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Department of Toxic Substances Control

California Water Boards
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Supplemental Guidance:

Screening and Evaluating Vapor Intrusion

FINAL DRAFT

California Department of Toxic Substances Control

California State Water Resources Control Board

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Final Draft
Supplemental Guidance:
Screening and Evaluating Vapor Intrusion

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California State Water Resources Control Board
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Disclaimer: This document is guidance and is not regulation or a water quality control plan or policy, therefore, use of this Supplemental Guidance is optional. This Supplemental Guidance describes a proactive approach for evaluating vapor intrusion in California. This Supplemental Guidance is not binding on California Environmental Protection Agencies or staff, or on stakeholders or other members of the public. This Supplemental Guidance does not exclude alternative methodologies, nor does it provide prescriptive or inflexible requirements. This Supplemental Guidance does not supersede or implement laws or regulations and does not have the force or effect of law.

Petroleum releases from underground storage tanks (USTs) must be evaluated for vapor intrusion using the State Water Resources Control Board's Resolution 2012-0062, Low-Threat Underground Storage Tank (UST) Case Closure Policy (LTCP), which became effective August 17, 2012 (State Water Board, 2012b).

California Department of Toxic Substances Control

CALIFORNIA Water Boards
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

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Contents

Executive Summary

Introduction

The Department of Toxic Substances Control (DTSC), San Francisco Bay Regional Water Quality Control Board (SF Bay Regional Water Board), Los Angeles Regional Water Board, Santa Ana Regional Water Board, State Water Resources Control Board (State Water Board), and Office of Environmental Health Hazard Assessment (OEHHA) developed this Supplemental Guidance to promote state-wide consistency for screening buildings for vapor intrusion (VI) and to establish appropriate sampling to protect building occupants from vapors off-gassing from sources of subsurface contamination. Addressing VI is critical to protect people from exposures that may pose a risk of adverse health effects. A workgroup, consisting of members from the agencies listed above under the guidance of California Environmental Protection Agency (CalEPA), prepared this document as a supplement to existing information, not as a standalone document. The urgency to protect building occupants from the short-term exposure effects of trichloroethylene (TCE) at relatively low concentrations was part of the impetus that led to the formation of the CalEPA VI Workgroup. The Supplemental Guidance sets forth one approach that may be used by practitioners and regulators when screening buildings for potential health risk to building occupants from subsurface vapor contamination. It does not provide guidance on the sampling required for all media (soil, soil gas, and groundwater) to determine the nature and extent of contamination in development of a conceptual site model (CSM). However, this Supplemental Guidance does describe a framework for screening buildings for VI concerns.

Revisions to the Draft Supplemental Guidance

This Supplemental Guidance has been revised from the draft version shared with the public on February 14, 2020. The CalEPA VI Workgroup received over 620 comments from over 70 comment letters/emails on the Draft Supplemental Guidance. Individual comments are compiled in a tabular format and are available at both the DTSC's and State Water Board's VI websites (see below).

Some of the key changes to the Supplemental Guidance include:

- Clarification on the use of the Supplemental Guidance (Introduction)
- Clarification of building prioritization (Step 1)
- Clarification of soil gas sampling depths (Step 2)
- Clarification on heating, ventilation, and air conditioning (HVAC) operation during indoor air sampling (Step 3)
- Addition of post-screening approaches to refine current and future VI human health risk assessment (Step 4)
- Addition of lines of evidence (LOE) attachment (Attachment 1)

- Clarification of alignment between the Petroleum-Specific Considerations Attachment (Attachment 2) with the State Water Board's Low-Threat Underground Storage Tank Case Closure Policy

Key recommendations of the Supplemental Guidance that have not changed from the February 2020 draft are:

- Early assessment of VI risk to occupants of buildings during the investigation phase of a cleanup project
- Expedited response action for immediate threat to human health
- Appropriate and predictable sampling approach to generate high-quality data to evaluate potential VI risk at a building
- Use of United States Environmental Protection Agency (USEPA) VI attenuation factors (AFs) for the initial screening of buildings
- Development of a high-quality, building-specific dataset needed for improved risk management decisions
- Assessment of future VI risk using subsurface data
- Inclusion of the high-quality VI data collected using the Supplemental Guidance in the GeoTracker database
- Public engagement early and throughout the site investigation

Sitewide assessment, cleanup goals, mitigation, long-term monitoring, remediation, and case/site closure are outside the scope of the Supplemental Guidance.

The Supplemental Guidance is available at the State Water Board's and DTSC's websites (see below). The websites also provide general information on VI, the February 2020 Draft Supplemental Guidance, a table of public comments received on the Draft Supplemental Guidance, general responses to the most frequent comments, and Final Draft Supplemental Guidance:

State Water Board: https://www.waterboards.ca.gov/water_issues/programs/scp/vapor_intrusion/

DTSC: https://www.dtsc.ca.gov/vapor-intrusion/

Background

Vapor intrusion is the migration of chemical vapors from the subsurface into buildings and is a frequent problem at contaminated sites. If uncontrolled, chemical vapors can migrate into buildings and pose a risk to human health. Vapor migration in the subsurface, through building foundations, and within buildings is complex and influenced by many natural and human-caused factors. These factors include climate (e.g., temperature, pressure, precipitation), building conditions (e.g., foundation type and status, age, size), and HVAC operation. The combination of these factors can result in significant spatial and temporal variability in subsurface and indoor air vapor concentrations. With the potential for such high variability, the probability of false negatives increases, which poses a concern that potential human health risks associated with VI into indoor air will be underestimated. To address this, the Supplemental Guidance provides a proactive approach to evaluate and manage VI health risks. This Supplemental Guidance incorporates information from recent technical and regulatory publications that have highlighted the variable nature of vapor behavior and lessons learned in the assessment of VI.

This Supplemental Guidance provides information and recommendations on the following topics:

- Establishing a four-step evaluation process to assess VI
- Using USEPA 2015 AFs
- Considering sewers as a potential VI migration route and pathway of exposure when sewers intersect contaminated subsurface media
- Building a California-specific VI database

Scope, Applicability, and Relation to Existing Guidance and Policy

This Supplemental Guidance describes a preliminary VI screening process that practitioners and regulators may use to determine if current or future building occupants are at risk from VI. After preliminary screening, the risk assessment may be refined using additional data and LOE to determine appropriate response actions. Every site and building are unique and have their own complexities and limitations, so the recommended process and sampling procedure described in this guidance may be modified. Alternative approaches could be applied if technically sound and scientifically supported.

This Supplemental Guidance addresses assessment of VI risk from vapor forming chemicals (VFCs)[1] but does not constitute complete guidance for the overall evaluation and management of VI. This Supplemental Guidance may be used in conjunction with existing California guidance (DTSC Vapor Intrusion Guidance [2011a], the DTSC Vapor Intrusion Mitigation Advisory [2011b], and the Interim Framework for Assessment of Vapor Intrusion at TCE-Contaminated Sites in the San Francisco Bay Region [2014]). To the extent that an issue is discussed in this Supplemental Guidance, that discussion reflects the agencies' current position on that issue.

Additionally, USEPA continues to use the framework set forth in its 2015 OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air (USEPA, 2015a) at any site being evaluated pursuant to the Comprehensive Environmental Response, Compensation, and Liability

[1] Vapor forming chemical (VFC) – A volatile chemical that USEPA recommends be routinely evaluated during a site-specific VI assessment when it is present as a subsurface contaminant (USEPA, 2015a). A volatile chemical is defined as a chemical with a vapor pressure greater than 1 milliliter of mercury, or Henry's law constant greater than 10^{-5} atmosphere-meter cubed per mole and include volatile organic compounds and mercury.

Act (CERCLA), the corrective action provisions of the Resource Conservation and Recovery Act (RCRA), and EPA's brownfields program where vapor intrusion may be of potential concern. **Petroleum releases from underground storage tanks (USTs) must be evaluated for VI using the State Water Board's Resolution 2012-0062, Low-Threat Underground Storage Tank (UST) Case Closure Policy (LTCP**), **which became effective August 17, 2012 (State Water Board, 2012b).** Attachment 2 describes petroleum-specific issues that should be considered when using this Supplemental Guidance for other petroleum release sites.

Vapor Intrusion Attenuation Factors

The USEPA recommends the use of empirically-derived AFs (USEPA, 2015a). These AFs are protective of public health under most building occupancy scenarios and may be used for the initial screening of sites in California. Site-specific AFs derived from mathematical models, such as the Johnson and Ettinger model, may not be appropriate for the initial screening of occupied buildings. The following table shows the USEPA's recommended AFs for screening buildings during a VI assessment.

Table 1: Medium-Specific Attenuation Factors for VI to Indoor Air

Medium	Attenuation Factor
Crawl Space Gas	1
Subslab Soil Gas	0.03
Soil Gas	0.03
Groundwater (generic)	0.001
Groundwater (fines)	0.0005

Evaluation of Lines of Evidence

Lines of evidence in a VI evaluation include sampling data and other qualitative and quantitative information collected prior to and during the site investigation and building evaluation. The LOEs are used to develop and refine the CSM and support decision-making throughout the process. Each LOE is weighted based on relevance, representativeness, and quality in supporting an evaluation of VI, and may be weighted differently at another site or for a different building at the same site.

Multiple LOEs should be used to reduce the overall uncertainty when considerable uncertainty is associated with one or more individual LOEs. In addition to VFC concentration data, LOEs also include an understanding of site history, contaminant sources, release mechanisms, contaminant migration, location of possible preferential pathways, location of nearby receptors, information about the construction of potentially impacted buildings, and the conceptual understanding of the potential for VI.

Transport of Vapor Contamination Through Sewers

Sampling sewer air may be an important LOE in diagnosing the source of VFCs in indoor air. Recent scientific literature highlights the importance of sewer lines as a potential preferential pathway for vapor migration. Vapors may enter sewer pipes that intersect contaminated soil or groundwater that may be off-gassing chemicals into the vapor phase. Once inside the sewer pipe, VFCs can be transported beneath or directly into buildings. Soil gas and groundwater sampling alone may not adequately evaluate the potential risk posed by VFCs in sewers. Where VFCs are likely to have impacted sewer air, and the conduit(s) connects to or has the potential to release vapors below a specific building, then an indoor air investigation for that building should proceed.

Four-Step Process for Vapor Intrusion Assessments

This Supplemental Guidance outlines and describes a four-step process (shown in the following flow chart) to determine whether buildings located near known or suspected subsurface VFC contamination are potentially affected by VI that may pose a health risk to occupants. The four-step process is summarized below:

- Prioritize buildings in proximity to source contamination for a VI assessment
- Collect exterior soil gas samples to determine if buildings have potential for VI
- Collect indoor air, subslab soil gas, and outdoor air samples if subsurface contamination poses potential VI risk to building occupants
- Evaluate the need to manage current and future VI risk based on both indoor air and subsurface data

California GeoTracker Vapor Intrusion Database

To better understand how human-caused and natural factors influence VI, data collected through implementation of the Supplemental Guidance will be compiled into the State Water Board's GeoTracker statewide data management system. These features exist within the Electronic Submittal of Information (ESI) portal to capture building-specific information, appropriate VFC sample types, and electronic laboratory data provided by responsible parties and their assigned contractors. Lead agencies review and approve ESI. Once GeoTracker has sufficient statewide data, the CalEPA workgroup will evaluate the VI database to determine if the development of California-specific AFs is possible.

Conclusion

Understanding the potential risk associated with exposure to VFCs migrating from contaminated soil and groundwater into occupied buildings is the key element to ensure adequate protection of human health. Assessing the potential risk to occupant health, screening the vulnerability of individual buildings to VI, and estimating nature of contaminant distribution over time pose many challenges to regulators, practitioners, and the public. Through a four-step process outlined in this Supplemental Guidance, regulators and practitioners can evaluate whether occupants of buildings located near known or suspected subsurface VFC sources are at potential health risk from VI. Moreover, this Supplemental Guidance provides a reasonable framework for risk management decisions.

The USEPA empirically-derived AFs (USEPA, 2015a) are recommended for the screening of buildings. Data collected during site investigations and reported to GeoTracker will be compiled in a California database to support development of California-specific AFs that may be incorporated into a future version of this Supplemental Guidance.

Flowchart

Four-Step Process for Screening and Evaluating Vapor Intrusion (VI)

Known or suspected release of a Vapor Forming Chemical (VFC)?
- NO → Outside the scope of this guidance
- YES → Petroleum* Underground Storage Tank (UST) Case?
  - YES → Follow the Low-Threat UST Case Closure Policy
  - NO → Step 1

Step 1: Prioritize Buildings and Select Sampling Approach for VI Evaluation

1A – Expedite VI Evaluation if Acute or Short-Term Hazards are Present

1B – Prioritize Buildings for VI Evaluation

Is the building:
- within 100 feet of the most contaminated area (vadose zone or groundwater); or
- connected to release area by preferential pathways (e.g., sewer, utility)?

NO → Add buildings as the extent of soil gas is delineated

YES → **Is the building:** unoccupied or potential future building on open lot?
- YES → Assess future VI risk after full site characterization
- NO → 1C

1C – Select Sampling Approach for Next Step: Soil Gas (Step 2) or Indoor Air (Step 3)

Is the building:
- directly above a Release Area (see definition in next section);
- near contaminated groundwater plume;
- above a groundwater plume that is less than 5 feet below ground surface; or
- connected to conduits intersecting significant contamination?

YES → **Go to Step 3 to Evaluate VI Risk Using Indoor Air Data**

NO → Step 2

Step 2: Evaluate Vapor Intrusion Risk Using Soil Gas Data

2A – Evaluate Spatial Distribution of Shallow Soil Gas Contamination

Sampling Method: See 2015 CalEPA Soil Gas Advisory

Lateral Sampling Locations: Select sampling locations outside building foundation (exterior soil gas) that can be used to evaluate distribution of shallow soil gas contamination for VI risk assessment.

1. Sample in areas of suspected spills or leaks to determine the location of all release areas (i.e., areas of estimated vadose zone soil contamination extending out from primary sources)
2. Step out soil gas sampling in all directions from a release area. Continue to step out until soil gas plume is delineated and distribution of contamination is reasonably understood
3. Samples used to screen for VI should be collected between the building and the nearest vapor source (i.e., release area or groundwater plume), laterally as close as possible to the target building

Sampling Depths – At Least Two Depths:

1. Sample at the depth of known or suspected vadose zone soil contamination
2. Sample at a depth just above known or suspected groundwater contamination (see text if source depth greater than 20 feet below ground surface)

2B – Estimate Human Health Risk from VI

Estimate human health risk and hazard from potential vapor intrusion using the maximum soil gas VFC concentrations from sample location specified above (Step 2A, considering both depths) and 0.03 attenuation factor

Risk ≥ 1 X 10^{-6} or HI ≥ 1 **
- YES → **Go to Step 3 to Evaluate VI Risk Using Indoor Air Data**
- NO → 2C & 2D

2C & 2D – Evaluate Temporal Variability to Determine Next Step

Repeat soil gas sampling in different season → **Risk ≥ 1 X 10^{-6} or HI ≥ 1 ****
- YES → **Go to Step 3 to Evaluate VI Risk Using Indoor Air Data**
- NO → **Low VI Priority Building Go to Step 4C.1**

* For non-UST petroleum releases see Attachment 2 for petroleum-specific considerations.

** Consider other lines of evidence discussed in Attachment 1 when risk or hazard are near the point of departure.

Step 3: Evaluate VI Using Concurrent Indoor Air, Subslab, and Outdoor Air Data

3A – Public Participation

Plan, schedule, and conduct in-person visits with individual property owners and building occupants according to the site-specific Public Participation Plan developed for the site.

3B – Conduct In-Depth Evaluation of Building

- Complete Building Survey Form
- Screen for indoor sources and vapor entry points
- Locate and remove potential indoor air sources of VFCs
- Observe surrounding area for potential outdoor sources

3C – Evaluate Spatial Distribution of Contamination using Concurrent Sampling

These sampling recommendations are for small, single story, slab-on-grade foundation buildings. Modify the number of samples for large buildings and modify subslab samples for building with other foundation types (see text section “Application to Other Building Types”).

Indoor Air Samples
Sampling Method: See 2011 DTSC VIG
Select 3 Locations Considering:
- Primary living/working areas
- Near slab/floor penetrations
- Near suspected maximum subsurface contamination

Subslab Samples
Sampling Method: See 2015 CalEPA Soil Gas Advisory
3 Locations Co-located with the indoor air samples (alternatively, exterior soil gas can be considered, see text)

Outdoor Air Samples
Sampling Method: See 2011 DTSC VIG
Select 3+ Locations:
Around building to account for wind direction changes. Avoid site contamination and localized outdoor sources.

Potential Complementary Sampling:
- Exterior Soil Gas
- Vapor Entry Point
- Pressure and Temperature Measurements
- Vapor Conduit Air ***

3D – Assess Risk using the Maximum Indoor Air and Subslab Soil Gas Concentrations

- Determine whether VI is occurring
- Estimate current VI risk and hazard using maximum measured indoor air concentrations
- Estimate future VI risk and hazard using potential future indoor air concentrations predicted from maximum subslab soil gas concentration and an attenuation factor of 0.03

Current VI: Risk ≥ 1X10^{-6} or HI ≥ 1
YES → Step 4
NO → 3E & 3F

3E & 3F – Evaluate Temporal Variability (Repeat Step 3C) to Determine Next Step

- One to two more sampling events (two to three events total)
- At least one sampling event in a different season
- One event with HVAC-Off and HVAC-On sampling or an alternative approach using other lines of evidence

Current or Future VI: Risk ≥ 1 X 10^{-6} or HI ≥ 1 **
NO → **Low VI Priority Building Go to Step 4B.1 and 4C.1**
YES → Step 4

Step 4: Decide if Risk Management is Needed to Address Current and Future VI Risk

Receptor Risk Building Scenario	Primary Media for VI Risk and Hazard Calculations	Potential Response Actions
Current VI Risk to Occupants of Existing Buildings	Indoor Air Data	See Step 4B
Future VI Risk to Occupants of Existing Buildings	Subsurface Data	See Step 4C
Future VI Risk to Occupants of Future Buildings (Open Lot)	Subsurface Data	See Step 4D

** Consider other lines of evidence discussed in Attachment 1 when risk or hazard are near the point of departure.
*** See Attachment 3 for sewer air or other vapor conduit air sampling considerations.

Introduction

Vapor intrusion is the migration of chemical vapors from the subsurface into indoor air and is a frequent concern when VFCs are present in soil or groundwater near existing or future buildings. If uncontrolled, chemical vapors can migrate into buildings and pose a risk to human health. Vapor migration in the subsurface, through building foundations, and within buildings is complex and influenced by many natural and human-caused factors. Recent technical and regulatory publications have highlighted challenges and lessons learned in the assessment of VI.[2] Historically, practitioners and state regulators have used various approaches to assess vapor migration and predict if subsurface concentrations pose a risk to building occupants, thus resulting in potentially conceptually inconsistent VI assessment and risk management from site to site.

The intent of this document is to update and supplement existing VI guidance in California by incorporating recent advances in VI and to promote state-wide consistency. This Supplemental Guidance provides information and recommendations on the following topics:

- Using USEPA 2015 AFs
- Establishing a four-step evaluation process:
    - Prioritizing buildings near contamination for VI evaluation
    - Screening buildings by sampling exterior soil gas
    - Evaluating buildings by sampling indoor air, subslab soil gas, and outdoor air
    - Managing current and future VI risk
- Considering sewers as a potential VI migration route and pathway of exposure
- Building a California-specific VI database

This Supplemental Guidance should be used within the context of investigation of known or suspected releases of VFCs. The approach in this Supplemental Guidance should be used in conjunction with full site characterization and the development of a CSM. This document provides a reasonable framework for evaluating VI with a high level of confidence and promoting consistency at state-lead sites in California. The preceding flow chart illustrates the steps described in this Supplemental Guidance for screening and evaluating VI.

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[2] McHugh et al., 2007; Eklund et al., 2008; Folkes et al., 2009; Luo et al., 2009; Holton et al., 2013; Pennell et al., 2013; USEPA, 2015a; Schuver, et al., 2018

A – Scope and Applicability

The recommendations in this Supplemental Guidance are focused on the protection of current occupants of buildings from potential exposure to VFCs that can contaminate indoor air through the VI pathway. The same logic is extended to the evaluation and management of future VI risk for existing buildings, future buildings constructed on open lots, or redevelopment sites.

A1 – Scope

VI at residential or commercial buildings located near known or suspected subsurface contamination by VFCs can be evaluated through the four-step process described below. Step 1 describes how to prioritize buildings and decide whether to screen buildings based on soil gas in Step 2, or proceed directly to an indoor air evaluation, described in Step 3. Step 4 provides a framework for making risk management decisions.

The guidance describes a focused investigation for potential risk to building occupants. This Supplemental Guidance describes procedures for evaluating VI at cleanup sites and cases with releases of VFCs but does not constitute complete guidance for the overall subsurface investigation and evaluation and management of VI. This Supplemental Guidance does not provide details on how to conduct a full site characterization of all media or how to collect vapor samples. Cleanup goals, remedial strategies, and closure criteria should be established on a site-specific basis, which is outside the scope of this document. Investigation of sites without known or suspected chemical releases, as a precautionary measure (e.g., due diligence investigations), is outside the scope of this document.

Use of this Supplemental Guidance does not take the place of professional judgment. Due to the complexity of VI, many professional disciplines may be needed to evaluate and mitigate exposure. Accordingly, a multidisciplinary project team should be gathered to provide sound, scientific judgment when evaluating VI issues and to make decisions concerning potential human exposure. To comply with the Geologist and Geophysicist Act, codified in Section 7835 of the California Business and Professions Code, and the Professional Engineers Act, codified in Sections 6700-6799 of the California Business and Professions Code, any report submitted that contains geologic or engineering conclusions, recommendations, or technical interpretations must be signed and stamped by an appropriately licensed professional who takes responsibility for the report's technical content.

Professional judgment should be used during any VI investigation and explained in VI investigation reports. This document does not eliminate the need for work plans or sampling and analysis plans.

This Supplemental Guidance does not preclude the use of alternative approaches for evaluating exposure, nor does it provide prescriptive or inflexible requirements.

Alternative approaches and technologies should be supported by adequate technical documentation.

A2 – How to Use the Supplemental Guidance

Practitioners, regulators, and responsible parties may follow this Supplemental Guidance for VI evaluation. From a regulatory perspective, the Supplemental Guidance may be used:

- To assist all parties in meeting California (H&SC 25356.1.5, CWC §13304, State Water Board resolution 92-49) and Federal requirements (Code of Federal Regulations, Title 40, Subpart E)
- As applicable, to support an order or directive (e.g., an order may reference this guidance for expected elements of a workplan).

The Supplemental Guidance should not be used:

- As a regulation, order, or directive. California and Federal statutes and regulations should be the basis for any such order or directive. This guidance itself is not legally binding and does not require any specific actions. The basis of any such order or directive must be California and Federal statutes or regulations.
- As the sole basis for sampling and analysis that may be required to build a sitewide conceptual model and determine the nature and extent of contamination in all media of concern (e.g., soil, surface water, groundwater, soil gas).
- For closure of a regulatory case, since case closure is based upon standards and policies of the regulatory agency, and remedial and closure objectives agreed upon between the lead regulatory agency and the responsible party. Remedial and closure objectives are based on multiple LOEs, completeness of a CSM, and evidence that exposure pathways are eliminated through remediation and/or ongoing mitigation measures and agreed upon by all parties.

A3 – When to Use the Supplemental Guidance

The primary use of the Supplemental Guidance should be at initial site investigation and initial screening of buildings when VFCs are present or subsurface vapors have been identified at a site. Additionally, the Supplemental Guidance can also be used at future phases of investigation and cleanup when a building assessment should be conducted or when new information is identified, data gaps exists, or land use changes (e.g., commercial to residential). Figure 1 illustrates a typical cleanup case progression and when the Supplemental Guidance could be used.

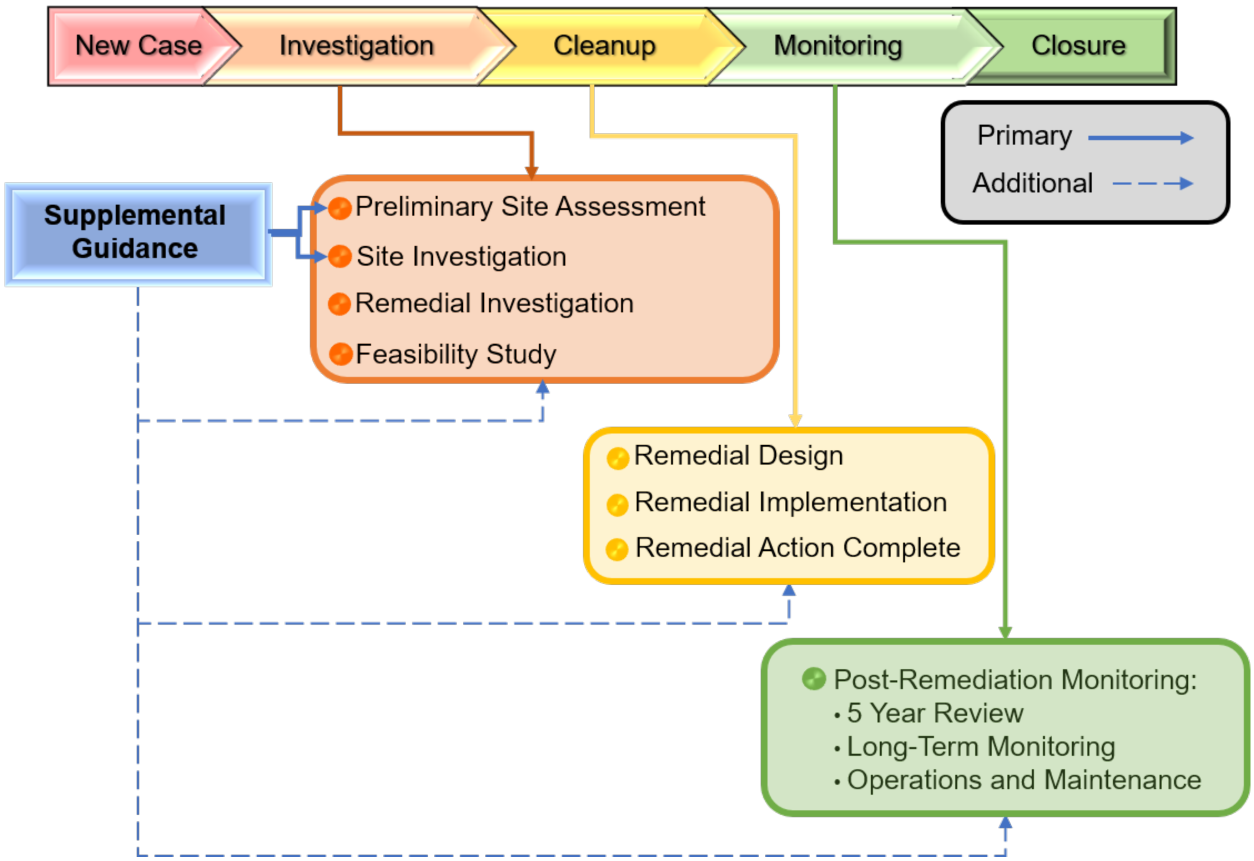

Figure 1. Typical Cleanup Case Progression and Applicability of the Supplemental Guidance

B – Relation to Existing Guidance or Policy

This Supplemental Guidance is meant to supplement, and be used in conjunction with, existing California VI guidance documents. To the extent that an issue is discussed in this Supplemental Guidance, that discussion reflects the agencies' current position on that issue.

Planning for public outreach should begin as soon as VFCs are suspected in the subsurface at locations near or adjacent to existing buildings. The Vapor Intrusion Public Participation Advisory (DTSC, 2012) should be applied as appropriate. The appropriate agency's public participation office should be consulted regarding the public engagement process and to develop a site-specific Public Participation Plan.

Additionally, USEPA continues to use the framework set forth in its 2015 OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air (USEPA, 2015a) at any site being evaluated pursuant to CERCLA, the corrective action provisions of the RCRA, and EPA's brownfields program where vapor intrusion may be of potential concern. **Petroleum releases from USTs must be evaluated for VI using the State Water Board's LTCP**

(State Water Board, 2012b). Attachment 2 describes petroleum-specific issues that should be considered when using this Supplemental Guidance for other (non-UST) petroleum release sites.

C – Conceptual Model for Vapor Intrusion

The conceptual model for VI includes transport of VFCs through the subsurface toward the building, vapor entry into the building, and contaminant mixing with indoor air. “Primary sources” are release points of contamination, such as tanks, waste ponds, sumps, drains, pipelines, clarifiers, spills, and landfills. “Secondary sources” are VFCs that migrated from a primary source and occur in the subsurface as a non-aqueous-phase liquid (NAPL), adsorbed-phase contamination, or dissolved-phase contamination. The secondary sources (referred to as subsurface sources in this document) may be present in the vadose zone, in groundwater, or within sewer or other conduits (USEPA 2015a).

Overall, vapor transport in the subsurface is controlled by contaminant partitioning, diffusion (transport from high to low concentration), and advection (transport from high to low pressure) (USEPA, 2012a). Diffusion typically dominates the transport of vapor phase contaminants from a subsurface source toward a building or ground surface. Vapors near the building can be transported by both diffusion and advection into indoor air via cracks or other openings. Advection resulting from negative indoor air pressure relative to the subsurface immediately adjacent to the building (i.e., the building’s envelope) typically dominates transport of vapors into indoor air (Johnson, 2005; Yao et al., 2013; USEPA, 2015a). Building HVAC operations (e.g., stack effects from heating/air conditioning) and weather conditions (e.g., barometric pressure, wind, and temperature) can affect the pressurization of a building.

In this Supplemental Guidance, the terms “vapor entry point,” “preferential pathway[3],” and “vapor conduit” are assigned specific meanings:

- “**Vapor entry point**” is used to describe any penetration in the building foundation (or subsurface walls) such as cracks, expansion joints, utility conduits, sumps, and elevator shafts, through which subsurface vapors can be transported into the building.
- “**Preferential pathway**” is a general term used to define all high-capacity transport pathways for vapors from the subsurface source to the building foundation or into the building (ITRC, 2007; DTSC, 2011a; McHugh et al.,

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[3] In the future, the term “preferential pathway” may be discontinued within vapor intrusion nomenclature due to its ambiguity (Kapuscinski, 2021). Stakeholders, when addressing or discussing potential preferential pathways, should state specifically the type of pathway under evaluation rather than rely on potentially ambiguous terms.

2017b). Examples of potential preferential pathways are bedrock fractures, sand lenses, dry wells, rodent tunnels, vapor pathways inside conduits (e.g., sewers, storm drains, utilities, fiber optic cable housing), and engineered backfill material along conduits.

- **"Vapor conduit**" is a subset of preferential pathways that provide little to no resistance to vapor flow. For example, vapors can flow through the pipes of the sanitary sewer, utility conduits, or other drains or conduits. When a vapor conduit penetrates the building foundation, the preferential pathway can also serve as a potential vapor entry point.

Recent evidence highlights the importance of sewer lines as potentially significant vapor conduits (Pennell et al., 2013; Guo et al., 2015; Jacobs et al., 2015 and 2016; Kastanek et al., 2016; McHugh et al., 2017a and 2017b; Wallace et al., 2017; and ESTCP, 2018b, c, and d). VFCs may enter sewer pipes[4] that intersect contaminated soil or groundwater. Also, sewers may contain VFCs from waste discharge into the sewer network (see Attachment 3). Once inside the sewer pipe, VFCs can be transported beneath or directly into the building. While sewer plumbing systems inside buildings are designed to prevent sewer gases from entering the building, many components of sewer systems leak or become compromised. Compromised features can include cracked, separated, or punctured pipes; loose fittings; degraded toilet gaskets (e.g., wax rings); and dry plumbing traps (e.g., p-traps) (Pennell et al., 2013). Both the sewer pipe itself and backfill material can be preferential pathways. Due to greater void space in the pipe, vapor transport can be greater than the backfill (porous media). Testing at two research houses indicated the sewer acted as a preferential pathway for transport of VFC-contaminated air through the pipes into indoor air (Guo et al., 2015; McHugh et al., 2017a). Overall, this evidence shows that conventional methods used to assess VI (i.e., groundwater and soil gas sampling outside the building) may not adequately represent the potential risk posed by VFCs.

This Supplemental Guidance describes when the sewer pathway should be integrated into a VI evaluation. Attachment 3 provides more information on sewers, findings of select sewer VI studies, and methods for sampling sewer air.

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[4] Sewer pipes are not the only pertinent conduit that can interest contamination. Other utilities, such as storm, electrical, water, telephone, and fiber optic, can potentially cause conduit vapor intrusion and these pathways should be identified and evaluated as appropriate.

D – Vapor Attenuation Factors

Vapor attenuation refers to the reduction in VFC concentrations that occurs during vapor migration in the subsurface, coupled with the dilution that can occur when the vapors enter a building and mix with indoor air (Johnson and Ettinger, 1991). The AF is a unitless number defined as the ratio between the indoor air concentration (C_{IA}) for a given VFC and its subsurface concentration as follows, using soil gas concentrations (C_{SG}) as an example:

$$AF = \frac{C_{IA}}{C_{SG}}$$

The AF is an inverse measure of the overall decrease in concentration due to attenuation mechanisms that occur as vapors migrate from the subsurface into a building. That is, the greater the attenuation, the smaller the value of AF (USEPA, 2012b; USEPA, 2015a). Concentrations of VFCs in soil gas (subslab soil gas, exterior soil gas, or deeper soil gas) or groundwater can be used to estimate indoor air concentrations.

The indoor air concentration of a VFC can be estimated from a subsurface concentration and the AF by rearranging the equation above:

$$C_{IA} = C_{SG} \times AF$$

Indoor air concentrations and potential risk estimated from groundwater VFC concentrations can be used as a supporting line of evidence but should rarely be a primary line of evidence for VI decision-making. See Attachment 4 for more information on using groundwater data to evaluate VI risk.

D1 – Recommended Attenuation Factors for Screening

USEPA recommends empirically-derived AFs as shown in Table 2 (USEPA, 2015a). These conservative AFs are protective of public health under most building occupancy scenarios and can be used for the initial screening of sites in California unless alternative approaches (see D2) are established. Site-specific AFs based on mathematical models, such as the Johnson and Ettinger model, may not be appropriate for the initial screening described in Steps 1 through 3 of this Supplemental Guidance for the following reasons:

Table 2: Medium-Specific Attenuation Factors

Medium	Attenuation Factor
Crawl Space Air	1
Subslab Soil Gas	0.03
Soil Gas	0.03
Groundwater (generic)	0.001
Groundwater (fines)[5]	0.0005

- Current VI models with scientifically defensible input parameters cannot predict the range of results observed in empirical VI studies (Derycke, et al., 2018; USEPA, 2012b);
- Current VI models do not address how buildings change over time as they are modified, damaged, age, or as ventilation and/or HVAC operation change; and
- An increasing number of studies are showing that preferential pathways such as vapor conduits can contribute to VI (Pennell et al., 2013; Guo et al., 2015; Jacobs et al., 2015 and 2016; Kastanek et al., 2016; McHugh et al., 2017a and 2017b; Wallace et al., 2017; and ESTCP, 2018b, c, and d), but current VI models do not consider this pathway.

If both groundwater and soil gas data are available, the soil gas data should be used to screen for VI. Groundwater is generally considered to be less reliable than soil gas for predicting indoor air concentrations. Screening with groundwater may be appropriate at sites where representative soil gas samples cannot be or have not yet been collected. Further information is provided in Step 1.

[5] A groundwater AF of 0.0005 can be used when laterally continuous fine-grained soils exist in the vadose zone, which are defined as soils with 50% or more of the material passing through a No. 200 (0.075 mm) sieve, consistent with the definition of silt within Unified Soil Classification System. If the stratigraphy is not documented or unknown, the generic groundwater attenuation factor should be used.

D2 – Alternatives for Screening

Although this guidance supports the use of USEPA's AFs (USEPA, 2015a) for initial screening of buildings, alternative approaches may be used if supported by adequate technical and site information. Alternative approaches should evaluate the spatial and temporal variability of VFC concentrations in various media; be based on multiple LOEs; account for on-site and off-site building types, and current and future site and building conditions. Alternative approaches may need more sampling than proposed in this guidance to confirm that the alternative satisfies data quality objectives (DQO) for the investigation.

E – Evaluation of Lines of Evidence

Lines of evidence in a VI evaluation include sampling data and other qualitative and quantitative information collected prior to and during the site investigation and building evaluation. The LOEs are used to develop and refine the CSM and support decision-making throughout the process. Each LOE is weighted based on relevance, representativeness, and quality in supporting an evaluation of VI, and may be weighted differently at another site or for a different building at the same site.

Multiple LOEs should be used to reduce the overall uncertainty when considerable uncertainty is associated with one or more individual LOEs. In addition to VFC concentration data, LOEs also include an understanding of site history, contaminant sources, release mechanisms, contaminant migration, location of possible preferential pathways, location of nearby receptors, information about the construction of potentially impacted buildings, and the conceptual understanding of the potential for VI.

The nature and concentrations of VFCs in groundwater, soil gas, and indoor air can vary greatly spatially and temporally (McHugh et al., 2007; Eklund et al., 2008; Folkes et al., 2009; Luo et al., 2009; Holton et al., 2013; Pennell et al., 2013; USEPA, 2015a; Schuver, et al., 2018). Typical limited sampling that does not reflect the variability presents uncertainties. Indoor air sampling data are the preferred LOE for assessing current risks for building occupants, supported by other LOEs (e.g., subsurface data, building construction and condition, preferential migration pathways, building survey, ventilation/HVAC operation, outdoor air data). Subsurface data are preferred for estimating potential future risks, supported by additional LOEs (e.g., source type/strength, depth and lateral location relative to buildings, site stratigraphy, soil properties, depth to groundwater, plume stability).

