ECF-200PW1-16-0077
Revision 0

Soil Vapor Extraction Endstate Tool Calculations for the 216-Z-9, 216-Z-1A, and 216-Z-18 Waste Sites in the 200-PW-1 Operable Unit

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

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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Terms

CCU	Cold Creek unit
OU	operable unit
PNNL	Pacific Northwest National Laboratory
ppmv	parts per million by volume
SVE	soil vapor extraction
SVEET	Soil Vapor Extraction Endstate Tool

1 Purpose

This calculation supports evaluation of the soil vapor extraction (SVE) systems in the 200-PW-1 Operable Unit (OU) presented in DOE/RL-2014-48, *Response Action Report for the 200-PW-1 Operable Unit Soil Vapor Extraction Remediation*. The calculation is used to estimate the groundwater contaminant concentration resulting from a contamination source in the vadose zone.

2 Background

Guidance was developed by scientists and remediation experts at Pacific Northwest National Laboratory (PNNL), the U.S. Army Corps of Engineers, and the U.S. Environmental Protection Agency to provide a technical basis for supporting SVE system performance evaluation and remedy decision (PNNL-21843, *Soil Vapor Extraction System Optimization, Transition, and Closure Guidance*, hereafter referred to as the SVE Closure Guidance). The SVE Closure Guidance discusses evaluation of SVE systems to assess whether SVE should be continued (perhaps with optimization), whether remediation should transition to a different remedy, or whether the SVE system should be turned off and the site closed. The companion Soil Vapor Extraction Endstate Tool (SVEET) software is a tool to help identify the impact of the remaining vadose zone source on groundwater concentrations, which is one aspect of the evaluation.

SVE has been used at the 200-PW-1 OU since 1992 to remove carbon tetrachloride from the vadose zone. Carbon tetrachloride was discharged to three waste sites in the 200-PW-1 OU: 216-Z-9, 216-Z-1A, and 216-Z-18. SVE at these 200-PW-1 OU waste sites has exhibited diminishing returns for mass removal of carbon tetrachloride in recent years, and carbon tetrachloride soil gas concentrations are mostly below the cleanup target of 100 parts per million by volume (ppmv) identified in EPA et al., 2011, *Record of Decision Hanford 200 Area Superfund Site 200-CW-5 and 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*. Thus, the process outlined in the SVE Closure Guidance (PNNL-21843) was used as a guide for identifying the technical information suitable to support the evaluation described in DOE/RL-2014-48.

The SVEET software provides estimates of groundwater contaminant concentration resulting from a contamination source in the vadose zone. The SVEET software is based on a generalized conceptual model and interpolation of results from 972 numerical model simulations. The SVEET tool constrains users to enter values for input parameters within permissible ranges. Of note, the SVEET software tool does not allow input of a source size greater than a 50 m by 50 m area. However, when the source strength is defined using a soil gas concentration, the impact to groundwater increases linearly as the source size increases. Therefore, groundwater concentration results obtained for key source width input values (10, 20, 30, and 50 m) can be linearly extrapolated to results for a 90 m source width.

3 Methodology/Calculation Approach

The specified input data (listed in the Input and Assumptions Section below) was entered into the SVEET software. Upon entry of all data inputs, results were immediately available. For a given waste site, the four groundwater concentration results (at source widths of 10, 20, 30, and 50 m) were regressed (outside of the SVEET software) to determine the best-fit line. This best-fit line was used to calculate the groundwater concentration for a source width of 90 m.

4 Input and Assumptions

The calculation applied the standard assumptions identified for the SVEET software as described in the SVE Closure Guidance (PNNL-21843). Among other things, SVEET calculations assume steady-state conditions with a constant-strength source and groundwater that was initially clean (i.e., is only affected

by the defined vadose zone source). Table 1 identifies all of the SVEET inputs for the three waste sites of interest. Several inputs are discussed in more detail in the subsequent narrative.

