remedial alternatives in the feasibility study (FS).

In addition to the data quality assessment (DQA), this RI report for the Plutonium/Organic-Rich Group OU consists of three main components: summary of the investigation approach (Chapter 2.0), presentation of the results (Chapter 3.0), and the refined conceptual models of contaminant distribution (Chapter 3.0).

The Plutonium/Organic-Rich Group OU consists of 17 *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) past-practice and UPR waste sites. This RI report focuses primarily on the characterization of four representative waste sites:

- 216-Z-1A Tile Field
- 216-Z-9 Trench
- 241-Z-361 Settling Tank
- 216-A-8 Crib.

In addition, this RI report also focuses on the significant characterization activities conducted to define the nature and extent of the "dispersed" carbon tetrachloride vadose-zone plume that has migrated away from the 200-PW-1 OU waste sites.

In 2002, the U.S. Department of Energy (DOE), Richland Operations Office (RL); the U.S. Environmental Protection Agency (EPA); and Washington State Department of Ecology (Ecology) conducted a thorough review of the cleanup approach that was being applied through DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program* (Implementation Plan), and identified improvements to accelerate cleanup of these waste sites. As part of this improved approach to accelerating waste-site cleanup, these three agencies (the Tri-Parties) agreed to consolidate the 23 process-based OUs into 12 groups based on similarities between contaminant sources (02-RCA-0341, "Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) Change Requests for the Central Plateau Project (CPP) Activities"; contains Modifications M-013-02-01, M-015-02-01, M-016-02-01, and M-020-02-01, approved in June 2002). As a result of this process, the 200-PW-1 Plutonium/Organic-Rich Process Condensate/Process Waste Group OU, the 200-PW-3 Organic-Rich Process Condensate/Process Waste Group OU, and the 200-PW-6 Plutonium-Rich Process Condensate/Process Waste Group OU were consolidated into one group – the Plutonium/Organic-Rich Group OU – because the waste sites in all three OUs received plutonium- and/or organic-rich process condensates and process wastes. As part of the consolidation effort, all of the waste sites in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs were aligned with representative waste sites based on similarities between their contaminant distribution models. This analogous waste-site approach allows data collected from representative waste sites to be extrapolated to similar or analogous waste sites in the early stages of assessment to support remedial alternative evaluation and selection (DOE/RL-98-28, Section 2.5.1).

The Plutonium/Organic-Rich Group OU representative waste sites were selected for characterization because the available data concerning waste-stream inventories and effluent volumes received suggest that contaminant levels present in the subsurface beneath these receiving sites represent average or worst-case conditions for the waste sites in the OU. The representative waste sites were evaluated by implementing the DQO process. The DQO process was used to determine the data that should be collected to assess site conditions and support remedial decision making. During the DQO process, the existing data at the 216-Z-1A Tile Field and the 241-Z-361 Settling Tank were determined to be sufficient to support evaluation of remedial alternatives, but RIs were required at the 216-Z-9 Trench and the 216-A-8 Crib to resolve data gaps (CP-15371, *Remedial Investigation Data Quality Objectives Summary Report for the Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit Representative Waste Sites*). This RI report summarizes the historical or existing data from the four representative waste sites in addition to the RI data collected as a result of the DQO process as applicable. In addition, this RI report summarizes the existing data on the nature and extent of contamination at the analogous waste sites. Two of the sites, the 216-Z-8 French Drain and the 216-Z-10 Injection/Reverse Well, are not analogous to any representative waste site but they have sufficient historical data to support selection of remedial alternatives. In this report, these two sites are referred to as "unique waste sites," and the historical data from these sites also are summarized.

The characterization and remediation of waste sites at the Hanford Site are addressed in the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989). This agreement addresses the integration of cleanup programs under CERCLA and the *Resource Conservation and Recovery Act of 1976* (RCRA) to provide a standard approach to directing cleanup activities and to ensure that applicable regulatory requirements are met. The Tri-Party Agreement requires that both CERCLA remedial actions and RCRA corrective actions processes be satisfied simultaneously. Details of this integration for the 200 Areas are presented in DOE/RL-98-28, Chapter 2.0, and in DOE/RL-2001-01, *Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan; Includes: 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units* (Work Plan, Section 1.1). This paragraph documents that this Tri-Party Agreement requirement was considered when preparing the RI report.

The Plutonium/Organic-Rich Group OU waste sites are located in the 200 East and 200 West Areas near the center of the Hanford Site in south-central Washington State (Figure 1-1). The 200-PW-1 and 200-PW-6 OU waste sites are all located in the 200 West Area. The 200-PW-3 OU waste sites are located in the 200 East Area. The waste sites in the Plutonium/Organic-Rich Group OU are listed in Table 1-1, and their locations are shown in Figures 1-2 through 1-4.

During calendar year 2006, a DQO process was conducted with the Tri-Parties to determine if supplemental characterization was needed for Central Plateau waste sites. During the DQO process, the Tri-Parties agreed that several waste sites should be transferred from the 200-PW-1 and 200-PW-3 OUs to other OUs. The Tri-Parties determined that supplemental characterization data are needed for the waste sites listed in Table 1-2, with the exception of UPR-200-W-110. Given the new data requirements resulting from the DQO process, the supplemental characterization data could not be gathered and analyzed for these waste sites in time for inclusion in this RI, thus putting the Tri-Party Agreement milestone at risk. The waste sites identified for supplemental characterization are being transferred outside the scope of this RI (Tri-Party Agreement Change Request C-07-01, "Federal Facility Agreement and Consent Order: Transfer of Waste Sites from 200-PW-1 and 200-PW-3 Operable Units to other Operable Units," dated April 10, 2007) to other appropriate 200 Area OUs in Appendix C of the Tri-Party Agreement, with schedules that provide additional time for gathering and analyzing the supplemental characterization data. The Work Plan (DOE/RL-2001-01) identified that UPR-200-W-110 should be in the 200-CW-5 OU, because it is located by the 216-Z-1 Ditch and the 216-Z-19 Ditch. This change originally was proposed in Tri-Party Agreement Change Request C-01-01, which was never approved. This change was approved in Change Number C-07-01 and included in Table 1-2. UPR-200-W-125 is being transferred to the 200-UW-1 OU in accordance with Tri-Party Agreement Change Number C-07-02 (approval pending).

The RI fieldwork was conducted in accordance with the Work Plan (DOE/RL-2001-01). Data were collected to characterize the nature and extent of chemical and radiological contamination and the physical conditions in the vadose zone underlying the historical boundaries of the 216-Z-9 Trench (200-PW-1 OU) and the 216-A-8 Crib (200-PW-3 OU). Surface radiological surveys, borehole drilling, soil and soil-vapor sampling, dense, nonaqueous-phase liquid (DNAPL) characterization, and borehole geophysical surveys were conducted during the field activities. These activities are summarized in WMP-26264, *Borehole Summary Report for*

Well 299-W15-46 (C3426) Drilled at the 216-Z-9 Trench; WMP-30566, *Borehole Summary Report for Well 299-W15-48 (C3427) Drilled at the 216-Z-9 Trench*; WMP-27020, *Borehole Summary Report for Characterization Borehole C4545 Drilled at the 216-A-8 Crib;* DOE/RL-2006-58, *Carbon Tetrachloride Dense Non-Aqueous Phase Liquid (DNAPL) Source Term Interim Characterization Report*; and DOE/RL-2007-22, *Carbon Tetrachloride Dense Non-Aqueous Phase Liquid (DNAPL) Source Term Characterization Report Addendum.* The data from the activities conducted at the representative waste sites, as well as existing data from the waste and unique waste sites, will support the evaluation of remedial alternatives in the FS.

In addition to characterization of the representative waste sites, the RI included characterization of the dispersed carbon tetrachloride vadose-zone plume. As previously noted, the primary organic contaminants discharged to the 200-PW-1 OU waste sites were carbon tetrachloride, TBP, and commercial lard oil. The carbon tetrachloride has migrated beyond the 200-PW-1 OU waste-site boundaries, resulting in a dispersed carbon tetrachloride vadose-zone plume. The purpose of the RI of the dispersed plume was to determine the nature and extent of the carbon tetrachloride contamination and whether there are additional carbon tetrachloride sources in the vadose zone that are current sources or may be future sources of groundwater contamination. The dispersed-plume RI activities, which were conducted in two phased steps, included the following:

- Passive and active soil-vapor surveys at engineered facilities that could be potential sources of carbon tetrachloride
- Subsurface soil and soil-vapor sampling in direct-push holes, boreholes, and wells
- Modeling studies of carbon tetrachloride DNAPL transport in the vadose zone beneath the 216-Z-9 Trench
- Geostatistical analyses
- Particle tracking
- Sampling in the top of the aquifer and deep vadose zone to evaluate whether vadose-zone sources currently are impacting groundwater
- Delineating the subsurface topography of fine-grained layers that could have influenced the contaminant migration pathways, such as the top of the Cold Creek unit (CCU), in the area surrounding the three primary carbon tetrachloride waste sites.

These activities are summarized in CP-13514, *200-PW-1 Operable Unit Report on Step I Sampling and Analysis of the Dispersed Carbon Tetrachloride Vadose Zone Plume*; DOE/RL-2006-58; DOE/RL-2007-22; SGW-33829, *200-PW-1 Operable Unit Report on Step II Sampling and Analysis of the Dispersed Carbon Tetrachloride Vadose-Zone Plume*; and other reports that are referenced in this RI report.

The comprehensive strategy for investigation of DNAPL in the 200 West Area was developed in fiscal year (FY) 2003 (DOE/RL-2001-01, Chapter 6.0). The DNAPL strategy included borehole drilling at the 216-Z-9 Trench, investigation of any continuing sources indicated by the dispersed

carbon tetrachloride plume investigation, and activities implemented by the Alternatives for Carbon Tetrachloride Source Term Location Project. This Project included (1) development of a viable conceptual model for the presence/absence of DNAPL in the vadose zone and unconfined aquifer, (2) evaluation/proposal of characterization technologies to validate the model, and (3) performance of the selected characterization activities to confirm the conceptual model that will describe the nature, extent, and mass of DNAPL. These characterization activities are summarized in DOE/RL-2006-58 and DOE/RL-2007-22.

This RI report was prepared in fulfillment of Tri-Party Agreement Milestone M-015-45A, "Submit Plutonium/Organic-Rich OU Remedial Investigation Report Including the Past Practice Waste Sites in the 200-PW-1 OU Plutonium/Organic-Rich Process Condensate/Process Waste Group OU, 200-PW-3 Organic-Rich Process Condensate/Process Waste Group OU, and 200-PW-6 Plutonium-Rich Process Condensate/Process Waste Group OU" (Ecology et al., 1989).

1.1 PURPOSE

This RI report focuses on the characterization of the 216-Z-1A Tile Field, 216-Z-9 Trench, 241-Z-361 Settling Tank, 216-A-8 Crib, 216-Z-8 French Drain, 216-Z-10 Injection/Reverse Well, the dispersed carbon tetrachloride vadose-zone plume, and the investigation of the presence and distribution of DNAPL carbon tetrachloride in the vadose zone. Data from these investigations include both existing data and data collected as part of the RI process from May 2002 to January 2007.

The data presented as part of this RI report also were evaluated to determine if sufficient data had been collected to support risk assessment and remedial decision making. The RI data evaluation is documented in D&D-30565 and summarized in Section 1.2.1. However, the baseline risk assessment will be included in the FS for this Group OU in accordance with Tri-Party Agreement Change Notice TPA-CN-146, *Change Notice for Modifying Approved Documents/Work Plans In Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records, DOE/RL-2001-01, Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units.* This RI report also provides data to support the evaluation of alternatives in the FS with regard to meeting potential applicable or relevant and appropriate requirements (ARAR) and identifies the potential for any significant data gaps that might need to be addressed prior to remedial-action decision making.

1.2 DATA EVALUATION METHODOLOGY

The data presented as part of this RI report were evaluated to determine if sufficient data had been collected to support risk assessment, the FS development and evaluation of remedial alternatives, and selection of a preferred remedy or remedies. The data evaluation process was preceded by collection and validation of the data. A DQA of the RI data was performed, and the results are presented in D&D-30565. The data were collected under the Work Plan (DOE/RL-2001-01, Chapter 4.0), based on the DQOs established for this OU (BHI-01544, *Remedial Investigation Data Quality Objective Summary Report for the 200-PW-1 Operable*

Unit Dispersed Carbon Tetrachloride Vadose Zone Plume – Step I; CP-15371; CP-15372, *Remedial Investigation Data Quality Objectives Summary Report for the 200-PW-1 Operable Unit Dispersed Carbon Tetrachloride Vadose Zone Plume – Step II*; and CP-15373, *Data Quality Objectives Summary Report for Investigation of Dense, Nonaqueous-Phase Liquid Carbon Tetrachloride in the 200 West Area*). In accordance with the quality assurance/quality control (QA/QC) procedures specified in the sampling and analysis plans (SAP) in the Work Plan (DOE/RL-2001-01, Appendices B through E), at least 5 percent of all laboratory data were validated. A summary of the data validation is presented in the DQA report, D&D-30565. Summary tables providing the frequency of detection and minimum and maximum detected values are provided in Appendix A of this RI report. In Chapter 3.0, only the analytes that were detected above background values are presented in the tables; however, all of the analyte results are presented in Appendix B.

1.2.1 Summary of the Data Quality Assessment Report for the 200-PW-1 and 200-PW-3 Operable Units

The results of the DQA of the RI data are presented in D&D-30565. The report includes assessment of the sampling and the analytical results from Boreholes C3426 and C3427 at the 216-Z-9 Trench and Borehole C4545 at the 216-A-8 Crib. It also includes an assessment of the field-screening data collected for the dispersed carbon tetrachloride vadose-zone plume investigation. This subsection summarizes the key findings from the DQA report (D&D-30565).

A quality assessment was performed on two groups of data. The first data group consisted of data from the three boreholes sampled for the RI/FS (Boreholes C3426, C3427, and C4545). The second data group consisted of data from field screening conducted to determine the extent of the dispersed carbon tetrachloride vapor plume in the vadose zone. This assessment found that, overall, the data collected are of the right type, quality, and quantity to support the decisions required in the RI/FS. Specific findings of this assessment, including the exceptions to the general good quality of the data and the impacts of those exceptions, are summarized in the following paragraphs.

1.2.1.1 Borehole C3426 (Vertical Well 299-W15-46 at the 216-Z-9 Trench)

For Borehole C3426, an adequate amount (93.2 percent) of the primary soil data required was obtained. However, Tc-99, Sr-90, and Th-232 results were not obtained at most of the planned depths. Nevertheless, measurements were obtained at reasonably nearby depths, so that adequate coverage of the subsurface lithologies was achieved. No data were obtained for hexavalent chromium at the depths corresponding to the CCU (33 to 35.5 m [108.5 to 116.5 ft] below ground surface [bgs]), so it may be necessary to use total chromium as an upper bound for hexavalent chromium in this depth range. Total chromium values are typically 30 or more times greater than the hexavalent chromium concentrations in the borehole. Except for hexavalent chromium in the CCU, modeling of contaminant distributions should not be unduly hindered by lack of data.

Detection limits exceeded the preliminary action limits for about 12.5 percent of the determinations. This is not an unreasonably large number of exceedances, and the data are

distributed over a number of contaminants of potential concern (COPC) and depths, so the usability of the data is not severely impacted. Blank sample results showed that contamination from sampling and/or laboratory operations was infrequent and minor. Overall precision, as assessed from field duplicate and split-sample results, was higher than desired, but nevertheless was judged to be usable.

Several results were qualified because the holding time limit was exceeded. The total petroleum hydrocarbon (TPH) analysis results (diesel and kerosene ranges) for sample B17N52 were rejected (flagged "UR"), because the holding time was more than two times the limit. Holding-time limits were not met for the chloride, fluoride, and sulfate analyses in sample B17N52. However, the samples were properly preserved, and holding times were less than two times the limits, so these results were qualified as approximate ("J"). Although these sample results were qualified, there still are sufficient sample results available to support remedial decisions.

1.2.1.2 Borehole C3427 (Slant Well 299-W15-48 at the 216-Z-9 Trench)

All samples specified in the SAP (DOE/RL-2001-01) were collected. However, because the base of the upper gravel-dominated sequence (H1) of the Hanford formation was not as deep as expected, no samples were taken in this stratum or at the contact of the H1 with the underlying sand-dominated unit (H2) of the Hanford formation. Therefore, data from other boreholes (e.g., C3426) must be used to characterize the H1 unit and its contact with the H2 unit.

All required analytical data were obtained for the samples, except for Aroclors[1] at the 25.8 m (84.8 ft) bgs depth. The lack of some data at this interval is not critical, because the interval is bounded by other samples in the same unit, and radical variations are not expected.

Laboratory precision and accuracy are acceptable, as determined from formal validation and examination of the field duplicate and split-sample data. However, the field duplicate analyses for the field screening vapor samples did not meet the 25 percent precision requirement of the SAP. Because these data are used to support the laboratory data, which will be used for risk evaluation and evaluation of remedial alternatives, the overall impact will not prevent decision making. The sampling and analysis precision was sufficient to detect concentration differences between sample locations, which satisfies the purpose for these samples.

Detection limits generally were satisfactory. However, because of high Pu-239 and Am-241 concentrations, detection limits for other alpha emitters were not always achieved. This is not a serious problem; the plutonium and americium will be considered in the remediation decisions because of their significant detections as alpha emitters.

Contamination of the methanol used to preserve the high-range volatile organic analyte (VOA) samples analyzed in the laboratory may result in artificially elevated values for some volatile organic compounds (VOC). However, the low-range results for most analytes at most depths were acceptable. The low-concentration range results can be used for decision making.

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[1] Aroclor is an expired trademark.

No analytical results were rejected in formal data validation. However, a number of vapor sample results from field screening for the 36 to 37.6 m (118.3 to 123.4 ft) bgs sampling interval were rejected in the DQA process. Because there are many other vapor measurements at the same depth, and because these field-screening data are used to support the laboratory data in the RI decision-making process, these rejections will have little impact.

1.2.1.3 Borehole C4545 (Vertical Borehole at the 216-A-8 Crib)

All primary soil data and QC data required were obtained for Borehole C4545. Precision and accuracy were acceptable. Detection limits exceeded limits set in the SAP only infrequently. Contamination from sampling and/or laboratory operations was infrequent and minor. No analytical results were rejected for use in the RI/FS decision-making process.

1.2.1.4 Dispersed-Plume Field Screening

For the dispersed plume, two subsets of carbon tetrachloride soil-vapor data were selected for assessment. Seven data points exhibiting high concentrations of carbon tetrachloride vapor in 1993 near the 216-Z-9 Trench were selected as representative of historical concentrations deep in the vadose zone near the release sites. Carbon tetrachloride vapor data, collected inside the security fence surrounding the PFP in accordance with the Work Plan (DOE/RL-2001-01), were selected as representative of concentrations at shallower depths and farther removed from the release sites.

The data subset collected under the Work Plan fully met the goals established in the Work Plan for that data set. The required detection limit of 1.0 parts per million by volume (ppmv) was met in all measurements. Blank sample results demonstrated that the measurements were not affected by contamination from sources other than the samples. Accuracy, as assessed by measurement of standard gas samples, and precision, as assessed by measurement of field duplicate samples, met the intent of the SAPs.

QC data were not available to support the historical data subset. Without QC data, a complete and rigorous DQA could not be performed. However, substantial indirect evidence was found to show that the data provide reasonable measures of carbon tetrachloride in the soil gas.

- The active sampling methods and QC practices used in 1993 for field-screening measurements of downhole soil vapors are similar to those used today. As documented in the DQA for Borehole C3427 and other sources, these methods easily are capable of producing quality data.

- The VOC monitoring instruments used were checked frequently and challenged periodically with calibrated gas standards (BHI-00720, *Performance Evaluation Report for Soil Vapor Extraction Operations at the Carbon Tetrachloride Site, February 1992 – September 2001*, p. 5-1).

- A spatial evaluation of the dispersed-plume results/data was conducted and the data reasonably trend from high concentrations where carbon tetrachloride was known to be discharged to negligible concentrations in areas away from the points of discharge.

These trends are qualitatively consistent with the knowledge of the release history and the physical properties of the soil.

Thus, although numerical QC data are not available, documentation provides adequate evidence that suitable equipment, sampling, and measurement methods were employed and that reasonable results were obtained. These field-screening results will not be used for risk evaluation. Given the large volume of soil-vapor data with consistent concentrations, the quality of the field screening is usable to support the evaluation of remedial alternatives.

The identification of COPCs is deferred to the baseline risk assessment, which will be included in the FS.

1.2.2 Human-Health Risk Evaluation

The human-health risk evaluation is deferred to the FS, in accordance with Tri-Party Agreement Change Notice TPA-CN-146, for all six representative and unique waste sites. The human-health risk assessment approach will follow four basic steps.

1. The RI sample results initially will be screened to select the applicable data set for humans and, within that data set, COPCs will be selected that could be health concerns.

2. Contaminant sources, pathways, receptors, exposure duration and frequency, and routes of exposure will be evaluated to quantitatively assess the amount of exposure to the COPCs.

3. A toxicity assessment will be performed that summarizes the carcinogenic and noncarcinogenic effects associated with the COPCs and provides toxicity values that are used to estimate the dose-response relationship.

4. Risk characterization will be performed that integrates the quantitative and qualitative results of the data evaluation, exposure, and toxicity-assessment sections.

1.2.3 Modeling Approach

The fate and transport evaluation of COPCs is deferred to the FS.

1.2.4 Ecological Risk Evaluation Methodology

The ecological risk evaluation is deferred to the FS.

1.2.5 Representative Waste-Site Approach

The concept and rationale for using representative waste sites is discussed in the Implementation Plan (DOE/RL-98-28, Section 2.5.1). By grouping sites with similar waste-site history, contaminants, location, and geology, and by then choosing one or more representative waste sites

for comprehensive field investigations, including sampling, the amount of site characterization can be reduced. Findings from site investigations at representative waste sites are extended to apply to other sites in the OU waste group that were not characterized. Sites for which field data have not been collected are assumed to have chemical and radioactive characteristics similar to those sites that were characterized. Pre-record of decision (ROD) or post-ROD confirmatory investigations of limited scope, rather than full characterization activities, can be performed at the sites not selected as representative waste sites.

Data from representative waste sites are used to evaluate remedial alternatives and to select one or more alternatives to apply for the entire OU waste group. Although a degree of uncertainty exists in employing the analogous-site concept, substantial benefit is realized in the early selection of a remedy that allows early cleanup action to be performed.

Selection of representative waste sites is fundamental to the implementation of the analogous waste-site approach. These sites often are indicative of worst case and typical conditions in an OU and, in some cases, have been characterized extensively. The representative waste sites evaluated in this RI report were identified as being representative of sites within their OU in the Implementation Plan (DOE/RL-98-28, Appendix G) and during the OU consolidation process and were confirmed through the DQO process (CP-15371). Therefore, data collected from these sites and the resulting contaminant distribution models are anticipated to be representative of the analogous waste sites in the OUs.

Existing data on each representative waste site have been assembled and evaluated to develop a conceptual understanding of the contaminant distribution beneath these waste sites. The approach that was used to further investigate, characterize, and evaluate the representative waste sites is presented in the Work Plan (DOE/RL-2001-01, Chapter 4.0). The preliminary remediation strategy for carbon tetrachloride also was identified in DOE/RL-2001-01, Chapter 6.0. This preliminary remediation strategy will be further developed in the FS, the proposed plan, and the eventual ROD for this OU. Four separate DQO processes were conducted for the Plutonium/Organic-Rich Group OU (BHI-01544, CP-15371, CP-15372, and CP-15373) to define the radiological and nonradiological contaminants to be characterized and to specify the number, type, and location of samples to be collected at the representative waste sites and the dispersed carbon tetrachloride vadose-zone plume. The results of these DQO processes formed the basis for the Work Plan (DOE/RL-2001-01, Chapter 4.0).

A proposed plan and ROD will be written to identify the preferred remedy (or remedies) for all waste sites in the OU. The ROD will include criteria for any post-ROD confirmatory sampling and analysis needed to verify that all remaining (or analogous) waste sites in the OU meet the conceptual model for the waste group. If a waste site is significantly different from, and fails to meet, the contaminant distribution model, and the selected remedy is not appropriate, the site will be reevaluated based on historical and any new information. The reevaluation could result in a decision to use a contaminant distribution model established for a different OU. The reevaluation also could result in a decision to do additional confirmatory sampling. Changes to the preferred alternative would be evaluated as needed, based on confirmatory data. The analogous waste-site approach focuses on the typical and worst-case sites as representative waste sites; therefore, data from the representative waste sites should bound the analogous waste sites within the OU. Also, the ability to use data and information from applicable waste sites outside

the OUs helps reduce the potential to reassign waste sites between OUs. A separate DQO process will be conducted to identify data needs and quality requirements to support the confirmatory sampling design.

1.3 WASTE-SITE DESCRIPTION AND HISTORY

The Plutonium/Organic-Rich Group OU consists of cribs, tile fields, settling tanks, trenches, a UPR waste site, an injection/reverse well, and a french drain that received plutonium and/or organic-rich process condensates and process wastes. Carbon tetrachloride, TBP, and commercial lard oil are the primary organic-rich contaminants discharged to the 200-PW-1 OU, which resulted in the release of carbon tetrachloride DNAPL at the waste sites and the migration of the dispersed carbon tetrachloride vadose-zone plume away from the waste sites.

Representative waste sites were selected based on similarities between contaminant distribution models. A waste site might be aligned with a representative waste site of the same OU or in a different OU because of the resemblance between contaminant distribution models in a different OU (DOE/RL-2001-01, Chapter 1.0). Data collection at representative waste sites emphasized verifying the conceptual contaminant distribution model, in addition to supporting preparation of a risk evaluation and FS. Data collection also will support remedial-action decision making for the representative waste sites and the analogous waste sites aligned with their conceptual contaminant distribution models (CP-15371).

The following sections describe the representative waste sites and the dispersed carbon tetrachloride vadose-zone plume in detail. Information was obtained from the Work Plan (DOE/RL-2001-01, Sections 2.2, 2.3, and 2.4). The six waste sites were selected as representative or unique waste sites for the following reasons.

- The 216-Z-1A Tile Field was selected as the "typical" representative source term waste site in the 200-PW-1 OU because of its plutonium and carbon tetrachloride inventory and its current level of characterization.

- The 216-Z-9 Trench was selected as the "worst case" representative source term waste site in the 200-PW-1 OU, because it has the highest plutonium inventory and a high carbon tetrachloride inventory in terms of the volume of carbon tetrachloride released, compared to the infiltration area of the receiving site.

- The 241-Z-361 Settling Tank was selected as a representative waste site in the 200-PW-1 OU, because it has a high plutonium inventory that has not been released to the environment and because of its current level of characterization.

- The 216-A-8 Crib was selected as the "worst case" representative waste site in the 200-PW-3 OU, because it has a relatively high fission product inventory compared to other waste sites in the Plutonium/Organic-Rich Group OU and a significant inventory of organic solvents including compounds other than carbon tetrachloride.

- The 216-Z-8 French Drain was identified as a unique waste site in the 200-PW-6 OU because of its previous characterization, and it is not analogous to any representative waste site.

- The 216-Z-10 Injection/Reverse Well was identified as a unique waste site in the 200-PW-6 OU because of its previous characterization, and it is not analogous to any representative waste site.

The 200-PW-1 OU includes three representative waste sites and five analogous waste sites that received mostly acidic aqueous and organic (mostly carbon tetrachloride, TBP, and lard oil) process and laboratory wastes containing large amounts of americium and plutonium and some uranium. The waste discharged to the soil column in this OU was generated at the Z Plant Complex (now referred to as the PFP Complex) from 1949 through 1973.

The 200-PW-3 OU includes one representative waste site and four analogous waste sites. The 200-PW-3 OU waste sites received organic-rich wastes (primarily refined kerosene [NPH], TBP, and butanol) from the A Plant (PUREX process). The waste can be classified as ranging from acidic to basic, with moderate amounts of uranium and plutonium and small amounts of fission products (except the 216-A-8 and 216-A-24 Cribs, which received larger amounts of fission products).

The 200-PW-6 OU includes two unique waste sites and two analogous waste sites. The waste sites received neutral/basic process wastes from the Plutonium Isolation Facility, which operated from approximately 1945 to 1949, and from the recovery of uranium and plutonium by extraction (RECUPLEX) process, which recovered plutonium from Z Plant liquid and solid scraps from 1955 to 1962. The 200-PW-6 OU waste sites received plutonium-rich wastes from the PFP Complex, but did not receive organic-rich wastes from that complex (DOE/RL-2006-51).

Summary information on the six representative and unique waste sites is presented in Tables 1-3, 1-4, and 1-5.

1.3.1 216-Z-9 Trench

The 216-Z-9 Trench is located in the 200 West Area, about 213 m (700 ft) east of the 234-5Z Building and 152 m (500 ft) south of 19th Street (Figure 1-2). The 216-Z-9 Trench consists of a 6 m (20-ft)-deep excavation with a 37 by 27 m (120- by 90-ft) concrete cover. The walls of the trench slope inward and downward to the 18 by 9 m (60- by 30-ft) floor space, which had a slight slope to the south. The underside of the concrete cover was paved with acid-resistant brick/tiles. The cover of the trench is supported by six concrete columns. Figure 1-5 shows the 216-Z-9 Trench construction.

From July 1955 through June 1962, the 216-Z-9 Trench received all solvent and aqueous wastes from the RECUPLEX process that operated in the 234-5Z Building (e.g., Z Plant). To help present how the plutonium- and organic-rich contaminants were commingled in the liquid wastes discharged to the 216-Z-9 Trench, the following brief description of the RECUPLEX operation

is summarized from WHC-SD-EN-TI-248, *Conceptual Model of the Carbon Tetrachloride Contamination in the 200 West Area at the Hanford Site.*

The RECUPLEX process used nitric and hydrofluoric acids to produce soluble plutonium as plutonium nitrate and a carbon tetrachloride-TBP solvent to recover the plutonium from the plutonium nitrate solutions. A criticality accident forced the closure of the RECUPLEX process in April 1962.

Two solvents were used for the entire period of RECUPLEX operation. An 85:15 ratio (by volume) of carbon tetrachloride to TBP was used in the extraction and stripping columns for the bulk of the separations. A 50:50 ratio of carbon tetrachloride to dibutyl butyl phosphonate (DBBP) was used for batch rework of process liquids that did not meet waste-discharge specifications because of plutonium concentrations. With exposure to ionizing radiation and nitric acid, the TBP in the solvent gradually would degrade to dibutyl phosphate (DBP). DBP has a much greater affinity for plutonium than TBP and would not work in the process because of its poor stripping properties. The degraded solvent was periodically discharged batch-wise and replaced with fresh solvent. The DBBP solution was discharged after each use. 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 Pu-239/240 and Am-241.

Tetrachloroethylene and tetrabromoethane were used at different times in combination with carbon tetrachloride as a diluent for TBP or for cleaning agents (ARH-2915, *Nuclear Reactivity Evaluations of 216-Z-9 Enclosed Trench*). Degradation products of carbon tetrachloride include chloroform and methylene chloride. Breakdown products of TBP include DBP, monobutyl phosphate, and butyl alcohol.

Another source of carbon tetrachloride discharged to the soil was in a cutting oil used in the Z Plant. "Fabrication oil" (a 75:25 volumetric mixture of carbon tetrachloride and lard oil) was used as a lubricant on Z Plant plutonium cutting and milling tools. In 1967, the composition of stored fabrication oil was estimated to be a 50:50 volumetric mixture of carbon tetrachloride and lard oil from the evaporation of carbon tetrachloride. The carbon tetrachloride also was used to clean the cutting oil from the millings and work surfaces. The carbon tetrachloride/oil mixture was disposed of to the same waste sites where solvent was disposed of.

The 216-Z-9 Trench received approximately 4.1 million L (1.1 Mgal) of high-salt, acidic, aqueous, and organic liquid waste from the RECUPLEX process. Material discharged to the trench reportedly included 130,000 to 480,000 kg (286,600 to 1,058,219 lb) of carbon tetrachloride, 8,580 Ci of Am-241, and 500,000 kg (1,102,310 lb) of nitrate (DOE/RL-91-58, *Z Plant Source Aggregate Area Management Study Report*; DOE/RL-96-81, *Waste Site Grouping for 200 Areas Soil Investigations*). The carbon tetrachloride was discharged to the 216-Z-9 Trench in combination with other organics, and as a small entrained fraction of process aqueous wastes, and as DNAPL.

When the 216-Z-9 Trench was retired in 1962, it had received approximately 50 to 150 kg (110 to 330 lb) of plutonium. The bulk of this material was expected to be bound to the upper

few inches of sediments and sludge in the bottom of the trench. Subsequent sampling and soil-removal activities have shown that soil penetration was more extensive than expected.

Mining took place at the 216-Z-9 Trench in 1976 and 1977 to remove plutonium. The upper 0.3 m (1 ft) of soil was removed from the floor of the trench. The mining operation removed an estimated 58 kg (128 lb) of plutonium. Based on data acquired during the mining operation, an estimated 48 kg (106 lb) of plutonium remains in the 216-Z-9 Trench (RHO-ST-21, *Report on Plutonium Mining Activities at 216-Z-9 Enclosed Trench*). The plutonium-contaminated sediment and sludge recovered during the mining operation was drummed and disposed of in Trench T-01 of the 218-W-4C Burial Ground. The 6.4 m (21-ft)-deep open space beneath the concrete cover over the 216-Z-9 Trench remains void of soil and contains only the mining equipment (DOE/RL-91-58, RHO-ST-21, ARH-2915). The concrete cover has an uncertain life-span.

No UPRs were associated with this trench.

1.3.2 216-Z-1A Tile Field

The 216-Z-1A Tile Field is located in the 200 West Area, about 153 m (500 ft) south of the 234-5Z Building and immediately south of the 216-Z-1 and 216-Z-2 Cribs and adjacent to the 216-Z-3 Crib (Figure 1-2). The tile field piping consists of 20 cm (8-in.)-diameter perforated vitrified clay pipe placed on a 1.5 m (5-ft)-deep gravel bed, 4 m (14 ft) bgs (Figure 1-6). The piping consists of a 79 m (260-ft)-long north-south trunk or main pipeline with seven pairs of 21 m (70-ft) laterals spaced at 11 m (35-ft) intervals in a centered, herringbone pattern. The piping system was overlaid with 15 cm (6 in.) of cobbles and 1.5 m (5 ft) of sand and gravel.

The tile field was used in this configuration from 1949 to 1959. The waste stream discharged to the adjacent 216-Z-1 and 216-Z-2 Cribs (1949-1952) and the 216-Z-3 Crib (1952-1959) that overflowed to the tile field consisted of neutral to basic (pH 8 to 10) process waste and analytical and development laboratory waste from the Z Plant via the 241-Z-361 Settling Tank. The total volume discharged from 1949 to 1959 was approximately 1 million L (264,172 gal).

Before the 216-Z-1A Tile Field was reactivated in 1964, a sheet of 0.05 cm (0.02-in.)-thick polyethylene and a 30 cm (1-ft)-thick layer of sand and gravel were added, and the liquid waste discharge piping was routed directly to the central distributor pipe in the tile field. Between 1964 and 1969, a 5 cm (2-in.)-diameter stainless steel pipe was progressively inserted inside the central distributor pipe to divide the tile field into three operational sections (216-Z-1AA, -1AB, and -1AC). During that period, the tile field received the aqueous and organic waste from the Plutonium Reclamation Facility (PRF). No other waste disposal site received PRF wastes during that period, except on two brief occasions while modifications were being made to the piping system. On those two occasions, the waste was discharged to the adjacent 216-Z-1 and 216-Z-2 Cribs.

Wastes from the PRF were discharged from 1964 to 1969 to the 216-Z-1A Tile Field (and the associated 216-Z-1 and 216-Z-2 Cribs). The PRF replaced RECUPLEX in 1964 and operated until 1979. The PRF had essentially the same mission as RECUPLEX and used similar but superior solvent-extraction-column technology. An 80:20 ratio (by volume) of carbon

tetrachloride to TBP was used as the extractant. An americium recovery system was installed in the 242-Z Waste Treatment Facility in 1964. The process used a 70:30 volumetric mixture of carbon tetrachloride and DBBP. Between 1964 and 1970, americium was recovered by a batch operation.

From 1964 to 1969, the 216-Z-1A Tile Field received approximately 5.2 million L (1.37 Mgal) of liquid waste from Buildings 234-5Z (PFP), 236-Z (PRF), and 242-Z (Waste Treatment Facility), and miscellaneous laboratory waste. Material discharged to the tile field reportedly included 57 kg (126 lb) of plutonium, 268,000 kg (591,000 lb) of carbon tetrachloride, 30,000 kg (66,000 lb) of TBP, 20,300 kg (44,800 lb) of DBBP, 3,430 Ci of Am-241, and 3,000 kg (6,615 lb) of nitrate (DOE/RL-91-58, DOE/RL-96-81). The carbon tetrachloride was discharged to the 216-Z-1A Tile Field in combination with other organics, and as a small entrained fraction of process aqueous wastes, and as DNAPL.

No UPRs were associated with the 216-Z-1A Tile Field.

1.3.3 241-Z-361 Settling Tank

The 241-Z-361 Settling Tank is located approximately 35 m (115 ft) north of the 216-Z-1A Tile Field (Figure 1-2). The 241-Z-361 Settling Tank is an underground reinforced-concrete structure 8.5 m (28 ft) long and 4.5 m (15 ft) wide, with a 1 cm (3/8-in.)-thick steel liner. The tank has inside dimensions of 7.9 by 4.0 m (26 by 13 ft) with 0.3 m (1-ft)-thick walls. The bottom slopes, resulting in an internal height variation between 5.2 and 5.5 m (17 and 18 ft). The top is 0.6 m (2 ft) below grade. Two 15 cm (6-in.)-diameter stainless steel inlet pipes from the 241-Z Treatment and Storage Tanks enter the settling tank from the north. A single 20 cm (8-in.)-diameter stainless steel pipe exits the tank from the south. Several risers are visible above grade. The plan view of the 241-Z-361 Settling Tank, indicating location and identification of tank risers, is presented in Figure 1-7, and the side view of the 241-Z-361 Settling Tank is presented in Figure 1-8.

The tank served as the primary solids settling tank for liquid waste from the 234-5Z, 236-Z, and 242-Z Buildings from 1949 to 1973. Effluent in the tank was discharged to the 216-Z-1A Tile Field, 216-Z-1 and 216-Z-2 Cribs, and the 216-Z-3 Crib. When the tank was in use, the contents were neutralized by adding fly ash, and later sodium hydroxide, to raise the pH to the 8 to 10 range. Liquid samples collected in March 1975, however, had a pH as low as 4. Before this characterization, it was assumed that the pH was greater than 2, which renders the plutonium mostly insoluble (HNF-8735, *241-Z-361 Tank Characterization Report*).

After 25 years of service, approximately 239 cm (94 in.) (height) or 62.7 m^3 (82.05 yd^3) of solids remain in the tank. Sludge samples collected from various depths in the tank from 1975 to 1985 indicate that plutonium concentrations range from 0.09 to 1.00 g/L of sludge. Based on these measurements, the inventory in the tank was estimated to be between 26 and 75 kg (57.3 and 165.4 lb) of plutonium.

Additional sampling was conducted from 1999 to 2001 (HNF-8735). Phase I activities included opening of the 241-Z-361 Settling Tank in 1999. A high-efficiency particulate air (HEPA) filter was installed on a passive vent, which then was monitored for combustible vapors, and a

tank-headspace vapor sample was collected and analyzed for VOCs. Volatile and semivolatile organics present in the tank included Freon[2], chloroform, tetrachloroethylene, isobutane, methylcyclopentane, trichloroethylene, and carbon tetrachloride. Phase I also included an inspection of the inside of the tank using a video camera.

Phase II activities included collection of two full-depth sludge core samples from the tank for detailed chemical analysis, and collection of tank-headspace vapor samples during sludge sampling to evaluate the potential for release of volatile compounds by disturbance of the sludge. Downhole nondestructive assay techniques were used in the existing aluminum dry wells in the 241-Z-361 Settling Tank to provide additional information on the distribution of radioisotopes in the sludge.

Helical piers were installed in 1999 to support an above-ground structure for sampling the tank. These piers extend beneath the depth of the tank bottom, and some are within a few feet of the tank, allowing monitoring of potential radiological contamination upon their removal.

Characterization of the tank and sludge indicated the following.

- About 25 kg (55 lb) of Pu-239 and about 4 kg (8.8 lb) of other fissile isotopes (primarily Pu-240) remain in the tank.
- The pH of the sludge suggests that the plutonium is insoluble, thus limiting mobility in the event of a leak.
- Very low concentrations of potentially hazardous materials such as ammonia, nitrates, and organic compounds are in the sludge.
- Headspace sampling indicates that flammable-gas concentrations are far below the lower flammability limit.

In-tank video records suggest that imminent structural failure of the tank is not a concern.

1.3.4 Dispersed Carbon Tetrachloride Vadose-Zone Plume

Before the dispersed-plume RI, carbon tetrachloride had been found throughout the vadose zone within a 0.2 km^2 (0.1 mi^2) area that included the known carbon tetrachloride waste sites near PFP (BHI-00720). Within this area, carbon tetrachloride had been found both within and beyond the boundaries of the known waste sites. Because one of the main purposes of the dispersed-plume RI was to determine its extent, the size and scale of the dispersed carbon tetrachloride vadose-zone plume investigation area was quite large. Laterally, the investigation area was defined as the area outside of the known waste sites to the boundaries of the carbon tetrachloride groundwater plume that underlies an 11 km^2 (4.2 mi^2) area within the 200 West Area. Vertically, the investigation area included the entire vadose zone from the ground surface to the

[2] Freon is a trademark of E. I. du Pont de Nemours and Company, Wilmington, Delaware.

water table, which varies in depth from about 40.2 m (132 ft) to greater than 75 m (246 ft) in the 200 West Area.

The main contributor of carbon tetrachloride in the 200 West Area was releases of waste from the PFP Complex. To focus the dispersed-plume RI, seven potential modes of carbon tetrachloride release were identified that may be associated with the carbon tetrachloride in the environment. These release modes included leaks from drums of carbon tetrachloride in the drum storage area; releases of heating, ventilation, and air conditioning system condensate to engineered waste sites; plant process releases to the ground; leaks from plant process piping and drains to the ground under the PFP; leaks from effluent-discharge pipelines; deliberate discharges through engineered liquid waste sites such as the 216-Z-1A Tile Field and the 216-Z-9 Trench; and releases from burial grounds. The release modes are depicted in Figure 1-9. In addition to investigating the seven potential release modes, the dispersed-plume RI included investigation of the deep vadose zone and the top of the aquifer in eight areas of persistent carbon tetrachloride concentrations in the groundwater plume. The scope of these investigations is described in Section 2.4.

1.3.5 216-A-8 Crib

The 216-A-8 Crib is located approximately 177 m (580 ft) east of the A Tank Farm (Figure 1-3). The bottom dimensions of the crib are 259 by 6 m (850 by 20 ft). The long axis of the crib trends to the east-northeast. A 61 cm (24-in.)-diameter, Schedule 20, perforated distribution line extends the length of the crib and rests on a 2 m (6.5-ft)-thick layer of rock capped by a 30 cm (12-in.)-thick layer of gravel (Figure 1-10). The gravel fill is mounded over the distribution line. Two layers of Sisalkraft paper[3] cover the gravel and prevent overlying native sand backfill from filling the void space. The crib floor was excavated to a uniform elevation of 195 m (639.5 ft) above mean sea level. The depth of the excavation varied from 4.9 to 5.8 m (16 to 19 ft) below the 1955 ground surface. The site was surface stabilized in September 1990 by the addition of 0.6 m (2 ft) of clean fill (DOE/RL-92-04, *PUREX Plant Source Aggregate Area Management Study Report*). Water entered the crib through the 216-A-508 Diversion Box, located due west of the crib. The crib was permanently isolated in April 1995 by filling the 216-A-508 Control Structure with concrete.

The 216-A-8 Crib received vapor condensate from the operation of several ventilation systems associated with the A, AX, AY, and AZ Tank Farms. The A Tank Farms complex first received self-boiling waste from PUREX in early 1956. The self-boiling waste generated a vapor phase that contained radioactive, organic, and inorganic contaminants. Between 1955 and 1958, the vapor phase was mixed directly with cooling water in two contact condensers, resulting in a large volume of liquid waste. During this time, the crib received more than 99 percent of its reported uranium load, 98 percent of its plutonium load, and 83 percent of its beta fission-product load. Approximately 87 percent of the liquid waste, by volume, that the crib received during its 30-year-long operational life came from the contact condenser system during these 30 months (DOE/RL-92-04).

[3] Sisalkraft (paper) is a trademark of Fortifiber Corporation, Los Angeles, California.

In 1960, a surface condenser system was installed in the 241-A-401 Tank Farm Condenser Pit to replace the contact condenser system. This system used cooling water in pipe coils to indirectly contact (i.e., chill) the vapor phase. This condensation system reduced the volume of liquid waste sent to the crib but increased the concentration of most contaminants in the waste. The 241-A-702 Tank Farm Fan House replaced the 241-A-401 Tank Farm Condenser Pit in 1969 and provided de-entrainment filters to control non-condensable vapors exiting the surface condensers. Between 1966 and 1976, the 216-A-8 Crib received more than 149 million L (39.4 Mgal) of liquid waste from the surface condenser system. During this time, the AY and AZ Tank Farms were added to the then-active A and AX Tank Farms. Process changes at PUREX, or in tank farm operations, reduced the concentration of uranium and plutonium transported in vapors to the surface condenser system. The 216-A-8 Crib also received 600 L (158.4 gal) of surface condenser liquid waste in 1978.

In the early 1980s, surface condenser systems were installed on individual tanks in the AY and AZ Tank Farms. In these systems, the condensed vapor was routed back to the tank. Because the cooling water in the pipe coils could become contaminated by a coil failure or pinhole leak, the waste stream was discharged to cribs. The cooling water routinely would have no, or minimal amounts, of contamination. The 216-A-8 Crib received cooling water from the individual surface condensers in 1983 and from 1984 to 1985.

Over its operational life, the 216-A-8 Crib received an estimated 1.15 billion L (303.8 Mgal) of process effluent, which is estimated to be greater than 30 times the pore volume beneath the site (DOE/RL-92-04, DOE/RL-96-81). The hazardous chemical inventory for the 216-A-8 Crib was previously estimated as 320,000 kg (705,479 lb) of ammonium carbonate, 130,000 kg (286,600 lb) of DBP, and 50,000 kg (110,231 lb) of hexone (WHC-EP-0287, *Waste Stream Characterization Report*). Earlier estimates of the inventory also included 46,000 kg (101,412 lb) of NPH (refined kerosene) (DOE/RL-96-81). However, when the potential dilution factor from the contact condenser system and the potential concentration factor from the improved surface condenser system are taken into account, the calculated quantities of DBP and NPH are only approximately 24,030 kg (52,977 lb) and 8,400 kg (18,519 lb), respectively. Based on additional evaluations, the inventory of hexone at the 216-A-8 Crib is believed to be negligible (DOE/RL-2001-01, Section 2.3.2.4).

The Work Plan (DOE/RL-2001-01, Section 2.3.2.4) lists the organic inventory for the 216-A-8 Crib, based on BHI-01496, *Groundwater/Vadose Zone Integration Project Hanford Soil Inventory Model* (SIM, Rev. 0). The organic inventory (mean values), based on RPP-26744, *Hanford Soil Inventory Model, Rev. 1* (SIM, Rev. 1), includes 128,582 kg (283,470 lb) of TBP; 55,107 kg (121,488 lb) of NPH; 1,364 kg (3,007 lb) of butanol; and 0.16 kg (0.35 lb) of ammonia, which is significantly larger than the SIM, Rev. 0, values (BHI-01496). The reason for the difference in the organic inventory between the two models is the changes in the SIM inventory conceptual model for the waste site. The 216-A-8 Crib was considered at its capacity in 1958, but it was intermittently reactivated over a period of years until 1985. During the review and revision of waste-site definitions between the publication of SIM, Rev. 0 (BHI-01496), and SIM, Rev. 1 (RPP-26744), it was discovered that uncertainty existed concerning whether wastes had been discharged to the 216-A-8 Crib or the 216-A-24 Crib during the times that the 216-A-8 Crib was either inactive or intermittently active (1971-1978). After the 216-A-8 Crib was taken out of service, waste was diverted to the 216-A-24 Crib. The

216-A-24 Crib received PUREX organic waste. These uncertainties were the result of operational issues at the 216-A-508 Diversion Box during the period and, because of the ambiguity surrounding these occurrences, the SIM, Rev. 1, assumed that a significant volume of PUREX organic waste was diverted to, and discharged at, the 216-A-8 Crib.

The Work Plan (DOE/RL-2001-01, Section 2.3.2.4) listed the radionuclide inventory for the 216-A-8 Crib, based on BHI-01496. The radionuclide inventory (mean values), based on RPP-26744, decayed through January 1, 2001, includes 8.6 Ci of Sr-90; 2,410.3 Ci of Cs-137; 24,560.8 Ci of H-3 (tritium); 390.8 kg (861.57 lb) of total uranium; and 3.9 Ci of Pu-241 (RPP-26744). The radionuclide inventory also increased as a result of the changes in the SIM inventory conceptual model for the waste site.

1.3.6 216-Z-8 French Drain

The 216-Z-8 French Drain is located east of the 234-5Z Building, and approximately 94 m (308 ft) northwest of the 216-Z-9 Trench in the 200 West Area (Figure 1-4).

The french drain bottom dimensions form a 1.5 by 1.5 m (5 by 5 ft) square with angled walls. The bottom 0.9 m (3 ft) of the excavation is backfilled with clean, graded gravel. A seal of building paper was laid over the gravel with a 0.9 m (3-ft)-diameter hole to match the two sections of a 0.9 m (3 ft) vitrified clay pipe placed end-to-end, over the hole. A concrete collar was poured around the bottom of the clay pipe, on the top of the building paper. The clay pipe also was filled with gravel and capped with building paper and a wire-mesh-reinforced concrete slab to seal the top of the structure. The overflow pipe from the 241-Z-8 Settling Tank entered through the center of the french drain's concrete cap. Woven wire mesh was placed at the opening of the pipe into the french drain to ensure a void space at the waste inlet. The entire structure was backfilled, resulting in the top of the structure being 2.5 m (8 ft) below grade. Waste overflow entered the gravel-filled excavation at 4.4 m (14 ft) below grade from the 241-Z-8 Settling Tank. The total volume filled with gravel in the french drain was more than 4 m^3 (141 ft^3). The french drain was designed assuming a net porosity of 30 percent, such that more than 1,000 L (265 gal) of solution could be accommodated. This was sufficient capacity to permit the waste solution to percolate into the sediments beneath the french drain between batch discharges of waste and rinse water from the 241-Z-8 Settling Tank (RHO-RE-EV-46P, *216-Z-8 French Drain Characterization Study*).

The 216-Z-8 French Drain received low-level plutonium-contaminated waste from the 234-5Z Building from 1955 to 1962. No organic waste was discharged to the 216-Z-8 French Drain. The waste stream was dilute and nearly neutral, with no fission or activation product content, and was relatively low in both disposal rate and total disposal volume. It is estimated that 9,590 L (2,530 gal) of liquid waste containing an estimated 48.2 g (1.7 oz) of plutonium overflowed from the 241-Z-8 Settling Tank to the 216-Z-8 French Drain by the time the French drain was retired in 1962 (RHO-RE-EV-46P).

1.3.7 216-Z-10 Injection/Reverse Well

The 216-Z-10 Injection/Reverse Well is located approximately 30.5 m (100 ft) east of the 231-Z Building in the 200 West Area (Figure 1-4). The 216-Z-10 Injection/Reverse Well also has been known as the 231-W Reverse Well, 231-W-151 Dry Well or Reverse Well, 231-Z Well, 299-W15-51, 231-W-150, and 216-Z-2.

The 216-Z-10 Injection/Reverse Well was drilled in September 1944. The well was 0.15 m (6 in.) in diameter and constructed of Schedule 40 steel pipe. The drilling log reported depth to bottom at 45.7 m (150 ft) bgs and a capped flange extending approximately 0.31 m (1 ft) above grade. Three inlet pipes enter the well, at 1.5 m (5 ft), 1.8 m (6 ft) and 2.1 m (7 ft) bgs. Historical drawings suggest that a 1.3 cm (0.5-in.) copper tube extends from ground surface to 5.1 m (2 ft) bgs, where it enters the 216-Z-10 Injection/Reverse Well, and may extend to the well bottom. The well was perforated from 36 to 45.7 m (118 to 150 ft) bgs, with a cement plug in the bottom. On November 24, 1944, the well was tested with 7,571 L (2,000 gal) of water pumped into the well at a rate of 379 L (100 gal) a minute. The results of this test showed no static water 5 minutes after pumping had stopped (HW-9671, *Underground Waste Disposal at Hanford Works*). During drilling of well 299-W15-42, it was estimated that the depth to the highest recorded water table in the area of the 216-Z-10 Injection/Reverse Well was 58.22 m (191 ft) bgs. This suggests that the water table did not rise to the 216-Z-10 Injection/Reverse Well perforated intervals in later years.

The 216-Z-10 Injection/Reverse Well received process and laboratory waste from the 231-Z Building via the 231-Z-151 Sump between February and June 1945. It is estimated that 988,000 L (260,000 gal) of liquid containing up to 50 g (1.7 oz) of plutonium was discharged to the well at approximately 76 L/min (20 gal/min). No other radionuclides were reported to have been released to the 216-Z-10 Injection/Reverse Well (HW-9671).

The well plugged with sludge in June 1945 and was subsequently deactivated by capping the pipeline to the injection/reverse well west of the 231-W-151 Diversion Box (231-Z-151 Sump). The rapid reduction in the well's effectiveness was attributed to the long perforation depth subjecting the well to washing in of sand, silt, and clay during the discharge of wastes and effectively sealing the well (*Waste Information Data System* Hanford Site database [WIDS] and HW-9671).

Figure 1-1. Location of the Hanford Site.

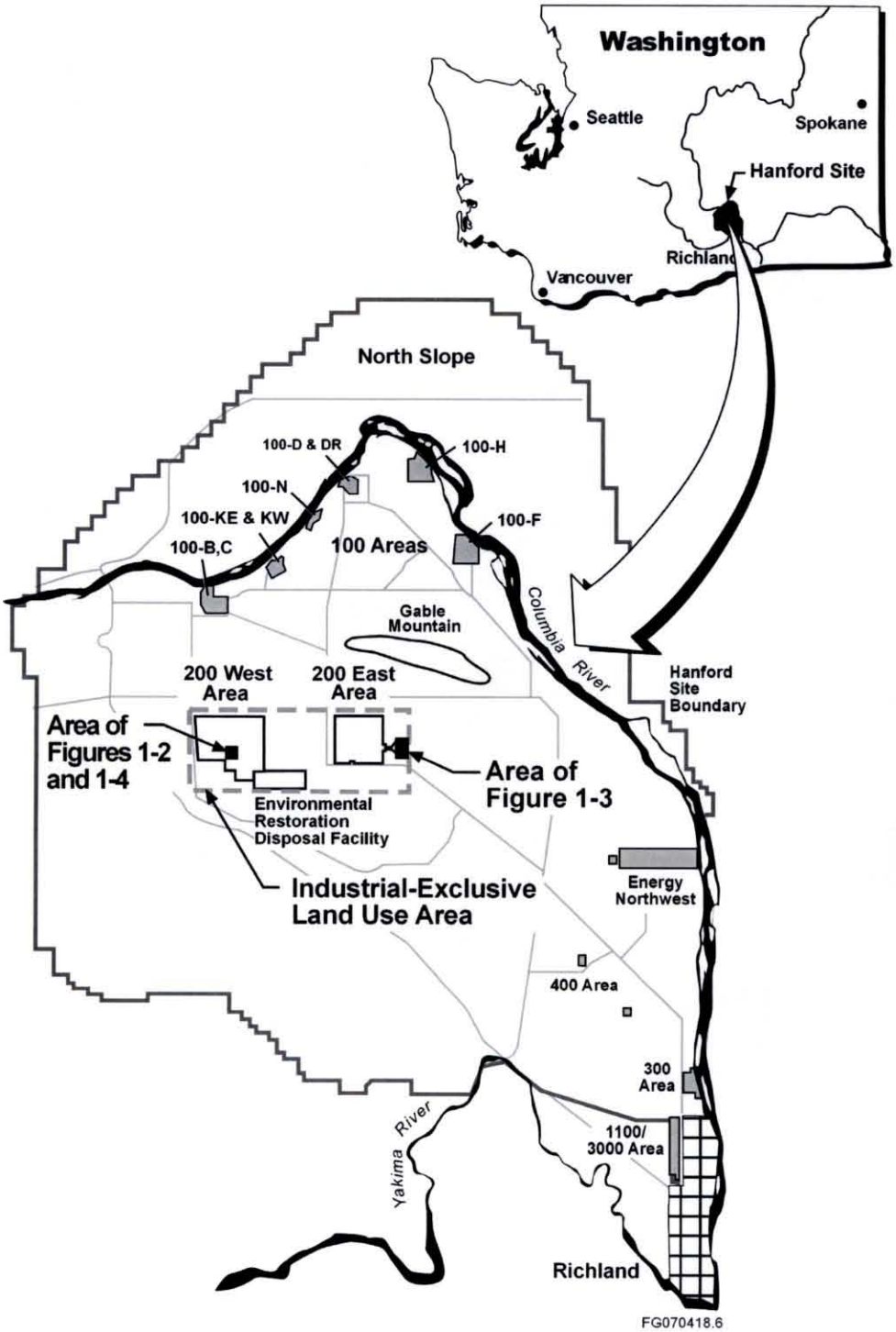


Figure 1-2. 200-PW-1 Operable Unit Waste Sites in the 200 West Area.

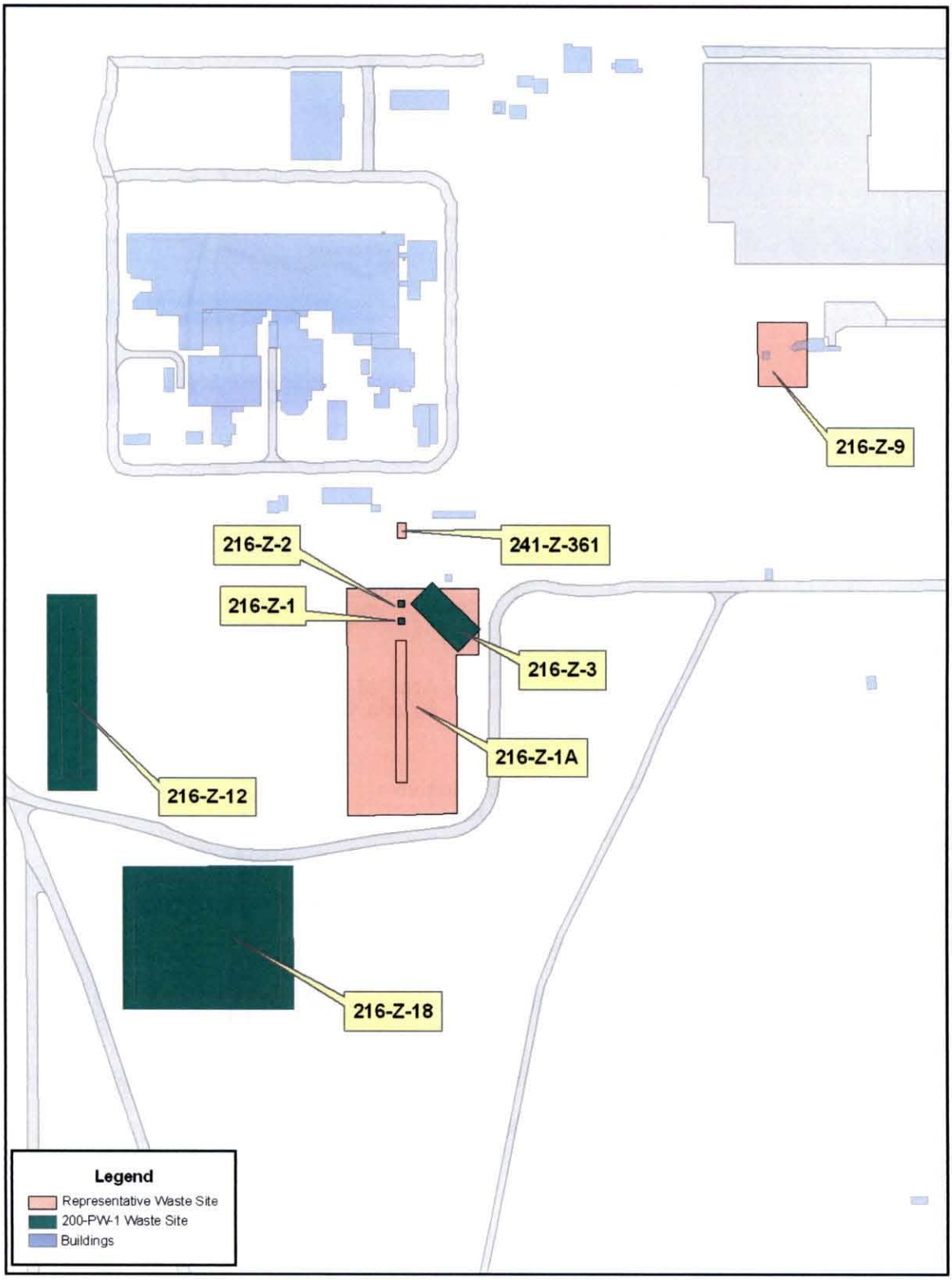


Figure 1-3. 200-PW-3 Operable Unit Waste Sites in the 200 East Area.

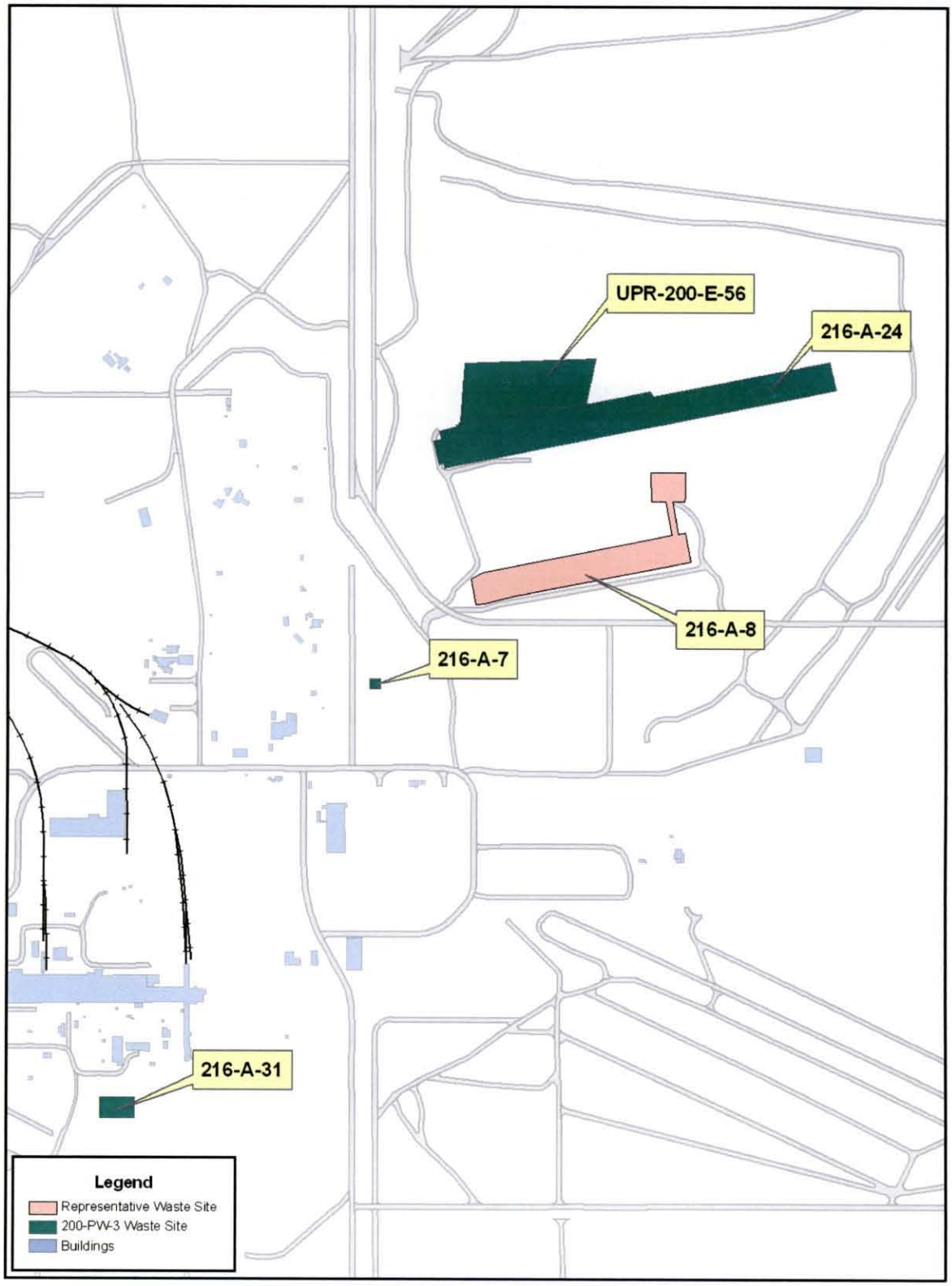


Figure 1-4. 200-PW-6 Operable Unit Waste Sites in the 200 West Area.

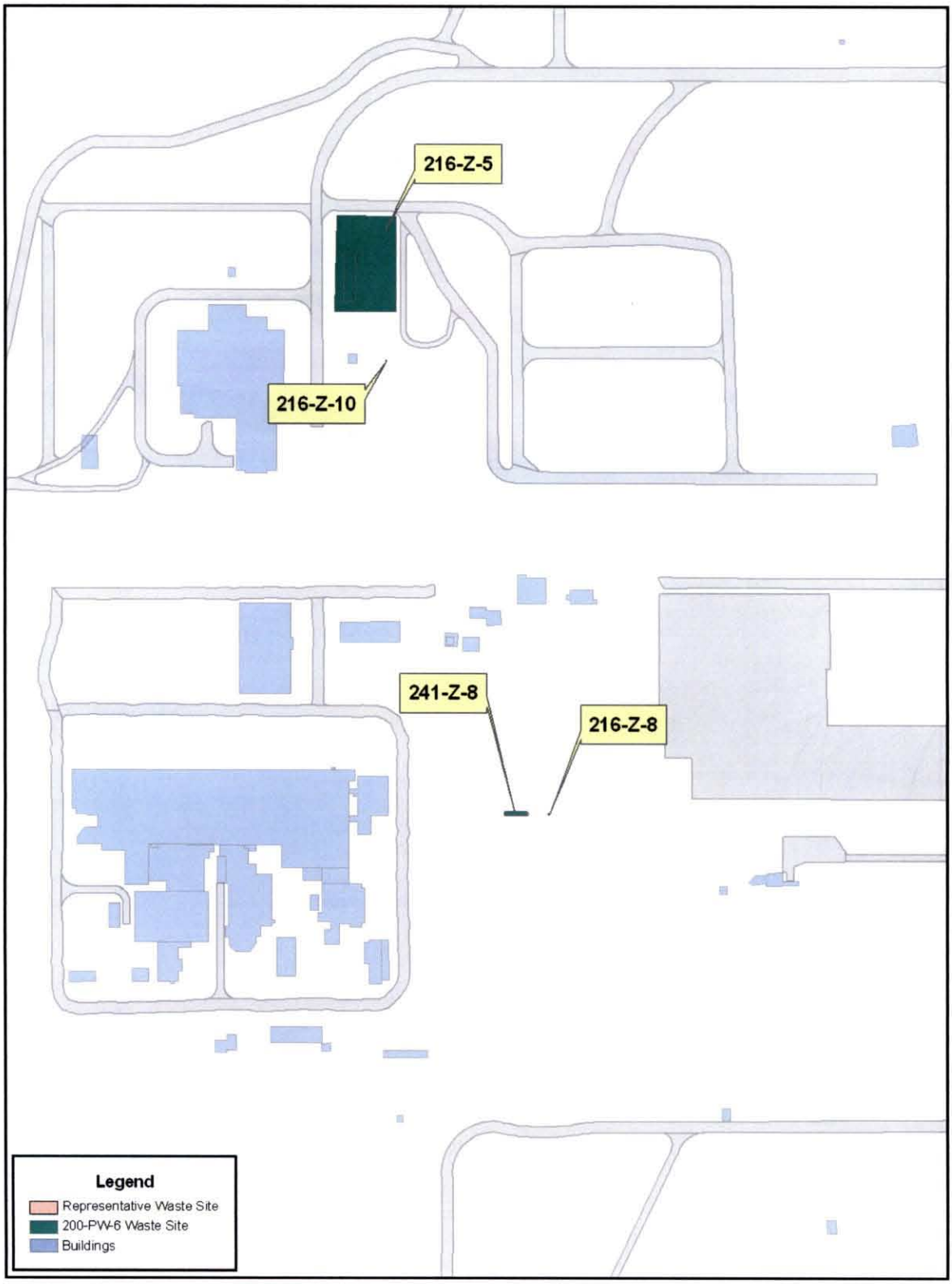
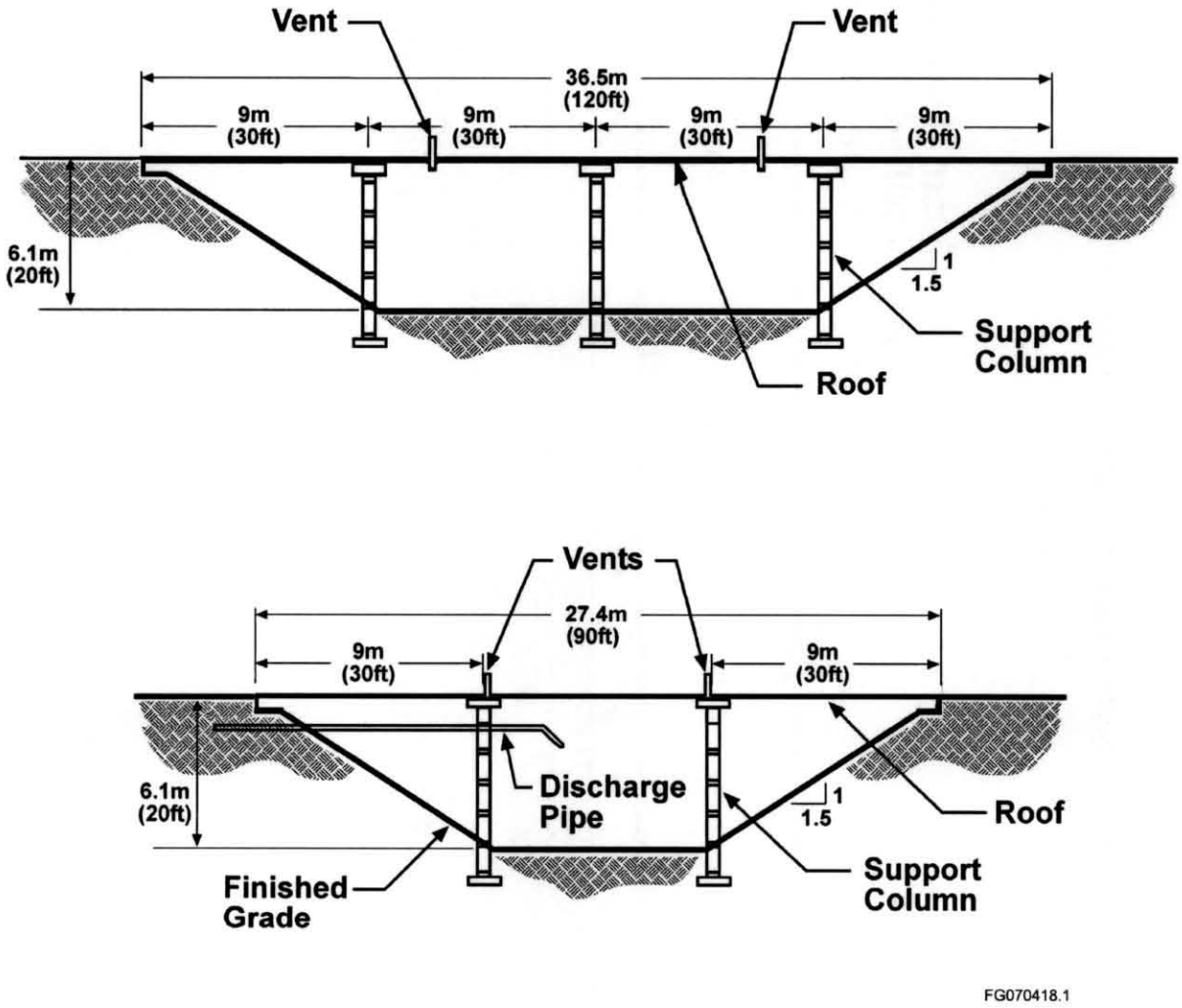


Figure 1-5. Section Views of the 216-Z-9 Trench.

(From DOE/RL-2001-01; clay brick liner also is on the underside of the concrete roof)



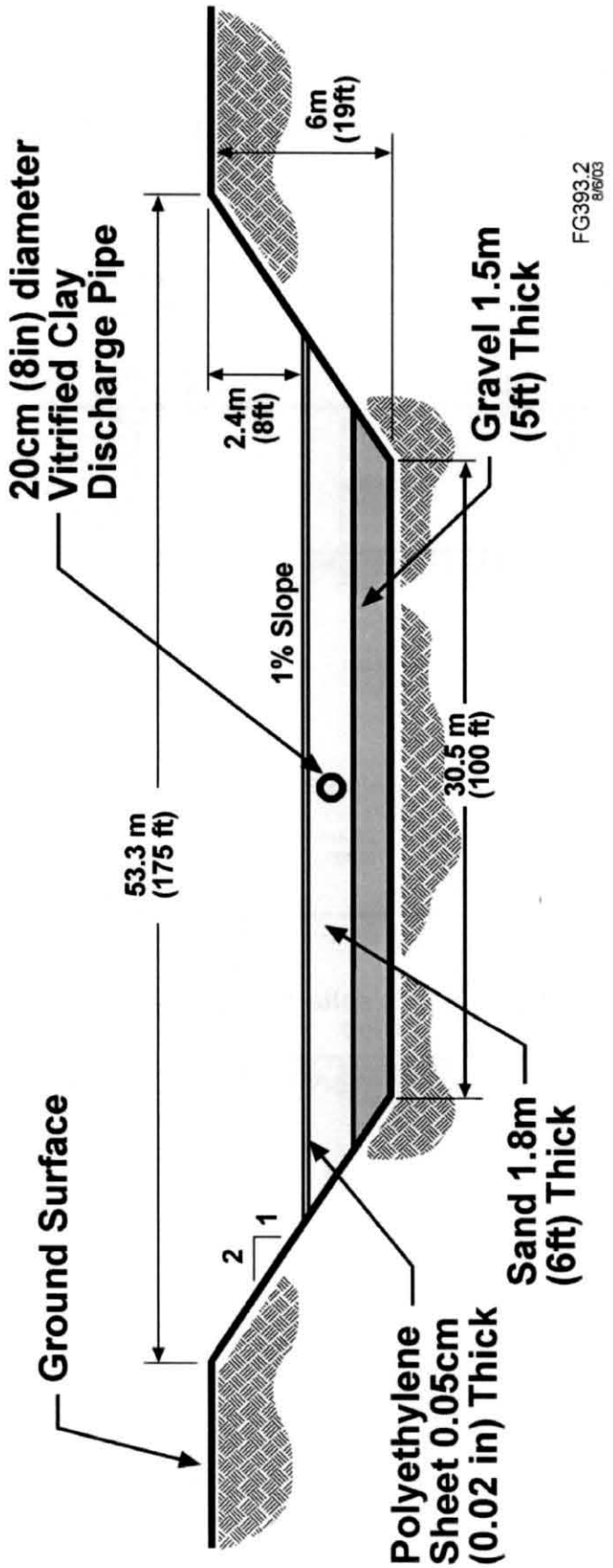


Figure 1-6. Section View of the 216-Z-1A Tile Field.

(From DOE/RL-2001-01)

Figure 1-7. Plan View of the 241-Z-361 Settling Tank, Indicating Location and Identification of Tank Risers.

(From HNF-8735).

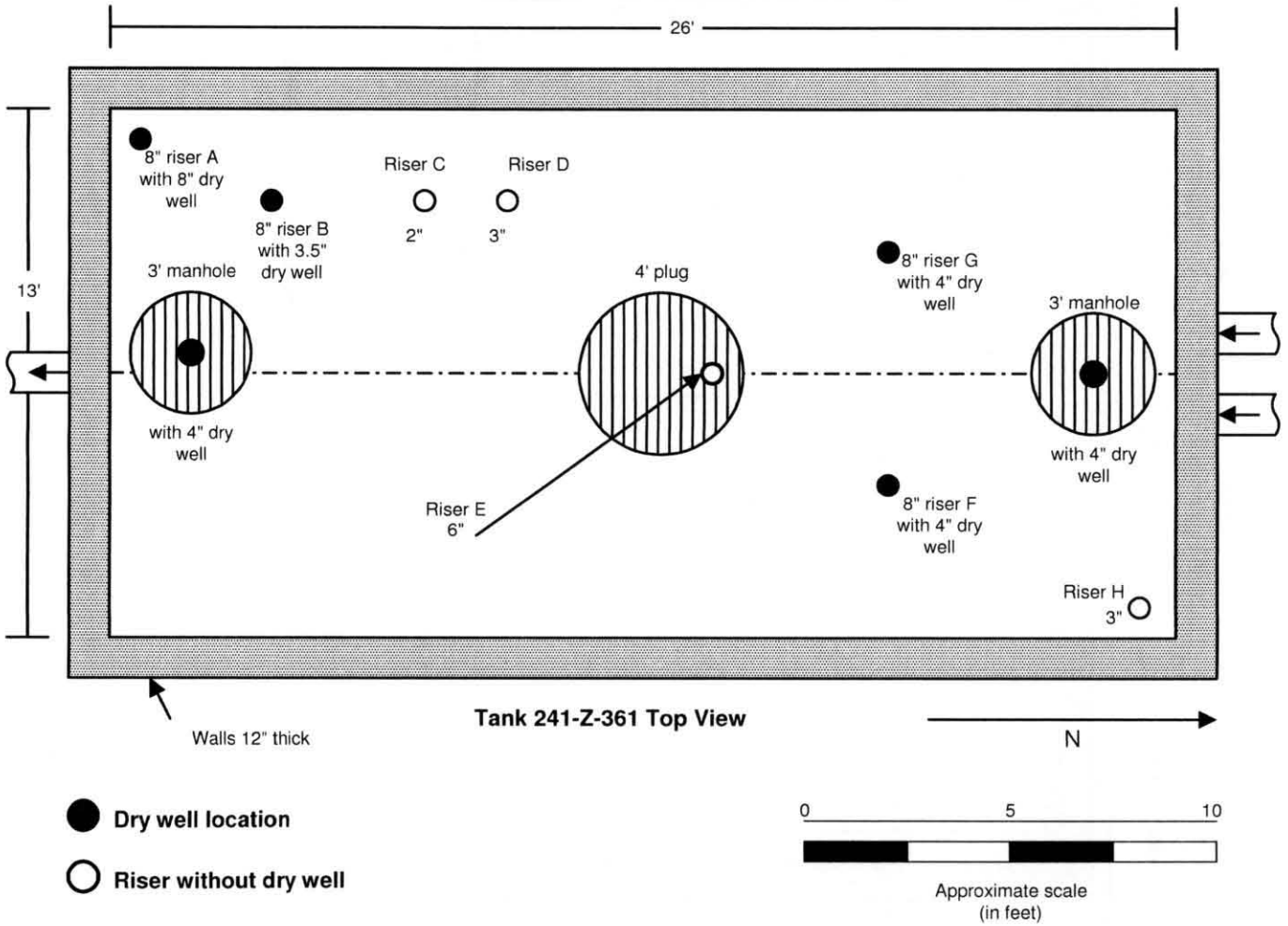
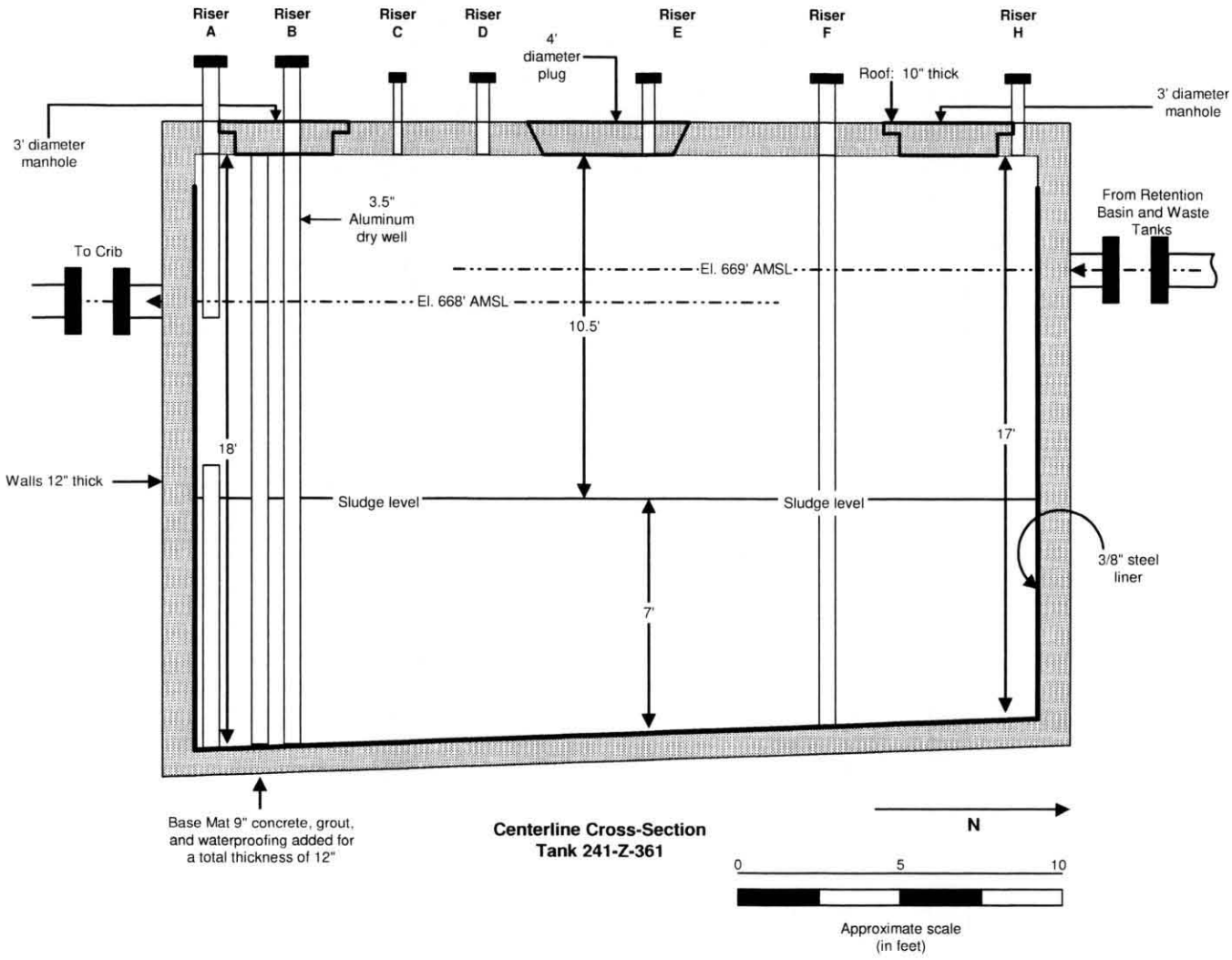


Figure 1-8. Side View of the 241-Z-361 Settling Tank.

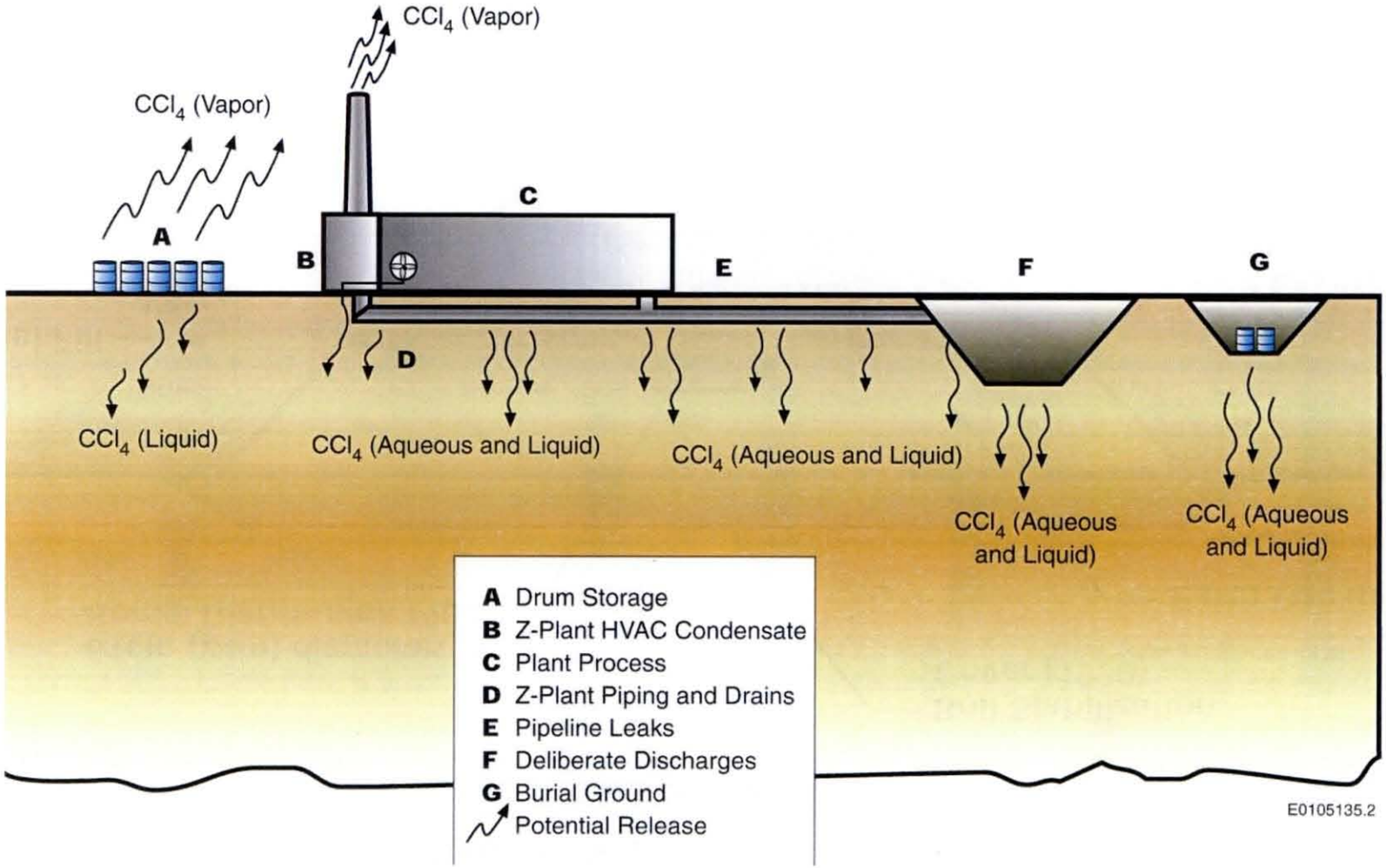
(From HNF-8735)



AMSL = above mean sea level.

Figure 1-9. Potential Carbon Tetrachloride Release Modes in the 200 West Area.

(From DOE/RL-2001-01)



HVAC = heating, ventilation, and air conditioning.

Figure 1-10. Section View of the 216-A-8 Crib.

(From DOE/RL-2001-01)

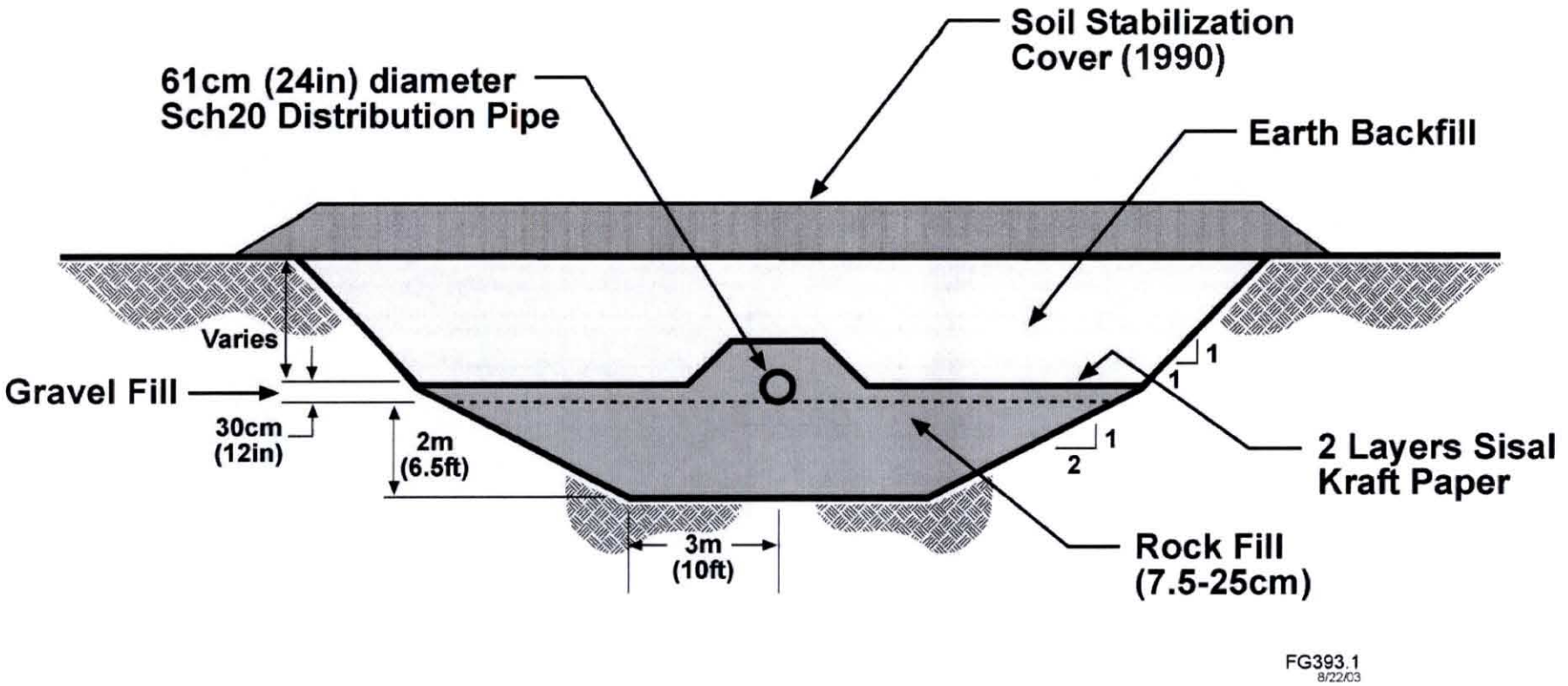


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Table 1-1. Alignment of 200-PW-1, 200-PW-3, and 200-PW-6 Operable Unit Representative or Unique and Analogous Waste Sites.

