Appendix H

Organic Contaminants in the 200 Area Landfills

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Terms

B&K	Brüel & Kjær
bgs	below ground surface
COC	contaminant of concern
CCU	Cold Creek unit
CPT	cone penetrometer test
CY	calendar year
DNAPL	dense nonaqueous-phase liquid
DOE	U.S. Department of Energy
FY	fiscal year
GAC	granular-activated carbon
OU	operable unit
PFP	Plutonium Finishing Plant
PMM	project management meeting
ppmv	parts per million by volume
RI	remedial investigation
RSW	retrievably stored waste
SAP	sampling and analysis plan
SVE	soil vapor extraction
TPA	Tri-Party Agreement
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989)
TRU	transuranic
VOC	volatile organic compound

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H1 Organics in the 200-SW-2 Operable Unit Landfills

This appendix describes presence of organic contamination associated with the 200-SW-2 Operable Unit (OU) landfills.

H1.1 Carbon Tetrachloride Waste Disposal

Carbon tetrachloride contained in aqueous and organic liquid waste generated during plutonium-processing operations at the Plutonium Finishing Plant (PFP) was discharged primarily to three subsurface infiltration facilities: 216-Z-9 Trench from 1955 to 1962, 216-Z-1A Tile Field (and associated 216-Z-1 and 216-Z-2 Cribs) from 1964 to 1969, and 216-Z-18 Crib from 1969 to 1973. The recovery of uranium and plutonium by extraction from plutonium processing operations was discontinued after a criticality incident in April 1962 and was replaced in May 1964 by the Plutonium Reclamation Facility. No liquid organic waste associated with these operations was discharged to cribs between April 1962 and May 1964, and no liquid organic waste was discharged to cribs after 1973.

Three other sites near Z Plant also received carbon tetrachloride waste: the 216-Z-12 Crib, 216-Z-19 Ditch, and 216-T-19 Crib. The 216-Z-12 Crib received analytical and development laboratory waste from Z Plant from 1959 to 1973 and is estimated to have received a small volume of organics, which included carbon tetrachloride. The 216-Z-19 Ditch was used to convey process cooling water and steam condensate from Z Plant from 1971 to 1981; apparently, carbon tetrachloride was occasionally or accidentally released to this ditch because heavy organic was noted in the outfall. Between 1973 and 1976, aqueous waste saturated with carbon tetrachloride was sent to the 242-T evaporator. During that time, the 216-T-19 Crib received carbon tetrachloride in the overhead condensate discharged from the evaporator.

H1.2 Carbon Tetrachloride Soil Vapor Extraction

Carbon tetrachloride was found in the unconfined aquifer beneath the 200 West Area at the Hanford Site in the mid-1980s. Groundwater monitoring indicated that the carbon tetrachloride plume was widespread and that concentrations were increasing. In response to this contamination, removal of carbon tetrachloride from the vadose zone in the 200 West Area was initiated in 1992 using soil vapor extraction (SVE), followed by aboveground vapor treatment using granular-activated carbon (GAC). By March 1993, three SVE systems (located near the three primary carbon tetrachloride disposal sites noted previously) were in operation, with a total capacity of 85 m^3/min (3,000 ft^3/min).

Between 1992 and 1997, the strategy for SVE was to operate year-round using up to three SVE systems with design capacities of 14.2 m^3/min, 28.3 m^3/min, and 42.5 m^3/min (500 ft^3/min, 1,000 ft^3/min, and 1,500 ft^3/min). Operation of the three SVE systems was temporarily suspended in June 1993 because a GAC canister overheated at the 216-Z-9 site. The first system was restarted 5 months later, and the last system was restarted 12 months later. In fiscal year (FY) 1997, a rebound study (BHI-01105, *Rebound Study Report for the Carbon Tetrachloride Soil Vapor Extraction Site, Fiscal Year 1997*) was conducted throughout the carbon tetrachloride SVE sites to determine the increase in carbon tetrachloride vapor concentrations following temporary system shutdown. Operations of all three SVE systems (14.2 m^3/min, 28.3 m^3/min, and 42.5 m^3/min) were suspended from November 1996 to July 1997, when all three SVE systems were restarted and continued operating through the end of September 1997.

The operating strategy was modified in 1998, based on the results of the rebound study (BHI-01105) and the declining rate of carbon tetrachloride removal during continuous extraction operations. Only the 14.2 m^3/min system was used for carbon tetrachloride removal from 1998 through 2008. Instead of

operating year-round, this SVE system was operated in a cyclic or periodic mode during these years. The 14.2 m^3/min system typically operated from April through September each year, alternating between the 216-Z-9 site and the 216-Z-1A/216-Z-18/216-Z-12 site (for approximately 3 months at each site). The system was maintained in standby mode from October through March to allow time for carbon tetrachloride vapor concentrations to rebound. During this time, operation of the SVE system was temporarily suspended during FY 2000 as a result of higher priority remediation activities competing for limited funding. Two new SVE systems, each with a design capacity of 14.2 m^3/min, were installed and operated in 2009. One new SVE system was operated at the 216-Z-1A/216-Z-18/216-Z-12 site, and one system was operated at the 216-Z-9 site. Each system operated from April 1 through September 30, 2009; March 1 through October 31, 2010; March 1 through October 31, 2011; and April 2 through October 4, 2012.

Between April 1991 (when the pilot test was conducted) and October 2012, approximately 80,107 kg (176,604 lb) of carbon tetrachloride was removed from the vadose zone (SGW-54566, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Calendar Year 2012*). Of this total, 54,966 kg (121,178 lb) was removed from the 216-Z-9 well field, and 25,141 kg (55,426 lb) was removed from the 216-Z-1A/216-Z-18 well field.

H1.3 Concentration Changes Over Time

Carbon tetrachloride concentrations in the extracted soil vapor have decreased significantly at the 216-Z-9 and 216-Z-1A/216-Z-18/216-Z-12 well fields during SVE operations. Carbon tetrachloride concentrations in soil vapor extracted from the 216-Z-9 Well Field using the active SVE systems have declined from approximately 30,000 parts per million by volume (ppmv) at startup in March 1993 to a maximum of 14 ppmv in calendar year (CY) 2012. Carbon tetrachloride concentrations in soil vapor extracted from the 216-Z-1A/216-Z-18/216-Z-12 well field using the SVE systems have declined from approximately 1,500 ppmv at startup in February 1992 to a maximum of 11 ppmv in CY 2012. This decrease in concentration with continued extraction is typical of SVE operations and represents removal of the volatile contaminant originally available in the readily swept pore spaces. Once that mass has been effectively removed, peak contaminant vapor concentrations at the beginning of each pumping cycle reflect the amount of carbon tetrachloride released from low-permeability sediments during the preceding nonoperational period. Once pumping has commenced, contaminant concentration rapidly decreases, approaching a concentration level that may reflect the rate of continued contaminant release from low-permeability sediments.

At the 216-Z-1A/216-Z-18/216-Z-12 site, an increase in carbon tetrachloride concentrations occurred in CY 2012 when the second set of extraction wells was brought online; concentrations then declined to approximately 6 ppmv by the end of 2012 extraction operations. At the 216-Z-9 site, concentration declined to approximately 7 ppmv by the end of 2012 extraction operations.

For the 216-Z-9 and 216-Z-1A/216-Z-18/216-Z-12 sites, the initial concentrations following the inactive (rebound) period have generally declined over the years. Although initial concentrations at the 216-Z-9 site have been much higher than at the 216-Z-1A/216-Z-18/216-Z-12 site, tailing concentrations toward the end of the extraction pumping campaign are similar in magnitude.

A treatability study in 2011 demonstrated that the accumulation of carbon tetrachloride during rebound periods at the 216-Z-9 site has gradually decreased during recent years (PNNL-21326, *Treatability Test Report: Characterization of Vadose Zone Carbon Tetrachloride Source Strength Using Tomographic Methods at the 216-Z-9 Site*). Figures H-1 and H-2 show the maximum rebound carbon tetrachloride vapor concentration and the asymptotic concentration (concentration at the end of the operations cycle)

for the same period of cyclic operations. The maximum concentrations were significantly higher than the asymptotic concentrations during the earlier cycles. Since then, the maximum and asymptotic concentrations at both sites have declined, and now there are only small differences between maximum and asymptotic concentrations. These small differences between the initial and final concentrations in an operational cycle indicate that the rebound in carbon tetrachloride concentrations during the shutdown period has significantly declined.

H1.4 Soil Vapor Extraction from the 218-W-4B Landfill

During FY 2007, an additional SVE system was operated at the 218-W-4B Landfill from December 2006 through July 2007 (SGW-37111, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Fiscal Year 2007*). Elevated concentrations of carbon tetrachloride were detected in Trench T-07 during the environmental release investigation that was performed in support of retrieval operations for retrievably stored waste (RSW). The SVE system was operated at Trench T-07 to minimize release of carbon tetrachloride from the trench to the environment and to protect site workers. Vapor extraction was conducted in support of waste retrieval activities. Vapor extraction from Trench T-07 was performed using five vent risers as extraction points. Operations were planned to continue 24 hr/d; however, during the winter months, operations frequently were limited to dayshift because of problems with lines freezing. At least one vapor sample was collected on each day that the system was operated. The vapor extraction points were moved periodically from west to east as vapor extraction operations reduced the carbon tetrachloride concentrations and as waste retrieval progressed. The system was removed permanently to allow retrieval operations to remove the remaining waste at the end of Trench T-07. The maximum carbon tetrachloride concentration detected was 1,270 ppmv. Final concentrations of carbon tetrachloride prior to removal of the system were less than 50 ppmv.

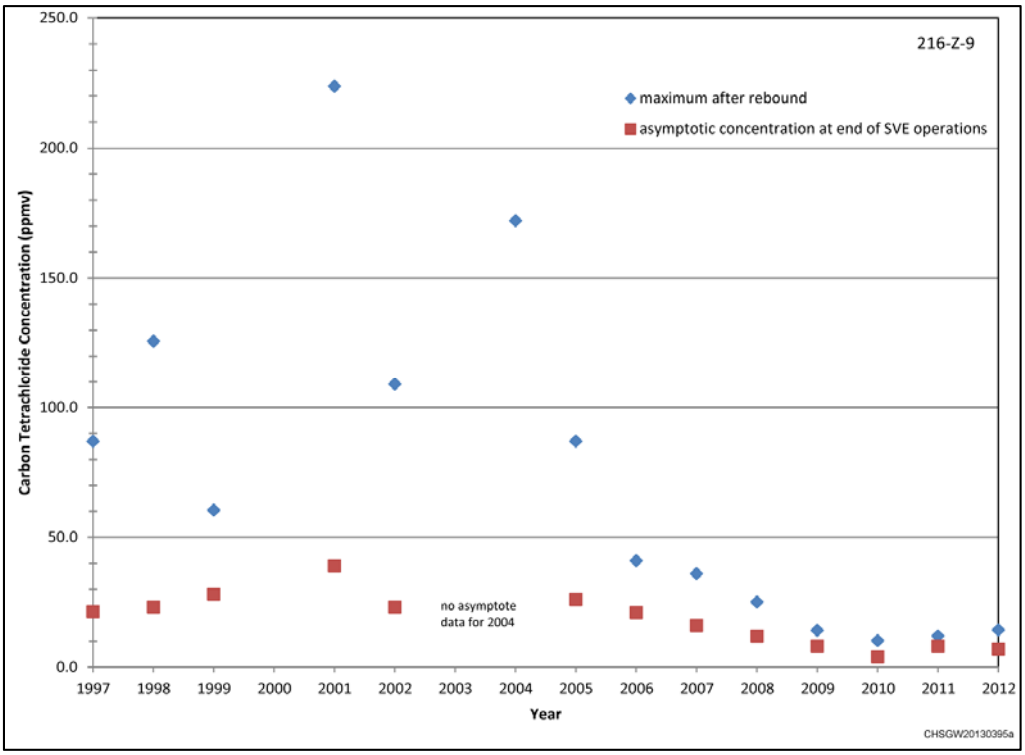

Figure H-1. Initial (Maximum after Rebound) and Final Carbon Tetrachloride Vapor Concentrations during SVE Cyclic Operations at the 216-Z-9 Trench