Table 1. SVEET Data Inputs for the 216-Z-9, 216-Z-1A, and 216-Z-18 Waste Sites

User Input Source/Transport Parameters	216-Z-9	216-Z-1A	216-Z-18	Data Source[a]
Contaminant	Carbon tetrachloride	Carbon tetrachloride	Carbon tetrachloride	—
Temperature (°C)	16	16	16	PNNL-22062, pg. 1.2
Average moisture content (wt %)	6.5	6.5	6.5	PNNL-21326, Figure 4.31
Average recharge (cm/yr)	0.4	0.4	0.4	PNNL-21326, Table 4.9
Vadose zone thickness (m)	60	60	60	Estimated from the cross sections in Appendix A of DOE/RL-2014-48
Depth to top of source (m)	24	29	29	
Source thickness (m)	6	6	6	
Source width (m)	90[b]	90[b]	90[b]	PNNL-21326, Table 4.9
Groundwater Darcy velocity (m/d)	0.00545	0.00545	0.00545	PNNL-21326, Table 4.9
Distance to compliance well[c] (m)	25	25	25	—
Compliance well screen length (m)	10	10	10	PNNL-21326, Figure 4.38
Source strength input type	Gas concentration	Gas concentration	Gas concentration	—
Source gas concentration (ppmv)	24.7[d]	13.9[e]	9.65[e]	DOE/RL-2014-48, Table B-1 SGW-54566, Table D-1 and Table E-1

References: DOE/RL-2014-48, *Response Action Report for the 200-PW-1 Operable Unit Soil Vapor Extraction Remediation*.

PNNL-21326, *Treatability Test Report: Characterization of Vadose Zone Carbon Tetrachloride Source Strength Using Tomographic Methods at the 216-Z-9 Site*.

PNNL-22062, *Abiotic Degradation Rates for Carbon Tetrachloride and Chloroform: Final Report*.

SGW-54566, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Calendar Year 2012*.

a. Dashed items are SVEET inputs selected for the calculation; thus, they do not have a data source.

b. The SVEET software does not allow a source width value larger than 50 m. However, for a source strength specified as a gas concentration, the results for several source widths ≤50 m can be linearly extrapolated to a source width of 90 m. Values of 10, 20, 30, and 50 m were used as input to SVEET, and the results were extrapolated to 90 m.

c. A downgradient distance of 25 m is the nearest compliance well location that is available in SVEET for these scenarios.

d. Data source is DOE/RL-2014-48, Table B-1.

e. Data source is SGW-54566, Tables D-1 and E-1.

ppmv = parts per million by volume

SVEET = Soil Vapor Extraction Endstate Tool

For the 200-PW-1 OU, the key factor for impact on groundwater concentrations is the carbon tetrachloride contamination emanating from the Cold Creek unit (CCU) into the zone below the CCU. Thus, data on carbon tetrachloride soil gas concentrations below the CCU were used to define the carbon tetrachloride source strength for the SVEET calculations. Of the soil gas samples collected at the 216-Z-9 site in 2014 (Table B-1 in Appendix B of DOE/RL-2014-48), the highest concentration detected below the CCU was 24.7 ppmv at well 299-W15-86 on May 15, 2014. The 2014 carbon tetrachloride soil gas concentrations beneath the 216-Z-1A and 216-Z-18 sites (Table B-1 in Appendix B of DOE/RL-2014-48) were all below the detection limit, except for an atypical (i.e., much higher than historic concentrations) result of 21.4 ppmv at well 299-W18-247L. Therefore, the maximum result from the 2012 to 2013 time period was selected for the SVEET calculations as a conservative soil gas concentration below the CCU at the 216-Z-1A and 216-Z-18 sites. At the 216-Z-1A site, well 299-W18-246L had an average result of 13.9 ppmv on July 15, 2012 (Table D-1 in Appendix D of SGW-54566, *Performance Evaluation Report for Soil Vapor Extraction Operations at the 200-PW-1 Operable Unit Carbon Tetrachloride Site, Calendar Year 2012*). At the 216-Z-18 site, well 299-W18-247L had a result of 9.65 ppmv on May 20, 2012 (Table D-1 in Appendix D of SGW-54566).

The vertical position and thickness of the source zone (i.e., the CCU) is estimated from the cross sections in Appendix A of DOE/RL-2014-48. The vadose zone thickness of nominally 60 m (197 ft) can be represented in SVEET. However, SVEET constrains the source zone thickness to be between 10 and 50 percent of the vadose zone thickness, so the nominal 4 m (13 ft) thickness of the CCU source zone must be represented as 6 m (20 ft) thick. Because the thickness of the CCU source zone was adjusted, the distance between ground surface and the top of the source zone was also adjusted to maintain an accurate distance between the bottom of the CCU source and the groundwater. The distance between the source and the groundwater is a key aspect with respect to the influence of vadose contamination on concentrations in the groundwater. The distance from the bottom of the CCU to groundwater is nominally 30 m at the 216-Z-9 site and 25 m at the 216-Z-1A and 216-Z-18 sites; thus, the depths to the top of the source are 24 m and 29 m, respectively.

