SUMMARY REPORT
STATE OF MAINE
VAPOR INTRUSION STUDY FOR PETROLEUM SITES

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Department of Environmental Protection

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The project team is also grateful for the support of Nathan Stevens of Cumberland Farms, Inc., in allowing Maine DEP and its consultants access to numerous service station sites throughout the State of Maine. Cooperative investigation of these sites formed the backbone of the vapor intrusion research summarized herein.

1.0 Study Objectives

Automobile service stations, both active and defunct, are found in virtually every Maine city and town. Despite best management practices, spills of gasoline and other contaminants are not uncommon, and present a risk of impact to the environment. For several decades, service station operators and regulatory officials have successfully investigated and cleaned up spills, and have continually improved guidance for spill prevention and response. This guidance has focused largely on soil and groundwater, but in recent years investigators have sought to better understand risks posed by petroleum and solvent vapors, also referred to as volatile organic compounds (VOCs).

Gasoline, for example, is one hundred percent volatile and contains relatively toxic compounds such as benzene, toluene, ethylbenzene, and xylenes. Other potential VOCs at service stations include petroleum-based and chlorinated parts cleaners such as trichloroethylene and tetrachloroethylene (PCE). VOCs can migrate through unsaturated soils and enter homes and businesses through basements and utilities. The phenomenon of VOCs moving through soil and into a building or utility is commonly referred to as “vapor intrusion.”

Through a statewide vapor intrusion study, the Maine Department of Environmental Protection (Maine DEP) has sought to better understand risks posed by vapor intrusion, and to evaluate conventional tools and methods for assessing risk. While the focus has been on sites with a history of gasoline releases, many of the sites investigated also included use of parts cleaners, and analysis of soil vapor during the study included chlorinated solvents and their breakdown products.

A primary objective was to target sites considered by current convention and guidance to pose a moderate to high risk of vapor intrusion as Maine DEP seeks to gain an understanding of the magnitude and prevalence of petroleum vapor intrusion (PVI). With this understanding, an appropriate level of resources and required response can be applied for petroleum facilities that fall under the Maine DEP’s purview.

With data and experience from the statewide study, Maine DEP has critically evaluated the relevance of current guidelines for assessment of vapor intrusion risk [1]. These guidelines include, for example, pathway screening criteria that currently trigger vapor intrusion investigation for petroleum sites. The criteria include:

- Location of buildings, utilities or other preferential pathways within 30 feet horizontally or vertically from petroleum contaminated media (soil, groundwater or soil vapor).
- The release of gasoline discharges of 10 or more gallons where oil saturated soil or free product groundwater contamination are found within 50 feet of a routinely occupied building or underground utilities connected to neighboring buildings.

Maine DEP acknowledges that vapor intrusion risk may not follow straightforward separation distance criteria or discharge volumes thresholds. The statewide study has therefore included assessment of a number of factors that influence whether a vapor migration pathway is "complete," and when further action is required to evaluate risk to a receptor. Key assessment components for the study included:

- Source areas of contamination and strength of the source(s)
- Frequency and attributes of complete pathways at both onsite and offsite buildings.
- Lateral and vertical attenuation of VOCs in soil vapor with distance from source areas (e.g., underground tanks or pump islands).
- Vapor intrusion risk posed by VOCs migrating in contaminated groundwater.
- Influence of utilities on vapor intrusion and role as potential preferred migration pathways.
- Characteristics and variability of vapor intrusion risk inherent to Maine's geology and climate.

Maine DEP is also aware of research over the past several years that indicates substantial differences in vapor intrusion risk for petroleum release sites compared to those of chlorinated solvent releases or other non-petroleum VOCs. The key appears to be the higher susceptibility of petroleum compounds to biodegradation compared to chlorinated compounds. Maine DEP has used data from the statewide vapor intrusion study to critically review research that suggests rapid attenuation of petroleum vapors in the presence of abundant oxygen.

With a better understanding of vapor intrusion risk, Maine DEP will be able to refine its regulatory guidance and minimize the costly, time consuming, and often times confounding investigation of sites with low risk. Conversely, the Department will be able to more effectively identify scenarios where vapor intrusion poses a significant risk to receptors and design an investigation to collect valuable information with regard to discerning the VI pathway.

2.0 Methodology

2.1 Study Site Overview

Maine DEP's soil vapor intrusion study included fourteen sites throughout the state of Maine, ranging from Berwick in southern Maine to Presque Isle in the northern part of the state (Figure 2.1). As Shown in Table 2.1, site characteristics included varied soil types and water table depths, providing a broad range of environments for soil vapor evaluation. Sub-slab samples were collected from 12 of the 14 sites to evaluate vapor intrusion risk to the respective buildings. The study included groundwater characterization based on installation of fifty-three groundwater monitoring wells, in addition to data collected from existing monitoring wells at sites in Milo, Portland (Forest Ave), Lewiston and Presque Isle. Repeat and extended sample rounds and investigations were conducted in December, 2010 (Phase IIB) to evaluate seasonal effects on soil vapor and groundwater quality, and to follow up where off-site risk was indicated by results of the September 2010 investigation (Phase IIA).

Each site (except for Presque Isle) included operating service stations with a history of petroleum releases, including leaks from underground storage tanks (USTs), piping, and incidental spills, ranging from less than 10 gallons to nearly 1,000 gallons. With few exceptions, the site investigations were located within the boundaries of the operating service stations, the majority of which were owned by Cumberland Farms, Inc.

2.2 Consultant Selection

Following an open, competitive Request for Proposal process, Maine DEP contracted with five environmental consulting firms to conduct the soil vapor investigations at the 14 sites. The firms selected were:

- GEI Consultants, Inc.
- MACTEC Engineering and Consulting, Inc.
- MAI Environmental
- Ransom Environmental Consultants, Inc.
- Summit Environmental Consultants, Inc.

2.3 Site Selection

Maine DEP worked collaboratively with Cumberland Farms, Inc. to identify seventeen gasoline station sites for potential vapor intrusion investigation. The initial criteria were to select sites located in densely developed, mixed use (residential and commercial) areas. The surroundings and use predicate limited clean-up of historical releases due to structural concerns associated with buildings, roadways utilities, and underground petroleum tanks and piping. Developed infrastructure (underground utilities such as sewer, water and gas) presented the possibility of multiple preferential pathways for vapors to migrate. The mixed use presented a stricter exposure scenario where residential targets also applied due to nearby residential properties.

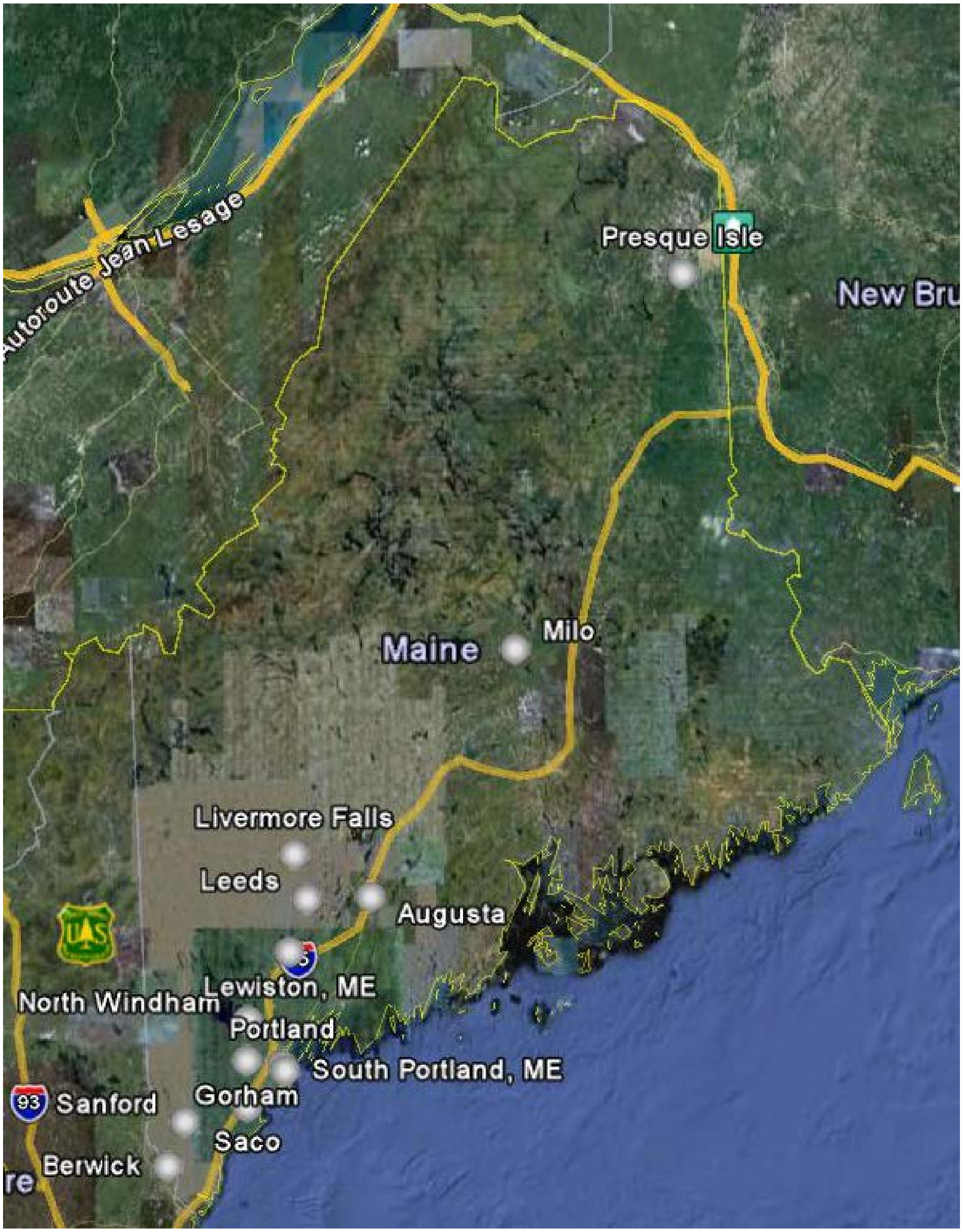


Figure 2.1 Study Site Locations (image from Google Earth

Table 2.1 General Site Characteristics and Sample Location Summary

Site Name	Location	Sub-Slab Soil Gas	Exterior Soil Gas	Monitoring Wells	Soil Samples	General Soil Type	Approximate Depth to Groundwater (ft.)
Cumberland Farms	Augusta	1	4	1	0	Sand & gravel fill; silt, sand	34
Cumberland Farms	Berwick	1	7	4	4	Sand & gravel fill; sand	8-10
Cumberland Farms	Gorham	1	5	0	2	Sand & gravel fill; clay > 16 ft	>16*
Twin Bridge Market	Leeds	0	4	4	5	Sand; silt & clay below 7 ft	4-5
7-11	Lewiston	3	5	6	2	Sand & gravel fill; clay	12-20
Cumberland Farms	Livermore Falls	1	4	3	1	Sand fill; sand, silt, till	5-8
Reuben's Market	Milo	1	7	5	1	Sand; silt & clay below 5-14 ft	5-12
Cumberland Farms	North Windham	1	4	4	0	Sand & gravel fill; sand	13-15
Cumberland Farms	Portland, Forest Ave	1	21	4	2	Sand & gravel fill; sand	18-20
Cumberland Farms	Portland, Wash. Ave	0	17	7	3	Sand & gravel fill; silt, clay > 3-7 ft	4-6
Cumberland Farms	Saco	1	6	4	2	Sand & gravel fill; sand, silt	8-10
Cumberland Farms	Sanford	2	18	5	4	Sand & gravel fill; sand	16-17
Cumberland Farms	South Portland	1	7	1	5	Sand & gravel fill; sand	44
Patten's Mobil & Met Life	Presque Isle	2	11	5	15	Sand and gravel fill; silty till	8-9
	Totals	**16**	**120**	**53**	**46**		

* Groundwater was not encountered within the boring depth.

A Phase I Environmental Site Assessment (ESA) was completed by the consulting firms for each site, including screening for vapor intrusion risk. Based on Phase I ESA findings, Maine DEP selected ten sites for Phase II vapor intrusion assessment which were interpreted to represent the highest risk of vapor intrusion among the sites evaluated.

The ten initial study sites were supplemented with four gasoline stations not operated by Cumberland Farms in Leeds, Milo, Lewiston, and Presque Isle. Each of the selected study sites had a history of gasoline leaks or spills and posed a potential risk of vapor intrusion to structures on and off the site. A directory of consultant reports for each of the sites is provided in Appendix A.

Sites were selected that included risk of petroleum vapor intrusion (PVI) due to storage and dispensing of petroleum products, and chlorinated vapor intrusion (CVI), from vehicle maintenance activities using chlorinated solvents. For sites with vapor intrusion from both sources, the term “VI” is used.

2.4 Investigation Work Plan

The Phase I ESAs were valuable for identifying prior site use, release history, and whether operations included automotive repair and associated solvent use (e.g., PCE), in addition to dispensing gasoline. The Phase I ESAs also identified potential off-site sources of contamination that could impact interpretation of vapor intrusion data.

Based on the Phase I ESA data, a Site-Specific Quality Assurance Project Plan (SSQAPP) was developed for Phase II investigation of each study site. Each SSQAPP included a Conceptual Site Model (CSM) that identified likely contaminant types, source areas, migration pathways, exposure routes and target receptors. The CSM provided the basis for identifying locations for soil borings, groundwater monitoring wells and soil gas sampling.

2.5 Field Exploration

The field work for the initial Phase IIA investigations was conducted in August and September 2010. Follow up soil vapor and groundwater sampling was conducted as part of Phase IIB investigation at selected sites in December 2010. Details on the field investigation methodology and findings are found in the individual Phase II site reports prepared by the consultants.

Test borings and installation of groundwater monitoring wells were conducted with direct push drilling. Groundwater samples were collected from small diameter “microwells,” and soil vapor was sampled from dedicated “implants” installed either by hand or using the direct push drill rig. Soil vapors were sampled from beneath building slabs or basement floors by hand drilling and sampling through dedicated tubing. Hand borings were also used for completion of borings within utility backfill during assessment of potential preferred migration pathways.

Two methodologies were used for evaluating the seal around vapor probe implants:

- Measurement of carbon dioxide and oxygen, and comparison of concentrations to ambient air; an effective seal is indicated by carbon dioxide concentrations at least an order of magnitude higher in the subsurface than ambient air, and oxygen generally lower than ambient air.
- Helium shroud tests (conducted at sites in Gorham and North Windham) involving the release of helium within a shroud or “tent” over the sample location; an effective seal is indicated for helium leakage rates at less than 20 percent.

Soil samples from the test borings were screened for VOCs in the field using a photoionization detector (PID). Subsurface measurements of percent oxygen and carbon dioxide were evaluated as indicators of biodegradation. Soil vapors were also tested in the laboratory for oxygen, carbon dioxide and methane as indicators of biodegradation and to evaluate field measurements against lab tests.

Subsurface and sub-slab differential pressure measurements were collected from groundwater monitoring wells, soil vapor implants and sub-slab points following completion of the Phase IIA investigation. The measurements were collected to assess whether subsurface pressure gradients were detectable and their potential influence on vapor flow.

2.6 Chemical Testing

Petroleum contamination in source areas was characterized by testing a select number of soil samples for volatile petroleum hydrocarbons (VPH) by the Massachusetts DEP method. Groundwater samples were also tested for VPH to allow assessment of vapor intrusion risk from the groundwater pathway.

Soil vapor and indoor air samples were tested for air-phase petroleum hydrocarbons (APH) by the Massachusetts DEP method. For 13 sites with past operations that included automobile maintenance and potential use of chlorinated solvents, vapor testing also included VOC analysis by EPA Method TO-15. Soil vapor and indoor air samples were collected using appropriately sized SUMMA canisters and calibrated flow valves for the specified sample interval. For evaluation of field instrument accuracy, samples of soil gas from each study site were also submitted to a laboratory for testing of oxygen, carbon dioxide and methane.

2.7 Quality Assurance/Quality Control (QA/QC)

The chemical testing laboratories used for the study were certified by the State of Maine for the required soil and groundwater analyses. The State of Maine does not have a certification program for air testing laboratories; however the air testing laboratory used for the study is certified by Massachusetts for the Massachusetts DEP APH analysis and certified by EPA for the EPA TO-15 analysis. Environmental samples were collected in laboratory-prepared containers, preserved according to analyte requirements and transported under chain-of-custody protocol.

