Supplemental Site Investigation Report – Soil Gas and Temporary Monitoring Well Sampling and Analysis

318 State Avenue NE Property
Olympia, Washington

for
City of Olympia

July 3, 2017

GeoEngineers
Earth Science + Technology

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Supplemental Site Investigation Report Soil Gas and Temporary Monitoring Well Sampling and Analysis

318 State Avenue NE Property Olympia, Washington

File No. 0415-049-06

July 3, 2017

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INTRODUCTION

This report presents the results of soil gas sampling and groundwater sampling from a temporary monitoring well at the City of Olympia (City) 318 State Avenue NE property in Olympia, Washington (Property) (Figure 1).The sampling was performed to support the goal of achieving a No Further Action (NFA) determination for the southeastern portion of the Property under the Washington State Department of Ecology (Ecology) Voluntary Cleanup Program (VCP). The soil gas sampling was performed to evaluate the potential for vapor intrusion into indoor air and the groundwater sampling was performed to evaluate whether chlorinated solvents are present at concentrations greater than cleanup levels in the area of a proposed redevelopment on the southeast corner of the Property (Figure 2).

Soil gas samples were collected on April 21, 2015 from four locations in the area of the proposed development of a housing complex. In addition, one temporary monitoring well was installed on the northern edge of the proposed redevelopment area. Soil gas samples were submitted for analysis to Eurofin Labs in Folsom, California and the water sample was submitted for analysis to Test America Laboratory in Fife, Washington. Soil gas and groundwater samples were collected in accordance with the Soil Vapor Sampling Work Plan (GeoEngineers 2015) provided in Appendix A.

BACKGROUND

Remedial actions were performed in September and October 2009 to remove soil and fill containing contaminants including chlorinated solvents at concentrations greater than the Model Toxics Control Act (MTCA) cleanup levels (CULs). Soil and fill with contaminant concentrations greater than CULs were excavated and disposed of offsite as part of cleanup activities. The results of the soil remedial action are presented in the Remedial Action Construction Report prepared for the Property (GeoEngineers 2010).

Groundwater compliance monitoring was initiated following completion of soil remedial actions to monitor the concentrations and natural attenuation of residual chlorinated solvents in groundwater at the Property. Residual chlorinated solvents include tetrachloroethene (PCE), trichloroethene (TCE), 1,1-dichloroethene (DCE), cis and trans isomers of 1,2-dichloroethene (cis-1,2-DCE and trans-1,2-DCE) and vinyl chloride (VC). The results of groundwater compliance monitoring indicate that natural attenuation of chlorinated solvents and associated degradation products continue to occur at the Property. The detected concentrations of PCE, TCE and associated degradation products cis-1,2-DCE and trans-1,2-DCE in groundwater samples collected from the Property remain below the CULs for these compounds. Detected concentrations of VC in groundwater samples collected from wells MW-03, MW-16, and MW-18 were greater than the MTCA Method A CUL during the August 2014 groundwater monitoring event (Figure 2) (GeoEngineers 2014).

The southeast portion of the Property is to be redeveloped (Figure 2) by constructing a residential housing complex. The soil gas sampling, analysis and evaluation was performed to assess the presence and, if present, the concentration of residual chlorinated solvents in soil gas in the area of the proposed redevelopment. The results of the soil gas sampling and analysis were compared to soil gas screening level criteria, which is protective of indoor air, provided in Ecology's Draft Guidance for Evaluating Soil Vapor Intrusion in Washington State (Ecology 2009) as updated in April 2015 to revise the soil gas screening levels provided in Appendix B of the guidance document (Ecology 2015). The groundwater sampling from the temporary monitoring well, groundwater analysis and evaluation was performed to assess the concentrations of residual chlorinated solvents in the area of the proposed redevelopment. The results of the groundwater sampling and analysis were compared to MTCA groundwater cleanup levels protective of the highest beneficial use for groundwater. Ecology does not consider groundwater at the property as a likely potable water source (Ecology 2015). Therefore, the highest beneficial use for groundwater is as marine surface water. The results were also compared to the MTCA Method B groundwater screening level protective of indoor air provided in Ecology's Draft Guidance for Evaluating Soil Vapor Intrusion in Washington State (Ecology 2009) as updated in April 2015 (Ecology 2015).

FIELD ACTIVITIES

Soil gas and groundwater sample locations were identified within the proposed redevelopment area on the northern and western boundaries adjacent to where chlorinated solvents have previously been detected in groundwater (i.e., MW-03, MW-16 and MW-18) as well as in the center of the proposed redevelopment area. Soil gas and groundwater sample locations are shown on Figure 2. Field activities performed during the April 2015 supplemental site investigation are discussed in the following sections.

Soil Gas Sampling

Direct-push tooling was advanced to 3 feet below ground surface (bgs) at each of the four soil gas sample locations, which was approximately 1 foot above the groundwater level as measured in the temporary well (TW-1) and monitoring well MW-17. The depth to groundwater was also measured to be approximately 4 feet bgs in MW-17 on the day of sampling.

Leak detection procedures were implemented at each sample location, including placing a sampling shroud containing helium over each sampling location. At sampling probe locations SG-1 and SG-2, a 2.5-foot radius of bentonite was also applied across the surface of the gravel backfill in an effort to reduce the potential for breakthrough between the surface and the sampling probe prior to being covered by a shroud. Soil gas sample location SG-2 was advanced at three separate locations in the vicinity of the proposed sample location due to the concentrations of helium measured in the sample train prior to or following sample collection during the first two attempts. The third and final sample (SG-2-ALT-2) appeared to be acceptable based on field measurements for leak detection.

Each soil gas sample was collected using a laboratory-provided individually certified 1-liter summa canister set to a flow rate of less than or equal to approximately 200 milliliters per minute (ml/m). The canister was filled with soil gas for approximately five minutes or until the remaining canister vacuum was approximately 5 inches of mercury. Soil gas samples were submitted for analysis of chlorinated solvents including PCE, TCE, 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE, and VC as well as helium (leak detection tracer gas) and methane by United Stated Environmental Protection Agency (EPA) Method TO-15LL and ASTM International (ASTM) D 1946, respectively. Soil gas sampling procedures, including tracer gas testing, are presented in the Soil Vapor Sampling Work Plan (GeoEngineers 2015) (Appendix A).

The barometric pressure measured on the three days prior to sampling was reviewed to evaluate the potential effect on the soil gas results. The barometric pressure on the three days prior to soil gas sampling appeared to be on a downward trend with a slight increase in pressure on the day of sampling. A downward trend in vapor pressure may enhance vapor intrusion from the subsurface. The daily barometric pressure readings are as follows (National Oceanic and Atmosphere Administration [NOAA] 2015):

Date	Barometric Pressure (Inches of Mercury)
April 18, 2015	30.08
April 19, 2015	29.88
April 20, 2015	29.68
April 21, 2015	29.78

Temporary Well Groundwater Sampling

One temporary monitoring well, TW-1, was installed adjacent to the north boundary and within the area of the proposed redevelopment (Figure 2). The temporary well was installed by advancing a 1.5-inch-diameter soil core with a solid point at the tip, using a direct-push drill rig, to 12 feet bgs. Since a solid point was used no soil cuttings were generated. A 10-foot section of ¾-inch-diameter polyvinyl chloride (PVC) slotted well casing with 5 feet of blank PVC (i.e., not slotted) to extend the well above the ground surface was inserted into the core. The core was then removed leaving the temporary well casing and blank in the boring.

A depth to groundwater measurement was taken and the depth to groundwater was measured to be 4 feet bgs. Then groundwater was purged from the well until the groundwater was relatively clear. Approximately 1 gallon of groundwater was purged from the well using a peristaltic pump. The temporary well was left in place for approximately six hours, while soil gas sampling was performed, before groundwater sampling was performed.

The groundwater sample was collected using low-flow/low-turbidity sampling techniques to minimize the suspension of particulates in the sample. The groundwater sample was obtained from the temporary well using new vinyl tubing and a peristaltic pump. Groundwater was pumped at approximately 0.5 liters per minute from the approximate mid-point of the saturated screened interval to collect the sample.

Water quality parameters were measured during purging using an YSI 556 MPS water quality meter with a flow-through cell. The measured water quality parameters included electrical conductivity, dissolved oxygen (DO), potential hydrogen (pH), reduction potential (ORP), and temperature. Turbidity measurements were collected using a Hach 2100Q turbidity meter. The groundwater sample was collected once the water quality parameters generally varied by less than 10 percent (pH, turbidity, and DO), 3 percent (conductivity), and/or 10 units (ORP) on three consecutive measurements. The purge water was stored in labeled 30-gallon drums for future permitted off-site disposal.

Following well purging, the flow-through cell was disconnected and the groundwater sample was collected in appropriate laboratory prepared and provided containers. The sample was protected and placed into a cooler with ice and picked up by a courier for delivery to TestAmerica Laboratory in Fife, Washington, for analysis following appropriate chain-of-custody procedures. The groundwater sample was submitted for analyses of chlorinated solvents including PCE, TCE, 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE, and VC by EPA Method 8260.

ANALYTICAL RESULTS

The results from the soil gas and groundwater sample collection and analysis performed in April 2015 are summarized in the following sections. Table 1 presents the results of soil gas sample analyses. Table 2 summarizes the results for the chemical analysis of the groundwater sample collected from the temporary well. Appendix B contains the laboratory analytical reports and Appendix C contains the Data Quality Assessment Reports presenting the results of data validation of the chemical analyses.

Soil Gas

Chlorinated Solvents

Chlorinated solvents and degradation products were detected in the soil gas samples collected for analysis (SG-1, SG-2-ALT-2, SG-3, SG-4 and DUP 1) (Table 1). PCE was detected in the samples collected from SG-2 and SG-4 at concentrations less than the screening level. TCE was detected in the samples collected from all four sample locations. The concentrations of TCE detected in samples SG-2-ALT-2 and SG-4 were greater than the MTCA Method B soil gas screening level. VC was detected in samples collected from SG-1 and SG-3 at concentrations less that the screening level. 1,1-DCE and trans 1,2-DCE were not detected in any of the samples. Cis 1,2-DCE was detected in samples collected from SG-Alt-2 and SG-4. A screening level is not available for Cis 1,2-DCE.

Based on the results of the soil gas sample collection and analysis, TCE concentrations in soil vapor in the proposed redevelopment area are greater than the MTCA Method B screening level. Sample SG-2-ALT-2 collected from the approximate center of the proposed redevelopment area and SG-4 located on the northwest portion of the proposed redevelopment area exceeded the screening level. Based on leak detection results (i.e., helium concentrations) (see in both samples SG-2-ALT-2 and SG-3 are likely slightly diluted due to breakthrough (as discussed in the helium section above). Based on the results, the redevelopment of the property will need to include engineered controls to mitigate the potential for vapor intrusion in structures constructed at the Site.

Helium (leak detection gas) was detected in the soil gas samples collected from SG-1, SG-2-ALT-2, SG-3 and DUP 1 ranging from 7 to 16 percent by volume. Helium was not detected in SG-4. Methane was detected in samples collected from all sample locations at concentrations ranging from 0.00095 to 0.016 percent by volume.

Groundwater Sampling

Only VC was detected in the groundwater sample collected from temporary well TW-1 (Table 2). The detected concentration of VC was greater than the MTCA groundwater cleanup level for protection of the highest beneficial use of groundwater. The highest beneficial use for groundwater is as marine surface water. The detected concentration of VC was also greater than groundwater cleanup level based on protection of indoor air (Table 2). However, as described in the previous section, the results from analysis of soil gas samples collected from the southeast portion of the property were less than soil gas screening levels that are protective of indoor air, indicating that the VC in groundwater may not be causing soil gas concentrations that would exceed criteria for indoor air. PCE, TCE, 1,1 DCE and cis- and trans-1,2-DCE were not detected above laboratory detection limits in groundwater which were less than the cleanup levels.

DISCUSSION

Soil Gas

Helium

Helium is used as a tracer gas to evaluate the potential for leaks in the sample train and/or soil gas probe entry point. The goal is for the helium concentration is to be less than 5 percent by volume (%/vol.) in the sample. Sample SG-4 did not have helium detected in the sample above the laboratory detection limit (0.12%/vol). Sample SG-2-ALT-2 had 7%/vol which was slightly above the target of 5%/vol. Sample SG-1, the duplicate sample collected at SG-1 (Dup 1) and SG-3 had helium concentrations of 13 and 16%/vol indicating that there likely was some breakthrough between the sample point in the ground (i.e., approximately 3 feet bgs) and surface which may have caused the soil gas sample to be partially diluted by air. Sampling locations SG-1 through SG-3 were within the previous soil remedial action area that was backfilled with granular fill that is more permeable than the soil at SG-4. The increase permeability likely increased breakthrough at these locations.

Chlorinated Solvents

Based on the results of the soil gas sample collection and analysis, TCE concentrations in soil vapor in the proposed redevelopment area are greater than the MTCA Method B screening level (Table 1). Sample SG-2-ALT-2 collected from the approximate center of the proposed redevelopment area and SG-4 located on the northwest portion of the proposed redevelopment area exceeded the screening level. Based on leak detection results (i.e., helium concentrations) in samples collected from SG 1 and SG-3, and to a lesser extent SG-2-ALT-2, are likely slightly diluted due to breakthrough (as discussed in the helium section above). Based on the results, redevelopment of the property will need to include an evaluation of possible mitigation (i.e., engineered controls) for the potential for vapor intrusion in structures constructed at the Property.

Methane

The analysis for methane was added based on field screening results which indicated methane was present in soil gas. Detected methane concentrations in soil gas at the property were low (Table 1).

Groundwater

Chlorinated Solvents

VC was the only chlorinated compound detected in the groundwater sample collected from temporary monitoring well TW-1. VC is the last chlorinated compound in the degradation of chlorinated solvents including PCE and TCE as well as DCE which is an initial degradation compound. Because only VC was detected, the results indicate that the VC at TW-1 was the result of groundwater migration from areas with residual concentrations of PCE, TCE and DCE such as in the vicinity of monitoring well MW-03.

REFERENCES

GeoEngineers, 2010, “Remedial Action Construction Report, 318 State Avenue NE, Olympia, Washington,” January 5, 2010.

GeoEngineers, 2014, “Groundwater Compliance Monitoring Data Summary Report – August 2014, 318 State Avenue NE Property, Olympia, Washington,” October 17, 2014.

GeoEngineers, 2015, “Draft Soil Vapor Sampling Work Plan, 318 State Avenue NE, Olympia, Washington,” April 1, 2015.

National Oceanic and Atmospheric Administration, 2015, http://www.ncdc.noaa.gov

Washington State Department of Ecology, 2009, “Draft Guidance for Evaluating of Soil Vapor Intrusion in Washington State,” October 2009.

Washington State Department of Ecology, March 27, 2015, Email from Eugene Radcliff to Iain H. Wingard, City of Olympia RI.

Washington State Department of Ecology, 2015, “Revised Table B-1 from Appendix B of the Draft Guidance for Evaluating of Soil Vapor Intrusion in Washington State,” http://www.ecy.wa.gov/programs/tcp/policies/VaporIntrusion/2015-changes.html, April 2015.

LIMITATIONS

This Groundwater Monitoring Report has been prepared for use by the City of Olympia. GeoEngineers has performed these services in general accordance with the scope and limitations of our proposal.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with the generally accepted environmental science practices for groundwater monitoring in this area at the time this report was prepared. No warranty or other conditions, express or implied, should be understood.

TABLE 1

SUMMARY OF SOIL GAS SAMPLE RESULTS

318 STATE AVENUE NE
OLYMPIA, WASHINGTON

			Volatile Organic Compounds							
		Analyte	**Tetrachloroethene (PCE)**	**Trichloroethene (TCE)**	**1,1-Dichloroethene (1,1-DCE)**	**Cis-1,2-Dichloroethene (cis 1,2-DCE)**	**Trans-1,2-Dichloroethene (trans 1,2-DCE)**	**Vinyl Chloride (VC)**	**Methane[2]**	**Helium[3]**
		Unit	**(µg/m^3)**	**(µg/m^3)**	**(µg/m^3)**	**(µg/m^3)**	**(µg/m^3)**	**(µg/m^3)**	**(%)**	**(%)**
		MTCA Method B Screening Level[1]	**321**	**12.3**	**3,050**	**NE**	**NE**	**9.33**	**NA**	**NA**
Location	**Sample ID**	**Sample Date**								
SG-1	**SG-1**	**4/21/15**	1.6 U	1.6 U	0.94 U	0.94 U	0.94 U	1.9	0.0033	16
	DUP 1	**4/21/15**	1.6 U	1.5	0.94 U	0.94 U	0.94 U	2.1	0.0038	13
SG-2-ALT-2	**SG-2-ALT-2**	**4/21/15**	3.3	220	0.90 U	1.2	0.90 U	0.58 U	0.0082	7
SG-3	**SG-3**	**4/21/15**	1.5 U	10	0.87 U	0.87 U	0.87 U	1.1	0.016	13
SG-4	**SG-4**	**4/21/15**	30	2,500	4.6 U	13	4.6 U	3.0 U	0.00095	0.12 U

Notes:

[1] MTCA Method B shallow soil (sub-slab) gas screening levels. The shallow soil gas screening levels are from updated Table B-1 in Appendix B of the Draft Guidance for Evaluating Soil Vapor Intrusion in Washington State (Ecology, 2009).

[2] Methane was analyzed based on field instrument reading, that indicated the presence of methane in the soil gas.

[3] Helium is used as a leak detection tracer gas. In general, the target is to have less than 5% helium.

MTCA = Model Toxics Control Act

µg/m^3 = microgram per cubic meter

U = The analyte was not detected at a concentration greater than the identified reporting limit

J = The analyte concentration is estimated

Bold indicates analyte was detected

Gray shading indicates concentration is greater than screening level

NA = Not Applicable

NE = Not Established

TABLE 2

SUMMARY OF GROUNDWATER SAMPLE RESULTS[1]

318 STATE AVENUE NE
OLYMPIA, WASHINGTON

			Volatile Organic Compounds					
		Analyte	**Tetrachloroethene (PCE)**	**Trichloroethene (TCE)**	**1,1-Dichloroethene (1,1-DCE)**	**Cis-1,2-Dichloroethene (cis 1,2-DCE)**	**Trans-1,2-Dichloroethene (trans 1,2-DCE)**	**Vinyl Chloride (VC)**
		Unit	**(µg/l)**	**(µg/l)**	**(µg/l)**	**(µg/l)**	**(µg/l)**	**(µg/l)**
		MTCA Groundwater Cleanup Levels[2]	**8.85**	**7**	**3.2**	**NE**	**4,000**	**1.6**
		Groundwater Screening Level for Soil Vapor Intrusion[3]	22.9	1.55	130.0	NE	NE	0.347
Location	**Sample ID**	**Sample Date**						
TW1	TW1-042115	04/21/15	0.5 U	0.2 U	0.1 U	0.2 U	0.2 U	**2.6**

Notes:

[1] The parameters presented are the groundwater compliance monitoring parameters specified in the Groundwater Compliance Monitoring Plan (GeoEngineers, 2010).

[2] MTCA groundwater cleanup levels based on the highest beneficial use of groundwater as marine surface water. The cleanup levels provided are the lowest of the available marine surface water criteria including MTCA Method B surface water (Chapter 173-340 WAC). Water Quality Standards for Surface Waters of the State of Washington (Chapter 173-201A WAC), National Recommended Water Quality Criteria (Clean Water Act Section 304) and National Toxics Rule (40 CFR 131).

[3] Groundwater Screening Level based on Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation on Remedial Action (Ecology, 2009) as updated in 2015 (Ecology, 2015) to revise screening levels in Appendix B.

MTCA = Model Toxics Control Act

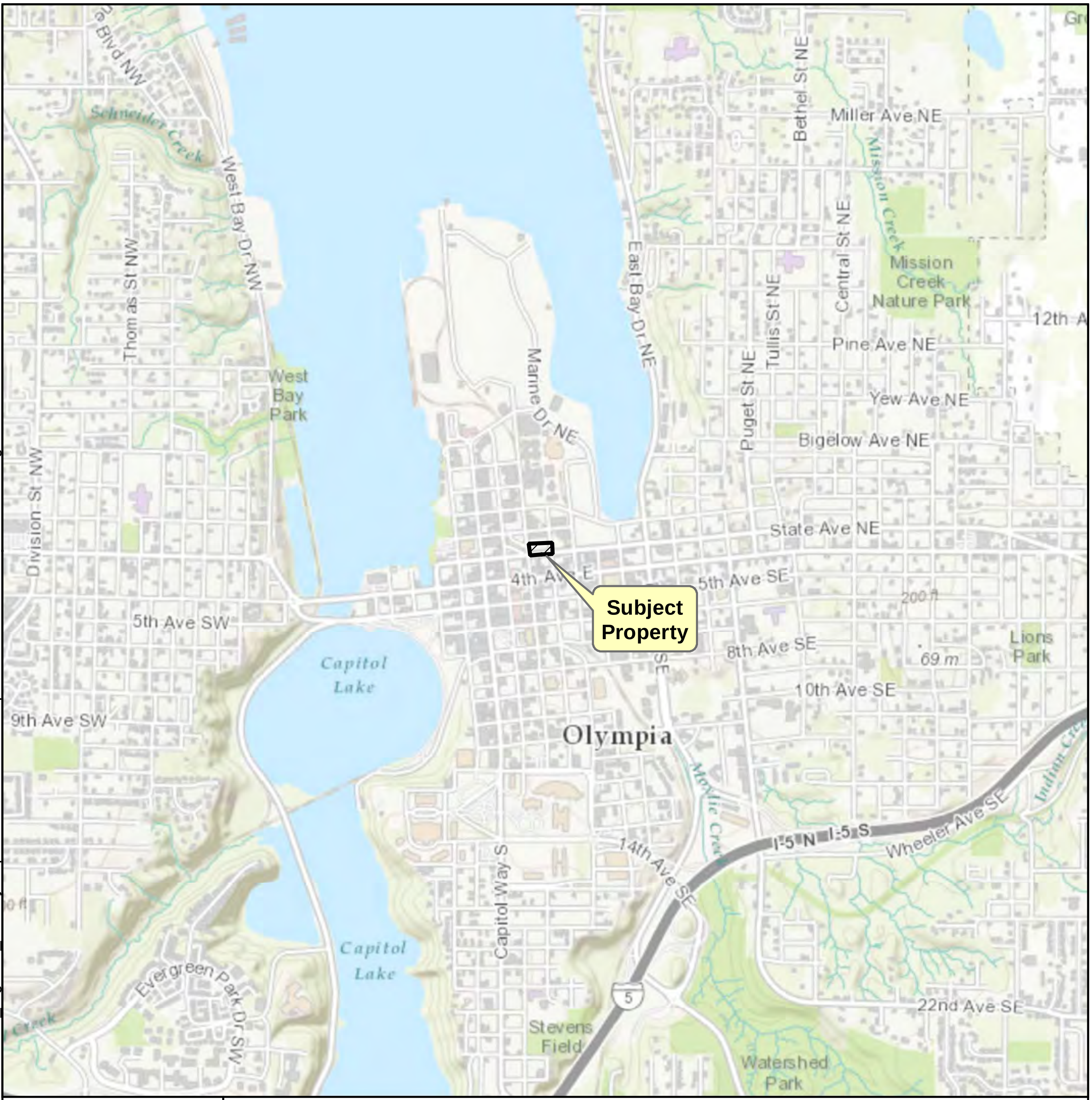
NE = Not Established

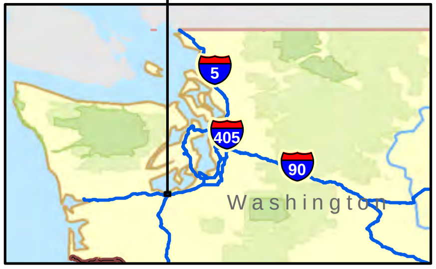
µg/l = microgram per liter

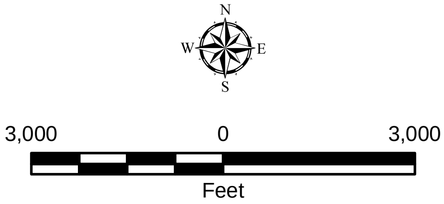
U = The analyte was not detected at a concentration greater than the identified reporting limit

Bold indicates analyte was detected

Gray shading indicates concentration is greater than the cleanup level







Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. It is unlawful to copy or reproduce all or any part thereof, whether for personal use or resale, without permission.

Data Sources: 2008 Shaded Relief from ESRI, 2008 Topographic Maps from National Geographic Society
Projection: NAD_1983_StatePlane_Washington_North_FIPS_4601_Feet
Datum: D_North_American_1983

Vicinity Map

318 State Avenue NE
Olympia, Washington

GeoEngineers

Figure 1

Office: TAC Path: \\tac\projects\0\0415049\GIS\MXDs\041504903_Figure1_VicinityMap.mxd Map Revised: 08 October 2014 cgonzales

Map Revised: 22 May 2015 ccabrera

Path: \\tac\projects\0\0415049\GIS\MXDs\041504906_SoilGasExplorations.mxd

Office: TAC

Well	Event	Result
MW-3		
Vinyl Chloride	August 2014	0.25 µg/L
MW-16		
Vinyl Chloride	August 2014	0.52 µg/L
MW-18		
Vinyl Chloride	August 2014	2.7 µg/L

Notes:
1. MTCA = Model Toxics Control Act, ug/L = micrograms per liter.
2. The locations of all features shown are approximate.
3. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Sources: Approximate Property Boundary from Thurston County parcels (revised by GeoEngineers). Aerial photograph 2013 from ESRI. Data Frame Rotated 356 degrees.

Projection: NAD_1983_StatePlane_Washington_South_FIPS_4602_Feet
Datum: D_North_American_1983

Soil Gas and Temporary Groundwater Well Locations

318 State Avenue NE
Olympia, Washington

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Figure 2

APPENDIX A

Soil Gas Sampling and Analysis Plan

Soil Vapor Sampling Work Plan

318 State Avenue NE Property
Olympia, Washington

for
City of Olympia

April 1, 2015

GeoEngineers

1101 South Fawcett Avenue, Suite 200
Tacoma, Washington 98402
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Soil Vapor Sampling Work Plan

318 State Avenue NE Property
Olympia, Washington

File No. 0415-049-06

April 1, 2015

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APPENDICES

1.0 INTRODUCTION

This Work Plan (WP) has been prepared to describe the procedures for performing soil gas sampling, analysis and evaluation to support achieving a No Further Action (NFA) designation under the Washington State Department of Ecology (Ecology) Voluntary Cleanup Program (VCP) for the southeastern portion of the City of Olympia's (City's) 318 State Avenue property (Property). The location of the Property is shown in Figure 1 and Property features are shown in Figure 2. The scope of investigation activities presented in this WP are based on discussions with the Washington State Department of Ecology (Ecology) in a meeting held on March 12, 2015.

Soil gas sampling, analysis and evaluation are being performed to assess the migration of residual chlorinated solvents from groundwater at the Property. Groundwater compliance monitoring performed since the completion of remedial activities to remove contaminated soil at the Property indicates that residual chlorinated solvents are present in groundwater on the northern portion of the Property. A proposal has been advanced to redevelop the southeast portion of the Property to construct a new mixed-use (i.e., commercial and residential) building. The purpose of the soil gas sampling, analysis and evaluation described in this WP is to assess the presence and, if present, the concentration of residual chlorinated solvents in soil gas in the area of the proposed redevelopment. The results of the soil gas sampling and analysis will be compared to the criteria provided in Ecology's Draft Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action (Ecology, 2009/Appendix A).

The following sections of this Work Plan present the protocols to be used to perform soil gas sampling and analysis, quality assurance/quality control (QA/QC) and evaluation of the results.

2.0 BACKGROUND SUMMARY

Remedial actions were performed in September and October 2009 to remove soil and fill containing contaminants including chlorinated solvents at concentrations greater than the Model Toxics Control Act (MTCA) cleanup levels (CULs). Soil and fill with contaminant concentrations greater than CULs were excavated and disposed of offsite as part of cleanup activities. The results of the soil remedial action are presented in the Remedial Action Construction Report prepared for the Property (GeoEngineers, 2010).

Groundwater compliance monitoring was initiated following completion of soil remedial actions to monitor the concentrations and natural attenuation of residual chlorinated solvents in groundwater at the Property. Residual chlorinated solvents include tetrachloroethene (PCE), trichloroethene (TCE), 1,1-dichloroethene (DCE), cis and trans isomers of 1,2-dichloroethene (cis-1,2-DCE and trans-1,2-DCE) and vinyl chloride (VC). The results of groundwater compliance monitoring indicate that natural attenuation of chlorinated solvents and associated degradation products continue to occur at the Property. The detected concentrations of PCE, TCE and associated degradation products cis-1,2-DCE and trans-1,2-DCE in groundwater samples collected from the Property remain below the CULs for these compounds. Detected concentrations of vinyl chloride (VC) in groundwater samples collected from wells MW-03, MW-16, and MW-18 were greater than the MTCA Method A CUL during the August 2014 groundwater monitoring event (Figure 2) (GeoEngineers, 2014). Groundwater monitoring to evaluate the natural attenuation of chlorinated organic solvents is performed on a semi-annual basis.

A proposal has been advanced to re-develop the southeast portion of the Property to construct a new mixed-use (i.e., commercial and residential) building (Figure 2). The soil gas sampling, analysis and evaluation is being performed to assess the presence and, if present, the concentration of residual chlorinated solvents in soil gas in the area of the proposed redevelopment. The results of the soil gas sampling and analysis will be compared to the soil gas screening level criteria, which is protective of indoor air, provided in Ecology's Draft Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action (Ecology, 2009/Appendix A) and Ecology's updated Cleanup Levels and Risk Calculations (CLARC) database.

3.0 SOIL GAS INVESTIGATION TASKS

The soil vapor sampling activities are organized into four tasks that include the following:

- Pre-field activities;
- Soil gas sampling;
- Laboratory analysis; and
- Data evaluation and reporting.

The following sections describe the activities to be performed as part of each task.

3.1. Pre-Field Investigation Activities

Several activities are necessary in order to prepare for soil gas sampling. The pre-field activities include the following:

- Coordination and scheduling of field activities with subcontractors (private utility locator, drilling contractor and analytical laboratory);
- Prepare a Health and Safety Plan to be used by GeoEngineers' field employees.
- Conducting a site visit prior to drilling to collect soil gas samples to mark the proposed exploration locations;
- Completing a "One-Call" utility locate;
- Meeting with a private utility locate contractor prior to drilling to clear each proposed exploration location; and
- Recording barometric pressure for up to three days prior to sampling and the day of sampling.

3.2. Soil Gas Sampling

Soil gas sampling will be performed to assess the presence of chlorinated solvents including PCE, TCE, 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE, and VC in shallow, vadose zone soil. Soil gas samples will be collected from four locations from 1-inch-diameter cores installed using direct-push drilling equipment. The cores installed for soil gas sampling will be advanced to within approximately 1.0 foot of the current groundwater level at the Property. Soil gas samples will be collected from each location for analysis of chlorinated solvents. Soil gas sampling setup and sample collection will be completed in general accordance with Ecology's Draft Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and

Remedial Action, Appendix C.2 (Ecology, 2009/Appendix A). It should be noted that the soil gas samples will be collected at depths shallower than recommended in Ecology's guidance (i.e., <5 feet below ground surface [bgs]). Precautionary measures, as identified below, will be taken to best collect a representative soil gas sample given the Property conditions at each sample location.

Sample locations were identified within the proposed redevelopment area on the northern and western boundaries adjacent to where chlorinated solvents have been detected in groundwater (i.e., MW-03, MW-16 and MW-18) as well as in the center of the proposed redevelopment area. The proposed sampling locations are shown on Figure 2. Soil gas samples will be collected using the following protocol:

- Direct-push tooling will be advanced to approximately one foot above the groundwater level which is estimated to be approximately two to three feet below ground surface (bgs) at four locations. The depth of sampling was determined based on the most recent compliance groundwater monitoring results which indicate the groundwater may be shallow as approximately three feet bgs. A separate, initial core will be advanced at the beginning of soil gas sampling to identify the depth to groundwater at the Property at the time of sampling.
- The Geoprobe Post-Run Tubing (PRT) System sampling protocol presented in Appendix B will be used to collect the soil gas sample. New fluoropolymer (Teflon®) tubing will be attached to a Geoprobe® PRT adaptor. The PRT adaptor will be lowered through the Geoprobe® tooling and engaged to an Expendable Point Adaptor.
- The tubing (aboveground) will be connected to a sampling manifold and “summa” type (summa) canister. The summa canister sampling protocol presented in Appendix C will be used to collect the soil gas sample.
- Hydrated bentonite will be placed around the soil-gas probe where it enters the ground surface and in an approximately a 5-foot diameter around the soil gas sampling probe. The 5-foot diameter of hydrated bentonite will be placed in an effort to prevent ambient air interaction and to obtain the most representative soil gas sample at the shallow sample depth.
- Each probe will remain in place for a minimum of 20 to 30 minutes prior to sampling (per Oregon Guidance for Assessing and Remediating Vapor Intrusion in Buildings, 2010) to allow for soil vapor to equilibrate.
- The sampling manifold will be vacuum tested by briefly introducing a vacuum to the aboveground portion of the sampling train and checking for loss of vacuum. If vacuum loss is observed, connections and fittings in the sample train will be checked and adjusted.
- A plastic shroud will be placed over the sample container and soil-gas probe where it enters the ground surface.
- The shroud will be charged with helium gas and the helium concentration inside of the shroud will be measured using a hand-held helium monitor.
- The sampling train (above and below ground components) will be purged using a landfill gas meter, peristaltic pump, evacuated summa canister or disposable syringe. After purging three sampling train volumes, the helium concentration within the sampling train will be measured and recorded. If helium is measured at a concentration greater than 10 percent of the shroud concentration the fittings will be tightened, the bentonite seal will be checked and the previous purging and measurement tests will be repeated.

- The soil-gas sample will be collected using a laboratory provided individually certified 1-liter summa canister set to a flow rate of less than or equal to approximately 200 milliliters per minute. The 1-liter canister was selected to collect a soil gas sample as quickly as possible and to achieve method reporting limits that would meet Ecology's soil gas screening level criteria. The canister will be filled with soil gas for approximately five minutes or until the remaining canister vacuum is approximately five inches of mercury. The initial and final canister vacuum will be recorded.
- Following the sample collection, the sample train will be re-evaluated for the presence of helium.
- Soil-gas samples will be submitted to the laboratory for analysis.
- Following collection of each soil-gas sample, the tooling will be removed from the ground and each boring will be backfilled with bentonite and hydrated in accordance with the state's guidance for decommissioning borings (Washington Administrative Code [WAC] 173-160-381).

3.3. Laboratory Analysis

GeoEngineers will utilize the services of Air Toxics (Eurofins) to complete the soil-gas analyses on the samples from the Property. The following analytical methods will be used to meet the soil gas screening levels and to provide the appropriate analytical QA/QC:

- PCE, TCE, 1,1- DCE, cis-1,2-DCE, trans-1,2-DCE, and VC in soil gas using a modified Environmental Protection Agency (EPA) Method TO-15 low level; and
- Helium in soil gas using method ASTM 1946.

The soil gas reporting limits to be achieved for this investigation are presented in Appendix D.

Upon receipt of the final analytical data, a data quality review will be completed for all the sample results. The data will be tabulated to facilitate screening and evaluation utilizing Ecology's Draft Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action (Ecology, 2009) and Ecology's updated Cleanup Levels and Risk Calculations (CLARC) database. The soil gas screening levels are presented in Appendix D.

4.0 QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

The following sections describe the field and laboratory QA/QC procedures to be implemented during the soil gas sampling and analysis activities.

4.1. Location Control

GeoEngineers will record the location of each exploration with a handheld global positioning system (GPS) meter or each location will be measured to physical features at the property if GPS measurements cannot be obtained.

4.2. Sample Custody

4.2.1. Sample Containers and Storage

All samples obtained for chemical analysis will be collected in laboratory-prepared individually SIM certified summa canisters. The summa canisters will be filled until the remaining vacuum is approximately five inches of mercury. Samples will be stored prior to and following sampling in the laboratory provided shipping containers.

4.2.2. Field Custody Procedures

Possession of samples will be documented using chain-of-custody procedures. Proper sample handling procedures, including security and integrity of the samples, will be the responsibility of the individual/company identified on the chain-of-custody. The chain-of-custody form will be signed and dated in the appropriate places by parties involved with a transfer of custody of the samples.

4.2.3. Laboratory Custody Procedures

Upon receipt of the samples at the laboratory, the custody seals will be broken, the chain-of-custody form will be signed by the laboratory personnel, and the conditions of the samples will be recorded on a sample receipt form. The original chain-of-custody form will remain with the laboratory and copies will be returned to the relinquishing party.

4.3. Quality Assurance and Quality Control

4.3.1. Field Duplicates

One field duplicate will be collected during the soil vapor sampling event. The field duplicate will be one of two samples collected concurrently (utilizing a laboratory-provided sampling 'T') from one sample location to assess data variability. The field duplicate will be analyzed by the same analytical methods used for primary samples. Relative percent differences (RPDs) for the field duplicate will be calculated to assess the data precision and accuracy and potential variability caused by sample handling.

4.3.2. Laboratory Quality Assurance and Quality Control

The laboratory maintains an internal quality assurance program as documented in its laboratory quality assurance manual. The laboratory uses a combination of laboratory blanks, surrogate recoveries, and duplicates to evaluate the analytical data quality. The laboratory also uses data quality goals for individual chemicals or groups of chemicals based on the long-term performance of the test methods. The laboratory analytical report will provide the results for QA/QC analyses so that a Level II data quality review can be performed. The results of the Level II data quality review will be provided in the report presenting the results of soil gas analyses.

5.0 REPORTING

GeoEngineers will prepare a soil vapor sampling report following completion of field activities, receipt of the laboratory analytical data and data quality review. The soil vapor sampling report will include a summary of the field activities, analytical data and a comparison of the chemical analytical data to MTCA Method B soil gas screening levels in Ecology's Draft Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action (Appendix A/Ecology, 2009) and Ecology's updated Cleanup Levels and

Risk Calculations (CLARC) database. If needed, recommendations will be provided for additional assessment and/or soil gas intrusion mitigation options to be implemented during Property redevelopment activities.

6.0 LIMITATIONS

We have prepared this Work Plan for use by the City of Olympia. This Work Plan is not intended for use by others and the information contained herein is not applicable to other sites.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted environmental science practices in this area at the time this work plan was prepared. No warranty or other conditions express or implied should be understood.

Any electronic form, facsimile or hard copy of the original document (email, text, table, and/or figure), if provided, and any attachments are only a copy of the original document. The original document is stored by GeoEngineers, Inc.

7.0 REFERENCES

Ecology, 2009, Draft Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action, Publication No. 09-09-047. October 2009.

GeoEngineers, 2010, Remedial Action Construction Report, 318 State Avenue NE, Olympia, Washington, January 5, 2010.

GeoEngineers, 2014, Draft Groundwater Compliance Monitoring Data Summary Report, August 2014, 318 State Avenue NE, Olympia, Washington, April 16, 2015.

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. It is unlawful to copy or reproduce all or any part thereof, whether for personal use or resale, without permission.

Data Sources: 2008 Shaded Relief from ESRI, 2008 Topographic Maps from National Geographic Society
Projection: NAD_1983_StatePlane_Washington_North_FIPS_4601_Feet
Datum: D_North_American_1983

Office: TAC Path: \\tac\projects\0\0415049\GIS\MXDs\041504903_Figure1_VicinityMap.mxd Map Revised: 08 October 2014 cgonzales

Vicinity Map

318 State Avenue NE
Olympia, Washington

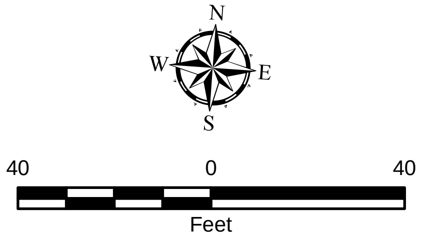
GEOENGINEERS

Figure 1

Legend

- Proposed Soil Gas Exploration Location
- MW-03 Monitoring Well Sampled for Groundwater Analysis and used to Monitor Groundwater levels
- MW-01 Existing Monitoring Well Previously Sampled for Groundwater Analysis and to Monitor Groundwater levels
- ● Vinyl Chloride at concentrations greater than MTCA Method A (0.2 ug/l)
- CSZ 1 Contaminated Soil Zones (CSZ) Remediated in September-October 2009
- Approximate Property Boundary
- Parcel Boundary
- Approximate Limits of Proposed Property Redevelopment

Well	Event	Result
MW-3		
Vinyl Chloride	August 2014	0.25 µg/L
MW-16		
Vinyl Chloride	August 2014	0.52 µg/L
MW-18		
Vinyl Chloride	August 2014	2.7 µg/L



Notes:
1. MTCA = Model Toxics Control Act, ug/L = micrograms per liter.
2. The locations of all features shown are approximate.
3. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Sources: Approximate Property Boundary from Thurston County parcels (revised by GeoEngineers). Aerial photograph 2013 from ESRI. Data Frame Rotated 356 degrees.

Projection: NAD_1983_StatePlane_Washington_South_FIPS_4602_Feet
Datum: D_North_American_1983

Proposed Soil Gas Explorations

318 State Avenue NE
Olympia, Washington

GeoEngineers

Figure 2

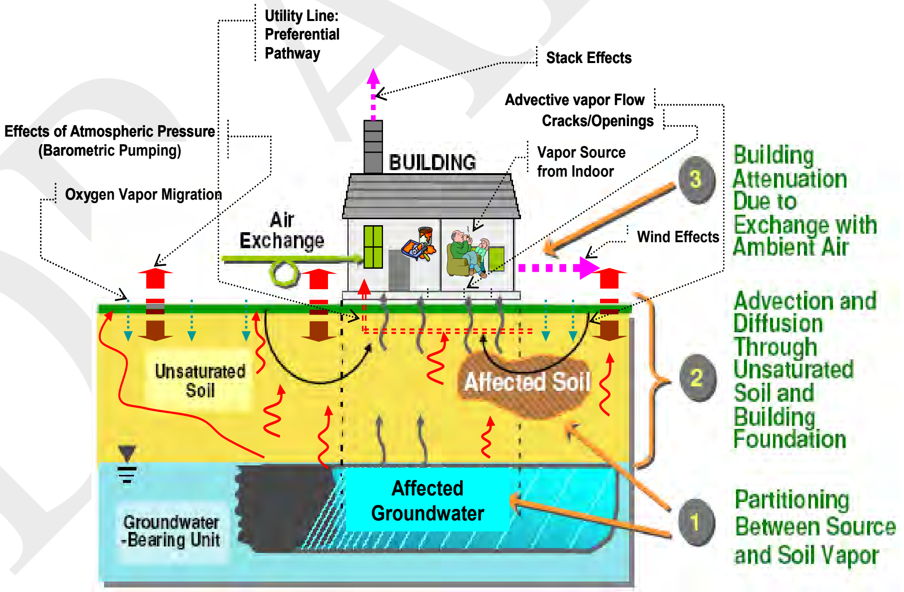
APPENDIX A

Ecology's Draft Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action

DEPARTMENT OF
ECOLOGY
State of Washington

Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action

Washington State Department of Ecology
Toxics Cleanup Program



Typical Example of Vapor Intrusion Pathway

Review DRAFT
October 2009

Publication no. 09-09-047

If you have special accommodation needs, please contact the Toxics Cleanup Program at (360) 407-7170. Person with hearing loss may call 711 for Washington Relay service (http://www.washingtonrelay.com/). Persons with a speech disability may call 877-833-6341.

This Guidance is available on the Department of Ecology's website at:
http://www.ecy.wa.gov/programs/tcp/policies/pol_main.html

For a printed copy of this document, please contact:

Department of Ecology
Toxics Cleanup Program
(360) 407-7170

Review Draft
October 2009

Refer to Publication No. 09-09-047

Questions or Comments regarding this document should be addressed to:

Washington State Department of Ecology
Toxics Cleanup Program
PO Box 47600
Olympia, WA 98504-7600

Keywords: Vapor Intrusion (VI), MTCA, Soil vapor/gas, Indoor air, Models, Sub-slab, Johnson and Ettinger, Volatilization, Groundwater, VOC, Screening levels, Tiers, Attenuation, Mitigation

Disclaimer: This document provides guidance on how to evaluate and respond to the vapor intrusion exposure pathway pursuant to the Model Toxics Control Act (MTCA) Cleanup Regulation, chapter 173-340 WAC. It does not establish or modify regulatory requirements. This document is not intended, and cannot be relied on, to create rights, substantive or procedural, enforceable by any party in litigation with the State of Washington. The Washington State Department of Ecology (Ecology) reserves the right to act at variance with this guidance at any time. Any regulatory decisions made by Ecology in any matter addressed by this guidance will be made by applying the governing statues and administrative rules to the relevant facts.

The mention of trade names or commercial products in this Guidance is for illustrative purposes only, and does not constitute an endorsement or exclusive recommendation for use at MTCA sites. Equipment other than that listed may be used provided that the resulting performance meets the project data quality objectives.

Contributors (in alphabetical order): Marcia Bailey (EPA Region 10); Dave Bradley, Martha Hankins, Ed Jones, Peter Kmet, Craig McCormack, Hun Seak Park, Craig Rankine, Charles San Juan, and Steve Teel (Ecology).

Acknowledgments: The Washington State Department of Ecology gratefully acknowledges Dan Gallagher (California Department of Toxic Substances Control) and Elizabeth Allen (San Francisco Bay Regional Water Quality Control Board); Envirogroup Limited; David Bartenfelder (US Environmental Protection Agency's Office of Superfund Remediation and Technology Innovation); Farallon Consulting; Geosyntec Consultants; Ms. Cathy Hendrickson; Henning Larsen (Oregon Department of Environmental Quality); Pioneer Technologies; Sound Environmental Strategies; Barbara Trejo (Washington State Department of Health); and, Mark Adams, Jerome Cruz, and Dean Yasuda of Ecology, for their review and helpful comments during development of the document.

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Chapter 1 Introduction

1.1 Purpose

Volatile hazardous substances (such as gasoline and solvents) released into the environment can contaminate soils, soil gas, and underlying groundwater. The migration of volatile hazardous substances from the subsurface to indoor air is called ***vapor intrusion***. It is a potential migration pathway at sites where volatile hazardous substances are present in the subsurface and occupied buildings are in the vicinity of the contamination. Because vapor intrusion can potentially lead to unacceptable indoor exposures to contaminants released into the environment, the Washington State Department of Ecology (Ecology) expects that remedial investigations will include an evaluation to determine if vapor intrusion is unacceptably impacting indoor air quality whenever volatile hazardous substances are present in the subsurface at a site. Ecology also expects **subsurface media cleanup levels to be protective of indoor air quality.**

Ecology developed this guidance to assist potentially liable persons (PLPs)[1], site managers, and consultants evaluating vapor intrusion as part of applying the Model Toxics Control Act (MTCA) cleanup regulations. The guidance contains:

- A process for evaluating the vapor intrusion pathway during a remedial investigation and feasibility study (see WAC 173-340-350).
- Recommended methods and techniques for soil gas sampling.
- Recommended references for indoor air, crawl space, sub-slab and ambient air sampling, and vapor intrusion mitigation techniques.
- Recommended methods for deriving subsurface media concentrations that protect indoor air quality from contaminated subsurface media.

The purpose of this guidance is to provide a **practical** guide for assessing vapor intrusion at sites in Washington where volatile chemicals in the subsurface might pose a threat to indoor air quality.

1.2 Applicability

This guidance may be used by anyone in Washington State concerned about whether subsurface vapor-phase contaminants may pose a health threat to people inside buildings. It is written primarily for environmental professionals investigating the vapor intrusion pathway at cleanup sites (as described below in Section 1.3). MTCA is the primary statute governing cleanup of hazardous wastes in Washington. At sites where there has been a confirmed release, the owner or

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[1] This guidance uses this term broadly to refer to the individual or party responsible for site cleanup. This is not intended to limit responsibility to only those designated as PLPs per RCW 70.105D.040. It is a general reference to the *responsible party*. Please see Appendix A‘s ―PLP” definition.

operator must comply with MTCA cleanup regulations in Chapter 173-340 of the Washington Administrative Code (WAC).

Persons responsible for cleanup **must** consider the vapor intrusion pathway when conducting a Remedial Investigation and Feasibility Study (RI/FS) under the MTCA cleanup regulations at sites where vapor intrusion may potentially lead to unacceptable indoor air contamination.[2] Ecology recognizes that a number of technically sound approaches to evaluating vapor intrusion can be used to demonstrate whether human health is being adequately protected.[3] We do not require that investigators follow the procedures outlined in this guidance unless the procedures are also required by regulation. However, the guidance describes a practical, **tiered** approach organized around a number of decision points, and is consistent with MTCA rule requirements and many other vapor intrusion guidance documents. Ecology expects its own site managers will use this document when they review documents submitted by PLPs.

Current and future scenarios

This guidance applies to scenarios where an occupied building currently exists on a site. It also applies to situations where buildings have not yet been constructed within a contaminated site area. As stated in WAC 173-340-702 (4), cleanup standards and actions must be protective of current and potential future site and resource uses.

Workplace exposures to toxic, volatile substances

This guidance applies to most scenarios where indoor receptors may be exposed to hazardous substances by breathing indoor air contaminated by soil gas. However, there are exceptions. Because certain manufacturing jobs require working with toxic, volatile substances, workers in industrial settings may be exposed to hazardous vapors used in their company‘s industrial or manufacturing process. Workplace safety for these workers is regulated by both the Washington Department of Labor & Industries (LNI) Division of Occupational Safety and Health (DOSH) and the federal Occupational Safety and Health Administration (OSHA).[4] The chemicals used in such a workplace could be the same substances found in soil gas beneath the building. As discussed in c) below, this guidance does **not** apply to potential vapor intrusion scenarios where the receptors at risk are workers routinely exposed to higher concentrations of the same chemical(s) as part of an industrial/manufacturing process, when those exposures are directly regulated by OSHA.

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[2] See: WAC 173-340-357(3)(f)(i); WAC 173-340-450(2)(c) & (3)(a)(i); WAC 173-340-720(1)(c) & (1)(d)(iv); WAC 173-340-740(3)(b)(iii)(C) & (3)(c)(iv); WAC 173-340-745(2)(c) & (5)(b)(iii)(C); and WAC 173-340-750.

[3] In 2002 EPA published a draft guidance for evaluating the vapor intrusion to indoor air pathway from groundwater and soils. Since that time, a number of states, the Department of Defense, and ITRC have also produced VI guidance.