The size of the source area (i.e., areal footprint) at the 216-Z-9 site was determined in the treatability test report (PNNL-21326, *Treatability Test Report: Characterization of Vadose Zone Carbon Tetrachloride Source Strength Using Tomographic Methods at the 216-Z-9 Site*) to be nominally 90 m by 90 m. Data are not available for the 216-Z-1A and 216-Z-18 sites to calculate the source size in the same manner. Thus, the source size for the 216-Z-1A and 216-Z-18 sites was conservatively assumed to be the same as for the 216-Z-9 site (i.e., 90 m by 90 m). As discussed in the Background section, a source width of 90 m cannot be directly entered into SVEET. Rather source width values of 10, 20, 30, and 50 m can be entered and the results can be extrapolated to a groundwater concentration for a source width of 90 m.

5 Software

Version 1.0.0 of the publicly available[1] SVEET software was used to perform the calculation on a personal computer running a Windows® 7 operating system and Excel® version 12 (i.e., Excel 2007) spreadsheet software. The SVEET software has undergone quality assurance review and approval by PNNL as part of the software design and testing.

[1] The SVEET software is available online at http://bioprocess.pnnl.gov/SVEET_Request.htm.

® Windows is a registered trademark of Microsoft Corporation in the United States and/or other countries.

® Excel is a registered trademark of Microsoft Corporation in the United States and/or other countries.

6 Calculation

Twelve cases were calculated in SVEET, four for each of the three waste sites. The four cases for a given waste site varied only in the source width input parameter value (one case each for 10, 20, 30, and 50 m). The SVEET calculations provided a groundwater concentration at the specified compliance well location (i.e., 25 m downgradient from the center of the source area) that was estimated to result from the defined vadose zone source. Figures 1 through 4 show both the inputs and the calculation results for all 12 cases.

	A	B	C	D	E	F
21	SVE Endstate Tool (SVEET)					Version 1.0.0
22	Described in: *Soil Vapor Extraction System Optimization, Transition, and Closure Guidance*					2012-Sep-24
23						
24	**User Input**					
25		Scenario Name:	—	Z-9	Z-9	Z-9
26		Contaminant:	—	CT	CT	CT
27	T	Temperature:	[°C]	16	16	16
30	ω	Avg. Moisture Content:	[wt %]	6.5	6.5	6.5
31	R	Avg. Recharge:	[cm/yr]	0.4	0.4	0.4
32	VZT	Vadose Zone Thickness:	[m]	60	60	60
33	L1	Depth to Top of Source:	[m]	24	24	24
34	z	Source Thickness:	[m]	6	6	6
35	w (= l)	Source Width (= Length):	[m]	10	20	30
36	q	GW Darcy Velocity:	[m/day]	0.00545	0.00545	0.00545
37	d	Distance to Compliance Well:	[m]	25	25	25
38	s	Compl. Well Screen Length:	[m]	10	10	10
39		Source Strength Input Type:	—	Gas Concentration	Gas Concentration	Gas Concentration
40	C_{gs}	Source Gas Concentration:	[ppmv]	24.7	24.7	24.7
41	$\dot{M}_{src}$	Source Mass Discharge:	[g/day]			
42						
43	**Calculated Input**					
46	STR	Source Thickness Ratio*:	[--]	0.100	0.100	0.100
48	SA	Areal Footprint of Source*:	[m²]	100	400	900
50	RSP	Relative Source Position*:	[--]	0.80	0.80	0.80
52	L2	Distance – Source to GW:	[m]	30.00	30.00	30.00
53	H	Henry's Law Constant**:	[--]	0.761	0.761	0.761
61						
62	**Result – Estimated Groundwater Contaminant Concentration at Selected Compliance Well**					
65	C_w	Final Groundwater Conc'n:	[µg/L]	6.2	8.9	11.7