Use of multiple LOEs provides a more comprehensive understanding of VI at a site and increases confidence in assessing and managing potential health risks from the VI pathway. Some LOEs may conflict, and this should be anticipated in the project planning process. When LOEs conflict or do not align, collecting additional LOES and/or additional samples may be necessary to update the CSM and support a confident decision (DTSC 2011a; SF Bay Water Board 2014; USEPA 2015a). Site-specific information and professional judgment should be used to evaluate all LOEs throughout the process.

Lines of evidence other than VFC concentration data are discussed in Attachment 1. The collection, evaluation and application of multiple LOEs for VI pathway assessment, site investigation, and response actions are also discussed in other California and USEPA guidance (DTSC 2011a; SF Bay Water Board 2014; USEPA 2015a; USEPA 2012a).

Step 1: Prioritize Buildings and Select Sampling Approach for Vapor Intrusion Evaluation

Site background information should be collected, and the type, quality, and quantity of data that are needed and the intended use of the data should be identified through the DQO process (CalEPA, 2015; DTSC, 2015; USEPA, 2015a). Known or suspected subsurface sources of VFC contamination should be investigated starting with Step 1A, below. Considerations for evaluating VI at non-UST petroleum release sites are presented in Attachment 2.

Planning for public outreach should begin when subsurface VFC contamination is suspected at locations near or adjacent to existing buildings. The risk posed by the VI exposure pathway is often perceived as more critical than other exposure pathways because people cannot avoid breathing the air of the environment in which they live and work. Plan, schedule, and conduct in-person visits with individual property owners and building occupants according to the site-specific Public Participation Plan (DTSC, 2012; USEPA, 2015a). The DTSC Vapor Intrusion Public Participation Advisory (DTSC, 2012) provides guidance on public engagement.

Step 1A – Expedite Vapor Intrusion Evaluations: Acute and Short-Term Hazard

When acute or short-term exposures may result in adverse health effects, promptly evaluate the need for immediate action and expedited turnaround times for laboratory analyses. Hazards can also include fire and explosion as well as acute toxicity (see DTSC, 2011a and USEPA, 2015a). For information about short-term response actions for TCE, see USEPA (USEPA, 2014a), DTSC's "Human Health Risk Assessment [HHRA] Note Number 5" (DTSC, 2014) or the SF Bay Regional Water Board's "Vapor Intrusion Framework" (SF Bay Regional Water Board, 2014).

Step 1B – Prioritize Buildings for Vapor Intrusion Evaluation

For situations where multiple buildings require investigation, a "worst first" approach should be employed for VI evaluations. When prioritizing which buildings should be evaluated first to address potential VI concerns, factors to be considered include proximity to contamination, vapor conduits, and building occupancy.

1B.1 – Proximity to Contamination

Buildings closest to the greatest subsurface contaminant concentrations should be prioritized for VI evaluations. The closer a building is to subsurface contamination, the greater the potential for VI. Both the lateral and vertical distance of a building from soil and groundwater contamination should be considered. Additional buildings further away from the primary source may be screened in a step-out fashion, as described in Step 2A.

- **Proximity to Source and Release Areas**
  Prioritize buildings within 100 feet of the *area of estimated vadose zone soil contamination and free product extending from a source* (release area) for VI evaluation. Due to the complexity of vapor migration in the subsurface and the many factors that influence vapors (e.g., subsurface source type and strength, soil types, vapor conduits, ground cover), evaluating buildings within a 100-foot inclusion zone of the source is a reasonable starting point for screening buildings. If the release area is not well defined, it may be approximated. As empirical data are collected, the inclusion zone should be reevaluated to address site-specific conditions.

  For non-UST petroleum releases, the recommended distance is 30 feet given the significant potential for petroleum VFCs to biodegrade in the subsurface (Attachment 2). For mixed petroleum/non-petroleum release sites, the 100-foot distance should be used during initial screening.

- **Proximity to Groundwater Plumes**
  Available groundwater information can be used to prioritize buildings for VI screening. Buildings overlying contaminated groundwater with high VFC concentrations are more likely to pose a VI risk. Shallow groundwater plumes are more likely to contribute to VI than deeper groundwater plumes. The presence of clean groundwater overlying a VFC plume can significantly reduce the potential for VI.

1B.2 – Contaminated Vapor Conduits

Buildings potentially connected to VFC subsurface sources through vapor conduits should be prioritized. Vapor conduits may include the sanitary sewer, drains, electrical pipes, or other pipes. It is important to evaluate vapor conduits because conventional methods (i.e., soil gas and groundwater sampling) may not detect the migration of VFCs through this transport mechanism. Situations where conduit air is likely to be impacted by site contamination include:

- Known discharge directly into a sewer or drain;
- Conduits intersecting soil contamination within a VFC release area;
- Conduits intersecting groundwater contamination; or
- Conduits located directly above contaminated groundwater.

In a study of dry cleaners in Denmark, VFCs in indoor air were attributable to the vapor conduit pathway in 20 percent of VI cases (Nielsen and Hvidberg, 2017). Higher risk sites are those with direct contact of sewer pipes with contaminated soil and groundwater while lower risk sites are those with sewer pipes located above, but separated, from the VFC subsurface source areas (Beckley and McHugh, 2020).

If it is determined that conduit air is likely to be impacted and the conduit(s) is connected to a building or has the potential to release vapors below a building, proceeding to an indoor air investigation (Step 3) is recommended for that building. If indoor air results indicate the presence of VFCs, but these VFCs do not appear to be migrating through subsurface soil, then sampling the air inside the vapor conduit should be considered. Hence, when indoor air is sampled to evaluate whether a VI condition exists for a building, contingency plans for vapor conduit air testing should be considered. Additionally, vapor conduits should be evaluated prior to the installation of VI mitigation systems. Conventional VI mitigation systems such as subslab depressurization may not mitigate exposures from vapor transport through conduits. See Attachment 3 for information on sewers as a potential VI pathway and the current understanding of sewer air sample collection methods.

1B.3 – Occupancy and Receptors

Currently occupied buildings should be given priority for VI evaluation. Residences and buildings with sensitive receptors, such as schools and day-care centers, should be high priority. VI evaluations should not be postponed unless it is confirmed that a building is unoccupied. Unoccupied buildings near subsurface contamination should be evaluated for potential VI prior to occupancy.

Step 1C – Select Sampling Approach: Soil Gas or Indoor Air

Some sites may be at the beginning of the investigation process, while others may be much further along but in need of a VI risk re-evaluation due to new information. In some situations, available LOEs (pre-existing information and sampling data) can be used to determine if soil gas sampling (Step 2) will be useful for screening or if it is more appropriate to go directly to indoor air sampling (Step 3). Situations that warrant proceeding to indoor air sampling include but are not limited to:

- Known or suspected release area directly below a building – External soil gas concentrations are likely lower than the concentration directly below the building at the same depth.
- Buildings near a significantly contaminated groundwater plume – Collecting soil gas concentration data before sampling indoor air (Step 3) would unduly delay direct evaluation of risk to occupants.
- Groundwater shallower than five feet beneath a building – Collecting soil gas samples may not be possible, soil gas samples may be impacted by the capillary fringe, or soil gas sample concentrations can be biased low due to ambient air infiltration.
- Buildings connected to vapor conduits that intersect significant levels of contamination.

For non-UST petroleum-only releases, pre-existing information and sampling data can be used for separation distance screening to identify when it is appropriate to consider a building low priority for further VI evaluation and proceed directly to Step 4. Separation distance screening can also indicate when it is appropriate to proceed directly to indoor air sampling. See Attachment 2 for further information on VI screening at non-UST petroleum release sites.

Step 2: Evaluate Vapor Intrusion Risk Using Soil Gas Data

Over the course of a site investigation, defining the nature and extent of contamination in all media is often an iterative process. Screening buildings for potential VI should be integrated early in the investigation to protect human health. As in many other aspects of site investigation, sampling for the full characterization of the nature and extent of the contamination may be more extensive than what is needed for initial screening for VI risk assessment. In this document, the focus is on the collection of information to assess potential risk to human health and not, for example, to develop the design of a remedy. Evaluation of VI risk typically focuses on shallow soil gas, while deeper soil gas sampling may be needed for complete subsurface source or plume characterization.

Screening for potential health risk to occupants of buildings should be conducted as soon as available information indicates the building(s) may be subject to VI–at an initial phase or during subsequent phases of a site investigation. Information that triggers screening for VI might be:

- Preliminary and qualitative LOEs such as known or suspected release of dry-cleaning solvents below a building,
- Definitive (qualitative and quantitative) LOEs from early phases of an overall site investigation, such as preliminary sampling at known or suspected release locations, or
- Definitive LOEs from later phases of the investigation conducted to address data gaps and/or further characterize distribution, such as when shallow groundwater or soil gas contamination is found to extend below off-site buildings.

Step 2 describes a general strategy to integrate VI screening into overall soil gas contamination investigations. This section first provides general guidelines for sample location and depth for the overall shallow soil gas investigation. Next, this section describes the specific samples that should be used to estimate potential health risks for occupants of current buildings or potential future buildings on open lots or redevelopment sites.

Collecting and analyzing soil gas concentration data is an appropriate early screening step to evaluate the potential for VI. Soil gas concentration data is generally preferred as a LOE for assessing VI risk over groundwater or soil matrix concentration data (USEPA, 2014c) for several reasons:

- Uncertainty in predicting contaminant partitioning from NAPL, groundwater or soil to soil gas (e.g., uncertainty in moisture content, Henry's law constants, and organic content in soil);

- Uncertainty in predicting transport through the capillary fringe;
- Heterogeneity in the soil matrix;
- Loss of VFCs during soil matrix sampling (see Attachment 1); and
- Potential VI risk posed by VFC soil concentrations less than typical reporting limits (5 µg/kg), as suggested by theoretical partitioning.

While soil gas data are the preferred LOE for assessing VI risk, soil matrix and groundwater concentration data are also useful to identify release areas, provide full characterization, and assess risk through other exposure pathways. Soil matrix and groundwater data are supporting LOEs for evaluating the VI risk and help determine soil gas sampling locations. Attachment 4 describes the use of groundwater data as a LOE for evaluating VI when soil gas data have not yet been collected or when soil gas sample collection is not feasible.

During development of sampling plans and DQO, consider collecting other LOEs that will be relevant to interpretation of shallow soil gas sampling results (see Attachment 1). The representativeness and quality of shallow soil gas data should be evaluated before it is used for decision making purposes.

Step 2A – Evaluate Distribution of Shallow Soil Gas Contamination

Soil gas sampling to screen individual buildings for VI should be integrated into the overall site characterization strategy. The objective is to evaluate the nature, distribution, and extent of shallow soil gas contamination and use that information to evaluate VI risk to building occupants. Sample locations and depths should be designed to characterize shallow soil gas contamination, near current or potential future buildings. Where soil gas contamination is extensive, this may be an iterative process with multiple soil gas sampling events stepping out laterally from suspected points of release within a site.

For non-UST petroleum release sites an additional objective is to evaluate whether there is a bioattenuation zone between petroleum subsurface sources and the building. In addition to analysis for VFC concentrations, soil gas samples should be analyzed for biogeochemical indicators (e.g., oxygen, carbon dioxide, methane) to assess bioattenuation. See Attachment 2 for further information on VI screening at non-UST petroleum release sites.

2A.1 – Soil Gas: Sampling Method

Active soil gas results should be used for assessing human health risks associated with VI. Use the sampling methods described in the Active Soil Gas Investigations Advisory (CalEPA, 2015). Current passive soil gas sampling methods are not generally accepted for risk assessment purposes but may be used as a supporting LOE as described in Attachment 1.

2A.2 – Sampling to Characterize Shallow Soil Gas Contamination

General guidelines for investigating the nature, distribution, and extent of shallow soil gas contamination are provided in this section to inform preliminary VI risk assessments. Additional guidance is provided in the DTSC 2011 Vapor Intrusion Guidance for more extensive soil gas investigations needed for reducing uncertainties in the CSM and to support interim and remedial action decisions.

Lateral Distribution

Evaluate the lateral distribution of shallow soil gas contamination. Select soil gas sample locations to help identify release areas and the distribution of contamination. In this Supplemental Guidance, the term **"release area"** is in concept *the area of estimated vadose zone soil contamination and free product extending from a primary source*. Soil gas sampling locations should initially be based on the location of known or suspected release(s), site operations, history of chemical use, topography, and geology. The sampling design should follow a grid or radial sampling pattern. Samples should be spaced to provide a good understanding of the location of all release areas and a conceptual understanding of how soil gas contamination can be transported from those areas. Placement of some of the soil gas samples will be modified by the location of current and likely future buildings, as described in Step 2A.3.

Sampling should start at the suspected points of release within a site and laterally step out until the soil gas plume is delineated. If VFC concentrations are unexpectedly elevated in certain locations, consider the presence of additional subsurface sources, highly permeable soil or fill, and vapor conduits, and adjust the sampling plan as appropriate. If vapor conduits are acting as preferential pathways, see Attachment 3, Sewers and Other Vapor Conduits as Preferential Pathways for VI, for information about sample collection methods.

Vertical Distribution

Evaluate the vertical distribution of shallow soil gas contamination. Soil gas samples from multiple depths should be collected to generate a depth profile for VFC contamination and vertically characterize shallow soil gas contamination. In general, soil gas samples should be collected from two depths within the recommended sampling range of 5 to 25 feet below ground surface (bgs). Collect one sample at approximately 15 feet below the building foundation or shallower based on groundwater depth. Collect an additional sample halfway between the building foundation and the deeper sample, ideally from the depth of maximum known or suspected soil contamination within this range. In general, the two selected shallow soil gas sampling depths should provide good coverage of the recommended sampling range. The samples should provide a reasonable understanding of the vertical soil gas VFC distribution to help identify the greatest shallow soil gas concentrations. For example, collecting soil gas sample data from at least two depths can help identify any unexpected shallow subsurface sources of soil gas contamination (e.g., soil contamination caused by groundwater depth fluctuations). The sample depths generally should be no shallower than 5 feet bgs as discussed in Attachment 1. Shallow groundwater can limit the ability to collect soil gas samples, in which case it will be necessary to rely on other LOEs.

Deeper soil gas sampling may be needed to fully characterize the vertical distribution of soil gas contamination. However, deep soil gas sampling plans will be site-specific and are beyond the scope of this guidance.

2A.3 – Soil Gas Sampling to Evaluate Risk to Building Occupants

Within the overall sampling plan to characterize shallow soil gas, select the specific locations and depths of soil gas samples that will be used to evaluate VI risk to building occupants.

Lateral Sample Location for Evaluating Risk

Current Buildings:

Soil gas data used for VI screening evaluations should be collected as close as possible to the building on the side(s) of the building where concentrations are expected to be greatest. Site-specific conditions such as utilities and access may limit options for sample placement. Samples should be located as follows:

a) *Buildings Potentially Impacted by Release Area Contamination*:
Soil gas samples should be collected between the building and the release area(s) as close to the building as possible, preferably within 10 lateral feet of the building. If access is limited or not granted, consider soil gas sampling in the nearest right-of-way.

b) *Buildings Potentially Impacted by Groundwater Contamination*
Soil gas samples should be collected between the building and the location of the maximum concentrations of VFCs in groundwater near the building, preferably within 10 lateral feet of the building.

Future Buildings:

Every potential future building or ground floor unit should have at least one soil gas sample location. For open lots without a specific development plan, use a recommended initial lateral spacing of 100 feet, starting at release area(s) and/or groundwater contamination. A sampling grid may be placed over a larger area to reduce the number of sampling mobilizations. This approach assumes that diffusion is the primary mechanism of vapor migration in the absence of preferential pathways (USEPA, 2015a). Adjustment of the lateral spacing should be based on site-specific conditions and the CSM. The soil gas data from the sample location with the greatest VFC concentrations (i.e., greatest cumulative risk) rather than site-wide average should be used for VI screening evaluations.

Vertical Sample Location for Evaluating Risk

Current Building Sample Depth:

Each soil gas sampling location should include at least two sampling depths, as described in Step 2A.2. Soil gas data from the depth with the greatest soil gas concentrations (i.e., greatest cumulative risk) should be used for VI screening evaluations. For soil gas sampling outside the building footprint, the sample depth with the greater soil gas concentrations will provide a conservative estimate of conditions immediately below the building. Less attenuation is expected beneath buildings with a slab (e.g., slab-on-grade or basement) due to the slab capping effect, which is a result of a concrete slab acting as a barrier or cap limiting the downward flow of ambient air and the upward venting of contaminated soil gas (Figure 2a) (Schumacher et al. 2010; USEPA, 2012a; Shen et al. 2014). Therefore, higher VFC concentrations collected from exterior soil gas samples located just above the shallow subsurface sources of contamination ("near-source soil gas") are less likely to underestimate subslab soil gas concentrations compared to shallower exterior soil gas samples with lower VFC concentrations (Figure 2b; DTSC, 2011a; USEPA, 2012a and 2015a).

If the subsurface vapor source at a particular building is soil or groundwater contamination that is deeper than 20 feet bgs, samples collected at approximately 15 feet below a building's foundation is expected to provide a conservative estimate of conditions immediately below the building. Soil gas samples less than 15 feet below a building's foundation is likely to underestimate the VI at buildings subject to the slab capping effect as illustrated in Figure 1b (USEPA, 2012a). Therefore, generally, the deepest soil gas samples for assessing risk when deep subsurface vapor sources are present should be approximately 15 feet below the foundation. Additional sample depths may be needed to characterize site specific conditions. The quality of shallow soil gas data should be evaluated as a LOE before it is used for decision making purposes. Quality control checks are discussed in the Active Soil Gas Advisory (CalEPA, 2015). Soil gas samples less than 5 feet bgs are generally not recommended for VI screening evaluations as discussed in Attachment 1. Barometric pressure trends at the time of sampling should be noted and used as a LOE for interpreting shallow soil gas sampling results.

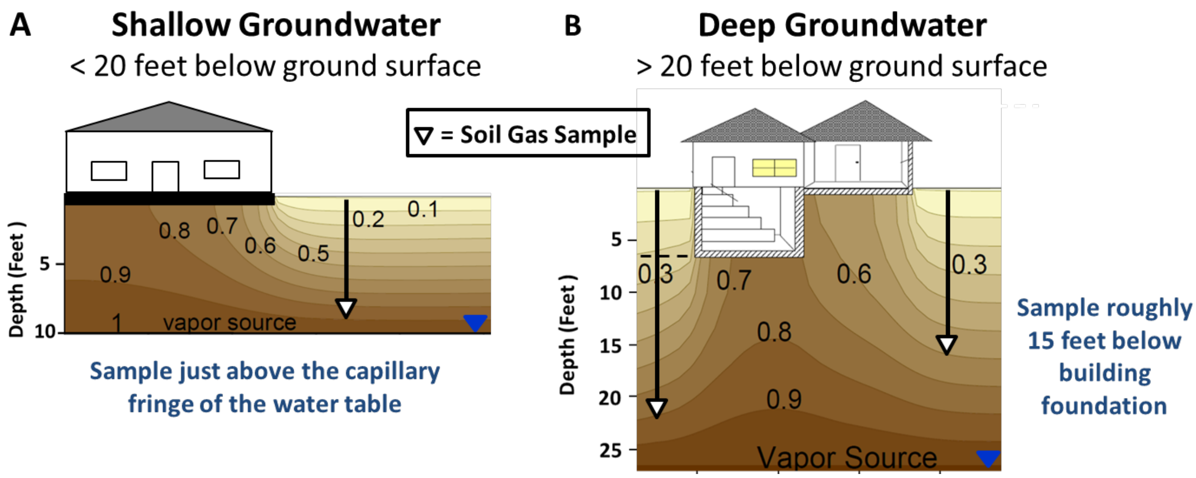

Figure 2. Diagram showing the slab capping effect for shallow or deep groundwater contamination scenarios and appropriate soil gas sampling depths for VI evaluation. The concrete slab acts as a barrier or cap that limits the infiltration of ambient air into soil and emission of contaminated soil gas to ambient air. The distribution of soil gas contamination is shown for homogeneous sand. The soil gas concentration contour lines are normalized by the subsurface source vapor concentration. Diagrams modified from *Conceptual Model Scenarios for the Vapor Intrusion Pathway* (USEPA 2012a), based on three-dimensional (3-D) mathematical model simulations (Abreu, 2005; Abreu and Johnson, 2005; 2006).

Future Building Sample Depth:

Soil gas sampling depths for VI screening evaluations at open lots or redevelopment sites should be selected as described above for existing buildings, with the following adjustments:

- Deep Subsurface Sources – When soil or groundwater contamination is greater than 20 feet bgs, the deeper of the two soil gas sample depths should be approximately 15 feet below either:
    - The planned foundation depth of the future building; or
    - The deepest potential foundation depth of likely future buildings when no current plans exist. This will be a site-specific determination based on geology/hydrogeology, property size, land use zoning, land use covenants, etc.
- Subslab Soil Gas Data at Redevelopment Sites – Subslab soil gas data collected at an unoccupied building that will be redeveloped might be used as a LOE in addition to near-source soil gas. The subslab soil gas data may not be representative of future conditions if there are extensive changes planned to the building, foundation, HVAC system, or to the space surrounding the building (e.g., extending foundation or paving adjacent to building). Post-redevelopment subslab soil gas data can also be collected to confirm future VI risk determinations.

Covering the ground surface with new building foundations, pavement or other surface cover is expected to result in reduced VFC emissions to ambient air and increased shallow soil gas concentrations ("capping effect") (Schumacher et al., 2010; USEPA, 2012a; Shen et al., 2014). Therefore, the sample collected from the depth with the greatest detected soil gas concentrations should be used to estimate potential VI health risk for occupants of future buildings, similar to the recommendation for current buildings.

Step 2B – Estimate Human Health Risk from Vapor Intrusion

The incremental cancer risk and noncancer hazard associated with indoor air exposure to chemicals of potential concern through the VI pathway should be estimated from soil gas concentration data collected in Step 2A. Preliminary screening of risk and hazard should be evaluated as described in the following sections.

2B.1 – Estimate Potential Indoor Air Concentration

Estimate the potential indoor air concentration of the VFC(s) (C_{IA} in micrograms per cubic meter (µg/m^3)) using Equation 1. Use the maximum concentrations detected in soil gas (C_{SG} in µg/m^3) samples located between the building and subsurface source, and closest (laterally) to current buildings or within the footprint of future buildings. The applicable AF should be used to estimate indoor air concentrations for screening at all buildings (see Introduction Sections D1 and D2). For non-UST petroleum release sites, see Attachment 2 for the adjusted equation where an adequate bioattenuation zone is present.

$$C_{IA} = C_{SG} \times AF$$

Equation 1

2B.2 – Estimate Cancer Risk and Noncancer Hazard Quotient

Calculate the cancer risk and noncancer hazard quotient (HQ) using the estimated C_{IA} from Equation 1. Select either the standard (Equations 2 and 3) or the simplified equations (Equations 4 and 5) as follows:

- **Standard Equations** – Input the most current chemical-specific toxicity criteria consistent with the regulation "Toxicity Criteria for Human Health Risk Assessment" (California Code of Regulations, Title 22, Division 4.5, Sections 68400.5, 69020-69022) and default receptor-specific exposure factors (current DTSC Human Health Risk Assessment (HHRA) Note 1 or SF Bay Regional Water Board's ESLs). For a listing of both required and recommended toxicity criteria see the most current DTSC HHRA Note 10.

$$\text{Cancer Risk} = \frac{C_{IA} \times IUR \times ET \times EF \times ED}{AT_c \times 365 \text{ days/year} \times 24 \text{ hrs/day}}$$

Equation 2

Equation 2 should be modified when appropriate to incorporate factors to account for susceptibility from early-life exposure to carcinogens (OEHHA, 2009; USEPA, 2005a; USEPA 2005b; USEPA 2020).

$$\text{Hazard Quotient} = \frac{C_{IA} \times ET \times EF \times ED}{RfC \times AT_{nc} \times 365 \text{ days/year} \times 24 \text{ hrs/day}}$$

Equation 3

IUR = Inhalation Unit Risk (cubic meter per microgram ($m^3/\mu g$))
RfC = Reference Concentration ($\mu g/m^3$)
ET = Exposure Time (hours per day)
EF = Exposure Frequency (days per year)
ED = Exposure Duration (years)
AT_c = Averaging Time for Carcinogens (years)
AT_{nc} = Averaging Time for Noncancer Toxic Effects (years), equal to ED

- **<u>Simplified Equations</u>** – Use indoor air (IA) screening levels (SLs) that are consistent with the site's conceptual model and exposure scenario. The appropriate cancer and noncancer IA SLs recommended by the oversight agency should be used (current DTSC HHRA Notes 3 through 5 and SF Bay Regional Water Board ESLs). The C_{IA} and IA SL inputs should have the same units (e.g., $\mu g/m^3$).

$$\text{Cancer Risk} = \frac{C_{IA} \times (1\times10^{-6})}{(\text{IA Cancer SL})}$$

Equation 4

$$\text{Hazard Quotient} = \frac{C_{IA} \times 1}{(\text{IA Noncancer SL})}$$

Equation 5

2B.3 – Estimate Cumulative Risk and Hazard

When more than one VFC is present, the cumulative cancer risk from all carcinogenic VFCs is calculated by summing the chemical-specific risks. The hazard index (HI) is calculated by summing the respective chemical-specific HQs for all detected VFCs. The HQs for noncarcinogenic toxicity posed by carcinogenic contaminants must be included. If the HI exceeds 1, then the HI may be recalculated for chemicals which have the same toxic manifestation or which affect the same target organ.

2B.4 – Evaluate Risk

For all site- and building-specific decisions, the nature and magnitude of potential risk and hazard and available LOEs should be evaluated. If the cumulative risks based on soil gas concentration data are below the points of departure (1×10^{-6} for cancer risk and 1 for HI), then proceed to Step 2C. **If the estimated risk or hazard exceeds the point of departure based on soil gas data, proceed to Step 3 for an indoor air investigation at current buildings.** The nature and magnitude of risk or hazard may indicate that indoor air sampling in Step 3 should be expedited or that proceeding directly to Step 4 for prompt implementation of mitigation measures is necessary to reduce risk or hazard. If the estimated risk or hazard exceeds the point of departure and the building is unoccupied or no building is present, proceed to Step 4 for site-specific evaluation, risk assessment refinements, and risk management decisions.

On a building specific basis, if the risk or hazard exceeds but is near the point of departure and LOEs are not consistent, a near-term interim step of collecting additional LOEs (including additional soil gas sampling) may be appropriate, before moving to Step 3 or 4, provided contamination does not pose a short-term hazard.

Step 2C – Evaluate Temporal Variability

When risk calculated from a single sampling event is below the points of departure, at least one additional sampling event is recommended before concluding that subsurface contamination is unlikely to pose a health risk. Contaminant plume migration and seasonal factors, including but not limited to, weather conditions, groundwater levels, soil temperature, and soil moisture, can cause significant temporal variability in soil gas contaminant concentrations. The second sampling event may not be warranted if VFCs are not detected in any environmental media within 100 feet and other LOEs agree that VI is unlikely (e.g., stable contaminant plume that is not likely to reach the building of interest).

2C.1 – Sampling Frequency

Soil gas probes should be sampled at least twice, in different seasons (e.g., as determined by average seasonal temperatures, precipitation [levels of rain/snow fall], or depth to groundwater).

2C.2 – Re-Evaluate Risk

The results of each sampling event should be evaluated for potential cancer risk and hazard as described in Step 2B.

Step 2D – Next Steps

Next steps are based on the nature and magnitude of potential risk and hazard and evaluation of available LOEs. If VFCs were not detected in any environmental media (Step 2A and 2C) or if after the additional sampling events, risk and hazard are confirmed to be below the points of departure, and LOEs are generally consistent, the building is considered low priority for further VI evaluation. Proceed to Step 4 for potential next steps at low priority current and future buildings. If the cumulative risk or hazard based on soil gas concentration data exceeds the point of departure, proceed to Step 3 for an indoor air investigation at current buildings. The nature and magnitude of risk or hazard may indicate that proceeding directly to Step 4 for prompt implementation of mitigation measures is necessary to reduce risk or hazard. If the building is unoccupied or no building is present, proceed to Step 4 for site-specific risk assessment refinements and risk management decisions **once the full site investigation is complete**.

On a building specific basis, if the risk or hazard are near the point of departure, and LOEs are not generally consistent, collecting additional LOEs, including additional soil gas sampling, may be appropriate to refine the CSM before moving to Step 3 or 4, provided contamination does not pose a short-term hazard.

Step 3: Indoor Air Investigation – Identify Buildings Where Vapor Intrusion is Occurring Using Concurrent Indoor Air, Subslab Soil Gas, Soil Gas, and Outdoor Air Sampling Data

Step 3 describes an indoor air investigation to determine if VI is occurring and to assess potential human health risks posed by subsurface VFCs migrating into indoor air. This section first provides recommendations regarding public participation activities needed to ensure the success of indoor air investigations. Next, this section describes a series of steps for the indoor air investigation from the building survey through multiple rounds of sampling and data interpretation.

Indoor air results are the primary LOE when evaluating risk to current occupants because they indicate the chemicals and concentrations to which receptors are exposed regardless of pathway (e.g., migration from the subslab region, migration via vapor conduits). Interpretation of indoor air results can be challenging due to the potential presence of VFCs in indoor air from non-subsurface or background sources. Background sources of VFCs include consumer products, chemical usage, building materials, or outdoor (ambient)[6] air (USEPA, 2011). For a slab-on-grade building, subslab soil gas and outdoor air concentration data should be concurrently collected with indoor air concentration data as part of a multiple LOEs approach, which decreases uncertainty and the challenges posed by the potential presence of VFCs. Subslab soil gas sampling results are used for characterizing the presence and concentrations of VFCs immediately below a building that can migrate into indoor air. Outdoor air

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[6] USEPA defines ambient air as the outdoor air surrounding a building or site (USEPA, 2015a). Outdoor air and ambient air are used interchangeably in this Supplemental Guidance.

sampling results are used to determine potential influences of outdoor air on indoor air quality.

Step 3A – Public Participation

The activities associated with indoor air investigations can be complex, stressful, and disruptive to building owners and occupants. The project team should acknowledge, evaluate, and address concerns throughout the investigation, evaluation, and if necessary, mitigation process. Creating open communication, clearly explaining what to expect, and addressing concerns should lead to a cooperative working relationship. Additional benefits include improved credibility, reduced delays, and broader public support. Developing a cooperative working relationship with owners and occupants for risk communication and gaining access for sampling is critical.

To minimize disruptions, be flexible with owners and occupants when looking for indoor sources of VFCs (e.g., inspecting cabinet contents), placing sampling equipment, or drilling through floors to install subslab vapor probes. The results of indoor air investigations should be communicated promptly to owners and occupants.

Step 3B – Conduct In-Depth Building Survey

The in-depth building survey should be used to support the:

- Development of a conceptual understanding of how VI may be occurring at the building;
- Design of the building-specific sampling plan to be implemented in Step 3C;
- Identify and address indoor sources of VFCs; and
- Interpret sampling results (e.g., determine whether VI is occurring) in Step 3D.1.

Building survey activities include visually examining the building (interior and exterior) and surrounding area, reviewing building layout and drawings, interviewing occupants, and conducting field screening.

Field screening information collected from in-depth building survey activities should be evaluated and used in designing the building-specific sampling plan in Step 3C. The information should be documented on the Building Survey Form (see Attachment 6) and reported.

3B.1 – Identify Building Type, Characteristics, and Condition

Document information about the building, including but not limited to, the design, use, age, size, dimensions, number and types of rooms, foundation/slab condition, and occupancy. When evaluating building use it is important to understand:

- Operation of a building's HVAC[7] system for selecting appropriate sampling locations and for interpreting the results of the indoor air investigation. Consider consulting the building engineer or other person with knowledge of the building's HVAC system.
- How occupants use windows and doors to ventilate the building. This will be useful in understanding typical use conditions, designing the building specific sampling plan, and interpreting the data.

See Attachment 6 for a comprehensive list. See the Vapor Intrusion Guidance (VIG) (DTSC, 2011a) for more information on conducting a building survey.

3B.2 – Locate and Remove Potential Indoor Sources of Vapor Forming Chemicals

As part of the building survey, identify and remove potential indoor sources (e.g., cleaners, glues, fingernail polish remover, aerosol sprays, paint, and dry-cleaned clothes) provided the occupants allow removal. USEPA recommends removal 24 to 72 hours before a sampling event (USEPA, 2015a). Not all indoor sources may be identifiable or removable. For example, VFCs adsorbed to carpets or other fabrics may continue to off-gas into indoor air and may be detected in indoor air samples. Introduction of new indoor sources prior to and during the sampling period also should be avoided, and if unavoidable, should be clearly documented and explained. In some situations, due to significant chemical usage, indoor air sampling may not be definitive, and an alternative approach may be undertaken (e.g., reliance on subsurface data, controlled pressure methods). Information about background sources include USEPA (2011) and MDEQ (2012). In addition, the Consumer Product Information Database (http://www.whatsinproducts.com/) provides information regarding the chemical content of consumer products.

3B.3 – Conduct Field Screening for Vapor Forming Chemicals Using a Sufficiently Sensitive Field Instrument

The purposes of field screening are to identify vapor entry points, and to identify indoor sources. This information should be used in the design of the building-specific sampling plan in Step 3C and facilitate interim mitigation (e.g., seal cracks or fill dry p-traps). Screening can include using field instruments or collecting grab samples for laboratory analysis. Direct readings or grab samples may be collected near possible indoor sources or near suspected vapor entry points. Field instruments that can detect low levels (e.g., parts per billion by volume detection limits) and speciate compounds are recommended over instruments that are less sensitive (e.g., parts per million by volume detection limits) or that only measure the total concentration of detectable VFCs. Other

[7] HVAC as used in this document refers to all types of heating, cooling, or ventilation systems in both residential and commercial buildings.

considerations in selecting instruments include reliability, calibration requirements, sensitivity to moisture, cost, and personnel training and experience for proper use.

3B.4 – Document Potential Outdoor Sources in the Surrounding Area

During the field screening, document information about nearby businesses or other operations that may emit VFCs to outdoor air. These can include gasoline stations, gasoline-powered engines, chemical storage areas, dry cleaners, and remediation or mitigation systems.

Step 3C – Evaluate Spatial Distribution

The distribution of VFCs inside and beneath a building should be investigated by collecting indoor air and subslab samples at multiple locations throughout the building. Outdoor air samples should be collected to evaluate the potential influence of ambient air on indoor air quality and aid in the interpretation of indoor air results.

Step 3C describes a generic sampling design and recommended numbers and locations of indoor air, subslab, and outdoor air samples for a small slab-on-grade building (1,500 square feet or less). The actual number, and locations of samples should be based on findings of the building survey and proposed in a building-specific sampling plan. In general, indoor air samples should be collected under typical use conditions as determined during the building survey. The sampling plan should include contingencies for adjusting sample locations and potential response actions that may be warranted to protect occupants. The VIG (DTSC, 2011a) summarizes the additional information to be included in a building-specific sampling plan.

3C.1 – Indoor Air: Sampling Method

Indoor air samples should be collected in accordance with the VIG (DTSC, 2011a), except where this Supplemental Guidance supersedes (e.g., locations and numbers of samples and sampling events). If the subsurface contamination is well characterized, the analyte list might be limited to the known or suspected subsurface VFCs. The field quality assurance/quality control (QA/QC) protocols for the collection of the indoor air samples should follow the recommendations in the VIG (DTSC, 2011) concerning canister certification, field duplicates, and trip blanks. Laboratories should follow the QA/QC protocols within the USEPA analytical method regarding instrument calibration, holding times, recovery acceptance, and calibration verification.

Time-integrated samples are preferred for sampling indoor air to evaluate chronic exposures because time-integrated samples characterize the average daily inhalation exposure for building occupants. Expedited turnaround times for laboratory analyses may be appropriate given the priority (Step 1) and subsurface threat level (Step 2 or existing information). Typical sampling methods include:

- Conventional sampling methods (e.g., canisters) typically have sampling durations of 24 hours for residential exposure and 8 hours for workplace exposure. However, longer duration samples (e.g., weeks) can be collected with canisters (ESTCP, 2020).

- Passive sampling methods also are suitable for collecting time-integrated indoor air samples. Appropriate use of passive samplers requires knowledge of the target chemicals, sorbent capabilities, and required detection limits. Passive samplers may not be suitable for all chemicals of concern due to challenges posed by chemicals with weak sorption characteristics. Practitioners should confirm with the passive sample supplier that the available uptake rates and reporting limits for target VFCs are viable. This information should be documented in the building-specific sampling plan. Detailed information on passive samplers is presented in *Engineering Issue: Passive Samplers for Investigations of Air Quality: Method Description, Implementation, and Comparison to Alternative Sampling Methods* (USEPA, 2014d).

3C.2 – Subslab Soil Gas: Sampling Method

Subslab soil gas samples should be collected in accordance with the Active Soil Gas Investigations Advisory (CalEPA, 2015). Subslab samples are typically grab samples. To avoid potential cross-contamination of indoor air samples from VFCs released during probe installation, purging, and sampling, subslab samples should be collected soon after indoor air samples (e.g., within 8 to 24 hours;). Alternatively, if subslab samples must be collected before indoor air sampling, allow sufficient time for subsurface VFCs released into indoor air during subslab sampling to dissipate (generally 24 to 72 hours, USEPA 2015a). Exterior soil gas sampling may be used as a surrogate for subslab sampling on a site-specific basis (e.g., permission to drill through floors is declined). However, exterior soil gas is unlikely representative of the concentration below the slab if the release occurred within or just below the building footprint.

3C.3 – Outdoor Air: Sampling Method

Outdoor air samples should be collected in accordance with the VIG (DTSC, 2011a) using the same method as indoor air sampling. USEPA generally recommends beginning ambient air sampling at least one hour before indoor air monitoring begins, but preferably two hours, and continuing to sample until at least 30 minutes before indoor monitoring is complete (USEPA, 2015a). This practice is recommended because most residential buildings have an air exchange rate in the range of 0.25 to 1.0 exchanges per hour. Recommended lag times may need to be adjusted for nonresidential buildings with different air exchange rates (e.g., lag times may be shorter if the expected indoor air exchange rate is higher for a nonresidential building). If the subsurface contamination is well characterized, the analyte list may be limited to the indoor air analyte list.