[4] OSHA approves, monitors, and partially funds state occupational safety and health programs. WISHA, the Washington industrial safety and health act, provides for the state‘s occupational safety and health program (chapter 296-800 WAC). OSHA requires state plans to be at least as effective as OSHA. OSHA and WISHA establish permissible exposure limits (PELs) to regulate work place exposure to chemicals. PELs are based on both risk and economic feasibility. For most VOCs, the human health-based indoor air cleanup levels required under MTCA are much lower than the PELs.

The guidance **does** apply, though, to situations where employees working indoors are not routinely exposed to chemicals as part of an industrial/manufacturing process. It also applies to workers exposed to vapor intrusion in general non-residential settings, like schools, libraries, hospitals, retail stores, office buildings, and daycare facilities.

Consider the following situations:

a) An <u>office worker</u> in a building that houses some type of manufacturing operation is potentially exposed to indoor air contamination as a result of vapor intrusion. This guidance applies to the office worker‘s potential exposure (and to those exposures other persons not involved in the industrial process may be subjected to).

b) A worker potentially exposed to certain volatile substances in vapor intrusion-contaminated indoor air uses a different chemical while working. The potential exposure to the substances in indoor air <u>caused by vapor intrusion</u> is addressed by this guidance.

c) A worker potentially exposed to vapor intrusion-contaminated indoor air is regularly and simultaneously exposed to <u>the same</u> hazardous chemical vapors in the workplace. The workplace vapor concentrations are routinely much higher than any levels expected from vapor intrusion. This worker understands that exposure to the particular chemical is part of the job and is enrolled in the company‘s OSHA-compliant employee protection program. Because the exposure scenario described here is regulated under OSHA, the guidance has not been developed to assess or otherwise address such a situation.[5]

   Although dry-cleaning businesses and automobile filling stations are not ―manufacturing operations," the same logic may apply to evaluating vapor intrusion in their associated buildings. That is, the guidance has not been developed to assess or otherwise address situations where a subsurface vapor intrusion source potentially threatens indoor air quality, but: a) indoor workers are regularly exposed to the same hazardous chemical vapors in the workplace due to the nature of the business; b) **the workplace-related vapor concentrations are routinely much higher than any levels expected from vapor intrusion**; and, c) the workers are enrolled in an OSHA-compliant employee protection program.

These examples are provided to show the different types of indoor receptors that may be exposed to vapor intrusion-related contaminants and which types the guidance has been created to help assess. Regardless of whom the indoor receptor is, and whether vapor intrusion is or is not assessed because of the nature of the indoor activity, PLPs are still required to appropriately address (clean up) contaminated groundwater and soils at their sites.

1.3 The Vapor Intrusion Pathway

The vapor intrusion pathway we are concerned about at cleanup sites starts at the subsurface contaminant source, travels through the vadose zone, and, by moving through or around

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[5] That is, the guidance‘s assessment recommendations are not applicable to this particular workplace. The guidance remains relevant for neighboring properties or for other buildings on the property where the conditions described here do not exist.

foundations, enters occupied buildings.[6] The pathway consists of a string of possibilities that, if connected, may result in unacceptable health risks. The pathway is influenced by the properties of the chemicals themselves, soil characteristics, ambient conditions, and the construction and ventilation features of the affected (or future) buildings.

In this guidance, **vapor intrusion** (**VI**) refers to the migration of hazardous volatile chemicals from subsurface soils or groundwater (or NAPL) into the indoor air of overlying buildings.

In the subsurface, a chemical may be dissolved in groundwater, present as a separate non-aqueous phase, or sorbed to soil particles. Due to its volatility it may also partially partition into the gas phase, filling the portion of the soil pore space not occupied by water. Within the deeper portions of the vadose zone, gas-phase chemicals move primarily via molecular diffusion. Nearer the surface and approaching buildings, however, pressure gradients can play a significant role in transport, and advection/convection of soil gas is generally the dominant transport mechanism influencing vapor intrusion.

Advection-driven pressure differentials between the building interior and the immediate subsurface (or crawlspace) move soil gas indoors.[7] Gas-phase chemicals can enter buildings through cracks, seams, or utility penetrations in subsurface (basement) walls and floors, or through floors in contact with the ground surface. They can contaminate crawlspace air, and then be drawn inside through openings in the building‘s lowest floor. See Figure 1 below for a depiction of the generic vapor intrusion conceptual model.

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[6] This guidance specifically addresses volatile substances moving from the subsurface into buildings. However, the air inside other enclosed structures such as manholes and utility vaults can also become contaminated due to below-ground intrusion of soil gases. In addition, other vapor-related exposure scenarios exist: contaminated soils or groundwater can release gases to the atmosphere such that exposure occurs through inhaling ambient air. Workers excavating below ground level at contaminated sites can be exposed to vapors (this is sometimes referred to as the ―trenching” scenario). Methane gas originating from landfills may move underground and infiltrate buildings. **Although much of the guidance's discussion may also apply to these scenarios, they are *not* specifically addressed in the document**.

[7] A pressure difference between the interior and subsurface can occur for various reasons, and the air pressure inside an occupied building is often lower than both ambient air and the subsurface. This creates the potential for both ambient air contaminants and contaminants present in shallow soil gas to move indoors.

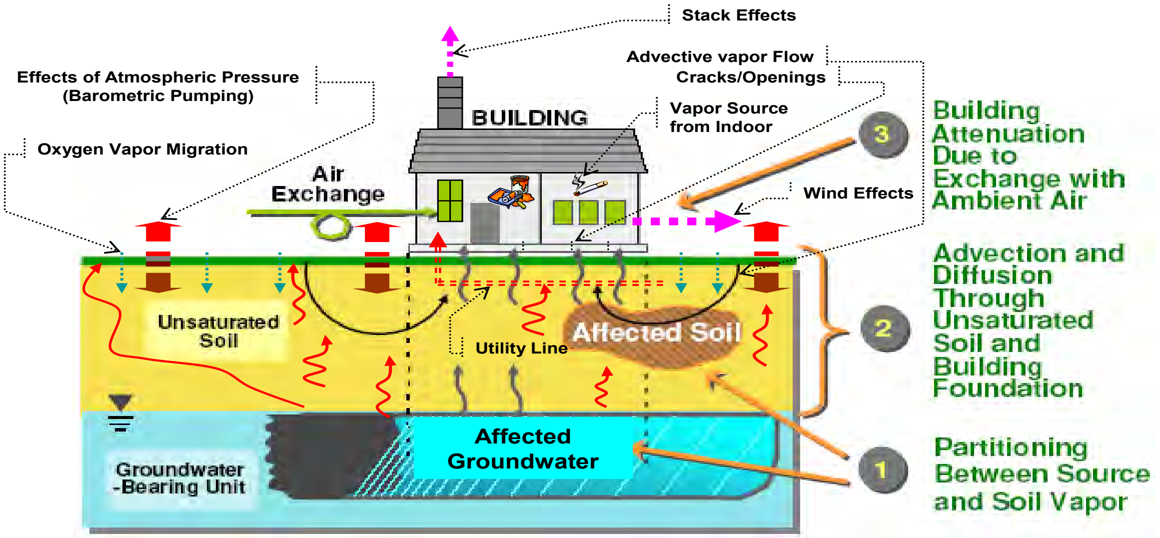

Figure 1. The vapor intrusion exposure pathway

Site-specific considerations

In rare cases, vapors accumulating in enclosed spaces can pose immediate safety hazards (such as explosions), acute health effects, or aesthetic problems (such as odors). These threats must be responded to immediately. Section 2.1 provides further information about indoor vapor scenarios requiring immediate response. Typically however, indoor chemical concentrations due to vapor intrusion are low and the primary concern is the more chronic health effect(s) associated with long term exposures. This is the scenario the guidance has been developed to address.

1.4 Using the Guidance

Ecology‘s vapor intrusion guidance document is brief and emphasizes ―how to” more than ―why.” It is organized around logical steps in the process of evaluating and responding to potential vapor intrusion problems. The general approach recommended here is *tiered*, with steps for ―screening-in” sites or buildings where vapor intrusion <u>might</u> be of concern while ―screening-out” sites or buildings where it is unlikely. Early screening steps are conservative by design with only those buildings least likely to be unacceptably impacted by vapor intrusion screened-out first. However, as investigators gather more site-specific data, less conservative decision-making becomes possible.

This guidance is not comprehensive. For many subjects we refer the reader to other documents, such as the more comprehensive state vapor intrusion guidance developed in California, New York, and New Jersey, the Interstate Technology Regulatory Council‘s (ITRC‘s) guidance, or topic-specific literature.

See Figure 2 on the following page for a schematic summary of this guidance‘s content.

1.4.1 The guidance’s approach to assessing VI

Tiering the vapor intrusion assessment is designed to help investigators gather required data in a cost-effective manner. The step-wise approach in this, and many other state and federal guidance documents, can be thought of as a progression of questions and decisions. At each succeeding step where a question is posed and answered, the investigator has an opportunity to conclude that subsurface contamination does not pose an unacceptable threat to indoor air quality. These points can be considered –off-ramps.” Some *off-ramps*, especially those early in the process, are essentially completions of the vapor intrusion assessment. In these cases no further assessment actions are generally required once the investigator has exited the screening process. Other off-ramps are of a more qualified nature. They may reflect scenarios where vapor intrusion is not unacceptably impacting indoor air, but only because of certain conditions that could change over time. Here, assessment off-ramps may lead to follow-up actions such as monitoring or the imposition of land use controls.

For example, a *preliminary* assessment may conclude that buildings are not currently close enough to subsurface contamination to be threatened by vapor intrusion. The off-ramp, then, is a conclusion that indoor receptors are not currently being exposed to vapor intrusion-caused air contamination. This conclusion may not hold, however, for receptors in a building constructed nearer the contamination in the future.

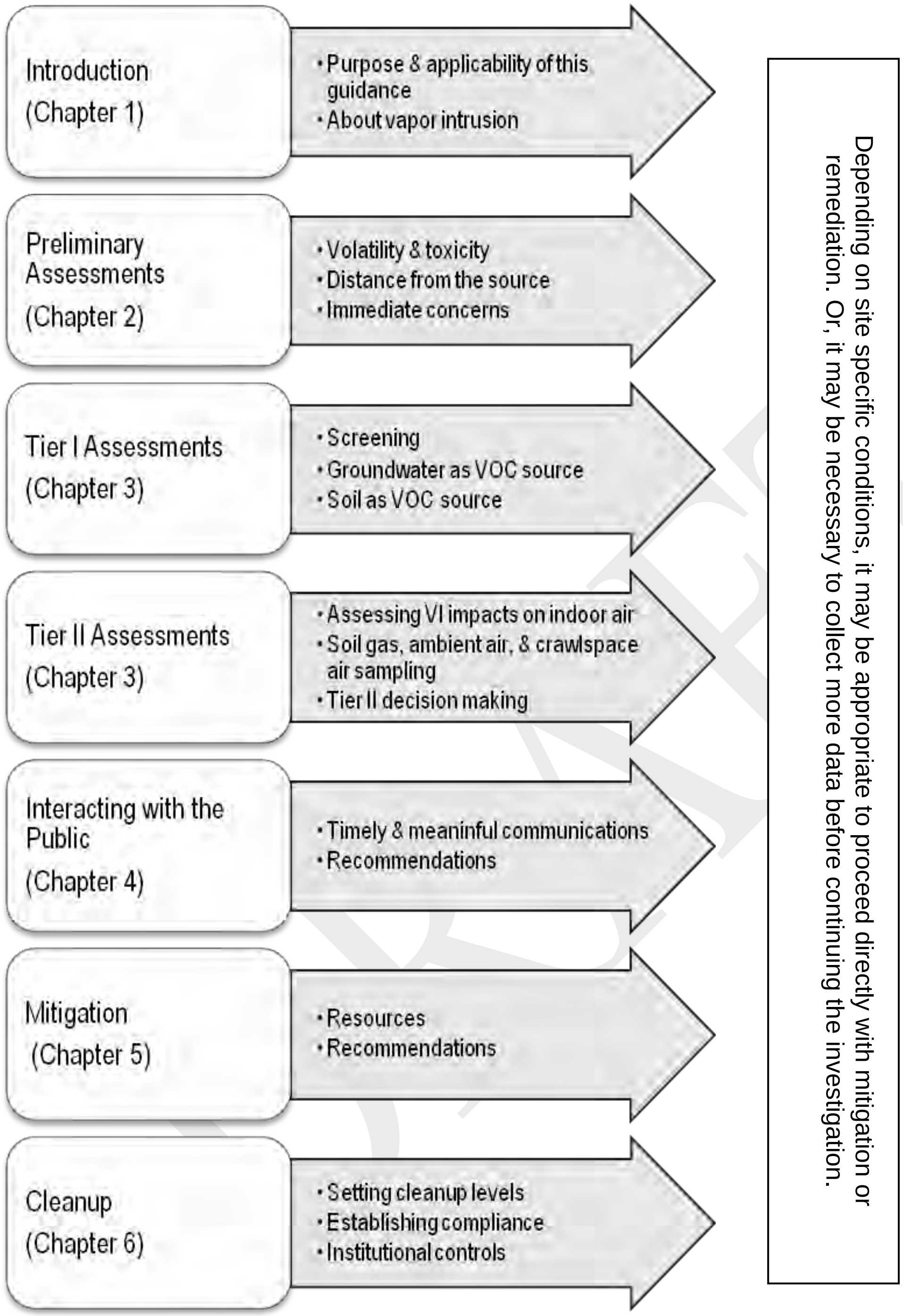

Figure 2. The step-wise content of the guidance document (first six chapters)

Likewise, a *Tier II* assessment may conclude that a particular building‘s indoor air is not being unacceptably impacted by vapor intrusion. The off-ramp, then, may be a decision that no further assessment of that building is needed. However, the subsurface contamination might still pose a potential threat to indoor air if the building were to be modified, used differently, or replaced by a different structure. Similarly, even though indoor air may not appear to be unacceptably impacted, soil gas concentrations may be significantly elevated. Decision-makers may therefore opt to monitor indoor air and/or soil gas concentrations over time to ensure the protectiveness of the assessment conclusion.

Preliminary Assessment

The goal of the preliminary assessment is to quickly identify whether the potential for vapor intrusion exists at a specific site, and if it does, which buildings may be affected.

Chapter 2 describes the basic steps in a preliminary assessment, asking:

- Could chemicals present at this site pose a potential vapor intrusion problem? That is, are the substances released, or their degradation products, sufficiently toxic and volatile? This is the first *off-ramp* opportunity. **If the chemicals present at the site are <u>not</u> sufficiently toxic and volatile, there is no further need to assess the pathway.**

- Are existing or planned buildings located close enough to subsurface contamination to be affected by vapor intrusion? Once a decision has been made that there are toxic, volatile substances in the subsurface, identifying the buildings and site areas where vapor intrusion might occur is the next step. This is the second *off-ramp* opportunity.

  If the chemicals present at the site are toxic and volatile, but **the contamination is far from any occupied existing or planned building, vapor intrusion is not currently posing a threat to indoor receptors.** There is no further need to assess the pathway, then, for the purpose of determining if mitigation or some other form of interim action is needed. However, as Chapter 2 explains, if future buildings could be constructed near subsurface contamination, vapor intrusion could potentially impact indoor air quality within those buildings. Since the site cleanup action must be protective of the indoor air quality in future as well as current buildings, PLPs will need to perform further assessment within these areas (as described in Chapter 3) to better estimate the significance of potential impacts.

Answering these questions will require certain site-specific information of high enough quality to make a confident decision. At some sites existing data may answer, or help answer, these questions and either allow the investigator to take an off-ramp to no further assessment, or establish the need for further investigation. In general, though, existing data may not be of sufficient quality and quantity for establishing the likelihood of potential vapor intrusion risks, especially as the investigator proceeds beyond a preliminary assessment to Tiers I and II. Investigators need to evaluate both the quantity and quality of their data before making screening decisions.

If the preliminary assessment concludes that there are toxic, volatile hazardous substances at the site and the contamination is either a) close to one or more currently occupied buildings, or b) close to an area where a building could be constructed in the future, investigators will need to continue assessing the pathway. Generally, the next steps involve looking at the concentrations of these substances in the subsurface and deciding if these concentrations are high enough to pose a potential vapor intrusion problem at any site building. This is called a Tier I assessment, or Tier I screening.

Tier I Assessment

Like the preliminary assessment, Tier I asks basic pathway questions and provides off-ramps for situations where it is apparent that the subsurface contamination is very unlikely to pose a vapor intrusion threat to particular buildings. In essence, for sites where contaminated groundwater is the subsurface source of vapors, it asks:

- Do the volatile, toxic substances present in shallow groundwater at this site pose a potentially unacceptable vapor intrusion source? That is, are the chemical concentrations high enough to constitute an unacceptable source? **If there is no volatile contamination in vadose zone soils (near current or future buildings of concern), no LNAPL, and shallow groundwater volatile concentrations are sufficiently low (below "screening levels" and expected to stay that way), there is no further need to assess the pathway.**[8] Or,

- Do the volatile, toxic substances present at this site in vadose zone[9] soil gas – assuming the soil gas data are properly representative – indicate a potentially unacceptable vapor intrusion source? **If subsurface soil gas concentrations are sufficiently low (and expected to stay that way), there is no further need to assess the pathway.**

For sites where contaminated vadose zone soil is the subsurface VI source, or where soil and groundwater (and/or LNAPL) are both contaminated, Tier I asks:

> Do the volatile, toxic substances present at this site in vadose zone soil gas indicate a potentially unacceptable vapor intrusion source (again, assuming existing data are properly representative)? **If subsurface soil gas concentrations are sufficiently low, there is no further need to assess the pathway.**

Section 3.1 describes the Tier I remedial investigation screening procedures for vapor intrusion. If the Tier I screening assessment concludes that there are volatile, toxic substances at the site, that the subsurface contamination is close to one or more occupied or future buildings, and that the contamination is significant enough to pose a threat to indoor air quality, investigators will

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[8] This assumes that these media were never significantly contaminated with volatile, toxic substances, or if contaminated at one time, the low concentrations now present also represent soil gas conditions. There have been reports of soil gas concentrations remaining elevated for some period following soil or groundwater remediation.

[9] Used here to mean the unsaturated zone above the water table. Although the capillary fringe is included in this zone, soil gas samples are typically collected from depths above this interval.

need to continue the pathway assessment. The next step,[10] Tier II, involves looking at the concentrations of volatile chemicals indoors – associated with vapor intrusion – and deciding if these concentrations are ―acceptable.”[11]

Tier II Assessment

Tier II asks: Is the volatile contamination in the subsurface unacceptably contaminating this particular building‘s indoor air? If the answer is no (that is, indoor air chemical concentrations – due to vapor intrusion – are sufficiently low), there is no need to assess the pathway further. Tier II, then, can provide an assessment *off-ramp* for the situation where it is apparent that even though there is significant subsurface contamination, vapor intrusion has not unacceptably impacted an existing building‘s indoor air quality.[12] Alternatively, Tier II sampling results may indicate that vapor intrusion is contaminating indoor air and that actions are necessary to protect the health of indoor receptors.

Section 3.2 describes measuring and evaluating indoor air, ambient air, and building foundation air (sub-slab soil gas and crawlspace air) volatile chemical levels and refers the reader to various state and other technical guidance.[13] It also discusses: a) how to minimize the influence, and – at least partially – account for, background sources of indoor air chemical concentrations, and b) how to interpret the results of indoor air sampling.

1.4.2 The affected community

Chapter 4 briefly discusses communicating with potentially exposed receptors. Once it becomes apparent that vapor intrusion may be unacceptably impacting indoor air quality investigators will need access to properties and buildings to collect samples and, possibly, mitigate.

1.4.3 Responding to indoor air contamination caused by VI and setting pathway-protective subsurface media levels

Chapters 2, 3, and 4 of the guidance focus on determining whether vapor intrusion may be threatening indoor air quality. In most cases, if indoor air quality in an existing building is

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[10] In some cases investigators may choose to remain in Tier I and collect new/additional data to improve the quality of their screening decisions.

[11] Readers familiar with other guidance may recognize that Ecology‘s ―Tier I” and ―Tier II” differ from some ―Tier 1” and ―Tier 2” assessments described elsewhere. Our Tier I is essentially an investigation that does not include indoor air sampling; Tier II includes indoor air sampling. Sub-slab soil gas sampling may be conducted during either Tier I or Tier II.

[12] Tier II may conclude with a decision that vapor intrusion is not currently resulting in unacceptable indoor air quality. However, as Chapter 3 explains, if the subsurface is significantly contaminated, there may still be a need to continue monitoring to ensure that any impacts remain acceptably low.

[13] Because indoor air can be contaminated by a number of different sources, Ecology recommends that ―multiple lines of evidence” be applied to decision-making when evaluating the vapor intrusion pathway during Tier II. Using multiple lines of evidence enables investigators to develop and support a hypothesis about the contributions soil gas is making to indoor air measurements.

indeed being threatened, mitigation measures will be employed to protect receptors until the subsurface source has been effectively cleaned up. In Chapter 5 the guidance briefly discusses vapor intrusion mitigation measures. Mitigation measures are utilized to protect indoor receptors from vapor intrusion, though they do not directly act upon the source of the soil gas contamination. Readers are referred to other available guidance for more information about the types of mitigation technologies available.

If subsurface levels of toxic, volatile substances are elevated, and pose a potential vapor intrusion threat (even if that threat is currently being mitigated by an active measure, or by characteristics of the current building that minimize the degree of intrusion or its impact[14]), the *source* of the problem must be addressed. Chapter 6 focuses on the contaminated vapor intrusion subsurface source and discusses approaches for establishing media concentrations protective of indoor air quality, regardless of the type of building that may exist in the future. It also discusses other vapor intrusion-related cleanup issues, such as institutional controls.

1.5 Updating the Guidance

Vapor intrusion assessment is an evolving science. Over time, as sites continue to be assessed nationwide, our understanding of the relationship between subsurface contamination and indoor air impacts will improve. Hopefully this will enable us to do better job of predicting the degree of vapor intrusion impact at any given building, and estimating the contribution to indoor air contaminant measurements only due to vapor intrusion.

In addition, it is anticipated that the MTCA cleanup regulations (WAC 173-340) will be modified in the near future as part of the Five Year Review process. More explicit requirements related to the vapor intrusion pathway are likely to be added.

Ecology therefore expects that, depending on the outcome of future regulatory changes and advances in the science of vapor intrusion assessment, certain recommendations and other information contained in this guidance may need to be revised.

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[14] It is possible that a future building in the same location may be more susceptible.

Chapter 2 Preliminary VI Assessment

As discussed in the Introduction, Ecology recommends a tiered approach to vapor intrusion (VI) assessment. This is simply a logical process of deciding, in successively more resource-intensive steps, whether the site contamination could pose, or is posing, a threat to indoor air quality. Figure 3 on the following page shows the basic steps involved in a preliminary assessment of the pathway. At this preliminary point the investigator is really only attempting to decide if: (1) the type of contamination at the site is volatile enough and toxic enough to pose a threat, and (2) occupied buildings are, or may later be, in the vicinity of the contamination.

The goal of a preliminary vapor intrusion assessment is to determine whether **any** potential exists for toxic vapors to be present in the subsurface that could migrate and enter nearby buildings. It requires little site-specific information on contaminant concentrations[15] and can be performed during the scoping process for a remedial investigation and feasibility study (RI/FS), or during Phase I or II environmental assessments.

A series of two questions provides the framework for deciding whether investigators should continue with an investigation of the VI exposure pathway. These questions are provided in an abbreviated form below, with further details in the following sections:

- **Are chemicals of sufficient volatility and toxicity known or reasonably suspected to be present? (See Section 2.2)**
- **Are occupied buildings present (or could they be constructed in the future) above or near site contamination? (See Section 2.3)**

If the answer to the first question is *no*, there is no subsurface VI source and no need to conduct further investigation to assess the pathway. If the answer is *yes*, the investigator must proceed to the second question. If the answer to this second question is also *yes*, the pathway will need to be assessed further, as described in Chapter 3.

If the answer to the first question is *yes*, but no occupied buildings exist near the contamination, vapor intrusion is not currently posing a threat to indoor receptors. There is no further need to assess the pathway, then, for the purpose of determining if mitigation or some other form of interim action is needed. However, if future buildings could be constructed near the subsurface contamination, vapor intrusion could potentially impact indoor air quality within those buildings. Investigators will therefore need to perform further assessment during the RI to better estimate the significance of these potential, future impacts.

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[15] Other than a conservative estimate of the boundaries of the contamination. Performing a preliminary VI assessment requires that the nature and extent of the soil and groundwater contamination only be known well enough to: a) identify the hazardous substances which are present, and b) conservatively estimate the extent of their presence, laterally and vertically.

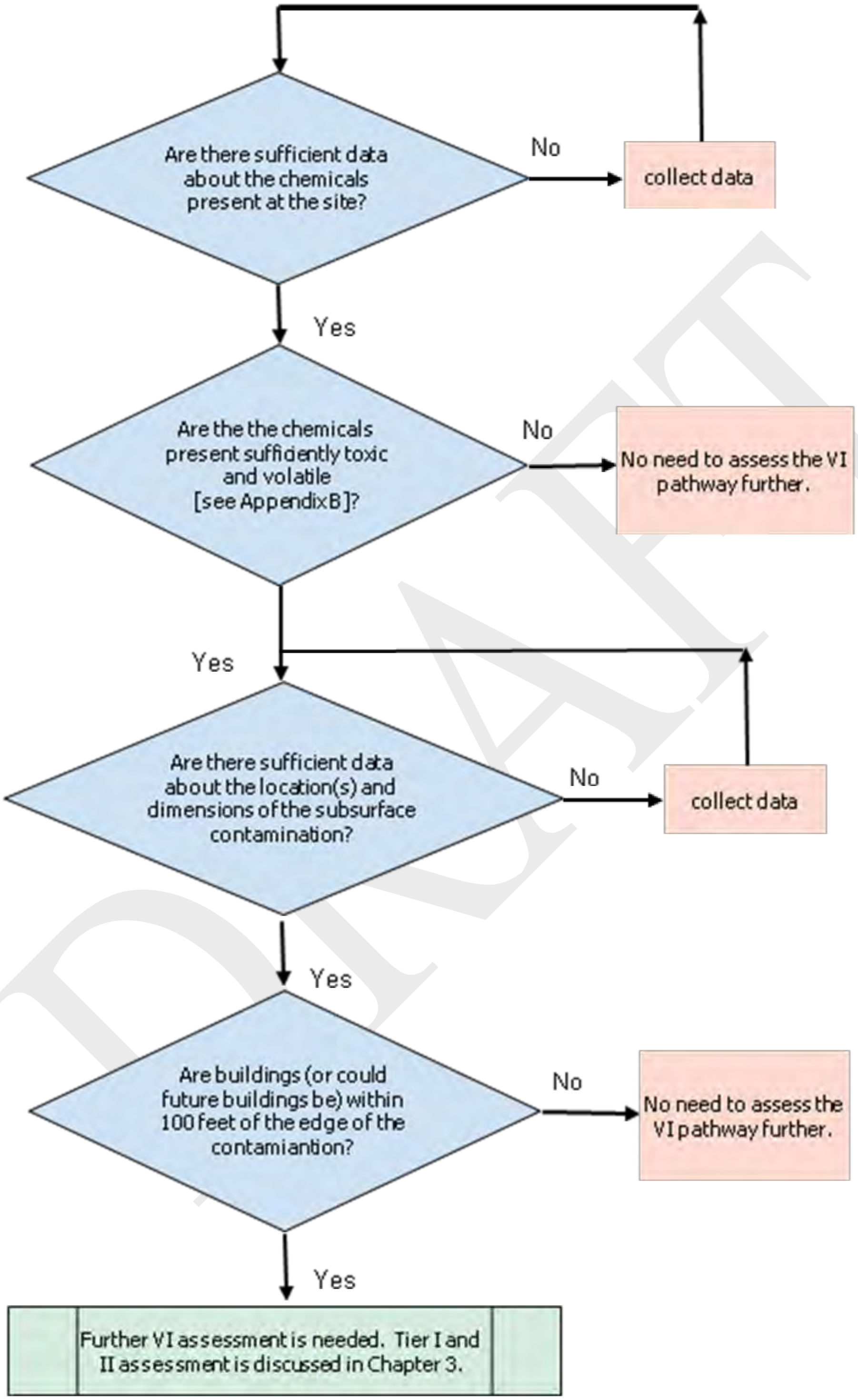

Figure 3. Preliminary Assessment.

The basic steps for deciding if further VI assessment is needed in Chapter 3.

2.1 Is Immediate Action Necessary?

Most vapor intrusion scenarios are not associated with safety concerns or indoor air concentrations that pose harmful acute exposures. This guidance was not developed to respond to these relatively rare situations. PLPs and site managers should be aware, however, that in certain situations, vapor intrusion hazards may require immediate attention. Investigators should take immediate action when short-term health or safety concerns are known, or reasonably suspected to exist. This includes scenarios where explosive or acutely toxic concentrations of vapors are present in a building. It also includes the following conditions:

- A spill is discovered in the interior of the structure (for example, a substance such as heating oil). This is not a vapor intrusion scenario but it does create vapor hazards.
- Odors are detected with a known or suspected source nearby. Odor complaints may indicate acute health concerns, and offensive but transient smelling odors may reduce the quality of life for occupants. It is prudent to investigate such complaints. For some chemicals (like benzene and naphthalene, for example) the odor detection threshold exceeds the indoor air concentration acceptable under MTCA.
- Building occupants report health problems. Hazardous vapors may cause headaches, dizziness, nausea, eye and respiratory irritation, vomiting, and confusion.
- Non-aqueous phase liquid (free product) contaminants are beneath or immediately adjacent to the building. Site investigators should consider the need for immediate actions when free product is floating on the water table directly below or close to the building.
- Some types of vapor can create a fire and/or explosion risk. When vapor concentrations are expected to be flammable or combustible, or are known to be corrosive or chemically reactive, investigators should immediately assess and respond to site conditions. Under MTCA, cleanup levels protective of air quality cannot exceed ten percent (10%) of the lower explosive limit for any hazardous substance or mixture of hazardous substances.[16]

> *CAUTION: Ecology advises that buildings with potential fire and explosive conditions be evacuated immediately, and the local fire department contacted.*

Most vapor intrusion scenarios are not associated with safety concerns or acute threats to human health. However, if indoor is being contaminated by soil gas at any concentration, the vapor intrusion exposure pathway is complete; that is, the building's occupants are being exposed to the contamination. It is not merely a ―potential" exposure. These scenarios often necessitate relatively quick action to abate the exposure, even though the most likely health impact is associated with long-term chronic exposure.[17] Fortunately, for many buildings, the speed and low cost of protecting receptors via mitigation (see Chapter 5) make this form of response

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[16] See WAC 173-340-750(3) and (4).

[17] It is not possible to determine with certainty how much time may elapse prior to the advent of adverse effects from the exposure.

attractive as an interim measure, implementable well before the comprehensive site cleanup action has been completed.

2.2 Are Contaminants of Concern Volatile and Toxic?

To pose a potential VI threat to indoor air, substances must be both volatile enough and toxic enough to contaminate soil gas to unacceptable levels. Appendix B contains a list of substances that could potentially contaminate indoor air to unacceptable levels via the VI pathway. These substances were identified by EPA in their 2002 draft VI guidance.[18] The list is primarily comprised of Volatile Organic Compounds (VOCs), as defined by WAC 173-340-200. Depending on site and building conditions, these substances are sufficiently volatile and toxic to pose a potential threat to indoor air quality via the VI pathway. If, as a result of site releases, these substances are present in site contamination, the proximity of the contamination to existing buildings should be estimated, as explained in Section 2.3 below.

The list of substances in Appendix B does not include every chemical that could potentially contaminate soil gas and indoor air.[19] On a site-specific basis, therefore, Ecology may identify circumstances where it becomes necessary to consider the volatility and toxicity of chemicals not included in the appendix.

2.3 Are Buildings Close Enough to the Contamination?

Soil vapor concentrations decrease with increasing distance from the subsurface contamination source and eventually fall to negligible levels. The decrease in concentration as a function of distance from the source depends on the soil characteristics, properties of the constituent chemicals, whether preferential pathways exist, and if biodegradation and chemical transformations may be occurring within the subsurface environment. Soil gas in the vicinity of buildings also may be subjected to pressure gradients, leading to the movement of the gas itself towards areas of lower pressure.

The lateral distance between the contamination and a building can limit the potential for vapor intrusion. Generally, buildings located more than 100 feet, horizontally, from the edge of the subsurface contamination are unlikely to experience unacceptable VI impacts.[20] Accordingly, there is no need to further assess the VI pathway for these buildings. The ―edge of the subsurface contamination,” for the purpose of a preliminary assessment, is defined by an

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[18] Chemicals listed in Table B-1 were obtained from two sources: the 2002 draft EPA VI Guidance and the 2005 California-EPA DTSC VI Guidance. Ecology added three total petroleum hydrocarbon (TPH) light fractions to the chemicals obtained from these two documents. Some chemicals listed in EPA‘s and DTSC‘s documents are not included in the table.

[19] EPA‘s 2002 guidance refers readers to Appendix D of its document for an explanation of the process used to select substances that are volatile enough and toxic enough to pose a potential VI concern. Ecology used this process, but limited the chemicals in Appendix B to, primarily, VOCs.

[20] From EPA (2002). Section 2.3.2 below describes the limitations on using this criterion. Note that the 100 feet distance criterion does not consider the aerobic biodegradation of VOCs. Petroleum hydrocarbons can significantly attenuate via this mechanism.

The ―100 foot rule” is generally applied to all sites, whether the contamination is close to, or far from, the ground surface. Contamination close to the ground surface, however, has less vertical distance to diffuse over (before soil gas is discharged to the atmosphere). All else being equal, therefore, the lateral extent of soil gas contamination for a near surface vapor source will typically be less than that for a deeper source.

estimate of where volatile organic compound (VOC)[21]concentrations in shallow groundwater or soil decrease to their practical quantitation limits.

If shallow groundwater – meaning groundwater at the water table or in perched zones above the water table – is not contaminated, and will not become contaminated in the future, groundwater is generally not considered a VI *source*. To be a VI source groundwater at the saturated/ unsaturated zone interface must contain volatile, toxic substances.

NOTE: Buildings constructed on property that is located within 100 feet, horizontally, from the edge of subsurface contamination could potentially be threatened by vapor intrusion. For areas within 100 feet of the contamination that are developable (whether a building currently exists or not), the pathway will need to be assessed as discussed in Chapter 3.

2.3.1 Limitations on the use of the "100-foot rule"

Although 100 feet is a good rule of thumb, in some situations Ecology may recommend that buildings be evaluated for possible VI impacts if they are farther than 100 feet from the edge of the contamination. For instance:

- When a continuous low permeability surface (such as concrete or asphalt) covers the ground between the contamination and the building, soil gas discharge to the atmosphere is restricted and this may enhance migration toward the building. In such a case, and especially when the soil or groundwater contamination is at depth, it would be prudent to consider buildings further in Tier I even if they are somewhat farther than 100 feet from the estimated edge of contamination.

- When the vadose zone geology has very high gas permeability (for example, fractured bedrock, Karst, or clay deposits with continuous fissuring), soil gas contaminants can follow fractures without substantial attenuation for distances exceeding 100 feet.

- If sewer, gas, or other utility lines are present at the site, and have been routed in trenches backfilled with materials significantly more permeable than native soils, soil gas contaminants may follow the backfilled conduit and pose a threat to buildings somewhat farther than 100 feet from the estimated edge of contamination.[22]

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[21] Substances in addition to VOCs (as defined by WAC 173-340-200) are included on Table B-1 because in some situations these substances may pose a vapor intrusion threat. The guidance, however, uses the term ~~-~~VOCs" throughout the document as a shorthand descriptor of the chemicals of concern for the VI pathway. The only inorganic substances listed in Table B-1 are mercury and hydrogen cyanide.

[22] Vapors may follow the more permeable routes associated with utility conduits. In urban areas, utility and sewer lines can influence the migration of contaminants if backfill provides a preferential flow pathway for soil gases. See the Wisconsin Department of Natural Resources' 2000 *Guidance for Documenting the Investigation of Utility Corridors*.

- When soil gas is under pressure, the 100-foot rule should not be used. This is typically seen at landfills, where methane gas – often containing VOCs – can travel much farther than 100 feet. Neither the 100-foot rule nor the preliminary and tiered assessment recommendations discussed in this guidance are intended for use at sites where landfill gases may pose a threat to indoor air quality.

In addition, when the source of contaminated soil gas is contaminated groundwater, the investigator will need to consider the future migration of VOCs in the plume. While there may currently be no buildings within 100 feet of the plume, VOC strength may increase in the future in the downgradient direction, threatening buildings that initially appeared to be too far away to be impacted.

If you determine from a preliminary assessment that there is no potential vapor intrusion concern at the site, and document your decision explaining your rationale, no further assessment is required for the pathway.

However, if it appears that vapor intrusion may potentially be creating unacceptable indoor air contamination, or could in the future, the VI assessment process described in Chapter 3 should be initiated.

Chapter 3 VI Assessment during the Remedial Investigation (Tiers I and II)

The vapor intrusion (VI) evaluation process recommended in this guidance can be used during the Remedial Investigation/Feasibility Study (RI/FS) to identify: a) sites that are, or are not, likely to pose a vapor intrusion threat; and b) individual buildings and site areas that are, or are not, potentially threatened by vapor intrusion. For each chemical being investigated, the process consists of three steps:

- Preliminary Assessment
- Tier I Assessment
- Tier II Assessment

Preliminary assessment was discussed in Chapter 2. Here we assume that a preliminary assessment has been completed and has concluded that: (1) site contamination includes VOCs,[23] and (2) occupied buildings are currently in the vicinity of the contamination, or could be in the future. The investigator must therefore determine whether the contaminant strength is such that it could pose a potential VI threat.

Commonly, the assessment process begins by adequately characterizing the nature and extent of the subsurface VOC contamination, an RI task. As stated in the MTCA regulations, the purpose of the RI is ―to collect data necessary to adequately characterize the site for the purpose of developing and evaluating cleanup action alternatives” (WAC 173-340-350(7)(a)). The investigator must therefore develop an understanding of the three-dimensional extent of the VOC ―plume” in shallow groundwater and/or vadose zone soil. Subsurface sampling activities should document contaminant source concentrations, including the extent of NAPL, and verify potential contaminant migration pathways pursuant to the site‘s conceptual site model (see section 3.2). While this is needed to a certain extent for the preliminary assessment, it becomes more important during Tiers I and II. The Tier I and II screening steps described in this guidance therefore assume that:

(1) the nature and extent of contamination in the media which contain the potential vapor intrusion source has been, or is being, adequately quantified; and,

(2) a site conceptual model, inclusive of potential vapor intrusion pathways and receptors, has been developed and is being re-visited as new information becomes available.

At the completion of the Preliminary Assessment the investigator will have identified the areas where VI could possibly be a problem. As Chapter 2 states, these will be those areas where

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[23] As noted in Chapter 2, the list of substances of potential concern for the vapor intrusion pathway (Table B-1) includes more chemicals than those defined as VOCs by WAC 173-340-200. This guidance document uses ―VOCs” as shorthand when referring to the substances of potential concern for the VI pathway.

VOCs are present in subsurface contamination and the areas within approximately 100 lateral feet of the contamination. Within these site areas there may be property with buildings, but there will also be property that has not been developed. The goal of Tier I is to look at the site areas identified in the Preliminary Assessment and determine which areas – or which portions of these areas – may potentially be threatened by VI. Although VOCs are present in the contamination, VOC concentrations may not be high enough to potentially create unacceptable indoor air levels.

VI assessment can have two goals. It can be initiated to determine if vapor intrusion is contaminating indoor air in an existing building, or it can be undertaken to determine if vapor intrusion could pose a threat to a future building, yet to be constructed.

While the screening tools described below for both Tiers I and II can be used to achieve the first goal (assessing the threat associated with an existing building), only Tier I can help investigators meet the second goal (assessing the threat posed to a future building). **Tier II relies upon indoor air measurements, and can only be conducted if a building is present.**

In those areas where buildings currently exist, Tier I evaluates whether subsurface contamination has the potential to unacceptably contaminate indoor air. This evaluation is based on the existing building and the type of receptors that currently occupy it. But when the building is not a residential structure, it also includes an assessment of:

a) whether subsurface contamination has the potential to unacceptably contaminate indoor air were a residential structure to replace the existing structure in the future; and,

b) whether subsurface contamination has the potential to unacceptably contaminate indoor air if the receptors of interest were (future) residents.

In those areas where buildings do not currently exist, Tier I attempts to assess the probability that indoor air may be impacted if a building is constructed in the future.

At the completion of the Tier I assessment, then, the investigator will have a site map showing:

- buildings where subsurface contamination could potentially result in unacceptable indoor air concentrations;
- areas (property) where subsurface contamination could potentially result in unacceptable indoor air concentrations in the future; and,
- areas (property) and buildings where subsurface contaminant concentrations are too low to potentially result in unacceptable indoor air concentrations.

At some sites it is possible that subsurface contaminant concentrations will be too low to potentially result in unacceptable indoor air concentrations in any site area. But if the Tier I assessment concludes that some VOC concentrations are sufficiently elevated to be problematic (that is, screening levels are exceeded, or modeled predictions of indoor air concentrations exceed acceptable levels), the existing buildings threatened (if any) should be identified. Investigators must then determine in Tier II whether actual indoor air VOC levels – due to VI – are unacceptable. This entails measuring VOC concentrations in indoor air, and comparing the measured concentrations due to vapor intrusion to acceptable levels. It will also usually mean collecting ―foundation air" (sub-slab soil gas or crawlspace air) and upwind ambient air samples. These samples are collected to better estimate the amount of contamination that has been contributed to the Tier II indoor air measurement from vapor intrusion exclusively. Indoor air quality may be affected by VI, but it is almost certainly affected by ambient (outdoor) air contamination that has come indoors, household product emissions, and other indoor materials emitting VOCs.

If the Tier I assessment concludes that VOC concentrations are sufficiently elevated to pose a VI threat, but only if a) buildings are constructed in particular areas in the future, or b) the existing building type or use changes, human health is currently protected (for this pathway). The assessment findings should then be utilized during site remedy selection to ensure that indoor receptors remain protected in the future.

3.1 Tier I Screening

Figure 4, the Tier I flowchart on the following page, assumes that a preliminary assessment has already concluded that there are: a) VOCs in the subsurface, and b) buildings presently in the vicinity of the contamination (or contaminated areas where buildings could be constructed in the future). Nevertheless, at many sites and for many buildings the investigator will often be able to determine, by focusing only on the nature and extent of volatile chemicals in the subsurface, that the contaminant source is simply too weak or too far away from buildings of interest to pose an unacceptable vapor intrusion threat. Tier I therefore asks: are the concentrations of VOCs in the subsurface high enough to pose a potentially unacceptable threat to indoor air quality within current or future site area buildings?

In Tier I the investigator:

- Begins by overlaying a figure showing existing building footprints and developable land on top of the site‘s VOC plume map(s).[24] The buildings and property where VI may be a concern can then be identified from their spatial relationships to the contamination.

- Measures VOC concentrations in shallow groundwater and/or soil gas (if they are not already known) near the buildings and developable areas of concern.

- Compares measured shallow groundwater or soil gas concentrations to generic screening levels developed using conservative (that is, health-protective) assumptions.

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[24] Groundwater contamination, unless it has reached a point where its lateral boundaries have stabilized, will migrate downgradient. The assessment process must factor-in the degree to which shallow groundwater VOC contamination is likely to expand beyond it current lateral dimensions.

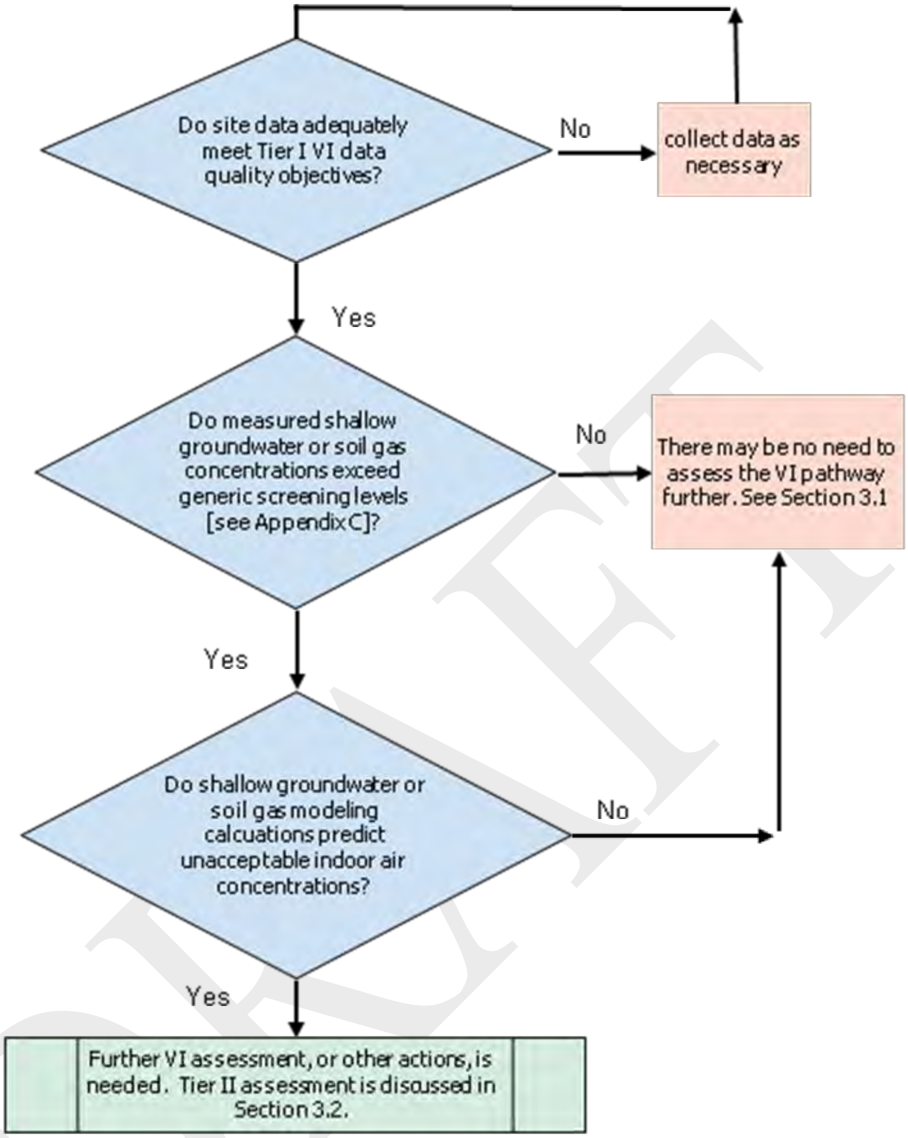

Figure 4. Tier I Assessment. The basic steps for performing a Tier I VI assessment.

- Inputs measured shallow groundwater or soil gas concentrations to a predictive model, such as the Johnson and Ettinger Model, and derives estimates of indoor air concentrations. These predicted concentrations can then be compared to acceptable indoor air levels (such as Method B or C air cleanup levels).

  This task (bullet #4) can be performed whether the subsurface VOC source medium is contaminated soil or shallow groundwater. It is an unnecessary Tier I step, however, if measured groundwater or soil gas concentrations are <u>below</u> generic screening levels.

Sections 3.1.1 through 3.1.3.3 below discuss how investigators can determine if concentrations of VOCs in the subsurface are high enough to pose a potentially unacceptable threat to indoor air quality within current or future site area buildings.

SUBSURFACE SOURCE	TIER I ASSESSMENT APPROACH
shallow groundwater (only)	Use measured groundwater concentrations (compare to SLs or input to predictive model). See Section 3.1.1; and/or use measured soil gas concentrations (compare to SLs or input to predictive model). See Section 3.1.3.
vadose zone soil (only)	Use measured soil gas concentrations (compare to SLs or input to predictive model). See Section 3.1.3.
shallow groundwater and vadose zone soil	Use measured soil gas concentrations (compare to SLs or input to predictive model). See Section 3.1.3.
LNAPL (on top of the water table)	Use measured soil gas concentrations (compare to SLs or input to predictive model). See Section 3.1.3.

3.1.1 Tier I: When groundwater is the subsurface VOC source

Shallow groundwater concentration data are compared to generic groundwater screening levels in Tier I to evaluate the need for further assessment or action to address the VI pathway. In deriving the screening levels for groundwater shown on Table B-1 in Appendix B, assumptions have been made about the vadose zone, threatened building, and receptors. These assumptions are discussed below in Section 3.1.1.1. Investigators should not apply the Appendix B screening levels if the site or buildings being evaluated are so inconsistent with these assumptions that the resulting decisions may not be conservative.

Concentrations of suspected contaminants in groundwater are typically measured during the remedial investigation, when the nature and extent of the contaminant plume is being characterized. The quality and representativeness of these data will need to be assessed to determine if they are adequate to the purpose of evaluating the VI pathway for any given building. Groundwater measurements should accurately represent shallow (water table or perched) groundwater contaminant concentrations very near, if not under, the building of concern.[25]

In general, for a VI screening evaluation, Ecology recommends comparing **maximum** building (existing or future)-specific measured shallow groundwater concentrations to screening levels. If these measured groundwater concentrations are below the screening values, and there is no soil contamination or LNAPL, it is reasonable to conclude that further VI assessment is not needed.

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[25] This generally requires: using short screens (10 feet or less); locating a portion of the screen above the water table; and, utilizing low-flow sampling techniques to minimize VOC loss.

In order to derive groundwater VI screening levels, ―acceptable” indoor air concentrations must first be established. In this guidance ―acceptable” indoor air concentrations are based on MTCA Method B (or, in appropriate situations, Method C) air cleanup levels. The groundwater screening levels in Table B-1 of Appendix B were derived, per VOC, using Equation 1 (below).

Equation 1. Generic groundwater VI screening levels

$$SL_{GW} = \frac{SL_{IA}}{VAF * UCF * H_{cc}}$$

Where

SL_{GW}	Screening level in groundwater protective of indoor air, µg/L
SL_{IA}	Acceptable indoor air screening level, µg/m^3. These levels are concentrations protective of human health and can be calculated using the methods and parameters in the MTCA cleanup regulations (WAC 173-340-750).
VAF	Vapor attenuation factor (VAF; unitless);[26] a default value of 0.001 should be assumed in Tier I
H_{CC}	Henry‘s Law constant, unitless[27]
UCF	Unit conversion factor, 1000 L/m^3

Groundwater screening levels calculated with Equation 1 are not site- or building-specific. They assume an attenuation of 1000 times between soil gas concentrations at depth – in equilibrium with shallow groundwater concentrations – and indoor air concentrations. That is, the VAF is assumed to be 0.001. This default VAF should represent most worst case conditions. It was found to be an adequately protective assumption for 95% of the buildings in EPA‘s vapor intrusion database (EPA, 2008).[28]

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[26] The VAF is the reciprocal of attenuation. It is defined as the indoor air concentration of a substance, due to vapor intrusion, divided by its subsurface soil gas concentration.