Notice | SVEET | HLC

Figure 1. SVEET Results Part 1

	A	B	C	D	E	F
21	SVE Endstate Tool (SVEET)					Version 1.0.0
22	Described in: *Soil Vapor Extraction System Optimization, Transition, and Closure Guidance*					2012-Sep-24
23						
24	**User Input**					
25		Scenario Name:	—	Z-9	Z-1A	Z-1A
26		Contaminant:	—	CT	CT	CT
27	T	Temperature:	[°C]	16	16	16
30	ω	Avg. Moisture Content:	[wt %]	6.5	6.5	6.5
31	R	Avg. Recharge:	[cm/yr]	0.4	0.4	0.4
32	VZT	Vadose Zone Thickness:	[m]	60	60	60
33	L1	Depth to Top of Source:	[m]	24	29	29
34	z	Source Thickness:	[m]	6	6	6
35	w (= l)	Source Width (= Length):	[m]	50	10	20
36	q	GW Darcy Velocity:	[m/day]	0.00545	0.00545	0.00545
37	d	Distance to Compliance Well:	[m]	25	25	25
38	s	Compl. Well Screen Length:	[m]	10	10	10
39		Source Strength Input Type:	—	Gas Concentration	Gas Concentration	Gas Concentration
40	C_{gs}	Source Gas Concentration:	[ppmv]	24.7	13.9	13.9
41	$\dot{M}_{src}$	Source Mass Discharge:	[g/day]			
42						
43	**Calculated Input**					
46	STR	Source Thickness Ratio*:	[--]	0.100	0.100	0.100
48	SA	Areal Footprint of Source*:	[m²]	2500	100	400
50	RSP	Relative Source Position*:	[--]	0.80	1.16	1.16
52	L2	Distance – Source to GW:	[m]	30.00	25.00	25.00
53	H	Henry's Law Constant**:	[--]	0.761	0.761	0.761
61						
62	**Result – Estimated Groundwater Contaminant Concentration at Selected Compliance Well**					
65	C_w	Final Groundwater Conc'n:	[µg/L]	16.6	4.1	5.8

Notice | SVEET | HLC

Figure 2. SVEET Results Part 2

	A	B	C	D	E	F
21	SVE Endstate Tool (SVEET)					Version 1.0.0
22	Described in: *Soil Vapor Extraction System Optimization, Transition, and Closure Guidance*					2012-Sep-24
23						
24	**User Input**					
25		Scenario Name:	—	Z-1A	Z-1A	Z-18
26		Contaminant:	—	CT	CT	CT
27	T	Temperature:	[°C]	16	16	16
30	ω	Avg. Moisture Content:	[wt %]	6.5	6.5	6.5
31	R	Avg. Recharge:	[cm/yr]	0.4	0.4	0.4
32	VZT	Vadose Zone Thickness:	[m]	60	60	60
33	L1	Depth to Top of Source:	[m]	29	29	29
34	z	Source Thickness:	[m]	6	6	6
35	w (= l)	Source Width (= Length):	[m]	30	50	10
36	q	GW Darcy Velocity:	[m/day]	0.00545	0.00545	0.00545
37	d	Distance to Compliance Well:	[m]	25	25	25
38	s	Compl. Well Screen Length:	[m]	10	10	10
39		Source Strength Input Type:	—	Gas Concentration	Gas Concentration	Gas Concentration
40	C_{gs}	Source Gas Concentration:	[ppmv]	13.9	13.9	9.65
41	$\dot{M}_{src}$	Source Mass Discharge:	[g/day]			
42						
43	**Calculated Input**					
46	STR	Source Thickness Ratio*:	[--]	0.100	0.100	0.100
48	SA	Areal Footprint of Source*:	[m²]	900	2500	100
50	RSP	Relative Source Position*:	[--]	1.16	1.16	1.16
52	L2	Distance – Source to GW:	[m]	25.00	25.00	25.00
53	H	Henry's Law Constant**:	[--]	0.761	0.761	0.761
61						
62	**Result – Estimated Groundwater Contaminant Concentration at Selected Compliance Well**					
65	C_w	Final Groundwater Conc'n:	[µg/L]	7.5	10.3	2.8