Representative or Unique Waste Site	Analogous Waste Site
216-Z-1A Tile Field[a]	216-Z-1 and 216-Z-2 Cribs[a]
	216-Z-3 Crib[a]
	216-Z-5 Crib[b]
	216-Z-12 Crib[a]
	216-Z-18 Crib[a]
216-Z-8 French Drain[b]	None
216-Z-9 Trench[a]	None
216-Z-10 Injection/ Reverse Well[b]	None
241-Z-361 Settling Tank[a]	241-Z-8 Settling Tank[b]
216-A-8 Crib[c]	216-A-7 Crib[c]
	216-A-24 Crib[c]
	216-A-31 Crib[c]
	UPR-200-E-56 unplanned release[c]

[a] 200-PW-1 Operable Unit waste site.
[b] 200-PW-6 Operable Unit waste site.
[c] 200-PW-3 Operable Unit waste site.

Table 1-2. Transfer of Waste Sites from 200-PW-1 and 200-PW-3 Operable Units to other Operable Units[a].

Waste Site	Transfer from	Transfer to
216-A-2	200-PW-3	200-MW-1[a]
216-T-19	200-PW-1	200-TW-1[a]
216-S-13	200-PW-3	200-PW-5[a]
215-S-14	200-PW-3	200-PW-5[a]
UPR-200-W-110	200-PW-1	200-CW-5[a]
UPR-200-W-125	200-PW-3	200-UW-1[b]

[a] In accordance with Federal Facility Agreement and Consent Order Change Number C-07-01, "Federal Facility Agreement and Consent Order: Transfer of Waste Sites from 200-PW-1 and 200-PW-3 Operable Units to other Operable Units."

[b] UPR-200-W-125 is being transferred to the 200-UW-1 Operable Unit in accordance with Federal Facility Agreement and Consent Order Change Number C-07-02 (approval pending).

Table 1-3. 200-PW-1 Plutonium/Organic Rich Process Waste Group Operable Unit Representative Waste Sites. (2 Pages)

Site Code	Site Name	Location	Dates of Operation	Source Facility	Contaminant/ Volume Released	Depth	Waste Site Dimensions	General Description
216-Z-1A	216-Z-1A, 216-Z-1A Tile Field, 234-5 Tile Field, 216-Z-1AA, 216-Z-1AB, and 216-Z-1AC	South of the 234-5Z facility perimeter fence and immediately south of the 216-Z-1&2 Cribs	1949 to 1969	Process and laboratory wastes from 234-5Z via the 241-Z-361 Settling Tank Overflow from the 216-Z-1, 216-Z-2, and 216-Z-3 Cribs, originally from PRF PRF wastes Uranium wastes from 236-Z Americium recovery wastes from 242-Z	6,200,000 L (1.64 Mgal) of effluent waste containing uranium, americium, plutonium, and carbon tetrachloride	--	79 x 53 m (260 x 175 ft)	The tile field is a below-grade trunk line oriented north to south with seven pairs of lateral pipes spaced in a herringbone pattern. The vitrified clay pipes lie on a gravel bed. The tile field received overflow effluent waste from the 216-Z-1, 216-Z-2, and 216-Z-3 Cribs. It was expanded in three sections known as 216-Z-1AA, 216-Z-1AB, and 216-Z-1AC.
216-Z-9	216-Z-9, 216-Z-9 Cavern, 234-5Z RECUPLEX Cavern, 216-Z-9 Trench, and 216-Z-9 Covered Trench	South of 19th Street and east of the 234-5Z Building	1955 to 1962	RECUPLEX waste including both aqueous and organics	4,090,000 L (1.1 Mgal) of effluent waste containing approximately 106 kg (234 lb) plutonium (of which an estimated 58 kg [128 lb] was later recovered, leaving 48 kg [106 lb] in the waste site), cadmium, nitrates, Am-241, and carbon tetrachloride; is highly acidic	6 m (21 ft)	37 x 27 m (120 x 90 ft)	The trench is a rectangular open structure with a concrete cover supported by six concrete columns. The underside of the concrete cover was lined with acid-resistant brick/tiles. Two stainless steel pipes were used to discharge waste to the trench. In 1973, characterization showed that it was necessary to reduce the amount of plutonium in the trench. Thus, the floor was mined for plutonium in 1976 and 1977. Approximately 58 kg (128 lb) of plutonium was recovered. In 1999, a gravel biobarrier was placed near the west side of the trench, because an alpha surface contamination adjacent to the west side of the crib resulted from an anthill.

Table 1-3. 200-PW-1 Plutonium/Organic Rich Process Waste Group Operable Unit Representative Waste Sites. (2 Pages)

Site Code	Site Name	Location	Dates of Operation	Source Facility	Contaminant/ Volume Released	Depth	Waste Site Dimensions	General Description
241-Z-361	241-Z-361 Settling Tank	South of the 236-Z Building; inside the Z Plant Complex security fence	1949 to 1973	Rubber glove line, remote mechanical A line, and remote mechanical C line Plutonium Finishing Plant process Laboratory wastes from 234-5Z via the 241-Z-361 Settling Tank Solvent and acidic aqueous wastes from the PRF in the 236-Z Building Americium recovery operations from the 242-Z Building	Approximately 750 L (200 gal) of liquid remains in the tank after pumping in 1975. 76,000 L (20,000 gal) of sludge remain (FH-0002791), containing small quantities of Am-241 and uranium, approximately 25 kg (55.12 lb) of Pu-239, 4 kg (8.82 lb) of other fissile isotopes (primarily Pu-240), very low concentrations of organics (carbon tetrachloride, tributyl phosphate), and nitrates	5.2 m (17 ft) depth of tank at inlet and 5.5 m (18 ft) depth of tank at outlet Top of tank is 1 m (2 ft) bgs	7.9 x 4 m (26 x 13 ft) length and width of tank	The site contains an underground reinforced concrete settling tank with a 3/8-in. stainless steel liner. Two 15 cm (6-in.) diameter stainless steel pipes entered the tank from the 234-5Z, 242-Z, and 236-Z Buildings via the sump tanks in the 241-Z Facility. A 20 cm (8-in.)-diameter stainless steel pipe exited the tank from the south. The tank was interim stabilized in 1985.

Updated from DOE/RL-2001-01, *Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan, Includes: 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*.

FH-0002791, "Submittal of Documentation in Fulfillment of TPA Milestone M-15-37B."

bgs = below ground surface.
PRF = Plutonium Reclamation Facility.
RECUPLEX = Recovery of Uranium and Plutonium by Extraction (Plant or process).

Table 1-4. 200-PW-3 Organic Rich Process Condensate/Process Waste Group Representative Waste Site.

Site Code	Site Name	Location	Dates of Operation	Source Facility	Contaminant/ Volume Released	Depth	Waste Site Dimensions	General Description
216-A-8	216-A-8, 216-A-8 Crib and Overflow Pond	East of the 200 East Area perimeter fence, east of the A Tank Farm	1955 to 1991	Vapor condensate from operation of several ventilation systems associated with the A, AX, AY, and AZ Tank Farms.	1,150,000,000 L (303,798,003 gal) of waste containing 390.8 kg (861.57 lb) uranium, 3.9 Ci Pu-241, 2,410.3 Ci Cs-137, 8.6 Ci Sr-90, 24,560.8 Ci tritium, 128,582 kg (283,470 lb) of tributyl phosphate, 55,107 kg (121,488 lb) of normal paraffin hydrocarbon, 1,364 kg (3,007 lb) butanol, and 0.16 kg (0.35 lb) ammonia	4 m (14 ft)	259 x 6 m (850 x 20 ft)	The crib has a 61 cm (24 in.) perforated distribution pipe placed horizontally 2 m (7 ft) below grade. The waste management unit contains 2 m (6.5 ft) of gravel fill and has been backfilled. The crib excavation is 1:2. The unit also contains four test risers, a vent riser, and two layers of Sisalkraft* paper for a barrier. The 216-A-508 Control Structure was used to divert effluent to either the 216-A-8 Crib or the 216-A-24 Crib. The 216-A-508 Control Structure is located west of the crib. Ancillary equipment includes Sampler Pit No. 2. The 216-A-8 Crib overflow occurred through a 41 cm (16-in.)-diameter pipe exiting to the north at the east end of the crib. The pipe emptied into a narrow ditch that flowed northward. A small overflow pond was excavated at the northeast end of the ditch to receive the excess wastewater from the crib. Tri-Party Agreement Milestone M-17-28 required that all discharge to the crib be ceased by September 1991. Condensate has not been discharged to the crib since early 1985. This site was surface stabilized in September 1990. The unit was permanently isolated on April 20, 1995, by filling the 216-A-508 Control Structure with concrete. The control structure filter and crib vent filters were removed and disposed of in August 1995. Radiological surveys are performed annually. Wells 299-E25-4, 299-E25-5, 299-E25-6, 299-E25-7, 299-E25-8, 299-E25-9, and 299-E25-14 monitor this unit. The data indicate that breakthrough to the groundwater has not occurred. However, the subsurface distribution of Cs-137 based on geophysical logging is uncertain. The crib and overflow areas are surrounded by chain and concrete AC-540 markers and posted with Underground Radioactive Material signs.

Updated from DOE/RL-2001-01, *Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan, Includes: 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units.*

*Sisalkraft (paper) is a trademark of Fortifiber Corporation, Los Angeles, California.

Tri-Party Agreement = *Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989).

Table 1-5. 200-PW-6 Organic Rich Process Condensate/Process Waste Group Unique Waste Sites. (2 Pages)

Site Code	Site Name	Location	Dates of Operation	Source Facility	Contaminant/ Volume Released	Depth	Waste Site Dimensions	General Description
216-Z-8	216-Z-8 French Drain	East of the 234-5Z Building, and north-west of the 216-Z-9 Trench	1955 to 1962	Overflow from the 241-Z-8 Silica Slurry Tank from the 234-5Z Building	9,590 L (2,533 gal) of liquid waste containing an estimated 48.2 g (1.7 oz) of plutonium	0.9 m bgs	1.5 m square by 0.9 m bgs	The french drain bottom dimensions formed a 1.5 by 1.5 m (5 by 5 ft) square with angled walls. The bottom 0.9-m (3 ft) of the excavation was backfilled with clean, graded gravel. A seal of building paper was laid over the gravel with a 0.9-m (3-ft)-diameter hole to match the two sections of a 0.9-m (3-ft) vitrified clay pipe placed end-to-end, over the hole. A concrete collar was poured around the bottom of the clay pipe, on the top of the building paper. The clay pipe also was filled with gravel and capped with building paper and a wire-mesh-reinforced concrete slab to seal the top of the structure. The overflow pipe from the 241-Z-8 Silica Slurry Tank entered through the center of the french drain's concrete cap. Woven wire mesh was placed at the opening of the pipe into the french drain to ensure a void space at the waste inlet. The entire structure was backfilled, resulting in the top of the structure being 2.5 m (8 ft) below grade. The 216-Z-8 French Drain received low-level plutonium-contaminated waste from the 234-5Z Building from 1955 to 1962. No organic waste was discharged to the 216-Z-8 French Drain. The waste stream was dilute and nearly neutral, with no fission or activation product content, and was relatively low in both disposal rate and total disposal volume. It is estimated that 9,590 L (2,533 gal) of liquid waste containing an estimated 48.2 g (1.7 oz) of plutonium overflowed from the 241-Z-8 Silica Slurry Tank to the 216-Z-8 French Drain by the time the french drain was retired in 1962 (RHO-RE-EV-46P).

Table 1-5. 200-PW-6 Organic Rich Process Condensate/Process Waste Group Unique Waste Sites. (2 Pages)

Site Code	Site Name	Location	Dates of Operation	Source Facility	Contaminant/ Volume Released	Depth	Waste Site Dimensions	General Description
216-Z-10	216-Z-10 Injection Well, 231-W Reverse Well, 231-W-151 Dry Well or Reverse Well, 231-Z Well, 299-W15-51, 231-W-150, and 216-Z-2	East of the 231-Z Building	February to June 1945	231-Z Building via the 231-Z-151 Sump	984,200 L (260,000 gal) of liquid containing up to 50 g of plutonium was discharged to the well at approximately 75.7 L/min (20 gal/min)	45.7 m (150 ft) bgs	Well 0.15 m (6-in.)-diameter and 45.7 m (150 ft) bgs depth	The 216-Z-10 Injection/Reverse well was drilled in September 1944. The well was 0.15 m (6 in.) in diameter and constructed of Schedule 40 steel pipe. The drilling log reported depth to bottom at 45.7 m (150 ft) bgs and a capped flange extending approximately 0.31 m (1 ft) above grade. Three inlet pipes enter the well at 1.5 m (5 ft), 1.8 m (6 ft), and 2.1 m (7 ft) bgs. Historical drawings suggest that a 1.3 cm (0.5-in.) copper tube extends from ground surface to 5.1 m (2 ft) bgs, where it enters the well and may extend to the well bottom. The well was perforated from 36 to 45.7 m (118 to 150 ft) bgs, with a cement plug in the bottom. The 216-Z-10 Injection/Reverse Well received process and laboratory waste from the 231-Z Building via the 231-Z-151 Sump between February and June 1945. It is estimated that 984,200 L (260,000 gal) of liquid containing up to 50 g of plutonium was discharged to the well at approximately 75.7 L/min (20 gal/min). No other radionuclides were reported to have been released to the 216-Z-10 Injection/Reverse Well (HW-9671). The well plugged with sludge in June 1945 and was subsequently deactivated by capping the pipeline to the reverse well west of the 231-W-151 Diversion Box (231-Z-151 Sump).

HW-9671, *Underground Waste Disposal at Hanford Works.*
RHO-RE-EV-46P, *216-Z-8 French Drain Characterization Study.*

bgs = below ground surface.

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2.0 REMEDIAL INVESTIGATION APPROACH AND ACTIVITIES

This chapter summarizes the data-collection activities performed during the Plutonium/Organic Rich Group OU RI at the representative waste sites and for the dispersed carbon tetrachloride vadose-zone plume. This summary includes tables and figures showing where the investigations were conducted, the rationale for collecting samples at specific locations or depths, and other details about the sampling methodology. The results of these RI activities are presented and discussed in Chapter 3.0.

This chapter also includes a summary of the performance evaluation of the interim-action soil-vapor extraction (SVE) that has been used since 1992 in the 200-PW-1 OU to minimize the migration of the dispersed carbon tetrachloride vadose-zone plume away from the waste sites. Because the dispersed carbon tetrachloride vadose-zone plume and its current or future potential to impact the groundwater in the 200 West Area is one of the focus areas of this RI report, this chapter also includes a summary section on the carbon tetrachloride groundwater plume in the 200-ZP-1 Groundwater OU.

The RI data-collection activities involved multiple DQO processes, SAPs, and resulting borehole summary or field reports. The following table shows the correlation between these various documents.

Investigation	Data Quality Objectives Report [a]	Sampling and Analysis Plan [a]	Field Report [a]
200-PW-1 OU Representative Site (216-Z-9 Borehole C3427)	CP-15371	DOE/RL-2001-01, Appendix B	WMP-30566
200-PW-3 OU Representative Site (216-A-8 Borehole C4545)	CP-15371	DOE/RL-2001-01, Appendix B	WMP-27020
200-PW-1 OU Step I Dispersed Plume	BHI-01544	DOE/RL-2001-01, Appendix C	CP-13514
200-PW-1 OU Step II Dispersed Plume	CP-15372	DOE/RL-2001-01, Appendix D	SGW-33829
200-PW-1 OU DNAPL (216-Z-9 Borehole C3426)	CP-15373	DOE/RL-2001-01, Appendix E	WMP-26264
200-PW-1 OU DNAPL Source Term	CP-15373	DOE/RL-2004-78	DOE/RL-2006-58 [b] DOE/RL-2007-22

[a] Full reference citations are located in Chapter 5.0.
[b] DOE/RL-2006-58 includes the individually approved test plans for field investigations.
DNAPL = dense, nonaqueous phase liquid.
OU = operable unit.

The DQO process is used to develop a data-collection strategy consistent with data uses and needs. The objectives identified include collecting data that will be used to define the nature and extent of radiological and chemical contamination; supporting evaluation of risks; and assisting in the evaluation, selection, and design of remediation alternatives.

Data were collected to characterize the nature and vertical extent of chemical and radiological contamination and the physical conditions in the vadose zone underlying the historical boundaries of the 216-Z-9 Trench (200-PW-1 OU) and the 216-A-8 Crib (200-PW-3 OU). Data-collection activities that previously were conducted to characterize the 216-Z-1A Tile Field (200-PW-1 OU) and the 241-Z-361 Settling Tank (200-PW-1 OU) also are summarized in this chapter. Data also were collected to characterize the nature, lateral extent, and vertical extent of the dispersed carbon tetrachloride contamination in the vadose zone and the presence and distribution of DNAPL carbon tetrachloride in the vadose zone (200-PW-1 OU).

2.1 216-Z-9 TRENCH REMEDIAL INVESTIGATION, 200-PW-1 OPERABLE UNIT

2.1.1 Sampling and Analysis of Characterization Boreholes

2.1.1.1 Well 299-W15-46 (Borehole C3426)

The area south of the 216-Z-9 Trench was selected for the vertical borehole DNAPL investigation using well 299-W15-46 (Borehole C3426) for the following reasons (CP-15373). The wells around the 216-Z-9 Trench are shown in Figure 2-1.

- Groundwater collected from well 299-W15-8, on the south side of the trench, contained low concentrations of plutonium. It is unknown if the borehole annulus provided the preferential pathway or if the plutonium was carried through the vadose zone by a carbon tetrachloride organic mixture (i.e., DNAPL).

- There are fewer SVE wells on the south side compared to the west, north, and east sides (Figure 2-1). Therefore, SVE may have had a lesser impact on the soils on the south side.

- Characterization of the trench before plutonium mining indicated that the region of the lowest floor elevation was in the south half of the trench (ARH-2915, p. 11). Most of the surface plutonium was accumulated in this region.

- The top of the CCU silt layer locally slopes to the southeast under the 216-Z-9 Trench site (BHI-01631, *Carbon Tetrachloride Field Investigation Report for Drilling in the Vicinity of PFP and the 216-Z-9 Trench*).

- Drilling and sampling to investigate DNAPL occurrence was conducted on the northeast corner of the 216-Z-9 Trench in 1995 at well 299-W15-32 (Figure 2-1). No DNAPL was detected (BHI-00431, *DNAPL Investigation Report*).

- Deepening of two wells through the CCU to groundwater on the north (well 299-W15-95) and west (well 299-W15-84) sides of the trench in 2001 did not indicate high concentrations of carbon tetrachloride (BHI-01631).

- The steep bank of the west side of the trench limits the placement of a borehole close to the trench.

- Recent geophysical surveys indicate the presence of anomalies that potentially could indicate DNAPL on both the southwest and northwest sides of the 216-Z-9 Trench (Waddell et al., 2003, *Non-Invasive Determination of the Location and Distribution of Free-Phase Dense Nonaqueous Phase Liquids (DNAPL) by Seismic Reflection Techniques, Final Report*).

- The floor of the crib is smaller than the surface footprint, because the trench walls slope inward with depth. The middle of the south side was selected, to position the borehole as close as possible to the floor of the trench (Figure 2-1).

Well 299-W15-46 (Borehole C3426) was drilled from October 2003 to May 2005. The primary purpose of well 299-W15-46 was to support characterization of the subsurface near the 216-Z-9 Trench for evaluation of DNAPL carbon tetrachloride for both the 200-ZP-1 OU RI (groundwater) and the 200-PW-1 OU RI (vadose zone) (DOE/RL-2001-01, Appendix E). The drilling and sampling activities were completed as described in WMP-26264.

Borehole 299-W15-46 was drilled to a total depth of 160 m (525 ft) bgs, but only that portion of the borehole within the vadose zone (to 70 m [229 ft] depth) is discussed in this RI report. Groundwater samples and additional soil samples from the water table to total depth also were collected to support the 200-ZP-1 Groundwater OU RI. The results for these samples are discussed in DOE/RL-2006-24, *Remedial Investigation Report for 200-ZP-1 Groundwater Operable Unit.*

During advancement of the borehole, drill cuttings and samples were field screened for the presence of VOCs and radionuclides. Soil samples were collected at specific depths during the installation of Borehole C3426 in accordance with the sample design in the SAP (DOE/RL-2001-01, Appendix E), as shown in the following table. A total of 10 soil and 12 vapor samples were collected during drilling activities in the vadose zone. The soil samples were submitted to analytical laboratories for chemical and radiological analysis and determination of physical properties. As described in D&D-30565, duplicate and split soil samples and associated liquid QC samples (equipment and trip blanks) also were obtained for laboratory analysis. Additional samples were collected to support radiological screening, waste management, physical-property testing, and Science & Technology studies related to the 216-Z-9 Trench contamination migration.

Approximate Sample Depths (ft bgs)			Project/Rationale for Sample
Split-Spoon Samples [a]	Soil-Vapor Samples [b]	Groundwater Samples [c]	
25	25	N/A	Waste designation sample near base of trench; 200-PW-1 OU (SVE) soil-vapor profile
N/A	45	N/A	200-PW-1 OU (SVE) soil-vapor profile
69	69	N/A	PNNL sample for CCl_4 mobility, plutonium mobility near H1/H2 contact (possible plutonium contamination); 200-PW-1 (SVE) soil-vapor profile

Approximate Sample Depths (ft bgs)			Project/Rationale for Sample
Split-Spoon Samples [a]	Soil-Vapor Samples [b]	Groundwater Samples [c]	
86	86	N/A	DNAPL sample above the CCU (possible plutonium contamination)
103	N/A	N/A	PNNL sample for CCl_4 mobility, plutonium mobility, CCl_4 transport above the CCU
106	106	N/A	DNAPL, 200-PW-1 OU sample at the top of CCU (zone of potential accumulation/sorption)
111	N/A	N/A	PNNL sample for CCl_4 transport within the CCU
115	115	N/A	DNAPL sample within the CCU (zone of potential perching)
119	119	N/A	DNAPL, 200-PW-1 OU sample at the bottom of the CCU (evaluate gradient through CCU)
121.5	N/A	N/A	PNNL sample for CCl_4 mobility, plutonium mobility below the CCU
N/A	138	N/A	200-PW-1 OU (SVE) soil-vapor profile
N/A	155	N/A	200-PW-1 OU (SVE) soil-vapor profile
170	170	N/A	200-PW-1 OU sample
180	180	N/A	DNAPL sample at historic high water table (top of historic high water table is 54.3 m [178 ft]) (evaluate vertical distribution of carbon tetrachloride between CCU and water table)
220	220	N/A	DNAPL sample at capillary fringe (zone of potential accumulation)
222.5	N/A	N/A	200-PW-1 OU sample within capillary fringe
225	N/A	225	DNAPL, 200-ZP-1 Groundwater OU remedial investigation/ feasibility study sediment and groundwater sample interval in shallow portion of unconfined aquifer (aquifer zone most likely to have received DNAPL) (collect sample within top 1 m [3 ft] of aquifer to evaluate presence of sharp vertical gradient)
227.5	N/A	227.5	PNNL sample for CCl_4 mobility in upper portion of aquifer

All depths are approximate.

[a] Depth of beginning of sample interval below ground surface. Additional samples may be collected if the geologic strata are not encountered in the specified sample.

[b] Soil-vapor sample collected after split-spoon sampler is removed from borehole. Inflatable packer installed and soil-vapor sample collected. Soil-vapor samples collected only at specified intervals.

[c] Assumes that the water table is at 68 m (225 ft) for purpose of this design. The depth of the water sample would be recorded as the depth of the bottom of the temporary casing below ground surface. Each groundwater sample interval will include water for carbon tetrachloride field screening as well as for laboratory analysis.

CCU = Cold Creek unit.
DNAPL = dense, nonaqueous-phase liquid.
N/A = not applicable.
OU = operable unit.
SVE = soil-vapor extraction.
PNNL = Pacific Northwest National Laboratory.

Soil-vapor samples were collected with a displacement pump from intervals isolated by an inflatable packer. The vapor samples were purged through TYGON[1] tubing into Tedlar[2]

[1] TYGON is a registered trademark of Norton Performance Plastics Corporation, a Saint-Gobain Company, Akron, Ohio.

[2] Tedlar is a registered trademark of E. I. du Pont de Nemours and Company, Wilmington, Delaware.

sampling bags. The soil-vapor samples then were analyzed for carbon tetrachloride using field-screening instruments.

Because of the proximity of the borehole to the 216-Z-9 Trench, which is known to be radioactively contaminated, full-time radiological monitoring was conducted during drilling and sampling in the vadose zone. Several different radiation detectors were used as part of the monitoring activities.

A sample of sediment from each split-spoon interval (except for the samples from the Pacific Northwest National Laboratory [PNNL]) was tested for visual indications of the presence of DNAPL. A small quantity of sediment was placed in a vial, and sufficient deionized water was added to barely saturate the sediment sample. Each sample was gently shaken, and the behavior of the liquid was observed upon inversion of the capped vial. It has been observed during testing before drilling that the presence of carbon tetrachloride in water-saturated samples can result in a sheeting action along the inner walls of the vial, with little or no sediment adhering to the walls of the vial, whereas in water-saturated sediment samples with no carbon tetrachloride present, considerable fine sediment tends to adhere to the vial walls. The sheeting occurs because the carbon tetrachloride reduces the interfacial tension. Observable sheeting of varying degrees was found in all sediment samples tested in this manner at well 299-W15-46 (Borehole C3426). After shaking the vial and allowing the sediment in the vial to settle, five drops of a 5 percent aqueous iodine solution were added to the supernatant liquid. In the presence of pure carbon tetrachloride DNAPL, the magenta liquid forms a distinct layer between the sediments and the supernatant liquid.

Based on the field-screening results of the vadose-zone samples and depth-discrete groundwater samples collected during well drilling (WMP-26264), the decision was made to complete the well for groundwater monitoring rather than SVE. Additional details about the borehole drilling, sampling, field screening, and well completion are documented in the borehole summary report (WMP-26264).

Borehole geophysical logging records the vertical distribution of gamma-emitting radionuclides in the soil surrounding the borehole as a means of locating and quantifying contamination, in addition to aiding in interpretation of subsurface stratigraphy. The borehole-logging equipment is calibrated annually, with calibration data used to calculate casing attenuation factors that convert measured peak-area count rates to radionuclide concentrations (WMP-27020). Geophysical logging using the Spectral Gamma Logging System (SGLS) was conducted between May and September 2004 during drilling through the vadose zone. The SGLS provided a continuous radiometric signature of the soils, measured through a single thickness of casing, throughout the entire interval of the vadose zone. Because of issues related to high radiation and carbon tetrachloride vapors, the need to downsize the casing at various depths, and safety reviews, it took several months to drill and sample this well through the vadose zone and complete the borehole geophysical logging.

2.1.1.2 Well 299-W15-48 (Borehole C3427)

The slant well (well 299-W15-48 [Borehole C3427]) is located 12.8 m (42 ft) north of the southern side of the 216-Z-9 Trench (at the surface), and 5.5 m (18 ft) east of the eastern side of

the 216-Z-9 Trench (at the surface) (Figure 2-1). The well also is located 3.7 m (12 ft) north of the southern side of the 216-Z-9 Trench (at the base) and 14.6 m (48 ft) east of the eastern side of the 216-Z-9 Trench (at the base).

The decision to drill the slant borehole under the southern portion of the 216-Z-9 Trench was made for the following reasons.

- The highest soil concentrations of carbon tetrachloride during previous drilling were detected in wells on the southern side of the waste site (well 299-W15-217 in 1992; well 299-W15-46 in 2004).
- Characterization of the trench before plutonium mining indicated that the region of the lowest floor elevation was in the south half of the trench (ARH-2915, p. 11). Most of the surface plutonium was accumulated in this region.
- The top of the CCU silt layer locally slopes gently to the southwest under the 216-Z-9 Trench floor.
- Drilling and sampling to investigate DNAPL occurrence was conducted on the south side of the 216-Z-9 Trench at well 299-W15-46 in 2003-2004. Field-screening results and soil-equilibrium calculations (which are discussed in Section 3.2.1) indicate that DNAPL is present in the upper vadose zone.
- Drilling and sampling to investigate DNAPL occurrence was conducted on the northeast corner of the 216-Z-9 Trench in 1995 at well 299-W15-32 (Figure 2-1). No DNAPL was detected (BHI-00431).
- Deepening of two wells through the CCU to groundwater on the north (well 299-W15-95) and west (well 299-W15-84) sides of the trench in 2001 did not indicate high concentrations of carbon tetrachloride (BHI-01631).

The primary focus of sampling beneath the 216-Z-9 Trench was to characterize the CCU for the presence of DNAPL carbon tetrachloride. However, samples also were collected from each major geologic unit and analyzed for radiological and chemical contaminants and physical properties. In the SAP (DOE/RL-2001-01, Table B-12), 12 soil samples and 9 soil-vapor samples were planned. Of the 12 planned soil samples, 8 were to be collected to support the 216-Z-9 Trench remedial and DNAPL investigations, and 4 were to be collected to support the PNNL contaminant transport studies. Of the 9 planned soil-vapor samples, 5 were to be collected to support the 216-Z-9 Trench DNAPL investigation, and 4 were to be collected to support the groundwater remedial actions evaluation of the 200-PW-1 OU interim action (SVE). The rationale for each planned sample depth was as follows:

- 14.6 to 15.4 m (48 to 50.5 ft): Characterize the vadose zone for DNAPL at the depth that corresponds to the initial depth of elevated plutonium concentrations in well 299-W15-8 south of the 216-Z-9 Trench

- 20.3 to 21.0 m (66.5 to 69 ft): Characterize the Hanford formation upper gravel sequence for 200-PW-1 OU COPCs as close as possible to the area underneath the footprint of the 216-Z-9 Trench
- 21.0 to 21.8 m (69 to 71.5 ft): Characterize the contact between the Hanford formation upper gravel and sandy sequences for contaminant transport and evaluation of SVE interim action
- 24.4 to 27.0 m (86 to 88.5 ft): Characterize the vadose zone for DNAPL within the Hanford formation sandy sequence to evaluate vertical distribution of contaminants
- 30.3 to 31.1 m (99.5 to 102 ft): Characterize the vadose zone near the top of the CCU, a zone of potential perching, for contaminant transport and evaluation of SVE interim action
- 31.2 to 32.0 m (102.5 to 105 ft): Characterize the Hanford formation sandy sequence for 200-PW-1 COPCs near the contact with the CCU, a zone of potential perching
- 32.3 to 33 m (106 to 108.5 ft): Characterize the CCU silt, a potential zone of sorption, for DNAPL
- 33.8 to 34.6 m (111 to 113.5 ft): Characterize the CCU silt/carbonate contact for contaminant transport and evaluation of SVE interim action
- 35.1 to 35.8 m (115 to 117.5 ft): Characterize the CCU silt/carbonate contact for DNAPL
- 35.8 to 36.6 m (117.5 to 120 ft): Characterize the bottom of the CCU for 200-PW-1 OU COPCs; evaluate contaminant gradients within the CCU
- 36.7 to 37.5 m (120.5 to 123 ft): Characterize the contact between the CCU and the Ringold Formation for DNAPL
- 37.6 to 38.4 m (123.5 to 126 ft): Characterize the top of the Ringold Formation for contaminant transport and evaluation of SVE interim action; evaluate gradient through the CCU.

The depths of the planned samples were adjusted slightly, based on new information about the stratigraphy anticipated beneath the trench. The new information was obtained during drilling of well 299-W15-46 south of the trench in 2003-2004 and the cross-well seismic investigation of the stratigraphy in the vicinity of the trench conducted in March 2005 (see Section 2.4). The modified depths were selected to meet the objectives of the sampling rationale in the SAP. The correlation between the sample depths in the SAP and the modified depths is provided in Table 2-1.

From a position 5.5 m (18 ft) east of the eastern side of the trench (at the surface), the angle of the borehole was selected to maximize the number of samples collected beneath the footprint of the trench floor (Figure 2-2). An angle of 32 degrees from vertical (58 degrees from horizontal) was selected so that all 7 lower samples (from the 5th sample at 26.4 m vertical or 86.5 vertical ft

bgs to the 11th sample at 36.2 m vertical or 118.7 vertical ft bgs) would be collected beneath the footprint of the trench.

On December 21, 2005, the EPA concurred with drilling and sampling the slant well in the southern half of the crib and expressed a preference for maximizing the number of samples to be collected beneath the footprint of the 216-Z-9 Trench.

Well 299-W15-48 (Borehole C3427) was drilled from February to May 2006. The primary purpose of this well was to gather data for further characterization of the distribution of radiological and chemical contamination directly beneath the 216-Z-9 Trench. The following sampling activities were completed as described in WMP-30566.

Well 299-W15-48 started on the east side of the 216-Z-9 Trench and was drilled at a 32-degree angle from vertical to the west to a total downhole depth of 44.3 m (145.5 ft) (Figures 2-1 and 2-2). During advancement of the borehole, drill cuttings and samples were field screened for the presence of VOCs and radionuclides. A total of 11 soil and 9 vapor samples were collected during drilling activities in the vadose zone. The soil samples were submitted to analytical laboratories for chemical and radiological analysis and determination of physical properties. As described in D&D-30565, duplicate and split soil samples and associated liquid QC samples (equipment and trip blanks) also were obtained for laboratory analysis.

Soil-vapor samples were collected with a displacement pump from intervals isolated by an inflatable packer. The vapor samples were purged through TYGON tubing into Tedlar sampling bags. The soil-vapor samples then were analyzed for carbon tetrachloride using field-screening instruments.

Because of the proximity of the borehole beneath the 216-Z-9 Trench, which is known to be radioactively contaminated, full-time radiological monitoring was conducted during drilling and sampling in the vadose zone. Several different radiation detectors were used as part of the monitoring activities.

A sample of sediment from each split-spoon interval also was tested for visual indications of the presence of DNAPL, using the methodology previously described for well 299-W15-46.

Geophysical logging using the SGLS and the neutron moisture logging system were conducted in May 2006 after the borehole was drilled to a total depth of 44 m (145 ft) downhole.

Well 299-W15-48 was completed as an SVE well. The well is screened from 43.0 to 33.8 m (141 to 111 ft) downhole (36.6 to 28.7 m or 120 to 94 ft vertical depth) under the floor of the trench. The well was connected to the SVE system on August 1, 2006. With only this well online to the SVE system, the well produced approximately 4.0 to 4.2 m^3/min (140 to 150 ft^3/min) of vapor at a vacuum of 279.4 to 304.8 cm (110 to 120 in.) of water. The initial carbon tetrachloride vapor concentrations extracted from the well were 74 ppmv. This carbon tetrachloride concentration is within the range of concentrations (2 to 390 ppmv) measured during drilling through this interval. Carbon tetrachloride concentrations declined with continued extraction and were measured at 26 ppmv on August 2, 2006. The preliminary evaluation is that (1) the well is able to be used successfully for vapor extraction, and (2) the extracted concentrations are consistent with those observed during drilling.

2.1.2 Borehole Geophysical Logging

Borehole geophysical logging data were collected from select boreholes within and around the 216-Z-9 Trench. This included the new RI wells 299-W15-46 and 299-W15-48, and existing wells 299-W15-82, 299-W15-85, and 299-W15-218. Previous geophysical logs in several boreholes may have misidentified various radionuclides (e.g., Cs-137). A discussion of the borehole geophysics is provided in Section 3.2.4.1.

Passive neutron logging was performed in the borehole to detect neutrons that may be generated by interactions of alpha particles with lighter elements such as iron, aluminum, sodium, magnesium, silicon, chlorine, and oxygen or from spontaneous fission. Where a transuranic radionuclide is in the form of a compound with one of these elements, the interaction most likely is because the distance that the alpha particle must travel is short. Many transuranic radionuclides decay predominantly by alpha particle emission, and the passive neutron system may be useful to identify the existence of these radionuclides where no gamma emissions are available for detection. No calibration is available for this logging system, and the data provided in Chapter 3.0 are to be used qualitatively.

2.1.3 Historical Contaminant Investigation

Figure 2-1 shows the location of wells around the 216-Z-9 Trench. Four borings were installed during 1954 (299-W15-8, 299-W15-82, 299-W15-84, and 299-W15-85) around the 216-Z-9 Trench and were used to monitor potential contamination spread from the structure during waste discharge operations. Additional drilling (e.g., new boreholes/well deepening) was performed in 1959 (wells 299-W15-6, 299-W15-9, 299-W15-86, and 299-W15-95), in 1966 (wells 299-W15-8, 299-W15-9, and 299-W15-86), and in 1967 (well 299-W15-101) to monitor for subsurface movement of disposed waste. The boreholes were monitored using scintillation surveys for detecting radioactive waste movement.

Additional borings were completed around the trench during 1992 (wells 299-W15-216 and 299-W15-217) and 1993 (wells 299-W15-218, 299-W15-219, 299-W15-220, and 299-W15-223). Borehole deepening was conducted in 2001 (wells 299-W15-84 and 299-W15-95). The boreholes drilled from 1992 to the present were sampled for soil, soil vapor, and/or groundwater during drilling. Drilling and sampling to investigate DNAPL occurrence was conducted on the northeast corner of the 216-Z-9 Trench in 1995 at well 299-W15-32. No DNAPL was detected in this well (BHI-00431).

During disposal of wastes to the 216-Z-9 Trench, accountability records indicated that plutonium was discharged to the trench. After the 216-Z-9 Trench was taken out of service in June 1962, it was postulated that errors had occurred in the estimate of the mass of plutonium discharged to the trench, and that criticality was possible because of the mass of plutonium within the trench. To refine the estimates of the mass of plutonium discharged to the 216-Z-9 Trench, to evaluate plutonium distribution within the trench, and to further evaluate criticality concerns, soil samples were collected from the trench in 1961, 1963, and 1973 (Figures 2-3a and b). The soil samples were analyzed for Pu-239 and Am-241.

Soil samples were collected from eight vertical soil borings advanced in 1961 and 1963 through 10 cm (4-in.)-diameter access points (Figure 2-3a, Nos. 5 to 12) in the trench roof. In 1973, 14 additional vertical samples and 11 angled samples were collected using a split-tube sampler through 20 cm (8-in.) access points (Figure 2-3b). Samples from Areas A, B, and C were collected at the same locations as the samples collected from Boreholes 6, 7, and 8 in 1961 and 1963. No soil-sample results are reported for Areas E and F (ARH-2915). The angled soil borings were advanced at angles ranging from 3.5 to 5 degrees from vertical. Additional sampling details are provided in ARH-2915, Appendix A.

The soil samples from 1973 were nondestructively analyzed for Pu-239 and Am-241 with lithium-drifted germanium detectors and using gamma energy analysis techniques. Soil samples from 1961 and 1963 were analyzed for plutonium. The soil sample results from these investigations are presented in Section 3.2.1.

The 216-Z-9 Trench was mined (under the concrete cover) with remote mechanical equipment between 1976 and 1978 because of the mass of plutonium estimated to reside within the 216-Z-9 Trench and because of criticality concerns. The upper 0.3 m (1 ft) of soil was removed from the floor of the trench. The mining operation removed an estimated 58 kg (128 lb) of plutonium. The mined soil was placed in soil canisters. The canisters then were placed in 208.2 L (55-gal) steel drums. A total of 653 drums were filled. Based on data acquired during the mining operation, an estimated 48 kg (106 lb) of plutonium remains in the 216-Z-9 Trench (RHO-ST-21). The plutonium-contaminated sediment and sludge recovered during the mining operation was drummed and disposed of in trench T-01 of the 218-W-4C Burial Ground. The 216-Z-9 Trench's 6 m (21-ft)-deep excavation remains void of soil and contains only the mining equipment (DOE/RL-91-58, RHO-ST-21, ARH-2915).

2.2 216-Z-1A TILE FIELD REMEDIAL INVESTIGATION, 200-PW-1 OPERABLE UNIT

2.2.1 Sampling and Analysis of Characterization Boreholes

During the DQO process, the existing data at the 216-Z-1A Tile Field were determined to be sufficient to support selection of remedial alternatives, so no new characterization boreholes were required for the RI (CP-15371). During the planning for the cross-well seismic reflection investigation of the tile field, it was determined that a new vadose-zone borehole was needed in the northern part of the tile field to obtain coverage of this area. Borehole P57 (C4965) was drilled in February 2006 in the northern part of the tile field. No soil or soil-vapor samples were collected from this borehole, but the drill cuttings were field screened for radioactivity and organic vapors.

2.2.2 Borehole Geophysical Logging

Borehole geophysical logging data were collected from select boreholes within and around the 216-Z-1A Tile Field. This includes the following 16 wells and one borehole.

299-W18-7	299-W18-79	299-W18-159	299-W18-167
299-W18-9	299-W18-80	299-W18-164	299-W18-168
299-W18-12	299-W18-81	299-W18-165	299-W18-169
299-W18-77	299-W18-85	299-W18-166	299-W18-170
C4965 (P57)			

Previous geophysical logs in several boreholes may have misidentified various radionuclides (e.g., Cs-137). A discussion of the borehole geophysics is provided in Section 3.2.4.1.

2.2.3 Historical Contaminant Investigation

Figure 2-4 shows the location of wells around the 216-Z-1A Tile Field. Before 1973, 26 wells were installed in and around the 216-Z-1A Tile Field and were monitored using scintillation surveys for detecting radioactive waste movement. The primary purpose of the pre-1973 wells was to provide information on the subsurface migration of wastes disposed of in the tile field. Wells 299-W18-56 through 299-W18-68 initially were completed in 1949, shortly after tile field construction, and were located within the interiors of the 216-Z-1, 216-Z-2, and 216-Z-3 Cribs and 216-Z-1A Tile Field waste-disposal sites. Before the restartup of the 216-Z-1A Tile Field in 1964, wells 299-W18-6 and 299-W18-7 were completed on the west and east side of the tile field, respectively. Wells 299-W18-6 and 299-W18-7 were installed for the purposes of groundwater monitoring and scintillation (gross gamma) probe access. Five additional vadose-zone wells (299-W18-85 to 299-W18-89) were installed around the perimeter of the 216-Z-1A Tile Field in 1969 to serve as scintillation (gross gamma) probe access locations. Wells 299-W18-76 to 299-W18-81 were installed in 1967 to evaluate the potential buildup of waste disposed of near the head of the crib (RHO-ST-17, *Distribution of Plutonium and Americium Beneath the 216-Z-1A Crib: A Status Report*).

In 1973, an investigation was initiated for the 216-Z-1A Tile Field to evaluate the distribution of plutonium and americium beneath the waste site. A total of 16 wells were completed from 1973 to 1979. Four of the wells (299-W18-149, 299-W18-150, 299-W18-159, and 299-W18-175) were located along the central distribution pipe for the tile field. Well 299-W18-170 initially was drilled to a depth of 9 m (30 ft), where an obstruction was encountered that could not be penetrated by drilling equipment. Subsequently, well 299-W18-175 was completed as a replacement location. The primary purpose of the wells located along the central distribution pipe was to evaluate impacts to the subsurface at locations where maximum waste discharge to the crib was expected to have occurred. Nine wells (299-W18-158, 299-W18-163 to 299-W18-169, and 299-W18-172) were completed around the perimeter of the tile field, to evaluate the lateral extent of subsurface impacts. Following completion of the initial 13 wells and a review of the collected data, 3 additional wells (299-W18-171, 299-W18-173, and 299-W18-174) were completed to further evaluate the lateral extent of subsurface impacts.

Samples were collected from the 1973-1979 boreholes for physical property analysis, as well as analysis of plutonium and americium. The plutonium and americium samples were analyzed using lithium-drifted germanium, intrinsic germanium, lithium-drifted silicon, and/or alpha energy detectors (RHO-ST-17).

Additional borings were completed around the tile field during 1992 (wells 299-W18-246 on the west side and 299-W18-248 on the east side) and 1993 (well 299-W18-252 located west of the tile field). Well 299-W18-174 within the tile field was deepened in 1993 to further evaluate subsurface impacts from the tile field. The boreholes drilled in 1992-1993 were sampled for soil, soil vapor, and/or groundwater during drilling.

2.3 241-Z-361 SETTLING TANK REMEDIAL INVESTIGATION, 200-PW-1 OPERABLE UNIT

The 241-Z-361 Settling Tank is located north of the 216-Z-1A Tile Field (Figure 1-2). Characterization of the 241-Z-361 Settling Tank and its contents was conducted from 1999 to 2001 to resolve an unreviewed safety question related to existing tank conditions. The characterization was performed in two phases: Phase I focused on opening the tank, characterizing the headspace vapor, and conducting a video camera survey of the tank interior. Phase II focused on characterizing the sludge and additional sampling of the tank headspace vapor (DOE/RL-2001-01, Section 3.3.1.3). Phase I sampling activities were conducted in 1999 under the requirements of the 241-Z-361 Settling Tank vapor sampling and analysis plan (HNF-2867, *Tank 241-Z-361 Vapor Sampling and Analysis Plan*). In 1999 and 2001, Phase II activities were conducted in accordance with the tank sludge characterization sampling and analysis plan (HNF-4371, *241-Z-361 Sludge Characterization Sampling and Analysis Plan*). The purpose of the Phase II investigation was to provide data for determining the waste-disposal pathways, if remediation were performed, and to provide data to support a second assessment of the potential for criticality. The details of which analytes exceed RCRA toxicity characteristics and underlying hazardous constituents are discussed in DOE/RL-2003-52, *Tank 241-Z-361 Engineering Evaluation/Cost Analysis*. The data from the tank characterization are summarized in Section 3.2.3 of this RI report; however, the comparison to RCRA waste-disposition requirements is not discussed in this RI report.

HNF-4371 identifies the type, quantity, and quality of data needed to support characterization of the sludge remaining in the 241-Z-361 Settling Tank. The procedures described in HNF-4371 were based on the results of the HNF-4225, *241-Z-361 Sludge Characterization Data Quality Objectives*, process for the tank. Characterization data were required to evaluate the need for an early removal action and, as required, to determine the appropriate methods for (1) removal of the sludge from the 241-Z-361 Settling Tank, (2) stabilization and packaging of the sludge, and (3) sludge disposal (HNF-8735). Results of Phase I and II activities are presented in HNF-8735.

Sampling and Analysis of Tank Content

Phase I activities included opening of the 241-Z-361 Settling Tank in 1999. A HEPA filter was installed on a passive vent, which then was monitored for combustible vapors, and a tank-headspace vapor sample was collected and analyzed for VOCs. Volatile and semivolatile

organics present in the tank included Freon[3], chloroform, tetrachloroethylene, isobutane, methylcyclopentane, trichloroethylene, and carbon tetrachloride. Phase I also included an inspection of the inside of the tank using a video camera (HNF-8735).

Phase II activities included collection of two full-depth sludge core samples from the tank for detailed chemical analysis, and collection of tank headspace vapor samples during sludge sampling to evaluate the potential for release of volatile compounds by disturbance of the sludge. Downhole nondestructive assay techniques were used in the existing aluminum dry wells in the 241-Z-361 Settling Tank to provide additional information on the distribution of radioisotopes in the sludge.

Helical piers were installed in 1999 to support an above-ground structure for sampling the tank. These piers extend beneath the depth of the tank bottom, and some are within a few meters (feet) of the tank, allowing monitoring of potential radiological contamination upon their removal (DOE/RL-2001-01, Section 3.3.1.3).

2.4 DISPERSED CARBON TETRACHLORIDE VADOSE-ZONE PLUME INVESTIGATION ACTIVITIES, 200-PW-1 OPERABLE UNIT

The investigation of the dispersed carbon tetrachloride vadose-zone plume was conducted in two steps. The study area for Step I of the investigation was the vadose zone overlying the highest concentration portion of the carbon tetrachloride groundwater plume. Step I was focused only on characterizing the shallow portion of the vadose zone. The study area for the Step II investigation included the vadose zone overlying the entire carbon tetrachloride groundwater plume. The Step II study also extends deeper in the vadose zone than the Step I investigation. Data collected in both Step I and Step II were augmented with existing data and data from other planned and ongoing characterization activities in the 200 West Area. Summaries of these studies are provided in Section 2.4.3.

The RI was conducted in accordance with the Step I and Step II SAPs and supplements found in Appendices C and D of the Work Plan (DOE/RL-2001-01) and DOE/RL-2004-78, *Work Plan for Integrated Approach for Carbon Tetrachloride Source Term Location in the 200 West Area of the Hanford Site*.

2.4.1 Step I Investigation Activities

The SAP for the Step I investigation was based on the systematic characterization of each of the seven potential release modes of carbon tetrachloride in the Step I study area. The correlation between potential release modes and elements of the Step I sampling design is provided in Table 2-2.

[3] Freon is a trademark of E. I. du Pont de Nemours and Company, Wilmington, Delaware.

The perimeter of the study area for the Step I investigation is illustrated in Figure 2-5. The potential release modes within this area, but outside the PFP Protected Area, were characterized from May through September 2002. The sampling methodology and results are documented in CP-13514. The release modes inside the PFP Protected Area were characterized during FY 2003 and are reported with the Step II investigations (see Section 2.4.2.5).

Soil-vapor sampling and analysis were used to explore the upper vadose zone within the Step I study area. The sampling was conducted at liquid-waste discharge pipelines, liquid-waste discharge sites, and solid-waste burial ground trenches (CP-13514). The vadose-zone sampling was conducted using either the GeoProbe[4] or cone penetrometer (CPT) direct-push technology. Sampling was conducted through vent risers into the burial ground trenches. The analyses were conducted using a field-screening instrument, the Innova 1312 multi-gas analyzer[5].

2.4.1.1 Liquid-Waste Discharge Pipelines

Soil-vapor samples were collected along six liquid-waste discharge pipelines to investigate potential leaks of carbon tetrachloride-bearing waste from the pipelines. The six pipelines conveyed waste to the 216-Z-7 Crib, 216-Z-9 Trench, 216-Z-12 Crib, 216-Z-18 Crib, 216-Z Ditches from the 234-5Z Building, and 216-Z Ditches from the 231-Z Building. Vapor sampling was eliminated along pipelines to the 216-Z-16 Crib, 216-Z-17 Trench, and 216-Z-21 Pond, because carbon tetrachloride vapor was not detected at the corresponding 216-Z-16 Crib, 216-Z-17 Trench, or 216-Z-21 Pond liquid-waste discharge sites (CP-13514; DOE/RL-2001-01, Appendix C).

Seventy-nine locations were investigated along liquid-waste discharge pipelines using a GeoProbe system. The GeoProbe system was used to collect soil-vapor samples to a maximum depth of 7.6 m (25 ft) bgs. Some sampling locations along pipelines also served as sampling locations at liquid-waste sites. Samples at these "dual-purpose" locations were collected using the CPT. The investigation locations at the liquid-waste discharge pipelines are shown in Figure 2-6.

2.4.1.2 Liquid-Waste and Heating, Ventilation, and Air Conditioning Condensate Discharge Sites

Soil-vapor samples were collected at nine liquid-waste discharge sites and two heating, ventilation, and air conditioning (HVAC) condensate discharge sites to investigate the potential discharge of carbon tetrachloride-bearing waste to the soil column at those sites. The nine liquid-waste discharge sites are the 216-T-19, 216-Z-7, 216-Z-12, 216-Z-16, and 216-Z-18 Cribs; 216-Z-1A Tile Field; 216-Z-8 French Drain; and 216-Z-9 and 216-Z-17 Trenches. The two HVAC condensate discharge sites are the 216-Z Ditch system (216-Z-1D, 216-Z-11, 216-Z-19 Ditches, and 216-Z-20 Crib) and the 216-Z-21 Pond.

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[4] GeoProbe is a registered trademark of GeoProbe Systems, Salinas, Kansas.

[5] 1312 multi-gas analyzer is a trademark of Innova AirTech Instruments A/S, Ballerup, Denmark.

Twenty-six locations were investigated at the liquid-waste discharge sites using a CPT. The maximum depth achieved using the CPT was 21.3 m (70 ft). Temporary soil-vapor monitoring probes were installed at five locations for subsequent sampling to confirm the initial results. The investigation locations at the liquid waste and HVAC-condensate discharge sites are shown in Figure 2-6.

Soil-vapor samples also were collected from Borehole C3808, drilled at the distal end of the 216-Z Ditch system as part of the 200-CW-5 OU RI and analyzed for carbon tetrachloride in support of the 200-PW-1 OU dispersed carbon tetrachloride vadose-zone plume investigation. Carbon tetrachloride was not detected in any of the soil-vapor samples, which were collected throughout the vadose zone (CP-12134, *Borehole Summary Report for Borehole C3808 in the 216-Z-11 Ditch, 200-CW-5, U-Pond/Z-Ditches Cooling Water Operable Unit*).

Five temporary soil-vapor monitoring probes were installed at four liquid-waste discharge sites for subsequent sampling to confirm the initial results.

2.4.1.3 218-W-4C Burial Ground

Sampling in the 218-W-4C Burial Ground was conducted in three phases. During the first phase, vapor samples were collected from 27 vent risers that generally were aligned with the centers of the engineered trenches. During the second phase, the GeoProbe was used to collect samples at 12 locations in the vadose zone to a maximum depth of 7.6 m (25 ft) bgs. The 12 locations were selected based on the results of the vent-riser sampling. The GeoProbe was used initially to collect vapor samples at each of the 12 locations, so that the results could be used to focus deeper sampling using the CPT. During the third phase, the CPT was used to collect samples at 5 of the 12 locations sampled using the GeoProbe. Maximum sample depth using the CPT was based on the depth where refusal was encountered.

During the first phase of the investigation in May 2002, vapor samples were collected from vent risers inside engineered trenches at trench T-01, trench T-04, and trench T-07. Most of the samples were collected near the base of the trench, which typically is approximately 5 m (16 ft) below the engineered surface overlying the trench. Carbon tetrachloride was detected at all but one of the 27 vent risers sampled. Most of the detections were less than 10 ppmv, but a distinct "hot spot" of elevated carbon tetrachloride concentration (maximum of 1,760 ppmv) was detected at the east end of trench T-04. The investigation locations of the burial ground trenches are shown in Figure 2-7.

During the second phase in August 2002, the GeoProbe was used to collect soil-vapor samples from the vadose zone at two depth intervals, approximately 4.6 to 4.9 m and 7.3 to 7.6 m (15 to 16 ft and 24 to 25 ft) bgs, at 12 sites. At two locations, an additional sample was collected at depths where health and safety monitoring detected elevated concentrations.

During the third phase of this investigation in September 2002, the CPT was used to collect soil-vapor samples from the five sites where carbon tetrachloride was detected during sampling using the GeoProbe. Samples were collected at the elevation corresponding to the base of the nearest trench and at other depths selected to provide a vertical concentration profile.

Three temporary soil-vapor monitoring probes were installed at two of the CPT locations for subsequent sampling to confirm the initial results.

During October-December 2003, vapor samples were collected through 84 existing vent risers in trenches T-01, T-04, T-07, T-20, and T-29 in the 218-W-4C Burial Ground and analyzed for VOCs using field-screening instruments. A vapor sample then was collected for laboratory analysis from the vent riser in each trench that had the highest carbon tetrachloride concentration, based on the field-screening results. The sampling was conducted in accordance with DOE/RL-2003-48, *218-W-4C Burial Ground Sampling and Analysis Plan*, which was developed to determine whether contaminants have been released to the vadose zone from retrievably stored waste[6] in the 218-W-4C Burial Ground in support of Tri-Party Agreement Milestone M-91-40 (Ecology et al., 1989, as amended). The sampling methodology was similar to that used to sample the vent risers in the 218-W-4C Burial Ground during Step I of the carbon tetrachloride vadose-zone investigation.

The samples collected in 2003 were analyzed for the following eight VOCs using a gas chromatograph: carbon tetrachloride, chloroform, methylene chloride, 1,1,1-trichloroethane, 1,1,2-trichloroethane, 1,1-dichloroethane, trichloroethylene, and tetrachloroethylene. For each of these eight VOCs, the highest concentration was detected at the east end of trench T-04, which is consistent with the results of the Step I investigation (CP-13514). The highest concentration of carbon tetrachloride detected was 668 ppmv. However, the field-screening results indicated that the concentrations of 1,1,1-trichloroethane and tetrachloroethylene exceeded the concentration of carbon tetrachloride. The laboratory analysis of vapor samples from trench T-04 detected 14,000 ppmv of tetrachloroethylene and 320 ppmv of 1-butanol. Because of the high dilution required to quantify the tetrachloroethylene in this sample, concentrations for the other analytes present could not be quantified.

2.4.2 Step II Investigation Activities

During the DQO process for the Step II investigation, two approaches were used to identify additional characterization activities. In one approach, the Step I investigation results and additional information were used to identify known or potential carbon tetrachloride release sites that needed to be characterized. Release sites are near-surface engineered facilities (or unplanned releases) that have the potential to release carbon tetrachloride to the vadose zone. In the other approach, areas of elevated concentrations in the groundwater plume were identified that may indicate the locations of carbon tetrachloride sources in the deep vadose zone that are contributing mass to the groundwater and that should be characterized. The purpose of the Step II investigation was to detect carbon tetrachloride accumulations in the vadose zone that are impacting or may impact groundwater in the future. The scope of the investigation also was broadened to include additional suspected carbon tetrachloride release sites and sources that are both within and beyond the Step I study boundaries. The study area for the Step II investigation includes the intermediate and deep vadose zone overlying the entire carbon tetrachloride groundwater plume (Figure 2-8).

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[4] Retrievably stored for purposes of the *Atomic Energy Act of 1954*.

Based on the Step I investigation results and evaluation of sites outside the Step I study area, the following known or potential carbon tetrachloride release sites were identified for further characterization in Step II during the DQO process (CP-15372):

- 216-Z-1A Tile Field
- 216-Z-9 Trench
- 216-Z-18 Crib
- 216-T-19 Crib
- 216-Z Ditch system (216-Z-1D, 216-Z-11, 216-Z-19 Ditches, and 216-Z-20 Crib)
- 216-Z-7 Crib
- 216-Z-12 Crib
- 216-Z-16 Crib
- 216-Z-17 Trench
- Trench T-04 in the 218-W-4C Burial Ground
- 216-S-25 Crib
- 218-W-3A Burial Ground.

Based on evaluation of elevated concentrations in the carbon tetrachloride groundwater plume that may indicate potential sources in the deep vadose zone, eight areas were identified for further characterization in Step II during the DQO process (CP-15372):

- Well 299-W10-20 adjacent to the 218-W-3A Burial Ground (Area 1)
- T Tank Farm (Area 2)
- T Plant (Area 3)
- Well 299-W11-10 east of T Plant (Area 4)
- Wells 299-W15-40 and 299-W10-5 near the 216-T-21 to 216-T-25 Trenches (Area 5)
- Well 299-W15-15 between the 218-W-4B and 218-W-4C Burial Grounds (Area 6)
- Well 299-W15-16 northeast of the 218-W-4C Burial Ground (Area 7)
- S-SX Tank Farm (Area 8).

The location of the eight areas of elevated concentrations in the carbon tetrachloride groundwater plume that were characterized in Step II is shown in Figure 2-9.

The Step II investigation sampling design is detailed in the Work Plan (DOE/RL-2001-01), Appendix D, Table D-8. That table is reproduced in this report as Table 2-3. Under the "Sample Collection Methodology" column, the boldface type has been added to help the reader locate the discussion of the specific investigation activities and the results of those investigations in this RI report.

2.4.2.1 Investigation of Vadose-Zone Plume Lateral Extent at the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib

This investigation was conducted in the vicinities of the primary carbon tetrachloride disposal sites to evaluate lateral migration beyond the waste site boundaries. As part of airflow modeling of SVE operations at the 216-Z-9 Trench, the applied vacuum in the Hanford formation sand was calculated to extend approximately 80 to 140 m (260 to 460 ft) beyond the trench boundaries for different configurations of on-line wells (BHI-00882, *Airflow Modeling Report for Vapor Extraction Operations at the 200-ZP-2 Operable Unit (Carbon Tetrachloride Expedited Response Action)*). Therefore, sampling at the 216-Z-9 Trench will continue to distances at least

225 m (750 ft) beyond the trench boundaries. The vertical sampling scheme is consistent with the Step I sampling (DOE/RL-2001-01, Appendix C). Sampling at the 216-Z-1A Tile Field and 216-Z-18 Crib used a similar strategy.

The investigation of the lateral extent of the dispersed carbon tetrachloride vadose-zone plume at the 216-Z-9 Trench, TX-TY Tank Farm, 216-Z-1A Tile Field, and 216-Z-18 Crib (the release sites) included passive soil-vapor surveys around the release sites and adjacent areas using an initial coarse grid-collector spacing of about 50 m (164 ft), followed by a refined grid-collector spacing of about 20 m (66 ft) to verify and refine the initial results (Figures 2-10 to 2-13).

The passive soil-vapor surveys deployed passive soil-gas collectors. All samples were collected following standard field procedures published by the vendor, Beacon Environmental Services, Inc. A summary of passive soil-vapor locations is shown in Table 2-4, and the details for each passive soil-vapor location are shown in Table 2-5. The field procedures routinely used during the passive soil-vapor surveys included the following steps.

1. Each sampler was deployed in the field by qualified technicians.
2. Each sampler was placed in the subsurface to a maximum depth of 10 cm (4 in.) below grade.
3. Samplers were deployed in prearranged survey patterns (e.g., coarse grid followed by refined grid spacing).
4. Soil was backfilled to seal and protect the samplers.
5. The sample point was flagged for identification and field-located with a Global Positioning System (GPS) unit.
6. The collector was left in place to adsorb compounds passively for a 72-hour minimum exposure period.
7. The collector then was retrieved from the field and wiped clean with cloth.
8. The collector was sealed again to protect from contamination.
9. Samples were identified and recorded with other relevant information.
10. Samples then were shipped to the vendor's laboratory for VOC analysis.

The passive soil-gas collector consists of a glass vial containing hydrophobic adsorbent cartridges with a length of wire attached to the vial for retrieval. Hydrophobic cartridges can effectively adsorb contaminants in high-moisture conditions. Passive soil-vapor samplers are prepared with two cartridges for subsequent duplicate or confirmatory sample analysis. The duration of exposure for all samples was a minimum of 3 days following the vendor's field procedures.

Table 2-4 summarizes the specific areas investigated in each passive soil-vapor survey, the total samples collected, deployment dates, and the barometric pressure range during each survey. As shown, the barometric pressure did not fluctuate significantly during any of the surveys.

The results from the subsurface samplers were converted from nanograms of mass to average emission flux rates to assist in comparing results from the various investigations with previous investigations. The following formula was used:

$$F = W/A/T$$

where:

F = average emission flux rate ($ng/m^2/min$)
W = contaminant mass (ng)
A = area (m^2) of sampler [$3.14159(0.0045\ m)^2$]
T = collection period (min).

The field locations of the passive soil-vapor survey points summarized in Table 2-4, along with the contoured emission flux-rate results from each survey, are shown in Figures 2-10 to 2-13.

Based on the results of the passive soil-vapor surveys, subsurface investigations were conducted at locations of elevated carbon tetrachloride soil vapor. The investigations used a 40-ton CPT to collect active soil-gas and soil samples and deploy FLUTe[7] liners to investigate the presence of carbon tetrachloride DNAPL. Based on the results of the CPT sampling, a deeper soil-sampling investigation of the vadose zone down to the top of the CCU around the 216-Z-9 Trench was started in May 2006 using a hydraulic hammer rig (HHR, a direct-push soil-sampling system). This soil-sampling investigation was intended to have been followed by a similar investigation around the 216-Z-1A Tile Field and the 216-Z-18 Crib, but this investigation was not conducted for reasons discussed at the end of this section. The method and results of the HHR investigations are presented in DOE/RL-2007-22.

The first CPT investigation was conducted from April 5 to May 20, 2005, using a 40-ton CPT truck, one of the heaviest CPT trucks available in North America (DOE/RL-2006-58). A total of 75 penetrometer tests were conducted at 18 locations near the 216-Z-9 Trench (Figure 2-14). (NOTE: Two of the locations shown in Figure 2-14 were investigated during the second CPT investigation described below.) Test measurements included tip stress, sleeve stress, pore pressure, soil resistivity, and collected depth-discrete active soil-vapor measurements every 1 m (3 ft) of depth. Six CPT locations adjacent to the 216-Z-9 Trench were logged for total gamma to support management of radiological hazards. The depth of refusal for these tests ranged from 2.1 to 35.4 m (7 to 116.1 ft), with an average push depth of 15.4 m (50.4 ft).

Split-spoon soil samples also were collected from depth intervals of interest at each location, based on the active soil-vapor results and/or stratigraphy. Based on review of the collected data, two locations were tested with FLUTe DNAPL ribbon samplers as a direct test for carbon tetrachloride as DNAPL.

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[7] FLUTe is a trademark of Flexible Liner Underground Technologies, LLC, Santa Fe, New Mexico.

The active soil-vapor samples were collected by using a sampling pump to fill a Tedlar bag. The vapor samples were immediately analyzed in the field for carbon tetrachloride, chloroform, carbon dioxide, and water content using a B&K 1302 photoacoustic gas analyzer[8]. Active soil-vapor samples also were collected in the same manner at 10 m (33 ft) bgs, 20 m (66 ft) bgs, and at refusal, and analyzed for comparative analysis using a different field-screening instrument (e.g., a different B&K 1302 photoacoustic gas analyzer, a field gas chromatograph, or equivalent).

The soil samples were field screened with the B&K 1302 photoacoustic gas analyzer and then submitted to analytical laboratories for analysis of volatile and semivolatile organics, total organic carbon, pH, conductivity, soil moisture, plutonium, and americium.

The second CPT investigation was conducted from July 19 to August 18, 2005, using the same 40-ton CPT truck and test measurements that were used in the first investigation. A total of 73 penetrometer tests were conducted at 23 locations in an area incorporating the 216-Z-1A Tile Field, 216-Z-18 Crib, and 216-Z-12 Trench (Figure 2-15). (NOTE: Two of the locations included in this second CPT investigation are shown in Figure 2-14.) The depth of refusal for these tests ranged from 0.35 to 28.2 m (1.1 to 92.5 ft) with an average push depth of 16.1 m (52.8 ft).

The CPT locations and refusal depths for the 216-Z-9 Trench and the 216-Z-1A Tile Field are summarized in Tables 2-6 and 2-7, respectively, and the general push locations are summarized in Figures 2-14 and 2-15, respectively.

A total of 53 boreholes were pushed at 9 unique locations adjacent to the 216-Z-9 Trench with the HHR between June 5 and November 27, 2006. The HHR locations and refusal depths adjacent to the 216-Z-9 Trench are summarized in Table 2-8 and the general push locations are summarized in Figure 2-16. There were 62 depth-discrete vadose-zone soil samples collected through the top of the CCU to identify potential DNAPL liquid carbon tetrachloride source term. Iodine field screening, to indicate the presence of carbon tetrachloride, was performed on a majority of samples. Slim-hole borehole geophysical instruments (less than 5.7 cm [2.24 in.] in diameter) also were raised and lowered down the HHR rod for collection of geophysical logging data. These spectral-gamma and neutron moisture-logging surveys were performed inside the casing to guide the selection of depth-discrete vadose-zone samples, assess radiological hazards, prepare for extraction of borehole rods, and support sample-management controls. One active soil-gas sample also was collected and field measured for carbon dioxide, carbon tetrachloride, chloroform, and water vapor. In addition, the HHR was used to install three, 1.9 cm (0.75-in.) diameter, GeoInsight[9] soil-vapor monitoring wells with a screen depth of approximately 19.0 to 19.5 m (DOE/RL-2007-22).

Subsequent additional HHR field investigations were not conducted at the 216-Z-1A Tile Field because of budgeting priorities for the DNAPL investigation (DOE/RL-2007-22). The HHR

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[8] 1302 photoacoustic gas analyzer is a trademark of Brüel and Kjær, S&V, Nærum, Denmark.

[9] GeoInsight is a trademark of GeoInsight, Inc., Manchester, New Hampshire.

216-Z-1A Tile Field investigation not only supported the DNAPL investigation, but also would have supported and completed one of the tasks in the Work Plan (DOE/RL-2001-01). Sampling of the Cold Creek silt was the focus during the Work Plan as the most likely location for retention of DNAPL in the soil column. The Stage 4 DNAPL investigation locations at the 216-Z-1A Tile Field and the 216-Z-18 Crib generally were planned to correlate with the locations of the Stage 2 CPT DNAPL investigation. The CPT investigation included the shallower zone at the 216-Z-1A Tile Field and the 216-Z-18 Crib. However, the objective of the Stage 4 DNAPL investigation was to sample to greater depths and target the Cold Creek silt. The carbon tetrachloride concentrations detected during the Stage 2 DNAPL investigation sampling were two to three orders of magnitude below the action level identified in the Work Plan as indicating proximity to DNAPL. Only two Stage 2 DNAPL investigation locations had carbon tetrachloride soil-gas concentrations exceeding 100 ppmv, and both were within the boundary of the 216-Z-1A Tile Field (DOE/RL-2006-58). Based on the Stage 2 DNAPL investigation results, it appears unlikely that Stage 4 DNAPL investigation sampling would have found significant concentrations of carbon tetrachloride through the top of the CCU. The 216-Z-9 Trench received significantly higher carbon tetrachloride loadings than the 216-Z-1A Tile Field. However, only a limited amount of DNAPL has been identified at the 216-Z-9 Trench, indicating that comparable high concentration regions of carbon tetrachloride at the 216-Z-1A Tile Field would have been less likely (DOE/RL-2007-22).

2.4.2.2 Investigation of Potential Accumulation Areas at the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib

This investigation was conducted near the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib waste sites to evaluate lateral migration beyond the waste site boundaries. The results were used to identify low points in the fine-grained layers in the vadose zone that could be source or DNAPL accumulation points. The CCU is the main fine-grained layer in the vadose zone present beneath the waste sites (see Section 3.1), which is why it was the main focus of the investigation. As part of the RI process, a thin silt lens was identified at 19.8 m (65 ft) bgs adjacent to the 216-Z-9 Trench as an additional focus area.

This investigation had three main components.

- Develop structure contour maps of the CCU in the area around the release sites to identify low points that could be accumulation areas for carbon tetrachloride as DNAPL.
- Collect soil-vapor samples above and within the CCU at low points to confirm potential DNAPL or source presence.
- Collect soil-vapor samples above and within the CCU at the locations northwest and southwest of the 216-Z-9 Trench, where an anomaly that could indicate DNAPL was identified in a 1999 seismic-reflection survey.

The methodologies used to complete these investigations are described below.

A variety of geologic cross sections and structure contour maps have been prepared over the years that have helped to depict the nature and subsurface geometry of the various geologic layers in the release site area (e.g., PNL-7866, *Characteristics of the Volatile Organic*

Compounds – Arid Integrated Demonstration Site; WHC-SD-EN-TI-008, *Geologic Setting of the 200 West Area: An Update*; WHC-SD-EN-TI-248; PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*; PNNL-14895, *Three-Dimensional Modeling of DNAPL in the Subsurface of the 216-Z-9 Trench at the Hanford Site*). The level of detail and variations in interpretation in these reports are caused by a variety of factors including size of the area and study purpose, data sets used or available (e.g., boreholes drilled to date, lithologic logs, geophysical logs, physical property data), differences in picking geologic contacts (see WMP-22817, *Geologic Contacts Database for the 200 Areas of the Hanford Site*), differences in the level of detail on borehole logs, and use of different well elevations. The structure contour maps in PNNL-14895 provide the most current and detailed interpretation of the subsurface geometry of the major geologic units in the study area. However, a more refined characterization of fine-grained vadose-zone layers around the release sites was needed for this investigation.

High-resolution characterization of the subsurface geometry of the fine-grained vadose-zone layers around the release sites was obtained by using lithologic profiling from electric cone penetration test data from the CPT investigations (see Section 2.4.2.1), combined with cross-well seismic reflection profiling that typically is used in oil field reservoir investigations. The results of these investigations provided resolution of the subsurface layer geometries of about 0.6 m (2 ft). .

The tip and sleeve stress data, which were obtained at 5 cm (2-in.) intervals over the full depth of each electric CPT push, and the calculated ratios of sleeve friction to tip resistance, were used to identify normalized soil-behavior type following Robertson, 1990, "Soil Classification Using the Cone Penetration Test." This produced highly detailed soil-behavior-type logs based on the soil engineering properties that were reviewed by a geologist to produce lithologic logs for each CPT location. The geologic review included selecting the deepest CPT push at each location and grouping similar soil-behavior types that were at least 15 cm (0.5 ft) thick into individual lithologic layers. This methodology produced highly detailed lithologic logs that identified fine-grained layers as thin as 15 cm (0.5 ft), significantly more detailed than the conventional driller's or geologist's borehole logs available for wells in the same area.

Twelve cross-well seismic-reflection survey profiles were collected from March 22-30, 2005, using existing wells around the 216-Z-9 Trench (Figure 2-17) (DOE/RL-2006-58). Because the source and receivers needed to be fluid coupled to transmit energy between the wells, removable FLUTe liners were deployed in the wells before they were filled with potable water. The piezoelectric seismic source swept with a frequency of 100 to 800 Hz, and reflections up to 400 to 500 Hz were obtained in the unconsolidated vadose-zone sediments. The longest inter-well distance was 81 m (267 ft), and logging depths typically were less than 61 m (200 ft).

Data processing resulted in tomographic velocity images from the first arrival picks. Reflection image processing included multichannel filtering to remove coherent noises such as tube waves, direct arrivals, and down-going reflections, as well as shear energy. After filtering the reflection, the data underwent deconvolution, imaging with the vertical seismic profile-common depth point transform, and migration to produce a final migrated reflection image. An example of a final cross-well profile, which is a tomographic image overlain with the migrated high-frequency seismic reflection image, is shown in Figure 2-18.

The final cross-well profiles then were interpreted to map the subsurface geometry of specific vadose-zone layers (DOE/RL-2006-58). The well locations and elevations and the borehole geologic (lithologic) logs for the wells used in the cross-well survey were obtained from the *Hanford Well Information System* (HWIS) database. This information, together with stratigraphic contacts (e.g., WMP-22817) were used to position stratigraphic columns for each well next to the corresponding seismic profile to help guide and constrain the interpretation to the extent feasible.

The key vadose-zone layers for this project were the fine-grained layers within the Hanford formation and the CCU, because they are the most likely layers to influence the transport and accumulation of contaminants in the vadose zone. After careful review of the seismic profiles and the well stratigraphy, the reflectors corresponding to the following contacts were identified for interpretation and mapping on each profile: the top of the Ringold Formation, the top of the CCU, a reflector in the middle of the Hanford formation sand-dominated unit, and a reflector near the top of this unit. These layers are labeled, respectively, 'Ringold,' 'Cold Creek Uz,' 'Mid Hanford Sand,' and 'Near Top Hanford Sand' in the interpreted profile shown in Figure 2-19.

Stratigraphic boundaries and seismic reflection boundaries do not always correspond in detail. The seismic reflections are indicative of changes in velocity and density, which can occur with facies changes as well as changes in stratigraphy. So rather than a single boundary reflection between stratigraphic units, the seismic boundary may be a sequence of reflections from overlapping facies boundaries, which makes interpreting the location of the stratigraphic boundary somewhat subjective. This is the geophysical equivalent of the subjective differences in picking geologic contacts in Hanford Site wells (see WMP-22817) previously described.

After these layers were interpreted on each seismic profile, and the interpretations were checked for reasonably good depth ties to each other and the well stratigraphy at the profile intersections, the location and depth of each interpreted layer at every 20th trace were interpolated based on the known well coordinates and elevations. The resulting data then were gridded and used to prepare two-dimensional subsurface topographic maps of each layer, which are shown in Figures 2-20 to 2-23.

As part of the geophysical interpretation of the cross-well profiles, an attempt was made to determine the lateral extent of a thin silt layer that was found from 19.8 to 20.4 m (65 to 67 ft) deep in well 299-W15-46, adjacent to the south side of the 216-Z-9 Trench (DOE/RL-2006-58).

At well 299-W15-46, from 19.8 to 20.4 m (65 to 67 ft), high carbon tetrachloride soil concentration (380,000 µg/kg) and high carbon tetrachloride soil-vapor concentrations (8,560 ppmv) were reported. In addition, field tests on this silt layer were positive for carbon tetrachloride as a DNAPL (WMP-26264).

The HHR vadose-zone investigation in 2006 was able to provide clear evidence of the presence and absence of DNAPL through the top of the CCU south of the 216-Z-9 Trench. The HHR vadose-zone investigation activities only identified one significant source of carbon tetrachloride DNAPL contamination. At well C5336 (P66), from 19.5 to 20.1 m (64 to 66 ft) bgs, the soil sample reported 390,000 µg/kg of carbon tetrachloride. This result directly correlates with the

soil sample from 19.4 to 20.1 m (63.5 to 66 ft) bgs at well 299-W15-46 (DOE/RL-2007-22). These two samples had the highest carbon tetrachloride soil concentrations found at any location in the subsurface of the 200 West Area since the beginning of the carbon tetrachloride contamination investigation in the early 1990s.

Although a single 0.6 m (2-ft)-thick silt layer is considered to be below the limit of resolution of the seismic profile data, after careful review of the profiles, seismic reflection effects were found that are suggestive of thin layer pinchouts or lenses in the expected depth range of the silt layer in well 299-W15-46. Although the cross-well data cannot conclusively identify these reflection effects with a silt layer, the characteristic thin layer reflections were mapped in the 18 to 21 m (60- to 70-ft) depth range for subsequent confirmation of lithology by direct sampling in the HHR investigations. The interpretation is that two or more thin lenses, possibly overlapping, are present within portions of the seismic profiles (DOE/RL-2006-58). The interpreted extent of the thin layer reflections is shown in Figure 2-24. This extent is approximately coincident with the lows observed in the contour map of the reflector in the middle of the Hanford formation sand-dominated unit (Figure 2-21), which would be expected if thin fine-grained layers were deposited in paleo-channels or ponds during the later stages of flood events typical of the Hanford formation sedimentation.

Eleven cross-well seismic reflection survey profiles were collected from February 27 to March 8, 2006, using existing wells and one newly installed well around the 216-Z-1A Tile Field (Figure 2-25) (DOE/RL-2006-58). To obtain seismic profiles through the northern part of the tile field, a new vadose-zone well (P57 in Figure 2-25) was drilled to 56.4 m (185 ft) depth from February 2-17, 2006, and a FLUTe liner was installed inside the 20 cm (8-in.) temporary casing. The well lining, data acquisition, and data-processing steps were the same as those previously described for the cross-well seismic investigation at the 216-Z-9 Trench. The longest inter-well distance was 119 m (390 ft), and logging depths typically were less than 55 m (180 ft).

The final cross-well profiles were interpreted, and structure contour maps of specific vadose-zone layers beneath the 216-Z-1A Tile Field were developed, using the process previously described. The reflectors corresponding to the following contacts were identified for interpretation and mapping on each profile: the top of the Ringold Formation, the top of the CCU, the base of the Hanford formation sand-dominated unit (e.g., the top of the Hanford formation gravel-dominated unit [H3]), and near the top of this unit. These layers are labeled, respectively, 'Top of Ringold,' 'Cold Creek Uz,' 'Base Hanford Sand,' and 'Near Top Hanford Sand' in the interpreted profile shown in Figure 2-26. The two-dimensional subsurface topographic maps of these layers are shown in Figures 2-27 to 2-30.

The resulting detailed geometry of the subsurface vadose-zone layers interpreted from the cross-well seismic reflection profiles was used to identify target depths for intrusive soil sampling as part of the HHR soil-sampling investigations around the release sites. These results are summarized in Section 3.2, and details are provided in DOE/RL-2007-2.

Eleven key existing wells around the release sites were geophysically logged in FY 2006 to support refinement of the interpretation of potential DNAPL accumulation areas (Figure 2-31). The specific wells and types of geophysical logging conducted are provided in Table 2-9.

A discussion of the borehole geophysics is provided in Section 3.2.4.1. The geophysical logging results are available at http://www.hanford.gov/cp/gpp/data/vzcp/vzcp.cfm.

In 1999, a seismic-reflection survey was conducted along four lines around the 216-Z-9 Trench (Waddell et al., 2003). This study suggested that amplitude-versus-offset technology could be used to directly detect the presence of subsurface carbon tetrachloride DNAPL. The study identified several seismic anomalies that could be attributed to possible carbon tetrachloride DNAPL near the top of the CCU silt unit and the top of the CCU caliche unit. These anomalies were found on line Z-9-2, an east-west line on the north side of the 216-Z-9 Trench that ran just north of well 299-W15-32, and on line Z-9-1, a NNW-SSE-trending line along the west side of the trench that ran through well 299-W15-217. These locations were investigated by passive soil-vapor locations 56, 59, 87, and 88 (Figure 2-10) and CPT locations P17, P20, and P24 (Figure 2-14). The results of these investigations are discussed in Section 3.2.4.1, but none of these locations had soil-vapor concentrations greater than 5 ppmv.

2.4.2.3 Investigation Adjacent to the 216-T-19 Crib, 216-Z Ditches, 216-Z-7 Crib, 216-Z-12 Crib, 216-Z-16 Crib, and 216-Z-17 Trench

Data collected at these release sites during Step I did not extend through the upper vadose zone, so the focus of the Step II investigation was to collect samples from the deep vadose zone. The sampling design indicated that, if possible, soil and soil-vapor sampling conducted during the borehole drilling planned for the 216-Z-7 Crib as part of the 200-LW-2 OU RI (DOE/RL-2001-66, *Chemical Laboratory Waste Group Operable Units RI/FS Work Plan, Includes: 200-LW-1 and 200-LW-2 Operable Units*) may be used to collect soil-vapor and soil sampling data at that site instead of the direct-push technology methods specified in the Step II sampling design.

The investigation adjacent to the 216-T-19 Crib, 216-Z Ditches, 216-Z-7 Crib, 216-Z-12 Crib, 216-Z-16 Crib, and 216-Z-17 Trench was completed using both direct-push technologies (Enhanced Access Penetration System [EAPS] and CPT) and borehole drilling.

The EAPS was used to collect soil-vapor samples from the shallow and deep vadose zone in six borings adjacent to the 216-Z-16 Crib, 216-Z-17 Trench, and the 216-S-25 Crib (Figure 2-32). The 216-S-25 Crib borings are discussed in Section 2.4.2.6.

The EAPS combines direct-push CPT and air-rotary-drilling methodologies into an integrated system. The principal differentiator in EAPS deployments is the drilling system used. Two drilling systems are available: 7.25 cm (2.875 in.) and 5 cm (2 in.). The 7.25 cm (2.875-in.) drill is the more powerful of the two and is recommended in situations where very hard materials are encountered. A typical scenario for the 7.25 cm (2.875-in.) drill system is to drill through shallow, upper refusing layers to expose softer, deeper layers that can be further penetrated by direct-push CPT. In this scenario, the center rods of the drill string are removed and 4.45 cm (1.75-in.) CPT rods and tools are advanced through the outer drill casing. The 5 cm (2-in.) drill system is an interchangeable direct-push and drilling system that can accomplish a penetration consisting of both direct-push and drilling methods. This system allows the changeover between penetration methods to be made at any point in the penetration and as many times as required (SGW-33829).

Soil-vapor samples were collected under two sampling regimes. The first and simplest was collection of soil vapor through a soil-vapor sampling cone that had been advanced to the target depth by direct push. In this case, samples were taken without any delay period, because the formation was regarded as undisturbed. The vapor samples were transported to the surface through Teflon lines pumped by a small bladder pump. Samples were collected in 1 L Tedlar bags.

The second regime was related to soil-vapor conditions after EAPS air-rotary-drilling activities. It is recognized that the natural soil-gas concentration of any analyte will be perturbed because of permeation of air into a formation, which is inevitable during air rotary drilling. For this project, a period of 12 hours was adopted for the formation to recover after drilling, based on modeling performed during EAPS development. After this rebound period, soil-vapor samples were collected through the soil-vapor sampling cone as the EAPS outer drill casing was retracted. The borehole was filled with grouting material just below the desired sampling depth and then the sample was taken.

Details concerning the drilling, pushing, and sampling of four of the EAPS boreholes are discussed below and are documented in SGW-33829.

216-Z-16 Crib – Borehole C4884 was located on the east side center of the 216-Z-16 Crib, 1.5 m (5 ft) from the edge. The CPT was pushed and soil-vapor samples were collected at 4.6, 7.6, and 15.2 m (15, 25, and 50 ft) bgs before refusal at 19.8 m (65 ft). The 7.25 cm (2.875-in.) EAPS was used to drill down to the desired depth of 46.1 m (151.3 ft), so that soil-vapor samples could be collected at 45.7 and 38.1 m (150 and 125 ft). At 30.4 m (100 ft), the outer drill casing broke before a soil-vapor sample could be collected, so the borehole was redrilled to that depth, and soil-vapor samples were subsequently collected at 30.4 and 22.9 m (100 and 75 ft) before the borehole was decommissioned.

Borehole C4883 was located on the north side center of the 216-Z-16 Crib, 1.5 m (5 ft) from the edge. The vapor sampling cone was used to take samples at 4.6, 7.6, and 12.5 m (15, 25, and 41 ft) bgs before refusal. The hole then was drilled with the 7.25 cm (2.875-in.) EAPS to 45.7 m (150 ft) and left overnight before collecting the soil-vapor sample at that depth. Subsequent soil-vapor samples then were collected at 38.1, 30.4, 22.9, and 15.2 m (125, 100, 75, and 50 ft) before the borehole was decommissioned.

216-Z-17 Trench – Borehole C4885 was located on the west side center of the 216-Z-17 Trench, 1.5 m (5 ft) from the edge. The 5 cm (2-in.) drill system was used to push to 16.3 m (53.5 ft) and collect soil-vapor samples at 4.6, 7.6, and 15.2 m (15, 25, and 50 ft) bgs. The borehole then was drilled to 20.6 m (67.5 ft) using the 7.25 cm (2.875-in.) EAPS. The 4.45 cm (1.75-in.) CPT was direct pushed to 36.9 m (121 ft). The 4.4 cm (1.75-in.) gas-sampling cone then was deployed but immediately met refusal at 37.5 m (123 ft), so the 7.25 cm (2.875-in.) EAPS was used to drill to the desired depth of 45.7 m (150 ft), and the hole was left overnight. Soil-vapor samples were collected at 45.7, 38.1, 30.4, and 22.9 m (150, 125, 100, and 75 ft) bgs before the borehole was decommissioned.

Borehole C4886 was located on the west side south of the 216-Z-17 Trench. The CPT vapor sampling cone was used to collect soil-vapor samples at 4.6, 7.6, 15.2, and 22.9 m (15, 25, 50,

and 75 ft) bgs before refusal at 30.4 m (100 ft). The 7.25 cm (2.875-in.) EAPS was used to drill to the desired depth of 45.7 m (150 ft), and the hole was left overnight. Soil-vapor samples were collected at 45.7, 38.1, and 30.4 m (150, 125, and 100 ft) bgs before the borehole was decommissioned.

216-T-19 Crib – Three EAPS boreholes were planned to be located adjacent to the 216-T-19 Crib. However, because significant radioactive contamination was expected at this location within 18.3 m (60 ft) of the ground surface, the EAPS air-rotary-drilling system had the potential to bring contaminated cuttings to the surface. The EAPS air-rotary-drilling system was not configured to work in a radiological environment. The air-rotary-drilling system had the potential to contaminate the drilling equipment and the interior of the support truck. The practical experience gained with the EAPS indicated that the direct-push system was unlikely to reach the desired depths by itself. In addition, the maximum shallow soil-vapor carbon tetrachloride concentration during Step I sampling at the 216-T-19 Crib was 1.5 ppmv, and the passive soil-vapor survey indicated relatively low carbon tetrachloride results. The EPA concurred that the investigation at the 216-T-19 Crib was not required, so no further investigation at this site was conducted.

216-Z Ditches and 216-Z-12 Crib – The 216-Z Ditches and 216-Z-12 Crib were investigated during the CPT investigation that was discussed in Section 2.4.2.1. Two pushes at location P41 at the head end of the 216-Z Ditches (Figure 2-15) met refusal at 13.25 and 13.65 m (43.5 and 44.8 ft) (Table 2-7). One push at location P47 on the east side of the 216-Z-12 Crib (Figure 2-16) met refusal at 0.35 m (1.1 ft), and two pushes at location P48 at the north end of the crib met refusal at 22.87 and 23.2 m (75.03 and 76.1 ft) (Table 2-7).

216-Z-7 Crib – Borehole C4183 was drilled and sampled through the 216-Z-7 Crib from the ground surface to the water table at 68 m (225 ft) as part of the investigation of this crib as a representative waste site of the 200-LW-2 OU (D&D-25461, *200-LW-1 and 200-LW-2 Operable Units - Borehole Summary for Boreholes in the 216-S-20, 216-T-28, and 216-Z-7 Cribs*, and DOE/RL-2005-61, *Remedial Investigation Report for the 200-LW-1 (300 Area Chemical Laboratory Waste Group) and 200-LW-2 (200 Area Chemical Laboratory Waste Group) Operable Units*). During the drilling, in situ soil-vapor samples were collected and analyzed in support of the 200-PW-1 OU RI. The soil-vapor samples were screened for volatile organics using hand-held organic vapor analyzers. The in situ soil-vapor samples were collected using the method described in Section 2.1.1.1 at borehole depths of 23 to 23.2 m, 29.4 to 29.6 m, 35.8 to 36 m, 45.5 to 45.7 m, 51.8 to 53.2 m, 59.4 to 60.5 m, and 66.8 to 67.7 m (75.5 to 76 ft, 96.5 to 97 ft, 117.5 to 118 ft, 149.4 to 150 ft, 170 to 174.5 ft, 195 to 198.5 ft, and 219 to 222 ft) (D&D-25461). The results are discussed in Section 3.2.4.3.