[27] Henry‘s Law constants for many VOCs can be found in the Ecology CLARC database or are available from EPA. The constants are temperature dependent. Screening Levels in Appendix B have been calculated using Hcc values adjusted to 13°C (average Washington shallow groundwater temperature).

[28] 85% of the buildings in this database were residences. 10% were commercial buildings and 5% were ―multi-use (a mixture of residential and non-residential).

3.1.1.1 Tier I: Limitations to the use of groundwater data for screening

Screening levels are based on a number of assumptions. Site or building conditions may be different than what has been assumed in calculating these levels. The limitations discussed below, associated with using this guidance‘s screening levels, also apply when groundwater VOC concentrations are input to a model (like the Johnson and Ettinger Model) to predict indoor air concentrations. If one or more of the five conditions apply to the site being assessed, Ecology generally recommends that investigators collect Tier I soil gas samples (as discussed in Section 3.1.3) or proceed to Tier II (Section 3.2).

(1) Table B-1 screening levels assume the vadose zone geology is not fractured bedrock, or Karst, with significant vertical fissuring. For this type of geology, the default VAF of 0.001 – and resulting groundwater screening levels – may not be conservative.

(2) If utility lines are present in the area and have been laid in trenches bedded and backfilled with relatively permeable materials, these ―corridors” may present preferential pathways for the movement of gas-phase VOCs. Table B-1‘s groundwater screening levels may not be conservative in these cases.[29]

(3) If utility lines penetrate the floor or walls and leave large unsealed openings into a building, if there are sumps in the floor of the building that are ―open” to soil gas, or if the building has an earthen floor, relatively more soil gas may enter the structure than is assumed when applying a VAF of 0.001. Table B-1‘s screening levels, therefore, may not be conservative in these cases.[30]

(4) If the water table is very shallow (less than 15 feet bgs or within a few feet of the building‘s lowest floor), very little attenuation is likely to occur in the vadose zone. In these cases, assuming an attenuation of 1000 times (a VAF of 0.001) may not be conservative and the screening levels in Table B-1 may not be adequately protective.

(5) The screening levels assume there is no LNAPL on top of the water table. If LNAPL is present, the screening levels may not be conservative, and are unlikely to be relevant. That is, where (and while) LNAPL covers the water table the *VI source* is the LNAPL itself, not the groundwater.

3.1.1.2 Tier I: Petroleum hydrocarbons in shallow groundwater

For the readily biodegradable petroleum components benzene, toluene, ethylbenzene, and xylenes (BTEX), Ecology will allow the assumption of ten times more attenuation when deriving generic groundwater screening levels, as long as subsurface conditions clearly favor a considerable degree of biodegradation. That is, for vadose zone conditions favoring aerobic biodegradation, and where the distance from the structure to the water table is more than a few

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[29] Utility corridors can provide preferential pathways for lateral VOC molecular movement in soil gas. If this occurs, groundwater concentration spatial patterns may not be good indicators of overlying soil gas concentrations.

[30] A VAF of 0.001 assumes that soil gas primarily enters buildings through small cracks in floors and at the footprint perimeter where the floor and walls interface. If, in actuality, intrusion occurs through significantly larger openings, this VAF value may not be sufficiently conservative.

meters, the groundwater to indoor air VAF can usually be assumed to be at least 0.0001 for these aromatic petroleum hydrocarbons. Investigators can therefore multiply the shallow groundwater screening levels in Table B-1 by ten for these constituents.

Note: if this is done, Ecology will then require site investigators to document conditions favorable to aerobic degradation. Such conditions require sufficient vadose zone oxygen content (4% or higher) and other conditions described by DeVaull (1997 & 2002).[31] Alternatively, investigators may demonstrate, through sampling that site soil gas actually attenuates to this degree within the vadose zone.

3.1.1.3 Tier I: When shallow groundwater VOC concentrations exceed screening levels

When shallow groundwater VOC concentrations in the vicinity of a building are below screening values, there is no soil contamination or LNAPL, and the assumptions of section 3.1.1.1 are not contradicted, it is reasonable to conclude that further assessment to address vapor intrusion is not needed. But if groundwater concentrations are above the generic screening values, further evaluation and/or action is needed. If the building of concern is an existing structure, the options include:

- Predicting maximum (that is, conservative estimates of) indoor air concentrations using the Johnson and Ettinger model (JEM) with conservative assumptions.[32] When site groundwater concentrations exceed Table B-1's screening levels, the JEM can be used to improve attenuation estimates based on site-specific considerations. This may lead to derived VAF estimates significantly lower than 0.001. Ecology recommendations regarding use of the JEM are included in Appendix D.

  If the JEM derives predicted indoor air concentrations that are above acceptable indoor air levels, or if site and/or building conditions disqualify the model's use, Tier II assessment, collection of soil gas samples, or mitigation is required. But JEM predictions can also offer a Tier 1 off-ramp, similarly to a comparison to generic screening levels. It is reasonable to conclude that further vapor intrusion assessment is not needed if:

  a) measured groundwater concentrations used in the JEM predict indoor air concentrations that are below acceptable levels,

  b) the JEM has been used conservatively,

  c) there is no soil contamination or LNAPL, and

  d) the *limitations* noted above in 3.1.1.1 and in Appendix D are not violated.

- Collecting and evaluating soil gas data (see Section 3.1.3 below).

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[31] Other vadose zone attributes conducive to aerobic biodegradation include sufficient soil moisture (available water greater than the wilting potential), an energy source (hydrocarbons), inorganic mineral nutrients (such as nitrate, phosphate, ammonia at natural background levels), and the presence of BTEX degrading microbes. See DeVaull, 1997 and 2002.

Note: The New Jersey VI guidance (2005) recommends multiplying the groundwater screening level by 10 for BTEX constituents.

[32] Generally, this step is only recommended if the screening levels are exceeded by less than 100 times.

- Proceeding to Tier II assessment (see Section 3.2 below).

- Implementing mitigation measures (see Chapter 5 below).

Where the building of concern is not an existing structure, fewer options are available. In this case the investigator can either:

- Predict maximum indoor air concentrations using the JEM as described above. It is reasonable to conclude that further vapor intrusion assessment is not needed if: a) measured groundwater concentrations input to the JEM predict indoor air concentrations that are below acceptable levels, b) the JEM has been used conservatively, c) conservative dimensions and other properties for a hypothetical future residential structure have been input to the model,[33] d) there is no soil contamination or LNAPL, and e) the *limitations* noted above in 3.1.1.1 and in Appendix D are not violated. Or,

- Collect and evaluate soil gas data (see Section 3.1.3 below).

3.1.2 Tier I: When contaminated vadose zone soil is the subsurface VOC source

If soils are contaminated with chemicals identified in Appendix B and a building is, or could be, nearby, the potential exists that VI could lead to unacceptable indoor air levels. Unlike groundwater, soil VOC concentration data are not used in Tier I to evaluate the need for further action to address the VI pathway.[34] Instead, if soil is contaminated with one or more of the substances in Appendix B, Ecology recommends that soil gas (and/or indoor air) usually be sampled to determine the potential vapor intrusion threat to nearby buildings. Tier I soil gas screening is described in Section 3.1.3 below.

3.1.3 Tier I: Using Soil Gas Concentration Data

When the subsurface VOC source is contaminated soils (in the vadose zone), shallow groundwater, LNAPL, a combination of these three, or simply soil gas itself,[35] soil gas concentration data can be used in Tier I to determine whether further evaluation is needed in Tier II to address the vapor intrusion pathway at existing buildings. These data can also be used, like groundwater data, to determine if the site cleanup action needs to address the potential for VI in future (not yet constructed) buildings. If measured concentrations are below levels that could lead to unacceptable indoor air concentrations, it is reasonable to conclude during Tier I that no further VI assessment is needed.

Investigators can utilize sub-slab or deeper soil gas concentrations during Tier I to estimate the strength of the potential VI source. Sub-slab sampling refers to the collection of soil vapors

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[33] This assumes that the investigator is attempting to evaluate the parcel/area for unrestricted use. If the assessment has a different goal, and the investigator is instead attempting to determine the vapor intrusion potential for a different type of future building, that building's dimensions may be input, if known.

[34] EPA has recommended that investigators not rely upon the JEM for deriving VOC soil matrix screening levels protective of the vapor intrusion pathway. The Agency believes that the associated (total) uncertainty is unacceptably high. See EPA 2002.

[35] At some sites (drycleaners, e.g.) there is the potential for a *vapor* release to the subsurface that only contaminates soil gas, not groundwater or vadose zone soils.

immediately beneath the basement floor or slab of the building of concern, often above the soil of fill layer in contact with the slab. Deeper soil gas samples are collected above the VOC source, whether this sample location is directly beneath the slab or outside of the footprint of the building of concern.

When groundwater is the only VI source, investigators should typically either collect sub-slab soil gas samples or soil gas samples just above the water table‘s capillary zone. For vadose zone VI sources, soil gas samples should usually be collected either sub-slab or just above the top of the soil contamination.

Measured soil gas concentrations are compared to generic screening levels or input to a model, like the JEM, and used to predict indoor air concentrations. As with groundwater, ―acceptable” indoor air concentrations must be established before deriving generic soil gas screening levels. In this guidance acceptable indoor air concentrations are based on MTCA Method B (or, in appropriate situations, Method C) air cleanup levels. The screening levels in Table B-1 of Appendix B were derived, per VOC, using Equation 2 below.

Equation 2. Generic soil gas VI screening levels

$$SL_{SG} = \frac{SL_{IA}}{VAF}$$

Where

SL_{SG}	Screening level in soil gas protective of indoor air, µg/m^3
SL_{IA}	Acceptable indoor air screening level, µg/m^3
VAF	Vapor attenuation factor (unitless). A default value of 0.1 should be assumed during Tier I when SL_{SG} will be compared to a sub-slab or shallow soil gas measurement. 0.01 should be assumed when SL_{SG} is compared to a deep measurement.[36]

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[36] EPA‘s draft VI guidance document (2002) suggests that generic soil gas screening levels can be utilized to assess the potential for unacceptable indoor air impacts. EPA‘s document recommends screening levels based on a VAF (which they, consistent with the JEM, denote as ―α”) of 0.1 for soil gas collected sub-slab. Screening levels based on a VAF of 0.01 are recommended for soil gas collected at greater depths.

On March 4, 2008, however, EPA issued another draft document entitled ―Vapor Intrusion Database: Preliminary Evaluation of Attenuation Factors.” For soil gas detections above the analytical reporting level, the 95th percentile database VAF was calculated to be about 0.3 (with a median value between 0.01 and 0.001). The sub-slab 95th percentile database VAF was calculated to be between 0.15 and 0.48 (with a median value similar to the soil gas value; again, only sub-slab detections above the reporting limit were used in the calculation). This suggests the possibility of certain scenarios leading to less attenuation than assumed in EPA‘s 2002 screening level recommendations. EPA does not appear to understand what these scenarios are (or, at least, understand them well enough to be able to advocate default attenuation factors for only a subset of the conditions an investigator might

Soil gas screening levels calculated with Equation 2 are not site- or building-specific. They assume an attenuation of:

a) 10 times between sub-slab soil gas concentrations and indoor air concentrations; and,

b) 100 times between soil gas concentrations at depth and indoor air concentrations.

This should lead to conservative decision-making at most sites.

In deriving soil gas screening levels assumptions must be made about the vadose zone, threatened building, and who the potentially exposed occupants are. These assumptions are discussed in Section 3.1.3.1. Investigators should not rely upon comparisons to screening levels or on predicted indoor air concentrations for decision-making in Tier I if the site and/or building being evaluated are so inconsistent with these assumptions that the resulting decisions may not be conservative.

Furthermore, even when shallow soil gas samples are collected close enough to the building to represent soil gas under the building, there may simply not be enough vadose zone between the sample depth and the building to justify assuming a VAF of 0.01. For samples collected shallower than 15 feet below ground surface (bgs), therefore, measurements should be compared to Appendix B‘s ―sub-slab soil gas screening levels,” not the ―deep soil gas screening levels.”

Soil gas measurements should accurately represent sub-slab contaminant concentrations, or deeper concentrations laterally near the building of concern. This also holds for soil gas samples collected to evaluate potential VI impacts for a building that could be constructed in the future. In general, for a VI screening evaluation, Ecology recommends using the maximum measured soil gas VOC concentrations associated with each existing or future building when comparing to screening levels or as inputs to a model. If these measured soil gas concentrations are below screening levels or predict acceptable indoor air concentrations it is reasonable to conclude that no further assessment is needed.

Due to the possibility of diluting the collected soil gas with atmospheric air, samples should not be collected from depths shallower than 5 feet bgs (unless located sub-slab). As a general rule, soil gas samples – other than sub-slab samples – should be collected right above the subsurface contamination (the VI source). Samples collected near the source often display less spatial variability in measured concentration levels, and investigators can usually sample from a relatively small number of points (laterally). When samples are collected from shallower depths, Ecology will generally require a larger number of collection points (that is, a *denser* sampling design).

When the VOC source is close to the ground surface or basement floor, soil gas samples other than sub-slab samples should be collected right above the top of the contamination. But samples collected from depths this close to the ground surface (assuming they are not collected directly

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encounter). Consequently, Ecology only recommends using generic soil gas screening levels during Tier 1 after consideration of the ―limitations” discussed in Section 3.1.3.1.

below the building), may not represent soil gas at the same depth directly below the building being evaluated. When relatively shallow samples are collected beyond the building footprint, the potential exists for underestimating soil gas concentrations immediately below the building. The uncertainty associated with adequately representing soil gas concentrations just below the building increases as shallow samples are collected further from the building of concern.

Soil gas measurement depths:

- Sub-slab. Compare results to the Appendix B sub-slab soil gas screening levels.
- If not sub-slab:
  1. collect samples deeper than 5' bgs.
  2. collect samples just above the subsurface VI source.
  3. for samples collected ~ 5-15' bgs, compare results to the Appendix B sub-slab soil gas screening levels.
  4. for samples collected deeper than ~15' bgs, compare results to the Appendix B deep soil gas screening levels.

The quality and **representativeness of soil gas data are critical** and will need to be assessed to determine if they are adequate for the purpose of evaluating the VI pathway at any given site and building. To acquire soil gas data that are representative of the depth of interest and locations (laterally) where gas could infiltrate the building, multiple samples will be necessary. Significant spatial variability in concentrations can be expected.

Soil gas samples for vapor intrusion decision-making are typically collected using Summa canisters, and analyzed per Method TO-15 (for VOCs).[37] Ecology expects soil gas sampling for vapor intrusion assessment to be documented in a pre-investigation work plan (sampling and analysis plan and project-specific quality assurance plan) and post-sampling report. Recommendations for VI-related soil gas sampling are provided in Appendix C.

3.1.3.1 Tier I: Limitations to the use of soil gas concentrations when predicting indoor air concentrations

The limitation on using groundwater screening levels when LNAPL is present on top of the

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[37] There may be good site-specific reasons for analyzing soil gas samples via SW-846 Method 8260. For example, where reporting limits do not need to be as low as those customarily attainable by TO-15, this may be a less costly option. Readers are referred to Air Toxics Limited's presentation to the April 2005 Air and Waste Management Association's Symposium on Air Quality Measurement Methods and Technology (http://www.airtoxics.com/literature/papers/Final_AWMA_TO15_8260.pdf).

In addition, most VI investigations will focus on subsurface VOCs (as defined in WAC 173-340-200). But as noted earlier, there are some substances included in Table B-1 that cannot be quantified via Method TO-15. If the investigator believes that soil gas may contain elevated concentrations of these constituents, alternative collection and analytical methods must be used to determine whether the substances may pose a potential vapor intrusion threat. Chlordane and heptachlor are examples. Quantify their presence in soil gas will require sampling methods other than TO-15 or TO-14. Naphthalene is another example. Although there are certain scenarios where naphthalene can be analyzed via TO-15, Method TO-17 is generally the preferred method.

water table need not limit the use of soil gas screening levels as long as the NAPL is below the depth of the soil gas collection/measurement. The first four limitations noted in Section 3.1.1.1, though, also apply to soil gas collected at depth. That is,

(1) Table B-1 screening levels assume the vadose zone geology is not fractured bedrock, or Karst, with significant vertical fissuring. A VAF of 0.01, and hence, the soil gas screening levels, may not be conservative for this type of geology.

(2) If utility lines are present in the area and have been laid in trenches bedded and backfilled with relatively permeable materials, these ―corridors" may present preferential pathways for the movement of gas-phase VOCs. Table B-1's soil gas screening levels may not be conservative in these cases.

(3) If utility lines penetrate the floor or walls and leave large unsealed openings, or if there are sumps in the floor of the building that are ―open" to soil gas, relatively more soil gas may enter the structure than is assumed when applying a VAF of 0.01. Table B-1's screening levels, therefore, may not be conservative in these cases.

(4) If the contamination is very shallow (within a few feet of the building's lowest floor), very little attenuation is likely to occur in the vadose zone. An assumption of 100 times attenuation (a VAF of 0.01) and the resulting screening levels in Table B-1 are unlikely to be conservative in these cases.

    ―Deep" soil gas screening levels can only be used for comparison to soil gas measurements if there is a suitable distance between the sample collection (or measurement) depth and the building's foundation. As with the groundwater screening levels, an assumption is being made in the derivation of the screening levels that vapor concentrations attenuate at least 10 times within the vadose zone between the measurement point and the sub-slab zone. If the vadose zone is only a few feet thick, or if contamination in that zone is shallow, this is a poor assumption and the deep screening levels are not appropriate. Likewise, if the investigator has simply chosen to collect soil gas at a relatively shallow depth, comparing the results to deep screening levels is usually inappropriate. As noted above in Section 3.1.3, samples should be collected at least 15 feet bgs if the ―deep" soil gas screening levels will be applied.

There are few limitations associated with using sub-slab soil gas data. However, if utility lines penetrate the floor or walls and leave large unsealed openings, if there are sumps in the floor of the building that are ―open" to soil gas, or if the building has an earthen floor, a VAF of 0.1 may not be conservative.

3.1.3.2 Tier I: Petroleum hydrocarbons in soil gas

As noted above, for certain petroleum hydrocarbon constituents that biodegrade significantly in the vapor phase, Ecology allows an additional attenuation factor of ten when subsurface conditions favor biodegradation. For conditions favoring biodegradation, then, and where the distance from the structure to the soil gas measurement is more than a few meters, the Table B-1 **deep** soil gas screening levels for BTEX constituents may be multiplied by ten (or, the indoor

BTEX concentration derived from inputting **deep** soil gas measurements to the JEM may be divided by 10).

No assumed biodegradation factor should be applied to sub-slab measurements or soil gas measurements collected from depths close to ground surface (or the basement floor). In addition, as noted above during the discussion of modifying groundwater screening levels, <u>if enhanced BTEX attenuation is assumed, Ecology will require investigators to document site conditions favorable to aerobic degradation</u>. Such conditions require sufficient vadose zone oxygen content (4% or higher) and the other attributes noted in Section 3.1.1.2. Alternatively, investigators may demonstrate, through sampling that site soil gas actually attenuates to this degree within the vadose zone.

3.1.3.3 Tier I: When soil gas VOC concentrations exceed screening levels

When soil gas VOC concentrations in the vicinity of an existing or future building are below screening levels, and the limitations of 3.1.3.1 are not contradicted, it is reasonable to conclude that further assessment to address vapor intrusion is not needed. But if concentrations are above the generic screening values, or if Tier I assessment tools cannot be used due to site or building conditions, further evaluation or action is needed. The options include:

- Proceeding to Tier II assessment (Section 3.2), if an existing building appears to be potentially threatened.

- Predicting maximum indoor air concentrations using the JEM.[38] JEM predictions can offer a Tier 1 off-ramp, similarly to a comparison to generic screening levels. Further vapor intrusion assessment is not needed if the following conditions are met:
    a) measured soil gas concentrations input to the JEM predict indoor air concentrations below acceptable levels,
    b) the JEM is used in a conservative manner (as described in Appendix D), and,
    c) the limitations specified in section 3.1.3.1 are not violated.

  If the JEM predicts unacceptable indoor air VOC concentrations within an existing building, or if site and/or building conditions disqualify its use, the investigator will need to proceed to Tier II or mitigate.

  If the building of concern is not an existing structure, the investigator can still use the JEM, but must input conservative dimensions and other properties, appropriate for a hypothetical future residence.[39] In this case, if the JEM predicts unacceptable indoor air VOC concentrations, the investigator will need to address the potential VI threat as part of the site cleanup action.

- Implementing mitigation measures (see Chapter 5 below).

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[38] Again, this is generally only recommended if the screening levels are exceeded by less than 100 times.

[39] As noted in Section 3.1.2, this assumes that the investigator is attempting to evaluate the parcel/area for unrestricted use. If, instead, the investigator is attempting to determine the vapor intrusion potential for a different type of future building, that building‘s dimensions may be input, if known.

As explained in Section 3.1.1.3, when shallow site groundwater appears to contain VOC levels high enough to pose an unacceptable VI threat, investigators have the option of collecting soil gas samples before sampling indoor air (Tier II). If soil gas is sampled, then, the investigator will have two ―lines of evidence” for assessing the strength of the subsurface VI source: groundwater concentration data and soil gas concentration data. Measured soil gas VOC levels, unlike groundwater levels, may suggest that subsurface contamination is too weak to lead to unacceptable indoor air concentrations. In these cases Ecology expects both lines of evidence to be evaluated before deciding whether further assessment, or other VI-related action, is needed.[40]

Investigators who have only sampled soil gas at depth also have the option of collecting additional, shallower soil gas data. For example, soil gas may be collected at various depths between the subsurface source and the building to better determine the actual degree of attenuation occurring in the vadose zone. Again, though, in these cases Ecology expects all relevant lines of evidence – including the deep measurements – to be evaluated before deciding whether further assessment, or other VI-related action, is needed.

3.2 Tier II Assessment

When Tier I screening fails to lead to a VI assessment off-ramp, the next steps are dictated by whether the building of concern currently exists. If no buildings currently exist, the assessment phase ends with the completion of Tier I. A Tier II assessment cannot be performed unless (or until) there is a building present. Readers may refer to Chapter 6 for a discussion of how the pathway should be addressed later in the cleanup process, whenever subsurface contamination poses a future VI threat.

When the building of concern is an existing structure, Tier II assessment can be used to determine what impact vapor intrusion is actually having on its indoor air. This requires that samples of indoor air be collected and analyzed. At the time indoor air samples are collected the investigator should typically also sample sub-slab soil gas or crawlspace air, as well as building-specific ambient (outdoor) air.[41] The results can then be evaluated together to better estimate how much of the measured indoor air contamination is likely to be due to vapor intrusion. Indoor air contaminant concentrations due to vapor intrusion are compared to acceptable indoor air levels in Tier II to determine the degree to which the pathway may be currently exposing receptors to subsurface contamination.

When developing a Tier II sampling and analysis plan, investigators should begin by constructing a site conceptual model. The purpose of such models is to provide a conceptual understanding of the potential for indoor exposures to contaminants based on the sources of

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[40] Measured soil gas concentrations can be lower than levels predicted from shallow groundwater concentrations for good reasons, and this is why Ecology often recommends that soil gas be measured when the VI source is VOC-contaminated groundwater that only marginally exceeds screening levels. When the only contaminants of concern are BTEX, for example, or the groundwater screening levels are only marginally exceeded, sampling soil gas can improve VI decision-making. However, soil gas measurements do not necessarily represent the actual subsurface VI threat better than shallow groundwater measurements. The quality and representativeness of both data sets should be assessed, and the reasons for obtaining soil gas concentrations lower than screening levels well-understood, before deciding in these cases to base the Tier I decision more on soil gas than groundwater results.

[41] When the guidance refers here and in later sections to ―ambient air” we mean air outside the building and outside of any crawlspace below the building.

contamination, the transport media, and likely intrusion routes. To be optimally useful for VI purposes the model should generally be building-specific and should, **for each building**, contain the following elements:

a) A plan view drawing of the building, showing its spatial relationship to the VOC source. If the source is shallow ground water, the ground water flow direction should be shown and estimates of nearby concentration contours for the VOCs of concern included.

b) If the building has an HVAC system, the drawing should show how air moves within the building and which rooms – if any – are pressurized when the HVAC system is operating.

c) A cross-sectional view of the building, unsaturated zone, and shallow ground water zone. The drawing should depict: how deep the water table is, how deep the VI source is (if it is not the water table), any perched saturated zones, how deep the building foundation extends, the vadose zone strata, and any NAPL known to be present. Ceiling heights should be indicated. Any foundation/ basement features of particular interest should be noted or depicted (such as sumps or other likely soil vapor routes into the building). Sectional-views should be drawn as realistically, and site-specifically, as possible. Even if rough, or hand-drawn, they should attempt to capture the critical characteristics (for VI assessment) of the unsaturated zone and building architecture.

d) A narrative section. This portion of the model should discuss the figures mentioned above and provide explanations for any critical assumptions made in depicting site conditions. It places the VI assessment in context and describes the originating source of the VOC contamination associated with the site (including estimates of release mass and age).

Readers interested in a fuller description of VI conceptual models and their uses should refer to Section 1.2 of ITRC 2007 and Chapter 2 of NJDEP 2005.

Once the sampling and analysis plan has been prepared, the sampling event may be scheduled. Please see Figure 5 on the following page for a summary of the Tier II process.

3.2.1 Tier II indoor air sampling events

Indoor air concentration data are used in Tier II to estimate indoor air VOC concentrations due exclusively to vapor intrusion. Ecology expects all Tier II indoor air sampling to be documented in a pre-investigation work plan (sampling and analysis plan and quality assurance project plan) and post-sampling report. In the work plan Summa™-type canisters should generally be proposed for sample collection, with samples being analyzed via Method TO-15 (for

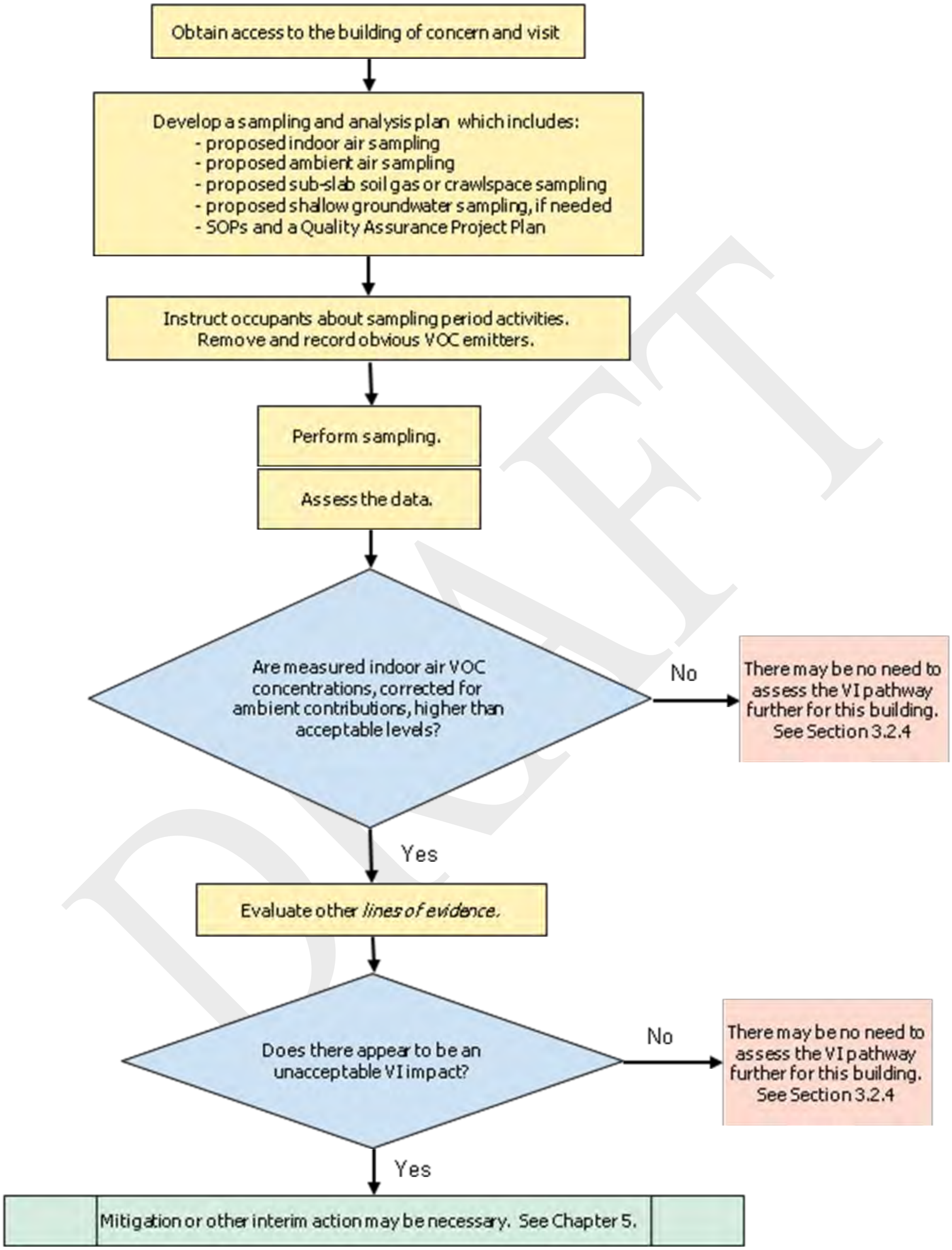

Figure 5. Tier II assessment process.

The figure summarizes the basic Tier II steps.

VOCs).[42] The analyte list should include those VOCs detected in the subsurface in the vicinity of the building.

The canisters used for indoor, outdoor, and crawlspace sampling will typically hold six liters of sample and be regulated to collect air over 24 hours (for homes) or 8 hours (for businesses). At a minimum, the lowest occupied level of the building should be sampled, with sampling designed to measure *reasonable worst case* (―upper bound"-type) VI conditions, indoor air impacts, and receptor exposures.[43]

During Tier II investigations, indoor air may only be sampled once or twice before a decision is made regarding mitigation (or the need for a cleanup action). With such infrequent sampling it is difficult to know if the VOC concentrations measured represent average population levels, median levels, RME-type levels (95% UCLs on the means), or sub-average levels. This is generally the case despite the investigator‗s best efforts to design the study to measure reasonable worst case-type VI impacts. Consequently, Ecology recommends that during Tier II the **maximum** VOC concentrations measured from ―occupiable" indoor areas be used when comparing to acceptable indoor air levels.[44]

This guidance does not include detailed recommendations for how to collect indoor air samples or Standard Operating Procedures for sampling. Detailed recommendations for VI-related indoor air sampling are included in several excellent state guidances. These include:

- The California Environmental Protection Agency, Department of Toxic Substance Control‗s February 2005 *Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air.*
- The Massachusetts Department of Environmental Protection‗s August 2007 *Standard Operating Procedure for Indoor Air Contamination* and April 2002 *Indoor Air Sampling and Evaluation Guide*

Good discussions of VI-related indoor air sampling are also contained in: the Colorado Department of Public Health and Environment‗s September 2004 *Indoor Air Guidance*; chapter 6 of the New Jersey Department of Environmental Protection‗s (NJDEP‗s) October 2005 *Vapor*

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[42] As noted earlier, the guidance document uses ―VOCs" as shorthand when referring to the substances of potential concern. Some Table B-1 substances cannot be quantified via Method TO-15. If the investigator believes that soil gas may contain elevated concentrations of these contaminants, alternative indoor air collection and analytical methods must be used to determine whether they pose a vapor intrusion threat

[43] Generally speaking, periods when the building is ―depressurized" are considered reasonable worst case VI conditions. *Depressurized* in this context refers to a lower indoor pressure relative to outdoor and subsurface pressures. This often occurs during the ―heating season" when the air temperature indoors is significantly higher than outdoor temperatures, and ventilating the interior space with outdoor air is minimized. It can also occur during periods of falling barometric pressure when indoor and outdoor pressures are less than subsurface pressure. Other conditions may also favor vapor intrusion, such as frozen or wet ground conditions, if soil gas contaminants preferentially migrate to the area beneath buildings.

[44] ―occupiable" meaning: regularly occupied living spaces such as bedrooms, dining rooms, living rooms, family rooms, kitchens, etc. Sampling shouldn‗t be conducted in spaces not normally occupied for lengthy time periods such as closets, furnace rooms, etc.

Intrusion Guidance; and, the New York State Department of Health's October 2006 *Guidance for Evaluating Soil Vapor Intrusion in the State of New York.*

3.2.1.1 Tier II: Minimizing indoor VOC contributions to the indoor air measurement

Background concentrations of VOCs can be a significant confounding factor in determining how much impact, if any, subsurface contamination sources are having on indoor VOC levels. Background concentrations can be due to either outdoor or indoor sources. Minimizing background contributions to indoor air contamination is critical to the vapor intrusion assessment if those contributions cannot be easily quantified.

Common household cleaners, solvents, paints, and adhesives; cigarette smoke; and, automobile exhaust from attached garages, all contain VOCs that may contribute to background indoor air VOC contamination. Ecology recommends removing, isolating, or controlling indoor volatile hazardous substances as much as possible prior to and during indoor air sampling. If the sources are portable, removing them is usually the most effective means of keeping their emissions from adding to the indoor air measurement.[45] Once indoor VOC emitters are removed, the area should be well-ventilated before sampling begins. Failure to identify and then remove or isolate indoor VOC emitters can lead to false indications of VI impact.

3.2.1.2 Tier II: Estimating ambient air contributions to the indoor air measurement

Upwind ambient air sampling is typically conducted as an adjunct to indoor air sampling in order to estimate the background contribution of certain VOCs to measured indoor concentrations. A simplifying assumption can be made that in the absence of indoor VOC emitters and vapor intrusion impacts, VOC levels indoors should be approximately the same as VOC concentrations measured in the outdoor air that is supplying the building (see Section 3.2.3 below).[46]

Ambient air samples should be collected and analyzed using procedures similar to those used for indoor air sampling. Ecology recommends using Summa canisters as collection devices and collecting the samples concurrently with indoor air samples.[47] Detailed recommendations for VI-related ambient air sampling are not included in this guidance, but are contained in several excellent state and federal documents. These include the documents referred to in Appendix C and 3.2.1 above.

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[45] This is commonly done several days before the onset of indoor air sampling, when the investigator surveys the indoor environment and notes potential VOC emitters (and especially those that may emit the same VOCs detected in subsurface contamination).

[46] Note that this discussion pertains to situations where ambient air data is being collected during a VI investigation to estimate the impact of outdoor air contamination on an indoor air measurement (which, as the text explains, will generally involve subtracting the ambient measurement results from the indoor air measurement results). Ambient air sampling may be conducted for other purposes. If, for example, the sampling is being conducted to develop a background air cleanup level based on statistics, the samples should be collected upgradient of any area potentially influenced by the site. See WAC 173-340-709 for requirements for establishing background concentrations for adjusting cleanup levels.

[47] Other states and EPA recommend that ambient collections begin at least one hour, and preferably 2 hours, before the indoor collection, and that sampling be terminated no more than 30 minutes after the indoor air collection is stopped (1993 EPA Air/Superfund National Technical Guidance, EPA-451/R-93-012). A small offset such as this makes sense, but it may also be impractical in certain cases to have different sampling-time periods.

When siting ambient air stations the investigator should keep in mind why ambient data are needed for the Tier II VI investigation, and what each sample is supposed to represent. This is true for ambient stations used during the assessment of either a single building or a group of buildings. Since Tier II ambient data are usually needed to estimate ambient VOC contributions to indoor air measurements, Ecology recommends:

a) siting the station upwind of the building being investigated (predictions of wind direction can be obtained from various local meteorological resources);

b) siting the station near the building being investigated, but not so close as to be influenced by VOC emissions emanating from that building;

c) locating the canister inlet well above the ground surface (approximately 2-3 meters); and,

d) locating the inlet well away from trees, airflow obstructions, and point sources of VOC emissions.

3.2.2 Tier II soil gas and/or crawlspace air sampling

During Tier II, sub-slab soil gas results can be used to help estimate the vapor intrusion contribution to the measured indoor air concentration. For this reason, sub-slab soil gas sampling is typically conducted when indoor air is sampled inside buildings that have basements or are constructed slab-on-grade.

Similarly, crawlspace samples may be collected between the floor of the building of concern and the surface soil of the crawlspace. These samples are generally located below any obvious floor penetrations, and well away from perimeter vents. Though they often result in VOC concentrations very similar to those found in first floor indoor samples, if crawlspace sample concentrations are higher than those detected in ambient and indoor air, it is an indication that VI may be contributing to indoor air contamination.[48]

Sub-slab soil gas and crawlspace air samples should usually be collected at the same time, or nearly the same time, as indoor air samples. Generally they are collected using Summa canisters and analyzed per Method TO-15 (for VOCs). Detailed recommendations for VI-related sub-slab soil gas and crawlspace sampling are not included here, but are contained in a number of references, including those noted above in Appendix C and Section 3.2.1.

3.2.3 Tier II: Estimating the indoor air concentration due to VI

The vapor intrusion assessment focus is not on general indoor air contamination, but on the subsurface contribution to indoor air contamination. It is expected that most measurements of indoor air VOCs will be affected by ―background” sources, and Ecology recommends that measured indoor air concentrations be *corrected* for this contribution if it can be done conservatively. Failing to accurately account for background VOC contributions can lead to exaggerating the perceived degree of vapor intrusion and installing unneeded mitigation systems.

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[48] Because crawlspace sampling often results in VOC concentrations very similar to those found in first floor indoor samples, EPA does not recommend that any attenuation be assumed between crawlspace air and indoor air.

Not only does unneeded mitigation entail unnecessary cost, but the installed system will not be effective (that is, it will be unable to reduce indoor air VOC concentrations to target levels.).

There are numerous methods for estimating background indoor VOC concentrations. Ecology recommends basing estimates of the background contribution on building-specific ambient air measurements. Indoor air measurements may be adjusted (that is, *corrected*) by subtracting these estimates when the estimates are based on ambient air measurements concurrently taken upwind of the building(s) in which indoor air samples are being obtained. This is, admittedly, an imperfect approach. It will obviously not account for any indoor VOC source contributions and/or indoor sinks (materials inside the building that absorb VOCs and then slowly emit them over time). Nor can it be assumed that an ambient air measurement near a building is truly an accurate reflection of the ambient air contribution to a particular VOC measurement associated with some indoor sampling location over one 24-hour period. Often there are only one, or perhaps two, Tier II ambient air sampling stations per building.

It appears, however, that:

a) this approach provides a reasonable estimate of the ambient contribution.[49] Actions/studies to better quantify the actual ambient contribution per building appear to be disproportionately costly, and resource-intensive, and lack any standardization; and,

b) even though there are multiple indoor air VOC databases, there is no properly conservative method for quantifying the indoor VOC-source contribution <u>at any given building</u>.[50]

Ecology therefore suggests that investigators use building-specific upwind ambient air measurement data as follows:

- When the measured building-specific upwind ambient air VOC level is the same or higher than the measured maximum indoor concentration for that VOC, assume that VI is unlikely to be significantly impacting indoor air quality. In this situation the ambient contribution to the indoor air concentration is probably close to 100%.

- When the measured indoor air concentration of a particular site-related VOC exceeds the measured ambient concentration of that VOC, assume that the contribution from ambient sources to the indoor air measurement is close to the measured ambient concentration. The VI contribution, which should be compared to acceptable indoor air levels, is <u>the difference</u> between the indoor measurement and the ambient measurement.

3.2.4 Tier II decision-making

This guidance does not suggest how PLPs should design indoor air sampling events to ensure that reasonable worst case VOC concentrations (due to VI) are measured. Nor does it recommend how many Tier II sampling events should be performed before concluding that

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[49] As long as the investigator is confident that the measured VOC levels represent the VOC concentrations in ambient air likely to have impacted indoor air quality within the building of interest during the sampling period.

[50] See the next section (3.2.4) for a discussion of Ecology's recommended use of indoor air databases.

indoor air quality is not being unacceptably impacted by VI. We believe these must be site- and building-specific decisions. In deciding how many events are merited, investigators will need to consider: a) the degree of soil gas contamination (higher concentrations suggesting the need for more than one event); b) the indoor air results (concentrations approaching acceptable levels suggesting the need for more than one event); and, c) the building and meteorological conditions encountered at the time of sampling (sampling during a season other than the ―heating season,” for example, usually suggests the need for at least an additional event during a colder period).

When maximum measured indoor VOC concentrations, ―corrected” as described above, are below Method B (or C, if applicable) air cleanup levels it is reasonable to conclude that vapor intrusion is not currently posing a problem requiring action. When a decision is made to not mitigate, however, the Tier II ―off-ramp” may not always be a conclusion of the assessment. Further actions may be needed to improve confidence in the protectiveness of the investigator‘s decision. Especially in those cases where soil gas levels are significantly elevated, indoor air will commonly need to be sampled more than once. It may even need to be sampled on a routine basis to ensure that indoor VOC levels remain consistently acceptable. Sometimes, due to the cost of such monitoring, installation of a mitigation system may actually be a more cost-effective response (assuming that post-mitigation monitoring requirements would be less onerous/costly).

If Tier II indoor air concentrations are above acceptable levels and it appears that the vapor intrusion contribution has led to concentrations above acceptable levels, action must be taken. Where measured indoor concentrations are well above acceptable levels, mitigation or other effective actions (see Chapter 5 below) should be quickly taken as interim measures. Where measured concentrations are above but very close to acceptable levels, and mitigation would be relatively expensive, repeat sampling should be conducted to confirm the degree of VI impact.

The easiest Tier II scenarios for decision-making are those where:

(1) both soil gas and indoor air VOC measurements are elevated; soil gas greatly exceeds screening levels; and, indoor air is significantly above acceptable levels. In these cases the subsurface contamination will require a cleanup action and mitigation or some other form of interim action should usually be implemented as soon as possible to protect receptors until the remedial action successfully attains groundwater and/or soil cleanup levels.

(2) indoor air VOC measurements are acceptable and Tier I-predicted indoor air concentrations (based on soil gas and/or groundwater measurements) are very close to acceptable levels. In these cases the subsurface contamination may exceed screening levels and require a cleanup action, but indoor air does not appear to be unacceptably contaminated and mitigation should be unnecessary.

Unfortunately, investigators will often be confronted with harder decisions. More difficult scenarios are presented when: a) indoor air VOC measurements are just barely acceptable and soil gas (or groundwater) VOC concentrations are decidedly elevated, or b) indoor air VOC measurements exceed, but are close to, acceptable levels, and soil gas (or groundwater) VOC concentrations are also only marginally elevated. In these two cases PLPs and site managers should usually re-sample indoor air to improve their confidence in the representativeness of the initial measurements.

As noted earlier, investigators should utilize *multiple lines of evidence* when assessing vapor intrusion and this is critical when presented with less than clear-cut scenarios, as described in the paragraph above. The Tier II decision matrices provided in Appendix E can be utilized as a guide for evaluating coupled indoor air and sub-slab soil gas results. The matrices embody the concept that indoor air data should not be used alone when making VI decisions; other pieces of information are critical to estimating the degree of VI contribution to the indoor air measurement. ITRC‘s (January 2007) and other state and federal guidance cited earlier describe additional investigation tools that can be used to more clearly understand the VI impact at a particular building. Examples of these tools include: utilizing tracer compounds and VOC ratios; measuring cross-slab pressure differentials; sampling soil gas at multiple depths;[51] passive soil gas sampling; and, flux chamber sampling.

The indoor concentrations of certain VOCs, such as the BTEX compounds, trimethylbenzenes, and perhaps tetrachloroethene and chloroform, may be higher than building-specific ambient (outdoor) levels, without any significant VI contribution. This can be the case even though actions have been taken pre-sampling to locate all obvious sources of indoor emissions and remove or isolate them. In those cases where the subsurface contaminants of concern include these compounds, therefore, it may be a poor assumption to conclude that the difference between a higher indoor concentration and a lower ambient contribution is primarily due to VI. Assessing other, secondary lines of evidence, such as data from applicable background indoor air databases, will often be needed to better estimate the true VI impact. Investigators should also examine the degree to which sub-slab soil gas is contaminated with the VOCs detected indoors, comparing the ratios of sub-slab to indoor air detections for these VOCs to those of VOCs not expected to be present in indoor air in the absence of VI.

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[51] Vertical soil gas profiles are often created to demonstrate and better quantify vadose zone attenuation. They may also be used to better locate the vapor source in the subsurface or investigate the effect subsurface utility corridors or vadose zone stratigraphic heterogeneities may be having on contaminant transport. See API (2005), DTSC (2005), and NJDEP (2005).

Chapter 4 Community Concerns & Involvement

When investigators identify a subsurface source of volatile chemicals near buildings, they should start making plans to investigate whether vapor intrusion might be a problem. Ecology recommends that once a preliminary assessment establishes the presence of subsurface VOCs within 100 feet of buildings, investigators should communicate to those potentially affected: a) the nature of the potential threat, and b) how the investigation will assess it.

This chapter discusses vapor intrusion-related interactions with the public. Although this material is presented here, following Chapter 3's discussion of assessment techniques, Ecology believes that investigators and regulators should consider the material before embarking on Tier I or II assessments.

Anticipating, listening to, and responding to community concerns can be a major part of a vapor intrusion investigation. Informing people that their homes or offices may be contaminated with harmful vapors requires thoughtful and considered communication. We have included only a brief introduction to the topic here. References included at the end of this chapter more fully discuss public involvement, both generally and in the context of vapor intrusion.

4.1 VI-related Communication with the Local Community

The degree to which the local community is knowledgeable about any given site, and the amount of effort expended by the PLP and Ecology to inform them of site-related developments, varies widely. At some sites, most members of the local community may know little about the site prior to being informed about the potential for VI. Learning that vapors inside your home may threaten your family's health can be understandably upsetting. People will often have many questions, and investigators will need to prepare for answering these questions.

Investigators, PLPs, and Ecology site managers should be prepared for strong and negative reactions from some people when they first hear about site-related contamination in their indoor air. Strong reactions can be expected from affected building owners and occupants, as well as others in the local community. It may not be possible to avoid angry and fearful responses, even when investigations are still in their early stages and VI's impact on indoor air quality has yet to be confirmed.

Site managers and investigators are therefore advised to seek out those more expert in communicating unwelcome environmental news to the public before sending notices or knocking on doors. The Ecology site manager, for example, might want to consult with someone at Ecology having risk assessment and community relations' expertise (public education and outreach staff, for example, and the public information officer), or previous VI experiences. Representatives from state and/or local health agencies can also be helpful when preparing for communications with the public. Assembling a multi-disciplinary team to plan for and then carry out communications with members of the affected public is advisable in cases where a sizable number of buildings will need to be assessed, or whenever investigators can expect significant public interest due to the nature of the site and its locale.

4.2 When Access to Private Property is Needed

A Tier I assessment will usually require at least one visit to the building to determine if Tier I screening/modeling techniques are appropriate.[52] In some situations, Tier II-type assessments may require four or more trips into each building. For example:

- Before writing the sampling and analysis plan, a look inside the building is usually needed to identify candidate sampling locations, investigate possible indoor air VOC sources, and explain the process to occupants.
- A visit to the building is usually conducted several days before indoor air sampling to remove potential indoor VOC-emitting sources.[53]
- A trip to the building is required to set-up sampling stations and begin sampling.
- A trip to the building is required to stop the sample collections and retrieve the sampling equipment.

Additional visits may be needed if also collecting sub-slab soil vapor samples on a different schedule than air samples. If mitigation is implemented, still more visits will be necessary.

Although some property owners and tenants may allow access informally, and may not be interested in the sampling or its results, Ecology recommends developing written access agreements that, once agreed to by the PLP and property owner/tenant, allow the project team to conduct the sampling needed for the assessment.[54] These formal agreements set out each party‘s responsibilities, and describe what information will be provided to the owners and tenants at each point in the process. Specifically, an access agreement should:

a) State what actions the owner will (and perhaps, will not) allow on his or her property.

b) Include procedures for scheduling site visits.

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[52] For example, during Tier I planning the investigator will usually want to inspect the bottom floor of the building to see if there are preferential VI pathways or other conditions requiring initiation of Tier II.

[53] Some investigators use this opportunity, say a week before indoor air sampling, to ask the building owner to ventilate those areas within the structure that will be sampled. Ecology suggests opening windows and doors for 10-20 minutes 48 hours before sampling begins.

[54] In some cases, building owners or tenants may be reluctant to provide access for indoor air sampling. The PLP and Ecology must then take into account the type of building, its use, why access is being denied, what other forms of access might be granted, how well the owner understands the potential risks associated with VI, and whether the owner is the receptor (or the only receptor). It may be appropriate in some instances to remind off-site commercial building owners about language in MTCA that limits liability to property owners, but only when they cooperate with remedial investigations and actions (see RCW 70.105D.020(17)(b)(iv)(D)).

Nevertheless, investigators should **not presume** that building owners and occupants will be opposed to proposals for sampling indoor air. Once a potential for VI has been communicated to the public, residents (especially) typically understand that various measurements need to be made and many will want to know if their homes are affected.

c) Include procedures for coordinating fieldwork and document submittals when a building owner or tenant chooses to hire a private consultant or attorney to oversee the Tier II sampling.

d) Include an attachment with instructions for the tenant, explaining what actions should and should not be done immediately before and during the sampling event.

e) Describe the information and documents that will be provided to the building owner and tenant.

f) Establish when the building owner and tenant can expect to receive copies of the sampling report. When preparing these reports, Ecology recommends providing a cover letter addressed to the owner and tenant, distilling the data, summarizing the findings, and describing the (likely) next steps. For reports which include indoor air data, describing the range of typical indoor concentrations for the VOCs detected is also often advisable.[55]

NOTE: Investigators should explain to owners and tenants that Tier II test results for their building will be reported to Ecology and that these types of documents, once submitted, are not confidential. They are available to the public upon request.[56]

4.3 Helpful Resources for Communications with the Affected Public

Chapter 4 is only a brief introduction to the topic of VI-related community involvement. The following general and vapor intrusion-specific references provide a fuller description of recommended public involvement practices and activities:

California Environmental Protection Agency, Department of Toxic Substances Control (DTSC), *Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air*, 2005.

Colorado Department of Public Health and Environment, *Indoor Air Guidance*, 2004.