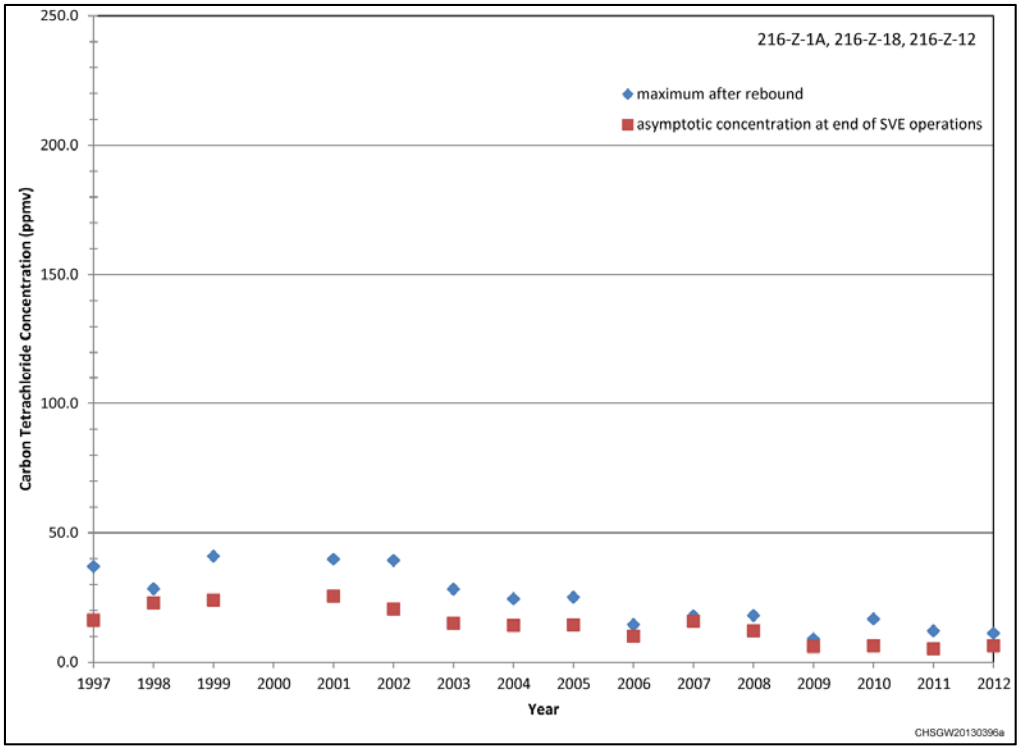

Figure H-2. Initial (Maximum after Rebound) and Final Carbon Tetrachloride Vapor Concentrations during SVE Cyclic Operations at the 216-Z-1A Tile Field, 216-Z-18 Crib, and 216-Z-12 Crib

H1.4.1 Soil Vapor Sampling in the 218-W-4B Landfill

In support of Tri-Party Agreement (TPA) (Ecology et al., 1989, *Hanford Federal Facility Agreement and Consent Order*) Milestone M-091-40, Requirement 2, soil vapor sampling is required in the 218-W-4B Landfill prior to and following waste retrieval. Due to lack of funding, post-retrieval sampling has been delayed. Pre-retrieval (Step I) sampling was completed in 2006. Data are summarized in Table H-1.

H1.5 Soil Vapor Extraction from the 218-W-4C Landfill

Elevated concentrations of carbon tetrachloride were detected at the east end of Trench 4 during the remedial investigation (RI) for the 200-PW-1 OU. During FY 2004, an additional SVE system was operated at the 218-W-4C Landfill from November 2003 through April 2004 (WMP-26178, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Carbon Tetrachloride Site, Fiscal Year 2004*). Four vent risers at the east end of Trench 4 were typically used as the extraction points. From initial startup until the end of January 2004, operation ranged from 2 to 7 hr/d, and carbon tetrachloride concentrations were monitored at the inlet of the SVE system every 2 hours. Based on the decline in carbon tetrachloride concentrations and the absence of detectable radiological activity at the vapor extraction system, operation of the system was extended to 24 hr/d in January 2004 to increase carbon tetrachloride removal efficiency and maximize personnel protection during drum removal activities. At the same time, monitoring was reduced from a 2-hour interval to once per day.

Table H-1. Summary of Activities Performed in Support of M-091-40, Requirement 2, Sampling and Analysis to Determine Potential Leaks from RSW Transuranic Waste in the 200-SW-2 OU Landfills

Landfill	Sampling and Analysis Plan	Step I Sampling	Step I Maximum Concentration of Carbon Tetrachloride (ppmv)[a]	Step II Sampling	Step II Maximum Concentration of Carbon Tetrachloride (ppmv)[a]
218-W-4C	September 2003	October 2003	668	October 2007/ April 2009	3.21
218-E-12B	December 2004	May 2005	Not detected	[b]	[b]
218-W-3A	May 2006	September 2005[c]	36	[b]	[b]
218-W-4B	June 2006	September 2006	7,580	[b]	[b]

a. Carbon tetrachloride concentrations are provided as a primary contaminant of concern. Other compounds detected during sampling are listed in Tables H-2 and H-3.

b. Sampling has not started; therefore, no results are available as of publication date.

c. Step I sampling for the 218-W-3A Landfill was completed as part of the 200-PW-1 Operable Unit sampling plan (see Section H2.2.1).

ppmv = parts per million by volume

Vapor samples were collected periodically at the inlet to the SVE system and analyzed offline using a photoacoustic gas analyzer. Carbon tetrachloride concentrations declined from approximately 75 ppmv to less than 2 ppmv. Based on an average system flow rate of 3.7 m^3/min, the carbon tetrachloride concentrations, and the hours of operation, approximately 11 kg of carbon tetrachloride was removed during FY 2004. The system was removed permanently to allow retrieval operations to remove bulk soil overburden covering the drums at the east end of Trench 4.

H1.5.1 Soil Vapor Sampling in the 218-W-4C Landfill

In support of TPA (Ecology et al., 1989) Milestone M-091-40, Requirement 2, post-retrieval soil vapor sampling was completed during 2007 and 2009 in the 218-W-4C Landfill (see Section H2.3). Pre-retrieval sampling was completed in 2003. Data are summarized in Table H-2.

H2 M-091-40, Requirement 2 Sampling

TPA (Ecology et al., 1989) Milestone M-091-40 requires completion of the retrieval and designation of contact-handled suspect transuranic (TRU) RSW in the 218-W-4B, 218-W-3A, and 218-E-12B Landfills.

Table H-2. Frequency, Minimal Concentrations, and Maximum Concentrations of Primary COCs Detected at the 218-W-4C Landfill during Step I Sampling

Compound	Number of Times Compound Was Detected[a]	Minimum Detected Concentration[b]	Maximum Detected Concentration	Trenches with Detected Compound
Total number of samples collected = 91[a]				
Dichloromethane (methylene chloride) (ppmv)	34	0.13	4.71	T-01, T-04, T-07
1,1-Dichloroethane (ppmv)	18	0.31	28.1[c]	T-01, T-04
Trichloromethane (chloroform) (ppmv)	25	0.27	283	All
1,1,1-Trichloroethane (ppmv)	63	0.16	2,337[c]	All
Carbon tetrachloride (ppmv)	56	0.24	668	T-04, T-07, T-20, T-29
Trichloroethene	33	0.10	25.5[c]	T-01, T-04, T-07
1,1,2-Trichloroethane (ppmv)	4	0.12	0.98	T-04
Tetrachloroethylene	39	0.35	1,717[c]	T-01, T-04, T-07, T-20

a. Number includes field-screened and laboratory samples. Field instrument reported concentrations of up to eight compounds. Laboratory analysis was able to detect all contaminants of concern.

b. Detections less than the practical quantitation limit are excluded.

c. Exceeds calibration range.

ppmv = parts per million by volume

H2.1 Background

Milestone M-091-40, Requirement 2 states that the U.S. Department of Energy (DOE) will sample and analyze, in accordance with approved sampling and analysis plans (SAPs), trench substrates to determine whether releases to the environment have occurred from waste containers. At the time the data quality objective process was initiated in 2003, the agreement included the 218-W-4C Landfill (Ecology, 2003, *Administrative Order No. 03NWPKW-5494*). The agreement also stated that vapor sampling through vent risers in the trenches should occur before waste retrieval. Based on the stipulations of the agreement in 2003, the following SAPs were developed for each landfill:

- DOE/RL-2003-48, *218-W-4C Sampling and Analysis Plan*
- DOE/RL-2004-32, *218-E-12B Burial Ground Sampling and Analysis Plan*
- DOE/RL-2004-70, *218-W-4B Burial Ground Sampling and Analysis Plan*
- DOE/RL-2004-71, *218-W-3A Burial Ground Sampling and Analysis Plan*

The following list summarizes the three-step process to complete the M-091-40 sampling requirements for the 218-W-4C, 218-W-4B, 218-W-3A, and 218-E-12B Landfills (detailed explanations of each step are provided in the referenced SAPs):

- Step I of the SAP occurs prior to waste retrieval. Soil vapor samples are collected passively or through existing vent risers to determine volatile organic compound (VOC) levels. Based on the location of the highest levels of VOCs detected during field screening, biased soil vapor sampling locations are selected for laboratory analysis. Samples are generally collected at the base of the trench, near the bottom of the existing vent risers. Results of Step I are used to determine biased sampling sites for Step II.

- Step II is initiated post-retrieval. Soil vapor sampling is conducted along the edges of the trench bottoms. Direct-push technology is used to obtain vapor samples at varying depths from the bottom of the trench. In addition to direct-push sampling in areas known to have contained TRU RSW, biased sampling is performed using results from Step I, visual observations, organic vapor monitoring, and radiological surveys on the trench floor and vadose zone soils.

- Step III sampling will assess available data and characterize substrate soils. Additional sampling may be required based on sampling results from Steps I and II.

TPA (Ecology et al., 1989) Milestone M-091-40, Requirement 2 requires quarterly reporting of sampling results. Quarterly reports were reviewed, and results of all sampling data are summarized in the following sections. A summary of activities performed in support of M-091-40, Requirement 2 sampling work is provided in Table H-1. Statistical analysis (i.e., median and mean) was not completed on data due to the limiting detection factors of the field instrumentation. Nondetection was not reported as 0, but was reported as not detected above the practical quantitation factor or “undetected.” In many cases, there are extreme outliers in contaminant detection (indicating a potential hot spot); therefore, a mean and median would not be representative of the samples collected. The purpose of the sampling plan was to determine the possibility of the presence of contamination and focus biased samples on areas where high levels of contamination were detected.

H2.2 Step I (Pre-Retrieval) Sampling Results

Samples were collected, prior to retrieval of TRU waste from several landfills, as discussed in the following subsections.