2.4.2.4 Activities at Trench 4 in the 218-W-4C Burial Ground

After the Step I investigation at trench T-04 in the 218-W-4C Burial Ground in 2002 detected elevated concentrations of carbon tetrachloride in the east end of the trench (see Section 2.4.1), and the 2003 vent-riser sampling in support of transuranic retrieval, an SVE system was operated at this trench from November 2003 through April 2004. The SVE system was operated to remove carbon tetrachloride from the burial ground trench to minimize release to the environment. Approximately 11 kg (24.25 lb) of carbon tetrachloride were removed from trench

T-04 in the 218-W-4C Burial Ground during FY 2004. The SVE system then was permanently removed to allow retrieval operations to remove the bulk of the soil overburden covering the drums at the east end of trench T-04 (WMP-26178, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Carbon Tetrachloride Site, Fiscal Year 2004*).

Soil-vapor sampling of the vadose zone was planned to be conducted at trench T-04 during the Step II investigation (Table 2-3) in accordance with the Work Plan (DOE/RL-2001-01). FH-0602151, "Area Unit Managers' Meeting, 200 Area Groundwater and Source Operable Units," Attachment 12, "Source Operable Units and Facilities Status," documents RL and EPA concurrence that existing data were sufficient, so that no additional vadose-zone investigations were needed at trench T-04 in the 218-W-4C Burial Ground.

2.4.2.5 Investigation in the Plutonium Finishing Plant Protected Area

The sampling design in the Step I SAP specified shallow soil-vapor sampling (to a depth of 1.5 m [5 ft]) within the PFP Protected Area. A systematic grid was to be used to identify the sampling locations, in accordance with the requirements of the SAP. The results of the shallow, grid-based sampling were to be used to guide selection of locations for deeper soil-vapor sampling using a direct-push technology. However, during the subsequent detailed planning, safety concerns were raised that necessitated using a different sampling strategy. A supplement to the SAP was prepared to formally communicate the revised strategy for the vadose-zone sampling within the PFP Protected Area and to obtain the concurrence of RL and the EPA. The supplement to the SAP was approved by the 200-PW-1 OU mangers in December 2002 and is included in Appendix C of the Work Plan (DOE/RL-2001-01).

As part of the revised sampling design, professional judgment was used, rather than shallow sampling on a grid spacing, to focus the deeper sampling. The Guzzler Vacuum Extraction System[10] (Guzzler) was used through the upper zone (to a minimum depth of 0.9 m [3 ft]) to clear the subsurface for the use of a direct-push technology for sampling. At a minimum, all of the locations selected in the revised strategy were investigated as described in the initial sampling design for focused, deeper sampling using a direct-push technology.

The 17 200-PW-1 OU sampling locations in the PFP Protected Area are shown in Figure 2-33. The rationale for selection of these locations, in order of priority, is provided in Table 2-10. Two locations (C4059 and C4060) are listed twice in Table 2-10 because each had two sampling rationales.

The primary objective of the Step I sampling was to characterize the dispersed plume in the upper 38.1 m (125 ft) of the vadose zone (i.e., above the CCU) in the immediate vicinity of the PFP. The sampling design for focused, deeper sampling using a direct-push technology specified sampling vapors at 4.6 and 7.6 m (15 and 25 ft) bgs, if possible, to indicate the vertical trend. At each location, vapor samples were collected at 7.6 m (25-ft) increments below the

[10] Guzzler is a trademark of Guzzler Manufacturing, Inc. (a subsidiary of Federal Signal Corporation), Streator, Illinois.

7.6 m (25-ft) depth and at the final depth when the GeoProbe was unable to advance deeper (i.e., refusal).

The 17 sample locations were identified in the PFP Protected Area and marked in the field in 2002. The excavation permit process was initiated, location surveys were performed, and ground-penetrating radar was performed at each site to determine any underground hazards. Based on concerns about potentially encountering subsurface hazards not identified by the ground-penetrating radar, a regulated guzzler was used to remove approximately 2.4 m (8 ft) of soil at each sampling location. The soil then was returned to the ground, and the GeoProbe was used for subsurface access for sampling.

Guzzler operations began on July 23, 2003, and were completed on July 28, 2003. The Guzzler, which is basically a large vacuum machine, was able to remove soil using a hose with a rigid attachment. The outside diameter of the hose attachment was about 20.3 cm (8 in.) in diameter, but a hole several times larger in diameter usually would result, because soil/aggregate at the top of the hole typically slid to the bottom. At sites with asphalt at the ground surface, the GeoProbe unit was used to break up the asphalt to allow the Guzzler to be used. All sites were backfilled with the material removed from the holes.

GeoProbe operations began on August 18, 2003, and were completed on August 28, 2003. The total depth and sampling intervals of each borehole are provided in Table 2-11. The GeoProbe system uses 4.45 cm (1.75-in.) outside diameter and 2.5 cm (1.0-in.) inside diameter carbon steel probe rods to provide access to the subsurface to obtain soil-vapor samples. This direct-push system provided a method to obtain soil-vapor samples at various depths without the radiological exposure to workers or the generation of waste associated with normal borehole drilling.

In general, the GeoProbe system was used to collect soil-vapor samples from three intervals at each location. Soil-probe rods were pushed as deep as possible (i.e., to refusal) to obtain vapor samples. The maximum depth penetrated below ground surface was 14.5 m (47.5 ft).

After they reached the refusal depth, the rods were pulled back approximately 0.3 m (1 ft) to allow an expendable probe point to fall out and create an uncased borehole for soil-vapor sampling. The depth to the bottom of the borehole was verified using a measuring tape. A 15.2 cm (6-in.)-long stainless steel screen attached to fluorinated ethylene propylene-lined TYGON tubing was lowered to the bottom of the borehole to obtain the soil-vapor sample. The probe-rod annulus typically was sealed with a fitted rubber stopper to ensure that the sample was being collected from the bottom of the borehole. The photoionization detector was used as a pump to purge the tubing and atmospheric air within the GeoProbe rod. After purging, the soil vapor was collected in a 1 L Tedlar bag for analysis. The samples then were analyzed within the 6-hour holding time using an Innova 1312 multi-gas analyzer.

After the soil-vapor sample was collected, the screen and tubing were removed from the borehole. Granular bentonite was added to the borehole to decommission the lower portion while the probe rods were retrieved. Bentonite was placed to approximately 7.6 m (25 ft) bgs. A soil-vapor sample was collected above this bentonite plug in the same manner as the first soil-vapor sample. The borehole again was partially decommissioned with granular bentonite to

the next sample interval, approximately 4.6 m (15 ft) bgs. After the final sample was collected, the borehole was decommissioned by filling it with granular bentonite to the ground surface. The maximum target depth of 38.1 m (125 ft) was not reached by any of the pushes. The maximum depth penetrated below ground surface was 14.5 m (47.5 ft), and the minimum depth was 8.7 m (28.5 ft).

2.4.2.6 Investigation Adjacent to the 216-S-25 Crib

This potential release site was not investigated during Step I, because it is located outside of the Step I study area. The Step II sampling design included collection of soil vapor from the shallow and deep vadose zone adjacent to the 216-S-25 Crib.

The EAPS was used to collect soil-vapor samples from the shallow and deep vadose zone and one groundwater sample in two borings adjacent to the 216-S-25 Crib (Figure 2-32). The EAPS operation and sampling methodology were discussed in Section 2.4.2.3. Details concerning the drilling, pushing, and sampling of the two EAPS boreholes used to investigate this site are discussed below and are documented in SGW-33829.

Borehole C4890 was located on the south side center of the 216-S-25 Crib, 0.9 m (3 ft) from the edge of the crib. A CPT probe with a gas-sampling port was initially pushed to 17.3 m (56.8 ft), and soil-vapor samples were collected at 4.6, 7.6, and 15.2 m (15, 25, and 50 ft). The 7.25 cm (2.875-in.) EAPS was used to drill to the desired depth of 68.3 m (224 ft) on July 7, 2005. On July 11, 2005, the water level in the boring was measured at 65.8 m (216 ft). A bladder pump was lowered through the drill casing into the groundwater, and the groundwater was pumped to the surface and collected in sample containers. This groundwater sample (*Hanford Environmental Information System* [HEIS] number B1DFF8) subsequently was analyzed for VOCs.

On July 12, 2005, a soil-vapor sample was collected at 65.5 m (215 ft), 0.3 m (1 ft) above the water table. Six samples were taken at 7.6 m (25-ft) intervals from 61 m (200 ft) up to 22.8 m (75 ft). As each sampling depth was completed, the boring was filled with bentonite to the elevation of the next sample. Upon completion of the soil-vapor sampling, the hole was decommissioned.

Borehole C4891 was located on the east side center of the 216-S-25 Crib, 1.2 m (4 ft) from the edge of the crib. The vapor sampler was advanced to 10.2 m (33.5 ft) by direct push, and soil-vapor samples were collected at 4.6 and 7.6 m (15 and 25 ft). The 5 cm (2-in.) EAPS drill then was used to 15.2 m (50 ft), where a soil-vapor sample was collected. This sample was collected before the prescribed 12-hour rebound time had elapsed. Drilling then resumed to 17.7 m (58 ft) before mechanical issues with the EAPS forced the work to stop. The cone was subsequently re-pushed to refusal at 17.7 m (58 ft). The 5 cm (2-in.) EAPS drill was used to drill from 17.7 to 21.6 m (58 to 71 ft). Investigation of mechanical problems during a direct push to the 22.8 m (75-ft) sampling interval found that the outer drill bit had detached and plugged the boring. Subsequent drill bit and mechanical problems resulted in two more borings, located 1.5 m (5 ft) away from the original boring, which were decommissioned after they reached 3.2 and 21.3 m (10.7 and 70 ft), respectively.

On July 20, 2005, the rig was moved another 1.5 m (5 ft) from the original location, and the 4.44 cm (1.75-in.) vapor-sampling probe was pushed to 22.8 m (75 ft) to collect the first soil-vapor sample, before encountering refusal at 27 m (88.5 ft). The 7.25 cm (2.875-in.) EAPS drill was used to drill the boring to 32.6 m (107 ft). The boring then was continued in direct-push mode with a 4.45 cm (1.75-in.) cone to the target depth of 45.7 m (150 ft) and was left overnight before soil-vapor sampling began. Soil-vapor samples were collected at depths of 45.7, 38.1, and 30.5 m (150, 125, and 100 ft) before the borehole was decommissioned.

2.4.2.7 Investigation at the 218-W-3A Burial Ground

The 218-W-3A Burial Ground was a suspect release site located adjacent to one of the groundwater "hot spots." The Step II sampling design at this site included both passive and active vapor sampling methods to investigate trench locations that may have received volatile organic wastes.

The investigation of the 218-W-3A Burial Ground included a passive soil-vapor survey of two trenches and vapor sampling of vent risers in engineered trenches within the burial ground. The passive soil-vapor survey deployed passive soil-vapor collectors using the methodology described in Section 2.4.2.1. Collectors were placed at 12 locations along trench T-06 and at 10 locations along trench T-9S from June 30 to July 5, 2005, as summarized in Table 2-12. After retrieval, the collectors were sent to the vendor's laboratory for analysis of VOCs.

Vapor samples from the 17 vent risers present in portions of trenches T-9S, T-3S, T-05, and T-08 were collected and analyzed using field-screening instruments (Figure 2-34). All of the vent risers in trenches T-9S (one riser), T-3S (three risers), and T-05 (six risers) were sampled on August 25, 2005, and all of the vent risers in trench T-08 (seven risers) were sampled on September 6, 2005. A sample location number (trench and riser) was established and recorded for each vent riser. The vent risers in each trench were numbered sequentially from west to east.

After removing the vent riser cap, a 15.2 m (50-ft)-long piece of TYGON tubing was lowered to the bottom of the riser or until refusal. The tubing measured 0.64 cm (0.25-in.) inside diameter and 0.95 cm (0.375-in.) outside diameter, with a metal filter on the lower end. The tubing was marked at 0.3 m (1-ft) intervals so that depth from the top of the riser to the bottom could be measured. The depth-to-bottom from the top of the riser typically was 5.8 to 6.4 m (19 to 21 ft). The tubing then was pulled back approximately 0.08 m (0.25-ft) to lift the filter off the bottom of the trench. The top of the riser was sealed to prevent intrusion of ambient air during purging and sampling.

The sample tubing was connected to a sampling pump, which was used to pump vapor from the bottom of the vent riser. The sampling pump was operated for 1 to 2 minutes to purge the tubing (purging time was dependent on the sampling-pump flow rate). When the sampling pump was operating, the VOC concentrations at the outlet of the pump were monitored using an organic vapor analyzer (OVA). When the VOC concentration readings on the OVA stabilized after purging, or at the discretion of the industrial hygienist and field sampler, the vapor was

introduced directly to a MIRAN SapphIRe Ambient Air Analyzer[11] for field-screening analysis of VOCs. Following sample analysis, the sample tubing was removed from the riser and the cap was replaced.

The results of these investigations are discussed in Section 3.2.4.6, but because none of the sample locations had significant soil-vapor concentrations of carbon tetrachloride that would warrant a vadose-zone investigation, no further investigations were conducted at the 218-W-3A Burial Ground for this RI.

2.4.2.8 Investigation of Groundwater "Hot Spots"

Eight carbon tetrachloride groundwater "hot spots" that have had persistent carbon tetrachloride concentrations were investigated in the Step II investigation. The existence and persistence of these "hot spots" are indicative of a continuing source at these locations. By "looking up" from the groundwater hot spots, the source of the contamination in the vadose zone may be identified.

The investigation of the eight groundwater "hot spot" areas shown in Figure 2-9 was conducted by collecting both soil-vapor and groundwater samples from existing wells in the vicinity of these "hot spots" and then comparing the sample results using Henry's law for the equilibrium partitioning of carbon tetrachloride between the vapor and aqueous phases (DOE/RL-2001-01, Appendix D, p. D-21). The list of wells in Table D-10 of the Work Plan (DOE/RL-2001-01) was revised during the pre-job planning, and the wells that were sampled and their rationale for selection are listed in Table 2-13. The well locations are shown in Figure 2-35.

The groundwater samples were collected from 31 wells between June 22, 2005, and June 21, 2006, using microsampler bailers. Samples were collected from approximately the upper 5 cm (2 in.) of the aquifer below the static water surface. The use of the microsampler surface bailer limits the amount of agitation at the air-water interface. Therefore, the collected samples are expected to provide a better representation of carbon tetrachloride concentrations at the top of the aquifer. Sampling using the microsampler, which fills from the top, required at least 58 cm (23 in.) of water in the well. When a well provided insufficient water for sampling (i.e., less than 58 cm of water in the well), the well was sampled using an alternative sampling method. The only wells that did not yield sufficient water for sample collection with the microsampler bailers were wells 299-W11-14 and 299-W15-16. The groundwater sample from well 299-W11-14 was collected using a wide-mouth 250 mL bottle secured to the end of an electronic tape (e-tape). No water was measured in well 299-W15-16 as part of this investigation.

The microsampling device consisted of a 58 cm (23-in.) length of TYGON tubing attached to the bottom of an e-tape. The e-tape was used to provide an electronic signal to indicate when the water column in the well was encountered. The closed end (bottom) of the tubing was positioned next to the sensor of the e-tape, and the top of the tubing was open to allow water to flow into the tubing. The device was lowered into the well until the e-tape indicated contact with the water surface. The depth to static water level was recorded based on the e-tape response.

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[11] MIRAN and the SapphIRe Ambient Air Analyzer are registered trademarks of Thermo Electron Corporation, Franklin, Massachusetts.

The micro-sampling device then was lowered and filled with water. The groundwater samples subsequently were transferred from the microsampling bailer to appropriate sample containers using a syringe or other method to minimize agitation and volatilization. If the groundwater in a well was recently disturbed (e.g., by groundwater sampling or maintenance), the groundwater system within the well was allowed at least 7 days to return to equilibrium following the disturbance before it was sampled with the microsampler.

All of the groundwater samples were laboratory analyzed for VOCs using EPA Method 8260 (SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update III-A*, as amended), because the field gas chromatograph stopped functioning.

The soil-vapor samples were collected from 30 wells between June 22 and November 23, 2005, using a Teflon-lined TYGON tube attached to the e-tape approximately 10 cm (4 in.) above the top of the microsampling TYGON tubing. A pump was used to draw the vapor to the surface, where it was collected in Tedlar bags. The vapor samples were collected immediately above the water table or above the bottom of the well if the well was dry. Because no water was measured in well 299-W15-16, a vapor sample was collected from the lowermost 0.6 m (2 ft) of the screened or perforated interval in the vadose zone.

Soil-vapor samples were collected during soil venting periods (e.g., when the barometric pressure was falling), to collect representative results. If necessary, the borehole was sealed to prevent inflow of atmospheric air until falling atmospheric and venting conditions existed before sampling began. Sealing of the wells was accomplished by using a large plastic bag placed over the top of the casing and then taped closed. During times with rising barometric pressure, the bag would be drawn tight against the well casing, and during times of falling barometric pressure, the bag would be inflated.

Vapor samples were collected in Tedlar bags through probes and/or TYGON tubing from the surface to just above the water surface. The tubing was purged from the line by using a portable diaphragm pump. The purging time was based on the length of the tubing and the pumping rate. After one volume of air had been purged, the line was attached to the Tedlar bags and a sample was collected. Analysis of the soil vapor was performed using a B&K 1302 photoacoustic gas analyzer or other field-screening instrument that could differentiate carbon tetrachloride from chloroform at the target-required quantitation limits (DOE/RL-2001-01, Table D-5).

To establish the carbon tetrachloride concentration gradient in the upper 3 m (10 ft) of the unconfined aquifer, depth-discrete groundwater samples were planned to be collected from one well in each groundwater hot spot area (DOE/RL-2004-78, Appendix A). The wells and sampling depths for the depth-discrete sampling are listed in Table 2-14. The depth-discrete groundwater samples were collected from all wells using the same equipment, except for well 299-W11-25B, where the water samples were collected by pumping after the borehole was drilled to 6, 12, 18, 24, 30, and 36 m (20, 40, 60, 80, 100, and 120 ft) below the water table (PNNL-15776, *Borehole Data Package for Two RCRA Wells 299-W11-25B and 299-W11-46 at Single-Shell Tank Waste Management Area T, Hanford Site, Washington*). A straddle packer system was used to isolate the well screen or perforated casing intervals (0.6 m [2-ft] interval in 10 and 15 cm [4 and 6-in.] wells and 0.9 m [3-ft] interval in 20 cm [8-in.] wells). Low-flow purging and sampling methods using a bladder pump were used to collect each groundwater

sample. Purge rates typically ranged from 150 to 500 mL/min until field parameters were stable, and then the sample was collected. The depth-discrete groundwater samples were collected from the top to the bottom of the well to minimize disturbance of the water column. The groundwater samples then were laboratory analyzed for VOCs, using EPA Method 8260 (SW-846).

2.4.2.9 Investigation of Possible Release Sites/Sources

In addition to the specific Step II investigation tasks described in the previous sections, a variety of investigations have been conducted within the Step II study area that provide useful information on the nature and extent of the dispersed carbon tetrachloride vadose-zone plume and possible release sites/sources. These investigations are summarized in this section, and the results are discussed in Section 3.2.4.8.

Burial Grounds Soil-Vapor Survey – As part of the 200-SW-2 OU investigation, a passive soil-vapor survey was conducted in 2006 along selected trenches in five burial grounds within the 200 West Area (D&D-28283, *Sampling and Analysis Instruction for Non-Intrusive Characterization of Bin 3A and Bin 3B Waste Sites in the 200-SW-2 Operable Unit*) (Figures 2-7 and 2-34). The passive soil-vapor survey deployed passive soil-gas collectors using the methodology described in Section 2.4.2.1.

T Plant Soil-Vapor Survey – A passive soil-vapor survey around the T Plant was conducted using the passive soil-gas collectors and the methodology described in Section 2.4.2.1. The collectors were placed at 30 locations (see Figure 2-36) around the plant from May 26 to June 1, 2005, as summarized in Table 2-15. After they had been retrieved, the collectors were sent to the vendor's laboratory for analysis of VOCs.

Fiscal Year 2001 to 2006 Well Drilling for Other Operable Units – Soil-vapor samples have been collected and analyzed for carbon tetrachloride in support of the 200-PW-1 OU RI in 12 wells that were drilled for the investigation of other OUs in the 200 West Area from FY 2001 to 2006. The soil-vapor samples are summarized in Table 2-16. The locations of the wells are shown in Figure 2-37.

Six soil samples were collected during the drilling of Borehole C3102 in the 216-T-26 Crib and were analyzed for carbon tetrachloride in support of the 200-PW-1 OU RI (DOE/RL-2002-42, *Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (Includes the 200-PW-5 Operable Unit)*). The 216-T-26 Crib is located east of the TY Tank Farm in the 200 West Area. Borehole C3102 was drilled from June 24 through July 26, 2001, in support of the RI for the 200-TW-1 OU. The soil samples were collected from the following intervals: 6.7 to 7.5 m (22 to 24.5 ft) bgs, 20.5 to 21.3 m (67.3 to 69.8 ft) bgs; 28.0 to 28.8 m (92 to 94.5 ft) bgs, 45.0 to 45.3 m (147.5 to 148.5 ft) bgs, 60.2 to 60.6 m (197.5 to 198.8 ft) bgs, and 68.9 to 69.2 m (226 to 227 ft) bgs.

In FY 2006, soil-vapor samples were collected during the drilling of six selected groundwater wells in locations of some of groundwater "hot spot" areas shown in Figure 2-35 or in areas where the groundwater has not been previously sampled. At each drilling location, soil-vapor samples are being collected approximately 1.5 m (5 ft) above the CCU, 1.5 m (5 ft) below the CCU, and just above the water table. One well (299-W10-25/299-W10-31) is in groundwater "hot spot" area 1, one well (299-W11-47) is in area 2, one well (299-W11-86) is in area 4, one

well (299-W15-224) is in area 7, and two wells are in areas where the groundwater has not been previously sampled (299-W14-71, 299-W14-72) (Figure 2-37). The soil-vapor samples collected from these wells are included in Table 2-16, and the results are discussed in Section 3.2.4.8.

Enhanced Access Penetration System Demonstration 2003 – A field demonstration of the EAPS was conducted in the 200 West Area from September 26 to October 29, 2003 (Applied Research Associates, 2004, *Enhanced Access Penetration System (EAPS) Draft Final Technical Report*). During this period, six boreholes were pushed and drilled in a north-south corridor along the east side of the burial grounds, extending from the southwest corner of the PFP in the south to the northeast corner of the 218-W-3 Burial Ground in the north. Soil-vapor samples were collected in four of the six boreholes, as follows: C4241 (10 samples), C4242 (16 samples), C4243 (1 sample), and C4244 (2 samples). Locations of the EAPS boreholes are shown in Figure 2-32.

The soil-vapor samples were collected by continuously drawing vapors from the piezo-vapor cone, typically through 1/8-in. internal diameter (3/16-in. outside diameter) Teflon tubing. The samples were drawn to the surface by a 2.5 L/min diaphragm pump or similar device and passed through a sampling "tee" at the surface. One branch exited to the atmosphere through a granular-activated carbon filter, while the other was connected to the inlet of a photoacoustic infrared analyzer in the CPT truck, where the sample was field screened for carbon tetrachloride.

Fiscal Year 1992 and 1993 Well Drilling Near Release Sites – In 1992 and 1993, as part of the 200 West Area Carbon Tetrachloride Expedited Response Action and the Volatile Organic Compounds – Arid Integrated Demonstration project, 11 wells were drilled and two existing wells were deepened around the 216-Z-9 Trench and 216-Z-1A Tile Field. The results of these investigations are reported in WHC-SD-EN-TI-063, *FY1992 Site Characterization Status Report and Data Package for Carbon Tetrachloride*; WHC-SD-EN-TI-202, *FY93 Site Characterization Status Report and Data Package for the Carbon Tetrachloride Site*; and BHI-00105, *FY 1993 Wellfield Enhancement Status Report and Data Package for the 200 West Area Carbon Tetrachloride Expedited Response Action.* In FY 2005, the chemical constituent data for 12 of these wells was entered into HEIS. The radionuclide analytical results for these 13 wells were not entered at that time, because the data were not available in electronic format; the VOC analytical results for well 299-W15-223 (a slant well) were not entered at that time because of HEIS limitations in entering geospatially oriented samples (other than well location coordinates and vertical sample depths).

In FY 1992, wells 299-W15-217, 299-W18-248, and 299-W18-249 were drilled to the CCU and completed as vadose-zone SVE wells. Soil-vapor and soil samples were collected from these wells for VOC, chemical, radiological, and/or physical property analysis.

In FY 1992, wells 299-W15-216, 299-W18-246, and 299-W18-247 were drilled to 5 m (16 ft) below the water table and completed as vadose-zone SVE wells. Soil-vapor, soil, and groundwater samples were collected from these wells for VOC, chemical, radiological, and/or physical property analysis.

In FY 1993, wells 299-W18-96 and 299-W18-174 were deepened, and new well 299-W15-223 was drilled at a 45-degree incline, to the CCU. All three wells were completed as vadose-zone

SVE wells and were deepened/drilled to the CCU. Soil-vapor and soil samples were collected from these wells for VOC, chemical, radiological, and/or physical property analysis.

In FY 1993, wells 299-W15-218, 299-W15-219, 299-W15-220, and 299-W18-252 were drilled to 5 m (16 ft) below the water table and completed as vadose-zone SVE wells. Soil-vapor, soil, and groundwater samples were collected from these wells for VOC, chemical, radiological, and/or physical property analysis.

Three of these wells, 299-W18-96, 299-W18-247, and 299-W18-249, are associated with the 216-Z-18 Crib, but they are included in this report to help understand the dispersed carbon tetrachloride vadose-zone plume in this area.

Fiscal Year 1991 Soil-Vapor Sampling – Soil-vapor monitoring points were installed from February 20 to 23, 1991. Twenty-two vapor-sampling points were constructed by driving stainless steel vapor-sampling probes to a depth of 1.2 to 1.5 m (4 to 5 ft). Then 3/16-in. Teflon tubing was installed in each point, extending from the vapor-probe depth to the ground surface. Locations of the 22 vapor sampling points are summarized in Table 2-17 and Figure 2-38.

Soil-vapor measurements were collected from the vapor sampling points on March 14, 1991, using an OVA equipped with an 11.7 eV lamp. The instrument was calibrated to a 100 parts per million (ppm) isobutylene standard before the vapor measurements were collected. For collecting the soil-vapor measurements, the OVA was connected to the tubing and vapor was pumped into the OVA for 1 to 2 minutes. The maximum parts-per-million reading was recorded during the 1- to 2-minute sampling period.

2.4.3 Non-Field Investigations

A variety of non-field investigations have been conducted on different aspects of the carbon tetrachloride contamination within the 200 West Area as part of the RI for the 200-PW-1 OU. The following subsections present summaries of some of the key study findings from these investigations.

2.4.3.1 Vadose-Zone Modeling

Fluor Hanford contracted with PNNL to improve the conceptual model for carbon tetrachloride distribution in the 200 West Area subsurface through numerical flow and transport modeling. The following summary is derived from PNNL-14895 and PNNL-15914, *Carbon Tetrachloride Flow and Transport in the Subsurface of the 216-Z-9 Trench at the Hanford Site: Heterogeneous Model Development and Soil Vapor Extraction Modeling*.

Three-dimensional fate and transport modeling was conducted to enhance the conceptual model of the vertical and lateral distribution of carbon tetrachloride beneath the 216-Z-9 Trench. Simulations targeted the migration of carbon tetrachloride and co-disposed DNAPL contaminants in the subsurface beneath the 216-Z-9 Trench. The DNAPL migration was simulated as a function of sediment stratigraphy and of the properties and distribution of

disposed waste. The geological aspects of the computer model were extracted from a larger EarthVision[12] geologic model of the 200 West Area that was developed during FY 2002.

PNNL simulated carbon tetrachloride migration using the STOMP multi-fluid flow and transport model (PNNL-12028, *STOMP Subsurface Transport Over Multiple Phases, Version 2.0, Application Guide*). A total of 23 three-dimensional simulations were conducted to examine carbon tetrachloride subsurface infiltration and redistribution before SVE remediation activities were implemented in 1993. The simulations consisted of 1 base case simulation and 22 sensitivity analysis simulations. The sensitivity simulations investigated the effects of eight variables on the movement and redistribution of DNAPL: (1) fluid composition; (2) disposal rate, area, and volume; (3) fluid retention; (4) permeability; (5) anisotropy; (6) sorption; (7) porosity; and (8) residual saturation. Additional simulations were conducted to investigate the effects of the SVE system.

The simulations indicated that substantial quantities of carbon tetrachloride accumulated in the CCU and that the CCU is the primary determinant of DNAPL movement and distribution in the vadose zone. The CCU is a relatively thin, laterally continuous unit comprising a silt layer and a cemented carbonaceous layer that is located approximately 40 m (131 ft) bgs and approximately 50 m (164 ft) above the water table. The simulations also showed that the lateral extent of the vapor-phase plume in the vadose zone was much more extensive than the lateral extent of the DNAPL. Vapor-phase carbon tetrachloride moved downward until it contacted either relatively impermeable units (e.g., the CCU) or the water table, and then moved laterally. The vapor plume also partitioned into the groundwater and onto the solid phase. The carbon tetrachloride in the CCU is expected to continue volatilizing and moving downward to relatively impermeable layers, where it could be removed through SVE or deeper to the water table. The simulations clearly demonstrate that "free-phase" carbon tetrachloride has not moved laterally from the footprint of the disposal facility. In most simulations, free-phase or dissolved carbon tetrachloride was predicted to enter the water table directly beneath the disposal area or through gaseous transport and subsequent partitioning into the aqueous phase over a widespread area.

In summary, the modeling results led to the following conclusions for updating the conceptual carbon tetrachloride distribution model.

- *Where is carbon tetrachloride expected to accumulate?* Free-phase carbon tetrachloride accumulates in the finer grained layers of the vadose zone but does not appear to pool on top of these layers.

- *Where are continuing liquid carbon tetrachloride sources of groundwater contamination suspected?* Free-phase carbon tetrachloride preferentially migrates vertically downward below the disposal area. Lateral movement of free-phase carbon tetrachloride is not likely; however, significant lateral migration of vapor-phase carbon tetrachloride is expected.

[12] EarthVision is a registered trademark of Dynamic Graphics, Inc., Alameda, California.

- *Where would DNAPL contamination in groundwater be suspected?* Sufficient carbon tetrachloride and other liquid wastes were disposed of for free-phase carbon tetrachloride to migrate as a DNAPL through the CCU and, in some sensitivity cases, across the water table. For the base case simulation, 43 percent of the original free-phase inventory (i.e., 450,000 kg [992,080 lb]) was still present in the vadose zone as a DNAPL in 1993. Most of the DNAPL was located just above and within the CCU. Approximately 27,000 kg (59, 524 lb) (i.e., 6 percent of the inventory) of DNAPL moved across the water table through the end of 1993.

- *What is the estimated distribution and state of carbon tetrachloride in the vadose zone?* The amount of carbon tetrachloride that accumulated in the vadose zone as a DNAPL through 1993 ranges from 19 to 65 percent of the total disposed of in the sensitivity simulations. The majority of the mass in 1993 typically was present in a free-phase DNAPL or sorbed phase. The center of mass for carbon tetrachloride in the vadose zone typically was directly beneath the disposal area and within the CCU.

- *How does SVE affect the distribution of carbon tetrachloride in the vadose zone?* SVE effectively removes carbon tetrachloride from the permeable layers of the vadose zone. The SVE that previously was applied to the 216-Z-9 Trench area likely removed a large portion of the carbon tetrachloride initially present in the permeable layers within the large radius of influence of the extraction wells. Finer grained layers with more moisture content are less affected by SVE and contain the remaining carbon tetrachloride in the vadose zone.

As summarized in PNNL-15914, additional three-dimensional modeling was performed to simulate carbon tetrachloride transport in a layered and heterogeneous system. Six additional sensitivity analyses were first performed using the groundwater model from PNNL-14895. Heterogeneous subsurface models then were constructed using either a pedotransfer function or a similar medial scaling method.

The layered heterogeneous modeling led to the following additional conclusions regarding migration of carbon tetrachloride in the subsurface.

- The layered heterogeneous model results indicated, consistent with the conceptual model presented in DOE-RL-2006-58, that DNAPL (if present) would tend to preferentially accumulate in the finer grained layers within the vadose zone.

- The presence of a large number of small-grained features within the vadose zone would limit the vertical migration of carbon tetrachloride DNAPL.

- Increased volatilization of carbon tetrachloride occurs with the presence of fine-grained layers, resulting in a higher distribution of carbon tetrachloride in the vapor, water, and sorbed phases.

- The modeling predicted that the CCU accumulates and retains the largest mass of carbon tetrachloride DNAPL in the vadose zone.

- The total mass of carbon tetrachloride calculated to have moved across the water table was 117,000 kg (257,940 lb). This mass is comparable to the average value of 132,000 kg (291,010 lb) of total mass within the aquifer, reported in PNNL-16509, *Geostatistical Analyses of the Persistence and Inventory of Carbon Tetrachloride in the 200 West Area of the Hanford Site*, and the total mass in the aquifer estimated as part of the carbon tetrachloride inventory summarized in DOE/RL-2006-58.

Based on this work, and the RI, the revised carbon tetrachloride contaminant distribution model for the 216-Z-9 Trench is discussed in Section 3.2.

2.4.3.2 Particle-Tracking Analysis

A particle-tracking analysis depicting movement of the carbon tetrachloride plume at the water table was reported in D&D-28793, *Particle Tracking Analysis and Animations Depicting Movement of the Carbon Tetrachloride Plume*. The purpose of this analysis was to evaluate the hydraulic flow fields during and after the carbon tetrachloride disposal to known waste sites, to determine if the distribution of carbon tetrachloride in groundwater is reasonable based on hydraulics alone. It was not intended to model the three-dimensional flow field in the unconfined aquifer and was used as a screening-level analysis to evaluate the need to look for other potential source locations. The following summary is derived from that report.

The animation files showed travel paths for hypothetical carbon tetrachloride particles in groundwater. The travel paths represent carbon tetrachloride movement at the average groundwater-flow velocity. The particle simulation is an estimate of the carbon tetrachloride travel path and does not indicate or imply carbon tetrachloride groundwater concentrations.

Hydraulic gradients and velocity vectors were calculated using annual computations of the water-table elevation and hydraulic conductivity of the unconfined aquifer from the Hanford Sitewide groundwater model that was developed by PNNL. The data from the Hanford Sitewide model were linearly interpolated onto a square grid with 75 m (246-ft) spacing that extended across the entire 200 West Area. The hydraulic derivatives and hydraulic velocities were calculated for every year at each point in the grid using an internal algorithm in the Tecplot[13] software package. Travel paths for each year then were calculated using a numerical integration scheme, the hydraulic velocity field, and a retardation factor that represents the ratio of groundwater velocity to contaminant velocity (e.g., a retardation factor of 2 means that the groundwater travels at twice the velocity of the contaminant, or that the contaminant travels at one-half the velocity of the groundwater). The end points of travel paths for a given year were input as starting points of travel paths for the following year.

The forward travel path simulations are initiated with hypothetical carbon tetrachloride particles in a circular distribution in groundwater around the known discharge sites. The simulation starts approximately 7 to 8 years following the carbon tetrachloride discharge for each site (i.e., the assumed vadose-zone travel time to reach groundwater). Discharge to the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib began in 1955, 1964, and 1969, respectively; so the

[13] Tecplot is a registered trademark of Tecplot, Inc., Bellevue, Washington.

carbon tetrachloride particles around the facilities start traveling in 1962, 1971, and 1977, respectively. The circumference of the circle of particles approximates the perimeter of each disposal facility. The radius is 23.0 m (75.5 ft) at the 216-Z-9 Trench, 72.2 m (236.9 ft) at the 216-Z-1A Tile Field, and 136 m (446.2 ft) at the 216-Z-18 Crib. The movement of the hypothetical carbon tetrachloride particles is calculated, tracked, and displayed each half year until 2002. The simulations add a new circle of particles around the facilities each year to represent how carbon tetrachloride from a continuing source might move through the unconfined aquifer.

The backward travel path simulation begins with hypothetical carbon tetrachloride particles positioned where the high-concentration portion of the groundwater plume existed in 2002. The reverse movement of the hypothetical carbon tetrachloride particles is calculated, tracked, and displayed backward in time each year from 2002 to the year when the carbon tetrachloride may have entered the aquifer.

The forward particle tracks provide estimations of the distance from the source sites that the advective front of the plume traveled since the carbon tetrachloride entered the aquifer. The reverse particle tracks provide an indication of where the carbon tetrachloride that was observed in 2002 might have originated. Both the forward and the reverse particle-track simulations indicate that most of the carbon tetrachloride is apparently retarded in the groundwater. The reverse particle-track analyses resulted in very little movement from the mid-1980s to 1996. The forward-tracking animations for nonretarded carbon tetrachloride indicate much greater movement than has been observed in Hanford Site groundwater monitoring programs. Furthermore, the high-concentration area of the plume (e.g., greater than 2,000 g/L) would not remain limited in area and near the source sites. The reverse-tracking animations indicate that a zero retardation factor value for existing groundwater contamination results in carbon tetrachloride sources that are farther away than the known source locations. A retardation factor of 4 produced both forward and reverse particle tracks representative of the current carbon tetrachloride distribution in groundwater. Selected snapshots of the animations from D&D-28793 are shown in Figures 2-39 to 2-41.

The particle tracks also indicate that there is not a continuing carbon tetrachloride source capable of sustaining the observed maximum concentrations where the plume centroid was found in 1996. Before initiation of the 200-ZP-1 Groundwater OU Phase II pump-and-treat operations in 1996, the high-concentration area of the plume was centered near the PFP and was offset to the north of the known discharge sites. If a continuing source existed at the discharge sites, then the maximum carbon tetrachloride concentrations in groundwater would occur around the discharge sites and not to the north. Drilling and sampling of PFP well 299-W15-42 did not reveal greatly elevated carbon tetrachloride concentrations in the vadose zone or groundwater. Therefore, it does not appear as though the elevated carbon tetrachloride concentration in groundwater beneath the PFP results from contaminants entering the aquifer from the vadose zone in that area. A continuing source of carbon tetrachloride groundwater contamination is not likely.

Well 299-W13-1 is located approximately 470 m (1,542 ft) east of the 200 West Powerhouse and beyond the extent of the particle-track figures. Carbon tetrachloride concentrations in well 299-W13-1 were greater than 1,200 µg/L at specific depths in the aquifer when sampled in December 2003. The well is located in the approximate path of carbon tetrachloride particles

that originate from the 216-Z-9 Trench for the simulation with a retardation factor less than 4. The agreement between the particle tracks and the well-sampling results validates the flow paths and velocities calculated by the Hanford Sitewide model.

As illustrated in Figure 2-39, the reverse particle-track simulations that start with particles distributed along the leading edge of the groundwater plume, where the carbon tetrachloride concentrations are 1,000 and 2,000 μg/L, indicate that the particles converge toward a common source area to the west of the 216-Z-1A Tile Field and the 216-Z-12 and 216-Z-18 Cribs. The cause of the offset is uncertain but could result from the Hanford Sitewide model grid spacing and discharge inputs. The 216-U-14 Ditch received about 1.9×10^9 L of discharge during a short period in 1991, resulting in a reversed hydraulic gradient. The unlined 216-Z-19 Ditch and 216-Z-20 Crib also received large volumes of discharged water. The 216-T-19 Crib received 4.5×10^8 L of discharge during operation.

The carbon tetrachloride source status (i.e., continuous or noncontinuous) and mobility (i.e., retarded or nonretarded) may be considered in a simplified "truth-table" format. The actual environment may contain elements of all four of the logical outcomes combining source and mobility options. The intent of the truth table is to address the carbon tetrachloride source and movement in a general sense. For the purpose of the truth table, "continuous source" refers to ongoing, nonattenuating contaminants that enter groundwater and are capable of sustaining concentrations at the levels currently observed in the high-concentration area of the carbon tetrachloride plume.

1. If the source of carbon tetrachloride remained continuous and the movement was nonretarded, the extent of the high-concentration area would be much larger than currently observed. The origin of the plume would remain fairly obvious and would include the known source areas. The carbon tetrachloride distribution within the plume area would be more uniform than is currently observed. The fact that the high-concentration area appears to have remained fairly restricted in size and near the known discharge sites contradicts the hypothesis that there is a continuous source and a nonretarded contaminant movement.

2. If the source of carbon tetrachloride remained continuous and the movement were retarded, the high-concentration area would be restricted in area and would encompass the known source areas. Such a scenario would be consistent with current data if the location where the carbon tetrachloride enters the groundwater were offset from the known discharge sites. The PFP well (299-W15-42) did not substantiate such a hypothesis.

3. If the source of carbon tetrachloride was noncontinuous and the movement were nonretarded, the high-concentration area would be much larger, extend much farther than currently observed, and consist of lower concentration values. The fact that the high-concentration area appears to have remained fairly restricted in size close to the known discharge sites seems to dispute this hypothesis. The effects of dispersion on the carbon tetrachloride in the aquifer would reduce the concentration and cause greater spreading of a more uniform plume.

4. If the source of carbon tetrachloride were noncontinuous and the movement were retarded, the high-concentration area would be restricted in area and would remain at or near the source areas. Such a scenario is the best description of current observations, unless the carbon tetrachloride arrived at the water table much later than 8 years after disposal began. The animations, including a retardation factor of 2 and 4, appear to best approximate the currently observed groundwater conditions.

2.4.3.3 Geostatistical Analysis of Carbon Tetrachloride Persistence

PNNL conducted a geostatistical analysis of the persistence of carbon tetrachloride groundwater concentration for eight areas of elevated carbon tetrachloride groundwater concentrations in the 200 West Area that were identified by Fluor Hanford (PNNL-16509). The purpose of this analysis was to help evaluate the potential for vadose-zone sources at these areas. The results of this report are summarized below and the eight areas are shown in Figure 2-42.

The available carbon tetrachloride data for the period of 1994 to 2004 were reviewed to identify a set of wells that were sampled regularly through the 10-year period. Data sets initially were selected from 53 wells for which carbon tetrachloride data were consistently available from 1996, 1998, 2000, and 2002. Consistent well locations were selected for each time period, so variations in concentration in a given area would not be caused by changes in well configurations. A fifth data set was added to represent conditions in 37 wells during 2004 and 11 wells during 2003; 5 wells from the initial four data sets could not be used in the 5^{th} data set, because they were not sampled in 2003 or 2004. Although the results for 2004 generally agreed with results for earlier time periods, the missing five well locations increased the degree of uncertainty. No significant differences were seen in the overall distribution of carbon tetrachloride concentrations over the 10-year time period. A slight decrease in concentrations was observed during the last two time periods.

The carbon tetrachloride concentration data were highly skewed, so concentration mapping was performed on normal-score data transforms. Experimental variograms were fit with isotropic models that showed a slight decrease in range from 1,200 m (3,937 ft) in 1996 and 1998 to 1,000 m (3,280.8 ft) in 2000 and 2002. The variogram range in 2004 was further reduced, but that may be an artifact of the missing well locations for the last time period. The decrease in range also might be caused by a slight decrease in the size of the plume.

PNNL generated 1,000 simulations of carbon tetrachloride concentration for each time period and found that 500 simulations were sufficient to characterize the spatial variability. The modeling summarized carbon tetrachloride spatial distribution in several ways, including calculation of median simulated values, the probability of exceeding several cut-off values, and calculation of percentiles of local distributions. Maps were prepared from the statistics to identify areas of high and low concentration for each time period and to provide measures of the uncertainty in carbon tetrachloride concentrations. Figure 2-42 is a summary map of the sub-areas that were identified by Fluor Hanford. The sub-areas are ranked in terms of the likelihood for containing persistent carbon tetrachloride sources.

The simulations of the individual sub-areas identified important differences. The differences suggest that some of the sub-areas might contain ongoing carbon tetrachloride sources. The simulations include the following notable results.

- Several of the northern sub-areas had relatively high median concentrations with low variability and little variation with time. The sub-areas with the highest median concentrations and lowest variability were sub-areas 3 and 4. Sub-areas 2 and 5 also are candidates for ongoing carbon tetrachloride sources, but they display greater variability over time. If the concentration reported for well 299-W10-1 in 1998 is not representative, then the median concentrations for sub-areas 2 and 5 are higher and less variable. Concentrations for sub-areas 2 and 5 then would resemble sub-areas 3 and 4.

- Sub-area 7 exhibited a significant decrease in median concentration during the last two time periods. The substantial concentration decrease could result from nearby pump-and-treat operations.

- Sub-areas 1 and 6 exhibited significant decreases in median concentration and are unlikely to contain ongoing sources for carbon tetrachloride release.

- Sub-area 8 showed an increasing median carbon tetrachloride concentration at a level that is significantly lower than all of the other sub-areas; it is unlikely to contain a significant continuing carbon tetrachloride source.

2.5 200-PW-1 OPERABLE UNIT SOIL-VAPOR EXTRACTION

SVE is being used to remove carbon tetrachloride from the vadose zone as an interim action at the 200-PW-1 OU (formerly designated as the 200-ZP-2 OU). A general overview is provided in SGW-33746, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Carbon Tetrachloride Site, Fiscal Year 2006*, which discusses system operation and effectiveness from February 25, 1992, through September 30, 2006. The following summary is primarily from that report.

Carbon tetrachloride was found in the unconfined aquifer beneath the 200 West Area in the mid-1980s. Groundwater monitoring indicated that the carbon tetrachloride plume was widespread and that concentrations were increasing. On December 20, 1990, the EPA and Ecology requested that the DOE proceed with work required to implement an expedited response action for removing carbon tetrachloride contamination from the unsaturated soils in the 200 West Area. The request was based on concerns that the carbon tetrachloride residing in the soils was continuing to spread to the groundwater and, if left unchecked, would significantly increase the areal extent of groundwater contamination. The purpose of the expedited response action was to minimize carbon tetrachloride migration within the vadose zone and away from the carbon tetrachloride disposal sites in the 200 West Area.

Carbon tetrachloride removal from the vadose zone was initiated in 1992 using SVE and vapor treatment with granular-activated carbon. Three SVE systems with a total capacity of 85 m^3/min were located near each of the three primary carbon tetrachloride disposal sites in March 1993.

The three primary carbon tetrachloride disposal sites are the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib subsurface infiltration facilities that were used from 1955 through 1973 for disposal of carbon tetrachloride aqueous and organic liquid wastes. The SVE and monitoring wells are shown in Figure 2-43.

Carbon tetrachloride concentrations in the extracted soil vapor have decreased significantly at all three sites during operation of the SVE systems. Initial carbon tetrachloride concentrations in extracted soil vapor were approximately 30,000 ppmv at the 216-Z-9 Well Field and 1,500 ppmv at the 216-Z-1A/Z-18 Well Field. In contrast, concentrations in extracted soil vapor were approximately 10 ppmv at the 216-Z-1A/Z-18 Well Field in July 2006 and 21 ppmv at the 216-Z-9 Well Field in September 2006. The decrease in measured carbon tetrachloride soil-vapor concentration from the upper (U) and lower (L) screened intervals in well 299-W15-218 near the 216-Z-9 Trench (Figure 2-44) is typical of the decreasing carbon tetrachloride soil-vapor concentration trend measured in the individual SVE wells at the three primary carbon tetrachloride disposal sites.

The primary source of the remaining carbon tetrachloride in the vadose zone at the 216-Z-9 Trench is a silt lens at 19.8 m (65 ft) bgs on the south side of the trench (DOE/RL-2007-22). At the 216-Z-1A Tile Field, the remaining carbon tetrachloride in the vadose zone is in the relatively low-permeability CCU, which is approximately 38 to 45 m (124.7 to 147.6 ft) bgs. Carbon tetrachloride is removed by the SVE system as it migrates from the lower permeability zone into the overlying and underlying higher permeability zones. The rate of removal is controlled by the carbon tetrachloride desorption and diffusion rates. At many monitoring locations, including locations within the higher permeability zones, the relatively low carbon tetrachloride rebound concentrations indicate that the readily available mass is removed (i.e., carbon tetrachloride already in the vapor phase or volatizing directly from residual nonaqueous phase liquid). The availability of additional mass for removal is controlled by desorption and diffusion kinetics for carbon tetrachloride, which is adsorbed within soil-particle micropores.

The operating strategy was modified in FY 1998 based on the results of BHI-01105, *Rebound Study Report for the Carbon Tetrachloride Soil Vapor Extraction Site, Fiscal Year 1997*, and the declining rate of carbon tetrachloride removal during continuous extraction operations. The 14.2 m^3/min SVE system was the only SVE unit operated during FYs 1998, 1999, 2001, 2002, 2003, 2004, 2005 and 2006. The system typically operated from April through September, and alternated between the 216-Z-9 Trench and the 216-Z-1A Tile Field/216-Z-18 Crib sites in approximately 3-month periods. The system was maintained in standby mode from October through March to allow time for carbon tetrachloride vapor concentrations to rebound. System operation temporarily was suspended during the entire period of FY 2000 as a result of higher priority remediation activities that competed for limited funding. The declining rate of carbon tetrachloride concentration in the soil vapor extracted from the SVE systems at the 216-Z-9 Trench and the 216-Z-1A Tile Field/216-Z-18 Crib sites from 1997 to 2005 is shown in Figures 2-45 and 2-46, respectively.

In FY 2006, the total availability of the system was 88 percent. Between November 1994 and September 2006, the monthly availability for all three systems averaged 87 percent, which is slightly below the objective of 90 percent availability. In FY 2006, approximately 76 kg (168 lb)

of carbon tetrachloride were removed from the 216-Z-1A/Z-18/Z-12 Well Field and 97 kg (213 lb) were removed from the 216-Z-9 Well Field. Between April 1991 (when the pilot test was conducted) and July 2006, approximately 24,604 kg of carbon tetrachloride were removed from the 216-Z-1A/Z-18/Z-12 well field. Between March 1993 and September 2006, approximately 54,280 kg of carbon tetrachloride were removed from the 216-Z-9 well field. Passive SVE systems were installed on eight wells in FY 1999 and operated from FY 2000 through FY 2006 to remove carbon tetrachloride from the vadose zone. Passive SVE is a natural process driven by barometric-pressure fluctuations and often is referred to as barometric pumping. The eight wells are located in the 216-Z-1A Tile Field/216-Z-18 Crib Well Field. Approximately 10 kg (22 lb) of carbon tetrachloride were removed from the vadose zone using passive SVE in FY 2006; between October 1999 and September 2006, approximately 80 kg (176 lb) of carbon tetrachloride were removed.

An estimate was prepared in 1993 for the disposition of carbon tetrachloride that had been discharged between 1955 and 1990 to the three primary disposal sites. It was estimated that 21 percent of the original carbon tetrachloride inventory discharged to the three primary disposal sites was lost to the atmosphere; 12 percent was partitioned into the vadose zone as vapor, dissolved, and adsorbed phases; 2 percent was dissolved in groundwater; and 1 percent was biodegraded. The remaining 64 percent of the carbon tetrachloride inventory was assumed to be in residual saturation and nonequilibrium sorption sites within the vadose zone and aquifer and possibly as DNAPL in groundwater.

The total mass of carbon tetrachloride removed from all sites (78,884 kg [173,909 lb]) represents approximately 10 percent of the original carbon tetrachloride inventory (average of approximately 750,000 kg (1,653,466 lb]) discharged to the soil column. An updated inventory evaluation based on the RI results is discussed in Section 3.2.

Non-operational soil-vapor monitoring data are collected monthly at wells and probes that are not online to the SVE system. The objectives of monitoring the non-operational wells and probes are (1) to measure carbon tetrachloride concentrations and trends near the vadose/atmosphere and vadose/groundwater interfaces to evaluate whether non-operation of the SVE system is negatively impacting the atmosphere or groundwater, and (2) to be cognizant of carbon tetrachloride concentrations and trends near the CCU to provide an indication of concentrations that can be expected during restart of SVE operations and to support selection of online wells. For each well field, the period of rebound begins when SVE operations are suspended temporarily.

Carbon tetrachloride concentrations rebound during periods of non-operation as a result of carbon tetrachloride accumulating in the pore spaces after apparent diffusion from sediment micropores, soil moisture, residual DNAPL, and/or low-permeability zones. When operations resume, initial extracted carbon tetrachloride concentrations are higher than the carbon tetrachloride concentrations at the previous shutdown. These initial concentrations generally will be lower than the initial concentrations following previous periods of rebound. However, the non-operational duration for each well field varies from year to year, which also may affect the rebound concentration.

For each period of rebound monitoring since FY 1997, the maximum rebound concentrations have occurred near the CCU (Figure 2-47).

Because carbon tetrachloride concentrations did not increase significantly at the near-surface probes, temporarily suspending operation of the SVE system appears to have caused minimal detectable vertical transport of carbon tetrachloride through the soil surface to the atmosphere. Because carbon tetrachloride concentrations did not increase significantly near the water table during this time, temporarily suspending operation of the SVE systems appears to have had no negative impacts on groundwater quality.

2.6 200-ZP-1 OPERABLE UNIT GROUNDWATER INVESTIGATIONS AND INTERIM ACTION

The RI for the 200-ZP-1 Groundwater OU was completed in 2006, and the 200-ZP-1 Groundwater OU FS will be prepared in 2007 concurrent with the 200-PW-1/3/6 OU FS. Additionally, the DNAPL Source Term project and other studies have prepared updated estimates of the inventory of carbon tetrachloride in the groundwater. An interim-action pump-and-treat system has been operating at the 200-ZP-1 Groundwater OU to control the high-concentration part of the carbon tetrachloride groundwater plume. A summary of these activities is provided in this section to help integrate the current understanding of the carbon tetrachloride contamination in the vadose zone and groundwater beneath the 200 West Area.

The conceptual model of the carbon tetrachloride groundwater plume presented in the 200-ZP-1 Groundwater OU RI (DOE/RL-2006-24) is that the plume extends vertically from the top of the unconfined aquifer near the disposal source areas by the PFP to the base of the unconfined aquifer at the top of the Ringold Formation lower mud (unit 8). The plume extends through the Ringold Formation to the top of basalt where the unit 8 confining layer is absent, as at well 299-W13-1. The conceptual model is that, as the distance from the source area increases in a downgradient direction, the highest carbon tetrachloride concentrations occur deeper in the unconfined aquifer. The model indicates that recharge from natural infiltration and less contaminated former wastewater discharges have contributed to reduced carbon tetrachloride concentrations in the upper portion of the unconfined aquifer in a downgradient direction from the source areas.

The DNAPL Source Term project reviewed available evidence on whether carbon tetrachloride DNAPL is present within the unconfined aquifer. The findings from that review are summarized below (DOE/RL-2006-58 and DOE/RL-2007-22).

- Depth-discrete groundwater sampling from 24 existing wells centered around the high-concentration portion of the carbon tetrachloride groundwater plume showed that the highest detected concentration (5,100 μg/L) is significantly less than the carbon tetrachloride solubility limit (800,000 μg/L).

- The total calculated mass of carbon tetrachloride in the groundwater plume decreased from 1991 to the present.

- Groundwater modeling indicates that if carbon tetrachloride DNAPL sources were present at mid-depth in the aquifer, they would produce concentrations in monitoring wells above those measured to date. A carbon tetrachloride DNAPL source at the bottom of the aquifer could produce concentrations in monitoring wells similar to those measured to date. The existing data do not support the emplacement of a deep source without leaving a residual detectable trace higher in the aquifer.

- The available evidence indicates that there is not a significant carbon tetrachloride DNAPL source within the aquifer beneath the 216-Z-9 Trench.

- High-concentration carbon tetrachloride vapors that were found in the deep vadose zone during a 1993 drilling program likely contaminated the shallow aquifer before startup of the interim-action SVE system around the 216-Z-9 Trench.

- Liquid waste-disposal sites near the primary carbon tetrachloride waste-disposal sites may have transported dissolved phase carbon tetrachloride to the unconfined aquifer.

To confirm that there is not a significant carbon tetrachloride DNAPL source within the unconfined aquifer beneath the 216-Z-9 Trench, a deep-well pumping and sampling test was conducted in 2006 to investigate carbon tetrachloride concentrations at the bottom of the aquifer beneath the 216-Z-9 Trench. However, there were several issues in connecting well 299-W15-6 to the existing pump-and-treat system. Problems with the pump and motor required continued maintenance, resulting in a decreasing extraction flow rate over the measurement period. It was estimated that a flow rate of 76 L/min (20 gal/min) could be obtained, but actual measured flow rates were only around 30 L/min (8 gal/min). It was determined the maximum steady-state flowrate was 30 to 38 L/min (8 to 10 gal/min). Therefore, initial samples were pulled from a zone close to the well, and later samples were more representative of water under the 216-Z-9 Trench. Because of the unanticipated low pumping rate, the time required to capture water from directly underneath the 216-Z-9 Trench was significantly increased. Six groundwater samples were analyzed from well 299-W15-6 to assess DNAPL carbon tetrachloride source terms deep in the unconfined aquifer. Results from September 2006 to January 2007 showed increasing carbon tetrachloride concentrations. However, the highest concentration of carbon tetrachloride reported was 2,400 parts per billion (ppb), which is only 25 percent of the 1 percent (8 ppm) dissolution limit for carbon tetrachloride. Although the carbon tetrachloride concentration initially was increasing as expected, the most recent sample shows a decrease.

Depth-discrete sampling results from 39 wells sampled during performance of the 200-ZP-1 Groundwater OU RI were used as input into RockWorks2004[14]. A solid model was generated from the data using an inverse-anisotropic modeling algorithm. The model was stratabound at the top with the water table elevation in the unconfined aquifer and was stratabound at the base with the elevation of the top of basalt. Using the solid model results, volumes of carbon tetrachloride within the 5 µg/L, 100 µg/L, 1,000 µg/L, 2,000 µg/L, and 4,000 µg/L contours were calculated using an aquifer porosity of 0.30. The mass of carbon tetrachloride within each volume then was calculated using the geometric mean concentration

[14] RockWorks2004 is a trademark of Rockware, Inc., Golden, Colorado.

within each contour interval (e.g., between the 100 µg/L and 1,000 µg/L contours). An order-of-magnitude mass of dissolved carbon tetrachloride of 96,500 kg (212,742 lb) was calculated. Using available and relatively limited chloroform groundwater analytical data, a chloroform mass of approximately 250 kg (551 lb) in the aquifer was calculated. Using the dissolved/sorbed/chloroform proportions from PNNL-16509, the Source Term project estimated the carbon tetrachloride inventory in the groundwater as 96,500 kg (212,746 lb) dissolved, 76,800 kg (169,315 lb) sorbed, and 23,600 kg (52,029 lb) degraded to chloroform (DOE/RL-2006-58).

Geostatistical analysis reported in PNNL-16509, calculated a mean total mass of carbon tetrachloride in the aquifer of 101,400 kg (223,548 lb), with a range within the 95 percent confidence interval of 64,300 to 164,100 kg (141,757 to 361,778 lb). Of the total amount, dissolved carbon tetrachloride was calculated to account for 48 percent of the total chlorinated mass below the water table, sorbed carbon tetrachloride accounts for 40 percent of the total, and chloroform accounts for 12 percent of the total. Adopting these proportions, and using the total mass of 101,400 kg (223,548 lb)of carbon tetrachloride reported in PNNL-16509, an estimated 48,672 kg (107,303 lb) of carbon tetrachloride is dissolved, 40,560 kg (89,419 lb) is sorbed to soil below the water table, and 12,168 kg (26,825 lb) has degraded to chloroform below the water table.

The 200-ZP-1 Groundwater OU interim-action pump-and-treat system was implemented in a three-phased approach. The 200-ZP-1 Groundwater OU pump-and-treat system wells are shown in Figure 2-48. Phase I operations consisted of a pilot-scale treatability test between August 29, 1994, and July 19, 1996, around the 216-Z-12 Crib. During this phase, contaminated groundwater was removed through a single extraction well (299-W18-1) at a rate of approximately 151 L/min (40 gal/min), treated using granular-activated carbon, and then returned to the aquifer through an injection well (299-W18-4). For more detailed information about operations during the treatability test, refer to DOE/RL-95-30, *200-ZP-1 Operable Unit Treatability Test Report*.

Concurrent with Phase I operations, EPA/ROD/R10-95/114, *Declaration of the Interim Record of Decision for the 200-ZP-1 Operable Unit*, was issued in June 1995. The selected remedy was to use groundwater pump-and-treat technology to minimize further migration of carbon tetrachloride, chloroform, and trichloroethylene in the groundwater and remove contaminant mass.

Phase II operations commenced August 5, 1996, in accordance with the interim ROD (EPA/ROD/R10-95/114) and Tri-Party Agreement Milestone M-16-04A (Ecology et al., 1989, as amended). The 1996 groundwater plume was the basis for the interim ROD. The well field configuration during Phase II operations consisted of three extraction wells (299-W15-33, 299-W15-34, and 299-W15-35), pumping at a combined rate of approximately 567.8 L/min (150 gal/min), and a single injection well (299-W15-29). Groundwater was treated using an air stripper to release carbon tetrachloride into a vapor phase, and granular-activated carbon was used to collect the vapor. For a detailed description of the treatment system setup and operation, refer to BHI-00952-02, *200-ZP-1 Interim Remedial Measure Quarterly Report, October – December 1996*. Phase II operations were terminated on August 8, 1997, to transition to Phase III operations.

Phase III operations began on August 29, 1997, satisfying Tri-Party Agreement Milestone M-16-04B (Ecology et al., 1989, as amended). The well field for Phase III operations was expanded to include six extraction wells (existing wells, plus new wells 299-W15-32, 299-W15-36, and 299-W15-37) and five injection wells (existing well, plus wells 299-W18-36, 299-W18-37, 299-W18-38, and 299-W18-39). The total pumping rate was increased to more than 800 L/min (>200 gal/min), versus a total treatment system capacity of 1,893 L/min (500 gal/min). The treatment process for the Phase III system uses the same air-stripping and granular-activated carbon systems for remediating contaminated groundwater. Extraction wells were installed to contain the high-concentration portion of the carbon tetrachloride plume located near PFP, as required by the interim ROD (EPA/ROD/R10-95/114). The southernmost extraction well, 299-W15-37, was converted to a monitoring well in January 2001 because of its limited impact on hydraulic capture of the high-concentration portion of the plume (DOE/RL-2001-53, *Fiscal Year 2001 Annual Summary Report for the 200-UP-1 and 200-ZP-1 Pump and Treat Operations*).

Two new extraction wells were drilled and brought online in FY 2004. Well 299-W15-45 replaced 299-W15-33, and well 299-W15-47 replaced 299-W15-32. Both new wells have been drilled deeper into the aquifer and were constructed with 15.2 m (50-ft) screens, starting 1.5 m (5 ft) below the water table in the upper, unconfined aquifer. The old wells have been reconfigured to monitor water levels.

The key achievement for the 200-ZP-1 Groundwater OU pump-and-treat system in FY 2005 was the expansion of the five-well extraction system to a total of nine wells, with the addition of four new extraction wells north of the existing baseline plume area. Extraction pumps were installed in existing monitoring wells 299-W15-40, 299-W15-43, 299-W15-44, and 299-W15-765, were connected to the 200-ZP-1 Groundwater OU treatment building, and formally started groundwater extraction on July 27, 2005. Since startup, the extraction system pumping rates have increased to between 946 and 1,230 L/min (250 to 325 gal/min).

The FY 2005 hydraulic capture analysis shows that the pump-and-treat system continues to capture the high-concentration levels of carbon tetrachloride (greater than 2,000 to 3,000 µg/L) at the extraction wells. Groundwater monitoring results for FY 2005 also show that carbon tetrachloride concentrations continue to decline in the unconfined aquifer (DOE/RL-2005-91, *Fiscal Year 2005 Annual Summary Report for 200-UP-1 and 200-ZP-1 Pump-and-Treat Operations*). Carbon tetrachloride contamination in the groundwater was reduced in the area of highest concentrations through mass removal. Over 322.3 million L (85.1 Mgal) of contaminated groundwater were treated in FY 2005 at an average flow rate of 715 to 1,116 L/min (190 to 295 gal/min). Treatment of the contaminated water resulted in the removal of 753.5 kg (1,661 lb) of carbon tetrachloride in FY 2005. Between the initiation of pump-and-treat operations in August 1994 and the end of FY 2005, approximately 2.76 billion L (725 Mgal) of water have been treated, resulting in the removal of 9,308 kg (20,520 lb) of carbon tetrachloride (DOE/RL-2005-91).

The reduction in carbon tetrachloride concentrations at the top of the unconfined aquifer underlying the primary carbon tetrachloride vadose-zone waste sites is shown by the changes in the carbon tetrachloride groundwater plume from 1990 to 2006, as illustrated in Figure 2-49.

The reduction likely resulted from the dual application of SVE remediation in the vadose zone and the pump-and-treat groundwater remediation in the source vicinity.

2.7 216-A-8 CRIB REMEDIAL INVESTIGATION, 200-PW-3 OPERABLE UNIT

2.7.1 Sampling and Analysis of Characterization Boreholes

The SAP for the 216-A-8 Crib included sampling activities to be conducted before the characterization borehole (C4545) was drilled, to determine the best location for this borehole (DOE/RL-2001-01, Appendix B). These activities included pushing five GeoProbe boreholes to depths of 3.7 to 4.6 m (12 to 15 ft) bgs, collecting and analyzing soil-vapor samples from these boreholes, collecting and analyzing soil-vapor samples from five existing wells, and geophysically logging six existing wells. The primary focus of the soil sampling in Borehole C4545 beneath the 216-A-8 Crib was to characterize the vadose zone for the nature and distribution of organic and radiological contaminants. The following sampling activities were completed as described in WMP-27020.

Soil-vapor sampling was conducted in July 2004 in five direct-push boreholes that were installed along the length of the 216-A-8 Crib using the GeoProbe. Figure 2-50 shows the location of the five boreholes (C4540, C4541, C4542, C4543, and C4544) and the characterization borehole (C4545). The five boreholes were advanced to depths of 3.7 to 4.6 m (12 to 15 ft) bgs and, before vapor sampling, the casing in each borehole was drawn back to provide a 0.3 m (1-ft) sampling interval of exposed formation at the bottom of the borehole. An organic vapor monitor was used to provide real-time field-screening feedback for soil-vapor samples collected from the five GeoProbe push holes. Soil-vapor samples were collected in Tedlar bags for field screening for specific VOCs using the Photovac 10S Plus[15] gas chromatograph and the Innova 1312 multi-gas analyzer. Four specific types of Dräger[16] tubes (colorimetric indicator tubes) were selected to cover the range of organic contaminants that might be present, in addition to the VOCs that could be analyzed using the gas chromatograph and Innova 1312 analyzer. These four types of Dräger tubes were used to test for ammonia, a range of easily oxidized compounds, and hydrocarbons.

Additional soil-vapor sampling took place at five existing wells at the 216-A-8 Crib (299-E25-4, 299-E25-5, 299-E25-7, 299-E25-8, and 299-E25-9) during April 2005. Figure 2-50 shows the locations of these five wells. In each well, a soil-vapor sample was obtained from the screened interval, which was isolated by using a packer. The packer was set at depths ranging from 69.5 to 72.8 m (228 to 239 ft). A field-screening instrument (MIRAN SapphIRe Ambient Air Analyzer) was used to analyze the soil-vapor samples for VOCs and semi-VOCs.

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[15] Photovac 10S Plus is a trademark of Photovac, Inc., Waltham, Massachusetts.

[16] Dräger is a trademark of OFI Testing Equipment, Inc., Houston, Texas.

Initial operation of the MIRAN Analyzer in spectrum-scan mode allowed scanning of each soil-vapor sample for the possible presence of up to five of the organic compounds in the instrument library. No organic compounds were detected in any of the soil-vapor samples from the five wells. As a result, the instrument was not reconfigured to analyze the samples in single-compound mode.

As stated in WMP-27020, in situ soil-vapor sampling from vent risers in the 216-A-8 Crib was not conducted because of radiological control concerns. The vent risers were determined to be inaccessible because of the presence of radiological contamination within the risers, leading to an unacceptable potential for spreading contamination to vapor-sampling equipment and sampling personnel.

Geophysical logging using the SGLS was conducted in five existing wells from which soil-vapor samples also were collected (299-E25-4, 299-E25-5, 299-E25-7, 299-E25-8, and 299-E25-9), and in one other existing well (299-E25-6), between April and July 2004. Figure 2-50 shows the locations of these wells.

The SAP (DOE/RL-2001-01, Appendix B) provided guidance for selection of the final location of Borehole C4545. This guidance states the following.

- The borehole will be drilled at the location of the highest organic concentrations.
- If no organics are detected or if the results are inconclusive, the borehole will be drilled at the location with the highest radionuclide concentrations.

The results of the soil-vapor sampling investigations in the shallow and deep vadose zone did not conclusively indicate the presence of organics at any of the locations sampled. However, the geophysical logging investigation clearly identified the location with the highest radionuclide concentrations. Existing well 299-E25-5 exhibited the highest radionuclide concentrations, with a maximum Cs-137 value of 30,800 pCi/g found at 7.6 m (25 ft) below the top of the casing. The second highest levels were found in existing well 299-E25-6, with a Cs-137 concentration of 50 pCi/g in the interval from 7.6 to 9.1 m (25 to 30 ft) below the top of the casing. The area with the highest radionuclide concentrations is located near the west end of the 216-A-8 Crib, as anticipated in DOE/RL-2001-01, Appendix B. Therefore, based on the Work Plan guidance and on the results of the soil-vapor sampling and borehole geophysical logging at the 216-A-8 Crib, Borehole C4545 was located on the south side of well 299-E25-5. This location is close to the center of the 216-A-8 Crib and closer to well 299-E25-6, where contamination appeared to be slightly deeper.

Soil samples were collected at specific depths during the installation of Borehole C4545, in accordance with the sample design in the SAP (DOE/RL-2001-01, Appendix B). The primary focus of sampling beneath the 216-A-8 Crib was to characterize the vadose zone for the nature and distribution of organic and radiological contaminants. Seven samples were to be collected, including one from each major geologic unit, during drilling of the vertical borehole. The rationale for each sample depth is as follows:

- 5.5 to 6.2 m (18 to 20.5 ft) -- Characterize the vadose zone immediately below the base of the crib; organic layer observed immediately below the 216-A-24 Crib

- 6.6 to 7.3 m (21.5 to 24 ft) -- Characterize the zone of highest cesium contamination detected during spectral gamma geophysical logging
- 15.2 to 16.0 m (50 to 52.5 ft) -- Characterize the zone just below the cesium contamination detected during spectral gamma geophysical logging
- 31.2 to 32.0 m (102.5 to 105 ft) -- Characterize the zone at the maximum depth of contamination indicated by gross gamma geophysical logging
- 54.1 to 54.9 m (177.5 to 180 ft) -- Characterize the contaminant distribution at the contact between the Hanford formation sand-dominated and lower gravel-dominated sequences
- 71.0 to 71.8 m (233 to 235.5 ft) -- Characterize the deep zone of cesium contamination detected during spectral gamma geophysical logging
- 79.7 to 80.5 m (261.5 to 264 ft) -- Characterize the capillary fringe to evaluate impact to groundwater.

Lithologic variations and changes in chemical or radiological contamination also resulted in the modification of some of the sampling intervals during drilling to ensure that the sampling objectives were met. The samples were submitted to analytical laboratories for chemical and radiological analysis and determination of physical properties. As described in D&D-30565, 12 soil samples (9 primary, 1 duplicate, and 2 split) and 8 associated liquid QC samples (1 equipment blank and 7 trip blanks) were obtained for COPC analysis. Additional samples were collected to support radiological screening, waste management, and physical property testing.

2.7.2 Borehole Geophysical Logging

As described in WMP-27020, SGLS logging of Borehole C4545 took place when the borehole was at a depth of 21.3 m (70 ft) bgs and again at the total borehole depth of 80.6 m (264.5 ft) bgs. The SGLS provided a continuous radiometric signature of the soils, measured through a single thickness of casing, to a depth approximately 0.3 m (1 ft) above the water table (measured at 79.76 m [261.67 ft] bgs on June 30, 2005).

Figure 2-1. Location of Wells Around the 216-Z-9 Trench.

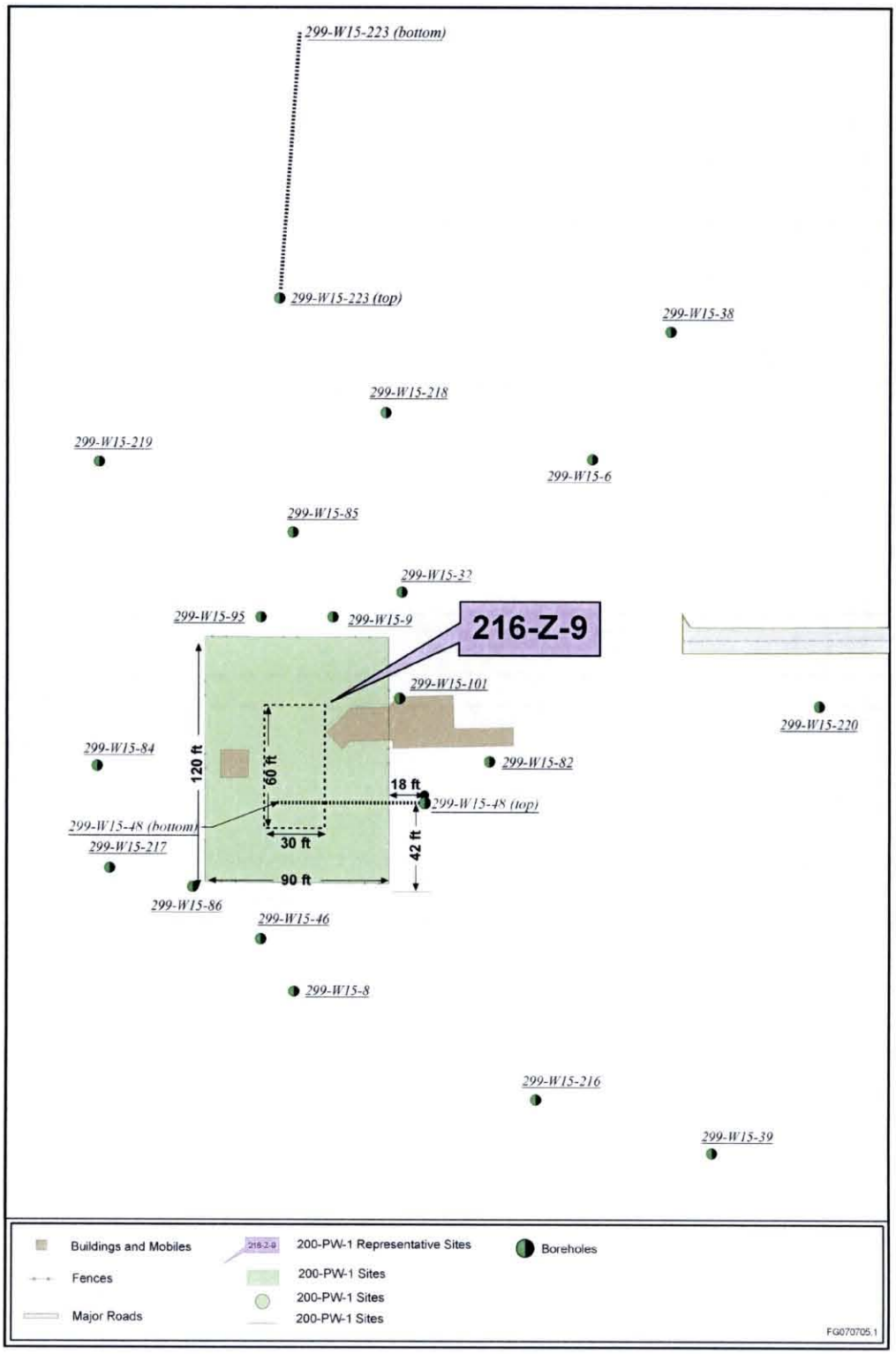

Figure 2-2. Slant Well 299-W15-48 (C3427) Orientation and Sampling at the 216-Z-9 Trench.

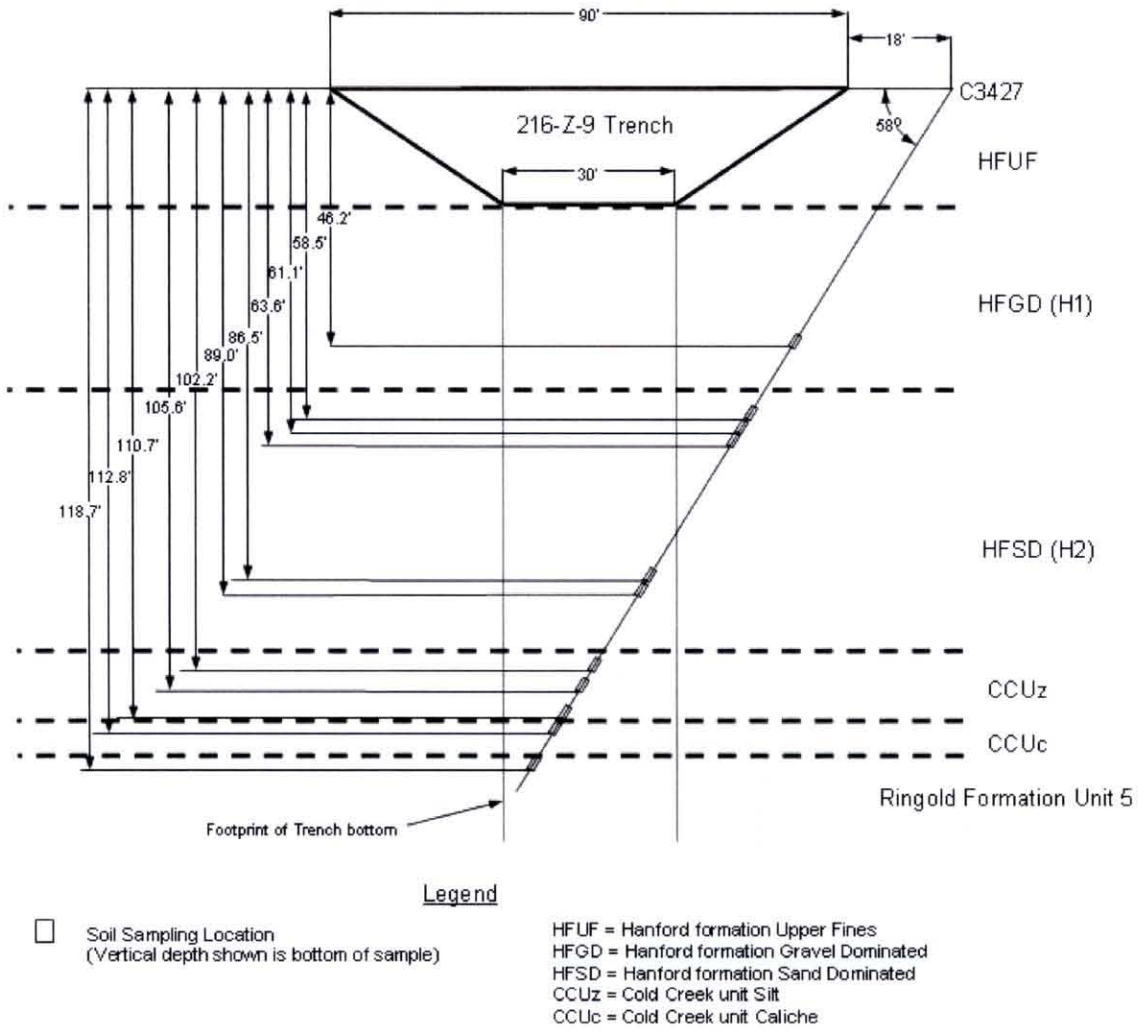

Figure 2-3a. Locations of 1961 and 1963 Historical Soil Samples in the 216-Z-9 Trench.

(From ARH-2915)

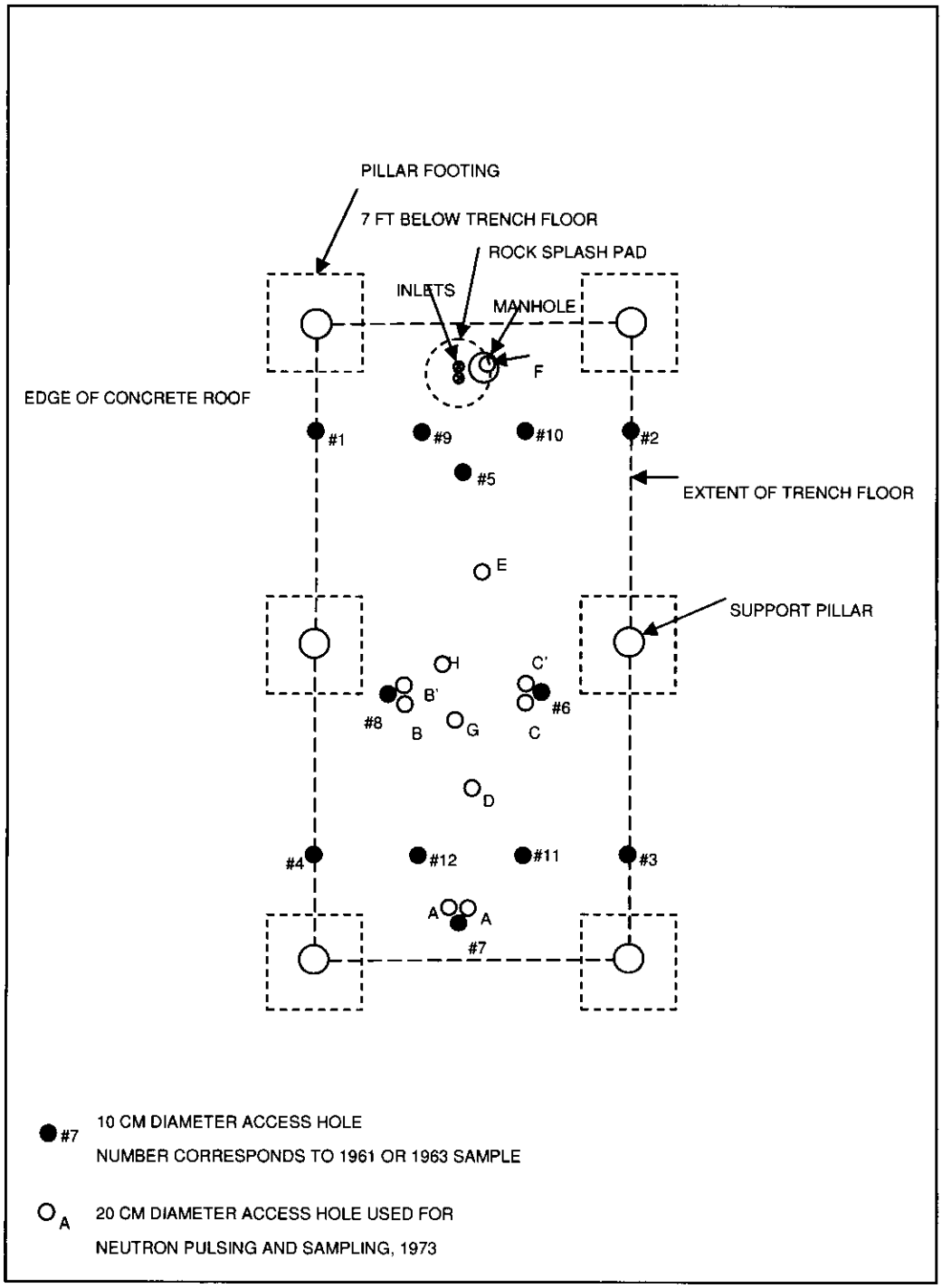

Figure 2-3b. Locations of 1973 Historical Soil Samples in the 216-Z-9 Trench.

(From ARH-2915)

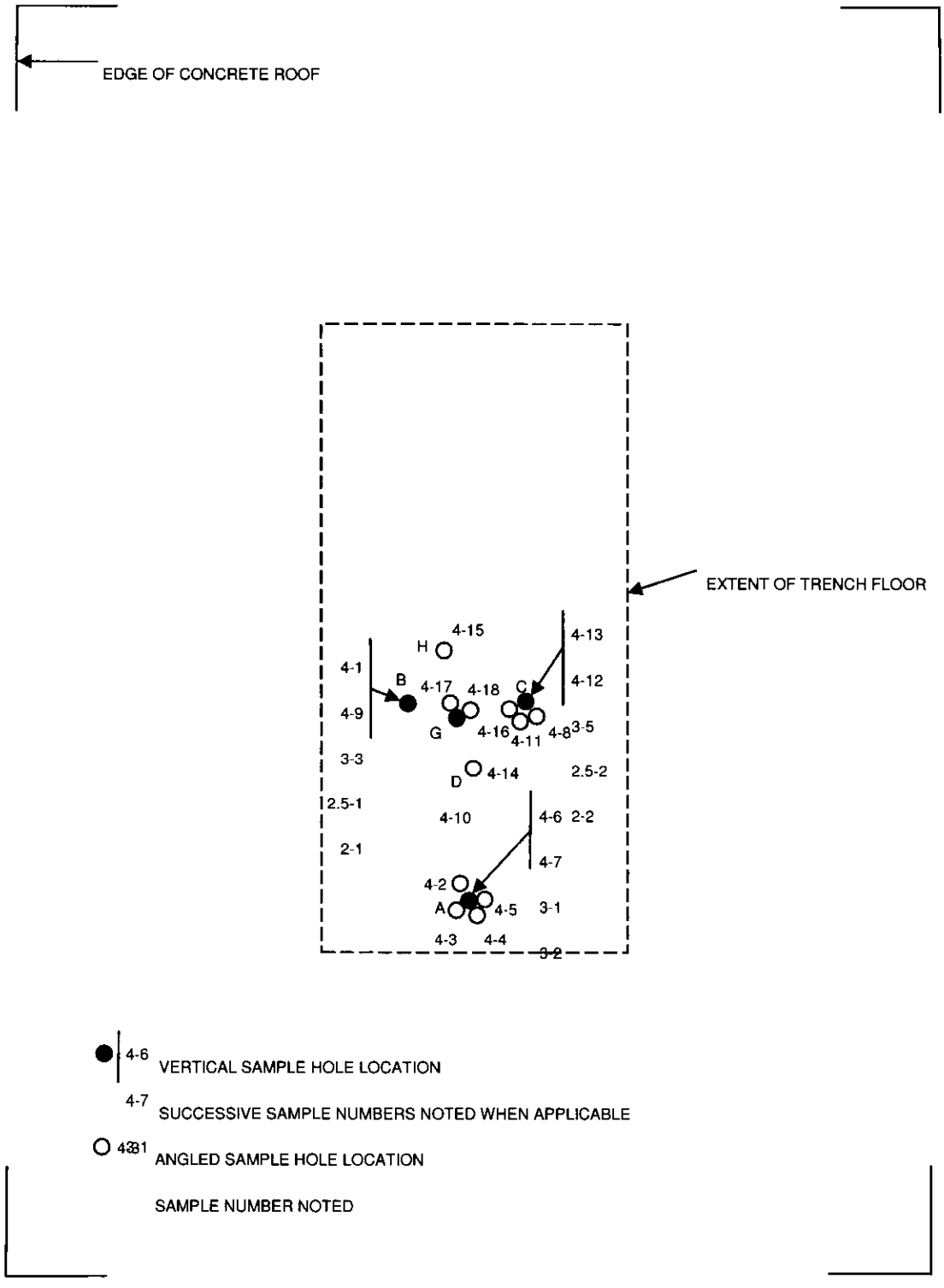

Figure 2-4. Location of Wells Around the 216-Z-1A Tile Field.

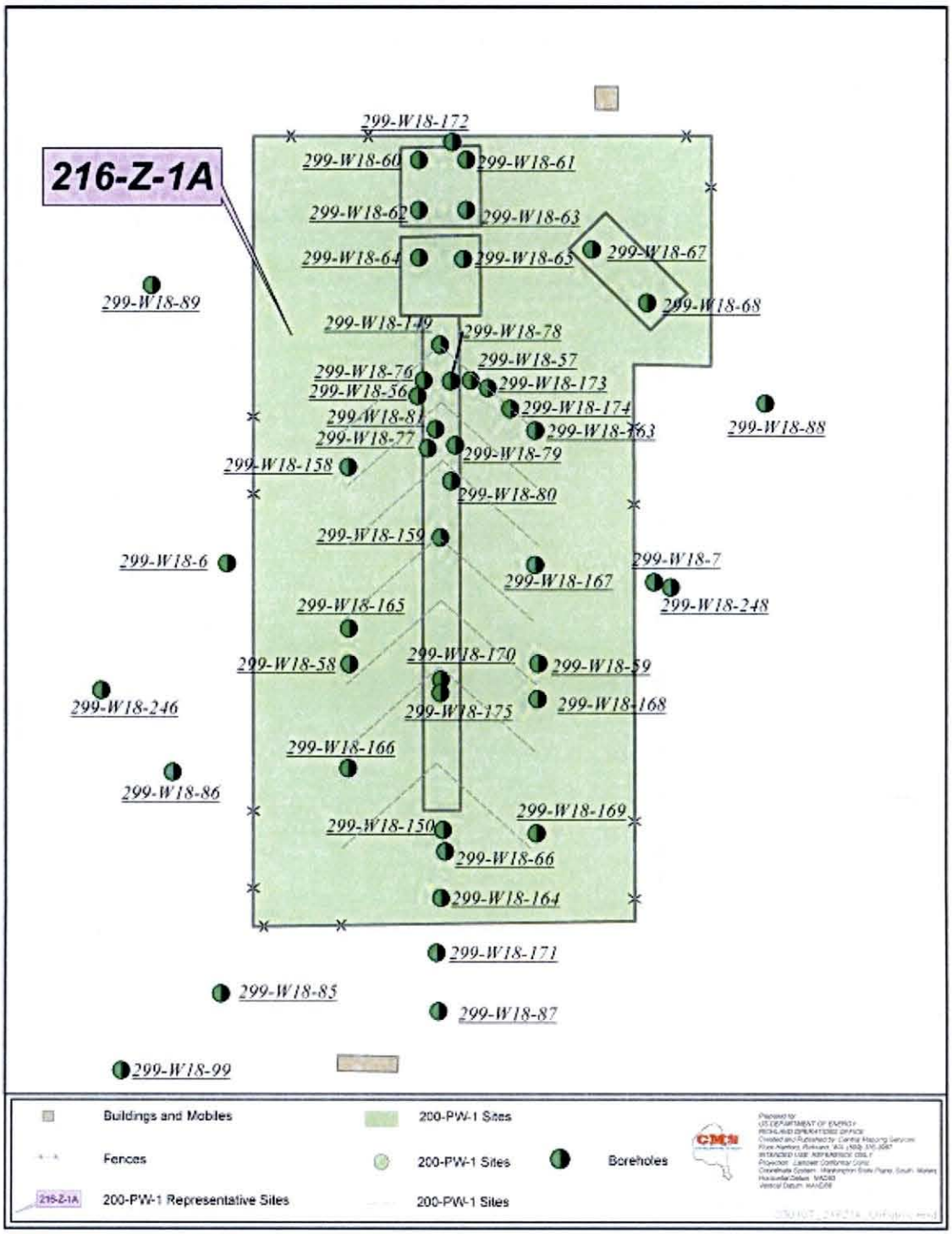

Figure 2-5. Step I Study Area for the Dispersed Carbon Tetrachloride Vadose-Zone Plume Investigation.