Ecology‘s 2008 *Guide to Public Involvement at the Department of Ecology* (#99-751).

ITRC (Interstate Technology and regulatory Council), *Vapor Intrusion Pathway: A Practical Guideline*, 2007.

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[55] Many residential owners and tenants are likely to request assistance from Ecology and/or the Washington State Department of Health if they have questions. Data reports in particular can be difficult to interpret. Building owners and/or tenants may expect not only a copy of the results of the study, but an explanation of what the agencies believe the data indicate. Ecology site managers should be prepared to offer this support when requested, and when responding to PLP VI-assessment plans and reports, should send copies of letters to both building owners and tenants.

[56] Per the Public Disclosure Law, Chapter 42.17 RCW.

Massachusetts Department of Environmental Protection, *Indoor Air Sampling and Evaluation Guide*, Appendix 2, 2002.

New Jersey Department of Environmental Protection, *Vapor Intrusion Guidance*, 2005.

New York State Department of Health, *Guidance for Evaluating Soil Vapor Intrusion in the State of New York*, 2005.

US EPA, RCRA Public Participation Manual, 1996 (EPA 530-R-96-007S, http://www.epa.gov/epaoswer/hazwaste/permit/pubpart/manual.htm).

US EPA, Superfund Community Involvement Handbook, 2005 (EPA-540-K-05-003), http://www.epa.gov/superfund/tools/cag/ci_handbook.pdf).

Chapter 5 Mitigation

Vapor intrusion mitigation is a supplemental or short-term remedial solution intended to protect indoor receptors threatened, or potentially threatened, by indoor air contaminated by soil gas. Mitigation can be ―built-into” a new structure or added to an existing structure. It can utilize exclusively passive measures, or incorporate active devices such as fans. Most vapor intrusion mitigation technologies are those which have been used successfully for radon mitigation. This guidance does not include information about the types of mitigation technologies available, when particular types should be selected over others, mitigation design, or how best to confirm and monitor mitigation effectiveness. The reader is referred to the following four documents for excellent presentations of these topics:

- EPA‘s *Indoor Air Vapor Intrusion Mitigation Approaches* (Engineering Issue, October 2008, EPA 600-R-08-115)
- Chapter 4 of ITRC‘s *Vapor Intrusion Pathway: A Practical Guideline*
- California Environmental Protection Agency, Department of Toxic Substances Control (DTSC), *Vapor Intrusion Mitigation Advisory*, April 2009.
- Massachusetts Department of Environmental Protection, *Guidelines for the Design, Installation, and Operation of Sub-slab Depressurization Systems*, December 1995.

Although retro-fitting existing buildings to incorporate active mitigation technologies such as sub-slab depressurization (see Figure 5-1) can be costly when the buildings are large or when other complicating factors create atypical expenses, installing mitigation as the building is being constructed is usually less expensive. Mitigating an existing single-family residence is also usually inexpensive. Because the costs for mitigating homes are typically so low, Ecology strongly recommends that residences be mitigated when the potential for unacceptable vapor intrusion impacts cannot be quickly ruled out and when cleanup actions focused on the subsurface VI source are unlikely to reach target concentration goals within a very short time frame. For residences, sub-slab or sub-membrane depressurization systems may be considered *presumptive* mitigation approaches, and should not typically require feasibility study-type evaluation prior to selection. Ecology recommends these systems be installed by an experienced certified radon mitigator or another environmental professional with similar experience with landfill gas or vapor mitigation system design and installation.

Ecology also recommends that non-residential buildings be mitigated when assessments conclude that vapor intrusion may be unacceptably contaminating indoor air and a cleanup action capable of quickly remediating the subsurface source is not ready for implementation. PLPs and site managers should expect, however, that mitigating large buildings will be more costly than mitigating houses, and may entail additional permitting requirements.[57]

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[57] Most mitigations of single-family dwellings will typically only require an electrical permit and inspection (assuming that an active, sub-slab or sub-membrane depressurization system is installed). However, the local air authority should routinely be contacted, regardless of the building type, to determine if a permit is required to discharge contaminated soil gas from beneath the building. Mitigations of commercial/ industrial buildings,

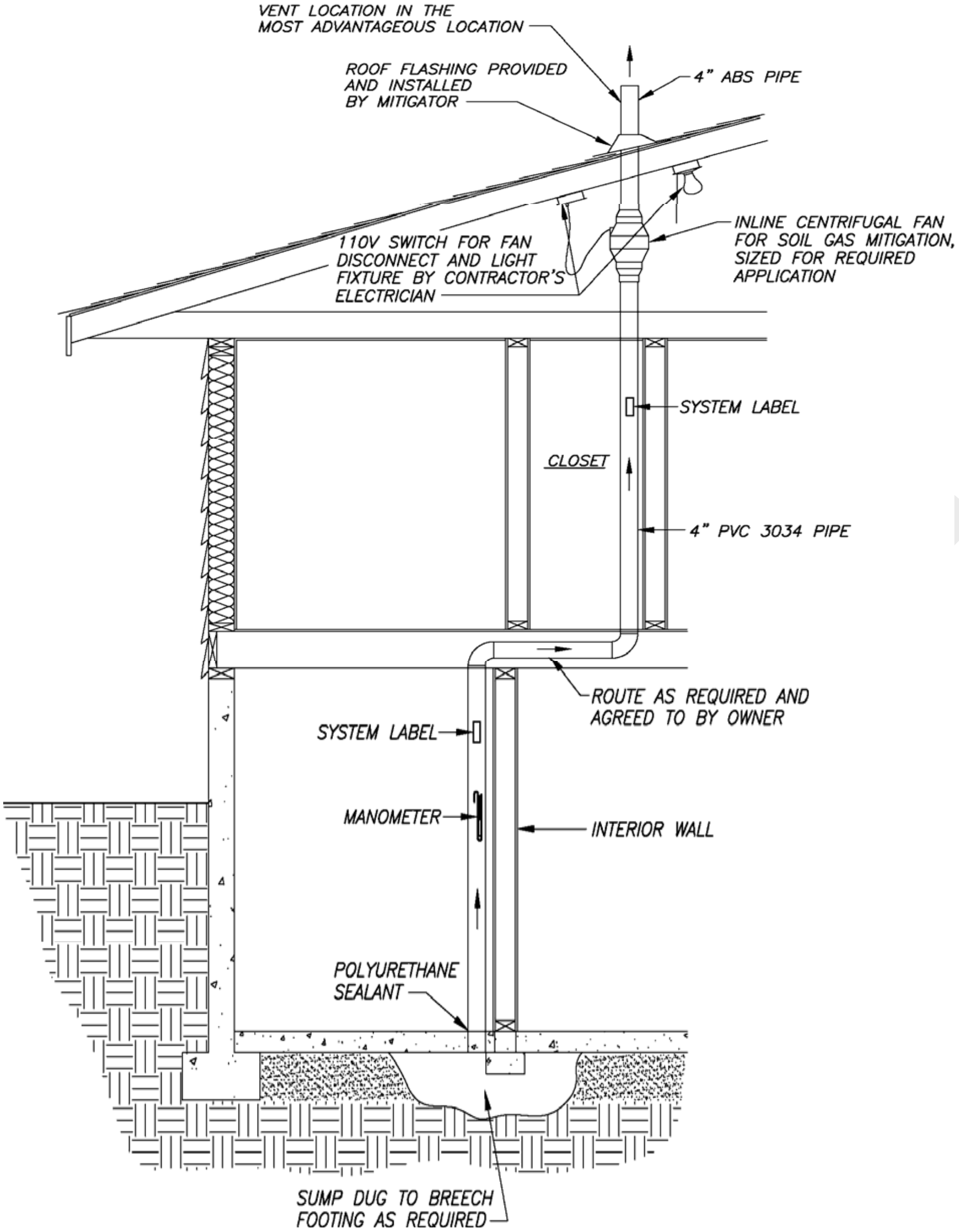

Figure 6. Cross-section of a sub-slab depressurization system

(Tri-Services Handbook for the Assessment of the Vapor Intrusion Pathway, February 2008). Note: installation of the mitigation fan in the attic is only an option if the attic is not, and will not be, occupied.

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depending on the building size and cost/complexity of the mitigation, may be subject to other regulatory requirements (e.g., mechanical and/or other permits).

Since active sub-slab and sub-membrane systems blow contaminated soil gas into the atmosphere above the building‘s roofline, care must be taken in designing the height of the stack and where – in relation to the building‘s windows and intake vents, as well as nearby building windows and vents – the gases are exhausted. ASTM standards for radon mitigation should, at a minimum, be met.[58]

Mitigation emissions

Mitigation systems, such as sub-slab or sub-membrane depressurization systems, do not, by definition, attempt to remediate the subsurface. Basically, their function is to re-route contaminated soil gas that could otherwise enter a building. In the absence of mitigation this soil gas would ―discharge” its contaminants to the atmosphere either directly, at the ground surface, or through the building to the atmosphere.

Commonly, the soil gas being emitted from a mitigation stack is not treated prior to discharge. There are certain mitigation scenarios, however, where investigators should assess the impacts of mitigation emissions to ambient air to ensure that human health is adequately protected. For example, the mitigations of some large buildings require much stronger blowers than are typically used for a house. The VOC emission rates from these systems‘ mitigation stacks may be much higher than those from residential systems. In addition, even if the implemented systems are relatively small, there may be cases where a number of systems have been installed in close proximity to one another. Here again, when the soil gas VOC concentrations being emitted are significantly elevated, the combined emission impact on ambient air should be assessed.

To determine if VI emissions may potentially be leading to unacceptable health impacts, and whether pre-discharge treatment should be considered, investigators usually perform air modeling. Several screening-level models are available for this purpose. The model can estimate air concentrations in the vicinity of the stack discharge, as well as at points nearby, corresponding to site-specific *reasonable, maximally-exposed* (RME) receptor locations.

Public input on mitigations as interim measures

In most cases when a decision is made to mitigate a single building as an interim action, the owner and occupants of that building are considered the ―affected public.” Obtaining permission from the building‘s owner and tenant(s), and any permitting authorities, will therefore be required before proceeding to install the system. Additional public involvement, beyond the minimum required for orders and consent decrees under WAC 173-340-600(16), will likely be required, depending on the public interest in the site and the number of residents and businesses affected.

Other interim actions

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[58] ASTM E 2121-03, Standard Practice for Installing Radon Mitigation Systems in Existing Low-rise Residential Buildings.

As discussed above, mitigation refers to an action that protects indoor air from vapor intrusion but does not attempt to remediate the subsurface source of VOC contamination. In some cases PLPs may prefer to take an action directly on the VI source. Soil vapor extraction (SVE) can often be effective as an interim action to reduce soil gas concentrations. Depending on the design of the system, SVE may be able to not only decrease soil gas contamination but also de-pressurize the sub-slab zone beneath buildings of concern. Removal of the contaminated soils may also be an option. Some quick-acting groundwater treatment systems may additionally be alternatives to mitigation, when the VI source is limited to the saturated zone. Regardless of the technology and which medium it acts upon, it should be capable of protecting indoor air quality as effectively and as quickly as the mitigation techniques discussed above.

Chapter 6 VI Considerations for Site Cleanup

Mitigation is only considered a form of "protection" from potentially harmful exposure. It is not a full cleanup remedy.

Vapor intrusion (VI) mitigation, as discussed in Chapter 5, is a supplemental or short-term solution.[59] Ecology does not expect mitigation systems to attain any VI-based media cleanup levels other than those air levels established to protect receptors inhaling indoor air. If subsurface media are so contaminated that they present a threat to human health via VI, however, cleanup levels for these media will need to be established. Remediation alternatives – beyond any mitigation already implemented – capable of attaining the cleanup levels must therefore be evaluated in a feasibility study. This chapter discusses site remediation considerations for scenarios where contamination poses, or potentially poses, an unacceptable threat to indoor air quality via the VI pathway.

6.1 Establishing Media Cleanup Standards for the VI Pathway

Regulatory requirements for establishing subsurface media cleanup standards protective of the vapor intrusion pathway are contained in WAC 173-340. Requirements for Method B and C groundwater and soil cleanup levels are currently described in WAC 173-340-720, and 173-340-740 and -745, respectively. Method A cleanup standards must adhere to the requirements of WAC 173-340-704.

None of these requirements describes a process for establishing a specific groundwater or soil cleanup concentration for a specific substance at an individual site that is necessarily protective of indoor air. Groundwater cleanup regulations at WAC 173-340-720(1)(d)(iv), however, stipulate that:

> d) The department may require more stringent cleanup levels than specified in this section where necessary to protect other beneficial uses or otherwise protect human health and the environment. Any imposition of more stringent requirements under this provision shall comply with WAC 173-340-702 and 173-340-708. The following are examples of situations that may require more stringent cleanup levels:
>
> (iv) Concentrations that eliminate or minimize the potential for the accumulation of vapors in buildings or other structures to concentrations which pose a threat to human health or the environment.

Similarly, soil cleanup regulations at WAC 173-340-740(1)(c)(vi) state that:

> c) The department may require more stringent soil cleanup standards than required by this section where, based on a site-specific evaluation, the department determines that this is

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[59] Mitigating vapor intrusion is akin, in some respects, to providing bottled water to residents whose drinking water wells have become contaminated. The residents are protected from the contamination in their wells, but the bottled water does nothing to clean-up the groundwater. By definition, subsurface sources of vapor–phase VOCs intruding into buildings will generally not be significantly remediated by mitigation.

> necessary to protect human health and the environment. Any imposition of more stringent requirements under this provision shall comply with WAC 173-340-702 and 173-340-708. The following are examples of situations that may require more stringent cleanup levels.
>
> (vi) Concentrations that eliminate or minimize the potential for the accumulation of vapors in buildings or other structures.

Method A Section 173-340-704(3) also has such language:

> (3) **More stringent cleanup levels.** The department may establish Method A cleanup levels more stringent than those required by subsection (2) of this section, when based on a site-specific evaluation, the department determines that such levels are necessary to protect human health and the environment. Any imposition of more stringent requirements under this provision shall comply with WAC 173-340-702 and 173-340-708.

The MTCA cleanup standards are intended to provide protection of indoor air quality as part of an overall cleanup action being implemented at a site. This chapter discusses various issues and scenarios associated with calculating subsurface concentrations that should be low enough to protect virtually any building located in the contaminated area.

To calculate VI-protective concentrations, investigators must identify target indoor air concentrations the subsurface source should be cleaned-up to protect. The MTCA regulations at WAC 173-340-750 provide Method B *unrestricted* (residential) air cleanup levels and Method C industrial air cleanup levels. While Method B can be thought of as the default method for calculating acceptable indoor air levels, industrial air cleanup levels are applicable when the building of concern is located on ―industrial” property (per WAC 173-340-200 and -745) and receptors are industrial workers.[60] In either case, Ecology‘s concern with indoor air quality in the context of vapor intrusion focuses exclusively on the contaminant concentrations in indoor air <u>coming from a subsurface source</u>.

For the VI exposure pathway, acceptable indoor air quality for the purposes of WAC 173-340 is defined as those indoor air concentrations resulting only from VI which do not exceed Method B or industrial air cleanup levels.

Therefore, whether the building is located on an industrial property, is a residence, a public building, or is a non-industrial commercial building, the focus remains on the subsurface contribution to indoor air contamination.

6.2 Establishing Protective Groundwater Concentrations for the VI Pathway

When shallow groundwater is contaminated with VOCs, and buildings are either near that contamination or could be constructed near the contamination in the future, Tier I assessment procedures in Chapter 3 describe how to determine if the contamination poses a potential VI threat. Basically, four different approaches are discussed:

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[60] Method C also applies to manholes or underground vaults where worker exposure is the concern.

(1) Comparing shallow groundwater concentrations to generic groundwater screening levels (provided in Appendix B).

(2) Comparing soil gas concentrations to generic soil gas screening levels (also in Appendix B).

(3) Inputting shallow groundwater concentrations into the JEM and predicting indoor air levels.

(4) Inputting soil gas concentrations into the JEM and predicting indoor air levels.

The first two approaches can tell the investigator whether the VOC strength in the subsurface is sufficient to pose a potential VI threat for any building.[61] The second two approaches can as well, if the building that is modeled conservatively represents a future house, reasonably prone to intrusion.[62]

When site shallow groundwater VOC concentrations exceed generic groundwater screening levels, then, and investigators are attempting to determine the extent to which concentrations should be reduced to protect current and future indoor air quality, there are primarily two options: a) use the groundwater screening levels themselves, or b) calculate site-specific groundwater screening levels using the JEM.[63] Under the second option, the JEM is used to *back-calculate* groundwater VOC concentrations that result in given indoor air levels (Method B air cleanup levels, for instance, if the future building of concern is a home). Please see Section 6.5 below.

At sites where Method A or B groundwater cleanup levels are being established that will be protective of ingestion (such as drinking water-based cleanup levels), these levels will often be low enough to also protect indoor air quality. Several substances identified in Appendix B, however, have groundwater VI screening levels lower than Method B drinking water-based cleanup standards.[64]

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[61] Ecology realizes that certain atypical structures could be constructed at a site that would be much more prone to VI impacts than most occupied buildings in Washington. But what we are referring to here is a small residential building with dimensions and ventilation rates consistent with the ―default” JEM assumptions listed in Appendix D. We are also assuming that the new building would have a non-earthen floor, have no open sumps, and have a basement or first floor above the seasonally-high water table. So admittedly, by ―any type of structure” we really mean ―almost all types of new structures that would be occupied for relatively long periods.”

We realize, therefore, that is it possible that a new, highly-susceptible building could be constructed on a property where Ecology has concluded that the subsurface contamination could not pose an unacceptable threat to human health via VI, and, because the building is unusually susceptible to VI, indoor air could be unacceptably contaminated. We believe this will only rarely occur, if at all. As part of the cleanup action plan development process, PLPs and site managers should re-visit the ―any structure” assumptions for the site in question and ensure that they appear conservative.

[62] Appendix D provides default parameter values for modeling such a house with the JEM.

[63] Please see Appendix D for an explanation of what Ecology considers a conservative application of the JEM.

An additional option is briefly discussed in Section 6.6.3. Under this option, site-specific groundwater screening levels can be calculated using empirically-derived attenuation factors.

[64] Some examples include: carbon tetrachloride, chloroform, tetrachloroethene, and trichloroethene

6.3 Establishing Protective Soil Concentrations for the VI Pathway

WAC 173-340-740(3)(b)(iii)(C)(III) currently states that:

> C) **Soil vapors.** The soil to vapor pathway shall be evaluated for volatile organic compounds whenever any of the following conditions exist:
>
> (III) For other volatile organic compounds, including petroleum components, whenever the concentration is significantly higher than a concentration derived for protection of ground water for drinking water beneficial use under WAC 173-340-747(4).

WAC 173-340-740(3)(b)(iii)(C) also states that subsection (3)(c)(iv)(B) contains methods that may be used to evaluate the soil to vapor pathway. Subsection (B) lists four –methods:”

> B) **Evaluation methods.** Soil cleanup levels that are protective of the indoor and ambient air shall be determined on a site-specific basis. Soil cleanup levels may be evaluated as being protective of air pathways using any of the following methods:
>
> (I) Measurements of the soil vapor concentrations, using methods approved by the department, demonstrating vapors in the soil would not exceed air cleanup levels established under WAC 173-340-750.
>
> (II) Measurements of ambient air concentrations and/or indoor air vapor concentrations throughout buildings, using methods approved by the department, demonstrating air does not exceed cleanup levels established under WAC 173-340-750. Such measurements must be representative of current and future site conditions when vapors are likely to enter and accumulate in structures. Measurement of ambient air may be excluded if it can be shown that indoor air is the most protective point of exposure.
>
> (III) Use of modeling methods approved by the department to demonstrate the air cleanup standards established under WAC 173-340-750 will not be exceeded. When this method is used, the department may require soil vapor and/or air monitoring to be conducted to verify the calculations and compliance with air cleanup standards.
>
> (IV) Other methods as approved by the department demonstrating the air cleanup standards established under WAC 173-340-750 will not be exceeded.

This guidance has not established soil VI screening levels for any of the Appendix B substances. When vadose zone soils are contaminated with VOCs, and buildings are either near that contamination or could be constructed near the contamination in the future, Ecology recommends that Tier I soil gas samples be collected to assess the potential VI threat. This is consistent with (B)(I) above. Ecology also recommends that the JEM not be used to predict indoor air concentrations from soil VOC concentrations.[65] So although (B)(III) allows modeling to be used for this purpose, at present Ecology is unaware of a model that will predict indoor air concentrations from soil inputs with an acceptable level of certainty.

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[65] Ecology believes that JEM indoor air predictions based on inputted (bulk) soil concentrations are likely to have significant associated uncertainty. EPA (US EPA, 2002) has, for this reason, not recommended the model for predicting indoor air concentrations from soil sources. If PLPs are interested in using a modeling method to calculate protective soil levels for TO-15 VOCs, that approach will need prior approval by Ecology.

Consistent with WAC 173-340-740(3)(b)(iii)(C)(III), at sites where soil cleanup levels are being established that will be protective of groundwater as a drinking water resource, these levels are likely to be low enough to be protective of indoor air via the VI pathway. However, this cannot be assumed at all sites.

6.4 Establishing Protective Soil Gas Concentrations for the VI Pathway

Regardless of the source of the subsurface contamination (i.e., whether groundwater, soil, and/or soil gas is contaminated, and whether LNAPL is or is not present), if buildings are either near that contamination or could be constructed near the contamination in the future, soil gas measurements can be used to assess the contamination's potential to unacceptably impact indoor air. Tier I procedures in Chapter 3 discuss the two basic approaches:

(1) Comparing soil gas concentrations to generic soil gas screening levels (provided in Appendix B).

(2) Inputting soil gas concentrations into the JEM and predicting indoor air levels.

The first approach can tell the investigator whether the VOC strength in the subsurface is sufficient to pose a potential VI threat for any building. So can the second approach if the building that is modeled conservatively represents a future house, reasonably prone to intrusion.

If investigators are attempting to determine the extent to which soil gas concentrations should be reduced to protect current and future indoor air quality, there are primarily two options: a) use the soil gas screening levels themselves, or b) calculate site-specific soil gas screening levels using the JEM.[66] As with groundwater, the JEM can be used to back-calculate soil gas VOC concentrations that would result in Method B or industrial air cleanup levels. This is discussed further in Section 6.5 below.

Soil gas concentrations low enough to conservatively protect indoor air quality have particular utility at the end of a cleanup action, when the PLP is attempting to demonstrate that the completed cleanup is adequately protective. The PLP can use these concentrations to demonstrate, through measurements, that residual site soil and/or groundwater contamination does not produce soil gas levels high enough to pose a VI threat. The soil gas measurements used for this purpose must then be taken at depths that correspond to the depths associated with the VI-protective concentrations being used. Both generic soil gas screening levels and model-generated protective soil gas concentrations are depth-specific (see Chapter 3, and Appendices B and D).

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[66] An additional option is briefly discussed in Section 6.6.3. Under this option, site-specific soil gas screening levels can be calculated using empirically-derived attenuation factors.

6.5 "Back-calculated" Subsurface Concentrations, Protective of Indoor Air Quality

As discussed above, the JEM can be used to back-calculate a groundwater or soil gas VOC concentration that would result in a given indoor air level. Unfortunately, the EPA JEM spreadsheets and on-line calculator are not structured to accept target indoor air levels that groundwater or soil gas concentrations can then be calculated to attain. This is problematic because EPA calculates risks and hazards somewhat differently than they are currently calculated in the MTCA regulations. Method B equations for indoor air cleanup levels in WAC 173-340-750 currently utilize reference dose and carcinogenic slope factor toxicity information (RfD_i and SF_i), whereas the JEM uses reference concentrations and unit risk factors (RfC_i and URF_i). The predicted groundwater and soil gas concentrations the model produces to be protective of indoor air (for a carcinogenic risk of 1E-6 risk or a non-carcinogenic hazard quotient of 1.0) are therefore not the same as those it would derive to be protective of Method B air cleanup levels. Calculating VI-protective groundwater and soil gas concentrations via the JEM must currently be accomplished through a two-step use of the model's *forward* calculation. Please refer to Appendix D, Table 2, for recommendations on how to accomplish this.

NOTE: The approaches described above for establishing subsurface media concentrations, protective of the VI pathway, may not account for bioattenuation in the vadose zone. As discussed in Chapter 3, some volatile petroleum hydrocarbons in soil gas are capable of significant biodegradation. Benzene, toluene, ethylbenzene, and xylenes, for example, are known to degrade when conditions in the vadose zone separating the contamination source and building are conducive to aerobic biodegradation. Using Appendix B groundwater or deep soil gas screening levels, or protective groundwater or deep soil gas concentrations back-calculated by the JEM, as cleanup targets, can therefore be overly conservative.

6.6 Other Cleanup-related Considerations

6.6.1 Soil gas/vapor contamination

The MTCA regulations do not contain requirements for calculating and then achieving <u>soil vapor</u> cleanup standards. Nevertheless, even if groundwater is remediated to concentrations below VI-protective cleanup levels, contaminated soil vapor may persist for a time and continue to pose a potential threat to indoor air quality. In this case – where groundwater and indoor air are at or below cleanup levels but soil vapor remains contaminated – site managers will need, at a minimum, to continue monitoring indoor air and soil vapor to ensure that indoor receptors are adequately protected.

In addition, there are some release scenarios where the VOC release to the subsurface is entirely in the gas phase. Tetrachloroethene (PCE) releases from drycleaner sites, for example, where the chemical in its gas phase is denser than air, may sometimes fall into this category. In these cases soils and groundwater may not be contaminated, but soil gas – and, potentially, indoor and ambient air – will be. So again, as long as soil vapor is contaminated, site managers may need to continue monitoring both indoor air and soil vapor to ensure that indoor receptors remain adequately protected.

6.6.2 Non-residential, non-industrial buildings

Where the building of concern is being used commercially (but is not located on an industrial property), and the most highly exposed receptors are workers, the Method B exposure assumptions in WAC 173-340-750 Equations 750-1 and 750-2 are likely to be overly conservative. Average body weight, for example, in Equation 750-1 is 16 kg (representing a child), whereas the receptors of concern at most commercial properties will be adults with an average weight closer to 70 kg. In addition, the amount of time exposed will often be less than default values: most receptors in a commercial building will not be exposed to contaminated indoor air 24 hours per day, seven days a week, all year long. Therefore, while subsurface source concentrations must eventually be remediated to cleanup levels derived from Method B air cleanup levels to free the property of any future development restrictions, current receptors can be considered protected if indoor air concentrations are somewhat higher than Method B air cleanup levels.

Indoor air VOC concentrations, fully protective of the current receptors inside a non-residential building, can be calculated by changing the inputs to Equations 750-1 and/or 750-2, as applicable, to better reflect exposures to an adult worker. The resulting protective air levels may be utilized to decide if interim measures are needed, or to phase the site cleanup.

6.6.3 Empirically-based, site-specific VAFs

Chapter 3 discusses two –sources” for VI attenuation factors (VAFs): (1) assumed VAFs for groundwater and soil gas recommended by EPA, and (2) VAFs calculated by the JEM. At relatively large sites, some PLPs may choose to empirically derive site-specific attenuation factors that can then be used to assess impacts to current buildings and derive VI-protective subsurface concentrations. Although this alternative may be approved by Ecology on a site-by-site basis, PLPs should be forewarned that such an approach is likely to be resource-intensive and will need, in the end, to be demonstrably conservative for the range of buildings, VI sources, and subsurface conditions the PLP intends to use the derived values for. A work plan (including a SAP and QA Project Plan) will need to be prepared, proposing the type of data to be collected, how those data will be used to estimate attenuation, and how the attenuation estimates will be used in making site decisions.

6.6.4 Multiple VOCs and pathways of exposure

While for the purposes of explanation it is often simpler to speak as if there is only one contaminant of interest, there will be many sites where multiple VOCs pose a vapor intrusion concern. VI-protective subsurface concentrations for these VOCs can be derived independently, as discussed above, but may then need to be adjusted downward, depending on the number of VOCs and the MTCA Method being employed.[67]

It should also be kept in mind that although our focus here is on vapor intrusion, the RI/FS must assess all viable exposure pathways. It is possible that an indoor receptor, breathing air impacted by VI, may also be exposed to contamination via another route, such as by drinking groundwater. In setting RI/FS media cleanup levels, therefore, attention must be paid to total, cumulative site risk. Where multiple pathways are likely to expose receptors in a non-mutually exclusive manner, cleanup levels are likely to need downward adjustment to ensure that cumulative site-contributed risks are acceptable.

6.7 Institutional Controls

Institutional controls, in the context of vapor intrusion and the MTCA regulations[68], are somewhat like mitigation actions. That is, they keep (or help keep) receptors from being unacceptably exposed to VI-contaminated indoor air, but do not remediate the subsurface contaminant source. Regulatory requirements for establishing protective institutional controls are contained in WAC 173-340-440. This section of the guidance discusses why certain controls may be needed at sites where VI is a concern.

Institutional controls are often used to ensure that the building/property use being assumed in the VI assessment and RI/FS continues in the future. While it may not have been necessary to implement a mitigation system for a commercial use which existed during the RI/FS, for example, a less restrictive use – such as future residential development– may require such a system if the subsurface remains contaminated. Changes in use could be related to how long receptors are exposed to indoor air or the types of receptors exposed (redevelopment of commercial property for residential use is an example). Usually the institutional control will need to be effective until the site remedy has resulted in attainment of media cleanup levels.

Institutional controls may also be needed to ensure that changes to the building‘s structure do not create new vapor intrusion problems. The investigator may assume, for example, that a particular building being used commercially will remain in use without modification (or that if it is replaced, it will be replaced by another, similar, commercial building). If the building investigated during the RI/FS is replaced by a different building in the future, however, or it is re-modeled, the soil gas impact on indoor air quality could easily be different. Institutional controls can be devised to make sure that the PLP and/or Ecology is notified if the property owner is contemplating building changes.

The degree of exposure to VI-related contamination may also change in the future even though the building remains the same, the amount of time receptors spend in the building (and/or the building *use*) stays the same, and the type of receptors exposed does not change. This is because

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[67] The acceptable MTCA risk threshold applies to all site-related contaminants. If there are multiple contaminants, the potential exists that even if all were to attain individually protective levels the total VI-associated risk would exceed the MTCA threshold.

[68] WAC 173-340-200 defines institutional controls. WAC 173-340-440(4) states that these controls are required when: media concentrations exceed established Method B cleanup levels; cleanup levels are established per Method C; an industrial soil cleanup level is established; or Ecology determines ―such controls are required to assure the continued protection of human health and the environment…”

it is possible that some change to the building‘s operation will be made in the future that affects indoor VOC concentrations. For example, the indoor/outdoor air exchange rate that was assumed – or demonstrated to exist – at the time the structure was investigated or modeled could decrease in the future due to remodeling or changes to the building‘s heating, ventilation, and air conditioning (HVAC) system. Dilution of any VI contributions to indoor air would then be expected to also diminish, with indoor air VOC concentrations increasing as a result. Such an increase might well go unnoticed if indoor air monitoring were not being conducted.[69] Similarly, a commercial building may currently be under constant positive pressure (with respect to the subsurface) and effectively minimizing VI as result. Future HVAC changes could result in a discontinuation of sufficient interior pressure to maintain this gradient. If so, soil gas intrusion rates could increase and impacts to indoor air may become no longer acceptable.

In general, institutional controls will commonly be needed when subsurface contamination poses a potential VI threat, and

a) actions to reduce source concentrations will either not be implemented quickly, or will take a relatively long time to reach cleanup goals,

b) mitigation is required, and

c) Ecology concludes continued operation of, and/or access to, the mitigation system is needed.

Institutional controls will also usually be needed when subsurface contamination poses a potential VI threat, and

a) actions to reduce source concentrations will either not be implemented, or will take a relatively long time to reach cleanup goals, and

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[69] Tier II assessment may conclude that VI is not currently a problem at a particular building, but many times – if soil gas is significantly contaminated – the investigator may not really know why. Low indoor VOC levels may be due to some building condition that the building owner or tenant is under no obligation to maintain. Operation of the HVAC system, for example, may be keeping concentrations at acceptable levels. HVAC systems can control the amount of outdoor air that is brought into the building. When they are operated at high air exchange rates they will dilute whatever impact vapor intrusion has on indoor air quality.

Some HVAC systems can also be designed to induce positive indoor air pressures. Investigators should therefore realize that indoor air in certain commercial buildings, or parts of buildings, can be positively pressurized with respect to the subsurface <u>at the time the building‘s indoor air is being sampled</u>. If so, it is likely that any indoor air measurements will indicate that VI is not a problem.

When a Tier II assessment concludes that any VI impacts appear to be acceptably minimal, PLPs and Ecology must decide if the reason is linked to <u>a building condition subject to change</u>. In situations where the building‘s HVAC system is operating in essence as a mitigation measure, as long as a source of VOCs continues to be present in the subsurface, VI is a potential threat and changes to HVAC system operation could lead to VI-sourced indoor VOC levels that are unacceptable. HVAC systems are commonly operated to efficiently warm, cool, and ventilate their buildings, not minimize VI. They may operate differently at different times of the day, on different days of the week, and at different times of the year. They are likely to operate somewhat differently depending on whom the tenant is and what the tenant does inside the building.

b) no buildings currently exist in the area of the contamination, but could be constructed there in the future.

In addition, controls are also likely to be needed when subsurface contamination does not currently pose a potential VI threat to a particular structure, but the threat might become unacceptable were:

a) the use of that structure to change (the types of receptors or exposure durations, for example),

b) the building to be re-modeled or a different building constructed, or

c) the ability of that structure to protect indoor air quality to change (due to changes in ventilation rates, or the installation of sumps, for example).

The ability of any controls to effectively achieve the protection they are intended to guarantee must also be factored into Ecology‘s decision regarding what constitutes a ―reasonable restoration timeframe” for the site in question. Reliance on relatively weak controls will commonly be appropriate only at sites where restoration (cleanup level attainment and retirement of the control) can be rapidly achieved.

6.7.1. Control Mechanisms

To safeguard against future undesirable changes (from a VI standpoint) within un-mitigated buildings, or in how they are used or occupied, the Ecology site manager should consider requiring controls and/or various PLP responsibilities in the site cleanup action plan. For instance, the PLP may be required to monitor indoor air concentrations and/or building conditions and use until media cleanup levels are attained. If building conditions or use change before media cleanup levels have been achieved, an action can be triggered to assess the consequences of the change. The action could be an inspection or investigation and/or the establishment of new cleanup or remediation levels; it could be mitigation. See WAC 173-340-440(8)(c).

When a PLP is under an order or consent decree, is a ―RCRA facility” owner or operator with a permit, or receives a ―no further action” under Ecology‘s voluntary cleanup program, these legal instruments can contain VI-related requirements that the PLP must comply with. For example, if Ecology concludes that the PLP should monitor certain building conditions and/or indoor air quality, a requirement for performing such tasks can be included in the order, decree, or permit.

Institutional controls will typically also be described in an environmental covenant on the property. The covenant can establish requirements associated with currently existing buildings, as well as property (parcels) not presently developed, but vulnerable to VI impacts should buildings be constructed.

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Appendix A: Acronyms, Abbreviations, Symbols, and Notation

AER or E_B: Indoor/outdoor air exchange rate for a given building

ASTM: American Society of Testing and Materials

$C_{\max}$: maximum pure vapor concentration at 25°C, M/L^3

CAP: Cleanup Action Plan (see WAC 173-340-200 and -380)

CLARC: The Ecology Toxic Cleanup Program's *Cleanup Level and Risk Calculations* database

Ecology: Washington State Department of Ecology

EPA: United States Environmental Protection Agency

FS: Feasibility Study (see WAC 173-340-200 and -350)

H_{cc} or HLC: Henry's Law Constant. H_{cc} is the unitless form. See http://www.epa.gov/superfund/health/conmedia/soil/pdfs/part_5.pdf

HI: Hazard Index

HQ: Hazard Quotient

HVAC system: a building's heating, ventilation, and air conditioning system

ITRC: Interstate Technology and Regulatory Council

JEM: Johnson and Ettinger Model

kg: kilograms

µg/l: micrograms per liter. A common unit for quantifying groundwater contaminant concentrations

µg/m^3: micrograms per cubic meter. A common unit for quantifying air and soil gas contaminant concentrations. Typically air and gas sampling results are reported in either µg/m^3 or parts per billion volume (ppbv).

To convert ppbv to µg/m^3: µg/m^3 = [ppbv X MW]/24.45

where MW is the compound's molecular weight

MTCA: the Washington State Model Toxics Control Act

MTCA Method B and Method C: two methods described in WAC 173-340 for calculating cleanup levels

NAPL: non-aqueous phase liquid. LNAPL refers to light NAPLs, less dense than groundwater. DNAPL refers to NAPLs denser than groundwater.

OSHA: the federal Occupational Safety and Health Administration

PAHs: poly-cyclic aromatic hydrocarbons

PCBs: poly-chlorinated biphenyls

PLP: Potentially Liable Person (see 70.105D.020(16)). In this guidance the term ―PLP" is used more broadly to refer to the site's responsible party. PLP, then, also refers to those conducting VCP and independent cleanups, even though these individuals may not have been designated as PLPs pursuant to a WAC 173-340-500 determination.

PQL: Practical Quantitation Limit (see WAC 173-340-200)

P_v : Vapor pressure of a chemical at 20°C. Often given in units of atmospheres.

QA/QC: Quality Assurance/Quality Control

Q_B : A parameter in the JEM representing the enclosed space volumetric air flow-rate

Q_{soil} : A parameter in the JEM representing the volumetric flow-rate of soil gas intruding indoors as a result of pressure gradients.

RCRA: Resource Conservation and Recovery Act

RfC: The inhalation RfC (expressed in units of mg of substance/m^3 air) provides a continuous inhalation exposure estimate. The inhalation RfC considers toxic effects for both the respiratory system (portal of entry) and effects peripheral to the respiratory system (extrarespiratory or systemic effects). Used in noncancer health assessments.[70]

RfD: (expressed in units of mg of substance/kg body weight-day) is as an estimate of a daily exposure to the human population that is likely to be without an appreciable risk of deleterious effects during a lifetime. An RfD can be derived from a no-observed-adverse-effect level (NOAEL), lowest (L)-OAEL, or benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used. Used in noncancer health assessments.[71]

RI: Remedial Investigation (see WAC 173-340-200 and -350)

RISK: Cancer Risk

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[70] Taken from IRIS (http://www.epa.gov/ncea/iris/help_ques.htm#rfd).

[71] Taken from IRIS (http://www.epa.gov/ncea/iris/help_ques.htm#rfd).

RME: Reasonable Maximum Exposure. RME is the highest exposure that can be reasonably expected to occur for a human or other living organisms at a site under current and potential future site use.

S : Pure water solubility of a chemical at 25°C

SAP: Sampling and Analysis Plan

SEPA: The State Environmental Policy Act (see WAC 197-11)

SFi: the inhalation carcinogenic slope factor. A slope factor is an upper bound on the increased cancer risk from a lifetime exposure to an agent. This estimate is usually expressed in units of proportion (of a population) affected per mg of substance/kg body weight-day.[72]

SL: Screening Level. SL_{SG}, for example, is a soil gas screening level. These media screening levels are advisory numbers; they have no regulatory effect.

SMD: Sub-Membrane Depressurization, a form of mitigation

SOP: Standard Operating Procedures

SSD: Sub-Slab Depressurization, a form of mitigation

SVOCs: semi-volatile organic compounds

Tier I: a vapor intrusion assessment to determine if subsurface contamination could be a potential threat to indoor air quality

Tier II: a vapor intrusion assessment to determine if subsurface contamination has unacceptably impacted indoor air quality

TO-15: EPA Toxic Organic Compendium Method for the Determination of VOCs in Ambient Air (EPA/625/R-96/010b). VOCs are defined by the Method as organic compounds having a vapor pressure greater than 0.1 Torr at 25°C and 760 mm Hg. Samples are collected in specially-prepared canisters and analyzed by gas chromatography/mass spectrometry (GC/MS). TO-15 is the method most commonly used for collecting and analyzing air samples for VOCs. A similar GC method, TO-14A (EPA/625/R-96/010b), may also be utilized under certain circumstances, depending on the analytes of interest.

The ―normal” mode in which the TO-15 mass spectrometer/analyzer operates is called the "SCAN" or "FULL SCAN" mode. For many compounds, a SCAN analysis can easily produce desired reporting limits. For others, however, very low detection limits are required for comparison to health-based screening or cleanup levels. This can be achieved by analyzing in Selected Ion Monitoring (SIM) mode, where the laboratory selects the particular m/e ratios that require increased sensitivity during quantification. Analysis containing both a full SCAN GC/MS analysis and a SIM method is possible.

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[72] Taken from IRIS (http://www.epa.gov/ncea/iris/help_ques.htm#rfd).

TO-17: EPA Toxic Organic Compendium Method for the Determination of Volatile Organic Compounds in Ambient Air Using Active Sampling Onto Sorbent Tubes (EPA/625/R-96/010b). The sampling procedure involves pulling a volume of air through a sorbent packing to collect VOCs followed by a thermal desorption-capillary GC/MS analytical procedure. This sorbent tube/thermal desorption/gas chromatographic-based monitoring method for volatile organic compounds (VOCs) in ambient air is sensitive to 0.5 to 25 parts per billion (ppbv) concentration levels. Sorbents are used singly or in multi-sorbent packings. Tubes with more than one sorbent, packed in order of increasing sorbent strength are used to facilitate quantitative retention and desorption of VOCs over a wide volatility range. Higher molecular weight compounds are retained on the front, least retentive sorbent; the more volatile compounds are retained farther into the packing on a stronger adsorbent. The sorbent or sorbent mix tailored for a target compound list, data quality objectives, and sampling environment, must be selected.

This is commonly the method of choice for collecting and analyzing gas or air samples where naphthalene is the primary contaminant of concern.

TPH: Total petroleum hydrocarbons

TSD: Treatment, Storage and/or Disposal

URFi: the inhalation unit risk factor for a carcinogen. A unit risk is an upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 $\mu g/m^3$ in air.

VAF: Vapor Attenuation Factor. Also called a vapor attenuation coefficient (α, or alpha”). It is used to describe the degree of attenuation between a source vapor concentration at a certain depth and the resulting indoor air concentration of that VOC. It is the reciprocal of the attenuation (so that if the concentration attenuates 1000 times, the VAF will be 0.001).

VI: Vapor Intrusion

VPH: Volatile Petroleum Hydrocarbons

VOC: Volatile Organic Chemical, or Compound. This term is defined in WAC 173-340. It includes those carbon-based compounds listed in EPA methods 502.2, 524.2, 551, 601, 602, 603, 624, 1624C, 1666, 1671, 8011, 8015B, 8021B, 8031, 8032A, 8033, 8260B, and those with similar vapor pressures or boiling points. See WAC 173-340-830(3) for references describing these methods. For petroleum, volatile means aliphatic and aromatic constituents up to and including EC12, plus naphthalene, 1-methylnaphthalene and 2-methylnaphthalene.

In this guidance the term ―VOC” is used more broadly to refer to all substances in subsurface contamination that may pose a threat to indoor air quality via vapor intrusion. These substances are identified in Appendix B.

WAC: Washington Administrative Code

Appendix B: Method B and C Screening Levels for Potential VI Contaminants of Concern

Substances

Chemicals listed in Table B-1 were obtained from three sources: (1) the 2002 draft EPA VI Guidance, (2) the 2005 California-EPA DTSC VI Guidance,[73] and (3) a listing of those volatile organic compounds, as defined by WAC 173-340-200, which currently have CLARC inhalation toxicity information.[74] The substances in Table B-1 represent many of the chemicals volatile and toxic enough to pose a potential threat to indoor air quality via the VI pathway.

EPA 2002, Appendix D, describes the composition of that document‘s Table 1 list of chemicals as follows:

> Under this approach, a chemical is considered sufficiently toxic if the vapor concentration of the pure component…poses an incremental lifetime cancer risk greater than 10^{-6} or results in a non-cancer hazard index greater than one... A chemical is considered sufficiently volatile if its Henry‘s Law Constant is 1×10^{-5} atm-m^3/mol or greater (US EPA, 1991). In our judgment, if a chemical does not meet both of these criteria, it need not be further considered as part of the evaluation.
>
> The maximum possible vapor concentration is that corresponding to the pure chemical at the temperature of interest. In this case, all calculations were performed at the reference temperature of 25° C using the equation:
>
> $$C_{max,vp} = S * H * 1000\ \mu g/mg * 1000\ L/m^3$$
>
> Where: $C_{max,vp}$ is the maximum pure component vapor concentration at 25° C [in $\mu g/m^3$],
> S is the pure component solubility at 25° C [in mg/L], and
> H is the dimensionless Henry‘s Law Constant at 25° C [(mg/L – vapor)/(mg/L – H_2O)].

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[73] California Environmental Protection Agency [CalEPA], *Interim Final Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air*, Department of Toxic Substances Control, December 2004; revised in 2005. The list of substances is described as a ―List of Chemicals to be Considered for the Vapor Intrusion Pathway.” It includes mercury, two PCBs, and cyanide. Explanatory text indicates that the list of chemicals was taken from the EPA 2002 guidance with the addition of fuel oxygenates and two volatile polychlorinated biphenyl congeners (monochlorobiphenyl and dichlorobiphenyl), substances which under certain conditions could pose a VI threat to indoor air quality.

[74] CLARC (Cleanup Levels and Risk Calculations) is an on-line database for chemical-specific information related to the establishment of cleanup levels under the Model Toxics Control Act (MTCA) Cleanup Regulation (chapter 173-340 WAC). https://fortress.wa.gov/ecy/clarc/Reporting/CLARCReporting.aspx

> To determine if a chemical is sufficiently toxic to potentially pose an unacceptable inhalation risk, the calculated pure component vapor concentrations were compared to target indoor air concentrations corresponding to an incremental lifetime cancer risk greater than 10-6 or a non-cancer hazard index greater than one.

Table B-1 includes all the substances on EPA's and DTSC's lists which are defined by WAC 173-340-200 as ―VOCs" and have CLARC inhalation toxicity information. In also includes three total petroleum hydrocarbon (TPH) light fractions and mercury. Providing a large list of chemicals in this guidance serves one fundamental purpose: it identifies those VOCs which could <u>possibly</u> pose a potential threat to indoor air via VI. If none of the contaminants of concern at a site are on the list, the site manager and PLP may conduct the RI/FS without evaluating VI.[75] If some of the contaminants of concern at the site are on the list, however, the site manager and PLP should start the VI screening process for those particular substances.

Ecology recognizes there are limitations to presenting a list of chemicals of concern for the VI pathway. For example, the toxicity data for chemicals on the list are being continually re-evaluated and updated by continued scientific inquiry. It is possible, then, that chemicals included on the list now will later be considered less toxic than current scientific information suggests. Conversely, the inhalation toxicity of some chemicals not included on the list may later be re-evaluated and found to be potentially harmful via VI. Furthermore, some of the chemicals on this list are seldom found at cleanup sites, or are unlikely to pose a significant VI risk unless they are present in the subsurface at high concentrations. However, on balance, Ecology believes this list provides a useful screening tool, and thus it has been included in this guidance.

The list of chemicals in Table B-1 below is advisory in nature: it is provided to help determine whether the vapor intrusion pathway may require assessment at a site. Some chemicals that could potentially pose an indoor air health risk have not been included.[76] **On a site-specific basis, therefore, Ecology may identify circumstances where it becomes necessary to consider the volatility and toxicity of chemicals not included in the table.**

Screening Levels

Table B-1 includes air cleanup levels and shallow groundwater screening levels. It also provides soil gas screening levels for two measurement depths: sub-slab soil gas and deep soil gas. Specifically, substances are provided with their:

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[75] As noted later in the text, while this statement will be true in most cases, there are some ―non-VOCs" which can, under certain circumstances, also contaminate indoor air via vapor intrusion.

[76] As described above, EPA's 2002 guidance refers readers to Appendix D of its document to evaluate, where appropriate, volatile chemicals not included in their Table. Appendix D's process of selecting only substances that are volatile enough and toxic enough to pose a potential VI concern appears to be a reasonable process for determining whether particular VOCs should be considered contaminants of potential concern for the VI pathway.

Table B-1 does not, however, include substances on EPA's (or DTSC's) list which are not VOCs. Some PAHs, pesticides, and PCBs, for example, can potentially contaminate indoor air via vapor intrusion when subsurface concentrations are particularly elevated.

a) Unrestricted (indoor) air cleanup level, calculated per Method B (for carcinogens as well as non-carcinogens)
b) Industrial (indoor) air cleanup level, calculated per Method C (for carcinogens as well as non-carcinogens)
c) Groundwater screening level, protective of a Method B air cleanup level (for carcinogens as well as non-carcinogens)
d) Groundwater screening level, protective of an industrial air cleanup level (for carcinogens as well as non-carcinogens)
e) Sub-slab soil gas screening level, protective of a Method B air cleanup level (for carcinogens as well as non-carcinogens)
f) Sub-slab soil gas screening level, protective of an industrial air cleanup level (for carcinogens as well as non-carcinogens)
g) Deep soil gas screening level, protective of a Method B air cleanup level (for carcinogens as well as non-carcinogens)
h) Deep soil gas screening level, protective of an industrial air cleanup level (for carcinogens as well as non-carcinogens)

The table only includes groundwater screening levels that are greater than solubility-limited concentrations. If maximum solubility-limited concentrations are lower than VI health-based groundwater concentrations, then the substance is not a VI contaminant of potential concern.

The subsurface screening levels in the table are not site- or building-specific. Groundwater screening levels assume there will be at least 1000 times attenuation between shallow groundwater concentrations (converted to equilibrium vapor phase concentrations[77]) and indoor air concentrations. Soil gas screening levels assume there will be at least 100 times attenuation between deep soil gas concentrations and indoor air concentrations, and ten times attenuation between sub-slab soil gas concentrations and indoor air concentrations.

Ecology recognizes the assumed attenuation factors utilized to calculate the groundwater and soil gas screening levels are conservative under most circumstances.[78] For example, the degree of attenuation between groundwater or deep soil gas and indoor air for certain petroleum hydrocarbons is likely at many sites to be considerably more than what is assumed here. These compounds often biodegrade in the vadose zone, leading to sub-slab concentrations lower than what would be predicted solely from diffusion-based vertical concentration profiles. See Chapter 3 for further discussion of this issue.

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[77] These are soil gas concentrations in equilibrium with shallow groundwater concentrations and are calculated using the VOC‘s Henry‘s Law Constant (Hcc). Hcc values are temperature dependent. The values used to derive the ground water screening levels in Table B-1 were adjusted from 25°C values to 13°C values. 13°C is assumed to better represent average Washington State shallow groundwater temperature.