H2.2.1 218-W-3A Landfill

The 218-W-3A Landfill contained TRU RSW in 14 trenches: T-9S, T-6S, T-01, T-04, T-05, T-06, T-08, T-10, T-15, T-17, T-23, T-30, T-32, and T-34. Vent risers were installed only in areas containing TRU RSW in Trenches T-05 and T-08. Soil vapor sampling was completed in September 2005 in support of the 200-PW-1 OU dispersed carbon tetrachloride vadose zone plume RI. Per an agreement between the Washington State Department of Ecology and DOE Richland Operations Office, the 200-PW-1 OU field-screened sampling data would be used in lieu of performing additional vent riser soil vapor sampling to satisfy the requirements in the 218-W-3A Landfill SAP (DOE/RL-2004-71). The field-screened data presented in this report are from the 200-PW-1 OU sampling activity.

Step I sampling was initiated in support of the 200-PW-1 OU SAP in August 2005 for the 218-W-3A Landfill. Soil vapor samples were collected from nine vent risers in Trenches T-05 and T-08 (06-AMCP-0073, “Burial Ground Sampling and Analysis Results for July – September 2005”). The highest concentration of carbon tetrachloride was detected during field screening in the west end of Trench T-08 at 36 ppmv. Of the 11 samples collected, 3 detected carbon tetrachloride that ranged from 5 to 36 ppmv. Tetrachloroethylene and methyl chloride were found at elevated concentrations in Trench T-08 at 460 ppmv and 186 ppmv, respectively. Laboratory analysis did not detect carbon tetrachloride in any samples. Laboratory analysis detected tetrachloroethylene at 4,200 ppmv in

Trench T-08. Step I sampling for the 218-W-3A Landfill is summarized in Table H-3. Figure H-3 presents locations of elevated contaminants of concern (COCs). Maximum concentrations of all compounds detected during Step I sampling are provided in Table H-4.

Table H-3. Frequency, Minimum Concentrations, and Maximum Concentrations of Primary COCs Detected at the 218-W-3A Landfill during Step I Sampling

Compound	Number of Times Compound Was Detected[a]	Minimum Detected Concentration[b]	Maximum Detected Concentration	Trenches with Detected Compound
Total number of samples collected: 15[a]				
Trichloromethane (chloroform) (ppmv)	1	4	4	T-05
1,1,1-Trichloroethane (ppmv)	4	9	18.8	T-05, T-08
Carbon tetrachloride (ppmv)	3	5	36	T-08
Trichloroethene (ppmv)	2	3	13	T-08
Tetrachloroethylene (ppmv)	12	3	4,200	T-05, T-08

a. Number includes field-screened and laboratory samples. Field instrument reported concentrations of up to eight compounds. Laboratory analysis was able to detect all contaminants of concern.

b. Detections less than the practical quantitation limit are excluded.

ppmv = parts per million by volume

H2.2.2 218-W-4C Landfill

The 218-W-4C Landfill contained TRU RSW in Trenches T-01, T-04, T-07, T-20, T-24, and T-29. Trench T-24 contained no vent risers.

Step I sampling for the 218-W-4C Landfill started in October 2003. Soil vapor sampling was completed on 84 vent risers in Trenches T-01, T-04, T-07, T-20, and T-29 (04-AMCP-0197, “Transmittal of the Burial Ground Sampling and Analysis Results for October – December 2003”). Field screening detected the highest concentrations of carbon tetrachloride from three vent risers at the east end of Trench T-04 ranging from 114 to 668 ppmv. Also in Trench T-04, trichloromethane was detected at a maximum concentration of 283 ppmv. The laboratory analysis of the vent riser samples did not detect carbon tetrachloride or trichloromethane in the Trench T-04 samples at the required dilution factor. However, the laboratory analysis detected elevated concentrations of 1,1,1-trichloroethane (2,337 ppmv) and tetrachloroethene (1,717 ppmv). Low levels of carbon tetrachloride were found in laboratory samples from Trenches T-07 and T-29 at 2.7 and 3.4 ppmv, respectively. Step I sampling for the 218-W-4C Landfill is summarized in Table H-2. Figure H-4 presents locations of elevated COCs. Maximum concentrations of all compounds detected during Step I sampling are provided in Table H-4.

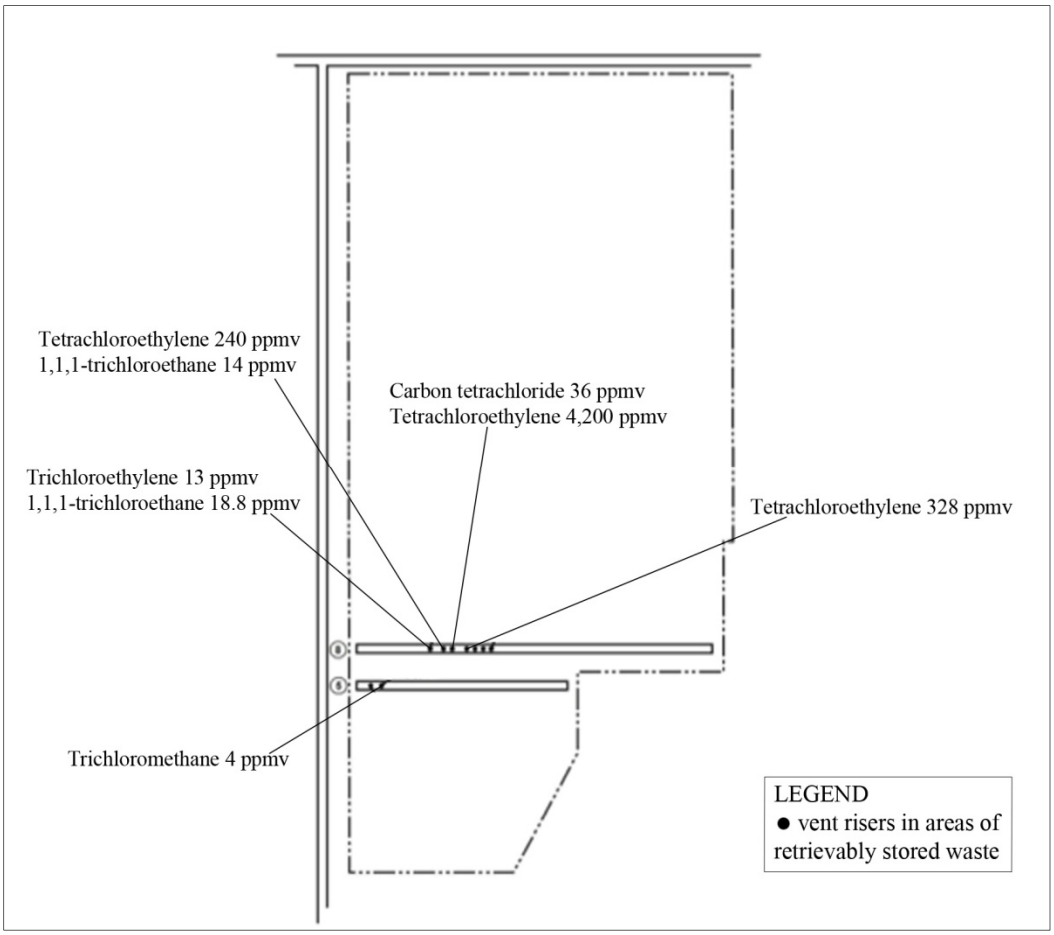

Figure H-3. Locations and Concentrations of Elevated COCs Detected during Step I Soil Vapor Sampling in Trenches T-05 and T-08 at the 218-W-3A Landfill

H2.2.3 218-E-12B Landfill

The 218-E-12B Landfill contained TRU RSW in Trenches T-17 and T-27. No vent risers exist in the 218-E-12B Landfill; therefore, passive soil vapor sampling was conducted in the overlying soil.

Step I soil vapor sampling was initiated in May 2005 for the 218-E-12B Landfill (05-AMCP-0414, "Transmittal of the Burial Ground Sampling and Analysis (SAP) Results for April–June 2005"). No carbon tetrachloride was detected. Tetrachloroethylene was detected at a maximum concentration of 34 ng per sample. Step I sampling for the 218-E-12B Landfill is summarized in Table H-5. Figure H-5 presents locations of elevated COCs. Maximum concentrations of all compounds detected during Step I sampling are provided in Table H-4.

Table H-4. Maximum Soil Vapor Concentrations for All Compounds Detected during Step I Sampling

Compound	Landfill			
	218-W-4C	218-E-12B	218-W-3A	218-W-4B
Dichloromethane (methylene chloride) (ppmv)	4.71	—	—	51.2
1,1-Dichloroethane (ppmv)	28.1[a]	—	—	--
1,1-Dichloroethene (ppmv)	—	—	1.6	5.6
1,2-Dichloroethane (ppmv)	0.13	—	0.62	--
Trichloromethane (chloroform) (ppmv)	283	—	4	155
1,1,1-Trichloroethane (ppmv)	2,337[a]	—	18.8	--
Carbon tetrachloride (ppmv)	668	—	36	7,580[b]
Trichloroethene (ppmv)	25.5[a]	—	13	8.4
1,1,2-trichloroethane (ppmv)	0.98	—	—	—
Tetrachloroethylene	1,717[a]	34 ng/sample[c]	4,200	124
1,2,4-Trimethylbenzene	—	30[c]	—	—
Methyl chloride	—	—	186	—
Acetylene (ppmv)	—	—	70	—
Nitrous oxide (ppmv)	—	—	19	—
Carbon dioxide (ppmv)	—	—	5,300	59,800
Methyl ethyl ketone (ppmv)	—	—	—	193
Dichlorobenzene, m- (ppmv)	—	—	—	171.69
CFC-113 (1,1,2-trichloro-1,2,2-tricluoroethane) (ppmv)	0.044	—	—	73
Epichlorohydrin (ppmv)	—	—	—	118.69
Tetrahydrofuran	—	—	—	132.4
Vinyl chloride	—	—	—	77.02
Propane (ppmv)	—	—	—	5.6
Methanol (ppmv)	—	—	—	53
Acetone (ppmv)	—	—	—	86
Toluene (ppmv)	—	—	—	0.63
Ethanol (ppmv)	—	—	—	1.2

Table H-4. Maximum Soil Vapor Concentrations for All Compounds Detected during Step I Sampling

Compound	Landfill			
	218-W-4C	218-E-12B	218-W-3A	218-W-4B

a. Exceeds calibration range.

b. Value is considered to be elevated due to instrumentation limitations in differentiating compounds (e.g., tetrachloroethylene) with similar infrared absorbance peaks. However, carbon tetrachloride was detected in elevated concentrations in several vent risers.

c. No vent risers were available at the 218-E-12B Landfill for sampling. Passive sampling was used, and results are given in units of mass, as provided by the laboratory analytical method.