Dedicated sample apparatus was used for collection of soil vapor and groundwater samples to minimize the potential for cross-contamination. In addition to the routine internal QA/QC protocol implemented by the testing laboratories, soil vapor field duplicates were collected at a rate of one per two study site locations.

Standard Operating Procedures (SOPs) developed by Maine DEP were used for the field work. The primary SOPs included:

- Maine DEP SOP # 2: "Groundwater Sample Collection for Site Investigation and Assessment Monitoring" March 25, 2009.
- Maine DEP SOP #5: "Soil Gas Sample Collection Method Utilizing Hand Tools" January 29, 2010.
- Maine DEP SOP #026: "Protocol for Collecting Soil Gas Samples" February 20, 2009.
- Maine DEP SOP #27: "Protocol for Collecting Sub Slab Soil Gas Samples" March 12, 2009.

A number of other applicable SOPs for the field activities are located in the Maine DEP "LUST Program Quality Assurance Plan," September 2010.

As noted, the integrity of the seal around the soil vapor implant was evaluated by comparing the concentration of oxygen and carbon dioxide between soil vapor and ambient air. In general, the concentration of carbon dioxide in soil vapor is expected to be at least an order of magnitude greater than that in ambient air, and the concentration of oxygen is often slighter lower in soil vapor than ambient air. The accuracy of field monitoring instruments for oxygen, carbon dioxide and methane was evaluated by laboratory testing of co-located samples.

2.8 Regulatory Guidelines

The soil vapor data were compared to applicable Maine DEP Soil Gas Targets (SGTs). SGTs are calculated by multiplying Indoor Air Targets (IATs) by a Maine DEP-adopted attenuation factor of 50 [1]. IATs are airborne concentrations of VOCs that are protective of adverse health effects from inhalation. IATs were developed using standard risk assessment methodology by the Maine Center for Disease Control [1].

Soil data were compared to Maine DEP's soil exposure guidelines for petroleum contaminated sites [2]. Exposure guidelines are provided for residential and commercial scenarios. The potential for vapor intrusion risk by the groundwater migration pathway was evaluated with Maine DEP's "Draft Vapor Intrusion Groundwater Screening Levels for Chronic Residential and Commercial Scenarios" [3].

2.9 Complete Pathway Assessment and Criteria

One criterion for pursuing off-site risk was evidence of heavy contamination or underground petroleum storage and piping near a property line with a building in close proximity (i.e., within

30 feet). This criterion was satisfied in Lewiston, Sanford and at the northern property line of the Portland – Forest Ave CFI. Another criterion was evidence of a potential preferential pathway intersecting heavy contamination or underground petroleum storage and piping. This criterion was satisfied at the property on the west side of the Portland – Forest Ave CFI as its sewer service passed through the backfill of the USTs.

For on-site buildings, a vapor intrusion or “receptor” pathway was considered complete when contaminant vapor concentrations in sub-slab soils exceeded the applicable residential or commercial chronic SGTs. For off-site buildings, a vapor intrusion pathway was considered complete when compounds were detected within the building envelope (near foundation groundwater, near foundation soil gas and subslab soil gas). If the building envelope pathway was deemed complete, indoor air samples were collected for APH and chlorinated TO-15 analysis so that the indoor air or “exposure” pathway could be evaluated.

3.0 Limitations

The study detailed herein is focused on gasoline releases at service stations and associated relatively minor releases of chlorinated solvents associated with automotive service. The findings should not be considered representative of soil vapor characteristics at sites where substantial releases of chlorinated solvents or non-petroleum organics have occurred, such as dry cleaners, automobile repair garages, or machine shops. Conditions identified at the study sites may also have been impacted by off-site sources of contamination not identified during the Phase I ESA.

The conclusions and recommendations provided herein are based on the findings of a limited number of study sites and associated explorations. The design of the study incorporated assessment of potential variability on soil vapor characteristics associated with soil type, water table depth, and nature of petroleum source, among others. However, the interplay of these and numerous other variables has not been fully characterized, and site-specific conditions must be taken into consideration when comparing the findings of this study to other locations.

Seasonal changes in soil vapor characteristics were evaluated by sampling a limited number of locations at selected sites in August/September 2010 and December 2010. High water table conditions at a number of proposed sample locations in December 2010 prevented comparison of data between several of the targeted locations.

The study has provided data on vapor intrusion risk to existing receptors at the sites. Future development of any site should contemplate potential vapor intrusion risk and additional data collection may be required. In addition, the data are from sites with historical releases where clean-ups were performed in accordance with guidance from the 1990s. The residual petroleum has weathered and conclusions may not apply to fresh releases.

4.0 Results

4.1 Soil Vapor Summary Data

Table 4.1 provides a summary of Maine DEP regulatory guideline exceedances for exterior soils (excludes sub-slab vapor samples). Data inclusive of all soil vapor sample points are illustrated on the plots in Appendix B. Table 4.1 includes 137 samples from 14 sites analyzed for APH and 119 samples from 13 sites analyzed for chlorinated VOCs by EPA Method TO-15. The data include two rounds of seasonal data for study sites in Portland (Forest and Washington Avenues), Lewiston, and Sanford.

The summary data indicate multiple areas of contaminant source area soils on each site investigated. The sources could not be fully delineated due to the limited number of explorations and likely presence of multiple sources, such as USTs, piping, and historic releases. The 13 sites analyzed for chlorinated VOCs were selected based on Phase I ESA data that indicated past sources of chlorinated compounds, such as vehicle repair work.

The greatest number of exterior Soil Gas Target (SGT) exceedances for both residential and commercial guidelines was exhibited by C5-C8 aliphatic hydrocarbons and benzene. The next highest total of SGT exceedances was exhibited by C9-C12 aliphatic hydrocarbons. Several analytes also had a relatively high number of samples with laboratory detection limits that exceeded the residential SGT (e.g., 1,3-butadiene, naphthalene and 1,2-dibromoethane). Of the 14 sites studied, 13 had at least one parameter exceeding residential SGTs, and 9 had at least one parameter exceeding commercial SGTs.

Concentrations of only one chlorinated compound, PCE, exceeded SGTs. Twenty-five samples analyzed exceeded the residential SGT at seven sites, and three samples exceeded the commercial SGT at one site. PCE was evaluated at sites where the Phase I ESA identified past automotive repair operations that may have included use of chlorinated solvents.

Based on the soil vapor summary data, three indicator compounds were selected for more detailed analysis: benzene, C5-C8 aliphatic hydrocarbons and PCE. PCE was selected given the opportunity to evaluate and compare trends relative to petroleum hydrocarbons (benzene and C5-C8 aliphatic hydrocarbons) and chlorinated hydrocarbons (PCE). 1,3-butadiene, a significant risk driver on many sites, was not selected because it was either frequently not detected, or had laboratory detection limits above SGTs.

4.2 Indicator Compounds

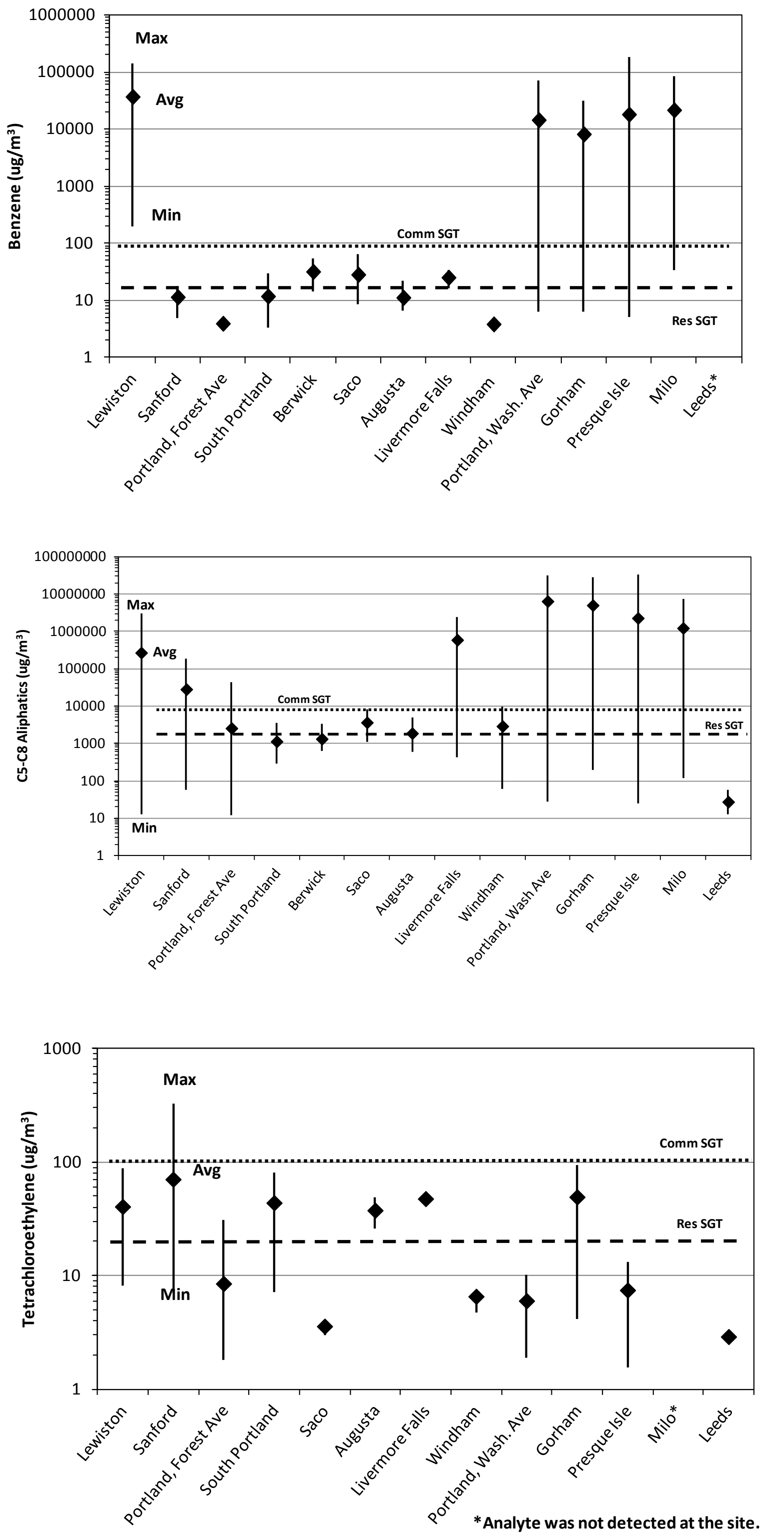
Soil vapor data for the three indicator compounds at each study site are shown on Figure 4.1. The plots illustrate relatively simple statistical data for assessment of soil vapor trends between locations - high, low and average values. The plots indicate that five of the fourteen sites have average concentrations of benzene that exceed the residential and commercial SGTs, and seven sites have concentrations of C5-C8 aliphatic hydrocarbons that exceed the SGTs. All but three of the sites have C5-C8 aliphatic hydrocarbon concentrations that exceed the residential SGT.

Table 4.1 Summary of Exterior Soil Gas Exceedances

Target Compound	Residential Soil Gas Target (SGT) ug/m^3	Commercial SGT ug/m^3	Samples Considered (Number of Sites Represented)	Exceedances of Residential SGT (Number of Sites)	Exceedances of Commercial SGT (Number of Sites)	Samples Below Laboratory Detection Limit	Laboratory Detection Limits > Residential SGT
1,3-Butadiene	4.0E+00	2.0E+01	137(14)	22 (9)	10 (4)	113	62
Benzene	1.6E+01	8.0E+01	137 (14)	38 (11)	19 (5)	75	17
C5-C8 Aliphatic Hydrocarbons	2.1E+03	9.0E+03	137 (14)	46 (13)	33 (9)	9	0
C9-C10 Aromatic Hydrocarbons	5.0E+02	2.2E+03	137 (14)	20 (8)	13 (5)	68	5
C9-C12 Aliphatic Hydrocarbons	2.1E+03	9.0E+03	137 (14)	29 (9)	15 (6)	42	1
Ethylbenzene	4.9E+01	2.5E+02	137 (14)	22 (8)	10 (5)	79	9
Methyl tert-Butyl Ether (MtBE)	4.7E+02	2.4E+03	137 (14)	4 (1)	3 (1)	114	11
Naphthalene	3.6E+00	1.8E+01	137 (14)	14 (7)	6 (4)	117	65
Total Xylenes	1.1E+03	4.4E+03	137 (14)	8 (4)	5 (4)	78	6
Toluene	5.0E+04	2.2E+05	137 (14)	3 (3)	3 (3)	67	0
1,1,1-Trichloroethane	5.0E+04	2.2E+05	119 (13)	0	0	114	0
1,1-Dichloroethane	7.5E+01	3.9E+02	119 (13)	0	0	118	16
1,1-Dichloroethylene	2.1E+03	9.0E+03	119 (13)	0	0	119	0
1,2-Dibromoethane	2.1E-01	1.0E+00	119 (13)	0	0	119	118
1,2-Dichloroethane	4.7E+00	2.4E+01	119 (13)	0	0	119	38
cis-1,2-Dichloroethene	6.5E+02	2.7E+03	119 (13)	0	0	117	8
trans-1,2-Dichloroethene	6.5E+02	2.7E+03	119 (13)	0	0	119	8
Tetrachloroethylene (PCE)	2.1E+01	1.1E+02	119 (13)	25 (7)	3 (1)	57	22
Trichloroethylene	6.0E+01	3.1E+02	119 (13)	0	0	110	16
Vinyl chloride	2.8E+01	1.4E+02	119 (13)	0	0	118	16

Notes:

1. Total xylenes is the sum of the p,m- and o-xylene fractions.
2. Soil Gas Targets are adjusted from the Indoor Air Targets (SGT=IAT*50) cited from the Maine Department of Environmental Protection's Indoor Air Targets for Chronic Residential and Commercial Scenarios at Multi-contaminant sites.
3. ug/m^3 = micrograms per cubic meter.
4. "(Number of Sites)" = Number of sites where SGT exceedances were identified.



*Analyte was not detected at the site.

Figure 4.1 Soil Vapor Data for Indicator Compounds at Study Sites

Maximum concentrations of PCE exceeded the residential SGTs at seven sites; the commercial SGT for PCE was exceeded at one study location – Sanford. Maine DEP indicated that a probable source of PCE at the site Sanford was a former off-site dry cleaning operation. Other study sites with potential off-site sources of PCE include Augusta, Gorham, Lewiston, and Windham (known dry cleaning operations in the neighborhood). There appears to be no obvious correlation between concentrations of petroleum hydrocarbons and PCE across the sites, consistent with the different sources and different biodegradation rates for each.

4.3 Near-Slab Vapor Concentrations

Testing of near-slab soil vapors can be an indicator of buildings at risk from vapor intrusion. Near-slab vapor concentrations for the indicator compounds at the study sites are shown on Figure 4.2. Soil vapor sample locations were considered "near slab" when completed within about 5 feet of the building, and at a depth of less than about 10 feet.

The data plots indicate exceedance of the residential SGTs for each of the indicator compounds. Concentrations of the petroleum indicator compounds, benzene and C5-C8 aliphatic hydrocarbons, also exceeded commercial SGTs. The test program identified no near-slab PCE vapor concentrations that exceeded commercial SGTs.

4.4 Sub-Slab Vapor Concentrations

Table 4.2 includes a summary of sub-slab soil vapor sample results and physical setting characteristics. As shown, neither of the two petroleum indicator compounds exceeded residential SGTs. Of interest, non "indicator" petroleum compounds (ethylbenzene, xylenes, naphthalene, C9-C10 aromatics and C9-C12 aliphatics) were detected at levels between the residential and commercial SGTs at the commercial building located on Patten's Mobil site in Presque Isle. The detection limit for benzene was slightly higher than the SGT at the Saco site, however the corresponding concentration of C5-C8 aliphatics suggests the concentration of benzene is likely below the SGT. The concentration of sub-slab PCE (28.5 µg/m^3) at the off-site residential building adjacent to the Sanford site was just above the residential SGT of 21 µg/m^3. The next highest concentration was 14 µg/m^3 detected at the commercial building located on the Lewiston site.

All but two of the sub-slab samples were collected from buildings with slab-on-grade construction. The two exceptions were sub-slab samples collected from beneath basements with concrete floors at residences in Lewiston and Sanford. The majority of the sub-slab samples were collected apparently downgradient from suspected contaminant source areas, with a broad range of water table depths (5 to 44 ft. below grade).