3C.4 – Indoor Air and Subslab Soil Gas: Location and Number of Samples

Paired indoor air and subslab samples are recommended to provide information about the source(s) of indoor air contamination by comparing detected VFCs concentrations in the subslab to concentrations in indoor air. Collect a sufficient number of co-located indoor air and subslab sample pairs per building to provide coverage across the building footprint, targeting these locations:

1) Primary living/work areas (e.g., bedroom, living room, or office).
2) Near slab/floor penetrations (e.g., bathroom, kitchen, or laundry room). Field screening results from Step 3B.3 may be helpful in selecting sampling locations.
3) Near suspected maximum subsurface contamination (e.g., near the center of the building, or known subsurface source).

For situations where the targeted locations are clustered in one area of a building due to the layout, additional locations should be sampled as needed for spatial coverage. The recommended number of sample pairs to provide adequate spatial coverage is three for a small building (≤1,500 ft^2) that has a single floor, has a single HVAC zone, and where the foundation is not segmented (e.g., grade beams). The section Application to Other Building Types provides further discussion for large and multistory buildings, crawl space buildings, and buildings with above-grade or below-grade parking structures. The proposed number of samples should be documented in the building-specific sampling plan and depends on building foundation type, size, internal configuration (e.g., layout, floors, rooms), use, ventilation (e.g., number of HVAC zones), and occupancy as determined during the building survey. Indoor air samples should be collected in the breathing zone (e.g., 3 to 5 feet above the floor for adults).

Sampling subslab soil gas is recommended as an LOE used to:

- Understand the extent and magnitude of VFC contamination beneath the building;
- Assess potential current and future VI risk; and
- Assist with distinguishing between indoor air VFCs originating from the subsurface contamination versus those originating from indoor or outdoor sources.

Subslab soil gas and indoor air sample pairs should be collected concurrently, which means that they should be collected as close together in time as possible while minimizing the potential for release of VFCs into indoor air during the subslab sampling process (see subslab sampling method paragraph above). Sampling concurrently, rather than in separate events, reduces temporal uncertainty and minimizes disturbance to building occupants.

3C.5 – Outdoor Air: Location and Number of Samples

A sufficient number of outdoor air samples should be collected to provide spatial coverage around the building to address potential changes in wind direction. Generally, three samples are recommended (DTSC 2011a). The proposed number and location of outdoor air samples should be included in the building-specific sampling plan.

Outdoor air samples should be collected at approximately six feet above the ground surface. Outdoor air sample locations should not be placed in the vicinity of localized outdoor sources (e.g., gasoline stations, gasoline-powered engines, chemical storage areas, dry cleaners, and remediation or mitigation systems). In addition, outdoor air samples should be placed where influences from subsurface sources are minimized (e.g., where outdoor air is not directly influenced by the release, and far from vent pipes). If subsurface VFCs are emitting to outdoor air at measurable concentrations, outdoor air results should not be considered ambient background. The results of samples placed near localized subsurface sources could promote an incorrect conclusion that outdoor source(s) are present. Professional judgement based on available LOEs should be used to interpret the contributions of outdoor air, subsurface sources, and indoor sources on concentrations detected in indoor air.

3C.6 – Additional Concurrent Lines of Evidence

Additional LOEs may be gathered concurrently with the indoor air sampling as follows:

- Differential Pressure Measurements – Measuring the pressure difference between the subsurface and indoor air (cross-slab pressure differential) indicates whether subsurface VFCs are potentially migrating into the building (i.e., depressurized building interior) or not (i.e., pressurized building interior) (USEPA, 2015a)) and is analogous to using the flow direction and gradient when interpreting groundwater data. The data may be helpful in interpreting indoor air results and in determining the best times and locations for future indoor air sampling (Schuver et al., 2018). See Attachment 1 for more information.
- Exterior Soil Gas Sampling – Soil gas data are useful for identifying the subsurface VFCs of concern and their concentrations. Soil gas sampling concurrently with the indoor air investigation should be considered for the following situations: (1) soil gas sampling has not yet been performed (e.g., the investigation began with Step 3); (2) only one soil gas sampling event has been performed (e.g., the indoor air investigation was initiated after the first soil gas sampling event after completion of Step 2B); (3) subslab soil gas samples cannot be collected during Step 3 (e.g., permission denied, physical access limitations); and (4) existing soil gas data are not representative (e.g., the data are not current, subsurface concentrations or conditions have changed). To provide the best comparison, soil gas samples should be collected concurrently with indoor air, ideally within 48 hours (USEPA 2012b).

- Vapor Conduit Air Sampling – If the indoor air investigation is undertaken because subsurface conduit air is likely impacted, per Step 1B.2, and the conduit is connected to a building or has the potential to release vapors below a building, vapor conduit air sampling should be performed concurrently with the indoor air investigation. If the source of indoor air VFC detections is unclear during interpretation of the data collected during Step 3C, vapor conduit air sampling should be considered during subsequent sampling events (Step 3E). Attachment 3 discusses sewer and other vapor conduit sampling methods.
- Vapor Entry Point Air Sampling - Indoor air may be screened as described in Step 3B.3 to assess whether VFCs are entering through particular features (e.g., cracks, openings to the subsurface). Vapor entry point samples typically are collected close to the feature rather than at breathing height. These data are used to interpret other indoor air results. Even if no VFCs are detected, VI may still be occurring under other conditions or at different vapor entry points.

Step 3D – Assess Risk from Contaminated Indoor Air and Subslab Soil Gas

This section describes the process to assess risk from VI. First evaluate the indoor air, subslab, and outdoor air data collected in Step 3C along with available LOEs to determine whether VI is occurring. Next, if VI is occurring, estimate the incremental cancer risk and noncancer hazard associated with all appropriate indoor air investigation data.

3D.1 – Determine Whether Vapor Intrusion is Occurring

The primary objective of the indoor air investigation is to determine whether subsurface VFCs are entering the indoor environment. Indoor air sampling results should be interpreted considering all available LOEs. If VI is determined to be occurring, then proceed to Step 3D.2 to estimate risks. If VI is determined not be occurring, proceed to Step 3E. Considerations for the LOEs developed during Step 3 are provided herein:

- Chemicals of Potential Concern (COPC) – The available subsurface data should be used to identify the chemicals of potential concern. See the Preliminary Endangerment Assessment Guidance Manual for information on how to identify COPCs (DTSC, 2015).
- Comparison of Subsurface and Indoor Air Sampling Results –
  - Constituent Ratios – Evaluating the ratio between concentrations of different chemicals in soil gas, subslab, and indoor air may help to confirm that indoor air impacts are due to VI. The relative ratios of VFC concentrations for many indoor and outdoor sources will be distinct from subsurface-derived VFC ratios. If the ratios of constituents in the indoor air are similar to the ratios observed in soil gas, one may conclude that the two are linked and that confounding sources are not likely present. This is

a reasonable assumption for shallow soil gas because volatile subsurface contaminants will move into indoor air at similar rates, when advection dominates.
    - Attenuation Factor Comparison – VI typically is driven by advection, thus VFCs move at approximately the same rate from beneath the building into indoor air. Therefore, chemical-specific AFs derived from indoor air and subsurface sampling data should be similar among the VFCs. If a chemical has a much larger AF than the other VFCs, it may indicate the presence of indoor or outdoor sources. For example, if the following subslab AFs are calculated: tetrachloroethylene (PCE) AF = 0.1, TCE AF = 0.0009, and cis-1,2-dichloroethylene AF=0.0011. These results indicate indoor or outdoor sources of PCE may be contributing to the elevated indoor air concentrations of PCE, in addition to VI. In this example, PCE should not be eliminated in the risk assessment; however, the understanding that indoor and/or outdoor sources are likely present will influence risk management decisions.
- <u>Indicator Chemicals</u> – VFCs not common in consumer products or typically not in ambient air can be indicative of VI when detected in subsurface and indoor air samples.
- <u>Outdoor Air Results</u> – Outdoor air sampling results are used to evaluate whether detections in indoor air samples could be the result of VFCs present in ambient air. In general, VI is not identified as the likely source of a chemical in indoor air unless indoor air VFC concentrations are greater than those found in outdoor ambient air samples.
- <u>Presence of Non-Subsurface Sources of Indoor Air Contaminants</u> – Consumer products that could be an indoor source of VFCs should have been removed during the building survey. However, building materials and furnishings can absorb VFCs and off gas for some time, even after the primary source has been removed.
- <u>Vapor Conduit Air Results</u> – If collected (Step 3C.6), vapor conduit air sampling data should be used as a LOE in determining whether VI is occurring through conduits.
- <u>Vapor Entry Point Results</u> – If collected (Step 3C.6), vapor entry point sampling data should be used as a LOE in determining whether VI is occurring. If the concentrations in vapor entry point samples are greater than those in the breathing height indoor air samples, this suggests VI is occurring. These pathway samples may be compared to indoor air screening levels as a conservative estimate of the potential risk.

3D.2 – Estimate Risk from Indoor Air Data

If VI is determined to be occurring in Step 3D.1, the indoor air samples collected from the breathing zone during the first sampling event (Step 3C) should be used to assess potential human health risks. The maximum measured indoor air concentration should be input into either the Standard Equations (Equations 2 & 3) or the Simplified SL Equations (Equations 4 & 5) in Step 2B. The appropriate receptor exposure parameters and the corresponding inhalation toxicity criteria are entered into the Standard Equations (see Step 2B.2); conservative default exposure parameter values should be used for screening. Alternatively, the Simplified SL Equations can be used when the CSM and the exposure scenario are consistent with those used to develop the risk-based indoor air screening levels (current DTSC HHRA Notes 1, 3, 4, and 10; current SF Bay Regional Water Board ESLs).

3D.3 – Estimate Potential Future Risk from Subsurface Data

Even when indoor air concentrations are low, potential risk associated with the subsurface VFC concentrations should also be estimated because changes in site or building conditions over time may increase VI and indoor air concentrations. For example, soil settling beneath the building or earth movement may increase openings in the foundation and enhance vapor entry. Building remodeling, changing ventilation or HVAC operation, and paving/covering the area surrounding the building are other changes that may affect VI. The risk and hazard under possible future conditions are estimated by:

- Predicting potential future indoor air (IA) concentrations using the maximum soil gas (SG) or subslab (SS) concentrations and generic, conservative AFs in Equation 1 of Step 2B; and
- Calculating the potential future indoor air risk and hazard, inputting the predicted future indoor air concentration into either the Standard Equations (Equations 2 & 3) or the Simplified SL Equations (Equations 4 & 5) as described in Step 2B.

3D.4 – Assess Cumulative Risk

The cumulative incremental cancer risk from carcinogenic VFCs should be calculated by summing all chemical-specific cancer risks. The HI for the VI pathway should be calculated by summing the chemical-specific HQs, including the HQs for noncarcinogenic effects posed by carcinogenic contaminants. If multiple chemicals are present and the HI exceeds 1 but HQs for individual chemicals are each less than 1, a toxicological evaluation to segregate chemicals by target organ(s) and/or mechanisms of action may be conducted to further evaluate hazard (DTSC, 2011a; DTSC, 2016). Risk from all potentially complete exposure pathways should be considered as part of the sitewide evaluation and is outside the scope of this document.

3D.5 – Evaluate Risk

Cumulative risks and hazard indices (HI) estimated from both indoor air data and from subsurface data should be used in the determination of appropriate mitigation and remediation response actions (see Step 4). If estimated risk or hazard exceeds the point of departure, proceed to Step 4. If all calculations of risk, based on both indoor air and subsurface data, do not exceed the point of departure, proceed to Step 3E to assess temporal variability.

Risk characterization integrates quantitative and qualitative LOEs into the VI risk assessment and identifies the important strengths and uncertainties for each component of the assessment as part of the discussion of the confidence in the risk assessment (USEPA, 1989 and 1995). Risk characterization is not considered complete unless the numerical expressions of risk are accompanied by explanatory text interpreting and qualifying the results (USEPA, 1989). In addition to exposure estimates and uncertainties, the chemical-specific toxicity and uncertainties must be considered when evaluating potential risks. For example, excessive hazard from acute or relatively short-term exposures, such as the developmental effects of TCE, may warrant more immediate and/or additional actions than in cases when the concern is linked to the effects resulting only from long-term exposure.

Step 3E – Evaluate Temporal Variability

The goal of Step 3E is to understand the variability of indoor air contamination over different seasonal, meteorological, and ventilation (e.g., HVAC operation, use of doors/windows) conditions.

The current understanding of VI is that heating of buildings during cold weather typically induces greater depressurization of the building relative to the subsurface, resulting in increased VI and higher indoor air concentrations of VFCs. However, other conditions may also increase VI, such as closed windows and doors, mechanical ventilation (e.g., exhaust fans), strong directional winds, and increased temperature of the roof and highest enclosed space on sunny days. Indoor air concentrations can also increase when the indoor air exchange rate is decreased. This situation may occur even on temperate days when building occupants close windows and doors to avoid poor ambient air quality or allergens, or for security purposes, thereby decreasing natural ventilation and indoor air exchange with outdoor air. The wide ranges in California geography, local climates, and building construction and conditions require consideration of many additional factors when planning site and building-specific sampling. Therefore, sampling is needed under different seasonal, meteorological, and ventilation conditions to evaluate temporal variability for a building.

3E.1 – Sampling Frequency

The sampling described in Step 3C should be repeated for one or more additional events, for a total of at least two events, before a building is considered low priority for VI. The second sampling event should be conducted in a different season (e.g., as determined by average seasonal temperatures). If needed as described below, an additional sampling event should be conducted at least one to two months after the second event.

One of the sampling events described above should include both HVAC-On and HVAC-Off scenarios to determine the effects of the HVAC operation on VI. This means two periods of sampling as part of that event: one period with the HVAC on and one period with the HVAC off. This captures a range of possible conditions and resulting risk to occupants, if HVAC use changes. For HVAC-On conditions, the HVAC should be operated for 36 hours using typical heating and cooling settings prior to sampling (HVAC system cycling on and off normally). HVAC-Off conditions can include non-operation of an HVAC system or fans and/or closed doors and windows. If possible, this evaluation should be conducted when operation of the HVAC system is most likely to increase VI as determined by building specific conditions and operations. For the HVAC-Off scenario, the sampling duration should begin with closed doors and windows at least 36 hours following shutdown of the HVAC (no outdoor air intake into the building), and continue while HVAC systems remain off (USEPA, 2013b).

HVAC-Off sampling should only be conducted when it is safe and feasible to do so. Other methods that could be proposed to evaluate the effect of HVAC operation on VI risk include continuous monitoring and controlled pressure methods. Methods for building VI evaluation are rapidly evolving. Practitioners should work with the regulatory agency to determine the appropriate implementation of these methods. See Attachment 1 for more information on LOEs.

If the CSM is robust and supported by multiple LOEs, two sampling events (including an HVAC assessment) may be sufficient to evaluate temporal variability. To make this decision, the following conditions should be met:

- The events are conducted in different seasons.
- Subsurface VFCs are either not detected in indoor air samples or the cumulative risk and hazard associated with detected concentrations are consistently below threshold values.
- No other indications of VI (e.g., elevated concentrations detected in pathway samples).
- All subsurface data demonstrate that contaminant concentrations are stable or decreasing across multiple sampling events.

If these conditions are not met, an additional sampling event should be conducted to evaluate temporal variability at least one to two months after the last sampling event. Based on the available information and areas of uncertainty, sampling may be conducted under typical use conditions or with modifications to HVAC.

3E.2 – Re-Evaluate Risk

After each sampling event, risk and hazards should be assessed in accordance with Step 3D. Risk characterization should also describe spatial and temporal variability in indoor air concentrations of VFCs migrating from the subsurface.

Step 3F – Next Steps

Based on all available LOEs, the next step to address current and future VI risk should be determined, as follows:

Current VI Risk:

- If VI is occurring and indoor air results indicate a cumulative cancer risk or HI exceeding the points of departure, then proceed to Step 4A.2 or 4B for site-specific current risk assessment refinements and current risk management decisions. Based upon the nature and magnitude of potential risk it may be appropriate to expedite mitigation measures.
- If after the conclusion of all sampling events, the indoor air risk levels are consistently below the points of departure, and there are no other indications that VI is occurring, the building would be considered low priority for current VI. Proceed to Step 4B.1 for potential next steps at the building.
- If the results are inconclusive (e.g., the breathing zone concentrations are below levels of concern while the pathway samples are elevated), then consider proceeding to Step 4A.2 or 4B for site-specific current risk assessment refinements and current risk management decisions.

Future VI Risk:

- If subsurface LOEs indicate the potential for excess VI risk to future receptors, then proceed to Step 4A.3 or 4C for site-specific future risk assessment refinements and future risk management decisions.
- If, after the conclusion of all sampling events, the risk and hazard based on subslab concentrations are consistently below the points of departure, the building would be considered low priority for future VI. Proceed to Step 4C.1 for potential next steps at the building.

Step 4: Current and Future Risk Evaluation and Management Decisions

Step 4 describes the process of using the characterization of health risks and all LOEs, both qualitative and quantitative, to determine the appropriate response action(s). Selection of specific response action(s) and timing should be made on a site-specific basis, considering all media, all LOEs, project objectives, and input from stakeholders. Remediation and mitigation decisions for VI should be made on a site-specific basis in consideration with all other potential exposure pathways at the site.

This section distinguishes between current and future risk where the latter includes two aspects: (1) future exposures at existing buildings due to changes to land use, building occupancy, building use, or building condition; and (2) future exposures in new buildings (e.g., development, redevelopment). While indoor air sampling data is the preferred LOE for assessing current risk to building occupants, subsurface sampling data is the preferred LOE for estimating potential future risk. Future risk has long been considered in risk assessment (USEPA, 1989 and 1991), and risk assessments typically include hypothetical exposure scenarios for reasonably foreseeable future land uses. However, as discussed in USEPA (2015a), consideration of future use is more complex for the VI pathway because of the complex ways that buildings can influence VI. Changes to the following factors may influence future VI risk:

- Land Use (e.g., commercial to residential, increased density)
- Building Use and Condition – Changes can alter an existing building's VI susceptibility. New or remodeled buildings may have different susceptibilities compared to previous structures on a property. Specific aspects include:
    - Occupancy (e.g., changes to work shifts, presence of sensitive receptors);
    - Hours of use;
    - Site development (e.g., new construction);
    - Building structure (e.g., settling, modifications, damage from catastrophic events); and
    - Building operation (e.g., new HVAC system, changed HVAC operation).
- Subsurface Conditions – Changes can alter soil permeability, moisture, or oxygenation and cause subsurface contaminant redistribution, such aspects include:
    - Surface grading, soil removal, or soil import;
    - Trenching and utility installation (create preferential pathways);
    - Building cover, hardscape, or pavement (enhance capping effect);
    - Landscaping/pavement removal (reduce capping effect);
    - Irrigation system (increase soil moisture); and
    - Water table fluctuations.

Step 4A – Risk Assessments to Support Risk Management Decisions

Table 3 illustrates the typical sampling data used when determining appropriate response actions for addressing both current (Step 4B) and potential future (Step 4C) VI risk. While the indoor air data for an existing building may indicate no current significant VI potential, it is important to recognize that subsurface contamination can remain a potential VI concern into the future. Changes to existing buildings may result in increased VI susceptibility. Therefore, VI risk and hazard calculations should primarily be based on indoor air data (from Step 3) for current building occupants and on subsurface data (from Step 2 and Step 3) for future occupants of existing or future buildings.

The preliminary risk assessment for current and future VI risk (Steps 2B and 3C) should be sufficient to help determine appropriate initial response actions for most sites. However, as more information and data become available and the CSM is updated, the risk assessment may be refined to help identify more site-specific response actions (Steps 4A.2 through 4A.4). During this process, multiple LOEs should be used in the risk assessment to provide a more comprehensive understanding of VI and to increase confidence in making risk management decisions regarding potential risk. These refinements may not be appropriate on all sites. Confirm the applicability with the regulator and other appropriate stakeholders. If any short-term health hazards are identified, appropriate mitigation measures should be implemented promptly. Additional sampling should not be used as a justification to delay measures to protect building occupants.

Response actions should be based on available LOEs. Lines of evidence may influence the potential for VI and may be weighted differently for each site and building, depending on their characteristics and quality. Some LOEs may conflict, and this should be anticipated in the project planning process. Professional judgment should be used to evaluate all LOEs throughout the process.

4A.1 – Risk Assessment Scenarios

The sampling results and estimated VI risk may vary among buildings on a site. Likely VI risk scenarios, based on media sampling and initial VI risk assessment, are described in Table 3 for both existing and future buildings. A building is considered low priority for further evaluation if current (Step 3C) and future (Step 2B or 3C) cumulative VI risk and hazard are consistently below the points of departure. The points of departure for cancer is risk less than 10^{-6} and for noncancer effects is hazard less than or equal to 1. Low priority VI risk is shown in green while VI risks that exceed the points of departure are shown in red. Acute or short-term exposures that may result in adverse health effects should be promptly evaluated for immediate response actions (Step 1A).

Table 3 – Risk Management Options Based on Current and Future Risk

Receptor Risk Building Scenario	Primary Media for VI Risk and Hazard Calculations	Potential Response Actions Select response actions to address current VI risk **and** future VI risk.
Current VI Risk to Occupants of Existing Buildings	**Indoor Air** Data	• Reassess Current VI Risk When Conditions Change (Step 4B.1) • Indoor Air Monitoring (Step 4B.2) • VI Mitigation (Step 4B.3) • Interim Remedial Action (Step 4B.4) • Institutional Controls (e.g., building use restrictions) (Step 4B.5)
Future VI Risk to Occupants of Existing Buildings	**Subsurface** Data	• Reassess Future VI Risk When Conditions Change (Step 4C.1) • Subsurface Monitoring (Step 4C.2) • Remedial Action (Step 4C.3) • Institutional Controls (e.g., land use restrictions) (Step 4C.4)
Future VI Risk to Occupants of Future Buildings (Open Lot)	**Subsurface** Data	• Reassess Future VI Risk When Conditions Change (Step 4C.1) • Subsurface Monitoring (Step 4C.2 and Step 4D) • Remedial Action (Step 4C.3) • Institutional Controls (e.g., land use restrictions) (Step 4C.4) • VI Mitigation (Step 4D)

Table 4 – Potential Response Actions for Common VI Risk Assessment Scenarios

Scenario	Media Sample Data	Current VI Risk to Occupants of *Existing* Buildings	Future VI Risk to Occupants of *Existing* or *Future* Buildings	Potential Response Actions
1) **Vapor Intrusion**	**SG, SS, & IA** Data	**IA Data** Exceeds PODs (Step 3C)	**SG & SS Data** Predict Future IA Risk Exceeds PODs (Step 2B and Step 3C)	See **Step 4B** and **Step 4C**
2) **Confounding Sources and Vapor Conduits**	**SG, SS, & IA** Data	**IA Data** Exceeds PODs (Step 3C)	**SS Data** Predicts Future IA Risk Below PODs (Step 2B) **SG Data** Predicts Future IA Risk Exceeds PODs (Step 2B)	See **Step 4B** and **Step 4C**
3) **Future VI Risk**	**SG, SS, & IA** Data	**IA Data** Below PODs (Step 3C)	**SG & SS Data** Predict Future IA Risk Exceeds PODs (Step 2B and Step 3C)	See **Step 4B.1** and **Step 4C**
4) **Attenuation through Soil**	**SG, SS, & IA** Data	**IA Data** Below PODs (Step 3C)	**SS Data** Predicts Future IA Risk Below PODs (Step 2B) **SG Data** Predicts Future IA Risk Exceeds PODs (Step 2B)	See **Step 4B.1** and **Step 4C.1** or **Step 4C.2**
5) **Low Priority Building**	**SG** Data Only	**SG Data** Predicts Current IA Risk Below PODs (Step 2B)	**SG Data** Predicts Future IA Risk Below PODs (Step 2B)	See **Step 4B.1** and **Step 4C.1**
6) **Future VI Risk with Development**	**SG** Data Only	NA – Open Lot or Redevelopment Site	**SG Data** Predicts Future IA Risk Exceeds PODs (Step 2B)	See **Step 4C** and **Step 4D**
7) **Low Priority Future Occupant**	**SG** Data Only	NA – Open Lot or Redevelopment Site	**SG Data** Predicts Future IA Risk Below PODs (Step 2B)	See **Step 4C.1** and **Step 4D**

Note: PODs – Points of Departure (i.e., cancer risk=10^{-6} and hazard index=1), NA – not applicable, SG – soil gas, SS – subslab, IA – indoor air, VI – vapor intrusion

The potential risk management response actions for the scenarios presented in Table 4 are discussed below.

<u>Scenario 1: Vapor Intrusion</u> – Current VI health risk is above points of departure based on indoor air data and future VI health risk is above points of departure based on subsurface data. Determine appropriate response action(s) based on the nature and magnitude of risk and hazard, LOEs, the overall CSM, and input from stakeholders. See Steps 4B and 4C for more information.

<u>Scenario 2: Confounding Sources and Vapor Conduits</u> – In some situations, risk or hazard estimated from indoor air and soil gas data will exceed the points of departure even though subslab sample data suggest VI is not likely occurring at the building (see Step 3D.1). This could mean the indoor air is impacted by non-VI confounding sources or that VI is occurring through a vapor conduit pathway. Potential outdoor and/or indoor air sources should be investigated and identified as described in Step 3D.1. In addition, vapor conduit sampling can be conducted, as discussed in Attachment 3, to rule out VI through the vapor conduit pathway.

- <u>Confounding Sources</u> – If indoor air impacts are shown to be solely from confounding sources, the building can be considered low priority for both current and future VI risk. Broader site investigation is needed to confirm this determination. Identify all release areas, conduct additional sampling to determine the distribution and extent of soil gas and groundwater contamination, and determine if VFC concentrations are stable or decreasing in the vicinity of the building(s). Reassess the risk to building occupants if LOEs or changes in the CSM suggest an increase in VI risk. See Steps 4B.1 and 4C.1 for more information.
- <u>Vapor Conduit Pathway</u> – If indoor air impacts are due to a vapor conduit, determine appropriate response action(s) based on the nature and magnitude of risk and hazard, LOEs, the overall CSM, and input from stakeholders. See Steps 4B and 4C for more information.

<u>Scenario 3: Future Vapor Intrusion Risk</u> – Indoor air data shows current VI health risk is below points of departure. However, soil gas and/or subslab soil gas data are above points of departure indicating a potential future VI risk. See Step 4C to determine appropriate response action(s) to address future VI health risk based on the nature and magnitude of future risk and hazard, LOEs, the overall CSM, and input from stakeholders. See Step 4B.1 for information about reassessing current VI risk if changes in the CSM based on the broader site investigation and/or changes at the building suggest a potential increase in VI risk to building occupants.

<u>Scenario 4: Attenuation in Soil</u> – Indoor air data shows current VI health risk is below points of departure. Subslab data predicts the future VI risk is low despite the presence of higher concentrations in exterior soil gas. Completion of the broader site investigation is needed to confirm the building is low priority for VI. Identify all release areas, conduct additional sampling to determine the distribution and extent of soil gas and groundwater contamination, and determine if VFC concentrations are stable or decreasing in the vicinity of the building. Reassess the risk to building occupants if changes in the LOEs or CSM suggest an increase in VI risk. See Steps 4B.1 and 4C.1 for more information.

Scenario 5: Low Priority Building – Exterior soil gas concentrations (Step 2) show that the current and future VI health risks are below points of departure, so an indoor air investigation (Step 3) is not performed. Completion of the broader site investigation is needed to confirm the low VI priority building determination. Identify all release areas, conduct additional sampling to determine the distribution and extent of soil gas and groundwater contamination, and determine if VFC concentrations are stable or decreasing in the vicinity of the building. Reassess the risk to building occupants if changes in the LOEs or CSM suggest an increase in VI risk. See Steps 4B.1 and 4C.1 for more information.

Scenario 6: Future Vapor Intrusion Risk with Redevelopment – Near-source soil gas samples (Step 2A.3) show a potential future VI health risk exceeding points of departure for occupants of future buildings constructed on the open lot or redevelopment site. Determine appropriate response action(s) based on the nature and magnitude of predicted future risk and hazard, LOEs, the overall CSM, and input from stakeholders. See Step 4C and 4D for more information.

Scenario 7: Low Priority Future Redevelopment – The VI pathway is incomplete because no buildings are on the site or buildings are unoccupied. Near-source soil gas samples (Step 2A.3) indicate future VI health risk is less than points of departure for occupants of future buildings constructed on open lots or redevelopment sites. Completion of the broader site investigation is needed to confirm the low VI priority building determination. Identify all release areas, conduct additional sampling to determine the distribution and extent of soil gas and groundwater contamination, and determine if VFC concentrations are stable or decreasing in the vicinity of the building. Reassess the risk to future building occupants if changes in LOEs or the CSM suggest an increase in VI risk. See Step 4C.1 and Step 4D for more information.

4A.2 – Existing Building: Refinements for Assessment of Current Vapor Intrusion Risk

After the preliminary screening, the assessment of current VI risk (Step 3C) can be refined to determine appropriate response actions. These refinements are options that can be considered and may not be suitable for every site. Additional rounds of indoor air sampling and/or additional sampling locations, beyond the data collected in Step 3, are needed for these approaches. The following are examples of refinements to an indoor air risk assessment:

- Use building-specific exposure parameters based on information from current building occupants (e.g., exposure duration or frequency). However, use of exposure assumptions less conservative than defaults may require institutional controls to ensure all relevant parties are aware of the building use restrictions.

- Once a sufficient number of indoor air samples have been collected in space and/or time at a building, a 95 percent upper confidence limit on the arithmetic mean (95% UCL) indoor air concentration may be used as the reasonable maximum exposure (RME) concentration, when appropriate (USEPA, 2002). A robust dataset is needed for statistical approximation, which usually implies the collection of at least eight sample locations and/or at least eight sampling events (USEPA, 1992). The maximum concentration should be used to estimate risk until sufficient indoor air data has been collected. This additional indoor air sampling generally occurs after any significant vapor entry points have been identified and sealed.
    - Averaging over space should only include indoor air samples from areas of the building within the same HVAC zone or unit within a multi-unit building. Estimating a building-wide RME concentration may not be appropriate if indoor air concentrations differ substantially between areas of the building. The building-wide RME needs to be protective of all building occupants and should consider the time each receptor spends in specific areas of a building.
    - Averaging over time should only occur if indoor air concentrations are relatively stable and/or decreasing. If concentrations suggest a potential short-term exposure risk (e.g., TCE), averaging is generally not recommended.

4A.3 – Existing Building: Refinements for Assessment of Future Vapor Intrusion Risk

After the preliminary screening, the assessment of future VI risk (Step 2B or 3C) can be refined to determine appropriate response actions. These refinements are options that can be considered and may not be suitable for every site. Additional sampling and/or collection of other LOEs will be needed, after completion of Steps 1 through 3, for these refinements.

Exposure Estimate Based on Multiple Rounds of Subsurface Sampling

Averaging soil gas concentrations over time may be appropriate when considering long term health effects. Site-wide spatial averaging is not typically recommended because building specific risk may be underestimated as only soil gas near a building can be reasonably anticipated to migrate towards the building.

For a building, a 95% UCL subslab concentration (or exterior soil gas, if subslab sampling is not feasible) can be determined once a sufficient number of samples have been collected (in space and/or time) and used to predict future VI risk and hazard. A robust dataset is needed for statistical approximation, which usually implies the collection of at least eight samples (USEPA, 1992). In addition, the following applies to averaging over space (lateral and vertical) and time:

- Spatial averaging should generally only include subslab samples from areas of the building within the same HVAC zone or unit within a multi-unit building.
- If subslab sampling is not feasible, averaging exterior soil gas data over space should only be conducted if all samples are distributed in a manner representative of vapors migrating from a subsurface source to the building. Averaging may be conducted only when concentrations near a building are generally homogeneous (e.g., a building impacted from an upgradient release to groundwater).
- “Hot spots” (i.e., areas including multiple sample locations with elevated concentrations) and “outliers” (i.e., individual samples with elevated concentrations) in subslab or soil gas should be addressed separately.
- Averaging soil gas samples from different depths within the same sample location is not recommended because the average may not be representative of conditions under the building (e.g., slab capping effect), as described in Step 2A.3.
- Averaging over time should only occur if subslab or soil gas concentrations are relatively stable and/or decreasing. If concentrations suggest a potential short-term exposure hazard (e.g., TCE), averaging is generally not recommended.

Potential Future Subslab to Indoor Air Attenuation Factors

A building’s subslab to indoor air AF ($AF_{SS\text{-}IA}$) can be calculated from current empirical data[8] but may not represent future VI risk given the potential subsurface and building changes described in the Step 4 introduction. To account for potential increases in VI, use an AF that is greater than the building’s current $AF_{SS\text{-}IA}$ for assessment of potential future VI risk. An applicable generic empirical AF should be selected in consultation with the regulatory agency and other stakeholders and considering all LOEs to ensure protection of human health.

[8] Paired subslab and indoor air samples can be used to calculate a building’s current $AF_{SS\text{-}IA}$. Averaging of indoor and/or subslab samples when calculating $AF_{SS\text{-}IA}$ can be done on a building-specific basis following the considerations discussed in the previous section.

Potential Future Soil Gas to Indoor Air Attenuation Factors

Paired near-source soil gas and subslab samples can be used to a determine building-specific soil gas to subslab AF (AF_{SG-SS}), as shown in Figure 3. The AF_{SG-SS} can then be multiplied by the USEPA AF of 0.03 (or another justified potential future AF_{SS-IA} as described in the preceding text) to calculate a potential future soil gas to indoor air AF (AF_{SG-IA}). The potential future AF_{SG-IA} can be used to determine future VI risk to occupants of existing buildings.

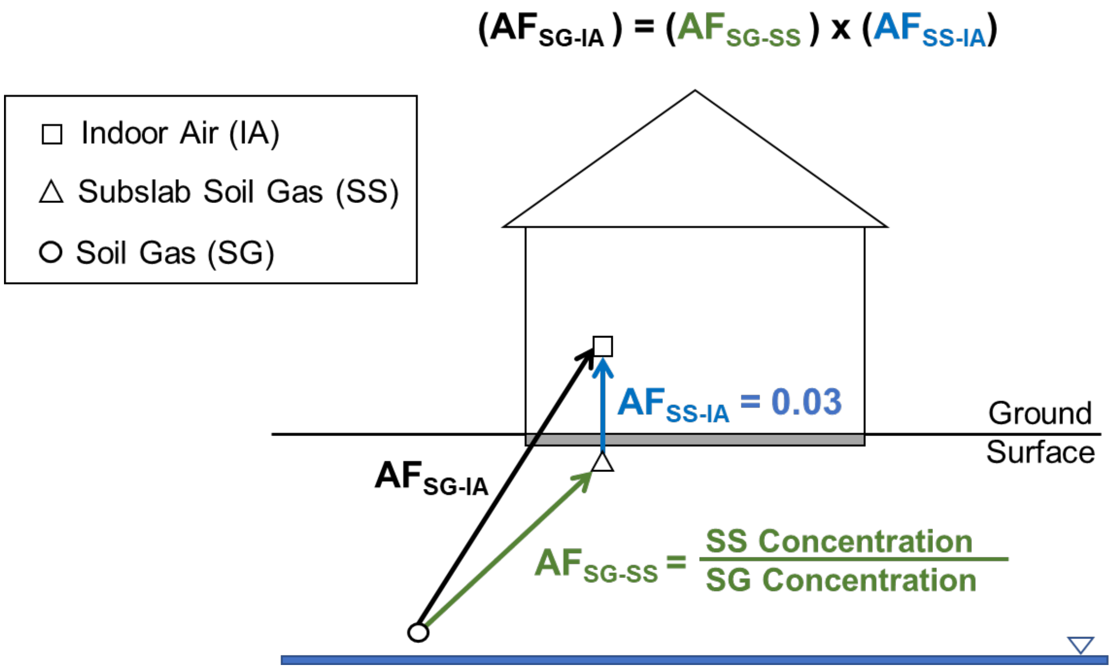

Figure 3. Diagram showing the how a building's soil gas to indoor air AF (AF_{SG-IA}) can be calculated using a generic empirical subslab to indoor air AF (AF_{SS-IA}) such as the USEPA AF of 0.03 and a soil gas to subslab AF (AF_{SG-SS}) derived from site-specific empirical subsurface data.

When subslab sampling is not feasible, models can be used to determine a potential future AF_{SG-IA} that can be used to predict future VI risk. The Johnson and Ettinger model (Johnson and Ettinger 1991) as implemented by USEPA (2017b) or other agencies is the most commonly used VI model. Use of the Johnson and Ettinger model or other appropriate models may be appropriate where the use is consistent with Attachment 1 and used in consultation with the regulatory oversight agency. To account for the future building changes as described in the Step 4 introduction, conservative model inputs should be used so that the AF_{SS-IA} is equal to the USEPA AF of 0.03 (or another justified potential future AF_{SS-IA} as described in the preceding text). This allows for site specific modeling of the attenuation through the soil column from the subsurface source to the subslab (AF_{SG-SS}) while keeping fixed the attenuation across the foundation (AF_{SS-IA}). In the Johnson and Ettinger model, the AF_{SS-IA} is represented by the ratio of the soil gas entry rate (Qsoil) and the building ventilation rate (Qbuilding). While this approach will "lock in" the selected potential future AF_{SS-IA} to account for future changes to that building, it allows for the overall AF_{SG-IA} to be reduced based on site-specific modeling of the attenuation through the soil column. In the 2017 version of the USEPA implementation of the Johnson and Ettinger model, the default Qsoil/Qbuilding ratio in the model can be directly adjusted (USEPA, 2017b).

4A.4 – Future Building: Refinements for Assessment of Future Vapor Intrusion Risk

After preliminary screening, the assessment of VI risk (Step 2B) for occupants of future buildings can be refined to determine appropriate response actions. This section applies to open lots or other properties where development/redevelopment should be evaluated. These refinements are options that can be considered and may not be suitable for every site. Additional sampling and/or collection of other LOEs will be needed, after completion of Step 2, for these refinements.