ppmv = parts per million by volume

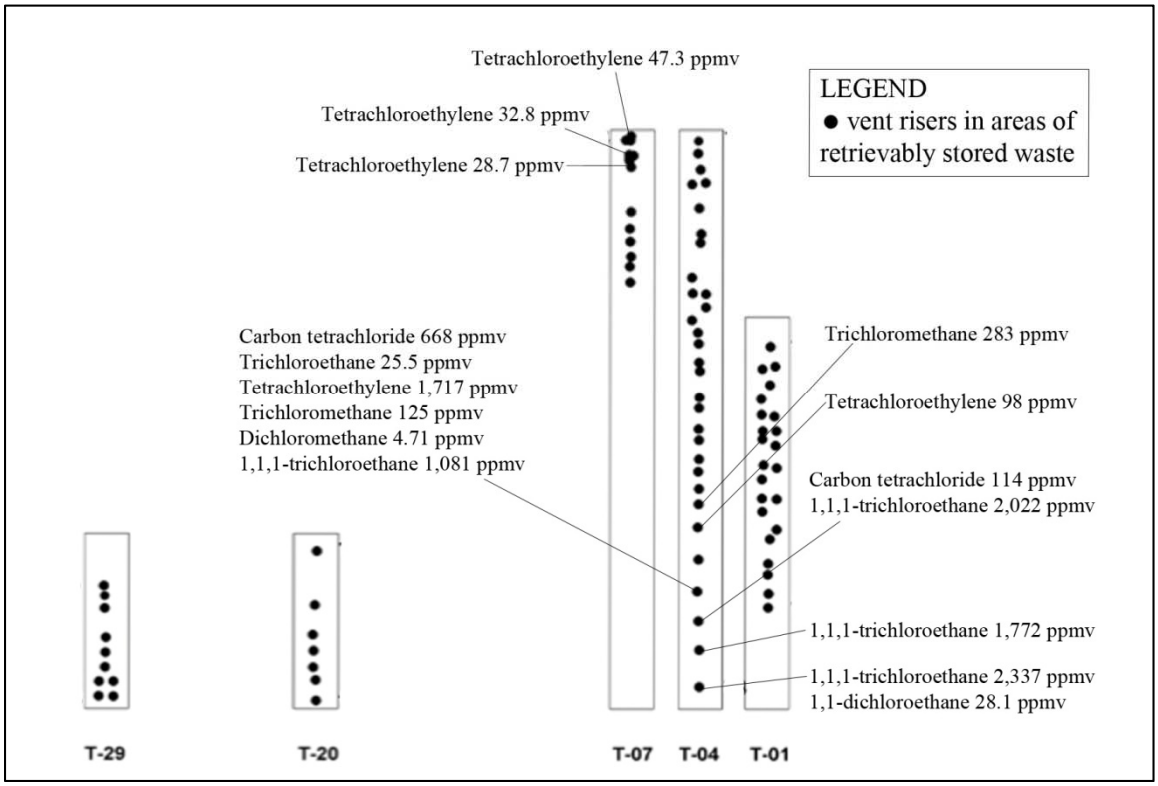

Figure H-4. Locations and Concentrations of Elevated COCs Detected during Step I Soil Vapor Sampling in Trenches T-01, T-04, T-07, T-20, and T-29 at the 218-W-4C Landfill

Table H-5. Frequency, Minimum Concentrations, and Maximum Concentrations of Primary COCs Detected at the 218-E-12B Landfill during Step I Sampling

Compound	Number of Times Compound Was Detected	Minimum Detected Concentration[a]	Maximum Detected Concentration	Trenches with Detected Compound
Total number of samples collected: 52				
Tetrachloroethylene (ng/sample)	3	26 ng/sample[b]	34 ng/sample[b]	T-27
1,2,4-Trimethylbenzene (ng/sample)	4	25 ng/sample[b]	30 ng/sample[b]	T-17, T-27

a. Detections less than the practical quantitation limit are excluded.

b. No vent risers were available at the 218-E-12B Landfill for sampling. Passive sampling was used, and results are given in units of mass, as provided by the laboratory analytical method.

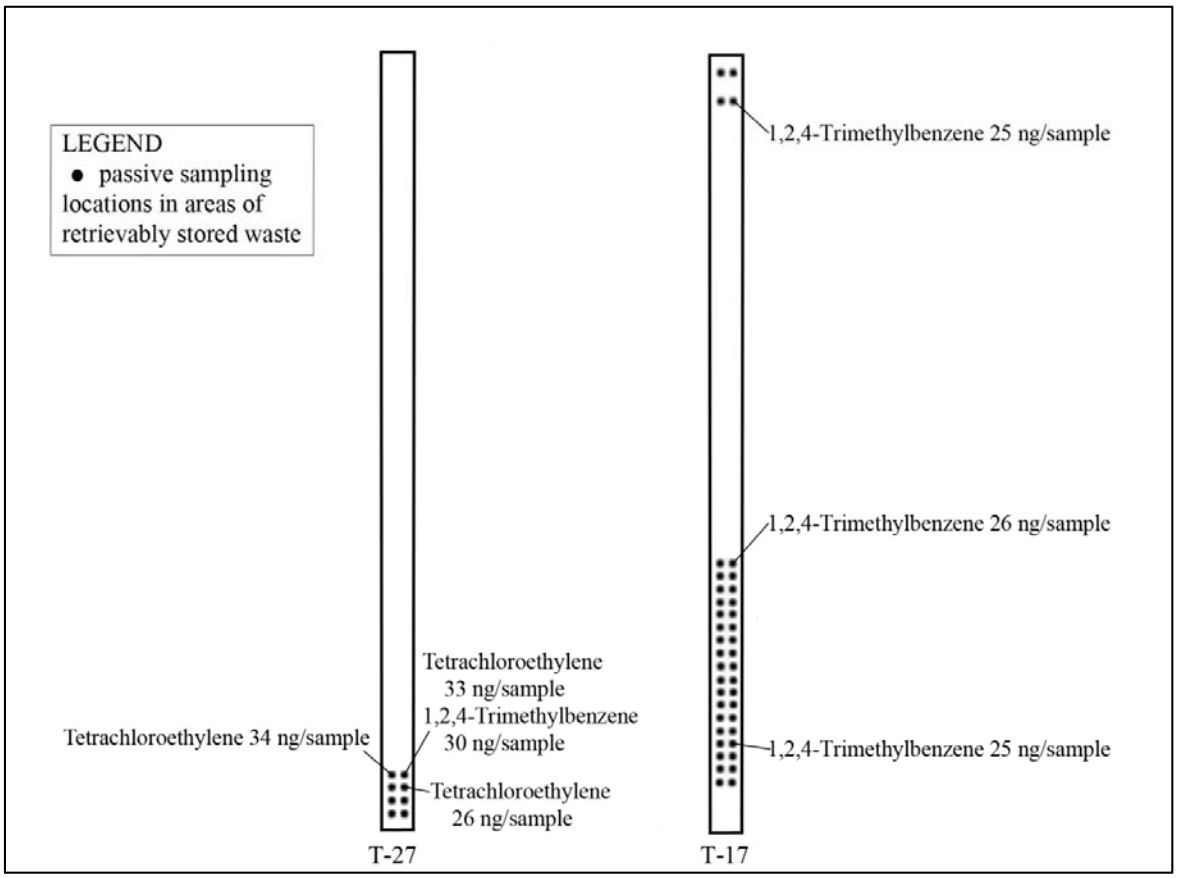

Figure H-5. Locations and Concentrations of Contaminants Detected during Step I Passive Soil Vapor Sampling in Trenches T-17 and T-27 at the 218-E-12B Landfill

H2.2.4 218-W-4B Landfill

The 218-W-4B Landfill contained TRU RSW in Trenches T-07 and T-11. Trench T-11 did not receive vent risers during waste burial and was not sampled as part of Step I.

Step I sampling was initiated in September 2006 for the 218-W-4B Landfill. Sampling was conducted on 18 existing vent risers at Trench T-07 (07-AMCP-0061, "Transmittal of the Burial Ground Sampling and Analysis Results for July – September 2006 Quarter"; 07-AMCP-0166, "Burial Ground Sampling and Analysis Results for October – December 2006"). Two different field-screening analyzers were used: (1) the Brüel & Kjær (B&K) 1302 photoacoustic gas analyzer, and (2) the MIRAN SapphIRe ambient air analyzer. The B&K results were suspected to be biased high due to interference from a co-contaminant (tetrachloroethene) with a similar peak. The highest concentration of carbon tetrachloride using the B&K analyzer was detected at the west end of Trench T-07 at 7,580 ppmv. The highest concentration of carbon tetrachloride using the MIRAN analyzer was detected in the same area of Trench T-07 at 274 ppmv.

Other elevated VOCs include dichloromethane, trichloromethane, and tetrachloroethene. Step I sampling for the 218-W-4B Landfill is summarized in Table H-6. Figure H-6 presents locations of elevated COCs. Maximum concentrations of all compounds detected during Step I sampling are provided in Table H-4. For conservatism, results reported in the table and figure include data from the suspect B&K analyzer, presumed to be biased high.

H2.3 Step II (Post-Retrieval) Sampling Results

Following retrieval of the TRU waste, follow-on sampling (Step II) was performed, as discussed in the following subsections.

H2.3.1 218-W-4C Landfill

Step II sampling for the 218-W-4C Landfill started in October 2007 on Trenches T-04, T-20, T-24, and T-29, following completion of waste retrieval (SGW-37027, *Burial Ground Sampling and Analysis Results for October – December 2007*). Soil vapor samples were collected from the vadose zone along the edge of the asphalt pad through 84 direct-push holes. Samples were collected at a depth between 1.8 to 10.5 m (5.9 to 34.4 ft) below the asphalt pad and screened onsite. Laboratory analysis is not identified in Step II of the SAP and was not performed. Visual inspections, radiological field screening, and records review identified no additional sites for biased soil vapor sampling for Step II.

Carbon tetrachloride was detected at low concentrations in all trenches sampled. The highest concentration of carbon tetrachloride was at the east end of Trench T-29 at 3.21 ppmv. The only elevated VOC in Trench T-04 was tetrachloroethylene at 43.06 ppmv. Tetrachloroethylene was not detected in the other three trenches. The highest VOC concentration in Trenches T-20 and T-24 was benzyl chloride with a maximum concentration of 74.24 ppmv and 185.54 ppmv, respectively. The VOC with the highest concentration in Trench T-29 was methane with a maximum concentration of 51.15 ppmv. Step II sampling for Trenches T-04, T-20, T-24, and T-29 at the 218-W-4C Landfill is summarized in Table H-7. Figures H-7, H-8, H-9, and H-10 present locations of elevated COCs. Maximum concentrations of all compounds detected during Step II sampling are provided in Table H-9.

Table H-6. Frequency, Minimum Concentrations, and Maximum Concentrations of Primary COCs Detected at the 218-W-4B Landfill during Step I Sampling

Compound	Number of Times Compound Was Detected[a]	Minimum Detected Concentration	Maximum Detected Concentration	Trenches with Detected Compound[b]
Total number of samples collected: 97[a]				
Dichloromethane (methylene chloride) (ppmv)	47	0.53	51.2	T-07
1,1-Dichloroethene (ppmv)	1	5.6	5.6	T-07
Trichloromethane (chloroform) (ppmv)	41	0.096	564.55	T-07
Carbon tetrachloride (ppmv)	78	0.96	7,580[c]	T-07
Trichloroethene (ppmv)	3	0.44	8.4	T-07
Tetrachloroethylene (ppmv)	11	0.053	124	T-07
Methyl ethyl ketone (ppmv)	40	1.01	193	T-07
Dichlorobenzene, m- (ppmv)	5	37	171.69	T-07
CFC-113 (1,1,2-trichloro-1,2,2-trifluroethane) (ppmv)	2	36.83	73	T-07

a. Number includes field-screened and laboratory samples. Field instrument reported concentrations of up to eight compounds. Laboratory analysis was able to detect all contaminants of concern.

b. Only Trench T-07 contained vent risers for sampling.

c. Value is considered to be elevated due to instrumentation limitations in differentiating compounds (e.g., tetrachloroethylene) with similar infrared absorbance peaks. The next highest concentration of carbon tetrachloride was detected in the same area of trench (274 ppmv).

ppmv = parts per million by volume

Step II sampling for Trenches T-01 and T-07 at the 218-W-4C Landfill began in April 2009 following completion of waste retrieval (SGW-41533, *Burial Ground Sampling and Analysis Results for April–June 2009*). Soil vapor samples were collected from the vadose zone along the edge of the asphalt pad through 84 direct-push holes. Samples were collected at a depth between 1.8 m to 9.8 m (5.9 to 32.2 ft) below the asphalt pad and screened onsite. Biased sampling locations were collected for laboratory analysis to allow for comparison with field screening and Step I results. As a result of visual inspections, radiological field screening, and records review, biased sampling sites were located adjacent to staining observed on the asphalt pad in Trench T-01.