(From CP-13514)

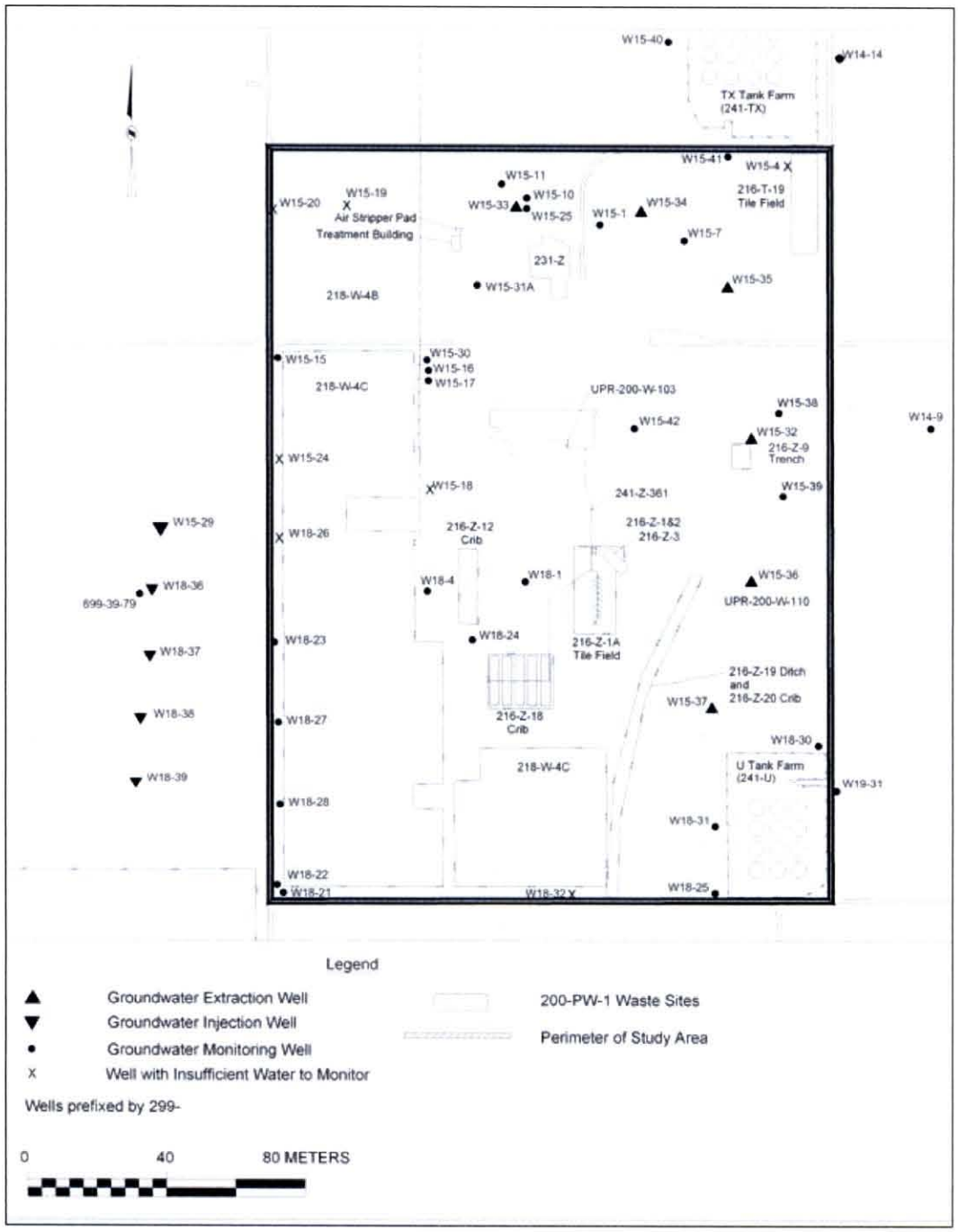

Figure 2-6. Step I Vadose-Zone Soil Vapor Sampling Locations Along Liquid-Waste Discharge Pipelines, 200 West Area.

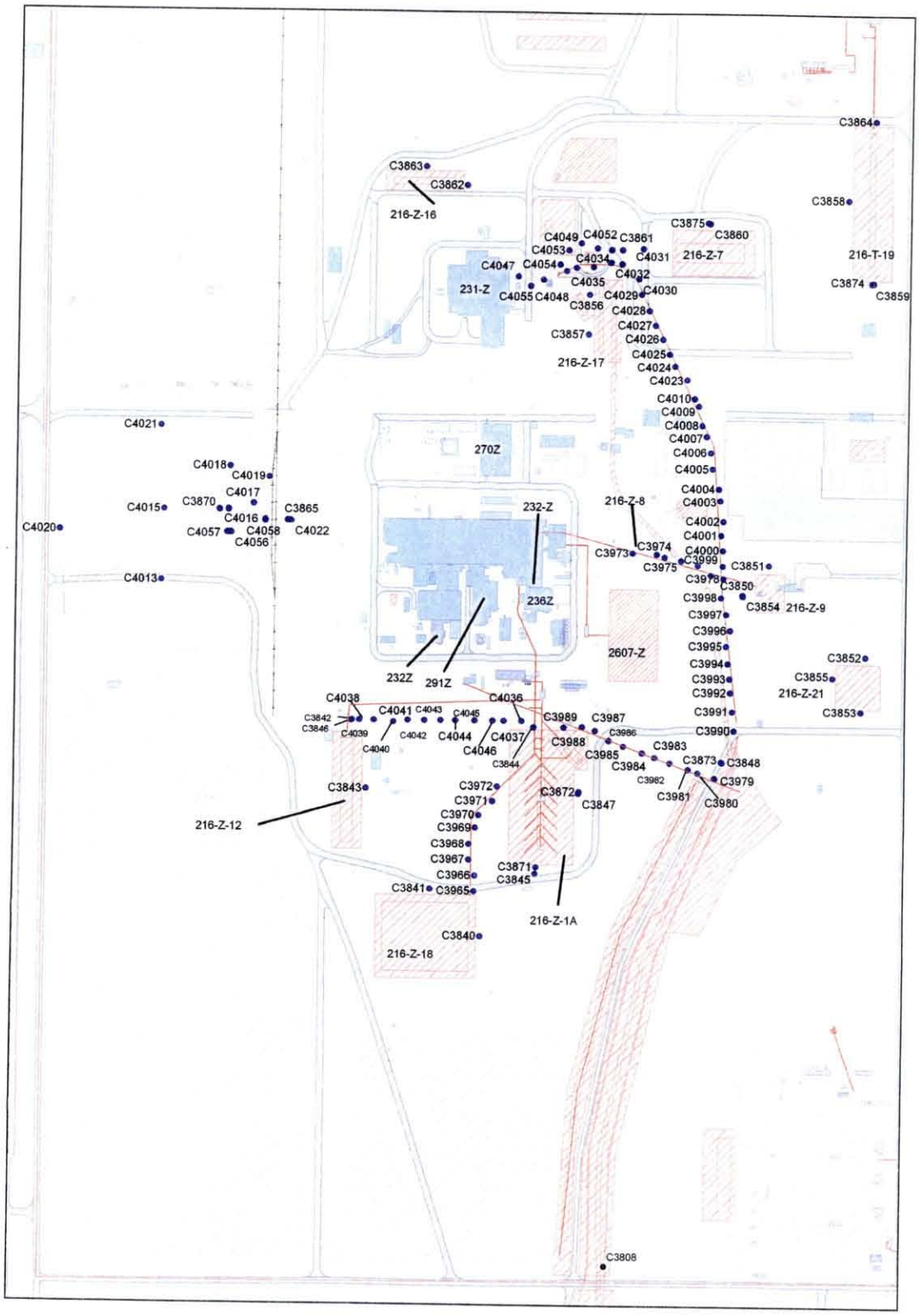

Figure 2-7. Location of Step I Vadose-Zone Soil Vapor Sampling Sites at the 218-W-4C Burial Ground.

(Modified from CP-13514)

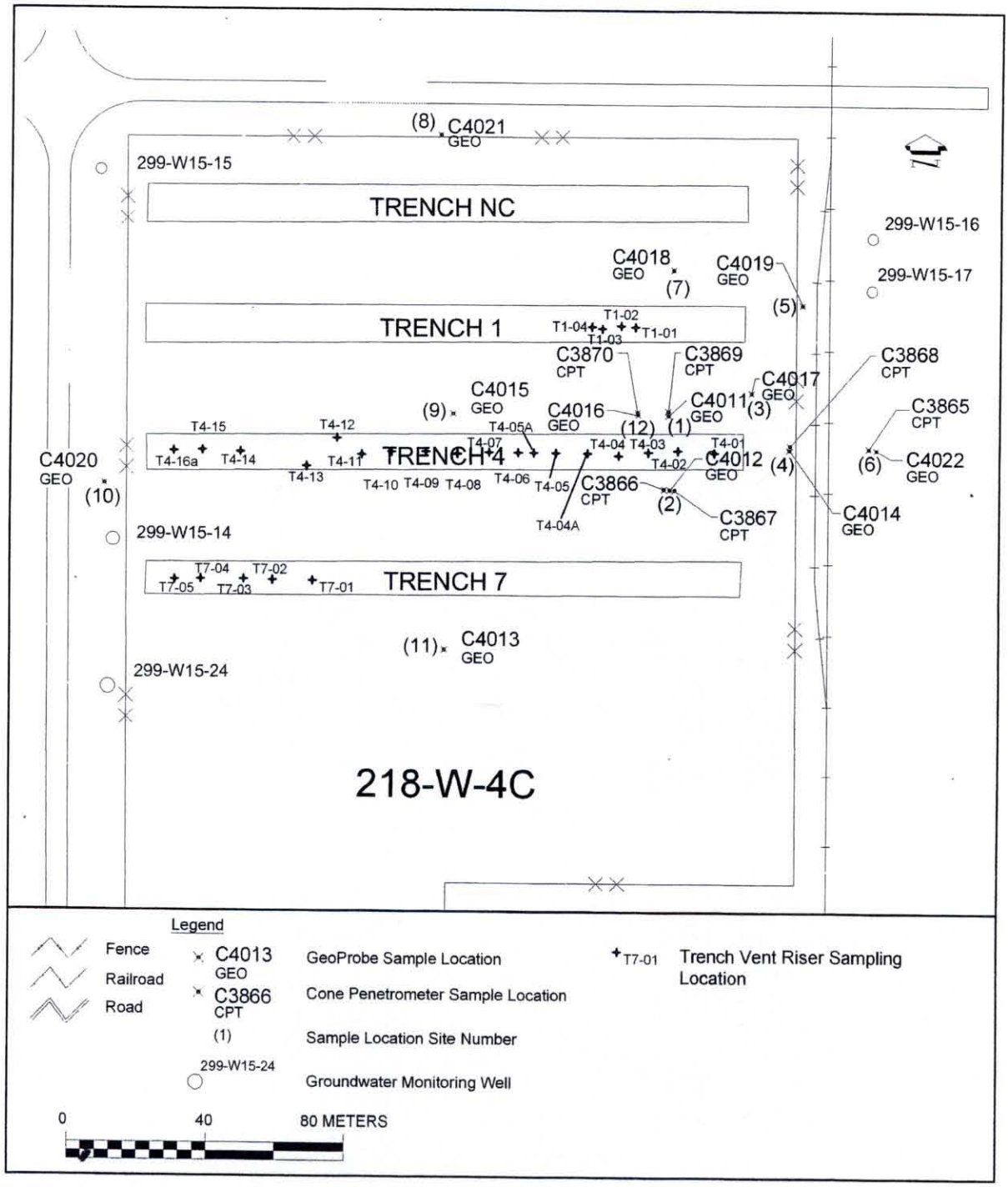

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Figure 2-8. Step II Study Area for the Dispersed Carbon Tetrachloride Vadose-Zone Plume Investigation.

(From PNNL-14187)

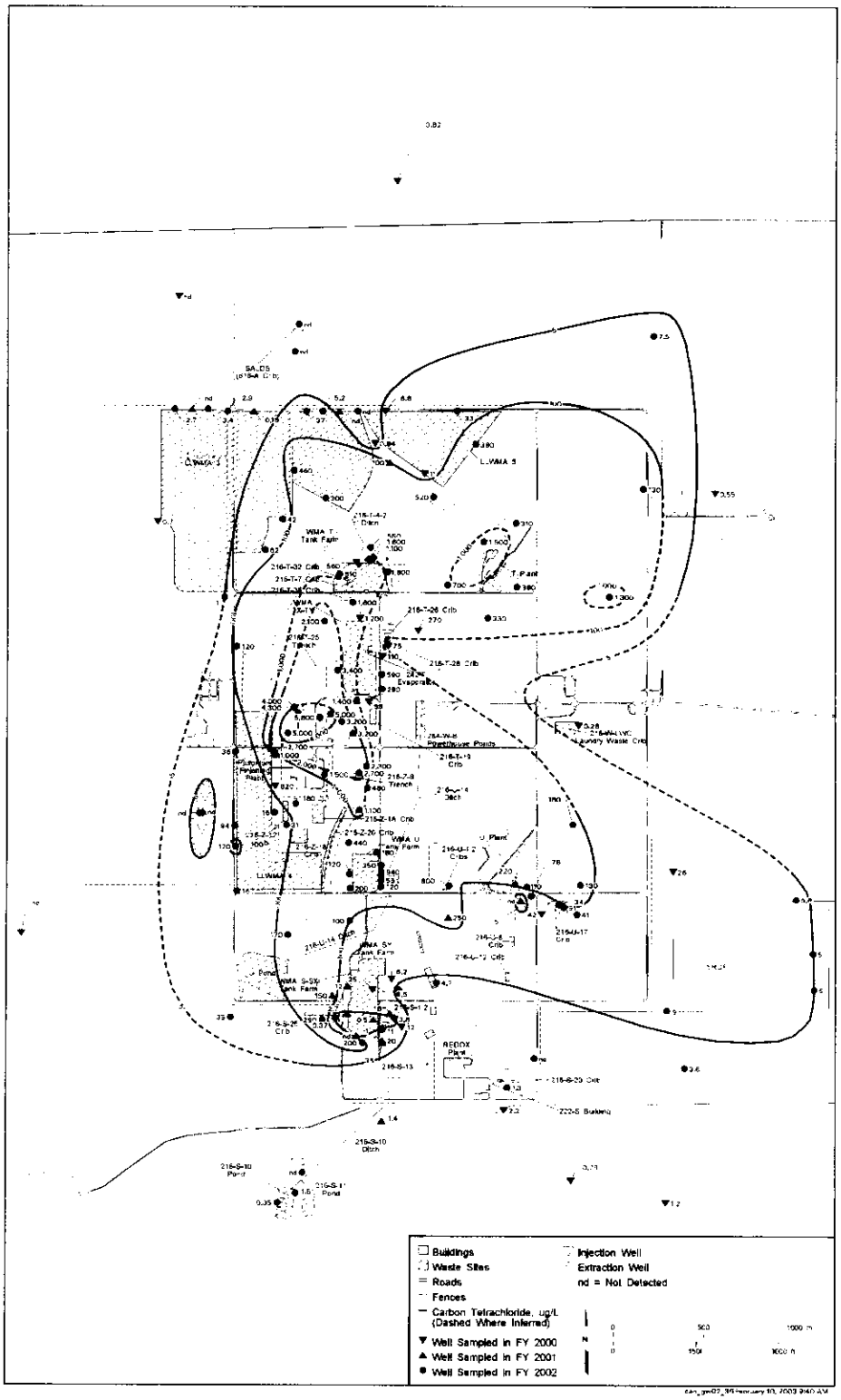


Figure 2-9. Step II Groundwater "Hot Spot" Sampling Areas.

(From DOE/RL-2001-01)

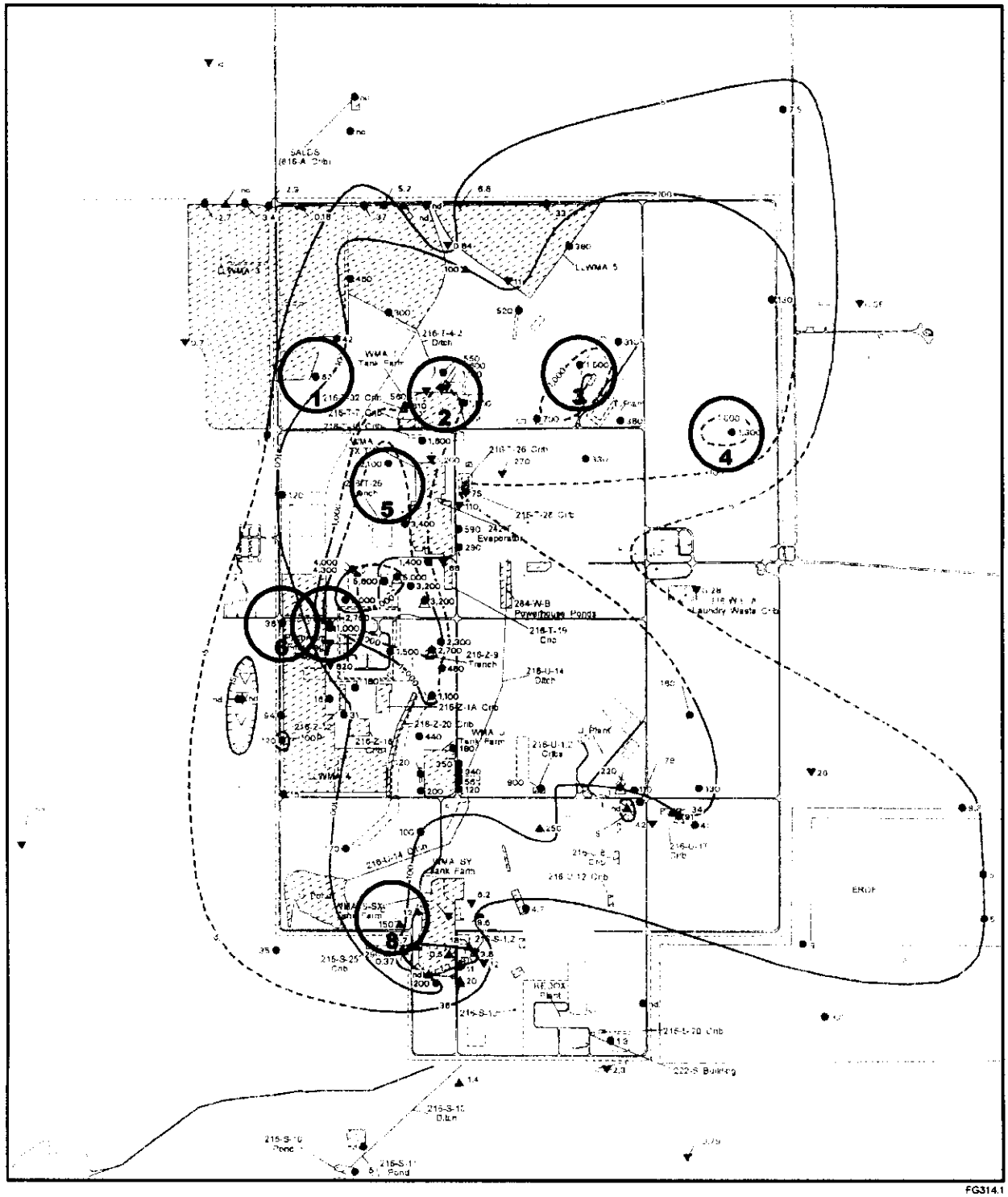


Figure 2-10. Passive Soil Vapor Points and Carbon Tetrachloride Flux Results Around the 216-Z-9 Trench.

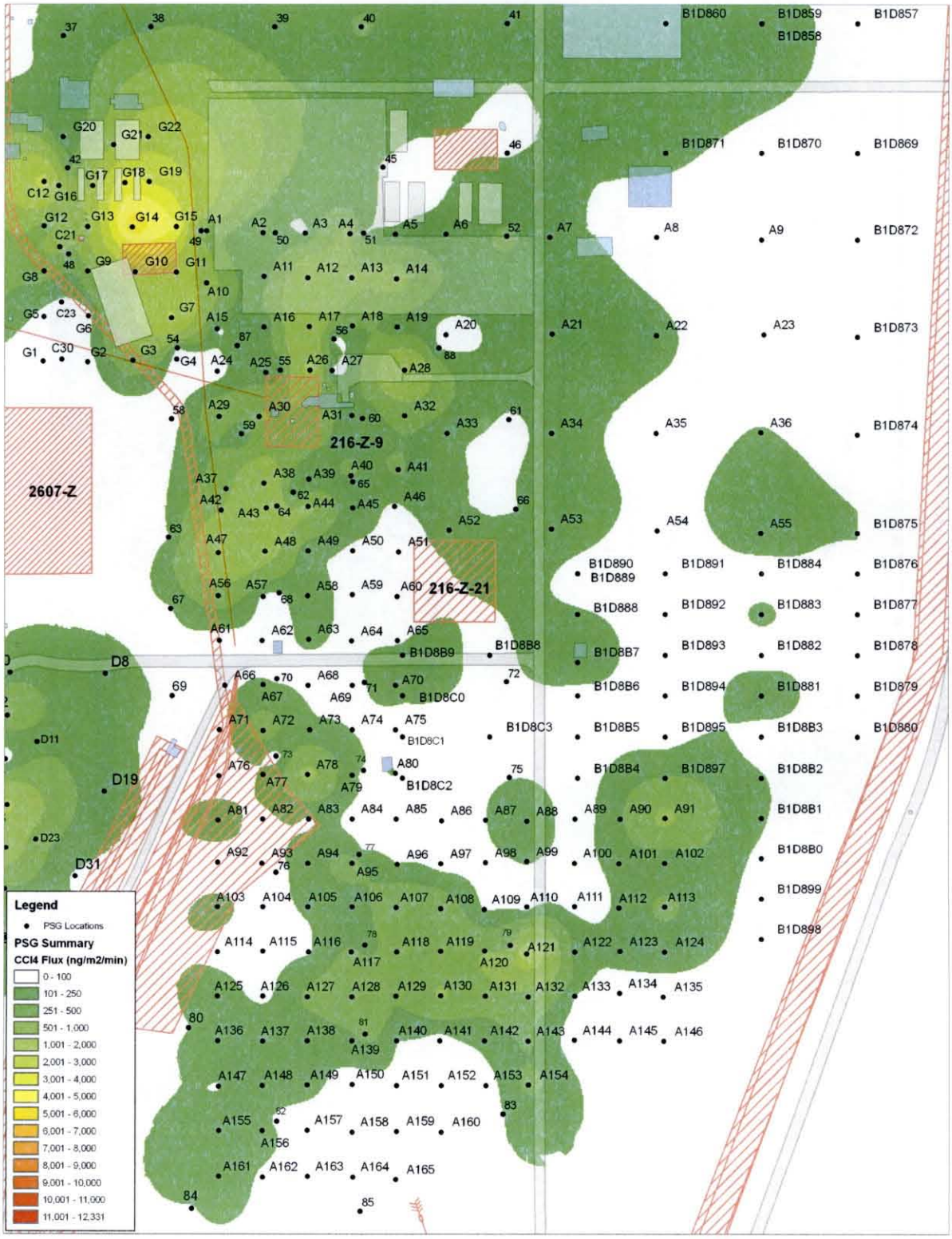


Figure 2-11. Passive Soil Vapor Points and Carbon Tetrachloride Flux Results Around the TX-TY Tank Farm Area.

Figure 2-12. Passive Soil Vapor Points and Carbon Tetrachloride Flux Results Around the Plutonium Finishing Plant Area.

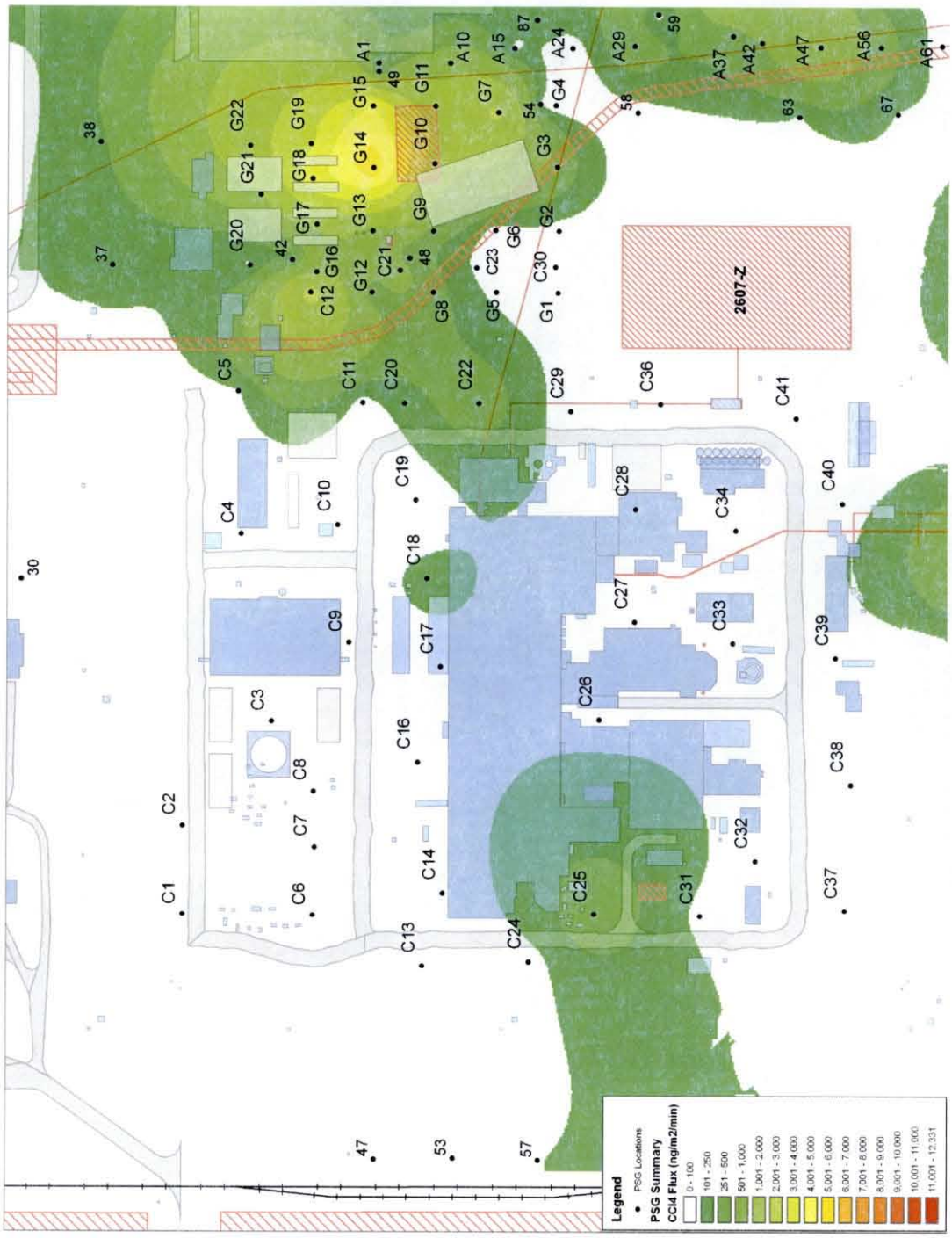


Figure 2-13. Passive Soil Vapor Points and Carbon Tetrachloride Flux Results Around the 216-Z-1A Tile Field.

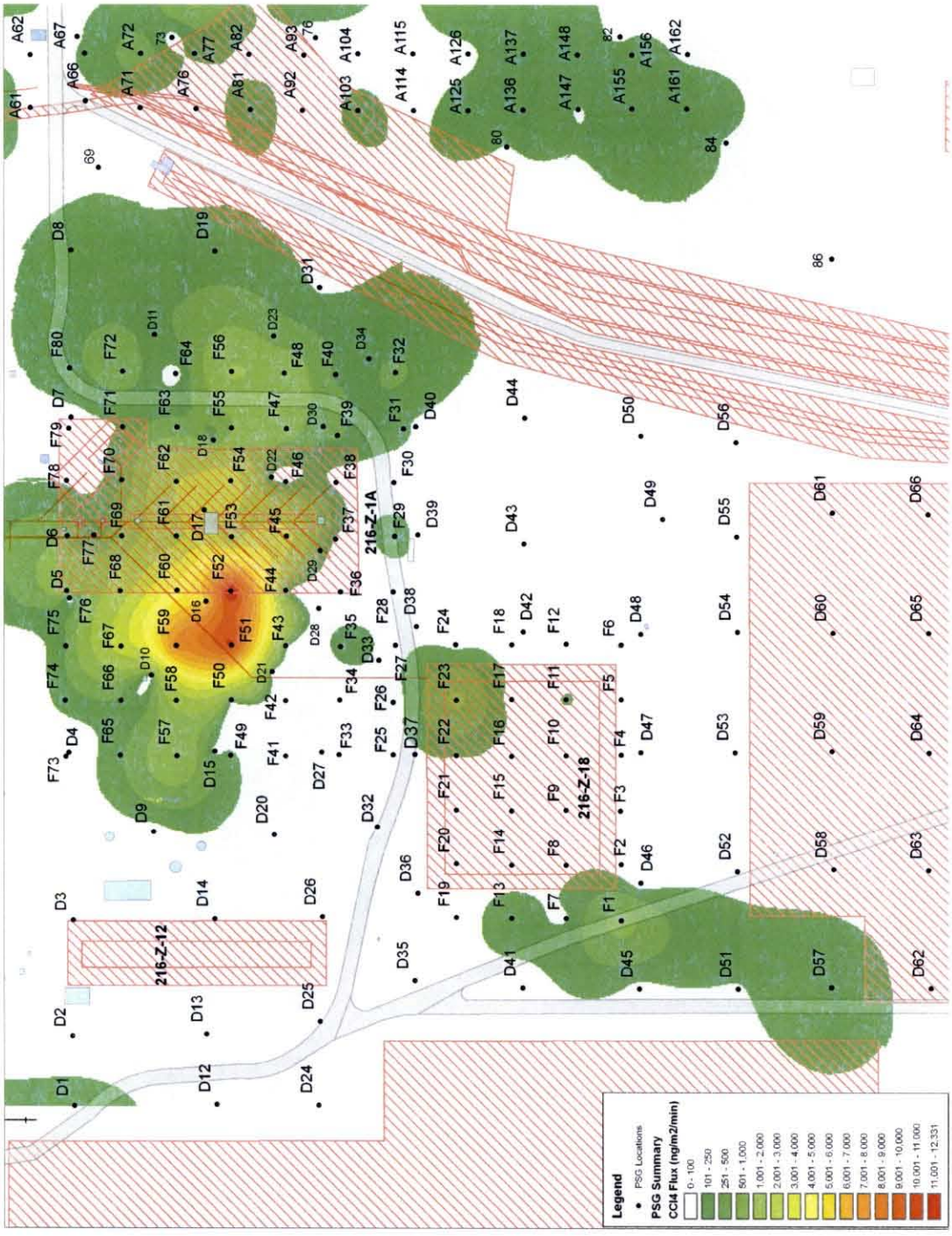


Figure 2-14. Location of Cone Penetrometer Penetrations Around the 216-Z-9 Trench.

(From DOE/RL-2006-58)

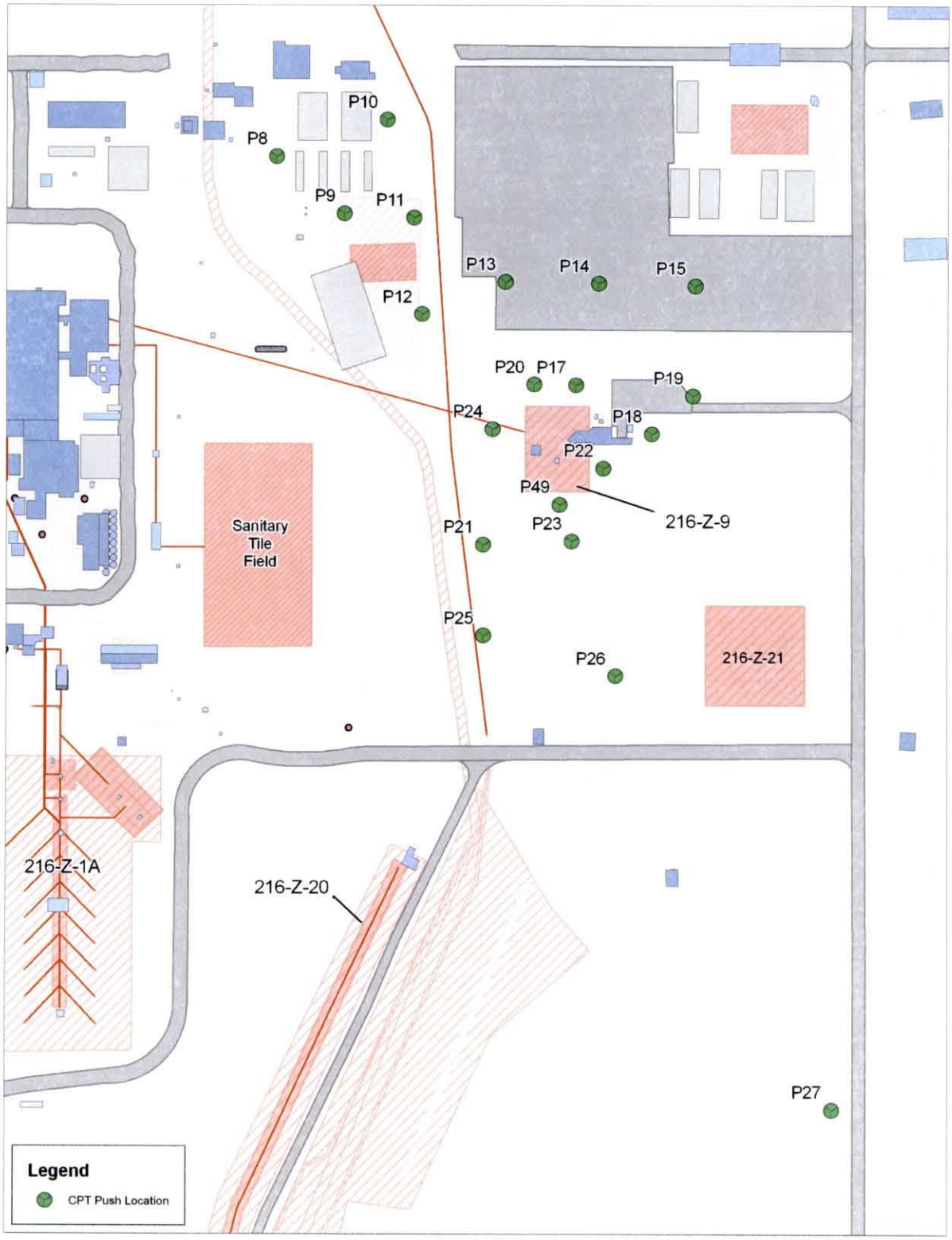


Figure 2-15. Location of Cone Penetrometer Penetrations Around the 216-Z-1A Tile Field.

(From DOE/RL-2006-58)

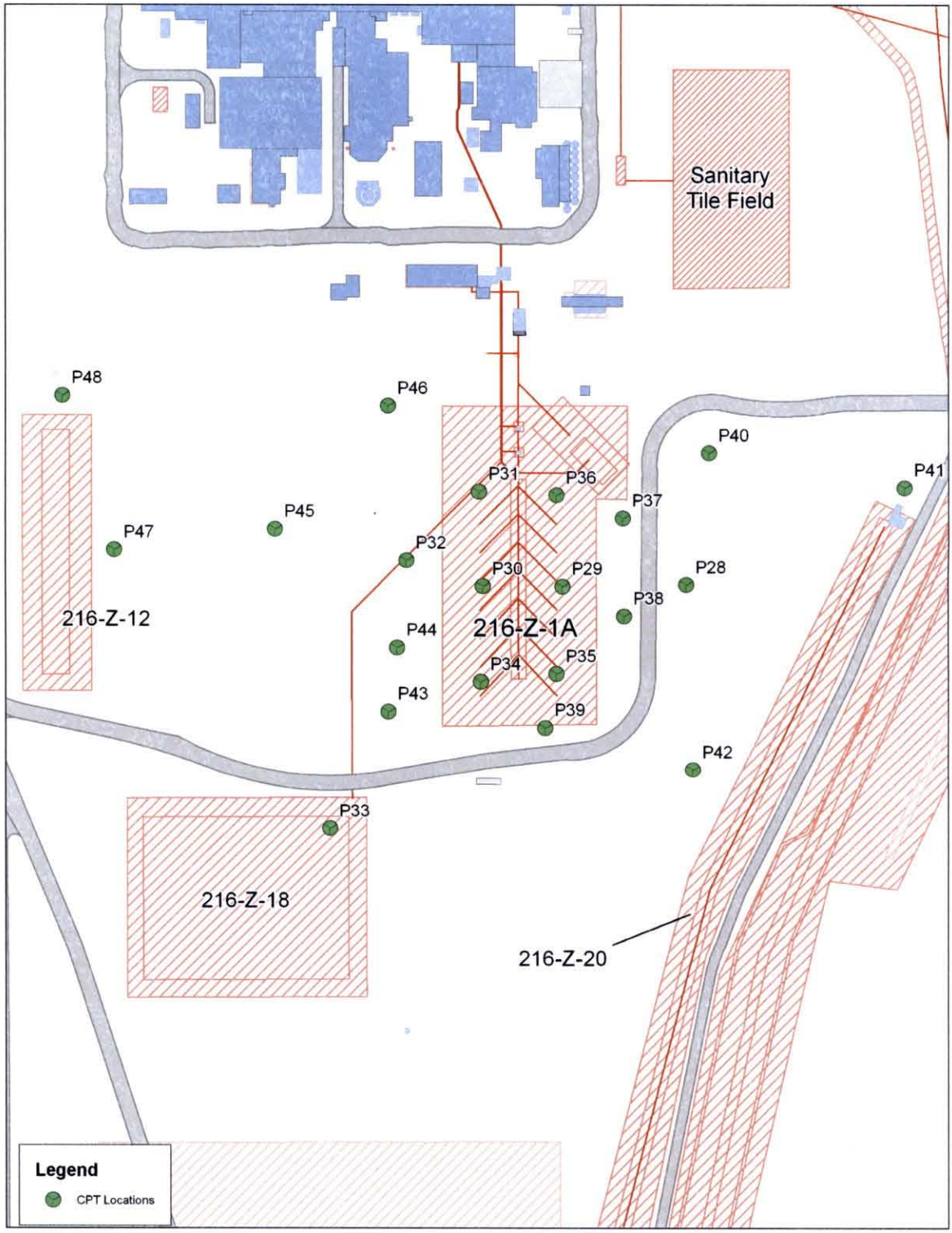


Figure 2-16. Location of Hydraulic Hammer Rig Penetrations Around the 216-Z-9 Trench.

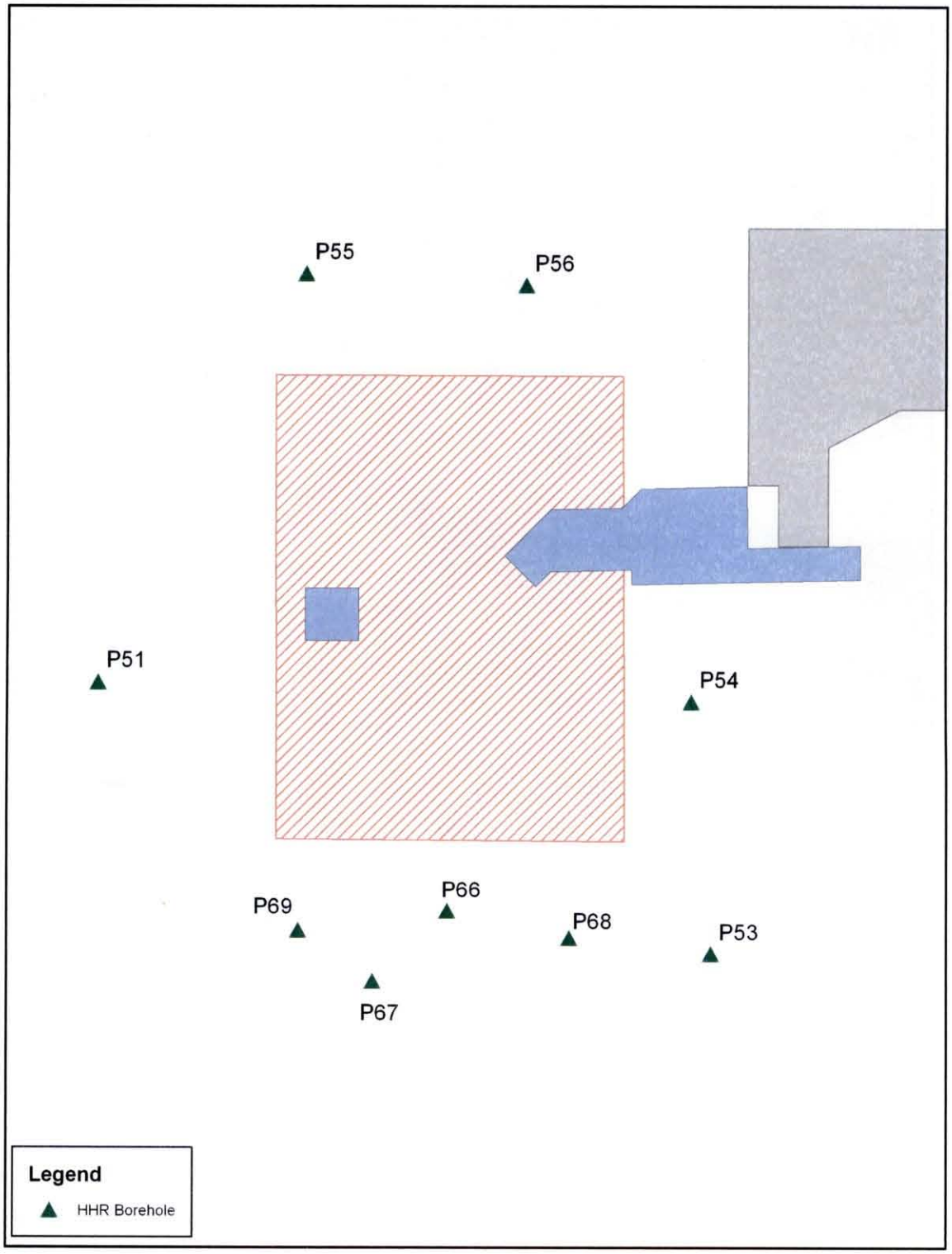


Figure 2-17. Location of Cross-Well Seismic Profiles Around the 216-Z-9 Trench.

(From DOE-RL-2006-58)

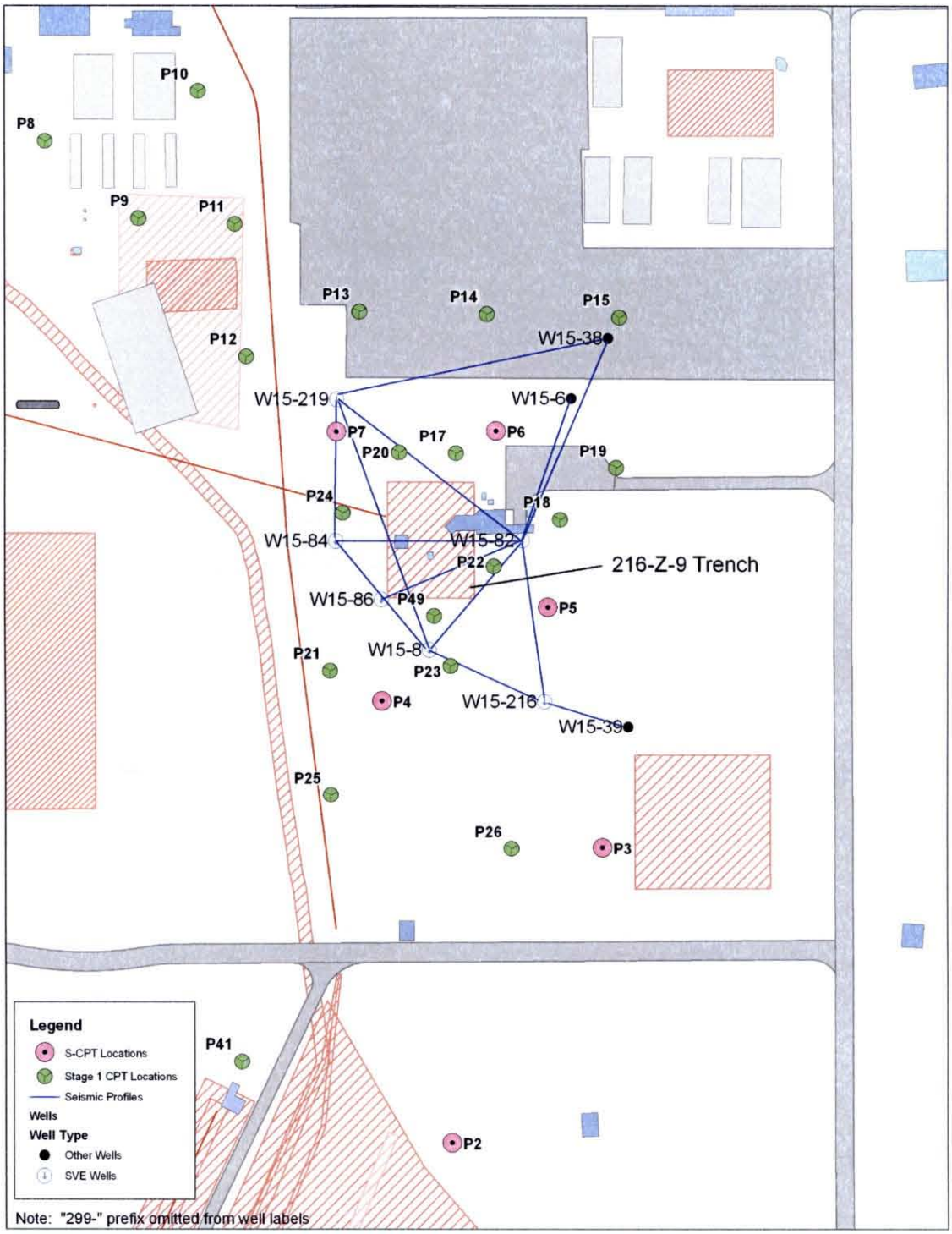
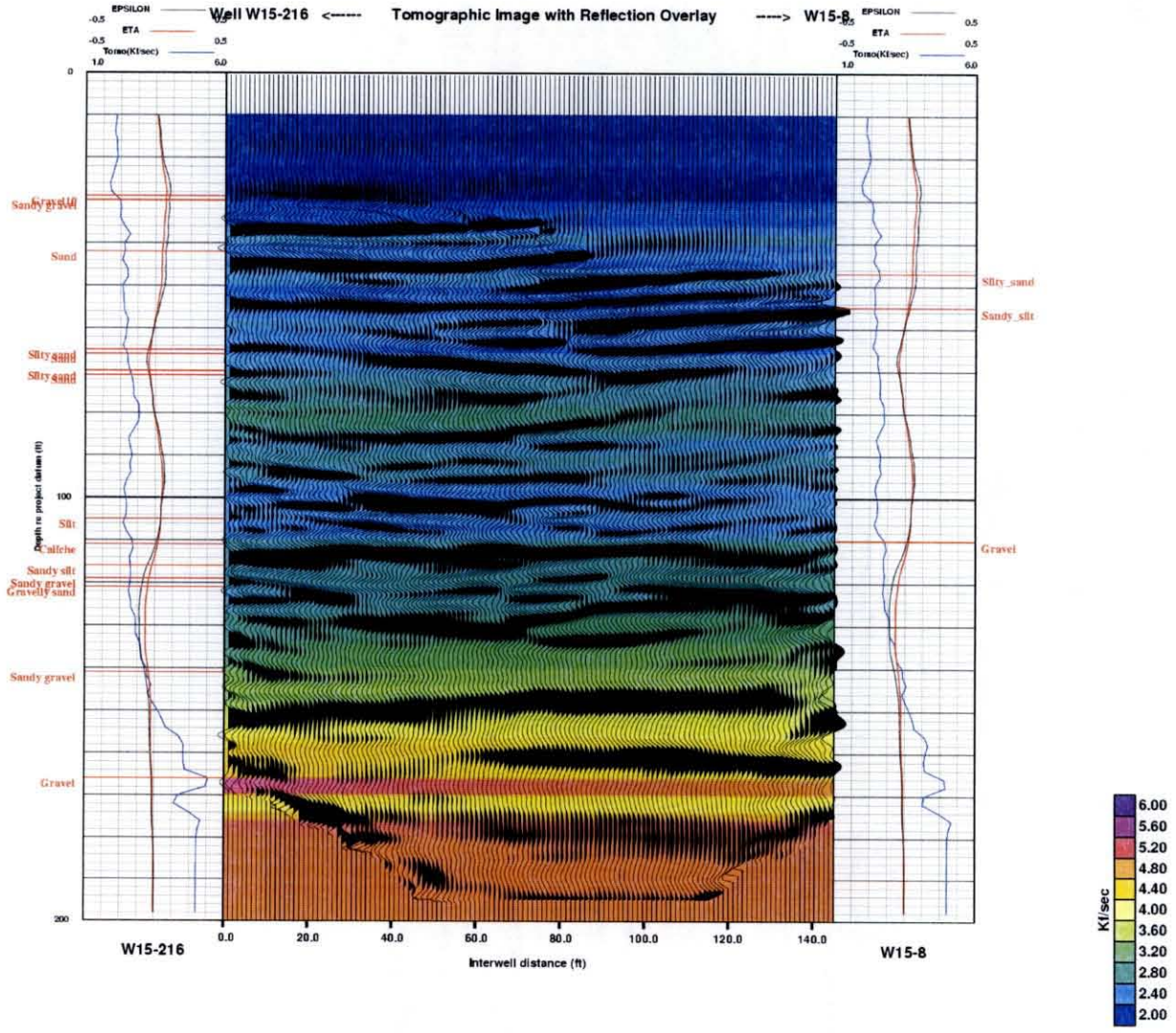


Figure 2-18. Final Tomogram with Migrated Reflection Image Overlay for Cross-Well Profile, Wells 299-W15-216 to 299-W15-8.

(From DOE/RL-2006-58)



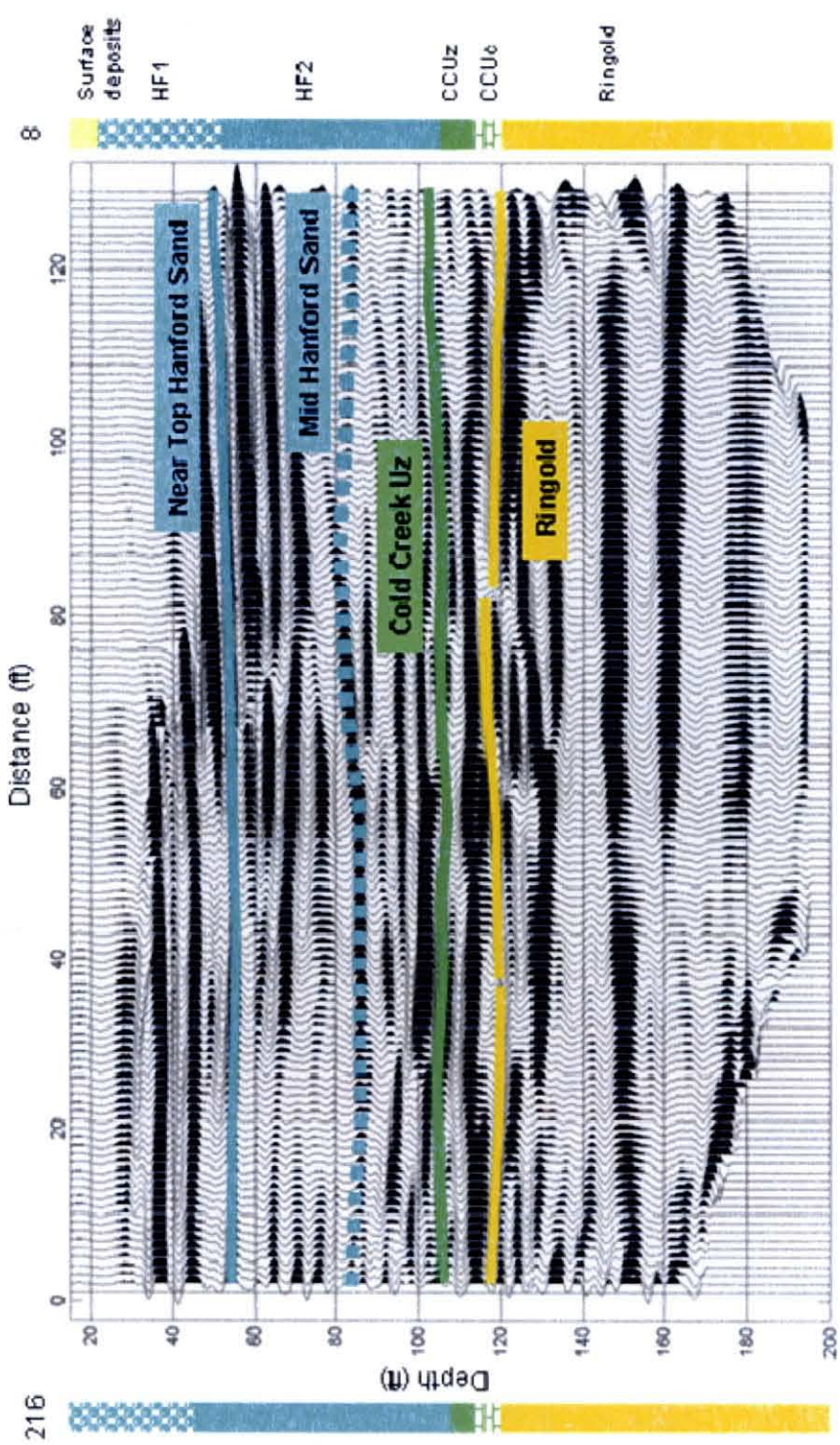


Figure 2-19. Interpreted Geologic Layers in Cross-Well Profile, Wells 299-W15-216 to 299-W15-8 at the 216-Z-9 Trench.

(From DOE/RL-2006-58)

Figure 2-20. Subsurface Topography of a Layer Near the Top of the Hanford formation Sand-Dominated Unit (H2), Interpreted from the Cross-Well Seismic Survey at the 216-Z-9 Trench.

(From DOE/RL-2006-58)

Elevation in Feet

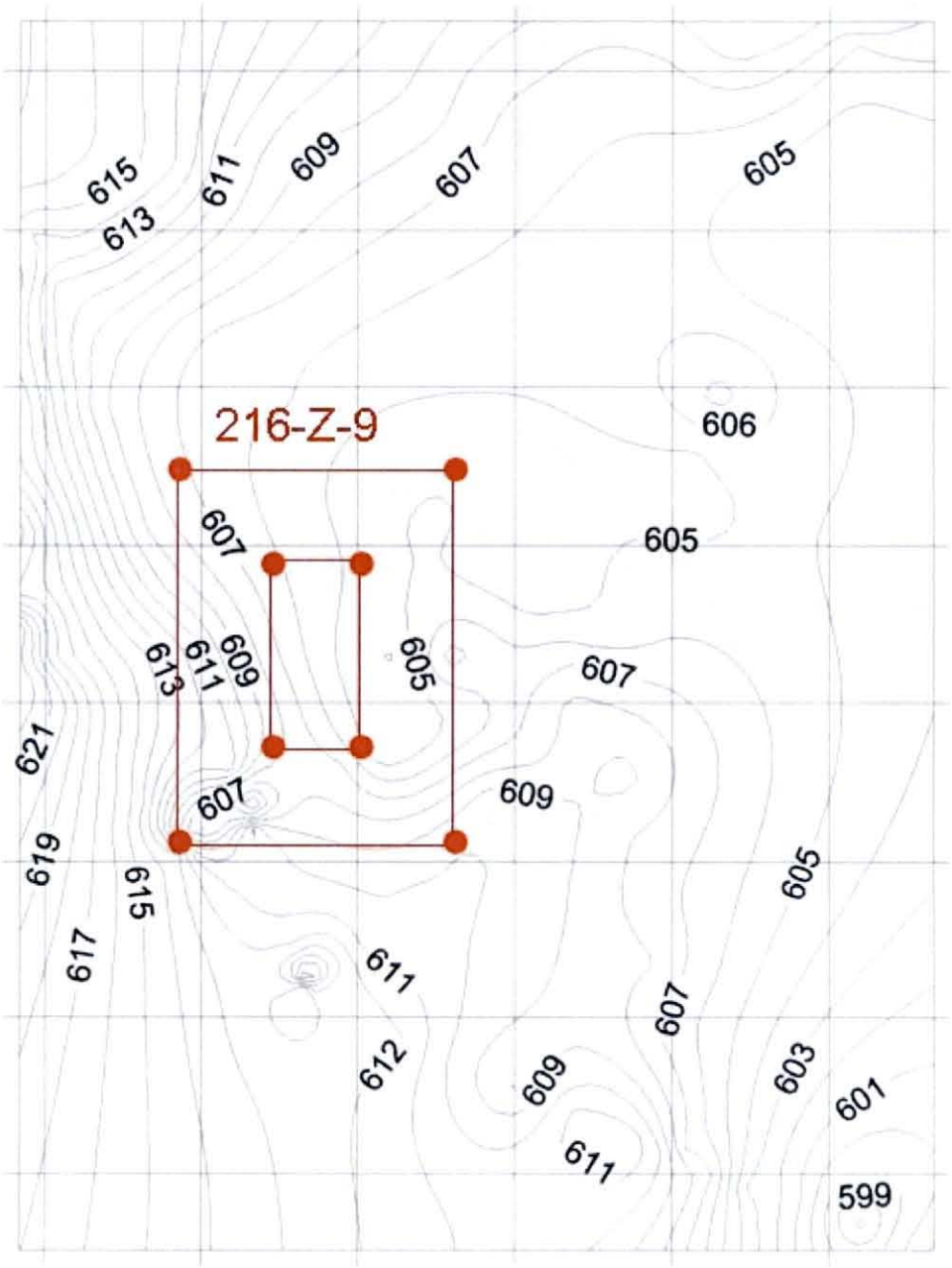


Figure 2-21. Subsurface Topography of a Layer near the Middle of the Hanford formation Sand-Dominated Unit (H2), Interpreted from the Cross-Well Seismic Survey at the 216-Z-9 Trench.

(From DOE/RL-2006-58)

Elevation in Feet

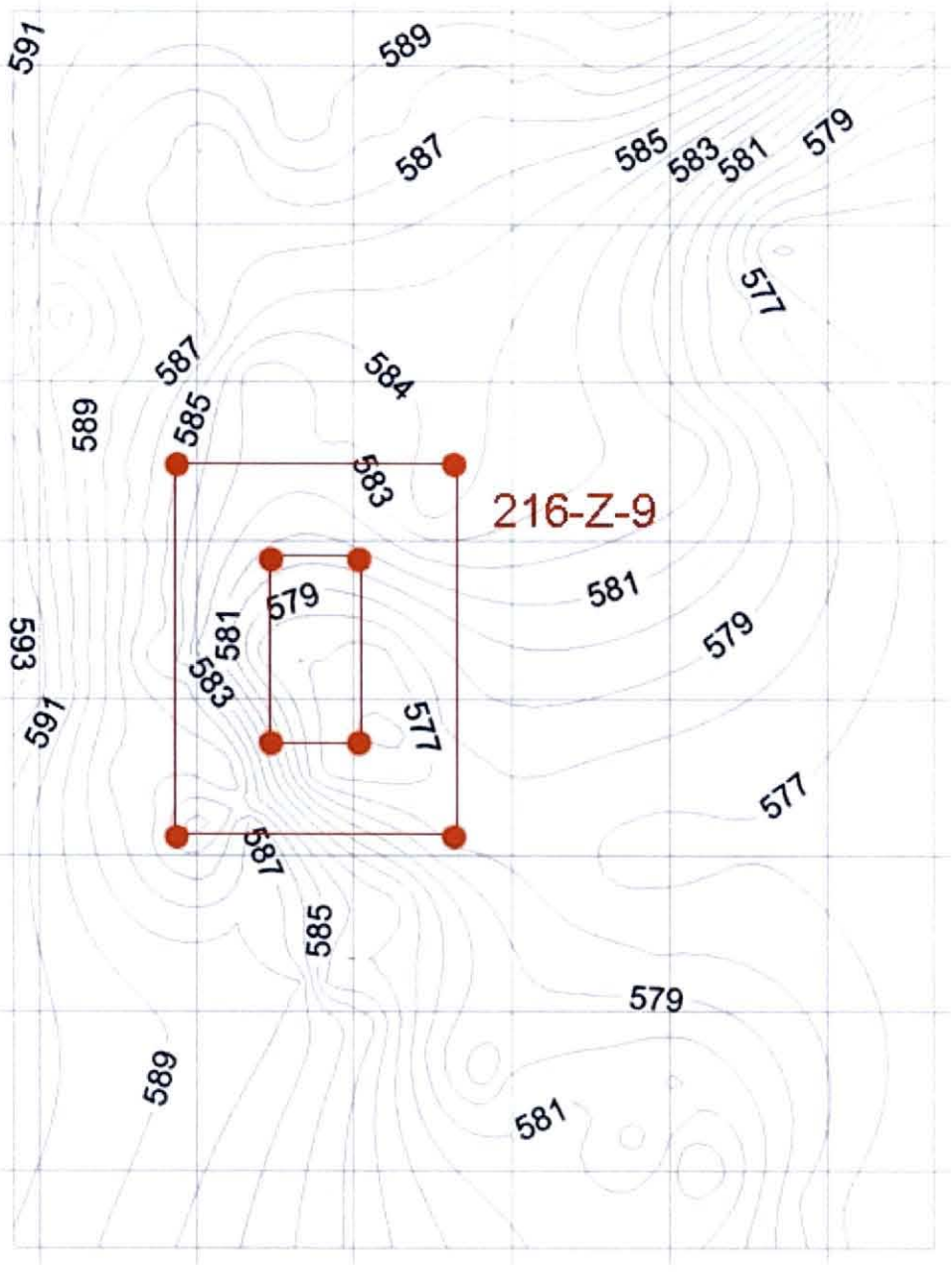


Figure 2-22. Subsurface Topography of the Top of the Cold Creek Unit Silt, Interpreted from the Cross-Well Seismic Survey at the 216-Z-9 Trench.

(From DOE/RL-2006-58)

Elevation in Feet

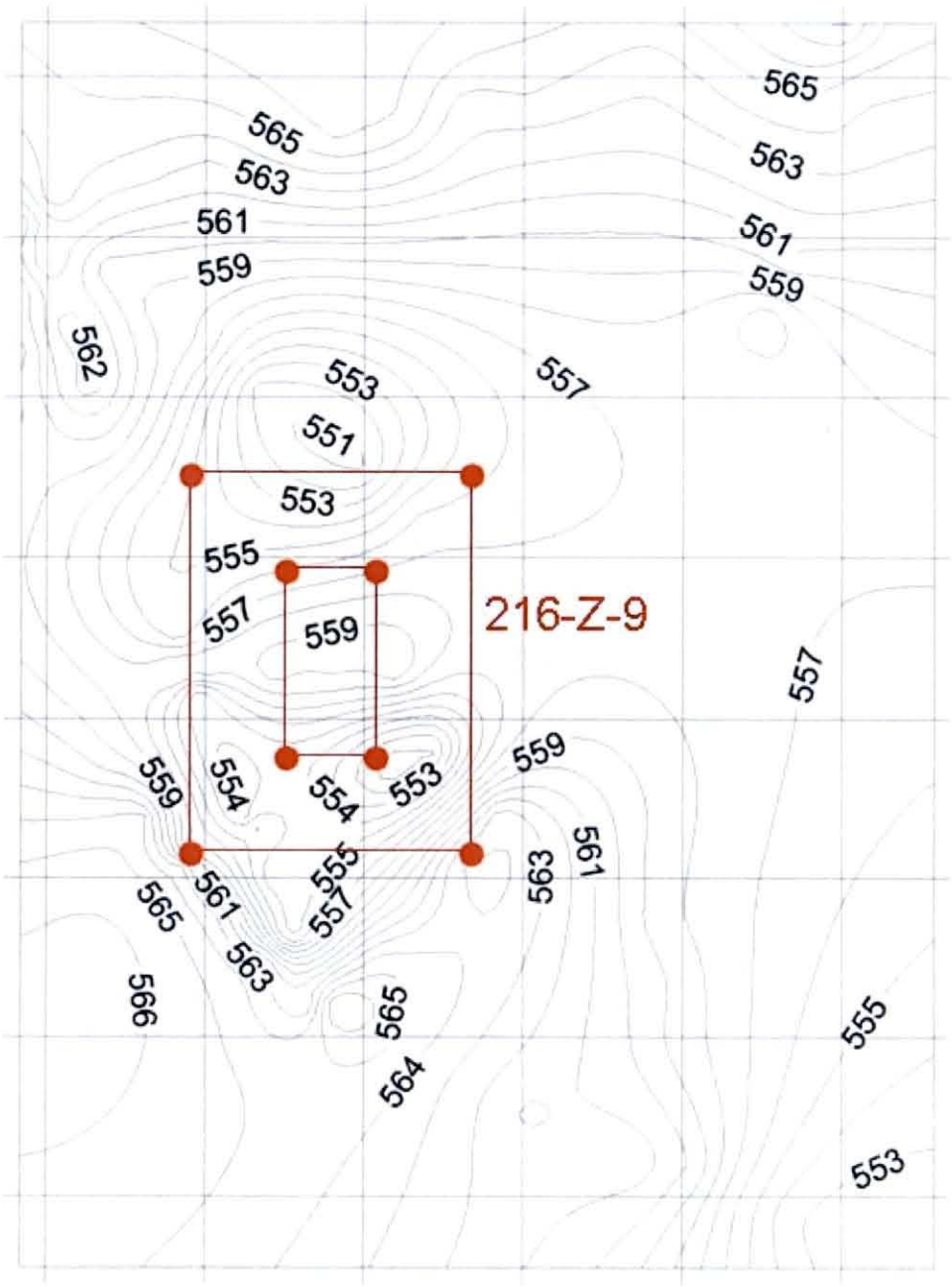


Figure 2-23. Subsurface Topography of the Top of the Ringold Formation, Interpreted from the Cross-Well Seismic Survey at the 216-Z-9 Trench.

(From DOE/RL-2006-58)

Elevation in Feet

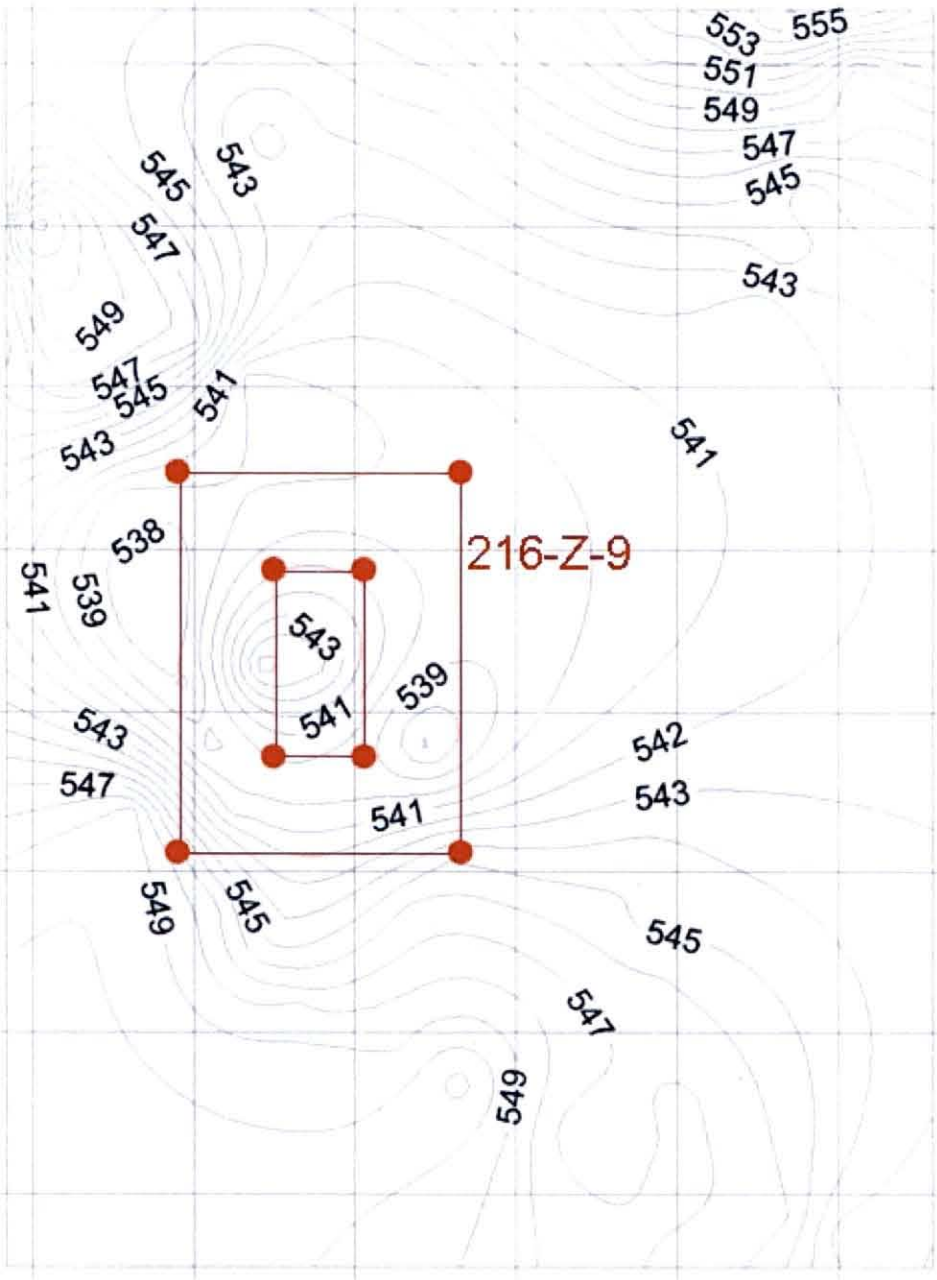
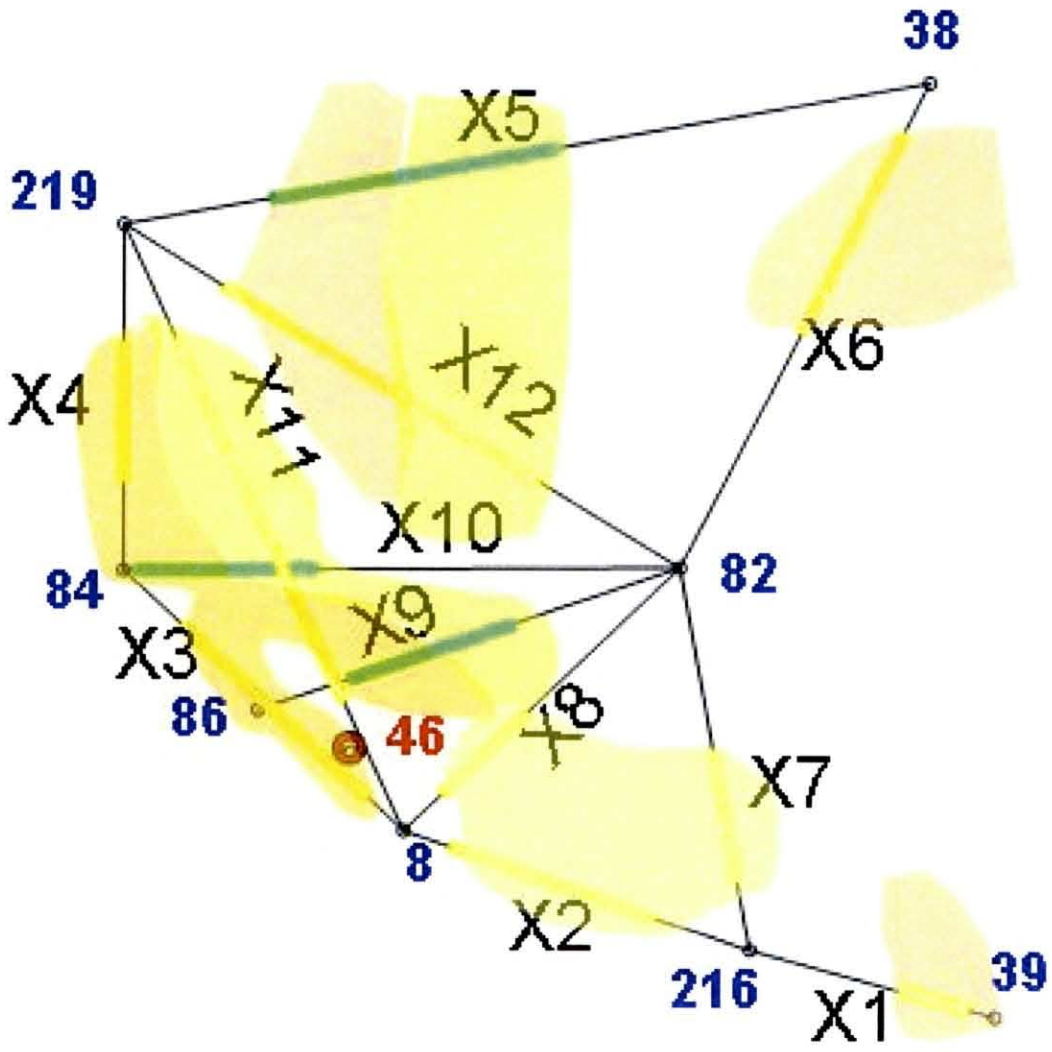


Figure 2-24. Interpreted Lateral Extent of Thin Layer Reflectors Beneath the 216-Z-9 Trench (that may Correlate with the Silt Layer from 19.8 to 20.4 m [65 to 67 ft] Deep in Well 299-W15-46).

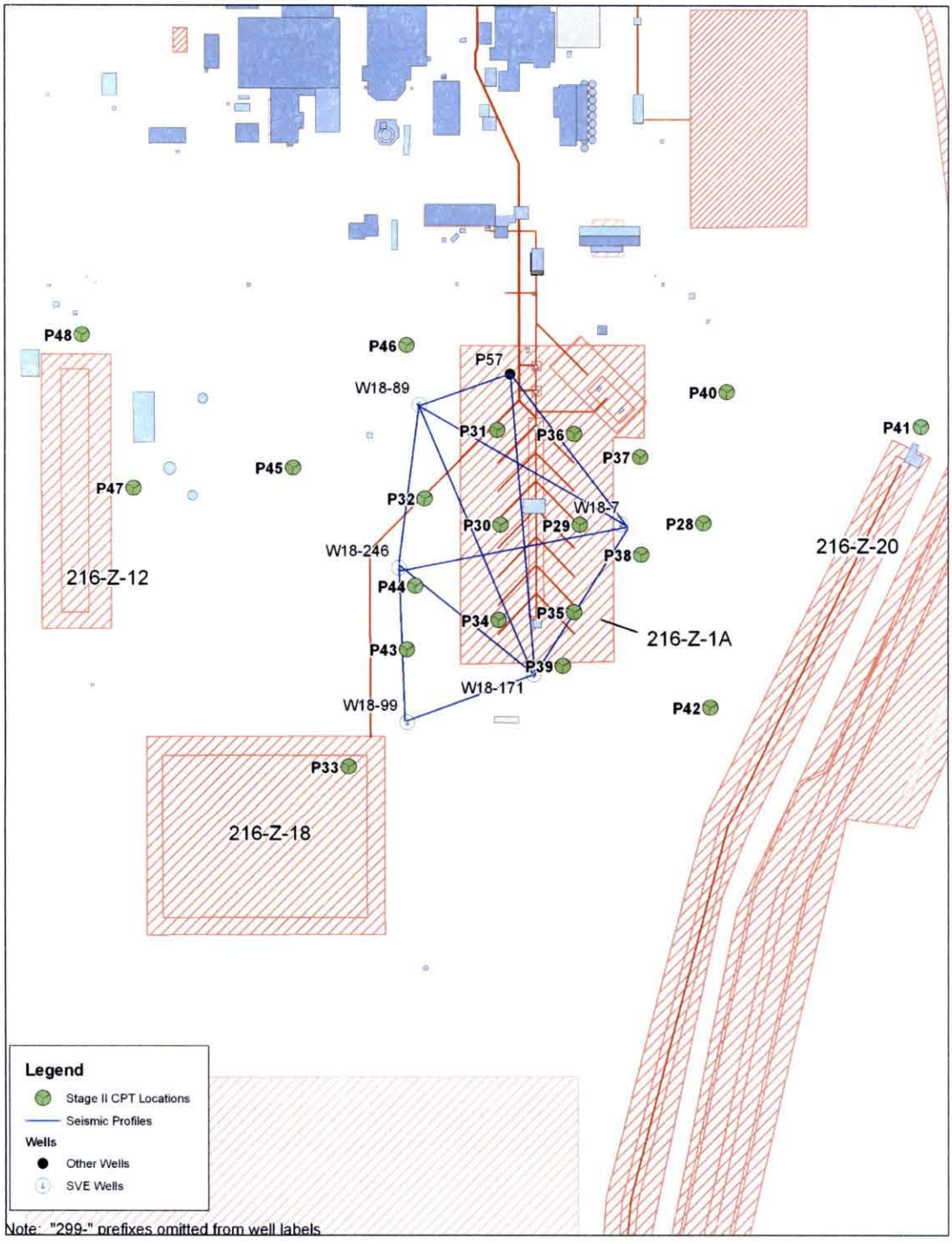
(Revised from DOE/RL-2006-58)



NOTE: Blue and red numbers are wells with "299-W15-" omitted. The yellow and tan colors represent the interpreted extent of two different thin layer reflectors.

Figure 2-25. Location of Cross-Well Seismic Profiles Around the 216-Z-1A Tile Field.

(From DOE/RL-2006-58)



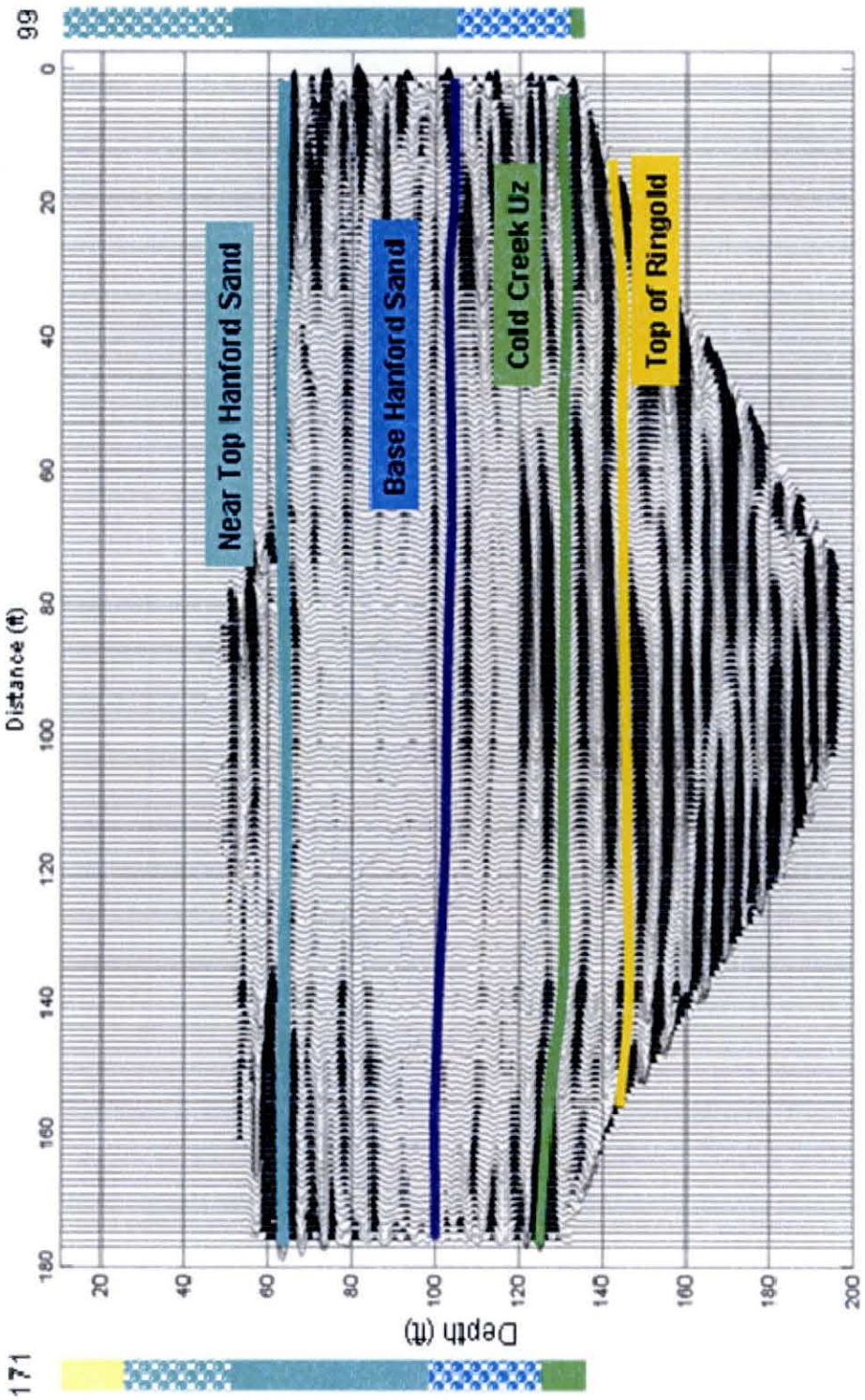
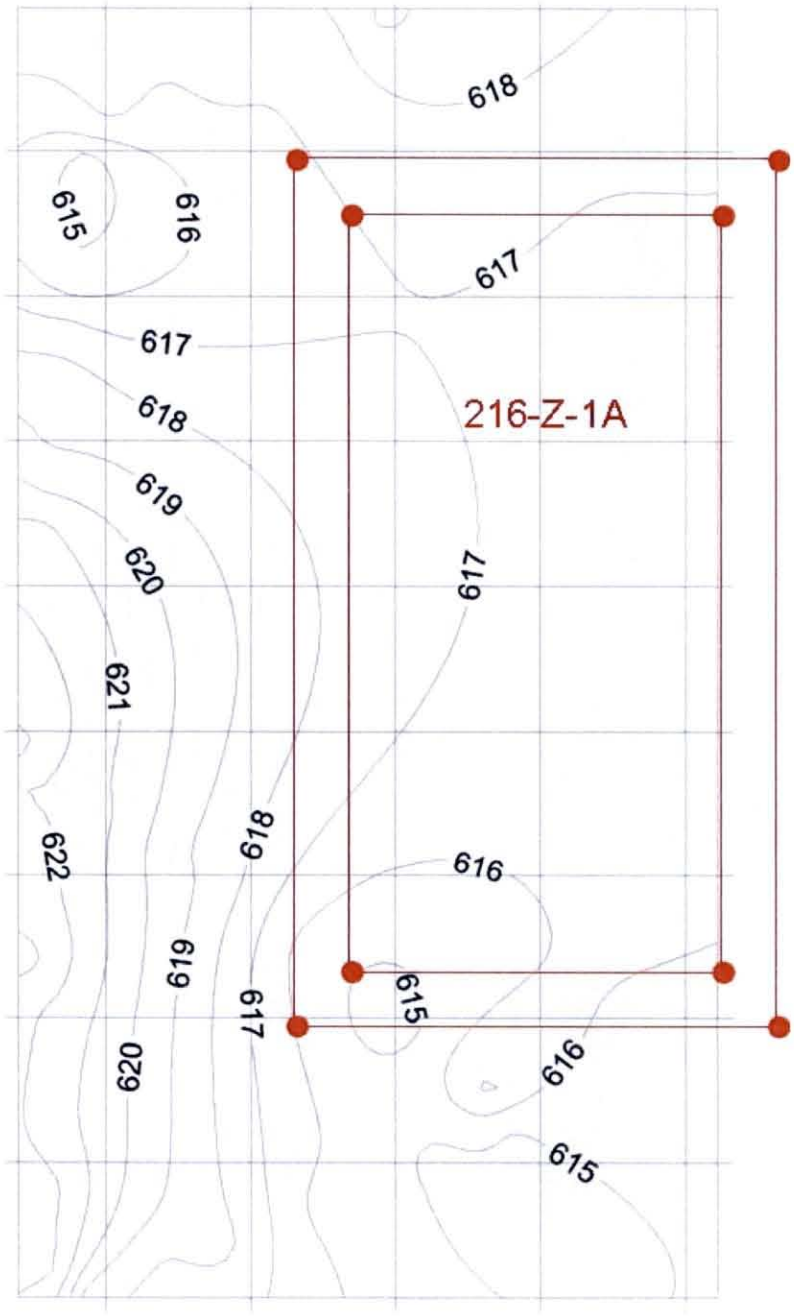


Figure 2-26. Interpreted Geologic Layers in Cross-Well Profile, Wells 299-W18-171 to 299-W18-99 at the 216-Z-1A Tile Field.

(From DOE/RL-2006-58)

Figure 2-27. Subsurface Topography of a Layer near the Top of the Hanford formation Sand-Dominated Unit (H2), Interpreted from the Cross-Well Seismic Survey at the 216-Z-1A Tile Field.

(From DOE/RL-2006-58)



Elevation in Feet. This shallow layer could not be fully imaged by the seismic profiles with large inter-well spacings, primarily along the east side of the tile field.

Figure 2-28. Subsurface Topography of the Top of the Hanford formation Gravel-Dominated Unit (H3), Interpreted from the Cross-Well Seismic Survey at the 216-Z-1A Tile Field.

(From DOE/RL-2006-58)

Elevation in Feet

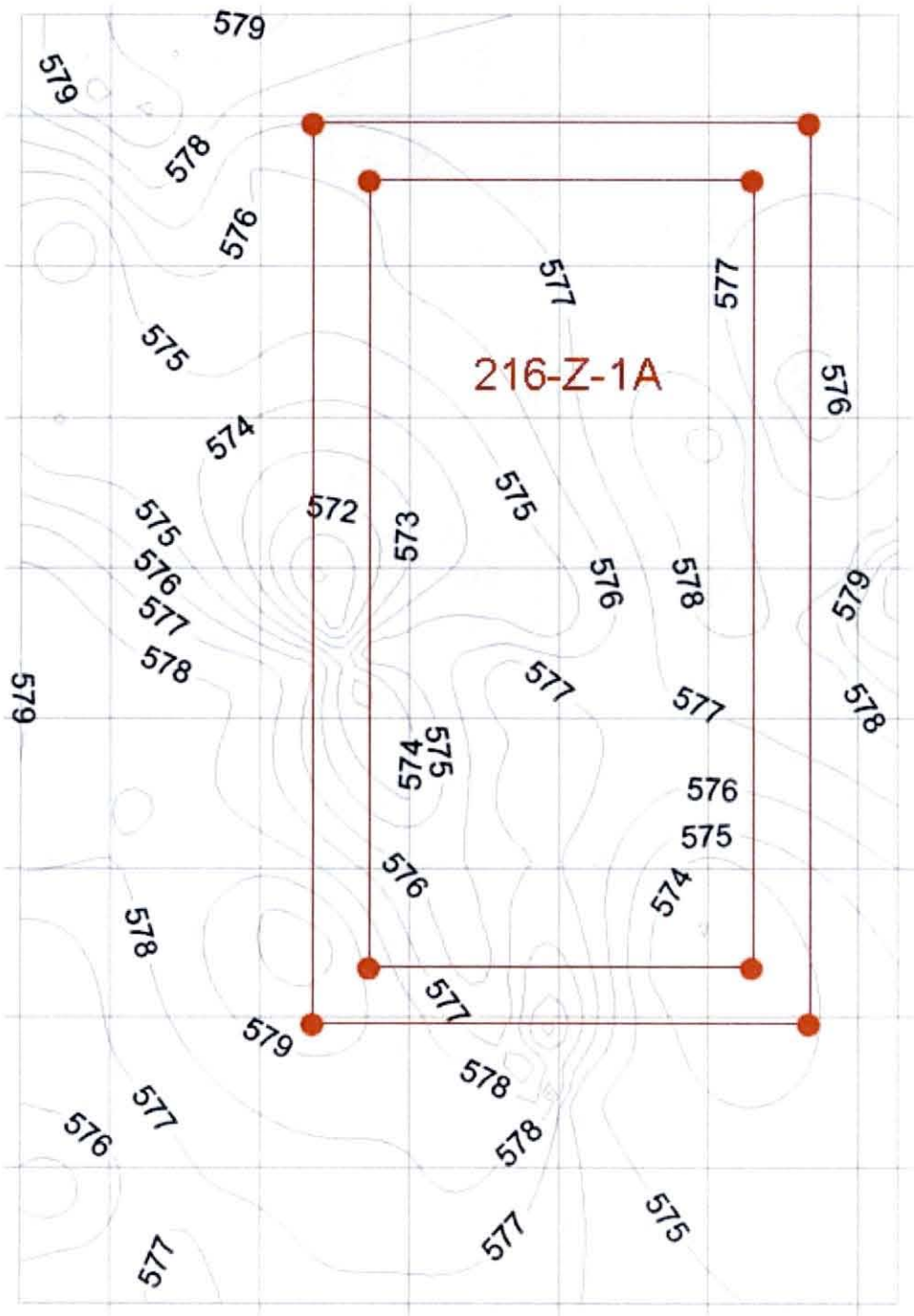


Figure 2-29. Subsurface Topography of the Top of the Cold Creek Unit Silt, Interpreted from the Cross-Well Seismic Survey at the 216-Z-1A Tile Field.