Exposure Estimate Based on Multiple Rounds of Soil Gas Sampling

Averaging soil gas concentrations over time may be appropriate when considering long-term health effects. Site-wide spatial averaging is not typically recommended because building specific risk may be underestimated as only soil gas near a building can be reasonably anticipated to migrate towards the building.

For a future building, a 95% UCL near-source soil gas concentration can be determined once a sufficient number of samples have been collected (in space and/or time) and used to predict future VI risk and hazard. A robust dataset is needed for statistical approximation, which usually implies the collection of at least eight samples (USEPA, 1992). In addition, the following applies to averaging over space (lateral and vertical) and time:

- Averaging soil gas data over space laterally should only be conducted for samples in locations that are representative of vapors migrating from a subsurface source to the building, as discussed in the Step 2A.3.
- "Hot spots" (i.e., areas including multiple sample locations with elevated concentrations) and "outliers" (i.e., individual samples with elevated concentrations) in subslab or soil gas should be addressed separately.
- Averaging soil gas samples from different depths within the same sample location is not recommended because the average may not be representative of

conditions under the future building (e.g., slab capping effect), as described in sample depth section of Step 2A.3.

- Averaging over time should only occur if soil gas concentrations are relatively stable and/or decreasing. If concentrations suggest a potential short-term exposure hazard (e.g., TCE), averaging is generally not recommended.

Potential Future Soil Gas to Indoor Air Attenuation Factors

Potential future near-source soil gas to indoor air AFs for future buildings can be estimated using the modeling approach discussed for existing buildings in Step 4A.3. The main difference between future and existing building evaluation, is the timeframe for verification sampling. **It is important that sampling occurs to either verify model predictions (e.g., AFs) or that the selected AF is adequately protective once new buildings are constructed. Contingency plans are recommended in case verification sampling shows an unexpected VI health risk at a new building.** Other approaches can be used with adequate justification.

Step 4B – Manage Current Vapor Intrusion Risk

Selection of specific response actions to protect current building occupants from VI will be made on a case-by-case basis, considering the nature and magnitude of the indoor air risk and hazard as determined in Step 3D or 4A.2. When the VI risk or hazard estimated from indoor air data exceeds the points of departure, response action(s) are warranted to alleviate the current risk to receptors.

This section describes each of the potential response actions for managing current VI risk listed in Table 4 and provides some considerations for selecting the appropriate response action(s). Step 4B.1 discusses options when the points of departure are not exceeded. Steps 4B.2 through 4B.5 discuss potential response actions if the point of departure is exceeded.

4B.1 – Reassess Current Vapor Intrusion Risk when Conditions Change

As discussed in Step 3D, a building may be considered low priority for current VI health risk if the cumulative risk and hazard based on the indoor air data are consistently below the points of departure. No response action is needed at low priority buildings unless conditions change or new information becomes available over the course of the sitewide investigation and cleanup. As the CSM evolves with additional sampling data and other LOEs, buildings should be re-evaluated for VI. Factors that may influence VI threat are described in Step 4 introduction.

If land/subsurface conditions may have changed to suggest a potential increase in VI, additional soil gas data should be collected to determine whether additional indoor air data are needed to determine the risk to current building occupants. Consider proceeding directly to indoor air sampling/monitoring when building conditions have changed and subsurface contaminant concentrations are likely to continue to pose a potential VI risk based on previous sampling events.

4B.2 – Additional Indoor Air Sampling to Monitor Current Vapor Intrusion Risk

Current VI health risks above the point of departure, based on indoor air data, may be acceptable without mitigation at certain buildings, with appropriate long-term monitoring. In those situations, ongoing indoor air and/or subsurface monitoring can be used to measure VFC concentration changes over time, reduce exposure uncertainties, and detect possible increases in concentrations. The monitoring frequency should be based on the contaminant(s) and consider potential changes that could increase VI risk such as:

- Seasonal temperature and barometric pressure changes;
- Water table fluctuations;
- Changes in soil moisture;
- Modifications to the building, ventilation (windows, doors, room fans), and/or HVAC system; or
- Groundwater or soil gas plume migration (plume stability).

The collection of additional data would provide the LOEs needed to justify deviation from the risk point of departure and demonstrate protectiveness. All risk management decisions should be described and justified in the remedy decision document and appropriate monitoring should be included in the long-term monitoring plan.

4B.3 – Vapor Intrusion Mitigation at Existing Buildings

VI mitigation is the preferred action for reducing unacceptable levels of current VI exposure until the site has been remediated to the cleanup goals. The appropriate method of mitigation and time frame for implementation should be commensurate with the nature and magnitude of the potential human health risk (e.g., urgent or accelerated response actions for TCE short-term inhalation hazard; USEPA, 2014a; DTSC, 2014; SF Bay Regional Water Board, 2014). Mitigation approaches may be tailored to the level of exposure and may be iterative if initial mitigation strategies do not reduce risk to below the points of departure. Mitigation approaches and technologies include short-term and long-term measures and require post-implementation monitoring:

- <u>Short term measures</u> – Increasing building pressurization, increasing air exchange rates, sealing conduits, and treating indoor air with portable purification systems are short-term mitigation options (USEPA, 2015, 2017a; DTSC, 2011b). Short-term mitigation options for the sewer pathway include adding water to dry p-traps and replacing deteriorated toilet seals (Jacobs et al., 2015).

- <u>Long term measures</u> – Subslab venting and subslab depressurization systems are common long-term mitigation technologies. Such systems may be required where remediation to reduce contaminant concentrations to acceptable levels might take years or is not technically feasible. Vapor barriers such as liners can be used in conjunction with these systems but are not an acceptable VI mitigation system when used alone (DTSC 2011b). For existing buildings, options may be limited by the existing construction. Long-term options for mitigating sewer VI can include sewer venting, installing check valves, lining the sewer pipe to prevent vapor entry, or rerouting the sewer pipeline (Wallace et al., 2017). Any modification of a site's sewer should only be done with the concurrence or approval of the local sewer utility district.

- Monitoring – As established practice, mitigation monitoring is necessary to demonstrate the initial and continued effectiveness of mitigation. For further information on VI mitigation, see the most current versions of the DTSC VIMA (DTSC, 2011b), the SF Bay Regional Water Board VI Framework (SF Bay Regional Water Board, 2014), and USEPA guidance (USEPA, 2015a).

4B.4 – Interim Remedial Action to Reduce Current Vapor Intrusion Risk

Interim remedial actions should be considered to expedite risk reduction when current VI risk to human health is unacceptable. Use interim remedial measures where feasible to control, minimize, or eliminate releases that pose an imminent VI threat to building occupants. This is especially appropriate at sites for which the time needed for evaluation, selection, and implementation of the final remedy will delay permanent risk reduction.

Examples of interim remedial actions to address current VI risk include, but are not limited to:

- Excavation of release areas to reduce or eliminate subsurface sources;
- Soil vapor extraction to reduce contamination in release areas and control subsurface migration of soil gas toward buildings;
- Groundwater pumping to restrict plume migration below downgradient buildings; and
- In situ groundwater treatment to reduce subsurface source contamination.

Buildings with high indoor air concentrations may also require VI mitigation measures and monitoring to protect current building occupants while interim remedial action measures are being implemented. Some remediation systems may temporarily increase the VI risk while remediation is ongoing. However, interim remedial measures should ultimately reduce vapor concentrations in the subsurface needed to protect building occupants.

4B.5 – Institutional Controls to Reduce Current Vapor Intrusion Risk

In situations where there is an unacceptable current indoor air risk, and mitigation is not effective or feasible, temporary changes in building use (e.g., reduce occupancy time and or location within a building) or relocation of building occupants may be the most appropriate initial response action for reducing receptor exposure in a timely fashion. Site-specific risk assessments should be submitted to justify the protectiveness of specific changes in building use. Temporary relocation of building occupants is typically only considered when acute or short-term hazards exist (e.g., TCE above short-term action levels in indoor air) and other controls are not immediately available or effective (USEPA, 2014a; DTSC, 2011a, 2011b, and 2014).

Step 4C – Existing Buildings: Manage Future Vapor Intrusion Risk

Selection of specific response actions to protect occupants of existing buildings from VI over time will be made on a case-by-case basis, considering the characterization of the subsurface and contamination, the nature and magnitude of the risk and hazard (Step 2B, 3C, or A4.2) and the following:

- Sitewide CSM and likelihood of potential changes to the CSM
- Refined risk assessment based on updated CSM and additional LOEs
- Potential for acute or short-term hazard
- Stakeholder preferences and risk perception and tolerance
- Feasibility studies and remedial action plans
- Financial assurance for ongoing mitigation and monitoring

This section describes each of the potential response actions for managing future VI risk and provides some considerations for selecting the appropriate response action(s).

4C.1 – Reassess Future Vapor Intrusion Risk when Conditions Change

No response action is needed at buildings where estimates of future VI risk and hazard are below points of departure, unless migration of subsurface contamination (e.g., plume expansion) has occurred causing an increase in potential VI risk. Sitewide investigations should assess whether subsurface contamination is migrating by collecting soil gas data over time. In addition, activities that may change contaminant migration/distribution (laterally and vertically) should be identified and monitored. Such activities may include, but are not limited to:

- Remedial activities;
- Trenching or new utilities that intersect soil or groundwater contamination and could enhance vapor migration; and
- Groundwater pumping (e.g., dewatering) or water table fluctuations.

The sitewide soil gas monitoring network should be designed to monitor potential increases in soil gas concentrations caused by natural and/or activity induced contaminant migration. This data should be used to reassess the future VI risk to occupants of nearby buildings following procedures discuss in Step 2 (and Step 4A.3, if applicable). No further reassessment of future VI risk is necessary once contamination migration is no longer a concern.

4C.2 – Additional Subsurface Sampling to Monitor Future Vapor Intrusion Risk

Potential future VI risk, based on subslab and/or exterior soil gas sampling, should be monitored as part of the sitewide investigation and cleanup, independent of current indoor air results at individual buildings. Subslab and/or soil gas monitoring may be the most appropriate response action to address future VI risk above the points of departure at some buildings when remediation is not warranted or feasible. In those situations, monitoring can be used to assess soil gas trends and to determine when buildings can be considered low priority for future VI risk. The soil gas monitoring frequency should consider potential factors that could increase VI risk:

- Seasonal temperature and barometric pressure changes;
- Water table fluctuations;
- Changes to soil moisture (e.g., changes to landscape watering, long term drought);
- Groundwater or soil gas plume migration; and
- Natural or activity induced subsurface contaminant migration (see 4C.1).

If subslab and/or soil gas concentrations increase, indicating a greater potential VI risk, indoor air sampling should be considered. Mitigation should be implemented, as warranted (see Step 4B.3). All risk management decisions should be described and justified in the remedy decision document and appropriate monitoring included in the long-term monitoring plan.

4C.3 – Remedial Action to Reduce Future Vapor Intrusion Risk

Remedial action decisions are based on the results of sitewide investigation, characterization of risk, and the technologies available to achieve site cleanup goals. Active remediation is the preferred response action to reduce or eliminate future VI risk at buildings. For sites with VI risk, the final remedy often includes both VI mitigation and active cleanup of site contamination. The evaluation and selection of the remedy should include a comprehensive evaluation of alternatives, with attention to factors such as the CERCLA evaluation criteria (USEPA, 1999) and the RCRA balancing criteria (USEPA, 1994), including but not limited to:

- Overall protection of human health and the environment;
- Long-term effectiveness and permanence;
- Short-term effectiveness;
- Reduction of toxicity, mobility, or volume;
- Community acceptance;
- Implementability; and
- Cost.

Remedial action objectives will be different for each site and can be based on site-specific AFs discussed in Step A4.3. If the objective is to achieve unrestricted land use, the goals for all media should be protective of all possible receptors and exposure scenarios. If institutional controls will be used to limit the land use, the remedial action objectives for soil gas may be adjusted accordingly.

DTSC provides information related to several soil-specific remediation technologies in Proven Technologies and Remedies Guidance– Remediation of Chlorinated Volatile Organic Compounds in Vadose Zone Soil (DTSC, 2010). USEPA (2018) provides guidance on soil vapor extraction. Other resources for information on remediation technologies include ITRC (itrcweb.org) and the USEPA-sponsored Contaminated Site Clean-Up Information (CLU-IN) Web Site (clu-in.org). All VI remedies should be designed, built, installed, operated, and maintained in conformance with standard geologic, engineering, and construction principles and practices by appropriately licensed professionals (see Introduction Section A1).

4C.4 – Institutional Controls to Manage Future Vapor Intrusion Risk

When remedial action objectives are not protective of all reasonably foreseeable future uses of the property, institutional controls (e.g., land use covenants restricting building use or land use) are needed to protect public health. Institutional controls can restrict certain land uses, limit building occupancy, and prohibit activities that are inconsistent with risk management plans. See DTSC (2011b) and USEPA (2012d), and references therein, for more information about institutional controls.

Step 4D – Future Buildings: Manage Future Vapor Intrusion Risk

Selection of specific response actions to protect occupants of future buildings from VI will be made on a case-by-case basis, largely considering the same factors discussed for existing buildings. In general, use Step 4C to manage VI risk to occupants of future buildings at open lots or redevelopment sites. The following are some additional considerations specific to managing risk at future buildings.

Soil Gas is Primary LOE – Risk and hazard estimations for future buildings should primarily be calculated using near-source soil gas data, following procedures in Step 2B and Step 4A.4. At redevelopment sites, subslab soil gas data from existing buildings within the footprint of planned new construction might be used as a LOE to determine appropriate response actions to protect future building occupants. Subslab VFC concentration data should not be used to rule out the VI exposure pathway. Subslab VFC concentration data from an existing building may underestimate the subslab VFC data for a future building for a number of reasons, including the following:

- Differences in building design, construction, and surrounding paved cover or landscaping.
- Footprint of future building is larger than existing building.
- The depth from the building foundation to the groundwater plume decreases after construction (e.g., soil grading, building design).

- More permeable soil conditions, vapor conduits below the future building, or new conduits to the future building.

Post-construction subslab VFC data should be collected and used as an additional LOE to reassess risk.

Vapor Intrusion Mitigation at Future Buildings – Future buildings constructed near or over soil gas contamination may need mitigation systems to protect occupants. Ideally, all feasible interim and/or final remedial actions should be taken in a timely fashion to reduce or eliminate the need for VI mitigation. For sites where conditions prevent or limit the amount of remediation, mitigation may be necessary as a long-term measure to alleviate exposure. See Step 4B.3 for more information on long-term monitoring of mitigation systems.

Application to Other Building Types

The concepts used for assessing spatial distribution and temporal variability of contamination can be applied in general terms to larger buildings, building with crawl space construction, and occupied spaces over parking structures (above- or below-ground). Sampling recommendations in Steps 2 and 3 were developed for a small, slab-on-grade building with only one HVAC zone; however, these recommendations can also be used for other building types.

For more complex buildings, understanding a building's HVAC system and the air flow through the building is critical to designing an indoor air investigation and interpreting the results. Also, these types of structures are more likely to have unusual features (e.g., utility tunnels) that can act as vapor conduits, and efforts should be made to understand building characteristics. Sampling considerations and recommendations for three common building types, labelled as Building I, II, III, are described below.

BUILDING I – Large Buildings and Multistory Buildings

For large or multistory buildings, the process and risk evaluation for Step 2 and Step 3 should be followed, with changes for Step 3 described below. In addition, for a mixed-use building, the risk evaluation should consider the most sensitive receptor. A combination of sampling approaches might be warranted depending on site-specific conditions.

I.A – Sample Locations in Step 3

The evaluation of large buildings warrants more sampling than described in Step 3C. The exact number and spacing of the samples should be determined based on the CSM, building characteristics, and DQO. Sample locations should be selected consistent with the criteria in Step 3C and should consider these additional sample locations:

- For large multi-unit structures, such as apartment buildings or strip malls, consider collecting at least one sample per ground floor unit.
- For buildings with foundations that segment the subsurface (e.g., grade beams), at least one sample should be collected in each separate area.
- For buildings with multiple HVAC zones, it may be appropriate to collect samples in each HVAC zone.
- For multistory buildings, sampling in occupied spaces on upper floors may be warranted in addition to sampling on the ground floor. Samples should be collected near conduits such as utilities, stairwells, or elevator shafts, that may provide a vapor pathway to the upper floors.
- If results of initial sampling show concentrations vary by more than an order of magnitude within a building; consider adding additional sample locations to evaluate the spatial distribution of VFCs.
- For large multi-unit buildings with a release area beneath a small section of the building (e.g., strip mall dry cleaners), consider a phased approach starting at the release area and working outward for each unit. For example, initially sample indoor air only at the units directly above the suspected release area and sample subslab soil gas below all units. Conduct further investigation based on the initial results.

I.B – Calculate Vapor Intrusion Risk Using Indoor Air in Step 3

Risk calculations described in Step 3D should be used for large or multistory buildings.

I.C – Sample Frequency in Step 3

Sampling frequencies discussed in Step 3E should also be used for large or multistory buildings.

BUILDING II – Crawl Space Buildings

Buildings with crawl spaces are common in California. A crawl space is unoccupied space beneath an occupied floor where a person cannot stand up. Sampling of crawl spaces provides an additional LOE regarding VI. In this Supplemental Guidance, all buildings with space below the floor level should be treated similarly, including crawl spaces, unfinished basements, mobile homes, and portable buildings. The characteristics of these spaces can vary widely. Crawl spaces may be open or may be almost entirely enclosed and may have dirt or concrete floors. Well-ventilated crawl spaces may decrease VFC concentrations but do not eliminate the potential for VI. Furthermore, if VI is occurring through the sewer or other vapor conduits, crawl space air samples may underestimate indoor air concentrations of VFCs.

Crawl space air samples can be collected as part of Step 2 or Step 3. If the crawl space is easily accessible from outside the building, consider sampling crawl space air concurrently with soil gas in Step 2; this may reduce inconvenience to building occupants. If crawl space air sampling is conducted in Step 3, the sampling should be concurrent with indoor air, soil gas, and outdoor air to characterize the vapor migration pathway(s).

A crawl space to indoor air AF of 1 should be used when calculating risk. USEPA found little vapor attenuation between crawl space air and indoor air. USEPA concluded either little attenuation occurs between the crawl space and indoor air space or that air exchange between the two spaces leads to approximate equilibration in the concentrations (USEPA, 2012b).

Indoor air concentrations remain the preferred LOE for evaluating the current risk to building occupants. While crawl space air data are a LOE for assessing current risk, the data should not be used for assessing future risk due to the dynamic nature of air in the crawl space. Subsurface data concentrations are the preferred LOE for evaluating future risk. Refer to Step 2 and 3 for planning and consideration of LOE and nature and magnitude of risk when determining next steps.

II.A – Crawl Space Air: Sampling Methods

Crawl space air samples should be collected using the same methods recommended for indoor air sampling in the VIG (DTSC, 2011a).

II.B – Crawl Space Air: Sample Locations in Step 2 and Step 3

The overall number and location of crawl space air samples should provide adequate building coverage, with a minimum of two samples (see section above for large buildings). The crawl space air sampling design should include the following locations:

- Near the center of the structure (away from vents to outdoor air);
- Near known or suspected subsurface VFC release areas; and
- Near emergent subsurface utilities.

II.C – Step 2 Specific Criteria for Crawl Space Air Sampling

Crawl space air samples are recommended in addition to soil gas samples as part of Step 2, depending on site-specific conditions. Outdoor air samples should be concurrently collected with crawl space air samples to allow for the identification of outdoor sources of VFCs potentially entering crawl space air.

- Exterior Crawl Space Access – Where access is readily available *from outside the building*, crawl space air and soil gas samples may be collected concurrently.
- Estimate VI Risk using Crawl Space Air – A crawl space to indoor air AF of 1 should be used when calculating risk, as described in Step 2B (crawl space air concentrations replace soil gas concentrations in Step 2B).
- Sample Frequency in Step 2C – Crawl space air should be sampled at least twice concurrently with soil gas, at times representative of two different seasons.

II.D – Step 3 Specific Criteria for Crawl Space Air Sampling

Crawl space air samples should be collected concurrently with indoor air, soil gas, and outdoor air samples.

- Evaluate the Source of VFCs in Indoor Air – Crawl space air data are used in Step 3 along with other LOEs to evaluate the migration pathway and other potential sources of VFCs in indoor air (i.e., outdoor and/or indoor sources).
- Estimate VI Risk using Crawl Space Air (Step 3D) – A crawl space to indoor air AF of 1 should be used when calculating risk, as described in Step 2B (crawl space air concentrations replace soil gas concentrations in Step 2B).
- Sample Frequency in Step 3E – Crawl space air sampling should be repeated during each indoor air sampling event to characterize temporal variability.

BUILDING III – Building with Above-Grade or Below-Grade Parking Structures

Ground floor parking garages (podium parking) and below-grade parking garages tend to minimize the potential for VI due to passive or active ventilation but should not be assumed to completely prevent the migration of subsurface VFCs to upper floors (USEPA, 2015a).

Parking garage features should be identified in the building survey and considered for building-specific sampling plans:

- Vapor Migration Pathways – Elevator shafts, stairwells, and utility conduits can allow migration of subsurface VFCs upward into the occupied floors.
- Sumps with Contaminated Groundwater – If the parking garage floor extends to or below the water table and contaminated groundwater infiltrates into the parking area, VFCs may volatilize directly from contaminated groundwater into the garage air.
- Occupied Spaces – Most parking garages are not regularly occupied, but some have parking attendants or utility rooms that may be occupied on a routine basis and should be considered for sampling.
- Other Sources of VFCs – Vehicle exhaust, laundry rooms (e.g., hotels), and chemical storage areas are common sources of chemicals in these spaces.

The results of the building survey should be used to develop the building-specific sampling plan.

The sampling approach for buildings with occupied space above parking garages is similar to the approach for buildings with crawl spaces (Building II). Sampling of parking garage air is recommended in conjunction with soil gas in Step 2 to provide additional information about VI while minimizing inconvenience to building occupants. Parking garage air samples are intended to determine if VI is occurring and are not representative of indoor air in the occupied upper floors. Sampling should focus on potential vapor migration pathways from the subsurface. Garage air samples collected concurrently with indoor air (occupied spaces above the parking garage), subslab (or soil gas), and outdoor air is recommended as described in Step 3. At least one outdoor air sample should be collected from a location near the HVAC intake(s) for the parking garage.

Indoor air concentrations in occupied spaces remain the preferred LOE for evaluating the current risk to building occupants. Garage air sampling can provide useful information on the VI pathway but should not be used to rule out vapor transport through conduits to upper floors. Sampling in occupied spaces on upper floors may be warranted in addition to sampling in the garage. Samples should be collected near conduits such as utilities, stairwells, or elevator shafts, that may provide a vapor pathway to the upper floors. Subsurface data concentrations are the preferred LOE for evaluating future risk. Refer to Step 2 and Step 3 for planning and consideration of LOE and nature and magnitude of risk when determining next steps.

III.A – Parking Garage Air: Sampling Methods

Parking garage air samples should be collected using the same methods recommended for indoor air sampling in the VIG (DTSC, 2011a).

III.B – Parking Garage Sample Locations in Step 2 and Step 3

The overall number and location of parking garage air samples should provide adequate building coverage. Samples should generally be collected from the lowest level of the garage. The following sampling locations should be considered in the design of any parking garage air sampling plan:

- In or near potential vapor migration pathways including elevators, stairwells, and utility conduits;
- In occupied spaces such as toll booths and attendant offices;
- For large parking areas, near the center of the structure on the lowest floor (away from vents); and
- Near known or suspected subsurface VFC release areas.

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Glossary of Acronyms & Abbreviations

Abbreviation	Meaning
3-D	Three-dimensional
AF(s)	Attenuation Factor(s)
AT_c	Averaging Time for Carcinogens (years)
AT_{nc}	Averaging Time for Noncancer Toxic Effects (years)
BGS	Below Ground Surface
CalEPA	California Environmental Protection Agency
CDPH	California Department of Public Health
C_{IA}	Indoor Air Concentration
CIPP	Cure-In-Place-Piping
C_{SG}	Soil Gas Concentrations
CSM	Conceptual Site Model
DQO	Data quality objective
DTSC	Department of Toxic Substances Control
ED	Exposure Duration (years)
EDF	Electronic Data Format
EPA	Environmental Protection Agency
ESI	Electronic Submittal of Information
ESLs	Environmental Screening Levels
EF	Exposure Frequency (days per year)
GC/ECD	Gas Chromatography-Electron Capture Detector
GC/MS	Gas Chromatography-Mass Spectrometry
HHRA	Human Health Risk Assessment
HI	Hazard Index
HVAC	Heating, Ventilation, and Air Conditioning
IA	Indoor Air
IUR	Inhalation Unit Risk ($m^3/\mu g$)
LOE(s)	Line(s) of Evidence
LTCP	State Water Board's Low-Threat Underground Storage Tank Case Closure Policy
µg/L	Micrograms Per Liter
$m^3/\mu g$	Cubic Meter Per Micrograms
PCE	Tetrachloroethylene; tetrachloroethene
PEEK	Polyetheretherketone
PHCs	Petroleum Hydrocarbons
PVI	Petroleum Vapor Intrusion
RfC	Reference Concentration ($\mu g/m^3$)
SF Bay Regional Water Board	San Francisco Bay Regional Water Quality Control Board

Abbreviation	Meaning
SG	Soil Gas
SL	Screening Level
SS	Subslab
State Water Board	State Water Resources Control Board
TCE	Trichloroethylene; Trichloroethene
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
VFCs	Vapor Forming Chemicals
VI	Vapor Intrusion
VIG	Vapor Intrusion Guidance
VIMA	Vapor Intrusion Mitigation Advisory
VISL	Vapor Intrusion Screening Level
$\mu g/m^3$	Micrograms Per Cubic Meter

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Attachment 1

Lines of Evidence

Attachment 1 – Lines of Evidence

Using multiple lines of evidence (LOEs) provides a more comprehensive understanding of vapor intrusion (VI) at a site and increases confidence in assessing and managing potential health risks from the VI pathway. Multiple LOEs should be used to reduce the overall uncertainty when considerable uncertainty is associated with one or more individual LOEs.

Lines of evidence are qualitative or quantitative information used to develop the conceptual site model (CSM) and support VI pathway evaluations. Lines of evidence can be diverse types of information, such as indoor air sampling data, subsurface sampling data, site history information, building condition, field instrument results, soil type, contaminant subsurface source type and strength, and results of mathematical modeling. Each LOE should be weighted (i.e., assigned importance) based on relevance, representativeness, and quality for a given VI evaluation, and may be weighted differently for another site, a different building at the same site, other scenarios for the same building (e.g., changes in condition, operation, or use), or for separate sampling events.

After each LOE is weighted, the available LOEs should be weighed (i.e., integrated and interpreted) in the multiple LOEs approach. It is not uncommon that all LOEs may not be in concordance. Ambiguous or discordant LOEs should be evaluated and explained rather than dismissed. The CSM should be revised with the collection of updated information and/or new LOEs. The evaluation of LOEs may be more or less formal depending on the complexity of the CSM. Further information regarding the application of multiple LOEs (also referred to as “weight of evidence”) is provided by USEPA (2015a and 2016b).

Typical LOEs used for developing the CSM and evaluating VI are summarized in the sections below along with some less commonly used methods.

Site Characterization

In general, the better a site is characterized, the less uncertainty is associated with the risk assessment, and the less conservative risk management decisions can be to ensure protection of human health. At sites with limited empirical data on site specific conditions, the assumptions that are made to compensate for limited data need to be conservative enough to balance the possibility that the available information may lead to underestimating the risk to human health.

Site History

The more that is known about the site history, operations, chemical use, and potential release locations and mechanisms, the less uncertainty the CSM will have and, hence, the less uncertain VI exposure estimates will be. Site history is important for many aspects of VI evaluations, from designing investigations to interpreting data. For example, knowledge of site history may help attribute the presence of a particular vapor forming chemicals (VFC) in indoor air to past site uses, rather than current indoor or outdoor sources.

Building Characteristics

A unique aspect of evaluating the VI pathway compared to other exposure pathways is the dynamic role of the built environment. A building's construction, condition, and use affect the migration (i.e., "intrusion") of contaminant vapors from the subsurface into indoor air, air mixing and exchange, and the resulting indoor air concentrations of VFCs. Additionally, changes in these factors over time can increase or decrease the potential for VI. Building characteristics important for evaluating VI include:

- **Building Design and Construction** – Buildings have different characteristics based on the design type. The following types of buildings are listed in order from those generally most susceptible to those least susceptible to VI considering surface area in contact with soil and degree of openness to outdoor air: dirt floor basement, slab on grade, crawl space, subterranean ventilated garage, open air garage, and podium construction. No building should be considered inherently safe. Features that penetrate the building envelope (e.g., elevator shafts, sumps, utility conduits) may render any building more susceptible to VI. This should be considered when selecting the media and locations to sample as well as remedial and mitigation options that are viable for the specific building.

- **Building Condition** – A building's condition can change over time due to deterioration of building materials, renovations, cracking/settling, or catastrophic events (e.g., earthquakes) and this should be considered when selecting remedial options and cleanup goals. If building design and construction are used to support risk management decisions, then monitoring the building condition over time is warranted to evaluate whether the assumptions continue to be applicable and protective (e.g., during operation and maintenance inspections or as part of five-year reviews).

- **Building Ventilation** – The way buildings are heated or cooled can greatly influence the potential for VI. Heating, ventilation, and air conditioning (HVAC) systems include heaters, fans, mechanical vents, and air conditioners. Operable windows and doors provide natural ventilation. Exhaust fans can locally depressurize a building's interior (e.g., bathroom, kitchen). The systems for each building should be identified and evaluated. HVAC systems are dynamic, frequently turning on and off, changing diurnally and seasonally, and may be reconfigured based on changes in building use or occupant preference. This variation should be considered when planning and conducting sampling, evaluating results, and making risk management decisions.

Subsurface Conditions

Subsurface conditions can significantly influence the potential for VI where the subsurface source of contamination is not in contact with the building foundation. In these situations, vapors must migrate toward the building through porous media or via preferential pathways. Primary factors influencing soil gas as the transport medium for vapor phase contaminants include:

- **<u>Geology and Stratigraphy</u>** – In general, coarse-grained soils (e.g., sands, gravels) allow for greater vapor migration than fine-grained soils (e.g., silts, clays). Additionally, drier soils allow for greater vapor migration than wetter soils. Continuous fine-grained layers can significantly reduce the potential for VI, which is why USEPA (2015a) provides a separate groundwater attenuation factor (AF) for fine-grained vadose zone soils when laterally extensive layers are present (see Introduction Section D2). Fractures may result in preferential pathways.

  Conditions in the vadose zone and soil gas VFC concentrations be changed by construction of a new building and/or supporting infrastructure (USEPA 2015a). Construction activities and site changes may result in significant changes in the subsurface moisture profile. While moisture conditioning for soil compaction may temporarily increase moisture content, building/hardscape construction decreases soil moisture content beneath the hardscape thereby enhancing VFC migration in soil gas. Utility corridors may modify the vertical and horizontal distribution of soil gas VFC concentrations. Accordingly, as site conditions change, other LOEs may change, especially subslab and deeper soil gas VFC concentrations.

- **<u>Groundwater Conditions</u>** – When groundwater contamination is the vapor source, important considerations include location of the water table relative to the building foundation, VFC transport through groundwater, fluctuations of the water table (e.g., seasonal, periods of drought, sea level rise, tidal), and representativeness of groundwater samples for evaluating the VI pathway. For situations where groundwater is in contact with the building foundation and can potentially infiltrate a building, the VI potential is greater through direct emissions of VFCs into indoor air from groundwater (e.g., equilibrium partitioning using Henry's law predicts that 5 µg/L of PCE in groundwater corresponds to 3,600 $\mu g/m^3$ PCE vapor above the water).

  Chemicals migrate through water via diffusion. The rate of diffusion through water is about four orders of magnitude less than diffusion through air. Consequently, to reach a building, VFCs in a groundwater plume would have to migrate upward through overlying and potentially clean recharge water and the capillary fringe. The capillary fringe is a transitional area of high soil moisture content at the base of the vadose above the water table. The capillary fringe is capable of significantly attenuating VFC vapors (McCarthy and Johnson, 1993;

USEPA, 2012a) though it can become contaminated due to water table fluctuations. Recognizing the rate of chemical diffusion through groundwater and the potential presence of a clean groundwater lens, groundwater samples collected near the water table are recommended to support VI evaluations (USEPA, 2015a). Declining water tables may leave residual vadose zone contamination that can readily partition into the vapor (gas) phase and more readily migrate (i.e., diffuse through soil gas rather than water).

- **Preferential Pathways/Conduits** – As discussed in Introduction Section C, subsurface drains and utility conduits can facilitate migration of vapor through the pipe itself and through more permeable backfill material. The presence of preferential pathways and their significance are not easily discerned by simple observation, review of building drawings, or traditional site characterization methods. Where conduits such as sewer lines intersect contaminated media, exterior soil gas sampling may underpredict the potential for VI. See Step 1B.2 and Attachment 3 for more information.

Site VFC Contamination Characterization

In general, the better the nature and distribution of contamination is characterized, the less uncertainty is associated with the VI health risk assessment and the more confidence is increased that management decisions are protective of human health. At sites with limited empirical data on the nature and distribution of contamination, conservative assumptions are needed to compensate for the uncertainty and the possibility that limited available information may lead to underestimating current and potential future risk.

For characterizing contaminant distribution as part of VI evaluations, the primary LOEs are VFC concentration data from various media. Indoor air sampling data are the preferred LOE for assessing current risks for building occupants because indoor air data represent the VFC concentrations at point of exposure. Indoor air data should be supported by other LOEs (e.g., subsurface data, building construction and condition, preferential migration pathways, building survey, ventilation/HVAC operation, outdoor air data). Subsurface data are preferred for estimating potential future risks, supported by additional LOEs (e.g., subsurface source type/strength, depth and lateral location relative to buildings, site stratigraphy, soil properties, depth to groundwater, plume stability). Typical LOEs for characterizing VFC concentrations and distribution, presented herein, are divided into two categories, air and subsurface data.

Air Data

Typical air VFC data LOEs used for VI evaluations are indoor air, outdoor air, and crawl space air.

- **Indoor Air** – Indoor air sampling results are the primary LOE when evaluating risk to current occupants because they indicate the chemicals and concentrations to which occupants are directly exposed. Indoor air data represent a composite of VFCs from subsurface contamination and other potential sources: migration from subsurface sources through small openings in the foundation or vapor conduits, indoor sources, and outdoor sources. Interpretation of indoor air results requires consideration of supporting LOEs to characterize indoor air VFCs from sources other than or in addition to subsurface contamination. See Step 3D.1 for further information.

- **Outdoor Air** – Outdoor air sampling results are used to determine potential influences of outdoor air contamination on indoor air quality, thus aiding with indoor air data interpretation and determining VI contribution. See Step 3C.5 and Step 3D.1 for further information. If there are detections of COCs in the ambient air data, regional ambient air data, such as the California Air Resources Board's online database (https://www.arb.ca.gov/adam/toxics/toxics.html) may be used to understand if the COCs are site related or documented regional conditions.

- **Crawl Space Air** – Crawl space air sampling results are used to determine VFC concentrations and distribution that may enter a building and degrade indoor air quality. VFCs in crawl space air samples can be the result of subsurface, indoor and/or outdoor sources and therefore require supporting LOEs for data interpretation. See the section Application to Other Building Types (Building II Crawl Space Buildings) for further information.

Subsurface Data

Typical subsurface VFC data LOEs used for VI evaluations are subslab soil gas and exterior soil gas. Additional LOEs may include VFC data for soil matrix, groundwater, and vapor conduit air, and measurements from field instruments.

- **Subslab Soil Gas** – Subslab soil gas sampling results are used for characterizing the presence and concentrations of VFCs immediately below a building that can migrate into indoor air. Many state guidance documents consider subslab soil gas data as the best subsurface indicator of potential indoor air contamination from VI because the subslab location is within the advective influence of the building and the uncertainty associated with attenuation from the subsurface source to the subslab is not a factor. See Step 3C.4 for further information. Near-source soil gas data, collected in accordance with Step 2A, are typically considered a conservative surrogate for subslab soil gas data.

- **Soil Gas** – Soil gas sampling results are used for characterizing VFCs emitted into soil gas from subsurface sources in soil and groundwater are the preferred subsurface data LOE over groundwater or soil matrix data (see Step 2 for further information). Near-source soil gas data are generally preferred over shallow exterior soil gas data (e.g., 5 feet or less below ground surface) because the latter is: (1) typically not representative of subslab soil gas concentrations where the subsurface vapor source is immediately below the building; (2) unlikely to be representative of future vadose zone conditions after development activities or subslab soil gas concentrations where the subsurface vapor source underlies an existing building; and (3) potentially subject to dilution by ambient air. Detailed discussion regarding soil gas sampling for VI evaluations is provided in Step 2A and additional information related to potential changes in vadose zone conditions is provided in the introduction to Step 4.

- **Soil Matrix** – In general, soil matrix sampling results should not be used for evaluating the VI pathway because of the uncertainty associated with estimating VFC partitioning from soil to soil gas, and the potential loss of volatiles during sample collection, preservation, and analysis (DTSC 2011b; USEPA 2014e, USEPA 2015a). Soil matrix data is an important line of evidence for characterizing the release area (i.e., high concentrations, non-aqueous phase liquid). Soil concentrations and estimates of total mass and contaminated volume of soil are important factors in characterizing subsurface source strength and stability of soil gas concentrations (and potential VI) over time (see Source Type and Strength, below). Soil matrix data is also useful when evaluating potential remedies.

  Soil samples for VFC analysis should be collected using USEPA Method 5035 for field preservation (e.g., low headspace sample containers, methanol preservation) (DTSC, 2004). Results of samples collected without proper field preservation can have significant low bias, potentially up to 90 percent VFC loss (Hewitt, 1994; Grant et al., 1996; Hewitt and Lukash, 1996). USEPA Method 5035 was first implemented in 1997 though the method use likely was inconsistent in California until after 2005, following state sampling guidance. Historically, soil matrix data were routinely used for evaluating VI. Hence, caution should be exercised when evaluating soil matrix data, especially older results.