[78] Provided the limitations in Chapter 3 are abided by.

Table B-1. ***Indoor Air Cleanup Levels, Groundwater Screening Levels, and Soil Gas Screening Levels***

Note: Numeric values are rounded and expressed with two significant numbers. The ***numerator*** *soil gas value is the screening level for* ***sub-slab*** *measurements; the* ***denominator*** *value is the screening level for* ***deep*** *soil gas measurements.*

		Method B							Method C						
		Risk Driver	Indoor Air CUL[79] (μg/m^3)		GW SL[80] (μg/L)		Soil Gas SL[81] (μg/m^3)		Risk Driver	Indoor Air CUL (μg/m^3)		GW SL (μg/L)		Soil Gas SL (μg/m^3)	
Name of Hazardous Substance	[82]**CAS #**		C[83]	NC	C	NC	C	NC		C	NC	C	NC	C	NC
2-chloro-1,3-butadiene (chloroprene)	126-99-8	NC		3.2		12		32/320	NC		7		25		70/700
acetaldehyde	75-07-0	C	1.1	4.1	530	1900	11/110	41/410	NC	11	9	5300	4200	110/1100	90/900
acetonitrile	75-05-8	NC		27		33000		270/2700	NC		60		72000		600/6000
acetophenone	98-86-2	NC		0.008		50		0.08/0.8	NC		0.018		110		0.18/1.8
acrolein (Propenal)	107-02-8	NC		0.0091		2.9		0.091/0.91	NC		0.02		6.4		0.2/2
acrylonitrile	107-13-1	C	0.037	0.91	16	390	0.37/3.7	9.1/91	C	0.37	2	160	850	3.7/37	20/200
aldrin	309-00-2	C	0.00051		0.32		0.0051/0.051		C	0.0051		3.2		0.051/0.51	
benzene	71-43-2	C	0.32	14	2.4	100	3.2/32	140/1400	C	3.2	30	24	230	32/320	300/3000
benzyl chloride	100-44-7	C	0.052		6.2		0.52/5.2		C	0.52		62		5.2/52	
bis(2-chloroethyl)ether	111-44-4	C	0.0076		26		0.076/0.76		C	0.076		260		0.76/7.6	
bromodichloromethane	75-27-4	C	0.0033		0.09		0.033/0.33		C	0.033		0.9		0.33/3.3	
bromoform	75-25-2	C	2.3		200		23/230		C	23		2000		230/2300	
bromomethane (bromomethane)	74-83-9	NC		2.3		13		23/230	NC		5		28		50/500
butadiene;1,3-	106-99-0	C	0.08	0.91	0.037	0.42	0.8/8	9.1/91	C	0.8	2	0.37	0.92	8/80	20/200
carbon disulfide	75-15-0	NC		320		400		3200/32000	NC		700		870		7000/70000
carbon tetrachloride	56-23-5	C	0.17		0.22		1.7/17		C	1.7		2.2		17/170	
chlorobenzene	108-90-7	NC		8		100		80/800	NC		18		220		180/1800
chlorodifluoromethane (Freon 22)	75-45-6	NC		23000		27000		230000/2300000	NC		50000		58000		500000/5000000
chloroform	67-66-3	C	0.11		1.2		1.1/11		C	1.1		12		11/110	
chloromethane	74-87-3	C	1.4		5.2		14/140		C	14		52		140/1400	
chloropropane;2-	75-29-6	NC		4.6		12		46/460	NC		10		26		100/1000
cumene (Isopropylbenzene)	98-82-8	NC		180		720		1800/18000	NC		400		1600		4000/40000
dibromochloromethane	124-48-1	C	0.0045		0.22		0.045/0.45		C	0.045		2.2		0.45/4.5	
dichlorobenzene;1,2-	95-50-1	NC		64		1800		640/6400	NC		140		4000		1400/14000
dichlorobenzene;1,4-	106-46-7	NC		370		7900		3700/37000	NC		800		17000		8000/80000
dichlorodifluoromethane (Freon 12)	75-71-8	NC		80		9.9		800/8000	NC		180		22		1800/18000
dichloroethane;1,1- (DCA)	75-34-3	NC		320		2300		3200/32000	NC		700		5000		7000/70000
dichloroethane;1,2- (DCA)	107-06-2	C	0.096	2.2	4.2	98	0.96/9.6	22/220	C	0.96	4.9	42	210	9.6/96	49/490
dichloroethylene;1,1- (DCE)	75-35-4	NC		91		130		910/9100	NC		200		280		2000/20000
dichloroethylene;1,2-,cis (DCE)	156-59-2	NC		16		160		160/1600	NC		35		350		350/3500
dichloroethylene;1,2-,trans (DCE)	156-60-5	NC		32		130		320/3200	NC		70		290		700/7000
dichloropropane;1,2-	78-87-5	NC		1.8		28		18/180	NC		4		62		40/400
dichloropropene;1,3-	542-75-6	C	0.63	9.1	1.6	23	6.3/63	91/910	C	6.3	20	16	51	63/630	200/2000
Diisopropyl Ether (isopropyl ether)	108-20-3	NC		180		2900		1800/18000	NC		400		6300		4000/40000
ethyl chloride	75-00-3	C	3	4600	12	18000	30/300	46000/460000	C	30	10000	120	40000	300/3000	100000/1000000

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[79] Indoor Air Cleanup Level calculated using Equations 750-1 (for carcinogens) or 750-2 (for carcinogens) defined by MTCA.

[80] Ground Water Screening Level or that concentration in the groundwater expected to not result in exceedance of the air cleanup level in an overlying structure under most circumstances (See Chapter 3 for more information on the appropriate use of these screening levels). GW SL = [Indoor Air CUL]/[Hcc* α *1000], where α = 1.0E-3.

[81] Soil Gas Screening Level that concentration in the soil gas just beneath a building (first value) or at 15 foot depth or greater (second value) expected to not result in exceedance of the air cleanup level in an overlying structure under most circumstances (see Chapter 3 for more information on the appropriate use of these screening levels). Soil Gas SL = [Indoor Air CUL]/[α], where α = 0.1 or 0.01, depending on the depth of the soil gas sample to be compared to.

[82] Chemical Abstracts Number.

[83] ―C" refers to the substance‘s toxicity as a carcinogen; ―NC" refers its toxicity as a non-carcinogen.

Table B-1. ***Indoor Air Cleanup Levels, Groundwater Screening Levels, and Soil Gas Screening Levels (Continued)***

		Method B							Method C						
		Risk Driver	Indoor Air CUL (μg/m^3)		GW SL (μg/L)		Soil Gas SL (μg/m^3)		Risk Driver	Indoor Air CUL (μg/m^3)		GW SL (μg/L)		Soil Gas SL (μg/m^3)	
Name of Hazardous Substance	CAS #		C	NC	C	NC	C	NC		C	NC	C	NC	C	NC
ethylbenzene	100-41-4	NC		460		2800		4600/46000	NC		1000		6100		10000/100000
ethylene dibromide (EDB)	106-93-4	C	0.011	0.16	0.74	10	0.11/1.1	1.6/16	C	0.11	0.35	7.4	23	1.1/11	3.5/35
ethylene oxide	75-21-8	C	0.025		1.6		0.25/2.5		C	0.25		16		2.5/25	
hexachlorobutadiene	87-68-3	C	0.11		0.81		1.1/11		C	1.1		8.1		11/110	
hexachloroethane	67-72-1	C	0.63		8.6		6.3/63		C	6.3		86		63/630	
hexane;n-	110-54-3	NC		320		7.8		3200/32000	NC		700		17		7000/70000
hydrogen cyanide	74-90-8	NC		1.4		390		14/140	NC		3		860		30/300
mercury (elemental)	7439-97-6	NC		0.14		0.89		1.4/14	NC		0.3		1.9		3/30
methacrylonitrile	126-98-7	NC		0.32		56		3.2/32	NC		0.7		120		7/70
methyl ethyl ketone	78-93-3	NC		460		350000		4600/46000	NC		1000		760000		10000/100000
methyl isobutyl ketone	108-10-1	NC		32		11000		320/3200	NC		70		24000		700/7000
methyl methacrylate	80-62-6	NC		320		46000		3200/32000	NC		700		100000		7000/70000
methyl tert-butyl ether (MTBE)	1634-04-4	C	9.6	1400	610	86000	96/960	14000/140000	C	96	3000	6100	190000	960/9600	30000/300000
methylcyclohexane	108-87-2	NC		1400		570		14000/140000	NC		3000		1300		30000/300000
methylene chloride	75-09-2	C	5.3	1400	94	24000	53/530	14000/140000	C	53	3000	940	53000	530/5300	30000/300000
naphthalene	91-20-3	NC		1.4		170		14/140	NC		3		360		30/300
nitrobenzene	98-95-3	NC		0.27		690		2.7/27	NC		0.6		1500		6/60
nitropropane;2-	79-46-9	C	0.00093	9.1	0.36	3500	0.0093/0.093	91/910	C	0.0093	20	3.6	7700	0.093/0.93	200/2000
styrene	100-42-5	C	4.4	460	78	8200	44/440	4600/46000	C	44	1000	780	18000	440/4400	10000/100000
tetrachloroethane;1,1,1,2-	630-20-6	C	0.34		7.4		3.4/34		C	3.4		74		34/340	
tetrachloroethane;1,1,2,2-	79-34-5	C	0.043		6.2		0.43/4.3		C	0.43		62		4.3/43	
tetrachloroethylene (PCE)	127-18-4	C	0.42	16	1	40	4.2/42	160/1600	C	4.2	35	10	88	42/420	350/3500
toluene	108-88-3	NC		2200		15000		22000/220000	NC		4900		33000		49000/490000
trichloro-1,2,2-trifluoroethane;1,1,2- (Freon 113)	76-13-1	NC		14000		1100		140000/1400000	NC		30000		2400		300000/3000000
trichlorobenzene;1,2,4-	120-82-1	NC		91		3900		910/9100	NC		200		8400		2000/20000
trichloroethane;1,1,1- (TCA)	71-55-6	NC		4800		11000		48000/480000	NC		11000		25000		110000/1100000
trichloroethane;1,1,2-	79-00-5	C	0.16		7.9		1.6/16		C	1.6		79		16/160	
trichloroethylene (TCE)	79-01-6	C	0.1	16	0.42	67	1/10	160/1600	C	1	35	4.2	150	10/100	350/3500
trichlorofluoromethane (Freon 11)	75-69-4	NC		320		120		3200/32000	NC		700		260		7000/70000
trimethylbenzene;1,2,4-	95-63-6	NC		2.7		24		27/270	NC		6		52		60/600
trimethylbenzene;1,3,5-	108-67-8	NC		2.7		25		27/270	NC		6		54		60/600
vinyl acetate	108-05-4	NC		91		7800		910/9100	NC		200		17000		2000/20000
vinyl chloride	75-01-4	C	0.28	46	0.35	57	2.8/28	460/4600	C	2.8	100	3.5	120	28/280	1000/10000
xylene;m-	108-38-3	NC		46		310		460/4600	NC		100		670		1000/10000
xylene;o-	95-47-6	NC		46		440		460/4600	NC		100		960		1000/10000
VPH [EC5-6 aliphatics + EC6-8 aliphatics] fraction	NE	NC				140			NC				310		
VPH [EC8-10 aliphatics + EC10-12 aliphatics] fraction	NE	NC				2.9			NC				6.4		
VPH [C8-10 aromatics + EC10-12 aromatics] fraction-[naphthalene]	NE	NC				1300			NC				2800		
APH [EC5-8 aliphatics] fraction	NE	NC		2700				27000/270000	NC		6000				60000/600000
APH [EC9-12 aliphatics] fraction	NE	NC		140				1400/14000	NC		300				3000/30000
APH [EC9-10 aromatics] fraction	NE	NC		180				1800/18000	NC		400				4000/40000

Appendix C: Soil Gas Sampling for VI Assessment

This appendix summarizes techniques and methods for sampling soil gas during a vapor intrusion (VI) assessment. It is comprised of the following four sections:

C.1 Sub-slab soil gas sampling

C.2 Soil gas sampling (not sub-slab)

C.3 Passive soil gas sampling.

C.4 Sources of information for soil gas sampling.

This appendix is intended to provide an overview of information regarding soil gas sampling that investigators should be aware of when developing sampling plans and assessing study data. Much more information is available in the open literature and should be consulted prior to undertaking a sampling program. For example, this appendix does not contain Standard Operating Procedures (SOPs) for sampling soil gas. Including such a large amount of information is beyond the scope of this guidance document. For additional information on these and other topics, consult the references in Section C.4.

Introduction

During the Tier I assessment the investigator is attempting to determine if soil gas concentrations at the site are high enough to pose a potential threat to current or future indoor air quality. At this point in the investigation there are typically no indoor air data. Usually there are groundwater and soil concentration data, and these have been used – during the Preliminary Assessment – to conclude that VI could possibly be a pathway of concern.

Chapter 3 states that during Tier I soil gas sampling can be used to estimate the strength of the subsurface VI source. For *active* sampling – i.e., sampling techniques that collect a certain volume of soil gas and analyze it to determine concentrations – there are two basic approaches:

a) sub-slab sampling, and

b) sampling from locations that are not ―sub-slab.”

Sub-slab soil gas sampling is discussed below in Section C.1; other active soil gas sampling is described in Section C.2

During a Tier II investigation soil gas is also often collected, generally at, or at nearly, the same time as indoor air samples. Typically, these will be sub-slab samples. The purpose of sampling soil gas during the Tier II investigation is to provide information that will better help approximate the contribution VI is making to the measured indoor air contamination. This is explained further in Section C.1.

C.1 Sub-slab soil gas sampling

Sub-slab sampling is generally considered the sampling of soil gas immediately below the building‘s basement floor or slab (for a building constructed slab-on-grade). While it is possible to collect soil gas at depth below a building‘s slab, this is not commonly done. When sub-slab soil gas sampling is referred to in this appendix, collections just below the slab are assumed. This distinction is important because the assumptions made about the attenuation of soil gas concentrations are different for deeper soil gas.

Likewise, soil gas samples can certainly be collected from just below pavement or other surface cover, beyond the footprint of the building of concern. But these samples are not what is being referred to here as *sub-slab*.

Sub-slab sampling, then, can only be conducted if there is a building. If the purpose of soil gas sampling is to determine the potential for VI to impact a future building‘s indoor air, and no building is currently in the area being assessed, investigators will need to use the techniques described in Section C.2 to collect soil gas samples.

Some investigators will choose to not collect sub-slab soil gas samples during Tier I. Collecting these samples requires that the investigator go indoors, and if permission is obtained for accessing the interior of the structure, often the investigator will want to also collect indoor air samples. When sub-slab samples are collected concurrently with indoor air samples, this is what the guidance calls a Tier II assessment.

During Tier II the investigator is attempting to determine if indoor concentrations within a building are unacceptably elevated due to VI. At this point in the investigation there are typically no indoor air data, but there may be soil gas data. Usually there are groundwater and/or soil concentration data. The existing subsurface data have been used – during the preceding Tier I – to conclude that VI could potentially impact the indoor air in a particular building located in a particular area.

It is possible that the type of soil gas sampling conducted during Tier II will not be sub-slab sampling. Some building owners, for example, may not give the investigator permission to drill holes through the building‘s slab. However, in most cases the type of soil gas sampling that will supplement a Tier II indoor air sampling event will be sub-slab sampling. These samples are collected to provide the investigator an idea of how high the soil gas VOC concentrations are directly below the building. From this information the investigator can better determine if the VOC levels measured indoors are due to VI or more likely caused by other sources. The relative levels of VOCs in sub-slab soil gas sampling results can also be compared to indoor measurements. For example, if compounds A and B are found in sub-slab soil gas at a concentration ratio of 10:1, one would expect a similar ratio in the indoor measurement, in the absence of contributions from other sources.

Sub-slab soil gas sampling conducted during Tier II is similar to that described for Tier I assessments. The primary differences are that: a) during Tier II the soil gas result(s) is not the only, or even primary, piece of information for making the assessment decision; and, b) the timing of sampling, and number of sampling events, are governed by the indoor air sampling schedule. When sub-slab sampling is coupled with indoor air sampling, sub-slab samples are often collected the day immediately before or after the indoor sampling event. In some cases, though, the investigator may choose to collect both indoor and sub-slab samples over the same period, if the collected soil gas volume is small.

Ecology recommends that sub-slab samples be collected via small holes through the flooring near the center of the floor space, away from perimeter locations where exterior walls meet the floor.[84] See Figure C-1 below. Prior to drilling holes in the slab, local utility companies should be contacted to identify and mark utilities coming into the building from the outside (e.g., gas, water, sewer, refrigerant, and electrical lines). Local electricians and plumbers may need to be consulted to identify the location of utilities inside the building.

Figure C-1. Drilling through a concrete slab using a rotary hammer drill (EPA 2006)

EPA‘s 2006 *Assessment of Vapor Intrusion in Homes Near the Raymark Superfund Site Using Basement and Sub-slab Air Samples,* EPA/600/R-015/147, provides a protocol for obtaining sub-slab soil gas samples that many guidance documents endorse. Some of the more critical sub-slab sampling guidelines, contained in most VI guidance, are listed below:

a) Sub-slab samples should not be collected if groundwater is so shallow that it contacts the floor/slab.

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[84] This recommendation refers to the room that is being sampled. Often the investigator will be sampling sub-slab soil gas beneath more than one room. There will also be cases where, because of the size of a basement, e.g., multiple sub-slab locations will be sampled. In all these cases it is generally preferable to site the sampling locations away from exterior walls and any floor/slab features or cracks that could pose a ―short-circuiting" route for the collection.

b) Sub-slab samples should not be collected from areas in the immediate vicinity of sub-slab underground utilities.

c) Sub-slab samples should not be collected from areas in the immediate vicinity of large floor cracks or drains, or near sumps.

d) The number of sub-slab samples needed depends on the size of the slab/floor, the expected lateral homogeneity/heterogeneity of VOC concentrations in soil gas immediately below the floor/slab, and the intended use of the data. In Tier I the accuracy and representativeness of the resulting data are critical, since the investigator will be relying on these data to decide if soil gas poses a potential VI threat. Multiple sampling locations will usually be required to ensure that the range of sub-slab soil gas VOC levels have been represented in the resulting data.

e) The choice regarding how long a period the sample should be collected over will, again, depend to some extent on what the investigator intends to do with the data. It will also depend, if the measurement is intended to represent something like an average sub-slab VOC concentration over an extended period (like 8 or 24 hours), on how much the investigator expects VOC concentrations to change over the period. If there are data to demonstrate, or it can be reasonably assumed, that little change is likely, a relatively short collection time should be acceptable.

f) The volume of sample collected will also depend on how the resulting data will be used. The sample volume is, at least indirectly, related to the period of time that the collection will occur over. Small volume collections have the advantage of sampling soil gas from only the point the investigator has chosen to measure; i.e., gases from distal locations are less likely to be collected in the sample. However, in order to attain detection limits as low as applicable screening levels, larger volumes will sometimes be required.

g) For basements, it is possible that the primary entry points for vapors may be through the sidewalls rather than from below the floor. Sub-slab sampling may therefore need to be augmented with samples collected through the basement walls.

h) Sub-slab soil gas sampling techniques are prone to the inadvertent collection of indoor air, entering the slab hole during the sampling period. Some leakage may occur despite the investigator‘s best efforts to seal the gap between the sampling probe and the slab hole, provide lock-tight fittings throughout the sampling apparatus, and minimize the sampling flowrate. For this reason efforts are typically taken as part of project QA/QC to determine how much indoor air may have entered the sample during a sub-slab collection. Often this is accomplished by shrouding the sample collector, apparatus, probe, and hole, and then delivering a tracer compound to the shrouded air volume. When the sample is analyzed the tracer compound can also be quantified, providing an estimate of how much indoor air may have entered the sample. See Figure C-2 below.

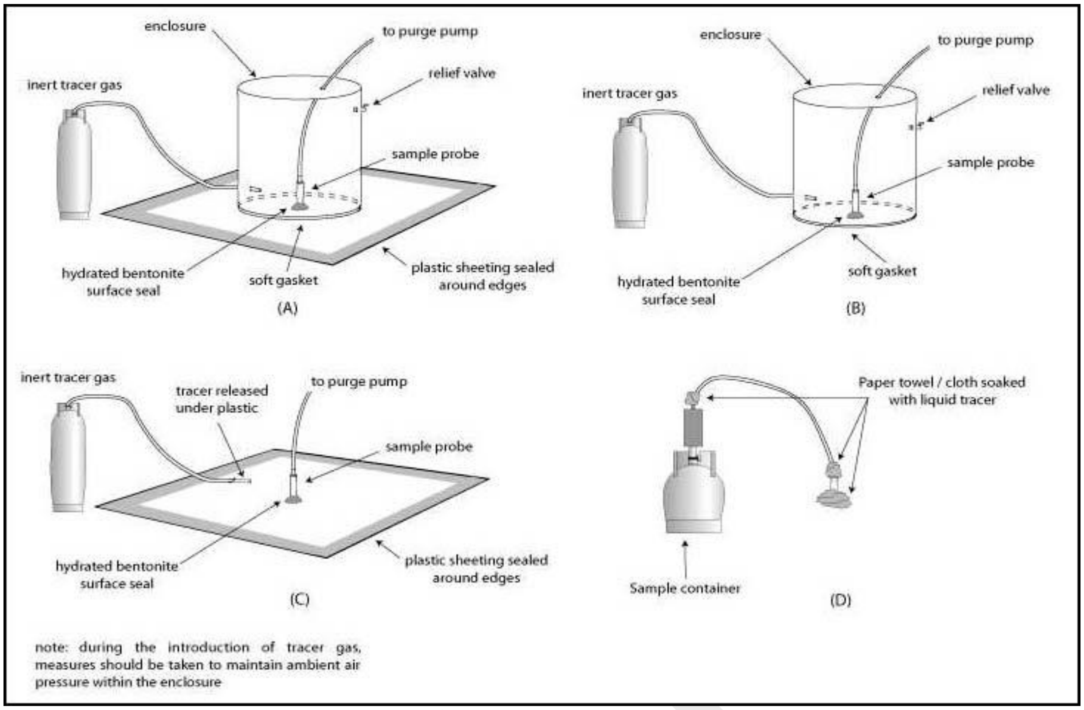

Figure C-2. Tracer gas applications when collecting soil gas samples (NYDOH, 2006)

i) Sub-slab samples can be collected from permanent or temporary probes. An advantage of the former is that these probes may be easier to seal within the slab hole and thereby leakage of indoor air into the sample may be minimized. Permanent probes are also usually preferred when the investigator believes that multiple soil gas sampling events will be needed. If permanent probes are utilized it is imperative that the probes be valved or capped off when not in use. Similarly, if temporary probes are used, the investigator must be sure to repair the slab hole in a manner that prevents the hole from being a soil gas conduit.

   A general sub-slab probe installation schematic for a ―permanent” probe is depicted in Figure C-3 on the following page. Note that the diagram does not show a valve; the preferred probe installation (see EPA 2006) utilizes a recessed threaded cap. However, if site conditions demand that the probe be valved, an air-tight valve must be used and maintained in the closed position at all times (except during sampling).

j) During Tier I, sub-slab soil gas samples are being collected without indoor air samples, and the resulting concentration data will be the primary inputs to the decision regarding the potential for a VI problem. Multiple separate sampling events may therefore be necessary to assure that representative soil gas conditions have been measured. At least one sampling event should be scheduled when the building is likely to be depressurized (with respect to the subsurface). Often this event is scheduled for the winter heating season, when temperatures inside the building are significantly higher than outdoor air temperatures.

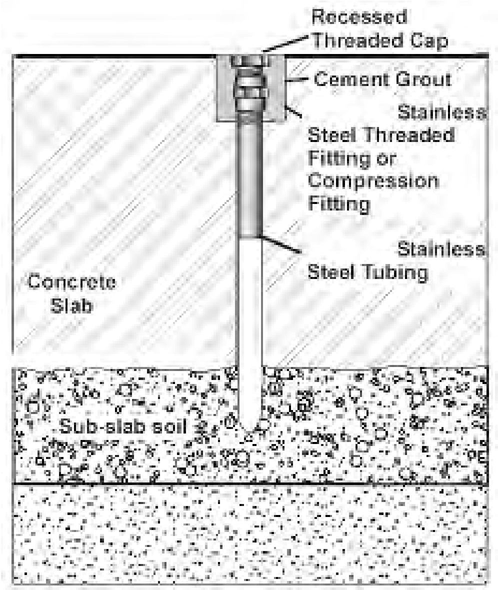

Figure C-3. Sub-slab soil gas probe schematic (NJDEP, 2005)

k) QA/QC is important whenever sampling soil gas for a VI assessment. It is especially important during Tier I sub-slab soil gas sampling because the results, as noted above, will be the main inputs to the decision regarding the potential for a VI problem. Data quality indicators should be identified in advance of sampling, with quality ―targets” established for each parameter.

C.2 Soil gas sampling from locations other than “sub-slab”

Soil gas samples collected from locations that are not ―sub-slab” include:

(1) Samples of soil gas collected below the building‘s basement floor or slab (for a building constructed slab-on-grade), but <u>at depth</u>. This is not commonly performed during either a Tier I or II assessment.

(2) Soil gas samples collected from below pavement or other surface cover, beyond the footprint of the building of concern, regardless of the depth.

(3) Soil gas samples collected below uncovered areas, beyond the footprint of the building of concern, regardless of the depth.

(4) Soil gas samples collected in areas where there are currently no buildings, regardless of the depth.

Investigators will often choose to collect Tier I soil gas samples outside the building of concern, beyond the building‘s footprint. These samples are commonly collected through a probe or rod driven into the ground, or through a vapor ―well.” The latter generally consists of small diameter (1/8” to 1/4”), inert nylon or Teflon tubing buried – and sealed – into a borehole. When these types of soil gas samples are collected during Tier I, the samples should be collected very close to the building, laterally.[85]

Ecology recommends the following three documents as references when developing site soil gas sampling plans:

- The revised California (DTSC and the California Regional Water Quality Control Board) *Active Soil Gas Sampling Advisory.* NOTE: the 2003 Advisory is due to be revised in 2010.
- Appendix D and Appendix F of the Interstate Technology and Regulatory Council‘s (ITRC‘s) January 2007 *Vapor Intrusion Pathway: A Practical Guideline.*
- Chapter 6 and Appendix I of the New Jersey Department of Environmental Protection‘s (NJDEP‘s) October 2005 *Vapor Intrusion Guidance*, and chapter 9 of NJDEP's 2005 *Field Sampling Procedures Manual.*

Good discussions of soil gas sampling are also contained in the documents listed in Section C.4. Some of the more critical soil gas sampling guidelines, contained in most VI guidance, are listed below:

a) As a general rule, soil gas samples should be collected just above the contaminant source. Samples collected near the source often display less spatial variability in measured concentration levels, and investigators can usually sample from a relatively small number of points (laterally). When samples are collected from shallower depths, well-separated in distance from the source, Ecology will generally require a larger number of collection points laterally.

   Ecology realizes there are some obvious advantages to sampling shallow soil gas, especially when the VI source – say groundwater – is at depth. Shallow samples have the potential to provide an indication of how much attenuation has actually occurred over the portion of the vadose zone between the source and the measurement point. The actual amount of attenuation may be significantly different than what is being assumed in Ecology‘s Appendix B screening levels or calculated by the Johnson and Ettinger model. Plus, shallower samples may provide an indication of how concentrated soil gas VOCs are at a location nearer the building of concern, which is valuable information.

   Despite these advantages, however, the current VI literature suggests that there can be wide spatial variability in measured soil gas concentrations. This seems to be particularly

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[85] Of course this only applies when assessing existing buildings. When assessing parcels without buildings the investigator will need to provide adequate sampling coverage over the entire parcel, or bias the sampling to collect soil gas from the most highly-contaminated areas beneath the parcel.

In addition, because buildings often have a drain next to the foundation, samples may need to be stepped-back from the building to avoid these drain systems (but not so far as to no longer be representative of soil gas beneath the building. A set-back of several feet from the building wall is recommended unless the building plans or persons with knowledge of the foundation construction provide information that would indicate another distance is more appropriate. As always, investigators should be sure to identify and mark the locations of underground utilities.

the case when the samples are collected distal from the subsurface source, at shallow depths. For this reason Ecology will usually require a denser sampling design, laterally, for shallow sampling than for sampling conducted nearer the source.

b) Due to the possibility of diluting the collected soil gas with atmospheric air, samples should seldom be collected from depths shallower than five feet bgs (or less than two to five feet below the depth of the foundation), unless they are –sub-slab” samples. This will also minimize barometric pumping effects.[86]

c) When the subsurface VOC source is close to the ground surface or basement floor, samples should be collected right above the top of the contamination. But samples collected from depths this shallow (assuming they are not collected directly below the building), may not represent soil gas at the same depth directly below the building being evaluated. Whenever relatively shallow samples are collected beyond the building footprint, the potential exists for underestimating soil gas concentrations immediately below the building. The uncertainty associated with adequately representing soil gas concentrations just below the building increases as shallow samples are collected further from the building of concern.

d) The number of soil gas samples needed to assess a building or area will depend on a number of factors. As explained above, Ecology will typically ask for more samples when the sample locations are relatively shallow. In general, the number of samples should be dictated by: a) the degree of spatial heterogeneity expected in soil gas VOC concentrations, and b) the use the data will be put to.

e) Soil gas samples can be collected over very short time periods, and small sample volumes may be selected to better represent the soil gas concentrations at a discreet depth and location. The collection period and volume at any given site and for any given project will depend on why the soil gas is being collected and how the data will be used. If the soil gas is collected over a short interval, investigators should not also utilize high sampling flowrates. Higher flowrates may exacerbate ambient air leakage into the sample. Investigators taking quick samples should also have a reasonable degree of confidence in the temporal stability of soil gas concentrations (for example, a lack of diurnal variability) at the site – or be able to select an interval when VOC concentrations are expected to exhibit near-maximum values).

If the volume of soil gas collected is small, the investigator will need to make sure that the analytical detection limits will be low enough to meaningfully compare the results to screening levels. There will also have to be more attention paid to selecting the proper purge volume. When collection volumes are small and/or sampling flowrates fast,

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[86] Soil gas sample at depths shallower than 5 feet below the ground surface can sometimes be collected from a location below an impermeable slab, such as some driveway and parking lot covers, or a garage floor. [87] California‘s guidance recommends that soil gas not be collected following a significant rain event. So does New Jersey‘s (–sizable rainfall”). Massachusetts agrees with these recommendations for samples collected outside the building footprint.

purging the desired amount of collected gas before collecting a sample becomes more critical to assuring properly representative data.

f) Two or more separate soil gas sampling events may be necessary before concluding that the VI potential is too weak to merit further assessment. This will depend on a number of factors. For example, repeat sampling may be indicated if: a) measured soil gas VOCs are below, but close to screening levels; b) a fairly small number of locations were sampled the first time; or, c) the investigator believes there could be considerable longer-term temporal (e.g., seasonal) variability in soil gas VOC concentrations at the depth being sampled, and the first sampling may not have represented average concentrations with a high degree of confidence.

g) Generally, irrespective of the data use, Ecology recommends that investigators not collect soil gas samples during or immediately following a heavy rain. From a practical standpoint it may be difficult to even collect samples during such adverse weather conditions. From a data quality perspective, the filling of the vadose zone soil pores with water will confound the question of how representative the measured soil gas concentrations are of those concentrations generally forming the VI source beneath the building.[87]

h) Like sub-slab sampling, soil gas sampling conducted outdoors is prone to the inadvertent collection of air, entering the bore hole during the sampling period. This leakage may occur despite the investigator‘s best efforts to seal the gap between the sampling probe and the hole, provide lock-tight sampling apparatus fittings, and minimize the sampling flowrate. Leakage testing is therefore typically performed to determine how much ambient air may have entered the sample during the soil gas collection period. Often this is accomplished by using the same techniques discussed above for sub-slab sampling.

i) Like sub-slab samples, outdoor soil gas samples can be collected from permanent or temporary probes. The same advantages and disadvantages discussed above for sub-slab sampling generally apply. See Figures C-4 and C-5 on the following page for a schematic and photograph, respectively, of typical, permanent, soil gas sampling probe installations. Note: the diagrams in Figure C-4 do not show how the top of the probe (and/or sampling tubing) is closed when not being sampled. If the top of the probe is valved (−⋈−), an air-tight valve should be selected and then maintained in the closed position (except during sampling).

j) QA/QC is important during soil gas sampling, and particularly during Tier I, because the results will be the main inputs to the decision regarding the potential for a VI problem. Data quality indicators should be identified in advance of sampling, with quality ―targets” established for each parameter.

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[87] California‘s guidance recommends that soil gas not be collected following a significant rain event. So does New Jersey‘s (―sizable rainfall”). Massachusetts agrees with these recommendations for samples collected outside the building footprint.

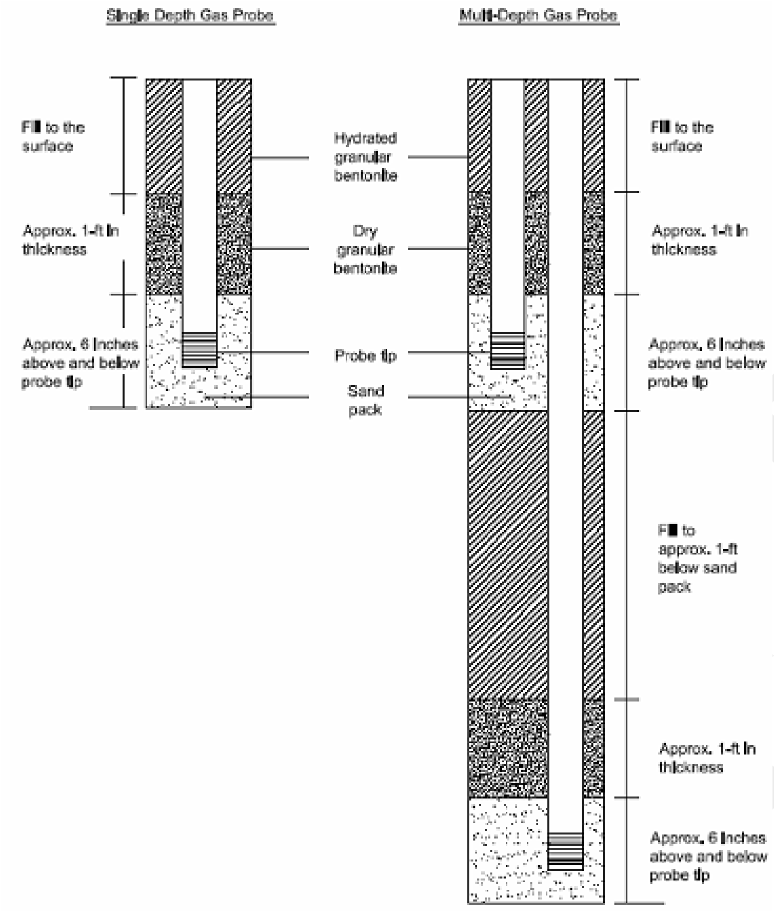

Figure C-4. Soil gas probe construction diagram (Missouri Risk-based Corrective Action for Petroleum Storage Tanks, *Soil Gas Sampling Protocol*, April 21, 2005)

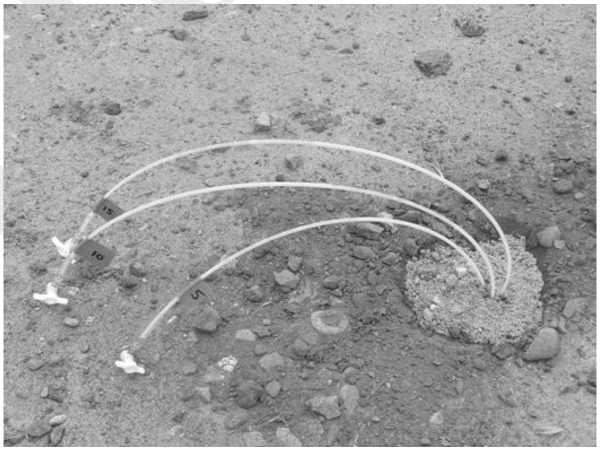

Figure C-5. Photograph of a multi-depth nested vapor well utilizing small diameter, inert tubing (from the H&P Mobile GeoChemistry, Inc., website, "How to Collect Reliable Soil-Gas Data"). *NOTE: valves turned off.*

C.3. Passive soil gas sampling

The type of soil gas sampling described above utilizes vacuum to pull vapors into a container. A sample from the container is then analyzed by an on- or off-site laboratory. However, several devices are available that rely on soil gas contact with a special adsorbent matrix. These devices are placed into the subsurface environment for a period of time, retrieved, and then sent back to the vendor for evaluation of the VOCs sorbed to the matrix. Results are usually quantified in units of mass, but the vendor can often estimate VOC strength in terms of soil gas concentration.

Passive samplers offer certain advantages to the investigator. They can be placed and left for several days, thereby providing an integrated type of measurement over a period longer than the periods typical of *active* soil gas sampling. Plus, once in place they exert few influences on the subsurface environment. For deeper soil gas locations this may be an attractive feature. If an investigator wants to know the concentration of VOCs in soil gas at a particular location, deep in the vadose zone, he essentially wants to know what effect diffusion from the VOC source below has had on those concentrations. The assumption is that this concentration has not been influenced by any advective flow of soil gas, only diffusion from the surrounding environment. Actively ―pulling” a sample from this depth exerts, and imposes, pressure on the environment that would not otherwise be there and the resulting advective flow of soil gas may have some effect on the representativeness of the sample concentration. Passive sampling can also be conducted relatively cheaply, can be deployed in tighter and wetter soils than active methods, and can often detect the presence of some SVOCs better than active methods.

Nevertheless, Ecology does not recommend that passive soil gas samplers be used routinely for VI assessments, or that they be viewed as substitutes for active soil gas sampling. Most state guidances consider their results to be more qualitative or semi-quantitative than quantitative, and will not accept them as the primary line of evidence that soil gas concentrations are too low to serve as a threat to indoor air quality. They may, however, be useful tools for specific applications (as described above) and PLPs and site managers interested in finding out more about these devices should refer to ITRC (2007) and the following sources:[88]

- USEPA Environmental Technology Verification Report, *Soil Gas Sampling Technology, GORE-SORBER Screening Survey* (EPA/600/R-98/095; August 1998)
- USEPA Environmental Technology Verification Report, *Soil Gas Sampling Technology, EMFLUX Soil Gas System* (EPA/600/R-98/096; August 1998)
- Gore™ module for passive soil gas collection at W. L. Gore & Associates
- *Emflux* passive samplers at Beacon Environmental

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[88] Ecology is not endorsing any particular product or company listed herein, and is not intentionally excluding any vendors of sampling devices. At this time, however, we are aware that the resources we have listed here can provide further information about vapor sampling devices during VI assessments. Refer to the Disclaimer of this guidance.

C.4. Sources of information for soil gas sampling

The following documents contain excellent discussions of soil gas sampling:

- American Petroleum Institute (API), November 2005, Collecting and Interpreting Soil Gas Samples from the Vadose Zone (#4741). See chapter 5 and appendix C.
- ASTM D5314-92, Standard Guide for Soil Gas Monitoring in the Vadose Zone (2001).
- California Environmental Protection Agency, Department of Toxic Substance Control (DTSC), February 2005, Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air. See Appendix G.
- California EPA (DTSC) Advisory for Active Soil Gas Investigations. As noted above, the 2003 Advisory is due to be revised in 2010.
- H&P Mobile Geochemistry‘s revised January 2004 Sub-slab Soil Vapor Standard Operating Procedures (for VI Applications).
- Interstate Technology and Regulatory Council (ITRC), January 2007, Vapor Intrusion Pathway: A Practical Guideline. See appendices D and F.
- Massachusetts Department of Environmental Protection, August 2008, Standard Operating Procedure for Indoor Air Contamination.
- Missouri Department of Natural Resources, April 21, 2005, Missouri Risk-Based Corrective Action (MRBCA) for Petroleum Storage Tanks, Soil Gas Sampling Protocol.
- New Jersey Department of Environmental Protection (NJDEP), October 2005, Vapor Intrusion Guidance. See chapter 6 and appendix I.
- New Jersey Department of Environmental Protection (NJDEP), 2005, Field Sampling Procedures Manual. See chapter 9.
- New York State Department of Health, October 2006, Guidance for Evaluating Soil Vapor Intrusion in the State of New York. See chapter 2.
- USEPA ERT, June 1996, Soil Gas Sampling SOP (#2042).
- USEPA, 2006, ―Assessment of Vapor Intrusion in Homes Near the Raymark Superfund Site Using Basement and Sub-slab Air Sample" (EPA/600/R-015/147).

Appendix D: The Johnson and Ettinger Vapor Intrusion Model (JEM)

US EPA‘s *On-line Tools for Site Assessment Calculation* website[89] notes that since ―vapor intrusion is a particularly difficult pathway to assess,…a screening-level model is often employed to determine if a potential indoor inhalation exposure pathway exists and, if such a pathway is complete, whether long-term exposure increases the occupants‘ risk for cancer or other toxic effects to an unacceptable level. A popular screening-level algorithm currently in wide use in the United States, Canada and the U.K. for making such determinations is the ‗Johnson and Ettinger‘…" model (JEM).

The website further states that the JEM is a ―simplified model to evaluate the vapor intrusion pathway into buildings." It ―has become increasingly popular with regulators and consultants over the last 10 years and several manuscripts have been published on its use... Briefly, the model is a one-dimensional analytical solution, which incorporates both advection and diffusion transport mechanisms to produce a unit-less *attenuation factor*. This attenuation factor[90] is a measure of how soil and building properties limit the intrusion of organic vapors into overlying buildings and is defined as the concentration of the compound in indoor air divided by the concentration of the compound in soil gas or groundwater. Chemical concentrations in groundwater will attenuate more than chemicals in soil gas due to the added limitations imposed by mass-transfer across the capillary fringe. The *larger* the attenuation factor produced by the model, the *greater* the intrusion of vapors into indoor air."

In this appendix several aspects of VI assessment modeling are discussed:

- JEM assumptions and restrictions[91]
- Default and non-default inputs for the JEM
- Instructions for using the JEM to predict indoor air VOC concentrations during VI assessment
- Instructions for using the JEM to obtain *building-specific* groundwater and soil gas concentrations protective of the VI pathway

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[89] http://www.epa.gov/athens/learn2model/part-two/onsite/JnE_lite_forward.htm

[90] Sometimes denoted as ▯ In this document we use the abbreviation, VAF.

[91] In this appendix it is assumed that the investigator is using the JEM if any VI modeling is performed. If a model other than the JEM is being considered, Ecology recommends that the PLP contact the Ecology site manager in advance to discuss its suitability.

EPA versions of the executable JEM can be found at: (http://www.epa.gov/oswer/riskassessment/airmodel/johnson_ettinger.htm) and at the Office of Research and Development, Athens, Georgia, website (http://www.epa.gov/athens/learn2model/part-two/onsite/JnE_lite.htm). The former provides JEM ―screening" and ―advanced" spreadsheets for four types of subsurface sources: groundwater, soil, soil gas, and NAPL. The latter provides an on-line calculator for groundwater and soil.

Model assumptions and restrictions

The JEM is a handy VI assessment tool and Ecology endorses its use during Tier I screening. But, like other models, it applies algorithms to generate results, and these algorithms require that assumptions be made about a host of site and building conditions. In some cases, these simplifying assumptions lead to estimates of attenuation (between the subsurface and indoor air) that are conservative. However, this is not always the case. Site complexity can also challenge the conservativeness of results, and users of the model must always take into account the differences between the site and building being modeled and what the JEM was designed to do, and not do.[92]

The JEM assumes that soils in the vadose zone are relatively homogeneous and isotropic, though horizontal layers of consistent soil types can be accommodated (with advanced versions of the spreadsheet model). Both diffusive and convective transport processes are assumed to be at steady state. Neither sorption nor biodegradation is accounted for in the transport of VOC vapor molecules.

Near-surface sources of contamination and very shallow ground water can be a problem for the model. EPA (2002) states that the JEM should not be used if subsurface vapor sources exist shallower than five feet below the foundation. EPA also notes that the top of the capillary fringe must be below the bottom of the building‘s floor in contact with soil (i.e., groundwater cannot be wetting the foundation). Otherwise, predictions may not be conservative. In addition, EPA cautions model users against:

- Accepting JEM predictions when there are sumps in the basement;[93]
- Using the JEM to predict indoor air levels within buildings with crawlspaces, earthen floors, or stone floors;
- Using the JEM to predict indoor air levels for fractured unsaturated zone geology;
- Using the JEM to predict indoor air levels within buildings where the air exchange rate is considerably less than 0.25 per hour, or when the building‘s indoor/outdoor pressure differential is greater than 10 Pascals;
- Assuming that the model will ―fit” site conditions where there is significant lateral movement of subsurface VOCs. The JEM model only considers vertical diffusion from the source. Significantly different permeability contrasts between vadose zone layers may cause lateral flow that the model will not approximate;

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[92] The uncertainty in determining key model parameters and sensitivity of the JEM to those key model parameters is qualitatively described in Table G-2 of EPA, 2002. A list of model input parameters for building-related properties, generally considered reasonably conservative, is provided in Table G-3 (EPA, 2002).

[93] Depending on the sump construction and purpose, it may not be conservative to rely upon JEM predictions of indoor air quality. The model assumes there are no significant preferential pathways for vapors crossing the basement/first floor slab.

- Using the JEM if the capillary fringe is likely to be contaminated and there are large fluctuations in water table elevations. The JEM assumes the capillary fringe is not contaminated, a poor assumption if shallow ground water is contaminated and the water table fluctuates significantly;

- Accepting the accuracy of JEM predictions when near-surface vadose zone soils are gravel, gravelly sand, or sandy gravel. Model defaults may not assure conservativeness in this event;

- Assuming that the model will ―fit” site conditions where there are significantly changing ambient/building pressures and soil gas flowrates (i.e., where a steady state assumption is unlikely to be conservative—such as during a passing weather front). Prediction uncertainty may increase as these rates and pressure differentials stray from what the model assumes and an ―average” of the changing values fails to adequately represent the effects of these parameters on those indoor air VOC concentrations the user is most interested in determining;

- Using the JEM groundwater-to-indoor air spreadsheets at sites with LNAPL; and,
- Using the JEM soil-to-indoor air spreadsheets. Although models such as the JEM have the ability to predict indoor air concentrations from VOC sources in subsurface soils, significant uncertainty may be associated with these predictions. At this time, therefore, EPA and Ecology do not recommend that investigators rely upon JEM predictions when the VI source is VOCs in vadose zone soils.[94]

The reader is directed to EPA‘s *User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings* (EPA, 2004) and *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* (EPA, 2002) for a full discussion of these limitations.

Model use at Ecology sites

When using screening models like the JEM, Ecology does not recommend that users attempt to model existing site conditions exactly. Rather, the model should be used conservatively and inputs should be selected so as to predict upper-bound indoor concentrations. In fact, the model should be used primarily in a ―default” mode (i.e., with conservative, generic inputs; see the discussion in the following section). If site-specific inputs are used these must be reasonable upper-bound values,[95] and should be limited to those inputs and values that predictions are significantly sensitive to, and which are relatively easy to measure.[96] In addition, it should be realized and acknowledged that if certain site-specific values are input to the model, the

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[94] As discussed in the guidance text, Ecology will allow use of the soil spreadsheet version of the JEM for those non-TO-15 SVOCs, pesticides, and PCBs in Appendix B that are unlikely to pose a VI threat unless they are present at high concentrations.

[95] That is, ―upper-bound” in terms of conservativeness. Here and throughout the appendix Ecology uses *upper bound* to refer to values at the conservative end of the range of expected values. ―Upper-bound” values for air exchange rate assumptions, for example, will be numerically low values, chosen to represent the low end of rates expected for the type of building being considered.

[96] ―Easy to measure” here refers to the straightforwardness of the measurement as well as the ability of the measurement to represent conditions that would be found at the site over time.

predicted indoor air values may need to be qualified accordingly. Large building dimension values, for instance, input to the model to reflect an existing structure, will result in indoor VOC predictions different from those for a smaller building, which might be constructed at that location in the future.

Ecology expects that the only realistic (non-default) values users will commonly input to EPA‘s model spreadsheets or on-line JEM calculator are:

- site-specific subsurface concentration values,
- building dimensions,[97]
- foundation types (basement or slab-on-grade) and slab thickness,
- soil types,[98]
- soil/groundwater temperatures
- depth to source distances, and
- soil types per vadose zone *layer* (when using the advanced spreadsheets)

In some cases the PLP will want to use a model such as the JEM to support a hypothesis that VI is very unlikely to be problematic at the site, even though, initially, modeled predictions of indoor air do not agree with this hypothesis when the model is *configured conservatively.*[99] That is, the PLP may believe that if model inputs were adjusted to better reflect actual building and/or subsurface conditions – as opposed to more worst-case, or non-site specific, conditions – indoor air predictions would be consistent with a hypothesis positing no unacceptable impacts. Instead of opting to sample indoor air, then, the PLP may prefer to measure selected JEM parameters and use those measurements to replace the default values.

It is not the Guidance‘s intent to prevent this, only to communicate that this is not Ecology‘s general preference and that PLPs should realize that Ecology is likely to demand a relatively high degree of confidence in the protectiveness of any values proposed to replace defaults. Any sampling will need to be designed so that the site-specific value the PLP obtains and uses in the model is clearly and properly representative of the range of conditions one would encounter at

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[97] If the investigator is attempting to assess a particular building, rather than a future building with unknown dimensions.

[98] If there are multiple types of soil textures found in borings under the building, the coarsest-grained texture should be input to the model unless a finer-grained sediment makes up an overwhelming percentage of the vertical profile. In addition, fine-grained soil textures should not be assumed to be present under the entire building footprint, and should not be input to the model *as a layer* unless it has been <u>demonstrated</u> that they are likely to exist under the entire footprint.

The 2004 EPA User‘s Guide (prepared by EQM) recommends selecting: SAND when the site-specific material is sand/gravel with < 12% fines (where fines are < 0.075 mm); LOAMY SAND when the when the site-specific material is sand or silty sand with 12-25% fines; and SANDY LOAM when the when the site-specific material is silty sand with 20-50% fines.

[99] i.e., when the inputs to the model are primarily default values, and any site-specific values used are clearly conservative.

the site over time. Such demonstrations may be resource-intensive, especially in the absence of building-specific soil gas and/or indoor air sampling.