(From DOE/RL-2006-58)

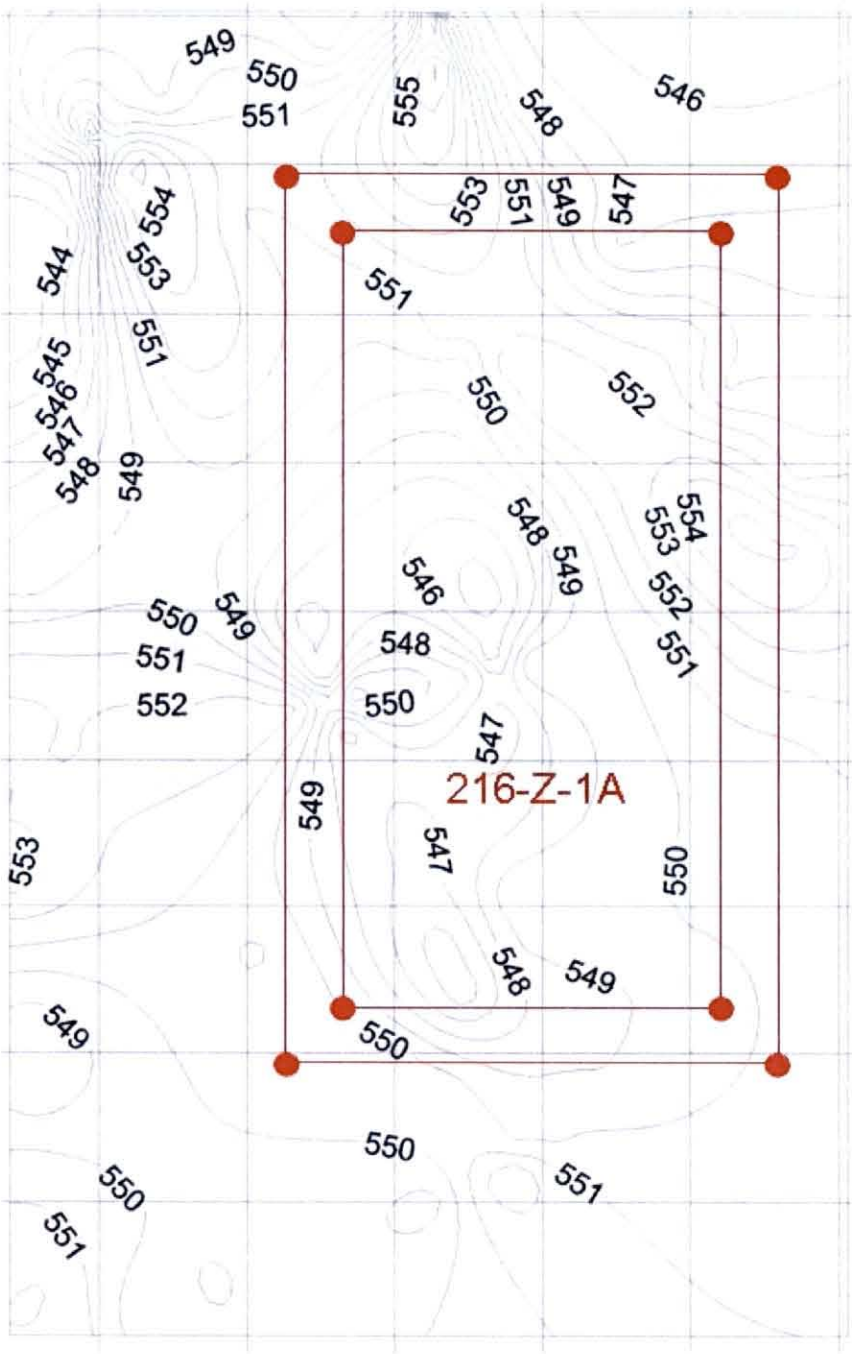


Figure 2-30. Subsurface Topography of the Top of the Ringold Formation, Interpreted from the Cross-Well Seismic Survey at the 216-Z-1A Tile Field.

(From DOE/RL-2006-58)

Elevation in Feet

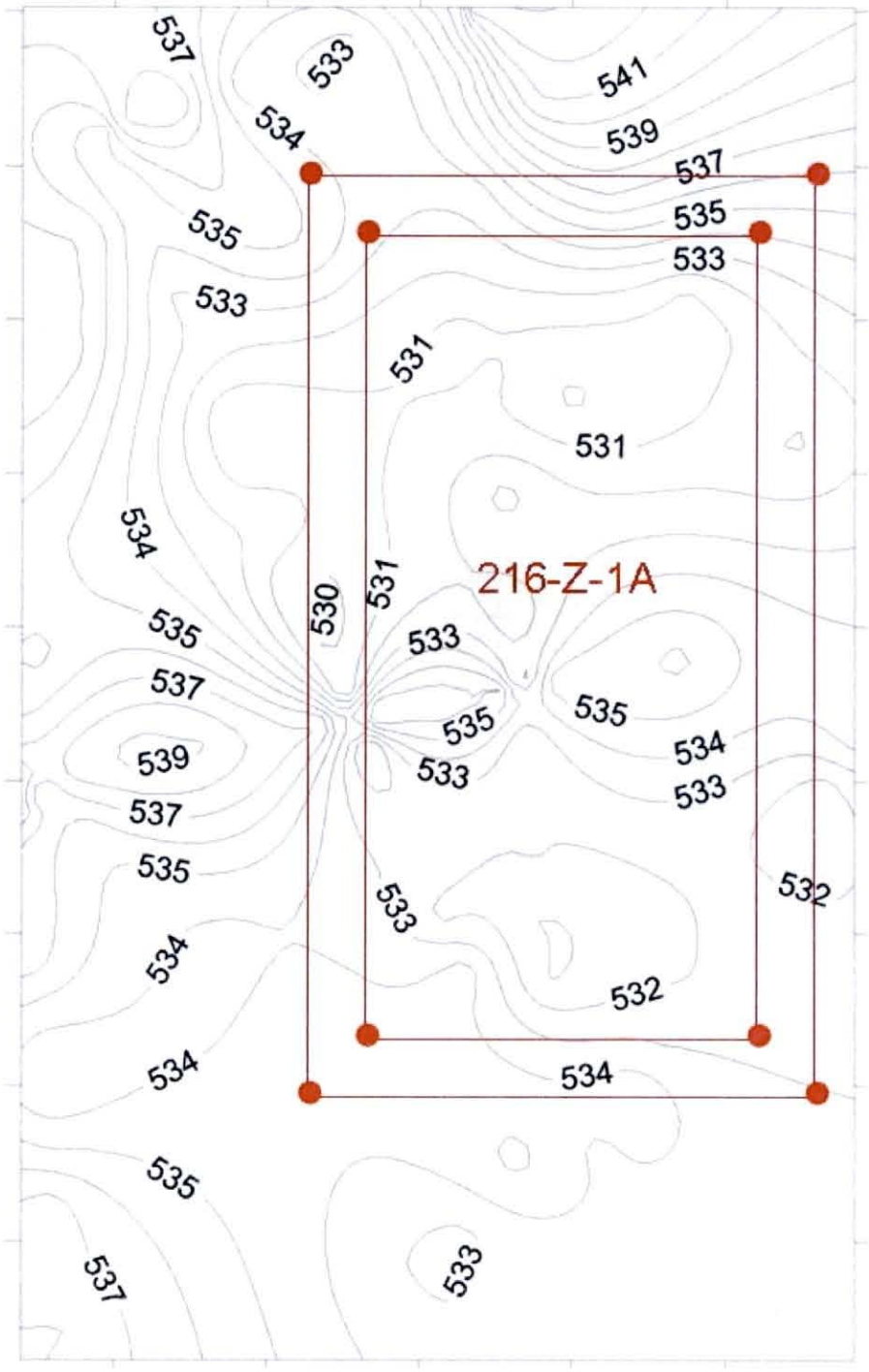


Figure 2-31. Location of Wells that were Geophysically Logged as Part of the Step II Investigation.

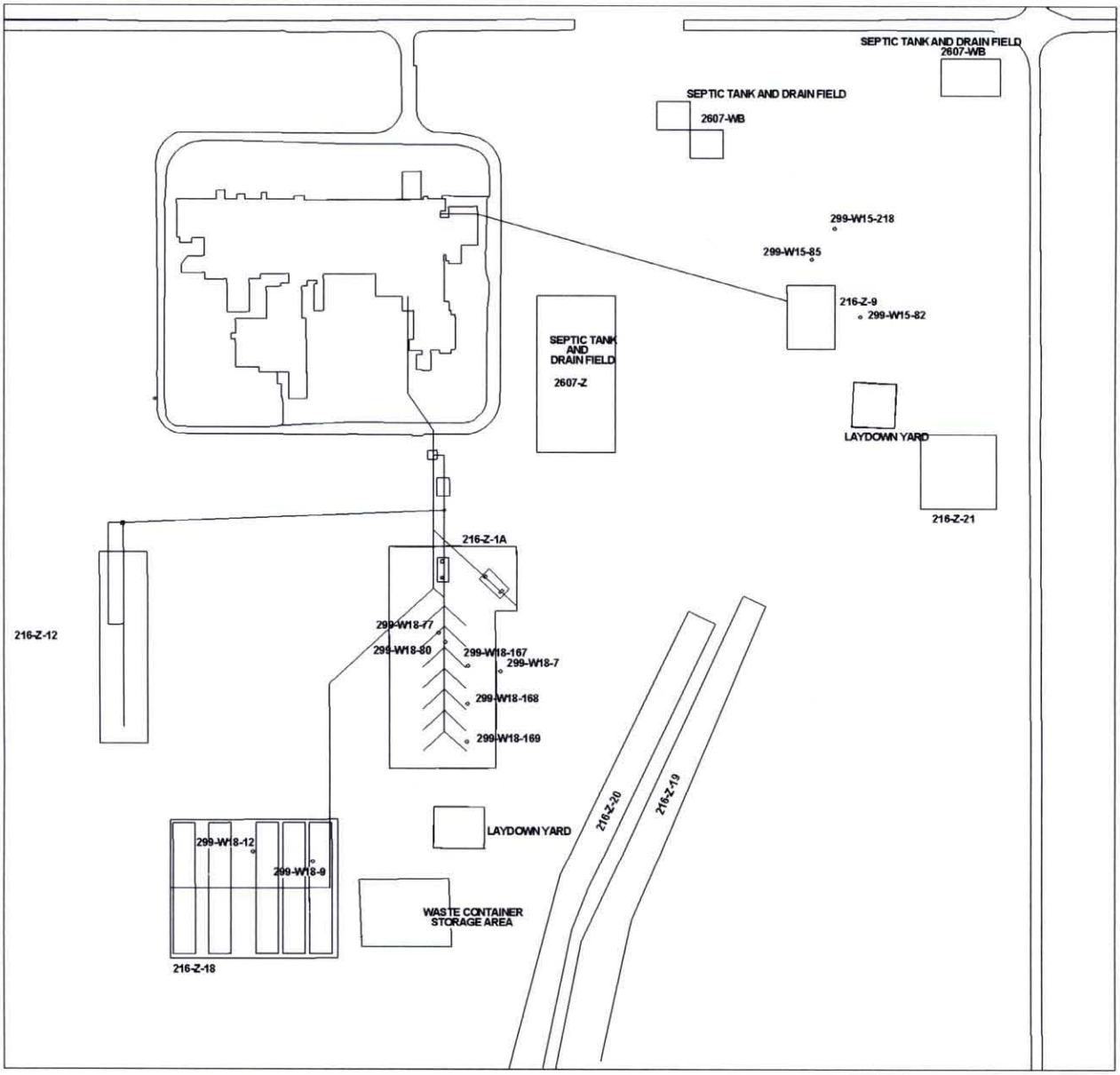


Figure 2-32. Location of Enhanced Access Penetration System Boreholes for the Dispersed Carbon Tetrachloride Vadose-Zone Plume Step II Investigation.

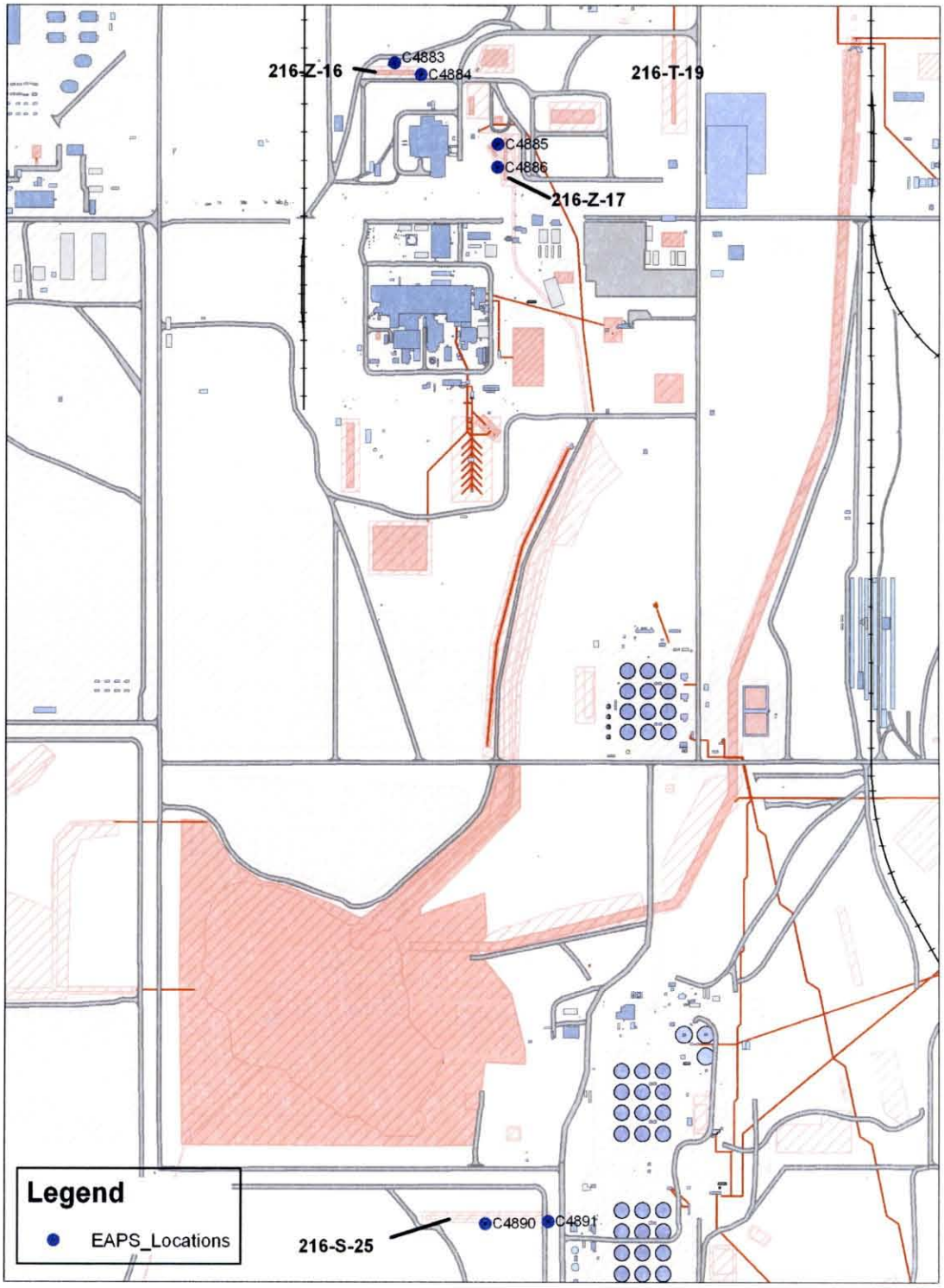
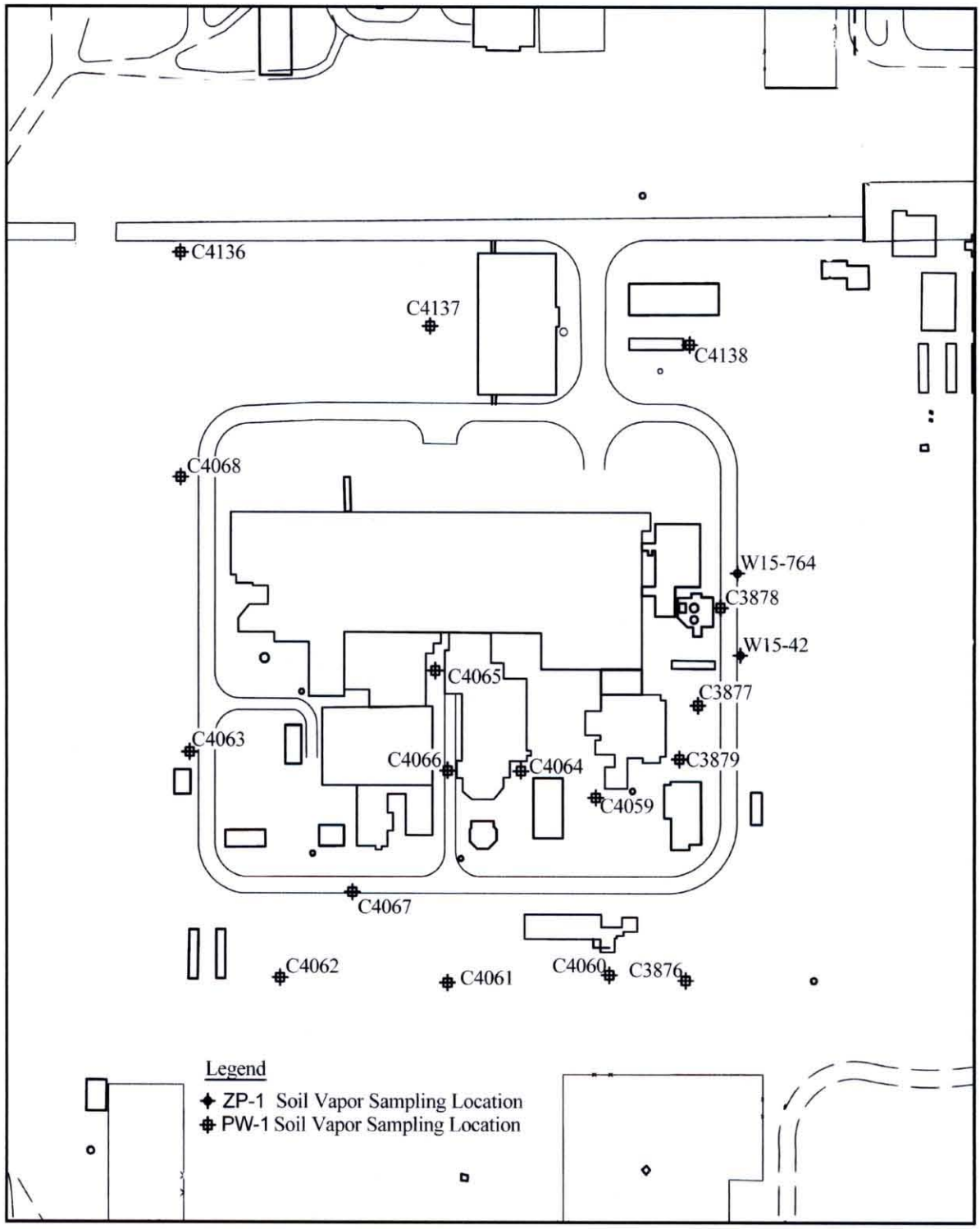


Figure 2-33. Soil Vapor Sampling Locations Within the Plutonium Finishing Plant Protected Area.



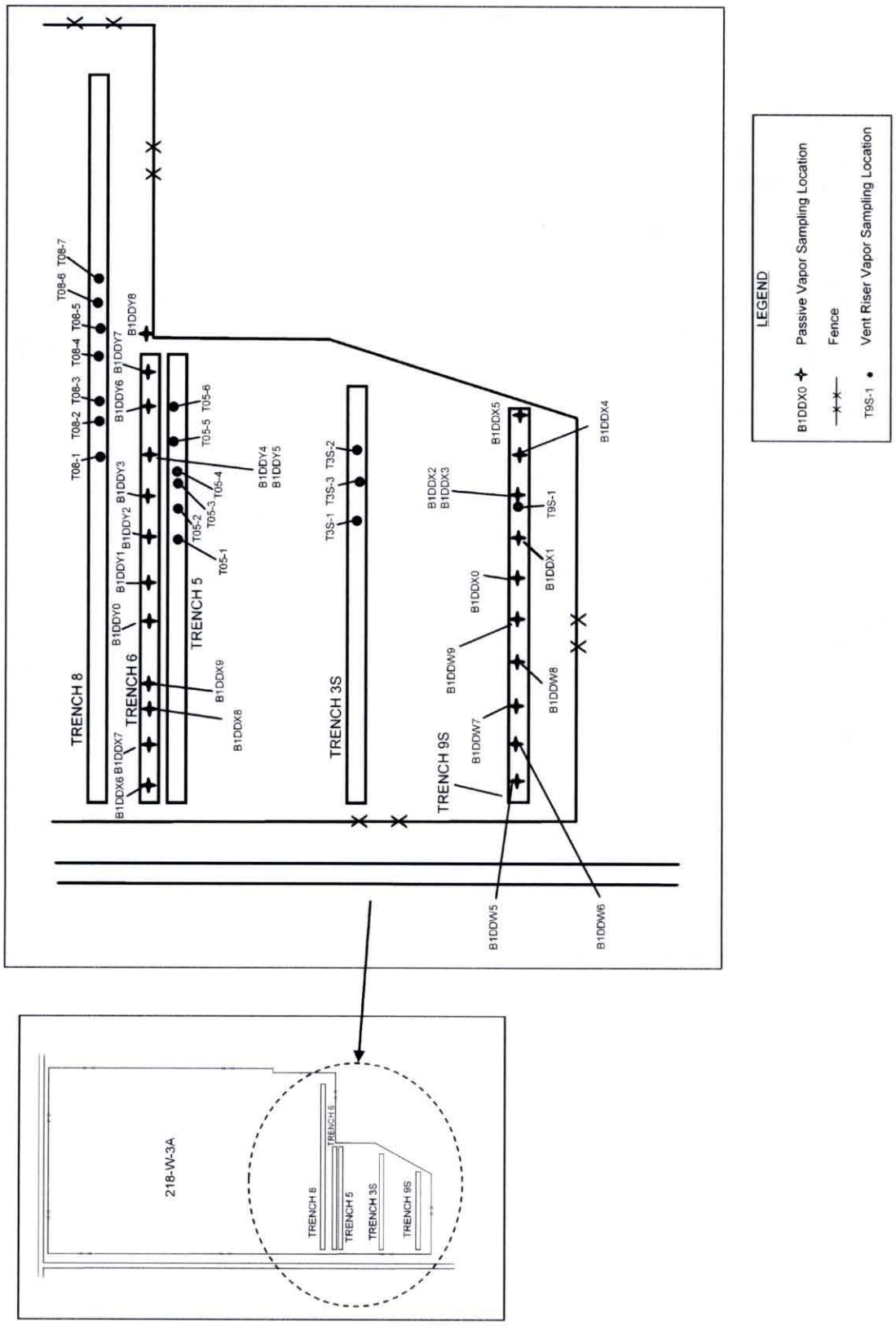


Figure 2-34. Vapor Sampling Locations at the 218-W-3A Burial Ground.

Figure 2-35. Location of Wells Sampled at the Eight Groundwater "Hot Spots."

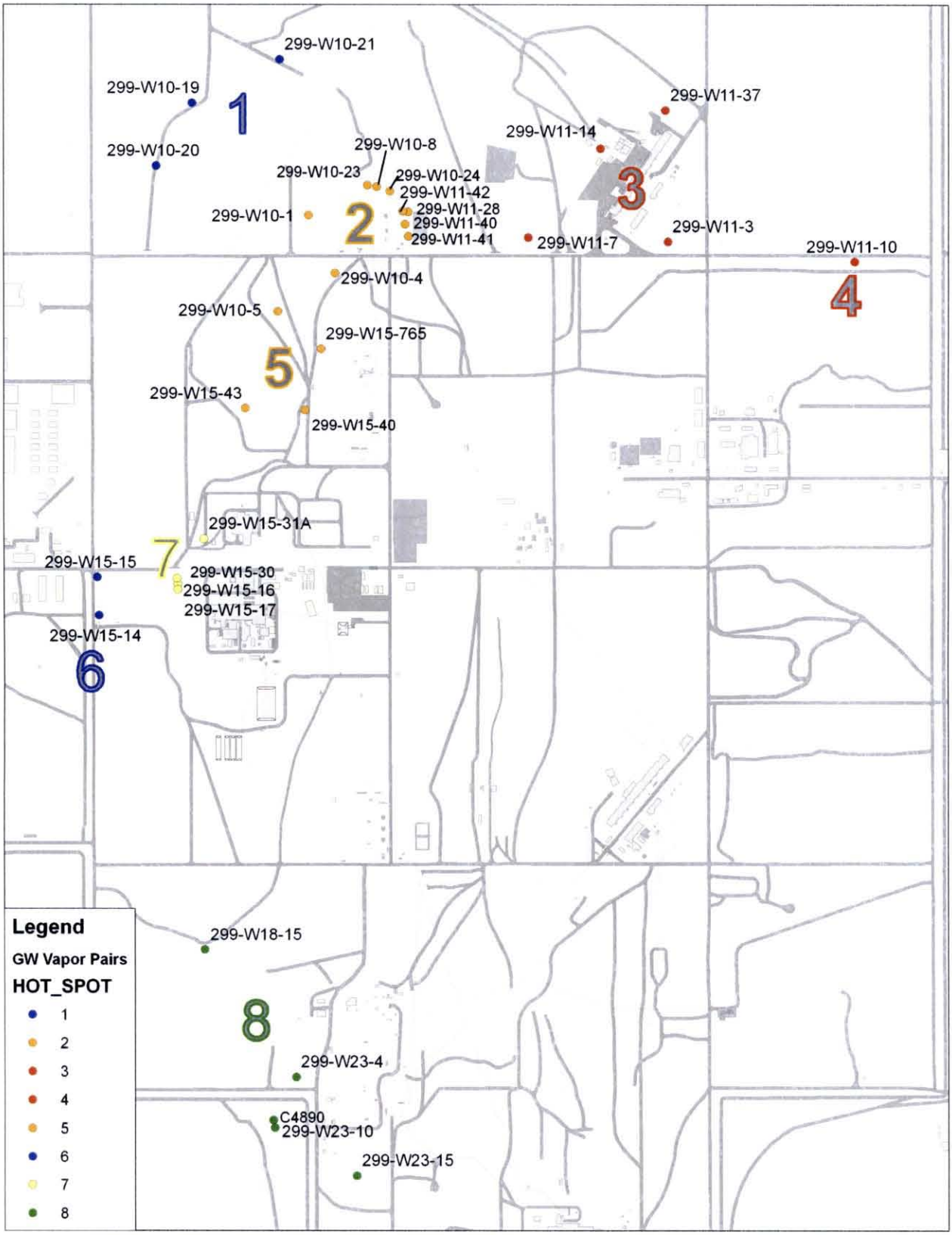


Figure 2-36. T Plant Soil-Vapor Survey Locations.

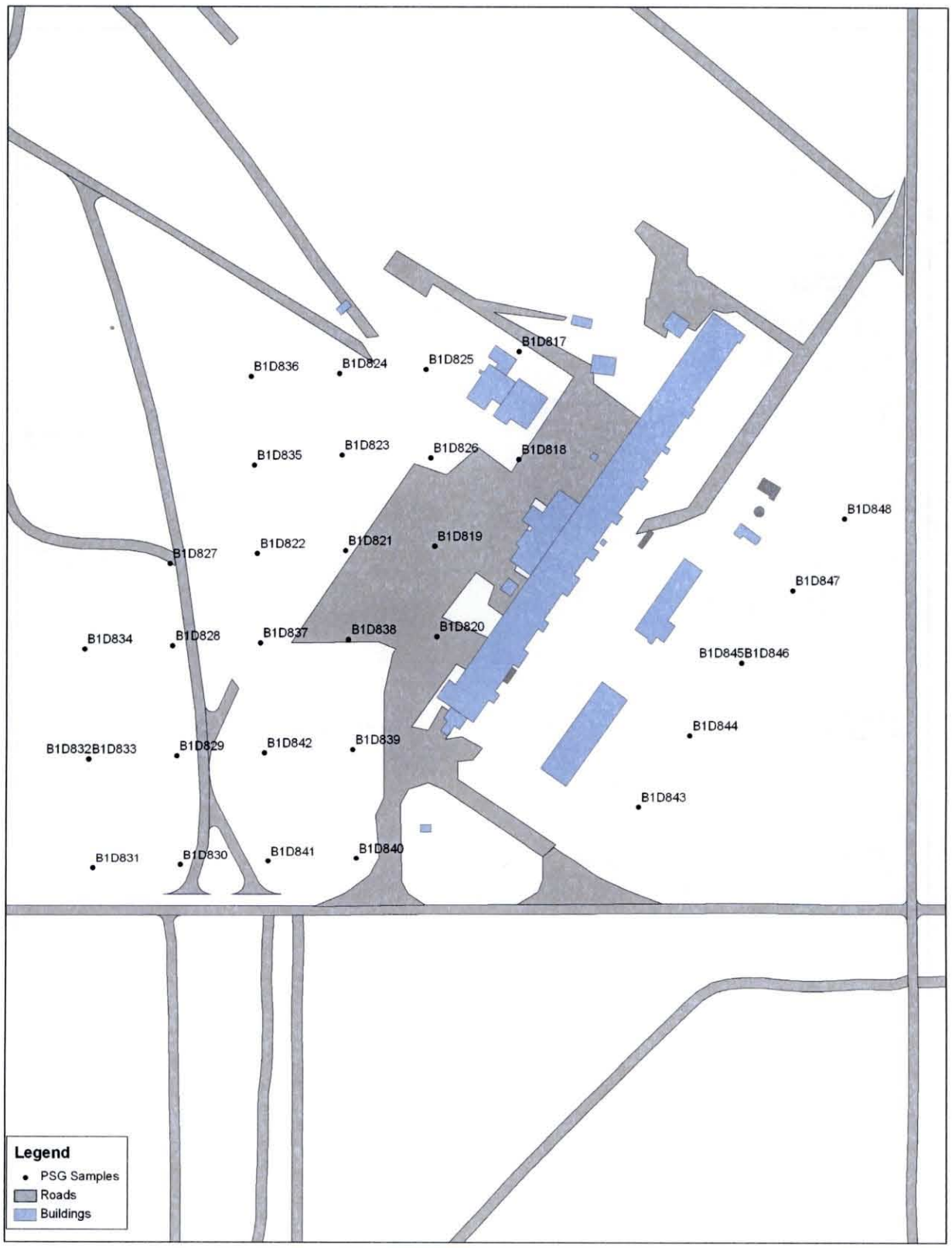


Figure 2-37. Location of Wells Drilled in the 200 West Area During Fiscal Years 2001 to 2006 and Sampled in Support of the 200-PW-1 Operable Unit Remedial Investigation.

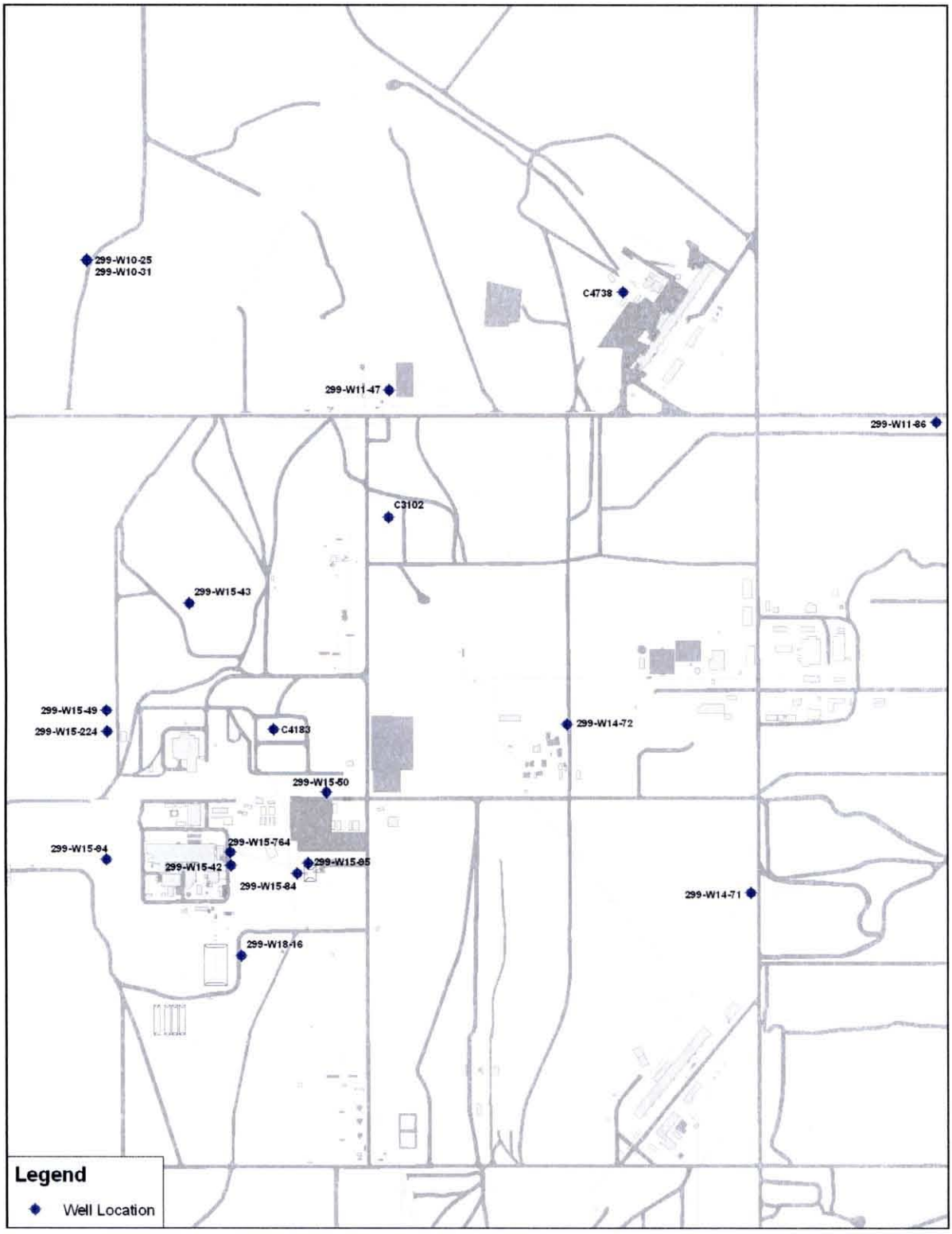


Figure 2-38. Location of Fiscal Year 1991 Active Soil Vapor Measurements.

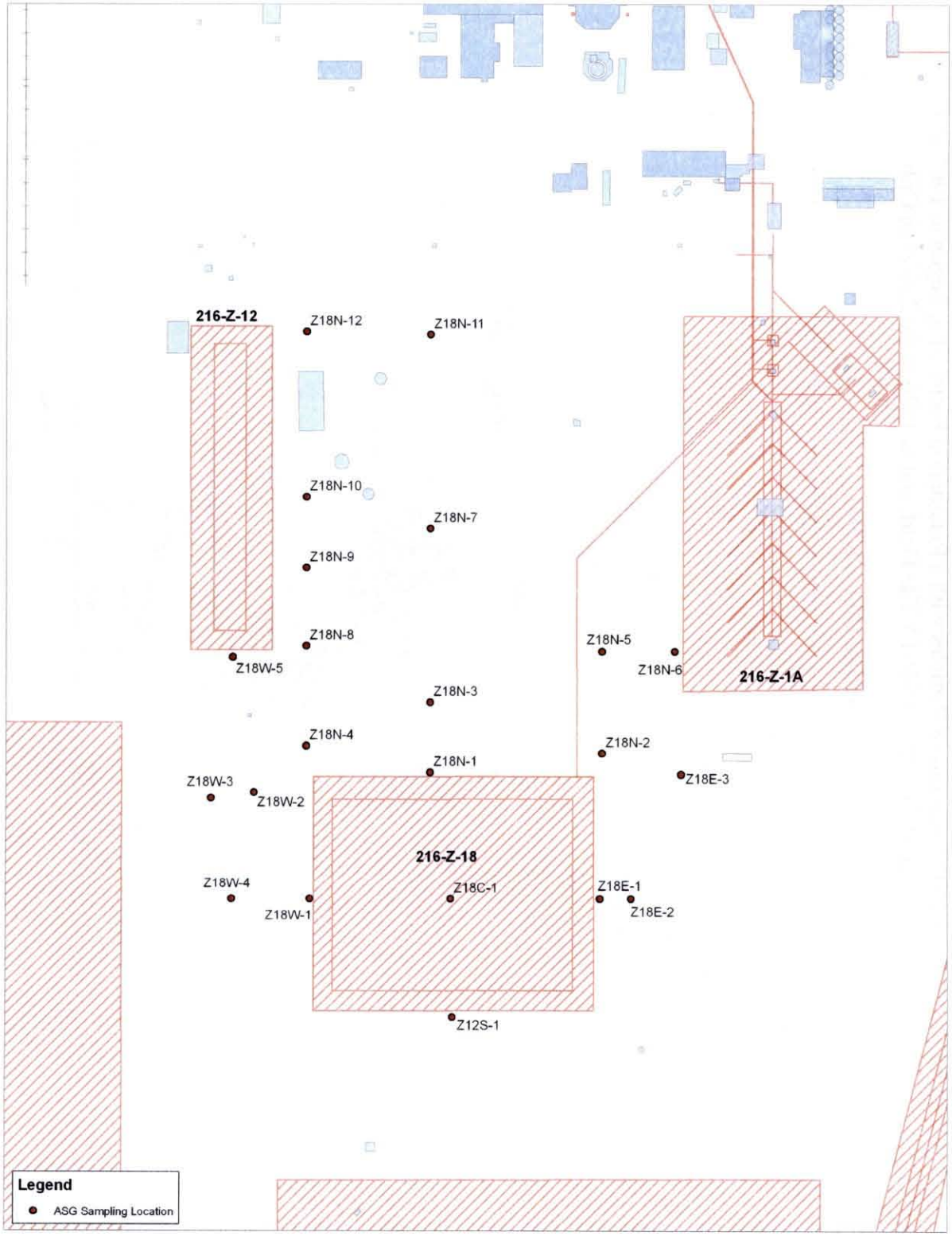


Figure 2-39. Year 2002 Locations of Particles with a Retardation Factor of 4, Begun in 1962 at the 216-Z-9 Trench, in 1971 at the 216-Z-1A Tile Field, and in 1976 at the 216-Z-18 Crib.

(From D&D-28793)

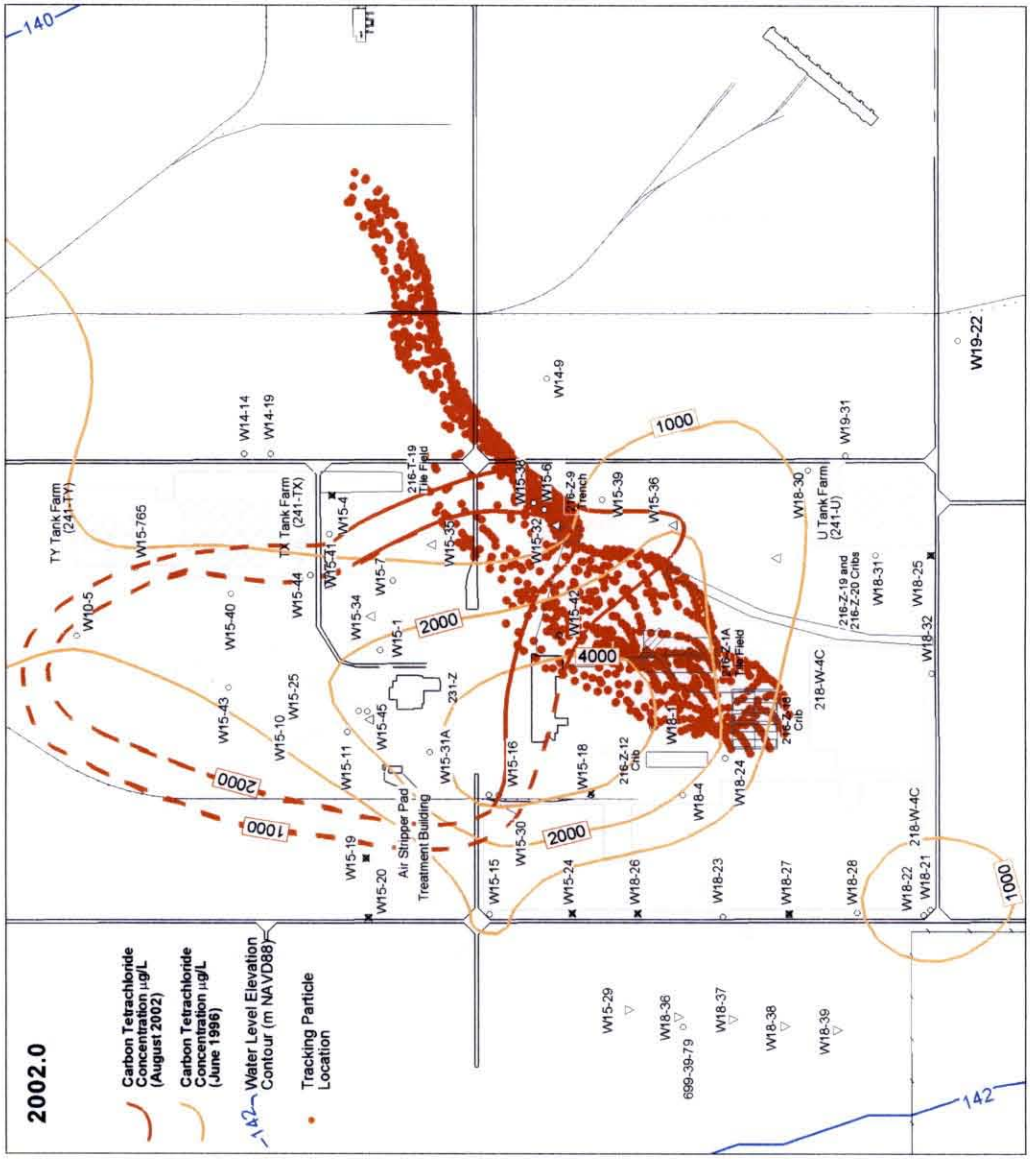


Figure 2-40. Year 2002 Locations of Particles with a Retardation Factor of 4, Begun in 1962 at the 216-Z-9 Trench, in 1971 at the 216-Z-1A Tile Field, and in 1976 at the 216-Z-18 Crib at Approximately Twice the Facility Radius.

(From D&D-28793)

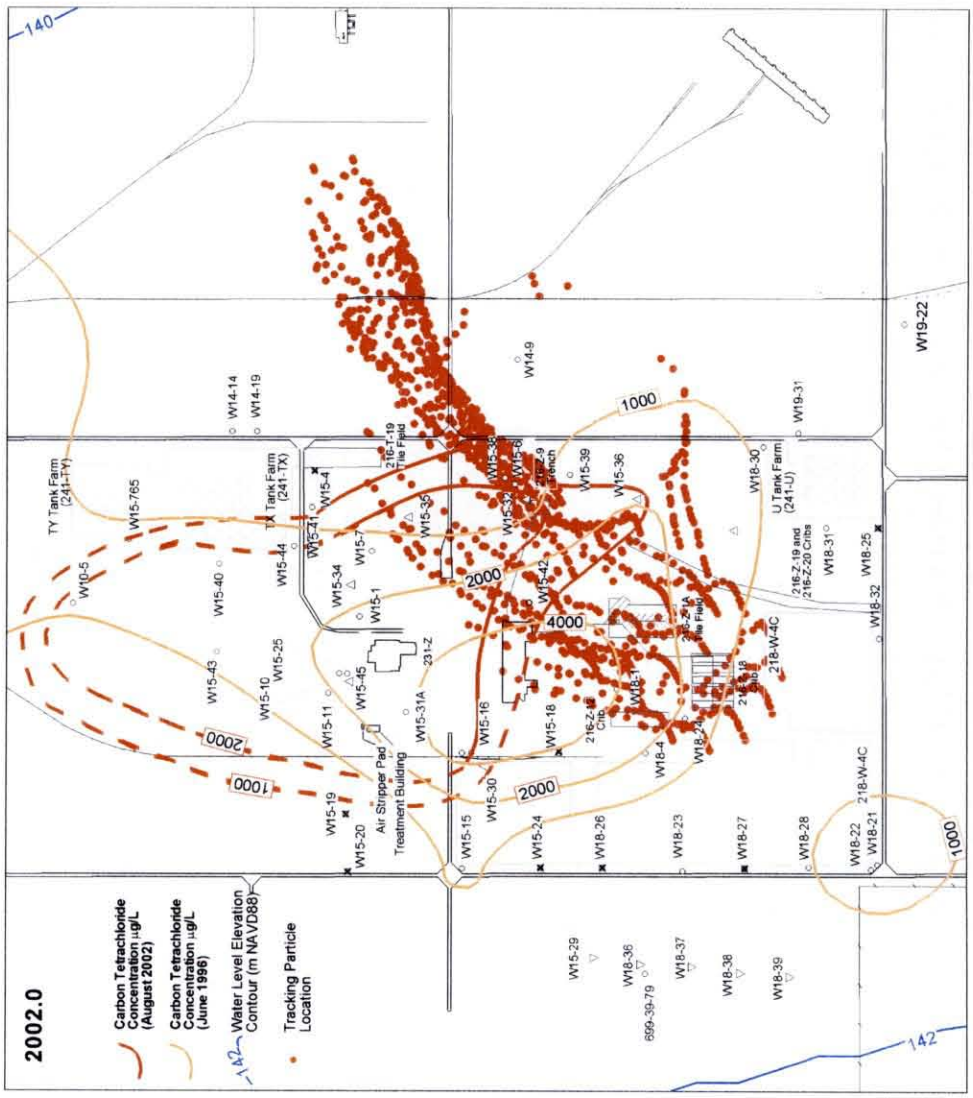


Figure 2-41. Year 1960 Locations of Reverse Particles, Starting Along the Leading Edge of the Carbon Tetrachloride Plume, 1,000 and 2,000 µg/L Isopleths in Year 2002, with a Retardation Factor of 4.

(From D&D-28793)

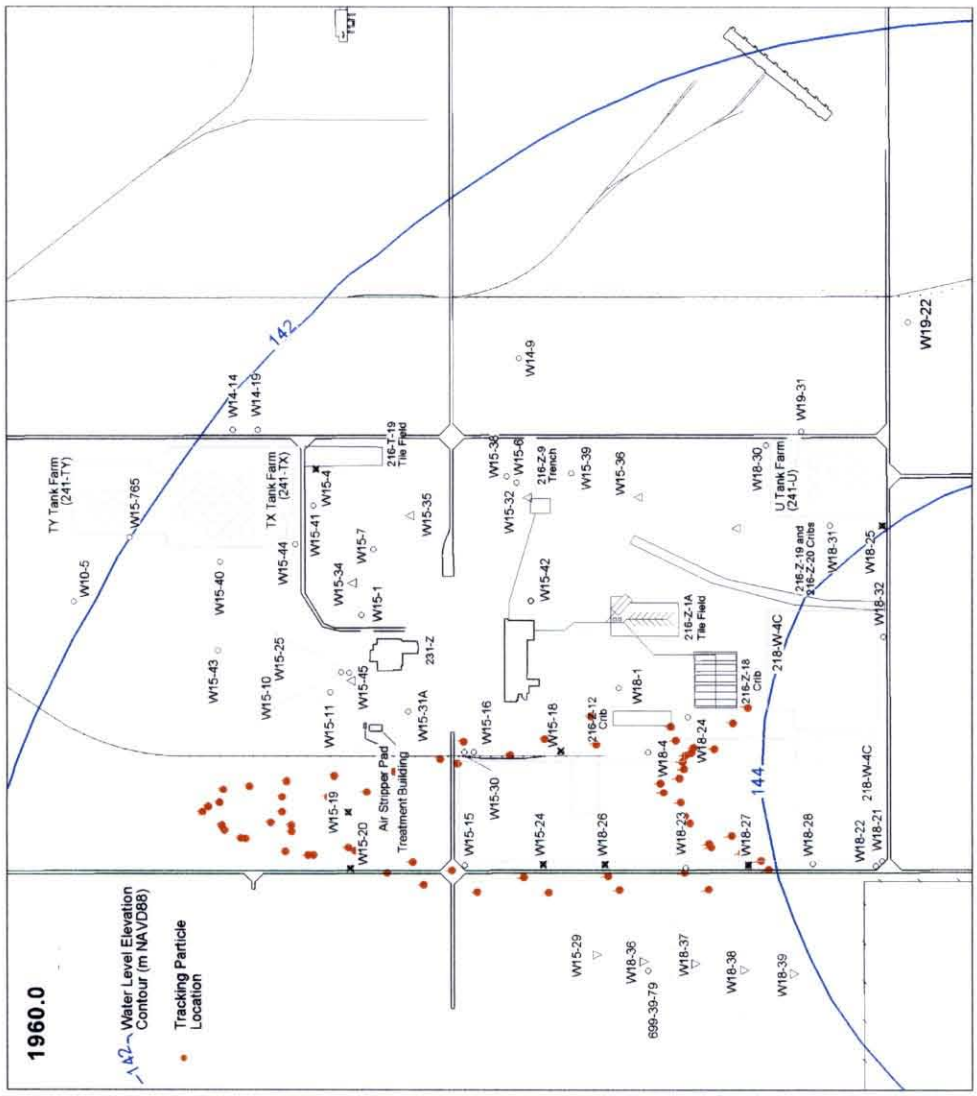
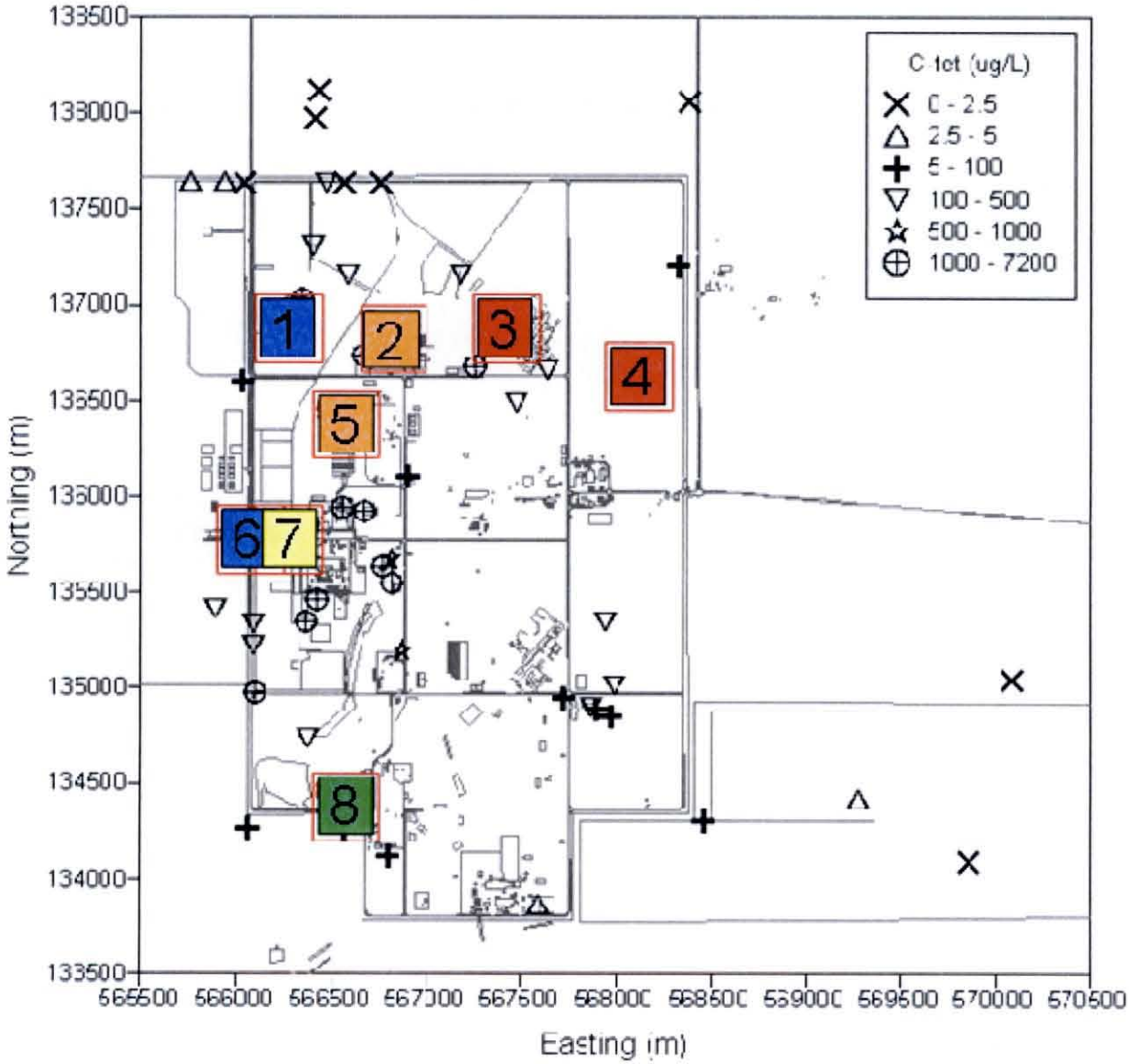


Figure 2-42. Summary Map of Classification of Sub-Areas, Based on Their Likelihood of Containing Persistent Carbon Tetrachloride Sources.

(From PNNL-16509)



Color scale ranges from red for high probability to blue for the lowest probability.

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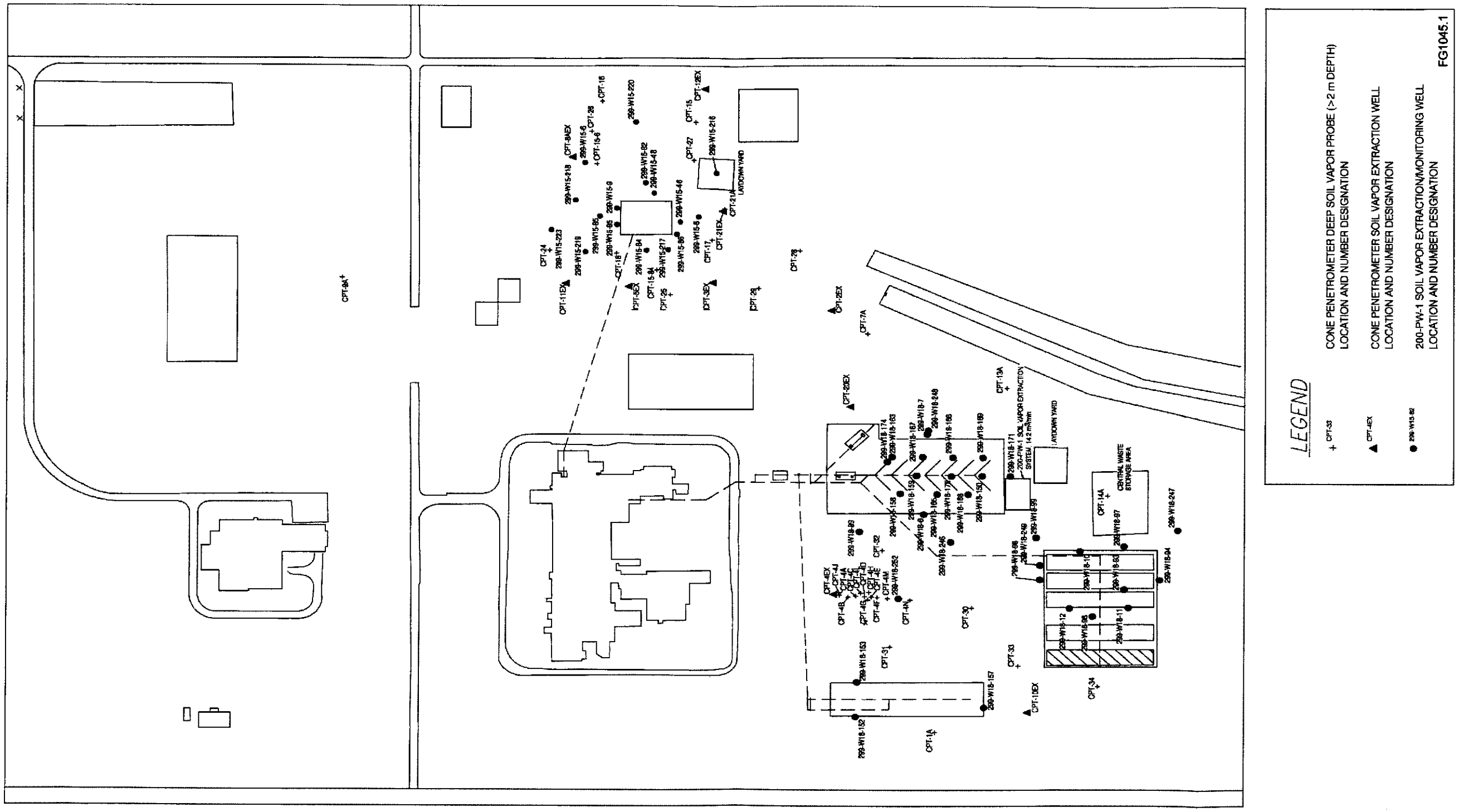
Figure 2-43. Map of Soil Vapor Extraction Well Locations.



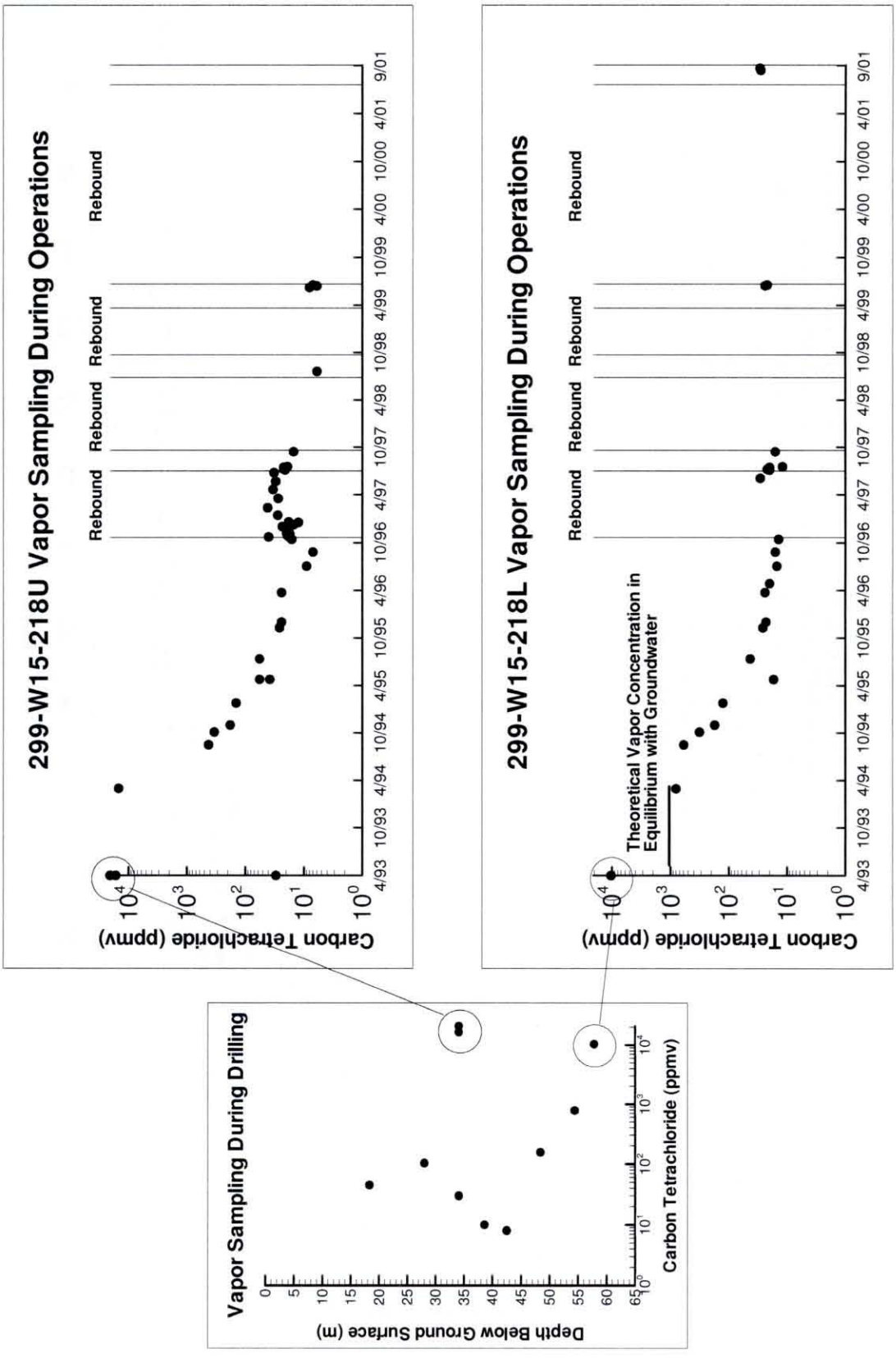


Figure 2-44. Carbon Tetrachloride Vapor Trends in Soil-Vapor Extraction Well 299-W15-218 at the 216-Z-9 Trench.

Figure 2-45. Carbon Tetrachloride Concentrations in Vapor Extracted from the 216-Z-9 Trench from 1997 through 2006.

(From SGW-33746)

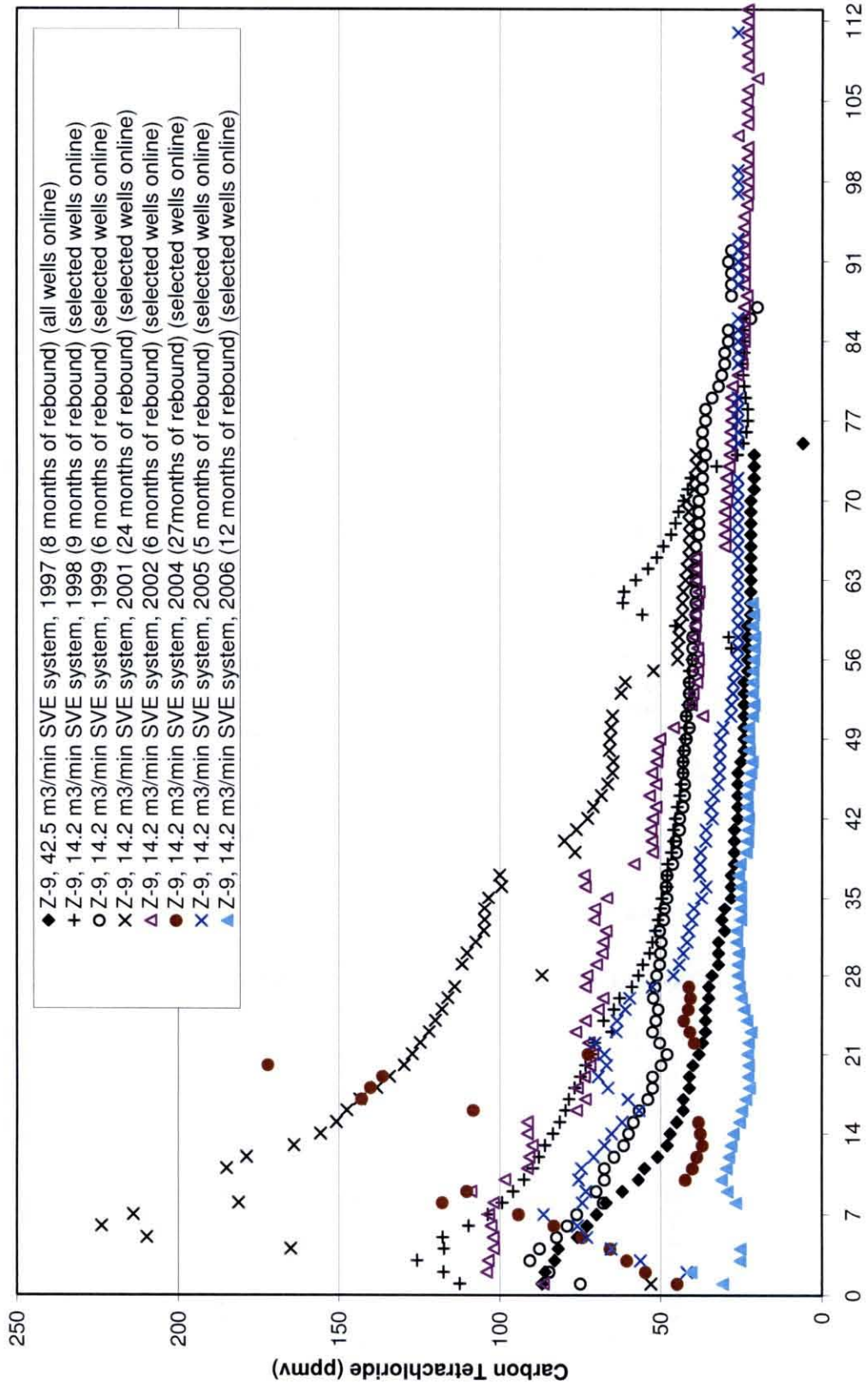


Figure 2-46. Carbon Tetrachloride Concentrations in Vapor Extracted from the 216-Z-1A Tile Field.

(From SGW-33746)

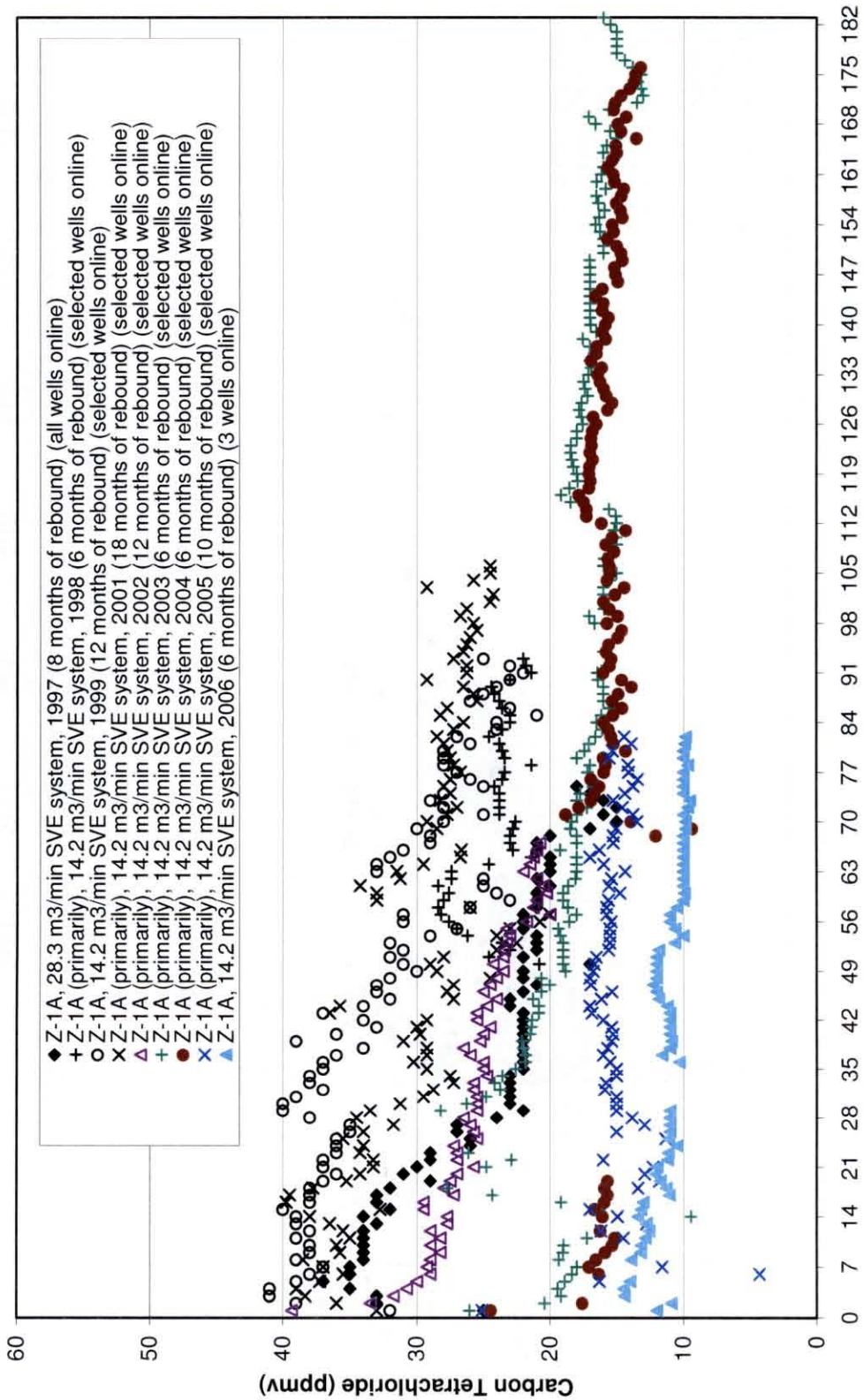
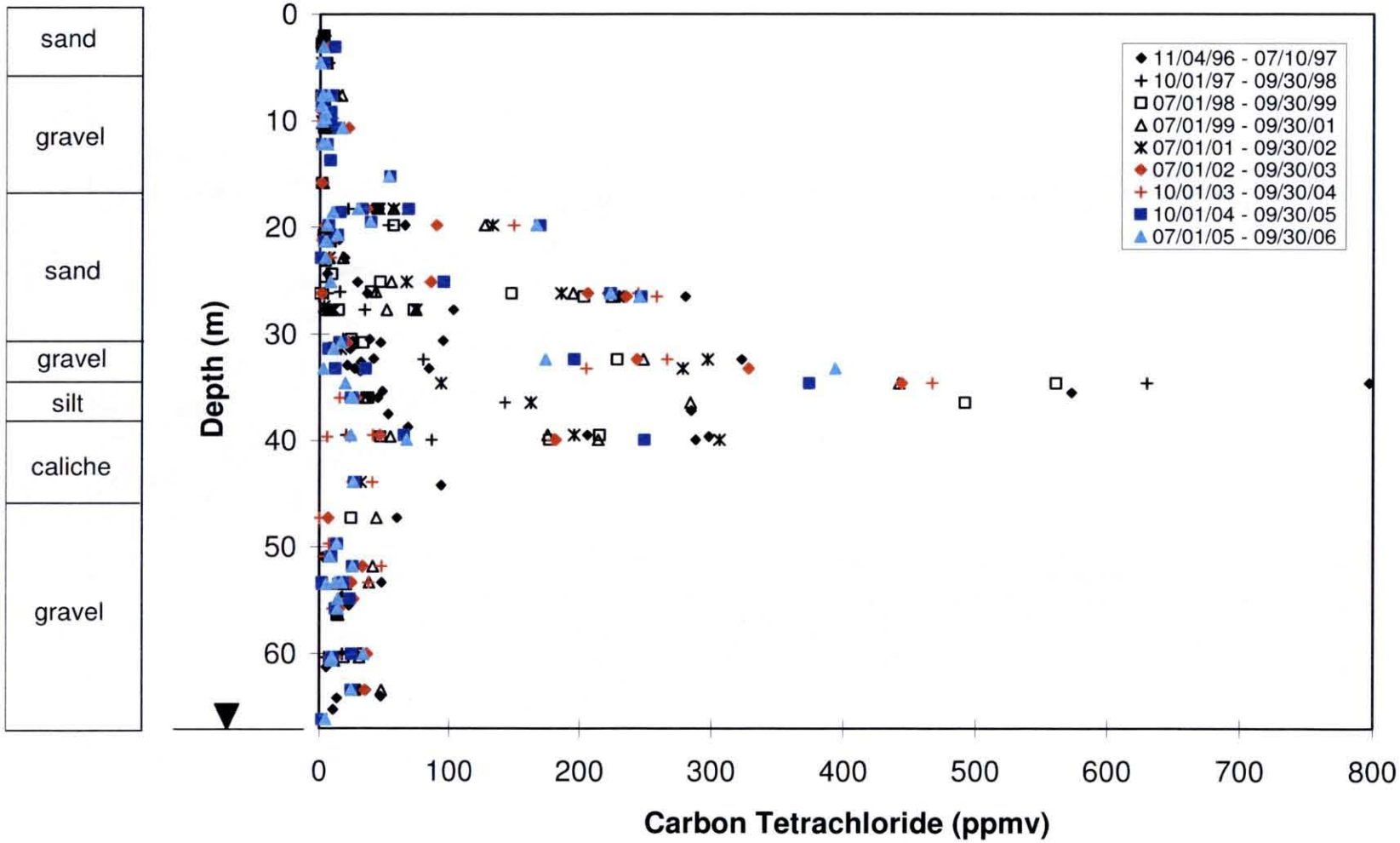


Figure 2-47. Fiscal Year 1997-Fiscal Year 2006 Rebound Concentration Plot Showing that the Maximum Rebound Concentrations are Near the Cold Creek Unit Silt.

(From SGW-33746)



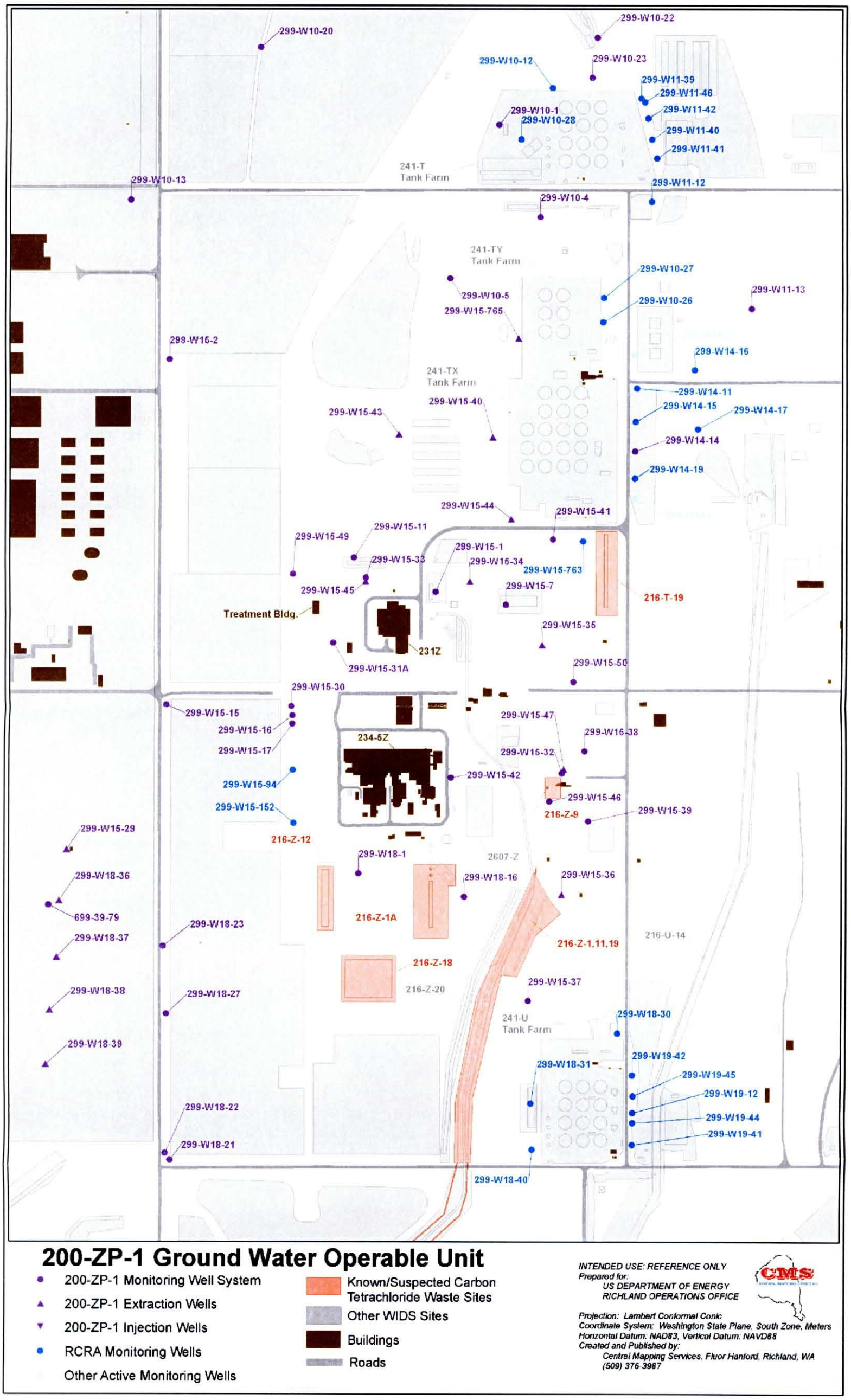


Figure 2-48. Pump-and-Treat Well Locations.

(From DOE/RL-2005-91)

Figure 2-49. Comparison of the Carbon Tetrachloride Plume beneath the 200 West Area at the Top of the Unconfined Aquifer.

(From PNNL-16346).

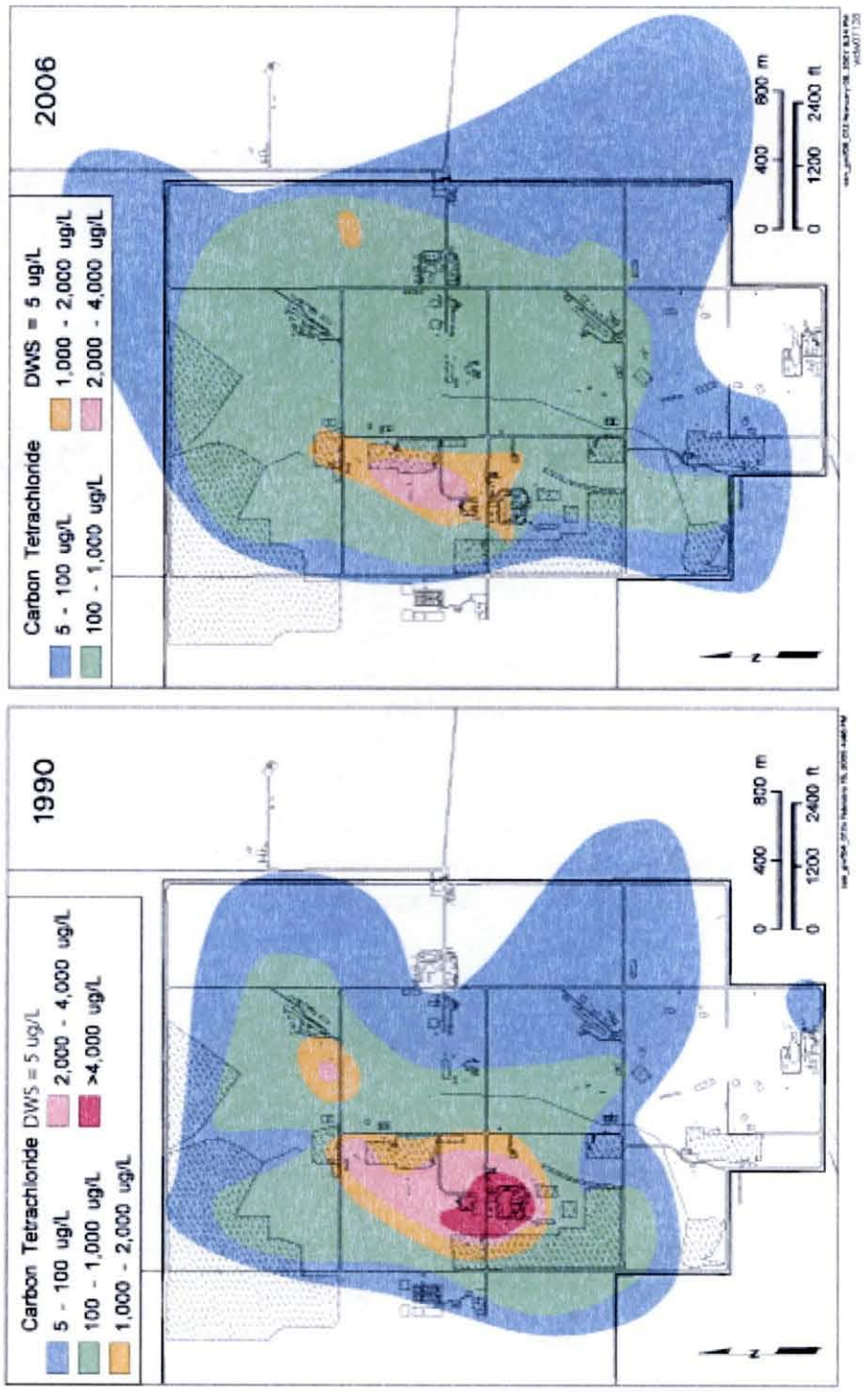


Figure 2-50. Location of Existing Boreholes, Direct-Push Boreholes, and Characterization Borehole C4545 at the 216-A-8 Crib.

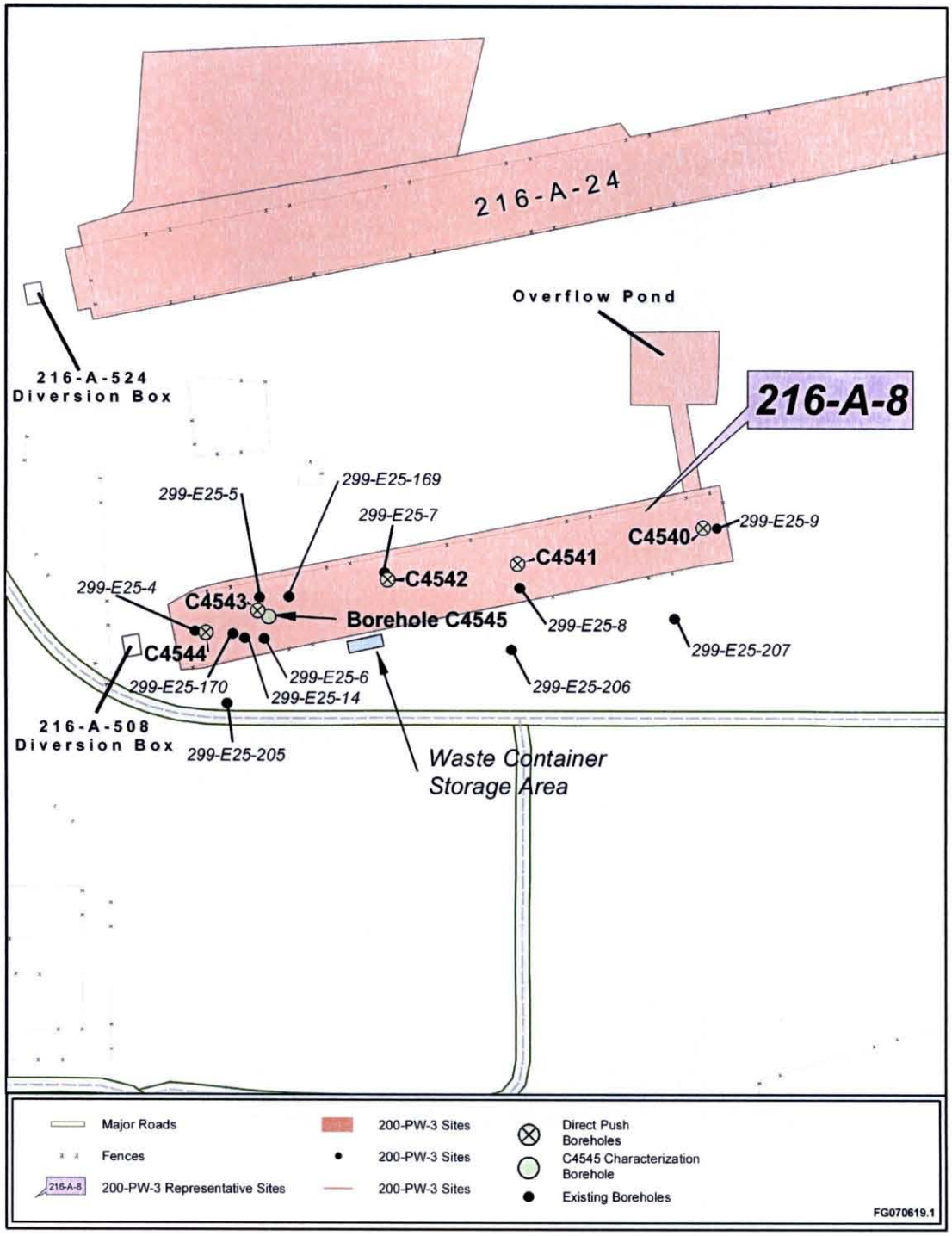


Table 2-1. Correlation Between Sample Depths in the Sampling and Analysis Plan and Modified Sample Depths in Slant Well 299-W15-48 (Borehole C3427), Based on New Information from Well 299-W15-46 (Borehole C3426) and the Cross-Well Seismic-Reflection Survey. (3 Pages)

Sample Depth in SAP [a] (vertical ft)	Rationale in SAP	Actual Sample Depth at Borehole C3426 [b] (vertical ft)	Observations at Borehole C3426 [b] (vertical ft)	Sample Depth at Borehole C3427 [c] (vertical ft)
48 – 50.5 ft	Characterize the vadose zone for DNAPL at the depth that corresponds to the initial depth of elevated plutonium concentrations in well 299-W15-8 south of the 216-Z-9 Trench	47.5 – 49.5 ft; 49.5 - 52.0 ft (50.5 – 53.0 ft PNNL sample)	First alpha encountered from 47.5 to 49.5 ft Interval with orange matrix from 49 – 49.5 ft	44.5 – 46.2 ft Soil Soil vapor
66.5 – 69 ft	Characterize the Hanford formation upper gravel sequence for 200-PW-1 Operable Unit COPCs as close as possible to the area underneath the footprint of the 216-Z-9 Trench		Hanford upper gravel sequence extends to 65 ft	56.8 – 58.0 ft (selected because this interval is the base of Hanford gravel and therefore is as close as possible to the area underneath footprint; and to ensure that the silt layer is not missed) Soil
69 – 71.5 ft	Characterize the contact between the Hanford formation upper gravel and sandy sequences for contaminant transport and evaluation of soil-vapor extraction interim action	63.5 – 66 ft	65 – 67 ft is silt layer between Hanford gravel sequence and Hanford sand sequence; sample interval has high CCl_4, TBP, PCE; 64.5-ft sample vial tests positive for DNAPL; cross-well seismic suggests that top of silt is 60 ft bgs at Borehole C3427	59.4 – 61.1 ft (selected to encounter "64.5 ft" depth in an inner liner) Soil Soil vapor
Not identified in SAP				61.9 – 63.6 ft (selected to ensure that the silt layer is not missed) Soil (VOCs only and PNNL liner)

Table 2-1. Correlation Between Sample Depths in the Sampling and Analysis Plan and Modified Sample Depths in Slant Well 299-W15-48 (Borehole C3427), Based on New Information from Well 299-W15-46 (Borehole C3426) and the Cross-Well Seismic-Reflection Survey. (3 Pages)

Sample Depth in SAP [a] (vertical ft)	Rationale in SAP	Actual Sample Depth at Borehole C3426 [b] (vertical ft)	Observations at Borehole C3426 [b] (vertical ft)	Sample Depth at Borehole C3427 [c] (vertical ft)
86 – 88.5 ft	Characterize the vadose zone for DNAPL within the Hanford formation sandy sequence to evaluate vertical distribution of contaminants	90.0 – 92.5 ft	Hanford sandy sequence extends from 67 – 108.5 ft; sample interval has high TBP; unknown clear liquid observed in field-screening DNAPL vial	84.8 – 86.5 ft (selected to correspond to 90.0-ft sample in Borehole C3426) (selected for duplicate sample) Soil Soil vapor 87.3 – 89.0 ft (selected to ensure that clear liquid is not missed) Soil (VOCs, SVOCs only and PNNL liner)
99.5 – 102 ft	Characterize the vadose zone near the top of the Cold Creek unit, a zone of potential perching, for contaminant transport and evaluation of soil-vapor extraction interim action	107.0 – 109.5 PNNL sample)		
102.5 – 105 ft	Characterize the Hanford formation sandy sequence for 200-PW-1 Operable Unit COPCs near the contact with the Cold Creek unit, a zone of potential perching		Cold Creek unit top is at 108.5 ft in Borehole C3426; Cold Creek unit top is predicted to be at 103 ft in Borehole C3427	100.5 – 102.2 ft (selected to characterize Hanford sandy sequence above Cold Creek unit) Soil Soil vapor
106 – 108.5 ft	Characterize the Cold Creek unit silt, a potential zone of sorption, for DNAPL	110.0 – 112.5	Cold Creek unit silt is from 108.5 – 116.5 ft	103.9 – 105.6 ft (selected to characterize top of silt) Soil Soil vapor 109.0 – 110.7 ft (selected to characterize bottom of silt) Soil (VOCs only and PNNL liner) Soil vapor
111 – 113.5 ft	Characterize the Cold Creek unit silt/carbonate contact for contaminant transport and evaluation of soil-vapor extraction interim action	(115.0 – 117.5 PNNL sample; 1 liner for 200-PW-1 Operable Unit) 117.0 – 119.5 ft	Cold Creek unit carbonate is from 116.5 – 118.0 ft; black crumbly layer from 118.0 – 118.5 ft	

Table 2-1. Correlation Between Sample Depths in the Sampling and Analysis Plan and Modified Sample Depths in Slant Well 299-W15-48 (Borehole C3427), Based on New Information from Well 299-W15-46 (Borehole C3426) and the Cross-Well Seismic-Reflection Survey. (3 Pages)

Sample Depth in SAP [a] (vertical ft)	Rationale in SAP	Actual Sample Depth at Borehole C3426 [b] (vertical ft)	Observations at Borehole C3426 [b] (vertical ft)	Sample Depth at Borehole C3427 [c] (vertical ft)
115 – 117.5 ft	Characterize the Cold Creek unit silt/carbonate contact for DNAPL		Cold Creek unit silt/carbonate contact is at 116.5 ft	111.5 – 112.8 ft (selected to include the silt/carbonate contact and bottom of the Cold Creek unit) Soil Soil vapor
117.5 – 120 ft	Characterize the bottom of the Cold Creek unit for 200-PW-1 Operable Unit COPCs; evaluate contaminant gradients within the Cold Creek unit			
120.5 – 123 ft	Characterize the contact between the Cold Creek unit and the Ringold Formation for DNAPL	119.0 – 121.5 ft		114.5 – 118.7 ft (selected to include the Cold Creek unit/Ringold contact) (selected for split sample) Soil Soil vapor
123.5 – 126 ft	Characterize the top of the Ringold Formation for contaminant transport and evaluation of soil-vapor extraction interim action; evaluate gradient through the Cold Creek unit.	(122.0 – 124.5 PNNL sample)	Ringold starts at 118.5 ft	114.5 – 18.7 ft (selected to characterize the top of the Ringold) Soil (VOCs only and PNNL liner) Soil vapor

[a] Depth does not account for 4 ft of fill added at Borehole C3426 before drilling began.
[b] Depth does account for 4 ft of fill added at Borehole C3426 before drilling began.
[c] Ground surface at Borehole C3427 is 4.5 ft lower than the ground surface at Borehole C3426.