The maximum level of carbon tetrachloride in Trenches T-01 and T-07 was 2.55 and 2.80 ppmv, respectively. Tetrachloroethylene was detected in both trenches, with a maximum concentration of 15.25 ppmv in Trench T-07. Step II sampling for the 218-W-4C Landfill Trenches T-01 and T-07 is summarized in Table H-8. Figures H-11 and H-12 present locations of elevated COCs. Maximum concentrations of all compounds detected during Step II sampling are provided in Table H-9.

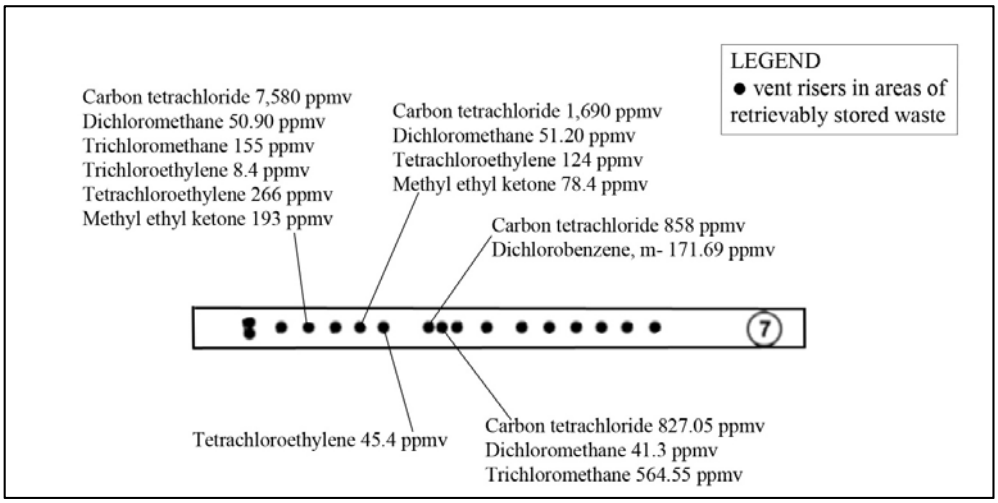

Figure H-6. Locations and Concentrations of Elevated COCs Detected during Step I (Pre-Retrieval) Soil Vapor Sampling in Trench T-07 at the 218-W-4B Landfill

Table H-7. Frequency, Minimum Concentrations, and Maximum Concentrations of Primary COCs Detected during Step II Sampling of Trenches T-04, T-20, T-24, and T-29 at the 218-W-4C Landfill

Compound	Number of Times Compound Was Detected	Minimum Detected Concentration*	Maximum Detected Concentration	Trenches with Detected Compound
1,1-Dichloroethane (ppmv)	7	1.32	13.89	T-29
1,1,1-Trichloroethane (ppmv)	11	0.37	9.40	T-20, T-24, T-29
Carbon Tetrachloroethylene	65	0.16	3.21	All
1,1,2-Trichloroethane (ppmv)	13	0.75	8.64	T-20, T-24
1,2-Dichloroethane (ppmv)	10	0.78	3.87	T-20
Tetrachloroethylene (ppmv)	38	0.69	43.06	T-04
Methyl chloride (ppmv)	13	1.01	28.87	T-20, T-24
Methane	14	7.04	51.15	T-04, T-29
Benzyl chloride	44	3.16	185.54	T-20, T-24
Trichlorofluoromethane (ppmv)	67	0.32	57.59	T-20, T-24

Table H-7. Frequency, Minimum Concentrations, and Maximum Concentrations of Primary COCs Detected during Step II Sampling of Trenches T-04, T-20, T-24, and T-29 at the 218-W-4C Landfill

Compound	Number of Times Compound Was Detected	Minimum Detected Concentration*	Maximum Detected Concentration	Trenches with Detected Compound

Note: 208 vapor samples were collected during Step II sampling of Trenches T-04, T-20, T-24, and T-29 at the 218-W-4C Landfill.

* Detections less than the practical quantitation limits are excluded. Detections reported with a low level of confidence are included.

ppmv = parts per million by volume

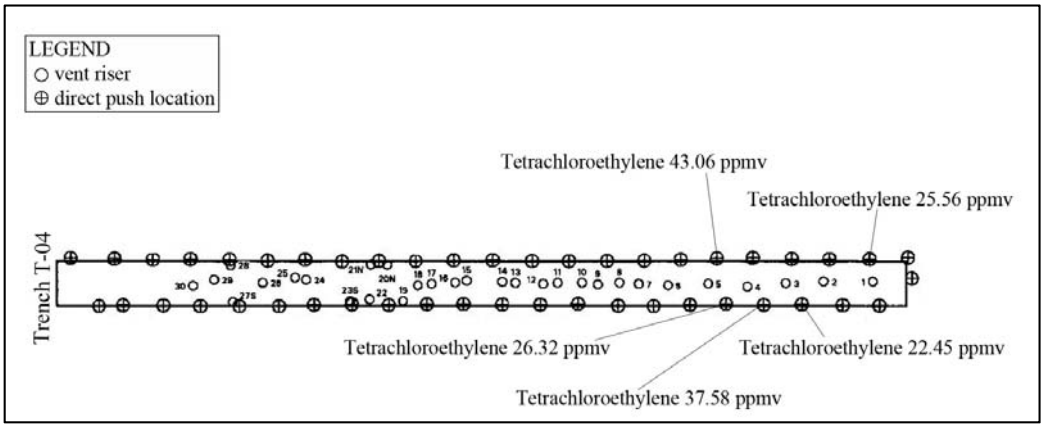

Figure H-7. Locations and Concentrations of Elevated COCs Detected during Step II Direct-Push Soil Vapor Sampling for Trench T-04 at the 218-W-4C Landfill

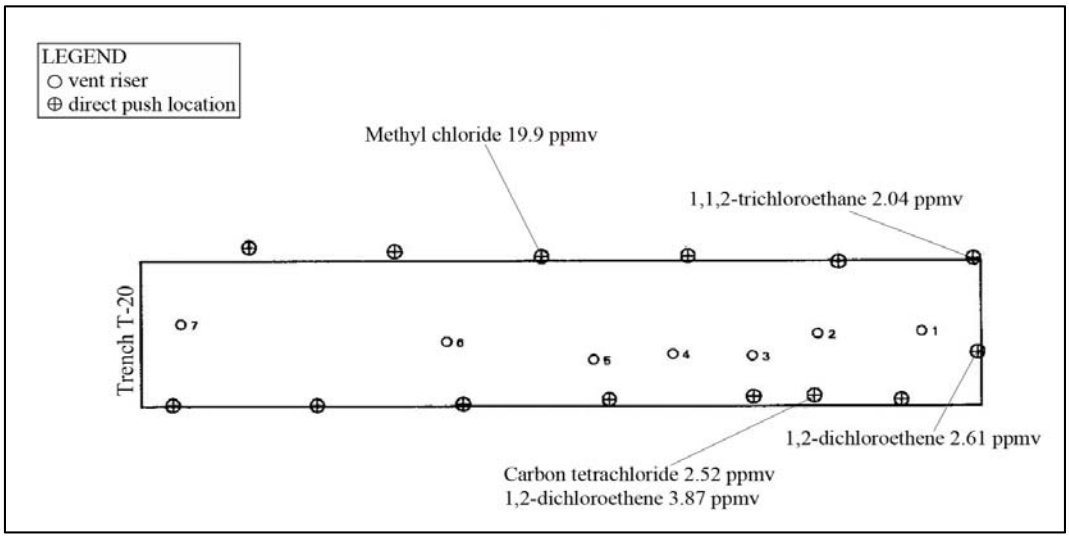

Figure H-8. Locations and Concentrations of Elevated COCs Detected during Step II Direct-Push Soil Vapor Sampling for Trench T-20 at the 218-W-4C Landfill

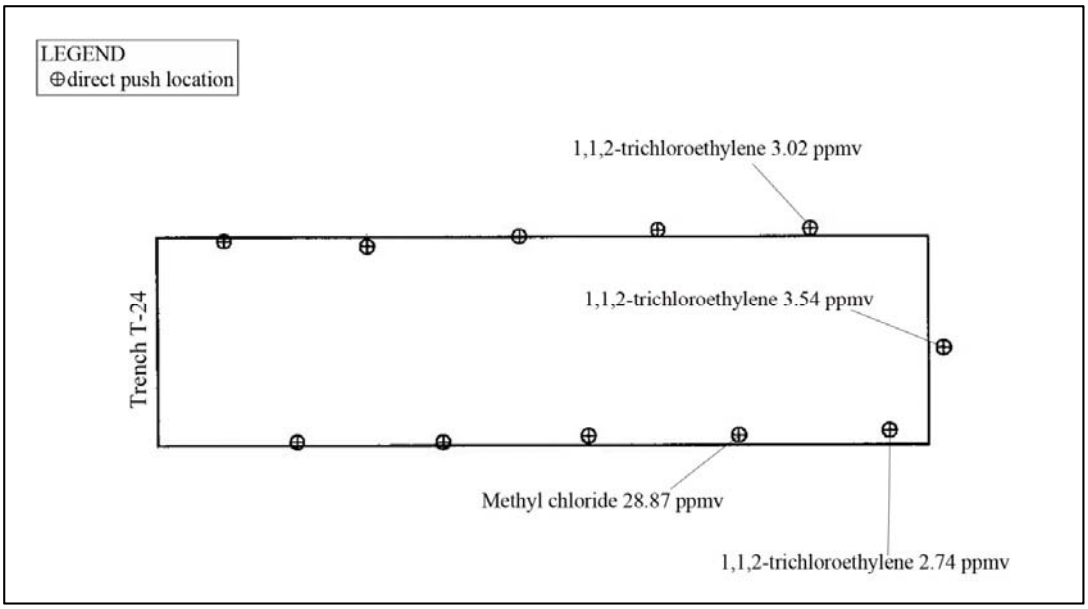

Figure H-9. Locations and Concentrations of Elevated COCs Detected during Step II Direct-Push Soil Vapor Sampling for Trench T-24 at the 218-W-4C Landfill