4.5 Co-Located Soil Vapor and Groundwater Data

Co-located soil vapor and groundwater quality data are plotted on Figure 4.3. The figure includes lines marking the residential SGTs and the Maine DEP draft groundwater vapor intrusion screening levels (GW SLs). GW SLs are target groundwater concentrations that result

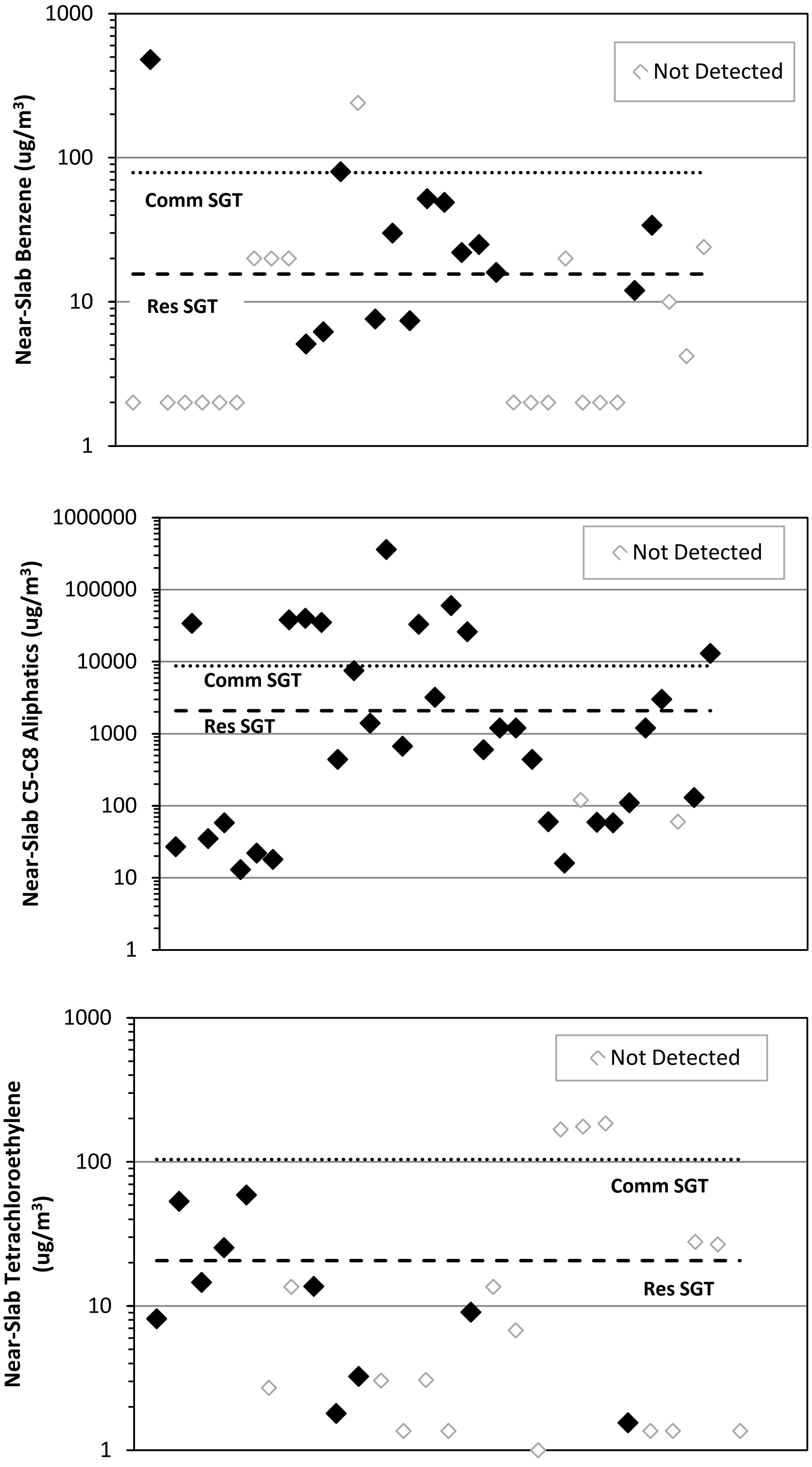


Figure 4.2 Near-Slab Sample Data

Table 4.2 Sub-Slab Soil Vapor Summary

Site	Sample ID	Benzene	C5-C8 Aliphatics	PCE	Oxygen	Building Description	Estimated Hydraulic Gradient Relative to Source Areas	Approximate Depth to Groundwater ft.
	Units	µg/m^3	µg/m^3	µg/m^3	%			
	Residential Soil Gas Target	16	2,100	21	NS			
Augusta	SV-03	<2	170	<1.36	17.9	Convenience Store, slab-on-grade	Downgradient	34
Berwick	SS-1	<2	160	N/A	17.6	Convenience Store, slab-on-grade	Upgradient	8-10
Gorham	SV-06	<2	200	<1.36	16.8	Convenience Store, slab-on-grade	Downgradient	>16 ft.
Lewiston	SSV-01 (9/29/10)	<2	20	<1.36	17.5	Convenience Store, slab-on-grade	Downgradient	12-20
Lewiston	SSV-01 (12/21/10)	<2	36	14	18.3	Convenience Store, slab-on-grade	Downgradient	12-20
Lewiston	SSV-02 (9/29/10)	<2	16	<1.36	18.2	Convenience Store, slab-on-grade	Downgradient	12-20
Lewiston	SSV-02 (12/21/10)	<2	53	5.4	18.3	Convenience Store, slab-on-grade	Downgradient	12-20
Lewiston	SSV-03	<2	100	6.63	18.3	Nearby residence, basement	Downgradient	8-20
Livermore Falls	SV-02	2.2	270	<1.36	16.5	Conv. Store/Vacant Space, slab-on-grade	Cross-gradient	5-8
Milo	SG-7	<2	24	<2.71	18.2	Convenience Store, slab-on-grade	Cross-gradient	5-12
North Windham	SV-06	<2	61	N/A	16.8	Convenience Store, slab-on-grade	Downgradient	13-15
Portland, Forest Ave	SG-8	<2	1400	2.46	19.5	Conv. Store/Rental Space, slab-on-grade	Unknown	18-20
Portland, Forest Ave	SG-8A	<2	170	2.68	18.3	Conv. Store/Rental Space, slab-on-grade	Unknown	18-20
Presque Isle	SV-104	<4	1100	N/A	18.8	Commercial, slab-on-grade	Downgradient	8-9
Presque Isle	SV-105	<2	25	N/A	19.5	Commercial, slab-on-grade	Downgradient	8-9
Saco	SV-107	**<44**	1000	<29.6	14.5	Convenience Store, slab-on-grade	Downgradient	8-10
Sanford	SV-108	<4.2	230	<2.89	17.8	Convenience Store, slab-on-grade	Cross-gradient	16-17
Sanford	SV-205	<4	1800	**28.5**	17.3	Nearby residence, basement	Downgradient	16-17
South Portland	SS-1	<2	57	5.68	18.2	Conv. Store/Restaurant, slab-on-grade	Upgradient	44

Notes:

1. Bolded values (or their estimated maximum) exceeded Maine DEP "Residential" Soil Gas Target (SGT).
2. "<" = Concentration was below laboratory detection limit.
3. "N/A" = No laboratory test was conducted for this analyte.
4. Groundwater flow direction was not determined at Portland CFI site 1805.

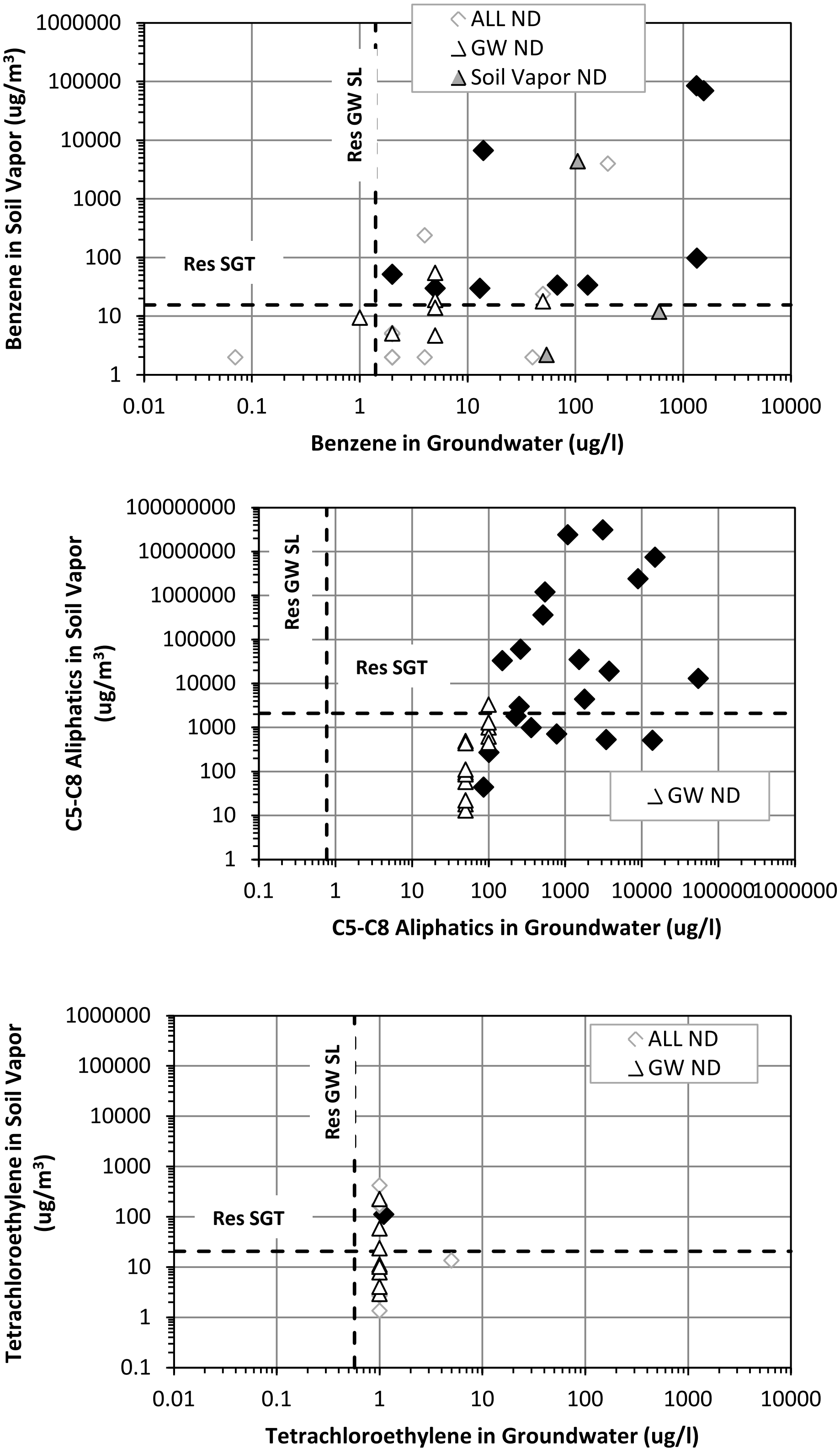


Figure 4.3 Co-Located Soil Vapor and Groundwater Data

in soil vapor levels reaching IATs based on partitioning across the water table according to Henry's Law.

The data plots indicate that the GW SLs are protective of SGT exceedances for each indicator compound. In no instance did the concentration of an indicator compound fall below the GW SL, yet exceed the corresponding SGT for soil vapor. The data were limited for PCE given the low number of samples tested and the relative high frequency that concentrations were not detected (ND).

In some cases the concentration of a compound exceeded the GW SL, yet the corresponding soil vapor concentration did not exceed the SGT. This finding suggests that the GW SLs are conservative, particularly for C5-C8 aliphatics where a GW SL two orders of magnitude higher appears protective of SGT exceedances. It should also be noted that soil vapor concentrations detected at some locations may be related to proximate sources, such as USTs or piping, resulting in elevated soil vapor concentrations not solely resulting from the groundwater pathway.

4.6 Soil Vapor Data vs PID Readings

Figure 4.4 shows plots of PID readings for the three indicator compounds. The plots for benzene and C5-C8 aliphatic hydrocarbons indicate general positive correlation with corresponding PID readings. In some instances, however, elevated PID readings did not correspond to elevated benzene or C5-C8 aliphatic hydrocarbons, and vice versa. No trends were apparent by the plot for PCE, potentially due to the influence of petroleum-based VOCs which were detected at significantly higher concentrations. That is, the elevated PID readings are due largely to elevated petroleum VOCs, not PCE.

Despite the variability in the data, PID instruments may aid in screening vapor intrusion risk. For PID readings less than 0.5 ppm, only two exceedances of the residential SGT were observed for benzene, and nine exceedances of the residential SGT were observed for C5-C8 aliphatics. The lack of PID response at locations where elevated benzene or C5-C8 aliphatics were observed may be due dust, moisture, or lamp strength, among others. In addition, the majority of the instruments used were not designed for accurate detection in the low ppm range; the instrument calibration gas is isobutylene at a concentration of 100 ppm.

A PID capable of detecting organic vapors down to 1 part per billion (ppb) was used during soil vapor sampling at the study site in North Windham. The organic vapors were significantly elevated, thus correlation between low soil gas concentrations and PID readings in the ppb range could not be assessed.

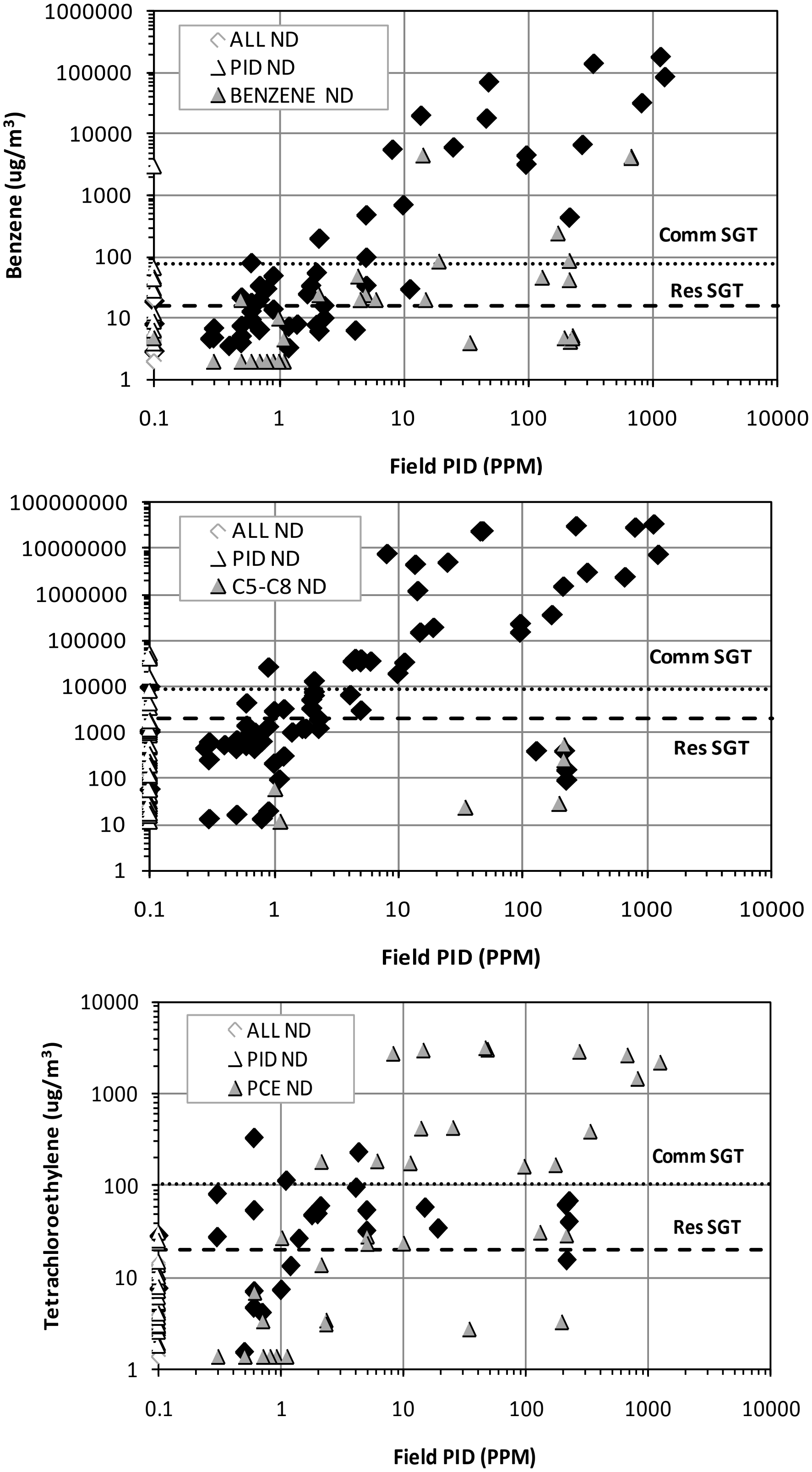


Figure 4.4 Indicator Compounds vs PID Readings

4.7 Concentrations in Soil vs Soil Vapor

Concentrations of the indicator compounds in soils were plotted against co-located concentrations in soil vapor in Figure 4.5. Samples were considered to be co-located if they were sampled from the same boring and within two vertical feet of one another. Although the data are limited in number, the plots indicate poor correlation between concentrations of the indicator compounds in soil vapor and in soils. Furthermore, there were many instances where concentrations in soils were not detected, yet the concentrations in soil vapor exceeded the residential SGT by several orders of magnitude.