DOE/RL-2001-01, *Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*).

bgs = below ground surface.
COPC = contaminant of potential concern.
DNAPL = dense, nonaqueous-phase liquid.
PCE = tetrachloroethylene.
PNNL = Pacific Northwest National Laboratory.
SAP = sampling and analysis plan (DOE/RL-2001-01, Appendix B).
SVOC = semivolatile organic compound.
TBP = tributyl phosphate.
VOC = volatile organic compound.

Table 2-2. Step I Sampling Design to Investigate Potential Carbon Tetrachloride Release Modes.

Potential Release Mode	Step I Sampling Design
Carbon tetrachloride drum-storage releases	***PFP facility area (drum-storage releases, PFP process releases, PFP piping and drain leaks, liquid- discharge pipeline leaks, liquid waste discharges)*** Shallow soil-vapor sampling using a systematic grid within the PFP facility area.* Deeper soil vapor sampling at shallow concentration hot spots and at known drum storage areas.
Z Plant complex process releases	
Z Plant complex piping and drain leaks	
Discharge pipeline leaks	
Deliberate discharges to engineered liquid-waste sites	
Z Plant complex heating, ventilation, and air-conditioning releases	***PFP heating, ventilation, and air-conditioning condensate waste sites*** Soil vapor sampling at selected locations at the french drains, ponds, and ditches that received heating, ventilation, and air-conditioning condensate.
Discharge-pipeline leaks	***Soils adjacent to liquid-discharge pipelines*** Soil-vapor sampling at predetermined spacing adjacent to pipeline pathways outside of the PFP facility area.
Deliberate discharges to engineered liquid-waste sites	***Liquid-waste discharge sites*** Soil-vapor sampling at selected locations at liquid-waste discharge sites that received carbon tetrachloride wastes.
Burial ground releases from waste containing carbon tetrachloride	***Burial grounds*** Vapor sampling at burial ground vent risers. Deeper soil-vapor sampling adjacent to burial ground trenches, including near vapor hot spots identified by vent-riser sampling.

*The 12/19/02 supplement to the SAP in DOE/RL-2001-01, *Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan, Includes: 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*, Appendix C, changed the shallow soil-vapor sampling locations from a systematic grid to locations identified by professional judgment because of safety concerns.

PFP = Plutonium Finishing Plant.

Table 2-3. Step II Sampling Design and Discussion Location in this Remedial Investigation Report. (6 Pages)

Sample Collection Methodology	Key Features of Design*	Basis for Sampling Design
	Release Sites	
Sampling using direct-push technology and/or passive, sorbent soil-vapor collectors to evaluate lateral extent of dispersed carbon tetrachloride vadose-zone plumes at the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib. **Investigation activities are described in Section 2.4.2.1, and the results are described in Section 3.2.4.1.**	Use a direct-push technology to collect soil-vapor samples to the north, south, and east of the 216-Z-9 Trench. Starting near the trench boundary, collect samples at approximately 15.2 m (50-ft) intervals, moving progressively farther from the trench. At a minimum, continue until the sampling locations are at least 225 m (750 ft) away from the 216-Z-9 Trench. Continue sampling until carbon tetrachloride concentrations are below detection. At a maximum, continue until the sampling locations are 300 m (1,000 ft) away from the trench. At each sampling location, collect samples from depths of 4.6 and 7.6 m (15 and 25 ft) bgs. Continue sampling at 7.6 m (25-ft) depth intervals until reaching 38.1 m (125 ft) bgs or until the direct-push technology cannot advance deeper into the subsurface (i.e., refusal). Analyze soil-vapor samples for VOCs using field-screening instrument. Passive, sorbent soil-vapor collectors may be used instead of, or in addition to, the direct-push technology to characterize the soil-vapor plume. During recent drilling of a vertical well on the south side of the 216-Z-9 Trench as part of the DNAPL investigation, a silt layer was identified from 19.8 to 20.4 m (65 to 67 ft) bgs. This silt layer appears to be associated with relatively high carbon tetrachloride vapor concentrations and the potential presence of DNAPL. The lateral distribution of the silt layer in the vicinity of the 216-Z-9 Trench will be investigated as an area of focus for the dispersed plume. Sampling in the vicinities of the 216-Z-1A Tile Field and 216-Z-18 Crib will be considered as the second phase of this task. If the results of the 216-Z-9 Trench sampling indicate that this sampling design should be modified, those proposed changes will be discussed with the U.S. Environmental Protection Agency.	This characterization will be conducted in the vicinities of the primary carbon tetrachloride disposal sites to evaluate lateral migration beyond the waste-site boundaries. As part of airflow modeling of soil-vapor extraction operations at the 216-Z-9 Trench, the applied vacuum in the Hanford sand was calculated to extend approximately 80 to 140 m (260 to 460 ft) beyond the trench boundaries for different configurations of on-line wells (BHI-00882). Therefore, sampling at the 216-Z-9 Trench will continue to distances at least 225 m (750 ft) beyond the trench boundaries. The vertical sampling scheme is consistent with the Step I sampling (DOE/RL-2001-01, Appendix C). The Enhanced Access Penetration System will be considered for investigating the silt layer at the 216-Z-9 Trench. Sampling at the 216-Z-1A Tile Field and 216-Z-18 Crib will be considered using a similar strategy.
Sampling using direct-push technology to evaluate potential accumulation areas at the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib. **Investigation activities are described in Section 2.4.2.2, and the results are described in Section 3.2.4.2.**	1. Develop Cold Creek unit topographic maps in the area surrounding the three primary carbon tetrachloride waste sites using technologies such as seismic response, barometric-pressure response, and/or geophysical logging of existing boreholes. 2. Collect soil-vapor samples above and within the Cold Creek unit low points and/or breakthrough locations using direct-push technology for confirmation of potential DNAPL or source presence. 3. Collect soil-vapor samples above and within the Cold Creek unit at the locations northwest and southwest of the 216-Z-9 Trench where an anomaly that potentially could indicate DNAPL was identified during the seismic-reflection survey in 1999. At each sampling location, collect samples from depths of 4.6 and 7.6 m (15 and 25 ft) bgs. Continue sampling at 7.6 m (25-ft) depth intervals until reaching 38.1 m (125 ft) bgs or until the direct-push technology cannot advance deeper into the subsurface (i.e., refusal). Analyze soil-vapor samples for VOCs using field-screening instrument.	This characterization will be conducted near the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib waste sites to evaluate lateral migration beyond the waste-site boundaries. The results will be used to identify low points in the formation that could be source or DNAPL accumulation points. This information will support deep vadose-zone investigations for source or DNAPL effects on groundwater.

Table 2-3. Step II Sampling Design and Discussion Location in this Remedial Investigation Report. (6 Pages)

Sample Collection Methodology	Key Features of Design*	Basis for Sampling Design
Sampling using direct-push technology adjacent to the 216-T-19 Crib and Tile Field, 216-Z-Ditches, 216-Z-7 Crib, 216-Z-12 Crib, 216-Z-16 Crib, and 216-Z-17 Trench liquid-waste discharge sites. **Investigation activities are described in Section 2.4.2.3, and the results are described in Section 3.2.4.3.**	Collect and analyze soil-vapor samples above, within, and below the Cold Creek unit. At each sampling location, collect samples from depths of 4.6 and 7.6 m (15 and 25 ft) bgs. Continue sampling at 7.6 m (25-ft) depth intervals until reaching groundwater at approximately 69 m (225 ft) bgs or until the direct-push technology cannot advance deeper into the subsurface (i.e., refusal). Analyze soil-vapor samples for VOCs using field-screening instrument.	Data collected at these release sites during Step I did not extend through the upper vadose zone. Data are needed during Step II in the deep vadose zone. If possible, soil and soil-vapor sampling conducted during drilling of a borehole planned for the 216-Z-7 Crib as part of the 200-LW-2 Operable Unit remedial investigation (DOE/RL-2001-66) may be used to collect soil-vapor and soil-sampling data at that site instead of the direct-push technology methods specified in this sampling design.
Contingency soil sampling at the 216-T-19 Crib and Tile Field, 216-Z-Ditches, 216-Z-7 Crib, 216-Z-12 Crib, 216-Z-16 Crib, and 216-Z-17 Trench liquid-waste discharge sites. **No soil sampling was conducted, because vapor concentrations did not exceed 1,200 ppmv – see Section 3.2.4.3.**	If feasible, collect and analyze soil samples at locations with carbon tetrachloride vapor concentrations exceeding 12,000 ppmv to evaluate the presence of DNAPL. Analyze the soil samples for the COPCs, COIs, and physical properties identified in the Work Plan (DOE/RL-2001-01, Appendix D). If feasible, collect and analyze soil samples at locations with carbon tetrachloride vapor concentrations exceeding 1,200 ppmv to evaluate the presence of a nearby carbon tetrachloride source. Analyze the soil samples for carbon tetrachloride.	If possible, a direct-push technology with soil-sampling capability (e.g., wireline cone penetrometer, Enhanced Access Penetration System) will be used to collect soil samples. The concentration of 12,000 ppmv is 10 percent of the concentration of saturated carbon tetrachloride vapor.
Sampling using direct-push technology at Trench T-04 in the 218-W-4C Burial Ground. No soil-vapor sampling was conducted because of sufficient existing data. **Investigation activities are described in Section 2.4.2.4.**	Collect and analyze soil-vapor samples above, within, and below the Cold Creek unit in the vadose zone adjacent to vent riser T4-04. Sample to both the north and south sides of Trench T-04. If possible, sample soil vapor directly under Trench T-04. At each sampling location, collect samples from depths of 4.6 and 7.6 m (15 and 25 ft) bgs. Continue sampling at 7.6 m (25-ft) depth intervals until reaching 69 m (225 ft) bgs or until the direct-push technology cannot advance deeper into the subsurface (i.e., refusal). Analyze soil-vapor samples for VOCs using field-screening instrument. Coordination is needed with the 218-W-4C Burial Ground waste-retrieval project.	Data collected near the hot spot in Trench 4 at the 218-W-4C Burial Ground did not extend through the upper vadose zone.

Table 2-3. Step II Sampling Design and Discussion Location in this Remedial Investigation Report. (6 Pages)

Sample Collection Methodology	Key Features of Design*	Basis for Sampling Design
Contingency soil sampling at Trench 4 in the 218-W-4C Burial Ground. **No soil sampling was conducted, because no further investigation was required at this site – see Section 2.4.2.4.**	If feasible, collect and analyze soil samples at locations with carbon tetrachloride vapor concentrations exceeding 12,000 ppmv to evaluate the presence of DNAPL. Analyze the soil samples for the COPCs, COIs, and physical properties identified in the Work Plan (DOE/RL-2001-01, Appendix D). If feasible, collect and analyze soil samples at locations with carbon tetrachloride vapor concentrations exceeding 1,200 ppmv to evaluate the presence of a nearby carbon tetrachloride source. Analyze the soil samples for carbon tetrachloride.	If possible, a direct-push technology with soil-sampling capability (e.g., wireline cone penetrometer, Enhanced Access Penetration System) will be used to collect soil samples. The concentration of 12,000 ppmv is 10 percent of the concentration of saturated carbon tetrachloride vapor.
Potential sampling using direct-push technology at Plutonium Finishing Plant Protected Area suspect release sites. **Investigation activities are described in Section 2.4.2.5, and the results are described in Section 3.2.4.4.**	Evaluate fiscal year 2003 Step I characterization results for Step II characterization requirements.	Carbon tetrachloride soil-vapor data from the Step I characterization must be evaluated to determine the potential for deeper vadose zone sources.
Sampling using direct-push technology adjacent to the 216-S-25 Crib liquid-waste discharge site. **Investigation activities are described in Section 2.4.2.6, and the results are described in Section 3.2.4.5.**	Collect and analyze soil-vapor samples above, within, and below the Cold Creek unit. At each sampling location, collect samples from depths of 4.6 and 7.6 m (15 and 25 ft) bgs. Continue sampling at 7.6 m (25-ft) depth intervals until reaching groundwater at approximately 69 m (225 ft) bgs or until the direct-push technology cannot advance deeper into the subsurface (i.e., refusal). Analyze soil-vapor samples for VOCs using field-screening instrument.	This potential release site was not investigated during Step I. Soil-vapor data adjacent to the 216-S-25 Crib site will be collected during Step II. The 216-S-25 Crib site is outside of the Step I study area.
Contingency soil sampling at the 216-S-25 Crib liquid waste discharge site. **No soil sampling was conducted, because vapor concentrations did not exceed 1,200 ppmv – see Section 3.2.4.5.**	If feasible, collect and analyze soil samples at locations with significant carbon tetrachloride vapor concentrations (exceeding 12,000 ppmv) to evaluate the presence of DNAPL. Analyze the soil samples for the COPCs, COIs, and physical properties identified in the Work Plan (DOE/RL-2001-01, Appendix D). If feasible, collect and analyze soil samples at locations with carbon tetrachloride vapor concentrations exceeding 1,200 ppmv to evaluate the presence of a nearby carbon tetrachloride source. Analyze the soil samples for carbon tetrachloride.	If possible, a direct-push technology with soil sampling capability (e.g., wireline cone penetrometer, Enhanced Access Penetration System) will be used to collect soil samples. The concentration of 12,000 ppmv is 10 percent of the concentration of saturated carbon tetrachloride vapor.

Table 2-3. Step II Sampling Design and Discussion Location in this Remedial Investigation Report. (6 Pages)

Sample Collection Methodology	Key Features of Design*	Basis for Sampling Design
Sampling at the 218-W-3A Burial Ground. **Investigation activities are described in Section 2.4.2.7, and the results are described in Section 3.2.4.6.**	1. Collect vapor samples in engineered trenches through caisson risers or vent risers if caisson risers or vent risers are accessible. 2. If feasible, use passive soil-vapor sampling methods (e.g., sorbent collectors or flux chambers) or active soil-vapor sampling methods (e.g., sampling from driven soil-vapor probes) on tops of trenches if vent risers are not available. Sample every 15 m (50 ft) along the length of the trench. The depth of the active vapor-sampling probes would be determined by ground-penetrating radar surveys. 3. Use direct-push technology to collect soil-vapor samples above the Cold Creek unit to the sides of the trenches if vent risers and passive or active shallow measurements are not available. Sample every 15 m (50 ft) along the length of the trench. Exploration using the direct-push technology should extend to a maximum depth of 15 m (50 ft). Sampling using passive or active methods or direct-push technology should be conducted approximately every 15 m (50 ft) along the length of the trench being investigated. At each sampling location, collect samples from depths of 4.6 and 7.6 m (15 and 25 ft) bgs. Continue sampling at 7.6 m (25-ft) depth intervals until reaching 15 m (50 ft) bgs or until the direct-push technology cannot advance deeper into the subsurface (i.e., refusal). Analyze soil-vapor samples for VOCs using field-screening instrument.	Cost-effective method to focus vadose-zone sampling in suspect burial ground release sites. The passive and active soil-vapor sampling methods will be deployed at locations of known shallow carbon tetrachloride contamination to evaluate their effectiveness. This sampling will provide soil-vapor concentration data from the vadose zone adjacent to hot spots identified in burial ground trenches.
Contingency soil-vapor sampling at hot spots at the 218-W-3A Burial Ground. **Soil-vapor sampling results did not warrant further vadose-zone investigation – see Section 3.2.4.6.**	If elevated carbon tetrachloride concentration hot spots are detected in activity #3 above, use direct-push technology to collect soil-vapor samples above, within, and below the Cold Creek unit to the sides of the trenches at locations of carbon tetrachloride hot spots. At each sampling location, collect samples from depths of 4.6 and 7.6 m (15 and 25 ft) bgs. Continue sampling at 7.6 m (25-ft) depth intervals until reaching groundwater at approximately 69 m (225 ft) bgs or until the direct-push technology cannot advance deeper into the subsurface (i.e., refusal). Analyze soil-vapor samples for VOCs using field-screening instrument.	This sampling will provide soil-vapor concentration data from the vadose zone adjacent to hot spots identified in burial ground trenches.
Contingency soil sampling at the 218-W-3A Burial Ground. **No soil sampling was conducted, because soil-vapor sampling results did not warrant further vadose-zone investigation – see Section 3.2.4.6.**	If feasible, collect and analyze soil samples at locations with carbon tetrachloride vapor concentrations exceeding 12,000 ppmv to evaluate the presence of DNAPL. Analyze the soil samples for the COPCs, COIs, and physical properties identified in the Work Plan (DOE/RL-2001-01, Appendix D). If feasible, collect and analyze soil samples at locations with carbon tetrachloride vapor concentrations exceeding 1,200 ppmv to evaluate the presence of a nearby carbon tetrachloride source. Analyze the soil samples for carbon tetrachloride.	If possible, a direct-push technology with soil-sampling capability (e.g., wireline cone penetrometer, Enhanced Access Penetration System) will be used to collect soil samples. The concentration of 12,000 ppmv is 10 percent of the concentration of saturated carbon tetrachloride vapor.

Table 2-3. Step II Sampling Design and Discussion Location in this Remedial Investigation Report. (6 Pages)

Sample Collection Methodology		Key Features of Design*	Basis for Sampling Design
Source Locations			
Soil vapor and groundwater sampling to investigate the following carbon tetrachloride groundwater "hot spots" (and possible associated release sites/sources). **Investigation activities are described in Section 2.4.2.8, and the results are described in Section 3.2.4.7.**		1. Conduct soil-vapor sampling in nearby deep wells, with full or partial screens in vadose zone, to evaluate direction of carbon tetrachloride migration. Sampling could be one time with downhole packer or continuous sampling using passive soil-vapor extraction-well setup. Approximately 36 wells will be sampled.	Existing groundwater hot spots are evidence for localized concentrations of carbon tetrachloride. "Looking up" from the hot spots may identify the source of the contamination. Persistent hot spots are indicative of a continuing source at that location.
Plume (well or location) (numbers refer to areas on Figure 2-35)	**Associated Potential Release Site**	2. Collect groundwater samples using micro-sampling techniques that allow a sampling device to fit through a small opening in the landing plate in existing wells, without requiring that the pump be removed. Conduct micro-sampling at the top of the aquifer in nearby groundwater wells to evaluate proximity to a source and/or type of source (e.g., vapor, DNAPL). Analyze the groundwater-sample headspace vapor for carbon tetrachloride using field-screening instrument. 3. Use direct-push technology to conduct soil-vapor sampling above, within, and below Cold Creek unit at locations of apparent continuing sources, based on evaluation of results of sampling described above. At each sampling location, collect samples from depths of 4.6 m and 7.6 m (15 and 25 ft) bgs.	Wells that are unsealed to atmosphere should be sampled during declining barometric pressure.
1. 299-W10-20	218-W-3A Burial Ground		
2. T Tank Farm	T Tank Farm		
3. T Plant	218-W-8, T Plant		
4. 299-W11-10	T Plant		
5. 216-T-25 Trench	216-T-25 Trench, 218-W-1 and 218-W-2 Burial Grounds, TX and TY Tank Farms	Continue sampling at 7.6 m (25-ft) depth intervals until reaching groundwater at approximately 69 m (225 ft) bgs or until the direct-push technology cannot advance deeper into the subsurface (i.e., refusal).	
6. 299-W15-15	218-W-4B and 218-W-4C Burial Grounds	Analyze soil-vapor samples for VOCs using field-screening instrument.	
7. 299-W15-16	218-W-4C Burial Ground		
8. West of S and SX Tank Farms	216-S-25 Crib, S and SX Tank Farms		

Table 2-3. Step II Sampling Design and Discussion Location in this Remedial Investigation Report. (6 Pages)

Sample Collection Methodology	Key Features of Design*	Basis for Sampling Design
Contingency soil sampling. **No soil sampling was conducted, because vapor concentrations did not exceed 1,200 ppmv – see Section 3.2.4.7.** **The investigation activities of other potential release sites/ sources are described in Section 2.4.2.9, and the results are described in Section 3.2.4.8.**	If feasible, collect and analyze soil samples at locations with significant carbon tetrachloride vapor concentrations (exceeding 12,000 ppmv) to evaluate the presence of DNAPL. Analyze the soil samples for the COPCs, COIs, and physical properties identified in the Work Plan (DOE/RL-2001-01, Appendix D). If feasible, collect and analyze soil samples at locations with carbon tetrachloride vapor concentrations exceeding 1,200 ppmv to evaluate the presence of a nearby carbon tetrachloride source. Analyze the soil samples for carbon tetrachloride.	If possible, a direct-push technology with soil sampling capability (e.g., wireline cone penetrometer, Enhanced Access Penetration System) will be used to collect soil samples. The concentration of 12,000 ppmv is 10 percent of the concentration of saturated carbon tetrachloride vapor.
Evaluation of groundwater plumes (NOTE: not a sampling activity). **The evaluation is discussed in Section 2.4.3.5, and other studies are discussed in Section 2.4.3.**	Conduct a statistical evaluation of groundwater concentrations over time to identify persistent hot spots that suggest a continuing source at that location. Track "new" or transient plumes to investigate whether they become persistent, indicating a new continuing source, or can be traced back to the original source	The statistical evaluation will identify groundwater plumes that may be indicative of vadose-zone sources.

*Step II sampling does not address all of the data gaps identified during the data quality objectives process. See the potential sampling design limitations discussion in the Work Plan (DOE/RL-2001-01, Appendix D, Section D3.2.6).

BHI-00882, *Airflow Modeling Report for Vapor Extraction Operations at the 200-ZP-2 Operable Unit (Carbon Tetrachloride Expedited Response Action).*

DOE/RL-2001-01, *Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan, Includes: 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units.*

DOE/RL-2001-66, *200-LW-1 300 Area Chemical Laboratory Waste Group Operable Unit RI/FS Work Plan.*

bgs = below ground surface.
COI = contaminant of interest.
COPC = contaminant of potential concern.
DNAPL = dense, nonaqueous-phase liquid.
ppmv = parts per million by volume.
VOC = volatile organic compound.

Table 2-4. Summary of Passive Soil-Vapor Sampling Around the Release Sites.

Field-Test Location (Grid)	Number of Samples	Quality Control (Trip Blanks + Duplicates)	Soil-Vapor Points	Deployment Dates	Barometric Pressure Range* (inches Mercury)
216-Z-9 Trench (coarse)	86	4	1-88	August 11-14, 2003	29.1-29.29
216-Z-9 Trench (refined)	165	8	A1-A80	September 13-16, 2004	29.010-29.236
			A81-A165	September 14-17, 2004	28.886-29.236
TX-TY Tank Farm (coarse)	53	3	B1-B53	September 15-18, 2004	28.884-29.161
Within Plutonium Finishing Plant (coarse)	39	2 + 2	C1-C41	November 11-15, 2004	29.241-29.624
216-Z-1A, 216-Z-12, and 216-Z-18 (coarse)	66	4 + 3	D1-D21, D23-D28, D30-D50		
			D22, D29, D51-D56	November 12-16, 2004	
			D57-D66	November 15-18, 2004	29.241-29.681
Outside TX Tank Farm (refined)	73	3	E1-E64, E66-E74	December 5-12, 2005	29.31-29.86
216-Z-1A and 216-Z-18 (refined)	80	4	F1-F80	January 31 – February 4, 2005	29.077-29.743
East of Plutonium Finishing Plant (refined)	22	1	G1-G22		
East and northeast of 216-Z-9 Trench (refined)	55	3 + 3	B1D853-B1D899, B1D8B0-B1D8B9, B1D8C0-B1D8C3	May 26 – June 2, 2005	28.84-29.38
TX Tank Farm	17	1	H1-H17	August 3-7, 2006	28.93-29.23
Total Samples	656	41			

*Barometric pressure recorded at Hanford Meteorological Station, 200 West Area.

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
1	08/11/2003	08/14/2003	566380.8	136017.8
2	08/11/2003	08/14/2003	566441.6	136019.8
3	08/11/2003	08/14/2003	566523.2	136021.2
4	08/11/2003	08/14/2003	566583.6	136037.6
5	08/11/2003	08/14/2003	566634.4	136022.2
6	08/11/2003	08/14/2003	566681.0	136021.0
7	08/11/2003	08/14/2003	566741.7	136020.4
8	08/11/2003	08/14/2003	566785.1	136022.0
9	08/11/2003	08/14/2003	566904.2	136023.3
10	08/11/2003	08/14/2003	566385.6	135961.3
11	08/11/2003	08/14/2003	566443.9	135957.7
12	08/11/2003	08/14/2003	566501.8	135974.8
13	08/11/2003	08/14/2003	566586.6	135963.4
14	08/11/2003	08/14/2003	566636.7	135962.8
15	08/11/2003	08/14/2003	566682.1	135959.9
16	08/11/2003	08/14/2003	566743.6	135959.1
17	08/11/2003	08/14/2003	566793.5	135961.4
18	08/11/2003	08/14/2003	566904.1	135953.5
19	08/11/2003	08/14/2003	566386.2	135920.6
20	08/11/2003	08/14/2003	566447.0	135914.7
21	08/11/2003	08/14/2003	566512.8	135918.3
22	08/11/2003	08/14/2003	566586.4	135910.7
23	08/11/2003	08/14/2003	566636.3	135911.9
24	08/11/2003	08/14/2003	566677.5	135894.5
25	08/11/2003	08/14/2003	566741.9	135912.0
26	08/11/2003	08/14/2003	566817.2	135920.9
27	08/11/2003	08/14/2003	566901.0	135914.1
28	08/11/2003	08/14/2003	566387.0	135857.4
29	08/11/2003	08/14/2003	566453.8	135847.4
30	08/11/2003	08/14/2003	566520.9	135837.1
31	08/11/2003	08/14/2003	566580.0	135844.9
32	08/11/2003	08/14/2003	566631.2	135850.0
33	08/11/2003	08/14/2003	566705.1	135845.6
34	08/11/2003	08/14/2003	566746.8	135868.5
35	08/11/2003	08/14/2003	566794.0	135850.2
36	08/11/2003	08/14/2003	566869.2	135851.5

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
37	08/11/2003	08/14/2003	566637.7	135803.0
38	08/11/2003	08/14/2003	566683.2	135807.5
39	08/11/2003	08/14/2003	566747.7	135807.7
40	08/11/2003	08/14/2003	566792.5	135807.5
41	08/11/2003	08/14/2003	566868.0	135809.5
42	08/11/2003	08/14/2003	566638.9	135735.5
45	08/11/2003	08/14/2003	566803.7	135735.9
46	08/11/2003	08/14/2003	566867.9	135743.3
47	08/11/2003	08/14/2003	566304.0	135704.3
48	08/11/2003	08/14/2003	566639.3	135691.2
49	08/11/2003	08/14/2003	566708.4	135703.0
50	08/11/2003	08/14/2003	566746.8	135702.2
51	08/11/2003	08/14/2003	566792.5	135701.8
52	08/11/2003	08/14/2003	566867.7	135700.6
53	08/11/2003	08/14/2003	566304.3	135674.8
54	08/11/2003	08/14/2003	566697.3	135643.0
55	08/11/2003	08/14/2003	566749.6	135631.3
56	08/11/2003	08/14/2003	566777.2	135647.5
57	08/11/2003	08/14/2003	566303.9	135643.1
58	08/11/2003	08/14/2003	566694.2	135606.6
59	08/11/2003	08/14/2003	566729.3	135598.8
60	08/11/2003	08/14/2003	566791.9	135606.7
61	08/11/2003	08/14/2003	566868.8	135606.5
62	08/11/2003	08/14/2003	566756.3	135568.9
63	08/11/2003	08/14/2003	566692.7	135546.2
64	08/11/2003	08/14/2003	566747.5	135562.0
65	08/11/2003	08/14/2003	566786.8	135574.5
66	08/11/2003	08/14/2003	566872.4	135560.8
67	08/11/2003	08/14/2003	566693.8	135509.3
68	08/11/2003	08/14/2003	566748.9	135516.7
69	08/11/2003	08/14/2003	566694.6	135464.2
70	08/11/2003	08/14/2003	566747.5	135472.8
71	08/11/2003	08/14/2003	566793.2	135470.7
72	08/11/2003	08/14/2003	566867.6	135471.5
73	08/11/2003	08/14/2003	566747.4	135433.0
74	08/11/2003	08/14/2003	566792.7	135425.6

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
75	08/11/2003	08/14/2003	566869.1	135422.4
76	08/11/2003	08/14/2003	566747.4	135372.6
77	08/11/2003	08/14/2003	566790.4	135382.1
78	08/11/2003	08/14/2003	566793.2	135334.9
79	08/11/2003	08/14/2003	566868.8	135334.4
80	08/11/2003	08/14/2003	566703.3	135292.6
81	08/11/2003	08/14/2003	566793.8	135288.9
82	08/11/2003	08/14/2003	566747.8	135244.5
83	08/11/2003	08/14/2003	566866.0	135248.6
84	08/11/2003	08/14/2003	566705.1	135200.5
85	08/11/2003	08/14/2003	566792.5	135199.3
86	08/11/2003	08/14/2003	566656.8	135156.3
87	08/11/2003	08/14/2003	566727.3	135643.9
88	08/11/2003	08/14/2003	566831.3	135642.6
A1	09/13/2004	09/16/2004	566712.5	135703.4
A2	09/13/2004	09/16/2004	566741.5	135702.4
A3	09/13/2004	09/16/2004	566763.4	135702.1
A4	09/13/2004	09/16/2004	566786.6	135701.8
A5	09/13/2004	09/16/2004	566810.0	135701.5
A6	09/13/2004	09/16/2004	566836.3	135701.5
A7	09/13/2004	09/16/2004	566889.9	135700.0
A8	09/13/2004	09/16/2004	566944.8	135700.0
A9	09/13/2004	09/16/2004	566999.0	135698.8
A10	09/13/2004	09/16/2004	566712.5	135676.5
A11	09/13/2004	09/16/2004	566742.1	135679.9
A12	09/13/2004	09/16/2004	566764.6	135679.3
A13	09/13/2004	09/16/2004	566787.5	135679.3
A14	09/13/2004	09/16/2004	566810.7	135678.7
A15	09/13/2004	09/16/2004	566718.0	135652.8
A16	09/13/2004	09/16/2004	566742.1	135653.7
A17	09/13/2004	09/16/2004	566765.5	135654.0
A18	09/13/2004	09/16/2004	566787.8	135654.3
A19	09/13/2004	09/16/2004	566811.0	135653.7
A20	09/13/2004	09/16/2004	566836.3	135649.7
A21	09/13/2004	09/16/2004	566891.1	135650.0
A22	09/13/2004	09/16/2004	566944.8	135649.4

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
A23	09/13/2004	09/16/2004	567000.2	135649.7
A24	09/13/2004	09/16/2004	566718.0	135631.1
A25	09/13/2004	09/16/2004	566743.0	135630.5
A26	09/13/2004	09/16/2004	566765.8	135631.7
A27	09/13/2004	09/16/2004	566777.4	135631.4
A28	09/13/2004	09/16/2004	566814.9	135631.7
A29	09/13/2004	09/16/2004	566718.9	135608.0
A30	09/13/2004	09/16/2004	566739.6	135608.0
A31	09/13/2004	09/16/2004	566787.5	135608.6
A32	09/13/2004	09/16/2004	566814.9	135608.3
A33	09/13/2004	09/16/2004	566836.9	135599.4
A34	09/13/2004	09/16/2004	566890.8	135599.4
A35	09/13/2004	09/16/2004	566944.5	135599.4
A36	09/13/2004	09/16/2004	566998.7	135599.7
A37	09/13/2004	09/16/2004	566722.6	135571.1
A38	09/13/2004	09/16/2004	566742.1	135573.8
A39	09/13/2004	09/16/2004	566765.2	135576.0
A40	09/13/2004	09/16/2004	566787.2	135577.8
A41	09/13/2004	09/16/2004	566811.6	135580.8
A42	09/13/2004	09/16/2004	566720.1	135560.1
A43	09/13/2004	09/16/2004	566743.3	135561.3
A44	09/13/2004	09/16/2004	566764.9	135561.9
A45	09/13/2004	09/16/2004	566788.1	135561.3
A46	09/13/2004	09/16/2004	566809.7	135561.9
A47	09/13/2004	09/16/2004	566718.6	135538.2
A48	09/13/2004	09/16/2004	566742.7	135538.8
A49	09/13/2004	09/16/2004	566764.9	135539.1
A50	09/13/2004	09/16/2004	566788.1	135539.1
A51	09/13/2004	09/16/2004	566811.9	135538.5
A52	09/13/2004	09/16/2004	566838.1	135549.7
A53	09/13/2004	09/16/2004	566890.8	135550.4
A54	09/13/2004	09/16/2004	566945.1	135549.4
A55	09/13/2004	09/16/2004	566998.7	135548.2
A56	09/13/2004	09/16/2004	566718.6	135515.6
A57	09/13/2004	09/16/2004	566741.8	135515.3
A58	09/13/2004	09/16/2004	566764.6	135515.6

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
A59	09/13/2004	09/16/2004	566787.8	135516.2
A60	09/13/2004	09/16/2004	566811.0	135515.3
A61	09/13/2004	09/16/2004	566719.2	135492.7
A62	09/13/2004	09/16/2004	566741.2	135492.7
A63	09/13/2004	09/16/2004	566765.2	135493.4
A64	09/13/2004	09/16/2004	566787.5	135492.4
A65	09/13/2004	09/16/2004	566811.3	135492.7
A66	09/13/2004	09/16/2004	566722.0	135469.6
A67	09/13/2004	09/16/2004	566741.8	135469.9
A68	09/13/2004	09/16/2004	566764.9	135469.6
A69	09/13/2004	09/16/2004	566787.8	135469.6
A70	09/13/2004	09/16/2004	566810.3	135469.6
A71	09/13/2004	09/16/2004	566719.2	135446.7
A72	09/13/2004	09/16/2004	566741.8	135446.4
A73	09/13/2004	09/16/2004	566765.8	135446.7
A74	09/13/2004	09/16/2004	566787.8	135446.7
A75	09/13/2004	09/16/2004	566810.3	135446.7
A76	09/13/2004	09/16/2004	566718.9	135423.2
A77	09/13/2004	09/16/2004	566741.8	135423.9
A78	09/13/2004	09/16/2004	566764.6	135423.9
A79	09/13/2004	09/16/2004	566787.8	135423.6
A80	09/13/2004	09/16/2004	566810.3	135424.5
A81	09/14/2004	09/17/2004	566718.6	135400.4
A82	09/14/2004	09/17/2004	566741.5	135401.0
A83	09/14/2004	09/17/2004	566765.2	135401.0
A84	09/14/2004	09/17/2004	566787.8	135401.0
A85	09/14/2004	09/17/2004	566810.7	135401.0
A86	09/14/2004	09/17/2004	566834.1	135400.1
A87	09/14/2004	09/17/2004	566857.0	135400.4
A88	09/14/2004	09/17/2004	566878.3	135399.8
A89	09/14/2004	09/17/2004	566903.0	135401.0
A90	09/14/2004	09/17/2004	566926.2	135401.0
A91	09/14/2004	09/17/2004	566949.3	135401.3
A92	09/14/2004	09/17/2004	566718.3	135378.4
A93	09/14/2004	09/17/2004	566741.2	135377.8
A94	09/14/2004	09/17/2004	566764.9	135377.8

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
A95	09/14/2004	09/17/2004	566787.8	135377.8
A96	09/14/2004	09/17/2004	566811.3	135377.2
A97	09/14/2004	09/17/2004	566833.8	135377.5
A98	09/14/2004	09/17/2004	566857.0	135378.1
A99	09/14/2004	09/17/2004	566878.3	135378.7
A100	09/14/2004	09/17/2004	566902.7	135377.8
A101	09/14/2004	09/17/2004	566925.6	135377.5
A102	09/14/2004	09/17/2004	566949.0	135377.8
A103	09/14/2004	09/17/2004	566718.3	135355.0
A104	09/14/2004	09/17/2004	566741.8	135355.0
A105	09/14/2004	09/17/2004	566764.9	135355.0
A106	09/14/2004	09/17/2004	566787.8	135355.0
A107	09/14/2004	09/17/2004	566810.7	135354.7
A108	09/14/2004	09/17/2004	566833.8	135354.1
A109	09/14/2004	09/17/2004	566856.4	135353.8
A110	09/14/2004	09/17/2004	566878.3	135355.0
A111	09/14/2004	09/17/2004	566902.7	135355.3
A112	09/14/2004	09/17/2004	566925.6	135354.4
A113	09/14/2004	09/17/2004	566949.0	135355.0
A114	09/14/2004	09/17/2004	566718.3	135331.5
A115	09/14/2004	09/17/2004	566741.8	135331.8
A116	09/14/2004	09/17/2004	566765.2	135331.5
A117	09/14/2004	09/17/2004	566787.5	135331.5
A118	09/14/2004	09/17/2004	566811.0	135331.5
A119	09/14/2004	09/17/2004	566833.8	135331.8
A120	09/14/2004	09/17/2004	566856.7	135332.1
A121	09/14/2004	09/17/2004	566878.3	135330.6
A122	09/14/2004	09/17/2004	566903.0	135331.5
A123	09/14/2004	09/17/2004	566926.2	135331.8
A124	09/14/2004	09/17/2004	566949.0	135331.5
A125	09/14/2004	09/17/2004	566718.3	135308.6
A126	09/14/2004	09/17/2004	566741.8	135308.6
A127	09/14/2004	09/17/2004	566764.6	135308.3
A128	09/14/2004	09/17/2004	566787.8	135308.3
A129	09/14/2004	09/17/2004	566810.7	135308.6
A130	09/14/2004	09/17/2004	566833.8	135308.9

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
A131	09/14/2004	09/17/2004	566857.0	135308.6
A132	09/14/2004	09/17/2004	566878.9	135308.3
A133	09/14/2004	09/17/2004	566903.0	135308.6
A134	09/14/2004	09/17/2004	566925.9	135310.2
A135	09/14/2004	09/17/2004	566948.4	135308.3
A136	09/14/2004	09/17/2004	566718.6	135285.8
A137	09/14/2004	09/17/2004	566741.8	135285.5
A138	09/14/2004	09/17/2004	566764.6	135285.8
A139	09/14/2004	09/17/2004	566787.8	135285.8
A140	09/14/2004	09/17/2004	566811.0	135285.8
A141	09/14/2004	09/17/2004	566833.5	135285.8
A142	09/14/2004	09/17/2004	566856.7	135285.8
A143	09/14/2004	09/17/2004	566878.9	135285.5
A144	09/14/2004	09/17/2004	566902.7	135286.1
A145	09/14/2004	09/17/2004	566925.9	135285.8
A146	09/14/2004	09/17/2004	566948.7	135285.5
A147	09/14/2004	09/17/2004	566718.9	135262.6
A148	09/14/2004	09/17/2004	566741.5	135262.9
A149	09/14/2004	09/17/2004	566764.6	135263.2
A150	09/14/2004	09/17/2004	566788.1	135263.5
A151	09/14/2004	09/17/2004	566811.0	135262.9
A152	09/14/2004	09/17/2004	566834.1	135262.9
A153	09/14/2004	09/17/2004	566857.3	135262.9
A154	09/14/2004	09/17/2004	566879.2	135263.2
A155	09/14/2004	09/17/2004	566719.2	135240.1
A156	09/14/2004	09/17/2004	566741.5	135240.1
A157	09/14/2004	09/17/2004	566764.6	135240.4
A158	09/14/2004	09/17/2004	566788.1	135239.5
A159	09/14/2004	09/17/2004	566811.0	135239.8
A160	09/14/2004	09/17/2004	566834.1	135239.5
A161	09/14/2004	09/17/2004	566719.2	135216.9
A162	09/14/2004	09/17/2004	566741.8	135216.6
A163	09/14/2004	09/17/2004	566764.9	135216.9
A164	09/14/2004	09/17/2004	566788.4	135216.6
A165	09/14/2004	09/17/2004	566810.7	135215.4
B1	09/15/2004	09/18/2004	566374.2	136524.5

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
B2	09/15/2004	09/18/2004	566438.8	136525.1
B3	09/15/2004	09/18/2004	566501.6	136525.7
B4	09/15/2004	09/18/2004	566562.8	136524.5
B5	09/15/2004	09/18/2004	566625.9	136525.1
B6	09/15/2004	09/18/2004	566689.0	136524.2
B7	09/15/2004	09/18/2004	566752.1	136524.5
B8	09/15/2004	09/18/2004	566815.2	136524.8
B9	09/15/2004	09/18/2004	566876.5	136524.8
B10	09/15/2004	09/18/2004	566375.4	136460.5
B11	09/15/2004	09/18/2004	566436.7	136460.8
B12	09/15/2004	09/18/2004	566500.1	136460.5
B13	09/15/2004	09/18/2004	566563.2	136460.8
B14	09/15/2004	09/18/2004	566625.9	136460.5
B15	09/15/2004	09/18/2004	566688.4	136460.5
B16	09/15/2004	09/18/2004	566854.8	136461.1
B17	09/15/2004	09/18/2004	566373.9	136396.8
B18	09/15/2004	09/18/2004	566437.0	136396.5
B19	09/15/2004	09/18/2004	566500.1	136396.5
B20	09/15/2004	09/18/2004	566563.2	136396.8
B21	09/15/2004	09/18/2004	566625.9	136396.8
B22	09/15/2004	09/18/2004	566688.7	136396.5
B23	09/15/2004	09/18/2004	566854.8	136396.8
B24	09/15/2004	09/18/2004	566373.6	136332.5
B25	09/15/2004	09/18/2004	566436.7	136332.5
B26	09/15/2004	09/18/2004	566500.1	136332.5
B27	09/15/2004	09/18/2004	566562.5	136332.5
B28	09/15/2004	09/18/2004	566627.2	136332.2
B29	09/15/2004	09/18/2004	566690.6	136334.0
B30	09/15/2004	09/18/2004	566855.2	136334.0
B31	09/15/2004	09/18/2004	566375.1	136268.2
B32	09/15/2004	09/18/2004	566436.7	136268.5
B33	09/15/2004	09/18/2004	566500.7	136268.8
B34	09/15/2004	09/18/2004	566563.5	136268.2
B35	09/15/2004	09/18/2004	566630.2	136268.8
B36	09/15/2004	09/18/2004	566874.7	136268.8
B37	09/15/2004	09/18/2004	566373.6	136204.8

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
B38	09/15/2004	09/18/2004	566436.4	136204.5
B39	09/15/2004	09/18/2004	566495.8	136204.8
B40	09/15/2004	09/18/2004	566625.9	136204.8
B41	09/15/2004	09/18/2004	566874.7	136204.8
B42	09/15/2004	09/18/2004	566373.3	136141.1
B43	09/15/2004	09/18/2004	566436.7	136140.7
B44	09/15/2004	09/18/2004	566496.4	136140.7
B45	09/15/2004	09/18/2004	566625.6	136140.4
B46	09/15/2004	09/18/2004	566874.4	136141.1
B47	09/15/2004	09/18/2004	566373.9	136076.4
B48	09/15/2004	09/18/2004	566437.3	136076.4
B49	09/15/2004	09/18/2004	566496.7	136076.1
B50	09/15/2004	09/18/2004	566563.2	136077.0
B51	09/15/2004	09/18/2004	566625.9	136076.7
B52	09/15/2004	09/18/2004	566689.0	136076.1
B53	09/15/2004	09/18/2004	566875.3	136076.7
C1	11/11/2004	11/15/2004	566396.1	135776.2
C2	11/11/2004	11/15/2004	566429.0	135776.2
C3	11/11/2004	11/15/2004	566467.8	135743.0
C4	11/11/2004	11/15/2004	566537.9	135754.6
C5	11/11/2004	11/15/2004	566590.9	135755.8
C6	11/11/2004	11/15/2004	566395.8	135727.4
C7	11/11/2004	11/15/2004	566421.1	135726.8
C8	11/11/2004	11/15/2004	566441.8	135727.1
C9	11/11/2004	11/15/2004	566497.3	135714.0
C10	11/11/2004	11/15/2004	566541.2	135718.3
C11	11/11/2004	11/15/2004	566586.6	135709.2
C12	11/11/2004	11/15/2004	566635.4	135726.5
C13	11/11/2004	11/15/2004	566376.6	135686.3
C14	11/11/2004	11/15/2004	566404.0	135678.7
C16	11/11/2004	11/15/2004	566452.5	135688.1
C17	11/11/2004	11/15/2004	566488.2	135679.6
C18	11/11/2004	11/15/2004	566521.1	135684.8
C19	11/11/2004	11/15/2004	566550.4	135689.0
C20	11/11/2004	11/15/2004	566586.3	135693.3
C21	11/11/2004	11/15/2004	566636.0	135695.1

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
C22	11/11/2004	11/15/2004	566586.3	135665.6
C23	11/11/2004	11/15/2004	566636.9	135666.5
C24	11/11/2004	11/15/2004	566378.1	135646.7
C25	11/11/2004	11/15/2004	566396.1	135622.3
C26	11/11/2004	11/15/2004	566468.4	135620.5
C27	11/11/2004	11/15/2004	566504.9	135607.3
C28	11/11/2004	11/15/2004	566547.0	135607.0
C29	11/11/2004	11/15/2004	566583.3	135631.4
C30	11/11/2004	11/15/2004	566637.2	135637.2
C31	11/11/2004	11/15/2004	566395.5	135582.7
C32	11/11/2004	11/15/2004	566415.9	135561.9
C33	11/11/2004	11/15/2004	566497.0	135570.5
C34	11/11/2004	11/15/2004	566539.1	135569.6
C36	11/11/2004	11/15/2004	566586.0	135597.9
C37	11/11/2004	11/15/2004	566397.6	135528.4
C38	11/11/2004	11/15/2004	566444.3	135526.3
C39	11/11/2004	11/15/2004	566491.5	135532.1
C40	11/11/2004	11/15/2004	566549.1	135529.6
C41	11/11/2004	11/15/2004	566580.8	135547.0
D1	11/15/2004	11/18/2004	566300.1	135474.2
D2	11/15/2004	11/18/2004	566328.8	135475.1
D3	11/15/2004	11/18/2004	566378.1	135474.8
D4	11/15/2004	11/18/2004	566449.2	135476.6
D5	11/15/2004	11/18/2004	566513.8	135476.3
D6	11/15/2004	11/18/2004	566540.3	135465.9
D7	11/15/2004	11/18/2004	566589.7	135475.7
D8	11/15/2004	11/18/2004	566659.8	135475.7
D9	11/15/2004	11/18/2004	566415.9	135440.9
D10	11/15/2004	11/18/2004	566481.5	135441.8
D11	11/15/2004	11/18/2004	566624.4	135440.6
D12	11/15/2004	11/18/2004	566300.7	135414.4
D13	11/15/2004	11/18/2004	566329.7	135418.7
D14	11/15/2004	11/18/2004	566378.8	135415.3
D15	11/15/2004	11/18/2004	566449.8	135415.3
D16	11/15/2004	11/18/2004	566512.6	135419.0
D17	11/15/2004	11/18/2004	566551.0	135419.9

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
D18	11/15/2004	11/18/2004	566580.2	135415.9
D19	11/15/2004	11/18/2004	566659.5	135415.3
D20	11/15/2004	11/18/2004	566414.7	135390.3
D21	11/15/2004	11/18/2004	566483.0	135391.2
D22	11/15/2004	11/18/2004	566564.7	135391.6
D23	11/15/2004	11/18/2004	566623.8	135390.6
D24	11/15/2004	11/18/2004	566300.4	135371.4
D25	11/15/2004	11/18/2004	566335.2	135370.8
D26	11/15/2004	11/18/2004	566379.7	135369.9
D27	11/15/2004	11/18/2004	566449.5	135370.2
D28	11/15/2004	11/18/2004	566509.5	135371.4
D29	11/15/2004	11/18/2004	566533.9	135370.8
D30	11/15/2004	11/18/2004	566586.0	135369.6
D31	11/15/2004	11/18/2004	566644.2	135371.1
D32	11/15/2004	11/18/2004	566418.4	135346.7
D33	11/15/2004	11/18/2004	566487.9	135346.1
D34	11/15/2004	11/18/2004	566614.4	135350.4
D35	11/15/2004	11/18/2004	566352.5	135330.9
D36	11/15/2004	11/18/2004	566389.7	135329.7
D37	11/15/2004	11/18/2004	566448.5	135330.9
D38	11/15/2004	11/18/2004	566501.9	135330.3
D39	11/15/2004	11/18/2004	566540.6	135329.7
D40	11/15/2004	11/18/2004	566586.0	135330.6
D41	11/15/2004	11/18/2004	566349.5	135285.8
D42	11/15/2004	11/18/2004	566499.8	135285.5
D43	11/15/2004	11/18/2004	566536.9	135285.2
D44	11/15/2004	11/18/2004	566589.7	135284.9
D45	11/15/2004	11/18/2004	566349.2	135236.7
D46	11/15/2004	11/18/2004	566394.3	135236.1
D47	11/15/2004	11/18/2004	566449.5	135236.1
D48	11/15/2004	11/18/2004	566498.8	135236.1
D49	11/15/2004	11/18/2004	566547.3	135227.0
D50	11/15/2004	11/18/2004	566582.4	135236.1
D51	11/15/2004	11/18/2004	566349.2	135195.3
D52	11/15/2004	11/18/2004	566399.2	135195.6
D53	11/15/2004	11/18/2004	566449.5	135196.5

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
D54	11/15/2004	11/18/2004	566499.8	135195.6
D55	11/15/2004	11/18/2004	566540.0	135195.9
D56	11/15/2004	11/18/2004	566579.6	135196.2
D57	11/15/2004	11/18/2004	566349.8	135156.2
D58	11/15/2004	11/18/2004	566400.1	135155.3
D59	11/15/2004	11/18/2004	566450.1	135155.9
D60	11/15/2004	11/18/2004	566499.5	135155.6
D61	11/15/2004	11/18/2004	566550.0	135155.9
D62	11/15/2004	11/18/2004	566349.5	135115.1
D63	11/15/2004	11/18/2004	566399.8	135116.0
D64	11/15/2004	11/18/2004	566449.5	135115.7
D65	11/15/2004	11/18/2004	566499.5	135116.0
D66	11/15/2004	11/18/2004	566549.4	135116.3
E1	12/05/2005	12/12/2005	566711.3	136039.6
E2	12/05/2005	12/12/2005	566735.1	136039.6
E3	12/05/2005	12/12/2005	566759.1	136038.0
E4	12/05/2005	12/12/2005	566780.5	136037.7
E5	12/05/2005	12/12/2005	566804.6	136036.8
E6	12/05/2005	12/12/2005	566827.7	136036.2
E7	12/05/2005	12/12/2005	566848.4	136049.0
E8	12/05/2005	12/12/2005	566872.5	136037.4
E9	12/05/2005	12/12/2005	566666.2	136058.5
E10	12/05/2005	12/12/2005	566688.7	136058.1
E11	12/05/2005	12/12/2005	566711.6	136058.1
E12	12/05/2005	12/12/2005	566734.5	136058.1
E13	12/05/2005	12/12/2005	566758.8	136058.5
E14	12/05/2005	12/12/2005	566780.5	136058.1
E15	12/05/2005	12/12/2005	566803.6	136058.8
E16	12/05/2005	12/12/2005	566826.5	136058.1
E17	12/05/2005	12/12/2005	566872.5	136058.1
E18	12/05/2005	12/12/2005	566918.6	136058.1
E19	12/05/2005	12/12/2005	566941.7	136058.1
E20	12/05/2005	12/12/2005	566665.6	136081.3
E21	12/05/2005	12/12/2005	566691.5	136082.5
E22	12/05/2005	12/12/2005	566711.6	136080.7
E23	12/05/2005	12/12/2005	566872.5	136081.3

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
E24	12/05/2005	12/12/2005	566895.7	136081.3
E25	12/05/2005	12/12/2005	566918.6	136081.3
E26	12/05/2005	12/12/2005	566941.7	136081.3
E27	12/05/2005	12/12/2005	566665.6	136104.2
E28	12/05/2005	12/12/2005	566688.7	136104.2
E29	12/05/2005	12/12/2005	566872.5	136104.2
E30	12/05/2005	12/12/2005	566895.7	136104.2
E31	12/05/2005	12/12/2005	566918.6	136104.2
E32	12/05/2005	12/12/2005	566941.7	136104.2
E33	12/05/2005	12/12/2005	566872.5	136127.3
E34	12/05/2005	12/12/2005	566895.7	136127.3
E35	12/05/2005	12/12/2005	566918.6	136127.3
E36	12/05/2005	12/12/2005	566941.7	136127.3
E37	12/05/2005	12/12/2005	566872.5	136150.2
E38	12/05/2005	12/12/2005	566895.7	136150.2
E39	12/05/2005	12/12/2005	566918.6	136150.2
E40	12/05/2005	12/12/2005	566941.7	136150.2
E41	12/05/2005	12/12/2005	566872.5	136173.1
E42	12/05/2005	12/12/2005	566895.7	136173.1
E43	12/05/2005	12/12/2005	566918.6	136173.1
E44	12/05/2005	12/12/2005	566941.7	136173.1
E45	12/05/2005	12/12/2005	566872.5	136196.2
E46	12/05/2005	12/12/2005	566895.7	136196.2
E47	12/05/2005	12/12/2005	566918.6	136196.2
E48	12/05/2005	12/12/2005	566941.7	136196.2
E49	12/05/2005	12/12/2005	566872.5	136219.1
E50	12/05/2005	12/12/2005	566895.7	136219.1
E51	12/05/2005	12/12/2005	566918.6	136219.1
E52	12/05/2005	12/12/2005	566941.7	136219.1
E53	12/05/2005	12/12/2005	566872.5	136242.2
E54	12/05/2005	12/12/2005	566895.7	136242.2
E55	12/05/2005	12/12/2005	566918.6	136242.2
E56	12/05/2005	12/12/2005	566941.7	136242.2
E57	12/05/2005	12/12/2005	566872.5	136265.1
E58	12/05/2005	12/12/2005	566895.7	136265.1
E59	12/05/2005	12/12/2005	566918.6	136265.1

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
E60	12/05/2005	12/12/2005	566941.7	136265.1
E61	12/05/2005	12/12/2005	566872.5	136288.3
E62	12/05/2005	12/12/2005	566895.7	136288.3
E63	12/05/2005	12/12/2005	566918.6	136288.3
E64	12/05/2005	12/12/2005	566941.7	136288.3
E66	12/05/2005	12/12/2005	566851.2	136314.2
E67	12/05/2005	12/12/2005	566872.5	136311.1
E68	12/05/2005	12/12/2005	566895.7	136311.1
E69	12/05/2005	12/12/2005	566918.6	136311.1
E70	12/05/2005	12/12/2005	566941.7	136311.1
E71	12/05/2005	12/12/2005	566826.5	136334.3
E72	12/05/2005	12/12/2005	566849.7	136334.3
E73	12/05/2005	12/12/2005	566872.5	136334.3
E74	12/05/2005	12/12/2005	566895.7	136334.3
F1	01/31/2005	02/04/2005	566378.1	135244.3
F2	01/31/2005	02/04/2005	566402.2	135244.3
F3	01/31/2005	02/04/2005	566425.1	135244.6
F4	01/31/2005	02/04/2005	566448.2	135244.3
F5	01/31/2005	02/04/2005	566471.4	135244.3
F6	01/31/2005	02/04/2005	566494.3	135244.3
F7	01/31/2005	02/04/2005	566379.1	135267.5
F8	01/31/2005	02/04/2005	566401.9	135267.5
F9	01/31/2005	02/04/2005	566425.4	135267.5
F10	01/31/2005	02/04/2005	566447.9	135267.5
F11	01/31/2005	02/04/2005	566471.4	135267.5
F12	01/31/2005	02/04/2005	566494.6	135267.5
F13	01/31/2005	02/04/2005	566379.1	135290.4
F14	01/31/2005	02/04/2005	566401.9	135290.4
F15	01/31/2005	02/04/2005	566425.1	135290.4
F16	01/31/2005	02/04/2005	566447.6	135290.4
F17	01/31/2005	02/04/2005	566471.4	135290.4
F18	01/31/2005	02/04/2005	566494.3	135290.4
F19	01/31/2005	02/04/2005	566379.4	135313.5
F20	01/31/2005	02/04/2005	566402.5	135313.5
F21	01/31/2005	02/04/2005	566425.4	135313.5
F22	01/31/2005	02/04/2005	566447.9	135313.5

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
F23	01/31/2005	02/04/2005	566471.1	135313.5
F24	01/31/2005	02/04/2005	566494.3	135313.8
F25	01/31/2005	02/04/2005	566448.2	135340.0
F26	01/31/2005	02/04/2005	566470.2	135340.0
F27	01/31/2005	02/04/2005	566494.0	135339.1
F28	01/31/2005	02/04/2005	566516.5	135340.0
F29	01/31/2005	02/04/2005	566540.0	135339.4
F30	01/31/2005	02/04/2005	566562.5	135339.7
F31	01/31/2005	02/04/2005	566585.1	135335.8
F32	01/31/2005	02/04/2005	566608.6	135339.1
F33	01/31/2005	02/04/2005	566448.2	135362.9
F34	01/31/2005	02/04/2005	566471.1	135362.6
F35	01/31/2005	02/04/2005	566493.4	135362.3
F36	01/31/2005	02/04/2005	566516.5	135362.3
F37	01/31/2005	02/04/2005	566538.8	135364.4
F38	01/31/2005	02/04/2005	566562.5	135364.1
F39	01/31/2005	02/04/2005	566582.4	135363.5
F40	01/31/2005	02/04/2005	566607.7	135364.4
F41	01/31/2005	02/04/2005	566447.6	135385.5
F42	01/31/2005	02/04/2005	566470.8	135385.5
F43	01/31/2005	02/04/2005	566493.7	135385.5
F44	01/31/2005	02/04/2005	566517.1	135385.5
F45	01/31/2005	02/04/2005	566540.0	135385.1
F46	01/31/2005	02/04/2005	566562.8	135385.5
F47	01/31/2005	02/04/2005	566585.1	135385.1
F48	01/31/2005	02/04/2005	566608.3	135386.1
F49	01/31/2005	02/04/2005	566447.9	135408.6
F50	01/31/2005	02/04/2005	566471.1	135408.3
F51	01/31/2005	02/04/2005	566494.0	135408.3
F52	01/31/2005	02/04/2005	566516.8	135408.6
F53	01/31/2005	02/04/2005	566539.7	135408.3
F54	01/31/2005	02/04/2005	566563.2	135408.6
F55	01/31/2005	02/04/2005	566585.4	135408.3
F56	01/31/2005	02/04/2005	566608.9	135408.3
F57	01/31/2005	02/04/2005	566447.6	135431.2
F58	01/31/2005	02/04/2005	566470.8	135431.5

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
F59	01/31/2005	02/04/2005	566493.7	135431.5
F60	01/31/2005	02/04/2005	566517.1	135431.2
F61	01/31/2005	02/04/2005	566540.0	135431.5
F62	01/31/2005	02/04/2005	566562.8	135431.5
F63	01/31/2005	02/04/2005	566585.7	135431.2
F64	01/31/2005	02/04/2005	566608.0	135431.8
F65	01/31/2005	02/04/2005	566447.9	135454.9
F66	01/31/2005	02/04/2005	566470.8	135454.6
F67	01/31/2005	02/04/2005	566493.4	135454.6
F68	01/31/2005	02/04/2005	566516.8	135454.9
F69	01/31/2005	02/04/2005	566540.0	135454.3
F70	01/31/2005	02/04/2005	566563.5	135454.3
F71	01/31/2005	02/04/2005	566585.7	135454.0
F72	01/31/2005	02/04/2005	566608.9	135454.0
F73	01/31/2005	02/04/2005	566447.3	135477.8
F74	01/31/2005	02/04/2005	566470.8	135478.1
F75	01/31/2005	02/04/2005	566493.4	135477.8
F76	01/31/2005	02/04/2005	566516.8	135477.5
F77	01/31/2005	02/04/2005	566540.0	135477.2
F78	01/31/2005	02/04/2005	566563.2	135477.5
F79	01/31/2005	02/04/2005	566585.1	135476.6
F80	01/31/2005	02/04/2005	566610.1	135476.3
G1	01/31/2005	02/04/2005	566627.5	135636.3
G2	01/31/2005	02/04/2005	566650.6	135636.0
G3	01/31/2005	02/04/2005	566674.1	135636.6
G4	01/31/2005	02/04/2005	566697.0	135637.2
G5	01/31/2005	02/04/2005	566627.8	135659.2
G6	01/31/2005	02/04/2005	566650.9	135659.5
G7	01/31/2005	02/04/2005	566694.2	135658.6
G8	01/31/2005	02/04/2005	566627.8	135682.6
G9	01/31/2005	02/04/2005	566650.6	135682.6
G10	01/31/2005	02/04/2005	566675.3	135682.3
G11	01/31/2005	02/04/2005	566696.7	135682.0
G12	01/31/2005	02/04/2005	566627.8	135705.8
G13	01/31/2005	02/04/2005	566650.6	135705.5
G14	01/31/2005	02/04/2005	566673.8	135705.2

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
G15	01/31/2005	02/04/2005	566696.7	135705.5
G16	01/31/2005	02/04/2005	566627.8	135728.7
G17	01/31/2005	02/04/2005	566653.1	135726.5
G18	01/31/2005	02/04/2005	566669.8	135728.0
G19	01/31/2005	02/04/2005	566682.6	135728.7
G20	01/31/2005	02/04/2005	566637.8	135751.5
G21	01/31/2005	02/04/2005	566664.0	135747.6
G22	01/31/2005	02/04/2005	566682.0	135751.5
H1	08/03/2006	08/07/2006	566826.4	136278.9
H2	08/03/2006	08/07/2006	566849.1	136265.4
H3	08/03/2006	08/07/2006	566825.9	136242.2
H4	08/03/2006	08/07/2006	566849.1	136218.8
H5	08/03/2006	08/07/2006	566825.9	136196.5
H6	08/03/2006	08/07/2006	566849.1	136173.1
H7	08/03/2006	08/07/2006	566825.9	136150.2
H8	08/03/2006	08/07/2006	566709.8	136127.3
H9	08/03/2006	08/07/2006	566757.3	136127.3
H10	08/03/2006	08/07/2006	566800.0	136127.3
H11	08/03/2006	08/07/2006	566849.1	136127.3
H12	08/03/2006	08/07/2006	566734.1	136104.2
H13	08/03/2006	08/07/2006	566779.6	136104.2
H14	08/03/2006	08/07/2006	566825.9	136104.2
H15	08/03/2006	08/07/2006	566757.3	136081.3
H16	08/03/2006	08/07/2006	566800.0	136081.3
H17	08/03/2006	08/07/2006	566849.1	136081.3
B1D853	05/26/2005	06/02/2005	567048.5	136023.3
B1D854	05/26/2005	06/02/2005	567048.5	135953.5
B1D855	05/26/2005	06/02/2005	567048.5	135914.1
B1D856	05/26/2005	06/02/2005	567048.5	135851.5
B1D857	05/26/2005	06/02/2005	567048.5	135809.5
B1D858	05/26/2005	06/02/2005	566998.9	135809.5
B1D859	05/26/2005	06/02/2005	566998.9	135809.5
B1D860	05/26/2005	06/02/2005	566949.2	135809.5
B1D861	05/26/2005	06/02/2005	566998.9	135851.5
B1D862	05/26/2005	06/02/2005	566998.9	135914.1
B1D863	05/26/2005	06/02/2005	566998.9	135953.5

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
B1D864	05/26/2005	06/02/2005	566949.2	136023.3
B1D865	05/26/2005	06/02/2005	566998.9	136023.3
B1D866	05/26/2005	06/02/2005	566949.2	135953.5
B1D867	05/26/2005	06/02/2005	566949.2	135914.1
B1D868	05/26/2005	06/02/2005	566949.2	135851.5
B1D869	05/26/2005	06/02/2005	567048.5	135743.3
B1D870	05/26/2005	06/02/2005	566998.9	135743.3
B1D871	05/26/2005	06/02/2005	566949.2	135743.3
B1D872	05/26/2005	06/02/2005	567048.5	135698.9
B1D873	05/26/2005	06/02/2005	567048.5	135648.4
B1D874	05/26/2005	06/02/2005	567048.5	135598.4
B1D875	05/26/2005	06/02/2005	567048.5	135548.1
B1D876	05/26/2005	06/02/2005	567048.5	135527.1
B1D877	05/26/2005	06/02/2005	567048.5	135506.1
B1D878	05/26/2005	06/02/2005	567048.5	135485.1
B1D879	05/26/2005	06/02/2005	567048.5	135464.1
B1D880	05/26/2005	06/02/2005	567048.5	135443.2
B1D881	05/26/2005	06/02/2005	566998.9	135464.1
B1D882	05/26/2005	06/02/2005	566998.9	135485.1
B1D883	05/26/2005	06/02/2005	566998.9	135506.1
B1D884	05/26/2005	06/02/2005	566998.9	135527.1
B1D888	05/26/2005	06/02/2005	566904.2	135506.1
B1D889	05/26/2005	06/02/2005	566904.2	135527.1
B1D890	05/26/2005	06/02/2005	566904.2	135527.1
B1D891	05/26/2005	06/02/2005	566949.2	135527.1
B1D892	05/26/2005	06/02/2005	566949.2	135506.1
B1D893	05/26/2005	06/02/2005	566949.2	135485.1
B1D894	05/26/2005	06/02/2005	566949.2	135464.1
B1D895	05/26/2005	06/02/2005	566949.2	135443.2
B1D896	05/26/2005	06/02/2005	566949.2	135422.2
B1D897	05/26/2005	06/02/2005	566949.2	135422.2
B1D898	05/26/2005	06/02/2005	566998.9	135338.2
B1D899	05/26/2005	06/02/2005	566998.9	135359.2
B1D8B0	05/26/2005	06/02/2005	566998.9	135380.2
B1D8B1	05/26/2005	06/02/2005	566998.9	135401.2
B1D8B2	05/26/2005	06/02/2005	566998.9	135422.2

Table 2-5. Passive Soil-Vapor Locations Around Release Sites. (19 Pages)

Soil-Vapor Point	Sample Date		Easting* (m)	Northing* (m)
	Emplaced	Extracted		
B1D8B3	05/26/2005	06/02/2005	566998.9	135443.2
B1D8B4	05/26/2005	06/02/2005	566904.2	135422.2
B1D8B5	05/26/2005	06/02/2005	566904.2	135443.2
B1D8B6	05/26/2005	06/02/2005	566904.2	135464.1
B1D8B7	05/26/2005	06/02/2005	566904.2	135481.4
B1D8B8	05/26/2005	06/02/2005	566859.2	135485.1
B1D8B9	05/26/2005	06/02/2005	566814.2	135485.1
B1D8C0	05/26/2005	06/02/2005	566814.2	135464.1
B1D8C1	05/26/2005	06/02/2005	566814.2	135443.2
B1D8C2	05/26/2005	06/02/2005	566814.2	135422.2
B1D8C3	05/26/2005	06/02/2005	566859.2	135443.2

*Horizontal datum NAD83, Washington State Plane Coordinates, south zone.

NAD83, *North American Datum of 1983*.

Table 2-6. Cone Penetrometer Summary Around the 216-Z-9 Trench. (3 Pages)

Well ID	CPT Push	Date	Easting[a] (m)	Northing[a] (m)	Ground Elevation[b] (m)	Refusal Depth (m)
C4698	P1	01/7/05	566878.2	135334.5	NM	7.2
C4743	P1A	01/12/05	566878.24	135334.5	NM	7.6
C4699	P2	01/10/05	566764.4	135423.8	NM	12.6
C4744	P2A	01/12/05	566764.25	135422.4	NM	10.1
C4700	P3	01/10/05	566811.0	135515.1	NM	8.2
C4701	P4	01/11/05	566742.8	135561.0	NM	14.6
C4745	P4A	01/12/05	566744.33	135560.9	NM	14.6
C4702	P5	01/12/05	566794.2	135589.9	NM	8.7
C4703	P6	01/10/05	566778.2	135644.3	NM	17.2
C4746	P6A	01/12/05	566775.90	135642.4	NM	17.1
C4704	P7	01/11/05	566728.7	135644.1	NM	12.2
C4747	P7A	01/11/05	566731.16	135639.3	NM	12.3
C4763	P8A	04/14/05	566637.5	135733.2	205.8	16.2
C4777	P8B	04/28/05	566637.8	135732.9	205.8	15.7
C4778	P8C	04/28/05	566638.1	135733.8	205.8	15.4
C4762	P9A	04/14/05	566666.2	135709.5	204.5	19.6
C4779	P9B	04/28/05	566669.2	135707.0	204.6	13.3
C4787	P9C	05/03/05	566668.3	135706.7	204.6	12.4
C4788	P9D	05/03/05	566667.7	135706.7	204.6	13.4
C4789	P9E	05/03/05	566668.3	135707.3	204.6	17.7
C4790	P9F	05/03/05	566667.7	135707.6	204.6	11.5
C4764	P10A	04/15/05	566684.5	135748.5	205.5	35.4
C4791	P10B	05/03/05	566684.5	135749.1	205.5	2.3
C4792	P10C	05/04/05	566684.5	135749.4	205.5	15.5
C4793	P10D	05/04/05	566684.5	135750.3	205.5	15.7
C4794	P10E	05/04/05	566684.5	135748.2	205.5	15.5
C4760	P11A	04/13/05	566696.0	135707.6	204.7	22.5
C4795	P11B	05/04/05	566697.9	135707.9	204.4	13.7
C4761	P12A	04/13/05	566699.4	135667.1	204.4	23.8
C4776	P12B	04/27/05	566698.8	135667.7	204.4	19.4
C4796	P12C	05/04/05	566699.1	135666.8	204.4	2.1
C4753	P13A	04/08/05	566734.8	135680.8	204.0	22.3
C4803	P13B	05/06/05	566734.8	135681.1	204.0	11.2
C4804	P13C	05/06/05	566734.8	135682.0	204.0	15.8
C4754	P14A	04/08/05	566774.4	135679.9	203.1	13.8

Table 2-6. Cone Penetrometer Summary Around the 216-Z-9 Trench. (3 Pages)

Well ID	CPT Push	Date	Easting[a] (m)	Northing[a] (m)	Ground Elevation[b] (m)	Refusal Depth (m)
C4755	P14B	04/08/05	566775.0	135679.9	203.1	21.3
C4797	P14C	05/04/05	566775.9	135679.6	203.1	13.6
C4805	P14D	05/06/05	566776.5	135679.6	203.1	14.1
C4806	P14E	05/06/05	566775.0	135679.6	203.1	11.9
C4756	P15A	04/08/05	566815.2	135679.0	202.8	19.8
C4798	P15B	05/04/05	566812.2	135679.0	202.8	9.8
C4807	P15C	05/06/05	566813.7	135679.0	202.8	15.8
C4856	P17A	05/18/05	566764.6	135637.2	202.6	25.8
C4859	P17B	04/19/05	566763.7	135637.2	202.6	25.0
C4860	P17C	05/19/05	566762.8	135637.2	202.6	7.9
C4861	P17D	05/19/05	566762.2	135637.2	202.6	14.3
C4862	P17E	05/19/05	566762.8	135637.2	202.6	15.8
C4863	P17F	05/20/05	566764.0	135637.2	202.6	32.2
C4864	P17G	05/20/05	566764.6	135638.1	202.6	30.2
C4748	P18A	04/05/05	566796.9	135616.5	202.0	20.3
C4749	P18B	04/06/05	566795.4	135615.9	202.0	20.2
C4771	P18C	04/20/05	566795.4	135617.1	202.0	5.3
C4772	P18D	04/20/05	566795.1	135617.1	202.0	22.0
C4784	P18E	05/02/05	566796.6	135617.4	202.0	9.4
C4785	P18F	05/03/05	566796.6	135616.8	202.0	13.6
C4786	P18G	05/03/05	566796.3	135617.7	202.0	12.9
C4750	P19A	04/06/05	566814.3	135632.6	201.2	9.9
C4751	P19B	04/07/05	566814.9	135632.6	201.2	10.8
C4773	P19C	04/21/05	566816.1	135632.6	201.2	9.4
C4774	P19D	04/26/05	566816.7	135632.6	201.2	10.2
C4775	P19E	04/26/05	566817.4	135632.6	201.2	10.1
C4857	P20A	05/18/05	566746.9	135637.2	202.7	12.0
C4858	P20B	05/18/05	566746.6	135637.2	202.7	13.7
C4757	P21A	04/12/05	566725.6	135570.2	205.3	11.3
C4758	P21B	04/12/05	566725.6	135569.6	205.3	11.2
C4808	P21C	04/12/05	566725.9	135571.1	205.3	12.8
C4783	P21D	05/02/05	566725.6	135571.4	205.3	11.4
C4752	P22A	04/07/05	566776.2	135602.2	201.7	20.5
C4759	P22B	04/12/05	566777.1	135602.8	201.7	20.4
C4799	P22C	05/05/05	566777.1	135602.5	201.7	12.0

Table 2-6. Cone Penetrometer Summary Around the 216-Z-9 Trench. (3 Pages)

Well ID	CPT Push	Date	Easting[a] (m)	Northing[a] (m)	Ground Elevation[b] (m)	Refusal Depth (m)
C4800	P22D	05/05/05	566777.1	135601.9	201.7	15.5
C4801	P22E	05/05/05	566777.1	135601.3	201.7	16.6
C4802	P22F	05/05/05	566777.1	135600.6	201.7	18.6
C4809	P22G	05/16/05	566777.1	135603.4	201.7	21.4
C4768	P23A	04/19/05	566763.1	135571.4	204.4	27.1
C4769	P23B	04/19/05	566763.1	135570.5	204.4	13.1
C4770	P23C	04/20/05	566761.6	135570.5	204.4	12.2
C4780	P23D	05/02/05	566764.9	135571.1	204.4	12.2
C4781	P23E	05/02/05	566764.6	135570.5	204.4	17.6
C4782	P23F	05/02/05	566764.6	135571.4	204.4	9.7
C4810	P24A	05/17/05	566729.6	135618.6	204.6	17.0
C4811	P24B	05/17/05	566729.6	135619.5	204.6	13.6
C4812	P24C	05/17/05	566729.6	135620.2	204.6	13.1
C4813	P24D	05/18/05	566729.6	135621.1	204.6	13.4
C4765	P26A	04/18/05	566781.7	135514.4	203.3	13.0
C4766	P27A	04/18/05	566873.4	135330.9	204.5	8.6
C4767	P27B	04/18/05	566873.7	135333.9	204.5	7.7

[a]Horizontal datum NAD83, Washington State Plane Coordinates, south zone
[b]Vertical datum NAVD88.

NAD83, *North American Datum of 1983*.
NAVD88, *North American Vertical Datum of 1988*.

CPT = cone penetrometer.
ID = identification (number).
NM = not measured.

Table 2-7. Cone Penetrometer Summary Around the 216-Z-1A Tile Field. (3 Pages)

Well ID	CPT Push	Date	Easting[a] (m)	Northing[a] (m)	Ground Elevation[b] (m)	Refusal Depth (m)
C4906	P25A	07/27/05	566725.6	135531.5	203.8	12.85
C4907	P25B	07/27/05	566726.2	135531.5	203.8	13.30
C4905	P28A	07/27/05	566612.2	135410.1	207.8	23.70
C4866	P29A	07/19/05	566563.5	135409.2	204.9	20.30
C4867	P29B	07/20/05	566563.5	135408.3	204.9	27.61
C4917	P29C	08/02/05	566564.4	135409.2	204.9	18.95
C4918	P29D	08/02/05	566564.7	135408.3	204.9	16.20

Table 2-7. Cone Penetrometer Summary Around the 216-Z-1A Tile Field. (3 Pages)

Well ID	CPT Push	Date	Easting[a] (m)	Northing[a] (m)	Ground Elevation[b] (m)	Refusal Depth (m)
C4919	P29E	08/02/05	566564.1	135409.8	204.9	16.95
C4920	P29F	08/02/05	566564.1	135408.9	204.9	12.20
C4921	P29G	08/02/05	566564.1	135408.3	204.9	12.15
C4871	P30A	07/21/05	566532.1	135409.5	204.3	11.25
C4872	P30B	07/21/05	566532.1	135408.6	204.3	11.00
C4925	P30C	08/03/05	566531.8	135409.8	204.3	10.75
C4932	P30D	08/04/05	566531.8	135410.4	204.3	23.93
C4934	P30E	08/05/05	566530.8	135410.4	204.3	22.41
C4963	P30F	08/16/05	566531.2	135411.1	204.3	12.25
C4964	P30G	08/16/05	566531.2	135409.5	204.3	24.36
C4958	P30H	08/17/05	566531.2	135410.1	204.3	17.76
C4959	P30I	08/17/05	566531.2	135409.2	204.3	13.30
C4960	P30J	08/17/05	566532.7	135410.4	204.3	18.29
C4961	P30K	08/17/05	566533.0	135409.8	204.3	11.28
C4962	P30L	08/18/05	566531.2	135410.4	204.3	18.90
C4873	P31A	07/21/05	566530.5	135446.7	204.7	22.11
C4926	P31B	08/03/05	566530.2	135447.3	204.7	2.19
C4933	P31C	08/04/05	566531.2	135447.3	204.7	12.80
C4874	P32A	07/21/05	566501.9	135419.6	208.7	21.26
C4904	P32B	07/27/05	566501.6	135420.2	208.7	20.10
C4927	P32C	08/03/05	566500.7	135419.0	208.7	15.41
C4928	P32D	08/04/05	566501.0	135418.4	208.7	11.05
C4929	P32E	08/04/05	566500.7	135419.6	208.7	21.04
C4911	P33A	07/28/05	566471.7	135313.8	208.3	12.55
C4912	P33B	07/28/05	566471.7	135313.2	208.3	13.40
C4936	P33C	08/05/05	566471.4	135314.4	208.3	11.05
C4870	P34A	07/21/05	566531.2	135371.7	204.1	28.21
C4923	P34B	08/03/05	566532.1	135372.3	204.1	2.50
C4924	P34C	08/03/05	566531.8	135371.4	204.1	17.45
C4865	P35A	07/19/05	566561.0	135374.8	204.9	27.62
C4915	P35B	08/01/05	566561.6	135374.8	204.9	21.16
C4916	P35C	08/02/05	566561.6	135375.4	204.9	26.56
C4868	P36A	07/20/05	566561.0	135445.5	204.8	11.80
C4869	P36B	07/20/05	566561.0	135446.1	204.8	12.50
C4922	P36C	08/02/05	566561.3	135444.9	204.8	9.85
C4878	P37A	07/22/05	566587.2	135436.4	208.4	19.90

Table 2-7. Cone Penetrometer Summary Around the 216-Z-1A Tile Field. (3 Pages)

Well ID	CPT Push	Date	Easting[a] (m)	Northing[a] (m)	Ground Elevation[b] (m)	Refusal Depth (m)
C4879	P38A	07/25/05	566587.8	135397.6	207.4	27.21
C4935	P38B	08/05/05	566587.8	135398.3	207.4	26.06
C4880	P39A	07/25/05	566556.8	135353.8	206.8	12.35
C4897	P39B	07/25/05	566557.4	135353.8	206.8	12.35
C4903	P40A	07/26/05	566621.4	135462.0	207.8	20.10
C4908	P41A	07/28/05	566697.9	135448.5	204.2	13.25
C4909	P41B	07/28/05	566697.3	135449.2	204.2	13.65
C4910	P42A	07/28/05	566615.0	135337.3	206.6	21.10
C4875	P43A	07/22/05	566494.9	135360.2	208.7	24.80
C4898	P44A	07/25/05	566498.2	135385.2	209.4	22.36
C4930	P44B	08/04/05	566498.8	135385.2	209.4	21.34
C4899	P45A	07/25/05	566449.8	135432.1	209.0	15.00
C4900	P45B	07/26/05	566450.1	135431.5	209.0	15.55
C4876	P46A	07/22/05	566494.6	135480.2	208.0	11.90
C4877	P46B	07/22/05	566495.5	135480.2	208.0	12.70
C4901	P47A	07/26/05	566386.7	135423.9	208.6	0.35
C4902	P48A	07/26/05	566366.3	135484.5	209.7	23.20
C4931	P48B	08/04/05	566365.3	135485.1	209.7	22.87
C4913	P49A	08/01/05	566757.9	135586.9	203.4	14.25
C4914	P49B	08/01/05	566757.9	135586.3	203.4	16.20
C4939	P49C	08/12/05	566757.0	135585.4	203.4	9.76
C4940	P49D	08/12/05	566757.6	135585.4	203.4	14.75
C4941	P49E	08/15/05	566757.9	135585.4	203.4	0.55
C4942	P49F	08/15/05	566757.9	135585.4	203.4	12.40
C4943	P49G	08/15/05	566757.3	135585.1	203.4	15.15
C4944	P49H	08/15/05	566757.9	135585.1	203.4	13.75
C4945	P49I	08/15/05	566756.7	135584.2	203.4	13.51
C4946	P49J	08/16/05	566757.0	135584.2	203.4	11.05
C4956	P49K	08/16/05	566757.0	135584.2	203.4	14.30
C4957	P49L	08/16/05	566757.9	135584.2	203.4	13.50

[a]Horizontal datum NAD83, Washington State Plane Coordinates, south zone.
[b]Vertical datum NAVD88.

CPT = cone penetrometer.
ID = identification (number).

NAD83, *North American Datum of 1983*.
NAVD88, *North American Vertical Datum of 1988*.

Table 2-8. Hydraulic Hammer Rig Summary Around the 216-Z-9 Trench. (2 Pages)

Well ID	HHR Push	Date	Easting[a] (m)	Northing[a] (m)	Ground Elevation[b] (m)	Refusal Depth (m)
C5198	P51A	8/20/2006	566729.5	135604.5	204.9	36.9
C5199	P51B	8/21/2006	566729.4	135603.8	204.9	20.7
C5328	P51C	8/22/2006	566729.8	135603.1	204.9	28.7
C5329	P51D	8/28/2006	566729.4	135605.2	204.9	20.7
C5330	P51E	8/29/2006	566729.3	135605.7	204.9	31.7
C5331	P51F	8/31/2006	566729.2	135606.5	204.9	31.7
C5332	P51G	9/5/2006	566728.5	135604.5	204.9	36.0
C5333	P51H	9/21/2006	566728.6	135603.5	204.9	27.7
C5334	P51I	9/7/2006	566728.4	135605.7	204.9	35.1
C5200	P53A	8/15/2006	566777.1	135583.6	204.9	33.2
C5201	P53B	8/10/2006	566778.6	135583.5	204.9	20.1
C5240	P53C	8/14/2006	566777.9	135583.6	204.9	32.0
C5241	P53D	8/15/2006	566776.6	135583.6	204.9	19.2
C5242	P53E	8/16/2006	566775.6	135583.3	204.9	26.2
C5326	P53F	8/18/2006	566775.2	135583.3	204.9	29.3
C5327	P53G	8/17/2006	566774.6	135583.3	204.9	32.6
C5202	P54A	7/18/2006	566775.5	135603.1	202.4	33.2
C5203	P54B	7/17/2006	566775.5	135602.0	202.4	16.8
C5229	P54C	7/19/2006	566775.5	135601.0	202.4	28.7
C5230	P54D	7/20/2006	566776.5	135603.3	202.4	19.8
C5231	P54E	7/24/2006	566776.5	135604.3	202.4	25.6
C5232	P54F	7/24/2006	566775.3	135604.1	202.4	17.4
C5233	P54G	7/24/2006	566776.4	135602.4	202.4	17.4
C5234	P54H	8/2/2006	566776.7	135602.3	202.4	28.7
C5235	P54I	7/27/2006	566777.2	135604.2	202.4	19.8
C5236	P54J	7/28/2006	566777.0	135602.1	202.4	31.7
C5237	P54K	9/12/2006	566773.8	135602.7	202.4	17.8
C5238	P54L	8/8/2006	566774.1	135601.5	202.4	32.6
C5239	P54M	8/8/2006	566774.6	135602.2	202.4	33.8
C5204	P55A	6/8/2006	566745.7	135635.9	202.6	15.2
C5205	P55B	6/8/2006	566746.3	135635.9	202.6	19.5
C5221	P55C	6/8/2006	566746.6	135635.9	202.6	19.5
C5222	P55D	6/8/2006	566746.8	135635.9	202.6	19.5
C5223	P55E	6/27/2006	566747.5	135635.8	202.6	20.7
C5224	P55F	7/14/2006	566745.7	135636.6	202.6	25.6

Table 2-8. Hydraulic Hammer Rig Summary Around the 216-Z-9 Trench. (2 Pages)

Well ID	HHR Push	Date	Easting[a] (m)	Northing[a] (m)	Ground Elevation[b] (m)	Refusal Depth (m)
C5206	P56A	6/30/2006	566762.9	135635.1	203.2	26.8
C5207	P56B	7/3/2006	566762.4	135634.7	203.2	15.2
C5225	P56C	7/5/2006	566761.7	135635.1	203.2	29.9
C5226	P56D	7/6/2006	566760.9	135634.9	203.2	32.0
C5227	P56E	7/7/2006	566762.4	135635.4	203.2	32.9
C5228	P56F	7/10/2006	566761.9	135635.9	203.2	34.4
C5208	P66A	10/10/2006	566756.7	135586.8	204.2	35.4
C5336	P66B	10/23/2006	566755.8	135586.8	204.2	36.0
C5337	P66C	10/18/2006	566757.0	135585.8	204.2	18.6
C4937	P66D	10/19/2006	566754.8	135586.8	204.2	19.5
C5209	P67A	9/14/2006	566751.0	135581.5	204.2	33.2
C5335	P67B	10/6/2006	566751.2	135582.9	204.2	35.7
C5210	P68A	11/8/2006	566766.2	135584.9	203.9	34.9
C5339	P68B	11/16/2006	566765.2	135585.9	203.9	35.1
C5340	P68C	11/27/2006	566763.9	135586.4	203.9	19.7
C5211	P69A	11/27/2006	566745.1	135585.4	204.2	34.9
C5338	P69B	11/8/2006	566745.3	135587.1	204.2	35.9
C4938	P69C	11/13/2006	566746.6	135587.0	204.2	19.5

[a]Horizontal datum NAD83, Washington State Plane Coordinates, south zone.
[b]Vertical datum NAVD88.

HHR = hydraulic hammer rig.
ID = identification (number).

NAD83, *North American Datum of 1983*.
NAVD88, *North American Vertical Datum of 1988*.

Table 2-9. Geophysical Logging Conducted as Part of the Step II Investigation.

Well	Type of Geophysical Logging Conducted			Date Completed
	Spectral-Gamma Logging System	Passive-Neutron Logging System	Neutron-Moisture Logging System	
W15-82	Y	N	Y	08/10/2006
W15-85	Y	N	Y	02/07/2006
W15-218	Y	N	N	02/01/2006
W18-7	Y	N	N	01/20/2006
W18-9	Y	Y	Y	01/30/2006
W18-12	Y	N	Y	01/19/2006
W18-77	Y	N	N	07/13/2006
W18-80	Y	N	N	07/21/2006
W18-167	Y	Y	N	04/04/2006
W18-168	Y	Y	Y	07/17/2006
W18-169	Y	Y	Y	07/13/2006

N = No.
Y = Yes.

Table 2-10. Sampling Location Rationale in the Plutonium Finishing Plant Protected Area.

Well Identification Number	Temporary Sampling-Location Number*	Rationale
C4064	Z13	Investigation of the three French drains that received heating, ventilation, and air-conditioning condensate discharges.
C4066	Z14	
C4065	Z15	
C3879	17	Investigation of the drum-storage area. (NOTE: Two locations will be investigated per Table 3-3 in the sampling and analysis plan [DOE/RL-2001-01, Appendix C], because no shallow soil-vapor sampling will be conducted.)
C3877	24	
C4060	6	Investigation of the liquid-waste discharge pipeline to the 216-Z-1A Tile Field liquid-waste discharge site.
C4059	15	
C3494 (W15-764)	25	Investigation of the liquid-waste discharge pipeline to the 216-Z-9 Trench liquid-waste discharge site. (NOTE: The soil-vapor sampling was conducted during drilling of well 299-W15-764 [Borehole C3494].)
C4059	15	Investigation of liquid-waste discharges to unplanned release site UPR-200-W-103.
C4061	4	Investigation of liquid-waste discharge pipeline to the 216-Z Ditches system.
C4060	6	Investigation of liquid-waste discharges to the 241-Z-361 Settling Tank.
C3876	7	
C4068	28	Investigation near location of groundwater well 299-W15-16.
C4062	2	Investigation of southwest portion of Plutonium Finishing Plant Protected Area.
C4067	11	
C4063	20	
C4136	55	Investigation of northern portion of Plutonium Finishing Plant Protected Area.
C4137	46	
C4138	48	
C3878	26	Investigation of carbon tetrachloride tank storage area.

*Based on Figure 1 in the supplement to the SAP in DOE/RL-2001-01, *Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan, Includes: 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*, Appendix C, p. C-84.