- **Groundwater** – In general, groundwater sampling results can be used as a supporting LOE to evaluate VI potential, with caution. Reliance on groundwater data for VI evaluation is not preferred due to uncertainty in predicting VFC partitioning from groundwater to soil gas and transport through the capillary fringe. Attachment 4 provides a detailed discussion regarding the use of groundwater data as an LOE.

- **Vapor Conduit Air** – Vapor conduit air sampling is recommended as a supporting LOE to evaluate whether the conduit is a preferential pathway to indoor air. Characterization of VFCs the airspace of conduits aids interpretation of indoor air data. Further information is provided in Step 1B.2, Step 3B.6, and Attachment 3.

- **Field Instrument Measurements** – Field instruments such as photoionization and flame ionization detectors typically are employed during the building survey prior to indoor air sampling (Step 3B) to identify vapor entry points and locate potential indoor sources of VFCs. Field instruments may also be used to test vapor conduit air before sampling. Field instrument measurements are a supporting LOE and not a substitute for analysis using USEPA analytical methods (e.g., Method TO-15).

Contamination Characteristics

The nature, magnitude, and distribution of contamination are critical to understanding the potential for VI. Factors to consider include the following:

Source Type and Strength

Sites contaminated with non-aqueous phase liquid (NAPL) typically present a greater VI potential than sites with only dissolved-phase contamination. Subsurface source concentrations are typically much higher for NAPL sources than for dissolved-phase subsurface sources, leading to greater rates of mass diffusion (USEPA, 2015b). This greater rate of mass diffusion can be persistent because NAPL subsurface sources contain significantly greater mass than dissolved-phase subsurface sources for a given volume.

Contaminant Chemical/Physical Properties

Chemical/physical properties such as vapor pressure and the Henry’s Law Constant control the partitioning of individual VFC between phases (i.e., free phase, dissolved, sorbed, vapor) and migration potential and may be significantly different for each chemical. Vapor pressure is a measure of a chemical’s tendency to volatilize from the pure phase whereas the Henry’s Law Constant is a measure of the tendency of a chemical dissolved in water to volatilize. Chemicals of similar size can have significantly different partitioning characteristics. For example, naphthalene and TCE (TCE) have similar molecular weights yet TCE’s Henry’s Law Constant is about 20 times greater than naphthalene indicating a greater propensity to volatilize from the dissolved phase. To minimize uncertainty in predicting partitioning, soil gas sampling results are the preferred subsurface data LOE over groundwater data (see Step 2 for further information).

Some VFCs may undergo chemical transformation while in storage or after release to the environment. While most chlorinated VFCs are relatively persistent in the environment, some chemicals (e.g., petroleum hydrocarbons) are much less persistent due to their susceptibility to biodegradation. As explained in Attachment 2, petroleum hydrocarbon vapor concentrations can decrease by orders of magnitude over short vertical migration distances in the presence of oxygen and under a wide range of conditions. Chlorinated ethenes (e.g., tetrachloroethene, TCE) can biodegrade under reducing conditions. Vinyl chloride can also biodegrade in the subsurface under aerobic conditions (Patterson et a. 2013). The presence of co-contamination by multiple VFCs and semi- and non-volatile organic compounds, including petroleum hydrocarbons, may affect VFC fate and transport and is another important consideration. See Attachment 2 for the use of bioattenuation factors.

Vapor Transport Mechanisms

Vapor transport includes VFCs migration in soil gas through subsurface porous media or preferential pathway air toward the building, vapor entry into the building, and mixing with indoor air. Overall, vapor transport in the subsurface is controlled by contaminant partitioning (groundwater or soil moisture to soil gas), diffusion (transport from high to low concentration), and advection (transport from high to low pressure) (USEPA, 2012a). Further information is provided in Introduction Section C.

Contaminant Distribution Relative to Buildings

The depth and lateral distance of the subsurface source from existing or future buildings are important factors in the potential for VI. For a given subsurface source type (e.g., soil or groundwater contamination) and strength, the potential for VI is greater where the contamination is close to the building and covers more of the building footprint. The VI potential decreases with increasing lateral distance and depth and less coverage of the building footprint.

Contaminant Distribution Stability

Contaminant distribution, both in soil gas and groundwater, that has not reached steady-state conditions should be evaluated with caution and conservativism. Risk assessments based on current conditions may underestimate future risks if contaminant distribution is not stable and future subsurface concentrations increase near a particular building. See also Subsurface Conditions, above, regarding changes in contaminant distribution induced by site development.

Weather/Meteorological Conditions

Aboveground environmental factors influencing spatial and temporal variability in VI consist of weather phenomena such as barometric pressure, temperature, and wind. These factors should be considered in determining when and where to sample, and in interpreting results.

Barometric Pressure

Barometric pressure can influence soil gas concentrations during large barometric pressure cycles and can also influence the transport of soil gas into buildings (Massmann and Farrier, 1992; Robinson and Sextro, 1997; Robinson et al., 1997a, b). High barometric pressure (relative to the subsurface) can cause fresh air to migrate several meters into permeable soils thus lowering soil gas VFC concentrations. Conversely lower pressure relative to the subsurface may increase shallow soil gas

VFC concentrations as vapors move upward from deeper subsurface sources. The greatest variability is expected during periods of rising or falling barometric pressure. Indoor-to-subsurface pressure differences similarly can influence the potential for VI. During high barometric pressure periods, VI may be reduced or eliminated as the building is pressurized relative to the subsurface, while during low barometric pressure periods, VI may be enhanced.

Temperature Effects

Temperature differences between indoor air and the subsurface can result in convection driven by heated air that rises to upper levels of a building and leaks through roofs and upper-floor windows. The lower pressure of warm indoor air causes advective flow of soil gas from the subsurface through cracks and other openings in the foundation. The stack effect can be strongest during the colder weather when building interiors are heated or, potentially, on sunny days due to increased temperature of the roof and highest enclosed spaces.

Wind Effects

Wind effects on VI are caused by differences in interior building pressure resulting from wind on a building's surfaces. The indoor air pressure will be higher on the windward side of the building than on the leeward side. This situation results in ambient air infiltration into the building on the windward site and indoor air exfiltration from the building on the leeward side. Wind loads on the ground surrounding buildings can also affect the subslab distribution of VFCs and contribute to spatial and temporal variability (Luo et al., 2009; USEPA, 2012a). Given that wind direction is likely to vary, the effect may not be significant except potentially in regions where directional winds are consistent (e.g., coastal region afternoon onshore breezes).

Other Methods

Advancements in development of methods and technologies for characterizing VFC contamination at sites and evaluating VI are ongoing. Many of these methods are not routine or common. Hence, a work plan describing the proposed method and procedures along with justification should be submitted to the overseeing regulatory agency for review and input. Several of these methods are summarized below.

Continuous Monitoring

This method consists of repeatedly measuring VFC concentrations (e.g., indoor air, subslab, outdoor air) and potential indicators of VI (e.g., barometric pressure, cross-slab pressure differential, and temperature) within minutes to hours over a several day long field investigation (Hosangadi et al. 2017; Kram et al. 2020). Instruments may be configured to generate time series trends from multiple locations for several parameters. The data may be used to estimate VI risk and identify potential VI pathways and indoor sources. For risk assessment, the results should be confirmed with the method described in Step 3C. Continuous monitoring has been typically used after initial identification of elevated indoor air detections to help diagnose VI.

Controlled Pressure Method

This method can be used to evaluate a building's susceptibility to VI during a brief field investigation of a few days (McHugh et al. 2012; Lutes et al. 2019; Guo et al. 2020). The method involves two testing regimes, one under negative pressure conditions and one under positive pressure conditions. The pressure conditions are artificially induced using high flow fans. Indoor air VFC concentrations are measured over time during each testing regime. The negative pressure regime induces VI and may allow estimation of the upper end of indoor air concentrations under the current building condition while the positive pressure regime suppresses VI and can be helpful in identifying indoor sources of the target VFCs. The method has been suggested as an alternative to seasonal monitoring and could potentially be used to estimate building-specific AFs. Currently, regulatory guidance does not explain how to appropriately implement and interpret CPM. Guidelines for use are expected to be published for ESTCP Project ER-201501 (VI Diagnosis Toolkit) in 2021.

High Purge Volume Subslab Sampling

The method consists of extracting a large (e.g., over 500 liters) volume of soil gas from beneath a foundation to provide spatially averaged concentrations for larger areas rather than more highly variable data resulting from discrete sampling of smaller volumes of soil gas. Sampling a large, extracted volume of soil gas potentially reduces the possibility of missing an area of elevated concentrations compared to using multiple discrete sampling points (McAlary et al., 2010). This method is described in the Advisory—Active Soil Gas Investigations (CalEPA, 2015).

Indicators, Tracers, and Surrogates

Indicators, tracers, and surrogates (ITS) refers to different tools that can help with VI pathway assessment and monitoring by helping to determine the best times and locations for future indoor air sampling and potentially characterize reasonable maximum exposure (RME) conditions (Schuver et al., 2018). Typically, use of these tools requires that measurements be made over time to determine trends rather than relying on single point-in-time measurements. Currently, regulatory guidance for using these methods to help with VI pathway assessment is limited.

- **Barometric Pressure Trends** – Measuring the pressure difference between the outdoor air and indoor air (indoor-outdoor pressure differential) can indicate whether atmospheric conditions are promoting VI into a building. During a 9-day study of a building in San Diego, California, Kram et al. (2020) observed that the controlling factor on TCE indoor air concentrations was the change in barometric pressure with higher concentrations detected as barometric pressure began to fall (increased VI) and, vice-versa, lower concentrations detected as barometric pressure began to rise (decreased VI).

- **Cross-Slab Pressure Differential** – Measuring the pressure difference between the subsurface and indoor air (cross-slab pressure differential) can indicate whether subsurface VFCs are potentially migrating into the building (i.e., depressurized building interior) or not (i.e., pressurized building interior) (USEPA, 2015a). Pressure differentials typically are measured using micromanometers with pressure transducers and dataloggers installed at subslab probes. USEPA recommends that the pressure difference between the indoors and the subsurface be measured whenever indoor air samples are collected. Pressure differential data would be collected continuously starting several days before sampling and throughout the sample collection period. This involves measuring the differential at separate locations, away from probes used for subslab soil gas collection. Purging and sampling of such subslab probes could cause pressure disruptions.

- **Temperature and Differential** – Measuring the outdoor air temperature or the temperature difference between outdoor air and indoor air may indicate whether conditions favor VI and help determine when to sample indoor air. These measurements are most useful when daily outdoor temperatures are likely to be below 30 degrees Fahrenheit (Schuver et al., 2018).

- **Tracer Testing, Radon** – Naturally occurring radon may serve as a tracer to help identify those buildings that are more susceptible to soil gas entry than others because VI and radon entail similar mechanisms for soil gas migration and entry into structures (USEPA, 2015a). Radon may be used to confirm but not rule out whether the VI pathway is complete. Radon should not be used to quantitatively estimate building-specific VFC AFs because changes in radon concentrations typically are not proportional to changes in VFC concentrations (Schuver et al., 2018). Real-time radon measurements have been used in some investigations by USEPA to determine when VI is occurring and to collect samples for VFC analysis during these periods.

Mathematical Modeling

Mathematical models can be used to develop a conceptual understanding of the factors influencing VI at a particular site except for preferential pathways, which are not considered in currently available models. A commonly used mathematical model for VI is the USEPA implementation of the Johnson and Ettinger Vapor Intrusion Model (Johnson and Ettinger, 1991; USEPA, 2017b), which derives a vapor AF for predicting subsurface VI into indoor air and the resulting indoor air VFC concentrations. A similar VI mathematical model that additionally incorporates biodegradation and uncertainty analysis for the evaluation of petroleum VI is PVIScreen (USEPA, 2016a).

The use of models as an LOE to support risk management decisions requires more advanced characterization of subsurface conditions and contamination than is needed for screening. Following the preliminary VI screening (Steps 1 to 3) and development of a complete CSM, site-specific modeling of VFC migration potentially can be used in developing site-specific AFs and media concentrations protective of human health. Models should be only used as an LOE in an multiple LOEs evaluation when the following conditions are met: (1) the nature and distribution of VFC contamination at a site has been adequately characterized, (2) the model is applicable to site subsurface conditions and to the contamination, and (3) the model is adequately constructed, documented, and verified (USEPA 2015a). The most important element to ensure confidence in a model as an LOE is verification of model predictions (i.e., indoor air sampling data confirms the predicted AF or that the AF is adequately protective). The following should be considered when developing site-specific risk assessments based on alternative soil gas-to-indoor air AFs:

- The CSM should be robust and based on sufficient LOEs to document that the assumptions of the model and inputs are consistent with site and building conditions (e.g., geology and distribution of subsurface concentrations are homogeneous).

- Vapor conduits should be investigated and ruled out as possible exposure pathways due to the inability of models to evaluate this vapor migration pathway (e.g., no current **or potential future** VI conduits intersect soil or groundwater contamination).

- Model inputs should account for potential future changes in building conditions that could reduce VI attenuation and increase VI risk as described in Step 4. Recommendations regarding how to account for future building changes are described in "Potential Future Soil Gas to Indoor Air Attenuation Factors" in Step 4A.3.

- Subsurface-based model inputs should use data based on adequately characterized geology/hydrogeology underlying the building (see DTSC Vapor Intrusion Guidance [2011a] and the current SF Bay Regional Water Board ESL User's Guide).

- Models should use default receptor-specific exposure factors (DTSC Human Health Risk Assessment [HHRA] Note 1, 2019 or current SF Bay Regional Water Board's ESLs) to account for the uncertainty in predicting values of site-specific exposure parameters for future building occupants.

- Site-specific subsurface AFs should be applied to exterior near-source soil gas concentrations collected next to an existing building, similar to the sample location and depth recommendations described in Step 2 of this Guidance.

- Subslab concentrations, if available, should be used to confirm modeled subsurface vapor attenuation between the subsurface vapor source and the building foundation.

Passive Soil Gas Sampling

Passive soil gas samples should not be used in place of active soil gas samples collected according to Step 2. The passive soil gas sampling method consists of burying an adsorbent material into subsurface soil and subsequently retrieving and measuring organic vapors passively amassed onto the absorbent material (CalEPA, 2015). Traditionally, passive soil gas sampling has been used to: (1) evaluate whether a release has occurred; (2) characterize the overall near-surface soil gas contamination distribution at a site; (3) identify preferential pathways resulting from lithologic variability or sewer/utility corridors; and (4) qualitatively evaluate soil gas contamination in areas where active soil gas samples are difficult to obtain (e.g., near-surface groundwater conditions). This method is described in Appendix A of the Advisory—Active Soil Gas Investigations (CalEPA, 2015). Recently, some interest has been expressed for using passive soil gas results quantitatively for risk assessment (ESTCP, 2014; ASTM, 2017; DoD, 2019). Currently available passive soil gas sampling methods alone are not used to estimate human health risks and are generally not used to exclude or “screen out” buildings from further VI evaluation. If passive soil gas samples have been collected for another purpose and indicate potential health risks from VI, the results may be used to "screen in" or identify buildings where an indoor air investigation should be performed as described in Step 3.

Subslab Pneumatic Methods

This building-specific test method consists of monitoring ambient pressure gradients, performing vapor pumping tests to measure vacuum versus time and vacuum versus distance, subslab tracer testing to measure gas travel rates, flow rate and concentration measurements in vent pipes, and mathematical modeling (ESTCP, 2018; McAlary et al., 2018). The method is analogous to methods used for the design and performance monitoring of a groundwater extraction system. The data can be used to estimate the building-specific subslab AF via mass flux calculations, which provides insight into the protectiveness of the building structure and foundation under current conditions. Currently, regulatory guidance does not explain how to appropriately implement and interpret this method.

Attachment 2

Petroleum-Specific Considerations

Attachment 2 – Petroleum-Specific Considerations

Petroleum releases from underground storage tanks (USTs) must be evaluated for vapor intrusion (VI) using the State Water Board's Low-Threat Underground Storage Tank (UST) Case Closure Policy (LTCP) (State Water Board, 2012b).

Objectives

The objectives of Attachment 2 are to promote approaches for petroleum vapor intrusion (PVI) screening at non-UST petroleum releases that are similar to the LTCP's PVI approaches and to provide petroleum-specific recommendations when screening PVI threats for buildings using the Supplemental Guidance.

Background

Most petroleum hydrocarbons can biodegrade under aerobic (oxygenated) environmental conditions that are found at many sites (USEPA, 2012c). The VI threat related to petroleum hydrocarbon contamination in the subsurface is frequently reduced by biodegradation, which occurs under common conditions. Biodegradation by naturally occurring microbes takes place in the water phase (e.g., soil moisture). Aerobic biodegradation reduces the concentration of petroleum vapors in vadose zone soils where there is sufficient oxygen and clean soil between the petroleum contamination and building foundation. In general, oxygenated soil that supports biodegradation is defined as greater than one percent by volume oxygen in soil gas (USEPA 2015b). This phenomenon has been demonstrated with empirical data (Davis, 2009; Lahvis et al. 2013; USEPA, 2013a).

Figure A2-1 illustrates the typical vertical profile of petroleum hydrocarbon concentrations, oxygen, and carbon dioxide in the unsaturated zone above petroleum-contaminated soil or groundwater. The presence of sufficient concentrations of oxygen indicates the potential for biodegradation. The carbon dioxide profile should be the opposite of the oxygen profile and serves as a confirming line of evidence. Elevated methane concentrations indicate anaerobic (low oxygen) conditions. The methane concentration profile typically follows the same trend as the hydrocarbon concentration profile.

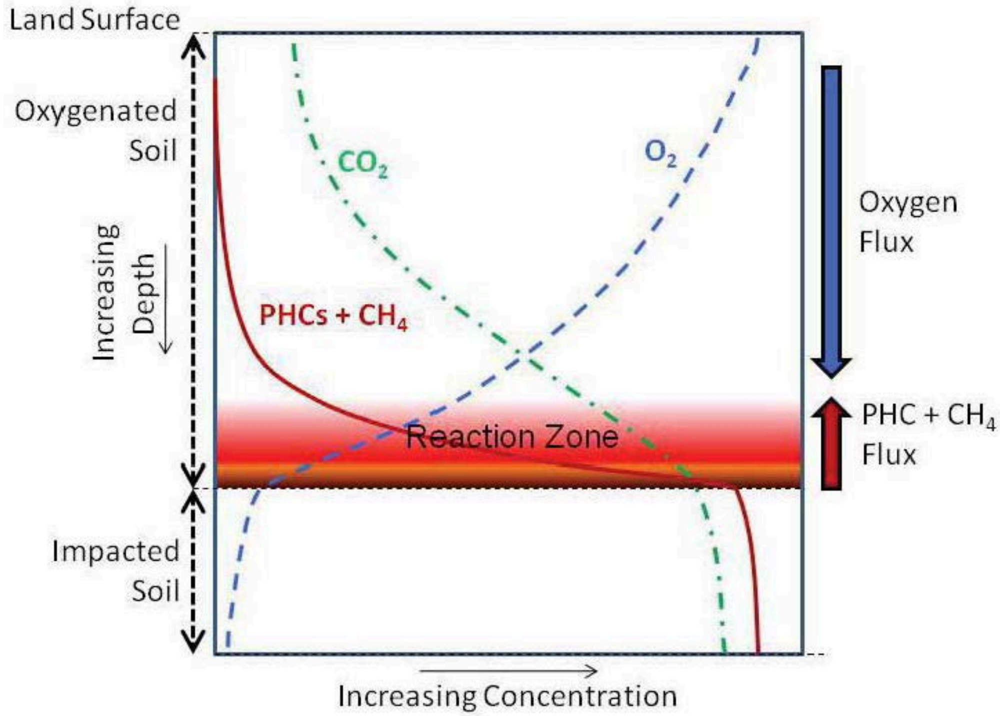

Figure A2-1. Diagram showing the typical vertical concentration profile in the unsaturated zone for petroleum hydrocarbons (PHCs) with biogeochemical indicators methane, carbon dioxide, and oxygen. With aerobic biodegradation in unsaturated soils, PHCs plus methane (red; solid line) degrade, carbon dioxide (green; dash-dot line) is produced, and oxygen (blue; dash line) is consumed. The aerobic biodegradation (bioattenuation) zone extends over the area of active biodegradation. The subsurface source zone, which is anaerobic, is characterized by the maximum vapor forming chemical concentrations and little biodegradation. Source: USEPA 2012c

PVI typically is of greater concern where there is less potential for biodegradation to adequately reduce petroleum VFC concentrations between a subsurface source and a building. Examples include situations where the petroleum release is directly beneath a building, large volume releases that can deplete subsurface oxygen, or preferential pathways (e.g., sewers) where the vapors could travel through the air space without biodegradation (McHugh et al., 2010; USEPA 2013a).

The subsurface biodegradation of petroleum VFCs can occur if there are suitable conditions (e.g., adequate oxygen) regardless of the petroleum site type. Types of petroleum sites include gasoline service stations, refineries, bulk storage facilities, oil exploration and production sites, pipelines and transportation, chemical manufacturing facilities, former manufactured gas plants, creosote wood-treating facilities, large-scale fueling and storage operations at federal facilities, and dry cleaners that use petroleum solvents. At larger petroleum release sites with a greater mass of hydrocarbons in the subsurface, oxygen may become depleted, and petroleum VFC concentrations may be insufficiently attenuated such that VI is more likely to occur and pose a risk. Therefore, it is not the site type/size but rather the size of the release that warrants greater scrutiny (e.g., demonstration of bioattenuation zone) during site investigation and screening.

USEPA along with many state and other agencies have developed PVI guidance or policies considering the likelihood for biodegradation. Typically, PVI guidance documents or policies employ separation distances as part of screening. The LTCP additionally includes soil gas oxygen concentration screening. Recommended PVI guidance and policies include USEPA (2015b), ITRC (2014), and State Water Board's Low-Threat UST Case Closure Policy (State Water Board, 2012b).

Description of PVI Screening Approaches

This section provides descriptions of the two LTCP PVI screening approaches based on separation distance and soil gas oxygen concentration—use of these approaches as part of the Supplemental Guidance is described in the following section. Both approaches rely on the potential for biodegradation of petroleum VFC vapors to evaluate whether an indoor air investigation is needed for a given building. Separation distance screening depends on a well-developed conceptual site model based on soil and/or groundwater data, and soil gas or indoor air sampling is only conducted when there is insufficient separation distance between the petroleum subsurface vapor source and the building. Soil gas oxygen concentration screening employs soil gas sampling for petroleum VFCs and biogeochemical indicators (e.g., oxygen). When sufficient oxygen is present in soil gas, a bioattenuation factor (BAF) is employed in addition to the soil gas AF (e.g., 0.03).

The separation distances and the BAF were developed based on theoretical (modeling) and empirical studies involving groundwater, soil, and soil gas data collected at numerous petroleum release sites. The final LTCP distances and BAF include safety factors (i.e., the values are more conservative than would be otherwise indicated if the results were only based on modeling and field studies). Further information is provided in the Technical Justification for Vapor Intrusion Media-Specific Criteria (State Water Board, 2012a).

Separation Distance Screening Approach

The separation distance approach relies on the minimum thickness/width of clean soil between a petroleum subsurface vapor source (e.g., contaminated soil or groundwater) and building foundation needed to effectively biodegrade hydrocarbons and prevent PVI or reduce indoor air petroleum VFC concentrations below risk-based screening levels. Soil samples should be collected for petroleum analysis between the known or suspected petroleum contamination and the building to confirm the thickness/width of clean soil available for bioattenuation. **Clean soil is defined as total petroleum hydrocarbon (TPH) concentrations less than 100 milligrams per kilogram (State Water Board, 2012b)**.

Separation distances depend on whether the petroleum subsurface vapor source is either: (1) light, nonaqueous phase liquid (LNAPL) in soil and groundwater; or (2) petroleum-contaminated groundwater (dissolved phase). The contamination (LNAPL, groundwater plume) is assumed to be stable or decreasing (i.e., not migrating). Petroleum VFC concentrations generated by LNAPL subsurface sources typically are significantly greater than those generated by dissolved-phase subsurface sources and require greater distances for attenuation of vapors. The following separation distances are recommended for different types of petroleum sources:

- LNAPL Subsurface Sources – **30 feet** (see illustrations in LTCP Appendix 1 and Appendix 2)
- Dissolved Subsurface Sources – The separation distances vary based on subsurface source strength and oxygen content (see illustrations in LTCP Appendix 3):
    - **5 feet** for low concentrations (e.g., benzene less than 100 μg/L);
    - **5 feet** for moderate concentrations (e.g., benzene between 100 and 1,000 μg/L) in areas with measured soil gas oxygen content equal to or greater than 4 percent.
    - **10 feet** for moderate concentrations (e.g., benzene between 100 and 1,000 μg/L) in areas with unknown or low oxygen content (less than 4 percent).

Soil Gas Oxygen Concentration Screening Approach

The soil gas oxygen concentration screening approach relies on soil gas samples collected in Step 2 and analyzed for both petroleum VFCs and biogeochemical parameters (e.g., oxygen, carbon dioxide, methane). The oxygen content is used to determine whether there is an adequate bioattenuation zone and select the appropriate BAF that can be applied in combination with the soil gas AF (e.g., 0.03), as follows:

- Inadequate Bioattenuation Zone
    - Oxygen Content: Less than 1 percent (**< 1%**)
    - BAF: **1.0** (assumes no bioattenuation)
- Weak Bioattenuation Zone
    - Oxygen Content: At least 1 and less than 4 percent (**1% ≤ x < 4%**)
    - BAF: **0.1**
- Strong Bioattenuation Zone
    - Oxygen Content: Equal to or greater than 4 percent (**≥ 4%**)
    - BAF: **0.001**

The BAF is not applied to subslab soil gas, crawlspace air, or indoor air because biodegradation is not expected to occur in the air phase (USEPA 2015a).

Use of PVI Screening Approaches

The following recommendations indicate how the LTCP PVI screening approaches, both separation distance and soil gas oxygen concentration, can be employed at non-UST petroleum release sites while following the Supplemental Guidance.

Step 1B.1 – Prioritizing Buildings for PVI Evaluation

Step 1B.1 describes the prioritization of buildings for screening based on a 100-foot distance from the area of estimated vadose zone soil contamination. For petroleum release sites, the distance should be adjusted to 30 feet given the potential for biodegradation. This distance is consistent with the separation distance for high strength subsurface sources (e.g., LNAPL in soil or groundwater). For mixed petroleum/non-petroleum release sites, the 100-foot distance should be used during initial screening (Steps 1 through 3).

Step 1C – Selecting the PVI Investigation Approach

Step 1C describes the selection of the approach for investigating potential VI for a building given currently available information for the site. If there is adequate soil and/or groundwater data, separation distance screening can be used at petroleum-only release sites to:

- Identify buildings, with sufficient bioattenuation zones, that can be considered low priority for further VI evaluation. Proceed to Step 4 for such buildings.
- Determine when it is appropriate to proceed directly to indoor air sampling (Step 3) at buildings near petroleum releases.

Step 2A – Evaluate Spatial Distribution of Soil Gas

During Step 2, multi-depth soil gas samples should be collected at least 5 feet beneath the building/foundation. Soil gas samples should be analyzed for biogeochemical parameters (e.g., oxygen, carbon dioxide, methane), in addition to VFCs, to determine which BAF is appropriate.

Step 2B.1 – Estimating Potential Indoor Air Concentrations

For sites employing the soil gas oxygen concentration screening approach for Step 2, the modified equation for predicting indoor air concentrations where an adequate bioattenuation zone is present also includes the use of the appropriate BAF, as follows:

$C_{IA} = C_{SG} \times AF \times BAF$ where:

C_{IA} – indoor air concentration

C_{SG} – soil gas concentration

AF – default attenuation factor

BAF – bioattenuation factor

1.0 BAF for oxygen content less than 1 percent or mixed releases

0.1 BAF for oxygen content greater than 1 percent

0.001 BAF for oxygen content greater than 4 percent

Step 3C.1 – Determine Whether VI is Occurring

Step 3C.1 describes the interpretation of indoor air data along with available lines of evidence given that non-subsurface sources of VFCs can confound the interpretation of indoor air data. Practitioners should be aware that there are numerous and widespread indoor and outdoor sources of petroleum VFCs such as vehicle emissions, consumer products, materials used for repairs and remodeling, and vehicle and fuel storage in attached garages (USEPA, 2011; ITRC, 2014; and McDonald et al., 2018). The interpretation of indoor air data during the evaluation of PVI can be more challenging than for VFCs that are less widely used (e.g., TCE).

Step 4A – Site-Specific Risk Assessment Refinements for Mixed Releases

As described above for Step 2B.1, a BAF of 1.0 (no bioattenuation) is used for mixed petroleum/non-petroleum releases during initial screening. Based on the results of the Step 2 and/or Step 3 investigation, if biodegradation of the petroleum chemicals from the mixed release is demonstrated, then the appropriate BAF could be used to refine the risk assessment (Step 4A).

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Attachment 3

Sewers and Other Vapor Conduits as Preferential Pathways for Vapor Intrusion

Attachment 3 – Sewers and Other Vapor Conduits as Preferential Pathways for Vapor Intrusion

Introduction

Subsurface vapors can be drawn into indoor air through two routes. Vapor can migrate through the soil and enter buildings through openings in the foundation. Alternatively, vapors can migrate through subsurface pipe networks (e.g., sewers, drains, etc.) and enter buildings. These pipe networks can contain vapor forming chemicals from waste discharge into the pipe network or through infiltration of groundwater or soil gas from contaminated areas. Underground piping can distribute contamination beyond delineated groundwater and vapor plumes. Vapor transport through pipe networks has been demonstrated with direct release to indoor air through dry plumbing traps (e.g., p-traps), loose pipe fittings, and cracked pipes. In addition, cracked pipes or loose fittings can occur below the building with discharge of the vapors to the sub-foundation region and subsequent migration to indoor air through openings in the foundation. The presence of preferential pathways and their significance are not easily discerned by simple observation, review of building drawings, or traditional site characterization methods.

Overview of Sewers

Sewers are a network of pipes designed to convey sewage from buildings to sewage treatment plants. Sewers are filled with odorous and potentially toxic gases that must be prevented from entering buildings. Plumbing-traps prevent the escape of these gases from the sewer. Traps are kept continuously filled with water to create a barrier to vapor flow. Plumbing traps are typically U-shaped pipes located under sinks, toilets, and drains. Sewers are typically vented to roofs to equalize pressure in the system and keep water in the traps and vent gases away from building occupants. Sewer laterals connect buildings to municipal sewer mains. These typically gravity-drain to municipal sewage treatment facilities. Sewer mains are designed to allow water to flow downhill but are neither water- nor gastight. Cracks may develop as the system ages or as the system is penetrated by roots. Sewer mains have maintenance holes located throughout the system, and buildings typically are required to have a sewer access port, or "cleanout" for maintenance purposes.

Historically, sewers were used for the disposal of industrial waste (Vroblesky et al., 2011; Central Valley Regional Water Board, 1992). Today, municipal sewage or permitted discharges may contain VFCs which are released directly into sewers.

Summary of Technical Studies

Numerous recent studies illustrate the potential for sewers to impact indoor air quality. These are a few of the key studies in chronological order of publication:

1. Riis et al. (2010) measured indoor air quality at 32 houses near or overlying subsurface contamination at a site in Denmark and found three houses with significant vapor intrusion (VI) problems. Due to the lack of clear correlation between subsurface contamination and indoor air concentrations, the sewer lines were tested and found to contain chlorinated solvents. Tracer gases were injected into the sewer and showed that sewer air was transported into the houses through joints, pipe penetrations and floor drains.
2. Pennell et al. (2013) studied a residential neighborhood in the Boston, Massachusetts, area adjacent to a chemical facility. Seventy properties were evaluated for VI. Elevated concentrations of tetrachloroethylene (PCE) were detected in indoor air on the first floor of a residence, but lower concentrations were observed in the basement. During the follow-up sampling event, similar results for PCE resulted but sewer odors were also observed. Sampling of the sewer detected PCE, and the elevated concentrations of PCE in the bathroom were attributed to a deteriorated seal on the toilet.
3. As indicated by Sivret et al. (2014), odorous compounds in sewers exhibit significant temporal variability. Their results indicate that strong diurnal variation occurs, with the greatest concentrations observed near midnight. Additionally, sampling at successive 10-minute intervals showed concentration changes of 50 to 100 percent, demonstrating the dynamic nature of sewer gas. The authors also noticed reduced concentrations of odorous compounds during rainfall events.
4. Guo et al. (2015) determined that a land drain system acted as a vapor conduit for trichloroethylene (TCE) migration into a home near Hill Air Force Base, Utah. At this residence, a lateral pipe, open at one end, terminated within the subfoundation gravel layer, and the other end of the lateral pipe connected to the neighborhood land drain system. The neighborhood land drain system contacted contaminated groundwater, providing a source for TCE inside the land drain system. Using a combination of controlled pressure testing, soil gas profiles, and mass flux estimates, the influence of the land drain system on indoor air was confirmed. TCE-containing vapor was directly transported through the land drain pipe to the subfoundation gravel layer and then into the building via cracks and other openings due to advection when the building was underpressurized.
5. McHugh et al. (2017c) conducted tracer, sewer vapor, soil gas, and indoor air testing at the USEPA research residential duplex in Indiana. The field investigation confirmed that the sewer line served as a local preferential pathway for the migration of vapors from the sewer into the duplex. Vapors were detected at multiple locations within the sewer, and tracers released into the sewer upstream and downstream were detected in the duplex. Furthermore, the mitigation system reduced indoor radon concentrations; however, a similar reduction in PCE was not observed, suggesting that most of the PCE did not originate from the vadose zone. The

migration pathway appears to be complex, with the tracer data suggesting there is leakage from the sewer lateral beneath the building rather than directly to indoor air.

6. Nielsen and Hvidberg (2017) state that sewer systems are a major VI pathway in more than 20 percent of the contaminated dry cleaner sites in central Denmark.
7. The California Department of Public Health (CDPH) issued a Safety Alert in 2017 concerning Cure-In-Place Pipe (CIPP). CIPP is one of several trenchless rehabilitation methods to repair existing sewers. CIPP is a jointless pipe-in-pipe tube inserted into existing damaged pipe. Hot water, UV light, or steam is used to cure the material to form a tight-fitting replacement pipe. CDPH issued the Safety Alert due to styrene vapors from the CIPP curing process entering nearby buildings.
8. The Environmental Security Technology Certification Program (ESTCP; 2018b, 2018c, and 2018d) measured 205 groundwater to sewer attenuation factors (AFs). The median AF for sewers below and above the water table was 0.0075 (N=65) and 0.00014 (N=140), respectively. The report also summarized and evaluated ten published studies and two confidential studies concerning sewer to building AFs from tracer testing. The sewer to building AFs ranged from 0.3 to less than 0.001 (N=87). The ESTCP (2018b, c, d) guidance recommends the use of an AF of 0.03 as a reasonable upper-bound for the screening of vapors migrating from sewers and utility tunnels into buildings.

Collection of Samples

These papers provide information on potential sampling approaches. Necessary permits or access agreements should be obtained prior to sampling. Other sampling techniques may be considered as appropriate.

Street Sampling

For street sewers, vapor samples can be collected at sewer maintenance hole covers. Air samples should be collected either through the existing vent holes or by removing the cover enough to allow passage of a sampling tube. Vapor samples are collected by lowering sampling tubing into the sewer. The sample should be collected approximately one foot above the surface of the liquid (liquid level) in the sewer. If needed, the liquid level should be determined with a water level meter. The sampling tubing should be weighted prior to introduction into the sewer and composed of either high-density polyethylene, Teflon, or polyetheretherketone (PEEK). Three volumes of air in the sample tubing should be purged prior to sampling. Air samples should be collected in either polymer gas sampling bags or passivated stainless steel canisters. A leak check compound, as described in CalEPA (2015), should be used to evaluate the integrity of the connection between the sampling tubing and the sampling container. The holding time for polymer bags is six hours, but steel canisters can be held 30 days prior to analysis.

Cleanout Sampling

Buildings are required to have a sewer access port or, “cleanout,” for maintenance purposes. Cleanouts provide access to the building’s sewer system and are usually composed of a simple screw-on cap connected to a y-fitting. Buildings may have more than one cleanout. Typically, cleanouts are located inside the building near the water heater, mounted in an exterior wall near the kitchen, or at grade along the building’s perimeter. The section of pipe used to access the sewer system is hereby referred to as “cleanout pipe”. For sampling, the cleanout cap should be removed, and the sampling tubing should be inserted as far as possible without contacting sewage. To place the sampling tubing into the center of the cleanout pipe, a collar should be installed at the end of the tubing to suspend the tubing off the cleanout pipe wall. A temporary cover should be placed on the cleanout opening to minimize the introduction of ambient air into the sewer. After the temporary cover is installed, the sewer should be allowed to equilibrate for about an hour before sample collection. At least three volumes of air should be purged from the tubing prior to sample collection. A leak check compound, as described in CalEPA (2015), should be used to evaluate the integrity of the connection between the sampling tubing and the sampling container.

If access to cleanout pipes is not available or readily apparent, then sewer samples may be collected inside buildings at the plumbing trap located below a sink. The sampling tubing is threaded down the drain and must extend past the liquid barrier in the plumbing trap. To ensure the tubing extends beyond the water barrier, the tubing length necessary for sampling should be determined. Once the tubing is beyond the water barrier, a small amount of air (one tubing volume or less) should be blown into the tubing to remove any trap water. After the water is blown from the tubing, three tubing volumes of air should be purged prior to sampling. A leak check compound, as described in CalEPA (2015), should be used to evaluate the integrity of the connection between the sampling tubing and the sampling container. As an alternative to threading the sampling tubing through the water trap, a small hole can be drilled in the sewer pipe downstream of the water trap, if there is sufficient pipe exposure between the trap and the building wall. The sample can be obtained by threading the pipe into the hole.