With a few key exceptions (the site-specific parameters identified above in ―Model use at Ecology cleanup sites"), Ecology generally discourages use of most site- or building-specific JEM inputs in the absence of confirmatory sampling. This is because Ecology sees the primary applicability of VI-assessment models as screening tools. Since indoor air concentrations due solely to VI are usually difficult to accurately measure, and often hard to even estimate, model predictions of indoor air VOC concentrations will rarely be able to be effectively validated at a specific site/building.[100] In our view the best that can be done, given the goal of erring on the side of protectiveness, is to ensure that – by selection of model inputs – modeled predictions over-estimate actual VOC levels. By restricting which inputs can be adjusted, and to what extent they can be adjusted away from a default setting, this can be achieved.

The JEM is a Tier I tool. If it predicts that indoor air concentrations due to vapor intrusion are at or below applicable cleanup levels, and the user has relied upon conservative inputs and building/soil properties, the VI assessment for that building may be terminated.[101]

Default and non-default JEM inputs

Table D-1 shows the various parameters that are inputs to the JEM and provides instruction on how to use the EPA version of the JEM. The column to the right notes those parameters which have default values that should routinely be used when assessing VI during Tier I. As discussed above, Ecology does not recommend that model users attempt to predict accurate indoor air impacts due to VI. Model default values should routinely be used, with the expectation that predictions will be conservative.

The *forward* calculation spreadsheet (or input screen for EPA‘s 2008 On-line version of the JEM) asks the model user to input:

a) the contaminant, contaminant concentration (in soil gas or shallow groundwater),

b) the depth to the ―source" (the soil gas sample depth or the water table),

c) the soil type,[102]

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[100] The opportunity for such verification (and then calibration) is only afforded by the consistent detections of a particular VOC in all three media (groundwater, soil gas, and indoor air), and where the detections in soil gas and indoor air are solely the result of VI contributions.

[101] This presumes that the site/building conceptual model is consistent with the conceptual model the JEM is based upon. Although some guidance, including EPA‘s draft 2002 OSWER document, recommend that no further action decisions be preceded by sub-slab or crawlspace (and/or indoor) air sampling, Ecology believes that one outcome from using the JEM properly is to screen-out sites/buildings where VI is very unlikely to pose unacceptable risks to indoor receptors. The reader should understand, however, that the model prediction is a snapshot, dependent on the media VOC concentrations which have been input at that time. If subsurface media concentrations increase, there may be a need to re-run the model. Consequently, there is a need to <u>know</u> whether these concentrations may be increasing, which may require continued monitoring. In addition, there will be cases where the indoor air prediction, while acceptable, is only marginally acceptable. Depending on the perceived degree of uncertainty associated with the prediction, Ecology may require that sampling be conducted to verify conclusions reached through modeling.

d) soil/groundwater temperature, and

e) building type (basement or slab-on-grade).

The model assigns or derives values for a number of properties, and calculates an attenuation factor and indoor air concentration. The model also calculates the risk or hazard associated with the predicted indoor air level based on several assumed exposure parameter values.

Some of the JEM‘s other property values can be changed. For example, if the investigator is assessing a particular building and attempting to estimate potential indoor air concentrations, that building‘s actual dimensions and slab thickness could replace the assigned/default mixing height (H_B), footprint area (L_B and W_B), and subsurface foundation area values, as well as the assumed slab thickness. While other soil and building property values may also be replaced (such as the soil moisture content, a sensitive model parameter), this is generally not recommended and is not considered using the JEM in its —default” mode. In the spreadsheet version of the model the user should typically enter the –SCS soil type” and allow the model to assign soil vapor permeability, not input a –user-defined” permeability. Similarly, users should typically allow the model to assign values for soil bulk density, total porosity, and water-filled porosity associated with the inputted SCS soil type, instead of entering alternative values.

Regardless of the parameter, if a non-default value is proposed to Ecology for use in the model Ecology will typically require a more resource-intensive demonstration that the proposed value is conservative if indoor air predictions (in the *forward* mode, or protective media levels in the *back-calculation* mode) are particularly sensitive to the parameter and the proposed value is significantly different than the default value.

Non-default soil values

In those cases where investigators propose to gather site-specific information to modify a subsurface default value such as vadose zone moisture content, Ecology will require a demonstration that the proposed non-default values are truly conservative. PLPs will generally then need to show that the value proposed represents:

- reasonable upper-bound values measured, or expected to be found, at the site. This is especially true if measurements have been taken at locations around the perimeter of the building; or,

- an appropriate upper confidence level on the central tendency of values existing at the site, if multiple measurements have been taken at locations beneath the building.

In either case the number of measurements must be large enough to adequately characterize the range and distribution of parameter values. The measurements must also represent the central tendency of values obtained over time, so that if certain seasons or events affect the parameter value, it is clear that the proposed value for use in the model has been selected to properly represent the frequency and magnitude of these impacts on the parameter.

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[102] Soil texture types are limited in the on-line version of the JEM to four sand and loam types. The EPA JEM spreadsheets include the option for additional soil types (clays, e.g.).

Non-default building values

The JEM can be used to predict indoor air concentrations for a specific building that currently exists on the property or a hypothetical building that may be present sometime in the future. If the investigator is attempting to derive indoor air concentrations for the latter case, Ecology expects model inputs to reflect a conservative hypothetical building (low air exchange rates [0.25 volume exchanges per hour]; low Q_{soil} values [5 L/min]; default house dimensions and small mixing volumes, etc.). For existing buildings, however, the modeler may use values that reflect what is known about the structure. For example, as discussed above, actual building dimensions may be input, as well as actual slab thickness.

If the investigator chooses to modify default air exchange rates (AER or E_B), Ecology expects a demonstration that the proposed non-default rates are truly conservative. If this demonstration is based on measurements, the number of measurements should be large enough to adequately characterize the range and distribution of the parameter‘s values. If certain seasons or events affect the parameter value, the proposed rate for use in the model must be a reasonable ―upper bound” rate (see footnote 7), taking into consideration the frequency, magnitude, and duration of any likely deviations from the selected rate.

In addition, inputs must be selected that correspond to actual building use and HVAC system operation. Air exchange rates in commercial buildings, for example, may be much different depending on the hour and day of the week. Some systems operate differently when employees are not present. If ‗work shift‘ exchange rates are to be used in the model, the PLP must determine what affect the – presumably – lower AERs during ―off-hours” have on VI and resulting indoor air concentrations during those periods when the HVAC system is either off or operating differently than during work shifts. The AER parameter in the model is a constant, and the model assumes that the AER value does not change. Indoor air VOC concentrations predicted by the model for a Monday morning, then, assume that the AER value input to the model has been maintained constantly since Friday afternoon. This may not be the case, and making the assumption may well underestimate indoor VOC levels workers are exposed to as they begin their shifts.

As with any data collection effort, Ecology will expect different levels of demonstration ―effort” depending on how the resulting data will be used and how close these data are to a critical value. For example, it may require little effort to successfully demonstrate that a newer commercial building‘s air exchange rate is at least one volume/hour.[103] But if the model will continue to predict unacceptable indoor air concentrations unless the inputted rate is as high as two volumes per hour, and this is the value the PLP is proposing, Ecology is likely to want considerably more information, or information that is perhaps based more on measurements than HVAC design specifications, before concluding that the air exchange rate for the building of concern is actually and consistently this high.

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[103] CalEPA‘s 2005 *Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air* suggests that users assume that AERs in California commercial buildings will be at least this high. So does Health Canada (2004). It reports the findings from two 1995 studies (Fang and Persily, 1995; Dols and Persily, 1995), showing that commercial AERs vary from 0.3 to 2.6 per hour.

Q_{soil}

The default value for Q_{soil} (the pressure-driven volumetric flowrate of soil gas into the structure) is 5 liters/minute for a typical residential building (house). This value should not be modified by the JEM user unless the building being assessed is considerably larger than an average residence. Some commercial buildings certainly fit into this category, and if 5 liters/minute is assumed for these structures, the model may under-predict the indoor air concentration. The State of New Jersey recommends that the Q_{soil} value for buildings larger than homes be input as:

(5 L/min) X (building perimeter in cm/4000 cm),

which appears to be an acceptable approach for adjusting this rate <u>if soil gas entry routes into the building in question are likely to be primarily located at the perimeter</u>. In the spreadsheet version of EPA's JEM the user also has the option of allowing the model to calculate Q_{soil}.[104]

JEM output

Table D-1 provides basic instructions on how to use EPA's version of the JEM. The model is designed to provide users several outputs. As noted above, the primary output in the *forward* mode[105] is a VAF value that estimates how much attenuation in VOC concentration can be expected between soil gas at a particular depth and indoor air. In the spreadsheet model this value is found on the *Intermediate Calculations Sheet* and is called the “indoor attenuation coefficient (α).” The On-line Calculator identifies the same parameter as the “Johnson & Ettinger Attenuation Factor (α)”. The model uses this estimate to predict an indoor air concentration. In the spreadsheet version of the model this predicted concentration is also found on the *Intermediate Calculations Sheet* and is called the “building concentration ($C_{building}$).” The On-line Calculator produces “low, high, and best estimate predicted indoor air concentrations” for the VOC modeled. Both versions of the model will also derive EPA's associated risk level (or hazard quotient) for the indoor air concentration predicted.

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[104] Guidance (EPA 2002) suggests that Q_{soil} should be within the range of 1 to 10 L/min. However, this is a low rate for buildings much larger than a typical small house (1000 ft2). The JEM spreadsheets will therefore frequently calculate a much larger Q_{soil} when building footprints significantly exceed those of a typical house. In general, this calculated value will be very conservative.

Several papers have been published by Paul Johnson and others which discuss the JEM:

- "Evaluation of the Johnson and Ettinger Model for Prediction of Indoor Air Quality" by Ian Hers, Paul Johnson, et al, 2001
- "Identification of Critical Parameters for the Johnson Ettinger (1991) Vapor Intrusion Model" by Paul Johnson, 2002 (API doc)
- "Identification of Application-specific Critical Inputs for the 1991 Johnson and Ettinger Vapor Intrusion Algorithm", by Paul Johnson, 2005 (NGWA doc)

Johnson suggests that for conservative assessments of VI the (Q_{soil}/Q_B) ratio should be close to 0.01. In most cases Ecology will want any manipulation of model inputs/assumptions to be consistent with the analyses discussed in these documents.

[105] In EPA's spreadsheet version of the JEM the *forward* calculation is initiated at the top of the Data Entry Sheet by choosing “calculate incremental risks from actual…concentration (enter X in YES box and initial…conc below).”

The output is similar for the *backward* calculation.[106] But in its back-calculation mode the JEM derives a VAF value and then uses it to calculate a soil, soil gas, or groundwater concentration that is protective of indoor air quality. The acceptable indoor air concentration the model uses to derive these protective subsurface concentrations is associated with a particular risk factor (such as 1E-6) for carcinogens or hazard quotient (HQ) for non-carcinogens.

While investigators assessing VI in Washington State may use the JEM's resulting VAFs and forward-mode predicted indoor air concentrations, the indoor air risks and HQs calculated by the model are not necessarily the same as those one would derive from re-arrangement of Equations 750-1 or 750-2. See section 6.5 in the guidance text and the section entitled ―Protective subsurface media levels using the JEM" below.

Assessment: comparing indoor air concentration predictions to "acceptable" levels

Chapter 3 of the guidance states that the JEM can be used during Tier I to assess VI impacts by inputting shallow groundwater concentrations, soil gas concentrations, and, for some limited substances, soil concentrations. The model can be used to predict indoor air levels for an existing building or a hypothetical building.

If the JEM is utilized to predict indoor air concentrations, predictions for residential and other non-industrial buildings should typically be compared to Method B air cleanup levels. Indoor air predictions for industrial buildings are usually compared to industrial air cleanup levels, especially when the future land use is expected to remain industrial.

Using the JEM to calculate protective subsurface media levels: Groundwater

In its back-calculation mode the JEM derives media concentrations that are intended to be protective of indoor air quality. For sites where contaminated groundwater is the only VI source, a shallow (water table) groundwater VOC concentration can be calculated by the model that would be predicted to potentially result in an acceptable indoor air concentration. When calculating such concentrations, users must typically assume properties for a hypothetical future house. If the current building's JEM properties are used, and the building is not a house, the PLP should understand that institutional controls may be needed as part of the site cleanup action to ensure that in the future there are not changes to the building (or replacement of the building with a new structure) that may cause the model's indoor air prediction to no longer be conservative.

When calculating VI-protective groundwater levels the model's Q_{soil} value should be set to 5 L/min if the existing or future building is a house. It should only be increased if the building being modeled is considerably larger (see the discussion under ―Default and non-default JEM inputs" above).

Using the JEM to calculate protective subsurface media levels: Soil gas

For sites where contaminated groundwater is the VI source, where soils (or only soil gas) are the

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[106] In EPA's spreadsheet version of the JEM the *backward* calculation is initiated at the top of the Data Entry Sheet by choosing ―calculate risk-based…concentration (enter X in YES box)."

source, where both groundwater and soils are contaminated with VOCs, or where there is LNAPL[107] at the water table, the JEM can derive a building-specific soil gas concentration that would be predicted to potentially result in an acceptable indoor air concentration. This soil gas concentration could be used post-remediation to show that subsurface conditions no longer pose a potential threat to indoor air quality via the VI pathway.

As with the calculation of protective groundwater levels, model users back-calculating protective soil gas concentrations must either assume properties for a hypothetical future house, or use the current building's properties (with the understanding that institutional controls may then be needed if the current building's dimensions, AERs, etc., are less conservative than those for house). Q_{soil} values should be set as discussed above.

Soils

EPA does not recommend using the JEM soil spreadsheets to predict indoor air concentrations from soil concentrations if this is the sole line of evidence relied upon for screening out a building. Ecology concurs and believes that the uncertainty associated with the indoor prediction is too high to merit such a use for the model. Consequently, Ecology has recommended soil gas sampling in cases where there the subsurface contamination is in the vadose zone. Soil gas concentrations can then be input to the JEM to predict potential indoor air concentrations.

JEM "Back-calculating"

Unfortunately, EPA's versions of the JEM are not structured to accept target indoor air levels that groundwater, soil, or soil gas concentrations can then be back-calculated to attain. This is problematic because EPA calculates risks and hazards somewhat differently than they are calculated in the MTCA regulations. Method B equations for indoor air cleanup levels in WAC 173-340-750 currently utilize reference dose and carcinogenic slope factor toxicity information (RfD_i and SF_i), whereas the JEM uses reference concentrations and unit risk factors (RfC_i and URF_i). The predicted groundwater and soil gas concentrations the model produces to be protective of indoor air (for a carcinogenic risk of $1x10^{-6}$ or a non-carcinogenic hazard quotient of one) are therefore not the same as those it would derive to be protective of Method B air cleanup levels. Calculating VI-protective groundwater and soil gas concentrations via the JEM must currently be accomplished through a two-step use of the model's *forward* calculation. Please see the instructions in Table D-2 below.

JEM-related documentation

Work plans and reports submitted to Ecology that include JEM-predicted concentrations or attenuation factors must contain sufficient documentation for a review and independent re-calculation of results. Usually this means submitting print-outs of the spreadsheets themselves or

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[107] EPA's OSWER website provides JEM spreadsheets for sites with NAPL. As with EPA's 3-phase groundwater and soil gas models, there is a screening-level NAPL spreadsheet and an advanced-level sheet. According to EPA: ―When NAPL is present in soils, the contamination includes a fourth or residual phase. In such cases, the…NAPL models…can be used to estimate the rate of vapor intrusion into buildings and the associated health risks. The…NAPL models use a numerical approach for simultaneously solving the time-averaged soil and building vapor concentration for each of up to ten soil contaminants. This involves a series of iterative calculations for each contaminant. The NAPL models are available in Excel." The website also provides a *NAPL Model User's Guide*.

the on-line calculator screens. The reviewer‘s attention should be drawn to any inputs or calculation modifications that utilize non-default values. If a variable such as air exchange rate has been modified from its default value to better represent the building‘s degree of ventilation, sufficient documentation must accompany the modeling print-outs to justify use of the building-specific rate.

Investigators utilizing the JEM must ensure that the conceptual VI model for the site and building of interest is similar to the conceptual VI model the JEM model is based upon. Simplifying assumptions have been made by the designers of the JEM in order to predict indoor air concentrations from subsurface media concentrations. These may be poor assumptions for the actual site/building being modeled, and may disqualify use of the model as a conservative screening tool. When submitting modeling documentation, therefore, PLPs should also include a discussion about JEM assumptions and limitations, stating how their use of the model is appropriate given these restrictions.

Table D-1 Recommended JEM default Input Settings[108] and instructions for using EPA’s version of the JEM in *forward* mode to estimate a building-specific VAF and an indoor air concentration

A. Open the EPA JEM spreadsheet or On-line Calculator			
B. Enter parameters to calculate the VAF and a predicted indoor air concentration			
Input parameter	Default input value	Unit	Descriptions/Comments
B.1 Enter General information			
Concentration for soil gas sample	Measured	µg/m^3	Use the highest concentration measured beneath/near the building
Concentration for soil	Measured	µg/kg	
Concentration for ground water	Measured	µg/L	
Depth of the sample	Measured	feet or m	Site-specific
Contaminant of concern (or VOC)	Select the hazardous VOC of concern		Site-specific. For petroleum contamination, use toluene as a representative substance.
Type of building	Building-specific		Selection between basement or slab-on-grade
Type of soil	Select the most representative Soil Conservation Service (SCS) soil texture type		The on-line version of the JEM only allows selection of 1 of 4 soil types (sand, loamy sand, sandy loam, and loam). Refer to Table G-4 of EPA (2002) for the selection of soil type based on site lithologic information.
Average soil/ground water temperature	55	°F	Can be measured, but is generally 47 to 57°F in WA.
B.2 Chemical properties: users may accept the default values stored or overwrite with chemical-specific information.			
CAS Number & Molecular Weight	Chemical-specific	g/mole	Will be assigned.

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[108] Taken from Table G-3 of the 2002 Draft EPA VI guidance and EPA‘s on-line calculator version of JEM model.

Input parameter	Default input value	Unit	Descriptions/Comments
Henry's Law Constant (**H**)	Chemical-specific	unitless	The model will assign a value and correct it for the inputted groundwater temperature. This value should usually be accepted. For soil gas inputs the HLC has no impact on the VAF or indoor air concentration calculated.
Free-Air Diffusion Coefficient (**D_a**)	Chemical-specific	cm^2/s	Accept the defaults (though these values can be overwritten)
Diffusivity in Water (**D_w**)	Chemical-specific	cm^2/s	Accept the defaults (though these values can be overwritten)
Unit Risk Factor (**URF**)	Chemical-specific	(µg/m^3)$^{-1}$	This value has no impact on the VAF or indoor air concentration calculated. However, if the user intends to use the risk the JEM associates with its predicted indoor air level, the URF must be consistent with WAC 173-340-750.
Reference Concentration (**RfC**)	Chemical-specific	mg/m^3	This value has no impact on the VAF or indoor air concentration calculated. However, if the user intends to use the HQ the JEM associates with its predicted indoor air level, the RfC must be consistent with CLARC and WAC 173-340-750.

B.3 Soil properties			
Total Porosity **(n);** Unsaturated Zone Moisture Content **(θ_w);** Capillary Zone Moisture Content at Air-Entry Pressure **($\theta_{w,cap}$);** Height of Capillary Zone **(CZ_h)**	Do not change these parameters. They are not considered to be inputs when running the model. Depending upon the soil type chosen, the model calculates these parameters from soil properties that the model assigns based on texture classification		
Input parameter	Default input value	Unit	Descriptions/Comments
Soil-gas Flow Rate Into the Building **(Q_{soil})**	5	L/min	5 L/min is the default rate for houses. For buildings with significantly larger footprints, larger Q_{soil} values must be used (see the Q_{soil} discussion in the appendix text).

B.4 Building properties			
Air Exchange Rate **(E_B or AER)**	0.25 (residential) and 0.5 (commercial)	hr^{-1}	To assess an existing commercial building, a higher rate can be entered. But adequate documentation must demonstrate that the higher rate is actually realized and maintained.
Building Mixing Height **(H_B)**	2.5 (slab-on-grade) or 3.7 (basement)	m	To assess an existing building, can be measured and input. For larger, non-residential buildings, the height of the lowest ceiling in any occupied rooms on the lowest floor should be entered.
Building Footprint Area **(F_B)**	100	m^2	To assess an existing building, can be measured and input.
Subsurface Foundation Area[109] **(A_B)**	106 (slab-on-grade) or 180 (basement)	m^2	To assess an existing building, can be measured and input.
Building Crack Ratio[110] **(η)**	0.00038 (slab-on-grade) or 0.0002 (basement)	unitless	Do not change this value; it is inter-calculated by the model
Building Foundation Slab Thickness **(L_{crack})**	0.1	m	To assess an existing building, can be measured and input.
B.5 Exposure parameter values may be disregarded if the only desired output is a VAF or a predicted indoor air concentration.			

C. Output values of primary interest are:

- **the "indoor attenuation coefficient (α)," found on the *Intermediate Calculations Sheet* of the EPA spreadsheet version of the model. EPA's On-line Calculator identifies the same parameter as the "Johnson & Ettinger Attenuation Factor (α)"**.

- **the model's predicted indoor air concentration. In the spreadsheet version of the model this concentration is found on the *Intermediate Calculations Sheet* and is called the "building concentration ($C_{building}$)." The On-line Calculator produces "low, high, and best estimate predicted indoor air concentrations" for the VOC modeled.**

The risk or hazard associated with the predicted air concentration will not necessarily be the same as the "MTCA risk" or "MTCA hazard."

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[109] Area of enclosed space below grade. This includes the area of the floor in contact with the underlying soil and the total wall area below grade.

[110] The ratio of crack to total floor area.

Table D-2. Calculating VI-protective groundwater and/or soil gas concentrations

objective	instruction	result
Derive an attenuation factor that will enable you to calculate a VI-protective groundwater or soil gas concentration for the VOC of interest.	(1) Run the JEM in the *forward* mode. (2) Any groundwater or soil gas VOC concentration can be input. (3) Use default values and, where allowed, site-specific values (see Table 1).	(1) An attenuation factor (α). (2) An indoor air concentration prediction (use the “best estimate” from the On-line Calculator).
Calculate the groundwater or soil gas input concentration for the desired MTCA Method (B or C) indoor air cleanup level.	(1) The predicted indoor air concentration from the step above is assigned *IAP*. (2) The applicable Method B or C air cleanup level is assigned *CUL*. (3) The VOC groundwater or soil gas concentration originally input to the JEM is assigned INPUT$_0$. (4) Calculate the VOC groundwater or soil gas concentration to be input to the JEM (INPUT$_1$) that should result in an air concentration equal to the applicable Method B or C air cleanup level: $\text{INPUT}_1 = (\text{CUL X INPUT}_0) / \text{IAP}$	INPUT$_1$ is the groundwater or soil gas concentration that should correspond to a predicted indoor air concentration equal to the Method B or C air cleanup level.
Re-calculate the predicted indoor air concentration for a modified groundwater or soil gas input concentration (INPUT$_1$). This inputted concentration should be the VI-protective groundwater or soil gas concentration.	(1) Enter the groundwater or soil gas INPUT$_1$ value for the VOC concentration and run the JEM in the *forward* mode. (2) Use default values and, where allowed, site-specific values.	The predicted indoor air concentration (“best estimate” for the On-line Calculator) should be the applicable Method B or C air cleanup level. If so, INPUT$_1$ is the VI-protective groundwater or soil gas concentration.

Appendix E. Decision Matrix Guidelines for Tier II Vapor Intrusion Assessment

The two tables below (E.1 and E.2) are intended to help decision-makers synthesize the information obtained during a Tier II investigation and make decisions about what steps should be taken next. The tables assume that this activity is occurring during the Remedial Investigation (RI), when investigators are assessing the potential for vapor intrusion (VI) to unacceptably impact a current building‘s indoor air.

The matrix, conceptually, reflects Ecology‘s preference that *multiple lines of evidence* be assessed before deciding whether an action should be taken to protect indoor receptors. The two lines of evidence explicitly represented in the matrix are indoor air concentration data and sub-slab sampling concentration data. While indoor air data provide a good indication of the level of indoor air contamination at the time the samples were collected, they are not usually capable, by themselves, of accurately quantifying the contribution made by VI. This is because the measured indoor air contamination is often due to multiple sources: outdoor air contamination that has come into the building; indoor sources of contamination; and, perhaps, contaminated soil gas that has entered the building via VI.

Sub-slab soil gas sampling, performed concurrently with indoor air sampling, provides the investigator information about the degree to which soil gas sampled immediately below the building is contaminated. If concentrations in this soil gas are high, VI may potentially be contaminating indoor air. If the soil gas concentrations are relatively low, VI is unlikely to be contributing significant contaminant mass to the indoor air space. If indoor air contamination is measured under this latter scenario, it is likely that other (non-VI) sources are the primary contributors.

The matrix is not a substitute for critical thinking or best professional judgment. It is only a general guide. Site-specific Tier II decisions will need to be based on site conditions and the conditions at any given site may lead to different decisions than the simple suggestions provided in the boxes below.

Recommended actions in the matrix:

(1) No Need for Mitigation: the measured concentration in indoor air is below the screening level. The measured sub-slab soil gas concentration is either below the generic screening level or only marginally above that level. VI does not appear to be a problem.

(2) Repeat sampling: several decision boxes suggest that sampling be repeated. In most of these cases the indoor air or sub-slab soil gas measurement has detected an elevated VOC concentration. Elevated indoor measurements coupled with relatively low sub-slab concentrations may indicate the presence of an indoor source of the VOC. This should be investigated. Elevated sub-slab measurements coupled with relatively low indoor air concentrations may indicate that the building was capable of resisting VI at the time the

indoor samples were collected, but the sub-surface source may be capable of contaminating indoor air in the future.

(3) Mitigate: the combination of indoor and sub-slab data suggests that VI may be unacceptably contaminating indoor air. Methods to mitigate exposures related to VI are described in Chapter 5 of this Guidance. Mitigation is considered a temporary measure implemented to address exposures related to VI until contaminated environmental media are remediated. In some cases, instead of mitigation, the responsible party may choose to implement an interim action that remediates the VI source. These types of actions are also discussed in Chapter 5.

Two matrices have been provided below, one for carcinogens (E-1) and one for non-carcinogens (E-2). They are very similar. Both are intended for buildings where the applicable ―acceptable” indoor air concentration is the Method B air cleanup level. However, since non-carcinogens may produce harmful effects once threshold exposures are reached, the middle column of Table E-2 has reduced the concentration range associated with ―marginally” unacceptable indoor air quality. This is consistent with Ecology‘s policy of requiring action when the Hazard Index (HI) clearly exceeds a value of 1.0.

Table E-1. Decision matrix for carcinogenic contaminants of concern.

Indoor air measurement[111]/ Sub-slab soil gas measurement	**Indoor air** concentration < indoor air SL	**Indoor air** concentration > indoor air SL, but < 10 times the SL	**Indoor air** concentration > 10 times the SL
Sub-slab soil gas concentration < applicable SL	no need for mitigation	Repeat sampling; investigate potential indoor sources	Repeat sampling; investigate potential indoor sources
Sub-slab soil gas concentration > applicable SL, but < 10 times the SL	no need for mitigation	repeat sampling; mitigate if multiple consecutive indoor air samples exceed the SL.	investigate potential indoor sources; mitigate if unable to locate/isolate indoor sources
Sub-slab soil gas concentration > 10 times the applicable SL	Repeat sampling	Repeat sampling; mitigate if multiple consecutive indoor air samples exceed the SL.	mitigate
No **Sub-slab** soil gas data	Repeat sampling if sub-slab soil gas concentration is likely to be > 10 times the SL; collect sub-slab data, if possible, during repeat sampling	Repeat sampling; collect sub-slab data if possible	mitigate

---

[111] This refers to the indoor measurement due to VI. Commonly this will be estimated to be the [max measured indoor concentration] – [representative measured, same-day, ambient air concentration]

NOTES to Table E-1:

(1) SL = screening level. Method B indoor air and sub-slab soil gas screening levels are provided in Appendix B, Table B-1.

(2) The table considers carcinogenic VOCs one by one. In some cases there will only be a single VOC that has the potential to unacceptably contaminate indoor air and the table can be used *as is*. However, there will be other cases where more than one VOC has the potential to lead to VI impacts. Investigators can use the table for each VOC separately, but then should also consider the combined risk impact that all VOCs will have on indoor air quality. For example, in the middle column, two VOCs may both exceed their indoor air screening levels, but each by only 6 times. Each VOC would therefore be evaluated under the middle column. Their combined associated inhalation risk, however, would be 1.2E-5 (assuming each had an indoor air SL set at a risk of 1E-6). This ―combined” risk value would be better evaluated by using the table‘s last column (from the left).

Table E-2. Decision matrix for non-carcinogenic contaminants of concern.

Indoor air measurement[112]/ Sub-slab soil gas measurement	**Indoor air** concentration < indoor air SL	**Indoor air** concentration > indoor air SL, but < 2 times the SL	**Indoor air** concentration > 2 times the SL
Sub-slab soil gas concentration < applicable SL	no need for mitigation	Repeat sampling; investigate potential indoor sources	Repeat sampling; investigate potential indoor sources
Sub-slab soil gas concentration > applicable SL, but < 10 times the SL	no need for mitigation	repeat sampling; mitigate if multiple consecutive indoor air samples exceed the SL.	investigate potential indoor sources; mitigate if unable to locate/isolate indoor sources
Sub-slab soil gas concentration > 10 times the applicable SL	Repeat sampling	Repeat sampling; mitigate if multiple consecutive indoor air samples exceed the SL.	mitigate
No **Sub-slab** soil gas data	Repeat sampling if sub-slab soil gas concentration is likely to be > 2 times the SL; collect sub-slab data, if possible, during repeat sampling	Repeat sampling; collect sub-slab data if possible	mitigate

NOTES to Table E-2:

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[112] As in Table E-1, this refers to the indoor measurement due to VI. Commonly this will be estimated to be the [max measured indoor concentration] – [representative measured, same-day ambient air concentration]

(1) SL = screening level. Indoor air and sub-slab soil gas screening levels are provided in Appendix B, Table B-1.

(2) The table considers non-carcinogenic VOCs one by one. In some cases there will only be a single VOC that has the potential to unacceptably contaminate indoor air and the table can be used *as is*. However, there will be other cases where more than one VOC has the potential to lead to VI impacts. Investigators can use the table for each VOC separately, but then should also consider the combined hazard impact that all VOCs will have on indoor air quality. For example, in the middle column, two non-carcinogenic VOCs may exceed their indoor air screening levels, but only by 1.5 times. Each would therefore be evaluated under the middle column. Their combined associated inhalation hazard index (HI), however, would be 3.0 (assuming each had an indoor air SL set at an HQ of 1). This –combined” hazard value would be better evaluated by using the table‘s last column (from the left).[113]

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[113] This example assumes that the health effects would be additive.

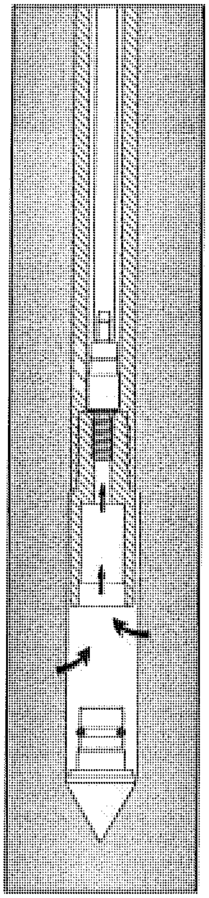
APPENDIX B

Soil Gas Sampling – PRT System Operation

Soil Gas Sampling – PRT System Operation

from Geoprobe Systems®

www.geoprobe.com
1-800-436-7762



Soil Gas Sampling using the Post-Run Tubing (PRT) System.

Soil Gas Sampling — PRT System Operation

Basics

Using the Post-Run Tubing System, one can drive probe rods to the desired sampling depth, then insert and seal an internal tubing for soil gas sampling. The usual Geoprobe probe rods and driving accessories and the following tools are required:

- PRT Expendable Point Holder
- PRT Adapter
- Selected PRT Tubing

Preparation

1. Clean all parts prior to use. Install O-rings on the PRT Expendable Point Holder and the PRT adapter.

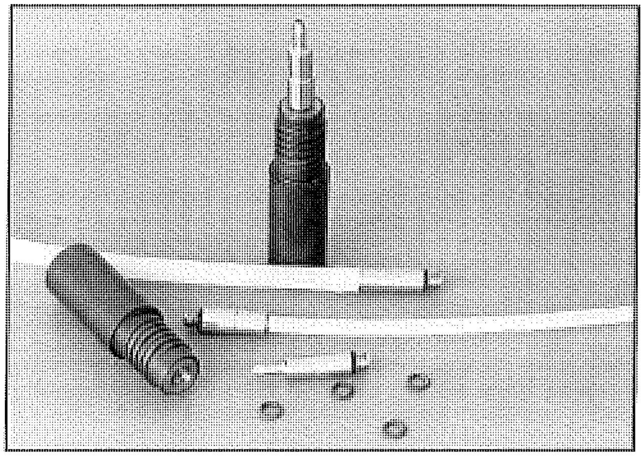
2. Inspect the probe rods and clear them of all obstructions.

3. TEST FIT the adapter with the PRT fitting on the expendable point holder to assure that the threads are compatible and fit together smoothly.

   NOTE: PRT fittings are left-hand threaded.

4. Push the adapter into the end of the selected tubing. Tape may be used on the outside of the adapter and tubing to prevent the tubing from spinning freely around the adapter during connection – especially when using Teflon tubing **(Figure 1)**.

   REMEMBER: The sample will not contact the outside of the tubing or adapter.



PRT SYSTEM PARTS
PRT Expendable Point Holder, PRT Adapters, Tubing, and O-rings.

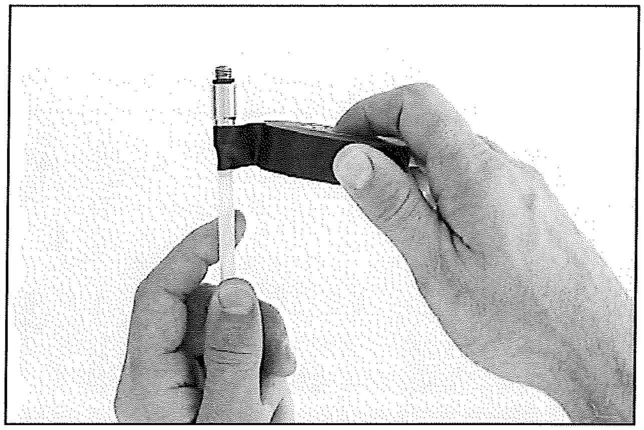


Figure 1. Securing adapter to tubing with tape. NOTE: Tape does not contact soil gas sample.

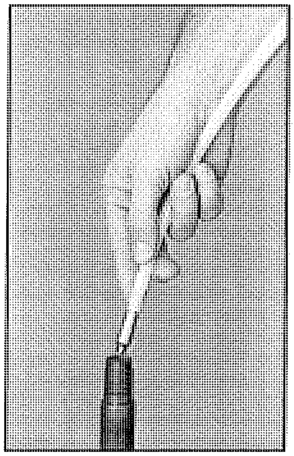


Figure 2. Insertion of tubing and PRT adapter.

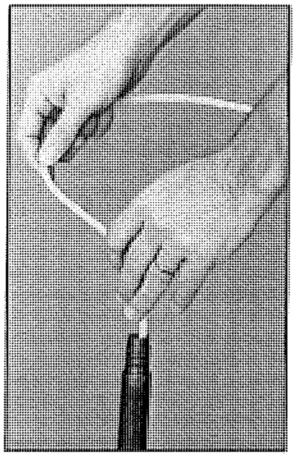
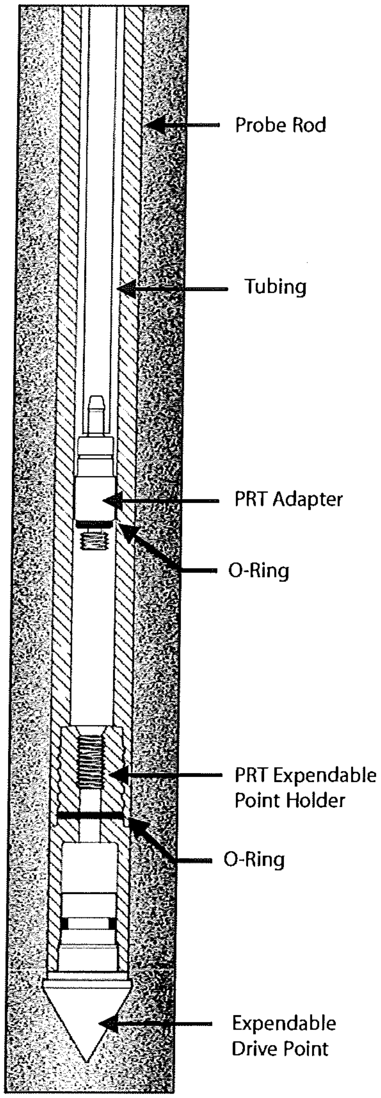


Figure 3. Engaging threads by rotating tubing.



A cross section of probe rods driven to depth and then retracted to allow for soil gas sampling. The PRT adapter and tubing are now fed through the rods and rotated to form a vacuum-tight connection at the point holder. The result is a continuous run of tubing from the sample level to the surface.

Probing

Drive the PRT tip configuration into the ground. Connect probe rods as necessary to reach the desired depth. After depth has been reached, disengage the expendable point by pulling up on the probe rods. Remove the pull cap from the top probe rod, and position the Geoprobe unit to allow room to work.

Connection

1. Insert the adapter end of the tubing down the inside diameter of the probe rods **(Figure 2)**.

2. Feed the tubing down the rod bore until it hits bottom on the expendable point holder. Allow about 2 ft. (610 mm) of tubing to extend out of the hole before cutting it.

3. Grasp the excess tubing and apply some downward pressure while turning it in a counterclockwise motion to engage the adapter threads with the expendable point holder **(Figure 3)**.

4. Pull up lightly on the tubing to test engagement of the threads. (Failure of adapter to thread could mean that intrusion of soil may have occurred during driving of probe rods or disengagement of drive point.)

Sampling

1. Connect the outer end of the tubing to the Silicone Tubing Adapter and vacuum hose (or other sampling apparatus).
2. Follow the appropriate sampling procedure for collecting a soil gas sample **(Figure 1)**.

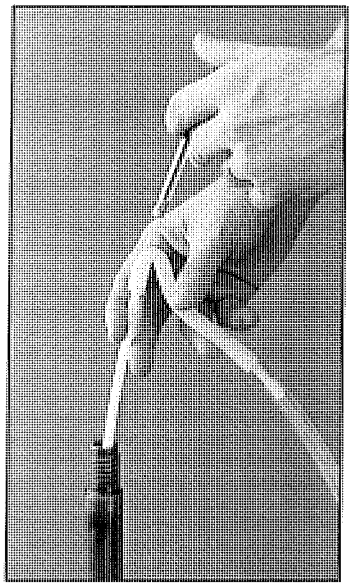


Figure 1. Taking a soil gas sample for direct injection into a GC with the PRT system.

Removal

1. After collecting a sample, disconnect the tubing from the vacuum hose or sampling system.
2. Pull up firmly on the tubing until it releases from the adapter at the bottom of the hole. (Taped tubing requires a stronger pull.)
3. Remove the tubing from the probe rods. Dispose of polyethylene tubing or decontaminate Teflon tubing as protocol dictates.
4. Retrieve the probe rods from the ground and recover the expendable point holder with the attached PRT adapter.
5. Inspect the O-ring at the base of the PRT adapter to verify that proper sealing was achieved during sampling. The O-ring should be compressed. This seal can be tested by capping the open end of the point holder applying vacuum to the PRT adapter.
6. Prepare for the next sample.

APPENDIX C
Summa Canister Sampling Protocol

- Soil Gas
- Vapor Intrusion
- Property Redevelopment
- Ambient Air Monitoring
- Indoor Air Quality
- Waste-to-Energy

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Guide to Air Sampling

Canisters and Bags

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Eurofins Air Toxics, Inc.
Guide to Whole Air Sampling – Canisters and Bags

Revision 6/27/14

Contents

Section 1.0 Introduction

Eurofins Air Toxics Inc. presents this guide as a resource for individuals engaged in air sampling. Air sampling can be more involved than water or soil sampling due to the reactivity of chemical compounds in the gas matrix and sample interaction with the equipment and media used. Ensuring that air samples are collected properly is an important step in acquiring meaningful analytical results. This guide is not a substitute for experience and cannot sufficiently address the multitude of field conditions. Note that this guide is intended for projects involving whole air sampling of volatile organic compounds (VOCs) in canisters and Tedlar® bags. Eurofins Air Toxics provides the "Guide to Sorbent-Based Sampling - Volatiles and Semi-Volatiles" for other types of sampling.

1.1 Whole Air Sampling of VOCs

There are three general ways to collect compounds in a gas phase sample. A sampler may collect the gas sample in a container, actively pump the vapor through a sorbent tube, solution or filter, or rely on passive sample collection onto a sorbent bed. This guide focuses on collecting a sample in the most common air sampling containers, Summa canisters and bags. The sample may be collected in the container either passively, relying on an evacuated canister to drive the sample collection, or actively using a pump to fill the container. The container is subsequently sealed and transported to the laboratory for analysis. The sample is referred to as a "whole air sample" and the compounds remain in the gas matrix inside the container.

As a general rule, whole air sampling is appropriate when target compounds are chemically stable and have vapor pressures greater than 0.1 torr at 25°C and 760mm Hg (EPA standard ambient conditions). Performance of a given compound in a whole air sample is dependent upon its chemical properties, the matrix of the sample, and the degree of inertness of the sample container.

1.2 Choosing Between Canisters and Bags

Table 1.2 compares the features and performance of Summa canisters and bags. Summa canisters or similarly treated canisters are rugged containers designed to provide superior inertness and extended sample storage times. Evacuated canisters also do not require a sampling pump for sample collection. By contrast, bags require a sample pump, but can be purchased inexpensively in bulk, require little preparation or cleaning, and take up little space prior to use. Unlike canisters, bags are typically not appropriate for ppbv-level VOC measurements due to their background artifacts and short hold-times. Over time, low molecular weight gases can diffuse through the bag material while chemicals with lower vapor pressures can condense on the bag surface thereby compromising analyte recoveries. Call your Project Manager at 800-985-5955 if you have questions regarding the appropriate sampling media.

Table 1.2 Comparison of Canisters to Bags

	Canisters	Bags
Type of Sampling	Passive (vacuum)	Active (pump required)
Media Hold Time	Up to 30 days recommended	Indefinite
Hold Time to Analysis	Up to 30 days	Up to 3 days
Surface Inertness	Excellent	Fair
Cleanliness	Batch or 100% certified to ppbv/pptv levels	Some VOCs present in the ppbv range
Sampling Application	Ambient air, soil/landfill gas	Soil/landfill gas, stationary sources, SVE systems
Rule of Thumb	"ppbv device"	"ppmv device"
Advantages	Inertness, hold time, ruggedness, no pump	Purchase/shipping cost, availability, convenience

Section 2.0 Canisters and Associated Media

This section provides a description of air sampling canisters, practical considerations for sampling, and step-by-step instructions for collecting grab and integrated samples. Photographs illustrate the correct way to assemble the various sampling components. Tables provide detailed information on many operational factors that ultimately influence the quality of the data obtained from a canister sample.

2.1 Introduction to Canisters

An air sampling canister is a container for collecting a whole air sample. A canister may be spherical or cylindrical and is constructed of specially treated stainless steel. The canister is prepared for sampling by evacuating the contents to a vacuum of approximately 29.9 inches of Mercury (in Hg). Opening the stainless steel bellows valve allows the air sample to enter the canister. Flow controllers can be utilized to restrict the flow and allow for collection at a desired flow rate or over a desired range. When the sample has been collected, the valve is closed and the canister is returned to the laboratory. Canisters range in volume from less than 1 liter (L) to 6 L. In general, 6 L canisters are used to collect ambient air samples and samples requiring time integration greater than 2 hours. One liter canisters are typically used for taking high concentration (i.e., greater than 5 ppbv) samples not requiring time integration such as soil vapor.

2.1.1 Summa Canister

A Summa canister is a stainless steel container that has had the internal surfaces specially passivated using a “Summa” process. This process combines an electropolishing step with a chemical deactivation step to produce a surface that is nearly chemically inert. A Summa surface has the appearance of a mirror: bright, shiny and smooth. The degree of chemical inertness of a whole air sample container is crucial to minimizing reactions with the sample and maximizing recovery of target compounds from the container. Eurofins Air Toxics maintains a large inventory of Summa canisters in 1 and 6 L volumes.

2.1.2 Canister Certification

Eurofins Air Toxics provides two types of canister cleaning certification, batch and 100%, depending upon the requirements of the project. The batch certification process is most appropriate for routine ambient air applications and high concentration applications such as soil vapor and landfill gas monitoring. The batch certification process begins by cleaning a set of canisters using a combination of dilution, heat and high vacuum. The cleaning batch is certified by analyzing a percentage of canisters for approximately 60 VOCs using GC/MS. The batch meets cleaning requirements if the target compound concentrations are below 0.2 ppbv. Alternatively, the 100% certification (i.e., individual certification) process is typically required for ambient and indoor air applications driven by risk assessment or litigation requiring pptv (parts per trillion by volume) sensitivity. If 100% certification is required, canisters are individually certified for a client-specific list of target compounds using GC/MS. When the 100% certified canisters are shipped, the analytical documentation demonstrating that they are free of the target compounds down to the project reporting limits is emailed to the client. When sampling with certified media, it is important to note that all media is certified as a train and must be sampled as such (i.e., a particular flow controller goes with a particular canister and is labeled as such).

Specify whether your project requires batch or 100% canister certification.

2.1.3 Canister Hold Time

Media Hold Time: Unlike water and soil environmental samples, which are collected in single-use, disposable vials and jars, air samples are collected in reusable summa canisters. Eurofins Air Toxics requires that canisters be returned within 15 days of receipt to effectively manage our inventory and to insure canisters meet performance requirements in the field. Evacuated canisters have a finite timeframe before the canisters naturally lose vacuum during storage. Using canisters beyond 15 days increases the risk of having unacceptable initial vacuum at the start of sampling.

Sample Hold Time: EPA Method TO-15 cites a sample hold time of up to 30 days for most VOCs. Several non-routine compounds, such as bis(chloromethyl)ether, degrade quickly and demonstrate low recovery even after 7 days. Reactive sulfur compounds such as hydrogen disulfide and methyl, ethyl, and butyl mercaptan are not amenable to storage in stainless steel summa canister, and either fused silica lined (FSL) canisters or Tedlar bags are required for sample collection.

2.2 Associated Canister Hardware

Associated hardware used with the canister includes the valve, brass cap, particulate filter and vacuum gauge. (Flow controllers are covered in detail in section 3.2.)

2.2.1 Valve

An industry standard 1/4" stainless steel bellows valve is mounted at the top of the canister. The valve maintains the vacuum in the canister prior to sampling and seals the canister once the sample has been collected. No more than a half turn by hand is required to open the valve. Do not over-tighten the valve after sampling or it may become damaged. A damaged valve can leak, possibly compromising the sample. Some canisters have a metal cage near the top to protect the valve.

To protect the valve and provide secure connections in the field, a replaceable fitting is attached to all canisters. As threads wear and require replacement, new fittings can be installed at the laboratory prior to shipping to the field. You will need a 1/2" wrench to secure the fitting while connecting or removing the required equipment to the canister.

2.2.2 Brass Cap

Each canister comes with a brass cap (i.e., Swagelok 1/4" plug) secured to the inlet of the valve assembly. The cap serves two purposes. First, it ensures that there is no loss of vacuum due to a leaky valve or a valve that is accidentally opened during handling. Second, it prevents dust and other particulate matter from damaging the valve. The cap is removed prior to sampling and replaced following sample collection.

Always replace the brass cap following canister sampling.

2.2.3 Particulate Filter

Particulate filters should always be used when sampling with a canister. Separate filters are provided to clients taking a grab sample, and filters are built into the flow controllers for clients taking integrated samples. The 2 micron filter is a fritted stainless steel disk that has been pressed into a conventional Swagelok adapter. This device has a relatively high pressure drop across the fritted disk and restricts the flow into the canister even when sampling without a flow controller. Table 2.2.3 lists the typical fill time for a grab sample using a 2 micron particulate filter.

Table 2.2.3 Grab Sample Fill Times for Canisters

CANISTER VOLUME	**2 micron filter**
6 L	<5 minutes
1 L	<1 minute

2.2.4 Fittings

All fittings on the sampling hardware are 1/4" Swagelok, and a 9/16" wrench is used to assemble the hardware. A 1/2" wrench is also required to tighten fittings onto a union connector. Compression fittings should be used for all connections. Never use tube-in-tube connections. It is critical to avoid leaks in the sampling train. Leaks of ambient air through fittings between pieces of the sampling train will dilute the sample and cause the canister to fill at a faster rate than desired. Eurofins Air Toxics can provide the necessary fittings and ferrules if requested.

2.2.5 Vacuum Gauge

A vacuum gauge is used to measure the initial vacuum of the canister before sampling, and the final vacuum upon completion. A gauge can also be used to monitor the fill rate of the canister when collecting an integrated sample. Eurofins Air Toxics provides 2 types of gauges. For grab sampling, a test gauge checks initial and final vacuums only and is not to be sampled through. For integrated sampling a gauge is built into the flow controller and may be used for monitoring initial and final vacuums, as well as monitoring the fill rate of the canister. Both gauges are considered to be rough gauges, intended to obtain a relative measure of vacuum change. Accuracy of these field gauges are generally on the order of +/-5 in Hg. Individuals with work plans that outline specific gauge reading requirements are strongly encouraged to purchase and maintain their own gauges in the field. In special cases, a laboratory-grade, NIST-traceable vacuum gauge can be provided upon request.

The vacuum gauges that are routinely provided are intended as a rough gauge measurement device (+/-5 in Hg accuracy).

Section 3.0 Sampling with Canisters

There are two basic modes of canister sampling: grab and integrated. A grab sample is taken over a short interval (i.e., 1-5 minutes) to provide a point-in-time sample concentration, while an integrated sample is taken over a specified duration or utilizing a specified flow rate. In both modes the canister vacuum is used to draw the sample into the canister. This is commonly referred to as passive canister sampling. Sections 3.1 and 3.2 detail procedures for grab and integrated sampling, and section 3.3 provides procedures specific to soil vapor collection.