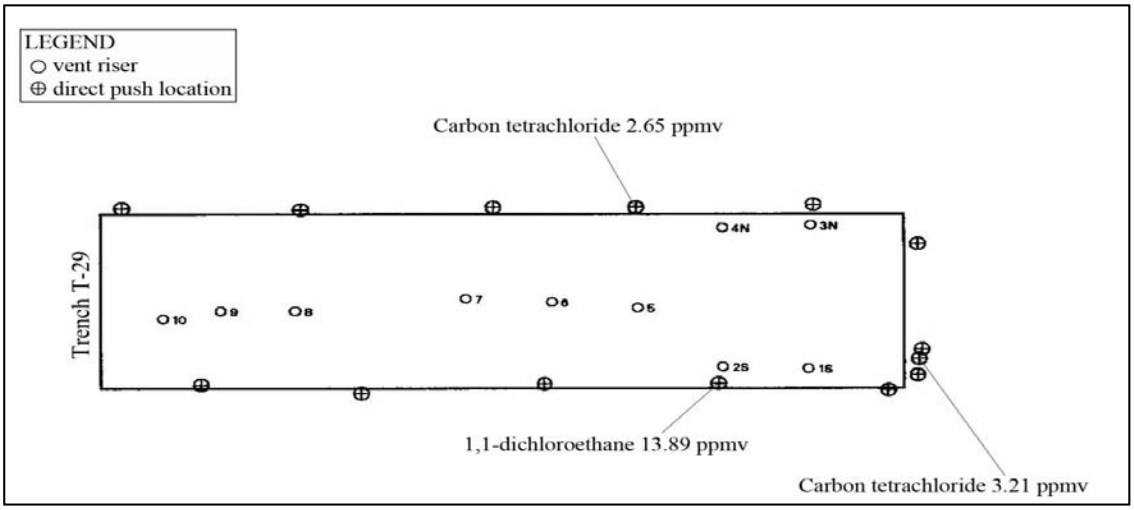

Figure H-10. Locations and Concentrations of Elevated COCs Detected during Step II Direct-Push Soil Vapor Sampling for Trench T-29 at the 218-W-4C Landfill

Table H-8. Frequency, Minimum Concentrations, and Maximum Concentrations of Primary COCs Detected during Step II Sampling of Trenches T-01 and T-07 at the 218-W-4C Landfill

Compound	Number of Times Compound Was Detected	Minimum Detected Concentration*	Maximum Detected Concentration*	Trenches with Detected Compound
1,1-Dichlororethane (ppmv)	1	10.29	10.29	T-01
Carbon tetrachloride	53	0.16	2.80	T-01, T-07
Trichloromethane (chloroform) (ppmv)	5	0.011	0.028	T-01
1,1,2-Trichloroethane (ppmv)	1	8.64	8.64	T-01
1,1,1-Trichloroethane (ppmv)	5	0.011	0.029	T-01
Trichloroethene (ppmv)	5	0.04	0.12	T-01
Tetrachloroethylene (ppmv)	37	0.80	15.25	T-01, T-07
Dichloromethane (methylene chloride) (ppmv)	1	7.12	7.12	T-01

Note: A total of 230 vapor samples were collected for field screening and laboratory analysis during Step II sampling of Trenches T-01 and T-07 at the 218-W-4C Landfill.

* Detections less than the practical quantitation limit are excluded. Detections reported with a low level of confidence are included.

ppmv = parts per million by volume

Per statements made in sampling reports (SGW-37027 and SGW-41533), data from the Step II 218-W-4C Landfill sampling did not indicate hot spots or large concentrations of VOCs. Both reports suggested that sufficient data were received from Steps I and II; therefore, efforts should be focused on Step III sampling and analysis requirements.

H2.4 Next Steps

Funding concerns for retrieval of TRU RSW in the 218-W-4C, 218-W-4B, 218-W-3A, and 218-E-12B Landfills halted operations at the end of 2011. Based on a review of M-091 Milestone project management meeting (PMM) minutes, no sampling has been conducted in support of M-091-40, Requirement 2, since the completion of Step II sampling at the 218-W-4C Landfill in April 2009. Per March 27, 2014 PMM minutes, no funding has been identified to retrieve TRU waste or perform sampling and analysis in FY 2014.

A description of work was developed in 2010 (SGW-47910, *Description of Work for the Step III Vapor and Soil Sampling Program at 218-W-4C Burial Ground for the 4, 20, and 27 Trenches*) to identify sampling methods for Step III at the 218-W-4C Landfill. Per PMM minutes, a cost estimate for further sampling at the 218-W-4C Landfill is being developed.

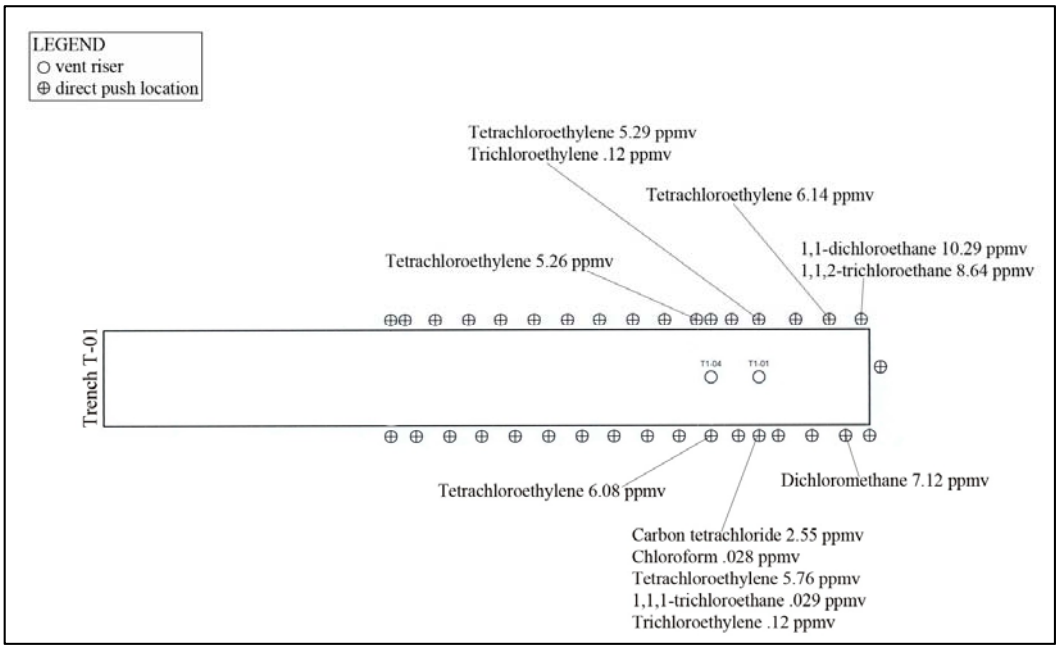

Figure H-11. Locations and Concentrations of Elevated COCs Detected during Step II Direct-Push Soil Vapor Sampling for Trench T-01 at the 218-W-4C Landfill

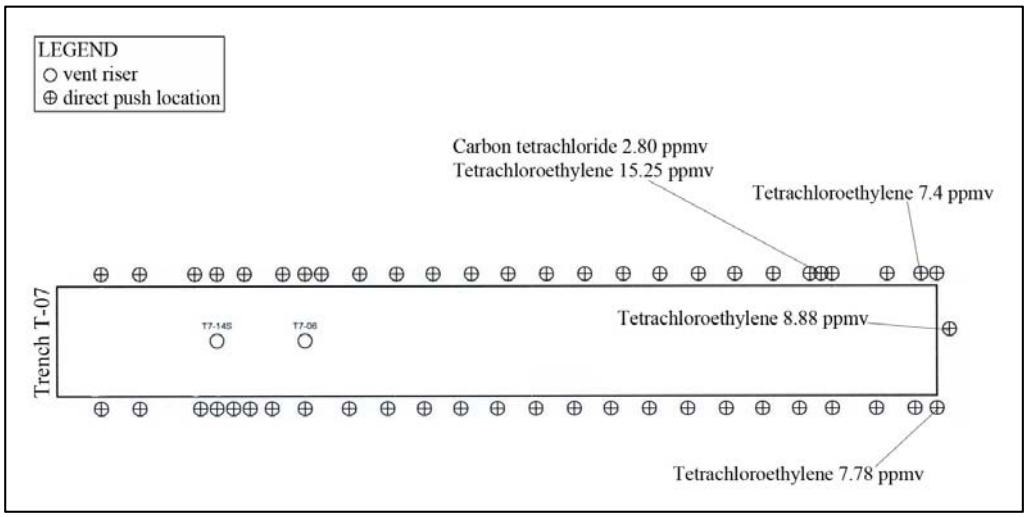

Figure H-12. Locations and Concentrations of Elevated COCs Detected during Step II Direct-Push Soil Vapor Sampling for Trench T-07 at the 218-W-4C Landfill

Table H-9. Maximum Soil Vapor Concentrations for all Compounds Detected in the 218-W-4C Landfill during Step II Sampling

Compound	Trenches T-04, T-20, T-24, and T-29, October 2007	Trenches T-01 and T-07, April 2009
Dichloromethane (methylene chlorine) (ppmv)	—	7.12
1,1-Dichloroethane (ppmv)	13.89	10.29
1,1,1-Trichloroethane (ppmv)	9.40	—
Carbon tetrachloride (ppmv)	3.21	2.80
1,1,2-Trichloroethane (ppmv)	3.54	8.64
1,2-Dichloroethylene (ppmv)	3.87	
Tetrachloroethylene (ppmv)	43.06	15.25
Trichloromethane (chloroform) (ppmv)	—	0.028
Methyl chloride (ppmv)	28.87	—
Acetylene (ppmv)	27.07	—
Nitrous oxide (ppmv)	4.49	—
Carbon dioxide (ppmv)	3,061	—
Toluene (ppmv)	51.11	—
Methane (ppmv)	51.15	—
Benzyl chloride (ppmv)	185.54	—
Trichlorofluoromethane (ppmv)	57.59	—
Chlorobenzene (ppmv)	5.75	—
Nitrobenzene (ppmv)	45.50	—
Phosgene (ppmv)	11.27	—

Note: Step II sampling was completed in two phases. Trench T-01 and T-07 waste retrieval was not complete; therefore, the trenches were not available for sampling in October 2007. Data are presented for each of the sampling efforts.

ppmv = parts per million by volume

H3 Characterization of DNAPL at the Hanford Site

The following discussion presents a summary of dense nonaqueous-phase liquid (DNAPL) at the Hanford Site.

H3.1 DNAPL Definition

DNAPLs are single or multicomponent liquids that are denser than water. Although not very soluble in water, many single and multicomponent DNAPLs are soluble enough to present potential risks to human health and the environment. The potential for significant long-term groundwater contamination by DNAPL chemicals at many sites is high due to their toxicity; limited solubility (but much higher than drinking water limits); and significant migration potential in soil gas, groundwater, and/or as a separate phase liquid. Migration and distribution of DNAPLs are highly variable and depend on many factors including, but not limited to, soil media, soil saturation, and other compounds present.

H3.2 DNAPL Migration and Distribution

DNAPLs migrate through the subsurface under the influence of gravity and capillary effects created in geologic media. Residual saturation has a large effect on DNAPL subsurface behavior. A discharged DNAPL flow through the unsaturated zone is dependent on chemical and physical characteristics of DNAPL in relation to soil gas, soil moisture, soil matrix, gravity, and pressure (ITRC, 2003, *An Introduction to Characterizing Sites Contaminated with DNAPLs*). As DNAPL moves through the subsurface, small droplets, or ganglia, are left behind in pore spaces as immobile droplets (ITRC, 2003).

Due to their small size and random distribution, DNAPLs are difficult to detect with soil borings and monitoring wells. The variations in pore size distributions, soil texture, soil structure, and mineralogy create a random and unpredictable distribution of ganglia (ITRC, 2003). These ganglia can serve as a long-term source of contamination for surrounding water and air.

Continuous source releases will most likely produce a few vertical flow pathways, and ganglia will not form; whereas, small discrete releases will most likely have a different pathway with each release. The formation of ganglia will occur quickly with small discrete releases as the mass of DNAPL decreases quickly, and the driving force of flow is nonexistent. Changes in the subsurface occur with each release and, over time, create a different matrix environment for each discrete release.