Passive Sampling

To provide an estimate of the average concentration over time, both street sewers and building cleanouts can be evaluated with passive air sampling devices. As discussed in Step 3B of this Supplemental Guidance, an appropriate evaluation of passive sampler efficacy should be performed before implementing a sampling program. The devices should be deployed in the middle of the maintenance hole or cleanout pipe, not contacting the maintenance hole or cleanout pipe walls. Maintenance holes and cleanouts should be covered with their lids to alleviate ambient air influences. The passive samplers should be deployed for three to ten days and field preserved (chilled) upon retrieval pursuant to the manufacturer’s specifications. The passive samplers should be analyzed pursuant to USEPA method TO-17.

Screening of Vapors in Sewer Air

A key conclusion of ESTCP guidance (2018b, c, d) is that VI should not be ruled out as an exposure pathway based solely on subslab, soil gas, or groundwater sampling data. The investigation protocol for sewer/utility conduit air consists of two steps:

- Desktop Screening – Identify the locations and depths of sewers and utility conduits in the vicinity of release areas or groundwater plumes. Review the information to classify the site as either a greater or lower threat as follows:
    - Greater threat – Sites where a sewer or utility conduit directly intersect a groundwater plume or release area.
    - Lower threat – Sites where the sewer or utility conduit in the vadose zone is above a groundwater plume or away from release areas.
- Field Sampling Investigation – For greater threat sites, sampling of sewer/utility conduit air is recommended. For lower threat sites, a conventional VI investigation is recommended first. Sewer/utility conduit air sampling can be conducted later if the conventional VI investigation indicates that preferential pathways are a concern.

The ESTCP guidance recommends the following sewer to indoor air AFs, developed based on tracer testing, as reasonable upper bound values to evaluate field data. VFCs in sewer air should be screened with these AFs:

- Sewer/utility air to indoor air: 0.03
- Groundwater to sewer/utility conduit air: 0.03

Note that these two AFs can be combined to yield an overall groundwater to sewer/utility conduit to indoor air AF of 0.001.

References – included in main text

Attachment 4

Groundwater as Line of Evidence to Evaluate Vapor Intrusion Risk

Attachment 4 – Groundwater as Line of Evidence to Evaluate Vapor Intrusion Risk

Introduction

Groundwater data are routinely collected during site cleanup activities to characterize the distribution of groundwater contamination, to evaluate if plumes are migrating, and to verify the effectiveness of remediation. Groundwater data can be used as a supporting line of evidence (LOE) to evaluate vapor intrusion (VI) potential when soil gas data have not yet been collected. When soil gas data are lacking, groundwater data can be used to confirm, but not rule out, whether the VI pathway is complete. Groundwater is a supporting LOE due to uncertainty of vapor migration and possible unknown site conditions (see below). This attachment describes the prediction of indoor air concentrations using groundwater data, calculation of cancer risk and noncancer HQ, and considerations when using groundwater data to predict indoor air concentrations.

Prediction of Indoor Air Concentrations Using Groundwater Data

The concentration of a vapor forming chemical migrating into indoor air through VI can be predicted from the groundwater concentration using two steps:

1. The VFC concentration in groundwater is used in the partitioning equation below to predict the equilibrium vapor concentration.

$$C_{Vapor-GW} = C_{GW}\ x\ H'\ x\ \left(\frac{1{,}000L}{m^3}\right)$$

where:

$C_{Vapor\text{-}GW}$	Vapor concentration in equilibrium with groundwater in µg/m^3
C_{GW}	Groundwater concentration in micrograms per liter (µg/L)
H’	Chemical-specific Henry’s Law constant (unitless) at the specified groundwater temperature.[9]

[9] The USEPA Regional Screening Levels supporting table “Chemical-Specific Parameters” is a source for these values at 25 °C. The Vapor Intrusion Screening Level (VISL) Calculator User’s Guide (USEPA, 2014) describes how to adjust H’ for different temperatures.

2. The equilibrium vapor concentration is multiplied by the USEPA groundwater-to-indoor air AF (0.001) to predict the indoor air concentration after vapors have migrated through the capillary fringe and vadose zone into a building, as shown below.

$$C_{IA} = C_{Vapor-GW} \; x \; AF_{GW}$$

where:

C_{IA}	Indoor air concentration in µg/m³
$C_{Vapor-GW}$	Vapor concentration in equilibrium with water in µg/m³
AF_{GW}	Generic groundwater to indoor air attenuation factor of 0.001 or 0.0005 if a laterally continuous, fine-grained vadose zone is present (USEPA, 2015a).[10]

Calculation of Cancer Risk and Noncancer Hazard Quotient

Use the standard equations in Step 2B.2 to estimate cancer risk and the noncancer HQ using the predicted indoor air concentration.

Considerations When Using Groundwater Data to Predict Indoor Air Concentrations

Groundwater data are not the preferred LOE for evaluating VI because of the uncertainties associated with the partitioning equations and uncertainty about transport through the capillary fringe. Additionally, groundwater concentrations may not reflect vadose zone contamination in that unknown or uncharacterized contaminant releases may exist in the vadose zone above the contaminated groundwater. The direct measurement of soil gas concentrations bypasses these uncertainties, which is why soil gas is recommended as a preferred line of evidence in Step 2. In general, groundwater data should not be used as the sole LOE to support a decision not to sample soil gas. However, groundwater data from the first water-bearing zone can be used as a supporting LOE to make inferences about potential VI. Groundwater data may be useful when soil gas and indoor air cannot be sampled (e.g., an open lot with shallow groundwater) or for determining where to place soil gas samples for characterization of VI potential in the portion of the groundwater plume distal from the release area.

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[10] A groundwater AF of 0.0005 can be used when laterally continuous fine-grained soils exist in the vadose zone, which are defined as soils with 50% or more of the material passing through a No. 200 (0.075 mm) sieve, consistent with the definition of silt within Unified Soil Classification System.

When groundwater data are used as a LOE for evaluating VI, the proximity of the groundwater data to the building under evaluation should be considered. While groundwater samples from directly beneath a building likely would be most representative of the potential VI threat, it may not be possible to collect such samples. In this case, collecting samples close to the building, potentially on the upgradient side, may be best for estimating groundwater concentrations directly beneath the building. In addition, groundwater samples collected near the top of the first water-bearing zone better represent the potential VI risk than samples collected at deeper depths.

References – included in main text

Attachment 5

Geo Tracker Uploading Guidance

Attachment 5 – GeoTracker Uploading Guidance

Disclaimer: GeoTracker Uploading Guidance is a living document.

For the current version of the GeoTracker Uploading Guidance please visit: https://www.waterboards.ca.gov/ust/electronic_submittal/docs/viesi_guide_v1.pdf

Guidance on Uploading Vapor Intrusion Information into GeoTracker

Electronic Submittal of Information Format

GeoTracker

California State Water Resources Control Board

Version 1

August 2019

Web site: http://geotracker.waterboards.ca.gov/esi

TABLE OF CONTENTS

I. INTRODUCTION

The State Water Resources Control Board (State Water Board) added capabilities to the GeoTracker database including building-specific information for a cleanup case and the ability to differentiate Field Points for collecting samples.

This document provides instruction on how to create relevant vapor intrusion (VI) information to be used in a VI assessment including a building profile and how to assign vapor data related to a specific building. This capability is performed through the VI Building Tool in the electronic submittal of information (ESI) portal of GeoTracker. This document assumes the reader is aware of the GeoTracker ESI process. If unfamiliar with the GeoTracker ESI process, the reader should familiarize themselves with the "Electronic Submittal of Information (ESI) Beginner's Guide"[1] (ESI Beginner's Guide). ESI users should use the tool to track VI assessments for their Site/Facility, as well as, list VI building profiles in the study area with an associated Site/Facility.

The VI Buildings Tool contains the ESI user's Site/Facility, which has associated VI data. The VI building tool should be used for all the ESI user's Site/Facility with a VI assessment. Through the VI building tool, VI data are uploaded, assigned the appropriate Field Point Class, and then associated with its respective building within the Site/Facility. VI building data attributes include both building attributes (e.g., design, occupants, foundation type) and sample attributes (e.g., location, media, concentration).

Note: The Site/Facility used in this document is not an actual case and created only for demonstration purposes.

II. FIELD POINT AND SAMPLING SETUP

The "ESI Beginners Guide" provides information for ESI accounts, how to claim a Site/Facility, add Field Points to a site, and/or upload (submit) ESI data files.

A summary of the procedures for logging into an ESI account and adding/uploading ESI features is presented below.

Log into GeoTracker ESI: https://geotracker.waterboards.ca.gov/esi/

Once ESI users have access and have followed the steps outlined in the "ESI Beginner's Guide" to claim their Site/Facility, they may begin to assign Field Points, upload VI data, and create VI building profiles.

[1] ESI Beginner's Guide: https://www.waterboards.ca.gov/ust/electronic_submittal/docs/beginnerguide2.pdf

A. SETTING UP FIELD POINTS FOR VAPOR INTRUSION ASSESSMENT

When using the new VI features of GeoTracker (explained in subsequent sections), it is necessary that existing and new Field Points used for collection of vapor samples be assigned appropriate names and the appropriate "Field Point Class." For example, a soil gas sample location (Field Point) can be collected from a temporary grab sample, soil gas probe, or a monitoring gas well. Thus, the soil gas Field Point should be assigned a Field Point Class of Soil Gas (SG), Monitoring Gas Well (MGW), or a Transient Subsurface Sampling Point (TRS), respectively.

Note: The Field Point is the type of the sample point and a Field Point Class defines the sample media.

The table below shows the available Field Points, appropriate naming convention, available Field Point Class and description of each of vapor type sample available for the GeoTracker VI functionality.

Field Point	**Appropriate Field Point Name**	**Available Field Point Class and (Valid Value)**	**Description**
Indoor Air	IA – 1a, IA1, IA – Bath B1, IA – 1	1. Indoor Air (IA)	Air sample collected from within building.
Subslab	SSV– 1a, SSV1, SS – Bath B1, SS – 1	1. Subslab Soil Vapor (SSV)	Soil vapor sample collected beneath building foundation footprint.
Crawl space	CSA – 1, CSA – 1a	1. Crawl Space Air (CSA)	Air sample collected in the crawl space area of the building.
Soil Gas	SG – 1, SG – 1a, SG – 1b, SG1, GRB – 1a	1. Soil Gas (SG) 2. Monitoring Gas Well (MGW) 3. Transient Subsurface Sampling Point (TRS)	Soil vapor sample collected outside of the building foundation footprint. For non-permanent sample locations, use transient subsurface sampling point.
Ambient Air/ Outdoor	AAS – 1, AAS – 1a, OA – 1, OA – 1a	1. Ambient Air Sample (AAS)	Air sample collected outside of the building.
Sewer Air	SWAG – 1, SWAG – 1a	1. Sewer Air Gas (SWAG)	Air/vapor sample collected within a sewer line.
Groundwater	MW – 1, GB – 1a	1. Remediation/Groundwater Monitoring Well (MW) 2. Transient Subsurface Sampling Point (TRS)	Groundwater sample collected associated with Site/Facility. For nonpermanent sample locations, use transient subsurface sampling point.

Note: Many existing vapor sample Field Points with a Field Point Class identified as "vapor" should be changed for existing Field Points that are to be used in a vapor intrusion assessment. To re-assign a Field Point to the appropriate Field Point class use the edit Field Point functionality in the ESI portal (refer to Section II.D***).***

B. SAMPLE ID NOMENCLATURE

The SAMPID (Sample ID) field in the GeoTracker Electronic Deliverable Format (EDF) (EDFSAMP, EDFTEST, and EDFFLAT files)[2] is the unique identifier assigned to a field sample as it appears on the Chain-of-Custody. The Sample ID normally is the same as the Field Point Name, although for certain scenarios the Sample ID will be different to indicate heating, ventilation, and air conditioning (HVAC) conditions or subsurface depth. The Sample ID field entry can be up to 25 characters long.

Heating, Ventilation, and Air Conditioning Settings

As part of VI investigations, some information about HVAC settings should be contained within the Sample ID. As such, a Sample ID for an indoor air or subslab sample should indicate if heating or air conditioning is on or off. It is highly recommended that the nomenclature presented in the table below for Sample ID be used when submitting this sample event scenario to standardize vapor entry and to help identify HVAC conditions during sample collection in the database.

SAMPID	Field Point Name	Field Point Class	Description
IA – 1 – HEAT ON	IA – 1	Indoor Air	Air sample collected from within a building with the heating system on.
IA – 1 – COOL ON	IA – 1	Indoor Air	Air sample collected from within a building with the cooling system on.
IA – 1 – HVAC OFF	IA – 1	Indoor Air	Air sample collected from within a building with the HVAC system off.
SSV – 1 – HEAT ON	SSV – 1	Subslab	Subslab sample collected from within a building with the heating system on.
SSV – 1 – COOL ON	SSV – 1	Subslab	Subslab sample collected from within a building with the air conditioning system on.
SS – 1 – HVAC OFF	SSV – 1	Subslab	Subslab sample collected from within a building with the HVAC system off.

Soil Gas Depths for a Single Sampling Point

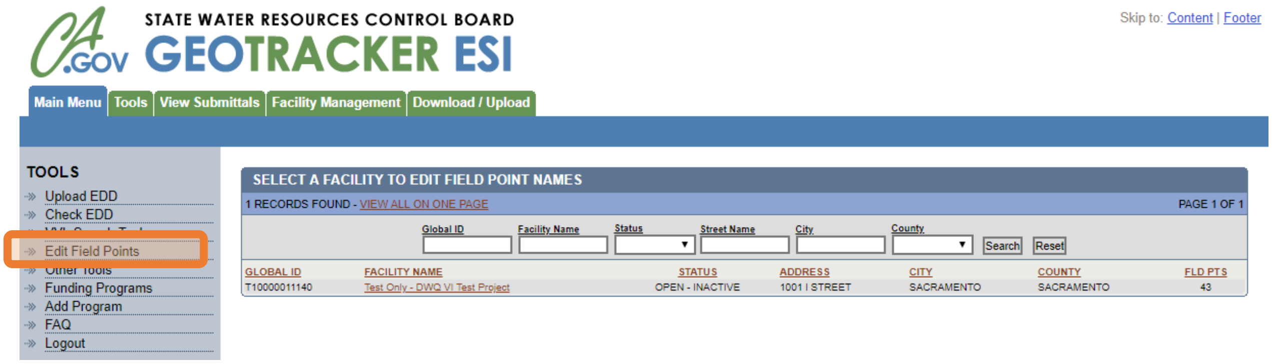
As part of VI investigations, information about depth-discrete sampling performed within a single sampling point should be contained within the Sample ID. As such, a Sample ID for this type of soil gas sample should indicate at what depth in feet the sample was collected. It is highly recommended that the nomenclature presented in the table below for Sample ID be used when submitting this sample event scenario to standardize vapor entry in the database.

SAMPID	Field Point Name	Field Point Class	Description
SG – 1a7.5 SG – 1b15.0	SG – 1	Soil Gas	Soil gas samples collected from a single sampling point at 7.5 feet and 15.0 feet.

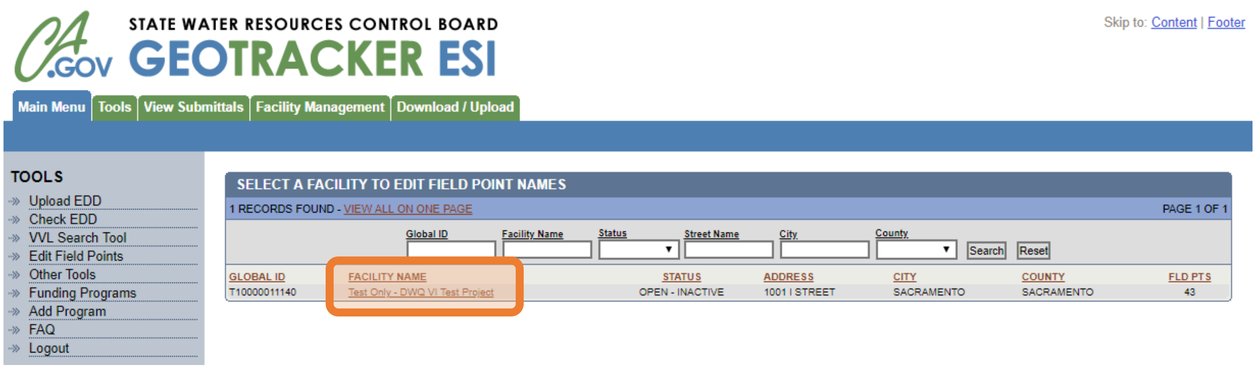
[2] https://www.waterboards.ca.gov/ust/electronic_submittal/docs/faq.pdf

C. CREATING FIELD POINT

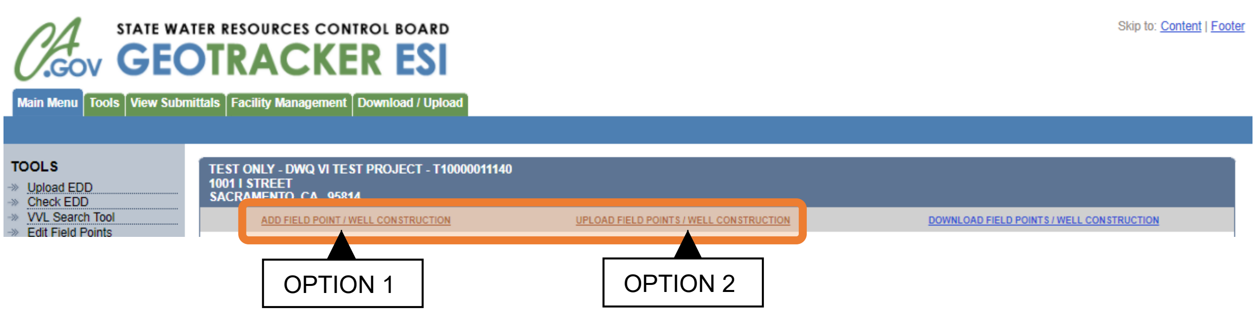
Under Tools on the left-hand side, select "Edit Field Points"; the user's claimed sites will be displayed.



Select the "Site/Facility" for adding/uploading Field Points.



The Site/Facility page has two options for creating a Field Point and assigning a Field Point Class for every sample location at the study area for the purposes of assessing VI. Described below is how ESI users can either add individual Field Points manually (Option 1) or use an upload feature to add more than one Field Point at a time (Option 2).

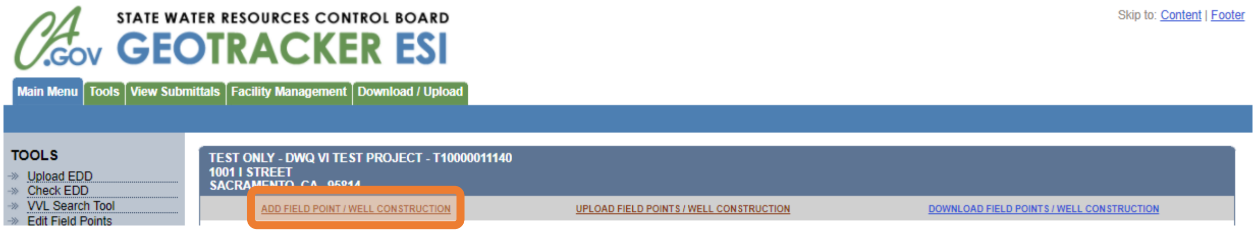


It is critical to have a <u>consistent</u> Field Point naming system and <u>assign</u> the appropriate Field Point Class. This will be important when assigning a Field Point to a VI building profile.

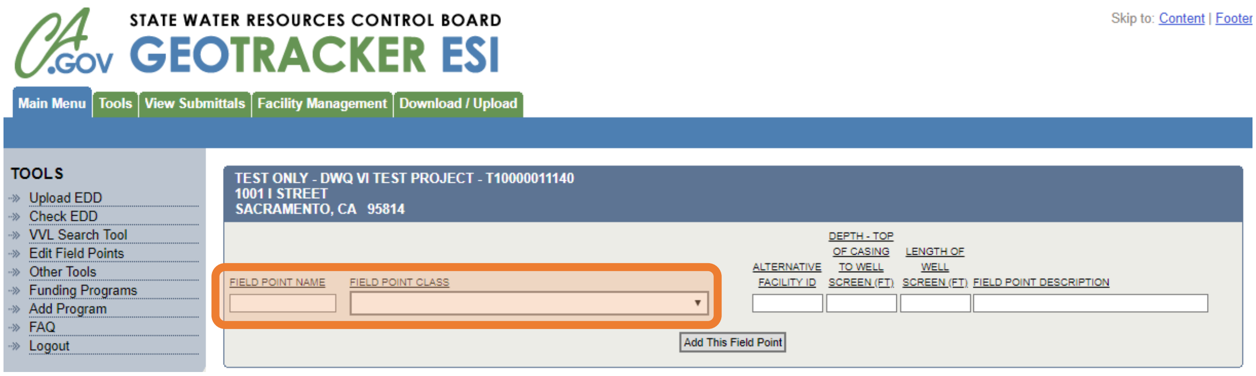
OPTION 1 – MANUALLY ADDING A FIELD POINT

The ESI user will manually enter the Field Point Name and select the Field Point Class. When appropriate the depth (top of casing to well screen), length of well screen, and Field Point description should be included (see below).

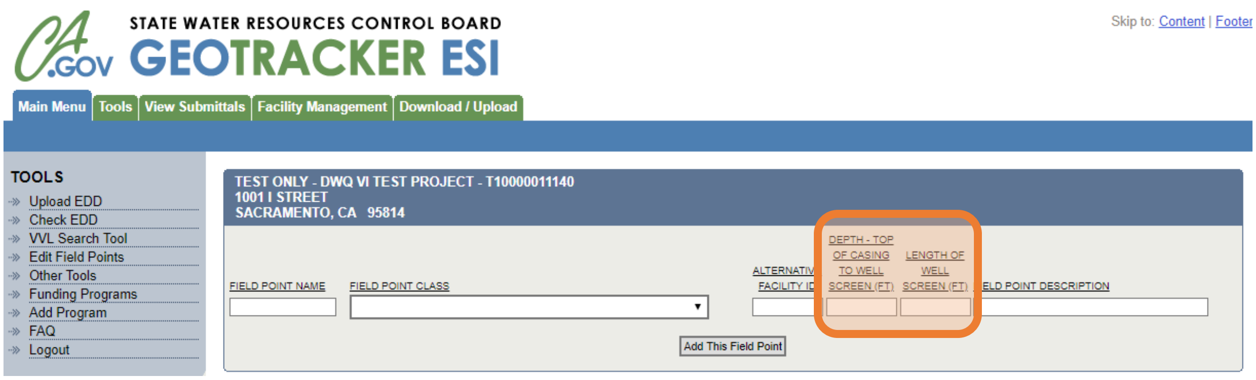
Select "Add Field Point/Well Construction."



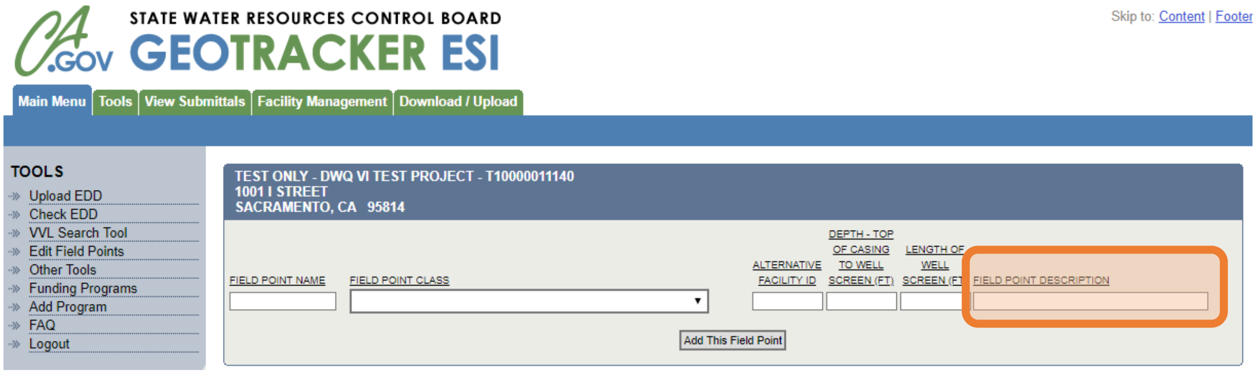
Input the assigned Field Point name and select the appropriate Field Point Class from the drop-down menu (described in Section II.A).



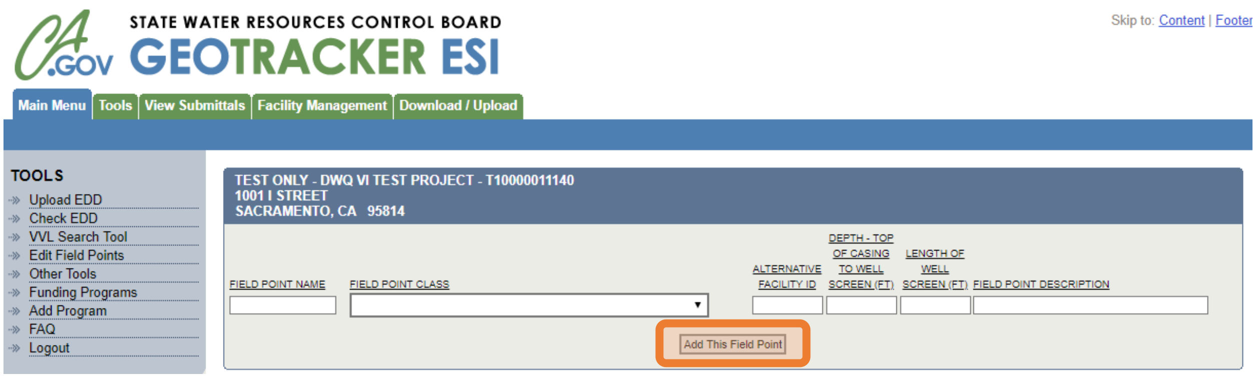
For Soil Gas and Groundwater Field Points, include the depth from the top of the casing to the well screen and the length of well screen.



For Field Point Description include the buildings name associated with the Field Point.



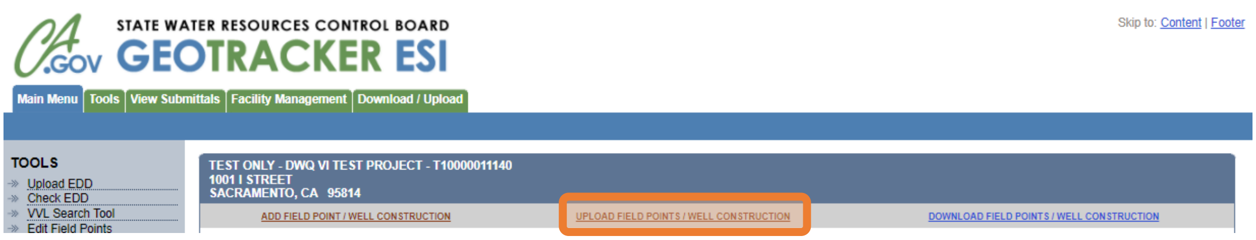
Select “Add This Field Point” to store the Field Point in the database.



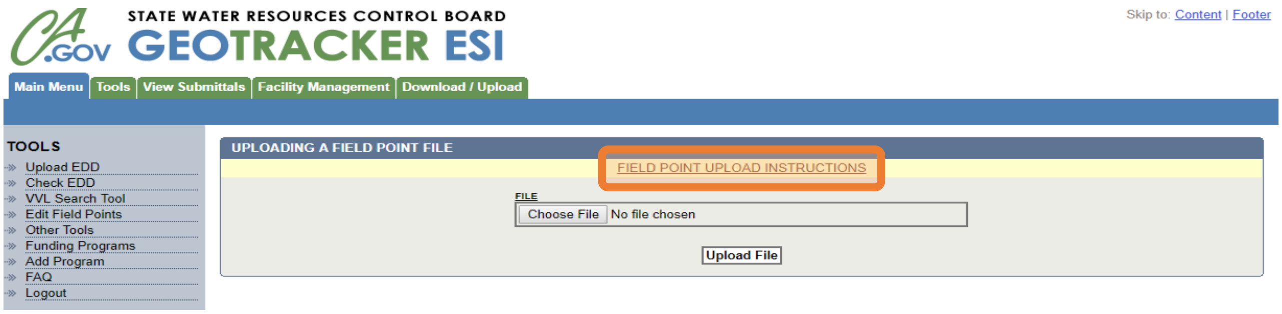
OPTION 2 – UPLOADING MANY FIELD POINTS

The ESI user will use an upload feature to add more than one Field Point at a time by using a text editor to create the upload file (see below).

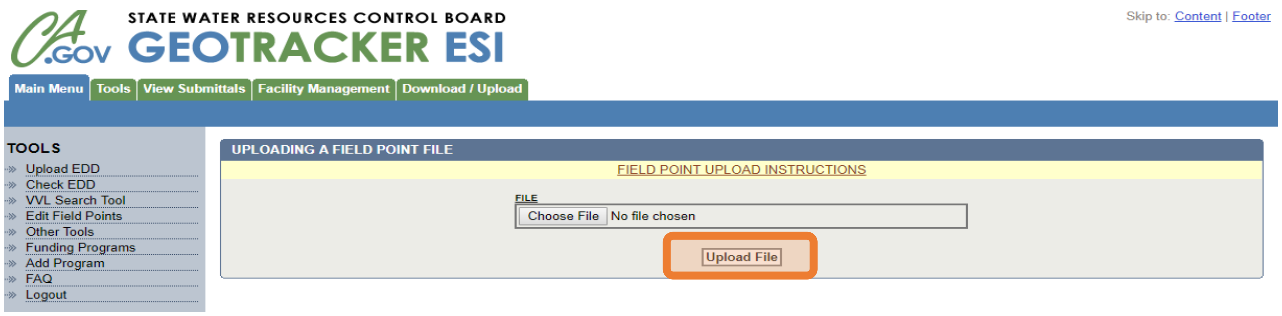
Select “Upload Field Points/Well Construction.”



Refer to “Field Point Upload Instructions” (shown below) for the type of files and format required for using this option.

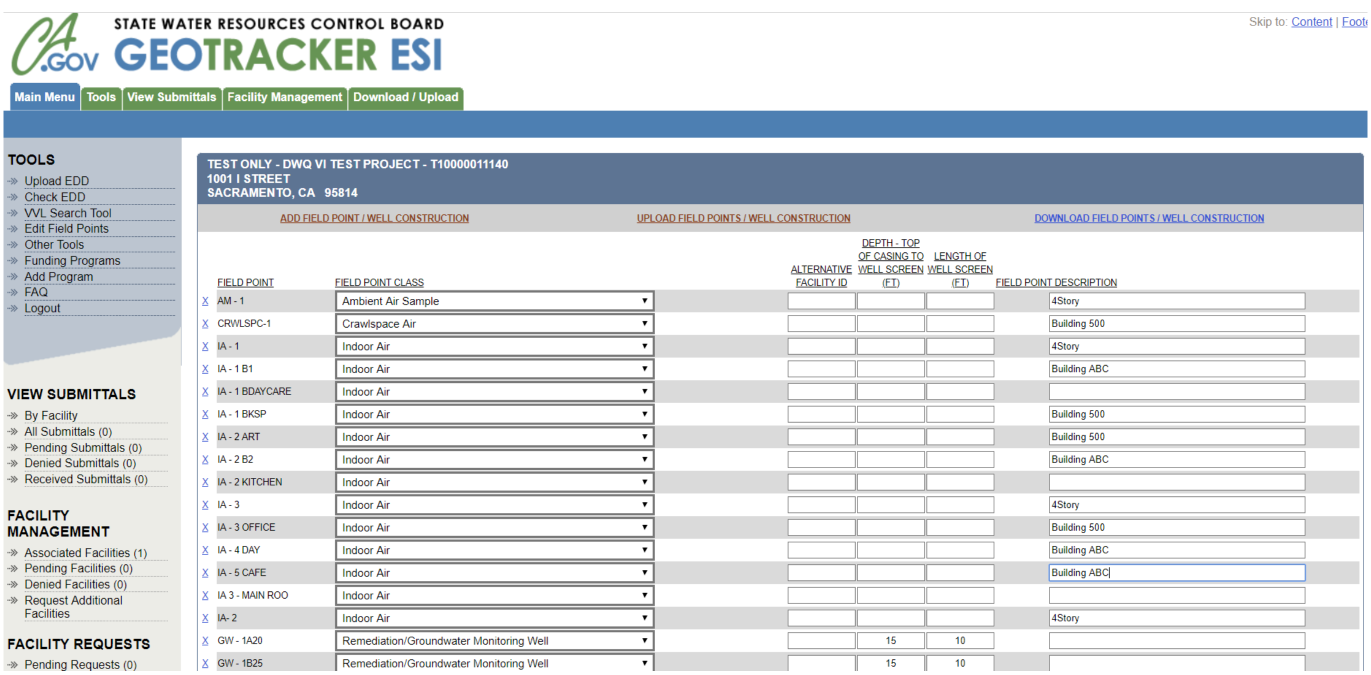


Choose the appropriate file and then select “Upload file” to store Field Points in the database.



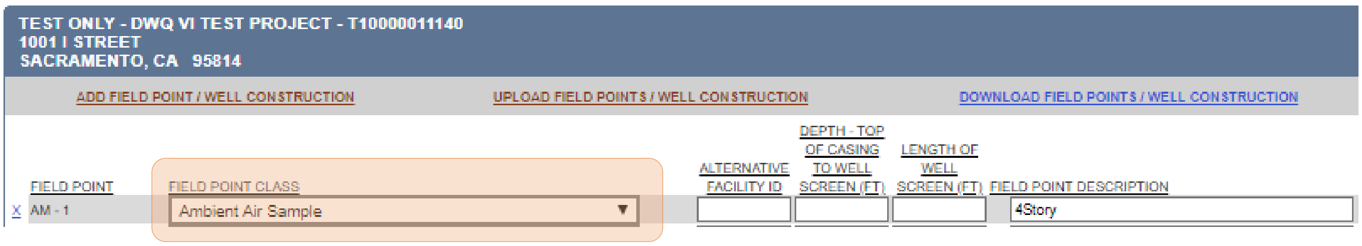
D. EDIT FIELD POINT

Once Field Points are added/uploaded to a Site/Facility, the list of Field Points for the VI study area will be stored in one location within the database shown below. This page also has the functionality to edit or delete Field Point information. Normally, the Alternative Facility ID is left blank.

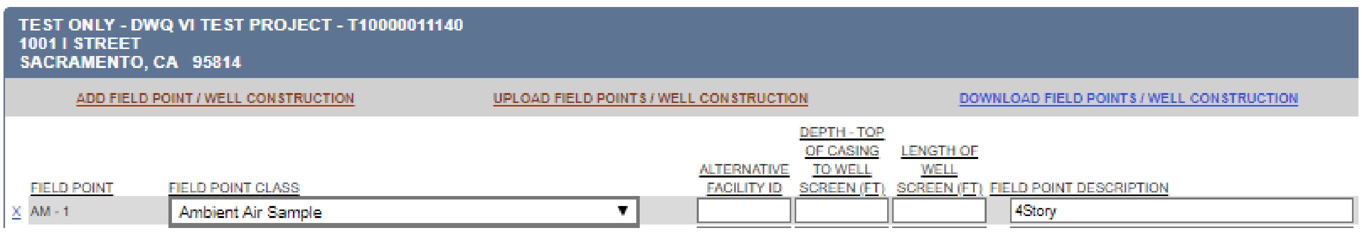


Note: The Field Point name can only be edited by deleting the Field Point and recreating the Field Point.

To edit Field Point Class, use the drop-down menu (refer to Section II.A).

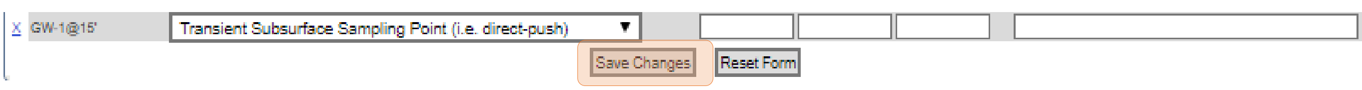


To edit depth (top of casing to well screen), length of well screen, or Field Point description, manually enter changes.

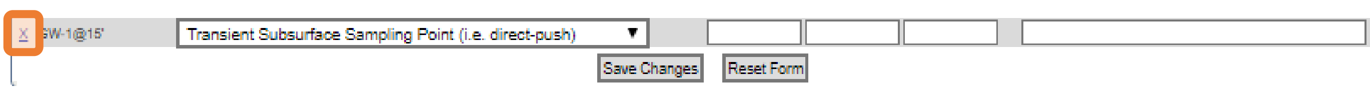


To save edits, select 

located at the bottom of the page.



To delete a Field Point, select X on the left-hand side of the list.



The system will ask the user to confirm deletion of the entry; select “OK” to delete Field Point from database.

Note: Once laboratory analytical data is uploaded to a Field Point, the Field Point is no longer available to be deleted.

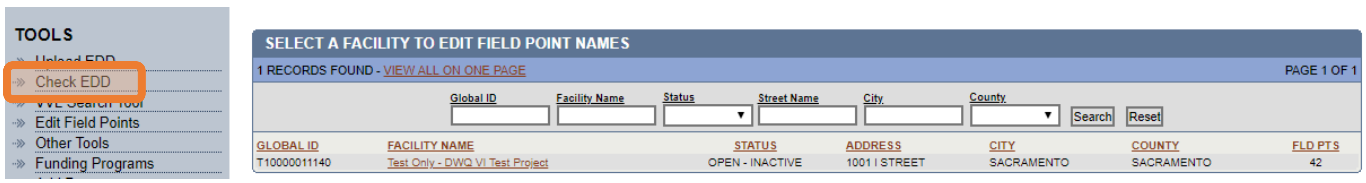
E. UPLOADING LABORATORY ANALYTICAL DATA TO FIELD POINTS FOR VAPOR INTRUSION ASSESSMENT

Once Field Points are created in the database for a Site/Facility, the user will need to upload laboratory analytical data (EDF) and the associated GEO_Report (written report) for a VI assessment. EDF files are normally created by the laboratory, not by the Responsible Party (RP) or consultant, but are normally uploaded by the RP or consultant, not by the laboratory (for information about the formatting and structure of EDF files, refer to "Technical Information on Uploading data").[3] The following sections outline how to check the data format, upload analytical data, and upload the associated report.