Regardless of the type of canister samples collected, the following rules apply:

- DO NOT use canister to collect explosive substances, radiological or biological agents, corrosives, extremely toxic substances or other hazardous materials. It is illegal to ship such substances and you will be liable for damages.
- ALWAYS use a filter when sampling. NEVER allow liquids (including water) or corrosive vapors to enter canister.
- DO NOT attach labels to the surface of the canister or write on the canister; you will be liable for cleaning charges.
- DO NOT over tighten the valve, and remember to replace the brass cap.
- IF the canister is returned in unsatisfactory condition, you will be liable for damages.
- DO NOT make modifications to the equipment connections and/or use Teflon tape unless approved by the laboratory.
- AND, if you have any questions or need any support, our experienced project management team is just a phone call away at 800-985-5955.

Use a 9/16” and 1/2” wrench to tighten Swagelok connections on the canister sampling train.

3.1 Grab Sampling Using Canisters

The most common hardware configuration used to take a grab sample is to simply attach a particulate filter to the canister inlet. A particulate filter is shown in section 2.2.3 and is used to prevent particulate matter from fouling the valve and entering the canister.

3.1.1 Step-By-Step Procedures for Canister Grab Sampling

These procedures are for a typical ambient air sampling application; actual field conditions and procedures may vary.

Before you get to the field:

1. Verify contents of the shipped package (e.g., chain-of-custody, canister, particulate filter, and gauge – if requested).
2. Make sure you include a 9/16” and 1/2” wrench in your field tool kit.
3. Verify the gauge is working properly.
4. Verify the initial vacuum of canister as described in the following section:

- **Verify Initial Vacuum of the Canister**: Prior to shipment, each canister is checked for mechanical integrity. However, it is still important to check the vacuum of the canister prior to use. Eurofins Air Toxics recommends doing this before going to the field if possible. The initial vacuum of the canister should be greater than 25 in Hg. If the canister vacuum is less than 25 in Hg, ambient air may have leaked into the canister during storage or transport and the sample may be compromised. Contact your Project Manager if you have any questions on whether to proceed with sample collection. If sampling at altitude, there are special considerations for gauge readings and sampling (see Section 5.2). The procedure to verify the initial vacuum of a canister is simple but unforgiving.

1. Confirm that valve is closed (knob should already be tightened clockwise).
2. Remove the brass cap.
3. Attach gauge.
4. Attach brass cap to side of gauge tee fitting to ensure a closed train.
5. Open and close valve quickly (a few seconds).
6. Read vacuum on the gauge.
7. Record gauge reading on “Initial Vacuum” column of chain-of-custody.
8. Verify that canister valve is closed and remove gauge.
9. Replace the brass cap.

When ready to sample:

1. Confirm that valve is closed (knob should already be tightened clockwise).
2. Remove brass cap.
3. Attach particulate filter to canister.
4. Open valve 1/2 turn (6 L canister normally takes less than 5 minutes to fill).
5. Close valve by hand tightening knob clockwise.
6. Verify and record final vacuum of canister (repeat steps used to verify initial vacuum). For grab samples, the ending vacuum is typically close to ambient pressure (0 in Hg).
7. Replace brass cap.
8. Fill out canister sample tag (make sure the sample ID and date of collection recorded on the sample tag matches what is recorded on the COC exactly).
9. Return canister in box provided.
10. Return sample media in packaging provided.
11. Fill out chain-of-custody and relinquish samples properly (it is important to note the canister serial numbers on the chain-of-custody).
12. Place chain-of-custody in box and retain pink copy.
13. Tape box shut and affix custody seal (if applicable) across flap.
14. Ship accordingly to meet method holding times.

Return all equipment used or unused to the laboratory. Unreturned canisters and associated hardware will result in additional charges as outlined in the media agreement.

3.2 Integrated Sampling with Canisters and Flow Controllers

As an alternative to an “instantaneous” grab sample, an air sample collected at a controlled rate is referred to as an integrated sample. Flow controllers or flow restrictors are devices which provide sample collection at a desired flow rate and/or sampling interval. By using a flow controller at a specified flow rate, air samples can provide information on average compound concentrations over a defined period. For example, an 8- or 10-hour integrated sample can be used to determine indoor air quality in the workplace. Similarly, a 24-hour integrated sample may be collected to determine residential exposure to indoor or outdoor air sources. In addition to using a flow controller for time-integrated sample collection, a flow controller may be required for soil gas collection to restrict the vacuum applied to the soil and pore water and to collect a representative sample with minimal intrusion of ambient air.

Eurofins Air Toxics provides two general types of flow controllers: mass flow controllers and critical orifice devices. Both devices are driven by differential pressure between ambient conditions and vacuum in the canister.

3.2.1 Mass Flow Controller

A mass flow controller employs a diaphragm that actively compensates to maintain a constant mass flow rate over the desired time period. As the differential pressure decreases, the flow rate decreases and the diaphragm responds by opening up to allow more air to pass through to maintain a stable flow rate. Mass flow controllers are calibrated in the laboratory to provide flow rates suitable for durations up to 24 hours. Durations greater than 24 hours are possible, however, performance of the flow controller is less reliable due to the low flow rates required.

3.2.2 Critical Orifice Devices

Eurofins Air Toxics has two types of critical orifice controllers – “capillary column” and “frit pressed”. Both types restrict the flow rate and the canister fill rate decreases as the canister fills to ambient pressure. These controllers are suitable for applications not requiring constant flow rate over the sampling period such as soil vapor collection or at sites in which temporal variability of VOCs is not expected. Critical orifice devices can cover intervals from 0.5 to 12 hours and flow rate from 10 to 250 ml/min. The “capillary column” device (also known as the Blue Body Flow Controller) restricts air flow by forcing the sample to enter a capillary column of minute radius. The flow rate is a function of the length of inert capillary column. The frit pressed device has a critical orifice machined to meet a set flow rate.

3.2.3 Sampling Interval and Flow Controller Setting

When you request canisters and flow controllers from Eurofins Air Toxics, you will be asked for the flow rate (soil vapor) or sampling interval (ambient air), and the flow controllers will be pre-set prior to shipment. The flow rate is set at standard atmospheric conditions (approximately sea level and 25°C). If samples will be collected at elevation or at ambient temperatures significantly different than 25°C, the canister will fill faster or slower depending on sample conditions. If you specify unusual sample conditions at the time of project set-up, we can set the flow controller accordingly. (See Section 5.2 for a discussion of collecting a sample at elevation.) Mass flow controllers should not be utilized for source or process samples in which the collection point is under vacuum or pressure. Please discuss these specific non-standard field conditions with your Project Manager at the time of project set-up.

Table 3.2.3 Flow Rates for Selected Sampling Intervals (mL/min)

Sampling Interval (hrs)	**4 min.**	**0.5**	**1**	**2**	**4**	**8**	**12**	**24**
6 L Canister	NA	167	83.3	41.7	20.8	11.5	7.6	3.8
1 L Canister	167	26.6	13.3	6.7	-	-	-	-

Note: Target fill volumes for 6 L and 1 L canisters are 5,000 mL and 800 mL, respectively.

3.2.4 Final Canister Vacuum and Flow Controller Performance

For time-integrated sample collection using a mass flow controller, the final vacuum of a canister should ideally be approximately 5 in Hg or greater. The flow rate will remain constant as the canister fills and will start to decrease as the canister vacuum approaches

5 in Hg. At this point, the differential pressure between the canister and ambient air is not sufficient to maintain the set flow rate. Because of normal fluctuations in the flow rate due to changes in field temperature and pressure, the final vacuum typically ranges between 3 and 10 in Hg.

- **If the residual canister vacuum is greater than 10 in Hg** (i.e., more vacuum), the actual flow rate is lower than the set point and less sample volume is collected. When the canister is pressurized prior to analysis, the pressurization dilution will be greater than normal. This will result in elevated reporting limits.
- **If the residual canister vacuum is near ambient pressure** for a time-integrated sample, the canister filled faster than calibrated. Once the vacuum decreases below 5 in Hg, the flow rate begins to decrease from its set point. This scenario indicates that the sample is weighted toward the first portion of the sampling interval. The sampler cannot be certain the desired sampling interval was achieved before the canister arrived at ambient conditions. Although the actual sampling interval is uncertain, the canister still contains a sample from the site.

Table 3.2.4 Relationship between Final Canister Vacuum, Volume Sampled, and Dilution Factor (6 L Canister)

Final Vacuum (in Hg)	**0**	**2.5**	**5**	**7.5**	**10**	**12.5**	**15**	**17.5**	**20**
Volume Sampled (L)	6	5.5	5.4	5	4	3.5	3	2.5	2
Dilution Factor*	1.34	1.46	1.61	1.79	2.01	2.30	2.68	3.22	4.02

*Canister pressurized to 5 psig for analysis

$$\textbf{Final Reporting Limit} = \text{Method Reporting Limit} \times \text{Dilution Factor (Canister Pressurization)} \times \text{Dilution Factor (Sample Analysis)}$$

$$\textbf{Dilution Factor (Canister Pressurization)} = \frac{\text{Final Pressure}}{\text{Receipt Pressure}} = \frac{14.7\text{ psig} + \text{Final Pressure (psig)}}{14.7\text{ psig}\left[\dfrac{1\text{-Receipt Vacuum (in Hg)}}{29.9\text{ in Hg}}\right]}$$

3.2.5 Considerations for Integrated Sampling with Canisters

Collecting an integrated air sample is more involved than collecting a grab sample. Sampling considerations include verifying that the sampling train is properly configured, monitoring the integrated sampling progress, and avoiding contamination.

- **Avoid Leaks in the Sampling Train**: A leak in any one of these connections means that some air will be pulled in through the leak and not through the flow controller. (Follow the leak check step #4 in 3.2.6).
- **Verify Initial Vacuum of Canister:** See Section 3.1.1 for instructions on verifying initial canister vacuum. A separate gauge is not necessary as both the mass flow controllers and critical orifice flow controllers have built-in rough gauges.
- **Monitor Integrated Sampling Progress**: When feasible, it is a good practice to monitor the progress of the integrated sampling during the sampling interval. The volume of air sampled is a linear function of the canister vacuum. For example, when using a 24-hour mass flow controller, at a quarter of the way (6 hours) into a 24-hour sampling interval, the canister should be a quarter filled (1.25 L) and the gauge should read approximately 6 in Hg lower than

the starting vacuum (~22 in Hg). More vacuum indicates that the canister is filling too slowly; less vacuum means the canister is filling too quickly. If the canister is filling too slowly, a valid sample can still be collected (see Section 3.2.4). If the canister is filling too quickly because of a leak or incorrect flow controller setting, corrective action can be taken. Ensuring all connections are tight may eliminate a leak. It is possible to take an intermittent sample; the time interval need not be continuous.

- **Avoid Contamination**: Flow controllers should be cleaned between uses. This is done by returning them to the laboratory.
- **Caution When Sampling in Extreme Temperatures**: Field temperatures can affect the performance of the mass flow controllers. Laboratory studies have shown that flow rates can increase slightly with decreasing temperatures. A flow rate increase of approximately 10% is expected when sampling at field temperatures of 5 to 10°C.

3.2.6 Step-by-Step Procedures for Integrated Sampling

These procedures are for a typical ambient air sampling application; actual field conditions and procedures may vary.

Before you get to the field:

1. Verify contents of the shipped package (e.g., chain-of-custody, canister, and flow controller)
2. Make sure you include a 9/16" and 1/2" wrench in your field tool kit.
3. Verify the gauge is working properly
4. Verify the initial vacuum of canister (section 3.1.1)

When ready to sample:

1. Confirm that valve is closed (knob should already be tightened clockwise).
2. Remove brass cap from canister.
3. Attach flow controller to canister. The flow controller is securely attached if the flow controller body does not rotate.
4. Place the brass cap at the end of the flow controller creating an air tight train, and quickly open and close the canister valve in order to check for leaks. If the needle on the gauge drops, your train is not airtight. In this case, try refitting your connections and/or tightening them until the needle holds steady.
5. Once the sample train is airtight remove the brass cap from the flow controller and open the canister valve a ½ turn.
6. Monitor integrated sampling progress periodically.
7. Verify and record final vacuum of canister (simply read built-in gauge).
8. When sampling is complete, close valve by hand tightening knob clockwise.
9. Detach flow controller and replace brass cap on canister.
10. Fill out canister sample tag (make sure the sample ID and date of collection recorded on the sample tag matches what is recorded on the COC exactly).
11. Return canisters and associated media in boxes provided. **Failure to return all of the provided equipment will result in a replacement charge as outlined in the media agreement.**
12. Fill out chain-of-custody and relinquish samples properly (it is important to note the canister serial numbers on the chain-of-custody).
13. Place chain-of-custody in box and retain pink copy.
14. Tape box shut and affix custody seal at each opening (if applicable).
15. Ship accordingly to meet method holding times.

3.3 Soil Gas Sample Collection

Canisters can be used for the collection of soil vapor by attaching the sampling train to the soil gas probe. Typically, a critical orifice flow controller is used to minimize the applied vacuum in order to minimize partitioning of VOCs from the soil or pore water to the soil vapor. Additionally, lower flow rates help to minimize the intrusion of ambient air into the soil vapor probe. In general, time-integration is not required for soil gas samples; however, there may be exceptions to this rule of thumb. For example, some regulatory guidance documents recommend concurrent indoor air and sub-slab soil vapor collection over a

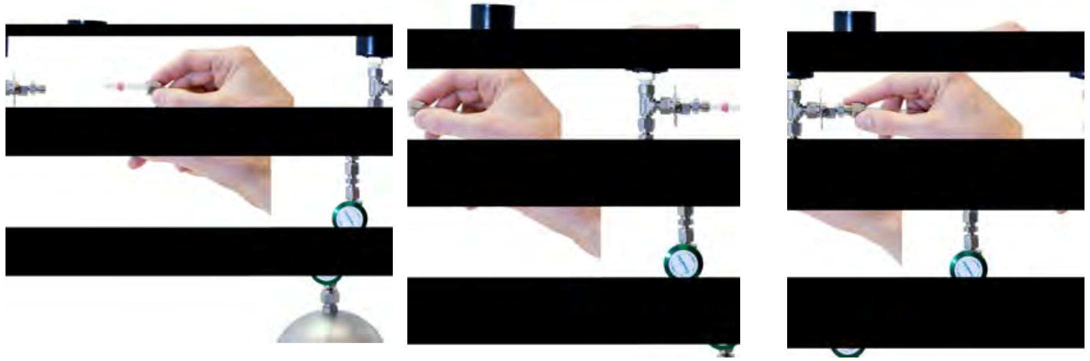
24-hour period. This means that a mass flow controller calibrated for a 24-hour sample would be required for the sub-slab as well as the indoor air sample.

3.3.1 Canister to probe connection – Tubing

Collection of a soil gas sample requires the use of tubing to connect the soil gas probe to the sample train. Teflon FEP tubing is recommended based on its low background and its inertness. Alternative tubing can be used if shown to meet data quality objectives. Please note that Low Density Polyethylene or flexible Tygon tubing is not recommended due to VOC adsorption during sample collection. Teflon tubing is provided by the laboratory upon request at the time of order. A charge based on the length will be assessed. It is important to store the tubing away from VOC sources during storage and transport to the site to minimize contamination.

3.3.2 Canister to probe connection –Fittings

To connect the tubing to the canister sampling train, a Swagelok fitting and a pink ferrule are used. The position of the ferrule is key to ensure the fitting is securely connected to the canister. See the figure below for the correct positioning and connection. The pink ferrule is flexible and cannot be over-tightened.



3.3.3 Leak Check Compounds Considerations

To determine whether ambient air is introduced into soil gas sample, a leak check may be used. Leak check compounds may be liquid or gaseous tracers. Liquid compounds are challenging to use effectively in the field and can be introduced into the sample due to improper handling in the field, erroneously indicating a leak in the sampling train. Liquid tracers such as isopropanol should never be directly applied to connections in the sampling train. Rather, the liquid is carefully applied to a cloth and placed near the connection or on the ground next to the probe. Great care must be used in the field to insure the liquid tracer is not handled during sampling train assembly or disassembly. Even a trace amount of a liquid tracer on a glove used to replace a canister brass cap can contaminate the sample. Liquid leak check compounds can interfere with the analytical runs, and even small leaks may result in analytical dilution and raised reporting limits when measuring ppbv target compound levels.

Gaseous tracers such as helium are typically used with shroud placed over the sampling equipment and/or borehole. To quantify the leak, the concentration of the tracer gas in the shroud should be measured.

Specify the leak check compound planned for your soil gas sampling event and record on the COC.

3.3.4 Step-by-Step Procedures for Soil Vapor Sampling

These procedures are for a typical soil vapor sampling application; actual field conditions and procedures may vary. Please consult your specific regulatory guidance for details.

Before you get to the field:

1. Verify contents of the shipped package (e.g., chain-of-custody, canister, tubing, fittings, and flow controller).
2. Make sure you include a 9/16" and 1/2" wrench in your field tool kit.
3. Verify the gauge is working properly.
4. Verify the initial vacuum of canister.

Prior to vapor collection:

- **Purge tubing adequately**. A long length of tubing has significant volume of "dead air" inside. Without purging, this air will enter the canister and dilute the sample. Consider using a handheld PID/FID to confirm that you have purged the tubing and are drawing sample air through the tubing. A standard rule of thumb is to utilize 3 purge volumes prior to sample collection. However, under certain circumstances, purge volumes of 1 to 10 may be appropriate. Please review your regulatory guidance and your site specific conditions in determining the appropriate purge volumes.
- **Don't sample water**. If moisture is visible in the sample tubing, the soil gas sample may be compromised. Soil gas probes should be at an appropriate depth to avoid reaching the water table. Additionally, subsurface vapor should not be collected immediately after measurable precipitation.

When ready to sample:

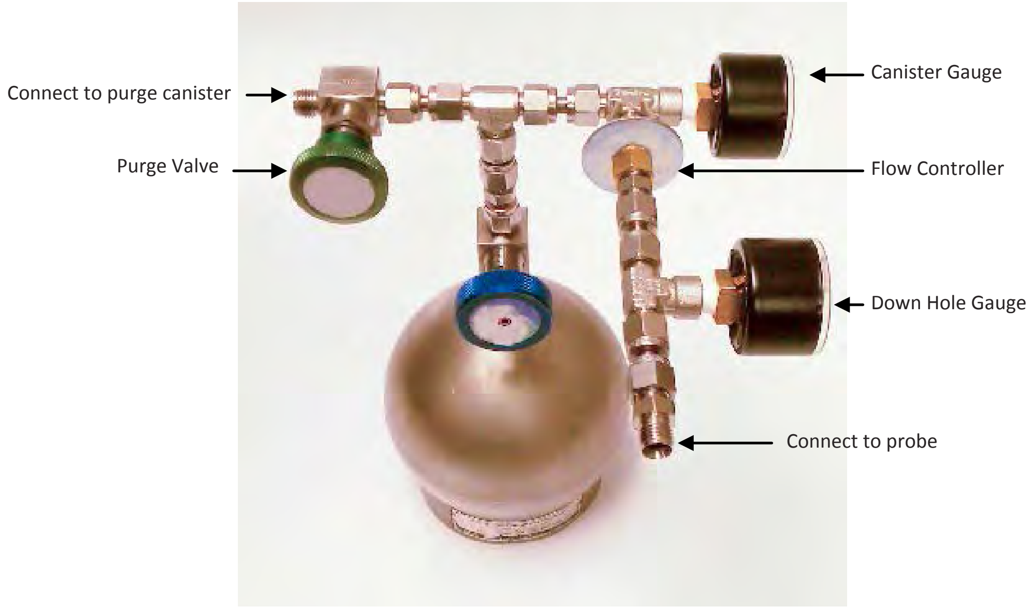
1. Confirm that valve is closed (knob should already be tightened clockwise).
2. Remove brass cap from canister.
3. Attach flow controller to canister if needed. The flow controller is securely attached if the flow controller body does not rotate. (Note: The frit-press flow controller and 1 L canister may be pre-assembled by the laboratory.)
4. Place the brass cap at the end of the flow controller creating an air tight train, and quickly open and close the canister valve in order to check for leaks. If the needle on the gauge drops, your train is not airtight. In this case, try refitting your connections and/or tightening them until the needle holds steady.
5. Once the sample train is airtight remove the brass cap from the flow controller and attach the probe tubing to the flow controller using the pink ferrule and Swagelok nut. (See 3.3.2 for proper positioning of the ferrule.)
6. Once the probe line has been purged and appropriate leak check measures have been implemented, open the canister valve a ½ turn.
7. Verify and record final vacuum of canister (simply read built-in gauge).
8. When canister fills to the desired end vacuum, close valve by hand tightening knob clockwise.

   Please note: Some projects require residual vacuum of approximately 5 in Hg at the end of sample collection even if time-integrated samples are not required. The residual vacuum serves to provide a check of the integrity of the canister during transport to the laboratory to insure no leaks occurred during shipment. A field vacuum reading similar to the lab receipt vacuum reading demonstrated that no leak occurred.

9. Detach tubing and flow controller and replace brass cap on the canister.
10. Fill out canister sample tag (make sure the sample ID and date of collection recorded on the sample tag matches what is recorded on the COC exactly).
11. Return canisters and associated media in boxes provided. **Failure to return all of the provided equipment will result in a replacement charge as outlined in the media agreement.**
12. Fill out chain-of-custody and relinquish samples properly (it is important to note the canister serial numbers on the chain-of-custody).
13. Place chain-of-custody in box and retain pink copy
14. Tape box shut and affix custody seal at each opening (if applicable)
15. Ship accordingly to meet method holding times

3.4.4 Collecting Soil Gas Samples with Sampling Manifolds

If required, Eurofins Air Toxics can provide a sampling manifold to assist with leak checking the sampling train, purging the sampling line, and monitoring the vacuum applied to the soil gas bore hole during sample collection. The manifold is shown below:



The 'Down Hole Gauge', located prior to the flow restrictor, is a vacuum gauge that monitors the vacuum applied to the soil gas probe. Because this is not a flow meter but a measure of pressure/vacuum, the gauge should read at zero if there is sufficient flow from the soil. If the gauge begins to read a vacuum, then the flow is being restricted. Low flow, high vacuum conditions can be encountered when sampling in low permeability soil. The 'Canister Gauge', in line after the flow controller and prior to the purge canister, is a vacuum gauge that indicates to the sampler whether or not the canister is filling properly at the expected rate. This setup enables the sampler to evaluate the lithologic conditions at the site and determine if a valid soil gas sample is being taken. Finally, when duplicate samples are required, the manifold can be used as a duplicate sampling "T" by simply replacing the purge canister with another sample canister.

There are several options to use as a purge vacuum source to attach to the purge valve connection – a Summa canister, sampling pump or sampling syringe. The below instructions assume a Summa canister will be used as a purge volume source since other sources are generally provided by the client.

When ready to sample:

Leak Check Test

1. Confirm that canister valves are closed (knob should already be tightened clockwise).

2. Remove brass caps from both the sample canister and the purge canister. (Unless using certified media, there is no difference between the two).

3. Attach manifold center fitting to sample canister.

4. Attach purge canister to the Purge Valve end of the manifold by attaching provided Teflon tubing and compression fittings.

5. Confirm that there is a brass cap secured at the inlet of the manifold creating an air tight train, make sure the manifold valve above the purge canister is open, and quickly open and close the purge canister valve in order to check for leaks. If the needle on the gauge drops, your train is not airtight. In this case, try refitting your connections and/or tightening them until the needle holds steady.

Purging

6. Once the sample train is airtight remove the brass cap from the manifold inlet, connect the tubing from the sample port using a compression fitting and open the purge canister valve, 1/2 turn.

7. Monitor integrated sampling progress periodically. *Please note, because the purge canister is inline after the flow restrictor the line will not purge faster than at a rate of 167 ml/min.

8. Once the desired purge volume is met close both the manifold valve and the purge canister valve by hand tightening the knobs clockwise.

9. If sampling at multiple locations, the purge canister can be disconnected from the manifold and used to begin purging the next sample location without compromising the sample train.

Sampling

10. The line is now ready to be sampled. Open the sample canister valve and monitor sampling progress periodically.

11. When the sampling is complete close the valve and replace the brass cap on the canister; record final vacuum of canister (simply read built-in gauge).

12. Fill out canister sample tag (make sure the sample ID and date of collection recorded on the sample tag matches what is recorded on the COC exactly).

13. Return canisters in boxes provided and all parts of the soil gas manifold. **Unreturned media will result in a replacement charged assessed as described in the media agreement**.

14. Fill out chain-of-custody and relinquish samples properly (it is important to note the canister serial numbers on the chain-of-custody).

15. Place chain-of-custody in box and retain pink copy.

16. Ship accordingly to meet method holding times.

Section 4.0 Sampling with Bags

This section provides a description of the types of air sampling bags, selecting the right bag for your application, practical considerations for sampling, and step-by-step instructions for collecting a grab sample. Photographs illustrate the correct way to assemble the various sampling components.

4.1 Introduction to Bags

Air sampling bags are containers used to collect whole air samples for landfill gas, soil gas and stationary source applications. Bags can be constructed from various materials which can differ in terms of stability characteristics and cleanliness. In general, air sampling bags are best suited for projects involving analysis of compounds in the ppmv range. They can be used to collect sulfur compounds, but only if the fittings are non-metallic (e.g., polypropylene, Teflon®, or Nylon).

Air sampling bags are equipped with a valve that allows for filling. Sample collection requires a pressurized sampling port, a low flow rate pump or a lung sampler. The bag expands as the vapor sample is pulled in. When the target volume of the sample is collected, the valve is closed and the bag is returned to the laboratory. Bag materials should be selected based on the specific application. Common air sampling bags include Tedlar film and FlexFoil. Eurofins Air Toxics maintains a limited inventory of air sampling bags in 1 L, 3 L and 5 L volumes.

4.1.1 Tedlar® Film

Tedlar® is a trade name for a polyvinyl fluoride film developed by DuPont Corporation in the 1960’s. This patented fluoropolymer has been used in a wide variety of applications including protective surfacing for signs, exterior wall panels and aircraft interiors. Tedlar® film is tough yet flexible and retains its impressive mechanical properties over a wide range of temperatures (from well below freezing to over 200°F). Tedlar® exhibits low permeability to gases, good chemical inertness, good weathering resistance and low off-gassing.

Tedlar® bags may be used to collect samples containing common solvents, hydrocarbons, chlorinated solvents, sulfur compounds, atmospheric and biogenic gases and many other classes of compounds. Compounds with low vapor pressures such as Naphthalene are not appropriate for Tedlar bags as recovery is very low even under short sample storage times. Low molecular compounds such as Helium and Hydrogen can diffuse through the Tedlar bag material resulting in poor storage stability.

4.1.2 Tedlar® Bag Suppliers and Re-use

Compounds commonly detected from analyzing new Tedlar® bags include methylene chloride, toluene, acetone, ethanol, 2-propanol, phenol, and dimethylacetamide. While levels of these common artifacts are typically in the ppbv range, the cleanliness of bags can vary significantly between vendors, and purchasing bags directly from an unknown vendor should be avoided. Once the Tedlar® bag is used for sample collection, the surface has been exposed to moisture and possible VOCs. It may irreversibly adsorb many VOCs at the low ppbv level. A series of purges with certified gas may not remove the VOCs from the surface. Consider your data quality objectives to determine whether re-using Tedlar® bags is appropriate.

4.1.3 Hold Time for a Tedlar® Bag

The media hold time for a Tedlar® bag is indefinite if stored out of sunlight in a cool, dry location.

The sample hold time to analysis varies by method and compound. See Table 4.1.3 for recommended sample storage times for commonly requested parameters.

Table 4.1.3 Recommended Maximum Sample Storage Times for Tedlar® Bags

Analytical Method	Chemical Class	Storage Time
ASTM D5504	Suite of sulfur compounds including Reactive Sulfur compounds (Hydrogen sulfide, Methyl mercaptan)	24 hours
ASTM D1946 ASTM D1945	Atmospheric and natural gases: CO, CO2, CH4, C2-C5 hydrocarbons (He and H_2 not recommended)	Up to 3 days
Modified TO-14A, TO-15, TO-3, TO-12	Volatile Organic Compounds (VOCs)	Up to 3 days

4.1.4 FlexFoil Bags

FlexFoil bags are made from an opaque and flexible material with 4-ply construction resulting in high physical strength to minimize rupture and leakage and low permeability to provide good stability for low molecular weight compounds. FlexFoil bags are ideal for target compounds such as Hydrogen and Helium and can be used for the suite of atmospheric and natural gas components. While the reactive sulfur compounds, Hydrogen Sulfide and Methyl Mercaptan, show good stability over 24 hours in FlexFoil bags, other sulfur compounds demonstrate low recovery. Table 4.1.4 summarizes the compounds and the hold times amenable to FlexFoil bags.

Table 4.1.4 Recommended Maximum Sample Storage Times for FlexFoil Bags

Analytical Method	Chemical Class	Storage Time
ASTM D5504	Hydrogen sulfide, Methyl mercaptan only Not recommended for full sulfur list.	24 hours
ASTM D1946 ASTM D1945	Atmospheric and natural gases Full List	Up to 3 days

4.2 Air Bag Sampling

Using a bag to collect an air sample normally involves "active" sampling, unlike an evacuated canister that can be filled "passively" by simply opening the valve. There are two methods commonly used to fill a bag: a pump or a lung sampler.

- **Sampling with a Pump**: The most common method for filling a bag is to use a small pump with low flow rates (50-200 mL/min) and tubing to fill the bag. Eurofins Air Toxics, Inc. does not provide pumps but pumps may be rented from equipment providers or purchased from manufacturers such as SKC or Gilian.
- **Sampling with a Lung Sampler**: A "lung sampler" may be used to fill a bag. Although a little more complicated than simply using a pump, the main advantage to using a lung sampler to fill a bag is that it avoids potential pump contamination.

A bag with attached tubing is placed in a small airtight chamber (even a 5-gallon bucket can work) with the tubing protruding from the chamber. The sealed chamber is then evacuated via a pump, causing the bag to expand and draw the sample into the bag through the protruding tube. The sample air never touches the wetted surfaces of the pump. Eurofins Air Toxics does not provide lung samplers, but they can be rented from equipment suppliers or purchased by manufacturers such as SKC Inc.

4.2.1 Considerations for Bag Sampling

Some considerations for collecting a bag sample:

- **Fill the bag no more than 2/3 full**: Allow for possible expansion due to an increase in temperature or decrease in atmospheric pressure (e.g., the cargo hold of a plane)
- **Keep the Tedlar® bag out of sunlight**: Tedlar® film is transparent to ultraviolet light (although opaque versions are available) and the sample should be kept out of sunlight to avoid any photochemical reactions
- **Protect the bag**: Store and ship the bag samples in a protective box at room temperature. An ice chest may be used, but DO NOT CHILL
- **Fill out the bag label**: It is much easier to write the sample information on the label before the bag is inflated. Make sure to use a ball-point pen, never a Sharpee or other marker which can emit VOCs.
- **Provide a "back-up" bag**: Consider filling two bags per location in the rare occasion that a defective bag deflates before analysis. The "hold" sample does not need to be documented on the Chain-of-Custody and should have an identical sample ID to the original sample indicating that it is the "hold" sample
- **Avoid Contamination**: Care should be taken to avoid contamination introduced by the pump or tubing. Begin sampling at locations with the lowest compound concentrations (e.g., sample the SVE effluent before the influent). Decontaminate the pump between uses by purging with certified air for an extended period; better yet, use a lung sampler. Use the shortest length possible of Teflon® tubing or other inert tubing. DO NOT REUSE TUBING. If long lengths of tubing are used, consider purging the tubing with several volumes worth before sampling. If you are concerned about sampling for trace compounds, you shouldn't be using a Tedlar® bag (see Section 1.2)
- **Don't Sample Dangerous Compounds in a Bag**: Do not ship any explosive substances, radiological or biological agents, corrosives or extremely hazardous materials to Eurofins Air Toxics. Bag rupture during transit to the laboratory is possible and the sampler assumes full liability.

4.2.2 Step-by-Step Procedures for Bag Sampling (Pump)

Note: These procedures are for a typical stationary source (e.g., SVE system) sampling application; actual field conditions and procedures may vary.

Before you get to the field:

1. Verify contents of the shipped package (e.g., chain-of-custody, bag, and tubing/fittings – if requested).
2. Verify pump cleanliness and operation (Eurofins Air Toxics does not provide pumps).

When ready to sample:

3. Purge sample port.
4. Attach new Teflon® tubing from sample port or probe to low flow rate pump.
5. Purge tubing.
6. Fill out bag sample tag.
7. Attach additional new Teflon® tubing from the pump outlet to the bag valve.
8. Open bag valve.
9. Collect sample (FILL NO MORE THAN 2/3 FULL).
10. Close bag valve by hand tightening valve clockwise.
11. Return filled bags in a rigid shipping container (DO NOT CHILL).
12. Fill out chain-of-custody and relinquish samples properly.
13. Place chain-of-custody in box and retain pink copy.

14. Tape box shut and affix custody seal (if applicable) across flap.
15. Ship first overnight or priority overnight to meet method holding times.

Expedite delivery of air sampling bags to the laboratory for analysis.

Section 5.0 Special Sampling Considerations

This section provides recommendations for the collection of field QC samples such as field duplicates. Considerations for sampling at altitude, sampling SVE ports and using sample cylinders are presented.

5.1 Field QC

To measure accuracy and precision of the field activities, project plans often include field duplicates, field blanks, ambient blanks, trip blanks and/or equipment blanks.

5.1.1 Field Duplicate

A field duplicate is a second sample collected in the field simultaneously with the primary sample at one sampling location. The results of the duplicate sample may be compared (e.g., calculate relative percent difference) with the primary sample to provide information on consistency and reproducibility of field sampling procedures. Due to the nature of the gas phase, duplicate samples should be collected from a common inlet. The configuration for collecting a field duplicate includes stainless steel or Teflon® tubing connected to a Swagelok "T". If integrated samples are being collected and the sample duration is to be maintained, the sample train should be assembled as follows: each canister should have a flow controller attached, then the duplicate sampling T should be attached to the flow controllers. If the collection flow rate from the sample port is to be maintained then the duplicate sampling T should be connected to the canisters; then the flow controller is connected to the inlet of the sampling T.

Alternatively, if the project objective is to assess spatial or temporal variability, then field duplicates may be deployed in close proximity (ambient air sampling) or samples may be collected in succession (soil vapor).

5.1.2 Field Blank

A field blank is a sample collected in the field from a certified air source. Analysis of the field blank can provide information on the decontamination procedures used in the field. Clean stainless steel or Teflon® tubing and a certified regulator should be used. It is imperative that individually certified canisters (the sample canister and the source canister/cylinder, if applicable) be used to collect a field blank.

5.1.3 Ambient Blank

An ambient blank is an ambient air sample collected in the field. It is usually used in conjunction with soil gas or stationary source (e.g., SVE system) sampling. Analysis of the ambient blank can provide information on the ambient levels of site contaminants. It is recommended that an individually certified canister be used to collect an ambient blank.

5.1.4 Trip Blank

When sampling for contaminants in water, the laboratory prepares a trip blank by filling a VOA vial with clean, de-ionized water. The trip blank is sent to the field in a cooler with new sample vials. After sampling, the filled sample vials are placed back in the cooler next to the trip blank and returned to the laboratory. Analysis of the trip blank provides information on decontamination and sample handling procedures in the field as well as the cleanliness of the cooler and packaging.

When sampling for compounds in air, a trip blank provides little, if any, of the information above. A trip blank canister can be individually certified, evacuated, and sent to the field in a box with the sample canisters. Since the valve is closed and the brass cap tightened, it is questionable if the trip blank canister contents are ever “exposed” to sampling conditions. The trip blank VOC concentrations essentially provide information regarding the cleanliness and performance of the trip blank canister. Results cannot necessarily be applied to the associated field sample canisters accompanying the trip blank. **Eurofins Air Toxics does not recommend collecting a trip blank for air sampling.**

5.2 Considerations for Sampling at Altitude

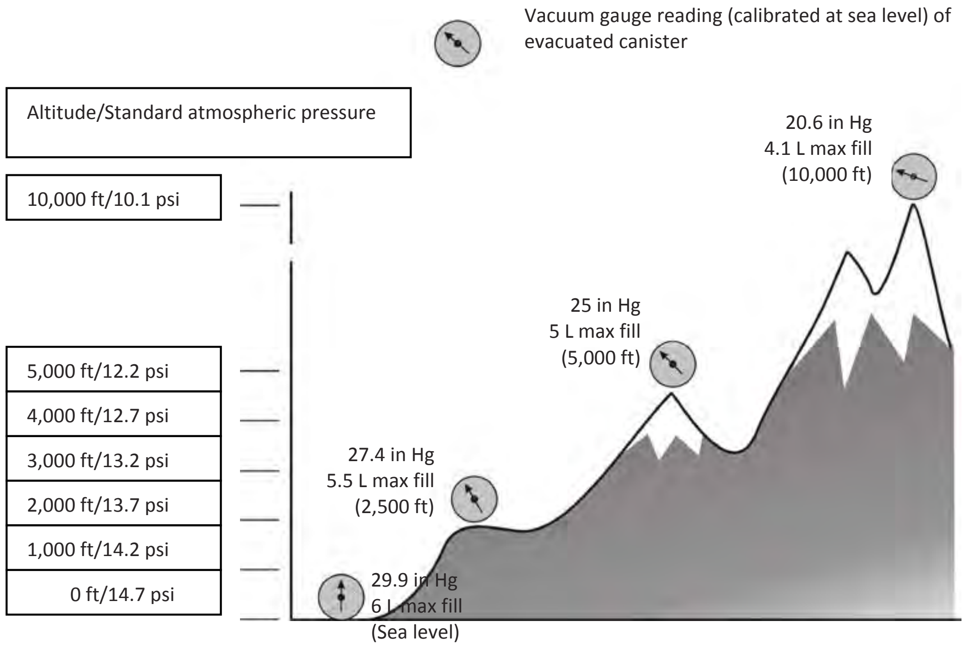
Sampling at altitudes significantly above sea level is similar to sampling a stationary source under vacuum in that target fill volumes may be difficult to achieve. The figure to the right illustrates the relationship between increasing altitude and decreasing atmospheric pressure. Ambient conditions in Denver at 5,000 ft altitude are quite different from ambient conditions at sea level. Canister sampling is driven by the differential pressure between ambient conditions and the vacuum in the canister.

There is less atmospheric pressure in Denver and 5 L is the maximum fill volume of standard air assuming the canister is allowed to reach ambient conditions (i.e., final gauge reading of 0 in Hg). Theoretically, if you sample high enough (e.g., in space), no sample would enter the canister because there is no pressure difference between the evacuated canister and ambient conditions. To fill a canister to 6 L in Denver, you would need to use an air pump.

Sampling at altitude also affects gauge readings. The gauges supplied by Eurofins Air Toxics, Inc. (see Section 2.2.4) measure canister vacuum relative to atmospheric pressure and are calibrated at approximately sea level. Before sampling at altitude, the gauges should be equilibrated (see Section 3.1). But even after equilibrating the gauge, verifying the initial vacuum of a canister at altitude is misleading. In Denver at 5,000 ft, expect the gauge to read 25, not 29.9 in Hg. You do not have a bad canister (i.e., leaking or not evacuated properly). The canister is ready for sampling and the gauge is working properly.

Rule of Thumb: For every 1,000 ft of elevation, the gauge will be off by 1 in Hg and the fill volume will be reduced by 1/5 L.

If you have questions about sampling at altitude, please call your Project Manager at 800-985-5955.



5.3 Considerations for SVE/LFG Collection System Sampling

There are some additional sampling considerations for collecting grab samples (canister or bag) from a Soil Vapor Extraction (SVE) system or landfill gas (LFG) collection system. The general challenge with these samples arises from the need to employ a length of tubing to direct the landfill gas or process air to the canister or bag. Tubing introduces the potential for contamination and diluting the sample.

- **Use inert tubing**. Teflon® tubing is recommended. Tubing with an outer diameter of ¼" works best with the fittings on the particulate filter. (See Section 3.3.1).
- **Do not reuse tubing**.
- **Purge tubing adequately**. A long length of tubing has significant volume of "dead air" inside. Without purging, this air will enter the canister and dilute the sample. Consider using a handheld PID/FID to confirm that you have purged the tubing and are drawing sample air through the tubing.
- **Avoid leaks in the sampling train**. Leaks of ambient air through fittings between pieces of the sampling train (e.g., tubing to particulate filter) will dilute the sample.
- Always use compression fittings for all connections; never use tube in tube connections.
- **Purge the sample port**. A sample port on an SVE system or LFG collection system can accumulate solids or liquids depending upon the location of the port in the process and the orientation of the port. An influent sample port located upstream of a filter or moisture knock-out can be laden with particulates or saturated with water vapor. Heavy particulate matter can clog the particulate filter and foul the canister valve. It is important to prevent liquids from entering the canister. A sample port oriented downward may have liquid standing in the valve. Purge the sample port adequately before connecting the sampling train.
- **Consider the effects of sampling a process under vacuum or pressure**. When collecting a grab sample from a stationary source such as an SVE system or LFG collection system, some sample ports may be under vacuum or pressure relative to ambient conditions. When the sample port is under vacuum, such as the header pipe from the extraction well network, it may be difficult to fill the canister with the desired volume of sample. A vacuum pump may be used to collect a canister grab sample from a sample port under considerable vacuum. See the related discussion on sampling at altitude in Section 5.2. When the sample port is under pressure, such as the effluent stack downstream of the blower and treatment system, you may inadvertently pressurize the canister. Only a DOT-approved sample cylinder should be used to transport pressurized air samples (see Section 5.4). Under no circumstances should a Summa canister be pressurized more than 15 psig. Bleed off excess pressure by opening the valve temporarily while monitoring the canister with a pressure gauge.

5.4 Considerations for Sample Cylinder Sampling

Sample cylinders, also known as "sample bombs", are DOT-approved, high pressure, thick-walled, stainless steel cylinders with a valve at each end. They were intended for collecting a pressurized sample for petroleum gas applications. Sample cylinders differ from sample canisters in that they do not have a Summa-passivated interior surface and are not evacuated prior to shipment. Sample cylinders are not suitable for analysis of hydrocarbons at ppbv levels. Sample cylinders can be used for analysis of natural gas by ASTM D-1945 and calculation of BTU by ASTM D-3588. Eurofins Air Toxics assumes that clients requesting a sample cylinder have a pressurized process and sample port with a built-in gauge and 1/4" Swagelok fitting to attach to the sample cylinder. Eurofins Air Toxics has a limited inventory of 500 mL sample cylinders that are particularly suited for landfill gas collection systems (i.e., LFG to energy applications). This section provides step-by-step procedures for sampling with a sample cylinder.

Inform the lab during project set up if hazardous samples (e.g. high Hydrogen Sulfide concentrations) will be collected to verify the lab can safely handle the samples.

Step-by-Step Procedures for Sample Cylinder Sampling

These procedures are for a typical stationary source sampling application and actual field conditions; procedures may vary. Follow all precautions in the site Health and Safety Plan when dealing with a pressurized sample port and sample cylinder. Follow required DOT guidelines for packaging and shipping.

1. Verify contents of the shipped package (e.g., chain-of-custody, sample cylinder, particulate filter).
2. Verify that gauge on sample port is working properly.
3. Purge sample port.

4. Remove brass caps on either end of cylinder.
5. Attach particulate filter to upstream valve.
6. Attach filter/cylinder assembly directly to the sample port.
7. Open both valves 1/2 turn.
8. Allow sample air to flow through sample cylinder (approximately 10 L for a 500 mL cylinder).
9. Close downstream valve of sample cylinder by hand tightening knob clockwise.
10. Allow sample cylinder to pressurize to process pressure (max 100 psig).
11. Close upstream valve of sample cylinder and sample port.
12. Detach filter/cylinder assembly from sample port and remove particulate filter.
13. Replace brass caps.
14. Fill out sample cylinder sample tag.
15. Fill out chain-of-custody and relinquish samples properly.
16. Include the chain-of-custody with the samples and retain pink copy.
17. Pack, label, and ship according to DOT regulations.

Follow DOT regulations for packaging and shipping hazardous samples.

eurofins | Air Toxics

Eurofins Air Toxics, Inc.
180 Blue Ravine Road, Suite B | Folsom, CA 95630
Tel | 1-800-985-5955 | Fax | 916-985-1020
www.AirToxics.com

APPENDIX D

Project Soil Gas Laboratory Reporting Limits

APPENDIX D

Soil Gas Reporting Limits and Screening Levels

318 State Avenue NE

Olympia, Washington

Compound[1]	Method Reporting Limit (ppbv)	Method Reporting Limit (µg/m^3)	Estimated Final Method Reporting Limit for 1L (µg/m^3)	MTCA Method B Soil Gas Screening Level[2] (µg/m^3)
Vinyl Chloride	0.10	0.26	0.69	2.8
1,1-Dichloroethene	0.10	0.40	1.06	910
trans-1,2-Dichloroethene	0.10	0.40	1.06	270
cis-1,2-Dichloroethene	0.10	0.40	1.05	160
Trichloroethene	0.10	0.54	1.42	3.7
Tetrachloroethene	0.10	0.68	1.8	96

Surrogate	Method Limits
1,2-Dichloroethane-d4	70-130
Toluene-d8	70-130
4-Bromofluorobenzene	70-130

<u>Notes:</u>
[1] Analysis method is Modified TO-15-LL
[2] Lowest of the carcinogenic and non-carcinogenic screening level
NE = not established
µg/m^3 = micrograms per cubic meter
ppbv = parts per billion by volume
MTCA = Model Toxics Control Act

APPENDIX B
Laboratory Reports

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TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

TestAmerica Laboratories, Inc.
TestAmerica Seattle
5755 8th Street East
Tacoma, WA 98424
Tel: (253)922-2310

TestAmerica Job ID: 580-49217-1
Client Project/Site: 318 State AVE NE (WA)

For:
GeoEngineers Inc
1101 Fawcett, Suite 200
Tacoma, Washington 98402

Attn: Mr. Iain Wingard

Authorized for release by:
4/27/2015 3:09:43 PM

Robert Greer, Project Manager I
(253)922-2310
robert.greer@testamericainc.com

Table of Contents

Case Narrative

Job ID: 580-49217-1

Laboratory: TestAmerica Seattle

Narrative

Job Narrative
580-49217-1

Comments

No additional comments.

Receipt

The samples were received on 4/21/2015 3:50 PM; the samples arrived in good condition, properly preserved and, where required, on ice. The temperature of the cooler at receipt was 6.3º C.

Except:

A trip blank was submitted for analysis with these samples; however, it was not listed on the Chain of Custody (COC).

GC/MS VOA

No analytical or quality issues were noted, other than those described in the Definitions/Glossary page.