H3.3 DNAPL Detection

Determining the source of contamination, the history of contamination release from the source area, date of release, and what and how much was released is critical to assessing the ultimate behavior and distribution of the contamination. DNAPL behavior varies, depending on what other compounds are present at disposal. It is important to evaluate the site-specific DNAPL to determine all compounds present and specific characteristics (ITRC, 2003).

U.S. Environmental Protection Agency DNAPL guidance (EPA, 2014, *Contaminated Site Clean-Up Information*) suggests using soil gas detection as a method to determine DNAPL presence. Erratic, localized, very high organic vapor concentrations in soil gas (100 to 1,000 ppm), located just above the water table (where dense gas derived from DNAPL in the vadose zone will tend to accumulate), can infer the presence of DNAPL.

H3.4 DNAPL Characterization Study at the Hanford Site

This section provides a summary of activities performed in an ongoing study at the Hanford Site aimed at determining the presence and location of DNAPL. Characterization efforts are detailed in DOE/RL-2006-58, *Carbon Tetrachloride Dense Non-Aqueous Phase Liquid (DNAPL) Source Term Characterization Report*.

H3.4.1 Overview of Characterization Study

A multiphase effort to locate and characterize carbon tetrachloride existing in the subsurface as DNAPL started in 2003. The previous carbon tetrachloride conceptual model (based on the basic physics of DNAPL flow in the subsurface combined with some bounding knowledge of likely release areas and volumes) has been refined to incorporate new data and site-specific knowledge on the DNAPLs and sediments unique to the 200 West Area. Continuous characterization and remediation activities have been used to verify or refocus aspects of the conceptual model.

The high cost of conventional baseline characterization methods (i.e., drilling) limited the ability to collect the volume of data typically needed for a more complete DNAPL characterization. The depth requirements and characteristics of the site sediments challenged more innovative methods of subsurface access (e.g., direct penetration). However, field approaches incorporated with preliminary remediation activities and combined with recent laboratory experiments and numerical modeling led to a focused conceptual model with several clear avenues for additional targeted field activities.

An interim version of the updated conceptual model was produced as a result of the completed work, with a final model planned upon completion of all work. Two separate revised conceptual models were created: one for the 216-Z-9 Trench and a second for the 216-Z-1A Tile Field, as a representative of the other waste disposal sites.

To date, only one soil sample collected has been noted as containing DNAPL. The sample was at a depth of 19.8 m (65 ft) in well 299-W15-46, located just south of the 216-Z-9 slab edge.

H3.4.2 Phase I

During the Phase I investigation in August 2003, 86 passive soil gas samples were collected to gather data concerning the potential location of DNAPL source regions above the Cold Creek unit (CCU) around the 216-Z-9 Trench. The Phase I conceptual model hypothesized that the majority of the carbon tetrachloride remains in the vadose zone and resides as DNAPL in the fine-grained unit of the CCU as well as in the fine-grained layers above the CCU (DOE/RL-2006-58). A large amount of process water was co-disposed with carbon tetrachloride, which increased the lateral spreading of the dissolved-phase plume. The likely region of carbon tetrachloride DNAPL and dissolved-phase plume contamination increased from the vertical footprint of the waste disposal site to several meters outside the site footprint and down in a conical shape to the CCU.

H3.4.3 Phase II

Phase II began with a series of passive soil gas surveys. Results were used to focus Phase II invasive investigation stages with an emphasis on identifying any remaining DNAPL.

H3.4.3.1 Passive Soil Gas Sampling

Four progressively more focused passive soil gas surveys were conducted between September 13, 2004, and December 24, 2005. A total of 503 passive soil gas measurements were collected along pre-defined coarse and refined grids to investigate potential vadose zone sources of carbon tetrachloride contamination in the 200 West Area. The surveys collected data around the known carbon tetrachloride waste disposal sites and sources, where no data were currently available, in order to identify areas with high carbon tetrachloride surface flux rates, which are considered indicative of subsurface contaminant sources at or above the CCU. Survey results were primarily used to identify source regions warranting further invasive investigation.

Most of the measured high concentrations were determined to be in or around the three known disposal sites. The highest rates were identified in the 216-Z-1A Tile Field. The 216-Z-9 Trench rates are thought to be lower due to substantial evaporation of carbon tetrachloride on the 216-Z-9 Trench disposal rock splash pad and the high removal rate of carbon tetrachloride by SVE operations. It was determined that the possibility of a persistent unknown vadose zone source term within the test area is unlikely. Table H-10 lists the highest carbon tetrachloride flux rates (converted from ng/sample) identified in each area sampled. This is a qualitative flux and is a method used to normalize the measurements from the various field deployments.

Table H-10. Highest Calculated Carbon Tetrachloride Flux Rates Identified in Each Study Area

Survey	Field Test Location	Carbon Tetrachloride Flux ($ng/m^2/mi$)		
		Highest Soil Gas	Second Highest	Third Highest
#1	216-Z-9 Trench (refined)	1,562	1,251	1,120
	TX-TY Tank Farm (coarse)	864	834	233
#2	Plutonium Finishing Plant (coarse)	5,956	3,080	357
	216-Z-1A, 216-Z-12, and 216-Z-18 coarse)	497	465	432
#3	Outside TX Tank Farm (refined)	12,486	11,333	8,578
#4	216-Z-1A and 216-Z-18 (refined)	5,742	4,042	3,717

Data suggest that a potential carbon tetrachloride source exists in the subsurface of the eastern and southwest portion of the TX Tank Farm. Persistent subsurface carbon tetrachloride contamination is present at specific source locations around the 216-Z-1A Tile Field and PFP complex.

Excluding consideration of carbon tetrachloride, 4 other compounds targeted by the sampling equipment were identified in 13 of the 503 samples analyzed. The chloroform and chloromethane identified in this investigation have two possible sources: both compounds are anaerobic degradation products of carbon tetrachloride, and both would also result from the discharge of chlorinated water to the 200 West Area power plant pond. Perchloroethene was discharged at the 216-Z-9 Trench (WHC-SD-EN-TI-248, *1994 Conceptual Model of the Carbon Tetrachloride Contamination in the 200 West Area at the Hanford Site*), and its presence near the other discharge locations suggests that it was also discharged there (DOE/RL-96-81, *Waste Site Grouping for 200 Areas Soil Investigations*). Trichloroethene is a degradation product of perchloroethene (Table H-11). Combining the results of the Phase II passive soil gas surveys with the Phase I conceptual model, locations were identified where invasive investigation would have the highest probability of encountering carbon tetrachloride DNAPL. As this effort is ongoing, the final report will address the effectiveness of passive soil gas surveys in characterizing subsurface contaminant distribution by comparing passive soil gas survey results with those from the cone penetrometer test (CPT) and ongoing hydraulic hammer rig investigations.

Table H-11. Analytical Results for the Remaining Targeted Compounds

Survey	Field Test Location	Compound	Concentration (ng/trap)	Calculated Flux Rate (ng/m^2/min)
#1	216-Z-9	Trichloroethene	39	140
		Chloromethane	88	319
	TX-TY Tank Farms	Perchloroethene	34	124
		Chloromethane	110	400
#2	Near Plutonium Finishing Plant	Chloromethane	57	155
		Chloroform	231	629
		Perchloroethene	81	222
		Trichloroethene	32	88
	216-Z-1A, 216-Z-12, and 216-Z-18	Perchloroethene	121	327
		Chloromethane	40	110
#3	TX-TY Tank Farms	None	--	--
#4	216-Z-1A and 216-Z-18	Perchloroethene	331	906
		Chloroform	27	77
	East of Plutonium Finishing Plant	Trichloroethene	75	212
		Chloroform	165	467

H3.4.3.2 Invasive Investigations

The objectives of the invasive investigation were to provide further characterization of the vadose zone down through the top of the CCU and to refine delineation of carbon tetrachloride contamination with an emphasis on identifying any remaining DNAPL source term.

Stage 1 – CPT Sampling at the 216-Z-9 Trench

From April 2005 to May 2005, a CPT investigation was conducted at the 216-Z-9 Trench and entrance to PFP in areas where passive soil gas sampling detected carbon tetrachloride contamination. To support efforts to delineate carbon tetrachloride contamination in the vadose zone and locate potential sources, direct-push sampling via CPT was used to determine active soil gas concentrations and collect sediment samples for laboratory analysis. Two locations were tested with DNAPL ribbon samplers as a direct test for carbon tetrachloride DNAPL.

Fine-grained layers were found in the substrate. The fine-grained layers are significant in controlling downward DNAPL migration and represent zones where DNAPL could be trapped.

Active soil gas samples were collected at 1 m (3.3 ft) intervals for each penetration. A minimum vapor concentration of 12,000 ppmv was considered an indication of DNAPL concentrations in the surrounding soil. The samples were analyzed for chloroform and carbon dioxide as potential indicators of the degradation of carbon tetrachloride. Only three samples contained more than 100 ppmv carbon

tetrachloride. The highest measured vapor concentrations were located around the 216-Z-9 Trench and around and within the 216-Z-1A Tile Field. Results from these tests do not indicate that DNAPL sources exist within the radius of influence (1 to 10 m [3.28 to 32.8 ft]) of the measurement point.

Laboratory analysis of soil samples identified no carbon tetrachloride or chloroform contamination above the quantitation limits. The results support the hypothesis that carbon tetrachloride contamination in soil is more localized and present in discrete locations.

Inspection of the ribbon samplers revealed minor localized staining, which is not considered indicative of direct contact with carbon tetrachloride DNAPL. In order to provide a comparison to the field results, laboratory testing produced staining samples at varying degrees of carbon tetrachloride DNAPL concentrations. The staining noted in the laboratory tests, even at low levels of contamination, was significantly greater than the staining produced on the field-deployed ribbon samplers, supporting a conclusion that carbon tetrachloride DNAPL was not detected.

Stage 2 – CPT Sampling at 216-Z-1A, 216-Z-18, and 216-Z-12

The objectives and work plan for Stage 2 were the same as for Stage 1. Attempts to deploy a ribbon sampler were not successful for Stage 2.

Carbon tetrachloride concentrations detected during Stage 2 active soil gas sampling efforts were well below the 12,000 ppmv concentration to determine proximity to carbon tetrachloride DNAPL. Two locations had carbon tetrachloride concentrations greater than 100 ppmv, with a maximum detection of 512 ppmv. Both are located in the 216-Z-1A Tile Field.

Laboratory analysis detected no significant chemical contamination. Carbon tetrachloride and chloroform did not exceed quantitation limits. As with Stage 1, CPT did not reach the desired target depths (the CCU layer) at most sampling locations.

Stage 3

Initiated in June 2006, Stage 3 investigation is designed to collect soil samples from specific fine-grained layers from the CCU layer within the vadose zone adjacent to the 216-Z-9 Trench for laboratory analysis of VOCs. A hydraulic hammer rig is used to collect samples from depths that were not attained in the CPT investigation. Results will be documented in a final report.

Stages 4 and 5

Stages 4 and 5 of the vadose zone investigation are designed to sample and analyze fine-grained soils from the CCU in the area around the 216-Z-1A Tile Field. These two investigations will be conducted in sequence, following the completion of the Stage 3 investigation.

Additional Investigations

Soil gas response testing near the 216-Z-9 Trench and 216-Z-1A Tile Field was conducted using established vapor monitoring points in pre-existing vapor wells. Data were evaluated to determine the potential for DNAPL carbon tetrachloride sources within the radius of influence of each test. The testing produced no clear indication of DNAPL source material, but results were supportive of vapor diffusion from the contaminant source associated with the CCU. Two sampling locations produced elevated levels of carbon tetrachloride (205 and 208 ppmv), both of which had increasingly elevated levels as the sampling depth increased. These results are consistent with the conceptual model for carbon tetrachloride trapped in fine-grained layers of the CCU.