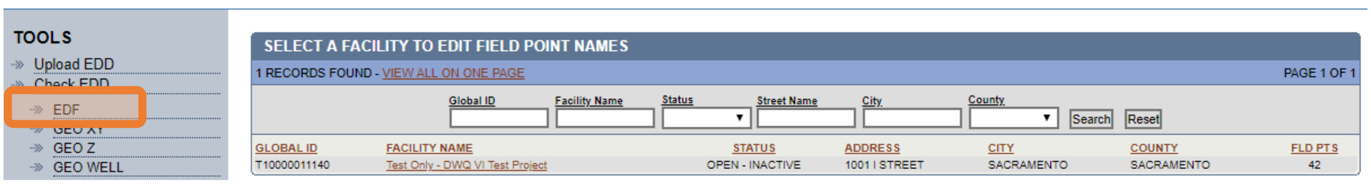
Check Laboratory Analytical Data

Before the laboratory analytical data for a VI assessment is uploaded to the database, verify that the EDF is valid to prevent errors in the upload format.

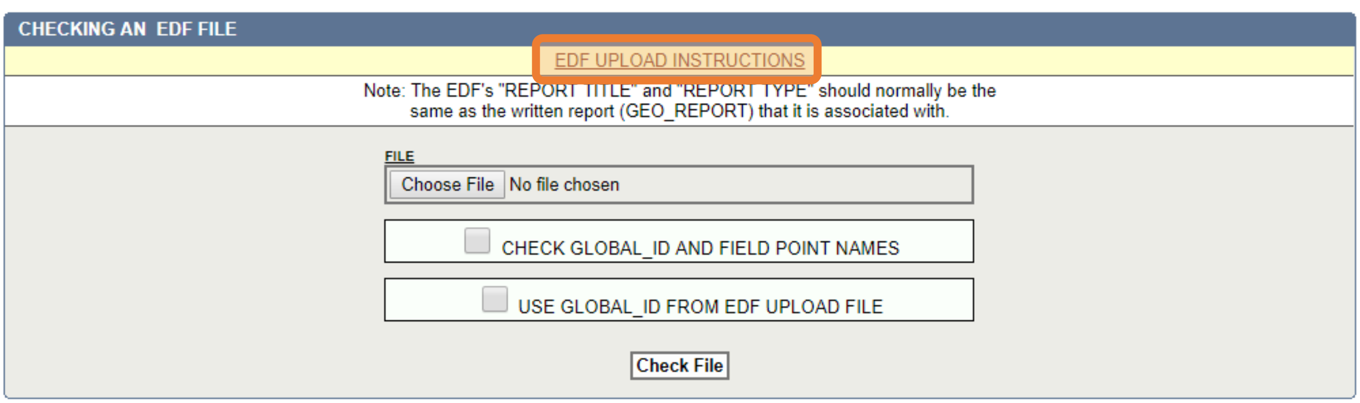
Under tools on the left-hand side, select "Check EDD."



Under check EDD, select "EDF."



Follow "EDF Upload Instructions" to error-check the lab analytical data file.



Upload Laboratory Analytical Data

Once the laboratory analytical data is verified, the EDF is ready to be uploaded to Field Points in the database.

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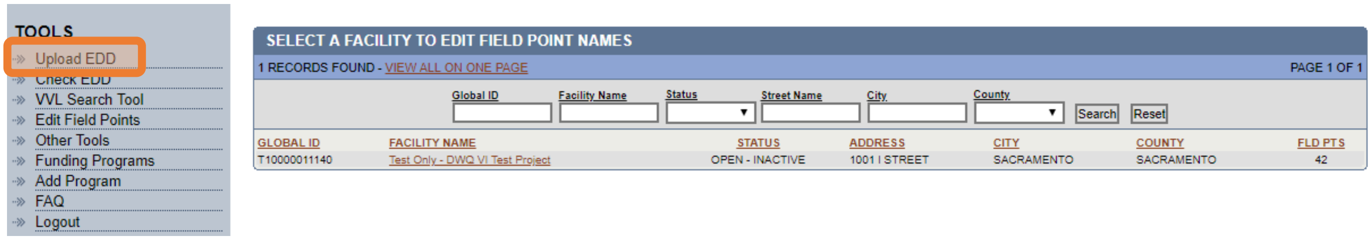
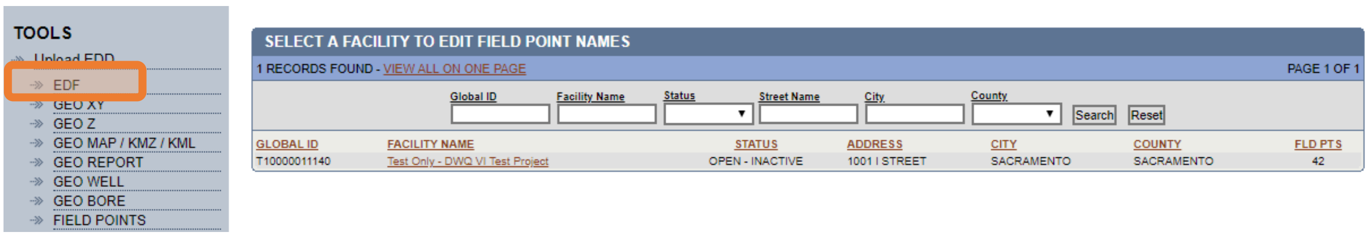
[3] https://www.waterboards.ca.gov/ust/electronic_submittal/index.shtml

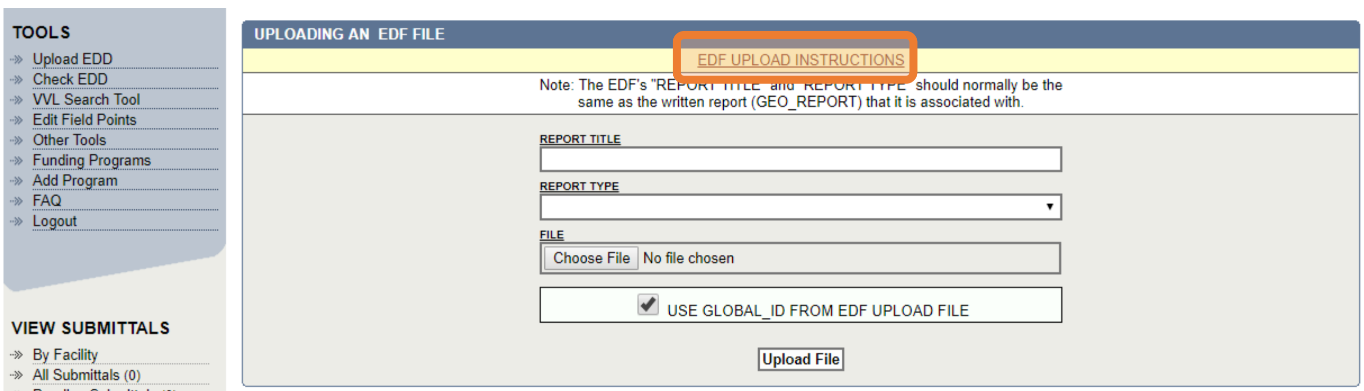
Under tools on the left-hand side, select “Upload EDD.”



Under Upload EDD, select “EDF.”



Follow “EDF Upload Instructions” to upload lab analytical data file.

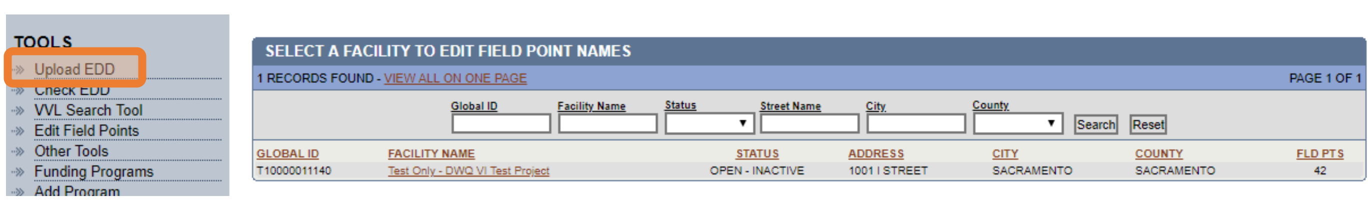


Note: The UPLOAD TITLE and REPORT TYPE for laboratory analytical data should match the UPLOAD TITLE and REPORT TYPE of its associated GEO_REPORT (the written report).

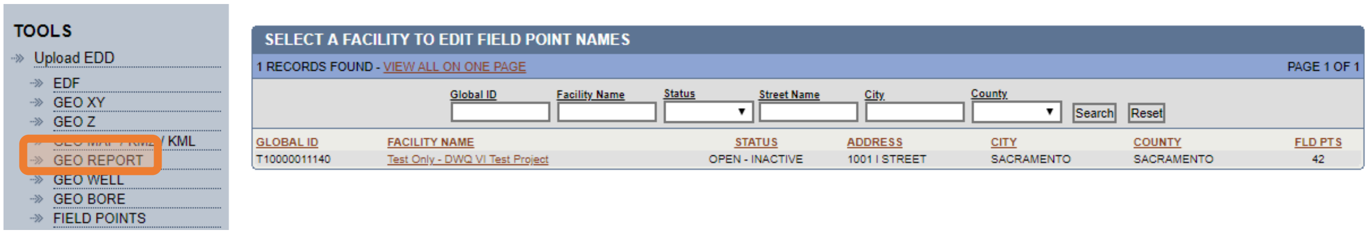
Upload GEO_Report Associated With Laboratory Analytical Data

The GEO_Report is an electronic version (PDF file format) of the complete written report. Upload the GEO_Report with the associated laboratory analytical data.

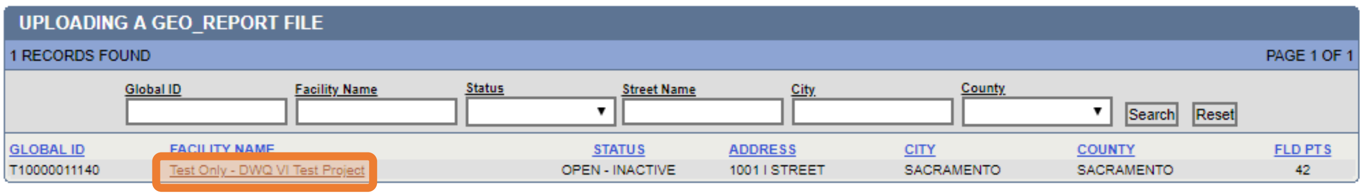
Under Tools on the left-hand side, select “Upload EDD.”



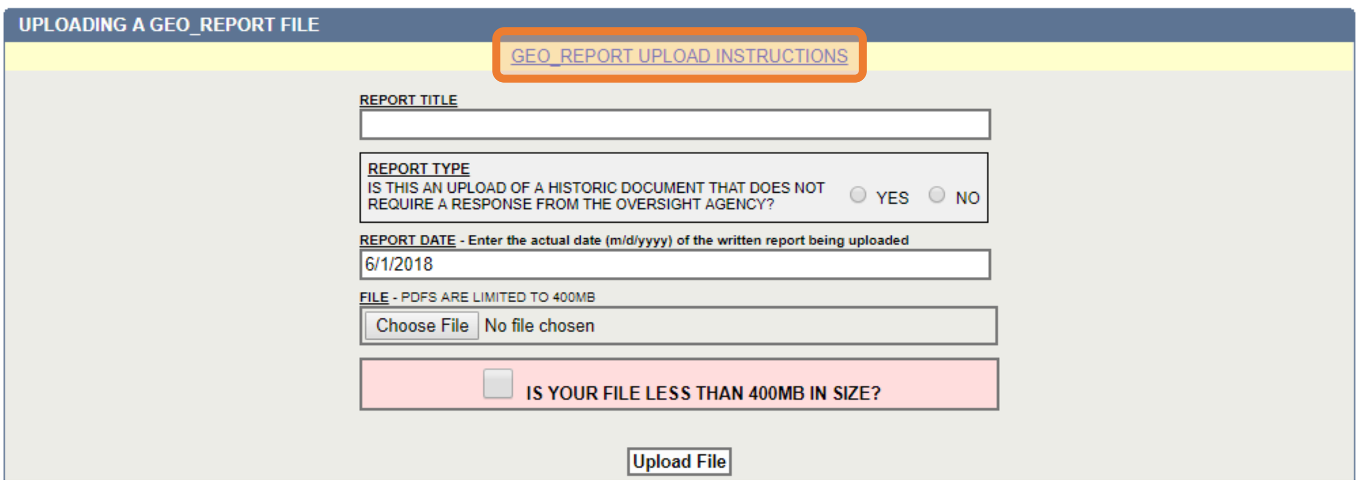
Under Upload EDD, select “GEO_Report.”



Select the facility for uploading.



Follow the “GEO_Report Upload Instructions” to upload the report associated with the laboratory analytical data.



F. GEOTRACKER ESI INFORMATION & CONTACTS

For additional information, refer to GeoTracker’s ESI informational page: https://www.waterboards.ca.gov/ust/electronic_submittal/index.shtml or contact the GeoTracker Help Desk: geotracker@waterboards.ca.gov.

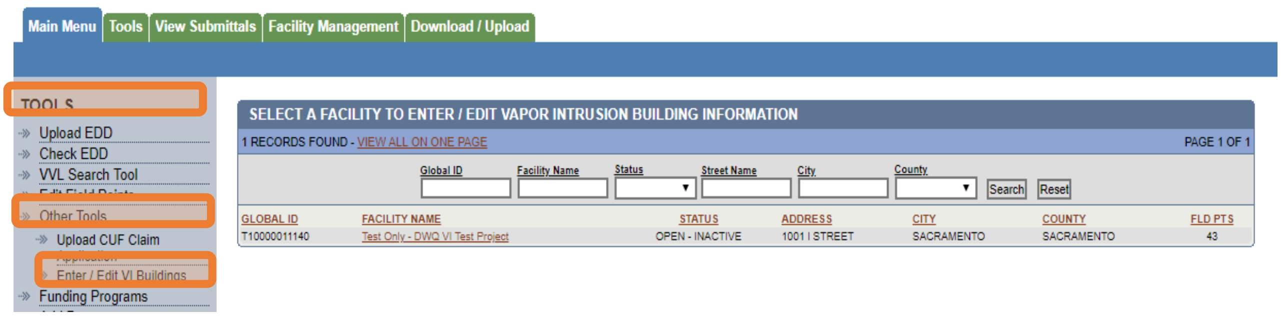
III. GEOTRACKER VAPOR INTRUSION ESI FUNCTIONALITY

The process for adding VI building profiles to a Site/Facility that will be used in a vapor intrusion assessment is outlined below. This process uses GeoTracker's ESI functionality for RPs and assigned contractors to enter the information.

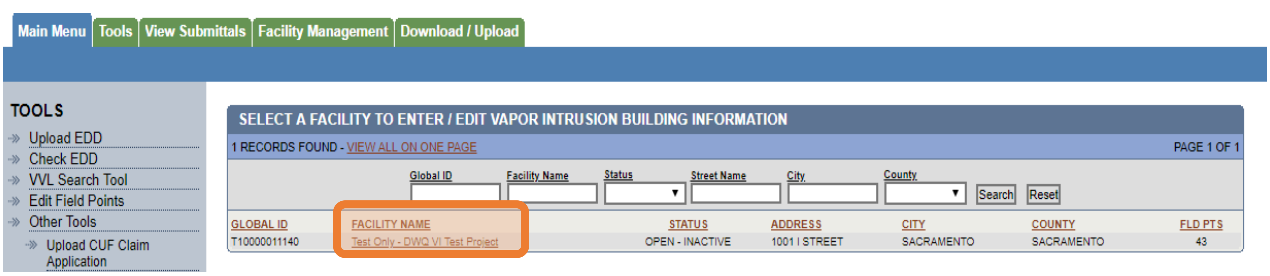
A. CREATING VAPOR INTRUSION BUILDING PROFILE

After adding Field Points and assigning the appropriate Field Point Class (refer to Section II.C), the next step is to create a building's VI building profile in the database. The VI building profile will also assist the user in co-locating Field Points within and in proximity to the building. It is important to co-locate indoor air and subslab samples when possible. VI building profiles are part of the conceptual site model for a Site/Facility and inputting each building's information into the database stores all available vapor data for a study area in one location.

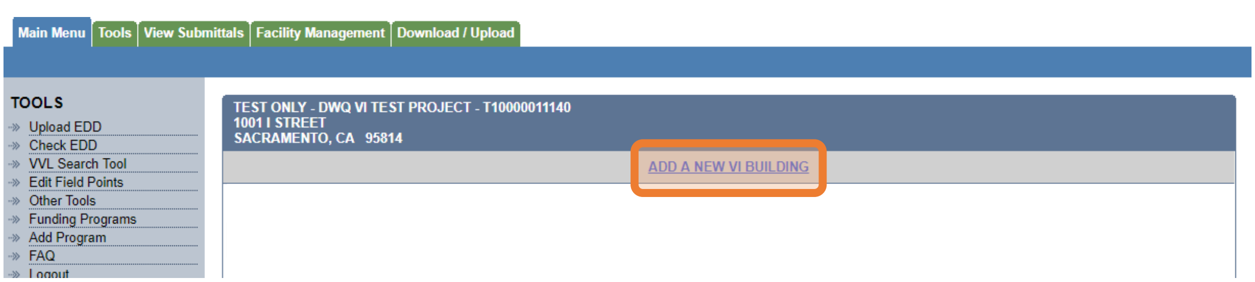
To add a VI building profile to a Site/Facility, under Tools on the left-hand side, select "Other Tools" and then select "Enter/Edit VI Buildings." This will display the available Site/Facilities the user has claimed.



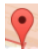
Select the Site/Facility to begin the process of adding VI building profiles for onsite and off-site buildings within the VI study area.



Select "Add a New VI Building" to create a VI building profile.

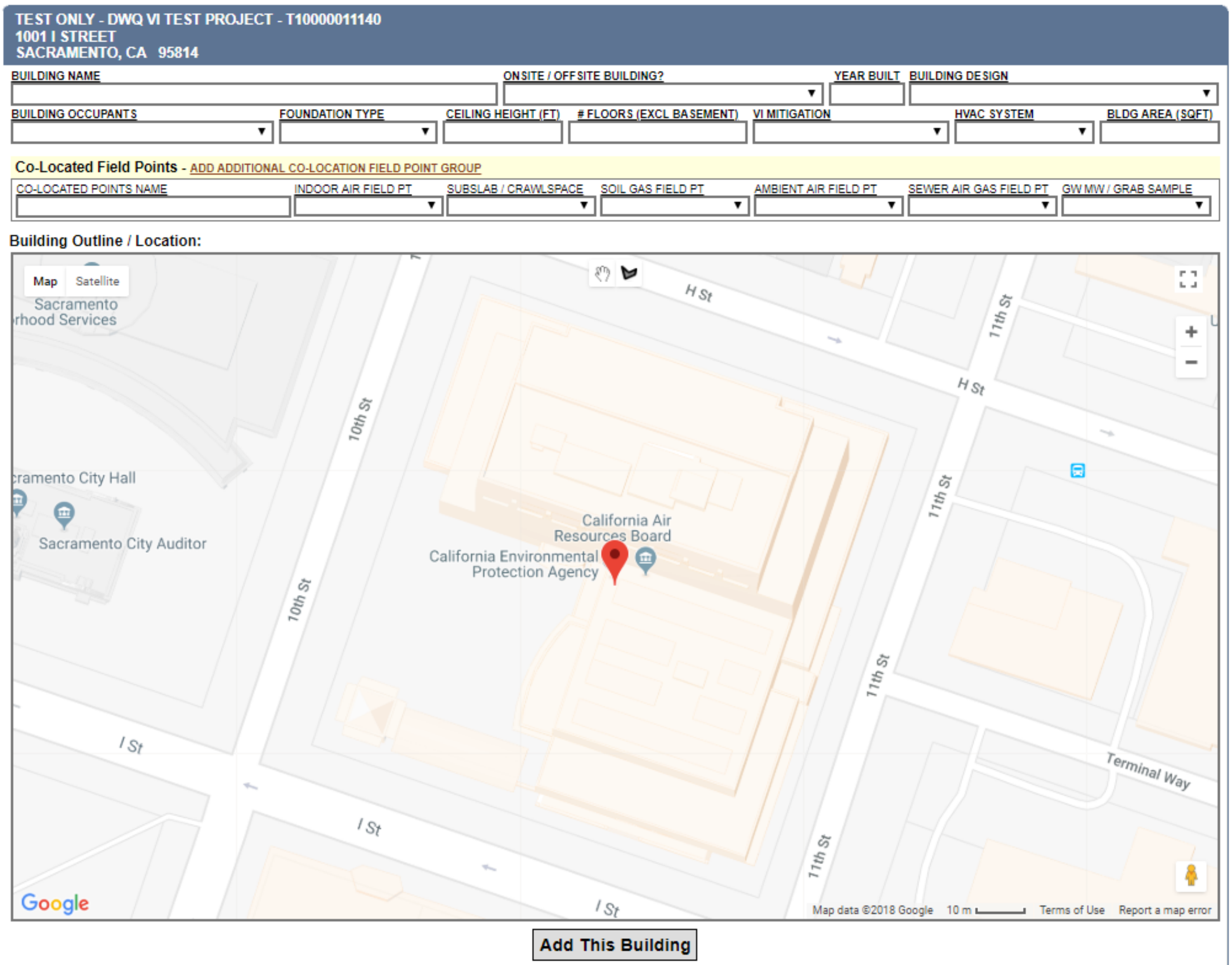


Shown below is the VI building profile page.

The locator pin  indicates the Site/Facility GeoTracker location.

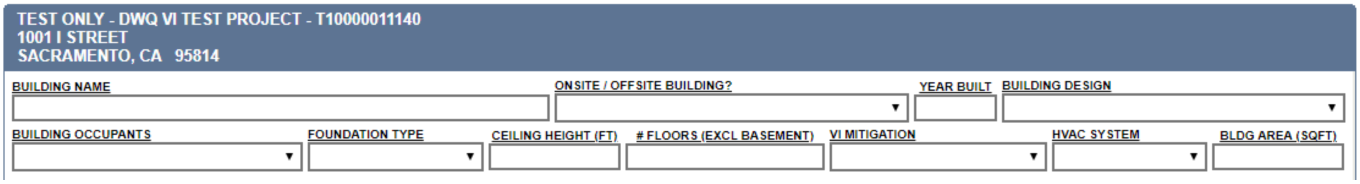
The Site/Facility's name, global ID, and address are displayed on the top menu and will be the same for all buildings in the study area for the purposes of assessing VI.

> ***Note: There are three sections (building-specific information, co-located Field Points, and building outline/location) to complete in the VI building profile (outlined below).***



B. BUILDING-SPECIFIC INFORMATION

The first section of the VI building profile is the building-specific information. This includes the Building Name, Onsite/Offsite Building, Year Built, Building Design, Building Occupants, Foundation Type, Ceiling Height (feet), Number of Floors, VI Mitigation, HVAC System, and Building Area.


TEST ONLY - DWQ VI TEST PROJECT - T10000011140
1001 I STREET
SACRAMENTO, CA 95814

BUILDING NAME | ONSITE / OFFSITE BUILDING? | YEAR BUILT | BUILDING DESIGN

BUILDING OCCUPANTS | FOUNDATION TYPE | CEILING HEIGHT (FT) | # FLOORS (EXCL BASEMENT) | VI MITIGATION | HVAC SYSTEM | BLDG AREA (SQFT)

Boxes that are blank indicate fields that will need to be entered manually.

Boxes with a triangle in the right corner indicate a drop-down menu. The options are defined in Table 1 below for each field.

Table 1: BUILDING SPECIFIC INFORMATION

Field	Drop-Down Option	Description
Building Name	- -	User-defined name for a site building.
Onsite/Offsite Building	Offsite – building is outside of facility/site footprint	Building is outside of site/facility property boundary.
	Onsite – building is within facility/site footprint	Building is within site/facility property boundary.
Year Built	- -	The year the building was built.
Building Design	Single Unit Residential	A single unit building designed for residential use (e.g., single-family home).
	Multi-Unit Residential	Multiple unit building designed for residential use (e.g., duplex, apartments).
	Single Unit Commercial	A single unit building designed for commercial use of one business.
	Multi-Unit Commercial	A building with multiple separate units designed for commercial use (e.g., strip mall).
	Multi-Unit Mixed Use	A multiple unit building with a combination of units either designed for commercial or residential use.
	Auditorium	A large building or hall with an open space designed for gatherings (e.g., church, theater).
	School	A large building designed with multiple rooms to facilitate educational activities.

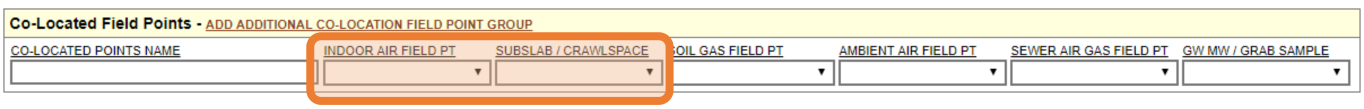
Field	Drop-Down Option	Description
	Industrial	A large building designed for the systematic processing of goods or products (e.g., packaging plant).
	Manufacturing Facility	A building designed for the manufacturing of goods from raw materials (e.g., chemical plants, research and development facilities).
	Warehouse	A large building designed to store raw materials or manufactured goods.
	Other	A building with a design type not listed.
Building Occupants	Residential	Occupants could be inside building for up to 24 hours a day.
	Commercial	Occupants could be inside building for up to 8 hours a day (typical work day).
	Residential Unit Over Commercial Unit	Residential use is prohibited only on the first floor for the occupied space.
	Sensitive Use	Building occupants that may have significantly increased sensitivity or exposure to contaminants by virtue of their age (e.g., school, child care, retirement community) or heath condition (e.g., medical facility).
	Other	Building occupants not listed.
Foundation Type	Slab-on-Grade	There is no space between the ground and the foundation system (bedding gravel and slab).
	Crawl Space	An area of limited height between the ground surface and the ground floor of a building, giving access to wiring and plumbing.
	Partial Crawl Space	Foundation is partially a crawl space and partially slab-on-grade.
	Basement	One or more floors of a building that are either completely or partially below the ground surface. Basement foundation is assumed slab-on-grade.
	Partial Basement	Foundation is partially a basement and partially slab-on-grade.
	Podium	The lowest floor of the building is constructed with more than 5 feet above the ground surface and not regularly occupied (e.g., car port beneath a building).
	Earthen	Made of compressed earth with no covering.
	Secondary Slab Pour	Modifications have been made to the original slab-on-grade foundation (e.g., remodels, garage addition, porch addition).
	Other	Foundation type is not listed.

Field	Drop-Down Option	Description
Ceiling Height (ft)	- -	The distance from the averaged floor height to the averaged ceiling height of the lowest floor, measured in feet.
# Floors (excluding Basement)	- -	Total number of floors within the building excluding the basement (i.e., 3 story building = 3).
VI Mitigation	Vapor Intrusion Barrier Only	A subslab liner (passive membrane or vapor barrier) is a material or structure installed below a building to limit the upward flow of vapors.
	Passive Vented System	A system designed to function by venting soil gas (or crawl space air) to the exterior of the building. Passive venting relies on natural thermal and wind effects to withdraw vapors from below the building.
	Active Vented System	A venting system equipped with a fan-powered vent that actively draws soil gas (or crawl space air) from beneath the building to the exterior of the building.
	Subslab Depressurization	A system designed to continuously create lower pressure directly underneath a building floor relative to the pressure within the building.
	Other	A vapor intrusion mitigation system not listed above.
	None	No vapor intrusion mitigation system in place.
HVAC System	Cooling Only	The building contains a system whose purpose is to provide cooling or significant ventilation within the building (e.g., air conditioner, whole house fans).
	Heating Only	The building contains a system whose purpose is to generate heat within the building (e.g., furnaces, fireplaces, baseboard heaters, radiators, or other regularly used system).
	Heating & Cooling	The building contains both a cooling system and a heating system.
	None	No heating or cooling systems are installed in the building.
Building Area (ft^2)	- -	The building's foundation footprint in square feet (e.g., 1,200 ft^2).

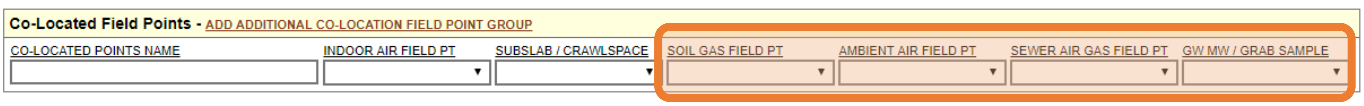
C. CO-LOCATED FIELD POINTS

The second section of the VI building profile allows the user to link each Field Point with a building for a VI assessment with the following Field Point Class types: indoor air, subslab, crawl space, soil gas, ambient (outdoor) air, sewer gas air, and groundwater. Within a building the user should co-locate the indoor air Field Points with the associated subslab (or crawl space) Field Points that are collected within the same area of the building (e.g., bathroom, kitchen, office, etc.). The co-located indoor air and subslab Field Points are the primary data pairs for a building. All applicable soil gas, ambient air, sewer air gas, and groundwater Field Points should be linked to the building as secondary data Field Points, and if appropriate linked to the primary data pair.

Primary Data Pair – Indoor Air and Subslab (or Crawlspace) Field Points



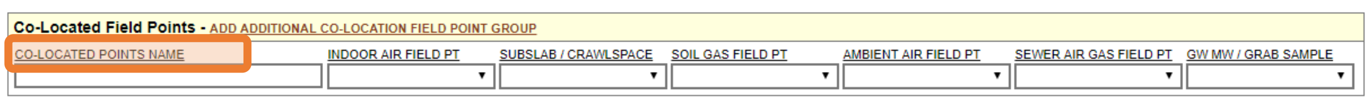
Secondary Data – Soil Gas, Ambient Air, Sewer Air Gas, and Groundwater Sample Field Points



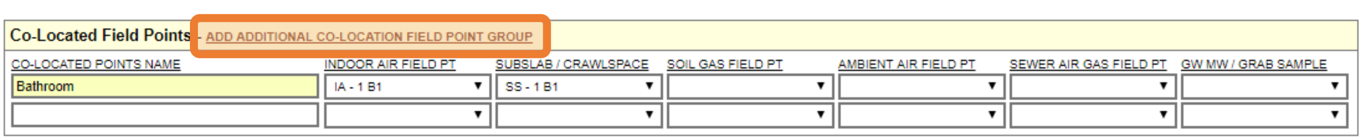
Adding a Co-Located Field Point Group

The database has the capability for the user to set up multiple Field Point Groups for a building. All co-located and linked Field Points for a building should be listed in this section of the VI building profile tool.

The "Co-Located Points Name" refers to either the specific area within the building (e.g., bathroom, kitchen) where the primary data pairs were collected or to the building name linked to the secondary data Field Points.



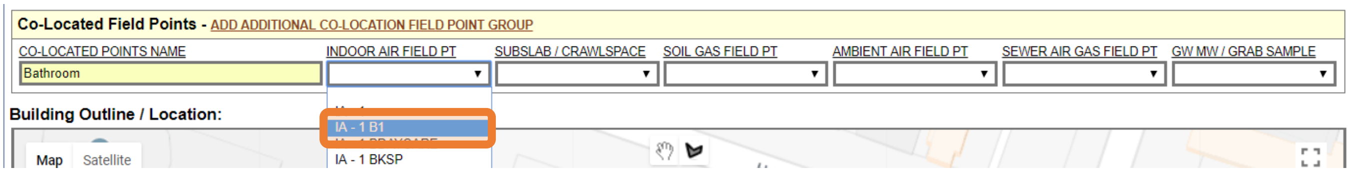
To set up multiple Field Point Groups, select "Add Additional Co-Location Field Point Group" for as many co-located or linked Field Points as needed.



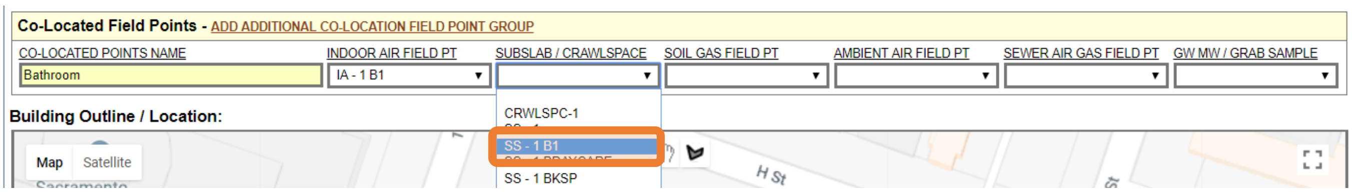
Once a co-located area has an assigned Co-Located Points Name (e.g., bathroom, building name), the associated primary data pair and secondary data Field Points should be populated by using the drop-down menu.

Co-Locating Field Point Process – Primary Data Pair

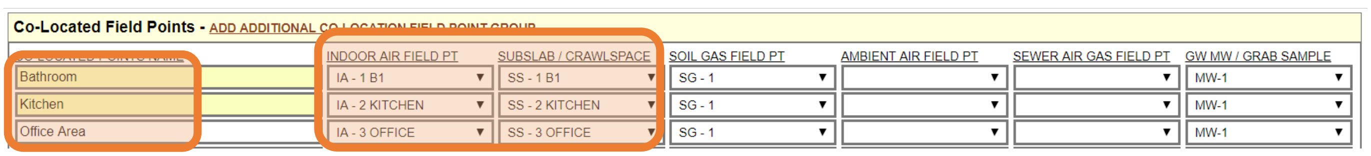
First, populate the primary data pair by clicking in the Indoor Air Field Point box; then select from the drop-down menu, and select the correct Field Point that is associated with that specific area.



Next, complete the primary data pair by clicking in the Subslab/Crawlspace Field Point box and selecting from the drop-down menu the correct Field Point that is paired with the Indoor Air Field Point and the specific area.



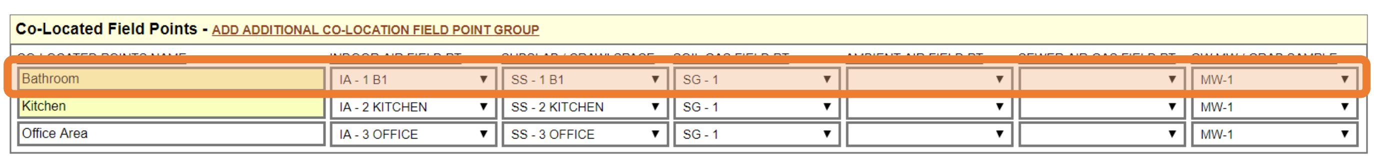
Continue to add the primary data pairs and co-locate to the specific areas within the building.



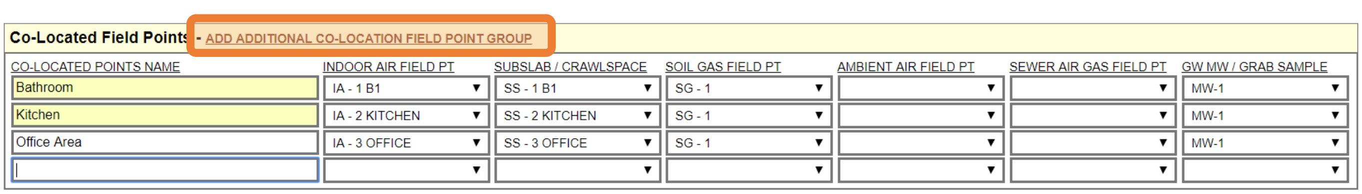
Co-Locating Field Point Process – Secondary Data

Next, populate the secondary data Field Points by clicking in the Soil Gas Field Point box, Ambient Air Field Point box, Sewer Air Gas Field Point box, or Groundwater Sample Field Point box, and select from the drop-down menu the correct Field Point that is linked to the building.

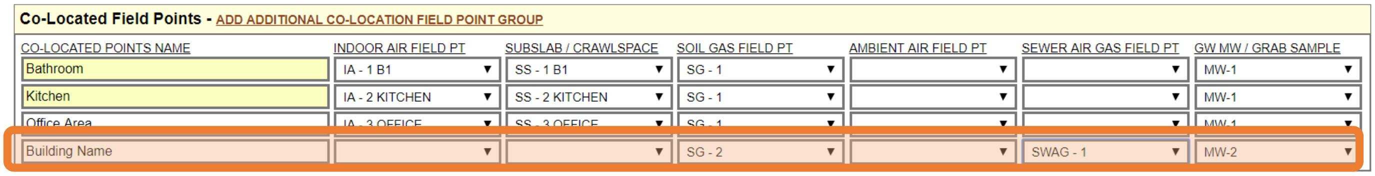
To link a secondary data Field Point to a primary data pair, select a secondary data Field Point from the drop-down box menu on that row.



To link a secondary data Field Point to the building, select “Add Additional Co-Location Field Point Group” to add a blank Co-Located Points Name.



Enter the appropriate building name, then select the secondary data Field Points from the drop-down box menu on that row.