The data plots show several exceedances of the residential SGTs for soil vapor, yet only one exceedance of the residential RAG (C5-C8 aliphatic hydrocarbons) for co-located soils. These data indicate that while Remedial Action Guidelines (RAG) are protective for direct contact with outside soils, they are not protective of inhalation risk from potential vapor intrusion into buildings, as denoted by the residential SGTs.

The lack of correlation between indicator compound concentrations in soils and those in soil vapor may be linked to several variables such as soil texture, composition, moisture, and sample handling. In addition, relatively high concentrations in soil vapor may be the result of migration from a nearby source, as opposed to a source in the soil.

4.8 Oxygen and Carbon Dioxide

Field and laboratory measurements of oxygen (O_2) and carbon dioxide (CO_2) were obtained at soil gas sampling locations. In addition to assessment of vapor probe seals (refer to Section 5.0, QA/QC), oxygen is an indicator of conditions favorable for petroleum biodegradation, and carbon dioxide is an indicator of past or ongoing biodegradation.

The plots in Figure 4.6 include laboratory measurements of oxygen and carbon dioxide vs C5-C8 aliphatic hydrocarbons at each soil vapor sampling point. C5-C8 aliphatics were selected for data comparison given the widespread detection of these compounds at each site. The plots indicate no clear correlation between C5-C8 aliphatics and either oxygen or carbon dioxide. Relatively abundant oxygen with respect to biodegradation potential (i.e., greater than 15 percent) is associated with both relatively high and low concentrations of C5-C8 aliphatics. Likewise, carbon dioxide concentrations indicative of biological activity are distributed throughout a broad range of C5-C8 aliphatic concentrations.

The findings indicate that while conditions appear favorable for biodegradation, relatively high concentrations of petroleum hydrocarbons persist in soil vapor at the study sites. Contributing to this persistence is the proximity of relatively concentrated source areas, as indicated by strong petroleum odors, oil stains, and pockets of phase-separated product observed at some of the sites. It should also be noted that oxygen is one of many factors influencing biodegradation; other factors include abundance of petroleum-degrading bacteria, soil moisture, nutrients and source concentration, among others.

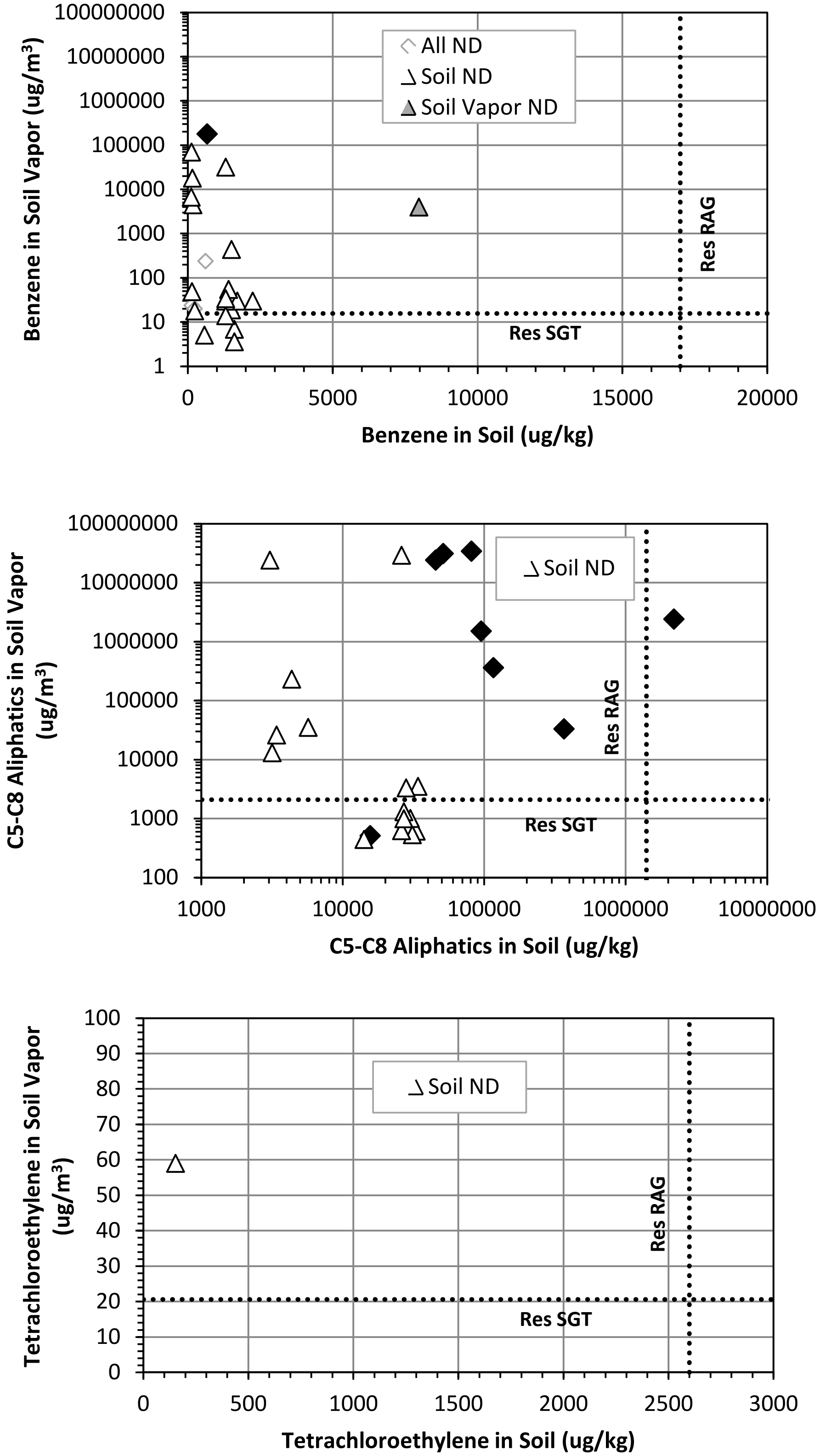
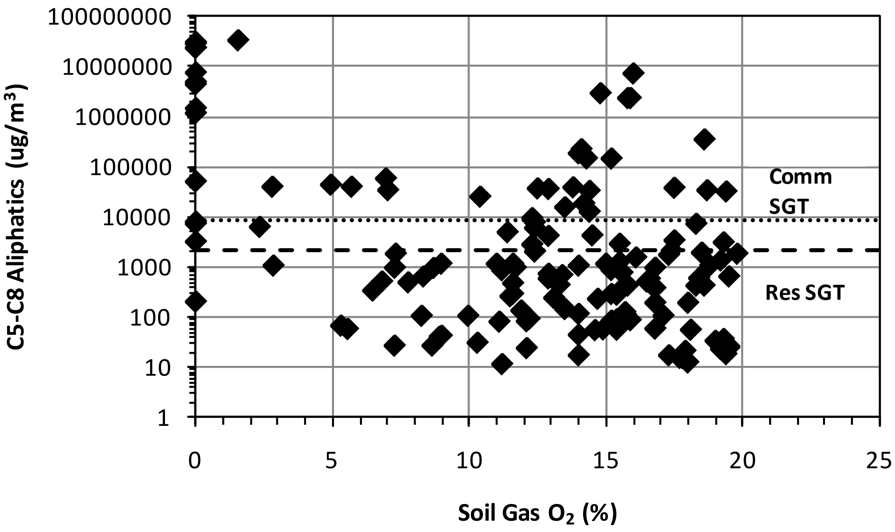


Figure 4.5 Compounds in Soil vs Soil Vapor



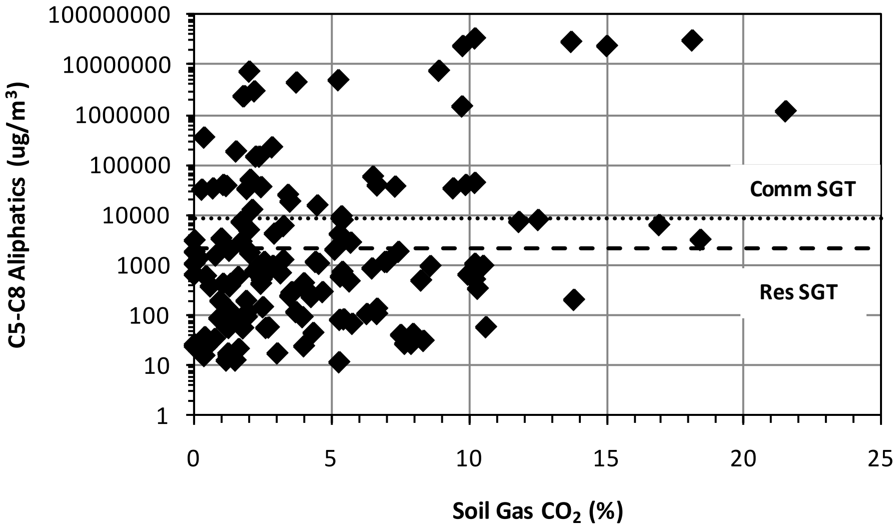


Figure 4.6 Oxygen and Carbon Dioxide

4.9 Methane

Methane gas was sampled in the field and laboratory as an indicator of petroleum biodegradation. The laboratory results indicated largely non-detect values, excluding a cluster of values greater than 20 percent which correspond to the study site on Washington Avenue in Portland. Given that elevated methane concentrations were not identified at other sites with similar petroleum impacts, it is possible the source of methane is the decay of naturally occurring organic material. However, a review of the boring logs for the Washington Avenues site did not indicate observation of obvious organic material at depth.

While methane is non-toxic, the gas poses a risk of explosion if present at concentrations above the Lower Explosive Limit (LEL). The concentrations of methane detected at some locations at the Washington Avenue site exceeded the LEL, warranting caution for activities that may generate an ignition source where methane gas may be present in the subsurface.

4.10 Lateral and Vertical Attenuation

A key objective of the statewide vapor intrusion study was to evaluate the attenuation of soil vapor concentrations both laterally and vertically away from contamination source areas. Ongoing research by Robin Davis of the Utah Department of Environmental Quality and others indicates rapid vertical attenuation of petroleum vapors from source areas [4, 5]. The research indicates that as little as five feet of “clean” soils (i.e., soils not contaminated directly by a petroleum release) are adequate for attenuation of soil vapor to non-detectable concentrations over a groundwater plume with dissolved contaminants. Approximately 10 feet of clean soils is referenced as adequate for attenuation of soil vapor above or adjacent to a non-aqueous phase-separated liquid (NAPL) gasoline source [5]. The attenuation is driven, in part, by biodegradation in the presence of oxygen [4].

The Maine DEP statewide vapor intrusion study identified numerous examples of lateral attenuation. In the majority of cases, attenuation of petroleum vapor concentrations was evident, but not to the extent predicted by some researchers [4, 5]. For example, Figure 4.7 shows lateral attenuation at the Sanford, Maine site, with concentrations of C5-C8 aliphatics decreasing from over 100,000 $\mu g/m^3$ in the suspected source area to non-detect over a distance of about 27 feet. It is likely that the rate of attenuation was not higher given the influence of petroleum-impacted soils and impacted groundwater along the line of wells.

In follow up investigations at the two Portland Cumberland Farms facilities in December of 2010, the September data was used to locate sample points upgradient and sidegradient of identified source areas to evaluate lateral attenuation with distance from source soil. The effort was unsuccessful as water levels were elevated and concentrations reduced relative to the September round. Given the limitations of the study data, more lateral attenuation case studies are needed to further evaluate attenuation trends.

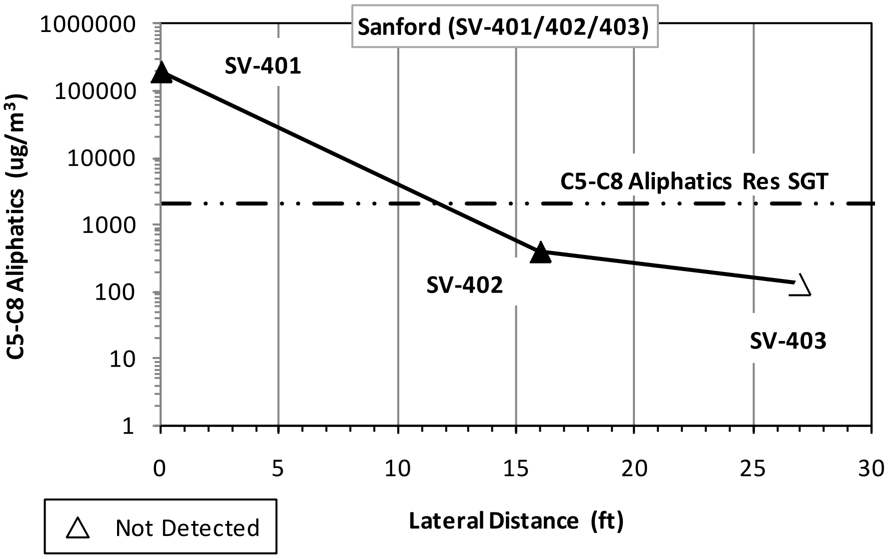


Figure 4.7 Lateral Attenuation, Sanford

Figure 4.8 illustrates attenuation factors for C5-C8 aliphatic hydrocarbons and PCE. The data include seven sites with paired near-slab/sub-slab samples separated by less than 20 feet. Attenuation factors were calculated as the ratio of sub-slab to near-slab concentrations. Benzene attenuation data for the same sites were not plotted given non-detect concentrations for all but one of the sites.

For C5-C8 aliphatics, relatively high rates of attenuation were observed (factors less than 0.01) over a relatively short distance for the majority of locations. As with the Sanford site example noted above, lateral attenuation was less than that suggested by Davis' research on vertical attenuation [4]. It is possible that lateral attenuation at the sites was less pronounced given the proximity of petroleum vapor sources to sub-slab samples, and potential "overlapping" vapor contributions from multiple sources. Oxygen did not appear to be a limiting factor given concentrations greater than about 15 percent for each sub-slab sample (refer to Table 4.2).

For PCE, lateral attenuation factors in Figure 4.8 generally ranged between about 0.01 and 1; one attenuation factor greater than 1 resulted from an elevated detection limit. While limited, the data indicate slightly higher attenuation factors than those for the C5-C8 aliphatics.

Vertical attenuation of petroleum vapors was evaluated with plots of C5-C8 aliphatics, oxygen and carbon dioxide vs. depth (refer to Figure 4.9); the plot format was used by Robin Davis who has researched vertical attenuation of petroleum vapors emanating from the water table [4]. Plots of C5-C8 aliphatics were used to illustrate trends given the frequent non-detection of benzene.