Vista Engineering conducted thermal and air exchange measurements associated with the 216-Z-9 Trench in order to support the hypothesis of high evaporation rates. Initial data collection began in May 2006; all data collection systems were in operation by June 1, 2006. The current intent is to continue data collection to the end of the CY. Data collected are used to help determine the potential for evaporation and measure the natural air exchange occurring within the 216-Z-9 Trench.

H3.4.4 Testing for DNAPL in Groundwater

Historically, carbon tetrachloride as DNAPL has not been found in any 200 West Area groundwater samples, and the highest carbon tetrachloride concentration found in groundwater is about 1 percent of the carbon tetrachloride solubility limit. Depth-discrete groundwater sampling was conducted from November 2004 to May 2005 in the 20 deepest existing wells around the high-concentration portion of the carbon tetrachloride groundwater plume. All of the sampled results were significantly less than the solubility limit of carbon tetrachloride in water, suggesting that no significant quantity of DNAPL exists near well intervals sampled. However, understanding that the likelihood of detecting DNAPL or contaminant concentrations near saturation is low, data are not conclusive regarding the presence or absence of significant DNAPL in the unconfined aquifer.

It was hypothesized that if there were a DNAPL source in the unconfined aquifer, it would be in the 216-Z-9 Trench area at the very bottom of the aquifer on the top of the Ringold Formation lower mud unit. A well pumping test was designed to detect potentially elevated concentrations of carbon tetrachloride. Testing had not started when the characterization report was written.

H3.4.5 Updated Conceptual Model

The refined conceptual model is that carbon tetrachloride contamination persists primarily in the vadose zone, but a considerable amount also may be found below the water table, most likely as dissolved phase, with a small probability for DNAPL. Vadose zone contamination exists in the subsurface and, along with a trapped and immobile, high-concentration aqueous phase, is the likely main and persistent source of contamination at the site. DNAPL is generally retained in the fine-grained sediments (mostly by capillary forces rather than by sorption onto natural organic matter). The vadose zone sediments containing the majority of the DNAPL are the fines and caliche of the CCU.

Other fine-grained layers at shallower depths (particularly under and near the waste disposal sites) also may contain a significant amount of DNAPL. The concept is strongly supported by soil field-screening results from the drilling of well 299-W15-46, located 4.6 m (15 ft) south of the 216-Z-9 Trench. As documented in WMP-26264, *Borehole Summary Report for Well 299-W15-46 (C3426) Drilled at the 216-Z-9 Trench*, moist sandy sediments collected at 19.7 m (64.5 ft) below ground surface (bgs), at a contact with a silt layer, tested positive for DNAPL (field screen with aqueous iodine solution). Laboratory analysis of soils collected in the interval between 19.4 and 20.1 m (63.5 and 66.0 ft) bgs showed a carbon tetrachloride concentration of 380,000 µg/kg. This silt layer is not as laterally continuous as the CCU, but rather is typical of the thin discrete silt zones found with the heterogeneous Hanford formation, especially the sand- and silt-dominated units. The presence of these layers is significant both because of the contaminant mass they may contain and because of the difficulty accessing the contaminant in these zones by SVE or other flow-based remediation strategies. An additional potentially important reservoir for carbon tetrachloride is the intragranular pores space in the sands and gravels. Recent experiments have shown that the intraparticle pores comprise a significant fraction of the total porosity of these sediments and may be a large and slow-releasing DNAPL source (Tokunaga et al., 2003, “Moisture Characteristics of Hanford Gravels: Bulk, Grain-surface, and Intragranular Components”).

Because there are few wells with the short screen interval necessary to identify thin discrete DNAPL zones that could be present at the site, the relatively low-aqueous concentrations measured must be placed in perspective. Large screen zones and permeable materials provide substantial dilution capacity, and the resulting low, diluted concentrations can easily bias an interpretation to reject the presence of DNAPL. A key factor supporting the presence of a significant DNAPL source in the unconfined aquifer is the persistence of groundwater concentrations even during the operation of the pump-and-treat system. Conflicting with these lines of evidence are the data from the recent vertical well (299-W15-46), immediately south of the 216-Z-9 Trench, which found no DNAPL in sediment samples collected below the phreactic surface.

The billions of gallons of water from the wastewater disposal facility operations from 1944 to 1995 and the evidence of their influence on the 200 West Area (e.g., shallow perched water zones) provide a mechanism for moving large quantities of carbon tetrachloride into the aquifer without a DNAPL source below the water table. It may also help explain the apparent movement of the center of carbon tetrachloride mass in transition from the vadose zone to the saturated zone.

Carbon tetrachloride that was held up in the vadose zone provided the source material for the dissolved-phase groundwater plume. Water disposed in the trench and in other nearby disposal sites flushed over the trapped DNAPL and its corresponding dense vapor-phase plume, dissolved it, and created a dissolved plume that migrated to the water table. It is not believed that DNAPL reached the aquifer or is a persistent source in the aquifer.

H4 Conclusions

Because of the inherent uncertainty of detecting and determining the presence of DNAPL, the information contained in this appendix will be used to make assumptions on the potential presence of DNAPL in the 200-SW-2 OU. As a result of the M-091-40 soil gas sampling requirements, the 218-W-3A, 218-W-4C, and 218-W-4B Landfills are assumed to contain DNAPL in the vadose zone due to high detections, based on soil gas of organics that have a high probably of being DNAPLs. Supporting this assumption, during SVE operations at the 218-W-4B Landfill, carbon tetrachloride was detected at a level indicating the presence of DNAPL.

Sampling in the landfills that have an assumed presence of DNAPL is included in the SAP (Appendix A) for the 200-SW-2 work plan by way of passive and active soil gas samples and sampling during the direct pushes and horizontal borings. Sampling will be done to gain a better understanding of the presence and extent of contamination and the suspected behavior of DNAPL contamination in the vadose zone.

H5 References

04-AMCP-0197, 2004, “Transmittal of the Burial Ground Sampling and Analysis Results for October – December 2003” (letter to Michael A. Wilson, Washington State Department of Ecology, from Keith A. Klein), U.S. Department of Energy, Richland Operations Office, Richland, Washington, March 17. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D4399052.

05-AMCP-0414, 2005, “Transmittal of the Burial Ground Sampling and Analysis (SAP) Results for April–June 2005” (letter to Michael A. Wilson, U.S. Department of Ecology, from Matthew S. McCormick), U.S. Department of Energy, Richland Operations Office, Richland, Washington, September 20. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA01058832.

06-AMCP-0073, 2005, "Burial Ground Sampling and Analysis Results for July – September 2005" (letter to Michael A. Wilson, Washington State Department of Ecology, from Matthew S. McCormick), U.S. Department of Energy, Richland Operations Office, December 14. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA01562285.

07-AMCP-0061, 2006, "Transmittal of the Burial Ground Sampling and Analysis Results for July – September 2006 Quarter" (letter to Jane A. Hedges, Washington State Department of Ecology, from Matthew S. McCormick), U.S. Department of Energy, Richland Operations Office, Richland, Washington, December 19. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA04110576.

07-AMCP-0166, 2007, "Burial Ground Sampling and Analysis Results for October – December 2006," (letter to Jane A. Hedges, Washington State Department of Ecology, from Matthew S. McCormick), U.S. Department of Energy, Richland Operations Office, Richland, Washington, April 24. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA04902597.

BHI-01105, 1997, *Rebound Study Report for the Carbon Tetrachloride Soil Vapor Extraction Site, Fiscal Year 1997*, Rev. 0, Bechtel Hanford, Inc., Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D198067101.

DOE/RL-96-81, 1997, *Waste Site Grouping for 200 Areas Soil Investigations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D197197143.

DOE/RL-2003-48, 2003, *218-W-4C Sampling and Analysis Plan*, Rev. 0, U.S. Department of Energy, Richland, Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0082375H.

DOE/RL-2004-32, 2004, *218-E-12B Burial Ground Sampling and Analysis Plan*, Rev. 0, U.S. Department of Energy, Richland, Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D7228581.

DOE/RL-2004-70, 2006, *218-W-4B Burial Ground Sampling and Analysis Plan*, Rev. 0, U.S. Department of Energy, Richland, Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA02967771.

DOE/RL-2004-71, 2006, *218-W-3A Burial Ground Sampling and Analysis Plan*, Rev. 0, U.S. Department of Energy, Richland, Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA02722900.

DOE/RL-2006-58, 2006, *Carbon Tetrachloride Dense Non-Aqueous Phase Liquid (DNAPL) Source Term Characterization Report*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA04193109.

Ecology, 2003, *Administrative Order No. 03NWPKW-5494*, Washington State Department of Ecology, Olympia, Washington. Available at: http://listserv.wa.gov/cgi-bin/wa?A3=ind0305&L=HANFORD-INFO&E=0&P=1500633&B=------%3D_NextPart_001_01C319AC.1AEEE900&T=text%2Fplain.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington. Available at: http://www.hanford.gov/?page=81.

EPA, 2014, *Contaminated Site Clean-Up Information*, Dense Nonaqueous Phase Liquids (DNAPLs) Overview, Technology Innovation and Field Services Division, Office of Superfund Remediation and Technology Innovation, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://cluin.org/contaminantfocus/default.focus/sec/Dense_Nonaqueous_Phase_Liquids_(DNAPLs)/cat/Overview/.

ITRC, 2003, *An Introduction to Characterizing Sites Contaminated with DNAPLs*, Technology Overview, The Interstate Technology & Regulatory Council, Washington, D.C. Available at: http://www.itrcweb.org/Guidance/GetDocument?documentID=21.

PNNL-21326, 2012, *Treatability Test Report: Characterization of Vadose Zone Carbon Tetrachloride Source Strength Using Tomographic Methods at the 216-Z-9 Site*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1210310436.

SGW-37027, 2008, *Burial Ground Sampling and Analysis Results for October – December 2007*, Rev. 0, Fluor Hanford, Inc., Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA06941074.

SGW-37111, 2008, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Fiscal Year 2007*, Rev. 0, Fluor Hanford Inc., Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0809171000.

SGW-41533, 2009, *Burial Ground Sampling and Analysis Results for April – June 2009*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0909210820.

SGW-47910, 2010, *Description of Work for the Step III Vapor and Soil Sampling Program at 218-W-4C Burial Ground for the 4, 20, and 27 Trenches*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0082355H.

SGW-54566, 2013, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Calendar Year 2012*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0086023.

Tokunaga, Tetsu K., Keith R. Olson, and Jiamin Wan, 2003, "Moisture Characteristics of Hanford Gravels: Bulk, Grain-surface, and Intragranular Components," *Vadose Zone Journal* 2(3):322-329. Available at: https://publications.lbl.gov/islandora/object/ir%3A121250.

WHC-SD-EN-TI-248, 1994, *1994 Conceptual Model of the Carbon Tetrachloride Contamination in the 200 West Area at the Hanford Site*, Rev. 0, Westinghouse Hanford Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D196075664.

WMP-26178, 2005, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Carbon Tetrachloride Site, Fiscal Year 2004*, Rev. 0, Fluor Hanford, Inc., Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA776140.

WMP-26264, 2008, *Borehole Summary Report for Well 299-W15-46 (C3426) Drilled at the 216-Z-9 Trench*, Rev. 1, Fluor Hanford, Inc., Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1005130009.