Notice | SVEET | HLC

Figure 3. SVEET Results Part 3

	A	B	C	D	E	F
21	SVE Endstate Tool (SVEET)					Version 1.0.0
22	Described in: *Soil Vapor Extraction System Optimization, Transition, and Closure Guidance*					2012-Sep-24
23						
24	**User Input**					
25		Scenario Name:	—	Z-18	Z-18	Z-18
26		Contaminant:	—	CT	CT	CT
27	T	Temperature:	[°C]	16	16	16
30	ω	Avg. Moisture Content:	[wt %]	6.5	6.5	6.5
31	R	Avg. Recharge:	[cm/yr]	0.4	0.4	0.4
32	VZT	Vadose Zone Thickness:	[m]	60	60	60
33	L1	Depth to Top of Source:	[m]	29	29	29
34	z	Source Thickness:	[m]	6	6	6
35	w (= l)	Source Width (= Length):	[m]	20	30	50
36	q	GW Darcy Velocity:	[m/day]	0.00545	0.00545	0.00545
37	d	Distance to Compliance Well:	[m]	25	25	25
38	s	Compl. Well Screen Length:	[m]	10	10	10
39		Source Strength Input Type:	—	Gas Concentration	Gas Concentration	Gas Concentration
40	C_{gs}	Source Gas Concentration:	[ppmv]	9.65	9.65	9.65
41	$\dot{M}_{src}$	Source Mass Discharge:	[g/day]			
42						
43	**Calculated Input**					
46	STR	Source Thickness Ratio*:	[--]	0.100	0.100	0.100
48	SA	Areal Footprint of Source*:	[m²]	400	900	2500
50	RSP	Relative Source Position*:	[--]	1.16	1.16	1.16
52	L2	Distance – Source to GW:	[m]	25.00	25.00	25.00
53	H	Henry's Law Constant**:	[--]	0.761	0.761	0.761
61						
62	**Result – Estimated Groundwater Contaminant Concentration at Selected Compliance Well**					
65	C_w	Final Groundwater Conc'n:	[µg/L]	4.1	5.2	7.2

Notice | SVEET | HLC

Figure 4. SVEET Results Part 4

The groundwater concentration results for the four cases at a waste site were linearly extrapolated to an estimated groundwater concentration at the compliance well location for a 90 m by 90 m source size. Figure 5 shows the linear extrapolation and the resultant groundwater concentrations.

		SVEET GW Conc'n Output (µg/L)				Extrapolated GW Conc'n (µg/L)
Site	**width (m):**	**10**	**20**	**30**	**50**	**90**
216-Z-9		6.2	8.9	11.7	16.6	27
216-Z-1A		4.1	5.8	7.5	10.3	17
216-Z-18		2.8	4.1	5.2	7.2	12

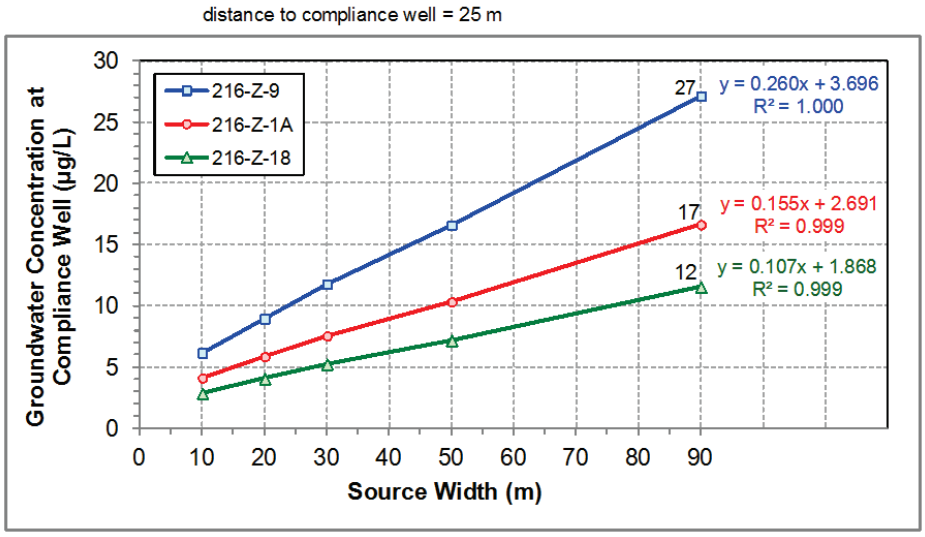

Figure 5. SVEET Results Extrapolated to a Source Width of 90 m

7 Results/Conclusions

Final results for the 216-Z-9, 216-Z-1A, and 216-Z-18 waste sites are shown in Table 2.

Table 2. SVEET Analysis Results for the 216-Z-9, 216-Z-1A, and 216-Z-18 Waste Sites (90 m Source Width, 25 m from Source Center)

Estimated Groundwater Concentration (µg/L) for the Three Waste Sites		
216-Z-9	**216-Z-1A**	**216-Z-18**
27	17	12

8 References

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