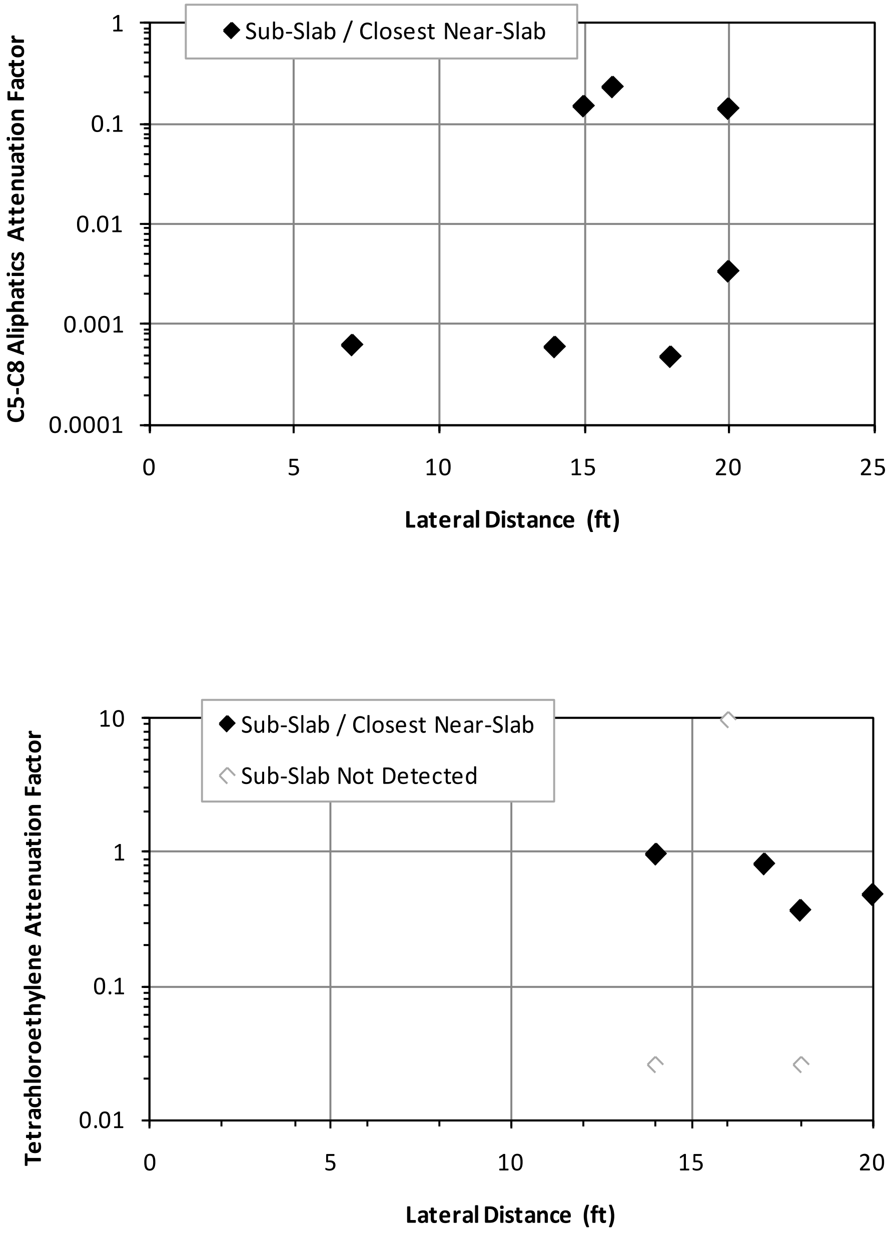
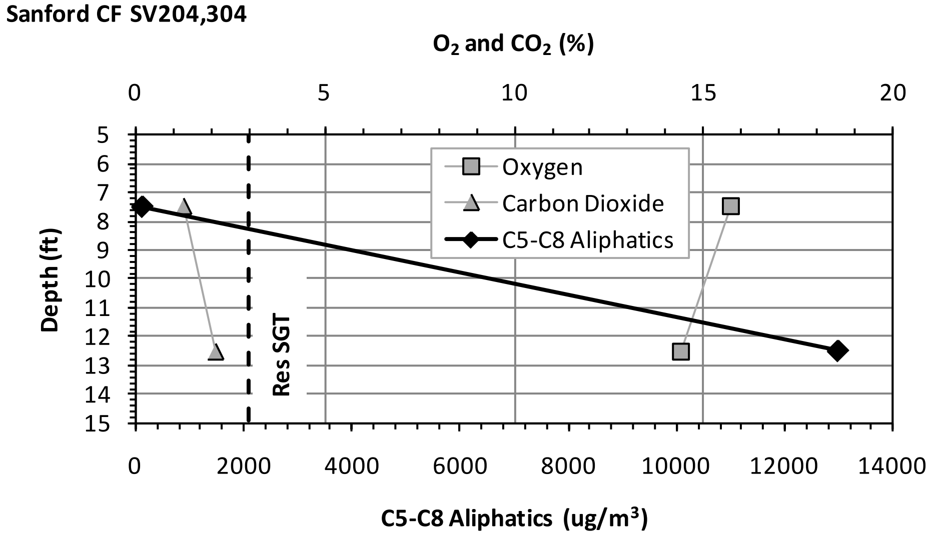


Figure 4.8 Lateral Attenuation for Sub-Slab, Near-Slab Samples



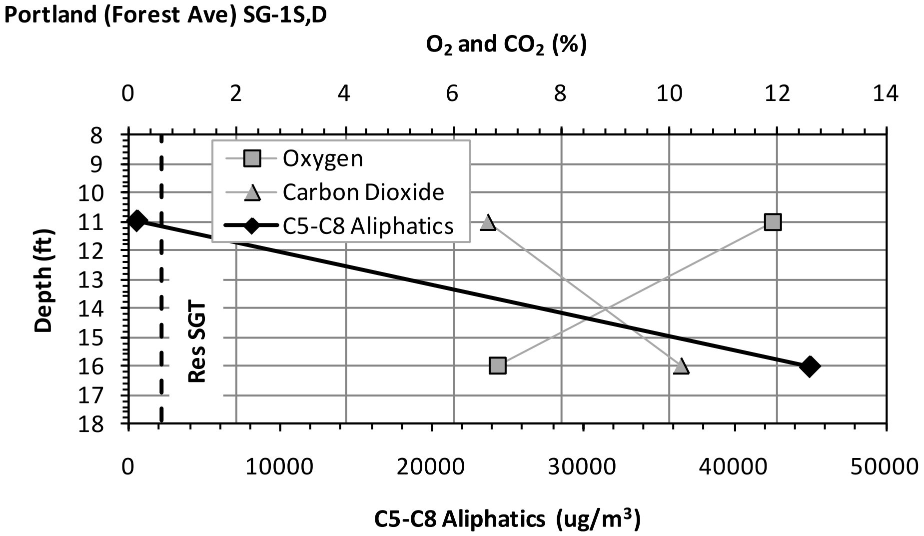


Figure 4.9 Vertical Attenuation Plots – C5-C8 Aliphatics

As shown on the examples in Figure 4.9 (sites in Sanford and Portland), relatively rapid vertical attenuation was observed over a vertical distance of about 5 feet; the attenuation factor for both sites was about 0.01. In each case, the deeper sample location was collected from about 2 feet above the water table, interpreted to be the primary source of petroleum in soil vapor at these locations. The data also indicate a slight drop in oxygen concentration and an increase in carbon dioxide concentration with depth. This finding is consistent with Davis's research that evidence of biodegradation includes consumption of oxygen and enrichment of carbon dioxide [4].

Figure 4.10 includes vertical attenuation plots for PCE at two sites (Sanford and Portland). For the site in Sanford, a vertical attenuation factor of about 0.4 was observed with increasing distance above the water table, the likely source of PCE in soil vapor. At the Portland site, the concentration of PCE remained virtually unchanged with increasing distance above the water table. The data supports the understanding that chlorinated solvents, like PCE, are more resistant to biodegradation and will attenuate at significantly lower rates than petroleum compounds.

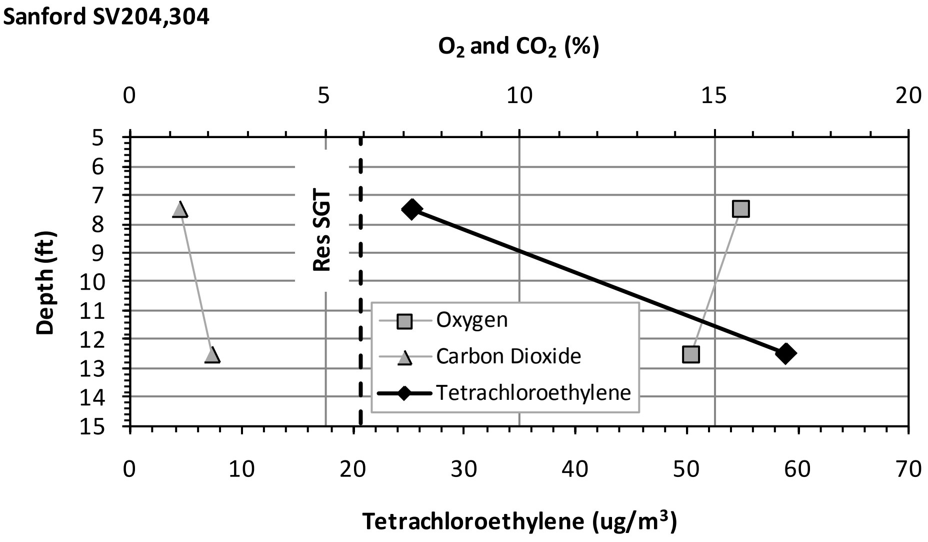
4.11 Preferred Migration Pathways

A number of soil vapor samples were collected from utility backfill to evaluate potential preferred vapor migration pathways. Evaluation of the data in the site-specific study reports indicated no significant evidence that the utilities preferentially transported petroleum contaminant vapors toward receptors, primarily buildings on the sites. The data are supported by measurements of soil gas pressure at several locations, which indicate no significant pressure differential between utilities and surrounding soils.

A key factor to consider in assessing preferred vapor migration pathways is the composition of subsurface soils. Preferred vapor transport is more likely in settings where a relatively coarse utility backfill (e.g., sand, gravel) is surrounded by low permeability soils, such as silt and clay. At the majority of sample locations for the statewide vapor intrusion study, soils consisted broadly of relatively high permeability granular materials (refer to Table 2.1). This is not unexpected given the development of each site with widespread fill for building foundations, UST backfill and related urban filling.

4.12 Seasonal Testing

Potential seasonal influences on soil vapor concentrations were evaluated at four of the study sites: Lewiston, Portland – Forest Avenue, Portland – Washington Avenue, and Sanford. Soil vapor sampling at each was conducted in September and December 2010. The seasonal data show a substantial drop in soil vapor concentrations between the September and December sampling events. For example, total APH concentrations dropped between 78 and more than 99 percent for sample locations at the Portland – Washington Avenue site. Groundwater elevation data collected for the two seasonal events indicate an increase in groundwater levels up to about 1.5 feet from September to December, potentially resulting in dilution of dissolved contaminant concentrations, and submergence of soils containing volatile constituents. The degradation rate may also be influenced by cooler seasonal temperatures and associated lower rates of volatilization.



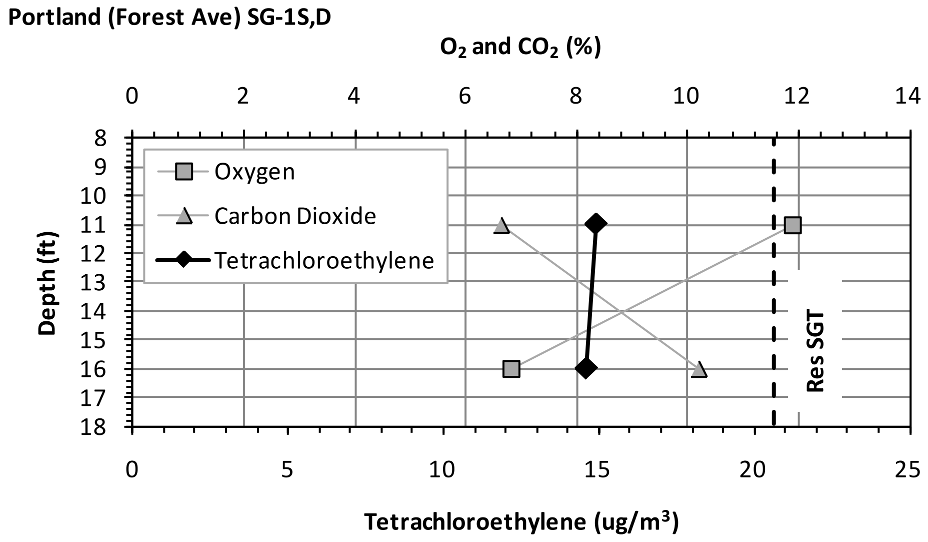


Figure 4.10 Vertical Attenuation Plots - PCE

4.13 Subsurface Pressure Gradients

Subsurface soil pressures, including five sub-slab locations, were non-detect for 99 of 118 measurements. The instrument detection limit was either 0.005 or 0.01 inches water. Positive pressure was detected at thirteen locations ranging from 0.005 to 0.2 inches water. Negative pressure was detected at six locations ranging from -0.005 to -0.02 inches water. Given the limitations of the data, trends were not apparent regarding pressure gradients in the vicinity of buildings and utilities. The low pressure readings below building slabs, as indicated by non-detectable pressure differential, indicate relatively neutral pressure conditions between the building interior and subsurface soils.

4.14 Off-Site Pathway Analysis

Risk of PVI was evaluated at four off-site residential properties in Lewiston and Sanford, and along the northern and western property lines of the Portland – Forest Ave site. The first three sites were selected given evidence of heavy petroleum contamination, underground petroleum storage tanks, or piping within 30 feet of an off-site building. The fourth site (western border of the Portland - Forest Ave site) included a potential preferential pathway that intersected heavy petroleum contamination, underground petroleum storage tanks, or piping within 30 feet of an off-site building.

Of the four buildings, only receptors at Sanford and Lewiston had complete pathways to the building envelope and, accordingly, these two receptors were selected for sub-slab and indoor air analysis. A complete indoor air pathway was not indicated based upon the sub-slab concentrations.

In the course of pursuing PVI impacts at properties considered vulnerable, a complete CVI pathway (e.g., PCE) was identified at two study sites – Sanford and Lewiston. In Sanford, PCE was detected in soil gas beneath an off-site residential basement at a concentration above the residential soil gas target. PCE was not detected in groundwater sampled near the residence, but the study report noted that automobile repair operations on the adjacent service station site may have included use of solvents containing PCE. Sampling of indoor air at the residence did not identify PCE at concentrations above the IAT so the CVI indoor air pathway was incomplete.

In Lewiston, indoor air testing identified concentrations of chlorinated solvents, including PCE, at concentrations above IATs in a residence adjacent to the service station study site. PCE and TCE were detected in the sub-slab vapor and the shallow groundwater near the foundation. PCE was also detected in the soil gas near the petroleum source. Despite this evidence of a complete indoor air CVI pathway, the investigation report notes that a dry cleaner had been identified upgradient from the residence and cross-gradient from the petroleum facility. It is possible, therefore, that the drycleaner impacted both the service station site and the residence.

5.0 QA/QC

The QA/QC discussion herein focuses on study-wide findings relative to vapor probe seal integrity and comparison of field and laboratory results for three gases, oxygen, carbon dioxide and methane. Additional QA/QC information can be obtained by reviewing the individual consultant reports for each study site.

5.1 Vapor Probe Seal

Field measurements of carbon dioxide and oxygen in ambient air and the subsurface were obtained to assess the integrity of vapor probe seals at both exterior and building interior sample locations. Measurements of carbon dioxide and oxygen were collected just before and after sample collection.

With few exceptions, concentrations of carbon dioxide in the subsurface were at least an order of magnitude greater than ambient air, indicating no obvious leakage past the seal during sampling. Oxygen concentrations were generally less than ambient air, further supporting seal integrity. Concentrations of both gases before and after sampling were generally similar, indicating no obvious compromise of seal integrity during the sampling events. At the Presque Isle study site, sub-slab sampling detected a relatively low post-sample carbon dioxide and slightly elevated oxygen, indicating possible leakage of ambient air.

Helium tests were conducted during sampling at two sites (Gorham and North Windham) to evaluate soil vapor implant seals. At both sites, the testing indicated very low rates of leakage within acceptable limits. The data corroborated well with measurements of carbon dioxide and oxygen which indicated no obvious leaks.

5.2 Field vs Laboratory Testing for O_2, CO_2 and Methane

Calibrated field instruments were used for real-time measurement of oxygen (O_2), carbon dioxide (CO_2) and methane during sampling of soil vapor. Co-located samples were also collected for laboratory analysis to evaluate the relative accuracy of field instrumentation.

Figure 5.1 shows plots of the laboratory vs field values for oxygen, carbon dioxide and methane. The plots indicate reasonably good correlation between laboratory and field values for oxygen and carbon dioxide, with coefficients of determination of 0.95 and 0.69, respectively. The closer the coefficient of determination is to one, the better the data fit the straight line equation.

The laboratory values for methane did not correlate well with those for the field instruments. In several instances, for example, significant concentrations detected by field instruments corresponded to non-detectable concentrations in the laboratory. This observation is likely related to the detection of interfering combustible gases by the field instrument. In addition to methane, field instruments may respond to ethane, hexane, isobutene, propane and toluene, among others [6]. These constituents may have been present at the study sites resulting in false-positive detection, or elevated readings of methane.