Table 2-11. Guzzler/GeoProbe Boreholes within the Plutonium Finishing Plant Facility Area. (2 Pages)

Well ID	Temporary Number*	Guzzler Total Depth (ft bgs)	Ground Surface	Guzzler Operation Date	GeoProbe Total Depth (ft)	Sample Intervals (ft bgs)		Sample Date
C3876	7	5	Gravel	07/23/03	34.2	14	14.5	08/19/03
						23.7	25	08/18/03
						33.2	34.2	08/18/03
C3877	24	7.6	Gravel	07/23/03	46.7	15	15.6	08/20/03
						24.4	27.3	08/20/03
						45.8	46.5	08/20/03
C3878	26	7.5	Asphalt	07/24/03	45.4	14	14.5	08/18/03
						25	25.5	08/18/03
						43.6	44.2	08/18/03
C3879	17	8	Asphalt	07/24/03	41.3	13.1	13.8	08/19/03
						25	27	08/19/03
						40.3	41.1	08/19/03
C4059	15	8.1	Gravel	07/24/03	42.9	15.5	17.6	08/20/03
						23.8	24.6	08/20/03
						41.7	42.8	08/20/03
C4060	6	8	Gravel	07/24/03	36	13.5	14	08/22/03
						25	25.5	08/22/03
						35	35.5	08/22/03
C4061	4	8	Gravel	07/24/03	36.5	15.5	16.5	08/25/03
						24	25	08/25/03
						35.5	36.5	08/25/03
C4062	2	8	Gravel	07/24/03	31	14	14.7	08/26/03
						24	25	08/26/03
						30	31	08/26/03
C4063	20	8	Gravel	07/24/03	42.2	13.5	15.3	08/26/03
						22.8	23.3	08/26/03
						41.4	42.2	08/26/03
C4064	Z-13	6.9	Gravel	07/25/03	28.5	14	14.5	08/21/03
						27.3	28.5	08/21/03
C4065	Z-15	7.3	Asphalt	07/25/03	44	15	16	08/25/03
						22.2	23.2	08/25/03
						43	44	08/25/03
C4066	Z-14	8	Asphalt	07/25/03	40	14.5	15	08/21/03
						24.5	25.5	08/21/03
						39	40	08/21/03
C4067	11	8	Gravel	07/25/03	39	15.5	17.5	08/28/03
						24.3	25.3	08/28/03
						38	39	08/28/03
C4068	28	8	Gravel	07/25/03	32	14.3	14.8	08/26/03
						25	26	08/26/03
						31	32	08/26/03

Table 2-11. Guzzler/GeoProbe Boreholes within the Plutonium Finishing Plant Facility Area. (2 Pages)

Well ID	Temporary Number*	Guzzler Total Depth (ft bgs)	Ground Surface	Guzzler Operation Date	GeoProbe Total Depth (ft)	Sample Intervals (ft bgs)		Sample Date
C4136	55	7.7	Gravel	07/28/03	36	15.5	16.5	08/27/03
						23.5	25	08/27/03
						35	36	08/27/03
C4137	46	7.9	Gravel	07/28/03	38.5	14	14.5	08/27/03
						24.8	25.3	08/27/03
						37.3	38.3	08/27/03
C4138	48	8	Asphalt	07/28/03	47.5	14.5	15.5	08/28/03
						22	25	08/28/03
						46.5	47.5	08/28/03

*Based on Figure 1 in the supplement to the SAP in DOE/RL-2001-01, *Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan, Includes: 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*, Appendix C, p. C-84.

GeoProbe is a registered trademark of GeoProbe Systems, Salina, Kansas.

bgs = below ground surface.
ID = identification (number).

Table 2-12. Passive Soil-Vapor Survey at the 218-W-3A Burial Ground.

Field Sample Point	Date Emplaced	Date Extracted	HEIS Number	Northing* (m)	Easting* (m)
T9S-1	06/30/2005	07/05/2005	B1DDX4	136876.562	566220.983
T9S-2	06/30/2005	07/05/2005	B1DDW5	136876.374	566099.286
T9S-3	06/30/2005	07/05/2005	B1DDW6	136876.397	566114.498
T9S-4	06/30/2005	07/05/2005	B1DDW7	136876.421	566129.710
T9S-5	06/30/2005	07/05/2005	B1DDW8	136876.444	566144.923
T9S-6	06/30/2005	07/05/2005	B1DDW9	136876.468	566160.135
T9S-7	06/30/2005	07/05/2005	B1DDX0	136876.491	566175.347
T9S-8	06/30/2005	07/05/2005	B1DDX1	136876.515	566190.559
T9S-9	06/30/2005	07/05/2005	B1DDX2	136876.538	566205.771
T9S-9D	06/30/2005	07/05/2005	B1DDX3	136876.538	566205.771
T9S-10	06/30/2005	07/05/2005	B1DDX5	136876.585	566236.196
T06-1	06/30/2005	07/05/2005	B1DDY8	137047.617	566266.356
T06-2	06/30/2005	07/05/2005	B1DDX6	137046.446	566099.024
T06-3	06/30/2005	07/05/2005	B1DDX7	137046.470	566114.236
T06-4	06/30/2005	07/05/2005	B1DDX8	137046.493	566129.448
T06-5	06/30/2005	07/05/2005	B1DDX9	137046.505	566137.054
T06-6	06/30/2005	07/05/2005	B1DDY0	137046.540	566159.872
T06-7	06/30/2005	07/05/2005	B1DDY1	137046.563	566175.085
T06-8	06/30/2005	07/05/2005	B1DDY2	137046.587	566190.297
T06-9	06/30/2005	07/05/2005	B1DDY3	137046.610	566205.509
T06-10	06/30/2005	07/05/2005	B1DDY4	137046.634	566220.721
T06-10D	06/30/2005	07/05/2005	B1DDY5	137046.634	566220.721
T06-11	06/30/2005	07/05/2005	B1DDY6	137046.657	566235.933
T06-12	06/30/2005	07/05/2005	B1DDY7	137046.681	566251.146

*Horizontal datum NAD83, Washington State Plane Coordinates, south zone.

NAD83, *North American Datum of 1983*.

HEIS = *Hanford Environmental Information System* database.

Table 2-13. Wells Identified for Soil-Vapor and Groundwater Sampling at the Groundwater Hot-Spot Areas. (2 Pages)

Groundwater Hot-Spot Location [a]	Associated Potential Release Site	Well	Depth to Groundwater (ft Below Top of Casing)		Depth to Bottom (ft Below Top of Casing)	Screen Interval (ft)	Length of Screen Above Water Table (ft)	Length of Screen Below Water Table (ft)
1. 299-W10-20	218-W-3A Burial Ground	299-W10-19	N/A[b]	09/06/05	238.3	214.4 – 234.5	20.1	0
		299-W10-20	240.1	09/19/05	245.2	221.7 – 241.6	18.4	1.5
		299-W10-21	229.7	09/19/05	232.2	209.3 – 229.3	20	0
2. T Tank Farm	T Tank Farm	299-W10-1	234.5	08/29/05	302.8	190 – 270	44.5	35.5
		299-W10-4	228.6	09/26/05	238.8	190 – 245	38.6	16.4
		299-W10-8	238.7	08/25/05	250.7	211 – 251	27.7	12.3
		299-W10-23	260.0	09/19/05	261.2	225.8 – 260.9	34.2	0.9
		299-W10-24	243.8	09/20/05	268.4	232.9 – 268.0	11	24.1
		299-W11-28	N/A[b]	08/25/05	247.4	224.0 – 244.9	20.9	0
		299-W11-40	243.5	11/23/05	272.2	238.1 – 273.1	5.4	29.6
		299-W11-41	245.9	09/26/05	273.7	236.7 – 271.7	9.2	25.8
		299-W11-42	247	09/30/05	273.8	236.8 – 271.8	10.2	24.8
3. T Plant	218-W-8 Burial Ground; T Plant	299-W11-3	279.9	10/11/05	287.8	254 – 267	13	0
						277 – 287.8	0	10.8
		299-W11-7	268.4	09/27/05	274.5	245 – 290	23.4	21.6
		299-W11-14	277.0	06/21/06	276.9	250 – 313	27	36
		299-W11-37	285.6	09/27/05	294.3	260.2 – 291.3	25.4	5.7
4. 299-W11-10	T Plant	299-W11-10	293.8	08/30/05	300.3	256 – 304	37.8	10.2
5. 216-T-25 Trench	216-T-25 Trench, 218-W-1 and 218-W-2 Burial Grounds, TX-TY Tank Farms	299-W10-5	229.1	08/30/05	241.1	175 – 220	45	0
		299-W15-40	226	06/22/05	256.4	218.0 – 253.1	8	27.1
		299-W15-43	229	06/23/05	266.2	226.4 – 261.4	2.6	32.4
		299-W15-765	224	06/22/05	259.2	220 – 255	4	31

Table 2-13. Wells Identified for Soil-Vapor and Groundwater Sampling at the Groundwater Hot-Spot Areas. (2 Pages)

Groundwater Hot-Spot Location [a]	Associated Potential Release Site	Well	Depth to Groundwater (ft Below Top of Casing)		Depth to Bottom (ft Below Top of Casing)	Screen Interval (ft)	Length of Screen Above Water Table (ft)	Length of Screen Below Water Table (ft)
6. 299-W15-15	218-W-4B and 218-W-4C Burial Grounds	299-W15-14	205.3	08/30/05	219.9	unknown	unknown	unknown
		299-W15-15	250.6	09/26/05	252.8	223 – 255	27.6	4.4
7. 299-W15-16	218-W-4C Burial Grounds	299-W15-16	N/A[b]	09/29/05	243.5	208 – 238	30	0
		299-W15-17	239.5	09/29/05	432.3	422.5 – 432.5	0	10
		299-W15-30	240.7	09/29/05	263.5	218.1 – 258	22.6	17.3
		299-W15-31A	236.1	09/22/05	255.6	212.5 – 252.4	27	12.9
8. West of S-SX Tank Farms	216-S-25 Crib, S-SX Tank Farm	299-W18-15	217	09/22/05	239.4	170 – 243	47	26
		299-W23-4	218.2	06/21/06	249.7	180 – 300	38.2	81.8
		299-W23-10	221.3	09/22/05	223.4	165 – 178	13	0
						186 – 230	35.3	8.7
		299-W23-15	213	09/22/05	unknown	185.7 – 222.4	27.3	9.4

[a] See Figure 2-35 for locations.
[b] Well is dry.

N/A = not applicable.

Table 2-14. Wells for Depth-Discrete Groundwater Sampling.

Groundwater Hot-Spot Area	Well Selected for Depth-Discrete Groundwater Sampling
1	The key well, 299-W10-20, does not have sufficient water for depth-discrete sampling.
2	Sample well 299-W11-42. The water table was estimated to be at 245 ft in this well in July 2005, and the well was estimated to have 35 ft of water. Sample at 5 ft and 10 ft below the static water level. Well 299-W11-25B, which was drilled adjacent to well 299-W11-39, was sampled at depth-discrete intervals every 20 ft below the water table to the Ringold Formation lower mud unit during drilling in February 2005.
3	The key well, 299-W11-14, does not have sufficient water for depth-discrete sampling.
4	Sample well 299-W11-10. The water table was estimated to be at 291.8 ft in this well in July 2005, and the well was estimated to have 8.5 ft of water. Sample at 4 ft and 8 ft below the static water level.
5	Three key wells, 299-W15-40, 299-W15-43, and 299-W15-765, were sampled at depth-discrete intervals by Vista Engineering in January 2005.
6	The key well, 299-W15-15, does not have sufficient water for depth-discrete sampling.
7	One key well, 299-W15-30, was sampled at depth-discrete intervals by Vista Engineering in February 2005.
8	Sample well 299-W23-4. The water table was estimated to be at 219.6 ft in this well in July 2005, and the well was estimated to have 30 ft of water. Sample at 5 ft, 15 ft, and 25 ft below the static water level.

Table 2-15. Passive Soil-Vapor Survey at T Plant.

Field Sample Point	Date Emplaced	Date Extracted	HEIS Number	Northing* (m)	Easting* (m)
1	05/26/2005	06/01/2005	B1D831	136649.526	567282.987
2	05/26/2005	06/01/2005	B1D832	136711.219	567280.699
2-DUP	05/27/2005	06/01/2005	B1D833	136711.219	567280.699
3	05/26/2005	06/01/2005	B1D834	136773.152	567278.338
4	05/26/2005	06/01/2005	B1D830	136651.385	567332.916
5	05/26/2005	06/01/2005	B1D829	136713.139	567330.624
6	05/26/2005	06/01/2005	B1D828	136774.991	567328.305
7	05/26/2005	06/01/2005	B1D827	136821.135	567326.585
8	05/26/2005	06/01/2005	B1D841	136653.306	567382.895
9	05/26/2005	06/01/2005	B1D842	136714.999	567380.553
10	05/26/2005	06/01/2005	B1D837	136776.836	567378.26
11	05/26/2005	06/01/2005	B1D822	136826.816	567376.448
12	05/26/2005	06/01/2005	B1D835	136876.722	567374.605
13	05/26/2005	06/01/2005	B1D836	136926.721	567372.741
14	05/26/2005	06/01/2005	B1D840	136655.161	567432.823
15	05/26/2005	06/01/2005	B1D839	136716.921	567430.538
16	05/26/2005	06/01/2005	B1D838	136778.67	567428.242
17	05/26/2005	06/01/2005	B1D821	136828.635	567426.403
18	05/26/2005	06/01/2005	B1D823	136882.567	567424.36
19	05/26/2005	06/01/2005	B1D824	136928.569	567422.671
20	05/26/2005	06/01/2005	B1D820	136780.452	567478.24
21	05/26/2005	06/01/2005	B1D819	136831.224	567477.041
22	05/26/2005	06/01/2005	B1D826	136881.144	567474.477
23	05/26/2005	06/01/2005	B1D825	136931.083	567471.891
24	05/26/2005	06/01/2005	B1D818	136880.144	567524.500
25	05/26/2005	06/01/2005	B1D817	136941.083	567524.500
26	05/26/2005	06/01/2005	B1D843	136684.475	567592.72
27	05/26/2005	06/01/2005	B1D844	136725.14	567621.875
28	05/26/2005	06/01/2005	B1D845	136765.79	567650.983
28-DUP	05/27/2005	06/01/2005	B1D846	136765.79	567650.983
29	05/26/2005	06/01/2005	B1D847	136806.422	567680.069
30	05/26/2005	06/01/2005	B1D848	136847.085	567709.192

*Horizontal datum NAD83, Washington State Plane Coordinates, south zone.

HEIS = *Hanford Environmental Information System* database.

NAD83, *North American Datum of 1983*.

Table 2-16. Soil-Vapor Samples Collected During Fiscal Year 2001 to Fiscal Year 2006 Well Drilling. (2 Pages)

Well Name	Well Identification Number	SAF	Reference	Location	Date Sampled	Comment
299-W10-25	C4987	F05-003	SGW-33829	East of 218-W-3A Burial Ground	April 2006	Casing deviated; replaced by well 299-W10-31 (C5194) during drilling
299-W10-31	C5194	F05-003	SGW-33829	East of 218-W-3A Burial Ground	April 2006	Replacement for well 299-W10-25 (C4987)
299-W11-47	C4990	F05-003	SGW-33829	East of T Tank Farm	January-February 2006	
299-W11-86	C5101	F05-003	SGW-33829	East of T Plant	June 2006	Well damaged during completion; replaced by well 299-W11-87 (C5407)
299-W14-71	C5102	F05-003	SGW-33829	North of U Plant	August-September 2006	
299-W14-72	C5103	F05-003	SGW-33829	East of 200 W Powerhouse Ponds	September 2006	
299-W15-224	C4986	F05-003	SGW-33829	East of 218-W-4B Burial Grounds	February 2006	
299-W15-42	C3803	B01-115	BHI-01631	East of PFP	November 2001 – January 2002	
299-W15-43	C3955	F05-003	SGW-33829	West of TX Tank Farm	June 2005	
299-W15-49	C4301	F03-022	SGW-33829	Northeast of 218-W-4B Burial Ground	November 2004	
299-W15-50	C4302	F03-022	SGW-33829	North of 216-Z-9 Trench, south of 216-T-19 Crib and Tile Field	January 2005	
299-W15-764	C3494	B01-115	BHI-01631	East of PFP by 216-Z-9 Trench effluent lines	October 2001	
299-W15-84	A7384	B01-088	BHI-01631	216-Z-9 Trench	June 2001	Existing well deepened

Table 2-16. Soil-Vapor Samples Collected During Fiscal Year 2001 to Fiscal Year 2006 Well Drilling. (2 Pages)

Well Name	Well Identification Number	SAF	Reference	Location	Date Sampled	Comment
299-W15-94	C4684	F05-003	SGW-33829	East of 218-W-4C Burial Ground	September 2005	
299-W15-95	A7394	B01-088	BHI-01631	216-Z-9 Trench	May - June 2001	Existing well deepened
299-W18-16	C4303	F03-022	SGW-33829	East of 216-Z-1A Tile Field	November 2004	
C3102	C3102	B01-097	BHI-01606	216-T-26 Crib	July 2001	
C3808	C3808	B02-053	CP-12134	216-Z-11 Ditch	May 2002	
C4183	C4183	F05-003	D&D-25461	216-Z-7 Crib	March 2005	
C4738	C4738	F03-022	SGW-33829	216-T-33 Crib	February 2005	

BHI-01606, *Borehole Summary Report for Borehole C3102 in the 216-T-26 Crib, 200-TW-1 Scavenged Waste Group Operable Unit.*

BHI-01631, *Carbon Tetrachloride Field Investigation Report for Drilling in the Vicinity of the PFP and the 216-Z-9 Trench.*

CP-12134, *Borehole Summary Report for Borehole C3808 in the 216-Z-11 Ditch, 200-CW-5 U-Pond/Z-Ditches Cooling Water Group Operable Unit.*

D&D-25461, *200-LW-1 and 200-LW-2 Operable Units - Borehole Summary for Boreholes in the 216-S-20, 216-T-28, and 216-Z-7 Cribs.*

SGW-33829, *200-PW-1 Operable Unit Report on Step II Sampling and Analysis of the Dispersed Carbon Tetrachloride Vadose Zone Plume.*

HEIS = *Hanford Environmental Information System* database.
PFP = Plutonium Finishing Plant.
SAF = Sampling Authorization Form (number).

Table 2-17. 1991 Active Soil-Vapor Sample Locations Around the 216-Z-1A Tile Field/216-Z-18 Crib Areas.

Point ID	Sample Date	Easting* (m)	Northing* (m)
Z18S-1	03/14/1991	566438.5	135244.3
Z18C-1	03/14/1991	566437.9	135284.6
Z18E-1	03/14/1991	566488.2	135284.6
Z18E-2	03/14/1991	566498.5	135284.6
Z18E-3	03/14/1991	566515.3	135326.6
Z18N-1	03/14/1991	566430.9	135327.2
Z18N-10	03/14/1991	566389.1	135419.9
Z18N-11	03/14/1991	566430.9	135474.2
Z18N-12	03/14/1991	566389.1	135475.1
Z18N-2	03/14/1991	566488.8	135333.6
Z18N-3	03/14/1991	566430.9	135350.7
Z18N-4	03/14/1991	566389.1	135336.1
Z18N-5	03/14/1991	566488.8	135367.8
Z18N-6	03/14/1991	566513.2	135367.8
Z18N-7	03/14/1991	566430.9	135409.2
Z18N-8	03/14/1991	566389.1	135369.6
Z18N-9	03/14/1991	566389.1	135396.1
Z18W-1	03/14/1991	566390.3	135284.6
Z18W-2	03/14/1991	566371.7	135320.5
Z18W-3	03/14/1991	566357.1	135318.7
Z18W-4	03/14/1991	566364.1	135284.6
Z18W-5	03/14/1991	566364.4	135365.9

*Horizontal datum NAD83, Washington State Plane Coordinates, south zone.

NAD83, *North American Datum of 1983*.

ID = identification number.

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3.0 REMEDIAL INVESTIGATION RESULTS

This chapter describes the hydrogeologic framework in the Plutonium/Organic-Rich Group OU and the nature and extent of contamination at the six representative and unique waste sites and for the dispersed carbon tetrachloride vadose-zone plume evaluated during the RI. The information presented in this chapter consists of site-specific data (e.g., geologic logs, soil and soil-vapor sampling results) collected during the RI and existing information derived from DOE/RL-98-28, DOE/RL-2001-01, and other 200 Areas and site-specific reports.

3.1 HYDROGEOLOGIC FRAMEWORK

This section summarizes the geology and hydrogeology associated with the 200 Areas inclusive of the Plutonium/Organic-Rich Group OU. Additional information on the hydrogeologic setting of the OU can be found in the Implementation Plan (DOE/RL-98-28, Appendix F), the Work Plan (DOE/RL-2001-01, Section 2.1), and other documents as cited in the text.

3.1.1 Topography

The 200-PW-1, 200-PW-3, and 200-PW-6 OUs include wastes sites located in the 200 East and 200 West Areas of the Hanford Site. The 200 Areas are located on a broad, relatively flat area that constitutes a local topographic high commonly referred to as the 200 Areas Plateau (Figure 3-1). The plateau is a giant flood bar (Cold Creek Bar) that was formed during cataclysmic ice-age floods from glacial Lake Missoula. The flood bar may have started forming during the earliest floods 1 to 2 million years ago. The Cold Creek Bar trends generally east-west, with elevations between 197 and 225 m (647 to 740 ft). The plateau drops off rather steeply to the north and east into a former flood channel that runs east-southeast with elevation changes of between 15 and 30 m (50 and 100 ft). The plateau gently decreases in elevation to the south into the Cold Creek valley. Most of the 200 West Area and the southern half of the 200 East Area are situated on the Cold Creek Bar, while the northern half of the 200 East Area lies on the edge of a former flood channel. A secondary flood channel running south from the main channel bisects the 200 West Area. The buried former river and flood channels may provide preferential pathways for contaminant movement in the vadose zone and groundwater. More detail on the physical setting of the 200 Areas and vicinity is provided in the Implementation Plan, Appendix F (DOE/RL-98-28).

Waste sites in the 200 West Area are situated on a relatively flat area within the secondary flood channel that bisects the 200 West Area. Surface elevations range from approximately 201 to 217 m (660 to 712 ft). Waste-site surface elevations in the 200 East Area range from about 189 m (620 ft) in the northern portion to about 220 m (720 ft) in the southern portion. The ground surface in the 200 East Area slopes gently to the northeast.

3.1.2 Geology Summary

The 200 East and 200 West Areas of the Hanford Site are located within the Pasco Basin, a relatively large depression in southeastern Washington. Over the last 16 million years, the basin filled with materials that form rocks (i.e., volcanic lava flows) and unconsolidated sediments (e.g., silt, sand, gravel). Beneath the ground surface, major geologic units of interest (from oldest to youngest) include the Elephant Mountain Member basalt of the Saddle Mountains Basalt Formation, Columbia River Basalt Group, Ringold Formation, CCU, Hanford formation, and surficial deposits (Figure 3-2).

Basalt is a volcanic rock extruded from the earth during volcanic events. The Elephant Mountain Member basalt is the uppermost basalt unit encountered beneath the 200 East and 200 West Areas of the Hanford Site and generally has been the deepest geologic unit penetrated by RIs. The basalt is laterally continuous beneath the 200 East and 200 West Areas except for a relatively small area north of the 200 East Area boundary, where the basalt is not found because it most likely was removed by subsequent erosion.

The Ringold Formation is a semiconsolidated to unconsolidated sedimentary deposit. It consists of heterogeneous deposits of clay, silt, sand, gravel, and cobbles deposited by old rivers and lakes after the basalt was deposited. The Ringold Formation is important to the study area, because typically it is the unit where groundwater is located in the 200 West Area. Wells drilled to sample groundwater typically are completed within the Ringold Formation.

Above the Ringold Formation, the CCU is encountered. The CCU comprises old river, windblown, and soil deposits. The main divisions of the CCU are the lower caliche and the upper silt. Caliche generally comprises ancient soil in which minerals have leached to lower soil horizons. The leached minerals, typically calcium carbonate, accumulate in the lower horizons and cement the soil grains together, forming a "hardpan" layer. The CCU caliche within the study area typically contains calcium carbonate cement and other materials such as sand, silt, and clay in a hardened matrix. However, the presence and amount of calcium carbonate cement is variable, so the physical properties of this unit vary from "soil like" to "rock like." The CCU is an important unit in the study area, because these finer grained geologic deposits impede the vertical migration of liquid and contaminants in the subsurface beneath the waste site. The CCU generally is absent beneath the 200 East Area because of nondeposition or erosion subsequent to deposition.

The Hanford formation is found beneath the study area above the CCU, or above the Ringold Formation where the CCU is not present. The Hanford formation comprises heterogeneous mixtures of silt, sand, gravel, cobbles, and boulders deposited during Pleistocene (Ice Age) floods. Clastic dikes can be present within the Hanford formation. Clastic dikes are subvertical intrusions of sediment into overlying or underlying sediments. The clastic dikes also may impede or enhance the migration of liquid and contaminants in the subsurface. Within the Hanford formation are localized lenses of silt and very fine sands (i.e., fine-grained deposits) that also influence the movement of liquids and contaminants in the subsurface. The Hanford formation is important to the study area, because it is the geologic unit directly beneath the waste sites that contamination passed through to reach the CCU and groundwater.

Overlying the Hanford formation are surficial deposits that mostly comprise windblown (eolian) silt and sand. Fill material also was placed at some locations within the 200 East and 200 West Areas and consists of reworked Hanford formation sediments.

A simplistic model of contaminant transport (i.e., movement) in the subsurface beneath the 200 East and West Areas would consist of liquid materials being disposed of on or below the ground surface. The contamination then percolates through the unconsolidated sediments (i.e., the Hanford formation, CCU, and upper Ringold Formation units) and ultimately to the groundwater. The unsaturated geologic materials above the groundwater collectively are referred to as the vadose zone. Transport of contamination within the vadose zone is a relatively complex process influenced by the physical and chemical properties of both the soil and contamination.

Some of the contamination in the liquid disposed of at the ground surface (e.g., carbon tetrachloride) can evaporate (volatilize) at the ground or during vertical movement through the soil. The remaining contamination moves vertically through the vadose zone. However, as the contamination passes through the different (heterogeneous) geologic layers in the vadose zone, it spreads out in all directions (disperses) based on the soil and contamination properties. When contamination encounters finer grained materials (silt layers and the CCU), the contamination spreads out laterally until a vertical pathway is found that allows the contamination to continue to move vertically downward. When the contamination reaches the water table, it disperses and moves with the groundwater. Groundwater flow beneath the 200 East and 200 West Areas is generally toward the Columbia River.

Because of the different depths and the varying material properties of the geologic units beneath the 200 East and 200 West Areas, various subsurface access methods were used to reach different depths and achieve the sampling goals at the different waste sites investigated for this RI. These subsurface access methods are described in this RI report. In general, percussion probe drilling technology (i.e., GeoProbe) is used to reach depths of less than 15 m (50 ft) bgs. CPT was used to reach depths of about 23 m (75 ft) bgs. The HHR, EAPS, and drilling technologies (e.g., sonic or cable tool drilling) were used to reach the CCU and the deeper vadose zone down to the groundwater.

3.1.3 Geology

The 200-PW-1, 200-PW-3, and 200-PW-6 OUs are located in the Pasco Basin, one of several structural and topographic basins of the Columbia Plateau. Basalts of the Columbia River Basalt Group and a sequence of suprabasalt sediments underlie the representative waste sites and the dispersed carbon tetrachloride vadose-zone plume. From oldest to youngest, the major geologic units of interest are the Elephant Mountain Member of the Saddle Mountains Basalt Formation, Columbia River Basalt Group, the Ringold Formation, the CCU, the Hanford formation, and surficial deposits. Figure 3-3 shows a generalized stratigraphic column for the 200 Areas.

Elephant Mountain Member. The Elephant Mountain Member of the Saddle Mountains Basalt Formation, Columbia River Basalt Group is the uppermost basalt unit (i.e., bedrock) in the 200 Areas (DOE/RL-98-28, Appendix F). Except for a small area north of the 200 East Area

boundary where it has been eroded away, the Elephant Mountain Member is laterally continuous throughout the 200 Areas. The RI field investigations did not penetrate to the basalt.

Ringold Formation. The Ringold Formation consists of an interstratified fluvial-lacustrine sequence of unconsolidated to semiconsolidated clay, silt, sand, and granule-to-cobble gravel deposited by the ancestral Columbia River (PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System 200-East Area and Vicinity, Hanford Site, Washington*, and PNNL-13858). These sediments, shown in Figure 3-3, consist of four major units (from oldest to youngest): the fluvial gravel and sand of Unit 9 (basal coarse); the buried soil horizons, overbank, and lake deposits of Unit 8 (lower mud); the fluvial sand and gravel of Unit 5 (upper coarse); and the lacustrine mud of Unit 4 (upper fines). Units 9 and 5 consist of silty-sandy gravel with secondary lenses and interbeds of gravelly sand, sand, and muddy sands to silt and clay. Unit 8 (lower mud) consists mainly of silt and clay. Unit 4 (upper fines) consists of silty over-bank deposits and fluvial sand. Units 6 and 7 are not present beneath the 200 West and East Areas; Unit 4 is not present in the 200 East Area, and it is discontinuous in the 200 West Area (PNNL-12261 and PNNL-13858). The two RI boreholes at the 216-Z-9 Trench penetrated into the Ringold Formation Unit 5. The RI borehole at the 216-A-8 Crib penetrated into Ringold Unit 9. Boreholes drilled as part of the carbon tetrachloride dispersed-plume investigation also penetrated into the Ringold Formation Unit 9.

Cold Creek unit. The CCU includes several post-Ringold Formation and pre-Hanford formation units present beneath a portion of the 200 East and West Areas (DOE/RL-2002-39, *Standardized Stratigraphic Nomenclature for Post-Ringold Formation Sediments Within the Central Pasco Basin*). The CCU includes the sediments formerly identified as the Plio-Pleistocene unit, caliche, early Palouse soil, pre-Missoula gravels, and sidestream alluvial facies in previous site reports. The CCU has been divided into five lithofacies: fine-grained, laminated to massive (fluvial-overbank and/or eolian deposits, formerly the early Palouse soil); fine- to coarse-grained, calcium-carbonate cemented (calcic paleosol, formerly the caliche); coarse-grained, multilithic (mainstream alluvium, formerly the pre-Missoula gravels); coarse-grained, angular, basaltic (colluvium); and coarse-grained, rounded, basaltic (sidestream alluvium, formerly sidestream alluvial facies) (DOE/RL-2002-39). The two RI boreholes at the 216-Z-9 Trench penetrated the CCU. At the 216-Z-9 Trench, the CCU is present from about 33 to 36 m (108.27 to 118.11 ft) depth and consists of two distinct layers. The upper silt layer is about 2.5 m (8.2 ft) thick, and the lower "caliche" layer is about 0.5 m (1.64 ft) thick and varies from gravel, sand, and silt with a calcium carbonate cemented matrix. The RI borehole drilled to investigate the 216-A-8 Crib did not encounter the CCU, because it is not present in the vicinity of the 216-A-8 Crib.

Hanford formation. The Hanford formation is the informal stratigraphic name used to describe the Pleistocene cataclysmic flood deposits in the Pasco Basin (DOE/RL-2002-39). The Hanford formation consists predominantly of unconsolidated sediments that range from boulder-size gravel to sand, silty sand, and silt. The sorting ranges from poorly sorted (for gravel facies) to well sorted (for fine sand and silt facies). The Hanford formation is divided into three main facies associations: interbedded sand- to silt-dominated (formerly called the Touchet beds or slackwater facies); sand-dominated (formerly called the sand-dominated flood facies); and gravel-dominated (formerly called the Pasco gravels), which have been further subdivided into 11 textural-structural lithofacies (DOE/RL-2002-39). Beneath the representative waste sites, and

where carbon tetrachloride has migrated beyond the boundaries of the known carbon tetrachloride disposal sites, the Hanford formation includes all three facies associations. The gravel-dominated facies are cross-stratified, coarse-grained sands and granule-to-boulder gravel. The gravel is uncemented and matrix-poor. The sand-dominated facies are well-stratified fine- to coarse-grained sand and granule gravel. Silt in these facies is variable and may be interbedded with the sand. Where the sand and silt content is low in the gravel-dominated facies, an open-framework texture is common. Clastic dikes are common in the Hanford formation but rare in the Ringold Formation (DOE/RL-98-28; DOE/RL-2002-39). They appear as vertical to subvertical sediment-filled structures, especially within sand- and silt-dominated units. The two RI boreholes at the 216-Z-9 Trench and the RI borehole at the 216-A-8 Crib penetrated into the Hanford formation. In general, from shallowest to deepest, the Hanford formation units encountered beneath the 200 West Area included an upper fines unit (HFUF), the upper gravel-dominated sequence (H1), a sand-dominated sequence (H2), and a lower gravel-dominated sequence (H3). Not all of these units are laterally continuous beneath the waste sites.

The cataclysmic floodwaters that deposited sediments of the Hanford formation locally reshaped the topography of the Pasco Basin. The floodwaters deposited a thick sand and gravel bar (Cold Creek Bar) that constitutes the higher southern portion of the 200 Areas, informally known as the 200 Areas Plateau. In the waning stages of the ice-age floods, these floodwaters also eroded a channel north of the 200 Areas in the area currently occupied by West Lake and the former Gable Mountain Pond. Both pre-Hanford formation erosion and the floodwaters removed all of the Ringold Formation from this area and deposited Hanford formation sediments directly over basalt.

Surficial Deposits. Surficial deposits include Holocene eolian sheets of sand that form a thin veneer over the Hanford formation across the site, except in localized areas where the deposits are absent. Surficial deposits consist of very fine- to medium-grained sand to occasionally silty sand. Silty deposits less than 1 m (approximately 3 ft) thick also have been documented at some open trench waste sites where fine-grained, windblown material settled out through standing water over many years (DOE/RL-98-28, Appendix F). Fill material was placed in and over some waste sites during construction and for contamination control. The fill consists of reworked Hanford formation sediments and/or surficial sand and silt.

3.1.4 Hydrostratigraphy

The focus of this RI was on the distribution of contaminants within the vadose zone beneath the representative waste sites and within the dispersed carbon tetrachloride vadose-zone plume. Vadose-zone hydrostratigraphic units in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs include the Ringold Formation, the CCU, the Hanford formation, and surficial deposits (see Figure 3-3). The base of the unconfined aquifer typically is the top of the Ringold Formation Unit 8 (lower mud) at the 200 West Area and the top of the basalt (Elephant Mountain Member) at the 200 East Area.

Vadose Zone. The vadose zone is the area between the ground surface and the water table. The vadose zone is approximately 104 m (340 ft) thick in the southern section of the 200 East Area

and thins to the north to as little as 0.3 m (1 ft) near West Lake (just south of the west end of Gable Mountain in Figure 3-1). Sediments in the vadose zone are dominated by the Hanford formation, although the CCU and part of the Ringold Formation are above the water table in the 200 West Area. Because erosion during cataclysmic flooding removed much of the Ringold Formation north of the central part of the 200 East Area, the vadose zone is dominantly composed of Hanford formation sediments between this area and Gable Mountain. The basalt also projects above the water table in the northern part of the 200 East Area.

In the 200 West Area, the vadose-zone thickness ranges from 40 to 75 m (132 to 246 ft). Sediments in the vadose zone are the Ringold Formation, the CCU, and the Hanford formation. Erosion during cataclysmic flooding removed some of the CCU and the Ringold Formation, especially in the northern part of the 200 West Area.

Historically, and as recently as the early 1990s, perched water has been documented above the CCU at locations in the 200 West Area. While liquid-waste disposal facilities were operating, localized areas of saturation or near saturation were created in the soil column. With the reduction of artificial recharge in the 200 Areas in 1995, downward flux of liquid in the vadose zone beneath these waste sites has been decreasing. However, moisture content in the vadose zone is expected to remain elevated above preoperational conditions for some time.

A limited number of soil samples were collected to determine moisture content, grain-size distribution, bulk density, and specific gravity. The physical-property testing data collected during the RI is summarized in Appendix B.

Unconfined Aquifer. The top of the unconfined aquifer in the 200 Areas occurs within the Ringold Formation, the CCU, or the Hanford formation, depending on location. The base of the unconfined aquifer is the top of the Ringold Formation Unit 8 (lower mud), or the top of the basalt where Unit 8 is absent at the 200 West Area, and the top of the basalt at the 200 East Area. Groundwater in the unconfined aquifer flows from recharge areas where the water table is higher (west of the Hanford Site) to areas where it is lower, near the Columbia River (PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*). In the northern half of the 200 East Area, the water table is present within the Hanford formation, except in areas where basalt extends above the water table. In the central and southern sections of the 200 East Area, the water table is located near the contact between the Ringold Formation and the Hanford formation.

Depth to groundwater in the 200 East Area and vicinity ranges from about 54 m (177 ft) near the B Pond to about 104 m (340 ft) near the southern boundary of the 200 East Area. The water table across the 200 East Area is very flat (Figure 3-4), making it difficult to determine groundwater flow direction based on water-level measurements from monitoring wells. The configuration of contaminant plumes, however, indicates that groundwater flows to the northwest in the northern half of the 200 East Area and to the east/southeast in the southern half of the 200 East Area. Identifying the specific location of the groundwater divide between the northern and southern sections is hampered by the flat water table. The transmissive Hanford formation sediments are the cause of the flat water table in the 200 East Area (PNNL-15670).

The water table has been declining since surface liquid discharges were terminated in the 200 East Area in the mid-1990s. In the 200 East Area, the elevation of the water table declined by an average of 0.13 m (0.4 ft) from March 2004 to March 2005. This is greater than the previous annual decline (0.09 m [0.3 ft] from March 2003 to March 2004) and is below the average rate of decline observed from June 1997 to March 2002 (0.17 m/yr [0.56 ft/yr]) (PNNL-15670).

Groundwater beneath the 200 West Area occurs primarily in the Ringold Formation. Depth to water varies from about 40.2 m (132 ft) to greater than 75 m (246 ft). In the 200 West Area, groundwater in the unconfined aquifer typically flows from west to east (Figure 3-5). The surface elevation of the water table beneath the 200 West Area currently is declining at a rate of 0.36 m/yr (1.2 ft/yr) in those areas not influenced by pump-and-treat remediation systems (PNNL-15670).

Recharge to the unconfined aquifer within the 200 Areas is from artificial sources and, less significantly, from natural precipitation. According to estimates, 1.7 trillion L (450 billion gal) of liquid waste, some containing radionuclides and hazardous chemicals, have been released to the ground on the Hanford Site since 1944. Much of this contamination remains above the water table, but some reached groundwater (DOE/RL-2002-68, *Hanford's Groundwater Management Plan: Accelerated Cleanup and Protection*). Most sources of artificial recharge were terminated in 1995. The artificial recharge that does continue largely is limited to liquid discharges from sanitary sewers, two state-approved land-disposal structures (one east of the 200 East Area and one north of the 200 West Area), and 140 small-volume, uncontaminated miscellaneous liquid discharge streams.

3.1.5 Summary of Hydrogeologic Conditions at Representative Waste Sites

3.1.5.1 216-Z-1A Tile Field

The 216-Z-1A Tile Field is located in the 200 West Area within a north-south secondary flood channel. The surface elevation around this site is approximately 207 m (679 ft). Stratigraphic units of interest are, in descending order, the Hanford formation, the CCU, and the Ringold Formation Unit 5. The top of the unconfined aquifer is in the silty sandy gravels of Ringold Formation Unit 5, and the base of the aquifer is the top of Ringold Formation lower mud (Unit 8). The stratigraphy in the vicinity of the 216-Z-1A Tile Field is based on the borehole log from well 299-W18-7 (presented in Figure 3-6), located adjacent to the tile field. The Hanford formation upper gravel-dominated sequence (H1) was encountered from the ground surface to approximately 18 m (59 ft) bgs, underlain by the Hanford formation sand-dominated sequence (H2, 18 to 29 m [59 to 95 ft] bgs), the Hanford formation lower gravel-dominated sequence (H3, 29 to 37 m [95 to 121 ft] bgs), the CCU silt and caliche units from approximately 37 to 42 m [121 to 138 ft] bgs, and the gravelly Ringold Formation Unit 5, below 42 m (138 ft) bgs.

Groundwater beneath the 216-Z-1A Tile Field is approximately 71 m (234 ft) bgs, based on nearby well 299-W18-16 on December 2004. The stratigraphy generally is consistent with the borehole logs from other wells within and adjacent to the tile field.

3.1.5.2 216-Z-9 Trench

The 216-Z-9 Trench is located in the 200 West Area within a north-south secondary flood channel. The surface elevation of this site is approximately 201 m (660 ft). Stratigraphic units of interest are, in descending order, the Hanford formation, the CCU, and the Ringold Formation Unit 5. The top of the unconfined aquifer is in the silty sandy gravel of Ringold Formation Unit 5, and the base of the aquifer is the top of Ringold Formation lower mud (Unit 8). The stratigraphy shown in Figure 3-7 is based on the borehole log from well 299-W15-46, which was drilled on the south side of the trench for this RI. The upper 1.2 m (4 ft) of this well encountered backfill material used for drill-pad construction, which comprised crushed rock, sand, and silt. Below the drill-pad fill, fine-grained sands and silts of the Hanford formation upper fines (HFUF) were encountered to a depth of 6 m (20 ft). Below the HFUF, to a depth of 10.5 m (34.5 ft), the sediments encountered were the upper gravels of the Hanford formation (H1). These sediments were dark gray fine-to-coarse sand and gravelly sand. The interval from 10.5 to 33 m (34.5 to 108.5 ft) bgs consisted of sediments from the sand-dominated sequence of the Hanford formation (H2). A layer of dense, well-compacted, dark brown silt was encountered from 19.8 to 20.4 m (65 to 67 ft) bgs. The interval from 33 to 36.1 m (108.5 to 118.5 ft) bgs consisted of the CCU. Dense, well-compacted, dark brown silt and sand comprising the upper silt-dominated facies of the CCU was encountered from 33 to 35.5 m (108.5 to 116.5 ft) bgs. The CCU caliche was encountered from 35.5 to 36.1 m (116.5 to 118.5 ft) bgs. The interval from 36.1 to 69.5 m (118.5 to 228 ft) bgs consisted of grayish brown sandy gavel with variable silt, sand, and sandy gravel of the Ringold Formation Unit 5. In November 2004, the water table was measured at 68 m (223 ft) bgs (WMP-26264). The stratigraphy generally is consistent with the borehole logs from other wells adjacent to the trench.

Figure 3-8 shows the stratigraphy from the slant well (299-W15-48) drilled at the 216-Z-9 Trench for this RI.

3.1.5.3 241-Z-361 Settling Tank

The 241-Z-361 Settling Tank is located approximately 35 m (115 ft) north of the 216-Z-1A Tile Field in the 200 West Area. The surface elevation and hydrogeologic conditions at this representative waste site are the same as those for the adjacent 216-Z-1A Tile Field (Section 3.1.5.1).

3.1.5.4 216-A-8 Crib

The 216-A-8 Crib is located approximately 177 m (580 ft) east of the A Tank Farm in the 200 East Area, at a surface elevation of approximately 198 m (650 ft). The stratigraphic unit of interest is the Hanford formation. The top of the unconfined aquifer is in the Ringold Formation Unit 9, and the base of the aquifer is the top of the basalt. The stratigraphy shown in Figure 3-9 is based on the log from Borehole C4545, which was drilled through the crib for this RI. The upper portion of Borehole C4545 encountered 0.5 m (1.5 ft) of crushed rock, used to construct the drill pad, overlying the crib construction backfill consisting of 1.4 m (4.5 ft) of gravelly sand, 2.1 m (7.0 ft) of sand, and 1.8 m (6.0 ft) of very coarse gravel. The interval beneath the crib construction backfill, extending from 5.8 to 54.3 m (19.0 to 178.0 ft) bgs, consists of well-stratified, very fine- to coarse-grained sands belonging to the sand-dominated sequence of

the Hanford formation (H2). Several intervals within Hanford formation (H2) contain finer grained silty sands. The interval from 54.3 to 74.8 m (178.0 to 245.5 ft) bgs consists of the gravel-dominated sequence of the Hanford formation (H3). These gravels consist of poorly sorted, angular to sub-rounded heterolithic cobbles (basalts and other dominantly igneous lithologies). The interval from 74.8 to 80.6 m (245.5 to 264.5 ft) bgs (total depth) consists of sandy gravels of the Ringold Formation Unit 9. These sediments consist of clast- to matrix-supported pebble (2 to 64 mm [0.008 to 2.5 in.]) to cobble (64 to 256 mm [2.5 to 10 in.]) heterolithic gravels with a fine- to coarse-grained sandy matrix. Lenticular sand and silt interbeds also are characteristic of the Ringold Formation Unit 9. The stratigraphy underlying the 216-A-8 Crib is shown in Figure 3-9. The stratigraphy generally is consistent with the borehole logs from other wells adjacent to the crib. Groundwater beneath the 216-A-8 Crib was about 80 m (261.7 ft) bgs at Borehole C4545 in June 2005.

3.1.5.5 216-Z-8 French Drain

The 216-Z-8 French Drain is located approximately 93 m (305 ft) northwest of the 216-Z-9 Trench in the 200 West Area. The surface elevation and hydrogeologic conditions at this waste site are the same as those for the adjacent 216-Z-9 Trench (Section 3.1.5.2).

3.1.5.6 216-Z-10 Injection/Reverse Well

The 216-Z-10 Injection/Reverse Well is approximately 30.5 m (100 ft) east of the 231-Z Building in the 200 West Area. The 216-Z-10 Injection/Reverse Well also has been known as the 231-W Reverse Well, 231-W-151 Dry Well or Reverse Well, 231-Z Well, 299-W15-51, 231-W-150, and 216-Z-2. The surface elevation is approximately 204 m (670 ft).

Well 299-W15-59 is located 4.6 m (15 ft) from the 216-Z-10 Injection/Reverse Well. At well 299-W15-59 the borehole geophysics reported the CCU fine-grained sediment between 35 and 37.5 m (115 and 123 ft). Between 37.8 and 42.1 m (123 and 138 ft) results are characteristic of the carbonate paleosols of the CCU. The Ringold formation is present from 42.1 m (138 ft) to groundwater (DOE-EM/GJ918-2005, *Log Data Report for 299-W15-59 (A7360)*). Groundwater beneath the 216-Z-10 Injection/Reverse Well was approximately 58.8 m (193 ft) bgs at nearby well 299-W15-1, in 1945, and was 68.6 m (225 ft) bgs at well C4183 in April 2005. Well C4183 is 116 m (380 ft) east of the 216-Z-10 Injection/Reverse Well.

3.2 OPERABLE UNIT CONTAMINATION

The data evaluation and data summary tables for the RI data collected at well 299-W15-46, well 299-W15-48, and Borehole C4545 are presented in Appendix B.

3.2.1 Nature and Extent of Contamination in the 216-Z-9 Trench

The nature and extent of contamination summarized in this section are representative of the 216-Z-9 Trench in the 200-PW-1 OU. The nature and extent of contamination at this location are based on the evaluation of all available data. Available data for this representative waste site

include historical and new geophysical logging results, new soil and soil-vapor sampling results, numerical-simulation results, and other data-collection and -analysis results. The data and analysis were integrated to develop and refine a contaminant distribution model for the representative waste site.

The following provides a summary of important RI findings related to the 216-Z-9 Trench.

- Approximately 58 kg (128 lb) of plutonium were removed from the 216-Z-9 Trench as part of trench floor mining activities completed from 1976 to 1978. An estimated 48 kg (106 lb) of plutonium remains in the trench.
- The highest concentrations of plutonium and americium are located at the trench floor and generally decrease with depth below the floor.
- Radioactive contamination was identified in several boreholes using geophysical logging methods. The contamination was detected to a maximum depth of 59.4 m (195 ft) bgs.
- Radioactive contamination in soil samples was detected to a maximum depth of 37.2 m (122 ft) bgs.
- Soil-vapor samples collected from boreholes drilled in the vicinity of the trench revealed carbon tetrachloride and other organic vapors at concentrations up to 20,910 ppmv in 1993. This is 17 percent of the soil-vapor concentration, indicating carbon tetrachloride saturation in the vadose zone.
- Soil samples from boreholes near the 216-Z-9 Trench revealed carbon tetrachloride DNAPL in soil up to 380,000 µg/kg in well 299-W15-46 from 19.4 to 20.1 m (63.5 to 66 ft bgs). At HHR push location Borehole C5336 (P66), adjacent to this well, the maximum carbon tetrachloride DNAPL detected in soil was 390,000 µg/kg. Maximum concentrations of COPCs detected in soil samples are summarized in Section 3.2.1.3.
- An SVE system has been operated near the 216-Z-9 Trench as an interim remedial action. Between March 1993 and September 2006, approximately 54,280 kg of carbon tetrachloride were removed from the 216-Z-9 well field, and soil-vapor concentrations measured in the RI boreholes were significantly less than pre-SVE operation concentrations.
- In general, the highest concentrations of COPCs detected in the vadose-zone soils have been in fine-grained layers (i.e., silts).
- Geophysical methods were used to map and contour the surface of key geologic layers beneath the trench. The subsurface contours of these layers were used to guide the HHR soil-sampling investigation of the CCU for carbon tetrachloride DNAPL.

3.2.1.1 Historical Contaminant Investigation Summary

Between 1954 and 1967, nine wells were drilled around the 216-Z-9 Trench. Scintillation probe profiles were completed on each of the borings at least once between 1963 and 1970, and

at least once more between 1973 and 1976. Contamination was detected in two borings (wells 299-W15-8 and 299-W15-86) at 15.2 to 38.1 m (49.5 to 125 ft) bgs. The profiles are available in ARH-ST-156, *Evaluation of Scintillation Probe Profiles from 200 Area Crib Monitoring Wells.*

Sampling for the collection of data necessary to evaluate the mass of plutonium in the trench was conducted through the trench roof during 1959, 1961, and 1963. Concern over the potential for a critical mass accumulation of plutonium on the floor of the trench prompted an additional sampling event through the trench roof during 1973. The maximum depth of penetration for these samples was 3 m (9 ft) below the trench floor. Both plutonium and americium were found in relatively high concentrations from the bottom of the trench to total depth (Tables 3-1 and 3-2). Samples from the bottom of the trench to 15 cm (6 in.) below the floor yielded Pu-239 concentrations of up to 1.2×10^{12} pCi/L and Am-241 concentrations of up to 1.4×10^{11} pCi/L. At a depth of 3 m (9 ft), Pu-239 and Am-241 concentrations were 2.0×10^{9} pCi/L and 1.4×10^{8} pCi/L, respectively. ARH-2915 reports that the soil pH was 4.1 at a depth of 2.4 m (8 ft) and generally acidic through the 3 m (9-ft) soil column tested below the base of the trench. Details of the sampling are found in ARH-2915. The uppermost 30 cm (12 in.) of the trench floor subsequently were excavated in 1976 (RHO-ST-21). See Section 2.1.3 for a discussion of mining results.

Radioactive contamination was identified in two borings during geophysical logging of borings proximal to the trench, well 299-W15-8 in 1992 and well 299-W15-95 in 1998. Geophysical logging of well 299-W15-8 revealed Cs-137 from 15.2 to 59.4 m (50 to 195 ft) bgs (never exceeding 1 pCi/g), Pa-233 between 15.5 and 37 m (51 and 121 ft) bgs (maximum activity was 20 pCi/g at 35 m [115 ft]) bgs, and Pu-239 from 15.1 to 32.3 m (50 to 106 ft) bgs (maximum activity of 300,000 pCi/g was detected 15.5 m [51 ft] bgs) (WHC-SD-EN-TI-021, *Results of Spectral Gamma-Ray Logging of Select Boreholes for the 200 Aggregate Area Management Study*). Geophysical logging of well 299-W15-95 detected Cs-137 near the ground surface at an activity of <1 pCi/g (PNNL-11978, *Results of 1998 Spectral Gamma-Ray Monitoring of Boreholes at the 216-Z-1A Tile Field, 216-Z-9 Trench, and 216-Z-12 Crib*). Geophysical logging of well borings 299-W15-82, 299-W15-84, and 299-W15-85 in 1998 did not detect any artificial radionuclides (PNNL-11978). However, it appears that americium was misinterpreted as Cs-137 in the geophysical logs. A discussion of the borehole geophysics is provided in Section 3.2.4.1. No deep vertical borings have been drilled through the footprint of the trench because of its design. The trench is an open enclosure nearly 6.4 m (21 ft) in depth at the maximum, with a concrete slab roof supported by six columns. Low levels of plutonium and americium were detected in groundwater from well 299-W15-8 on May 7, 1990, and November 13, 1991, before the groundwater table declined below the elevation of the bottom of the well and the well went dry.

Analyses of soil samples from borings completed during 1992 and 1993 (wells 299-W15-216, 299-W15-217, 299-W15-218, 299-W15-219, 299-W15-220, and 299-W15-223) and deepened in 2001 (wells 299-W15-84 and 299-W15-95) indicate that radioactive contaminants are present within two intervals of one well near the southwest edge of the trench (WHC-SD-EN-TI-063). Well 299-W15-217, approximately 12 m (39 ft) west of the trench, contains two lead and two radium isotopes, along with gross alpha and gross beta contamination; maximum concentrations of metals and gross alpha are found at depths of 35.3 and 37.1 m (116 and 122 ft) bgs, and

maximum concentrations of gross beta are found at 16.6 m (54.5 ft) bgs. Groundwater samples collected from the southernmost well (well 299-W15-216) contained Co-60 (maximum of 2.19 pCi/L), Ru-106 (maximum of 29.5 pCi/L), Sb-125 (maximum of 6.84 pCi/L), and Cs-137 (maximum of 3.47 pCi/L). These contaminants could have been in the inventory from the 216-Z-9 Trench, although there are no direct data to support that conclusion.

During drilling of wells 299-W15-216, 299-W15-217, 299-W15-218, 299-W15-219, 299-W15-220, and 299-W15-223, soil-vapor and soil samples were collected for analyses of VOCs (carbon tetrachloride and associated breakdown products). Soil-vapor and soil samples also were collected from wells 299-W15-84 and 299-W15-95 when these wells were deepened in 2001. The highest carbon tetrachloride vapor concentrations detected within these boreholes were from well 299-W15-217 (7,126 ppmv from a depth of 24.7 m [81 ft]) and well 299-W15-218 (20,910 ppmv from a depth of 34 m [111.8 ft], and 10,380 ppmv from a depth of 57.8 m [189.7 ft]). The highest concentrations of carbon tetrachloride detected in the soil samples were from well 299-W15-217 (37,817 µg/kg at a depth of 34.7 m [114 ft]), from well 299-W15-218 (15,794 µg/kg from a depth of 33.5 m [110 ft]), and from well 299-W15-219 (11,688 µg/kg from a depth of 34.9 m [114.5 ft]). The highest concentrations of carbon tetrachloride in soil vapor and soil generally were associated with finer grained units (i.e., Hanford formation silts and the CCU) within the vadose zone. These results are further discussed in Section 3.2.4.8.

An SVE system was installed in March 1993 and operated from that time to the present in the vicinity of the 216-Z-9 Trench. Between March 1993 and September 2006, approximately 54,280 kg of carbon tetrachloride were removed from the 216-Z-9 well field by the SVE system (SGW-33746). Soil-vapor samples collected during operation of the SVE demonstrate that soil-vapor concentrations in the vicinity of the 216-Z-9 Trench have been decreasing over time. Soil-vapor sampling activities are summarized in Section 2.5.

3.2.1.2 New Geophysical Logging Summary

As part of the investigation activities completed during drilling of wells 299-W15-46 and 299-W15-48, geophysical logging using the SGLS was performed. The geophysical log data reports are included in Appendix E of WMP-26264 and Appendix D of WMP-30566, and the key findings are summarized below.

Well 299-W15-46 (Borehole C3426)

Protactinium-233, Am-241, and Pu-239 were the man-made radionuclides detected in borehole well 299-W15-46. No man-made radionuclides were detected below 36.6 m (120 ft). Protactinium-233, a decay product of Np-237, was detected between 14.3 and 36.6 m (47 and 120 ft) with a maximum concentration of approximately 100 pCi/g at 36 m (118 ft).

Americium-241 was detected from 14 to 18.6 m (46 to 61 ft), at concentrations ranging from 56,000 to 145,000 pCi/g. It also was detected almost continuously from 19.2 to 36 m (63 to 118 ft) at concentrations ranging from just above the minimum detectable level of approximately 20,000 to 400,000 pCi/g; the maximum concentration is measured at 35.4 m (116 ft).

Plutonium-239 was detected between 14.3 and 15.5 m (47 and 51 ft), with a maximum concentration of approximately 284,000 pCi/g at 14.6 m (48 ft). It also was detected almost continuously between 16.8 and 26.2 m (55 and 86 ft) at concentrations ranging from approximately 27,000 to 221,000 pCi/g; the maximum concentration is measured at 19.8 m (65 ft). Plutonium-239 also was detected at 33.5 and 35.4 m (110 and 116 ft) at concentrations of 41,000 and 58,000 pCi/g, respectively.

The passive neutron detector indicated elevated count rates between 14 and 36 m (46 and 118 ft). The highest count rates (4 to 5 counts per second) are detected at approximately 14.6, 33.5, and 35.4 m (48, 110, and 116 ft). At these depths Am-241, Pu-239, and Pa-233 also are detected. It is possible that these radionuclides and perhaps other isotopes of plutonium exist continuously throughout the relatively high-neutron count-rate interval (14 to 36 m [46 to 118 ft]) even where no isotope was identified at levels above the respective minimum detectable level.

Well 299-W15-48 (Borehole C3427)

Protactinium-233, Am-241, Pu-239, and Pu-241 were the man-made radionuclides detected in well 299-W15-48; Pu-240 also is inferred to exist. Protactinium-233, a decay product of Np-237, was detected between 15.2 and 38.7 m (50 and 127 ft) downhole (12.9 to 32.8 m or 42.4 to 107.7 ft vertical depth) with a maximum concentration of approximately 29 pCi/g at 40 m (118 ft) downhole (30.5 m or 100.1 ft vertical).

Americium-241 was detected from 15.5 to 37.2 m (51 to 122 ft) downhole (13.2 to 31.5 m or 43.3 to 103.5 ft vertical) at concentrations ranging from 40,000 to 245,000 pCi/g; the maximum concentration is measured at 36.9 m (121 ft) downhole (31.3 m or 102.6 ft vertical). Low-energy gamma rays attributed to Am-241 were detected that normally would be severely attenuated by the 17/32-in.-thick steel and 1/4-in.-thick polyvinyl chloride casings in the borehole during the logging and by the borehole geophysical-tool housing itself. The fact that these gamma rays consistently were detected indicated that the source most likely originates inside the steel casing as a result of internal contamination from the drilling/sampling process. The internal contamination extends at least from approximately 9.8 m (32 ft) downhole to the bottom of the borehole at 43.9 m (144 ft) downhole (8.3 to 37.2 m or 27.1 to 122.1 ft vertical).

Plutonium-239 generally was detected between 15.5 and 37.2 m (51 and 122 ft) downhole (13.2 to 31.5 m or 43.3 to 103.5 ft vertical). The dominant interval is between 18.9 and 26.5 m (62 and 87 ft) downhole (16 to 22.5 m or 52.6 to 73.8 ft vertical) with a maximum concentration of approximately 657,000 pCi/g at 22 m (72 ft) downhole (18.6 m or 61.1 ft vertical).

Because separation of the Pu-240 and Pu-241 isotopes is very difficult, it is virtually certain that they will exist together in the waste stream. The maximum Pu-240 activity in this borehole could be estimated near 40,000 pCi/g. Because of the absence of a relatively high-yielding gamma ray from Pu-240, no direct measurement with the SGLS can be made.

Plutonium-241 concentrations are estimated to range between 2 and 10 pCi/g. This concentration is not determined directly, so the uncertainty is greater than for other radionuclides.

Because this borehole is known to be internally contaminated, probably on the inside of the steel casing, and the activity of this contamination cannot be quantified, it should be presumed that all the identified radionuclides could exist to some degree inside the casing. The effect of this internal contamination is to cause a slight overestimation of radionuclide concentrations.

The passive neutron detector indicated elevated count rates between 14.3 and 37.5 m (47 and 123 ft) downhole (12.2 to 31.8 m or 39.9 to 104.3 ft vertical). The highest count rates (4 counts per second) are detected where the highest Pu-239 concentrations are measured at approximately 19.2 m (63 ft) downhole (16.3 m or 53.4 ft vertical) and 21.3 m (70 ft) downhole (18.1 m or 59.4 ft vertical); at these depths Am-241 and Pa-233 also are detected. This count rate is considerably lower (4 vs 2,600 counts per second) than observed in other PFP waste-disposal sites such as the 216-Z-1A Tile Field and the 216-Z-12 Crib. This suggests that the compounds in the 216-Z-9 Trench are in the form of nitrates or oxides rather than fluorides, as postulated for the other PFP waste-disposal sites. Fluorine has a cross section for capturing alpha particles that is 100 times greater than that for the other light elements.

3.2.1.3 New Soil Analytical Results Summary

The soil samples collected during the drilling of wells 299-W15-46 and 299-W15-48 at the 216-Z-9 Trench were not analyzed for DBP, monobutyl phosphate (MBP), or DBBP, because analytical methods were not available. Instead, the concentrations of TBP, phosphate, and phosphorus were measured with the intent to use these results to evaluate for the presence of DBP, MBP, and DBBP.

The approach of the evaluation was to compare the concentration of phosphate in the sample to the concentration of phosphate in the TBP. The following method was used to compare these concentrations.

The molecular weight of TBP is 266.313. Phosphorus is 11.63 percent of the molecular weight of TBP. The phosphate anion is 35.66 percent of the molecular weight of TBP. If the phosphate result is analyzed as phosphate, multiply the TBP value by 0.3566 to get the equivalent concentration of phosphate. If the phosphate result is analyzed as phosphorus, multiply the TBP value by 0.1163 to get the equivalent concentration of phosphorus. The difference between the phosphate result and the phosphate in TBP is either inorganic phosphates or DBP/MBP. Similarly, the difference between the phosphorus result and the phosphorus in TBP is either inorganic phosphates or DBP/MBP.

The results of the calculations for samples from wells 299-W15-46 and 299-W15-48 with detections of TBP and phosphorus are presented in Tables 3-3 and 3-4, respectively. None of the samples had detections of phosphate, with the exception of two samples from well 299-W15-48. These two samples were not considered for this evaluation, because phosphate also was detected in the associated blanks.

Based on the results, it appears that trying to use inorganic phosphate data for evaluation is not viable, because the inorganic phosphate method does not detect very much of the phosphate from TBP. This may reflect the fact that TBP is not very soluble, and the organic-phosphorus bonds would need to be broken for the inorganic analytical methods to account for the phosphate.

Comparison between total phosphorus and the phosphorus in TBP was used as the primary method to evaluate the presence of DBP, MBP, and DBBP. In samples from well 299-W15-46, the difference between the total phosphorus and the phosphorus in TBP ranged from approximately 350,000 to 500,000 µg/kg. In samples from well 299-W15-48, the difference ranged from approximately 550,000 to 700,000 µg/kg. These concentrations fall within the nominal range for normal soil background levels for phosphorus. Although phosphorus background levels tend to be location-specific and have not been established for the Hanford Site, existing data indicate a nominal range of approximately 600,000 to 1,100,000 µg/kg (R. Weiss, personal communication [*Conversion of TBP Results*]). Because the phosphorus that is present in the sample and is not accounted for by the TBP falls within the range for soil background, it cannot be concluded that it indicates the presence of DBP, MBP, and/or DBBP. When the estimated soil backgrounds are included in the evaluations, no significant discrepancies are seen between total phosphorus results and reported TBP values.

In addition, because DBP, MBP, and DBBP are contaminants or degradation products of TBP, they are likely to be detectable only when the soil sample has higher concentrations of TBP contamination. Three samples from each of these two wells contained enough TBP to be likely candidates for detection of DBP, MBP, or DBBP: samples B17N46, B17TM6, and B17N52 from well 299-W15-46 (Table 3-3) and samples B1HK27, B1HK32, and B1HK52 from well 299-W15-48 (Table 3-4). If present in significant quantities, DBP, MBP, and likely DBBP should show up as tentatively identified compounds in the semivolatile organic analyte analysis used for TBP. However, none of these compounds were identified as tentatively identified compounds in these samples. Therefore, the significant presence of DBP, MBP, and/or DBBP in these samples is unlikely.

Well 299-W15-46

Radioactive COPCs for the 200-PW-1 OU were detected in the vadose zone at the 216-Z-9 Trench in Borehole C3426 (well 299-W15-46) to a depth of 57 m (186.3 ft) bgs. Background levels for the 200-PW-1 OU radionuclide COPCs are shown in Table 3-5. Only the background values for naturally occurring radionuclides in subsurface soils were used to screen the RI results. The maximum results for the Borehole C3426 samples are presented in Appendix A and are summarized in the following table, which presents the radionuclide COPCs detected above background levels (and those with no available background value) and the depth interval of the maximum concentration.

Radionuclide Contaminant of Potential Concern	Maximum Concentration (pCi/g)	Depth Interval (ft bgs)	
		Top	Bottom
Americium-241	309,000	109.5	112
Neptunium-237	28.9	109.5	112
Plutonium-238	657	109.5	112
Plutonium-239/240	115,000	63.5	66
Radium-228	2.79	109.5	112
Strontium-89,90	13.4	63.5	66
Technetium-99	18	47.5	50
Uranium-234	11.8	48.5	50
Uranium-235	0.13	119.5	122

Background levels for the 200-PW-1 OU nonradionuclide COPCs are shown in Table 3-6. The following table presents the nonradionuclide COPCs detected above background levels (and those with no available background value) and the depth interval of the maximum concentration.

Contaminant of Potential Concern	Maximum Concentration (mg/kg)	Depth Interval (ft bgs)	
		Top	Bottom
Arsenic	11	47.5	50
Cadmium	40.2	90	92.5
Chromium	162	119.5	122
Copper	26.3	119.5	122
Hexavalent chromium	0.75	63.5	66
Lead	620	115	117.5
Mercury	1.02	174	176.5
Nickel	72.9	119.5	122
Selenium	3.76	119.5	122
Silver	2.88	174	176.5
Ammonium ion	192	109.5	112
Fluoride	7.8	90	92.5
Nitrate	5,910	109.5	112
Nitrite	12.1	47.5	50
Sulfate	456	63.5	66
Acetone	0.66	117	119.5
Carbon tetrachloride	380	63.5	66
Chlorobenzene	0.00098	115	117.5
Chloroform	4.9	63.5	66
1,1-Dichloroethane	0.0011	115	117.5
Methyl ethyl ketone[a]	0.080	117	119.5
Methyl isobutyl ketone[b]	0.0012	117	119.5
Methylene chloride	0.020	119.5	122
Tetrachloroethene	17	63.6	66
Toluene	0.0013	117	119.5
Trichloroethene	0.0011	115	117.5
Tributyl phosphate	2,100	63.5	66
Aroclor-1248	1.6	63.5	66
Oil and grease	2,400	63.5	66

[a] 2-Butanone (CAS 78-93-3).
[b] 2-Pentanone, 4-Methyl (CAS 108-10-1).
Aroclor is an expired trademark.
bgs = below ground surface.
CAS = Chemical Abstracts Service.

Well 299-W15-48

Radioactive COPCs for the 200-PW-1 OU were detected in the vadose zone beneath the 216-Z-9 Trench in Borehole C3427 (well 299-W15-48) to a downhole depth of 42.7 m (140 ft) bgs. Background levels for the 200-PW-1 OU radionuclide COPCs are shown in Table 3-5. The maximum results for the Borehole C3427 samples are presented in Appendix A and are summarized below. The following table presents the radionuclide COPCs detected above background levels (and those with no available background value) and the depth interval of the maximum concentration.

Radionuclide Contaminant of Potential Concern	Maximum Concentration (pCi/g)	Downhole Depth Interval (ft bgs)	
		Top	Bottom
Americium-241	131,000	118.5	120.5
Neptunium-237	10.5	122.5	124.5
Plutonium-238	3,680	70	72
Plutonium-239/240	254,000	70	72
Radium-226	2.16	131.5	133
Radium-228	1.64	70	72
Total beta radiostrontium	1.18	131.5	133
Technetium-99	272	70	72
Thorium-232	1.89	135	140

Depth interval = downhole depth (not converted to vertical).
bgs = below ground surface.

Background levels for the 200-PW-1 OU nonradionuclide COPCs are shown in Table 3-6. The following table presents the nonradionuclide COPCs detected above background levels (and those with no available background value) and the depth interval of the maximum concentration.

Chemicals of Potential Concern	Maximum Concentration (mg/kg)	Downhole Depth Interval (ft bgs)	
		Top	Bottom
Arsenic	8.4	131.5	133
Bismuth	156	135	140
Cadmium	118	122.5	124.5
Chromium	22.8	52.5	54.5
Hexavalent chromium	0.45	52.5	54.5
Lead	17	122.5	124.5
Mercury	0.799	100	102
Nickel	23.3	100	102
Selenium	2.93	131.5	133

Chemicals of Potential Concern	Maximum Concentration (mg/kg)	Downhole Depth Interval (ft bgs)	
		Top	Bottom
Silver	1.23	135	140
Ammonium ion	21.5	135	140
Fluoride	51.4	118.5	120.5
Nitrate	6,990	100	102
Phosphate	3.9	135	140
Sulfate	255	70	72
Acetone	2.9	131.5	133
Benzene	0.0037	70	72
Carbon tetrachloride	6.3	128.5	130.5
Chloroform	0.36	131.5	133
Ethylbenzene	0.0008	73	75
Hydraulic fluids (Grease)[a]	2,440	70	72
Normal paraffins (greases and cutting oils)[a]			
Methyl ethyl ketone [b]	1.7	122.5	124.5
Methylene chloride	0.140	100	102
Tetrachloroethene	0.22	70	72
Toluene	0.0038	131.5	133
Trichloroethene	0.0013	73	75
Tributyl phosphate	3,000	70	72
Xylene	0.003	73	75
Aroclor-1248	1.3	70	72

Depth Interval = downhole depth (not converted to vertical).
[a]Result reported for oil and grease.
[b]2-Butanone (CAS 78-93-3).
bgs = below ground surface.
CAS = Chemical Abstracts Service.
Aroclor is an expired trademark.

3.2.1.4 Contaminant Distribution Model

The preliminary contaminant distribution model presented in the Work Plan (DOE/RL-2001-01, Section 3.4) generally is supported by the RI data with some changes (Figure 3-10), including the correct understanding that DNAPL carbon tetrachloride was found in a small area at 19.8 m (65 ft) bgs south of the 216-Z-9 Trench. Based on the preliminary contaminant distribution model in the Work Plan, the highest radiological contamination was expected from the base of the trench to several meters below and then was expected to decrease with depth. For the radionuclides detected above background levels, the next highest concentrations were reported at a depth of 34 m (111.8 ft) (in the upper part of the CCU silt lens in well 299-W15-46, adjacent to

the south side of the trench. These detected contaminant concentrations are deeper than initially postulated in the preliminary contaminant distribution model.

Relatively high concentrations of several semivolatile organic compounds, metals, and radionuclides were found to be present deeper in the vadose zone in well 299-W15-46, which also was predicted by the preliminary contaminant distribution model in the Work Plan. The highest concentrations appear to be associated with fine-grained layers within the Hanford formation and the CCU.

The soil-sampling intervals, lithology, field-screening measurements, and borehole geophysical logs for Boreholes C3426 and C3427 are show in Figures 3-11 and 3-12, respectively. Vertical concentration profile plots for those COPCs that had a detected value above background (and COPCs with no available background value) are shown in Figure 3-13 for Borehole C3426 (well 299-W15-46) and in Figure 3-14 for Borehole C3427 (well 299-W15-48).

The vadose-zone soil samples in wells 299-W15-46 and 299-W15-48 were field screened for visual indication of the presence of carbon tetrachloride as DNAPL, as discussed in Section 2.3 of WMP-26264 (for 299-W15-46) and in Section 2.3 in WMP-30566 (for 299-W15-48). The only soil sample that had a positive field test for carbon tetrachloride DNAPL was a sample from 19.5 m (64 ft) bgs from well 299-W15-46. This was the first time that positive evidence of carbon tetrachloride DNAPL was found at any location in the subsurface of the 200 West Area since the beginning of the carbon tetrachloride contamination investigation in the early 1990s. This sample was in a thin silt layer from 19.8 to 20.4 m (65 to 67 ft) deep in well 299-W15-46. This silt layer reported a high carbon tetrachloride soil concentration (380,000 µg/kg) and one of the highest carbon tetrachloride soil-vapor concentrations (8,560 ppmv) in the borehole (WMP-26264). Within this same silt lens, the highest carbon tetrachloride soil concentration was reported at Borehole C5336 (P66) of 390,000 µg/kg as part of the HHR investigation south of the 216-Z-9 Trench and directly adjacent to well 299-W15-46 (DOE/RL-2007-22). The high concentration of carbon tetrachloride detected within the silt layer is consistent with the Work Plan model (i.e., carbon tetrachloride present in finer grained layers).

3.2.1.5 Borehole C3426 and Borehole C3427 Comparison

Figures 3-15 and 3-16 present vapor concentration profiles for carbon tetrachloride and chloroform from Boreholes C3426 (well 299-W15-46) and C3427 (well 299-W15-48). As shown in the figures, soil-vapor concentrations detected in Borehole C3427 generally were lower than those detected in Borehole C3426. However, carbon tetrachloride concentrations detected in soil samples from Borehole C3427 were relatively higher than those in soil samples from Borehole C3426, except for the high concentration of carbon tetrachloride detected in Borehole C3426 from a depth of 19.4 to 20.1 (63.5 to 66 ft) bgs.

The highest concentration of carbon tetrachloride detected at the 216-Z-9 Trench was found at Borehole C5336 (P66), with the HHR (390,000 µg/kg) on the south side of the trench, approximately 6 m (20 ft) east of well 299-W15-46 (DOE/RL-2007-22). At Borehole C3426, carbon tetrachloride in the soil of 380,000 µg/kg was detected at a depth of 19.4 to 20.1 m (63.5 to 66 ft) bgs. However, 6 m (20 ft) south and 6 m (20 ft) west of well 299-W15-46, the carbon tetrachloride concentrations in the silt layer reduce significantly to levels of only a few

100 µg/kg. This shows that a large variability exists in the distribution of carbon tetrachloride in the vadose zone. Relatively low concentrations of carbon tetrachloride (i.e., less than 300 µg/kg) were detected in the other samples collected from Borehole C3426. The highest carbon tetrachloride concentration in Borehole C3427 was detected near the thin silt layers (i.e., a depth of approximately 19.8 m [65 ft] bgs) and the CCU. Concentrations at depths of 20.4 to 21.0 m (67 to 69 ft) and 22.3 to 22.9 m (73 to 75 ft) were 2,600 and 1,500 µg/kg, respectively. Concentrations near the CCU were 6,300 µg/kg (39.2 to 39.8 m or 128.5 to 130.5 ft) and 4,100 µg/kg (40.1 to 40.5 m [131.5 to 133 ft]). The detections of the highest concentrations of carbon tetrachloride within fine-grained vadose-zone sediments is consistent with the current conceptual site model presented in DOE/RL-2007-22 that DNAPL, if present, is located in fine-grained units within the vadose zone (i.e., 19.8 m [65 ft] silt lens of the Hanford formation).

Field screening of soils from the 19.4 to 20.1 m (63.5 to 66 ft) sampling interval in Borehole C3426 indicated the possible presence of carbon tetrachloride DNAPL (WMP-26264). In addition, soil physics calculations for this silt layer indicate that any concentration of carbon tetrachloride detected above 275 mg/kg (275,000 µg/kg) is suggestive of DNAPL. Because the concentration of carbon tetrachloride detected within the 19.4 to 20.1 m (63.5- to 66-ft) sampling interval in Borehole C3426 (380,000 µg/kg) is greater than 275 mg/kg (275,000 µg/kg), carbon tetrachloride DNAPL is likely to be present in the silt layer at this location. The carbon tetrachloride result at Borehole C5336 (P66) of 390,000 µg/kg, discussed above, is suggestive of DNAPL in this location as well.

The differences in concentrations of carbon tetrachloride in soil and vapor samples from borehole wells 299-W15-46 and 299-W15-48 may be caused by the following.

- The SVE system was operated between the time that well 299-W15-46 was completed and the drilling of well 299-W15-48 was started. The lower concentrations of carbon tetrachloride soil vapor measured in well 299-W15-48, compared to those in well 299-W15-46, may be caused partly by the timing of the operation of the SVE system. Because well 299-W15-48 was drilled beneath the trench (a covered, open trench), the vadose zone is thinner at this borehole and may respond to the SVE system differently than it does at well 299-W15-46, where the vadose zone is thicker.

- Fewer SVE wells have operated on the south side of the trench, compared to the other sides of the trench. The greater number of SVE wells that have operated near well 299-W15-48 most likely draw more vapor away from this well, compared to well 299-W15-46.

- The geologic layers beneath the 216-Z-9 Trench are heterogeneous. Carbon tetrachloride concentrations in the dissolved, DNAPL, and vapor phases are not evenly distributed in and around the trench.

- Disposal operations at the 216-Z-9 Trench ended in 1962. The trench floor slopes from north to south, and well 299-W15-46 is located south of the trench floor. From the time that disposal to the trench ended until the sampling in borehole well 299-W15-46 began, carbon tetrachloride DNAPL may have migrated along a preferential flow path to

near the location of borehole well 299-W15-46 and away from the location of well 299-W15-48.

Carbon Tetrachloride Inventory

A revised carbon tetrachloride inventory was developed based on data collection during the carbon tetrachloride DNAPL source term investigation (DOE/RL-2007-22). The inventory was updated based on interim remedial actions (i.e., SVE and groundwater pump-and-treat activities) implemented at the site, information on the disposal practices at the 216-Z-9 Trench, and additional data collected during site-investigation activities completed since 1993. Based on thermal exchange measurements using two instrumentation strings installed within the air space of the 216-Z-9 Trench during 2006, the minimum air change is estimated at 10 percent in the winter season (42 percent of the disposed carbon tetrachloride evaporated) and the maximum air change is estimated at 20 percent in the summer season (72 percent of the disposed carbon tetrachloride evaporated). Measurements were taken in 2006 during a period when the trench was not actively vented and the risers were sealed. These conditions are more conservative than conditions during actual disposal periods. These refinements bring the unaccounted inventory down to a maximum of 40 percent and a minimum of 21 percent, based on the average carbon tetrachloride disposal volumes to the 216-Z-9 Trench (DOE/RL-2007-22).

Contaminant Distribution Model

Relatively lower vapor concentrations and higher soil concentrations (except for the 19.4 to 20.1 m [63.5- to 66-ft] sample from Boreholes C3426 and C5336 [P66]) were detected in Borehole C3427 than in Borehole C3426. The concentrations generally are consistent with the 216-Z-9 Trench contaminant distribution model presented in Figure 3-10. Disposal information from the 216-Z-9 Trench reveals that ponding occurred within the trench during disposal. The ponding indicates that soils were saturated beneath the trench bottom and that soil pore spaces may have been clogged with precipitates from the disposed liquid wastes. Some carbon tetrachloride disposed of on the trench floor likely evaporated before percolating into the soil column. Below the trench floor, carbon tetrachloride as vapor most likely was located primarily near the trench walls (i.e., on the fringes of the saturated soil column) and preferentially migrated vertically and laterally away from the trench and not directly below the trench floor, as indicated by the lower carbon tetrachloride vapor concentrations detected in Borehole C3427, compared to Borehole C3426. Additionally, the SVE system has pulled vapor from beneath the trench footprint during system operations. Some of the carbon tetrachloride (both dissolved and as possible DNAPL) moved vertically to finer grained layers within the vadose zone (i.e., silt layers within the Hanford formation and the CCU) and then migrated laterally along the finer grained units as evidenced by the carbon tetrachloride DNAPL found in Borehole C3426 (19.4 to 20.1 m [63.5- to 66-ft] sample) and Borehole C5336 (P66; 19.8 to 20.1 m [65 to 66 ft] bgs). Some of the carbon tetrachloride moved vertically through the CCU into the groundwater.

Based on the data collected to date, it appears that the lateral extent of the carbon tetrachloride DNAPL in the 19.8 m (65 ft) bgs silt layer is about 9.2 m (30 ft) to 21.3 m (70 ft) from Borehole C3426 (well 299-W15-46). The estimated amount of carbon tetrachloride at the 19.8 m (65 ft) bgs silt layer is 50 to 100 kg (110.23 to 220.46 lb) (DOE/RL-2007-22).

3.2.2 Nature and Extent of Contamination in the 216-Z-1A Tile Field

The nature and extent of contamination summarized in this section are representative of the 216-Z-1A Tile Field in the 200-PW-1 OU. Evaluation of the nature and extent of contamination at this location is based on the evaluation of all available data. Available data for this representative waste site include historical and new geophysical logging results, new soil and soil-vapor sampling results, and other data-collection and analysis results. The data and analysis were integrated to develop and refine a contaminant distribution model for the representative waste site.

The following provides a summary of important RI findings related to the 216-Z-1A Tile Field.

- In 1963, scintillation probe profiles monitoring the tile field indicated contamination from gamma-emitting radionuclides.
- The highest concentrations of radionuclides occur in sediments located immediately beneath the crib, below the distribution pipe.
- The maximum vertical extent of radiological contamination detected in soil, as detected by borehole geophysical logging, is 37 m (121 ft).
- The maximum vertical extent of radiological contamination detected in soil samples from the tile field area was 46.8 m (153.5 ft).
- Soil samples from the tile field area revealed a maximum carbon tetrachloride concentration of 6,561 mg/kg. Maximum concentrations of other COPCs are summarized in Section 3.2.2.3.
- An SVE system has been operated near the tile field. Between April 1991 (when the pilot test was conducted) and July 2006, approximately 24,604 kg of carbon tetrachloride were removed from the 216-Z-1A/Z-18/Z-12 well field was removed by the SVE system.
- Geophysical methods were used to map and contour the surface of key geologic layers beneath the tile field.

3.2.2.1 Historical Contaminant Investigation Summary

Before 1973, scintillation (gross gamma) surveys were used as the principal means of detecting contamination from gamma-emitting radionuclides. In 1963, all scintillation probe profiles monitoring the tile field indicated background levels of radiation. Available scintillation profiles are documented in ARH-ST-156. By 1973, 26 wells had been drilled in and around the 216-Z-1A Tile Field. No chemical data were collected from these 26 wells.

Radioactive contaminants were detected in three boreholes (wells 299-W18-56, 299-W18-57, and 299-W18-58) at the tile field in 1965 (ARH-ST-156). The maximum vertical extent of contamination (21.3 m [70 ft]) was observed in well 299-W18-56. The radiation intensity increased in two of these wells between 1965 and 1968 as a result of continuing disposal.

Radiation intensity decreased 3 years after discharges to the tile field were terminated in 1969. Based on the scintillation profiles in ARH-ST-156, radioactive contaminants were detected relatively high up in the sediment column beneath the tile field, and breakthrough to groundwater had not occurred.

The next major investigation of the tile field is reported in RHO-ST-17. Sixteen boreholes were drilled starting in 1973 to determine the distribution of plutonium and americium (i.e., actinides) in sediments beneath the tile field. Soil samples were collected approximately every 1.5 m (5 ft) where contamination was not detected, every 0.3 m (1 ft) in zones of contamination, and wherever there was a change in sediment type. Screening of sediments was performed with portable radiation survey instruments. Selected samples were analyzed by granulometric and actinide analytical techniques.

The following conclusions are presented in RHO-ST-17 regarding the distribution of actinides detected.

- The highest concentration of Pu-239/240 (40,000,000 pCi/g) and Am-241 (2,500,000 pCi/g) occurs in sediments located immediately beneath the crib, below the distribution pipe.
- The concentration of actinides in sediments generally decreases with depth beneath the waste-distribution system, with the exception of silt-enriched horizons and boundary areas between major sedimentary units.
- The maximum vertical extent of actinide contamination (defined by the 10 pCi/g isopleth) is located approximately 30 m (100 ft) below the bottom of the crib and 30 m (100 ft) above the 1978 water table.
- The estimated lateral extent of contamination is within a 10 m (33-ft) wide zone encompassing the perimeter of the crib.

An SVE system installed in the early 1990s continues to operate in the vicinity of the 216-Z-1A Tile Field and the 216-Z-18 Crib. Between April 1991 (when the pilot test was conducted) and July 2006, approximately 24,604 kg of carbon tetrachloride were removed from the 216-Z-1A/Z-18/Z-12 well field by the SVE system (SGW-33746). Soil-vapor samples collected during operation of the SVE demonstrate that soil-vapor concentrations in the vicinity of the 216-Z-1A Tile Field have been decreasing over time.

3.2.2.2 Geophysical Logging Summary at the 216-Z-1A Tile Field

The Radionuclide Logging System has been used to evaluate the extent of radiological contamination in 13 boreholes in and adjacent to the 216-Z-1A Tile Field. Most of the boreholes were logged in 1993 and 1998 (PNNL-11978). The predominant radionuclides detected during logging were Am-241, Pa-233, and Pu-239. Cesium-137 and Co-60 were detected less frequently. However, it appears that americium was misinterpreted as Cs-137 in the geophysical logs. A discussion of the borehole geophysics is provided in Section 3.2.4.1. Maximum contaminant levels generally were detected along the central axis of the tile field near the main discharge pipe at wells 299-W18-81, 299-W18-149, 299-W18-159, and 299-W18-170. Results

from the survey indicate that higher levels of contamination were detected on the north end of the tile field (head end) associated with the main discharge pipe. Contamination generally decreases with depth and distance from the discharge pipe and head end of the tile field. Maximum activities typically were detected at depth within 3.4 m (11 ft) of the discharge pipe.

The maximum vertical extent of radiological contamination (8 pCi/g of Pa-233) detected is 37 m (121 ft) bgs at borehole well 299-W18-174. However, the bulk of the contamination detected was less than 21.3 m (70 ft) bgs. Maximum activities were detected in well 299-W18-159 as follows:

- Am-241 (2,500,000 pCi/g)
- Pa-233 (63 pCi/g)
- Pu-239 (25,000,000 pCi/g)
- Cs-137 (23 pCi/g).

Geophysical logging also was used at the 216-Z-1A Tile Field to assess the capability of a passive neutron tool to detect transuranic-contaminated soils (i.e., containing transuranic radionuclides with half-lives longer than 20 years at concentrations greater than or equal to 100,000 pCi/g). Objectives of the evaluation were to (1) test a small-diameter Gamma Logging System passive gamma probe for the detection of transuranic radionuclides in soil (e.g., Pu-239, Am-241), (2) assess a passive neutron detector capability to detect transuranic radionuclides at concentrations at or near 100,000 pCi/g in soil, and (3) determine if a functional relationship exists between different transuranic radionuclides and the neutron detector in soil matrices. The tile field was selected for this evaluation because it contains boreholes with a passive neutron flux field and a large range of transuranic radionuclide concentrations. Results from the logging indicated that a small-diameter, Gamma Logging System passive gamma probe is capable of detecting transuranic-contaminated soil, and a passive neutron detector is capable of detecting transuranic radionuclides at or near concentrations of 100,000 pCi/g in soil. The third test objective was not successfully demonstrated, because there were too many differences in the configuration of boreholes. The differences do not allow for baseline comparison of neutron responses from Am-241 and Pu-239. Details of this logging activity are presented in BHI-01436, *Proof-of-Principle Demonstration of a Passive Neutron Tool for Detection of TRU-Contaminated Soil at the 216-Z-1A Tile Field.*

3.2.2.3 216-Z-1A Tile Field Contamination – Analytical Data

The radioactive COPCs Am-241 and Pu-239/240 for the 200-PW-1 OU were detected in the vadose-zone soil beneath the 216-Z-1A Tile Field in wells 299-W18-149, 299-W18-150, 299-W18-159, 299-W18-163, 299-W18-164, 299-W18-165, 299-W18-166, 299-W18-167, 299-W18-168, 299-W18-169, 299-W18-172, 299-W18-173, 299-W18-174, and 299-W18-175. In addition, Pu-239/240 was detected in wells 299-W18-85, 299-W18-86, 299-W18-87, and 299-W18-88, and Am-241 was detected in well 299-W18-171. Plutonium-239/240 was detected above background to a maximum depth of 41.8 m (137.14 ft) in well 299-W18-156. Americium-241 was detected at a maximum depth of 46.8 m (153.54 ft) in well 299-W18-164. Background levels for the 200-PW-1 OU radionuclide COPCs are shown in Table 3-5. The results for the plutonium and americium analyses are presented in Appendix D and are summarized below.

Well 299-W18-174 was deepened in 1993 to further evaluate subsurface impacts from the tile field. The well was deepened from a depth of 14.9 m to 40 m (48.88 to 131.23 ft). The following COPCs were detected in soil samples collected from the borehole: Am-241, Np-237, chromium, copper, nickel, lead, chloride, fluoride, nitrate, nitrite, phosphate, sulfate, phenol, chloroform, carbon tetrachloride, methyl ethyl ketone, methyl isobutyl ketone, tetrachloroethylene, toluene, and trichloroethylene.

The following table presents the radionuclide COPCs detected above background levels (and those with no available background levels), and the depth interval of the maximum concentration.

Radionuclide Contaminant of Potential Concern	Maximum Concentration (pCi/g)	Borehole Number	Depth Interval (ft bgs)	
			Top	Bottom
Americium-241	2,590,000	299-W18-149	11.2	11.2
Neptunium-237	40	299-W18-174	48.0	48.0
Plutonium-239/240	38,200,000	299-W18-149	11.2	11.2
Protactinium-233	36.7	299-W18-174	14.6	14.6

Data from RHO-ST-17, *Distribution of Plutonium and Americium Beneath the 216-Z-1A Crib: A Status Report*; see Appendix D of this RI report.
bgs = below ground surface.

Background levels for the 200-PW-1 OU nonradionuclide COPCs are shown in Table 3-6. The following table presents the nonradionuclide COPCs detected above background levels (and those with no available background value) in samples from well 299-W18-174 and the depth interval of the maximum concentration.