Glossary

Abbreviation	These commonly used abbreviations may or may not be present in this report.
¤	Listed under the "D" column to designate that the result is reported on a dry weight basis
%R	Percent Recovery
CFL	Contains Free Liquid
CNF	Contains no Free Liquid
DER	Duplicate error ratio (normalized absolute difference)
Dil Fac	Dilution Factor
DL, RA, RE, IN	Indicates a Dilution, Re-analysis, Re-extraction, or additional Initial metals/anion analysis of the sample
DLC	Decision level concentration
MDA	Minimum detectable activity
EDL	Estimated Detection Limit
MDC	Minimum detectable concentration
MDL	Method Detection Limit
ML	Minimum Level (Dioxin)
NC	Not Calculated
ND	Not detected at the reporting limit (or MDL or EDL if shown)
PQL	Practical Quantitation Limit
QC	Quality Control
RER	Relative error ratio
RL	Reporting Limit or Requested Limit (Radiochemistry)
RPD	Relative Percent Difference, a measure of the relative difference between two points
TEF	Toxicity Equivalent Factor (Dioxin)
TEQ	Toxicity Equivalent Quotient (Dioxin)

Client Sample Results

Client: GeoEngineers Inc
Project/Site: 318 State AVE NE (WA)

TestAmerica Job ID: 580-49217-1

Client Sample ID: TW1-042115

Date Collected: 04/21/15 15:00
Date Received: 04/21/15 15:50

Lab Sample ID: 580-49217-1

Matrix: Water

Method: 8260B - Volatile Organic Compounds (GC/MS)

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
cis-1,2-Dichloroethene	ND		0.20	0.20	ug/L			04/23/15 17:45	1
1,1-Dichloroethene	ND		0.10	0.10	ug/L			04/23/15 17:45	1
Tetrachloroethene	ND		0.50	0.50	ug/L			04/23/15 17:45	1
trans-1,2-Dichloroethene	ND		0.20	0.20	ug/L			04/23/15 17:45	1
Trichloroethene	ND		0.20	0.20	ug/L			04/23/15 17:45	1
Vinyl chloride	**2.6**		0.020	0.020	ug/L			04/23/15 17:45	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*104*		*75 - 120*		*04/23/15 17:45*	*1*
Trifluorotoluene (Surr)	*108*		*80 - 127*		*04/23/15 17:45*	*1*
Toluene-d8 (Surr)	*98*		*75 - 125*		*04/23/15 17:45*	*1*
Dibromofluoromethane (Surr)	*105*		*85 - 115*		*04/23/15 17:45*	*1*
1,2-Dichloroethane-d4 (Surr)	*103*		*70 - 128*		*04/23/15 17:45*	*1*

Client Sample Results

Client: GeoEngineers Inc
TestAmerica Job ID: 580-49217-1
Project/Site: 318 State AVE NE (WA)

Client Sample ID: Trip Blank

Lab Sample ID: 580-49217-2

Date Collected: 04/21/15 00:01
Matrix: Water
Date Received: 04/21/15 15:50

Method: 8260B - Volatile Organic Compounds (GC/MS)

Analyte	Result	Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
cis-1,2-Dichloroethene	ND		0.20	0.20	ug/L			04/22/15 16:37	1
1,1-Dichloroethene	ND		0.10	0.10	ug/L			04/22/15 16:37	1
Tetrachloroethene	ND		0.50	0.50	ug/L			04/22/15 16:37	1
trans-1,2-Dichloroethene	ND		0.20	0.20	ug/L			04/22/15 16:37	1
Trichloroethene	ND		0.20	0.20	ug/L			04/22/15 16:37	1
Vinyl chloride	ND		0.020	0.020	ug/L			04/22/15 16:37	1

Surrogate	*%Recovery*	*Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*105*		*75 - 120*		*04/22/15 16:37*	*1*
Trifluorotoluene (Surr)	*113*		*80 - 127*		*04/22/15 16:37*	*1*
Toluene-d8 (Surr)	*101*		*75 - 125*		*04/22/15 16:37*	*1*
Dibromofluoromethane (Surr)	*104*		*85 - 115*		*04/22/15 16:37*	*1*
1,2-Dichloroethane-d4 (Surr)	*96*		*70 - 128*		*04/22/15 16:37*	*1*

QC Sample Results

Method: 8260B - Volatile Organic Compounds (GC/MS)

Lab Sample ID: MB 580-187507/5
Matrix: Water
Analysis Batch: 187507

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
cis-1,2-Dichloroethene	ND		0.20	0.20	ug/L			04/22/15 13:33	1
1,1-Dichloroethene	ND		0.10	0.10	ug/L			04/22/15 13:33	1
Tetrachloroethene	ND		0.50	0.50	ug/L			04/22/15 13:33	1
trans-1,2-Dichloroethene	ND		0.20	0.20	ug/L			04/22/15 13:33	1
Trichloroethene	ND		0.20	0.20	ug/L			04/22/15 13:33	1
Vinyl chloride	ND		0.020	0.020	ug/L			04/22/15 13:33	1

Surrogate	*MB %Recovery*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*104*		*75 - 120*		*04/22/15 13:33*	*1*
Trifluorotoluene (Surr)	*114*		*80 - 127*		*04/22/15 13:33*	*1*
Toluene-d8 (Surr)	*101*		*75 - 125*		*04/22/15 13:33*	*1*
Dibromofluoromethane (Surr)	*102*		*85 - 115*		*04/22/15 13:33*	*1*
1,2-Dichloroethane-d4 (Surr)	*91*		*70 - 128*		*04/22/15 13:33*	*1*

Lab Sample ID: LCS 580-187507/6
Matrix: Water
Analysis Batch: 187507

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
cis-1,2-Dichloroethene	5.00	4.84		ug/L		97	80 - 130
1,1-Dichloroethene	5.00	4.67		ug/L		93	70 - 150
Tetrachloroethene	5.00	5.62		ug/L		112	40 - 180
trans-1,2-Dichloroethene	5.00	5.07		ug/L		101	80 - 140
Trichloroethene	5.00	5.11		ug/L		102	80 - 130
Vinyl chloride	5.00	5.11		ug/L		102	65 - 140

Surrogate	*LCS %Recovery*	*LCS Qualifier*	*Limits*
4-Bromofluorobenzene (Surr)	*100*		*75 - 120*
Trifluorotoluene (Surr)	*112*		*80 - 127*
Toluene-d8 (Surr)	*97*		*75 - 125*
Dibromofluoromethane (Surr)	*99*		*85 - 115*
1,2-Dichloroethane-d4 (Surr)	*90*		*70 - 128*

Lab Sample ID: LCSD 580-187507/7
Matrix: Water
Analysis Batch: 187507

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA

Analyte	Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
cis-1,2-Dichloroethene	5.00	5.17		ug/L		103	80 - 130	7	20
1,1-Dichloroethene	5.00	4.90		ug/L		98	70 - 150	5	20
Tetrachloroethene	5.00	6.13		ug/L		123	40 - 180	9	20
trans-1,2-Dichloroethene	5.00	5.49		ug/L		110	80 - 140	8	20
Trichloroethene	5.00	5.25		ug/L		105	80 - 130	3	20
Vinyl chloride	5.00	5.77		ug/L		115	65 - 140	12	20

Surrogate	*LCSD %Recovery*	*LCSD Qualifier*	*Limits*
4-Bromofluorobenzene (Surr)	*101*		*75 - 120*

Method: 8260B - Volatile Organic Compounds (GC/MS) (Continued)

Lab Sample ID: LCSD 580-187507/7
Matrix: Water
Analysis Batch: 187507

Client Sample ID: Lab Control Sample Dup
Prep Type: Total/NA

Surrogate	*LCSD %Recovery*	*LCSD Qualifier*	*Limits*
Trifluorotoluene (Surr)	*107*		*80 - 127*
Toluene-d8 (Surr)	*99*		*75 - 125*
Dibromofluoromethane (Surr)	*104*		*85 - 115*
1,2-Dichloroethane-d4 (Surr)	*91*		*70 - 128*

Lab Sample ID: MB 580-187604/5
Matrix: Water
Analysis Batch: 187604

Client Sample ID: Method Blank
Prep Type: Total/NA

Analyte	MB Result	MB Qualifier	RL	RL	Unit	D	Prepared	Analyzed	Dil Fac
cis-1,2-Dichloroethene	ND		0.20	0.20	ug/L			04/23/15 14:16	1
1,1-Dichloroethene	ND		0.10	0.10	ug/L			04/23/15 14:16	1
Tetrachloroethene	ND		0.50	0.50	ug/L			04/23/15 14:16	1
trans-1,2-Dichloroethene	ND		0.20	0.20	ug/L			04/23/15 14:16	1
Trichloroethene	ND		0.20	0.20	ug/L			04/23/15 14:16	1
Vinyl chloride	ND		0.020	0.020	ug/L			04/23/15 14:16	1

Surrogate	*MB %Recovery*	*MB Qualifier*	*Limits*	*Prepared*	*Analyzed*	*Dil Fac*
4-Bromofluorobenzene (Surr)	*104*		*75 - 120*		*04/23/15 14:16*	*1*
Trifluorotoluene (Surr)	*107*		*80 - 127*		*04/23/15 14:16*	*1*
Toluene-d8 (Surr)	*99*		*75 - 125*		*04/23/15 14:16*	*1*
Dibromofluoromethane (Surr)	*103*		*85 - 115*		*04/23/15 14:16*	*1*
1,2-Dichloroethane-d4 (Surr)	*101*		*70 - 128*		*04/23/15 14:16*	*1*

Lab Sample ID: LCS 580-187604/6
Matrix: Water
Analysis Batch: 187604

Client Sample ID: Lab Control Sample
Prep Type: Total/NA

Analyte	Spike Added	LCS Result	LCS Qualifier	Unit	D	%Rec	%Rec. Limits
cis-1,2-Dichloroethene	5.00	5.21		ug/L		104	80 - 130
1,1-Dichloroethene	5.00	4.77		ug/L		95	70 - 150
Tetrachloroethene	5.00	6.59		ug/L		132	40 - 180
trans-1,2-Dichloroethene	5.00	5.64		ug/L		113	80 - 140
Trichloroethene	5.00	5.57		ug/L		111	80 - 130
Vinyl chloride	5.00	5.44		ug/L		109	65 - 140

Surrogate	*LCS %Recovery*	*LCS Qualifier*	*Limits*
4-Bromofluorobenzene (Surr)	*103*		*75 - 120*
Trifluorotoluene (Surr)	*109*		*80 - 127*
Toluene-d8 (Surr)	*97*		*75 - 125*
Dibromofluoromethane (Surr)	*107*		*85 - 115*
1,2-Dichloroethane-d4 (Surr)	*98*		*70 - 128*

Method: 8260B - Volatile Organic Compounds (GC/MS) (Continued)

Lab Sample ID: LCSD 580-187604/7
Client Sample ID: Lab Control Sample Dup
Matrix: Water
Prep Type: Total/NA
Analysis Batch: 187604

Analyte			Spike Added	LCSD Result	LCSD Qualifier	Unit	D	%Rec	%Rec. Limits	RPD	RPD Limit
cis-1,2-Dichloroethene			5.00	5.02		ug/L		100	80 - 130	4	20
1,1-Dichloroethene			5.00	4.92		ug/L		98	70 - 150	3	20
Tetrachloroethene			5.00	5.70		ug/L		114	40 - 180	14	20
trans-1,2-Dichloroethene			5.00	5.28		ug/L		106	80 - 140	7	20
Trichloroethene			5.00	5.58		ug/L		112	80 - 130	0	20
Vinyl chloride			5.00	5.26		ug/L		105	65 - 140	3	20

Surrogate	*LCSD %Recovery*	*LCSD Qualifier*	*Limits*
4-Bromofluorobenzene (Surr)	*103*		*75 - 120*
Trifluorotoluene (Surr)	*109*		*80 - 127*
Toluene-d8 (Surr)	*96*		*75 - 125*
Dibromofluoromethane (Surr)	*103*		*85 - 115*
1,2-Dichloroethane-d4 (Surr)	*97*		*70 - 128*

Lab Chronicle

Client Sample ID: TW1-042115 **Lab Sample ID: 580-49217-1**
Date Collected: 04/21/15 15:00 **Matrix: Water**
Date Received: 04/21/15 15:50

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	8260B		1	187604	04/23/15 17:45	D1R	TAL SEA

Client Sample ID: Trip Blank **Lab Sample ID: 580-49217-2**
Date Collected: 04/21/15 00:01 **Matrix: Water**
Date Received: 04/21/15 15:50

Prep Type	Batch Type	Batch Method	Run	Dilution Factor	Batch Number	Prepared or Analyzed	Analyst	Lab
Total/NA	Analysis	8260B		1	187507	04/22/15 16:37	CJ	TAL SEA

Laboratory References:

TAL SEA = TestAmerica Seattle, 5755 8th Street East, Tacoma, WA 98424, TEL (253)922-2310

Certification Summary

Client: GeoEngineers Inc
Project/Site: 318 State AVE NE (WA)

TestAmerica Job ID: 580-49217-1

Laboratory: TestAmerica Seattle

The certifications listed below are applicable to this report.

Authority	Program	EPA Region	Certification ID	Expiration Date
Washington	State Program	10	C553	02-17-16

Sample Summary

Client: GeoEngineers Inc
Project/Site: 318 State AVE NE (WA)

TestAmerica Job ID: 580-49217-1

Lab Sample ID	Client Sample ID	Matrix	Collected	Received
580-49217-1	TW1-042115	Water	04/21/15 15:00	04/21/15 15:50
580-49217-2	Trip Blank	Water	04/21/15 00:01	04/21/15 15:50

TestAmerica Portland
9405 SW Nimbus Avenue
Beaverton, OR 97008
Phone: 503.906.9200 Fax:

Chain of Custody Record

091069

49217

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING
TestAmerica Laboratories, Inc.
TAL-8210 (0713)

Regulatory Program: ☐ DW ☐ NPDES ☐ RCRA ☐ Other:

Client Contact	Project Manager: Nick Rohrbach	Site Contact:	Date: 4/21/15
Company Name: Geoengineers	Tel/Fax: 253 732 2138	Lab Contact:	Carrier:
Address:	Analysis Turnaround Time		
City/State/Zip: Tacoma WA.	☐ CALENDAR DAYS ☐ WORKING DAYS		
Phone: 253-732-2138	TAT if different from Below ______		
Fax:	☒ Standard 2 weeks		
Project Name: 318 State Ave.	☐ 1 week		
Site: 0415-049-06	☐ 2 days		
P O #	☐ 1 day		

COC No: 1 of 1 COCs
Sampler: Cris Watkins
For Lab Use Only:
Walk-in Client:
Lab Sampling:
Job / SDG No.:

Sample Identification	Sample Date	Sample Time	Sample Type (C=Comp, G=Grab)	Matrix	# of Cont.	Filtered Sample (Y / N)	Perform MS / MSD (Y / N)	VOCs 8260 C *	Sample Specific Notes:
TWI-042115	4-21	1500	G	H2O	6			X	* Project
TRIP Blank and 4/21/15									specific POC
									list. Check w/
									PM N. Rohrbach

580-49217 Chain of Custody

Cooler/TB Dig/IR cor 6.3 °c unc 6.0 °c Az
Cooler Dsc 5m Blue/Whit @ Lab 1630
Wet/Packs Packing Bubble
w/o LC

Preservation Used: 1= Ice, 2= HCl; 3= H2SO4; 4=HNO3; 5=NaOH; 6= Other

Possible Hazard Identification:
Are any samples from a listed EPA Hazardous Waste? Please List any EPA Waste Codes for the sample in the Comments Section if the lab is to dispose of the sample.
☐ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ Return to Client ☐ Disposal by Lab ☐ Archive for________ Months

Special Instructions/QC Requirements & Comments:

Custody Seals Intact: ☐ Yes ☐ No	Custody Seal No.:		Cooler Temp. (°C): Obs'd:______ Corr'd:______		Therm ID No.:______
Relinquished by:	Company: Geoengineers	Date/Time: 4/21/15 /1550	Received by:	Company: TA SEA	Date/Time: 4/21/15 1550
Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:
Relinquished by:	Company:	Date/Time:	Received in Laboratory by:	Company:	Date/Time:

Login Sample Receipt Checklist

Client: GeoEngineers Inc

Job Number: 580-49217-1

Login Number: 49217

List Source: TestAmerica Seattle

List Number: 1

Creator: Abello, Andrea N

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	True	
The cooler's custody seal, if present, is intact.	N/A	
Sample custody seals, if present, are intact.	N/A	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	False	Received Trip Blanks not listed on COC.
Samples are received within Holding Time.	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	N/A	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	
Residual Chlorine Checked.	N/A	

Air Toxics

5/1/2015

Mr. Nick Rohrbach
GeoEngineers, Inc.
1101 Fawcett
Suite 200
Tacoma WA 98402

Project Name: 318 State Ave
Project #: 0415-049-06
Workorder #: 1504464A

Dear Mr. Nick Rohrbach

The following report includes the data for the above referenced project for sample(s) received on 4/24/2015 at Air Toxics Ltd.

The data and associated QC analyzed by Modified TO-15 are compliant with the project requirements or laboratory criteria with the exception of the deviations noted in the attached case narrative.

Thank you for choosing Air Toxics Ltd. for your air analysis needs. Air Toxics Ltd. is committed to providing accurate data of the highest quality. Please feel free to contact the Project Manager: Kelly Buettner at 916-985-1000 if you have any questions regarding the data in this report.

Regards,

Kelly Buettner

Kelly Buettner
Project Manager

WORK ORDER #: 1504464A

Work Order Summary

CLIENT: Mr. Nick Rohrbach
GeoEngineers, Inc.
1101 Fawcett
Suite 200
Tacoma, WA 98402

BILL TO: CORP Accounts Payables
GeoEngineers, Inc.
8410 154th Avenue NE
Redmond, WA 98052

PHONE: 253.383.4940

P.O. #

FAX:

PROJECT # 0415-049-06 318 State Ave

DATE RECEIVED: 04/24/2015

CONTACT: Kelly Buettner

DATE COMPLETED: 05/01/2015

FRACTION #	NAME	TEST	RECEIPT VAC./PRES.	FINAL PRESSURE
01A	SG-1	Modified TO-15	4.3 "Hg	15 psi
03A	SG-2-AIT 2	Modified TO-15	3.7 "Hg	14.7 psi
04A	SG-3	Modified TO-15	2.4 "Hg	14.9 psi
05A	SG-4	Modified TO-15	4.1 "Hg	15 psi
06A	DUP 1	Modified TO-15	4.9 "Hg	14.6 psi
07A	Lab Blank	Modified TO-15	NA	NA
07B	Lab Blank	Modified TO-15	NA	NA
08A	CCV	Modified TO-15	NA	NA
08B	CCV	Modified TO-15	NA	NA
09A	LCS	Modified TO-15	NA	NA
09AA	LCSD	Modified TO-15	NA	NA
09B	LCS	Modified TO-15	NA	NA
09BB	LCSD	Modified TO-15	NA	NA

CERTIFIED BY: Heidi Hayes

DATE: 05/01/15

Technical Director

Certification numbers: AZ Licensure AZ0775, NJ NELAP - CA016, NY NELAP - 11291,
TX NELAP - T104704343-14-7, UT NELAP CA009332014-5, VA NELAP - 460197, WA NELAP - C935
Name of Accreditation Body: NELAP/ORELAP (Oregon Environmental Laboratory Accreditation Program)
Accreditation number: CA300005, Effective date: 10/18/2014, Expiration date: 10/17/2015.
Eurofins Air Toxics Inc.. certifies that the test results contained in this report meet all requirements of the NELAC standards

LABORATORY NARRATIVE
Modified TO-15
GeoEngineers, Inc.
Workorder# 1504464A

Five 1 Liter Summa Canister (100% Certified) samples were received on April 24, 2015. The laboratory performed analysis via modified EPA Method TO-15 using GC/MS in the full scan mode.

This workorder was independently validated prior to submittal using 'USEPA National Functional Guidelines' as generally applied to the analysis of volatile organic compounds in air. A rules-based, logic driven, independent validation engine was employed to assess completeness, evaluate pass/fail of relevant project quality control requirements and verification of all quantified amounts.

Method modifications taken to run these samples are summarized in the table below. Specific project requirements may over-ride the ATL modifications.

Requirement	*TO-15*	*ATL Modifications*
Initial Calibration	</=30% RSD with 2 compounds allowed out to < 40% RSD	</=30% RSD with 4 compounds allowed out to < 40% RSD
Blank and standards	Zero Air	UHP Nitrogen provides a higher purity gas matrix than zero air

Receiving Notes

There were no receiving discrepancies.

Analytical Notes

Dilution was performed on sample SG-4 due to the presence of high level target species.

Definition of Data Qualifying Flags

Eight qualifiers may have been used on the data analysis sheets and indicates as follows:

B - Compound present in laboratory blank greater than reporting limit (background subtraction not performed).

J - Estimated value.

E - Exceeds instrument calibration range.

S - Saturated peak.

Q - Exceeds quality control limits.

U - Compound analyzed for but not detected above the reporting limit, LOD, or MDL value. See data page for project specific U-flag definition.

UJ- Non-detected compound associated with low bias in the CCV

N - The identification is based on presumptive evidence.

File extensions may have been used on the data analysis sheets and indicates as follows:

a-File was requantified

b-File was quantified by a second column and detector

r1-File was requantified for the purpose of reissue

Summary of Detected Compounds
MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

Client Sample ID: SG-1

Lab ID#: 1504464A-01A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.24	0.73	0.60	1.9

Client Sample ID: SG-2-AIT 2

Lab ID#: 1504464A-03A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
cis-1,2-Dichloroethene	0.23	0.30	0.90	1.2
Trichloroethene	0.23	41	1.2	220
Tetrachloroethene	0.23	0.49	1.5	3.3

Client Sample ID: SG-3

Lab ID#: 1504464A-04A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.22	0.43	0.56	1.1
Trichloroethene	0.22	1.9	1.2	10

Client Sample ID: SG-4

Lab ID#: 1504464A-05A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
cis-1,2-Dichloroethene	1.2	3.4	4.6	13
Trichloroethene	1.2	460	6.3	2500
Tetrachloroethene	1.2	4.4	7.9	30

Client Sample ID: DUP 1

Lab ID#: 1504464A-06A

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.24	0.82	0.61	2.1
Trichloroethene	0.24	0.28	1.3	1.5

Client Sample ID: SG-1

Lab ID#: 1504464A-01A

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**20042717**	**Date of Collection:**	**4/21/15 10:00:00 AM**
Dil. Factor:	**2.36**	**Date of Analysis:**	**4/27/15 09:03 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.24	0.73	0.60	1.9
1,1-Dichloroethene	0.24	Not Detected	0.94	Not Detected
trans-1,2-Dichloroethene	0.24	Not Detected	0.94	Not Detected
cis-1,2-Dichloroethene	0.24	Not Detected	0.94	Not Detected
Trichloroethene	0.24	Not Detected	1.3	Not Detected
Tetrachloroethene	0.24	Not Detected	1.6	Not Detected

Container Type: 1 Liter Summa Canister (100% Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	80	70-130
Toluene-d8	99	70-130
4-Bromofluorobenzene	103	70-130

Client Sample ID: SG-2-AIT 2

Lab ID#: 1504464A-03A

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**20042718**	**Date of Collection:**	**4/21/15 3:40:00 PM**
Dil. Factor:	**2.28**	**Date of Analysis:**	**4/27/15 10:56 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.23	Not Detected	0.58	Not Detected
1,1-Dichloroethene	0.23	Not Detected	0.90	Not Detected
trans-1,2-Dichloroethene	0.23	Not Detected	0.90	Not Detected
cis-1,2-Dichloroethene	0.23	0.30	0.90	1.2
Trichloroethene	0.23	41	1.2	220
Tetrachloroethene	0.23	0.49	1.5	3.3

Container Type: 1 Liter Summa Canister (100% Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	82	70-130
Toluene-d8	98	70-130
4-Bromofluorobenzene	102	70-130

Client Sample ID: SG-3

Lab ID#: 1504464A-04A

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**20042719**	**Date of Collection:**	**4/21/15 1:25:00 PM**
Dil. Factor:	**2.19**	**Date of Analysis:**	**4/28/15 05:31 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.22	0.43	0.56	1.1
1,1-Dichloroethene	0.22	Not Detected	0.87	Not Detected
trans-1,2-Dichloroethene	0.22	Not Detected	0.87	Not Detected
cis-1,2-Dichloroethene	0.22	Not Detected	0.87	Not Detected
Trichloroethene	0.22	1.9	1.2	10
Tetrachloroethene	0.22	Not Detected	1.5	Not Detected

Container Type: 1 Liter Summa Canister (100% Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	106	70-130
Toluene-d8	100	70-130
4-Bromofluorobenzene	103	70-130

Client Sample ID: SG-4

Lab ID#: 1504464A-05A

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**20042813**	**Date of Collection:**	**4/21/15 2:00:00 PM**
Dil. Factor:	**11.7**	**Date of Analysis:**	**4/28/15 04:54 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	1.2	Not Detected	3.0	Not Detected
1,1-Dichloroethene	1.2	Not Detected	4.6	Not Detected
trans-1,2-Dichloroethene	1.2	Not Detected	4.6	Not Detected
cis-1,2-Dichloroethene	1.2	3.4	4.6	13
Trichloroethene	1.2	460	6.3	2500
Tetrachloroethene	1.2	4.4	7.9	30

Container Type: 1 Liter Summa Canister (100% Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	78	70-130
Toluene-d8	95	70-130
4-Bromofluorobenzene	96	70-130

Client Sample ID: DUP 1

Lab ID#: 1504464A-06A

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**20042814**	**Date of Collection:**	**4/21/15 4:00:00 PM**
Dil. Factor:	**2.38**	**Date of Analysis:**	**4/28/15 05:54 PM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.24	0.82	0.61	2.1
1,1-Dichloroethene	0.24	Not Detected	0.94	Not Detected
trans-1,2-Dichloroethene	0.24	Not Detected	0.94	Not Detected
cis-1,2-Dichloroethene	0.24	Not Detected	0.94	Not Detected
Trichloroethene	0.24	0.28	1.3	1.5
Tetrachloroethene	0.24	Not Detected	1.6	Not Detected

Container Type: 1 Liter Summa Canister (100% Certified)

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	79	70-130
Toluene-d8	97	70-130
4-Bromofluorobenzene	101	70-130

Client Sample ID: Lab Blank

Lab ID#: 1504464A-07A

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**20042707**	**Date of Collection: NA**	
Dil. Factor:	**1.00**	**Date of Analysis:**	**4/27/15 10:43 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.10	Not Detected	0.26	Not Detected
1,1-Dichloroethene	0.10	Not Detected	0.40	Not Detected
trans-1,2-Dichloroethene	0.10	Not Detected	0.40	Not Detected
cis-1,2-Dichloroethene	0.10	Not Detected	0.40	Not Detected
Trichloroethene	0.10	Not Detected	0.54	Not Detected
Tetrachloroethene	0.10	Not Detected	0.68	Not Detected

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	81	70-130
Toluene-d8	94	70-130
4-Bromofluorobenzene	100	70-130

Client Sample ID: Lab Blank

Lab ID#: 1504464A-07B

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**20042806**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 4/28/15 09:47 AM**

Compound	Rpt. Limit (ppbv)	Amount (ppbv)	Rpt. Limit (ug/m3)	Amount (ug/m3)
Vinyl Chloride	0.10	Not Detected	0.26	Not Detected
1,1-Dichloroethene	0.10	Not Detected	0.40	Not Detected
trans-1,2-Dichloroethene	0.10	Not Detected	0.40	Not Detected
cis-1,2-Dichloroethene	0.10	Not Detected	0.40	Not Detected
Trichloroethene	0.10	Not Detected	0.54	Not Detected
Tetrachloroethene	0.10	Not Detected	0.68	Not Detected

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	79	70-130
Toluene-d8	95	70-130
4-Bromofluorobenzene	100	70-130

Client Sample ID: CCV

Lab ID#: 1504464A-08A

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**20042703**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 4/27/15 07:05 AM**

Compound	%Recovery
Vinyl Chloride	96
1,1-Dichloroethene	102
trans-1,2-Dichloroethene	95
cis-1,2-Dichloroethene	98
Trichloroethene	97
Tetrachloroethene	101

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	75	70-130
Toluene-d8	99	70-130
4-Bromofluorobenzene	100	70-130

Client Sample ID: CCV

Lab ID#: 1504464A-08B

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**20042802**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 4/28/15 06:37 AM**

Compound	%Recovery
Vinyl Chloride	95
1,1-Dichloroethene	102
trans-1,2-Dichloroethene	93
cis-1,2-Dichloroethene	101
Trichloroethene	96
Tetrachloroethene	100

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	73	70-130
Toluene-d8	98	70-130
4-Bromofluorobenzene	100	70-130

Client Sample ID: LCS

Lab ID#: 1504464A-09A

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**20042704**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 4/27/15 07:53 AM**

Compound	%Recovery	Method Limits
Vinyl Chloride	101	70-130
1,1-Dichloroethene	107	70-130
trans-1,2-Dichloroethene	86	70-130
cis-1,2-Dichloroethene	112	70-130
Trichloroethene	100	70-130
Tetrachloroethene	101	70-130

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	77	70-130
Toluene-d8	101	70-130
4-Bromofluorobenzene	101	70-130

Client Sample ID: LCSD

Lab ID#: 1504464A-09AA

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**20042705**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 4/27/15 08:54 AM**

Compound	**%Recovery**	**Method Limits**
Vinyl Chloride	101	70-130
1,1-Dichloroethene	106	70-130
trans-1,2-Dichloroethene	87	70-130
cis-1,2-Dichloroethene	114	70-130
Trichloroethene	100	70-130
Tetrachloroethene	104	70-130

Container Type: NA - Not Applicable

Surrogates	**%Recovery**	**Method Limits**
1,2-Dichloroethane-d4	74	70-130
Toluene-d8	99	70-130
4-Bromofluorobenzene	102	70-130

Client Sample ID: LCS

Lab ID#: 1504464A-09B

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**20042803**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 4/28/15 07:21 AM**

Compound	%Recovery	Method Limits
Vinyl Chloride	100	70-130
1,1-Dichloroethene	104	70-130
trans-1,2-Dichloroethene	82	70-130
cis-1,2-Dichloroethene	110	70-130
Trichloroethene	97	70-130
Tetrachloroethene	102	70-130

Container Type: NA - Not Applicable

Surrogates	%Recovery	Method Limits
1,2-Dichloroethane-d4	74	70-130
Toluene-d8	99	70-130
4-Bromofluorobenzene	101	70-130

Client Sample ID: LCSD

Lab ID#: 1504464A-09BB

MODIFIED EPA METHOD TO-15 GC/MS FULL SCAN

File Name:	**20042804**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 4/28/15 08:05 AM**

Compound	**%Recovery**	**Method Limits**
Vinyl Chloride	99	70-130
1,1-Dichloroethene	104	70-130
trans-1,2-Dichloroethene	84	70-130
cis-1,2-Dichloroethene	110	70-130
Trichloroethene	98	70-130
Tetrachloroethene	103	70-130

Container Type: NA - Not Applicable

Surrogates	**%Recovery**	**Method Limits**
1,2-Dichloroethane-d4	73	70-130
Toluene-d8	99	70-130
4-Bromofluorobenzene	103	70-130

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5/1/2015

Mr. Nick Rohrbach
GeoEngineers, Inc.
1101 Fawcett
Suite 200
Tacoma WA 98402

Project Name: 318 State Ave
Project #: 0415-049-06
Workorder #: 1504464B

Dear Mr. Nick Rohrbach

The following report includes the data for the above referenced project for sample(s) received on 4/24/2015 at Air Toxics Ltd.

The data and associated QC analyzed by Modified ASTM D-1946 are compliant with the project requirements or laboratory criteria with the exception of the deviations noted in the attached case narrative.

Thank you for choosing Air Toxics Ltd. for your air analysis needs. Air Toxics Ltd. is committed to providing accurate data of the highest quality. Please feel free to contact the Project Manager: Kelly Buettner at 916-985-1000 if you have any questions regarding the data in this report.

Regards,

Kelly Buettner

Kelly Buettner
Project Manager

WORK ORDER #: 1504464B

Work Order Summary

CLIENT:
Mr. Nick Rohrbach
GeoEngineers, Inc.
1101 Fawcett
Suite 200
Tacoma, WA 98402

BILL TO:
CORP Accounts Payables
GeoEngineers, Inc.
8410 154th Avenue NE
Redmond, WA 98052

PHONE: 253.383.4940

P.O. #

FAX:

PROJECT # 0415-049-06 318 State Ave

DATE RECEIVED: 04/24/2015

CONTACT: Kelly Buettner

DATE COMPLETED: 05/01/2015

FRACTION #	NAME	TEST	RECEIPT VAC./PRES.	FINAL PRESSURE
01A	SG-1	Modified ASTM D-1946	4.3 "Hg	15 psi
03A	SG-2-AIT 2	Modified ASTM D-1946	3.7 "Hg	14.7 psi
04A	SG-3	Modified ASTM D-1946	2.4 "Hg	14.9 psi
05A	SG-4	Modified ASTM D-1946	4.1 "Hg	15 psi
06A	DUP 1	Modified ASTM D-1946	4.9 "Hg	14.6 psi
07A	Lab Blank	Modified ASTM D-1946	NA	NA
07B	Lab Blank	Modified ASTM D-1946	NA	NA
08A	LCS	Modified ASTM D-1946	NA	NA
08AA	LCSD	Modified ASTM D-1946	NA	NA

CERTIFIED BY: Heidi Hayes

DATE: 05/01/15

Technical Director

Certification numbers: AZ Licensure AZ0775, NJ NELAP - CA016, NY NELAP - 11291,
TX NELAP - T104704343-14-7, UT NELAP CA009332014-5, VA NELAP - 460197, WA NELAP - C935
Name of Accreditation Body: NELAP/ORELAP (Oregon Environmental Laboratory Accreditation Program)
Accreditation number: CA300005, Effective date: 10/18/2014, Expiration date: 10/17/2015.
Eurofins Air Toxics Inc.. certifies that the test results contained in this report meet all requirements of the NELAC standards

LABORATORY NARRATIVE
Modified ASTM D-1946
GeoEngineers, Inc.
Workorder# 1504464B

Five 1 Liter Summa Canister (100% Certified) samples were received on April 24, 2015. The laboratory performed analysis via Modified ASTM Method D-1946 for Methane and Helium in air using GC/FID or GC/TCD. The method involves direct injection of 1.0 mL of sample.

Method modifications taken to run these samples are summarized in the table below. Specific project requirements may over-ride the ATL modifications.

Requirement	***ASTM D-1946***	***ATL Modifications***
Calibration	A single point calibration is performed using a reference standard closely matching the composition of the unknown.	A minimum of 5-point calibration curve is performed. Quantitation is based on average Response Factor.
Reference Standard	The composition of any reference standard must be known to within 0.01 mol % for any component.	The standards used by ATL are blended to a >/= 95% accuracy.
Sample Injection Volume	Components whose concentrations are in excess of 5 % should not be analyzed by using sample volumes greater than 0.5 mL.	The sample container is connected directly to a fixed volume sample loop of 1.0 mL on the GC. Linear range is defined by the calibration curve. Bags are loaded by vacuum.
Normalization	Normalize the mole percent values by multiplying each value by 100 and dividing by the sum of the original values. The sum of the original values should not differ from 100% by more than 1.0%.	Results are not normalized. The sum of the reported values can differ from 100% by as much as 15%, either due to analytical variability or an unusual sample matrix.
Precision	Precision requirements established at each concentration level.	Duplicates should agree within 25% RPD for detections > 5 X's the RL.

Receiving Notes

There were no receiving discrepancies.

Analytical Notes

There were no analytical discrepancies.

Definition of Data Qualifying Flags

Seven qualifiers may have been used on the data analysis sheets and indicate as follows:
B - Compound present in laboratory blank greater than reporting limit.
J - Estimated value.
E - Exceeds instrument calibration range.
S - Saturated peak.
Q - Exceeds quality control limits.
U - Compound analyzed for but not detected above the detection limit.
M - Reported value may be biased due to apparent matrix interferences.
File extensions may have been used on the data analysis sheets and indicates as follows:
a-File was requantified
b-File was quantified by a second column and detector
r1-File was requantified for the purpose of reissue

Summary of Detected Compounds
NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

Client Sample ID: SG-1

Lab ID#: 1504464B-01A

Compound	Rpt. Limit (%)	Amount (%)
Methane	0.00024	0.0033
Helium	0.12	16

Client Sample ID: SG-2-AIT 2

Lab ID#: 1504464B-03A

Compound	Rpt. Limit (%)	Amount (%)
Methane	0.00023	0.0082
Helium	0.11	7.0

Client Sample ID: SG-3

Lab ID#: 1504464B-04A

Compound	Rpt. Limit (%)	Amount (%)
Methane	0.00022	0.016
Helium	0.11	13

Client Sample ID: SG-4

Lab ID#: 1504464B-05A

Compound	Rpt. Limit (%)	Amount (%)
Methane	0.00023	0.00095

Client Sample ID: DUP 1

Lab ID#: 1504464B-06A

Compound	Rpt. Limit (%)	Amount (%)
Methane	0.00024	0.0038
Helium	0.12	13

Client Sample ID: SG-1

Lab ID#: 1504464B-01A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10043012**	**Date of Collection: 4/21/15 10:00:00 AM**
Dil. Factor:	**2.36**	**Date of Analysis: 4/30/15 02:29 PM**

Compound	**Rpt. Limit (%)**	**Amount (%)**
Methane	0.00024	0.0033
Helium	0.12	16

Container Type: 1 Liter Summa Canister (100% Certified)

Client Sample ID: SG-2-AIT 2

Lab ID#: 1504464B-03A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10043013**	**Date of Collection:**	**4/21/15 3:40:00 PM**
Dil. Factor:	**2.28**	**Date of Analysis:**	**4/30/15 03:20 PM**

Compound	Rpt. Limit (%)	Amount (%)
Methane	0.00023	0.0082
Helium	0.11	7.0

Container Type: 1 Liter Summa Canister (100% Certified)

Client Sample ID: SG-3

Lab ID#: 1504464B-04A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10043014**	**Date of Collection: 4/21/15 1:25:00 PM**
Dil. Factor:	**2.19**	**Date of Analysis: 4/30/15 03:44 PM**

Compound	**Rpt. Limit (%)**	**Amount (%)**
Methane	0.00022	0.016
Helium	0.11	13

Container Type: 1 Liter Summa Canister (100% Certified)

Client Sample ID: SG-4

Lab ID#: 1504464B-05A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10043015**	**Date of Collection: 4/21/15 2:00:00 PM**
Dil. Factor:	**2.34**	**Date of Analysis: 4/30/15 04:06 PM**

Compound	**Rpt. Limit (%)**	**Amount (%)**
Methane	0.00023	0.00095
Helium	0.12	Not Detected

Container Type: 1 Liter Summa Canister (100% Certified)

Client Sample ID: DUP 1

Lab ID#: 1504464B-06A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10043016**	**Date of Collection: 4/21/15 4:00:00 PM**
Dil. Factor:	**2.38**	**Date of Analysis: 4/30/15 04:33 PM**

Compound	**Rpt. Limit (%)**	**Amount (%)**
Methane	0.00024	0.0038
Helium	0.12	13

Container Type: 1 Liter Summa Canister (100% Certified)

eurofins | Air Toxics

Client Sample ID: Lab Blank

Lab ID#: 1504464B-07A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10043005**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 4/30/15 10:38 AM**

Compound	Rpt. Limit (%)	Amount (%)
Methane	0.00010	Not Detected

Container Type: NA - Not Applicable

Client Sample ID: Lab Blank

Lab ID#: 1504464B-07B

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10043004c**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 4/30/15 10:02 AM**

Compound	**Rpt. Limit (%)**	**Amount (%)**
Helium	0.050	Not Detected

Container Type: NA - Not Applicable

Client Sample ID: LCS

Lab ID#: 1504464B-08A

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10043002**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 4/30/15 09:00 AM**

Compound	%Recovery	Method Limits
Methane	105	85-115
Helium	102	85-115

Container Type: NA - Not Applicable

Client Sample ID: LCSD

Lab ID#: 1504464B-08AA

NATURAL GAS ANALYSIS BY MODIFIED ASTM D-1946

File Name:	**10043022**	**Date of Collection: NA**
Dil. Factor:	**1.00**	**Date of Analysis: 4/30/15 07:03 PM**

Compound	%Recovery	Method Limits
Methane	104	85-115
Helium	101	85-115

Container Type: NA - Not Applicable

APPENDIX C

Data Quality Assessment Summary

Data Validation Report

1101 Fawcett Avenue, Suite 200, Tacoma, Washington 98402, Telephone: 253.383.4940, Fax: 253.383.4923 www.geoengineers.com

Project:	City of Olympia – 318 NE State Avenue Site April 2015 Soil Gas Samples
GEI File No:	0415-049-06
Date:	May 4, 2015

This report documents the results of a United States Environmental Protection Agency (USEPA)-defined Stage 2A data validation (USEPA Document 540-R-08-005; USEPA, 2009) of analytical data from the analyses of soil gas samples collected on April 21, 2015, and the associated laboratory and field quality control (QC) samples. The samples were obtained from the 318 NE State Avenue Site located in Olympia, Washington.

OBJECTIVE AND QUALITY CONTROL ELEMENTS

GeoEngineers, Inc. (GeoEngineers) completed the data validation consistent with Eurofins Air Toxics Standard Operating Procedures (SOPs) 38 and 100, guidance in the USEPA Contract Laboratory Program *National Functional Guidelines for Organic Data Review* (USEPA, 2008), and USEPA Method TO-15 SIM.

- Data usability was assessed by determining if: The samples were analyzed using well-defined and acceptable methods that provide detection limits and reporting limits below applicable regulatory criteria;
- The precision and accuracy of the data are well defined and sufficient to provide defensible data; and
- The quality assurance/quality control (QA/QC) procedures utilized by the laboratory meet acceptable industry practices and standards.

In accordance with the Soil Vapor Sampling Work Plan (GeoEngineers, 2015), the data validation included review of the following QC elements:

- Data Package Completeness
- Chain-of-Custody Documentation
- Holding Times and Sample Preservation
- Surrogate Recoveries
- Method Blanks
- Matrix Spikes/Matrix Spike Duplicates
- Laboratory Control Samples/Laboratory Control Sample Duplicates
- Field Duplicates

VALIDATED SAMPLE DELIVERY GROUPS

This data validation included review of the sample delivery group (SDG) listed below in Table 1.

TABLE 1: SUMMARY OF VALIDATED SAMPLE DELIVERY GROUPS

Laboratory SDG	Samples Validated
1504464 (A and B)	SG-1, DUP 1, SG-2-AIT-2, SG-3, & SG-4

CHEMICAL ANALYSIS PERFORMED

Eurofins Air Toxics, Inc. (Eurofins), located in Folsom, California, performed laboratory analysis on the soil vapor samples using the following methods:

- Volatile Organic Compounds (VOCs) by modified method TO-15
- Methane and Helium by modified method ASTM 1946

DATA VALIDATION SUMMARY

The results for each of the QC elements are summarized below.

Data Package Completeness

Eurofins analyzed the soil vapor samples evaluated as part of this data quality assessment. The laboratory provided all required deliverables for the assessment. The laboratory followed adequate corrective action processes and all identified anomalies were discussed in the case narrative.

Chain-of-Custody Documentation

Chain-of-custody (COC) forms were provided with the laboratory analytical reports. All COC documentation parameters were met.

Holding Times and Canister Vacuum

The holding time is defined as the time that elapses between sample collection and sample analysis. Maximum holding time criteria exist for each analysis to help ensure that the analyte concentrations found at the time of analysis reflect the concentration present at the time of sample collection. Established holding times were met for all analyses.

The Soil Vapor Monitoring Work Plan states that final summa canister vacuums will be approximately 5 inches of mercury (in. Hg). The reason for this is to show that the canister did not complete the intake of the target analyte before the sampler measured the time interval of the initial volume of the sample. Also, the measurement of 5 in. Hg shows that the flow controllers used to regulate air flow into the canisters function properly when the summa canister vacuum is greater than 4 in. Hg. The final vacuum on the summa canisters were all greater than 5 in. Hg as noted at the time of sampling.

Eurofins Air Toxics indicated that they evaluate sample integrity by (1) comparing field and laboratory final vacuum measurements, (2) checking to see that the valve assembly on the canister is shut and that a brass cap has been secured to the inlet on the valve assembly, and (3) leak checking the valve assembly. Based on these sample integrity assessments, no data qualification is warranted with regard to the final canister vacuums observed in the field and at the laboratory.

Surrogate Recoveries

A surrogate compound is a compound that is chemically similar to the organic analytes of interest, but unlikely to be found in any environmental sample. Surrogates are used for organic analyses and are added to all samples, standards, and blanks to serve as an accuracy and specificity check of each analysis. The surrogates are added to the samples at a known concentration and percent recoveries are calculated following analysis. All surrogate percent recoveries for field samples were within the laboratory control limits.

Method Blanks

Method blanks are analyzed to ensure that laboratory procedures and reagents do not introduce measurable concentrations of the analytes of interest. A method blank was analyzed with each batch of samples, at a frequency of 1 per 20 samples. For all sample batches, method blanks for all applicable methods were analyzed at the required frequency. None of the analytes of interest were detected above the reporting limits in any of the method blanks.

Matrix Spikes/Matrix Spike Duplicates

Since the actual analyte concentration in an environmental sample is not known, the accuracy of a particular analysis is usually inferred by performing a matrix spike (MS) analysis on one sample from the associated batch, known as the parent sample. One aliquot of the sample is analyzed in the normal manner and then a second aliquot of the sample is spiked with a known amount of analyte concentration and analyzed. From these analyses, a percent recovery is calculated. Matrix spike duplicate (MSD) analyses are generally performed for organic analyses as a precision check and analyzed in the same sequence as a matrix spike. Using the result values from the MS and MSD, the relative percent difference (RPD) is calculated. The percent recovery control limits for MS and MSD analyses are specified in the laboratory documents, as are the RPD control limits for MS/MSD sample sets.

There were no MS/MSD analyses performed on any of the associated field samples.

Laboratory Control Samples/Laboratory Control Sample Duplicates

A laboratory control sample (LCS) is a blank sample that is spiked with a known amount of analyte and then analyzed. An LCS is similar to an MS, but without the possibility of matrix interference. Given that matrix interference is not an issue, the LCS/LCSD control limits for accuracy and precision are usually more rigorous than for MS/MSD analyses. Additionally, data qualification based on LCS/LCSD analyses would apply to all samples in the associated batch, instead of just the parent sample. The percent recovery control limits for LCS and LCSD analyses are specified in the laboratory documents, as are the RPD control limits for LCS/LCSD sample sets.

One LCS/LCSD analysis should be performed for every analytical batch or every 20 field samples, whichever is more frequent. The frequency requirements were met for all analyses and the percent recovery and RPD values were within the proper control limits.

Field Duplicates

In order to assess precision, field duplicate samples were collected and analyzed along with the reviewed sample batches. The duplicate samples were analyzed for the same parameters as the associated parent samples. Precision is determined by calculating the RPD between each pair of samples. If one or more of the sample analytes has a concentration greater than five times the reporting limit for that sample, then the absolute difference is used instead of the RPD. The RPD control limit for air samples is 20 percent.

SDG 1504464: One field duplicate sample pair, SG-1 and DUP 1, was submitted with this SDG. The precision criteria for all target analytes were met for this sample pair.

OVERALL ASSESSMENT

As was determined by this data validation, the laboratory followed the specified analytical methods. Accuracy was acceptable, as demonstrated by the surrogate and LCS/LCSD percent recovery values. Precision was acceptable, as demonstrated by the LCS/LCSD RPD values.

No analytical results were qualified. All data are acceptable for the intended use.

REFERENCES

U.S. Environmental Protection Agency (USEPA). "Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use," EPA-540-R-08-005. January 2009.

U.S. Environmental Protection Agency (USEPA). "Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review," EPA-540-R-08-01. June 2008.

GeoEngineers, Inc. "Soil Vapor Sampling Work Plan," prepared for City of Olympia. April 1, 2015.

GEOENGINEERS

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Data Validation Report

Project: City of Olympia – 318 NE State Avenue Site
April 2015 Temporary Well Groundwater Sample

GEI File No: 0415-049-06

Date: April 29, 2015

This report documents the results of a United States Environmental Protection Agency (USEPA)-defined Stage 2A data validation (USEPA Document 540-R-08-005; USEPA, 2009) of analytical data from the analyses of one groundwater sample collected on April 21, 2015, and the associated laboratory and field quality control (QC) samples. The sample was obtained from the 318 NE State Avenue Site located in Olympia, Washington.

OBJECTIVE AND QUALITY CONTROL ELEMENTS

GeoEngineers, Inc. (GeoEngineers) completed the data validation consistent with the USEPA Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review (USEPA, 2008) (National Functional Guidelines) to determine if the laboratory analytical results meet the project objectives and are usable for their intended purpose. Data usability was assessed by determining if:

- The samples were analyzed using well-defined and acceptable methods that provide reporting limits below applicable regulatory criteria;
- The precision and accuracy of the data are well-defined and sufficient to provide defensible data; and
- The quality assurance/quality control (QA/QC) procedures utilized by the laboratory meet acceptable industry practices and standards.

In accordance with the Quality Assurance Project Plan (QAPP), Appendix B of the Groundwater Compliance Monitoring Plan (GeoEngineers, 2010), the data validation included review of the following QC elements:

- Data Package Completeness
- Chain-of-Custody Documentation
- Holding Times and Sample Preservation
- Surrogate Recoveries
- Method and Trip Blanks
- Matrix Spikes/Matrix Spike Duplicates
- Laboratory Control Samples/Laboratory Control Sample Duplicates

VALIDATED SAMPLE DELIVERY GROUPS

This data validation included review of the sample delivery group (SDG) listed below in Table 1.

TABLE 1: SUMMARY OF VALIDATED SAMPLE DELIVERY GROUPS

Laboratory SDG	Samples Validated
580-49217-1	TW1-042115, Trip Blank

CHEMICAL ANALYSIS PERFORMED

TestAmerica Laboratories, Inc. (TestAmerica), located in Tacoma, Washington, performed laboratory analysis on the groundwater sample using the following method:

- Volatile Organic Compounds (VOCs) by Method SW8260B

DATA VALIDATION SUMMARY

The results for each of the QC elements are summarized below.

Data Package Completeness

TestAmerica provided all required deliverables for the data validation according to the National Functional Guidelines. The laboratory followed adequate corrective action processes and all identified anomalies were discussed in the relevant laboratory case narrative.

Chain-of-Custody Documentation

Chain-of-custody (COC) forms were provided with the laboratory analytical reports. The COCs were accurate and complete when submitted to the laboratory, with the following exception:

SDG 580-49217-1: The laboratory noted that the trip blank sample was not written on the COC. It was added by TestAmerica and VOC analysis was performed.

Holding Times and Sample Preservation

The sample holding time is defined as the time that elapses between sample collection and sample analysis. Maximum holding time criteria exist for each analysis to help ensure that the analyte concentrations found at the time of analysis reflect the concentration present at the time of sample collection. Established holding times were met for all analyses. The sample cooler arrived at the laboratory outside the appropriate temperatures of between two and six degrees Celsius. The out-of-compliance temperature is detailed below.

SDG 580-49217-1: The sample cooler temperature recorded at the laboratory was 6.3 degrees Celsius. It was determined through professional judgment that since the cooler temperature was just outside the control limits and the samples were received by the laboratory the same day they were collected, this temperature should not affect the sample analytical results.

Surrogate Recoveries

A surrogate compound is a compound that is chemically similar to the organic analytes of interest, but unlikely to be found in any environmental sample. Surrogates are used for organic analyses and are added to all samples, standards, and blanks to serve as an accuracy and specificity check of each analysis. The surrogates are added to the samples at a known concentration and percent recoveries are calculated following analysis. All surrogate percent recoveries for field samples were within the laboratory control limits.

Method and Trip Blanks

Method blanks are analyzed to ensure that laboratory procedures and reagents do not introduce measurable concentrations of the analytes of interest. A method blank was analyzed with each batch of samples, at a frequency of 1 per 20 samples. For all sample batches, method blanks for all applicable methods were analyzed at the required frequency. None of the analytes of interest were detected above the reporting limits in any of the method blanks.

Trip blanks are analyzed to assess whether field sampling or sample transport processes may have introduced measurable concentrations of volatile analytes of interest into project samples. None of the analytes of interest were detected above the reporting limits in the trip blank.

Matrix Spikes/Matrix Spike Duplicates

Since the actual analyte concentration in an environmental sample is not known, the accuracy of a particular analysis is usually inferred by performing a matrix spike (MS) analysis on one sample from the associated batch, known as the parent sample. One aliquot of the sample is analyzed in the normal manner and then a second aliquot of the sample is spiked with a known amount of analyte concentration and analyzed. From these analyses, a percent recovery is calculated. Matrix spike duplicate (MSD) analyses are generally performed for organic analyses as a precision check and analyzed in the same sequence as a matrix spike. Using the result values from the MS and MSD, the relative percent difference (RPD) is calculated. The percent recovery control limits for MS and MSD analyses are specified in the laboratory documents, as are the RPD control limits for MS/MSD sample sets.

There were no MS/MSD analyses performed on any of the associated field samples.

Laboratory Control Samples/Laboratory Control Sample Duplicates

A laboratory control sample (LCS) is a blank sample that is spiked with a known amount of analyte and then analyzed. An LCS is similar to an MS, but without the possibility of matrix interference. Given that matrix interference is not an issue, the LCS/LCSD control limits for accuracy and precision are usually more rigorous than for MS/MSD analyses. Additionally, data qualification based on LCS/LCSD analyses would apply to all samples in the associated batch, instead of just the parent sample. The percent recovery control limits for LCS and LCSD analyses are specified in the laboratory documents, as are the RPD control limits for LCS/LCSD sample sets.

One LCS/LCSD analysis should be performed for every analytical batch or every 20 field samples, whichever is more frequent. The frequency requirements were met for all analyses and the percent recovery and RPD values were within the proper control limits.

OVERALL ASSESSMENT

As was determined by this data validation, the laboratory followed the specified analytical methods. Accuracy was acceptable, as demonstrated by the surrogate and LCS/LCSD percent recovery values. Precision was acceptable, as demonstrated by the LCS/LCSD RPD values.

No analytical results were qualified. All data are acceptable for the intended use.

REFERENCES

U.S. Environmental Protection Agency (USEPA). "Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use," EPA-540-R-08-005. January 2009.

U.S. Environmental Protection Agency (USEPA). "Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review," EPA-540-R-08-01. June 2008.

GeoEngineers, Inc. "Groundwater Compliance Monitoring Plan," prepared for City of Olympia. April 16, 2010.