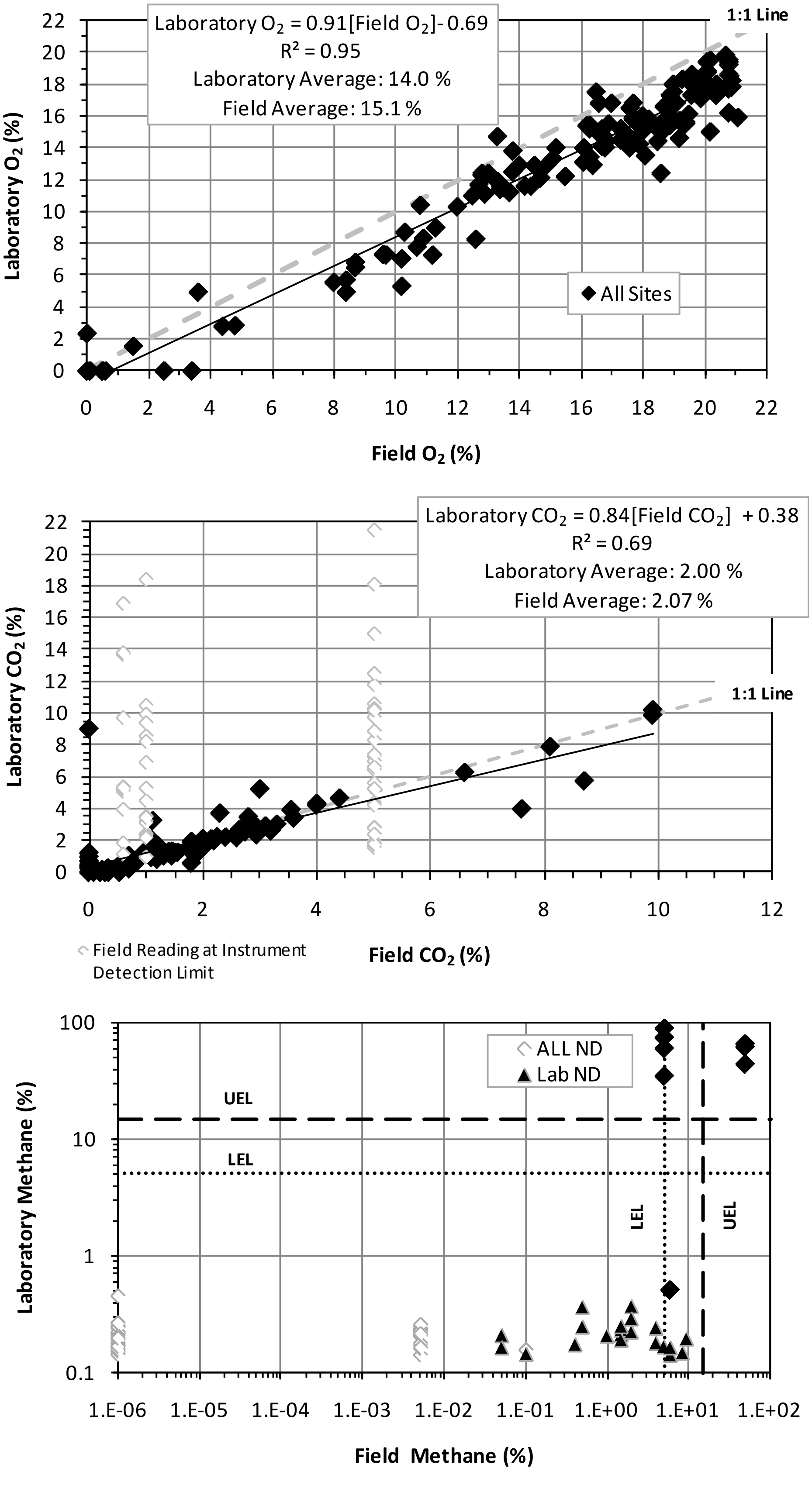


Figure 5.1 Field vs Laboratory Testing

6.0 Data Gaps

While the statewide study included a broad range of site conditions and numerous sample points, a number of data gaps remain relative to vapor intrusion risk. These gaps include:

1. Data on rates of lateral attenuation outside source areas (i.e., through “clean soils”) were limited given the prevalence of multiple petroleum sources and associated vapors along the vapor migration pathway on most sites.

2. Assessment of seasonal influences on petroleum or solvent vapor concentrations was limited to four sites. Data on these four sites was also limited due to slightly elevated water levels and submersion of vapor implants below the water table.

3. PID screening at all but one study site was conducted using instruments generally accurate to 1 ppm. Therefore, the instruments were of limited value in assessing vapor intrusion risk associated at soil vapor concentrations less than 1 ppm.

4. The sites consisted of relatively coarse granular fill or native sandy soils. As a result, conclusions could not be drawn regarding potential preferred vapor migration pathways in fine-grained soils.

5. The pressure differential measurements in soil and utility beddings were collected during late summer before heating season. The temperature differentials between buildings and the surrounding soil and utilities may induce drafts in the utilities and their bedding that could enhance vapor migration along preferential pathways in the winter.

7.0 Conclusions

The Maine DEP statewide vapor intrusion study included investigation of fourteen gasoline station sites with known historic releases of petroleum, and potential releases of chlorinated VOCs. Conclusions drawn from the study are provided below.

1. Complete PVI pathways are rare due to rapid attenuation of hydrocarbons in the presence of oxygen in the subsurface.
2. When not obvious due to odors, PVI is conceivable when petroleum releases result in oil-saturated soil, LNAPL, or grossly-contaminated groundwater within 30 feet of a receptor and within 15 feet of the ground surface. Grossly-contaminated groundwater is characterized herein as containing >1,000 ug/L benzene or > 10,000 ug/L total VPH and EPH.[7] Lower contaminant concentrations in groundwater may pose a significant VI risk when the groundwater lies less than 5 feet below a building foundation.
3. It is appropriate to continue evaluating the PVI pathway when soil gas samples collected within the building envelope exceed SGTs. Soil gas samples collected from outside the building envelope may serve to refine a conceptual site model or guide subsequent investigations, but are not direct indicators of unacceptable risk or a complete PVI pathway.
4. While commonly identified at the study sites, chlorinated solvents did not appear to be significant risk drivers, likely given the relatively small quantities used.
5. Maine’s interim groundwater screening criteria for vapor intrusion risk are overly conservative as they do not account for the biodegradation of hydrocarbons in the subsurface.
6. Based on prevalence of detection and toxicity, benzene and C5-C8 aliphatic compounds were identified as key indicators of petroleum vapor intrusion risk at the study sites. Other compounds (such as 1,3 Butadiene) are considered “indeterminate” risk drivers due to laboratory reporting limits exceeding risk based targets (see discussion is Section 4.1). PCE was the most prevalent chlorinated compound identified and is a key indicator of impact from automotive service operations.
7. Subsurface utilities were not observed to be preferred pathways for vapor migration, likely given the predominantly granular nature of backfill and native soils observed at the study sites. While utilities may act as preferred pathways for sites with fine grained soils, the significance of such pathways for petroleum vapor is likely limited given the rapid attenuation observed in the presence of oxygen.
8. Soil vapor concentrations may change significantly between seasons, and wide fluctuations may indicate nearby highly contaminated soil, including LNAPL, within the range of water table fluctuation.
9. Methane gas was detected at concentrations above the Lower Explosive Limit indicating that caution is warranted for subsurface activities that may create an ignition source.
10. Field measurement of ambient and soil gas concentrations of carbon dioxide is a valid and efficient means of evaluating the surface seal at soil vapor probes and points.

11. A Phase I ESA is valuable for identifying locations of current and historic on-site and off-site sources of contamination, contaminants of concern, and the geologic framework for assessing vapor intrusion risk.

8.0 Recommendations

Recommendations of the statewide vapor intrusion study include:

1. Complete additional research and develop vapor intrusion screening criteria based on PID readings. The research should include paired samples for PID screening and laboratory testing of APH and other target compounds.
2. Exclude investigation of potential preferred migration pathways for petroleum release sites given study data that indicates limited influence on vapor intrusion risk and futility of collecting representative data.
3. Maine’s interim groundwater screening levels for vapor intrusion risk should not be adopted given the lack of correlation between the screening criteria and intrusion risk.
4. For sites where measurement of methane is desirable, conduct measurements using an instrument capable of discriminating interfering gases.
5. Update the current Maine DEP Petroleum Remediation Guidelines to reflect the findings of this study. Proposed edits to the guidelines are included in Appendix C.
6. Update the Maine DEP “Vapor Intrusion Evaluation Guidance” to reflect the findings of the Statewide VI study.

9.0 References

1. Maine Department of Environmental Protection, “Vapor Intrusion Evaluation Guidance,” January 13, 2010.

2. Maine Department of Environmental Protection, “Remediation Guidelines for Petroleum Contaminated Sites,” December 1, 2009.

3. Maine Department of Environmental Protection, “Draft Groundwater Vapor Intrusion Screening Levels for Chronic Residential and Commercial Scenarios,” November 23, 2010.

4. Robin Davis, “Vapor Attenuation in the Subsurface from Petroleum Hydrocarbon Sources,” LUSTLine Bulletin 52, May 2006.

5. George DeVaull, “Assessing Vapor Intrusion at Petroleum Release Sites, Exclusion Distance Screening Criteria,” 25th Annual Conference on Soils, Sediments, Water and Energy, University of Massachusetts Amherst, October 19, 2009.

6. RKI Instruments, Inc., “Instruction Manual, Eagle Series, Portable Multi-Gas Detectors,” Third Edition, July 2001.

7. Robin Davis, “Update on Recent Studies and Proposed Screening Criteria for the Vapor-Intrusion Pathway,” LUSTLine Bulletin 61, May 2009.

Appendix A

Directory of Site Investigation Reports

Individual Phase I and Phase II site reports will soon be available for downloading at DEP's web site:

http://www.maine.gov/dep/ftp/vi-study_jan-2012/

1. GEI Consultants, Inc., 2010. "Limited Phase II Vapor Intrusion Investigation, 42 School Street, Berwick, ME," December 8.
2. GEI Consultants, Inc., 2010. "Limited Phase II Vapor Intrusion Investigation, 433 Cottage Road, South Portland, ME," December 8.
3. MACTEC Engineering and Consulting, Inc., 2011. "Limited Vapor Intrusion Investigation," Cumberland Farms, Inc. Store No. 1842 – Gorham, Maine," February 8.
4. MACTEC Engineering and Consulting, Inc., 2011. "Limited Vapor Intrusion Investigation, Cumberland Farms, Inc. Store No. 1836 – North Windham, Maine," February 8.
5. MAI Environmental, 2011. "Maine DEP Petroleum Vapor Triage Report Phase 2A and 2B, Cumberland Farms, Inc., 1336 Forest Avenue, Portland, Maine," April.
6. MAI Environmental, 2011. "Maine DEP Petroleum Vapor Triage Report Phase 2A and 2B, Cumberland Farms, Inc., 801 Washington Avenue, Portland, Maine," April.
7. MAI Environmental, 2011. "Subsurface Investigation Report, Twin Bridge Market, Leeds, Maine," February 7.
8. MAI Environmental, 2010. "Petroleum Vapor Intrusion (PVI) Investigation, Reuben's Market, 84 Elm Street (Route 16), Milo, Maine," December 21.
9. Ransom Environmental Consultants, Inc., 2011. "Petroleum Vapor Intrusion (PVI) Triage Study, Limited Phase IIA & IIB, Cumberland Farms Station #1803, 982 Main Street, Sanford, Maine," March 1.
10. Ransom Environmental Consultants, Inc., 2011. "Petroleum Vapor Intrusion (PVI) Triage Study– Phase IIA, Cumberland Farms Station #1822, 31 Elm Street, Saco, Maine," February 3.
11. Summit Environmental Consultants, Inc., 2011. "DRAFT Limited Vapor Intrusion Investigation, Former Metropolitan Life and Former Patten's Mobil Station Properties, 560 & 540 Main Street, Presque Isle, Maine," June 22.
12. Summit Environmental Consultants, Inc., 2011. Petroleum Vapor Intrusion (PVI), Limited Vapor Intrusion Investigation, 7-11 (Christy's), 345 Main Street, Lewiston, Maine," May 16.
13. Summit Environmental Consultants, Inc. and JBR Consulting Hydrogeologist, 2011. "Maine DEP Petroleum Vapor Triage Study Phase IIA, Cumberland Farms – Facility 1829, 5 Mount Vernon Avenue, Augusta, Maine," April 13.
14. Summit Environmental Consultants, Inc. and JBR Consulting Hydrogeologist, 2011. "Maine DEP Petroleum Vapor Triage Study Phase IIA, Cumberland Farms – Facility 1834, 53 Main Street, Livermore Falls, Maine," April 13.

Appendix B

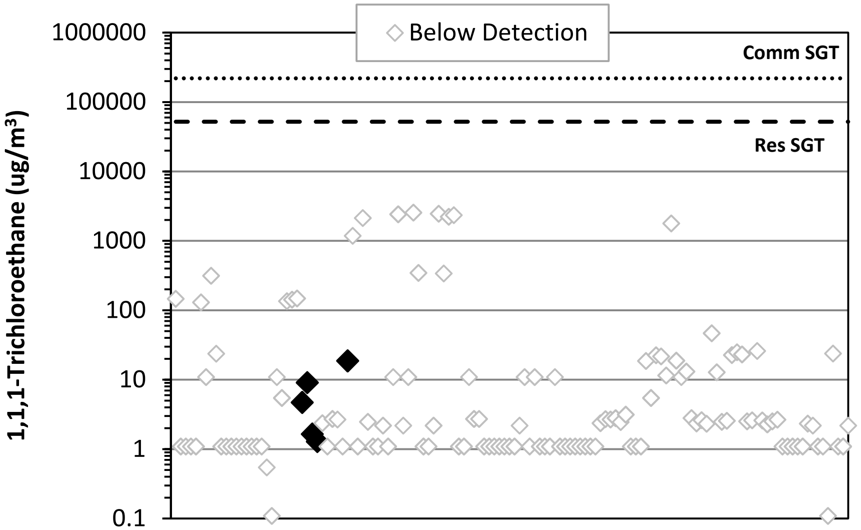
Target Compound Plots

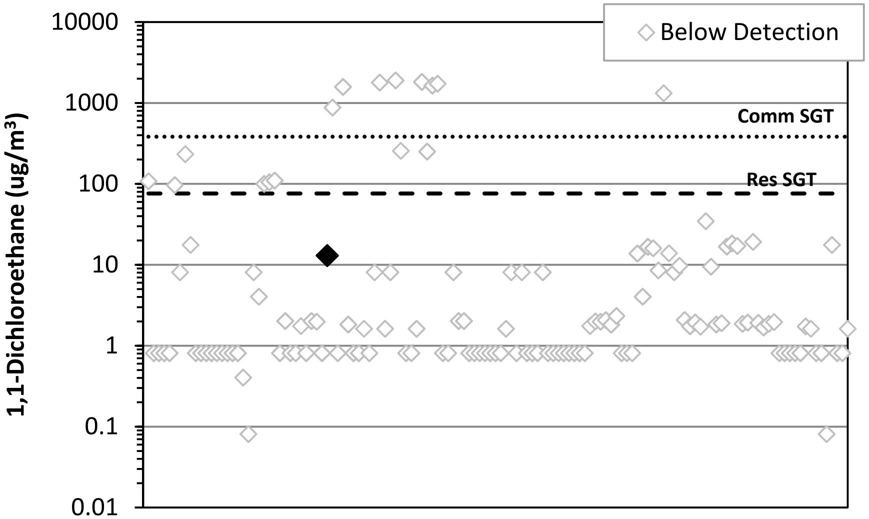
General Notes for Plots:

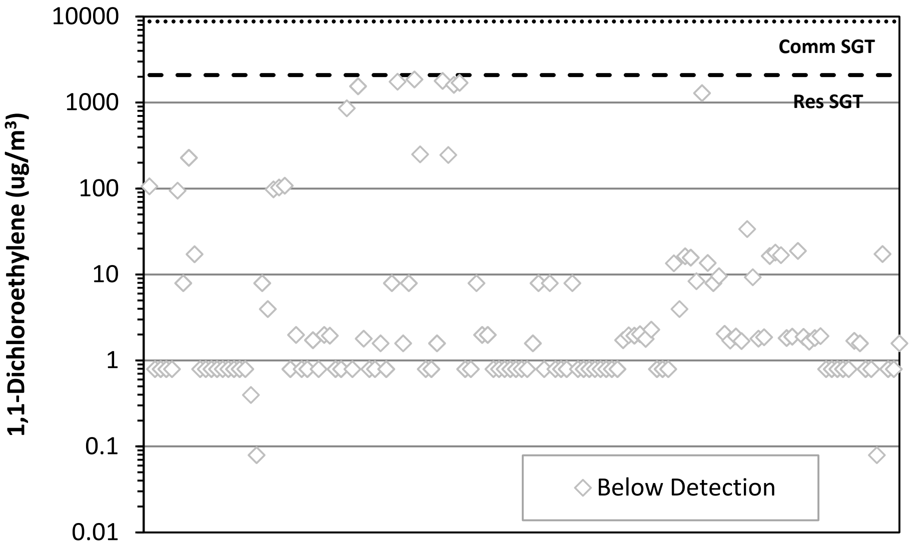
“Comm SGT” = Commercial Soil Gas Target

“Res SGT” = Residential Soil Gas Target

Soil Gas Targets are adjusted from the Indoor Air Targets (SGT=IAT*50) cited from the Maine Department of Environmental Protection's Indoor Air Targets for Chronic Residential and Commercial Scenarios at Multi-contaminant sites.