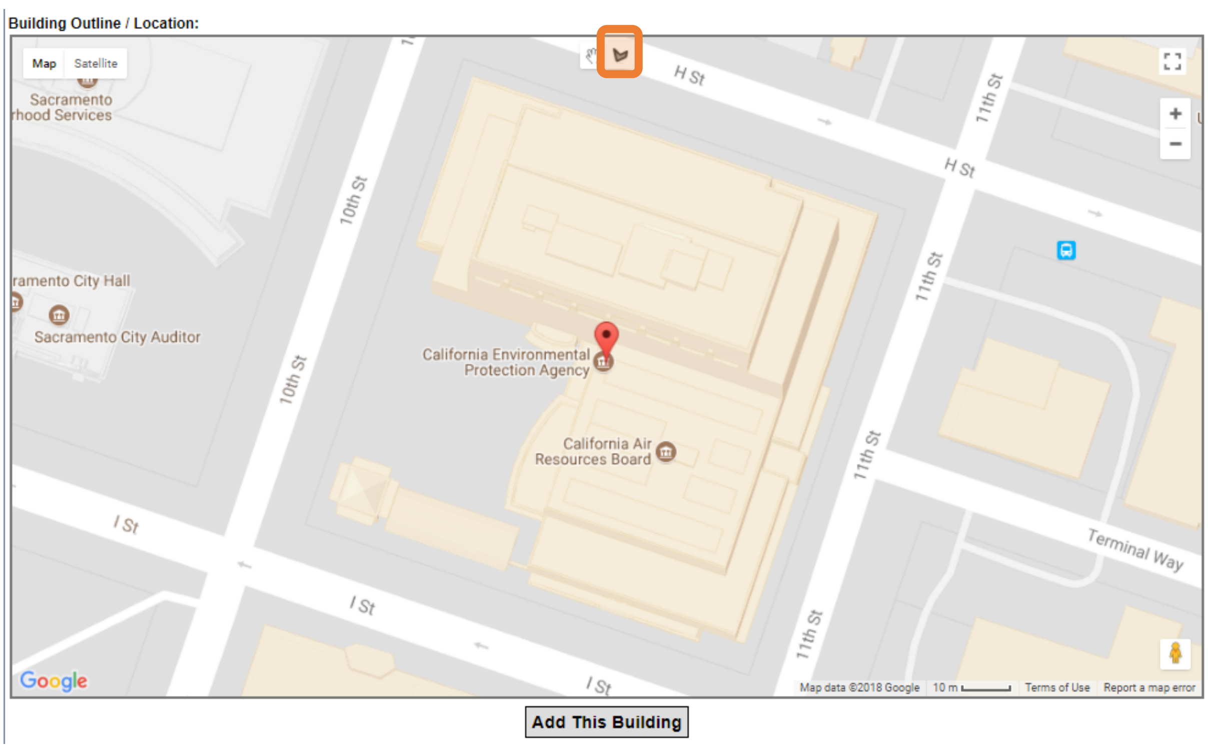
Check to make sure the appropriate Field Point is assigned to the correct Co-Located Points Name.

> ***Note: The drop-down boxes will only populate with the available Field Point that was assigned to a Field Point Class (refer to Section II.C). It is critical to check the Field Point to ensure it has the appropriate "Field Point Class," otherwise it will not populate as an option in the drop-down menu.***

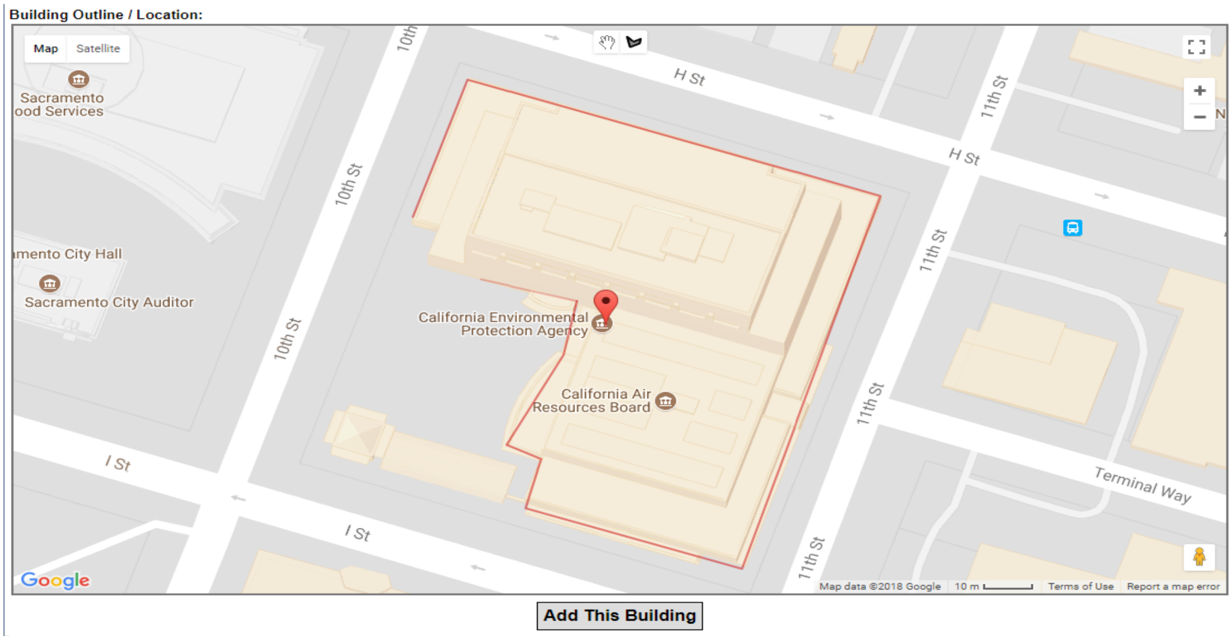
D. BUILDING OUTLINE/LOCATION

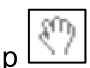
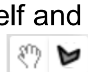
The third section of the building profile defines the spatial attributes of a building and Field Points associated with them. Certain Field Points do not have geospatial data collected and cannot be placed on a map, therefore drawing the building on the map is representative of those sample locations.

Select  the drawing tool at the top of the map to start drawing the building outline.

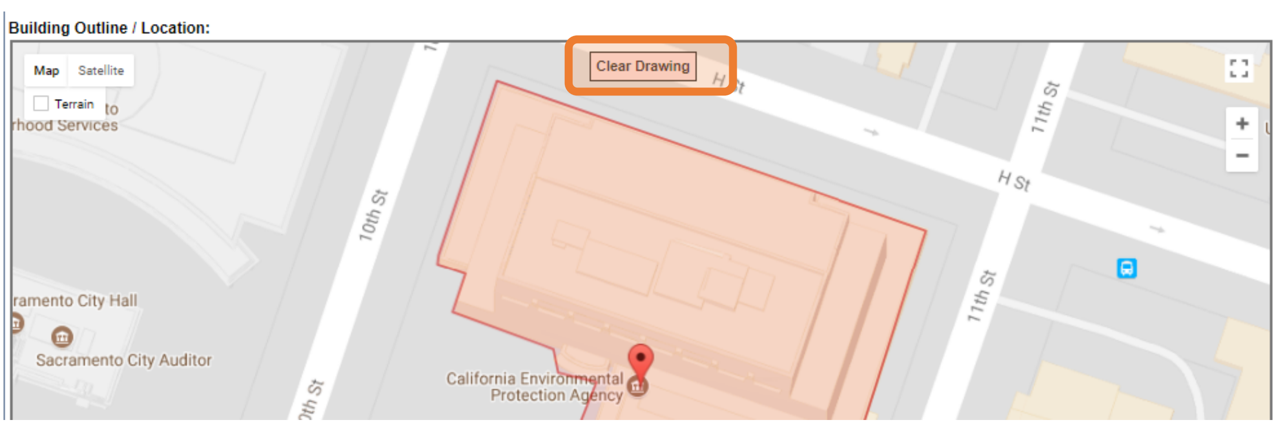


Each click on the map will place a point; use as many points necessary to outline the building shape.

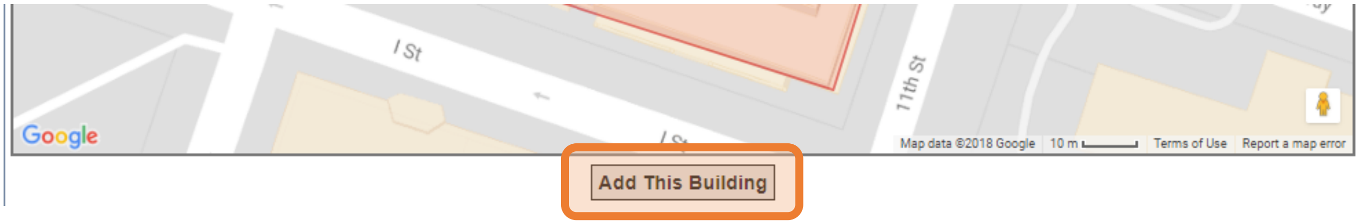


To complete the shape, double-click with mouse or select the hand at the top of the map  and the shape will connect itself and fill in with a shaded red color. Once the shape is connected, **Clear Drawing** will appear in place of .

Select "Clear Drawing" if a mistake was made while drawing and the building outline/location will be cleared.



To complete the VI building profile, select “Add This Building” located at the bottom of the page.



The VI building profile is now stored in the database.

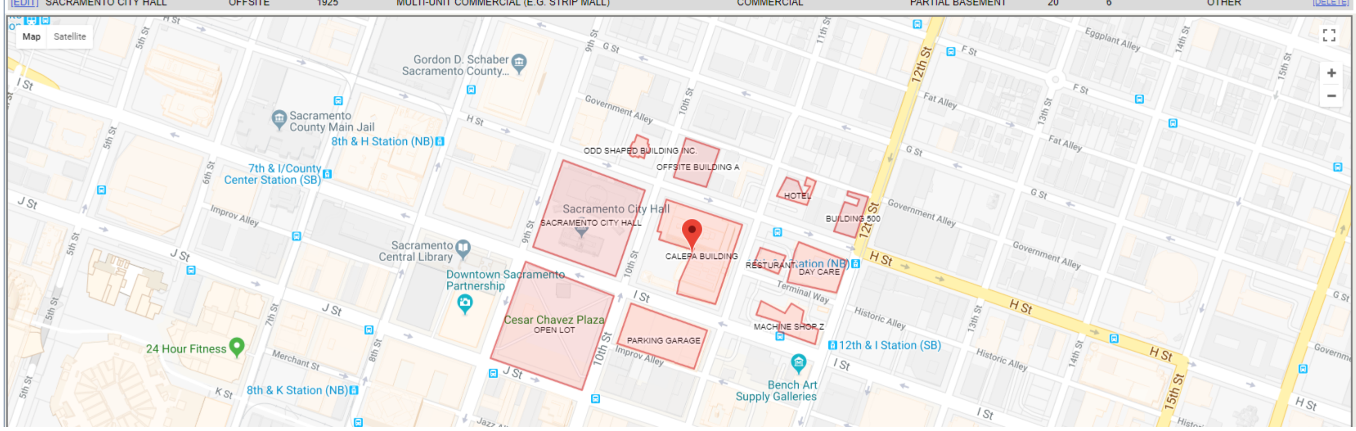
E. SITE/FACILITY BUILDING LIST

Once a VI building profile is stored within the Site/Facility database, the list of onsite and offsite buildings and their locations will be displayed on the Site/Facility page shown below. This page also has the functionality to edit or delete a building (described in the following section).

TEST ONLY - DWQ VI TEST PROJECT - T10000011140
1001 I STREET
SACRAMENTO, CA 95814

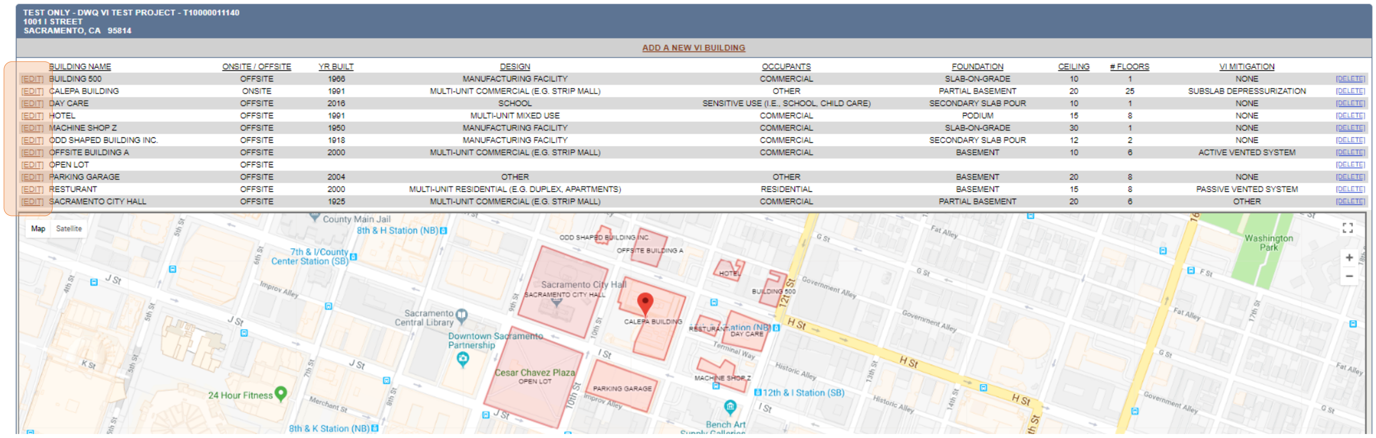
ADD A NEW VI BUILDING

	BUILDING NAME	ONSITE / OFFSITE	YR BUILT	DESIGN	OCCUPANTS	FOUNDATION	CEILING	# FLOORS	VI MITIGATION	
[EDIT]	BUILDING 500	OFFSITE	1966	MANUFACTURING FACILITY	COMMERCIAL	SLAB-ON-GRADE	10	1	NONE	[DELETE]
[EDIT]	CALEPA BUILDING	ONSITE	1991	MULTI-UNIT COMMERCIAL (E.G. STRIP MALL)	OTHER	PARTIAL BASEMENT	20	25	SUBSLAB DEPRESSURIZATION	[DELETE]
[EDIT]	DAY CARE	OFFSITE	2016	SCHOOL	SENSITIVE USE (I.E., SCHOOL, CHILD CARE)	SECONDARY SLAB POUR	10	1	NONE	[DELETE]
[EDIT]	HOTEL	OFFSITE	1991	MULTI-UNIT MIXED USE	COMMERCIAL	PODIUM	15	8	NONE	[DELETE]
[EDIT]	MACHINE SHOP Z	OFFSITE	1950	MANUFACTURING FACILITY	COMMERCIAL	SLAB-ON-GRADE	30	1	NONE	[DELETE]
[EDIT]	ODD SHAPED BUILDING INC.	OFFSITE	1918	MANUFACTURING FACILITY	COMMERCIAL	SECONDARY SLAB POUR	12	2	NONE	[DELETE]
[EDIT]	OFFSITE BUILDING A	OFFSITE	2000	MULTI-UNIT COMMERCIAL (E.G. STRIP MALL)	COMMERCIAL	BASEMENT	10	6	ACTIVE VENTED SYSTEM	[DELETE]
[EDIT]	OPEN LOT	OFFSITE								[DELETE]
[EDIT]	PARKING GARAGE	OFFSITE	2004	OTHER	OTHER	BASEMENT	20	8	NONE	[DELETE]
[EDIT]	RESTURANT	OFFSITE	2000	MULTI-UNIT RESIDENTIAL (E.G. DUPLEX, APARTMENTS)	RESIDENTIAL	BASEMENT	15	8	PASSIVE VENTED SYSTEM	[DELETE]
[EDIT]	SACRAMENTO CITY HALL	OFFSITE	1925	MULTI-UNIT COMMERCIAL (E.G. STRIP MALL)	COMMERCIAL	PARTIAL BASEMENT	20	6	OTHER	[DELETE]



F. EDIT/DELETE VAPOR INTRUSION BUILDING PROFILE

To edit or input additional building-specific information to a VI building profile, select [EDIT] located to the left of “Building Name”; this returns the user back to the VI building profile page.



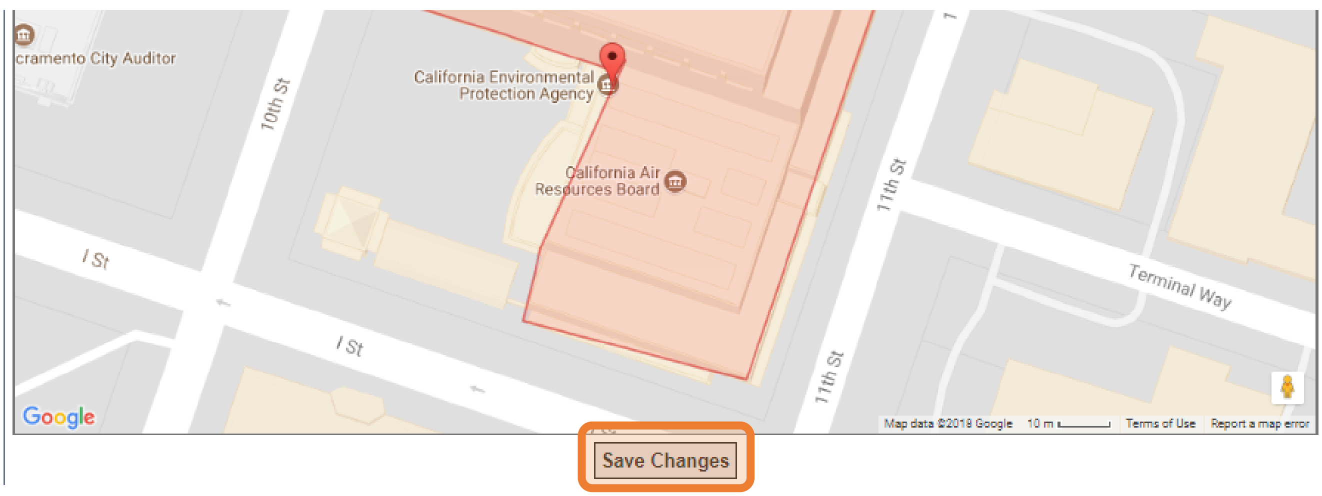
TEST ONLY - DWQ VI TEST PROJECT - T10000011140
1001 I STREET
SACRAMENTO, CA 95814

ADD A NEW VI BUILDING

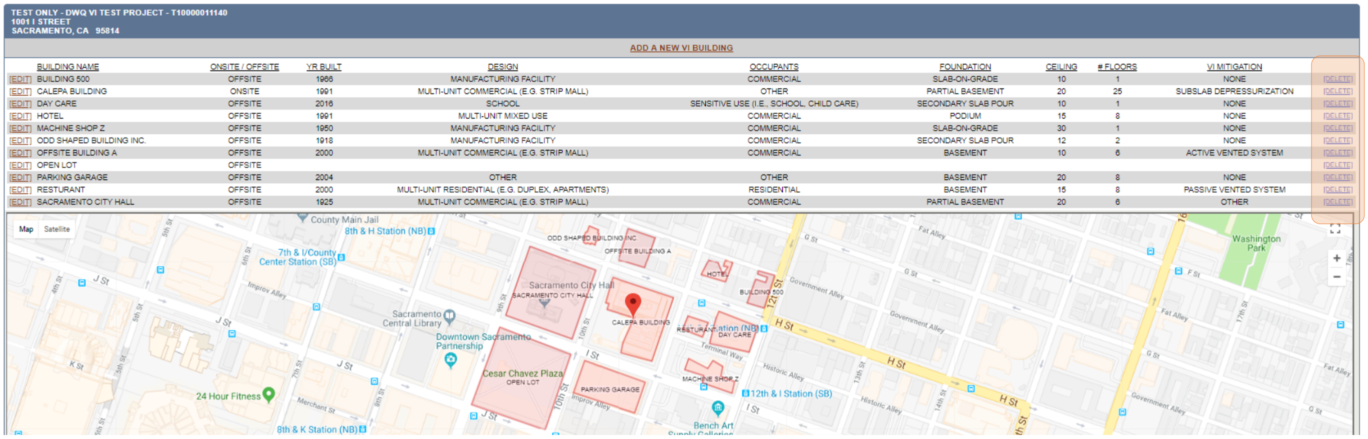
	BUILDING NAME	ONSITE / OFFSITE	YR BUILT	DESIGN	OCCUPANTS	FOUNDATION	CEILING	# FLOORS	VI MITIGATION	
[EDIT]	BUILDING 500	OFFSITE	1966	MANUFACTURING FACILITY	COMMERCIAL	SLAB-ON-GRADE	10	1	NONE	[DELETE]
[EDIT]	CALEPA BUILDING	ONSITE	1991	MULTI-UNIT COMMERCIAL (E.G. STRIP MALL)	OTHER	PARTIAL BASEMENT	20	25	SUBSLAB DEPRESSURIZATION	[DELETE]
[EDIT]	DAY CARE	OFFSITE	2016	SCHOOL	SENSITIVE USE (I.E., SCHOOL, CHILD CARE)	SECONDARY SLAB POUR	10	1	NONE	[DELETE]
[EDIT]	HOTEL	OFFSITE	1991	MULTI-UNIT MIXED USE	COMMERCIAL	PODIUM	15	8	NONE	[DELETE]
[EDIT]	MACHINE SHOP Z	OFFSITE	1950	MANUFACTURING FACILITY	COMMERCIAL	SLAB-ON-GRADE	30	1	NONE	[DELETE]
[EDIT]	ODD SHAPED BUILDING INC.	OFFSITE	1918	MANUFACTURING FACILITY	COMMERCIAL	SECONDARY SLAB POUR	12	2	NONE	[DELETE]
[EDIT]	OFFSITE BUILDING A	OFFSITE	2000	MULTI-UNIT COMMERCIAL (E.G. STRIP MALL)	COMMERCIAL	BASEMENT	10	6	ACTIVE VENTED SYSTEM	[DELETE]
[EDIT]	OPEN LOT	OFFSITE								[DELETE]
[EDIT]	PARKING GARAGE	OFFSITE	2004	OTHER	OTHER	BASEMENT	20	8	NONE	[DELETE]
[EDIT]	RESTURANT	OFFSITE	2000	MULTI-UNIT RESIDENTIAL (E.G. DUPLEX, APARTMENTS)	RESIDENTIAL	BASEMENT	15	8	PASSIVE VENTED SYSTEM	[DELETE]
[EDIT]	SACRAMENTO CITY HALL	OFFSITE	1925	MULTI-UNIT COMMERCIAL (E.G. STRIP MALL)	COMMERCIAL	PARTIAL BASEMENT	20	6	OTHER	[DELETE]

Note: *Since the VI building profile has already been stored in the database,* Save Changes *will now be at the bottom of the VI building profile page.*

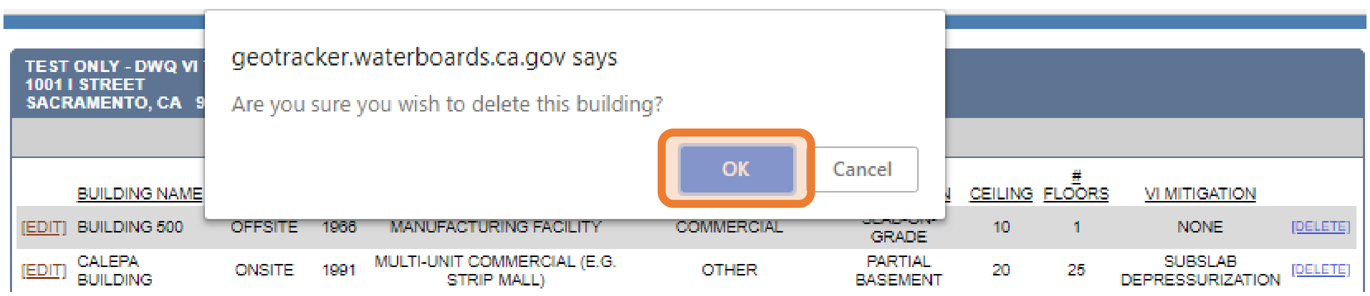
Select “Save Changes” to save modifications to the VI building profile.



To delete a VI building profile, select [DELETE] located to the right of VI Mitigation.



The system will ask the user to confirm deletion of the building, select "OK" to delete the building from the database.



Deleting a building from the database will <u>not</u> delete Field Points from the database.

IV. GEOTRACKER VAPOR INTRUSION DATABASE

One component of the State Water Board data management system (GeoTracker) is the VI database, which has the capability to easily accept electronic data to populate vapor concentration information for a Site/Facility and differentiate vapor concentration by the sample media. The VI database will also include building-specific information. Housing all this information in one database is a tool that helps RPs, contractors, and regulators evaluate sites for risk. The vapor concentration information is available through the public and secure portals.

The State Water Board will be assessing future modifications to the VI database to help with VI investigations.

APPENDIX A: GLOSSARY OF TERMS

EDD (Electronic Data Deliverable) – Information stored in a defined format, accessible via a computer (e.g., stored on diskette, internal hard drive, CD-ROM, magnetic tape, etc.).

EDF (Electronic Data Deliverable Format) – A comprehensive data standard designed to facilitate the transfer of electronic data files between data producers and data users. The GeoTracker EDF is specific to analytical laboratory data.

ESI (Electronic Submittal of Information) – Data submitted electronically.

Field Point – The name of a sample location (e.g., IA-1, SG-1, SSV-1, etc.).

Field Point Class – Defines the sample location's medium (e.g., indoor air sample, soil gas sample, subslab sample, etc.).

Study Area – The area that encompasses any building undergoing a vapor intrusion assessment for a particular Site/Facility.

Valid Value – Specially assigned, standardized coded value designating an approved (i.e., "valid") value for entry into a field in the database.

Vapor Intrusion Building Profile – Information collected on an individual building; the "profile" stores building-specific information, co-located Field Points, and building outline/location in one location in the GeoTracker database.

FREQUENTLY ASKED QUESTIONS

1. Why doesn’t my Field Point show up as part of the co-located Field Point drop-down option?

Check that the Field Point has the appropriate Field Point Class. Field Points will only populate in the associated Field Point class as a drop-down option.

2. What do I do with previously uploaded vapor concentration data?

Previously uploaded vapor concentration data will still be in the database and will not change. It will be useful to update the Field Point Class for the vapor (Field Point) to represent the sample medium. Prior to the added capabilities of the database, Field Point Class options were limited to vapor or air.

3. Why am I getting a Global ID or Field Point Name error while checking an EDF file?

The user uploading does not have access to the specific site (labs typically do not have access); leave both checkboxes (“Check Global_ID and Field Point Names” and “Use Global_ID from EDF upload file”) unchecked, and the user will be able to verify if the lab analytical data has errors.

4. What if I am the lab trying to upload EDF to a Site/Facility and the Site/Facility is not listed?

A lab will not be able to upload EDF to a Site/Facility without the Responsible Party (RP) claiming a site first. Contact the RP to gain access.

5. How do I delete a Field Point after uploading an EDF file?

Contact the GeoTracker Help Desk for assistance in deleting a Field Point.

6. How do I make corrections, additions, or delete an EDF submittal?

If your submittal has not been “Received” yet, you can delete it and then resubmit a corrected version. “Pending” submittals uploaded by you will have a “Delete Submittal” option. If your submittal has already been “Received,” you’ll need to contact your Lead Agency Regulator, who can retroactively “Deny” a previously “Received” submittal.

7. Where do I get help for troubleshooting?

Contact the GeoTracker Help Desk: geotracker@waterboards.ca.gov.

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Attachment 6

Building Survey and Indoor Source Screen Forms

Attachment 6 – Building Survey and Indoor Source Screen Forms

The forms provided may be helpful when following the Supplemental Guidance approach. Complete the Building Survey Form and Indoor Source Screen Form for each building where indoor air sampling is warranted to assess vapor intrusion risk.

Printable PDF versions of the Forms are included in this appendix and posted on the [State Water Board's Vapor Intrusion website](https://www.waterboards.ca.gov/water_issues/programs/scp/vapor_intrusion/): https://www.waterboards.ca.gov/water_issues/programs/scp/vapor_intrusion/.

Users may also request an electronic Microsoft Excel™ form to download and complete by emailing, DWQ-vaporintrusion@waterboards.ca.gov.

Users should gather information to enter into the forms during Step 3B of the indoor air investigation process described in this document. As appropriate, entries should either be typed in or selected from drop-down lists (green and yellow boxes). See Table 1 of Attachment 5 (GeoTracker Uploading Guidance) for the building field descriptions.

Indoor Air Source Screen Form

This form should be used while conducting field screening (Step 3B.3, Supplemental Vapor Intrusion Guidance). An Indoor Source Screen Survey of indoor air will help identify potential sources of vapor forming chemicals (VFCs) and/or potential subsurface vapor entry points. Common screening tools, such as, Photoionization Detector (PID), Gas Chromatography-Photoionization Detector (GC-PID), Gas Chromatography Mass Spectrometry (GC-MS), or Gas Chromatography-Electron Capture Detector (GC-ECD), should be used to detect the presence of VFCs in the air.

Use this form to document the room/area and location where the measurement was recorded during the Indoor Air Source Screen Survey, the field instrument type used, and the instrument reading and units. If a consumer product is identified and surrounding air tested, the location and the volatile ingredients of the product should be noted. (If the item(s) may be contributing VFCs to the indoor air, the items should be removed in advance of indoor air sampling.) This survey should be used to support the development of a conceptual understanding of how vapor intrusion may be occurring at the building and used in selecting sample locations for evaluating spatial distribution of VFCs in indoor air.

Site Information	Input
Building Address:	
Site/Facility Name:	
Screening Event Date:	
Screening Event Time:	
Event Weather Conditions:	
Name of Person(s) Conducting Sampling:	
Company Conducting Sampling:	
Field Instrument Type[1]:	
Instrument Calibration Date:	
Analyte Name:	

1 - Photoionization Detector (PID), Gas Chromatography-Photoionization Detector (GC-PID), Gas Chromatography-Mass Spectrometry (GC-MS), Gas Chromatography-Electron Capture Detector (GC-ECD), etc.

Indoor Air Source Screen Form

Sample Room/Area	Sample Location	Sample ID	Instrument Reading	Units	Volatile Ingredients in Consumer Products Identified Near Sample
-	-				
-	-				
-	-				
-	-				
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-	-				

Comments:

Indoor Air Source Screen Form Drop Down Lists

Sample/Room Area

- Bathroom
- Kitchen
- Bedroom
- Living Room
- Retail Area
- Workshop
- Garage
- Office
- Dining
- Storage
- Attic
- Other

Sample Location

- Breathing Zone (Indoor)
- Ambient Air (Outdoor)
- Foundation Opening
- Consumer Product
- Other

Building Survey Form

Type in or select answers from drop-down lists in the righthand column.
Upload answers to GeoTracker database for criteria marked with an asterisks (*).
See Table 1 in the *Guidance on Uploading Vapor Intrusion Information into GeoTracker* (Attachment 4 of Supplemental Vapor Intrusion Guidance) for a description of Building Design Type input choices.

Person Conducting Survey	Input
Name:	
Company:	
Phone Number:	
Email:	

Building Contact Information	Input
Name:	
Contact Title:	-
Phone Number:	
Email:	
Building Occupant Interviewed?	-

Building Information	Input
Date of Building Survey (dd/mm/yy):	
*Building Name:	
*Building Address (Street, City):	
Coordinates for Center of Building (Latitude, Longitude; decimal degrees to 0.00000):	
*Building Location Onsite/Offsite with respect to Site/Facility:	-
*Year Built (yyyy; approximate if unsure):	
*Building Occupants:	-

Building Survey Form

Building Dimensions	Input
*Building Footprint Area (within enclosed space; square feet [ft^2]):	
Building Dimensions (at grade; feet by feet):	
*Ceiling Height of Ground Floor (feet, [ft]):	
*Number of Floors (excluding the basement):	

Building Design	Input
*Building Design Type:	-
Has the design been modified?	-
*Foundation Type:	-
*Building Vapor Intrusion Mitigation System:	-
*Heating, Ventilation, & Air Conditioning (HVAC) System:	-
HVAC System has an Air Intake?	-
Type of Energy Used in Building?	-
Energy Primarily Used For?	-
Number of Units for Multi-Unit Buildings:	
Number of Rooms (average per unit for multi-unit buildings):	
Number of Exterior Doors:	
Number of Elevators:	
Number of Active Exhaust Fans (e.g., kitchen/bathroom):	
Chimney or Other Vertical Draft Source?	-

Building Slab	Input
Slab Thickness (inches; approximate if unsure):	
Largest Slab Penetration > 1 Foot Diameter:	-
Soil Type (USCS) 0 to 3 Feet Below Building:	-
Evidence of moisture intrusion from Below Slab?	-
Differential Pressure Measurement Points?	-

Building Survey Form

Building Windows and Doors	Input
Number of Windows and Exterior Doors:	
Weather Sealed Windows and Exterior Doors?	-
Average Area of Window Open to Outside Air (ft^2):	
Ventilation (e.g., windows, doors garage doors) Under Typical Use Conditions	-

Building Crawl Space	Input
Crawl Space Height (ft):	
Number Crawl Space Vents:	
Average Area per Crawl Space Vent (ft^2):	
Evidence of moisture intrusion into Crawl Space from Soil?	-

Building Basement	Input
Basement Height (ft):	
Basement Footprint Area (ft^2):	
Basement Wall Area Below Ground Surface (ft^2):	
Exposed Basement above grade?	-
Vents or Windows above-grade in exposed basement?	-
Unfinished Basement?	-
Evidence of moisture intrusion into Basement from Soil?	-

Building Survey Form

Factors Potentially Influencing Indoor Air Quality	Input
Is there an attached garage?	-
Is there smoking in the building?	-
Is there new carpet or furniture?	-
Have clothes or drapes been recently dry cleaned?	-
Has painting or staining been done within the last six months?	-
Has the building been recently remodeled?	-
Has the building ever had a fire?	-
Is there a hobby or craft area in the building?	-
Are scented products (e.g. air fresheners, scented candles) regularly used inside?	-
Is there a chemical storage area at the building (e.g., solvent cleaners)?	-
Is there a fuel oil tank on the property?	-
Is there a septic tank on the property?	-
Has the building been fumigated or sprayed for pests recently?	-
Historically the building was primarily used for?	-
Do current building occupants use solvents at another location (e.g., work, hobby)?	-

Building Survey Form

Meteorological Conditions	Input
Weather:	
Outdoor Temperature - High (°F):	
Outdoor Temperature - Low (°F):	
Indoor Temperature (°F):	
Barometric Pressure Reading (mmHg):	
Wind Direction:	-
Average Wind Speed (mph):	
HVAC Setting for Current Season:	-

Other Comments

(End of Form)

Building Survey Form Drop Down Lists

Contact Title:

Owner
Manager
Occupant
Other

Building Occupant Interviewed?

Yes
No

***Building Location Onsite/Offsite/Offsite with respect to Site/Facility**

Onsite
Offsite

***Building Occupants:**

Residential
Commercial
Residential Unit over Commercial Unit
Sensitive Use (e.g. Child Care or Medical Facility)

***Building Design Type:**

Single Unit Residential
Multi-Unit Residential (e.g. duplex, apartments)
Single Unit Commercial
Multi-Unit Commercial (e.g. strip mall)
Multi-Unit Mixed Use
Auditorium (e.g. church, theater)
School
Industrial
Manufacturing Facility
Warehouse
Other

Has the design been modified?

Yes
No
Unknown

***Foundation Type:**

Slab-on-Grade
Crawl Space
Partial Crawl Space
Basement
Partial Basement
Podium
Earthen
Secondary Slab Pour
Other

***Building Vapor Intrusion Mitigation System:**

Vapor Intrusion Barrier Only
Passive Vented System
Active Vented System
Subslab Depressurization System
Other
None

***Heating Ventilation, & Air Conditioning (HVAC) System:**

Heating Only
Cooling Only
Heating & Cooling
None

HVAC System has an Air Intake?

Yes
No
Unknown

Type of Energy Used in Building?

Natural Gas
Fuel Oil
Propane
Electricity
Wood
Kerosene
More Than One Type
Other
None
Unkown

Energy Primarily Used For?

Space Heating
Water Heating
Cooking
Drying Laundry (Interior)
Commercial/Industrial Processes
Other
Unknown

Chimney or Other Vertical Draft Source?

Yes
No

Largest Slab Penetrations > 1 Foot Diameter

Slump Elevator
Shaft
Floor Drain
Other
None

Soil Type (USCS) 0 to 3 Feet Below Building:

Fine
Coarse
Fine and Coarse
Unknown

Evidence of moisture intrusion from Below Slab?

Yes
No
N/A

Differential Pressure Measurement Points?

Yes
No
Unknown

Weather Sealed Windows and Exterior Doors?

All Sealed
Some Sealed
None Sealed
Unknown

Ventilation (e.g., windows, doors, garage doors) Under Typical Use Conditions

Most Windows and/or Doors Open
All Windows and Doors Closed
Minimal open Windows or Doors

Evidence of moisture intrusion into Crawl Space from Soil?

Yes
No
N/A

Exposed Basement above grade?

Yes
No
N/A

Vents or Windows above-grade in exposed basement?

Yes
No
N/A

Unfinished Basement?

Yes
No
N/A

Evidence of moisture intrusion into Basement from Soil?

Yes
No
N/A

Is there an attached garage?

Yes
No

Is there smoking in the building?

Yes
No
Unknown

Is there new carpet or furniture?

Yes
No
Unknown

Have clothes or drapes been recently dry cleaned?

Yes
No
Unknown

Has painting or staining been done within the last six months?

Yes
No
Unknown

Has the building been recently remodeled?

Yes
No
Unknown

Has the building ever had a fire?

Yes
No
Unknown

Is there a hobby or craft area in the building?

Yes
No
Unknown

Are scented products (e.g. air fresheners, scented candles) regularly used inside?

Yes
No
Unknown

Is there a chemical storage area at the building (e.g., solvent cleaners)?

Yes
No
Unknown

Is there a fuel oil tank on the property?

Yes
No
Unknown

Is there a septic tank on the property?

Yes
No
Unknown

Has the building been fumigated or sprayed for pests recently?

Yes
No
Unknown

Historically the building was primarily used for?

Dry Cleaner
Industrial Degreasing/Cleaning
Laboratory
Manufacturing
Painting/Finishing
Residential
Commercial Office
Warehouse
Other
Unknown

Do current building occupants use solvents at another location (e.g., work, hobby)?

Dy Cleaner
Industrial Degreasing/Cleaning
Laboratory
Manufacturing
Painting/Finishing
Other
None

Wind Direction:

N
NW
NE
W
S
SW
SE
E

HVAC Setting for Current Season?

Heating
Cooling
Off

End of Document