Nonradionuclide Contaminant of Potential Concern	Maximum Concentration (mg/kg)	Depth Interval (ft bgs)	
		Top	Bottom
Chromium (III)	19	118.5	118.5
Copper	24	56.0	56.0
Lead	11	124.9	125.4
Fluoride	16	124.9 and 128.9	124.9 and 128.9
Nitrate	250	56.0	56.0
Phosphate	1	56.0	56.0
Chloroform	0.135	131.0	131.0
Carbon Tetrachloride	6.561	127.1	127.1
Methyl ethyl ketone	0.180	56.0	56.0
Methyl isobutyl ketone	0.156	74.5	74.5
Tetrachloroethylene	0.050	128.9	128.9

Nonradionuclide Contaminant of Potential Concern	Maximum Concentration (mg/kg)	Depth Interval (ft bgs)	
		Top	Bottom
Toluene	0.040	71.5	71.5
Trichloroethylene	0.068	128.9	128.9

bgs = below ground surface.

3.2.2.4 Contaminant Distribution Model

The contaminant distribution model presented in the Work Plan (DOE/RL-2001-01, Section 3.4) generally is supported by the RI data (Figure 3-17). Based on the contaminant distribution model in the Work Plan, the highest radiological contamination was expected from the base of the crib to several meters below and then was expected to decrease with depth. For most of the radionuclides detected above background levels, the highest concentrations were reported from depths of 3.4 to 4.3 m (11.2 to 21.5 ft) directly beneath the tile field. Relatively low concentrations of several VOCs, metals, and radionuclides were found to be present deeper in the vadose zone, which also was predicted by the contaminant distribution model in the Work Plan.

No radiological contamination was detected based on field-screening measurements during the drilling of Borehole P57 in the northern part of the 216-Z-1A Tile Field. Using the radiological information obtained during the drilling of P57, the extent of the 10 pCi/g contour on the north side of the 216-Z-2 Crib was refined to be closer to and adjacent to this crib.

3.2.3 Nature and Extent of Contamination in the 241-Z-361 Settling Tank

The nature and extent of contamination summarized in this section are representative of the 216-Z-361 Settling Tank in the 200-PW-1 OU. Evaluation of the nature and extent of contamination at this location is based on the evaluation of all available data. Available data for this representative waste site includes sludge and tank-vapor sampling results and other data-collection and analysis results. The data and analysis were integrated to develop and refine a contaminant distribution model for the representative waste site.

The following provides a summary of important RI findings related to the 241-Z-361 Settling Tank.

- The settling tank currently contains approximately 75 m^3 (82 yd^3) of sludge. The sludge is contaminated with radionuclides, metals, organics, and polychlorinated biphenyls.
- Soils beneath the tank were scanned for radiological contamination in 1999 during installation of piers to support the tank. No radiological contamination was detected.
- The lack of detected radiological contamination on the piers installed beneath the depth of the tank bottom, and the apparent stability in the tank sludge level since 1975, suggests there has been no leak of tank contents to the soil column.

The 241-Z-361 Settling Tank was opened in 1999 as part of Phase I characterization activities. The concentrations of volatile and semivolatile organics present in the tank during vapor monitoring included the following: 0.24 to 0.83 ppmv of Freon[1] 11, 0.32 to 1.10 ppmv of chloroform, 0.32 to 2.00 ppmv of tetrachloroethylene, 0.22 to 0.50 ppmv of isobutane, 0.05 to 0.20 ppmv of methylcyclopentane, 0.35 to 0.88 ppmv of trichloroethylene, and 0.05 to 0.15 ppmv of carbon tetrachloride.

The results of the Phase II tank characterization investigation are reported in HNF-8735 and summarized in the Work Plan (DOE/RL-2001-01, Section 3.3.1.3). The 241-Z-361 Settling Tank currently contains approximately 75 m^3 (82 yd^3) of sludge. The principal radionuclide contaminant in the sludge is plutonium (25 kg [55.22 lb] of Pu-239 and 4 kg (8.82 lb) of other transuranic isotopes, primarily Pu-240, are present). Concentrations of Pu-239 in the 13 samples analyzed range from 69 to 428 mg/kg. Plutonium-240 concentrations ranged from less than detectable to 60.97 mg/kg in the 13 samples analyzed (DOE/RL-2001-01, Section 3.3.1.3). HNF-8735 reported that the sludge was believed to contain between 26 and 75 kg (57.32 and 165.35 lb) of plutonium (WHC-SD-EN-ES-040, *Engineering Study of 50 Miscellaneous Inactive Underground Radioactive Waste Tanks Located at the Hanford Site, Washington*) with a probable inventory of 26.8 kg (59.08 lb). A previous assessment of material unaccounted for estimated the tank contents as 31.2 kg (68.78 lb) plutonium (HNF-2012, *Engineering Study of the Criticality Issues Associated with Hanford Tank 241-Z-361*). This 1997 criticality study concluded that, although the plutonium inventory is potentially sufficient to generate a criticality, plutonium distribution within the sludge makes an inadvertent criticality extremely unlikely (HNF-2012).

The Am-241 concentration in the sludge ranged from nondetectable to <1 mg/kg in the samples analyzed. The concentrations of U-235 and U-238 were at trace levels. Analysis of the core samples showed that the plutonium is well distributed within the tank, and significant quantities of neutron-absorbing materials in the sludge further reduce any potential for criticality.

Videos of the tank interior show a small amount of free liquid visible on the surface, indicating that the sludge is saturated and the contents are over-moderated. The 1999 data indicate that the sludge ranges from 52.2 to 84.4 percent water. The average moisture content is approximately 70 percent. The pH of the sludge is between 8 and 9.2. Particle-size analysis was conducted on 14 composite sludge samples using a laser diffraction analyzer. The particle sizes for these samples ranged from 0.2 to 450 µm, and the average mean particle size was 139 µm (HNF-8735).

The total metals analysis of the sludge samples indicated an average of 112 mg/kg of cadmium, 10,000 mg/kg of chromium, 446 mg/kg of lead, 177 mg/kg of mercury, and 182 mg/kg of silver within the sludge. These analyses also indicated that arsenic, barium, nickel, and zinc had maximum concentration results of 23.4 mg/kg, 197 mg/kg, 3,360 mg/kg, and 622 mg/kg, respectively. Beryllium was not detected in any of the samples analyzed.

[1] Freon is a trademark of E. I. du Pont de Nemours and Company, Wilmington, Delaware.

The tank-characterization samples were analyzed for volatile and semivolatile organic compounds. The five VOCs detected and their maximum concentrations were 1-butanol (5,470 µg/kg), acetone (5,620 µg/kg), benzene (3,930 µg/kg), methylene chloride (1,250 µg/kg), and toluene (1,590 µg/kg). However, these results can be taken only as lower concentration estimates because of multiple QC issues with these samples (e.g., sample vial caps were removed twice before analysis for alpha contamination control; potential hot-cell and laboratory contaminants in samples and blanks; and samples were not refrigerated prior to analysis; HNF-8735).

The results for the semivolatile organic compounds all were below reporting limits and calibration levels. Concentrations ranged from not detected to 2 µg/kg for TBP and DBP (estimated values), and all DBBP results were not detected (HNF-8735).

The tank characterization samples show that the sludge contains an inventory of polychlorinated biphenyls at a calculated average concentration of approximately 28 ppm. The peak Aroclor[2] concentration detected was 160 mg/kg.

Still photographs of the interior of the tank were taken in 1975, and a video camera inspection was conducted in 1999. The level of the sludge surface, and consequently the apparent depth of the sludge in the tank, is very similar in the two sets of photographs. The level is estimated by comparing the relative distance from the sludge surface to the roof of the tank in both photographs. This observation suggests that the level of waste in the tank has not changed substantially over the years between 1975 and 1999.

The lack of detected radiological contamination on the piers installed beneath the depth of the tank bottom, and the apparent stability in the tank sludge level since 1975, suggests that there has been no leak of tank contents to the soil column (FH-0002791, "Submittal of Documentation in Fulfillment of TPA Milestone M-15-37B"). (NOTE: In HNF-EP-0924, *History and Stabilization of the Plutonium Finishing Plant (PFP) Complex, Hanford Site*, reference is made to the 241-Z-361 Settling Tank as "leaking." However, during further evaluation of pertinent records conducted during the preparation of the engineering evaluation, no documentation of any leaks was discovered for the 241-Z-361 Settling Tank. In addition, the liquid level was found to have remained constant during all of the liquid-level measurements for many years before the tank was isolated in 1973, indicating that the tank did not leak. The author of HNF-EP-0924 concurred that the statement regarding leaks from this tank appeared to be in error [verified by personal communication between the author of HNF-EP-0924 and Environmental Quality Management, Inc., who subsequently communicated the corrected information to the Work Plan author] [taken from DOE/RL-2001-01, Section 3.3.1.3]).

The 241-Z-361 Settling Tank contaminant distribution model presented in the Work Plan (DOE/RL-2001-01, Section 3.4) is based primarily on the Phase II tank characterization data and discussion in HNF-8735. This model is shown in Figure 3-18.

[2] Aroclor is an expired trademark.

3.2.4 Nature and Extent of Contamination of the Dispersed Carbon Tetrachloride Vadose-Zone Plume

As discussed in Section 2.4, the investigation of the dispersed carbon tetrachloride vadose-zone plume was conducted in two steps. Step I was focused on characterizing the shallow portion of the vadose zone overlying the highest concentration portion of the carbon tetrachloride groundwater plume. The Step II study extended deeper into the vadose zone and included the area overlying the entire carbon tetrachloride groundwater plume. The results of both the Step I and Step II investigations are presented and discussed in this section.

Because of the large number of investigation activities conducted, especially in the Step II investigation, the results are presented first for the Step I investigation. Then the Step II investigation results are presented in individual subsections that parallel the presentation of these activities in Section 2.4. A summary evaluation of the nature and extent of contamination of the dispersed carbon tetrachloride vadose-zone plume is presented at the end of this section as the contaminant distribution model in Section 3.2.4.9.

The following provides a summary of important RI findings related to the dispersed carbon tetrachloride vadose-zone plume.

- The dispersed plume results of the shallow, intermediate, and deep vadose zone generally correspond to the Hanford formation, CCU, and unsaturated Ringold Formation, respectively.

- The highest carbon tetrachloride concentrations in the shallow, intermediate, and deep vadose zone generally are located within about 75 to 150 (246 to 492 ft) of the release sites.

- The carbon tetrachloride concentrations in the vadose zone around the release sites are being reduced by the SVE system and are significantly less than the initial concentrations measured in 1992-1993.

- Outside of the area around the release sites, carbon tetrachloride vapor concentrations up to about 10 to 12 ppmv were found at various locations in the vadose zone, but these concentrations are not considered to have the potential for significant current or future groundwater impacts.

- The soil-vapor and shallow-groundwater sampling at wells within the eight carbon tetrachloride groundwater "hot spot" areas indicated that the deep vadose-zone soil-vapor concentrations are not significant sources of groundwater contamination in these areas.

- An area of high passive soil-vapor concentration was found northwest of the 216-Z-9 Trench near the entrance to the PFP. The active soil-vapor investigation of the pipelines near this area and several CPT investigations did not identify any potential release areas in the shallow vadose zone. CPT push location P10A had the highest active soil-vapor carbon tetrachloride concentration of 119 ppmv at 31.1 m (102.1 ft), above the top of the CCU. This area may be associated with contamination from the

216-Z-9 Trench that moved away from the trench area on the top of the CCU and that is outside the capture zone of the SVE system.

- Carbon tetrachloride DNAPL was found in both well 299-W15-46 and Borehole C5336 (P66) in the shallow vadose zone (19.8 m [65 ft] bgs silt layer), adjacent to the south side of the 216-Z-9 Trench.

Step I Results Summary

The Step I results are reported in CP-13514, and the vadose-zone investigation results are included in this report in Tables 3-7 to 3-9. The 218-W-4C Burial Ground vent riser results are not included in this discussion, because the samples were collected in an engineered facility (i.e., not in the environment) and were used to guide the subsequent vadose-zone investigations (see CP-13514).

The Step I soil-vapor sampling was conducted at engineered structures that had the potential to release carbon tetrachloride to the vadose zone. The engineered structures included liquid-waste discharge pipelines, liquid-waste discharge sites, and solid-waste burial ground trenches. The vadose-zone sampling was conducted using either the GeoProbe or CPT direct-push technology, and the analyses were conducted using a field-screening instrument.

The GeoProbe was used to conduct vadose-zone sampling along the liquid-waste discharge pipelines and burial ground trenches and consistently reached the target depth of 7.6 m (25 ft) bgs. The CPT was used to conduct vadose-zone sampling at the liquid-waste discharge sites and burial ground trenches to refusal. The target maximum depth for the CPT sampling was 38.1 m (125 ft) bgs. The maximum depth achieved using the CPT was 21.3 m (70 ft), and the average depth achieved was 13.7 m (45 ft). Sampling was conducted within the burial ground engineered trenches using the vent risers for access to guide the subsequent vadose-zone sampling in that area.

Relatively low concentrations of carbon tetrachloride (1 to 8 ppmv) were detected in some samples collected along the liquid-waste discharge pipelines leading to the 216-Z-18 and 216-Z-12 Cribs and the 216-Z-1D/-11/-19/-20 (Crib) Ditch system. The detections were typically, but not exclusively, in the samples collected from 7.6 m (25 ft) bgs. The cribs and ditches at the discharge ends of these pipelines are known to have received carbon tetrachloride liquid wastes. However, the relatively low concentrations detected along the pipelines suggest that any pipeline leaks were small or were naturally remediated (e.g., by diffusion or evaporation) since the pipelines last were used. The relatively low concentrations detected along the pipelines also may be a result of lateral migration of carbon tetrachloride in the vadose zone from the discharge sites. Carbon tetrachloride was not detected in samples collected along the pipeline to the 216-Z-9 Trench, which is known to have received large volumes of carbon tetrachloride. In 1993, a remote camera survey was completed of portions of the 216-Z-9 Trench waste-discharge pipelines (840 and 840D). The video survey did not indicate breaks or major cracks; however, both lines exhibited areas of severe pitting and corrosion. It could not be determined whether the pitting broke through the pipe walls, and small holes within the pipelines could have created leakage paths (WHC-SD-NR-ER-103, *Final Report for the Remote CCTV Survey of the Abandoned Process Effluent Drain Lines 840 and 840D in Support of the 200 West*

Area Carbon Tetrachloride ERA). The investigation results along the pipeline to the 216-Z-9 Trench confirm the findings from the camera survey that no significant release areas were found along the pipeline.

Relatively low concentrations of carbon tetrachloride (1 to 8 ppmv) were detected in some samples collected at the liquid-waste discharge sites 216-Z-12 Crib, 216-Z-1A Tile Field, 216-Z-1D/-11/-19/-20 (Crib) Ditch system, 216-Z-7 Crib, and 216-T-19 Crib. Of these, only the 216-Z-7 Crib was not known to have received carbon tetrachloride. The highest concentrations at each site were in samples collected from 9.1 to 18.3 m (30 to 60 ft) bgs. The relatively low concentrations suggest that there is no longer an active source of contamination in the upper vadose zone at these locations. Carbon tetrachloride was not detected in samples collected at the 216-Z-9 Trench or the 216-Z-18 Crib, both of which are known to have received large volumes of carbon tetrachloride but that have been remediated since 1992 using SVE.

Relatively high concentrations of carbon tetrachloride (maximum 1,760 ppmv) were detected within the east end of trench T-04 in the 218-W-4C Burial Ground. Carbon tetrachloride concentrations detected in samples collected from the vadose zone 3 months later were much lower (maximum 62.1 ppmv in August and 45.8 ppmv in September). The highest vadose-zone concentrations were in samples collected at site 2, near the location of the elevated concentration within the trench. At site 2, the highest concentrations were in samples collected at depths near the elevation of the floor of the trench. Carbon tetrachloride also was detected in samples from two other sites (site 1 and site 12) near the trench T-04 "hot spot" and at two sites (site 4 and site 6) east of trench T-04.

During October-December 2003, vapor samples were collected through 84 existing vent risers in trenches T-01, T-04, T-07, T-20, and T-29 in the 218-W-4C Burial Ground and analyzed for VOCs using field-screening instruments. A vapor sample then was collected for laboratory analysis from the vent riser in each trench that had the highest carbon tetrachloride concentration, based on the field-screening results. The sampling was conducted in accordance with DOE/RL-2003-48, which was developed to determine whether contaminants have been released to the vadose zone from retrievably stored waste[3] in the 218-W-4C Burial Ground in support of Tri-Party Agreement Milestone M-91-40 (Ecology et al., 1989, as amended).

The samples collected in 2003 were analyzed for the following eight VOCs using a gas chromatograph: carbon tetrachloride, chloroform, methylene chloride, 1,1,1-trichloroethane, 1,1,2-trichloroethane, 1,1-dichloroethane, trichloroethylene, and tetrachloroethylene. For each of these eight VOCs, the highest concentration was detected at the east end of trench T-04, which is consistent with the results of the Step I investigation (CP-13514). The highest concentration of carbon tetrachloride detected was 668 ppmv. However, the field-screening results indicated that the concentrations of 1,1,1-trichloroethane and tetrachloroethylene exceeded the concentration of carbon tetrachloride. The laboratory analysis of vapor samples from trench T-04 detected 14,000 ppmv of tetrachloroethylene and 320 ppmv of 1-butanol. Because of the high dilution required to quantify the tetrachloroethylene in this sample, concentrations for the other analytes present could not be quantified.

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[3] Retrievably stored for purposes of the *Atomic Energy Act of 1954*.

The most likely explanation for the carbon tetrachloride detected in the vadose zone in the 218-W-4C Burial Ground is that carbon tetrachloride was released from containers within trench T-04 and subsequently migrated from the trench to the vadose zone. (The explanation is based on the assumption that carbon tetrachloride could be present in the containers in trench T-04.) The detection of the highest vadose-zone concentrations at site 2 at the approximate elevation of the trench floor suggests that the trench is the source. The persistence of relatively higher concentrations in deeper samples at site 2 further suggests that the carbon tetrachloride migrated vertically within the vadose zone at this site. At each discrete depth sampled (with the exception of 4.6 m [15 ft] bgs), carbon tetrachloride concentrations are lower at the four sites to the west, east, and north of site 2; of those four, concentrations at each discrete depth are higher at site 1, the site closest to site 2. This pattern of decreasing concentrations away from site 2 suggests that carbon tetrachloride is diffusing from site 2.

During the Step I investigation, eight temporary soil-vapor monitoring probes were installed near several of the liquid-waste discharge sites and the 218-W-4C Burial Ground. Soil-vapor samples from these temporary probes were collected 17 times between October 2002 and November 2004 and analyzed to confirm the initial detections. The monitoring results from these temporary probes are summarized in Table 3-10. The highest carbon tetrachloride soil-vapor results from these temporary probes ranged from <1 ppmv at C3875 by the 216-Z-7 Crib to 48 ppmv at site 2 (C4057) at the 218-W-4C Burial Ground. The highest result at site 2 was from a depth of 2.7 to 2.9 m (8.9 to 9.4 ft), which is similar to the 45.8 ppmv at the 3 m (10-ft) depth measured at this site in September 2002. The monitoring of the temporary soil-vapor probes confirmed the initial Step I sampling results.

Step II Results Summary

The Step II results are reported in SGW-33829, and the vadose-zone investigation results are included in this report in Tables 3-11 to 3-19. The results of the Step II investigation are discussed below in Sections 3.2.4.1 to 3.2.4.8.

3.2.4.1 Results of Vadose-Zone Plume Lateral Extent at the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib

The lateral extent of the dispersed carbon tetrachloride vadose-zone plume was investigated using passive soil-vapor surveys initially deployed on a coarse grid spacing followed by refined grid spacing. The results of the passive soil-vapor surveys are summarized in Table 3-11, and the survey locations are shown in Figures 2-10 to 2-13. The highest carbon tetrachloride soil-vapor concentration measured during these passive soil-vapor surveys was 4,531 ng/trap at collector F52 near the west edge of the 216-Z-1A Tile Field (Figure 2-13). The results shown in Figures 2-10 to 2-13 have been converted to contoured flux values by accounting for the cross-sectional area of the sample collector and the total time that the collector was in place and are presented in units of nanograms per gram per square meter per minute. Based on the results of the passive soil-vapor surveys, CPT investigations were conducted that included collection of depth-discrete soil-vapor samples every 1 m (3 ft) of depth and collection of soil samples at selected locations. The results of the CPT active soil-vapor surveys are summarized in Table 3-12, and the general CPT investigation locations are shown in Figures 2-14 and 2-15. The highest carbon tetrachloride soil-vapor concentration measured during the active soil-vapor

sampling using the CPT was 512 ppmv at location P30E from a depth of 18.7 m (61.3 ft) in the west central part of the 216-Z-1A Tile Field (Figure 2-15).

The results of the CPT soil sampling are summarized in Table 3-13. Carbon tetrachloride was not detected in any of the soil samples above the analytical reporting limits.

The results of the HHR soil sampling are presented in Table 3-14. At HHR push location Borehole C5336 (P66) 390,000 µg/kg of carbon tetrachloride was detected south of the 216-Z-9 Trench, suggesting a DNAPL source. This result is consistent with the concentration of carbon tetrachloride at adjacent well 299-W15-46 at 19.8 m (65 ft) of 380,000 µg/kg.

Geophysical logging was conducted at 11 wells in the vicinities of the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib as part of the Step II investigation (Table 2-9). The SGLS was used at each well to identify specific gamma-emitting radionuclides. Passive-neutron logging was performed at selected wells. This logging method has been shown to be effective in qualitatively detecting zones of alpha-emitting nuclides, including transuranic radionuclides, even where no gamma emissions are available for detection. The passive-neutron signal depends on the concentration of alpha sources and also on the concentrations of lighter elements such as nitrogen, oxygen, fluorine, magnesium, aluminum, and silicon that emit neutrons after alpha capture. The Neutron-Moisture Logging System was used at selected wells to measure the volumetric moisture content in percent. Variations in moisture content observed throughout a borehole may aid in interpreting lithology changes.

A summary of the results, taken from the log data reports provided by S. M. Stoller[4], available at http://www.hanford.gov/cp/gpp/data/vzcp/vzcp.cfm, is as follows.

- Well 299-W15-82, east of the 216-Z-9 Trench: The only man-made radionuclide detected was Cs-137 near the ground surface at less than 1 pCi/g.

  The moisture data indicate some variability.

- Well 299-W15-85, north of the 216-Z-9 Trench: No man-made radionuclides were detected in this borehole.
  - The moisture log indicates considerable variability; the maximum volume percent moisture was approximately 15 percent.
- Well 299-W15-218, north of the 216-Z-9 Trench: No evidence of man-made radionuclides was detected in this borehole.

- Well 299-W18-7, east of the 216-Z-1A Tile Field: Am-241 was interpreted to be present from 41.9 to 48.0 m (137.5 to 157.5 ft) bgs at levels less than 100 nCi/g.
  - The vertical profiles of naturally occurring potassium, uranium, and thorium isotopes suggest that the top of the CCU exists at 41.9 m (137.5 ft) bgs. A low concentration of K-40 and elevated U-238 exhibited at this depth is characteristic of this unit,

[4] Stoller is a trademark of S. M. Stoller Corporation, Lafayette, Colorado.

suggesting "caliche." The Am-241 contamination appears to be associated with the unit.

- Elevated radon was observed between 28.5 and 57.5 m (93.5 and 188.5 ft) bgs. Elevated U-238 detected at 52.6 m (172.5 ft) bgs is believed to be naturally occurring and likely indicative of a thin silty zone.

- Well 299-W18-9, in the 216-Z-18 Crib: Am-241 was detected between 6.4 and 17.7 m (21 and 58 ft) bgs and between 19.8 and 20.7 m (65 and 68 ft) bgs. The maximum concentration was approximately 400,000 pCi/g at 7.3 m (24 ft) bgs. A minor amount of Cs-137 (approximately 0.1 pCi/g) also appears to be present.
  - Plutonium-239 was detected between 6.7 and 15.2 m (22 and 50 ft) bgs and between 16.8 and 17.7 m (55 and 58 ft) bgs. The maximum concentration was measured at approximately 400,000 pCi/g at 7.5 m (24.5 ft) bgs. The maximum concentration of Pu-241 was estimated as 16 pCi/g.
  - Neptunium-237 was detected using the SGLS by measuring a daughter product (Pa-233) that emits a prominent gamma ray. Protactinium-233 was detected between 6.7 and 18.0 m (22 and 59 ft) bgs and between 19.7 and 20.9 m (64.5 and 68.5 ft) bgs. The maximum concentration was approximately 19 pCi/g at 7.3 m (24 ft) bgs.
  - A slightly elevated Th-232 concentration is indicated between 6.7 and 7.3 m (22 and 24 ft) bgs; other less prominent indications are at approximately 9.1 m (30 ft) bgs and from 12.2 to 13.1 m (40 to 43 ft) bgs.
  - Uranium-232 is present at a maximum concentration of approximately 1 pCi/g. It is inferred, on the basis of the U-232 concentration, that less than 300 pCi/g of U-233 may be present in this waste stream.
  - Passive-neutron logging was performed in the borehole from the ground surface to 22.9 m (75 ft). The passive-neutron log indicated a maximum count rate of 8 counts per second at 7.3 m (24 ft) bgs.
  - The moisture data indicate some variability.

- Well 299-W18-12, in the 216-Z-18 Crib: No evidence of man-made radionuclides was detected in this borehole. The increase in natural uranium at 57.3 to 58.5 m (188 to 192 ft) bgs, and the associated decrease in natural potassium and thorium, are indicative of a caliche layer.
  - The moisture data indicate some variability.

- Well 299-W18-77, within the 216-Z-1A Tile Field: No evidence of man-made radionuclides was detected in this borehole.

- Well 299-W18-80, in the 216-Z-1A Tile Field: No evidence of manmade contamination was detected in this borehole from spectra collected using routine (i.e., 200-seconds-long) count times. However, spectra were collected at 1.9 and 5.9 m (6.3 and 19.5 ft) bgs, using 1,000-seconds-long count times. The spectra collected at 5.9 m (19.5 ft) bgs represent a measurement at the bottom of the borehole, where the driller's log indicated contamination at 20,000 d/min. Examination of spectra shows evidence of Am-241 at about 11,400 pCi/g and of Np-237 at about 0.88 pCi/g. These levels are below the minimum detectable activity for the 200-seconds-long measurements. From this it can be inferred that some degree of contamination is present near the bottom of the borehole.

- Well 299-W18-167, in the 216-Z-1A Tile Field: Am-241 was detected from 16.6 to 17.8 m (54.5 to 58.5 ft) bgs. The maximum concentration was approximately 250,000 pCi/g at 17.8 m (54.5 ft) bgs.
  - Plutonium-239 was detected at 17.8 m (54.5 ft) bgs. The maximum concentration was approximately 40,000 pCi/g.
  - Neptunium-237 was detected using the SGLS by measuring a daughter product (Pa-233) that emits a prominent gamma ray. Protactinium-233 was detected between 14.8 and 15.1 m (48.5 and 49.5 ft) bgs and from 16.3 to 16.9 m (53.5 to 55.5 ft) bgs. The maximum concentration was approximately 19 pCi/g at 17.8 m (54.5 ft) bgs.
  - Passive-neutron logging was performed in the borehole from 14.5 to 19.4 m (47.5 to 63.5 ft) bgs. The passive-neutron log indicated a maximum count rate of 3 counts per second at 17.8 m (54.5 ft) bgs.
- Well 299-W18-168, in the 216-Z-1A Tile Field: Am-241 was detected from 14.6 to 14.9 m (48 to 49 ft) bgs and from 16.2 to 18.6 m (53 to 61 ft) bgs. The maximum concentration was approximately 145,000 pCi/g at 14.9 m (49 ft) bgs.
  - Plutonium-239 was not detected in this borehole above a method-detection limit of approximately 25,000 pCi/g.
  - Neptunium-237 was detected using the SGLS by measuring a daughter product (Pa-233) that emits a prominent gamma ray. Protactinium-233 was detected between 14.0 and 19.2 m (46 and 63 ft) bgs. The maximum concentration was approximately 16 pCi/g at 14.9 m (49 ft) bgs.
  - Passive-neutron logging was performed in the borehole from 11.6 to 25.3 m (38 to 83 ft) bgs. The passive-neutron log indicated a maximum count rate of 3 counts per second at 14.9 m (49 ft) bgs.
  - Moisture data indicate some variability.
- Well 299-W18-169, in the 216-Z-1A Tile Field: Cs-137 was detected at 0.5 m (1.6 ft) bgs at 0.2 pCi/g.
  - Neptunium-237 was detected using the SGLS by measuring a daughter product (Pa-233) that emits a prominent gamma ray. Protactinium-233 was detected between 9.9 and 12.1 m (32.6 and 39.6 ft) bgs. The maximum concentration was approximately 2 pCi/g at 10.9 m (35.6 ft) bgs.
  - Americium-241 was inferred to be present at relatively low concentrations between 9.9 and 11.8 m (32.6 and 38.6 ft) bgs. This is consistent with the low concentrations observed for Pa-233 (and Np-237, which is a decay product of Am-241).
  - Plutonium-239 was not detected in this borehole above a method-detection limit of approximately 15,000 pCi/g.
  - Passive-neutron logging was performed in the borehole from 8.4 to 13.0 m (27.6 to 42.6 ft) bgs. The passive-neutron log indicated a maximum count rate of 0.8 counts per second at 10.2 m (33.6 ft) bgs.
  - Moisture data indicate some variability.

3.2.4.2 Results from Potential Accumulation Areas at the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib

The results of the cross-well seismic surveys at the 216-Z-9 Trench and the 216-Z-1A Tile Field were interpreted to prepare subsurface topographic contour maps of key vadose-zone layers at each of these sites. The subsurface topographic contour maps for the 216-Z-9 Trench area are shown in Figures 2-20 to 2-23, and those for the 216-Z-1A Tile Field are shown in Figures 2-27 to 2-30. The resulting detailed geometry of these subsurface vadose-zone layers was used to identify target depths for intrusive soil sampling around the release sites.

The CPT soil-vapor sampling results discussed in Section 3.2.4.1 also were used to investigate potential DNAPL or source locations above the CCU that were identified by the passive soil-vapor surveys.

The seismic anomalies that could be attributed to possible carbon tetrachloride DNAPL near the top of the CCU adjacent to the 216-Z-9 Trench (Waddell et al., 2003) were investigated by passive soil-vapor locations 56, 59, 87, and 88 (Figure 2-10) and CPT locations P17, P20, and P24 (Figure 2-14). The results from those investigation locations are provided in Tables 3-11 and 3-12. The highest carbon tetrachloride concentrations measured at these locations were 64 ng/trap at passive soil-vapor location 87 and 5 ppmv at CPT location P20 at a depth of 0.2 m (0.58 ft). These results are significantly less than concentrations expected from a DNAPL source; however, the vapor concentrations in the shallow depths of these investigations may have been affected by the SVE operations. The HHR investigation collected soil samples through the top of the CCU on all sides of the 216-Z-9 Trench. At HHR push location Borehole C5336 (P66) 390,000 µg/kg of carbon tetrachloride was detected south of the 216-Z-9 Trench, suggesting a DNAPL source. This result is consistent with the concentration of carbon tetrachloride at well 299-W15-46 at 19.8 m (65 ft) of 380,000 µg/kg (Table 3-14). However, significant carbon tetrachloride concentrations only were found south of the 216-Z-9 Trench, consistent with the results from well 299-W15-46.

3.2.4.3 Results Adjacent to the 216-T-19 Crib, 216-Z-Ditches, 216-Z-7 Crib, 216-Z-12 Crib, 216-Z-16 Crib, and 216-Z-17 Trench

As previously discussed in Section 2.4.2.3, because of radiological concerns with using the EAPS to investigate the 216-T-19 Crib and the relatively low carbon tetrachloride concentrations observed in Step I, the EPA concurred that a Step II investigation at this site was not required. The EAPS was used to collect soil-vapor samples from the shallow and deep vadose zone in four borings adjacent to the 216-Z-16 Crib and the 216-Z-17 Trench. The results of the EAPS active soil-vapor sampling are summarized in Table 3-15. The only carbon tetrachloride soil-vapor concentration detected in the EAPS samples from these locations was 9.06 to 9.14 ppmv from Borehole C4884 at a depth of 45.7 m (150 ft). This boring was located adjacent to the center of the 216-Z-16 Crib. The Step II results are consistent with the Step I results, in which no carbon tetrachloride was detected down to refusal depth of 20.4 m (67 ft) bgs at the 216-Z-16 Crib site.

The second highest carbon tetrachloride soil-vapor concentration measured in the EAPS samples was 7.31 to 7.34 ppmv from Borehole C4886 at a depth of 22.8 m (75 ft), which is located adjacent to the west side of the 216-Z-17 Trench. This was the only detection of carbon

tetrachloride at the 216-Z-17 Crib during the Step II investigation. The Step II results are consistent with the Step I results, in which no carbon tetrachloride was detected down to refusal depth of 12.2 (40 ft) bgs at the 216-Z-17 Trench site.

The 216-Z Ditches and 216-Z-12 Crib were investigated in the CPT investigation by push locations P41 at the head end of the 216-Z Ditches (Figure 2-15) and by P47 and P48 next to the 216-Z-12 Crib (Figure 2-15). The results of the active soil-vapor sampling are summarized in Table 3-13. The highest carbon tetrachloride soil-vapor concentrations measured at these locations were 4 ppmv from location P41 at a depth of 12.4 m (40.78 ft) and 18 ppmv from location P48 at a depth of 22 m (72.11 ft).

Borehole C4183 was drilled and sampled to evaluate subsurface impacts beneath the 216-Z-7 Crib as part of the 200-LW-2 OU RI (DOE/RL-2005-61, *Remedial Investigation Report for the 200-LW-1 (300 Area Chemical Laboratory Waste Group) and 200-LW-2 (200 Area Chemical Laboratory Waste Group) Operable Units*), and results are reported in D&D-25461, *200-LW-1 and 200-LW-2 Operable Units - Borehole Summary for Boreholes in the 216-S-20, 216-T-28, and 216-Z-7 Cribs*. The soil-vapor sampling results from this borehole are shown in Table 3-16. The highest carbon tetrachloride soil-vapor concentration was 12.2 ppmv at a total borehole depth of 67.7 m (222 ft), which is just above the water table.

3.2.4.4 Results in the Plutonium Finishing Plant Protected Area

The PFP Protected Area was investigated by both passive and active soil-vapor surveys. The 35 passive soil-vapor sampling points (C1-C11, C13-C20, C22, C24-C29, and C31-C41) are shown in Figure 2-12, and the results are included in Table 3-11. The results shown in Figure 2-12 have been converted to contoured flux values by accounting for the cross-sectional area of the sample collector and the total time the collector was in-place, and is presented in units of nanograms per square meter per minute. The highest concentration of carbon tetrachloride soil vapor measured in the passive soil-vapor survey was 147 ng/trap at sampling point C25 near the southwest corner of the PFP. This location is near push Borehole C4063, which had the highest detections of carbon tetrachloride in the active soil-vapor sampling, as discussed below.

Active soil-vapor samples were collected at 17 subsurface locations within the PFP Protected Area (Figure 2-33), and the results are summarized in Table 3-17.

Carbon tetrachloride concentrations were detected at Boreholes C3878, C4066, C4065, C4063, C4138, and C4067. Concentrations at the other locations all were below minimum detection values. Additionally, no consistent pattern was observed in the distribution of carbon tetrachloride contamination at the six sites that had detectable concentrations, other than at each sample location; the highest, or only, detection is at the deepest sampling depth. Of the six sites, one site (Borehole C4063) had detectable concentrations at all sampling depths. Borehole C3878 had detectable levels at the two deeper sample depths, and the other four locations had detectable levels only at the deepest sample depth.

At Borehole C4063, carbon tetrachloride was detected at all depths sampled (4.1 to 12.9 m [13.5 to 42.2 ft] bgs). The highest concentration of 4.24 ppmv was detected at the deepest depth, with decreasing concentrations at the shallower depths (2.32 ppmv at approximately 7 m [23 ft] bgs and 1.41 ppmv at approximately 4.3 m [14 ft] bgs). No reports are present to indicate

that an unplanned release of carbon tetrachloride occurred at or near the site. An unplanned release (UPR-200-W-1559) of sodium hydroxide did occur in the vicinity in May 1985, but the contaminated soil was collected and disposed of as hazardous waste.

Borehole C4067 had a carbon tetrachloride concentration of 2.41 ppmv at a depth of approximately 11.7 m (38.5 ft) bgs.

Two of the french drain sites (Boreholes C4065 and C4066) had detectable carbon tetrachloride concentrations. Borehole C4065 had 1.22 ppmv at approximately 13.3 m (43.5 ft) bgs, and Borehole C4066 had 1.33 ppmv at approximately 12 m (39.5 ft) bgs. The sampled concentration and depth are nearly identical for these sites, which are separated by approximately 30 m (100 lineal ft). No carbon tetrachloride was detected at the other french drain site (Borehole C4064) which reached refusal at approximately 8.7 m (28.5 ft) bgs, at which depth both of the other french drain sites had non-detect values for carbon tetrachloride.

Borehole C4138, northeast of the PFP, had a carbon tetrachloride vapor concentration of 1.21 ppmv at an approximate depth of 14.3 m (47 ft) bgs. Borehole C3878 (see below) also is located on the east side of the PFP Protected Area and had detectable carbon tetrachloride vapor concentrations.

Borehole C3878 had two depths (approximately 13.3 and 7.8 m [43.5 and 25.5 ft] bgs) where carbon tetrachloride vapor concentrations were detectable (1.78 ppmv and 1.01 ppmv, respectively). Borehole C3877, which had no recordable carbon tetrachloride vapor concentrations, is located approximately 30 m (100 lineal ft) from Borehole C3878 and had sample depths within a few meters below ground surface of the sample depths for Borehole C3878.

Results for soil-vapor sampling during drilling of Boreholes C3494 (well 299-W15-764) and C3803 (well 299-W15-42) are reported in Table 16 in BHI-01631. The maximum carbon tetrachloride vapor concentration detected in well 299-W15-42 was 49 ppmv from a depth of 25 m (82 ft) bgs. The maximum (and only) carbon tetrachloride vapor concentration detected in well 299-W15-764 was 18 ppmv from a depth of 24.4 m (80 ft) bgs.

The relatively low concentrations of carbon tetrachloride vapor measured suggest that there is not an active source of contamination in the upper vadose zone at these locations.

3.2.4.5 Results Adjacent to the 216-S-25 Crib

The soil-vapor sampling results for EAPS Boreholes C4890 and C4891 adjacent to the 216-S-25 Crib are included in Table 3-15. The only detectable concentration of carbon tetrachloride soil vapor was 1.89 ppmv in the sample from a depth of 65.5 (215 ft) from Borehole C4890.

The groundwater sample (HEIS number B1DFF8) collected from Borehole C4890 on July 11, 2005, was analyzed for VOCs. The only compounds detected in this sample were carbon tetrachloride at 1 µg/L (J – estimated) and chloroform at 14 µg/L.

3.2.4.6 Results at the 218-W-3A Burial Ground

The investigation of the 218-W-3A Burial Ground included a passive soil-vapor survey of two trenches, T-9S and T-06, and active vapor sampling from all 17 vent risers present, in portions of trenches T-9S, T-3S, T-05, and T-08 (Figure 2-34). The passive soil-vapor results are presented in Table 3-18. The highest carbon tetrachloride soil-vapor concentration was 231.08 ng/trap from sampling point T06-10D.

The field-screening results for the vapor samples collected through the vent risers in the 218-W-3A Burial Ground trenches are provided in Table 3-19. The only concentrations of carbon tetrachloride (5 to 36 ppmv) were detected in the western part of trench T-08.

3.2.4.7 Results of Groundwater "Hot Spots" Investigation

The likelihood that carbon tetrachloride detected in the vadose zone is or will be impacting groundwater was evaluated using Henry's Law for the equilibrium partitioning of carbon tetrachloride between vapor and aqueous phases. Areas of elevated carbon tetrachloride concentrations were further investigated to determine if the persistence of elevated concentrations were an indication of a continuing source. As a rule of thumb, the concentration of carbon tetrachloride in the vapor phase will be 0.156 ppmv per 1 µg/L of carbon tetrachloride in the aqueous phase, at 20 °C (DOE/RL-2001-01, Section D1.4.2). For example, if the soil-vapor concentration is 156 ppmv, the calculated equilibrium groundwater concentration will be approximately 1,000 µg/L. If the measured carbon tetrachloride groundwater concentration is less than the equilibrium value, then the vadose-zone soil vapor is likely to impact groundwater as the carbon tetrachloride vapor dissolves into the groundwater. However, if the measured carbon tetrachloride groundwater concentration is greater than the equilibrium value, then the vadose-zone soil vapor is not likely to impact groundwater, and the carbon tetrachloride in the groundwater will be expected to volatilize into the soil vapor.

Soil-vapor and groundwater samples were collected near the water table from 31 groundwater wells within eight areas identified as having elevated concentrations of carbon tetrachloride in groundwater (hot spots), as described in Section 2.4.2.8. The measured carbon tetrachloride concentrations in these samples are summarized in Table 3-20. Using the soil-vapor results and Henry's Law, the hypothetical groundwater concentration that would be in equilibrium with each soil-vapor measurement was calculated as shown in Table 3-20. The calculated hypothetical equilibrium groundwater concentrations then were compared to the measured carbon tetrachloride concentrations in groundwater to determine if the soil vapors could be impacting the groundwater. As shown in Table 3-20, in all but two cases, the measured groundwater concentrations are greater than the calculated equilibrium groundwater concentrations, indicating that the vadose-zone soil vapor in 29 of the 31 well locations is not impacting the groundwater.

In two cases (August 2005 sampling of well 299-W11-3 in Area 3 and sampling of well 299-W15-15 in Area 6), the measured groundwater concentrations are close to the calculated equilibrium groundwater concentrations, indicating that the vadose-zone soil vapor could be the source of the shallow groundwater concentration in these wells (Table 3-20). The October 2005 sampling results for well 299-W11-3 indicated that the soil vapor did not impact the groundwater, so the impact in this well may be anomalous or may vary temporally. In both of

these cases, the measured groundwater concentrations were low (6.9 and 21 µg/L of carbon tetrachloride), so the vadose-zone soil vapors are not significant sources of groundwater contamination at these wells.

To evaluate the carbon tetrachloride concentration gradient in the upper 3 m (10 ft) of the unconfined aquifer, depth-discrete groundwater samples were collected from selected wells within the groundwater "hot spot" areas. Vertical profile plots of the carbon tetrachloride results for the depth-discrete groundwater samples are shown in Figure 3-19 for Area 2 (wells 299-W11-25B and 299-W11-42), Area 4 (well 299-W11-10), Area 5 (wells 299-W15-40, 299-W15-43, and 299-W15-765), Area 7 (well 299-W15-30), and Area 8 (well 299-W23-4). In all but two wells (wells 299-W11-42 and 299-W15-30), the carbon tetrachloride concentration gradient increased with depth in the top of the unconfined aquifer. If there were potential source areas in the deep vadose zone near these wells, the carbon tetrachloride concentration in the groundwater was expected to be highest near the water table and then to decrease with depth in the aquifer.

The profile plot for well 299-W11-42 shows a slight decrease in concentration from the 1.5 to 3 m (5- to 10-ft) sample. However, the 14-day holding time for the deeper sample was exceeded before analysis, so this lower concentration may be due in part to this issue. The profile plot for well 299-W15-30 shows that the three depth-discrete samples all had the same carbon tetrachloride concentration of 1,500 µg/L. Although the reason for this trend is not clear, it does not appear to be related to a potential vadose-zone source, because the evaluation of the carbon tetrachloride soil-vapor and groundwater concentrations indicated that the soil vapor was not impacting the groundwater (Table 3-20) at this well.

3.2.4.8 Results of Possible Release Sites/Sources Investigations

The results are summarized in this section of a variety of investigations that have been conducted within the Step II study area that provide useful information on the nature and extent of the dispersed carbon tetrachloride vadose-zone plume.

Central Plateau Ecological Risk Assessment

In 2006 and 2007, passive and active soil-vapor sampling was conducted in the shallow vadose zone in the vicinities of the 216-Z-1A Tile Field, the 216-Z-9 Trench, and the 218-W-4C Burial Ground annex for the Central Plateau ecological risk assessment. Potential risks to burrowing animals that could be present in shallow soils containing carbon tetrachloride vapor concentrations were investigated. Because animal burrows were not found to exist in locations with known carbon tetrachloride vapor concentrations, artificial burrows were installed (D&D-32015, *Sampling and Analysis Instruction for Artificial Animal Burrows, in Support of the Central Plateau Ecological Risk Assessment*). The passive soil-vapor results were used for screening the locations in which to place the artificial burrows. The artificial burrows were installed near the 216-Z-1A Tile Field and the 218-W-4C Burial Ground annex. After allowing time for steady-state distribution of the soil-gas contamination to be established, the air within

the artificial burrows was sampled. The samples were collected in SUMMA[5] canisters and analyzed in the laboratory for carbon tetrachloride, chloroform, and methylene chloride. The maximum VOC concentration in the SUMMA canister samples was 0.15 ppmv of carbon tetrachloride in a sample from the vicinity of the 216-Z-1A Tile Field. This maximum detected carbon tetrachloride concentration was only 20 percent of the wildlife-screening threshold. Sample results are included in HEIS (Sampling Authorization Forms F06-040 and F06-041) and will be addressed by separate documents prepared in support of the Central Plateau ecological risk assessment.

Burial Grounds Soil-Vapor Survey

A passive soil-vapor survey, conducted as part of the 200-SW-2 OU preliminary RIs in 2006 within selected trench segments in the 218-W-3A, 218-W3AE, 218-W-4B, 218-W-4C, and 218-W-5 Burial Grounds in the 200 West Area, detected VOCs including carbon tetrachloride (SGW-32683, *Results of Passive Organic-Vapor Sampling*). Further investigation of landfill trench segments will be conducted as part of the 200-SW-2 OU RI.

T Plant Soil-Vapor Survey

The results of the passive soil-vapor survey around the T Plant are shown in Table 3-21. No carbon tetrachloride was detected in any of these samples above the laboratory method detection limit (25 ng/trap).

Fiscal Year 2001 to 2006 Well Drilling for Other Operable Units

The results of soil-vapor samples collected during well drilling from FY 2001 to FY 2006 are summarized in Table 3-16. The carbon tetrachloride vapor concentrations detected in most of these samples generally were less than 10 ppmv. The highest carbon tetrachloride soil-vapor concentration measured in these samples was 86.9 ppmv from well 299-W18-16 at a depth of 37.2 m (122 ft) bgs. This well is located on the east side of the 216-Z-1A Tile Field.

In samples collected from Borehole C3102, carbon tetrachloride was not detected in any of the soil samples, which were analyzed at an offsite laboratory (DOE/RL-2002-42). The soil-vapor sample was collected at a depth of 68.6 m (225 ft) bgs, which was 0.22 m (0.72 ft) above the water table. An inflatable packer was used to isolate the lower portion of the borehole, and the sample was pumped into a 1 L Tedlar bag for onsite analysis using a B&K 1302 multi-gas analyzer. The analytical results for this sample (HEIS number B12D87) were 4.12 ppmv carbon tetrachloride and 4.73 ppmv chloroform (BHI-01606, *Borehole Summary Report for Borehole C3102 in the 216-T-26 Crib, 200-TW-1 Scavenged Waste Group Operable Unit*).

In FY 2006, wells 299-W11-47 and 299-W15-224 had the highest carbon tetrachloride soil-vapor concentrations. At well 299-W11-47 at a depth of 40.5 m (133 ft), 2.49 ppmv was reported, and in well 299-W15-224 from a depth of 69.5 to 70 m (228 to 230 ft), 26.6 ppmv was reported.

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[5] SUMMA is a trademark of Moletrics, Inc., Cleveland, Ohio.

Enhanced Access Penetration System Demonstration 2003

The results of the active soil-vapor sampling conducted in four of the EAPS demonstration boreholes drilled in 2003 are presented in Table 3-22. The highest carbon tetrachloride soil-vapor concentration measured in these samples was 12.9 ppmv in Borehole C4242 at a depth of 45.1 m (148 ft). This borehole is located between the PFP and the 218-W-4C Burial Ground.

Well Drilling Near Release Sites

In 1992 and 1993, 11 wells were drilled, and in 2001 two existing wells were deepened around the release sites. The results of these investigations are reported in WHC-SD-EN-TI-063, WHC-SD-EN-TI-202, and BHI-00105. In FY 2005, the chemical constituent data for 12 of these wells were entered into HEIS. Because the location of these wells around the release sites is useful for determining the extent of the dispersed carbon tetrachloride vadose-zone plume, the analytical results in HEIS for these wells are included in Appendix C of this RI report.

In 1995, well 299-W15-32 was drilled and sampled to investigate DNAPL occurrence on the northeast corner of the 216-Z-9 Trench (Figure 2-1). No DNAPL was detected in the samples from this well (BHI-00431).

In 2001, wells 299-W15-84 and 299-W15-95, located on the west and north sides, respectively, of the 216-Z-9 Trench, were deepened and soil samples were collected for laboratory analysis. The analytical results for the samples collected during the deepening of these wells also are included in Appendix C.

The results of the FY 1992 and FY 1993 soil-vapor samples collected during drilling of some of these wells are provided in Table 3-23. The highest carbon tetrachloride soil-vapor concentration measured in these wells was 20,910 ppmv in well 299-W15-218 at a depth of 34.1 m (111.8 ft). This is 17 percent of the carbon tetrachloride vapor concentration, indicating carbon tetrachloride saturation of the vadose zone. This well is located north of the 216-Z-9 Trench.

The highest carbon tetrachloride concentrations measured in the soil samples collected during the drilling of the FY 1992-1993 and 2001 well drilling around the release sites are summarized in Table 3-24. The highest concentrations of carbon tetrachloride detected in the soil samples were 37,817 µg/kg in well 299-W15-217 from a depth of 34.7 m (114 ft) (near the 216-Z-9 Trench), 6,561 µg/kg in well 299-W18-174 from a depth of 36.9 m (121.1 ft) (near the 216-Z-1A Tile Field), and 1,957 µg/kg in well 299-W18-249 from a depth of 44.2 m (145 ft) (near the 216-Z-18 Tile Field).

Most of the FY 1992 and FY 1993 soil samples were collected before start-up of the SVE systems at these sites in 1993 (see Section 2.4.3.1). The results from these soil samples are useful for determining the extent of the dispersed carbon tetrachloride vadose-zone plume at that time. As shown in Table 3-24, most of the highest carbon tetrachloride concentrations in these soil samples were found at or near the depth of the CCU. The minimum extent of the high-concentration portion of the dispersed carbon tetrachloride plume at the CCU was from the release sites to the location of these wells (e.g., approximately 75 m [246 ft] from the release sites). The maximum extent cannot be defined with the FY 2002-2003 data set, but the more

recent Step II investigations are useful in bounding the dispersed carbon tetrachloride vadose-zone plume, as discussed in Section 3.2.4.9.

The results for wells 299-W15-84 and 299-W15-95 (collected in 2001) shown in Table 3-24 are significantly lower than the FY 1992-1993 well results and show the impact of the SVE system near the release sites in reducing the carbon tetrachloride concentrations in the vadose zone (see also Section 2.5).

Fiscal Year 1991 Soil-Vapor Sampling

Results for the 1991 active soil-vapor monitoring near the 216-Z-18 Crib area are shown in Table 3-25. Detected concentrations of carbon tetrachloride (as total OVA response) ranged from 1.492 ppmv (sample point Z18N-6) to 14.95 ppmv (sample point Z18N-8).

3.2.4.9 Contaminant Distribution Model of the Dispersed Plume

The results of the Step I and Step II investigations of the dispersed carbon tetrachloride vadose-zone plume are discussed by each investigation area or activity in the preceding sections. Because the geographic boundaries of the Step II investigation include the vadose zone overlying the carbon tetrachloride groundwater plume defined by the 5 µg/L contour, which covers approximately 11 km^2 (4.2 mi^2) and underlies most of the 200 West Area, this section provides a summary of the investigation results and an evaluation from a larger perspective for this data set.

During the DQO process for the Step II investigation, the vadose zone was divided into three zones to develop the sampling design and assess the current or future groundwater impacts. The three zones are the shallow, intermediate, and deep vadose zone, which correspond to the Hanford formation, the CCU, and the Ringold Formation down to the water table.

A database of the Step I and II investigation results was created in Microsoft Access[6] so the data could be sorted by sample type and sample depth, as well as other parameters. After they were sorted, the data points were plotted on a site base map using Geographical Information System software, so that the spatial coverage of the results could be evaluated. The number of investigation results in the database is summarized in the following table, and a summary map of all of the Step I and Step II investigation locations discussed in this report is shown in Figure 3-20.

Dispersed Plume Results by Sample Media [a]			
Vadose-Zone Interval	**Passive Soil Vapor**	**Active Soil Vapor [b]**	**Soil Samples [c]**
Shallow	749	1,800	330
Intermediate	0	27	68
Deep	0	273	182
Total sample results	749	2,100	580

[a]Data through September 13, 2006.
[b]At 1,249 separate locations.
[c]At 78 separate locations.

[6] Access is a trademark of Microsoft Corporation, Redmond, Washington.

Figures 3-21 and 3-22 show all of the passive soil-vapor results and an enlarged view of these results centered on the release sites. The location of the maximum passive soil-vapor result (4,531 ng/trap at F52) at the west edge of the 216-Z-1A Tile Field is shown in both figures. The passive soil-vapor samples were collected between August 2003 and December 2005, so they provide information about the current nature and extent of the dispersed carbon tetrachloride vadose-zone plume in the shallow vadose zone. The highest passive soil-vapor concentrations (e.g., the red and blue dots) are grouped in two areas. One area includes the 216-Z-1A Tile Field and extends approximately 20 m (66 ft) to the west. The second area is located northwest of the 216-Z-9 Trench near the entrance to the PFP. The active soil-vapor investigation of the pipelines near this area did not identify any near-surface releases, so this area may be associated with contamination from the 216-Z-9 Trench that moved away from the trench area on the top of the CCU, and is outside the capture zone of the SVE system.

Figures 3-23, 3-24, and 3-25 show the active soil-vapor results for the shallow, intermediate, and deep vadose zone, respectively, and Figures 3-26, 3-27, and 3-28 show enlarged views of each of the results from these depth intervals near the release sites. The active soil-vapor samples were collected between 1992 and 2006. The earliest samples were collected primarily near the release sites, with most of the remaining samples collected from 2001 to 2006 both near and away from the release sites. These results provide information about both the historic and the current nature and extent of the dispersed carbon tetrachloride vadose-zone plume throughout the vadose zone. The highest active soil-vapor concentrations are located near the release sites at all three depth intervals. The maximum active soil-vapor carbon tetrachloride concentration in each depth interval was located near the 216-Z-9 Trench (28,500 ppmv in the shallow vadose zone at well 299-W15-82, 25,500 ppmv in the intermediate vadose zone at well 299-W15-217, and 10,380 ppmv in the deep vadose zone at well 299-W15-218). Monitoring results in these wells, as part of the SVE system operation around the release sites, show that vapor concentrations have been significantly reduced (see Figure 2-44), and the more recent CPT investigations around the release sites generally have found carbon tetrachloride soil-vapor concentrations of less than 100 ppmv (yellow dots in Figure 3-26).

Figures 3-29, 3-30, and 3-31 show the soil sample results for the shallow, intermediate, and deep vadose zone, respectively. The soil samples were collected primarily from wells drilled in FYs 1992-1993, two wells deepened at the 216-Z-9 Trench in 2001, the CPT investigations conducted in 2005, and the HHR investigation in 2006. These results provide information about both the historic and the current nature and extent of the dispersed carbon tetrachloride vadose-zone plume throughout the vadose zone near the release sites. The maximum carbon tetrachloride concentration in soil in the shallow and intermediate vadose zone is located south of the 216-Z-9 Trench. Borehole C5336 (P66) had the highest concentration (390,000 µg/kg) in the shallow vadose zone, and well 299-W15-217 had the highest concentration in the intermediate vadose zone (37,817 µg/kg). The maximum carbon tetrachloride concentration in soil in the deep vadose zone is located in well 299-W18-174 (6,561 µg/kg at 8.3 m [27.1 ft] bgs) at the 216-Z-1A Tile Field.

Based on the results of the Step I and Step II investigations discussed in this report, the following conclusions are made concerning the nature and extent of the dispersed carbon tetrachloride vadose-zone plume.

- The highest carbon tetrachloride concentrations in the shallow, intermediate, and deep vadose zone generally are located within about 75 to 150 m (246 to 492 ft) of the release sites.

- The carbon tetrachloride concentrations in the vadose zone around the release sites are being reduced by the SVE system and are significantly less than the initial concentrations measured in 1992-1993.

- Outside of the area around the release sites, carbon tetrachloride vapor concentrations up to about 10 to 12 ppmv were found at various locations in the vadose zone, but these concentrations are not considered to have the potential for significant current or future groundwater impacts.

- The soil-vapor and shallow-groundwater sampling at wells within the eight carbon tetrachloride groundwater "hot spot" areas indicated that the deep vadose-zone soil-vapor concentrations are not significant sources of groundwater contamination in these areas.

- An area of high passive soil-vapor concentration was found northwest of the 216-Z-9 Trench near the entrance to the PFP. The active soil-vapor investigation of the pipelines near this area and several CPT investigations did not identify any potential release areas in the shallow vadose zone. CPT push location P10A had the highest active soil-vapor carbon tetrachloride concentration of 119 ppmv at 31.1 m (102.1 ft), above the top of the CCU. This area may be associated with contamination from the 216-Z-9 Trench that moved away from the trench area on the top of the CCU, and is outside the capture zone of the SVE system.

- Carbon tetrachloride DNAPL was found at 19.8 m (65 ft) bgs at both Borehole C5336 (P66) and well 299-W15-46 in the shallow vadose zone, adjacent to the 216-Z-9 Trench.

In PNNL-16198, *Carbon Tetrachloride Flow and Transport in the Subsurface of the 216-Z-18 Crib and 216-Z-1A Tile Field at the Hanford Site, Multifluid Flow Simulations and Conceptual Model Update*, the following assessment was provided to describe the magnitude of disposal at an undocumented source that would be needed from carbon tetrachloride for this source to have a significant impact on groundwater. A series of simulations was conducted to estimate the volume of DNAPL that is required to result in DNAPL movement across the water table for all three release sites (216-Z-9, 216-Z-1A, and 216-Z-18). The simulations revealed that at least 250 m^3 of DNAPL would be necessary for this movement to occur if the DNAPL had been disposed of at a typical waste site in the 200 West Area. Additional DNAPL volumes of that magnitude beyond what has been commonly reported for the three major release sites are not likely. Undocumented carbon tetrachloride sources also might have been the result of accidental spills. The maximum simulated infiltration depth of carbon tetrachloride DNAPL was 28 m (91.86 ft) for the case where 50 barrels were allowed to infiltrate in one day. This distance is not even enough for the carbon tetrachloride DNAPL to reach the CCU. The limited infiltration depth is directly related to sorption and mass transfer into the aqueous and gas phases,

as well as gaseous transport away from the infiltration zone because of advection and diffusion. Considering the size of the simulated carbon tetrachloride DNAPL spill volumes (up to 10 m^3), it also is unlikely that an undocumented spill of carbon tetrachloride DNAPL would have been able to reach the water table (PNNL-16198).

3.2.5 Nature and Extent of Contamination in the 216-A-8 Crib

The nature and extent of contamination summarized in this section are representative of the 216-A-8 Crib in the 200-PW-3 OU. Evaluation of the nature and extent of contamination at this location is based on the evaluation of all available data. Available data for this representative waste site include historical and new geophysical logging results and new soil and soil-vapor sampling results. The data and analysis were integrated to develop and refine a contaminant distribution model for the representative waste site.

The following provides a summary of important RI findings related to the 218-A-8 Crib.

- The highest radiological contamination associated with the crib was detected within 18 m (60 ft) of the ground surface.
- The maximum extent of radiological contamination detected near the crib by geophysical logging techniques was 76.5 m (251 ft) bgs. However, the source of the contamination at this depth is not known.
- Radioactive COPCs for the 200-PW-3 OU were detected in the vadose zone beneath the 216-A-8 Crib in Borehole C4545 to total depth (80 m [264.5 ft] bgs). A summary of the maximum concentrations of COPCs detected near the crib is presented in Section 3.2.5.3.

3.2.5.1 Historical Contaminant Investigation Summary

As part of the investigation activities to locate Borehole C4545, six other boreholes (wells 299-E25-4, 299-E25-5, 299-E25-6, 299-E25-7, 299-E25-8, and 299-E25-9) were geophysically logged using the SGLS between April and July 2004 (WMP-27020). The geophysical log data reports for these boreholes are included in WMP-27020. The only man-made radionuclide detected during the logging was Cs-137, and the highest concentrations were found in the western end (head end) of the 216-A-8 Crib. At the west end of the crib, the highest Cs-137 concentrations were 30,800 pCi/g in well 299-E25-5 at 7.6 m (25 ft) below the top of the casing, 50 pCi/g in well 299-E25-6 at 7.6 to 9.1 m (25 to 30 ft) below the top of the casing, and 13.1 pCi/g in well 299-E25-4 at 7.9 m (26 ft) below the top of the casing. In the other three boreholes along the rest of the crib, the highest Cs-137 concentrations were all found at 1.5 m (5 ft) below the top of the casing: 5.7 pCi/g in well 299-E25-7, 4.5 pCi/g in well 299-E25-8, and 13 pCi/g in well 299-E25-9 at the east end.

The historical gross gamma logging system and radionuclide logging system borehole geophysical log data for these six boreholes are presented and discussed in the geophysical log data reports in WMP-27020. Although there are differences in the depths and timing when gamma activity was detected in these boreholes, the nature and extent of gamma-emitting

radionuclides from this data set are best illustrated by the following summary from the well 299-E25-6 report.

The gross gamma logs digitized from RHO-LD-28, *Scintillation Probe Profiles From 200 East Area Crib Monitoring Wells*, are shown in Figure 3-32. These logs were converted to counts per second versus depth in feet for better comparison with the SGLS and radionuclide logging system data. As early as 1958, a zone of high gamma activity was observed from an approximately 4.6 to 18 m (15 to 60 ft) depth. Within this interval, the detector appears to be saturated. The 1958 and 1959 logs show abrupt increases in gamma activity at the bottom of the logged interval at 70 to 73 m (230 to 240 ft). This may indicate contamination at or near groundwater level. As discussed in Section 1.4.5, approximately 87 percent of the liquid waste, by volume, was discharged to the crib between 1955 and 1958. By 1963, the interval of detector saturation extended to about 32 m (105 ft). Gamma activity levels had increased significantly between 32 and 41 m (105 and 135 ft), and there appeared to be an abrupt decrease at 41 m (135 ft), suggesting additional contamination events and/or downward contaminant migration between 1959 and 1963. The 1968 and 1976 logs show significantly lower gamma activity levels and generally reflect the profile of the 1990 radionuclide logging system and the 2004 SGLS logs. Below the 12 to 18 m (40 to 60 ft) depth, the dominant contaminant may have been a radionuclide with a relatively short half-life, such as Ru-106. The 1976 log shows significantly greater gamma activity between approximately 6 to 23 m (20 to 75 ft). This may indicate an additional contamination event between 1968 and 1976. The SGLS Cs-137 log indicates contaminant migration to a depth of 22.5 m (74 ft). The historical data suggest that contaminants from the 216-A-8 Crib reached at least the 41 m (135 ft) depth. The SGLS log also detected Cs-137 between 69 and 71 m (227 and 234 ft), with a maximum concentration of about 3.2 pCi/g at 70 m (229 ft). Traces of Cs-137 also were detected intermittently between 74 and 76.5 m (243 and 251 ft). The source of this contamination is not known. Other boreholes in the vicinity also exhibit similar contamination profiles at approximately the same elevation. This contamination may have been deposited on the casing from groundwater contaminant plumes in the past, when groundwater levels were higher.

3.2.5.2 New Geological Logging

Borehole geophysical logging of Borehole C4545 took place on June 21, 2005, when the borehole was at a depth of 21.3 m (70 ft) bgs and again on July 5, 2005, at total depth of 80.6 m (264.5 ft) bgs (WMP-27020). Two intervals in Borehole C4545 showed detectable Cs-137; one interval from the ground surface to 1.5 m (5 ft) bgs and the other from 3.4 to 22.3 m (11 to 73 ft) bgs. The highest concentration zone lies between 3.4 and 7.6 m (11 and 25 ft) bgs, with a maximum concentration of approximately 1.5 million pCi/g measured at 6.1 m (20 ft) bgs. Potential casing contamination may be the cause of Cs-137 contamination observed at relatively low concentrations (e.g., below 10 pCi/g) between 12.2 and 22.3 m (40 and 73 ft) bgs and the cause of Cs-137 spikes at probable casing joints at 15.2 and 18.3 m (50 and 60 ft) bgs.

The laboratory sample results for Cs-137 from Borehole C4545 correlate with the borehole geophysical logging results. At 5.8 to 6.6 m (19 to 21.5 ft) bgs, Cs-137 results reached a maximum of 877,000 pCi/g. The second highest results for Cs-137 (3,730 pCi/g) were found in the samples from 8.3 to 9.1 m (27.5 to 30 ft) bgs.

3.2.5.3 216-A-8 Crib Contamination – Laboratory Data

Radioactive COPCs for the 200-PW-3 OU were detected in the vadose zone beneath the 216-A-8 Crib in Borehole C4545 to total depth (80 m [264.5 ft] bgs). However, only two radionuclides (C-14 and tritium) were detected above background levels below the sample interval at 14.9 to 15.7 m (49 to 51.5 ft). Background levels for the 200-PW-3 OU radionuclide COPCs are shown in Table 3-26. The maximum results for the Borehole C4545 samples are presented in Appendix A and are summarized below.

Because none of the Borehole C4545 samples were collected in shallow soils (<4.6 m [<15 ft]) all of the sample results represent deep soils (ground surface to total depth). The following table presents the radionuclide COPCs detected above background levels and the depth interval of the maximum concentration.

Radionuclide Contaminant of Potential Concern	Maximum Concentration (pCi/g)	Depth Interval (ft bgs)	
		Top	Bottom
Carbon-14	89.7	27.5	30
Cesium-137	877,000	19	21.5
Europium-155	0.055	49	51.5
Plutonium-239/240	55.7	19	21.5
Technetium-99	79.6	19	21.5
Total radioactive strontium	4,380	19	21.5
Tritium	8.5	234	236.5

Background levels for the 200-PW-3 OU nonradionuclide COPCs are shown in Table 3-27. The following table presents the nonradionuclide COPCs detected above background levels (and those with no available background value) and the depth interval of the maximum concentration.

Nonradionuclide Contaminants of Potential Concerns	Maximum Concentration (mg/kg)	Depth Interval (ft bgs)	
		Top	Bottom
Cadmium	0.240	104	106.5
Chromium (III)	41.8	178	180.5
Hexavalent chromium	0.278	27.5	30
Selenium	1.8	19	21.5
Acetone	0.019 J	19	21.5
Acetonitrile	0.012 J	25	27.5
Ethyl acetate	0.023	25	27.5
Decane	0.5 J	104	106.5
Nonadecane	1.6 J	104	106.5
Di-n-butylphthalate	0.69	178	180.5
Aroclor-1254	0.039	234	236.5

bgs = below ground surface.
J = laboratory-estimated value.
Aroclor is an expired trademark.

The contaminant distribution model presented in the Work Plan (DOE/RL-2001-01, Section 3.4) is supported by the RI data, with some minor changes (Figure 3-33). Based on the contaminant distribution model in the Work Plan, the highest radiological contamination was expected from the base of the crib to several meters below and then was expected to decrease with depth. For most of the radionuclides detected above background levels, the highest concentrations were reported in the 5.8 to 6.6 m (19 to 21.5 ft) bgs sample collected directly beneath the crib, confirming the conceptual model that radionuclide contamination generally is confined to a relatively short vertical interval below the crib.

The contaminant distribution model in the Work Plan predicted a possible organic-rich layer, with no significant radionuclide content directly beneath the crib. Low concentrations of several organic compounds (acetone, acetonitrile, and ethyl acetate) were present in the sample intervals beneath the crib where the highest radiological contamination also was found, but a separate organic-rich layer was not present. Low concentrations of several semivolatile organic compounds, metals, and radionuclides were found to be present deeper in the vadose zone, which also was predicted by the contaminant distribution model in the Work Plan.

The soil-sampling intervals, lithology, field-screening measurements, and borehole geophysical logs for Borehole C4545 are shown in Figure 3-34. Vertical concentration profile plots for those COPCs that had a detected value above background (and COPCs with no available background value) are shown in Figure 3-35.

3.2.6 216-Z-8 French Drain

Characterization well 299-W15-202 was drilled in 1980, and soil samples were collected to define the plutonium and americium distribution beneath the 216-Z-8 French Drain (RHO-RE-EV-46P). The well was located less than 1 m (3 ft) south of the 216-Z-8 French Drain and was drilled to 53.6 m (176 ft) bgs. A maximum value of 457 pCi/g Am-241 was reported at 6.1 m (20 ft) bgs, near the bottom of the 216-Z-8 French Drain structure. A maximum Pu-239 value of 4,620 pCi/g was reported at 7.6 m (25 ft) bgs. Results indicate that plutonium and americium were sorbed onto sediments within a few meters beneath the french drain. Based on these results, the nature and extent of contamination are suspected to be confined to a shallow vadose zone directly adjacent to the 216-Z-8 French Drain. It is unlikely that the contaminants disposed to the 216-Z-8 French Drain reached groundwater. The contaminant distribution model is presented in Figure 3-36.

3.2.7 216-Z-10 Injection/Reverse Well

In 1947, three monitoring wells (299-W15-59, 299-W15-60, and 299-W15-61) were drilled 4.6 m (15 ft) from the 216-Z-10 Injection/Reverse Well for the collection of characterization soil samples (HW-9671). The wells were drilled to 53.3 m (175 ft) bgs, which was 7.6 m (25 ft) below the bottom of the reverse well.

Characterization soil samples were collected at a minimum frequency of every 1.5 m (5 ft), and every 0.3 m (1 ft) where contamination was suspected to exist. A total of 210 soil samples from the three monitoring wells were collected, including field duplicates, and analyzed in the

laboratory using an alpha counter (HW-9671). HW-9671 did not state the method reporting limit that was used; therefore, the method reporting limit from HW-22682, *Calculation Constants Used by Regional Survey, Part II Alpha Sample Counting Ratite Conversion Factors*, of 0.15 pCi/g, was used as a surrogate value. Contamination, specifically plutonium, was not detected in any of the soil samples. In 2005, passive neutron logging to detect alpha contamination was conducted at this site, and the results confirm the HW-9671 findings that plutonium has not moved 4.6 m (15 ft) laterally from the injection/reverse well toward the soil borings (completed as vadoze-zone wells 299-W15-59, 299-W15-60, and 299-W15-61). At well 299-W15-59, Cs-137, Co-60, and Eu-154 were the man-made radionuclides detected in this borehole. Cesium-137 was detected near the ground surface at approximately 1 pCi/g, and at 24.4 m (80 ft) near its minimum detection level of approximately 0.2 pCi/g. Cobalt-60 was detected between 39.93 and 40.84 m (131 and 134 ft) at concentrations of less than 0.2 pCi/g. Europium-154 was detected between 29.26 and 29.87 (96 and 98 ft). The maximum Eu-154 concentration was approximately 0.25 pCi/g. At well 299-W15-60, Cs-137 was the only man-made radionuclide detected. Cesium-137 was detected at a few locations near its minimum detection level of approximately 0.2 pCi/g. At well 299-W15-61, Cs-137 and Eu-154 were the man-made radionuclides detected. Cesium-137 was detected near the ground surface and at a few locations near its minimum detection level of approximately 0.2 pCi/g. Europium-154 was detected at 28.19 and 34.90 m (92.5 and 114.5 ft) near its minimum detection level of approximately 0.6 pCi/g (DOE-EM/GJ918-2005; DOE-EM/GJ919-2005, *Log Data Report for 299-W15-60 (A7361)*; DOE-EM/GJ920-2005, *Log Data Report for 299-W15-61 (A7362)*). The nature and extent of remaining contamination at the 216-Z-10 Injection/Reverse Well are expected to be confined within the 9.1 m (30-ft)-diameter lateral circle formed by the three vadose-zone wells to the vertical perforated zone of the injection/reverse well. The contaminant distribution model is presented in Figure 3-37.

3.2.8 Analogous Waste Sites

Conceptual site models were developed for each of the waste sites in the 200-PW-1, 200-PW-3, and 200-PW-6 OUs. Figures 3-38 through 3-49 present the contaminant distribution models for the 216-Z-1 and 216-Z-2 Cribs, 216-Z-3 Crib, 216-Z-5 Crib, 216-Z-12 Crib, 216-Z-18 Crib, 241-Z-8 Settling Tank, 216-A-7 Crib, 216-A-24 Crib, 216-A-31 Crib, and UPR-200-E-56, respectively. Each conceptual site model is based on all available existing data for the subject waste site. Sources of data used for each model include results of soil and soil-vapor sampling before and during the RI, borehole geophysical logging, geologic logs, process history, estimates of contaminant inventories, site drawings and maps, and historical data compilations and summaries. Supporting information and references for the data sources used to prepare the contaminant distribution models are provided on the figures and in Appendix E.

3.3 IMPACTS TO GROUNDWATER

Groundwater is monitored routinely at the Hanford Site. Wells and aquifer tubes are sampled to characterize groundwater flow, groundwater contamination radionuclides, and nonradiological constituents, and to determine the extent of the contamination. Groundwater-remediation progress, ingestion risk, and dose also are assessed.

The following provides a summary of important findings related to groundwater impacts. Details of this assessment are provided in the following subsections.

- Two of the representative waste sites, the 216-Z-9 Trench and the 216-A-8 Crib, have discharged effluent volumes greater than their soil column pore volume, which indicates that the volume of effluent released was sufficient to reach the unconfined aquifer during operation of these waste sites. However, based on currently available site data, including soil-moisture content measurements, these waste sites are not considered to be significant current sources of groundwater contamination.

- All available information indicates that the 241-Z-361 Settling Tank has not leaked, so this site is not considered to be a past or current source of groundwater contamination.

- The 216-Z-1A Tile Field has not been considered to be a past source of groundwater contamination, because the effluent volume discharged at this site was much less than the soil-column pore volume. However, based on the dispersed carbon tetrachloride vadose-zone plume data presented in Section 3.2.4.9, significant concentrations of carbon tetrachloride exist in the vadose zone adjacent to this site, so it is possible that this site was a past source of groundwater contamination, but it is not a significant current source.

3.3.1 Current Impact to Groundwater from the 216-Z-9 Trench

A total of 4.09×10^6 L (1.08×10^6 gal) of acidic high-salt liquid was discharged into the 216-Z-9 Trench, or about 1.5 times the estimated pore volume beneath the trench. The last groundwater samples from well 299-W15-8 were collected in 1991, before the water level dropped below the well screen. At that time, the results indicated low levels of both plutonium and americium (up to 8.3 and 5.9 pCi/L, respectively) in the groundwater. The presence of americium and plutonium in the groundwater in 1991, as well as the discharge of liquids greater than the pore volume beneath the trench, suggests that effluent and contaminants discharged to the trench previously have impacted the unconfined aquifer.

As reported in DOE/RL-2006-24, no radioactive plumes (or contaminants) above maximum contaminant levels have been identified in the area of the 216-Z-9 Trench. Currently seven nonradioactive groundwater plumes are in the vicinity of the trench: carbon tetrachloride, chloroform, trichloroethylene, nitrate, chromium (total), tetrachloroethylene, and methylene chloride. Technetium-99 also has been detected, but not above the maximum contaminant level. The presence of these groundwater contaminants is attributed to past waste-disposal practices at the 216-Z-9 Trench as well as at other adjacent facilities. Because the 216-Z-9 Trench received large inventories of carbon tetrachloride and nitrate, it is considered a major contributor of groundwater contamination in the 200 West Area for these two compounds.

Soil samples were collected in 2005 from Borehole C3426 (completed as well 299-W15-46) for laboratory analyses of soil-moisture content. Measured soil moisture contents in samples from the Hanford formation ranged from 4.2 to 4.4 percent. Measured moisture contents in the CCU ranged from 19.1 to 23.6 percent, and moisture content in the Ringold Formation ranged from 2.8 to 6 percent. These values of soil moisture content for the granular soils of the Hanford

formation and Ringold Formation, and for the more porous silt unit of the CCU, indicate that the vadose-zone soils beneath the trench are unsaturated. Considering the current unsaturated vadose-zone conditions, as well as the operation of the SVE system in the vicinity of the 216-Z-9 Trench since 1993, which further decreases soil moisture content, it is not likely that the remaining COPCs in the vadose zone are a significant current source of groundwater contamination.

Soil Vapor Extraction Interim Action

Since 1992, an interim action in the 200-PW-1 OU has used SVE to remove carbon tetrachloride from the vadose zone in the vicinity of the 216-Z-9 Trench and 216-Z-1A Tile Field, two of the primary carbon tetrachloride disposal sites. Initiation of the interim action was based on the assumption that contamination in the vadose zone posed a continuing threat to groundwater and that if no interim action were taken, the groundwater quality would continue to degrade. The success of the remedial action can be evaluated by comparing the potential for transport of carbon tetrachloride between the soil vapor and the groundwater before and during the remedial action using Henry's Law as a guideline. Henry's Law describes the equilibrium partitioning of a compound between the aqueous and vapor phases.

During Initiation of Soil Vapor Extraction. The in situ carbon tetrachloride soil vapor concentration measured near the water table during installation of well 299-W15-218 at the 216-Z-9 site in 1993 was 10,400 ppmv. The carbon tetrachloride groundwater concentration measured at the same time at well 299-W15-218 was 6,500 µg/L. At this well in 1993, the measured vapor concentration was an order of magnitude higher than the equilibrium vapor concentration (approximately 1,000 ppmv) predicted using Henry's Law and the measured groundwater concentration. In 1994, carbon tetrachloride vapor concentrations ranging from approximately 100 to 2,400 ppmv were measured during SVE operations in 216-Z-9 Trench wells with open intervals near the groundwater.

In 1994, carbon tetrachloride vapor concentrations ranging from 150 to 600 ppmv were measured during SVE operations in 216-Z-1A wells with open intervals near the groundwater. At this time, the carbon tetrachloride groundwater concentration was approximately 2,100 µg/L in well 299-W18-1. In some locations, the measured vapor concentrations were higher than the equilibrium vapor concentration (approximately 300 ppmv) predicted using Henry's Law and the measured groundwater concentration.

These evaluations using measurements made during initiation of SVE suggest that the carbon tetrachloride concentration gradient at some locations would drive carbon tetrachloride from the vadose zone to the groundwater.

Following Initial Soil Vapor Extraction. Carbon tetrachloride vapor concentrations measured near the groundwater during the 1996-1997 rebound study were compared to groundwater concentration data collected from nearby groundwater wells as apart of the 200-ZP-1 OU groundwater pump-and-treat-project. At both the 216-Z-9 Trench and the 216-Z-1A Tile Field, the measured vapor concentrations were an order of magnitude less than the equilibrium vapor concentrations predicted using Henry's Law and site groundwater concentrations. Based on this

comparison, the carbon tetrachloride concentration gradient in 1997 would drive carbon tetrachloride from the groundwater to the vadose zone.

2005-2006 Evaluation of Interim Actions. Between 1990 and 2006, the carbon tetrachloride concentrations at the top of the unconfined aquifer underlying the primary carbon tetrachloride source waste sites have been reduced (Figure 2-49). This reduction likely has resulted from the dual application of SVE remediation in the vadose zone and pump-and-treat remediation in the groundwater in the vicinity of the source waste sites.

One objective for the pump-and-treat interim remediation is the reduction of the carbon tetrachloride groundwater concentration below 2,000 µg/L. This goal for groundwater has been met in the 216-Z-1A area and nearly achieved in the 216-Z-9 area. Concentrations in groundwater extraction well 299-W15-32 (and replacement well 299-W15-47) near the 216-Z-9 Trench have declined from approximately 8,000 µg/L in 1997 to concentrations of 1,000 to 3,000 µg/L in 2005. Concentrations in groundwater monitoring well 299-W18-1, west of the 216-Z-1A Tile Field, have declined from approximately 1,700 µg/L in 1997 to 50 µg/L in 2005. A new groundwater monitoring well, 299-W18-16, was installed east of the 216-Z-1A Tile Field in FY 2005. The average carbon tetrachloride concentration in groundwater from this well was 540 µg/L in 2005.

Maximum carbon tetrachloride vapor concentrations measured near the groundwater during FY 2005 rebound monitoring and SVE restart at the 216-Z-9 Trench ranged from 22 to 27 ppmv. These measured concentrations, which were similar to the deep vapor concentrations measured in this area in the 1996-1997 rebound study (5 to 60 ppmv), are still an order of magnitude less than the equilibrium vapor concentration (150 to 450 ppmv) predicted using Henry's Law and the 216-Z-9 Trench groundwater concentration measured in FY 2005.

Maximum carbon tetrachloride vapor concentrations measured near the groundwater during FY 2005 at the 216-Z-1A Tile Field were 25 ppmv. These measured concentrations are similar to the deep vapor concentrations measured in this area during the 1996-1997 rebound study (10 to 50 ppmv). The FY 2005 concentrations are slightly higher than the equilibrium vapor concentration (10 ppmv) predicted using Henry's Law and the 216-Z-1A Tile Field groundwater concentration measured at well 299-W18-1 in FY 2005. A vapor concentration of 25 ppmv would be in equilibrium with a groundwater concentration of approximately 160 µg/L, which is an order of magnitude below the objective for the pump-and-treat interim remediation. The relatively low carbon tetrachloride concentration in groundwater west of the 216-Z-1A Tile Field may be the result, at least in part, of ingress of cleaner, treated water injected upgradient of this site as part of the pump-and-treat operations for the 200-ZP-1 OU. The FY 2005 vapor concentration is lower than the equilibrium vapor concentration (approximately 85 ppmv) predicted using Henry's Law and the 216-Z-1A Tile Field groundwater concentration measured at well 299-W19-16 in FY 2005.

The reduction of carbon tetrachloride vapor concentrations in the area remediated using SVE has reduced the threat to groundwater, based on the calculation using Henry's Law. However, as carbon tetrachloride concentrations in both groundwater and the vadose zone change, the direction of contaminant movement between these media may change based on the concentration gradients (SGW-33746).

3.3.2 Current Impact to Groundwater from the 216-Z-1A Tile Field

The total effluent volume (5.3×10^6 L [1.4 million gal]) discharged to the 216-Z-1A Tile Field over its period of operation is 12 percent of the estimated soil-pore volume. As reported in DOE/RL-2006-24, no radioactive plumes (or contaminants) above maximum contaminant levels have been identified in the area of the 216-Z-1A Tile Field. The lack of radiological groundwater contamination is consistent with the contaminant profiles in RHO-ST-17 and more recent geophysical logs. As indicated in RHO-ST-17, the maximum vertical extent of radiological contamination in the vadose zone is approximately 30 m (100 ft) bgs. However, geophysical logging suggests that Pa-233 extends to 37 m (121 ft) bgs.

However, based on the dispersed carbon tetrachloride vadose-zone plume data presented in Section 3.2.4.9, there are significant concentrations of carbon tetrachloride in the vadose zone adjacent to this site, so it is possible that this site was a past source of groundwater contamination. The operation of the SVE system in the vicinity of the 216-Z-1A Tile Field since 1993 has further decreased soil moisture in the vadose zone, so it is not likely that the remaining COPCs in the vadose zone are a significant current source of groundwater contamination.

The impact of the SVE interim action in reducing the potential for carbon tetrachloride in the vadose zone to impact groundwater at the 216-Z-1A Tile Field is discussed in Section 3.3.1.

3.3.3 Current Impact to Groundwater from the 241-Z-361 Settling Tank

Characterization of the 241-Z-361 Settling Tank and its contents was conducted from 1999 to 2001 to resolve an unreviewed safety question related to tank conditions. Still photographs of the interior of the tank were taken in 1975, and a video camera inspection was conducted in 1999. The level of the sludge surface, and consequently the apparent depth of the sludge in the tank, is very similar in the two sets of photographs. The level is estimated by comparing the relative distance from the sludge surface to the roof of the tank in both photographs. This observation suggests that the level of waste in the tank has not changed substantially over the years between 1975 and 1999 (HNF-8735).

Helical piers were installed in 1999 to support an above-ground structure for sampling the tank. These piers extend beneath the depth of the tank bottom, and some are within a few meters of the tank. Some piers that were removed and reinstalled were surveyed for radioactive contamination on removal, and no radiological contamination was detected (FH-0002791).

The lack of detected radiological contamination on the piers that were installed beneath the depth of the tank bottom and then removed, and the apparent stability in the tank sludge level since 1975, suggests that there has been no leak of tank contents to the soil column (FH-0002791), and therefore groundwater has not been impacted by the tank.

3.3.4 Current Impact to Groundwater from the Dispersed Carbon Tetrachloride Vadose-Zone Plume

Soil and soil-vapor samples collected between 1991 and 1993 near the 216-Z-9 Trench, 216-Z-1A Tile Field, 216-Z-18 Crib, and 216-Z-12 Crib indicated that carbon tetrachloride was present throughout the vadose zone within a 0.2 km^2 (0.1 mi^2) area. Maximum soil-vapor concentrations of carbon tetrachloride exceeded 10,000 ppmv near the CCU and above the water table at the 216-Z-9 Trench (e.g., in well 299-W15-218 [Figure 2-44]). In contrast, soil-vapor concentrations of carbon tetrachloride were an order of magnitude lower at similar depths at the other sites.

An expedited response action was initiated in 1992 using SVE and was based on concerns that the carbon tetrachloride residing in the vadose zone was continuing to spread to the groundwater and that, if left unchecked, the carbon tetrachloride would significantly increase the lateral extent of groundwater contamination. The purpose of the expedited response action was to minimize carbon tetrachloride migration within the vadose zone and away from the release sites.

The significant RIs conducted for the dispersed carbon tetrachloride vadose-zone plume since 1991 have generated more than 3,400 sample results from more than 2,100 locations in the 200 West Area. These investigations have led to a refined conceptual model concerning the current nature and extent of the dispersed carbon tetrachloride vadose-zone plume and its current impact on groundwater (see Section 3.2.4.9 and the SVE summary in Section 2.5). The key findings concerning the dispersed carbon tetrachloride vadose-zone plume are summarized below.

- The highest carbon tetrachloride concentrations in the shallow, intermediate, and deep vadose zone generally are located within about 75 to 150 m (246 to 492 ft) of the release sites.

- Carbon tetrachloride concentrations in the extracted soil vapor have decreased significantly at all three sites during operation of the SVE systems. Initial carbon tetrachloride concentrations in extracted soil vapor were approximately 30,000 ppmv at the 216-Z-9 Well Field and 1,500 ppmv at the 216-Z-1A/Z-18 Well Field. In contrast, concentrations in extracted soil vapor were approximately 10 ppmv at the 216-Z-1A/Z-18 Well Field in July 2006 and 21 ppmv at the 216-Z-9 Well Field in September 2006.

- From 1997 to 2005, the rebound carbon tetrachloride vapor concentrations measured during the shutdown period of the SVE system at the 216-Z-9 Trench each year show that the maximum concentrations (300 to 800 ppmv) are near the CCU, and the concentrations in the deep vadose zone near the water table are less than 100 ppmv (Figure 2-44). The intermittent operation of the SVE systems appears to have had no negative impacts on groundwater quality at the release sites, so the dispersed carbon tetrachloride vadose-zone plume at the release sites is not considered to be a significant current source of groundwater contamination. These maximum rebound concentrations also are less than the 1,200 ppmv soil-vapor concentration guideline that was established

in the Step II dispersed plume DQO (CP-15372) that was used to decide if soil sampling should be conducted to evaluate the presence of a nearby carbon tetrachloride source.

- Outside of the area around the release sites, carbon tetrachloride vapor concentrations up to about 10 to 12 ppmv were found at various locations in the vadose zone, but these concentrations are not considered to have the potential for significant current or future groundwater impacts.

- The soil vapor and shallow groundwater sampling at wells within the eight carbon tetrachloride groundwater "hot spot" areas indicated that the deep vadose-zone soil-vapor concentrations are not significant sources of groundwater contamination in these areas.

3.3.5 Current Impact to Groundwater from the 216-A-8 Crib

The large waste-stream volumes discharged to the 216-A-8 Crib are known to have impacted groundwater, but it has not been determined whether the contaminant transport occurred uniformly through the soil column or if poor seals in nearby monitoring wells provided a preferential migration pathway. Short-lived beta emitters were detected in groundwater at the crib within 13 months of the start of operations, but longer lived beta and gamma emitters that were predicted to arrive in January 1958 apparently did not.

Soil samples were collected in 2005 from Borehole C4545 for laboratory analysis of soil-moisture content. Soil-moisture content ranged from 2.3 to 9.4 percent in the vadose zone beneath the crib. These values of soil-moisture content for the granular soils of the Hanford formation and Ringold Formation beneath the crib indicate that the vadose zone beneath the crib is unsaturated. Therefore, the remaining COPCs in the vadose zone are unlikely to be a significant current source of groundwater contamination.

The 216-A-8 Crib overlies a known groundwater contamination plume of I-129 and is within a few hundred meters of known plumes of tritium and chromium. Waste-stream characterization for the 216-A-8 Crib does not include these species as major components of the waste-stream discharge (WHC-EP-0367, *Liquid Effluent Study Final Project Report*), so it is unlikely that this crib contributed significantly to these plumes. In addition, PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*, does not report any current impacts to groundwater from the 216-A-8 Crib.

3.3.6 Current Impact to Groundwater from the 216-Z-8 French Drain

Results indicate that plutonium and americium are sorbed onto sediments within a few meters beneath the 216-Z-8 French Drain. The remaining COPCs in the vadose zone are unlikely to be a significant current source of groundwater contamination.

3.3.7 Current Impact to Groundwater from the 216-Z-10 Injection/Reverse Well

The remaining contamination at the 216-Z-10 Injection/Reverse Well is suspected to be confined within the 9.1 m (30-ft)-diameter lateral circle formed by the three vadose-zone wells and to the vertical perforated zone of the injection/reverse well. The remaining COPCs in the vadose zone are unlikely to be a significant current source of groundwater contamination.

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