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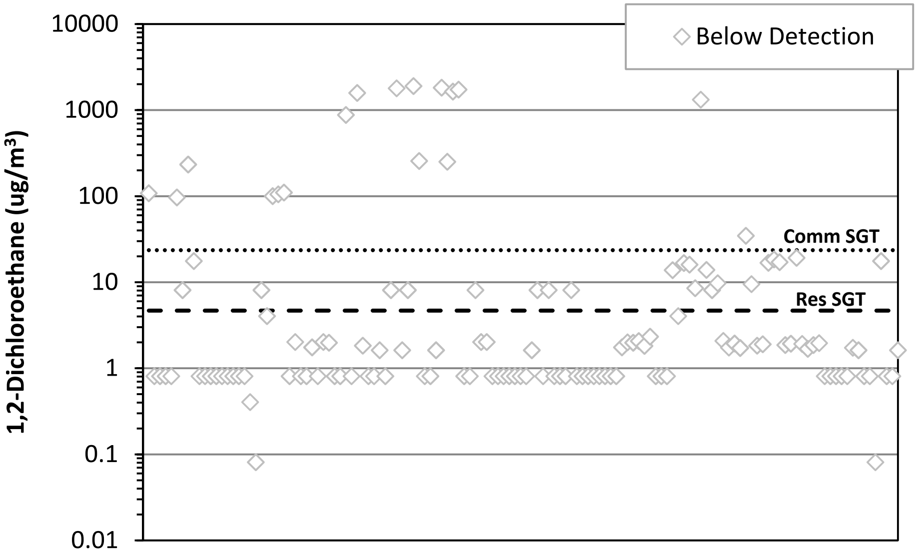
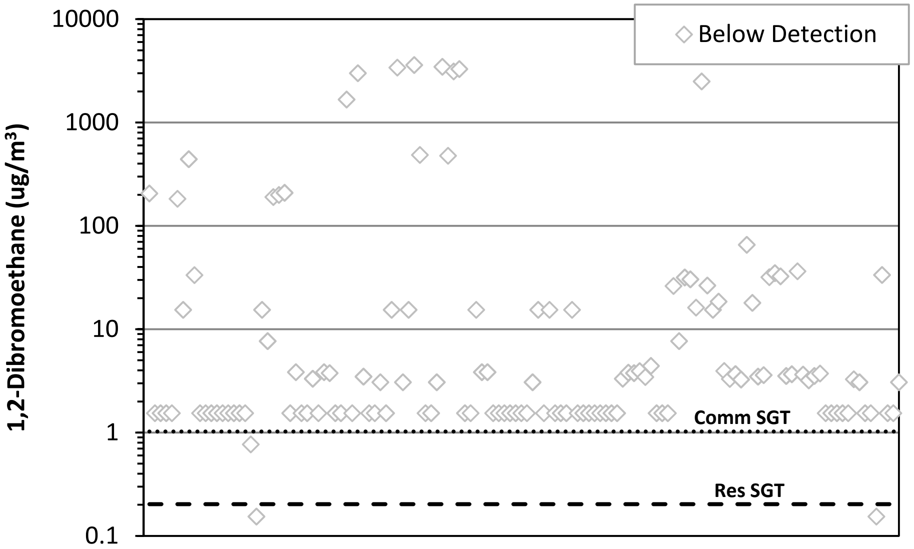
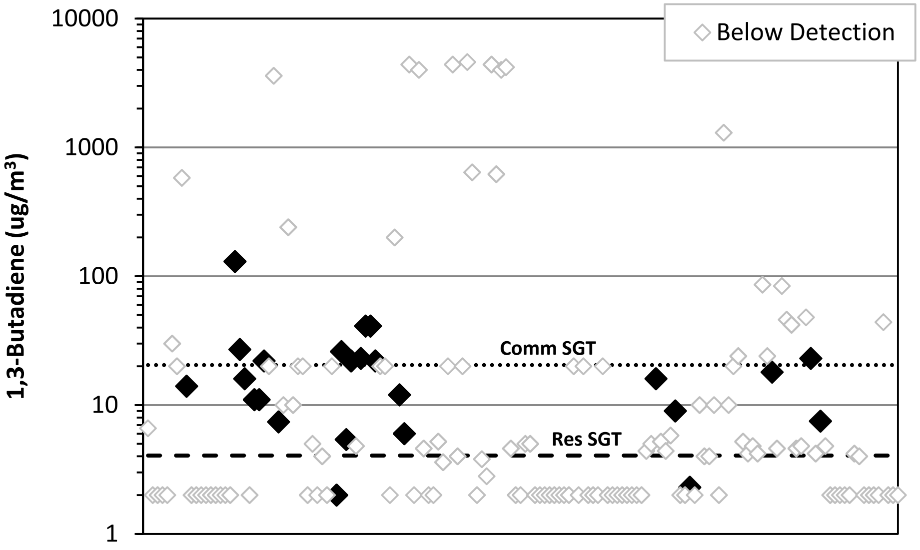
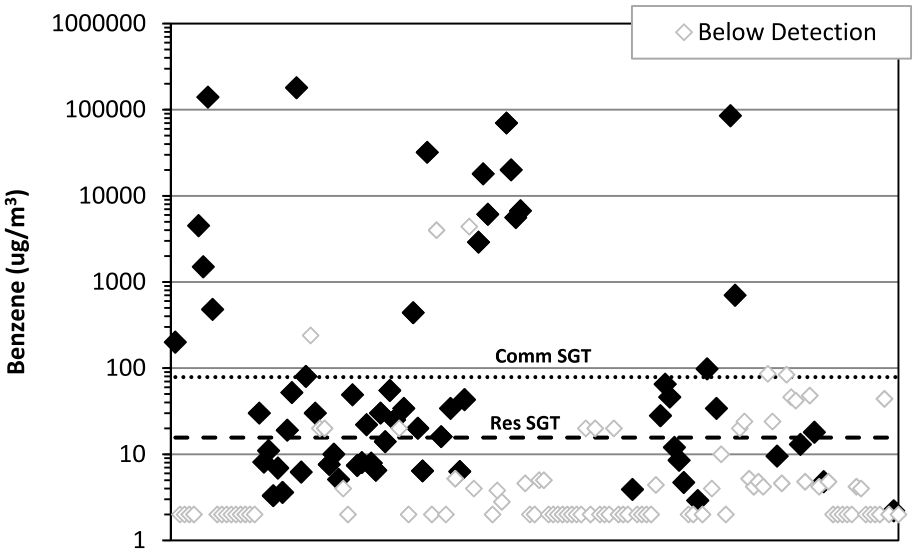
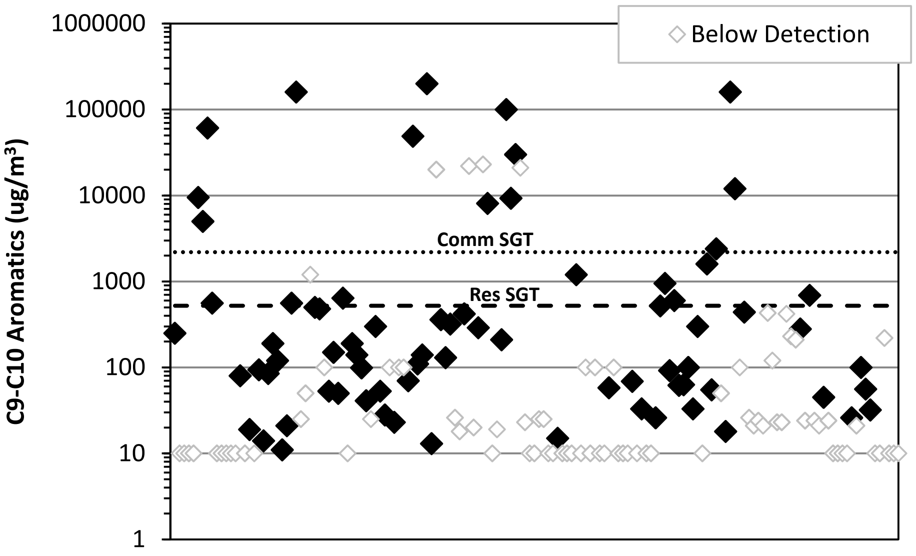
10000
1000
100
10
1
0.1
0.01
Comm SGT
Res SGT
Below Detection

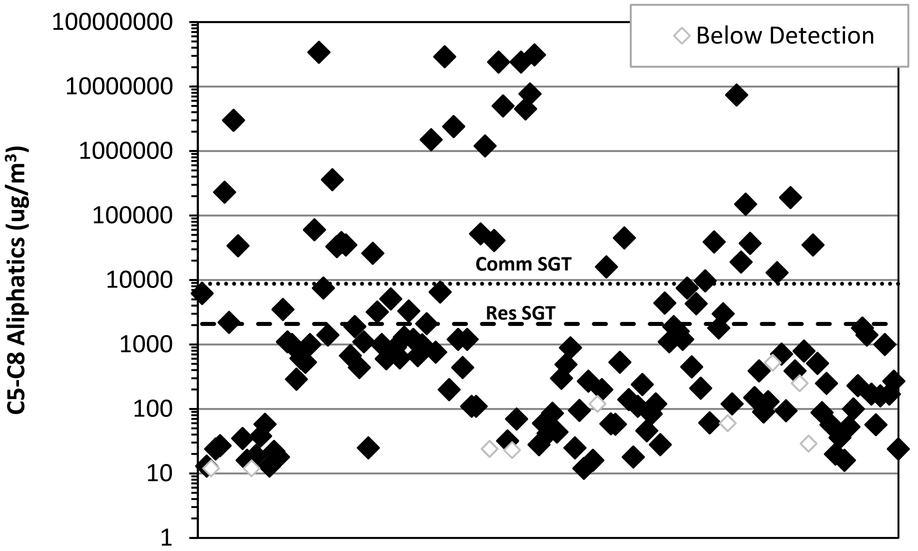

1,2-Dichloroethane (ug/m³)
10000
1000
100
10
1
0.1
0.01
Below Detection
Comm SGT
Res SGT

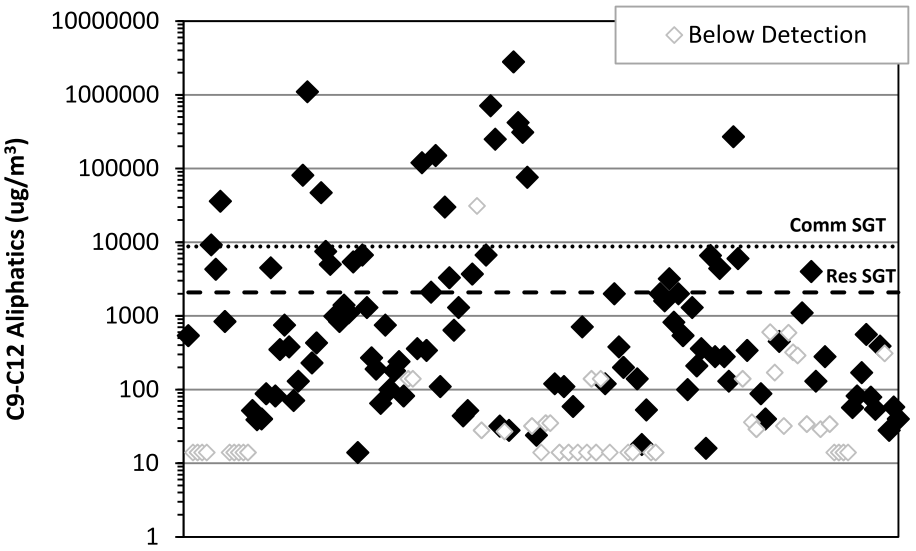

1,2-Dibromoethane (ug/m³)
10000
1000
100
10
1
0.1
Below Detection
Comm SGT
Res SGT

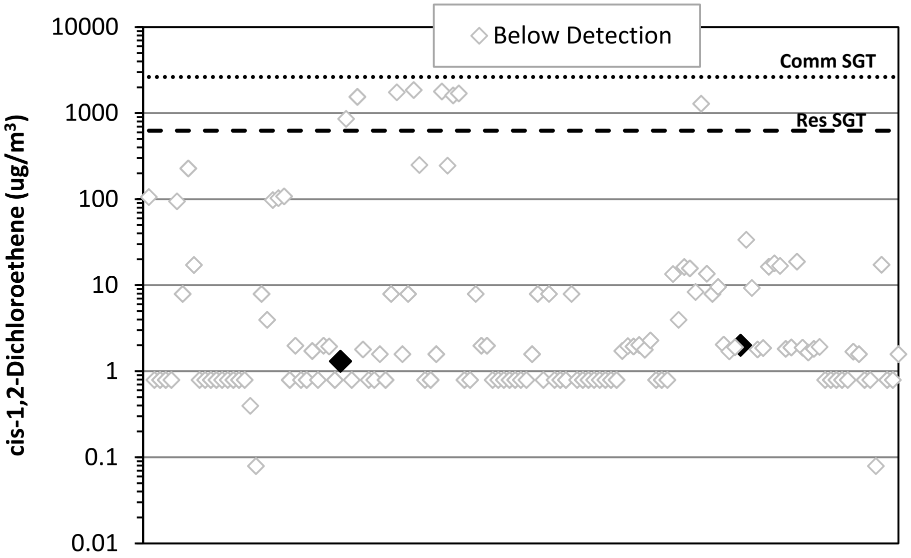

1,3-Butadiene (ug/m³)
10000
1000
100
10
1
Below Detection
Comm SGT
Res SGT


Below Detection
Benzene (ug/m³)
1000000
100000
10000
1000
100
10
1
Comm SGT
Res SGT

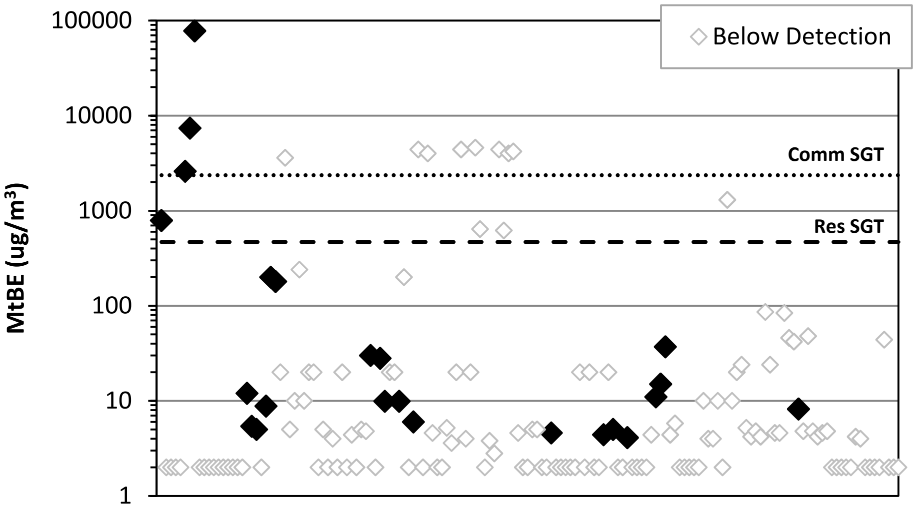

Below Detection
C9-C10 Aromatics (ug/m³)
1000000
100000
10000
1000
100
10
1
Comm SGT
Res SGT


Below Detection
C5-C8 Aliphatics (ug/m³)
100000000
10000000
1000000
100000
10000
1000
100
10
1
Comm SGT
Res SGT

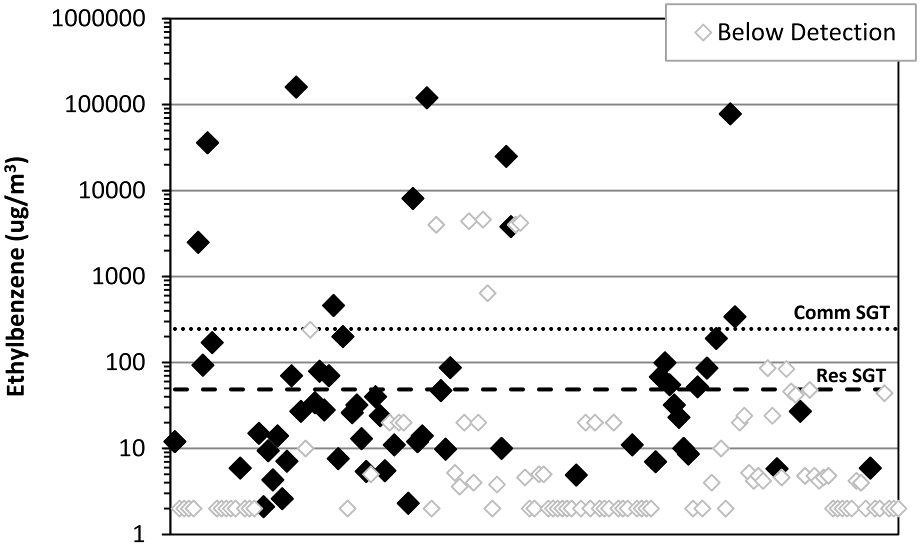

Below Detection
C9-C12 Aliphatics (ug/m³)
10000000
1000000
100000
10000
1000
100
10
1
Comm SGT
Res SGT



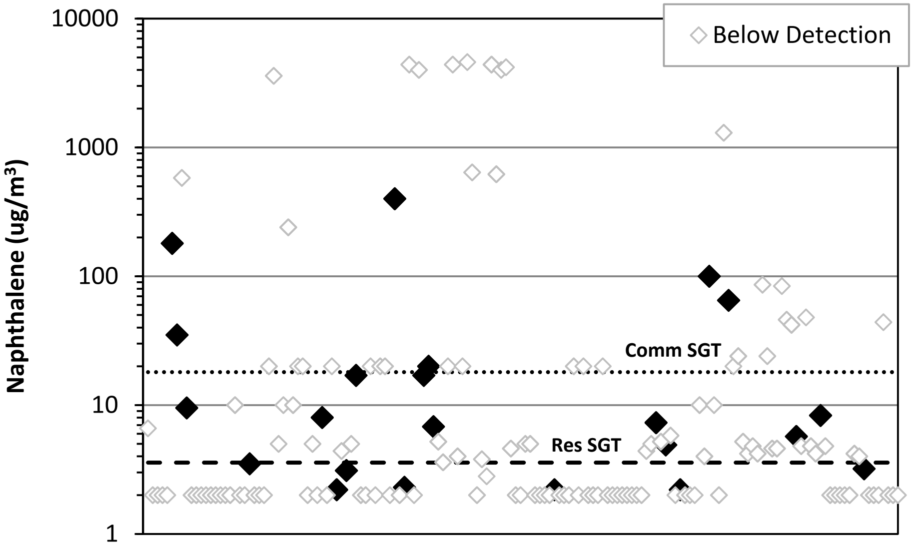
cis-1,2-Dichloroethene (ug/m^3)
◇ Below Detection
Comm SGT
Res SGT
10000
1000
100
10
1
0.1
0.01



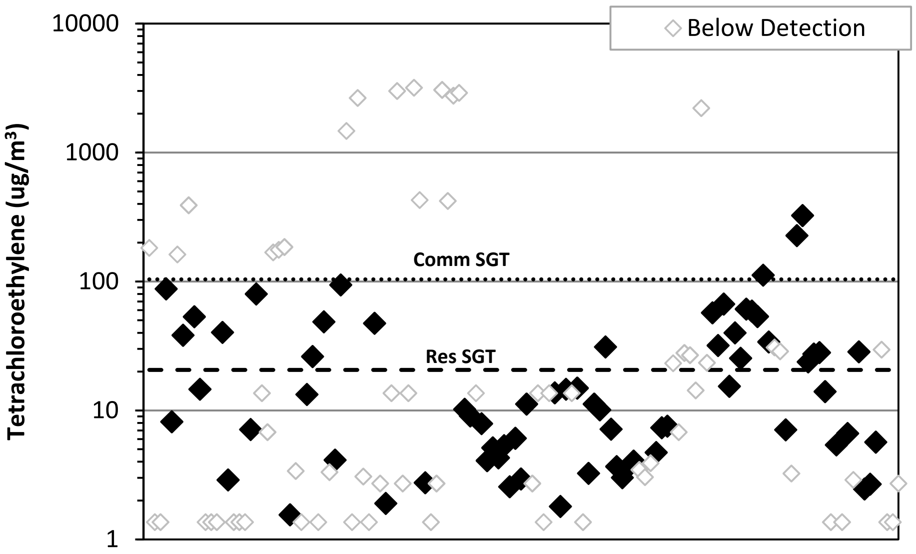
MtBE (ug/m^3)
◇ Below Detection
Comm SGT
Res SGT
100000
10000
1000
100
10
1

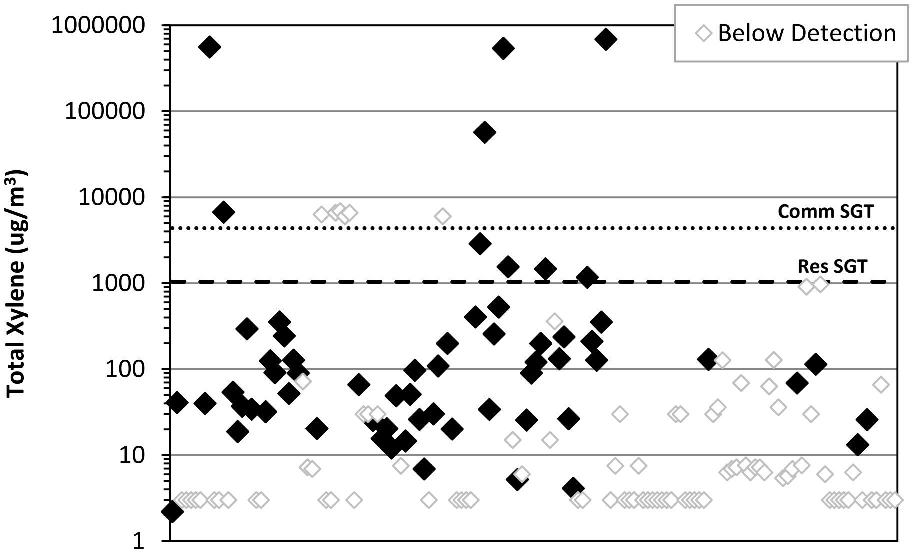


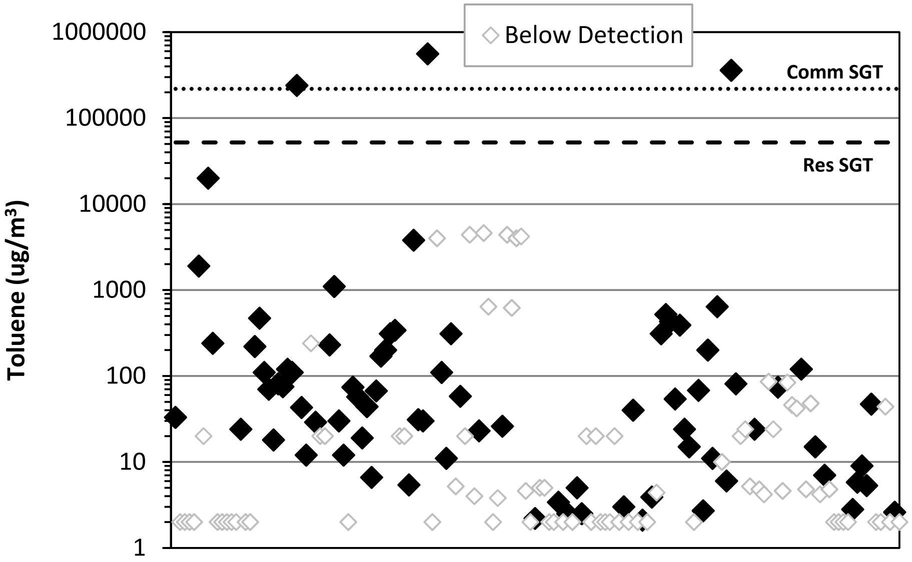
Ethylbenzene (ug/m^3)
◇ Below Detection
Comm SGT
Res SGT
1000000
100000
10000
1000
100
10
1

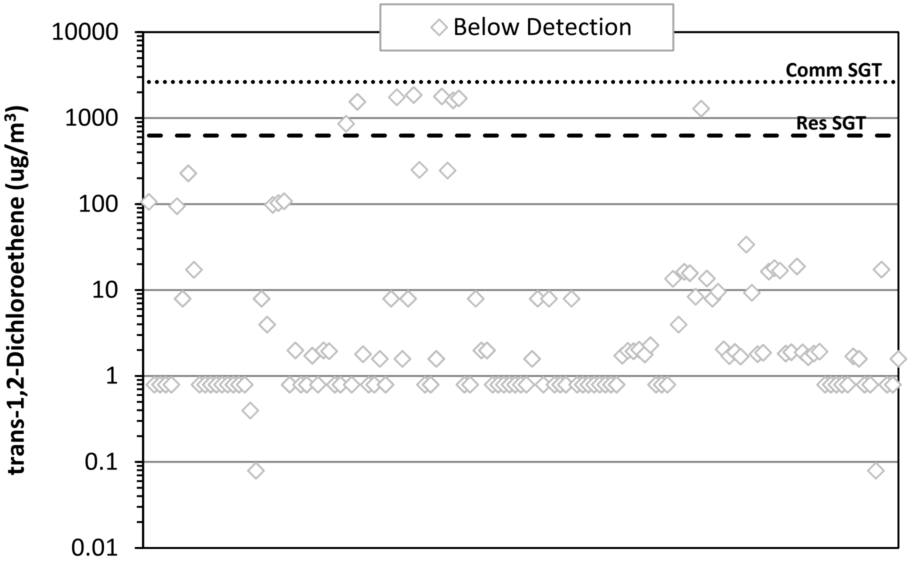


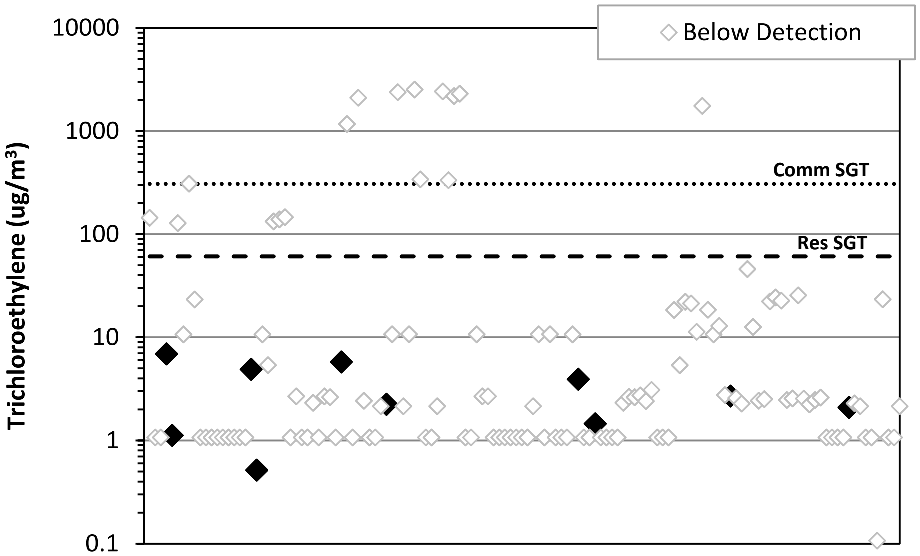
Naphthalene (ug/m^3)
◇ Below Detection
Comm SGT
Res SGT
10000
1000
100
10
1

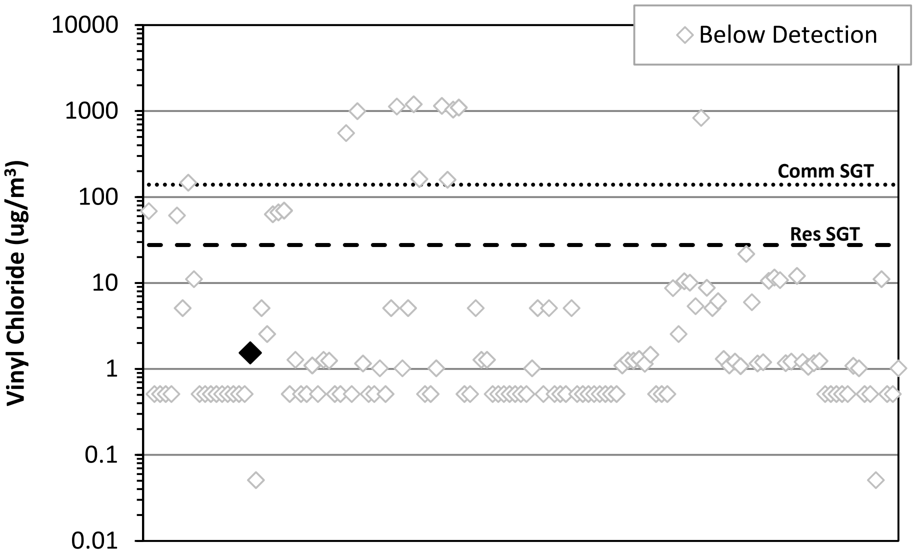

Below Detection
Tetrachloroethylene (ug/m³)
10000
1000
100
10
1
Comm SGT
Res SGT


Below Detection
Total Xylene (ug/m³)
1000000
100000
10000
1000
100
10
1
Comm SGT
Res SGT


Below Detection
Toluene (ug/m³)
1000000
100000
10000
1000
100
10
1
Comm SGT
Res SGT


Below Detection
trans-1,2-Dichloroethene (ug/m³)
10000
1000
100
10
1
0.1
0.01
Comm SGT
Res SGT


Below Detection
10000
1000
100
10
1
0.1
Trichloroethylene (ug/m3)
Comm SGT
Res SGT


Below Detection
10000
1000
100
10
1
0.1
0.01
Vinyl Chloride (ug/m3)
Comm SGT
Res SGT

Appendix C

Proposed Updated Maine DEP Petroleum Remediation Guidelines

6. Indoor Air Pollution & Petroleum Vapor Intrusion Evaluation (draft)

6.1. Remediation of Obvious Human Exposure to Petroleum Vapors.

When vapor exposure is obvious in an occupied building, indoor air quality sampling and remediation should be considered with the objective of mitigating the exposure of building occupants to petroleum constituents as soon as practical. Indicators of obvious petroleum vapor exposure include strong petroleum odors or PID readings above ambient background within the building.

Remediation measures are to be approved by the Department prior to implementation. Explosion hazard assessment and mitigation are outside the scope of this guidance.

6.2. Investigation of Off-Site Buildings and On-Site Mixed Use Buildings.

When it is not obvious that building occupants are being exposed to petroleum vapors, the potential for a complete vapor intrusion pathway to receptors should be investigated at petroleum discharge sites where oil-saturated soil, LNAPL, or grossly-contaminated groundwater are located within 30 feet of a receptor and within 15 feet of the ground surface. Grossly-contaminated groundwater is characterized herein as containing >1,000 ug/L benzene or >10,000 ug/L total VPH and EPH. Further evaluation of VI risk should also be conducted when contaminated groundwater is less than 5 feet below a building foundation or chlorinated solvents are detected in groundwater.

Such investigations are to be conducted in accordance with Bureau guidance entitled “Vapor Intrusion Evaluation Guidance” (VI guidance) **(*insert link when available*).** Where an evaluation concludes there is a complete vapor intrusion pathway, or a complete pathway is likely in the near future, indoor air quality monitoring and remediation are to be considered, and implemented as soon as practical with the Department’s approval.

6.3. Vapor Intrusion Risk Evaluation.

Soil gas and indoor air sampling results are to be evaluated in accordance with the VI guidance and compared to the health risk based Indoor Air Target Levels contained there and developed by the MCDC.